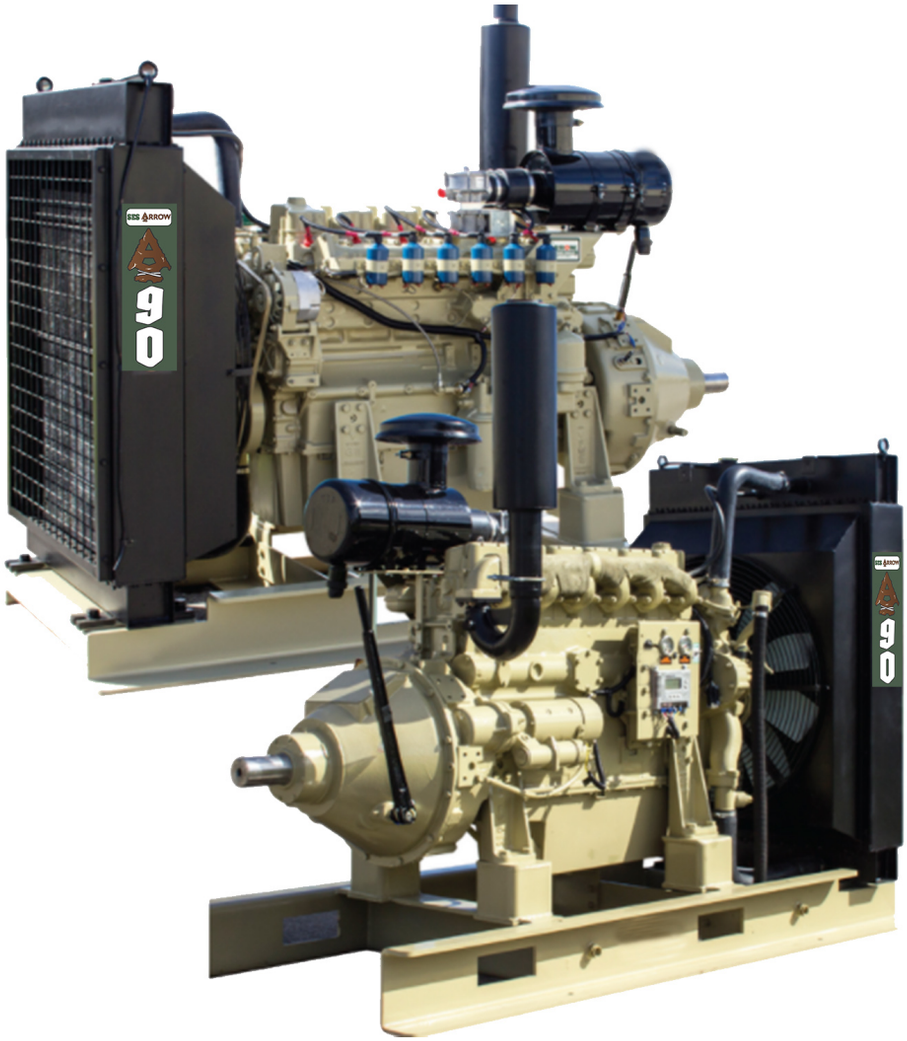
SES ARROW

ENGINES



SES 90 ENGINES

SES ARROW MANUFACTURING
1224 N LEWIS AVE TULSA, OK, 74110
PHONE (918) 928-6235
WWW.SESARROWMFG.COM

SAFE OPERATING PROCEDURES

SES Stationary Engines

DO NOT operate this engine unless you have been instructed & trained in its safe use and operation.

Hard hat & safety glasses must be worn at all times while working on or around equipment.

Long and loose hair must be contained.

Protective footwear must be worn at all times.

Protective clothing must be worn at all times.

Hearing protection must be worn while working on or around equipment.

Rings and jewelry should not be worn while operating equipment.

PRE-OPERATIONAL SAFETY CHECKS

1. The equipment must be used in accordance with manufacturer's instructions.
2. Ensure the area is clean and clear of grease, oil, and objects that may be a slip or trip hazard.
3. Familiarize yourself with and check all engine operations and controls.
4. Check all safety devices are in good working condition.
5. Ensure work area is well ventilated and free from exhaust fumes before operating.
6. Ensure all flammable materials are correctly stored or disposed of before operating.
7. Faulty equipment must not be used. Immediately report suspect equipment.

OPERATIONAL SAFETY CHECKS

1. Engine must not be operated unless the person is qualified to operate the equipment.
2. Ensure work area around engine has been cleared of tools and debris before starting.
3. Be aware that during operation, parts of the engine or equipment are hot or rotating.
4. When performing any preventive maintenance or repairs on the engine or equipment ensure that the battery (if fitted) is disconnected, the fuel supply has been turned off and proper lock out/tag out procedures have been followed.

POTENTIAL HAZARDS

- Hot components
- Entanglement hazards – rotating parts
- Fuel supply – LPG/NG vapors
- Exhaust fumes
- Confined space – trapping, tripping hazards
- Crushing hazards
- Fire
- Shock hazard

Note: This SOP does not necessarily cover all possible hazards associated with the engine operation and should be used in conjunction with other PPE safety procedures.

MED-F-002

SES ARROW MFG- 1224 N Lewis Ave, Tulsa, OK 74110

1 + (918) 852-2752

A-90

PARTS, OPERATION, & MAINTENANCE

Please let our customer service department know if you discover any discrepancies within this manual. We appreciate your feedback. Call 1+ (918) 852-2752.

TABLE OF CONTENTS

1 Specifications

1.1 Engine Description

1.1.1 Cylinder Heads

The individual cylinder heads are made of cast iron equipped with helical inlet ports designed for air/fuel efficiency. The heads have a specially designed gasket that provides reliable sealing of the fuel, coolant, and oil passages. The intake and exhaust valves are made of high temperature resistant material.

1.1.2 Crankcase & Cylinder Liners

The cylinder liner O-rings provide an excellent oil and coolant seal on the outer diameter while the inner diameter is plateau honed. The cylinder liners are centrifugal cast.

1.1.3 Rotating Assembly

The pistons are made of an aluminum alloy which is lower in weight, has good thermal conductivity, and offers higher temperature stability. The connecting rods and crankshaft are designed to accommodate a wide range of loads. The bearings are designed to withstand the higher stresses due to the combustion process. The special design of the spray nozzle protects the piston from overheating and seizing. The forged crankshaft is provided with two counterweights for each crank pin, giving it the best dynamic balance and reduced bearing loads.

1.1.4 Cooling System

The cast in coolant passages and integrated twin thermostats provide for maximum efficiency of the cooling system.

1.1.5 Ignition System

The CD1 ignition is a capacitor discharge, electronic microcircuit based ignition system for 1 to 8 cylinder industrial engines. It may be powered by 12 or 24 VDC and has no moving parts. It works with one step-up coil per cylinder. Engine timing should be set to 24 degrees BTDC. Using digital circuitry, the CD1 unit processes a signal from the magnetic pickup that is sensing reference holes or protrusions in the balancer assembly. This provides an accurate and consistent timing reference directly from the crankshaft. Indication LEDs convey whether proper signals are being received and if the corresponding output signals are correct.

1.1.6 Lubrication System

The A-90 engine is equipped with an oil pump that is driven by the crankshaft through an intermediate gear. The lubricating oil is drawn from the crankcase and passes through an oil/water heat exchanger which results in faster engine warm-up and maximum oil cooling, providing the best lubricating quality. Contaminates are filtered by a combination of disposable cartridges and a large centrifuge in the bypass circuit.

1.1.7 Electrical Components

A-90 engines are provided with a heavy duty 12v starter for reliable operation. The engine is also equipped with a 63 amperage charging system.

1.1.8 Liquid Cooled Exhaust Manifold

The A-90 is equipped with a liquid cooled exhaust manifold, the liquid cooled exhaust manifold reduces the surface temperature and radiant heat transfer thus lowering the risk of heat related damage to vital engine components.

1.1.9 Engine Numbering System

The model designation, engine rating, and engine serial number are documented on a nameplate which is attached to the right side of the engine block. When ordering parts or correspondence related to the engine it is essential to provide the model designation and complete engine serial number.

1.2 Engine Specifications

Parameter	A90 NA	A90 TA
Number of cylinders	6	
Cylinder arrangement	Vertical Inline	
Working Cycle	4-stroke Natural Gas Engine	
Fuel System	Carburetor	
Cooling System	Liquid Cooled	
Direction of Rotation	Counter clockwise from flywheel end	
Number of Flywheel Teeth	150	
Compression Ratio	9.0:1	
Bore x Stroke	8.8L (118mm x 135mm) 4.65in x 5.32in	
Swept Volume / Cylinder	90 cu. in. (1.47 L)	
Firing Order	1-5-3-6-2-4 (from front end)	
Starter	12V or 24V electric starter	
BMEP @ 1800 rpm Continuous Power	89.0	129.7
Rated HP @ 1800 RPM Continuous	109	150
Rated HP @ 1800 RPM Intermittent	125	165
Maximum Operating Speed	1800 rpm	
Genset Power Rating (Prime)	83 kW @ 1800 rpm / 61 kW @ 1500 rpm	
Genset Power Rating (Standby)	75 kW @ 1800 rpm / 68 kW @ 1500 rpm	
Power consumed by radiator fan	7 hp @ 1800 rpm	
Fuel Pressure	4 - 8 inches water	8 psi max from main regulator
Engine weight with flywheel, housing, and radiator	Power Unit (open) 3500 lbs	Genset Unit (open) 3850 lbs

ENGINE SPECIFICATIONS	
Max Speed + HP (continuous duty)	1800 RPM @ 109 HP (NA only)
Fuel Consumption	BTU / HR = 7933 @ 1800 (NA only)
Oil Consumption Max	.004 LBS / HP-HR

1.3 Cooling System

COOLING SYSTEM SPECIFICATIONS	
Type of cooling	Liquid circulation cooling with belt driven pump
Thermostat (Qty 2)	165°F (optional 180°F or 195°F)

Use soft water for engine cooling and anticorrosion oils to avoid rust formation. Water should be clear and free of any corrosive chemicals such as chloride, sulfates and acids. We recommend using a coolant blend of deionized water and rust preventing compound as mentioned below:

WATER QUALITY	MIN	MAX
pH value	6.5	8.5
The content of chloride ion mg/liter	-	100
Content of carbonate mg/liter	-	100
Content of overall anion mg/liter	-	150
Degree of hardness when using an anti freezing agent	3	12
Degree of hardness of the carbonate	3	-
Degree of hardness when using chemical anticorrosive agent. Not the manufactures instructions.	0	10

1.4 Lubrication System

LUBRICATION SYSTEM SPECIFICATIONS	
Type of lubrication	Forced feed lubrication with gear pump
Oil Filters	2 - spin on, paper filters in main stream and 1 - centrifuge filter in bypass
Oil type	Refer to *"OIL TEMPERATURES METHOD" on page 5*
Oil capacity - Oil change	21.0 Qts - 22.0 Qts

1.4.1 Lubrication Guide

Lubrication intervals listed are for normal operation and should coincide with other preventive maintenance services, however under unusual conditions, intervals should be shortened if there is evidence of dirt, sludge or breakdown of lubricant.

Keep all lubricants in closed containers and store them in a clean dry place away from heat. Always protect the lubricants from dust, dirt or moisture. Keep lubrication equipment clean and ready for use at all times.

Before lubricating, wipe surrounding areas clean to prevent dirt or other foreign matter from entering the lubrication system. Use a cloth moistened with solvent to remove any old or hardened lubricants. After lubricating, remove any excess lubricant and wipe any spilled lubricant from parts not requiring lubrication.

Lubricating Oils

The performance of a lubricant, like that of any manufactured product, is the responsibility of the refiner and producer. Also, the engine operator, to a large degree, controls the oil's performance, for the operator is the one who must make decisions on oil changes, filter changes, loads, general maintenance and operating conditions.

Note

Synthetic lubricating oils are not recommended by SES Arrow Engine Company.

Service Conditions

Oil performance will reflect engine load, temperature, fuel quality, atmospheric dirt, moisture and maintenance. If oil performance problems arise or are anticipated, the oil supplier should be consulted.

Extended oil change intervals should be utilized with caution on any engine using highly dispersant oils. The dispersants function by absorption of particles of contaminants; however, when dispersant saturation is reached, these oils tend to "dump out" all of the suspended contaminants in a relatively short period of time. Laboratory analysis will not predict the "dump out" point precisely; consequently, closer operator attention to engine conditions is required when establishing an extended oil change interval.

Fuels with hydrogen sulfide should consult the factory for recommendations/requirements. When fuel is burned in an engine combustion chamber, any sulfur it contains is converted to sulfur oxides, which will combine with water vapor to form acids. These acids can cause serious corrosive damage to engine components. The engine oil should be compounded to neutralize the acids and inhibit corrosion. This is done by building alkalinity into the oil via the additive formulation. The commonly used measure of relative alkalinity is termed "Total Base Number" (TBN). The higher the number, the greater the reserve alkalinity or acid neutralizing capacity of an oil.

Lube oil suppliers will supply information about the TBN levels of their products. An oil analysis program will keep the user informed of the TBN level of his oil in service so that adequate corrosion protection is maintained.

Since low operating temperatures promote condensation of acid-bearing fumes in the crankcase, engine coolant temperatures should also be maintained at 185°F (85°C) minimum.

Selecting Oil Viscosity

The correct lubricating oil viscosity, often referred to as weight, must be determined with the engine operating under its normal loaded speed and temperature.

Start and load engine as described under 5.2 Start Up.

After oil and coolant temperatures stabilize, note the temperature of the oil in the oil pan. Use an accurate temperature gauge. Compare this temperature with the following chart. The correct oil viscosity will be found in the right hand column.

OIL TEMPERATURES METHOD

Oil Pan Operating Temperatures	SAE Viscosity Numbers
210°F - 250°F (99°C - 121°C)	40
160°F - 210°F (71°C - 99°C)	30
130°F - 160°F (54°C - 70°C)	20

Engines operating with low oil temperatures - below 160°F (71.1°C) - can be expected to show excessive sludging and wear. Engines operating with high oil temperatures - above 230°F (110°C) - may experience lacquering and ring sticking due to oil oxidation. If oil temperatures cannot be corrected to the normal operating range, more frequent oil changes may help in extending engine life.

When the actual operating oil temperature is not known, an estimate of the SAE oil grade to use can be made by assuming the oil pan operating temperature will be 120°F (48.9 ° C) degrees above the ambient air temperature in heavy duty service. For example, at an ambient air temperature of 70°F (21.1°C), estimated oil pan operating temperature would be 190°F (87.7°C). Use SAE 30 as indicated in the above table. NOTE: This is only an estimate since the type of installation determines the amount of air circulation for cooling around the oil pan. Actual oil pan operating temperatures should be measured whenever possible.

NOTE

Multi-viscosity oils, 10W30 for example, should be used only when cold starting conditions make it absolutely necessary. Oil change periods should be reduced by 50% for engines using multi-viscosity oil because multi-viscosity oils may rapidly lose their highest viscosity rating in industrial service.

1.5 Ignition Systems

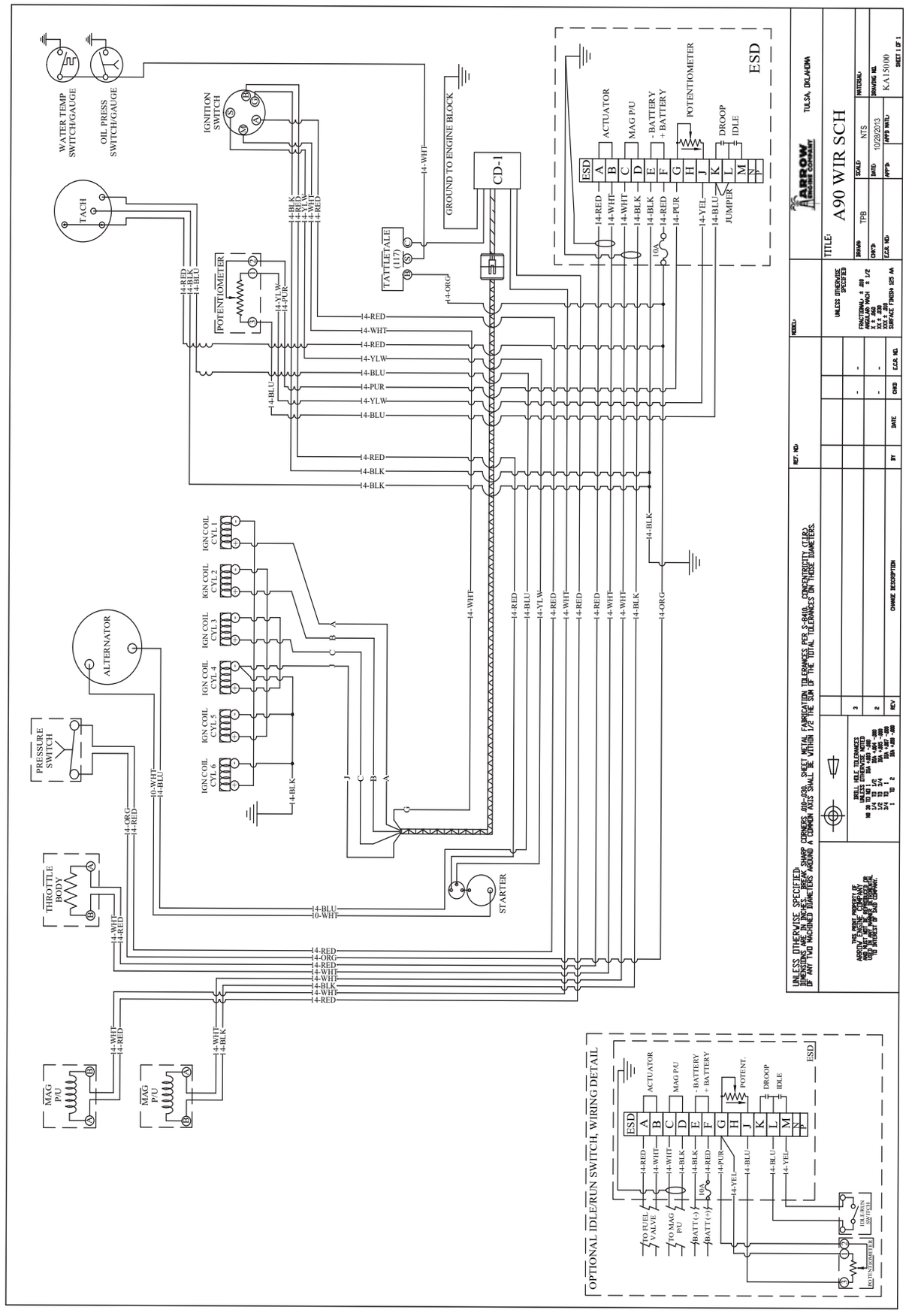
1.5.1 CD1 Ignition Systems

CD1 is a capacitor-discharge, electronic microcircuit based ignition system for 1 to 8 cylinder industrial engines. It may be powered by either 12 or 24 VDC, and has no moving parts. It works with the step-up coils (one per cylinder.)

Engine timing should be set to 24° BTDC.

Employing digital circuitry, the CD1 unit processes signal from a magnetic pickup, sensing drilled reference holes or protrusions. This provides accurate and consistent timing referenced directly to the crankshaft or camshaft. The CD1 uses high energy, capacitor-discharge principle which provides maximum engine performance and can extend spark plug life three to five times when compared to an inductive system. Indicating LED's convey whether proper pickup signals are being received and if the corresponding output signals are correct.

CD1 WIRING DIAGRAM



1.5.2 Single Fire Ignition Timing

New Distributor Installation Instructions

1. Roll the engine to 30 BTDC compression stroke #1 cylinder (radiator end).
2. Using the correct gasket and 6 M8 bolts and nuts, install the timing unit housing onto the engine. Tighten the 6 M8 fasteners in a crisscross pattern to 13-18 ft-lbs. There is no indexing required at this point.
3. Make sure that the taper on the shaft and the tapered bore in the reluctor are both clean and dry.
4. Place the reluctor on the shaft and align the #1 marked slot with the 2 marks in the housing at the 12 o'clock position.

FIGURE 1. Single Fire Ignition

5. Place a drop of RED thread locker on the shaft and start the M14 nut on the shaft. There are no washers under the nut.

FIGURE 2. Single Fire Ignition

6. While holding the reluctor in position, tighten the M14 nut to 10-15 ft-lbs.
7. Check that the reluctor is still aligned and further tighten the M14 nut to 40-45 ft-lbs.
8. Using 8 M4 socket head screws install the back plate and gasket with the mag pickup hole at 12 o'clock and with the center recess inwards toward the M14 nut.

FIGURE 3. Single Fire Ignition

The gasket has an offset hole and installs only one way.

9. Rotate the cover so that the M4 screws are centered in the slots and tighten them to 8-10 ft-lbs.
10. Thread the mag pickup in till it just touches the reluctor wheel and back it off ¾ -1 turn and tighten the lock nut.

Re-installation of assembled distributor

1. Roll the engine to 30 BTDC compression stroke #1 cylinder (radiator end).
2. Re install distributor as shown in figure #1.

1.6 Fuel

SES Arrow A-90 gas engines are designed to burn natural gas. All power ratings are based on natural gas with a heat value of 900 BTU/ cu. ft. (LHV)

Required fuel conditions:

1. Maximum liquid fuel hydrocarbons at the coldest expected engine mounted regulator fuel outlet temperature is 2% or less by gaseous volume.
2. Maximum total organic halide content, expressed as chlorine concentration (TOHC1), is 60 micrograms/liter.
3. Maximum permissible free hydrogen is 12% by volume.
4. Maximum solid particle size is 5 microns.
5. No liquid water is permitted at the outlet of the engine mounted fuel regulator at the coldest expected temperature.

1.6.1 Fuel Systems Natural Gas Carburetion

The SES Arrow carburetor is structurally simple, con-sisting of a main body with a conventional but-terfly throttle valve and a diaphragm operated gas metering valve. The amount of air going to the engine is measured by an airflow measuring valve. This valve rises in direct proportion to the air volume passing through it. The gas metering valve is mechanically fixed to the air measuring valve. As the air valve rises, the gas valve rises with it, thus opening the gas passage propor-tionately to the amount of air entering the engine. This establishes and holds a definite fuel/ air ratio throughout the engine operating range.

1.7 Ignition Firing Order

FIRING SPECIFICATIONS	
Firing order (6 cyl. engines)	1-5-3-6-2-4 (from fan side)

1.8 Valve Specifications

NA - VALVE SPECIFICATIONS	
Valve clearance - intake valve	(0.36 mm) (when warm) 0.014 in
Valve clearance - exhaust valve	(0.56 mm) (when warm) 0.022 in

TA - VALVE SPECIFICATIONS	
Valve clearance - intake valve	(0.36 mm) (when warm) 0.014 in
Valve clearance - exhaust valve	(0.56 mm) (when warm) 0.022 in

NOTE: Valve lash should be set from flywheel end (1-5-3-6-2-4)

1.9 Air System

AIR SYSTEM SPECIFICATIONS	
Air filter	Dry air filter with one way paper filter cartridge and restriction indicator

1.10 Electrical System

ELECTRICAL SYSTEM SPECIFICATIONS	
System Voltage	12V / 24V
Starter	12V / 24V
Alternator	12V 63AMP/24V 25AMP

1.11 Torque Specifications

1.11.1 Tightening Torques

To prevent faulty assembly, the following information on tightening of high tensile bolts is important. The bolts are to be tightened in stages as specified.

		Ft-lbs		
		Initial Torque	Final Torque	
Fastener	**Size**	**Stage 1**	**Stage 2**	**Stage 3**
Cylinder Head Bolts Short Long	 M14X139 M14X159	37	74	103+/-7
Connecting Rod Bolts	M16X1.5X73	37		155+/-7
Main Bearing Cap Bolts	M16X150			195
Balance Weight Bolt	M16X50			190+/-6
Flywheel Bolt	M16X45			175+/-7
Crank Pulley Bolt	M20X1.5X65			220+/-7
Flywheel Housing Bolt	M12X55			75+/-3
Rocker Arm Support Bolt	M10X80			55
Liquid Cooled Manifold Nut	M10			35+/-5
Foot Bolt to Block	M12			65+/-5

*As per international standards.

- Threads and seating surfaces of fasteners to be cleaned and coated with engine oil before assembly.
- When replacing main or connecting rod bearings during overhaul always use new bolts for main bearing cap and connecting rods.
- Apply initial torque and tighten the bolts according to the torques in stages as specified in the table above.
- As to international standards all M8X1.25 screws/bolts of 8.8 quality must be torqued to
  18 ft/lbs.
- As to international standards all M10X1.5 screw/bolts of 8.8 quality must be torqued to 25 ft/lbs.

1.12 ESD5100 Series Speed Control Unit Specifications

1.12.1 Introduction

The ESD5100 Series speed control unit is an all electronic device designed to control engine speed with fast and precise response to transient load changes. This closed loop control, when connected to a proportional electric actuator and supplied with a magnetic speed sensor signal, will control a wide variety of engines in an isochronous or droop mode. It is designed for high reliability and built to withstand the engine environment.

Simplicity of installation and adjustment was foremost in the design. Non-interacting performance controls allow near optimum response to be easily obtained.

Other features include; adjustable droop and idle operation, inputs for accessories used in multi-engine or special applications, protection against reverse battery voltage, transient voltages, accidental short circuit of the actuator and fail-safe design in the event of loss of speed sensor signal or battery supply.

1.12.2 Description

Engine speed information for the speed control unit is usually received from a magnetic speed sensor. Any other signal generating device may be used provided the generated frequency is proportional to engine speed and meets the voltage input and frequency range specification. The speed sensor is typically mounted in close proximity to an engine driven ferrous gear, usually the engine ring gear. As the teeth of the gear pass the magnetic sensor, a signal is generated which is proportional to engine speed.

Signal strength must be within the range of the input amplifier. An amplitude of 0.5 to 120 volts RMS is required to allow the unit to function within its design specifications. The speed signal is applied to Terminals C and D of the speed control unit. Between these terminals there is an input impedance of over 33,000 ohms. Terminal D is internally connected to Terminal E, battery negative. Only one end of the cable Shield should be connected.

When a speed sensor signal is received by the controller, the signal is amplified and shaped by an internal circuit to provide an analog speed signal. If the speed sensor monitor does not detect a speed sensor signal, the output circuit of the speed control unit will turn off all current to the actuator.

A circuit receives the speed sensor signal along with the speed adjust set point input. The speed range has a ratio of 8:1 and is adjusted with a 25 turn potentiometer. The output from the circuit is the input to the dynamic control section of the speed control unit. The dynamic control circuit, of which the gain and stability adjustments are part, has a control function that will provide isochronous and stable performance for most engine types and fuel systems.

The speed control unit output circuit is influenced by the gain and stability performance adjustments. The governor system sensitivity is increased with clockwise rotation of the gain adjustment. The gain adjustment has a range of 33:1. The stability adjustment, when advanced clockwise, Increases the time rate of response of the governor system to match the various time constants of a wide variety of engines. The

speed control unit is a PID device, the "D", derivative portion can be varied when required.

During engine cranking , the actuator becomes fully energized and moves to the maximum fuel position, The actuator will remain in that state during engine cranking and acceleration. While the engine is at steady load. The actuator will be energized with sufficient current to maintain the governor speed set point.

The output circuit provides switching current at a frequency of about 500 Hz to drive the actuator. Since the switching frequency is well beyond the natural frequency of the actuator, there is no visible motion of the actuator output shaft. Switching the output transistors reduces its internal power dissipation for efficient power control. The output circuit can provide current of up to 10 amps continuous at 25°C for 12 and 24 VDC battery systems. The actuator responds to the average current to position the engine fuel control lever.

In standard operation, the speed control unit performance is isochronous. Droop governing can be selected by connecting terminals K and L and the percent of droop governing can be varied with the droop adjustment control. The droop range can be increased by connecting Terminals G and H.

The speed control unit has several performance and protection features which enhance the governor system. A speed anticipation circuit minimizes speed overshoot on engine start-up or when large increments of load are applied to the engine. Engine idle speed can be remotely selected and is adjustable. Accessory inputs to achieve variable speed operation and multi-engine control can be accepted by the ESD5100 Series speed control unit from GAC load sharing modules, automatic synchronizers, ramp generators and other accessory engine control modules. Protection against reverse battery voltage and transient voltages is provided. The design is fail-safe in the event of loss of speed sensor signal or battery supply.

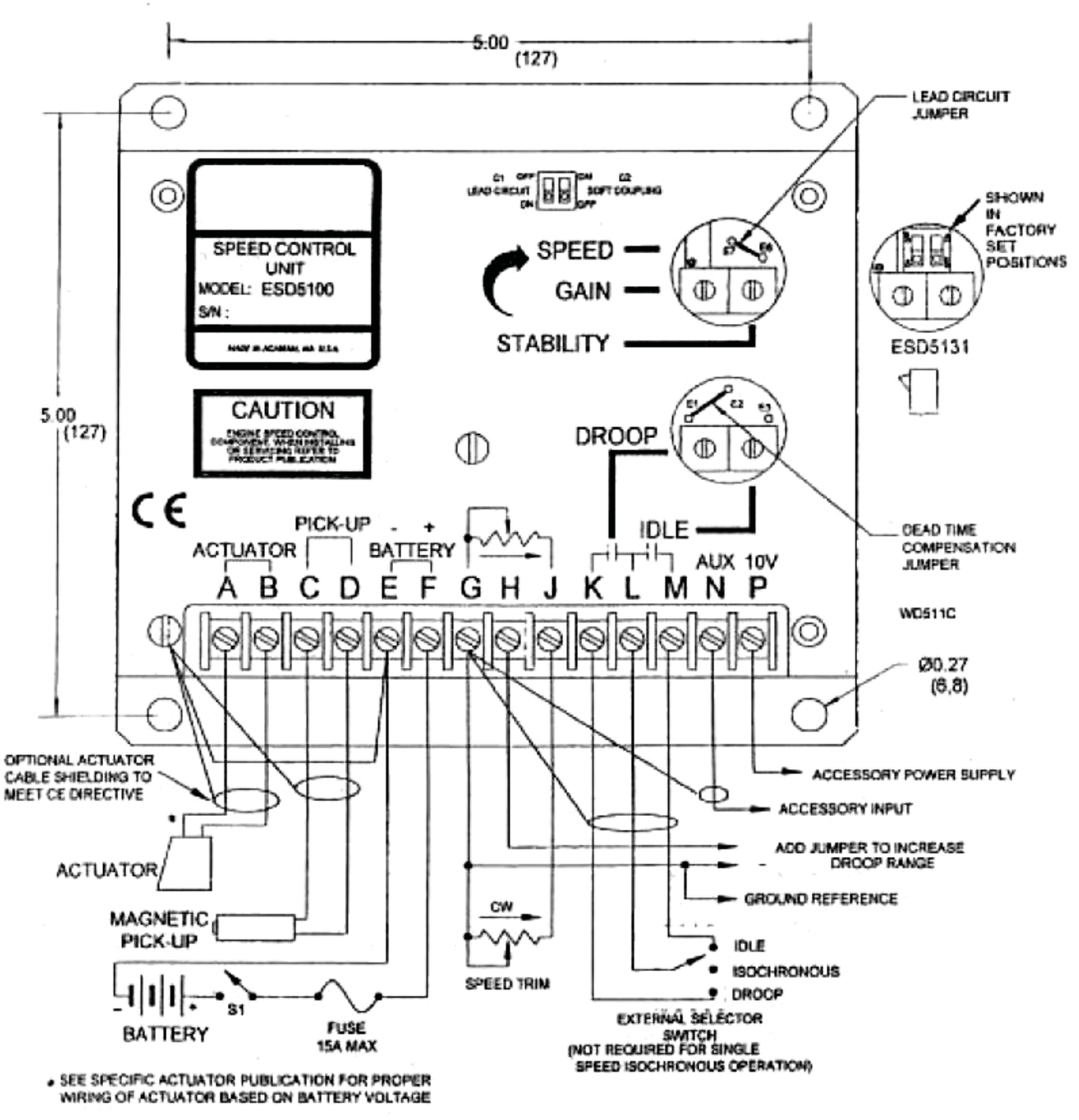
1

ESD SPEED CONTROL SPECIFICATIONS

Performance	Isochronous Operation	±0.25 % or better
	Speed Range /Governor	1K - 7.5K Hz Continuous
	Speed Drift with Temperature	±0.5% Typical
	Idle Adjust CW	Min. 1200 Hz Below set speed
	Idle Adjust CCW	Min. 4100 Hz Below set speed
	Droop Range	1 - 5% Regulation*
	Droop Adj. Max. (K-L Jumpered)	875 Hz, 75 Hz per 1.0 A change
	Droop Adj. Min. (K-L Jumpered)	15 Hz, 6 Hz per 1.0 A change
	Speed Trim Range	±200 Hz
	Remote Variable Speed Range	500 - 3.7 kHz
Terminal Sensitivity	J	-115 Hz, ±15 Hz/Volt @ 5 K Impedance
	L	-735 Hz, ±60 Hz/Volt @ 65 K Impedance
	N	-148 Hz, ±10 Hz/Volt @ 1 M Impedance
	P	10 VDC Supply @ 20 ma Max
Physical	Dimensions	See DIAGRAM 2
	Weight	1.2 lb. (0.545 kg)
	Mounting	Any Position, vertical preferred
Reliability	Vibration	1G, 20-100 Hz
	Testing	100% Functionally Tested

ESD SPEED CONTROL SPECIFICATIONS		
Environmental	Ambient Operating Temperature Range	-40° to +185°F (-40° to +85°C)
	Relative Humidity	up to 95%
	All Surface Finishes	Fungus proof and corrosion resistance
Input Power	DC Supply	12 or 24 ± 20% VDC Battery Systems** (Transient and Reverse Voltage Protected)
	DC Supply Type	Negative Ground (case isolated)
	Power Consumption	100 MA (No actuator current)
	Speed Signal Range	0.5 – 50 VAC
	Actuator Current Range @ 77°F (25°C)	10 Amps continuous***

FIGURE 1. System Wiring and Outline



1.12.3 Installation

The ESD5100 Series speed control unit is rugged enough to be placed in a control cabinet or engine mounted enclosure with other dedicated control equipment. If water, mist, or condensation may come in contact with the controller, it should be mounted vertically. This will allow the fluid to drain away from the speed control unit. Extreme heat should be avoided.

WARNING

An overspeed shutdown device, independent of the governor system, should be provided to prevent loss of engine control, which may cause personal injury or equipment damage. DO NOT rely exclusively on the governor system electric actuator to prevent overspeed. A secondary shut off device, such as a fuel solenoid, must be used.

1.12.4 Wiring

Basic electrical connections are illustrated in Figure 3.1. Actuator and battery connections to Terminals A, B, E, and F should be #16 AWG (1.3 mm sq.) or larger. Long cables require an increased wire size to minimize voltage drops.

The battery positive (+) input, Terminal F, should be fused for 15 amps as illustrated. The ESD5100 series is suitable for 12 VDC and 24 VDC operation.

Magnetic speed sensor wires connected to Terminals C and D MUST BE TWISTED AND/OR SHIELDED for their entire length. The speed sensor cable shield should ideally be connected as shown in Diagram 2. The shield should be insulated to insure no other part of the shield comes in contact with engine ground, otherwise stray speed signals may be introduced into the speed control unit. With the engine stopped, adjust the gap between the magnetic speed sensor and the ring gear teeth. The gap should not be any smaller than 0.020 in. (0.45 mm). Usually, backing out the speed sensor 3/4 turn after touching the ring gear teeth will achieve a satisfactory air gap. The magnetic speed sensor voltage should be at least 1 VAC RMS during cranking.

1.12.5 Adjustments Before Starting Engine

Check to insure the GAIN and STABILITY adjustments, and if applied, the external SPEED TRIM CONTROL are set to mid position.

Start Engine

The speed control unit governed speed setting is factory set at approximately engine idle speed. (1000 Hz, speed sensor signal)

Crank the engine with DC power applied to the governor system. The actuator will energize to the maximum fuel position until the engine starts. The governor system should control the engine at a low idle speed. If the engine is unstable after starting, turn the GAIN and STABILITY adjustments counterclockwise until the engine is stable.

1.12.6 Governor Speed Setting

The governed speed set point is increased by clockwise rotation of the SPEED adjustment pot. Remote speed adjustment can be obtained with an optional 5K Speed Trim Control.
(See Figure 3.1)

1.12.7 Governor Performance

Once the engine is at operating speed and at no load, the following governor performance adjustment can be made.

1. Rotate the GAIN adjustment clockwise until instability develops. Gradually move the adjustment counterclockwise until stability returns. Move the adjustment one division further counterclockwise to insure stable performance (270° pot).

2. Rotate the STABILITY adjustment clockwise until instability develops. Gradually move the adjustment counterclockwise until stability returns. Move the adjustment one division further to insure stable performance (270° pot).

3. Gain and stability adjustments may require minor changes after engine load is applied. Normally, adjustments made at no load achieve satisfactory performance. A strip chart recorder can be used to further optimize the adjustments.

If instability cannot be corrected or further performance improvements are required, refer to section *"8.7 Governing Systems" on page 79*. In this section, information can be found regarding troubleshooting procedures as well as instructions on adjusting the DIP switch positions of the ESD5131.

1.12.8 Idle Speed Setting

After the governor speed setting has been adjusted, place the optional external selector switch in the IDLE position. The idle speed set point is increased by clockwise rotation of the IDLE adjustment control. When the engine is at idle speed, the speed control unit applies droop to the governor system to insure stable operation.

1.12.9 Speed Droop Operation

Droop is typically used for the paralleling of engine driven generators.

Place the optional external selector switch in the DROOP position. DROOP is increased by clockwise rotation of the DROOP adjustment control. When in droop operation, the engine speed will decrease as engine load increases. The percentage of droop is based on the actuator current change from engine no load to full load. A wide range droop is available with the internal control. Droop level requirements above 10% are unusual.

If droop levels experienced are higher or lower then these required, contact GAC for assistance.

After the droop level has been adjusted, the rated engine speed setting may need to be reset. Check the engine speed and adjust that speed setting accordingly.

1.12.10 Accessory Input

The Auxiliary Terminal N accepts input signals from load sharing units, auto synchronizers, and other governor system accessories, GAC accessories are directly connected to this terminal. It is recommended that this connection from accessories be shielded, as it is a sensitive input terminal.

If the auto synchronizer is used alone, not in conjunction with a load-sharing module, a 3 M ohm resistor should be connected between Terminals N and P. This is required to match the voltage levels between the speed control unit and the synchronizer.

When an accessory is connected to Terminal N, the speed will decrease and the speed adjustment must be reset. When operating in the upper end of the control unit frequency range, a jumper wire or frequency trim control may be required between Terminals G and J. This increases the frequency range of the speed control to over 7000 Hz

1.12.11 Accessory Supply

The +10 volt regulated supply, Terminal P, can be utilized to provide power to GAC governor system accessories. Up to 20 ma of current can be drawn from this supply. Ground reference is Terminal G.

1.12.12 Wide Range Remote Variable Speed Operation

Simple and effective remote variable speed can be obtained with the ESD5100 Series speed control unit.

A single remote speed adjustment potentiometer can be used to adjust the engine speed continuously over a specific speed range. Select the desired speed range and corresponding potentiometer value. (Refer to *"VARIABLE RANGE POTENTIOMETER VALUE" on page 17*.) If the exact range cannot be found, select the next higher range potentiometer. An additional fixed resistor may be placed across the potentiometer to obtain the exact desired range. Connect the speed range potentiometer.

To maintain engine stability at the minimum speed setting, a small amount of droop can be added using the DROOP adjustment. At the maximum speed setting the governor performance will be near isochronous, regardless of the droop adjustment setting.

VARIABLE RANGE POTENTIOMETER VALUE	
SPEED RANGE	**POTENTIOMETER VALUE**
900 Hz	1K
2,400 Hz	5K
3,000 Hz	10K
3,500 Hz	25K
3,700 Hz	50K

Hz to RPM

$$\frac{\text{HZx60}}{\text{\# Teeth}} = \text{RPM}$$

2 Installation

2.1 Cooling System

2.1.1 Cooling System Inhibitor

To prevent rust when using water alone, either use a recommended corrosion preventive or inhibitor or a 50/50 mixture of deionized water and antifreeze is recommended.

2.1.2 Cooling System Installation Recommendations

After the cooler installation is completed and prior to filling the cooling system, clean all dirt and welding spatter from low points in the system. Flush accessible sections of the piping and cooler to eliminate as much dirt as possible prior to operation of the engine.

After filling the system, check closely for leaks. Tighten all clamps and fittings prior to engine start up to avoid coolant loss at start up.

The following installation suggestions are offered to improve cooling system performance and make future maintenance easier and less time consuming.

1. Mount all cooling system components, such as water inlet connections, control valves and raw water pumps, with at least enough clearance to permit normal maintenance and removal and replacement of accessories at the front of the engine without major disruption of the cooling system.
2. Use suitable couplings so large portions of the piping and valves and raw water pump complex may be disconnected and moved aside as a unit for engine repair and maintenance. This avoids removal of individual pieces of pipe and working backwards to reach a given threaded connection.
3. Provide convenient drainage points to remove water from both fresh water and raw water systems.
4. Provide easily opened air vents to remove air blocks from cooling system piping and allow immediate priming of system.
5. Mount all belt driven water pumps so belts may be tightened easily. Locate pump couplings and drive pulleys so packing can be removed and replaced without major disassembly or pump removal.
6. Keep the system clean
7. Avoid electrolysis; use zinc anodes or other cathodic protection.

2.2 Fuel System

The major components in the natural gas fuel system are the regulators, coalescent filter, piping and the carburetor system.

Pressure regulators are designed to control the pressure of the gas as it enters the engine. Through an arrangement of a diaphragm and springs, the pressure of the natural gas coming to the engine is lowered and controlled. This supplies a constant steady supply of gas to the carburetor.

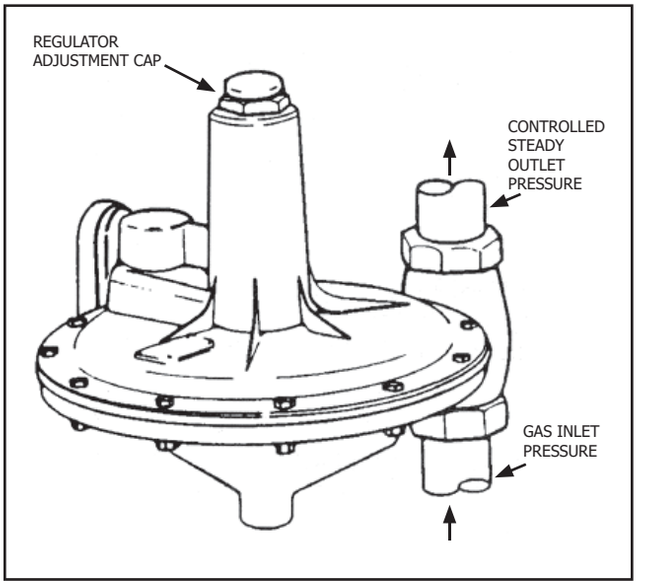


FIGURE 8. Natural Gas Regulator

There are two types of pressure regulators in the fuel system: a high pressure line, or "Big Joe", regulator mounted near the main fuel line, and a low pressure engine regulator.

The main regulator brings into the fuel line leading to the engine regulator at 7-8 psi. The engine regulator sets the gas pressure to the carburetor at 4-6" of water column for the A90-NA (0-6" for the A90 TA). From the engine mounted regulator the gas flows into the carburetor. Air is mixed with the gas, and it flows into the engine to be burned.

Gas pressure to the engine regulator must be 7-8 psi max. Low gas pressure will starve the engine of fuel and reduce engine output. High pressures could damage the regulator, allowing excessive fuel to flood the cylinders. This could lead to detonation and serious engine/carburetor damage.

Avoid fueling any gas operated equipment off of the supply line between the line regulator and the engine regulator. The supply pressure to the engine could be disrupted.

Regulators must be spaced according to the inner diameter of the pipe used. For a general rule of thumb, the maximum allowable distance between regulators is eight times the pipe ID. [For example, with a 2" pipe, the maximum distance between the regulators is 16" (406.4 mm)]. Regulators must be mounted in an upright position.

The maximum pressure drop across a line regulator is generally 50-75 psi (3.5-5.3 kg/cm^2). Consult the regulator manufacturer for specific information.

NOTE

A90 TA requires 7-8 psi.

2.3 Air Intake System

The following factors must be considered to ensure and adequate supply of intake air for internal combustion engines:

1. Air required for engines installed in heated and/or air conditioned buildings may change the heating and ventilating performance unless it is supplied with an external air intake source.
2. If an external air intake is required, it must be suitably designed to supply intake air of the proper temperature range. High intake air temperature results in power loss while lower intake air may hinder starting of automatic standby units. An external air source must also prevent the intake of exhaust gas from other equipment, flammable vapor, and entry of rain and water.
3. All intake ducting must be airtight to avoid entry to unfiltered air.
4. Restricted intake systems must be avoided. Sharp or numerous bends and undersized ducting will decrease the available air flow to the engine.
5. Engine heat radiation will affect air temperatures in the enclosed installations. Ventilation systems may be required.

2.4 Exhaust System

Engine exhaust system restriction must be kept to a minimum. The adverse effects of excessive back pressure include loss of power, poor fuel economy, excessive valve temperatures, and engine overheating. Check for undersized piping, a restricted silencer or muffler, or excessive turns or bends in the system if exhaust restriction is excessive.

Exhaust pipes must be adequately sized and supported using long radius elbows. The radius of the turn should be at least 4 to 5 times the pipe diameter to prevent restriction. Multiple connections to a common header are not recommended as this can result in erratic operation and potential engine damage. Locate the silencer as close to the engine as possible to help prevent pulsing effects.

Attention must be given to adequate silencing of the engine as unnecessary noise may, over time, damage the hearing of the operator and become a public nuisance. Objectionable noise is unnecessary today with the available mufflers which can be used to control the exhaust.

CAUTION

Maximum distortion of flexible exhaust connector, due to connected exhaust piping is ± ¼ inch (6.35mm) offset and ± ¼ inch (6.35mm) axial deflection.

2.5 Flywheel, Housing Runout, & Crankshaft Endplay

Even with the best maintenance, an engine can encounter trouble if such things as proper mounting, alignment with other equipment, flywheel and housing run out and sufficient crankshaft endplay are disregarded in the initial installation or in subsequent relocations of the engine. Although flywheel and housing run out and crankshaft endplay are firmly established within limits at the factory, such things as rough handling or improper installation of power take-offs or clutches may adversely affect these clearances and lead to serious engine damage. These items should be checked prior to operation.

A major factor in obtaining long service life from any engine and clutch or power takeoff assembly is the proper alignment of the flywheel housing, flywheel and pilot bearing bore. Distortion or lack of a common center on either of these parts will set up forces sure to be destructive to bearings, crankshaft, clutch and the driven equipment. In addition, because of normal manufacturing tolerances, when an engine is installed in a mounting formerly occupied by another engine, it is not safe to assume that the drive shaft of the power take off will automatically line up with a coupling located for the previous engine. In such circumstances, either the engine mounts must be shimmed or adjusted or the driven mechanism must be relocated and adjusted a few thousandths to bring the engine drive line from crankshaft bearing to driven shaft coupling into good alignment.

Check Housing Bore Runout

Make the following check for flywheel housing bore concentricity:

1. Support a dial indicator in the same general manner as shown and check the runout of the housing bore all the way around.
2. If the flywheel housing is out of alignment, loosen all of the flywheel housing bolts and proceed as follows.
3. Use a small bar inserted in a bolt hole to correct misalignment until the runout does not exceed 0.008” (0.2mm) total indicator reading.
4. Tighten bolts partially, working back and forth across the housing. Recheck bore concentricity with dial indicator.

Check Housing Face Runout

When making the above inspection, it is very important not to be misled by end movement of the crankshaft. To prevent this, use a pry bar to bring the shaft into full forward position at each point where the indicator reading is taken.

Mount a dial indicator on the flywheel housing as shown and check the runout of the pilot bearing bore. Runout should not exceed 0.005" (0.127mm) total indicator reading. Remount the dial indicator as shown to measure the runout of the flywheel face.
Again, it is emphasized that each reading must be taken with the crankshaft moved all the way forward to contact the thrust bearing. Unless handling has somehow distorted the wheel or crankshaft flange, maximum runout should not exceed 0.008" (0.2mm) total indicator reading.

Check Flywheel Face Bore Runout

Measure crankshaft endplay with a dial indicator mounted on the crankcase. Use a small pinch bar to move the crankshaft fully forward. Set the indicator at zero and use the bar to thrust the shaft to fully rearward. Check endplay reading on dial indicator with the tolerance given in the specifications.

Check Pilot Bearing Bore Runout

CAUTION

The importance of correct crankshaft endplay cannot be overstressed. Operation of an engine having insufficient or excessive crankshaft endplay can result in serious damage. Insufficient clearance will prevent proper lubrication of the thrust surfaces causing the main bearings to overheat and lock on the shaft.

2.6 Lifting Requirement

Inappropriate lifting might damage the engine while moving.

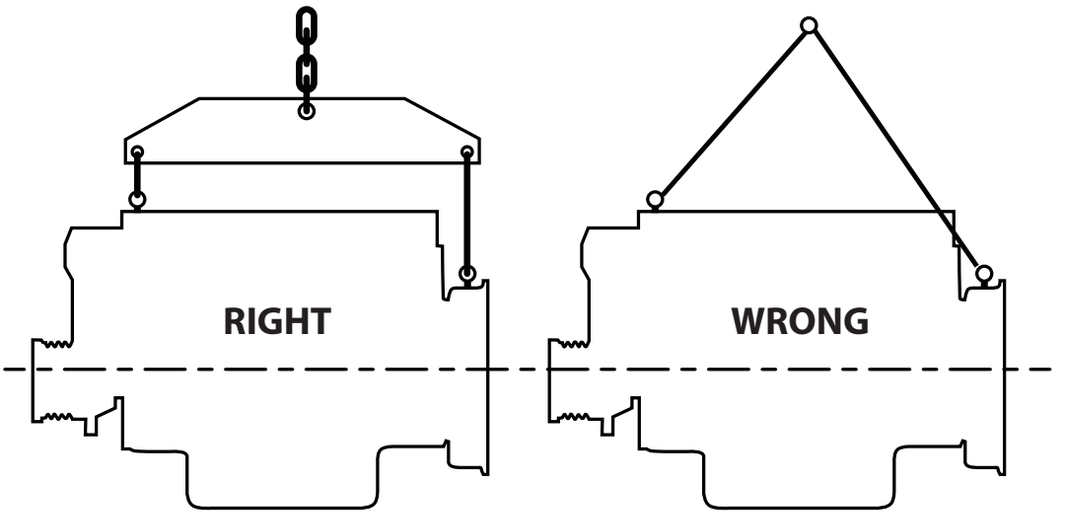


FIGURE 5. Engine lifting diagram

It is inappropriate to use a chain and a triangle to sling the engine up. In a triangle sling, the cylinder head bolt and the swinging ring are not kept in a line. The cylinder head bolt could be damaged or even fractured which may eventually lead to the failure of the engine.

3 Operation

3.1 Preparation Before Starting

The engine should not be started until it is properly installed in its final position. Check for free rotation - if the engine has not been rotated for some time, oil it through the spark plug openings and check for rotation by hand before attempting to start the engine. Any resistance to free cranking should be thoroughly checked out; rust and corrosion can cause the engine to seize.

Check the connections for proper battery polarity.

3.1.1 Filling Engine with Oil

The oil must be of the proper weight and clean. See *"1.4 Lubrication System" on page 4*.

1. Make sure the oil drain plug is installed and properly tightened.
2. Open the oil cap and fill the case with oil until the oil reaches the full level on the dipstick.
3. Replace the oil filler cap.

Always check oil level before starting engine.

3.1.2 Filling Cooling Fluid

The cooling fluid is a mix of clean deionized water and antifreeze. Please follow the antifreeze manufacturers recommended process and quantities.

NOTE

Frequent water adding and water changing might result in encrustation. Leaking of the cooling system should be repaired as soon as possible. Add clean deionized water if at all possible and avoid changing the cooling fluid if possible. Fill the cooling fluid into the water inlet of the radiator or heat exchanger and discharge the air of the cooling system. Refer to "1.3 Cooling System" on page 3 for more detailed information on the cooling fluid. The cooling fluid level must be checked every time the engine is started.

3.1.3 Attaching Gas Line

When starting the engine for the first time, purge air from the gas line. This will clear air and any foreign matter from the gas line and provide fuel for starting immediately.

CAUTION

Natural gas is highly explosive.

3.2 Startup

Before Starting

1. Be sure the main clutch, circuit breaker, or other power transmission devices are disengaged.
2. Trace through the external cooling system to make sure all control valves are properly opened and the drain cocks closed. Check the coolant level.
3. Inspect drive belts, water pump, alternator, and other equipment. Examine for good condition and correct tension.
4. Make certain all guards are secure on engine and driven equipment.
5. Check the air restriction indicator, if engine is so equipped. Clean air filter element and dust cap if indicator shows red. Check oil bath type air cleaner daily.
6. Check the oil level as indicated on the oil dipstick prior to starting engine. Stop engine and recheck oil level after 5 to 10 minutes of operation at a low idle. Add oil as required to bring level to full mark.
7. If the engine has been standing idle for some time, bar it over by hand to be sure it is free.
8. On the speed control unit, make sure the GAIN, STABILITY and (if applicable) SPEED TRIM CONTROL are set to the mid position.

Start

Crank the engine with DC power applied to the governor system. The actuator will energize

to the maximum fuel position until the engine starts. The governor system should control the engine at a low idle speed. If the engine is unstable after starting, turn the "Gain" and "Stability" adjustments counterclockwise until the engine is stable.

3.2.1 Quick Trouble Check Chart

Check Controls	Follow starting steps, resetting safety controls. Remote or automatic operation engines have special procedures.
Check Fuel System	Be sure fuel is getting to the engine. Check to assure that the valves are open. Check the possibility of water, rust or pipe scale.
Check the Cooling System	Check the coolant level and assure that the system is not air locked. Check that the radiator is not blocked by trash, that the shutter is open and the fan is operating. Check that the water valves are open to the heat exchanger.
Check the Intake/ Exhaust System for Blockages	Check to see if the air filter is dirty and check the air restriction indicator. Make sure the air intake or exhaust outlet is not capped.
Check Ignition	See if there is water on the ignition parts and wires. Check for signs of corrosion at the wire terminals or for broken wires. Check to see if the spark plugs are properly gapped.

If these checks do not solve the problem, refer to *Chapter* .

3.2.2 Break-In Procedure

New or overhauled engines should receive a break-in run. This operation can be performed with the lube oil weight specified in *"1.4 Lubrication System" on page 4*. After a warm up of approximately 30 minutes, proceed with a load and unload cycle. Repeated loading (minimum of half load, maximum full load) with equal idle periods in 5 minute intervals for a period of two hours. This results in a rapid break-in and quick seating of piston rings. Never idle for more than 15 minutes during the break in or for the first 100 hours of operation.

NOTE

Stand by generator engines should follow this procedure using a load bank.

3.2.3 Exercise of Standby Unit

It is recommended that a generator set or other standby units be exercised once each week. A record should be maintained of performance, incidental servicing and output of both the engine and driven equipment.

Always operate the engine long enough to stabilize oil and water temperatures at the normal operating level expected under load. Do not operate under no load conditions for other than very brief periods. Loads of at least one third up to the normal rated capacity are recommended. Ordinarily, an exercise run of one and one half hours will be needed to stabilize temperatures. If the engine cannot be loaded it should not be exercised for more than 10 minutes each exercise period.

It is recognized that some types of driven equipment cannot be operated without fairly extensive procedures to put them on line. Examples are hospital generators in some types of switching configurations; air conditioning compressors which can only be loaded by changing over to chilled water from heating water circulation; and pumps which are not set up for waste discharge or recirculation. In such cases, weekly exercise periods may have to be reduced, where possible, to operational periods long enough only to prove the engines ability to crank and start or checkout of starting circuitry and safety equipment with the starter disabled. In this event, special attention must be taken to prevent internal corrosion, sticking and gumming of fuel controls and deteriorated starting batteries. In all cases, arrangements should be made to run the engine

and driven equipment under load at least every 90 days.

Light Load Operation
We recommend the following maintenance schedule for A-90 engines that are consistently run at 25% or less of the continuous duty rating. This schedule is to be followed in addition to standard maintenance procedures.

Maintain engine jacket coolant temperature between 160°F and 190°F (82.25°C - 87.75°C)

Air cleaner elements should be checked periodically. Clean and replace as required.

At 50 hours of operation, run engine at 50% load or better to clean carbon off valves and pistons.

Inspection and overhaul schedule of cylinder heads should be updated to allow for a 25% reduction in hours between servicing.

Change lube oil every 750 hours.

When operating above 25% of continuous duty rating, follow normal maintenance schedule.

3.2.4 Engine Warm-up

Proper engine warm up is important for long engine life. A warm up period allows for an even thermal expansion of engine components. Also, the lubricant warms up and attains normal viscosity during warm up. Oil pressure is also built up assuring proper oil distribution and lubrication of vital engine parts.

NOTE

Standby units that require immediate full load pick up can be equipped to maintain a constant oil pressure and engine temperature. Consult your SES Arrow distributor for further information.

To warm the engine up, run the engine at medium engine speed with no load. Warm up engine until oil pressure stabilizes and coolant temperature reaches at least 100°F - 120°F (37.78°C-48.89°C.)

Caution

If adequate oil pressure is not indicated within 25 to 30 seconds shut the engine down at once and determine the cause. Never operate an engine without adequate oil pressure readings in the hope that a faulty gauge or cold oil is responsible. The problem could be something else and serious engine damage would result.

3.2.5 Governor Speed Setting

The Speed set point is increased by clockwise rotation of the "Speed" rotation pot.

Once the engine is at operating speed and at no load, the following governor performance adjustment may be made...

1. Rotate the "Gain" clockwise until instability develops. Gradually move the adjustment counterclockwise until stability returns. Move the adjustment one division further counterclockwise to insure stable performance (270°pot.)
2. Rotate the "Stability" clockwise until instability develops. Gradually move the adjustment counterclockwise until stability returns. Move the adjustment one division further counterclockwise to insure stable performance (270°pot.)
3. "Gain" and "Stability" adjustments may require minor changes after engine load is applied. Normally, adjustments made with no load achieves satisfactory performance. A strip chart recorder can be used to further optimize the adjustments.

If instability cannot be corrected or further performance improvements are required, refer to *Chapter "8 Troubleshooting" on page 78*.

3.3 Stopping Engine

Do not stop the engine with a full load. Decrease the speed before stopping the engine and let it idle for another 5 to 10 minutes. . Shut the power off after the engine is stopped

Any engine whose cooling system does not contain antifreeze must be drained after the engine is stopped to prevent the engine from being damaged in cold weather.

4 Maintenance

4.1 Time table for Maintenance

REGULAR SCHEDULED MAINTENANCE						
MAINTENANCE ITEM	**OPERATING TIME IN HOURS**					
	Day	**Wk**	**250**	**750**	**1000**	**Yr**
Check air restriction indicator and clean filter if the indicator is red	x					
Check oil and coolant levels	x					
Clean the air filter element*				x		
Check and tension the V-belt				x		
Clean the crankcase breather				x		
Spark Plugs - Inspect - gap 0.028” (0.711mm)				x		
Replace - Spark plugs				x		
Change the oil and oil filter element / disassemble and clean oil spinner unit.				x		
Check valve clearance				x		
Check anti-freeze concentration				x		
Carburetor - Inspect diaphragm and replace if cracked or deteriorated				x		x
Lubricate clutch at the manufactures recommended intervals.				x		

** More frequently in dusty conditions .*

4.1.1 Engine Performance Record

Engine operating information, recorded during regular inspections is necessary to apply proper Preventive Maintenance schedules. Accurate records help control costs by avoiding unnecessary servicing, ensuring needed servicing and provide trend information on the general engine condition. We recommend keeping a record of the following information, selecting items that apply to your engine:

- Hour Meter Reading
- Tachometer rpm
- Fuel Meter Reading
- Engine Oil Pressure
- Engine Oil Temp
- Coolant Temperature
- Gas Pressure at the Carburetor Intake
- Manifold Vacuum
- Crankcase Pressure pos/neg
- Unusual Noise(s) Or Vibration
- Oil Leaks
- Coolant Leaks
- Alternator Output

4.1.2 Fuels

SES Arrow A-90 gas engines are designed to burn natural gas. All power ratings are based on natural gas with a heat value of 900 BTU/ cu. ft. (LHV)

Required fuel conditions:

1. 900 to 1100 BTU's. Octane rating of at least 85.
2. Maximum liquid fuel hydrocarbons at the coldest expected engine mounted regula-tor fuel outlet temperature is 2% or less by gaseous volume.
3. Maximum total organic halide content, expressed as chlorine concentration (TOHC1), is 60 micrograms/liter.
4. Maximum permissible free hydrogen is 12% by volume.
5. Maximum solid particle size is 5 microns.
6. No liquid water is permitted at the outlet of the engine mounted fuel regulator at the coldest expected temperature.

4.2 Maintenance Procedures

4.2.1 Air Filter

An air restriction indicator device mounted in the piping from the circular style air filter serves as positive evidence when air filter service is necessary.

CAUTION

Unless the signal is locked in view indicating a clogged air cleaner, it will return to a normal setting upon engine shut down. Normally the element is serviced long before the gauge indicates a need but the operator is cautioned to check the gauge every day while the engine is running. After the element has been serviced, the reset button on the restriction indicator should be depressed to re-set it.

The A-90 engines use a circular style air cleaner. This style cleaner is has a pre-cleaner built into each assembly. Dirt trapped by this pre-cleaner will be collected in a dust cup on the end of the filter.

4.2.2 Check Connection Bolt

Check the bolts of the engine, generator and intake/exhaust manifold and the connections of bolts and hoses and retighten them if necessary.

4.2.3 Check and Tension V-belt

Press the V-belt - if the distortion is more than 3/8"-5/8" (10-15mm) the belt should be tightened or replaced.

To tighten the alternator belt, loosen the bolt (1), pull the alternator outwards, then tighten the bolt and check the belt tension by hand.

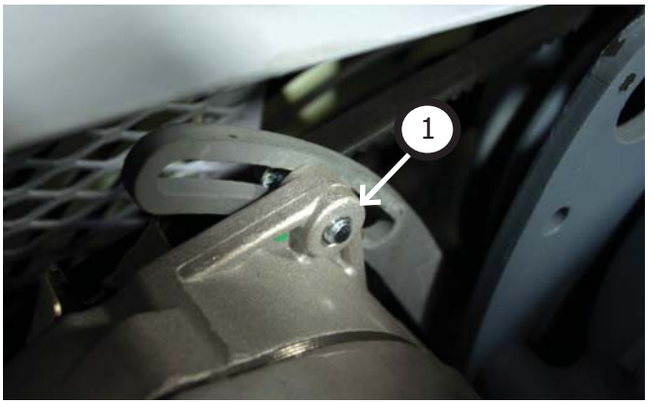


FIGURE 7. Alternator

4.2.4 Cooling System

The cooling water of the engine must be deionized water mixed with an anticorrosive (in warmer climates) or antifreeze (in cooler climates.)

Antifreeze

The cooling system of the bare engine holds about 13.6 Gal without provision for other equipment. When adding antifreeze compounds on a percentage basis remember to include the coolant volume of the radiator and other external parts of the cooling system. The following table may be used as a guide.

Please refer to the antifreeze manufacturers instructions for the mixing ratio of long acting anti freeze fluid.

ANTIFREEZE MIXING PERCENTAGES

Glycol content - %	25%	33%	50%	56%
Density at 60°F (15.6°C)		1.05	1.074	1.082
Radiator Glycerine (GPA)	55%	70%	100%	100%
Boiling point		220.1±2°F (104.5±1°C)	227.3±2°F (108.5±1°C)	230±2°F (110.0±1°C)
Freezing point	10±2°F (-12.2±1°C)	-0.4±2°F (-18±1°C)	-32.8±2°F (-36±1°C)	-49±2°F (-45±1°C)
Antifreeze to water ratio.	25/75	33/67	50/50	56/44

The concentration of the antifreeze should be checked once every 1,000 hours or once every season. The antifreeze should be changed every two years to avoid corrosion. Exhaust manifold requires draining if water is used.

4.2.5 Anticorrosive agent

Never fill the cooling system with only water, if the engine is to be exposed to sub freezing temperatures. If it is planned to leave the coolant in the engine at the next shutdown, mix the proper proportion of antifreeze and water before filling the engine.

4.2.6 Thermostat

Under normal conditions the heat sensitive thermostat in the water outlet will maintain temperatures within the desired limits.

4.2.7 Thermostat Inspection

Ordinarily, thermostats will seldom need replacement in the field. They should be checked from time to time however and are quickly accessible by removing the thermostat housing at the forward end of the cylinder head. The steps necessary to accomplish this are simply the removal of the water outlet connection hose, and the cap screws securing the housing. Thermostats

damaged by corrosion or other causes are not repairable and must be replaced.

4.2.8 Cleaning the cooling system

When clean deionized water is used as a coolant and when the proper inhibitors or antifreeze solutions are used, radiator and cooling passage accumulations will not be excessive. About once each year, however, the engine will benefit if the cooling system is cleaned of sludge and sediment. It is recognized that a number of excellent commercial cooling system clean-ers are available SES Arrow ENGINE COMPANY SUGGESTS, HOWEVER, THAT AN OPERATOR CONSIDERING THE USE OF SUCH A CLEANER FIRST INVESTIGATE ITS POSSIBLE REACTION WITH THE COPPER AND BRONZE PARTS IN THE ENGINE. If such a cleaner is used, follow the manufacturers recommendations carefully.

NOTE

Multi-viscosity oils, 10W30 for example, should be used only when cold starting conditions make it absolutely necessary. Oil change periods should be reduced by 50% for engines using multi-viscosity oil because multi-viscosity oils may rapidly lose their highest viscosity rating in industrial service.

4.2.9 Oil Consumption

Oil consumption should range from 0.0005 to 0.004 pounds per horsepower hour as determined by the following formula:

$$\text{LBS HP HR} = \frac{1.82 \times \text{Quarts of oil used}}{\text{Operating HP} \times \text{total hours of operation}}$$

4.2.10 Oil Changes

The oil level and condition should be checked prior starting the engine each morning. Replace oil at any time it is plainly diluted, broken down, thickened by sludge or otherwise deteriorated. Remember that some modern oils cannot be judged on the basis of color alone because the additives are intended to hold carbon particles in suspension. The standard filters supplied will not remove these particles. The dark appearance of the oil is not necessarily an indication that the oil should be changed. Whenever oil is changed the filters must be serviced. Oil performance will reflect engine load, temperature, fuel quality, atmospheric dirt, moisture and maintenance. Where oil performance problems arise or are anticipated, the oil supplier should be consulted.

RECOMMENDED OIL CHANGE INTERVALS

Hours	Usage
750	For continuous duty operation at continuous duty rating. Clean environment with oil sump temperature of 190-220°F
200	For engines operated in excess of continuous duty rating
500	For engines operated consistently at 25 or less of continuous duty rating (light load operation)
300	For engines in stand by service

If stand by service is less annually than hourly intervals listed, change oil annually.

Extended oil change intervals should be utilized with caution on any engine using highly dispersant oils. The dispersants function by absorption of particles of contaminants; however when dispersant saturation is reached, these oils tend to "dump out" all of the suspended contaminants in a relatively short period of time. Laboratory analysis will not predict the dump out point precisely. Consequently, close attention to engine conditions by the operator is required when establishing an extended oil change interval.

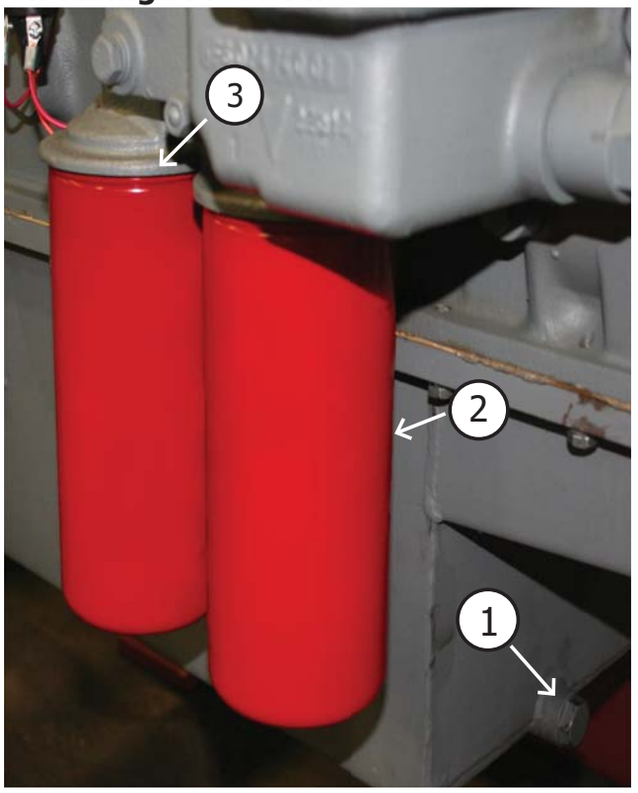
When using an engine oil with which you have no previous operating experience, a well monitored maintenance program should be conducted to observe the engines performance and interval condition for the first years usage. This procedure will help in determining if the new oil is compatible to your type of operation.

CAUTION

The use of some types of oil, as well as dusty environment, marginal installation, internal engine condition and/or operating the engine with malfunctioning carburetion equipment may require more frequent oil changes. We suggest the lubricating oil be monitored with a good oil

analysis program. Contact your local SES Arrow Dis-tributor for periodic engine maintenance.

Oil Change Procedure



1. Start the engine and run until reaching operating temperature.
2. Place an oil pan under the engine.
3. Remove the drain plug, (1), paying attention to the seal ring on the plug. (If applicable)
4. Drain the oil.
5. Replace the drain plug (1) with seal ring. (If applicable)
6. Replace the oil filter elements.

    a. Remove the oil filters (2)

    b. Apply oil on the filter seal rings (3) and tighten the new filter element by hand.
7. Fill with clean oil up to the full mark on the dipstick.
8. Operate the engine for a few minutes in order to circulate the oil throughout the system. Check the tightness of the new oil filter element while the engine is running.
9. Stop the engine and check to see if any additional oil is required. Bring the oil level to the "full" mark.

Not all oils in every type of engine will give maximum service. Therefore be careful to examine the oil after the first draining to determine whether it is standing up in service. Trial periods of 10 hours are suggested. At the end of such periods make a careful inspection of the oil depth gauge for sludging, frothing and emulsification. Such conditions call for more frequent changes or a different oil. In cold weather operation, low oil temperatures - below 160°F (71.1°C) - are particularly likely to cause sludge formation. Temperature control devices such as curtains or shutters should be used if needed in order to hold the oil temperature around 180°F (82.2°C).

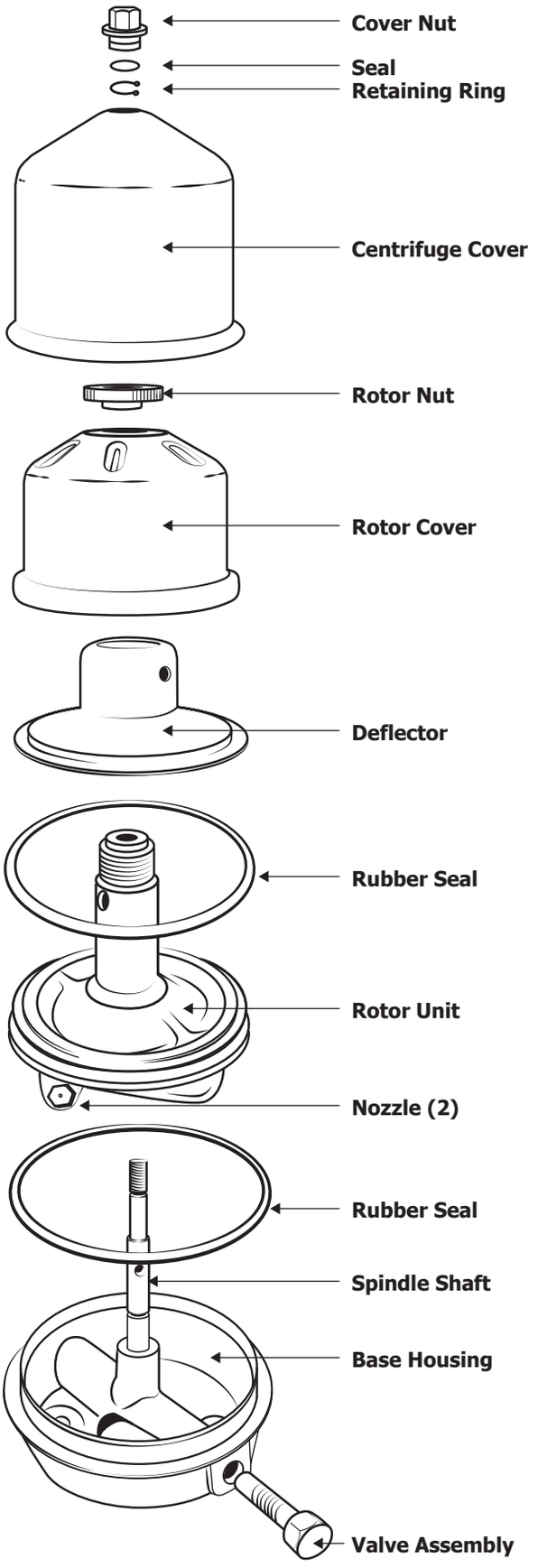
4.2.11 Oil Filters

Full flow filters are an integral part of the lubrication system. Never block off the filter even temporarily when running the engine. ALL OIL GOING TO THE ENGINE MUST PASS THROUGH THE FILTER. For this reason it is very important when changing oil that the element be changed and the filter parts thoroughly washed to prevent clogging or blocking of the oil flow to the engine. At the same time, the by pass valve should be examined for proper operation. To ensure a clean job without leaks it is important that the filter seal gasket be handled carefully and replaced at the same time as the element.

4.2.12 Centrifuge Oil Filter

The Centrifuge oil filter cleans your engine continuously when your engine is running. It separates dirt below 1 micron from engine oil thus lowering the wear rate of engine components drastically. It avoids harmful oil degradation and arrests depletion of oil additives increasing the oil life. The Centrifuge cleaner does not require any spare parts to be replaced and gives consistent performance throughout engine life.

CENTRIFUGE OIL FILTER

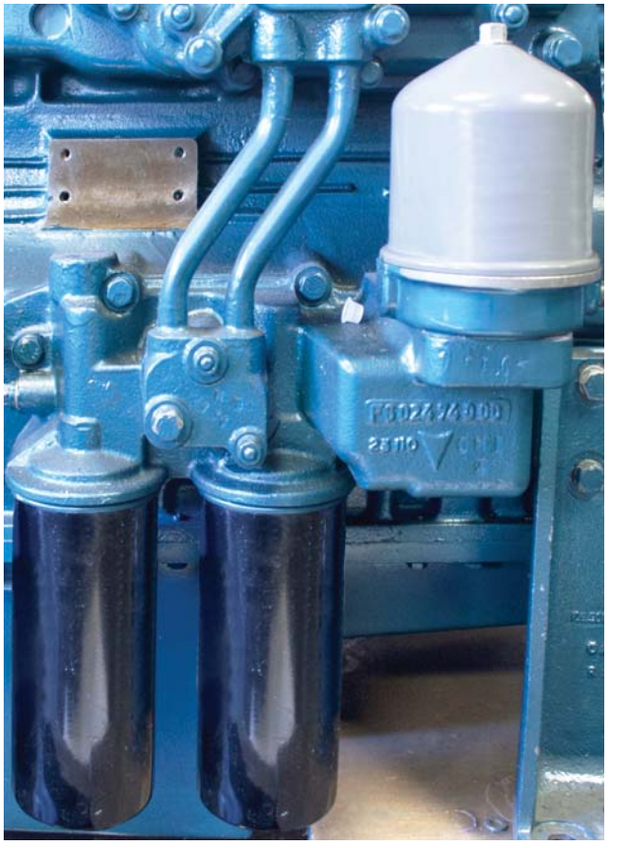


4.2.13 Cleaning frequency:

For consistent performance, the centrifuge rotor needs to be cleaned periodically. It is recommended that you service the centrifuge filter at every oil change period. The volume of dirt collected depends upon engine application, loading and environment in which engine is working. Exact time of servicing the centrifuge can vary depending on your oil change periods. Please follow the instructions below for cleaning the centrifuge filter.

4.2.14 Identification and Location

The Centrifuge is located on the same manifold on which full flow oil filter is mounted. The centrifuge can be easily identified with a dome shaped cover bearing instruction sticker. The exact location is as shown in this photograph.



4.2.15 Servicing Instructions:

- It is a precision assembly, handle with care.
- Carry out servicing preferably when the engine oil is still warm.
- All threaded parts in this centrifuge assembly have right hand threads.

- Servicing of the centrifuge require following tools: 13mm wrench, a blunt knife, small adjustable pliers, and waste rags for cleaning.

4.2.16 Servicing Procedure:

1. Unscrew top nut with a 13mm wrench and remove centrifuge cover. The centrifuge cover nut has a puller arrangement so that the cover will be lifted as you unscrew the nut.

2. Hold the rotor in hand and lift to remove it completely from central shaft. The rotor will contain about 7oz of oil, drain oil from rotor. The rotor has two bushings at its ends. Take care while removing rotor from central shaft. The rotor should not fall; otherwise it will damage the bushings.

3. Unscrew rotor nut by holding rotor assembly in hand. The rotor nut can be opened by hand. If it is tight, unscrew it with light pliers. Never grip the rotor nut tightly in clamping device like a bench vice. It may damage the rotor body permanently. Remove rotor cover and deflector inside. For removing rotor cover, remove the rotor nut completely, hold the rotor cover in hand and give a light blow to the rotor body at the rotor nut end by hand. The rotor body and deflector will come out from the opposite end.

4. After you open the rotor, you will see cake formed sticky dirt mass all around the rotor cover from inside. Remove the dirt by a blunt

knife. Clean the rotor cover and all rotors thoroughly. Be sure to clean the centrifuge center shaft.

5. Assemble rotor in correct sequence of parts. Match Arrow marks on rotor cover and rotor. Tighten nut firmly by hand. Install rotor on shaft and assemble cleaner cover.

4.2.17 Centrifuge Cleaner Check Points

1. Replace rubber rings if deformation or cuts are observed. Using damaged rubber rings will result in oil leakage and improper function of the centrifuge filter.
2. While assembling the rotor, ensure the rubber ring has taken proper seat in its place. This is necessary for proper sealing of rotor assembly.
3. Take care with the centrifuge housing and rotor body. They are made of aluminum, hence are susceptible to damage due to accident.
4. Always ensure that the arrow marks on rotor cover and rotors are matched after assembling the rotor. The rotor body is dynamically balance, mismatch of arrow marks on rotor cover and rotor will result in excessive vibrations of the cleaner and part breakage.
5. The rubber ring of the rotor is made of Viton rubber. Use genuine spare rubber rings only. Rubber ring of any other material will not deliver desired performance.

4.2.18 Centrifuge Cleaner Do Nots

1. Do not over tighten the top nut. Tighten just enough to prevent leakage of oil for centrifuge cover and housing. Over tightening the top nut will damage the threads in the centrifuge housing and damage the centrifuge permanently. Use 9 ft/lbs torque for tightening of centrifuge cover.
2. Do not hold the rotor nut in a clamping device like a bench vice. Extra clamping pressure on rotor nut may result in damaging the circularity of the upper bushing and will result in permanent damage to the rotor assembly.
3. Do not open or tamper with the valve assembly. The valve assembly is preset for opening oil pressure in engine's oil gallery. If the setting is lost or the valve assembly is damaged, there is a risk that your engine will not get enough oil or the centrifuge will not function properly.

4.3 Troubleshooting Chart

	Problem	Problem Cause	Action
1.	Leakage through cleaner.	Rectangular rubber ring damage.	Change rubber ring.
2.	Rotor does not rotate.	Nozzle block.	Open rotor and clean nozzles thoroughly. Reassemble the cleaner.
3.	Rotor does not rotate even after cleaning nozzles.	Entry valve blocked.	Do not open entry valve assembly. It requires special tools. Contact company representative.
4.	Rotor rotates but at low speed.	Leakage of oil through rotor assembly	Open rotor and ensure that the rubber ring has taken proper seat on rotor body. Then reassemble the rotor.
5.	Rotor speed very low or even rotor does not rotate	Brushes damaged permanently.	Ensure that the rotor is free on shaft. Else replace entire rotor assembly.
6.	Rotor rotates but at low speed	Rotor filled with dirt completely.	Time for cleaning the rotor.
7.	Abnormal vibrations of centrifuge cleaner.	Mismatch between arrow marks on rotor cover and rotor.	Open rotor and reassemble it properly.
8.	Cleaner does not collect any dirt.	Rotor not rotating at desired speed.	See point no 2 & 3. Consult authorized representative.

4.4 Compression Testing

NOTE

Throttle blade must be open during crank for correct pressure readings during compression testing.

To check the compression of gas engines, a standard automotive type compression tester with a threaded adaptor may be used.

Before checking compression, be sure the engine has been warmed up to operating temperature. Gas engines must have the throttle held wide open, and the ignition switch in off position. Note the number of compression strokes needed to obtain the highest pressure reading. Repeat compression testing for each cylinder using the same number of compression strokes as used for the first cylinder tested.

Uneven compression or pressures lower than normal call for further checking, Valve replacement or other overhaul procedures may be required to correct the problem.

4.5 Clean Breather Body

The breather body needs to be serviced periodically depending on conditions. Colder operation conditions and use of wet fuel can result in water buildup in the oil system resulting in the necessity for service.

The crankcase breather is located on the valve cover.

1. Loosen hose clamp (1.)
2. Clean the breather body in solvent.
3. Re-install the breather body
4. Tighten the hose clamp (1.)

4.6 Manifold Vacuum Test

Operate the engine until it is at normal operating temperature.

Connect vacuum gauge to the intake manifold and test with engine operating at idle speed with no load.

MANIFOLD VACUUM TEST

Gauge Readings	Engine Condition
18 - 19" Hg (457 - 483mm) at Idle Speed (approx.)	
High and steady	Good
Low and steady	Loss of power in all cylinders possibly caused by late ignition or valve timing, or loss of compression due to leakage around the rings.
Very Low	Manifold, carburetor or cylinder head gasket leak
Needle fluctuates steadily as speed increases	A partial or complete loss of power in one or more cylinders caused by: a leaking valve, cylinder head or intake manifold gasket leak, a defect in the ignition system or a weak valve spring.
Gradual drop in reading at engine idle	Excessive back pressure in the exhaust system.
Intermittent Fluctuation	An occasional loss of power possibly caused by a defect in the ignition system or a sticking valve.
Slow fluctuation or drifting of the needle	Improper idle mixture adjustment, or carburetor, spacer, or intake manifold gasket leak.

4.7 Spark Plug Adjustments

Misfiring or erratic operation may be due to faulty spark plugs caused by carbon accumulations and burning of the electrodes. They should be cleaned, inspected and the gaps checked approximately every 250 hours of operation or more often if the engine idles for prolonged periods. After 500 hours, it is advisable to replace the entire set when any spark plug is defective.

Deposits on the electrodes and insulator may be removed by commercial abrasive cleaners. Scraping the insulator is not recommended since the resulting scratches increase the tendency of carbon deposits to form.

After the spark plug has been cleaned, adjust the gap with a round wire gauging tool to 0.028" (0.711mm) by bending the outer electrode. As the spark plugs will have a tendency to burn the electrodes and widen the gap, it is important that gap be checked whenever the plugs are removed from the engine. Missing at low speeds is very often due to a wide spark plug gap.

Examine for cracked porcelain, leakage, burned electrodes, deposits on center insulator, correct gap, good washers and clean threads and seating surface. Remember a plug may appear satisfactory and still miss.

NOTE

When replacing spark plugs, use new gaskets. Proper seating of the gasket is necessary for sealing the combustion chamber and transferring heat from the plug. Use spark plug tap to clean threads, allowing for proper heat transfer.

4.8 Inspection & Servicing of Lube Oil Cooler

The plate-type cooler is located in the crankcase cavity. Under normal operating conditions, the oil cooler does not require any servicing. However when the cooler is removed during the engine overhaul, it is advisable to service it.

4.9 Adjusting the Carburetor (NA)

(Non emission equipped engines only.) To adjust the carburetors, take the following steps:

1. Open the gas regulating valve at the carburetor fuel inlet. With the dial cock open, the engine will hit and run.
2. With the engine at desired speed and load, adjust the dial cock so the engine runs the smoothest and easiest, with no knocking, deceleration, or fluctuation of speed.
3. Gradually close the fuel regulating valve at the carburetor inlet to a point where the engine just begins to fluctuate, opening it back up to where the engine just smooths out again. Then open the dial cock all the way.
4. Open the throttle all the way by hand to assure the engine will pick up load without hesitation or missing. If it does not, open the fuel regulating valve to a point where the engine will speed up smoothly. Proper fuel adjustments are important to insure efficient operation, full-rated power, and longest life.

4.10 Turbo Fuel System Setup

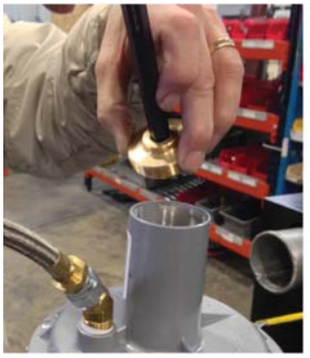
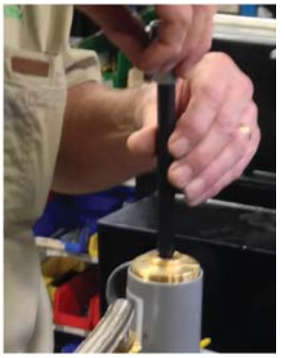
Fuel system components:

- Main fuel cut regulator
- Engine mounted regulator
- Push through fuel mixer
- 1 1/2" fuel control valve
- 1/2" boost balance tube

The main cut fuel regulator must have a 1/2" orifice and needs to be set at 8 psi for correct operation. More than 8 psi gas pressure will damage the engine mounted fuel regulator. The fuel control valve must be at least 1 1/4" as the rest of the fuel piping between the engine regulator and gas mixer.

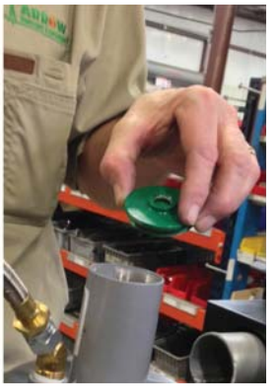
The engine mounted regulator consists of a main spring red in color and can be adjusted by removing the top threaded seal at the top. With engine off, unscrew the top threaded cap and remove the locking nut inside the regulator with the correct size Allen wrench.


Once the locking screw is removed, with the same Allen wrench, screw the spring adjusting nut all the way out of the regulator, counting the number of turns as the nut is removed.

Check spring for damage, then start threading the first regulator nut down 22 turns. The 22 turns should allow for good starting and the ability to operate under turbo boost pressure during high loads. More or less turns may be required depending on fuels or temps, etc. Be sure to re-install the second locking nut after adjustment.





If measuring fuel pressure between engine regulator and mixer during start up the pressure should be between 1 to 3 in (more gas pressure during start may cause hard starting or a flood condition). The push through mixer carb has one fuel adjustment screw on the back side of the mixer. The recommended setting is 5-6 turns out as a good starting point.

NOTE

The more turns out the richer fuel ratio, more turns in results in a leaner fuel ratio.

This screw can be set to find the middle range for automatic fuel mode on most AFR control systems keeping the fuel valve in the middle range.

The balance tube must remain in place and gives the engine regulator the ability to react to turbo boost pressure. The fuel pressure between the regulator and mixer carb must always be slightly higher than the turbo boost pressure. Turbo boost pressure on A-90 TA's run between 6-7 psi during full load. Thus explaining why the main 1/2' orifice cut regulator must maintain 8 psi during full load operation.

The push through carburetion system is much safer than some of the older designs because no fuel is introduced into the intercooler or boost pipe system which under certain conditions can cause an explosion resulting in intercooler/turbo damage or worse.

4.11 Speed Control Unit

The governed speed set point is increased by clockwise rotation of the SPEED adjustment pot.

To adjust the performance of the governor, please take the following steps:

1. Bring the engine to it's normal operating speed with no load.
2. Rotate the GAIN adjustment clockwise until instability develops. Gradually move the adjustment counterclockwise until stability returns. Move the adjustment one division further to insure stable performance (270° pot.)
3. Rotate the STABILITY adjustment clockwise until instability develops. Gradually move the adjustment counterclockwise until stability returns. Move the adjustment one division further to insure stable performance (270° pot.)
4. GAIN and STABILITY adjustments may require minor changes after engine load is applied. Normally, adjustments made at no load provide satisfactory performance. A strip chart recorder can be used to further optimize the adjustments.

If instability cannot be corrected or further performance improvements are required, please refer to the troubleshooting section *"8.7 Governing Systems" on page 79*.

4.11.1 Idle Speed Setting

After the governor speed setting has been adjusted, place the optional external selector switch in the IDLE position. The idle speed set point is increased by the clockwise rotation of the IDLE adjustment control. When the engine is at idle speed, the speed control unit applied droop to the governor system to insure stable operation.

4.12 Integral Throttle Body Actuator

4.12.1 Idle Adjustment

An adjustable idle stop setscrew is provided to set a fixed fuel opening, if desired. Using the appropriate Hex wrench, you must completely remove the first "locking" setscrew. This will give you access to the inner idle adjustment setscrew for adjustment using the same hex wrench. Turning the wrench clockwise will increase the fixed throttle opening. Typically, the engine speed should be set by unplugging the actuator or by turning off the governor power once the engine is running and then setting the engine speed to the desired setting. Adjustment is complete once you have replaced the locking setscrew. The locking setscrew should only be tightened to snug plus a 1/4 turn.

4.12.2 Wiring

All throttle body actuators are pre-wired for either 12 or 24 VDC systems. Use the included wire harness to connect the actuator to the speed control unit's output terminals. Prior to connecting the actuator cable, twist it so that there is about one complete twist per inch (2.5 cm) along the entire length of the cable. This will substantially reduce EMI effects on the control system. For applications where EMI is

still a concern, shielded cable for the actuator is recommended.

4.12.3 EMI (Defined)

Electromagnetic interference (EMI) is the radiation or induction of electromagnetic noise on a system. DC motors are a common source of EMI, as are most electromagnetic circuit components. They are potential sources of noise and can generate common-mode currents. EMI can result in degraded performance, data corruptions, or if strong enough can cause the system to fail completely. EMI can be radiated or conducted comes from magnetic and electrical sources, respectively. In the case of DC motors, both radiated and conducted emissions are present.

5 Clearances & Wear Limits

5.1 Cylinder Head

Description	Nominal Dimension	
	inch	mm
Cylinder Head		
Valve guide outside diameter	0.709 to 0.710	18.028 to 18.046
Valve guide bore in cylinder head	0.708 to 0.709	18.000 to 18.018
Valve guide inside bore diameter	0.472 to 0.473	12.000 to 12.018
LIMIT: Valve guide value	0.476	12.100
Intake valve stem diameter	0.470 to 0.471	11.946 to 11.960
LIMIT: Intake valve stem	0.469	11.920
Exhaust stem valve diameter	0.468 to 0.469	11.906 to 11.920
LIMIT: Exhaust stem valve	0.467	11.880
Intake valve stem clearance	0.001 to 0.002	0.040 to 0.072
LIMIT: Intake valve stem clearance	0.012	0.3
Exhaust stem valve clearance	0.003 to 0.004	0.080 to 0.112
LIMIT: Exhaust stem valve clearance	0.019	0.5
Intake seat bore in cylinder head	2.244 to 2.245	57.000 to 57.030
Intake seat outside diameter in cylinder head	2.249 to 2.250	57.127 to 57.140
Exhaust seat bore in cylinder head	2.126 to 2.127	54.00 to 54.030
Exhaust seat outside diameter in cylinder head	2.129 to 2.130	54.090 to 54.101
Depth of valve seat bore	0.457 to 0.460	11.600 to 11.700
Intake valve seat angle insert	30°	
Exhaust valve seat angle insert	45°	
Intake valve cone diameter	2.161 to 2.169	54.9 to 55.1
Exhaust valve cone diameter	2.004 to 2.012	50.9 to 51.1
Intake valve	29° to 30°	
Exhaust valve	44° to 45°	
Intake rim thickness	0.157	4
Exhaust rim thickness	0.082	2.1
LIMIT: Rim thickness	0.039	1
Intake valve recess (distance between cylinder head face and valve face) – Valve stand-in	0.023 to 0.029	0.60 to 0.75
LIMIT: Intake valve recess (distance between cylinder head face and valve face) – Valve stand-in	0.079	2
Exhaust valve recess (distance between cylinder head face and valve face) – Valve stand-in	0.039 to 0.047	1 to 1.2
LIMIT: Exhaust valve recess (distance between cylinder head face and valve face) – Valve stand-in	0.079	2

Description	Nominal Dimension	
	inch	mm
Cylinder Head (continued)		
Inner valve spring (total no of coils)	9.5	
Outer valve spring (total no of coils)	6.5	
Inner valve spring length	2.769	70.35
LIMIT: Inner valve spring length	2.638	67
Outer valve spring length	2.586	65.7
LIMIT: Outer valve spring length	2.441	62
Cylinder head bolt, long, nominal length	5.681 to 5.708	144.3 to 145
LIMIT: Cylinder head bolt, long, nominal length	5.720	145.3
Cylinder head bolt, short, nominal length	4.878 to 4.917	123.9 to 124.9
LIMIT: Cylinder head bolt, short, nominal length	4.929	125.2
Rocker support bore diameter	1.071 to 1.072	27.2 to 27.221
Rocker shaft outer diameter	1.072 to 1.073	27.235 to 27.256
LIMIT: Rocker support	1.069	27.156
Interference between rocker shaft and rocker support	0.001 to 0.002	0.014 to 0.056
Rocker shaft outer diameter for rocker lever	1.061 to 1.062	26.959 to 26.980
LIMIT: Rocker shaft outer diameter	1.058	26.880
Rocker lever inside diameter with bushing	1.063 to 1.064	27.0 to 27.021
Clearance between rocker shaft and rocker lever	0.001 to 0.002	0.020 to 0.062
LIMIT: Clearance between rocker shaft and lever	0.008	0.2
Cylinder head surface flatness	0.001 to 0.002	0.03 to 0.05
LIMIT: Cylinder head surface flatness	0.000	0.006
Intake valve clearance (warm)	0.014	0.356
Exhaust valve clearance (warm)	0.022	0.559
Bumping clearance	0.035 to 0.041	0.9 to 1.050
Bumping gasket thickness	0.049	1.25
Lifter inside diameter	1.218 to 1.242	30.950 to 31.550
Lifter outside diameter	1.414 to 1.415	35.924 to 35.949
LIMIT: Lifter diameter	1.411	35.849

5.2 Cylinder Liner

Description	Nominal Dimension	
	inch	mm
Cylinder Liner		
Cylinder liner bore, normal	4.645 to 4.647	118.000 to 118.027
WEAR LIMIT: Cylinder liner bore, normal	4.655	118.25
Cylinder liner bore, ovality	0.008	0.2
Cylinder liner, projection over block (liner protrusion)	0.002 to 0.005	0.06 to 0.14

5.3 Piston

Description	Nominal Dimension	
	inch	mm
Piston		
Piston diameter	4.634 to 4.635	117.719 to 117.739
Piston pin bore in piston	1.889 to 1.890	48.003 to 48.010
LIMIT: Piston pin bore	1.892	48.050
Piston outside diameter	1.929 to 1.889	48.994 to 48.000
Tapered compression ring groove width	0.113 to 0.115	2.885 to 2.915
Tapered angle	6°	
Scraper ring groove width	0.120 to 0.121	3.05 to 3.07
Oil control ring groove width	0.158 to 0.159	4.02 to 4.04
Clearance between piston skirt & liner	0.004 to 0.006	0.119 to 0.160
LIMIT: Clearance between piston skirt & liner	0.016	0.400

5.4 Piston rings

Description	Nominal Dimension	
	inch	mm
Piston Rings		
Tapered compression ring land clearance*	0.002 to 0.004	0.052 to 0.107
LIMIT: Tapered compression ring land clearance*	0.012	0.3
Scraper ring land clearance*	0.002 to 0.001	0.060 to 0.010
LIMIT: Scraper ring land clearance*	0.008	0.2
Oil control ring land clearance*	0.001 to 0.003	0.030 to 0.070
LIMIT: Oil control ring land clearance*	0.008	0.2
Tapered compression ring gaps**	0.019 to 0.020	0.25 to 0.50
LIMIT: Tapered compression ring gaps**	0.059	1.5
Scraper ring gaps**	0.011 to 0.023	0.30 to 0.60
LIMIT: Scraper ring gaps**	0.059	1.5
Oil control ring gaps**	0.019 to 0.022	0.25 to 0.55
LIMIT: Oil control ring gaps**	0.059	1.5

* Side clearance

** As measured in liner bore piston

5.5 Connecting Rod

Description	Nominal Dimension	
	inch	mm
Connecting Rod		
Crank end bore diameter (w/o shell)	3.346 to 3.347	85.0 to 85.022
Crank end bore diameter (with standard shell)	3.150 to 3.152	80.010 to 80.056
Number of under sizes	6 u/s in step of 0.25	
Clearance between crankshaft pin outside diameter and connecting rod bearing inside diameter	0.002 to 0.004	0.04 to 0.112
LIMIT: Clearance between crankshaft pin outside diameter and connecting rod bearing inside diameter	0.002*	0.4*
Width of bearing	1.445 to 1.456	36.7 to 37.0
Connecting rod width	1.921 to 1.923	48.80 to 48.85
Connecting rod side clearance normal	0.008 to 0.016	0.20 to 0.40
LIMIT: Connecting rod side clearance normal	0.031	0.8
Connecting rod small end bore w/o bushing	2.062 to 2.063	52.375 to 52.400
Connecting rod small end bore with bushing	1.891 to 1.892	48.03 to 48.045
LIMIT: Connecting rod small end bore	1.898	48.2
Clearance small end bushing and piston pin, normal	0.001 to 0.002	0.03 to 0.051
LIMIT: Clearance small end bushing and piston pin, normal	0.006	0.15

*Replacement of bearing is governed by oil pressure.

5.6 Intermediate Gear and Support

Description	Nominal Dimension	
	inch	mm
Intermediate Gear and Support		
Intermediate gear bore w/o bushing	3.150 to 3.151	80.0 to 80.030
Intermediate gear bore with bushing	2.953 to 2.954	75.010 to 75.040
Intermediate gear support journal diameter	2.950 to 2.951	74.93 to 74.95
Clearance intermediate gear bushing and journal diameter, normal	0.002 to 0.004	0.060 to 0.110
LIMIT: Clearance intermediate gear bushing and journal diameter, normal	0.007	0.18
Intermediate gear end play	0.002 to 0.004	0.060 to 0.110
Intermediate gear to crank gear backlash	0.078 to 0.009	0.078 to 0.227
Intermediate gear to camshaft gear backlash	0.004 to 0.011	0.106 to 0.277
Oil pump gear to crank gear backlash	0.003 to 0.009	0.078 to 0.221
Oil pump idler gear to oil pump gear backlash	0.003 to 0.017	0.076 to 0.436

5.7 Camshaft

Description	Nominal Dimension	
	inch	mm
Camshaft		
Bore 1 (flywheel end) Cam bore diam in crankcase w/o bearings	2.717 to 2.718	69.000 to 69.030
Bore 2 Cam bore diam in crankcase w/o bearings	2.726 to 2.728	69.250 to 69.280
Bore 3 Cam bore diam in crankcase w/o bearings	2.736 to 2.737	69.500 to 69.530
Bore 4 Cam bore diam in crankcase w/o bearings	2.746 to 2.747	69.750 to 69.780
Bore 5 Cam bore diam in crankcase w/o bearings	2.756 to 2.757	70.000 to 70.030
Bore 6 Cam bore diam in crankcase w/o bearings	2.766 to 2.767	70.250 to 70.280
Bore 7 Cam bore diam in crankcase w/o bearings	2.776 to 2.777	70.500 to 70.530
Bearing 1 Std. (flywheel end) Cam bore diameter in crankcase w/bearings	2.519 to 2.521	64.000 to 64.030
LIMIT: Bearing 1 Std.	2.522	64.060
Bearing 2 Std. Cam bore diameter in crankcase w/bearings	2.529 to 2.531	64.250 to 64.280
LIMIT: Bearing 2 Std.	2.532	64.310
Bearing 3 Std. Cam bore diameter in crankcase w/bearings	2.539 to 2.540	64.500 to 64.530
LIMIT: Bearing 3 Std.	2.542	64.560
Bearing 4 Std. Cam bore diameter in crankcase w/bearings	2.549 to 2.550	64.750 to 64.780
LIMIT: Bearing 4 Std.	2.551	64.810
Bearing 5 Std. Cam bore diameter in crankcase w/bearings	2.56 to 2.560	65.000 to 65.030
LIMIT: Bearing 5 Std.	2.561	65.060
Bearing 6 Std. Cam bore diameter in crankcase w/bearings	2.569 to 2.570	65.250 to 65.280
LIMIT: Bearing 6 Std.	2.571	65.310
Bearing 7 Std. Cam bore diameter in crankcase w/bearings	2.579 to 2.580	65.500 to 65.530
LIMIT: Bearing 7 Std.	2.581	65.560

5.8 Camshaft Journal Diameter

Description	Nominal Dimension	
	inch	mm
Camshaft Journal Diameter		
Journal 1 (flywheel end)	2.516 to 2.517	63.910 to 63.950
LIMIT: Journal 1	2.514	63.850
Journal 2	2.526 to 2.527	64.160 to 64.200
LIMIT: Journal 2	2.523	64.100
Journal 3	2.535 to 2.537	64.410 to 64.450
LIMIT: Journal 3	2.533	64.350
Journal 4	2.545 to 2.547	64.660 to 64.700
LIMIT: Journal 4	2.543	64.600
Journal 5	2.555 to 2.557	64.910 to 64.950
LIMIT: Journal 6	2.553	64.850
Journal 6	2.565 to 2.566	65.160 to 65.200
LIMIT: Journal 6	2.563	65.100
Journal 7	2.575 to 2.577	65.410 to 65.450
LIMIT: Journal 7	2.572	65.350
Clearance camshaft journal and bushing	0.002 to 0.005	0.05 to 0.12
LIMIT: Clearance camshaft journal and bushing	0.012	0.20*
Camshaft end play	0.003 to 0.007	0.070 to 0.170
Thrust plate thickness	0.194 to 0.196	4.940 to 4.970
Intake valve cam lift	0.304	7.72
Exhaust valve cam lift	0.338	8.58

* Replacement of bearing is governed by oil pressure.

5.9 Crankshaft

Description	Nominal Dimension	
	inch	mm
Crankshaft		
Crankshaft bore in crankcase w/o bearing	3.937 to 3.938	100.000 to 100.022
Crankshaft bore in crankcase with bearing (std)	3.741 to 3.743	95.020 to 95.072
Crankshaft journal diameter	3.737 to 3.738	94.930 to 94.950
LIMIT: Crankshaft journal diameter	3.734	94.850
Number of under sizes	6 u/s in steps of 0.25	
Hardness	58 + 3 HRC	
LIMIT: Hardness	50 HRC	
Clearance (Crankshaft journal outside diameter and main bearing inside diameter)	0.003 to 0.005	0.070 to 0.142
LIMIT: Clearance crankshaft journal)	0.012	0.30*
Journal width	1.823 to 1.824	46.3 to 46.339
LIMIT: Journal width	1.827	46.400
Fillet radius for journal	0.177 to 0.197	4.5 to 5
Fillet radius for pin diameter	0.226 to 0.246	5.75 to 6.25
Crank pin diameter	3.147 to 3.148	79.930 to 79.950
LIMIT: Crank pin diameter	3.144	79.850
Number of under sizes	6 u/s in steps of 0.25	
Hardness	58 + 3 HRC	
LIMIT: Hardness	50 HRC	
Thrust washer thickness	0.094 to 0.097	2.400 to 2.470
LIMIT: Thrust washer thickness	0.091	2.320
Thrust washer inside diameter	4.067 to 4.090	103.3 to 103.88

Description	Nominal Dimension	
	inch	mm
Thrust washer outside diameter	4.906 to 4.921	124.62 to 125
Crank pin width	1.931 to 1.937	49.05 to 49.2
Form tolerances for crankshaft – Roundness	0.0002	0.006
Form tolerances for crankshaft – Straightness	0.0002	0.006
Form tolerances for crankshaft – Parallelism	0.0001	0.005
Crankshaft end play	0.005 to 0.013	0.130 to 0.338
LIMIT: Crankshaft end play	0.031	0.8

* Replacement of bearing is governed by oil pressure.

5.10 Oil System

Description	Nominal Dimension
Oil System	
Oil pump engine speed	1800 rpm
Oil pump speed	1800 rpm
Oil pressure	65 to 75 psi

5.11 Water Pump

Description	Nominal Dimension
Water Pump	
Water pump speed	2300 rpm
Water pump flow rate	59 gpm
Water pump pressure	10.23 psi

6 Engine Storage

6.1 Basic Requirements

Preservation of engines and generators in storage involves several basic requirements. For new engines and generators, these are as follows:

1. Protection of machined metal surfaces, cylinders, valves, bearings and so on, from the effects of both dampness and salt or other corrosive substances in the atmosphere.
2. Protection of openings into the engine against the entrance of dirt, abrasive material and foreign matter of all types.
3. Protection of accessory equipment including carburetors, gas regulators, ignitions, starters, alternators and fan belts against corrosion, dirt, moisture saturation and progressive deterioration.
4. Protection of cooling system intercoolers and LPG vaporizers against freezing, rusting or seizure of water pump seals.
5. Protection of a general nature against the elements - rain, snow and extremes of temperature.
6. Protection of batteries by disconnecting and removing them to a slow charging station where they can be kept fully charged. If this is neglected, the plates may be damaged or ruined by becoming sulfated.
7. Protection of the alternator by covering all openings to prevent the entry of dust, moisture, dirt and rodents. A heavy craft paper will serve this purpose, where these openings are in the form of screened or louvered guards or covered plates, the protective paper should be placed under these removable parts. If this is not possible, a pressure sensitive tape can be used to hold the paper in position. Do not use masking tape - it is not suitable for this type of service and will be very difficult to remove after extended use. Application of protective paper should be on both inside and outside of large fixed louvered surfaces. Large open areas should have a corrugated cardboard backing for the paper.
8. Protect switchboards in the same manner as the alternators. In the case of engines previously operated, additional items must be considered.
9. Protection of interior engine parts - particularly bearings, cylinder walls and valves against corrosion by the products of combustion combined with atmospheric moisture and corrosion by lubricating oil contaminants.

The extent of the attention given to each of the foregoing points of possible damage depends on the judgement of the person in charge of the equipment. Generally speaking, the following factors should be taken into consideration before deciding how much or how little preservation is required.

1. The period of time the equipment is likely to be inoperative.
2. The severity of the weather and atmospheric conditions at the point of storage. The problems of storing equipment in a high humidity area, for example, differ greatly from storage problems in a location where the air is very dry and dusty.
3. The accessibility of the equipment for periodic inspection and attention. An engine on a showroom floor that may be turned over occasionally and given periodic oiling requires less extensive treatment than engines crated and stocked in a warehouse.

CAUTION

A-90 engines received from the factory are internally protected for up to six months for storage indoors. If the storage period exceeds six months, the engine should receive additional

storage preservatives. Engines stored outdoors or in a humid environment may require more frequent re-preservation.

6.2 Storing New Engines

Engines recently received from the factory and not intended to be used for an indefinite period may be stored successfully in the following manner. Engines stored outdoors or in a humid environment may require more frequent re-preservation. Circumstances may compel omitting some steps, while on the other hand, special conditions may point to greater emphasis on other steps.

6.2.1 Engine in Operable Condition

1. Mix an inhibitive type preservative oil with the engine lubricating oil in the proportions recommended by the manufacturer of the preservative oil. Operate engine until oil is hot. Cooling water used in this run should have inhibitor added in accordance to manufacturers instructions.

2. Remove air cleaners of gas engines With manually operated sprayer, squirt can or other means, inject preservative oil of a suitable type into the air intake while the engine is running. Approximately one minute is ordinarily adequate. If possible, stop engine by slugging enough oil through intake to stall. Continue injecting oil until the engine stops turning.

3. Drain oil and water while hot. If extra protection is desired, the rocker arm covers may be removed and a quantity of preservative oil poured over the rocker arm and valve mechanisms.

4. For gas engines not stopped by slugging, remove spark plugs and squirt or spray several teaspoons of preservative oil into each combustion chamber. Coat spark plugs and reinstall.

5. Wipe engine clean and dry. Apply wax type masking tape or like material to all openings such as intake openings in air cleaners, exhaust outlets, breathers and open line fittings.

6. Relieve tension on belts. This is important because continual tension on belts without the working action that occurs in normal operation causes deterioration of the rubber.

7. Apply a coating of heavy preservative compound with brush to all exposed machined surfaces such as flywheels.

Engines treated in accordance with these instructions will normally be protected for one year or longer. Continual inspection, however, is the only way to determine if protection is adequate. If possible, crank the engine by hand for one or two turns about once a month. This helps prevent seizure of water pump seals. If this is done, however, it is usually best to add more preservative oil to each cylinder. Some types of preservative oil are not well suited to periodic engine rotation because they are scraped from the cylinder walls which are then unprotected. Other oils are not scraped away and for this reason the operator should carefully investigate the characteristics of the preservative oil used.

6.2.2 When Engine is Not Operable

1. Open drains as required to remove oil and water.

2. With hand or mechanical operated atomizing spray (do not use ordinary compressed air) inject preservation oil into each cylinder.

3. Crank engine in normal direction about one quarter turn and spray each cylinder again. Do this about eight times or until engine has been turned through two complete revolutions. The purpose of this procedure is to expose each valve so it can be coated with oil.

4. Depending on the judgment of the operator as to the severity of storage conditions, open valve rocker covers, gear cover plates and as many points as possible where oil may be sprayed, poured or squirted over the interior parts. Replace all plugs and covers.

5. Remaining steps may be the same as listed in 5 and 6 for an operable engine.

6.3 Storing Engines That Have Been In Service

In the course of normal engine operation, residues of various combustion products, such as sulphur, accumulate in the combustion area and in the lubricating oil. Portions of these residues combine with atmospheric moisture to form corrosive compounds of a destructive nature. The following treatment will help reduce the damage from this source.

6.3.1 Engine in Operable Condition

Run engine until the original oil is hot. Drain.

If practical, run the engine with a good flushing oil in crankcase and drain oil and water while still hot.

Refill crankcase with preservative oil or with the proper grade of lube oil to which an inhibitive type preservative oil has been added in the proportion recommended.

Carry out previous instructions 5 and 6 as the circumstances indicate.

6.3.2 When Engine is Not Operable

Carry out instructions as for an inoperable new engine.

If the judgment of the operator and storage conditions warrant, the engine should be disassembled for treatment as a new engine. Ordinarily this last procedure is unnecessary except in cases where fuels containing considerable sulphur have been used or where extremely bad climatic conditions prevail.

6.4 Preservative Oil

The properties making an oil suitable for preservative requirements are good aging stability; high resistance to gumming, oxidation and polymerization; low pour point and viscosity; free from acids, asphalts, resins, tars and water.

6.5 Post Storage Engine Preparation

6.5.1 Requirements

The steps needed to bring an engine into active service after storage in accordance with these instructions are about the same as those normally carried out on any new engine. These are inspection, checking for free rotation, adequate cooling water or antifreeze, ample lubricating oil of the correct type and viscosity and proper adjustments. In addition, accumulated dust and dirt should be wiped or washed from the exterior before removing the covers over the engine openings. Removal of installed protection should occur upon normal inspection of the engine generator and switch gear interiors prior to start up. Partial removal may be necessary in the course of installation but this should be kept at a minimum. Engines that have not been rotated for some time should be oiled through the spark plug openings and cranked by hand or with the starting equipment before actually running. Any resistance to free cranking should be investigated - rust and corrosion can cause severe seizure that cannot be forced clear without engine damage.

CAUTION

All generators and switch gear which have been stored must be checked for installation resistance with a “megger” prior to being put into service. The megger used should produce 500 VDC. Disconnect voltage regulator, rotating diodes, suppressors and any other solid state devices which may be connected to the starter or rotor windings The megger value should be: operating voltage ÷ 1000+1 (ie, machine voltage of 480 VAC÷1000=0.480+1=1.480 megohms.) If any circuit to ground measures less than calculated value, consult the SES Arrow Engine Customer Service Department for any corrective measures as may be necessary.

6 Never attempt to start an engine that has been stored without first cranking it over with the spark plugs out. Spurting oil, water or preservative compound from these openings indicates possible hydraulic lock if an attempt had been made to operate. Continue to crank engine with starter until liquid is no longer ejected from openings. Inspect intake passages and manifolds for thickened preservative oil. Oil accumulated in this condition may melt when the engine warms up and cause a runaway.

7 Engine Disassembly

7.1 Cleaning and Inspection

- To ensure satisfactory performance of the engine after overhauling, all components should be cleaned and decarbonized.

CAUTION: During cleaning, avoid using sharp instruments, sandpaper, steel wool, or steel brush. These will damage the machined surface and finish of the components.

- Inspect the cleaned components for cracks, erosion, and pitting marks.
- Discard and replace unserviceable components that have reached wear limits or show visible damage.
- Check all reusable components for dimensional accuracy. Refer to the specifications in section *"5 Clearances & Wear Limits" on page 41*.
- Replace all bearings to avoid later complications and performance deterioration.
- If dish type core plugs are removed during cleaning and inspection, replace and fit again with proper mandrel to avoid leakages. Apply sealant.
- Special attention should be given to components like cylinder head, piston, and connecting rod and cylinder liner during servicing and inspection.

7.2 Top Overhaul Parts

- Valve springs
- Connecting rod bolts
- Cylinder head bolts
- Turbocharger overhaul kit
- Gaskets
- O-rings
- Copper washers
- Hoses and hose clips
- V-belts
- All rubber components
- Any parts with visible damage
- Parts which have reached wear limits

7.3 Precautions for Reassembly

- Check all components for damage, cracks, abnormal wear, scale formation, rust formation, and foreign particles. Treat and/or discard accordingly.
- Ensure that all components are properly cleaned before reassembly.
- If a delay is expected in assembly, all usable casting and steel components should be coated with rustproof oil, labeled, and stored properly to avoid damage to the machined surface.
- Ensure a dust-free atmosphere around the engine assembly.
- Ensure that the assembled parts are adequately lubricated.
- Ensure that all gaskets, o-rings, and copper washers are replaced with new ones. Remove the old gaskets by scraping with a blunt tool.
- Ensure that all fasteners are tightened as per the recommended torque values.
- Ensure that all parts are checked for their limit dimensional values. Replace or repair if abnormal.
- Ensure that proper gauges are used to check the dimensions, end plays, and backlashes.
- Ensure that proper tools are used for engine assembly and dismantling.
- Be aware of the particular reason for engine failure.
- All rubber components are to be replaced while assembling the engine.

- Ensure that oil is not spilling onto the assembly floor.
- Ensure that a cotton duster is not used as it would leave cotton dust in the assembled parts.
- Proper engineering adhesive should be used for a leak-proof assembly.
- Ensure that the engine is fitted on an engine-turning device.
- Spare parts should be stacked properly on the component cart. No component should lay on the floor.
- Ensure that the tool cart is used for stacking tools.
- Ensure that the assembler wears protective clothing while assembling the engine.
- Ensure the use of a proper lifting tackle and correct practice of crane handling while lifting the engine.

7.4 Engine Disassembly

7.4.1 Oil Pan Drain

- Drain the oil from the oil pan.

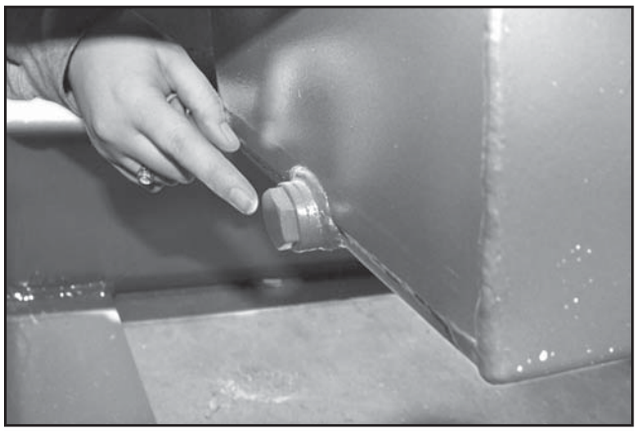


FIGURE 6. Oil Pan Drain

7.4.2 Battery

- Disconnect the battery. Remove negative connection first.
- Store battery in a dry place on a wooden plank.

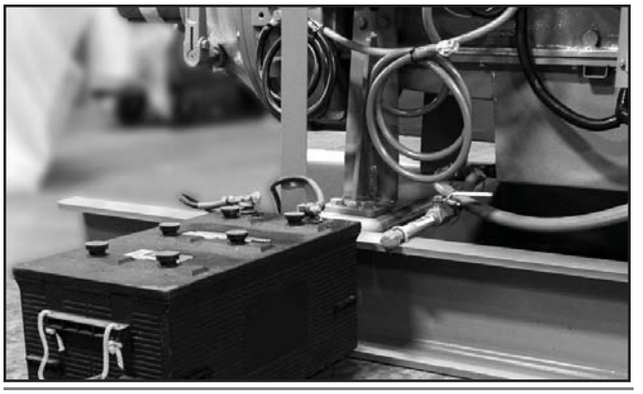


FIGURE 7. Battery

7.4.3 Wiring

- Disconnect wiring from alternator.

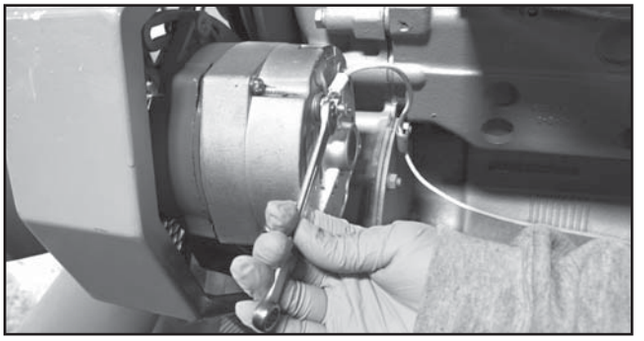


FIGURE 8. Alternator Wiring

- Disconnect wiring from the starter.
- Remove starter. Inspect and replace or service if needed.

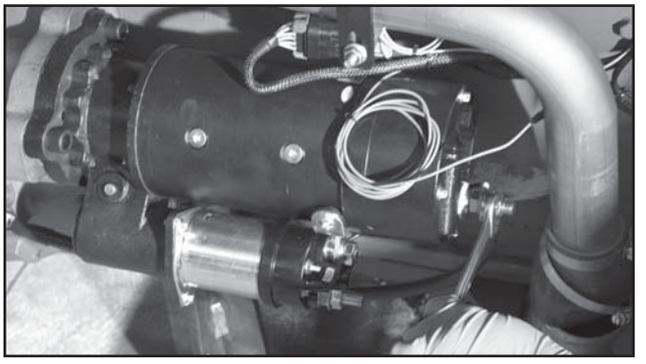


FIGURE 9. Starter

7.4.4 Radiator

- Remove the radiator pressure cap.

CAUTION: Do not attempt on a hot engine!

FIGURE 10. Radiator Cap

- Drain coolant from the radiator. (Use Water Drain Kit #SKA50577.)

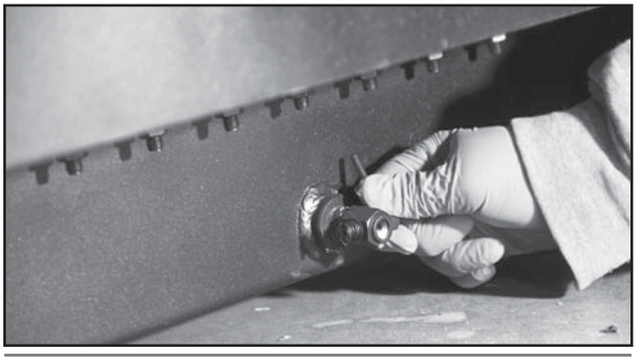


FIGURE 11. Radiator Drain Plug

- Disconnect the rubber hose on air cooler inlet and outlet pipes for all turbocharged engines.
- Replace if necessary.

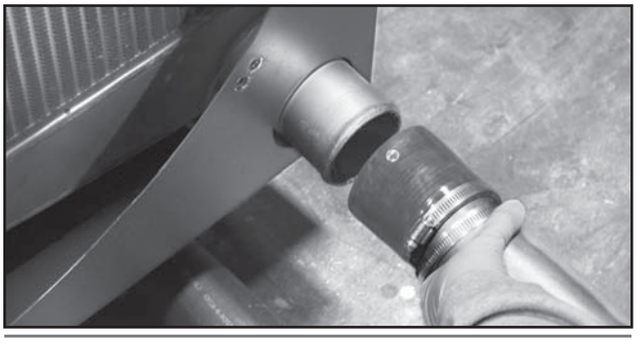


FIGURE 12. Air Cooler Inlet Pipe

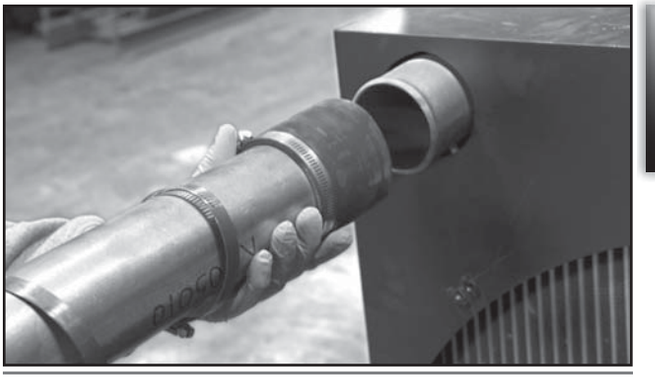


FIGURE 13. Air Cooler Outlet Pipe

- Disconnect the connection hoses on the radiator.
- Disconnect the radiator and boost air cooler pipes from the engine for all turbocharged engines.

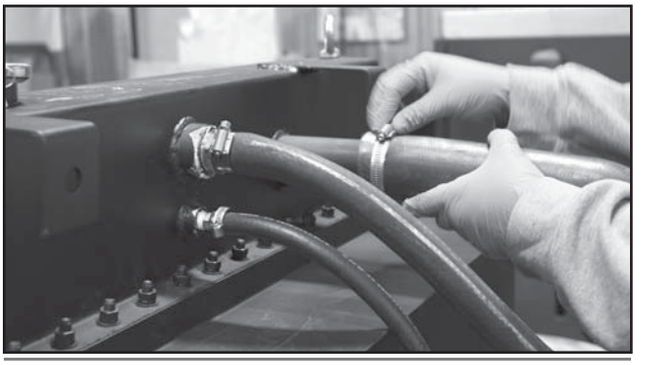


FIGURE 14. Radiator hoses

- Disconnect the radiator bolts from the base frame.

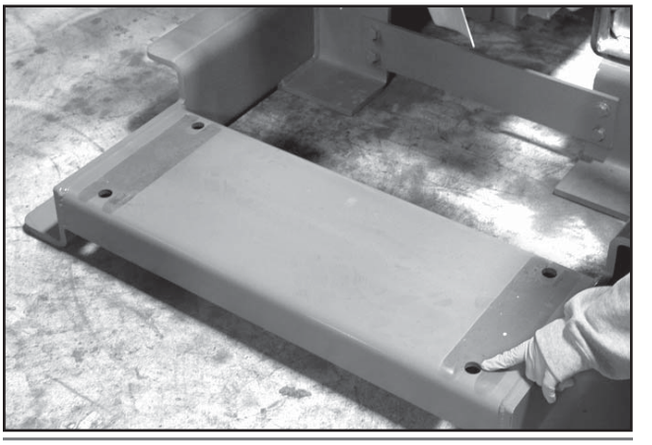


FIGURE 15. Radiator Base

FIGURE 16. Radiator Bolt

7.4.5 Fan

- Remove the fan.

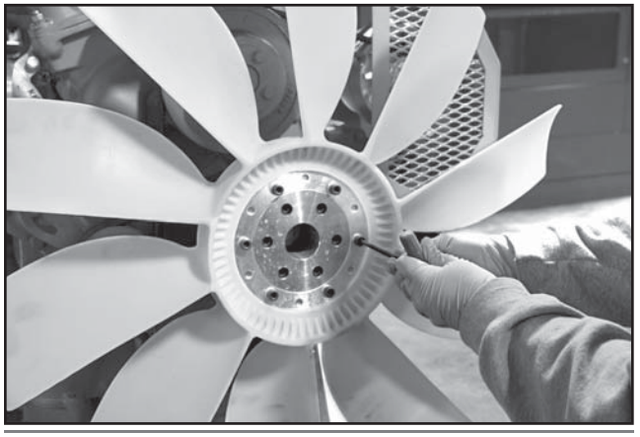


FIGURE 17. Fan

7.4.6 Air Cleaner

- Remove the air cleaner assembly and the mounting bracket

FIGURE 18. Air Cleaner Assembly

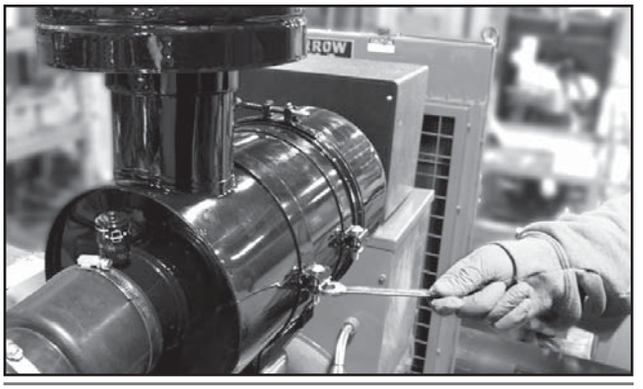


FIGURE 19. Air Cleaner Base

7.4.7 Belts

- Remove the belt guard.

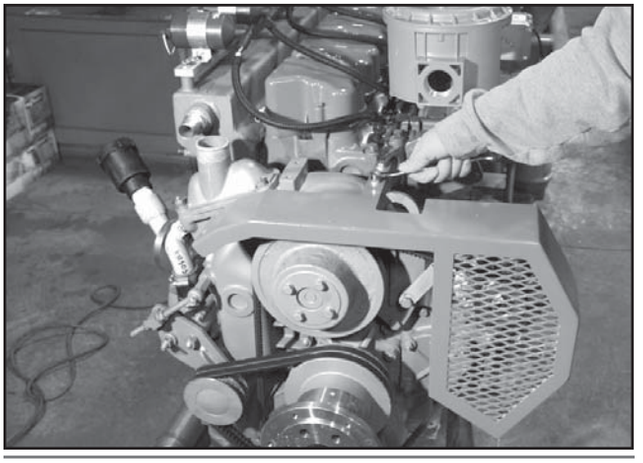


FIGURE 20. Belt Guard

- Remove and discard the fan belts.
- Remove and discard the alternator belt from bracket.

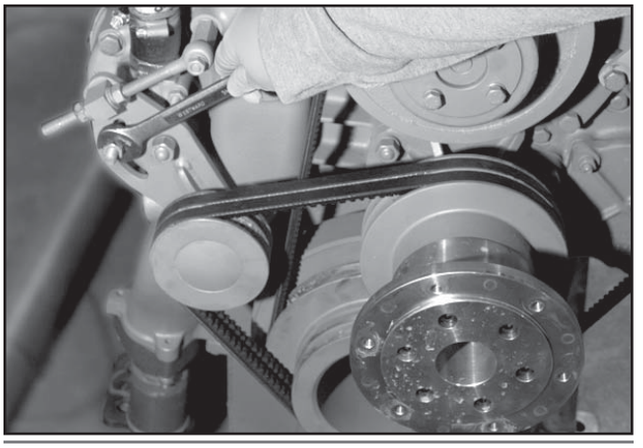


FIGURE 21. Belts

7.4.8 Alternator

. Remove the alternator

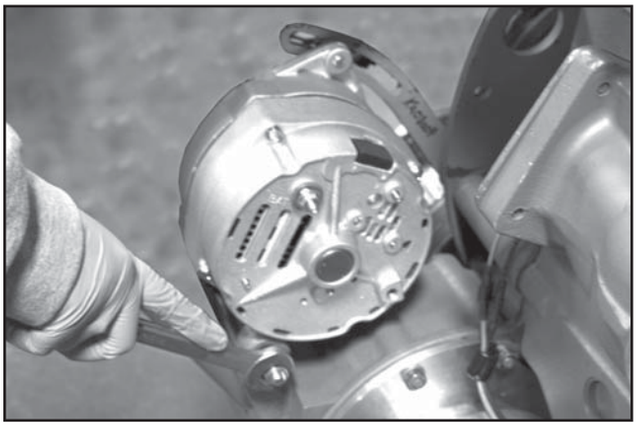


FIGURE 22. Alternator

7.4.9 Coil Bar

- Disconnect and remove the coil bar

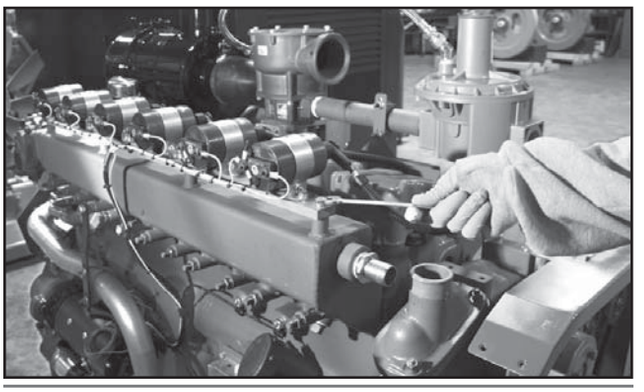


FIGURE 23. Coil Bar

7.4.10 Liquid Cooled Manifold

- Disconnect the liquid cooled exhaust manifold. Remove drain plug and drain the exhaust manifold.

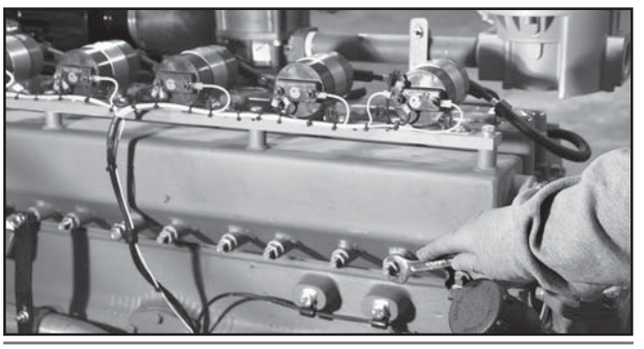


FIGURE 24. Liquid Cooled Manifold

7.4.11 Venting Pipe

- Disconnect and remove the venting pipe from cylinder heads.

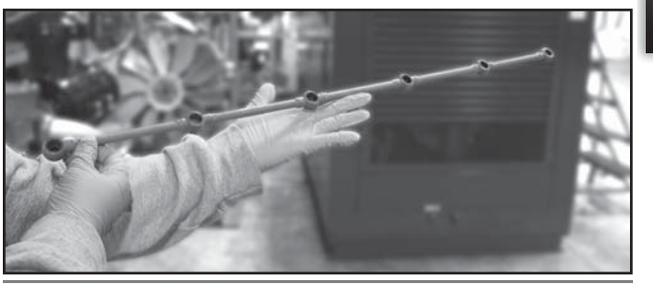


FIGURE 25. Venting Pipe

7.4.12 Intake Manifold

- Disconnect and remove the air inlet manifold and discard the gaskets.
- Check for presence of oil or dust. Oil indicates faulty turbocharger seals. Dust indicates faulty air cleaner, hose, and connections. Clean before replacing.

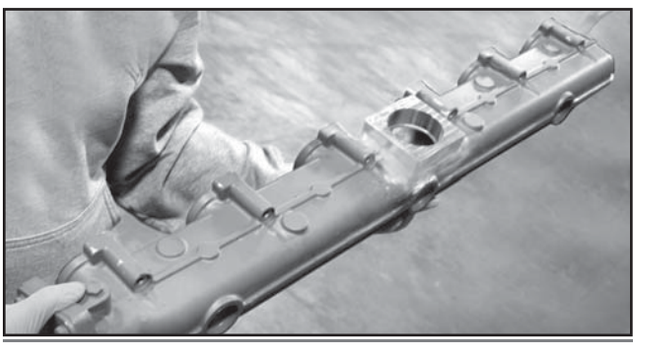


FIGURE 26. Intake Manifold

7.4.13 Rocker Arm Covers

- Remove the rocker arm covers and discard the gaskets.

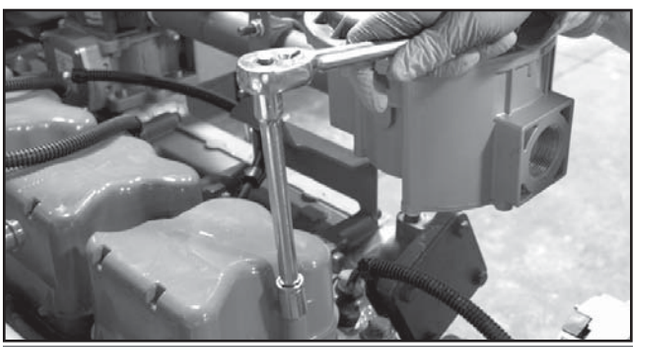


FIGURE 27. Rocker Arm Cover

- Remove rocker oil supply line and discard copper washers.

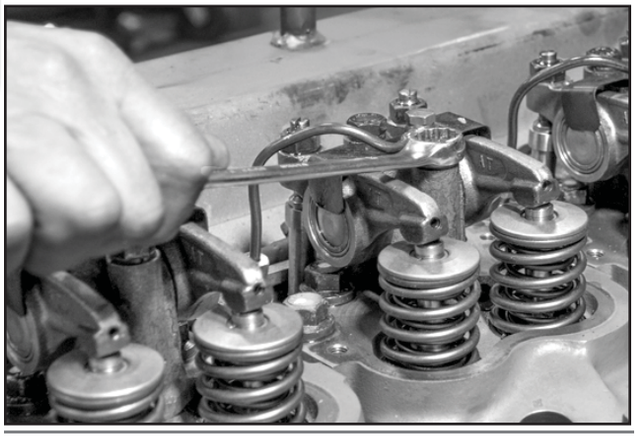


FIGURE 28. Rocker Oil Supply Line

- Remove the rocker assemblies with the pedestals from cylinder heads.

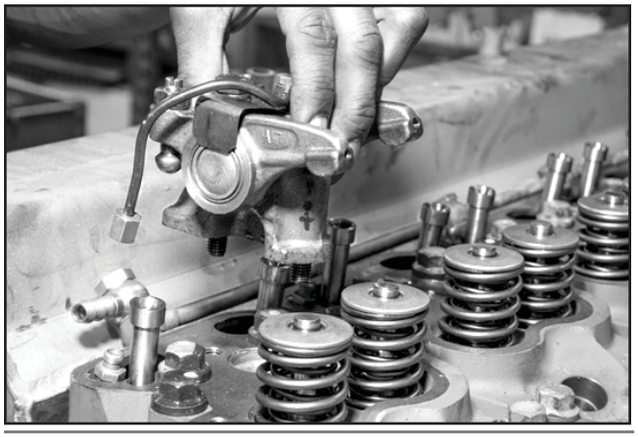


FIGURE 29. Rocker Assembly

7.4.14 Push rods

- Remove and inspect the push rods.
- Measure the inside diameter of the rocker lever bushing.
- Measure the outside diameter of the corresponding rocker shaft.
- Calculate the clearance between rocker bushing and shaft. Compare the reading with the clearance limit specifications. If the clearance is more than the specified limit, replace the rocker level bushing set.
- Inspect push rod cone and cup for bending or other damages. Check for concentricity by rolling on a smooth, flat surface with the palm of your hand.

FIGURE 30. Push Rods

7.4.15 Cylinder Head

- Loosen the cylinder head bolts.
- Each cylinder head has 7 bolts – 3 short (123.9 to 124.9 mm), 4 long (144.3 to 145 mm). Replace if the length of any bolts are increased beyond limit value.

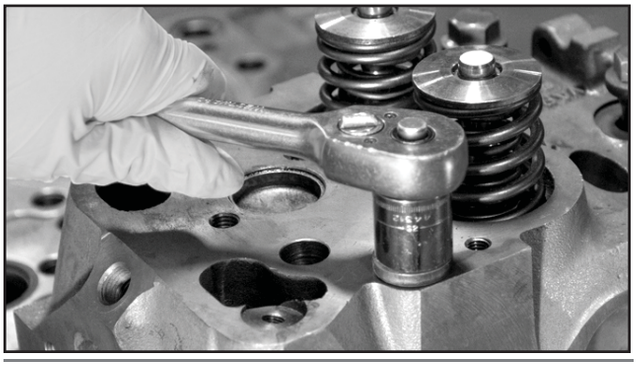


FIGURE 31. Cylinder Head Bolts

- Mark the cylinder head numbers on each head with paint or a permanent marker.

FIGURE 32. Cylinder Heads

- Remove cylinder heads.

7.4.16 Cylinder Head Assembly Inspection

- Before removing the valves from the head, check the valve recess. Valve recess is the distance between the cylinder head face and the valve face.
- This gap can be checked with the help of a straight edge and a feeler gauge set.
- Insert the maximum specified thickness feeler gauge between the valve face and the straight edge. If the gauge slides through the gap effortlessly, the gap is said to be more than specified. Replace the valve, valve seat insert, or both. Intake and exhaust valve recess limit: 0.079 in.

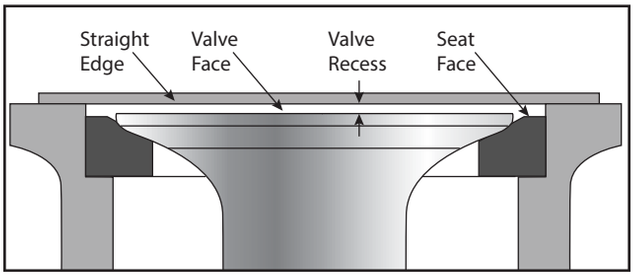


FIGURE 33. Valve Recess

- Mark the respective cylinder numbers on each valve face. The intake valve has a bigger cone diameter than the exhaust valve.
- Place the cylinder head on a flat surface with base support to inlet and exhaust valves.
- Remove springs, valve collets, spring cup and springs.
- Remove valve from the bottom.
- Remove and discard valve stem seal
- Remove carbon from the bottom face of the cylinder head. Avoid scuffing and nicking the machined surface while removing the carbon.
- Check the head face for pitting marks.
- Check the valve seat inserts for burn marks, heavy pitting, or other defects.
- Recondition or replace the seat if damaged.
- Check the intake and exhaust port faces (where the manifolds fit) for damage.
- Remove carbon from the exhaust and inlet ports.
- Inspect the valve cone for cracks, burns, erosion, etc. Replace if damaged.
- Inspect the valve stem diameter at four to five places for wear in both axis. Replace if stem is worn.

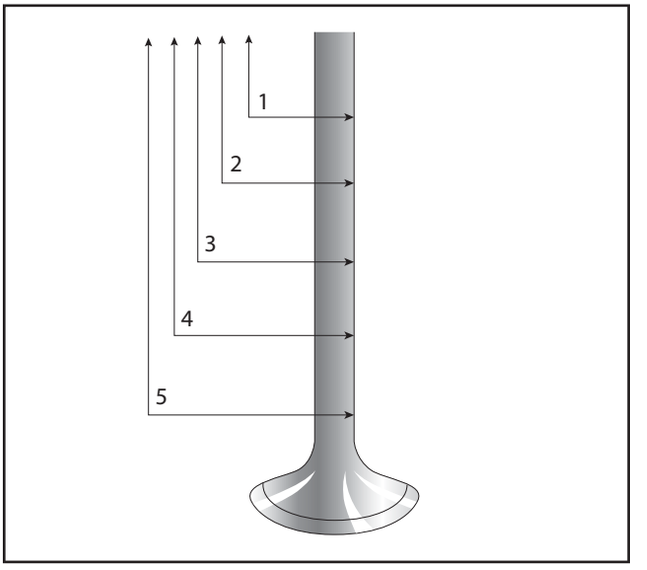


FIGURE 34. Valve Stem Diameter

- Check both inner and outer valve springs for pitting marks, cracks, and other defects.
- Measure the free length of springs against specifications and replace if required.

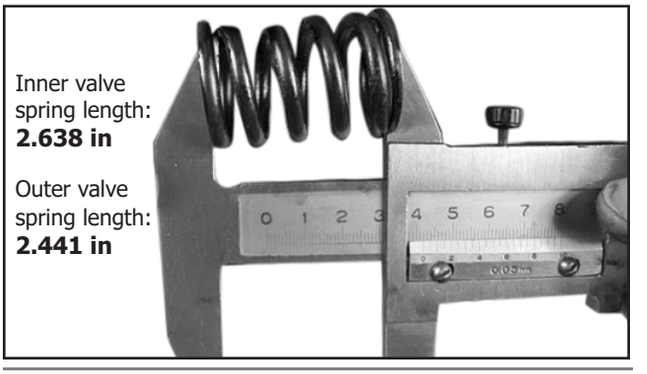


FIGURE 35. Measure Springs

- Remove carbon and clean the flat surface of the head. Check the flatness at three places.

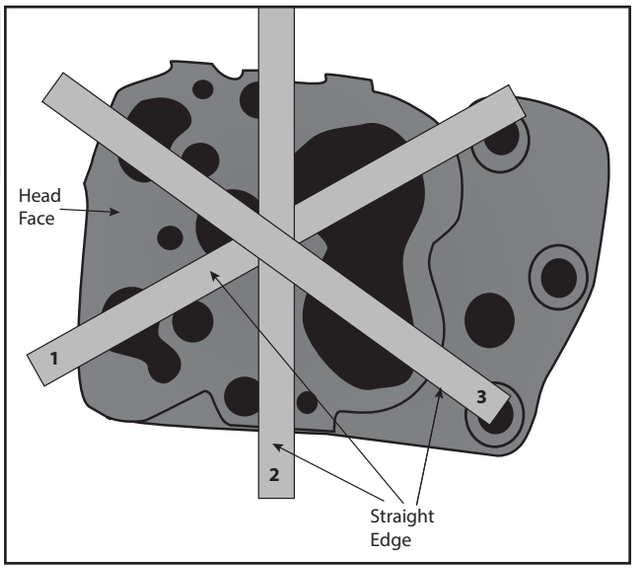


FIGURE 36. Head Flatness

- Use a straight edge and a .005" (0.020 mm) feeler gauge to ascertain the flatness of the head.
- Put the straight edge on the surface of the head and put the feeler gauge between the straight edge and the head (Not under the valve cavities).
- If the feeler gauge passes through the gap, the face of the head is damaged and requires repair/replacement.

7.4.17 Replacing Valve Guides

- Remove the old valve guide from the cylinder head top.
- Clean the guide bores in cylinder head with a dry cloth.
- Inspect the bores for scoring or other damage.
- Insert new valve guides by pressing them from the cylinder head top.
- After valve lapping, press new valve stem seals on the guide.

7.4.18 Replacing Valve Seat Inserts

- A-90 heads are fitted with replaceable valve seat inserts. SES Arrow recommends replacing valve seat inserts during a major overhaul.
- Use a puller or a chisel to remove the valve seat insert from the cylinder head. Alternatively, the insert can be removed by cutting it on an appropriate lathe in a machine shop.
- Clean and inspect the condition of the bore.
- Note that the outer diameter of the intake valve seat insert is greater than that of the exhaust valve insert.
- After removing the seat inserts, remove old valve guides and clean the valve guide bores.
- Choose ONE of the following methods to treat the valve seat inserts
  1. Cool in dry ice for about 30 minutes.
  2. Cool in liquid nitrogen for about 10 minutes
  3. Heat in an oven up to 130°C (not direct fire).
- Fit the insert in its bore and press it immediately with a suitable tool, taking the reference of the newly fitted guide.
- Ensure the seat fits squarely and completely in the bore.

CAUTION: When using liquid nitrogen, avoid direct contact with it to prevent injury to the body due to its sub-zero cooling effect. Wear gloves when using.

7.4.19 Valve Lapping

- Valve lapping should be done to ensure proper sealing of valves to avoid compression leakage and to achieve good combustion.
- Burnt valves, cracked valves, and valves with reduced rim thickness should be replaced.
- Check the condition of both the valve face and the valve seats in the head.
- If the valve face is in relatively good condition, only light lapping with a fine compound will be required to ensure a good seating.
- If valve face is damaged, the face will have to be refaced to the correct angle without reducing the rim thickness.
- Ensure the valve and cylinder head is thoroughly cleaned and decarbonized.

- Apply a small quantity of course lapping compound all around the valve seat.
- Dip the valve stem in fresh, clean oil and insert the numbered valve in the respective valve guide.

CAUTION: Ensure that no valve grinding paste touches the valve stem or valve guide. This will damage both.

- Lap the valve and seat by rotating the valve back and forth in a half turn with gentle but firm pressure with the help of a cupped valve grinding tool.
- After every few turns, lift the valve off slightly from the seat, give it a half turn, and tap gently. This is essential to uniformly spread the grinding paste.
- Keep grinding until the rough gritty feeling of the course compound turns relatively smooth.
- Remove the valve, wipe the compound from the valve and seat, and check for a contact pattern. When a relatively good flawless pattern is achieved, lap the valve again with the fine lapping compound.

CAUTION: Maintain a separate cloth and small quantity of diesel for wiping off the compound from the valve cone and seat inserts. This prevents accidental damage to the valve stem and guides.

- After lapping, visually inspect both the valve face and seat. The finished contact pattern on both should be even, without flaw or break, scratch, or depression marks.
- NOTE: If a shining line or scratches are visible on the seats after lapping, it is possible that the lapping was carried out with a heavy hand. Such valves will have to be lightly relapped again with the fine compound.
- Clean the valves and cylinder head to remove all trace of the harmful abrasive material and dry with compressed air.
- Before assembling the lapped valve assembly, confirm that the seating is good. This can be done by a pencil erase test.
- Wipe and lightly lubricate the valve stem. Assemble valve in its original seat with valve spring and new stem seal and lock it in position.
- After locking the valve, check sealing of the seats. This should be checked by carrying out the fuel leakage test.

7.4.20 Pencil Erase Test

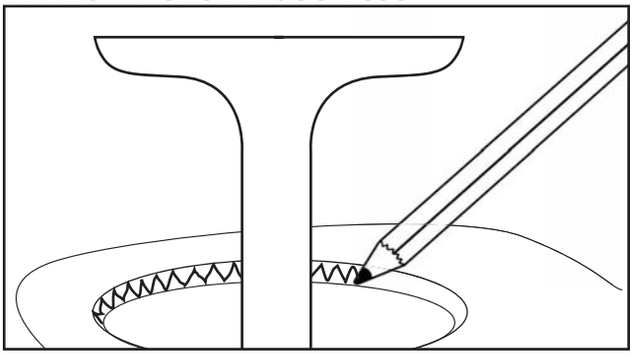


FIGURE 4. Pencil Erase Test

- The pencil erase test is a simple test. It should be carried out before assembling the valve to the cylinder head. This test ensures proper valve seating.
- Draw a zigzag line on the lapped valve's seat surface with a soft lead pencil.
- Fit the valve in its place in the head and turn it once to 90° or 1/4 turn with a gentle but firm pressure.
- Pull the valve out and inspect the pencil line. The lines should be completely erased from the seats. This proves proper seating and good sealing.
- If the pencil marks are not erased fully, repeat the lapping process.

7.4.21 Oil Filter Cartridges

- Remove the spin-on oil filter cartridges with a strap tool.

FIGURE 5. Oil Filters

7.4.22 Thermostat Elements

- Remove thermostat elements.
- Inspect for damage and replace if needed.

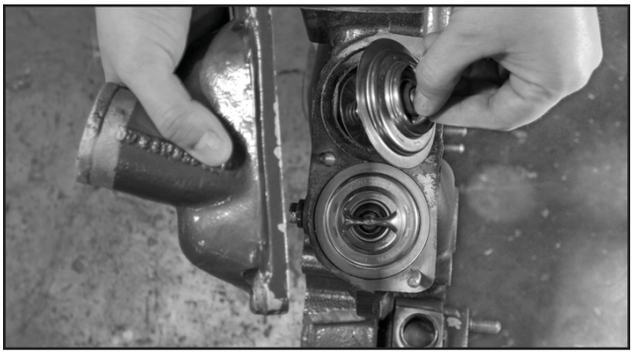


FIGURE 6. Thermostat

7.4.23 Oil Pan

- Remove the oil pan and discard the gasket.

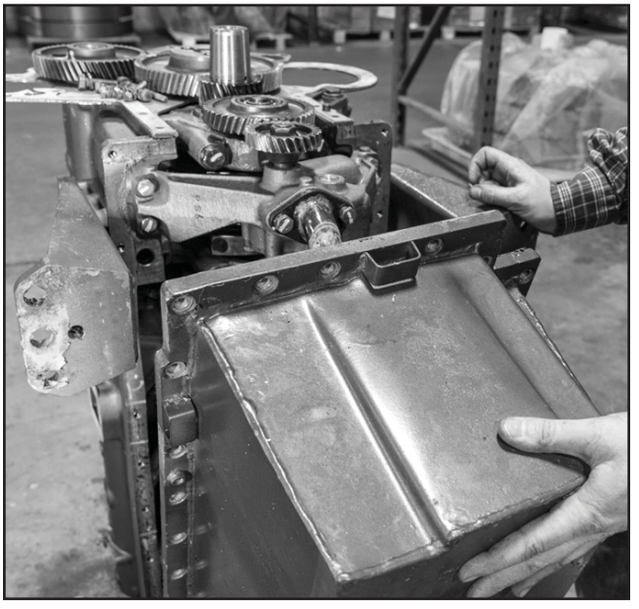


FIGURE 7. Oil Pan

7.4.24 Suction Tube Assembly

- Dismantle and remove the suction tube assembly with bracket and discard the gasket.

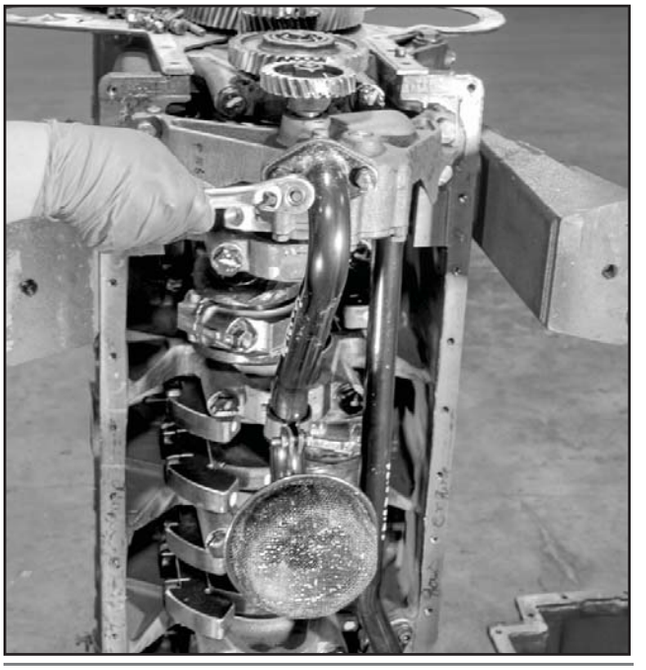


FIGURE 8. Suction Tube Assembly

CAUTION: Ensure a good seal during reassembly or it may cause low oil pressure.

7.4.25 Delivery Pipe

- Remove the delivery pipe and discard the gasket.
- Discard the o-ring in the oil pump housing for the delivery pipe.

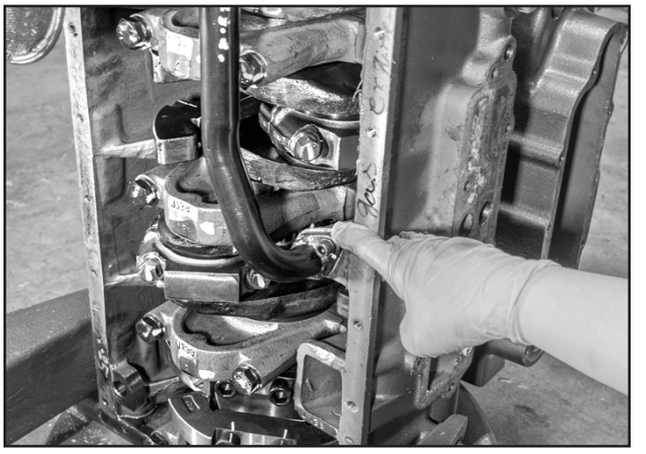


FIGURE 9. Delivery Pipe

7.4.26 Connecting Rod

- Inspect the end play of connecting rod in assembled condition.
- If no end play is found, connecting rod must be checked for bend and twist.
- Loosen connecting rod cap bolts a few threads.

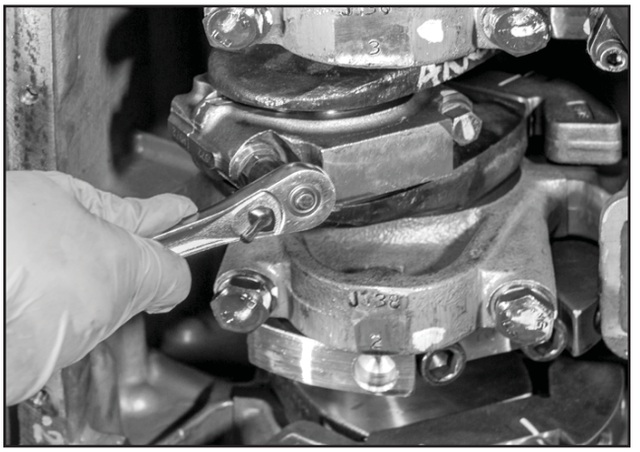


FIGURE 10. Connecting Rod

- Gently tap with a plastic hammer on the bolts head to dislodge the cap from the connecting rod.
- Remove the connecting rod cap with the bearing shell.

CAUTION: Do not disturb the bearing shells seating position in the connecting rod shank and cap.

- Rotate the crankshaft to a convenient position, then push the piston and connecting rod assembly out from the top of the cylinder liner.
- Check the numbers on connecting rod and cap and reassemble the connecting rod and cap together with the same numbers.

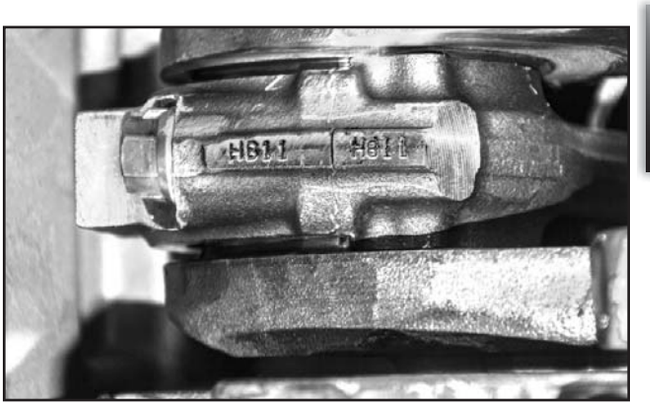


FIGURE 11. Rod & Cap Numbers

7.5 Inspecting & Servicing of Cylinder Liner

- Visually inspect the liner from the inside for excessive wear, step, scratch marks, or seizing. Discard if any are found.
- Inspect the liner externally for pitting and erosion.
- Check the liner bore with a dial bore gauge for ovality and taper wear at three levels (1 to 3) and at two positions (A and B).
- Compare readings with the specifications in section *"5 Clearances & Wear Limits" on page 41*. Replace the liner if wear limits are reached.
- Check the liner collar face under the collar for fretting or uneven wear marks. Discard the liner if any of the above faults are noticed, or if the tolerances are not within the recommended limits. Refer to section *"5.2 Cylinder Liner" on page 42*.

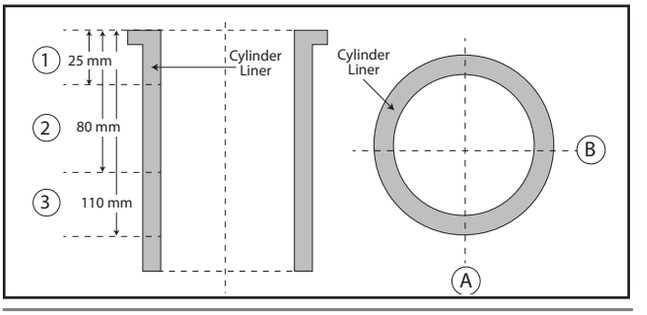


FIGURE 12. Cylinder Liner Bore Measurement

7.5.1 Checking of Liner Protrusion

- Tighten the liner clamping plate on crankcase to press the cylinder liner
- Set '0' on both dial gauges with reference surface.
- Fit the thin o-ring under the liner collar.
- Two grooves are provided at the bottom of the crankcase. Clean the grooves with a soft brush.
- Fit the two thicker o-rings in the grooves.
- Apply fresh lubricant to the liner area which comes in contact with the o-ring.
- Apply gasket adhesive to the liner collar resting face on crankcase. This seals the uneven machined surface, if any, and avoids coolant leakage from the o-ring.
- Insert the liner properly in the crankcase and tap it down lightly, or press it with a liner pressing tool.
- Place the liner protrusion checking gauge across the clamp, ensuring that both the dial gauge stylus will rest on liner step (where cylinder head gasket rests).
- Take the reading on both dial gauges.
- This reading is the actual liner protrusion of cylinder liner gasket face over crankcase.
- Compare readings with the specifications in section *"5.2 Cylinder Liner" on page 42* and discard if wear limits have been reached.

7.6 Inspecting & Servicing Connecting Rod

- Thoroughly clean the connecting rod assembly, especially the oil passage hole. Inspect the 'I' section of the connecting rods for notches or hit marks. If notches or hit marks are observed, replace the connecting rod.
- Inspect the connecting rod for bend or twist. This can be checked on the parallelism fixture. Replace the connecting rod if bend or twist is noticed.
- Visually inspect the large end bore for discoloration and damage. Replace if found.

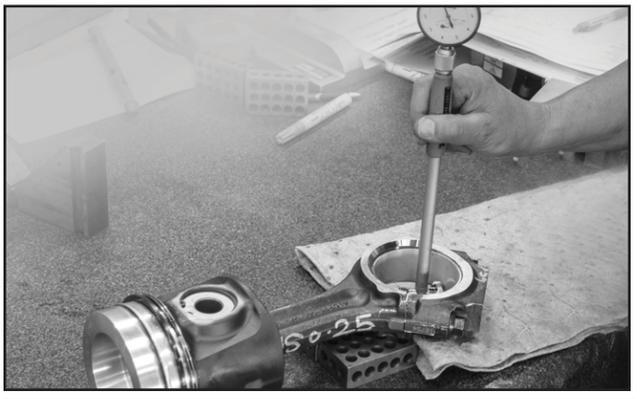


FIGURE 13. Dial Bore Gauge

- Check the large end bore diameter with a dial bore gauge. See specifications in section *"5.5 Connecting Rod" on page 44*.
- Check inside diameter of the small end bore with a dial bore gauge. Refer to section section *"5.5 Connecting Rod" on page 44* for specifications.

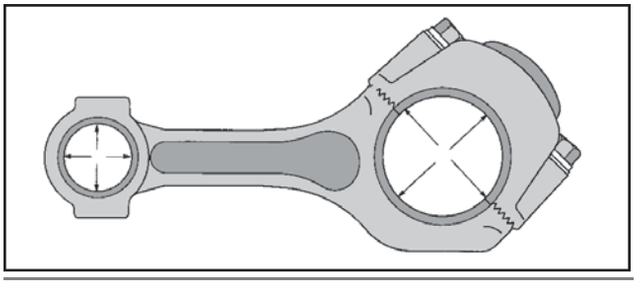


FIGURE 14. Connecting Rod Bore Diameter

- If any defects are noticed, replace the connecting rod.
- When pressing the new small end bearing, take care to match the profile of the bearing with that of the small end bore of the connecting rod.

IMPORTANT: The connecting rod bolts should ALWAYS be replaced during a major overhaul.

7.7 Inspection & Servicing of the Piston Assembly

- Remove piston rings from the piston and discard.

FIGURE 15. Piston Rings

- Remove carbon from the piston's crown with a blunt tool or an old piston ring.

CAUTION: Do not use sandpaper or a wire brush to clean the piston.

- Visually inspect the overall condition of the piston and check the piston crown for cracks, burn marks, pitting, and erosion. Check the piston outside diameter for seizure or scoring marks.
- Remove carbon from the ring groove with old discarded piston rings.

7.8 Checking the Land Clearance

- Check land (side) clearance between groove and piston ring.
- Use a new ring / feeler gauge for checking.
- Follow the same procedure for all three piston rings and compare with specifications in section *"5.4 Piston rings" on page 43*.

7.9 Piston Pin

- Inspect the piston pin bore diameter for wear and damage. Refer to section *"5.3 Piston" on page 43* for specifications.
- Inspect piston pin outside diameter at the center where the small end bushing fits. Refer to section *"5.3 Piston" on page 43* for specifications.

FIGURE 16. Piston Pin Bore Diameter

- Replace piston and pin assembly if any defects are noticed.

7.10 Checking Piston Ring Clearance

- The purpose of checking the piston ring end gap clearance is to check that the cylinder liner bore size is within the specified limits. The piston ring clearance is the gap between piston ring ends. The gap is crucial and should be maintained as specified in section *"5.4 Piston rings" on page 43*.
- The clearance should always be checked with new piston rings.
- Insert one ring at a time in the cylinder liner.
- Push ring down squarely with the help of piston to about 40-50 mm.
- Measure the gap between ring ends with a feeler gauge.
- Follow this procedure with the next set of the rings in another liner.
- Repeat the procedure with the rest of the rings in the set.

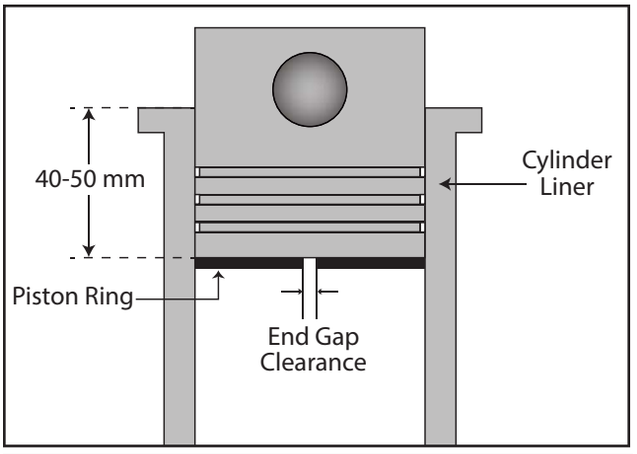


FIGURE 17. Piston Ring End Gap Clearance

- Retain the checked rings as a set with the respective liners only. Refer to specifications in section *"5.4 Piston rings" on page 43*.

7.11 Fitting Rings on Piston

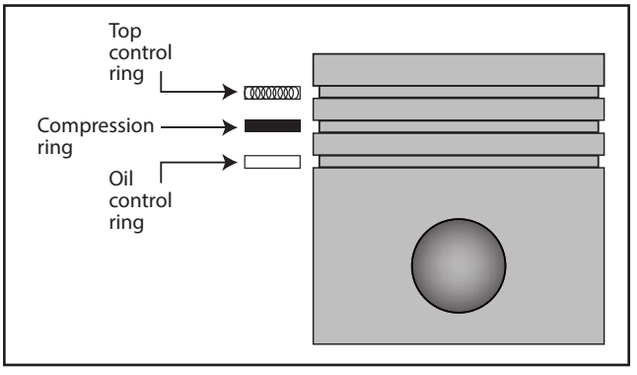


FIGURE 18. Piston Ring Installation

- Install piston rings with a ring expander to prevent damage and premature failure of the rings.
- Before installing piston rings, ensure that the piston ring grooves and rings are spotlessly clean.
- When installing the piston rings, ensure that the manufacturer's name or 'TOP' stamped on the ring is facing the piston crown.
- Install rings dry and in their correct sequence with ring gaps spaced at 120°.

CAUTION: Do not set ring gaps along the piston pin's axis.

7.12 Assembly of Piston & Connecting Rod

- Fit the circlip to one side of the piston pin bore groove.

FIGURE 19. Piston Circlip

- Apply fresh lubricant to the piston pin and connecting rod bearings.

FIGURE 20. Connecting Rod Lubrication

- Position the connecting rod in correct orientation to the piston.
- Fit the piston by hand (Piston pin is clearance fit and should be fitted by pushing it.)
- Lock the second circlip in place.

CAUTION: The ends of the circlips to be installed should face upwards.

FIGURE 21. Piston & Connecting Rod Assembly

- Insert the assembled piston and connecting rod into the crankcase.

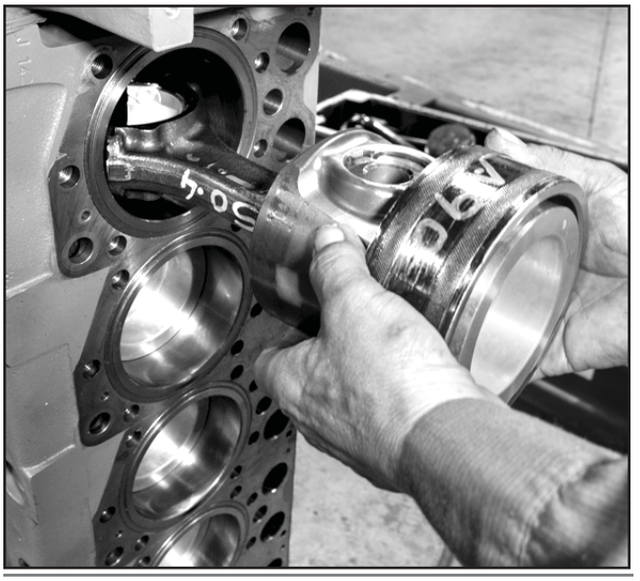


FIGURE 22. Installation of Assembly

- Lightly tap assembly into the cylinder.

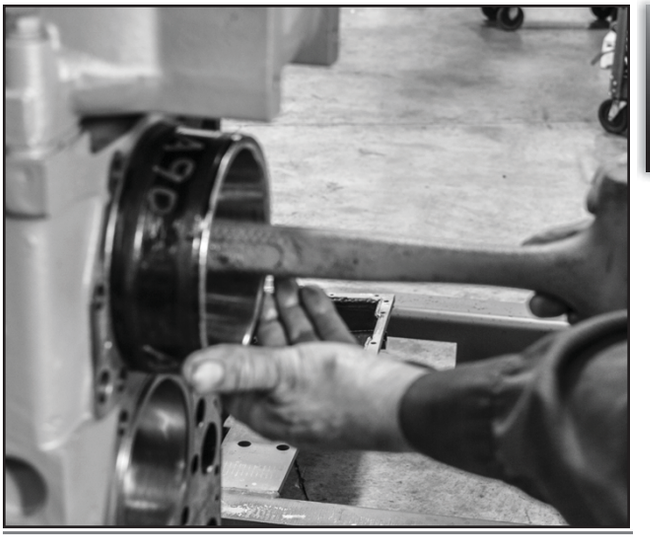


FIGURE 23. Tap Into Crankcase

- Install other half of the large end bore with bearing and secure with bolts.

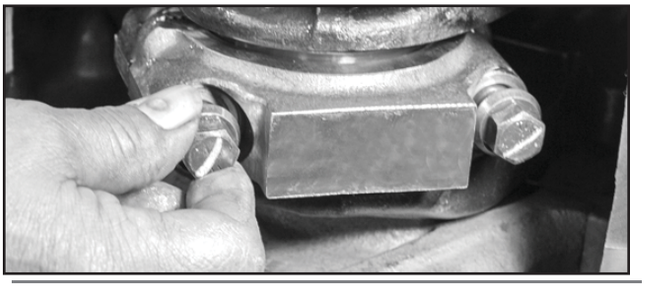


FIGURE 24. Bolt Together Large End Bore

- Torque the connecting rod bolts to 47 initial and 155 final ft lbs.

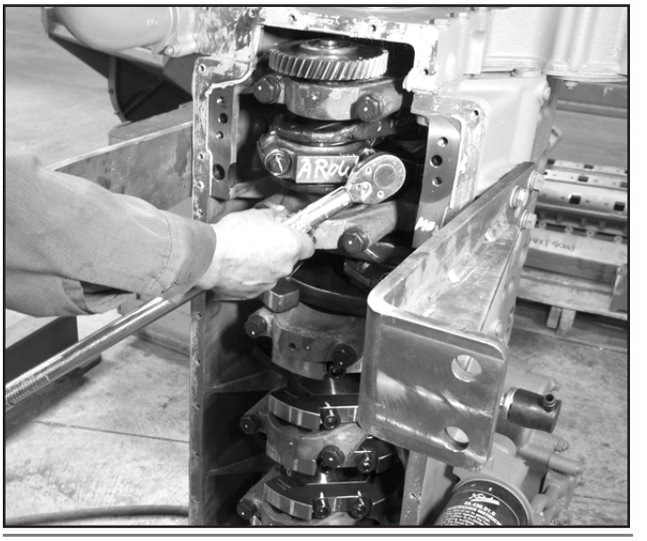


FIGURE 25. Torque Connecting Rod Bolts

7.13 Major Overhaul

- The recommended major overhaul period is 10,000 working hours of the engine. Before dismantling the engine, start the engine and run it on full load for about 45 minutes til oil is warm. Drain the oil from the engine.
- Refer to the previous sections in this chapter for top end disassembly.

The following components are recommended to be replaced during a major overhaul:

- Oil spray nozzles
- Cylinder liners with o-rings
- Piston assembly with piston rings
- Main bearings
- Connecting rod large end bearings
- Small end bushings
- Camshaft bushings
- Rocker lever bushings
- Thrust washer for crankshaft
- Thrust waster for intermediate gear
- Rocker adjusting screw with nut
- Camshaft assembly with gear and thrust plate (if camshaft thrust washer plate is worn-out)
- Intake and exhaust valves
- Valve guides
- Valve seat inserts
- Valve stem seals
- Valve keepers
- Valve springs
- Cylinder head gasket
- Main bearing cap bolts
- Balance weight bolts
- Connecting rod bolts
- Cylinder head Bolts
- Flywheel bolts
- Nozzle with copper washer
- Oil pump assembly
- Water pump assembly
- Thermostat elements
- Flywheel end and gear end oil seals
- Turbocharger overhaul kit (turbo only)
- All gaskets
- All o-rings
- All copper washers
- All hoses and hose clamps
- All v-belts
- Oil filter cartridges
- Air cleaner element

7.14 Major Overhaul Disassembly

7.14.1 Fan Drive

- Remove the fan drive assembly. Replace if needed.

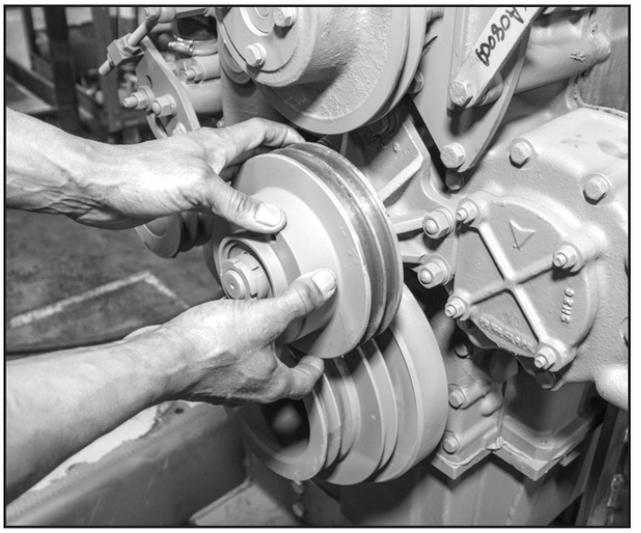


FIGURE 26. Fan Drive Pulley

7.14.2 Water Pump

- Remove and discard water pump assembly.

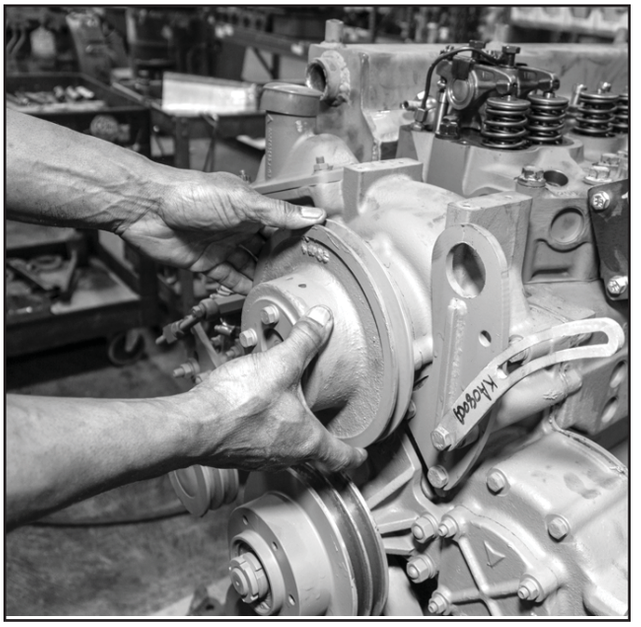


FIGURE 27. Water Pump

7.14.3 Crank Pulley

- Dismantle the crank pulley.

- Remove the center bolt and remove the driving hub.

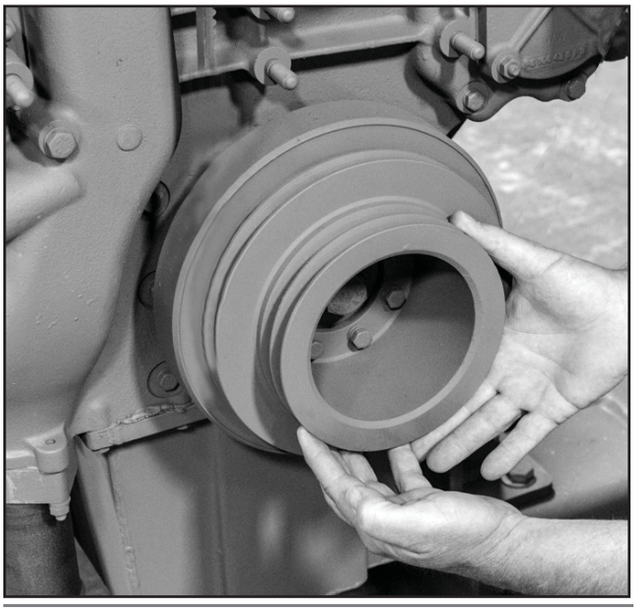


FIGURE 28. Crank Pulley

- Remove the harmonic balancer

FIGURE 29. Harmonic Balancer

- Remove the crank gear hub.

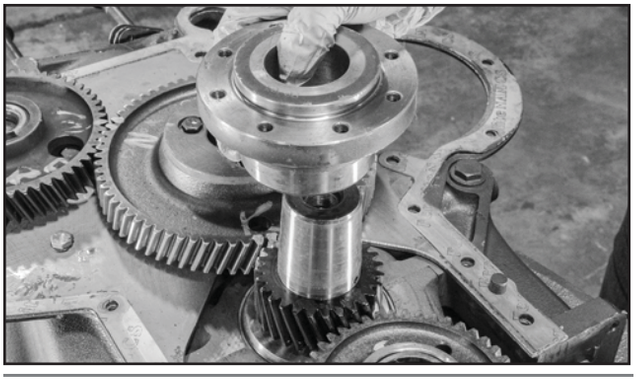


FIGURE 30. Crank Gear Hub

7.14.4 Relief Valve Assembly

- Remove the relief valve assembly from the oil filter header.

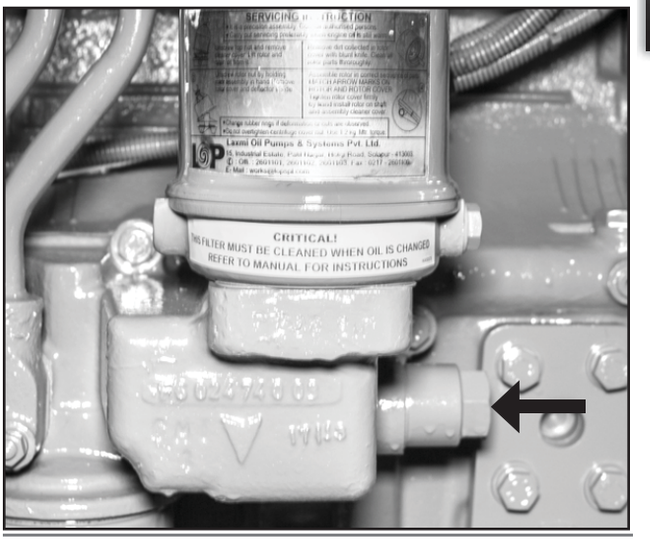


FIGURE 31. Relief Valve Assembly

7.14.5 Oil Pipe Assembly

- Dismantle the oil pipe assembly between the oil cooler and the filter header. Discard the gaskets.

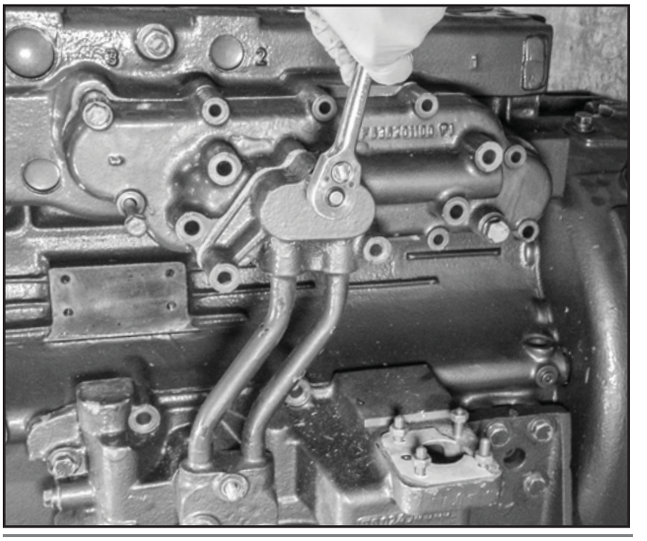


FIGURE 32. Oil Pipe Assembly

7.14.6 Oil Filter Header

- Remove the oil filter header from the crankcase.
- Remove the centrifugal oil filter.
- Clean or replace the oil filter.

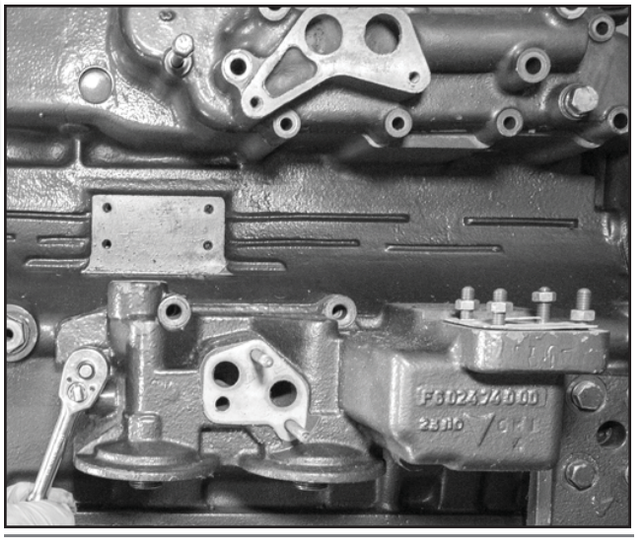


FIGURE 33. Oil Filter Header

7.14.7 Oil Cooler Assembly

- Remove the oil cooler assembly from the crankcase.
- Discard the gasket.

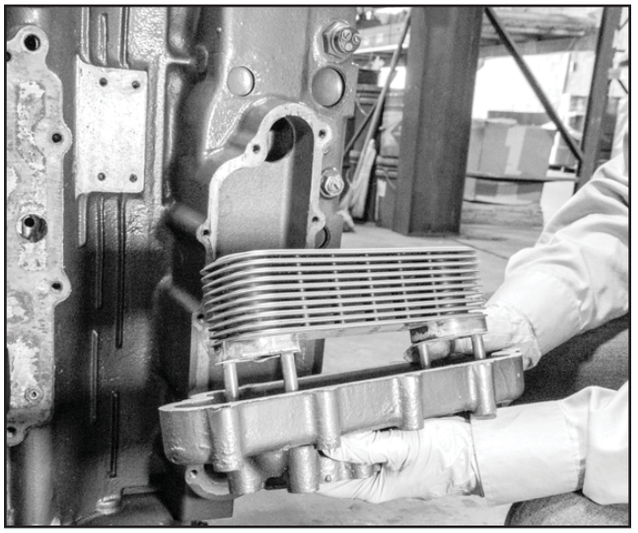


FIGURE 34. Oil Cooler Assembly

- Dismantle and separate the oil cooling element from the assembly.
- The plate-type cooler is located in the crankcase cavity. Under normal operating conditions, the oil cooler does not require any servicing. However, when the cooler is removed during an engine overhaul, it is advisable to service it.
- Clean the oil side (internally) by immersing the cooling element in clean solvent and shaking it vigorously until all the carbon and dirt comes out.
- Alternatively, clean the oil side (internally) by directing compressed air very slowly from the oil outlet of the element with the element dipped in solvent. This will clean the inside of the element by the agitation method.
- Rinse the element in fresh clean solvent and flush it with fresh lubricating oil.
- Clean the water side (externally). Seal the oil inlet and outlet openings of the cooler. Clean the cooler unit externally with soap solution and a brush. Remove rust and scale.

CAUTION: Do not use acid or alkaline-based cleaners. Do not use any sharp instrument to scrape off rust as this can damage the cooler element.

- Dry the oil cooler with compressed air or allow it to air dry in a clean, dust-free environment.
- Reassemble the oil cooler with new gaskets and torque to specifications in section *"1.11 Torque Specifications" on page 9*.

7.14.8 Flywheel

- Loosen and remove flywheel.
- Inspect the condition of the starter ring.

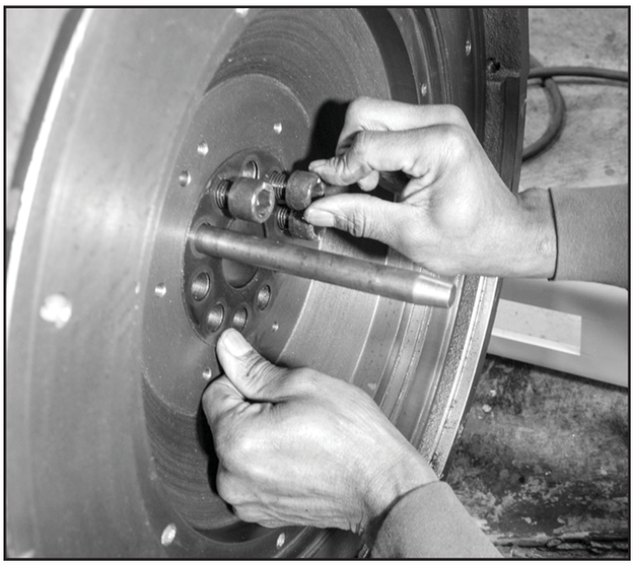


FIGURE 35. Flywheel

- Remove the flywheel housing

- Discard the oil seal and gasket.

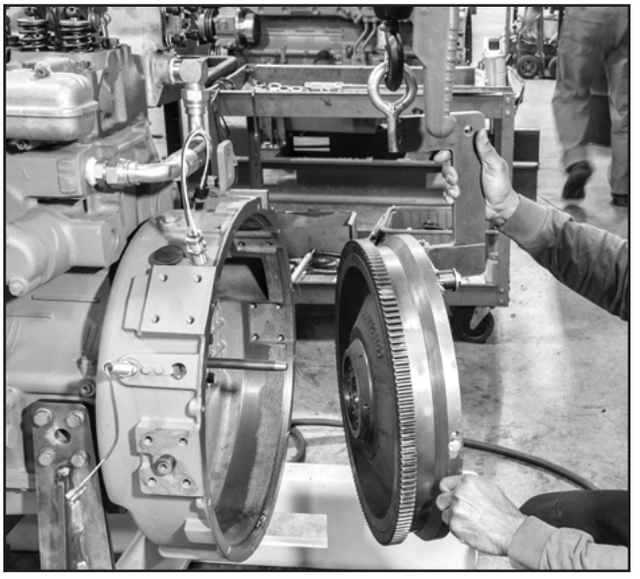


FIGURE 36. Flywheel Housing

7.14.9 Gear Casing Assembly

- Remove the gear casing assembly. Discard the oil seal and gasket.

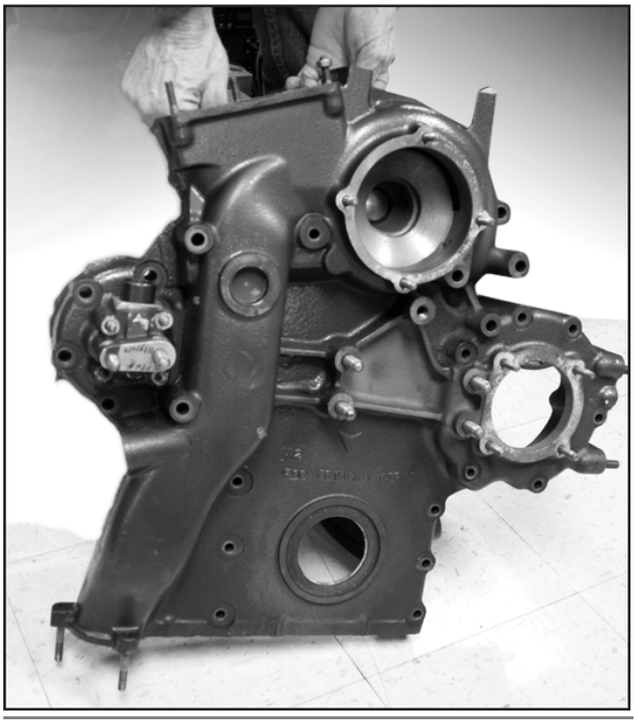


FIGURE 37. Gear Casing Assembly

- Remove the harmonic balancer.

7.14.10 Gear Backlash

- Check the gear backlash.
- Backlash is the gap between the meshing gear teeth.
- Attach a dial gauge pointer to one tooth of a gear whose backlash is required to be checked.

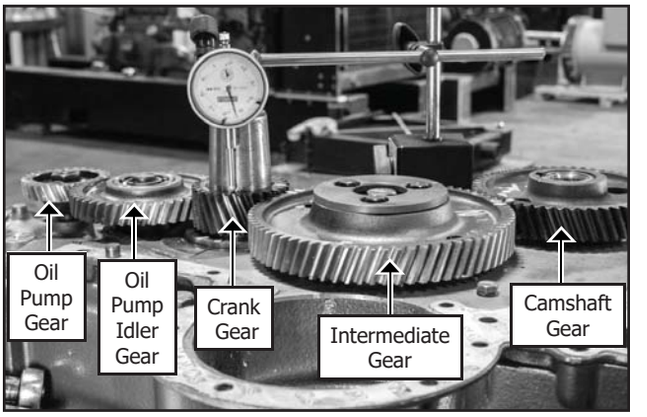


FIGURE 38. Gear Backlash

- Press dial gauge stylus against the gear.
- Set the dial to '0'.
- Hold the corresponding gear firmly with one hand. (Do not allow it to move while checking backlash).
- Lightly oscillate the required gear back and forth within its free movement range.
- Check the reading on the dial gauge.
- Repeat this procedure at four points of the gear. The average reading will be the backlash.

RECOMMENDED GEAR BACKLASH	
1. Intermediate Gear and Crank Gear	0.127-0.322 mm (0.005-0.013 in)
2. Oil Pump Idler Gear and Crank Gear	0.078-0.221 mm (0.003-0.009 in)
3. Oil Pump Gear and Oil Pump Idler Gear	0.076-0.436 mm (0.003-0.172 in)
4. Cam Gear and Intermediate Gear	0.106-0.277 mm (0.004-0.11 in)
5. Intermediate Gear and Single Fire Ignition Gear (turbo models only)	0.106-0.277 mm (0.004-0.011 in)

- Compare the reading with the recommended gear backlash values in the table above. Replace if limits are exceed

7.14.11 Intermediate Gear

- Remove the intermediate gear.
- Inspect the intermediate gear parts for wear and damage. If wear or damage is severe, replace the gear along with the bushing.
- Check the condition of the intermediate gear ball bearings for end play. If end play is found, replace the ball bearings.
- Check the condition of the intermediate gear shaft. Replace if worn or damaged.
- When installing a new intermediate gear shaft, dip it in liquid nitrogen for about five minutes, then press in the bearing cap.

CAUTION: Avoid direct contact with liquid nitrogen to avoid bodily injury due to sub-zero cooling.

- Check the intermediate gear's bushing inside diameter at two depths and at right angles in a pressed condition. Refer to specifications in section *"5.6 Intermediate Gear and Support" on page 44*.

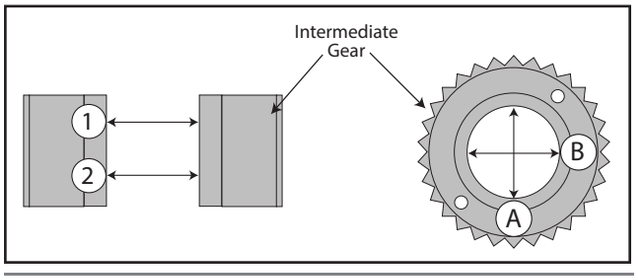


FIGURE 6. Intermediate Gear Inside Diameter

- Inspect the intermediate gear hub outside diameter with a micrometer at two depths and at right angles.

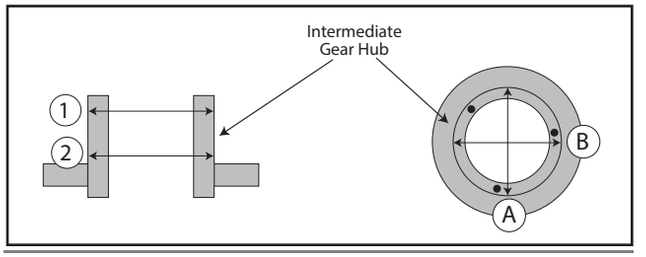


FIGURE 7. Intermediate Gear Hub Outside Diameter

- Compare the clearance between the intermediate gear bushing and the intermediate gear support journal to the specifications in section *"5.6 Intermediate Gear and Support" on page 44*. Replace the intermediate gear bushing if the clearance exceeds the limit value.
- Replace the thrust washer.
- Remove the intermediate gear hub and ring assembly.

7.14.12 Camshaft

- Check the camshaft end play.
- Unscrew the bolts of the thrust plate. Fully press tappets in their bores and pull out the camshaft, guiding it out from the central bearing zone through the opening in the crankcase.
- Do not separate the cam gear from the camshaft unless the thrust plate needs to be replaced.
- Check the cam journal diameter with a micrometer. If journals are worn, recondition or replace the camshaft. Refer to specifications in section *"5.8 Camshaft Journal Diameter" on page 46*.
- Calculate the clearance between camshaft journal and bushing. Compare the readings and ensure the clearance is within limit values in section *"5.7 Camshaft" on page 45*.

- Check the cam profile for excessive wear.
- Replace camshaft if the cam profile is damaged.

CAUTION: Do not try to recondition the camshaft's cam profile as this will affect the engine performance.

- Check that the oil gallery along the length of the camshaft is clean and open.
- Check the camshaft endplay.
- Check the thrust plate condition. If end gap exceeds the specified limit, replace the entire camshaft assembly. Refer to specifications in section *"5.7 Camshaft" on page 45*.

7.14.13 Crankshaft Disassembly

- Remove the front plate. Discard the gasket
- Check the crankshaft end play to establish the condition of thrust washer and crankshaft. Compare to specifications in section *"5.9 Crankshaft" on page 47*.
- Dismantle and discard the oil pump assembly.
- Loosen and remove the main bearing caps.
- Remove the crankshaft from the crankcase.
- Thoroughly clean the crankshaft before inspecting it.
- Visually inspect the crankshaft for wear, damages, and discoloration of pins or journals. Replace the crankshaft if cracks are detected on the fillet radius. In case of other damages, crankshaft can be reconditioned.

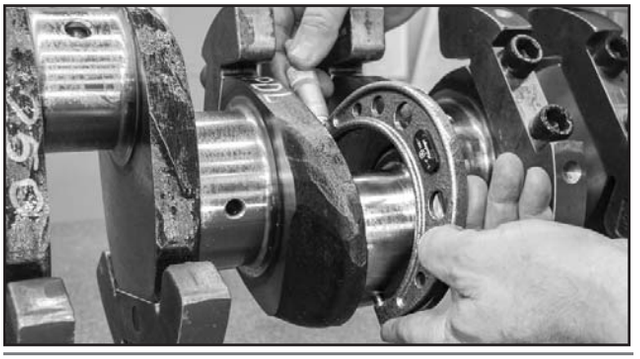


FIGURE 8. Journal and Pin Diameter

- Check the journal and pin diameters for wear and ovality with a micrometer. Compare the readings with specifications in section *"5.9 Crankshaft" on page 47*.
- Inspect the locating journal width where the thrust washers come in contact. Calculate the clearance, considering the bearing cap with standard thrust washer width. Refer to section *"5.9 Crankshaft" on page 47*. If the clearance has exceeded the limit value of crankshaft end play, replace the crankshaft.
- Inspect flywheel journal flange at the oil seal contact zone. If wear and deep grooving is noticed, replace the crankshaft.

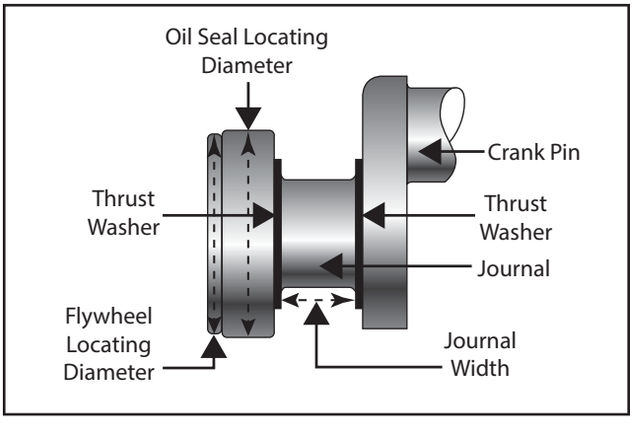


FIGURE 9. Crankshaft Inspection

- Check the surface hardness of the journals and pins with a non-indenting type hardness tester. Note and compare the values with specifications in section *"5.9 Crankshaft" on page 47*.
- Journals and pins should be checked for cracks. If cracks are noticed, under-size the crankshaft until the crack disappears.

CAUTION: If the crack is deep and reaches the soft core, it is advisable to replace the crankshaft.

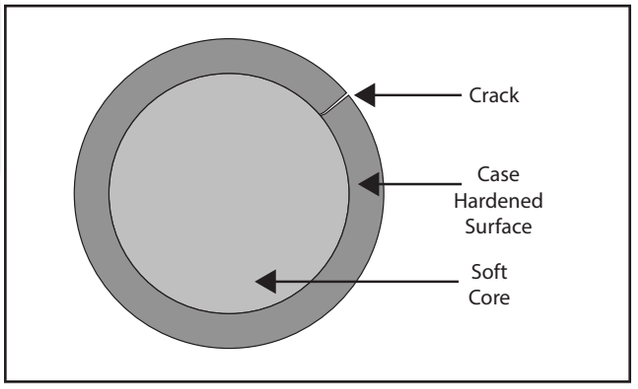


FIGURE 10. Inspect for cracks

- Check the crankshaft for bend
- Support crankshaft with V-Blocks on two journals as shown in the table below.

FIGURE 11. V-Blocks

- The run-out is to be checked by a dial gauge for the specific journal or flange as specified in the table.

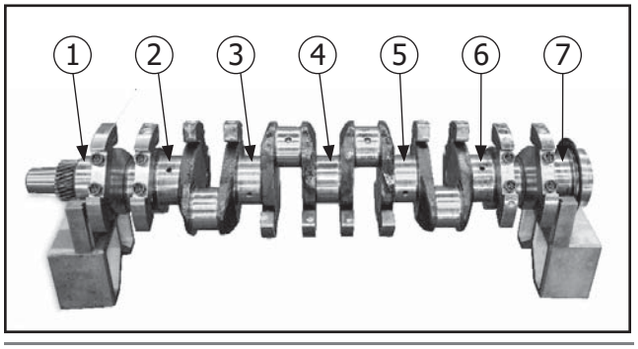


FIGURE 12. Crankshaft Journals

Sr. No.	To check 'run-out' of journal no.	Support crankshaft on V-Block journal no.	Permis-sible max run-out
1	FWE flange oil seal locating diameter	6 & 1	0.05 mm
2	FWE flange flywheel locating diameter	6 & 1	0.05 mm
3	Journal 1	6 & 2	0.055 mm
4	Journal 3	6 & 2	0.055 mm
5	Journal 4	6 & 2	0.08 mm
6	Journal 5	6 & 2	0.055 mm
7	Journal 7	6 & 2	0.055 mm
8	Crankshaft nose (50 dia)	6 & 2	

CAUTION: If bend or twist is observed, do not try to rectify as this will further damage the crankshaft and main bore of the crankcase.

- Check for proper fillet radius on crankshaft. Refer to specifications in section *"5.9 Crankshaft" on page 47*.
- Ensure that there is no mismatch of fillet radius with diameter of face.

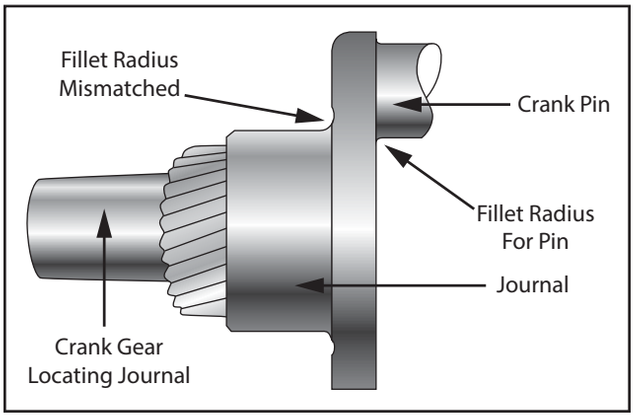


FIGURE 13. Fillet Radius

- Grind all journals and pins uniformly to the same under-size limits, within the tolerance given in specifications in section *"5.9 Crankshaft" on page 47*.
- Fillet radius of journals and pins must be maintained as specified.

- Remove all sharp corners and edges from the journals and pins.
- Remove and discard the bearings and thrust washers from the crankcase and caps.
- Unscrew and remove oil spray nozzles from the crankcase.

CAUTION: Sharp edges developed due to mismatch will lead to stress being concentrated in a sharp-edged area, thereby leading to breakage of crankshaft (through fillet radius) in a running condition. This is the main reason for crankshaft failure.

- Before sending the crankshaft for machining, remove the crank gear and balance weights. Number all weights and their locations before removing. Mark by PAINT OR PERMANENT MARKER ONLY in ascending order starting with number 1 at the balance weight nearest to the flywheel side. For convenience of refitting the weight exactly, all numbers should be marked on the camshaft side of the balance weights as well as on the crankshaft web.
- During machining, all journals and pins must be ground uniformly to the same under-size diameter and within the specified tolerance limit. Maintain the specified fillet radius of journals and pins. There should be no sharp corners/edges to the journals and pins. The sharp corners/edges should be removed by polishing and rounding off.
- There should be no visible tool marks/ scratches on the fillet radius or the polished surface areas.
- Sharp corners of oil holes should be rounded off and blended with the pin's curvature.

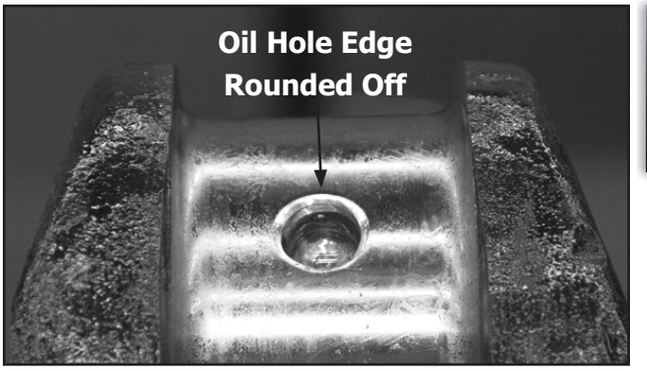


FIGURE 14. Oil Hole

CAUTION: Flywheel locating diameter where flywheel and oil seal locates MUST NOT BE MACHINED/ POLISHED/LAPPED.

- If crankshaft requires extensive rebuild-ing, please contact SES Arrow Engine for a new replacement.

7.14.14 Crankshaft Reassembly

- After grinding, check the journal and pin diameters for cracks.
- Check the thrust journal width.
- Check surface hardness of the newly ground journals and pins.

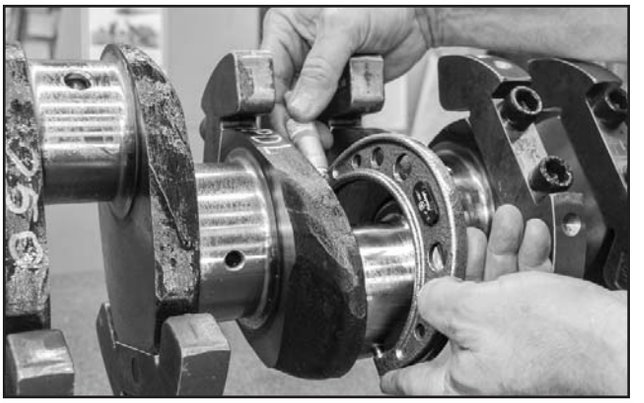


FIGURE 15. Journal and Pin Diameter

- Inspect the journal and pin diameters with a micrometer and compare with specifications in section *"5.9 Crankshaft" on page 47*.
- Inspect to ensure that the fillet radius of the ground journals and pins are maintained as specified.
- Check the straightness, out-of-roundness, and parallelism between journals and pins.

- Refer to specifications in section *"5.9 Crankshaft" on page 47*.

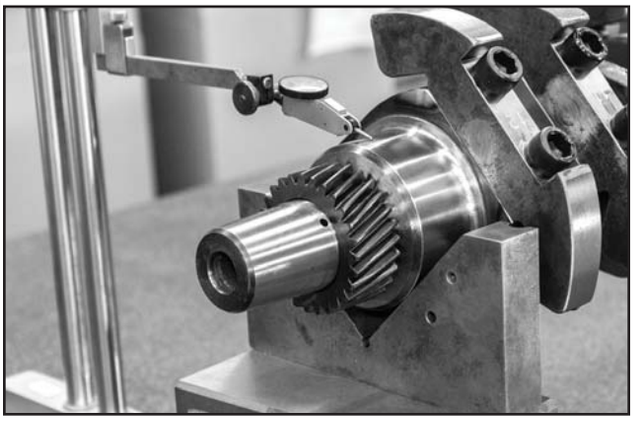


FIGURE 16. Inspect Journals and Pins

- Inspect and ensure that there are no visible tooling marks or scratches on the fillet radius and the finished surfaces of the crankshaft.
- Use the correct size tap to clean the threaded holes in the crankshaft where the balance bolt fits.
- Clean the crankshaft and oil passages with clean engine fuel and remove all traces of abrasive material from the oil passages. Dry with compressed air.
- Calculate the clearance between crankshaft journal and main bearing inside diameter. Ensure the reading is within the limit value in section *"5.9 Crankshaft" on page 47*.

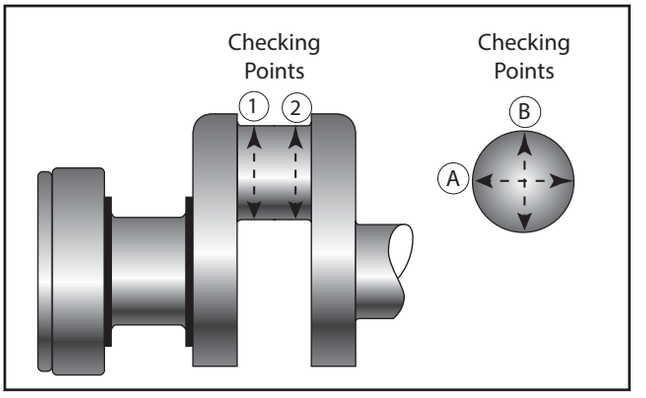


FIGURE 17. Checking Points

- Balance weight bolts should be replaced at every major overhaul. Refit the correct numbered balance weights to their respective webs and tighten bolts as per the torque specifications in the table in section *"5.9 Crankshaft" on page 47*.
- Fit the crank gear dowel pin.
- Fit the crank gear.
- Clean and wipe the main bearing bores in the crankcase.
- Install the cleaned, new bearings in the crankcase bore and caps (7 sets of bearing shell halves).
- Six bearing halves of the seat are with oil groove and hole. Fit these bearing shell halves in the crankcase bore Numbers 1-2-3-5-6-7.
- The other six halves, having only a small groove at the shell ends, should be fitted on bearing caps 1-2-3-5-6-7.
- The bearing shell with only a hole (without oil groove) fits in the 4th bore of the crankcase. The plain half of the set fits in the 4th main bearing cap.

CAUTION: Bearings are fitted dry. Do NOT apply oil to the bearing back or the bore.

- Bearing shells must fit tightly with a spring action in the bore cavity. (Adequate free spread).
- Fit the thrust washers in the grooves provided in the first bearing cap and bore.
- Wipe the crankshaft journals with a soft cotton-free cloth.
- Apply fresh oil to the crankshaft journals, installed bearings, and thrust washers.
- Gently lower and settle the crankshaft in the crankcase.
- Ensure the free rotation of the crankshaft by hand.
- Fit bearing caps after checking that the cap numbers and locating notch on crankcase and bearing cap are both on the same side.
- Ensure the free rotation of the crankshaft by hand.

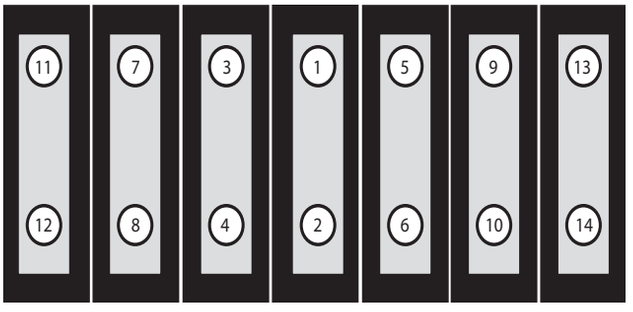


FIGURE 18. Crankshaft Bearing Torque

- Apply torque to the main bearing cap bolts as per the specifications in the table in section *"1.11 Torque Specifications" on page 9*. Follow the tightening sequence.
- Ensure free rotation of the crankshaft by hand after every torquing step.
- Inspect the crankshaft end-play with a feeler gauge or dial gauge comparing with the specifications given in section *"5.9 Crankshaft" on page 47*.

8 Troubleshooting

8.1 Methods

Good troubleshooting methods determine the cause or causes of unsatisfactory operation and point out the action needed to correct the problem. Knowledge of how engine systems work together with the troubleshooting chart in this unit and current indications from the engine instrument panel provide the best background information.

8.2 Operating Controls

A-90 engines are equipped with the following operating controls

1. Water temperature gauge
2. Oil pressure gauge
3. Throttle
4. Starter switch
5. Ignition switch

8.3 Electrical System

The engine electrical system consists of a heavy duty starter and alternator, switches and circuits. The engine is started by closing a circuit from battery to starter with the instrument panel switch that actuates the magnetic switch. Positive engagement of the pinion before cranking commences is accomplished by the starting motor solenoid. After cranking is completed and the engine starts, the alternator replenishes energy expended by the battery. Cutouts and regulators control the alternators output and protect the system from reverse currents and excessive charging rates. SES Arrow Engine Com-pany supplies engines with negatively grounded electrical equipment only. This standardization of electrical system polarity is standard practice for most equipment manufacturers and thus increases compatibility between SES Arrow supplied electrical equipment and that supplied by the equipment builder.

8.4 Cooling System

The cooling system used on the A-90 is of the pressure circulating type. The water enters the water pump inlet on the right side of the engine. The centrifugal pump pulls this supply of cool water through the pump body and into a water passage leading directly into the engine water jacket. The water enters the engine in the area of the cylinder sleeve lower ends. From here, the water flow is directed around the cylinder sleeves in an even manner until it passes upward from the crankcase and into the cored passages in the cylinder heads. These passages are carefully designed to allow cooling water access to all areas around the valves. Water is collected from the cylinder head and enters a thermostat housing at the forward end. The thermostat controls the exit temperature of the water. Back pressure at the water outlet must not exceed 7 pounds per square inch (34.474 kPa).

8.5 Air Intake System

With the exception of adequate supplies of clean oil and water, probably no other single service item contributes so much to engine life as a properly working air cleaner. This is particularly true under dusty and agricultural operating conditions, but surprising amounts of abrasive dirt are present in most atmospheres. When carried into the engine through the air inlet, such abrasives rapidly wear away cylinder walls, valve stems, bearings and other working parts.

Because the dust particles are so small, yet possess the ability to cause great damage, it is absolutely mandatory that air inlet connections be kept in tight condition to avoid taking in unfiltered air.

Although various installations will have differences in air cleaner types and arrangements, it

is important for the operator to realize that the common purpose of all air cleaners is to collect dirt and grit. Thus the cleaner itself must be cleaned as often as dirt accumulations start to build up. Sometimes this may be several times each day if conditions are especially dusty.

8.6 Exhaust System

Proper disposal of engine exhaust is critical to performance. Engines consume large amounts of air that must be pushed out of the cylinders through the manifolds and exhaust piping. Provision must be made to minimize the restriction or back pressure on the exhaust system.

Some of the adverse effects of excessive back pressure are...

1. Loss of power.
2. Poor fuel economy.
3. Excessive valve temperatures and premature wear.
4. Jacket water overheating.

The exhaust system of an engine with a particularly long exhaust pipe can accumulate quite a bit of condensed moisture. If allowed to run back through the piping into the engine after it is shut down the obvious rusting and sticking of valves, rings etc. and the possibility of a hydraulic "lock" become serious. Always provide a condensate trap and drain at some low point ahead of the engine manifolds.

8.7 Governing Systems

8.7.1 ESD5100/5131 Series Speed Control Unit

Insufficient Magnetic Speed Signal
A strong magnetic speed sensor signal will eliminate the possibility of missed or extra pulses. The speed control unit will govern well with 0.5 volts RMS speed sensor signal. A speed sensor signal of 3 volts RMS or greater at governed speed is recommended. Measurement of the signal is made at Terminals C and D.

The amplitude of the speed sensor signal can be raised by reducing the gap between the speed sensor tip and the engine ring gear. The gap should not be any smaller than 0.020 in (0.45 mm). When the engine is stopped, back the speed sensor out by 3/4 turn after touching the ring gear tooth to achieve a satisfactory air gap.

8.7.2 Electromagnetic Compatibility (EMC)

EMI Susceptibility
The governor system can be adversely affected by large interfering signals that are conducted through the cabling or through direct radiation into the control circuits.

All GAC speed control sensors contain filters and shielding designed to protect the unit's sensitive circuits from moderate external interfering sources.

Although it is difficult to predict levels of interference, applications that include magnetos, solid sate ignition systems, radio transmitters, voltage regulators or battery chargers should be considered suspect as possible interfering sources. If it is suspected that external fields, either those that are radiated or conducted, are or will affect the governor systems operation, it is recommended to use shielded cable for all external connections. Be sure that only one end of the shields, including the speed sensor shield, is connected to a single point on the case of the speed control unit. Mount the speed control to a grounded metal back plate or place it in a sealed metal box.

Radiation is when the interfering signal is radiated directly through space to the governing system. To isolate the governor system electronics from this type of interference source, a metal shield or a solid metal container is usually effective.

Conduction is when the interfering signal is conducted through the interconnecting wiring to the governor system electronics. Shielded cables and installing filters are common remedies.

In severe high-energy interference locations such as when the governor system is directly in the field of a powerful transmitting source, the shielding may require to be a special EMI class

shielding. For these conditions, contact SES Arrow Technical Service application engineering for specific recommendations.

Instability

Instability in a closed loop speed control system can be categorized into two general types. PERIODIC appears to be sinusoidal and at a regular rate. NON-PERIODIC is a random wandering or an occasional deviation from a steady state band for no apparent reason.

The ESD5131 Speed Control Unit was derived from the standard ESD5111 Speed Control Unit. All specifications, installation procedures, and adjustments, except those noted are identical.

The difference between the ESD5131 and the ESD5111 lies in the two DIP switches located under the upper access hole. Switch 1 controls the "Lead Circuit" found in the ESD5111. The normal position is "ON." Move the switch to the "OFF" position if there is fast instability in the system.

Switch 2 controls an additional circuit added in the ESD5131 that is designed to eliminate fast erratic governor behavior, caused by very soft or worn couplings in the drive train between the engine and generator. The normal position is "OFF." Move to the "ON" position if fast erratic engine behavior due to a soft coupling is experienced.

The PERIODIC type can be further classified as fast or slow instability. Fast instability is a 3 Hz or faster irregularity of the speed and is usually a jitter. Slow periodic instability is below 3 Hz, can be very slow, and is sometimes violent.

If slow instability occurs check the fuel system linkage for binding, high friction, or poor linkage. Be sure to check linkage during engine operation. Also look at the engine fuel system. Irregularities with carburetion or fuel injection systems can change engine power with a constant throttle setting. This can result in speed deviations beyond the control of the governor system. Adding a small amount of droop can help stabilize the system for troubleshooting.

NON-PERIODIC instability should respond to the GAIN control. If increasing the gain reduces the instability, then the problem is probably with the engine. Higher gain allows the governor to respond faster and correct for disturbance. Look for engine misfiring, an erratic fuel system, or load changes on the engine generator set voltage regulator.

If unsuccessful in solving instability, contact SES Arrow Technical Service for assistance.

System Inoperative

If the engine governing system does not function, the fault may be determined by performing the voltage tests described in Steps 1 through 4. Positive (+) and negative (-) refer to meter polarity. Should normal values be indicated during troubleshooting steps, and then the fault may be with the actuator or the wiring to the actuator. Tests are performed with battery power on and the engine off, except where noted.

STEP	TERMINALS	NORMAL READING	PROBABLE CAUSE
1	F(+) & E(-)	Battery Supply Voltage (12 or 24 VDC)	1. DC battery power not connected. Check for blown fuse 2. Low battery voltage. 3. Wiring error
2	C & D	1.0V AC RMS min. while cranking	1. Gap between speed sensor and gear teeth too great. Check gap. 2. Improper or defective wiring to the speed sensor. Resistance between D and C should be 30 to 1200 ohms. 3. Defective speed sensor
3	P(+) & G(-)	10V DC, Internal Supply	1. Short on Terminal P. (This will cause a defective unit.) 2. Defective speed control unit
4	F(+) & A(-)	1.0 - 2.0V DC while cranking	1. SPEED adjustment set too low. 2. Short/open in actuator wiring. 3. Defective speed control. 4. Defective actuator. See Actuator Troubleshooting

8

Unsatisfactory Performance

If the governing system functions poorly, perform the following tests.

SYMPTOM	TEST	PROBABLE CAUSE
Engine overspeed	1. Do not crank. Apply DC power to the governor system	1. Actuator goes to full fuel. Then disconnect speed sensor at Terminal C & D. If actuator still at full fuel-speed control unit defective. If actuator at minimum fuel position, erroneous speed signal. Check speed sensor cable.
	2. Manually hold the engine at the desired running speed. Measure the DC voltage between Terminals A(-) & F(+) on the speed control unit.	1. If the voltage reading is 1.0 to 2.0 VDC, a) SPEED adjustment set above desired speed b) Defective speed control unit 2. If the voltage reading is above 2.0 VDC, actuator or linkage binding 3. Set point of overspeed shutdown device set too low. 4. If the voltage reading is below 1.0 VDC, defective speed control unit
Overspeed shuts down engine after running speed is reached		1. Speed adjustment set too high. 2. OVERSPEED set to close to running speed. 3. Actuator or linkage binding. 4. Speed control unit defective
Overspeed shuts down engine before running speed is reached	Check impedance between Terminals C & D. Should be 30 to 1200 ohms	
Actuator does not energize fully while cranking	1. Measure the voltage at the battery while cranking	1. If the voltage is less than 7V for a 12V system, or 14V for a 24V system, check or replace the battery
	2. Momentarily connect Terminals A and F. The actuator should move to the full fuel position	1. Actuator or battery wiring in error 2. Actuator or linkage binding 3. Defective actuator 4. Fuse opens. Check for short in actuator or harness
Engine remains below desired governed speed	Measure the actuator output, Terminals A & B, while running under governor control	1. If voltage measurement is within 2 volts or more of the battery supply voltage level, then fuel control restricted from reaching full fuel position. Possibly due to mechanical governor, carburetor spring, or linkage interference. 2. Speed setting too low

8.8 Integral Throttle Body Actuator

These tests are to check for proper operation of the actuator only. If the actuator passes these tests, the problem is more than likely elsewhere in the system.

If the governor system fails to operate, the following test can be performed. Shut engine down, disconnect the actuator cable and measure the resistance through the wires while rotating the throttle plate. Next, check resistance from each wire to actuator housing again while rotating the throttle plate (See table below). The resistance will fluctuate when you manually rotate the plate, but the reading should settle back to a fixed value based on the table below. This test is only to insure that there is no obstruction, wire breakage or metal-on-metal contact inside the throttle body.

Measure the resistance from:

Red to White (12 VDC) ..... 2 Ohms

Red to White (24 VDC) ..... 8 Ohms

Red to Actuator Housing .....< 5 Mega ohms

White to Actuator Housing .....< 5 Mega ohms

Make sure to reconnect the actuator cable.

Next, energize the actuator to fill fuel (follow steps in the speed control publication) and manually move the actuator throttle plate to the de-energized position. You should feel no binding or sticking of the throttle plate

8.9 Engine Troubleshooting Chart

TROUBLESHOOTING CHART		
SYMPTOM	**PROBABLE CAUSE**	**REMEDY**
Crankshaft cannot be barred over **CAUTION Do not attempt to rotate the crankshaft with the starter.**	Seized piston.	Replace piston assembly and possibly sleeve. Determine cause of the seizure: insufficient ring gap, insufficient lubrication, inadequate cooling or overload.
	Coolant or obstruction in the cylinder.	Remove spark plugs and crank engine to vent cylinders of accumulated coolant.
	Cracked head.	Replace head.
	Cracked sleeve.	Replace sleeve.
	Blown head gasket.	Replace head gasket.
	Bearings too tight:	
	1. High spot on bearings.	Replace bearings.
	2. Improper torque.	Loosen bearing caps and re-torque.
	3. Main bearing caps installed out of location.	Check each bearing cap, place in proper location.
	Load not disengaged from the engine.	Disengage load.
Engine will crank but not start	**Insufficient cranking speed:**	
	1. Run down battery or electric starter malfunction.	Charge or replace battery; check the starter system, and battery cables.
	2. Lube oil viscosity is too high.	Change to a lower viscosity oil.
	Poor compression:	
	1. Worn rings.	Renew rings.
	2. Leaking valves.	Recondition head and valves.
	3. Leaking head gasket.	Replace head gasket.

TROUBLESHOOTING CHART		
SYMPTOM	**PROBABLE CAUSE**	**REMEDY**
Engine will crank but not start (cont'd)	**Fuel system inoperative:**	
	1. Insufficient fuel supply	Check gas pressure and carburetor adjustments.
	2. Ruptured line pressure regulator.	Replace diaphragm.
	3. Stiff carburetor diaphragm or worn air-gas valve assembly.	Replace air-gas assembly.
	4. Bent line pressure regulator control rod.	Replace control rod.
	Clogged intake air filter.	Remove and clean or replace.
	Safety shut-down control not re-set.	Re-set safety shut-down control.
Engine stops suddenly (cont'd)	**Fuel:**	
	1. Insufficient fuel supply.	Check gas pressure.
	2. Loose fuel control linkage.	Readjust and tighten.
	3. Clogged fuel supply line.	Replace line.
	Obstructed exhaust manifold.	Determine obstruction and remedy.
	Clogged intake air filter.	Remove and clean.
	Engine overspeed causes safety control to shut down engine.	Determine and correct cause of overspeed.
	Excessive load causes engine to stall.	Determine and correct cause of overload.
	Piston seizure:	
	1. Insufficient ring gap (applicable only immediately after overhaul.)	Replace scored piston, sleeve and rings. Adjust ring gap.

TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Engine stops suddenly	2. Insufficient lubrication.	Replace scored piston, sleeve and rings. Clean oil passages and/or determine cause of lack of lubrication.
	3. Insufficient cooling.	Replace scored piston, sleeve and rings. Clean and/or fill the cooling system.
	Seizure of bearing, main connecting rod, piston pin or camshaft.	Replace bearings - clean up or replace crankshaft, camshaft or piston pins as required.
	Dirt in lubricating oil.	Check lubricating oil filter
	Obstruction in cylinder.	Replace all parts that failed.
	Low oil pressure causes safety control to shut the engine down.	Inspect the lubricating oil system and components and correct the cause.
	High coolant temperatures causes safety control to shut down the engine.	Inspect cooling system and components and correct the cause.
Engine power loss	**Low compression pressure:**	
	1. Leaking head gasket.	Replace head gasket - inspect for warped cylinder head and/or crankcase - replace if necessary.
	2. Leaking exhaust-intake valves.	Recondition head and valves.
	3. Worn rings (excessive blow-by.)	Replace rings.
	4. Worn piston/liner.	Replace as necessary.
	5. Cracked piston.	Replace.
	6. Cracked cylinder head.	Replace.
	7. Misadjusted intake and exhaust valves (if recently overhauled.)	Adjust valves.
	8. Intercooler, Turbo or duct work dirty.	Check and clean.

TROUBLESHOOTING CHART		
SYMPTOM	**PROBABLE CAUSE**	**REMEDY**
Engine power loss (cont'd)	9. Restriction in intake and/or exhaust system.	Check for obstruction.
	10. Insufficient warm up period.	Follow recommended procedures.
	Insufficient fuel:	
	1. Cracked fuel lines.	Replace cracked line.
	2. Low gas pressure.	Check gas fuel system.
	Excessive exhaust system back pressure.	Correct as required.
	Dirty air intake.	Remove and clean or replace.
Engine will not reach rated speed.	Engine overload.	Determine and correct cause of the overload.
	Tachometer inaccurate.	Calibrate or replace tachometer.
	Insufficient fuel supply.	Check fuel supply system.
	Governor misadjusted or faulty.	Measure the actuator output, terminals H & J, while running under governor control. If the voltage measurement is within 1.5 volts of the battery supply voltage level, the fuel control restricted from reaching full fuel position. Possibly due to mechanical governor, carburetor spring, or linkage interference. If not, increase speed setting.
	Restricted air intake.	Correct cause.
Engine hunts or surges	Governor misadjusted or faulty.	Reprogram or replace the governor.

TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Low or fluctuating lubricating oil pressure. **CAUTION: Shut down engine immediately**	Insufficient oil.	Add oil as required.
	Gauge inaccurate.	Compare to master gauge - replace gauge.
	Oil gauge line plugged.	Renew gauge line.
	Engine operated at angles in excess of maximum safe tilt angles.	Operate within maximum safe tilt angles.
	Crankcase oil pressure relief valve relieves at low pressure.	Replace relief valve spring and or shim it to increase pressure to 25-30psi (172.36-206.84 kPa)
	Lubricating oil pressure regulating valve stuck in the open position.	Free valve.
	Lubricating oil filter plugged (full flow only.)	Change the element and clean the filter.
	Worn lubricating oil pump.	Repair or replace the pump.
	Worn bearing (connecting rod, main and crankshaft.)	Replace worn bearings.
	Lubricating oil dilution.	Change oil and filter element. Determine and correct the source of dilution.
	Cracked or leaking lubricating oil.	Repair or replace the piping.
	Low oil viscosity.	Change to a higher viscosity oil, as recommended in *"1.4 Lubrication System" on page 4*.
	Lubricating oil foaming.	Use oil grade recommended in *"1.4 Lubrication System" on page 4*.
	Clogged oil inlet screen.	Remove and clean screen.

TROUBLESHOOTING CHART		
SYMPTOM	**PROBABLE CAUSE**	**REMEDY**
High lubricating oil pressure.	Gauge inaccurate.	Compare to the master gauge and replace as needed.
	Oil temperature too low.	Raise temperature.
	Oil pressure regulating valve stuck in closed position.	Free valve.
	Oil viscosity is too high.	Change to a lower viscosity oil as recommended in the *"1.4 Lubrication System" on page 4*.
Low cooling water temperature.	Gauge inaccurate.	Compare to master gauge - replace as needed.
	Inoperative thermostat.	Replace thermostat.
High cooling water temperature **CAUTION: Cool water slowly.**	Gauge inaccurate.	Compare to master gauge - replace as needed.
	Cooling system is air bound.	Purge air from the cooling system.
	Low coolant level.	Fill cooling system.
	Worn water pump.	Replace or overhaul the water pump.
	Frozen coolant.	Completely thaw the cooling system before starting the engine.
	Poor coolant circulation.	Check entire coolant system.
	Blown head gasket.	Replace head gasket.
	Insufficient circulation of air.	Correct as required.
	Cracked head.	Replace head.
	Cracked sleeve.	Replace sleeve.
	Inoperative thermostat.	Replace thermostat.
	Late ignition timing.	Re-time.

TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
High lubricating oil consumption.	Oil leaks in lubricating oil system.	
	Improper viscosity.	Change to recommended viscosity.
	Leaking oil seal/s - rear and/or front.	Change seal/s.
	Worn intake valve guides.	Change head/renew guides or valve stem seals.
	Stuck or worn piston rings.	Renew rings.
	One or more pistons with rings upside down (if recently overhauled.)	Remove piston and correct the position of the rings.
High lubricating oil consumption.	Excessive connecting rod bearing running clearance.	Replace bearings.
	Crankcase breather plugged.	Clean.
Lubricating oil contaminated. **NOTE: Change oil before running the engine.**	**Lubricating oil contaminated with water:**	
	1. Sleeve seals leaking or sleeve cracked.	Replace sleeve and/or rings.
	2. Cracked crankcase.	Replace the crankcase. Yes, really.
	Lubricating oil contaminated with dirt:	
	1. Lubricating oil filter by-pass valve opening because the element is plugged.	Replace the element.
	2. Lubricating oil filter element punctured.	Replace element.
	3. Air intake punctured.	Replace the air intake filter.

TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
Excessive vibration **NOTE: Stop the engine at once to investigate the cause.**	**Foundation bolts:**	
	1. Loose.	Torque.
	2. Cracked.	Replace and torque all bolts.
	Crankshaft:	
	1. Cracked.	Replace and conduct a complete investigation of the entire engine.
	2. Loose flywheel.	Replace and/or torque as required.
High lubricating oil temperature.	Gauge inaccurate.	Compare to master gauge - replace as needed.
	Engine overload.	Determine and correct the cause of the overload.
	High cooling water temperature.	See High Cooling Water Temperature section of the chart.
	Low lubricating oil pressure.	Low Lubricating Oil Pressure causes.
Knocking or unusual noises.	Engine overload.	Determine and correct cause of overload.
	Overly advanced ignition timing.	Re-time.
	Loose bearings (failed.)	Replace bearings.
	Loose piston pins (failed.)	Replace piston pins and/or pin bushings as required.
	Damaged or excessively worn accessory drives.	Repair and replace components as required.
	Excessive crankshaft end play.	Replace main thrust bearing.
	Excessive valve clearance.	Readjust valve clearance.
	Sticking valves or rocker arms.	Free up or replace.
	Misfitted or excessively worn timing gears.	Replace.

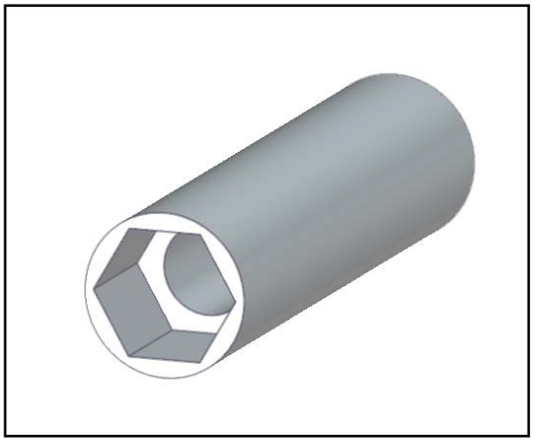
TROUBLESHOOTING CHART		
SYMPTOM	**PROBABLE CAUSE**	**REMEDY**
Excessive fuel consumption.	Leaks in the fuel system.	Repair as required.
	Late ignition timing.	Re-time.
	Engine overload.	Determine and correct causes of overload.
	Poor compression.	Determine causes and repair.
	Improper matching of torque convertor to engine and load.	Replace torque convertor.
Low gas pressure.	Incorrectly adjusted gas regulator.	Readjust.
	Insufficient line pressure.	Increase line pressure.
	Incorrect orifice and/or spring in the gas regulator.	Replace orifice and/or spring.
	Undersized gas regulator.	Replace with gas regulator of adequate size.
	Undersized piping.	Replace with piping of adequate size.
	Gas regulator mounted too far from engine.	Remount gas regulator as close to the carburetor as possible.
High gas pressure.	Incorrectly adjusted gas regulator.	Re-adjust
	Incorrect orifice and/or spring in the gas regulator.	Replace orifice and/or spring.
	Excessive line pressure.	Reduce line pressure.

9 Special Tools

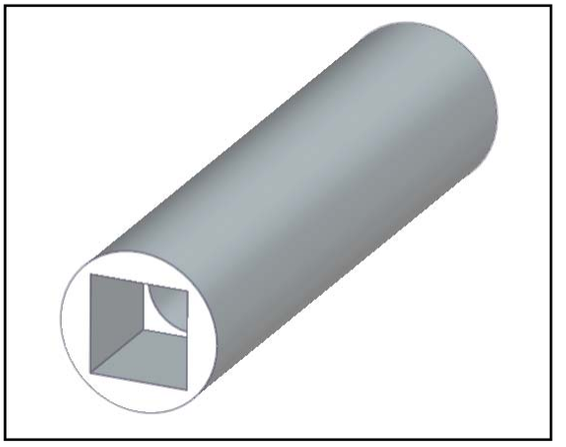
9.1 Required Tool

Tool may be ordered as follows:

SPARK PLUG SOCKET .....SES Arrow Part #KA50250 .....Qty: 1



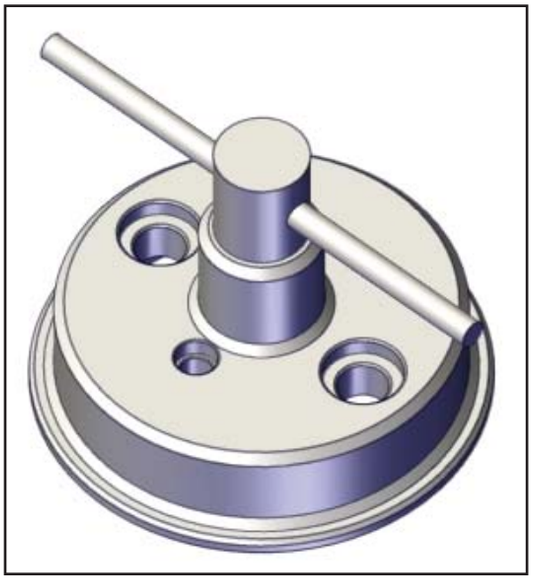
Hexagon end



Square end

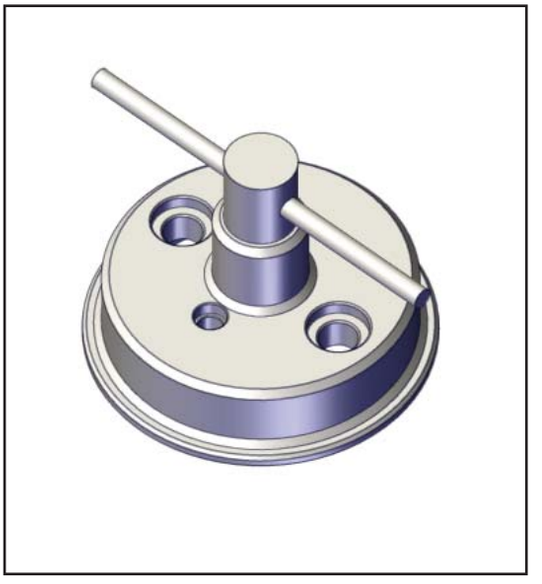
9.2 Optional Tool

Tool may be ordered as follows:



DRIVER, SEAL REAR MAIN

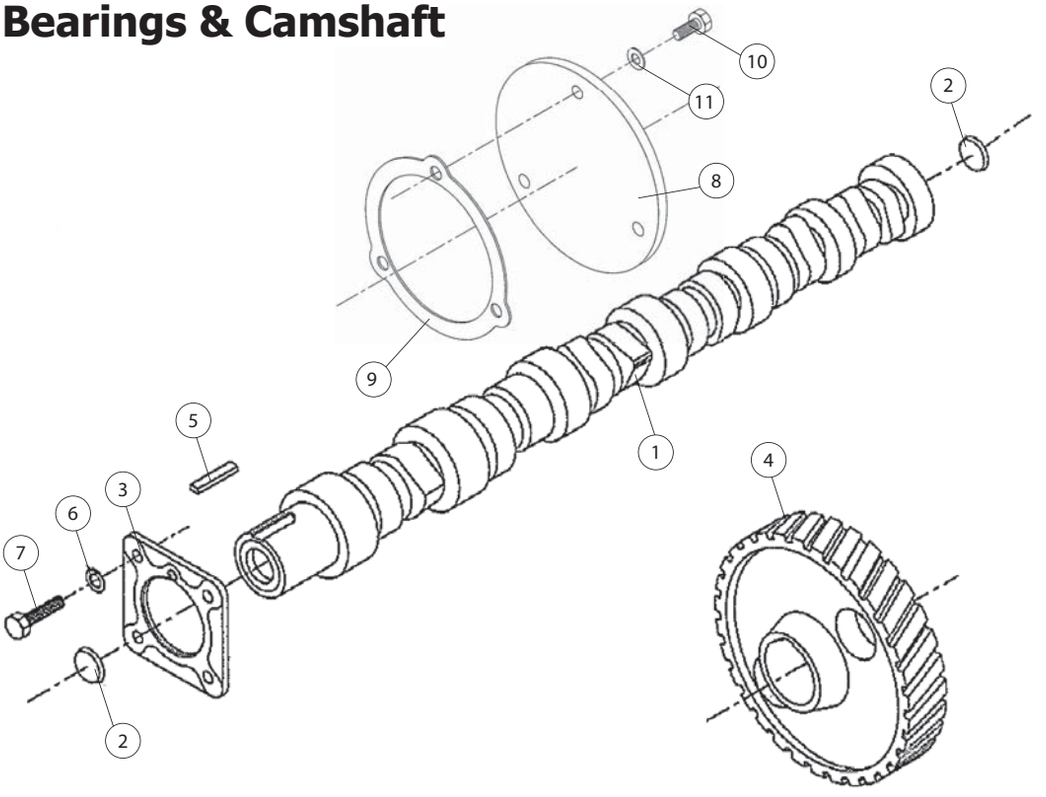
SES Arrow Part #KA50631..... Qty: 1



DRIVER, SEAL FRONT MAIN

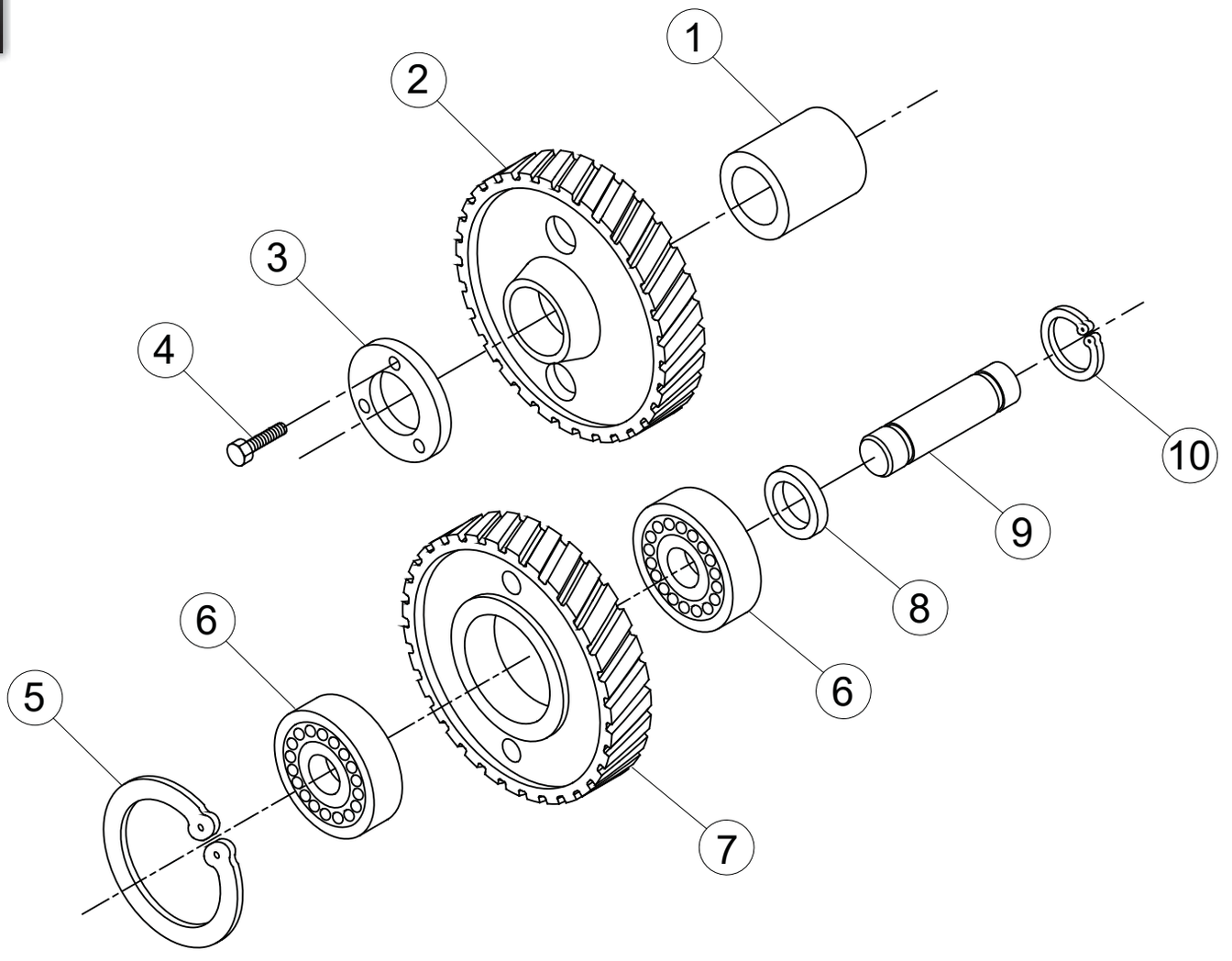
SES Arrow Part #KA50634..... Qty: 1

10.1 Bearings & Camshaft



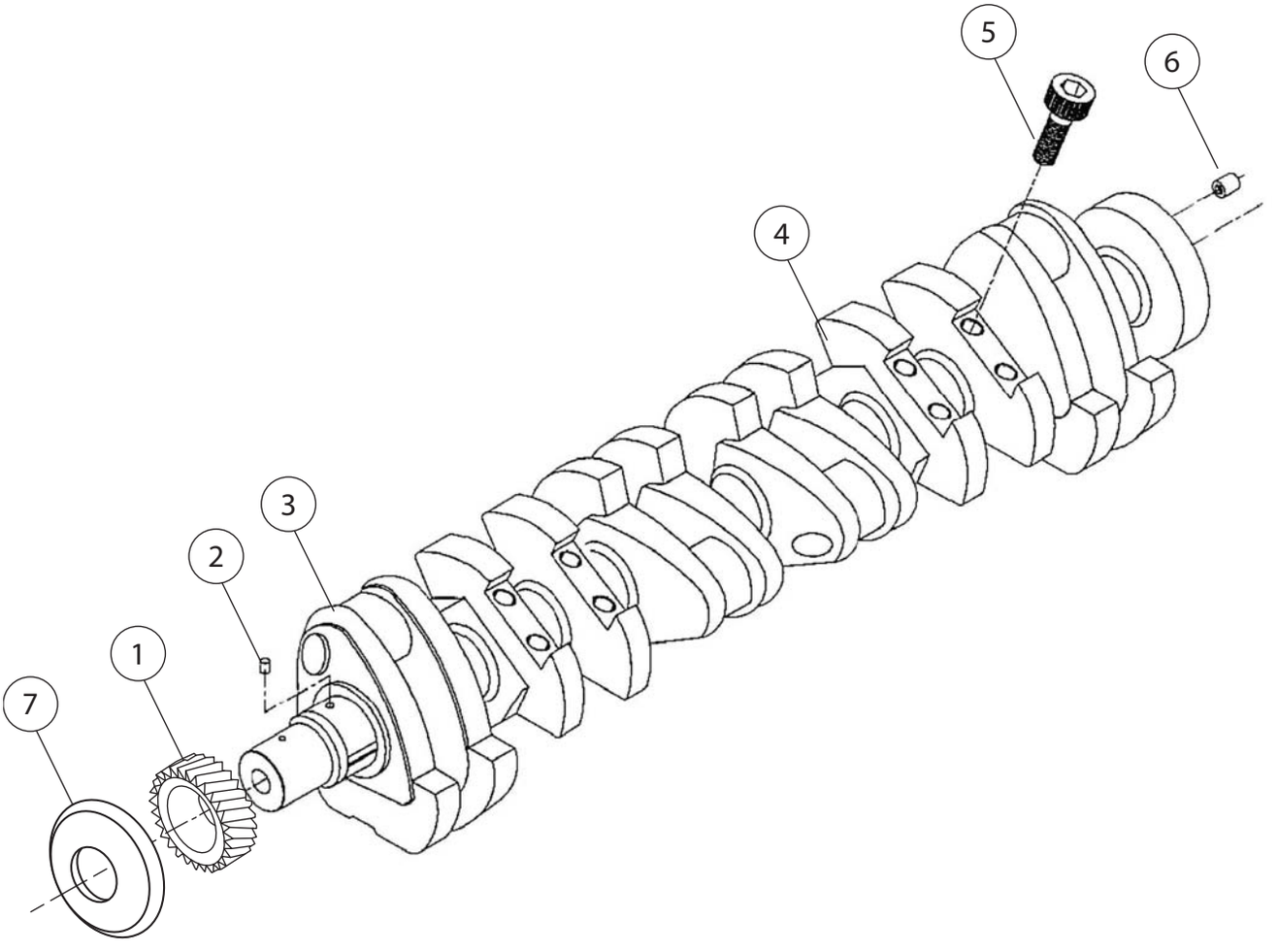
Bearings & Camshaft			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
KA50401		CAMSHAFT WITH CAM GEAR ASSY	
1	KA50403	CAMSHAFT	1
2	KA17002	CORE PLUG	2
3	KA50404	THRUST PLATE	1
4	KA50405	CAM GEAR	1
5	KA50406	PARALLEL KEY	1
6	KA19000	SPRING WASHER - M8	4
7	KA00008	SET SCREW M8X1.25X22-8.8	4
8	KA50407	PLATE, REAR CAM COVER	1
9	KA03021	GASKET, REAR CAM COVER	1
10	M6X20	SET SCREW M6X1X15-8.8	3
11	M06FW	PLAIN MACHINED WASHER	3

10.2 Intermediate Gears



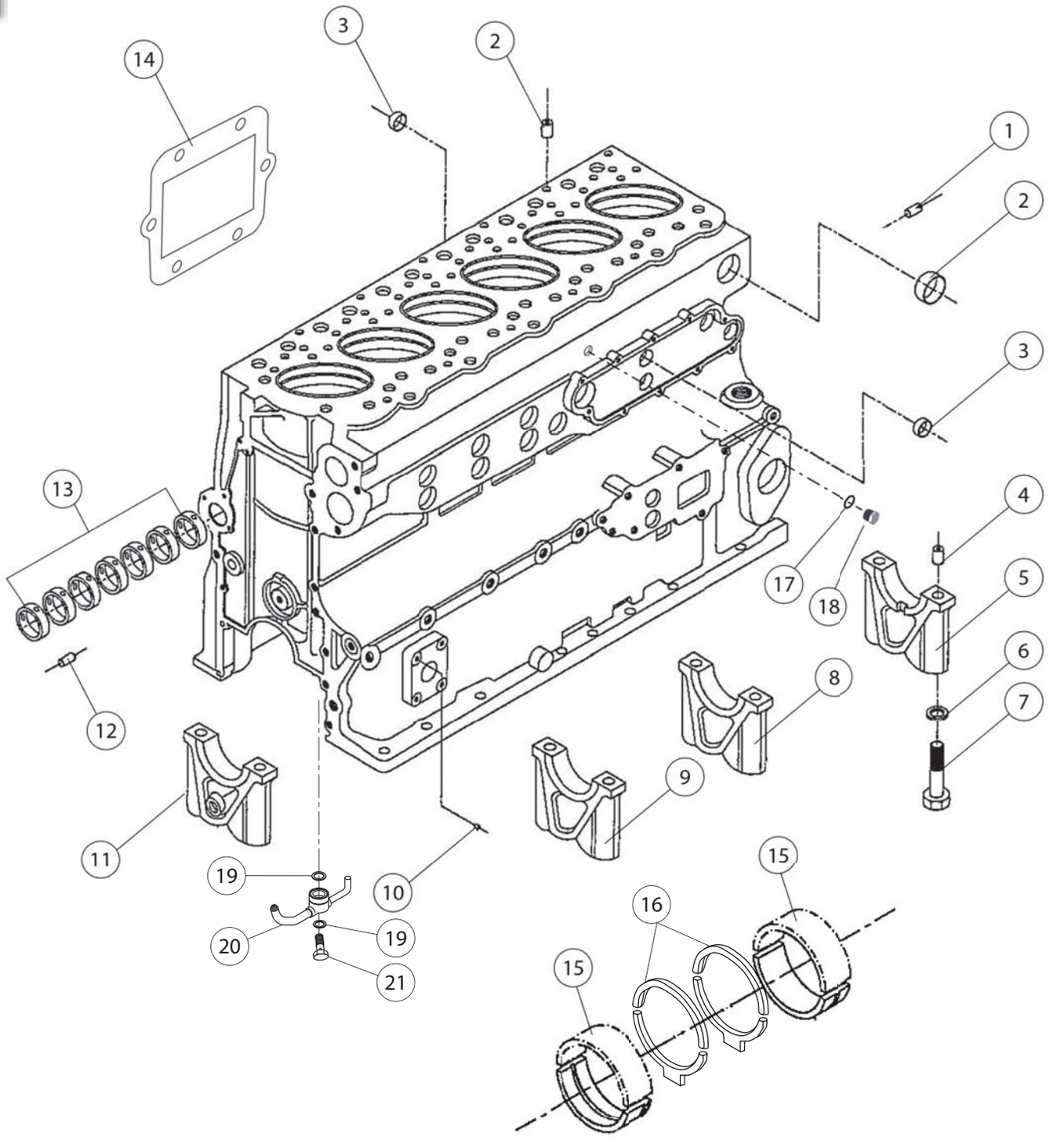
Intermediate Gears			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50611	INTERMEDIATE GEAR BUSH	1
2	KA50482	INTERMEDIATE GEAR W/ BUSHING	1
3	KA50610	BACK PLATE	1
4	KA00023	SET SCREW - M8X1.25X12 - 8.8	3
5	KA50609	CIRCLIP INTERNAL - 52 MM	1
6	KA50613	BALL BEARING	2
7	KA50617	INTERMEDIATE GEAR PUMP	1
8	KA16025	SPACER (20X28X1-DIN 988)	1
9	KA50612	INTERMEDIATE SHAFT.	1
10	KA50608	SNAP RING - 20 MM	2

10.3 Crank Shaft



Crank Shaft			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
KA50408		CRANKSHAFT ASSEMBLY (SOLD AS ASSEMBLY ONLY)	
1	KA50411	CRANKSHAFT GEAR	1
2	KA50412	DOWEL	1
3	KA50409	CRANKSHAFT	1
4	KA50410	BALANCE WEIGHT	12
5	KA00013	SCREW, SOCKET HEAD 16X50	24
6	KA50413	DOWEL PIN	1
7	KA50418	DEFLECTOR	1

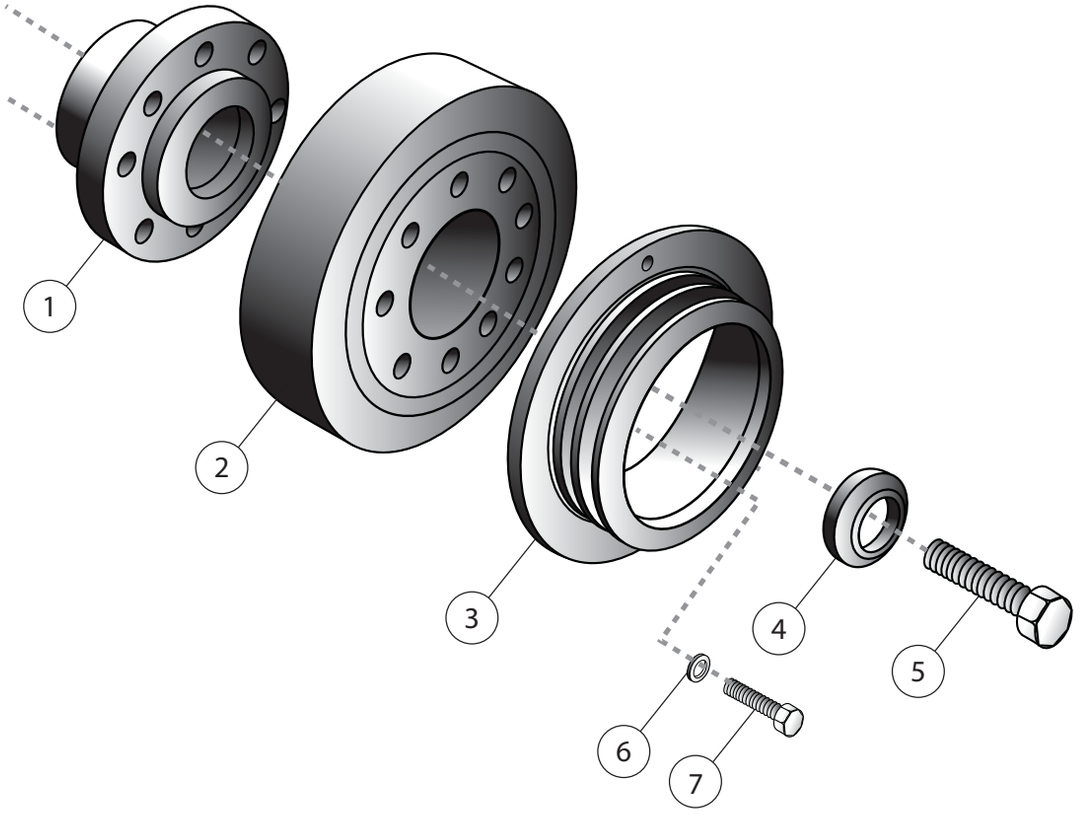
10.4 A-90 Crankcase



A-90 Crankcase			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
KA50436		CRANKCASE, ASSEMBLY	
1	KA50434	DOWEL PIN	6
2	KA50426	SEALING CAP	9
3	KA50425	SEALING CAP	10
4	KA50420	DOWEL PINS	7
5	KA50421	BEARING CAP	1
6	KA19008	WASHER, PLAIN WASHER, BEARING CAP	14
7	KA00026	BOLT, MAIN CAP	14
8	KA50424	BEARING CAP INTERMEDIATE	1
9	KA50423	BEARING CAP INTERMEDIATE	4
10	KA50358	DOWEL, FOOT MOUNTING	4
11	KA50422	BEARING CAP GEAR END	1
12	KA50435	DOWEL, GEAR CASING & FRONT PLATE	2
13	G-927-A90	A90 CAM BEARING KIT	1
14	KA03022	GASKET, COVER	1
15A	KA50386	BEARING (MAIN) (STD)	7
15B	KA50615	.020 MAIN BEARING	7
16	KA16011	THRUST WASHER SET	2
17	13023360	SEALING RING	1
18	01118960	PLUG	1
19	KA19016	COPPER WASHER	12
20	KA50619	OIL SPRAY NOZZLE ASSEMBLY	6
21	KA00019	BANJO BOLT, M12X1.5	6
22*	KA19004	BRASS WASHER	1
23	KA17001	PLUG	1

*Not shown.

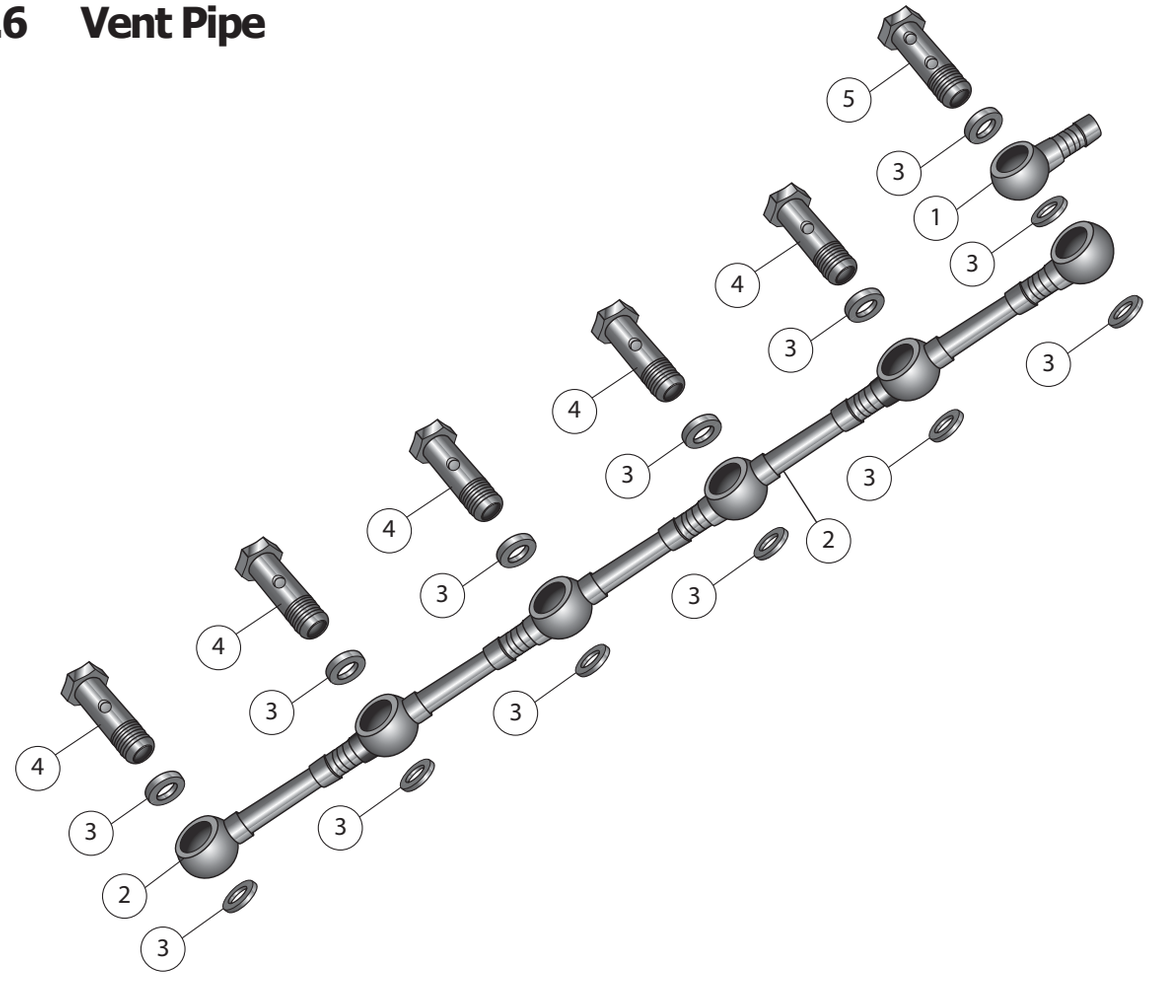
10.5 Crank Pulley



Crank Pulley			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50416	HUB, DRIVER	1
2	KA50415	DAMPER	1
3	KA50414	PULLEY	1
4	KA50417	PLATE, THRUST	1
5	KA00012	SCREW, HEX HEAD	1
6	KA19005	WASHER, PLAIN MACHINED	8
7	KA00011	SET BOLT	8
8*	SKA50514	AUXILIARY SHEAVE KIT, INCLUDES SHEAVE AND STUB SHAFT	

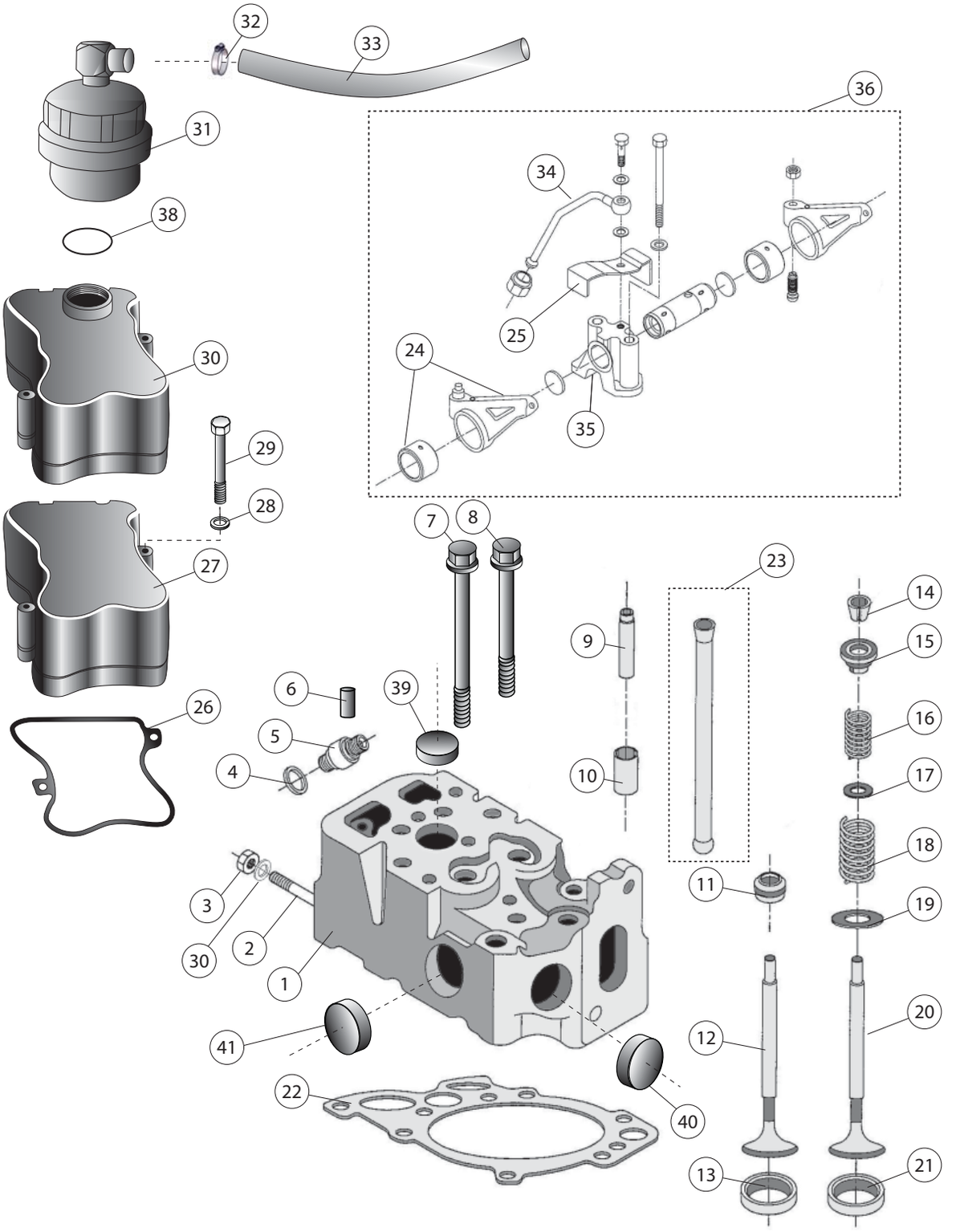
** Not Shown*

10.6 Vent Pipe



Vent Pipe			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	KA18000	FITTING, BANJO 14MM TO 3/8 HOSE	1
2	KA50290	PIPE COOLANT VENT	1
3	KA03004	SEALING RING FOR 14 MM BANJO FITTING	13
4	KA00004	BOLT, BANJO, SINGLE 14MM	5
5	KA00002	BOLT, DUAL STACK BANJO	1

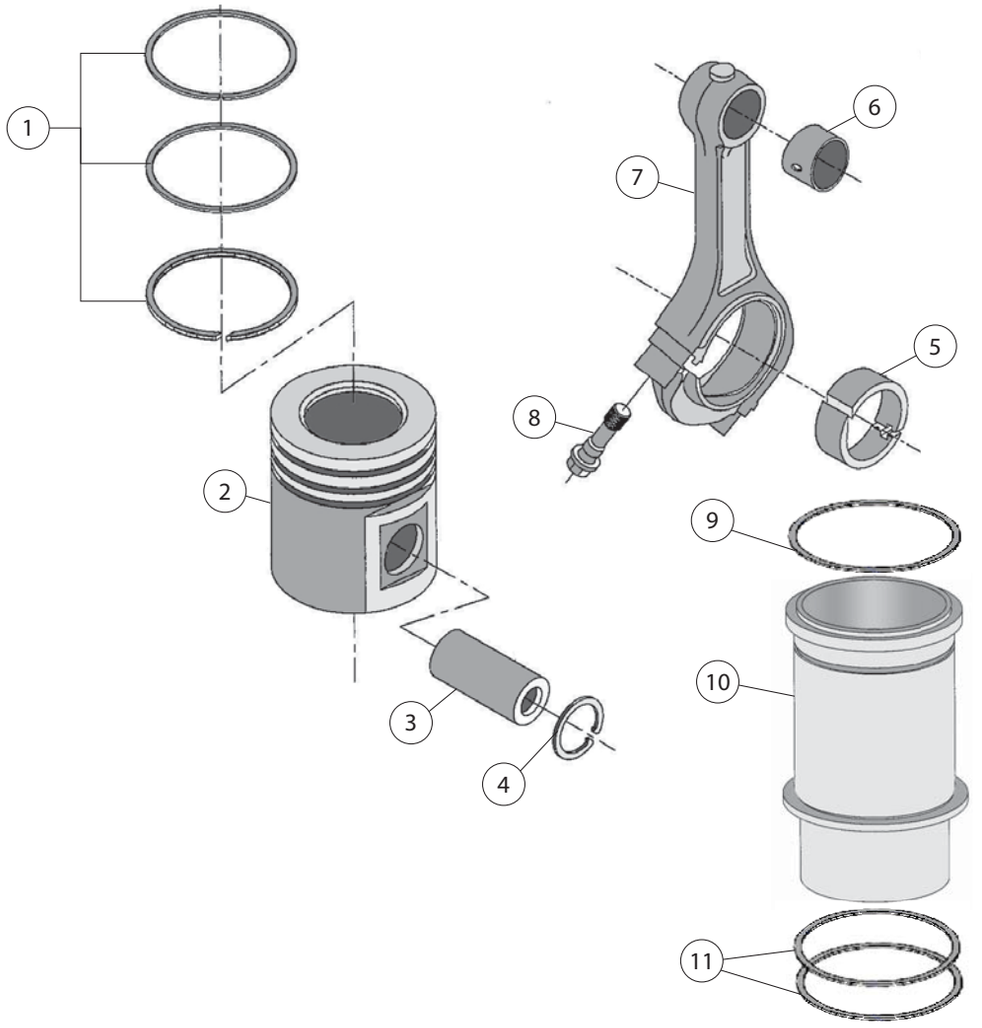
10.7 A-90 Cylinder Head



A-90 Cylinder Head			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**QTY**
1	KA50353	CYL HEAD ASSY (INCL #1, 4-6, 9-12, 16-26)	6
2	KA01008	STUD	12
3	M10NF	NUT, STAINLESS STEEL	12
4	KA19011	WASHER, COPPER	6
5	KA50445	SOCKET, STRAIGHT THREAD	6
6	KA50437	DOWEL, CRANK CASE TOP SIDE	12
7	KA00006	BOLT, CYLINDER HEAD (LONG)	24
8	KA00007	BOLT, CYLINDER HEAD (SHORT)	18
9	KA50370	VALVE GUIDE	12
10	KA50377	LIFTER	12
11	KA50372	VALVE, SEAL	12
12	KA50180	VALVE, EXHAUST	6
13	KA50603	VALVE, SEAT INSERT, EXHAUST	6
14	KA50371	VALVE, COLLET	12
15	KA50444	VALVE, SPRING CUP	12
16	KA50442	VALVE, SPRING (INNER)	12
17	KA19009	WASHER	12
18	KA50443	VALVE, SPRING (OUTER)	6
19	KA19010	WASHER	6
20	KA50460	VALVE, INLET	6
21	KA50351	VALVE SEAT INSERT (INLET)	6
23	KA03006	GASKET, CYLINDER HEAD	6
24	KA50378	PUSH ROD, ASSEMBLY	12
25	KA50373	ROCKER ARM AND BUSH ASSEMBLY	6
25	KA50590	ROCKER ARM RETAINER	6
26	KA03007	GASKET ROCKER COVER	6
27	KA50538	VALVE COVER	5
28	M08WS	LOCKWASHER	12
29	M8X1.25X65	BOLT	12
30	KA50539	VALVE COVER WITH OIL FILL	1
31A	SKA50600TA	CRANKCASE BREATHER (TURBO)	1
31B	SKA50600	CRANKCASE BREATHER (NA)	1
32	118224	HOSE CLAMP	1
33	1302280	HOSE, CRANKCASE VENT	1
34	KA50583	OIL FEED PIPE	6
35	KA50473	ROCKER ARM SUPPORT	6
36	KA50584	ROCKER ARM ASSEMBLY	6
*37	177487L	CLIP, 1.12 DIA X .38 SCR	1
38	KA03030	GASKET SEALING OIL FILL CAP EARLY ENGINE ONLY	1
39	KA17006	CORE PLUG 32MM	6
40	KA17008	CORE PLUG 36MM	12

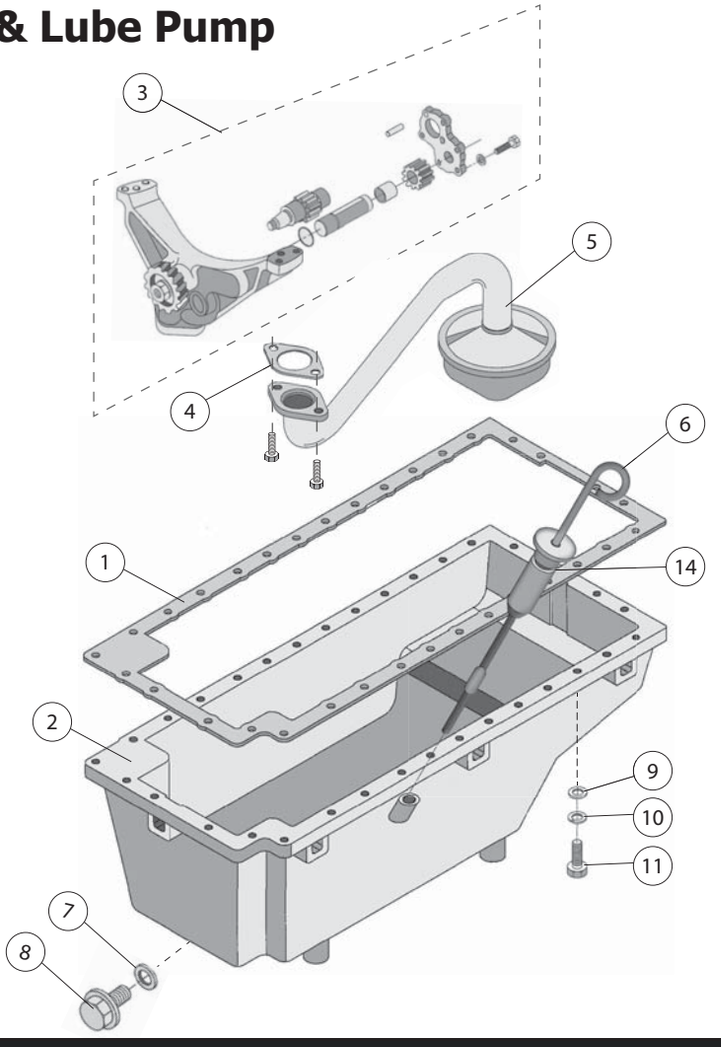
** Not Shown*

10.8 Piston and Connecting Rod Assembly



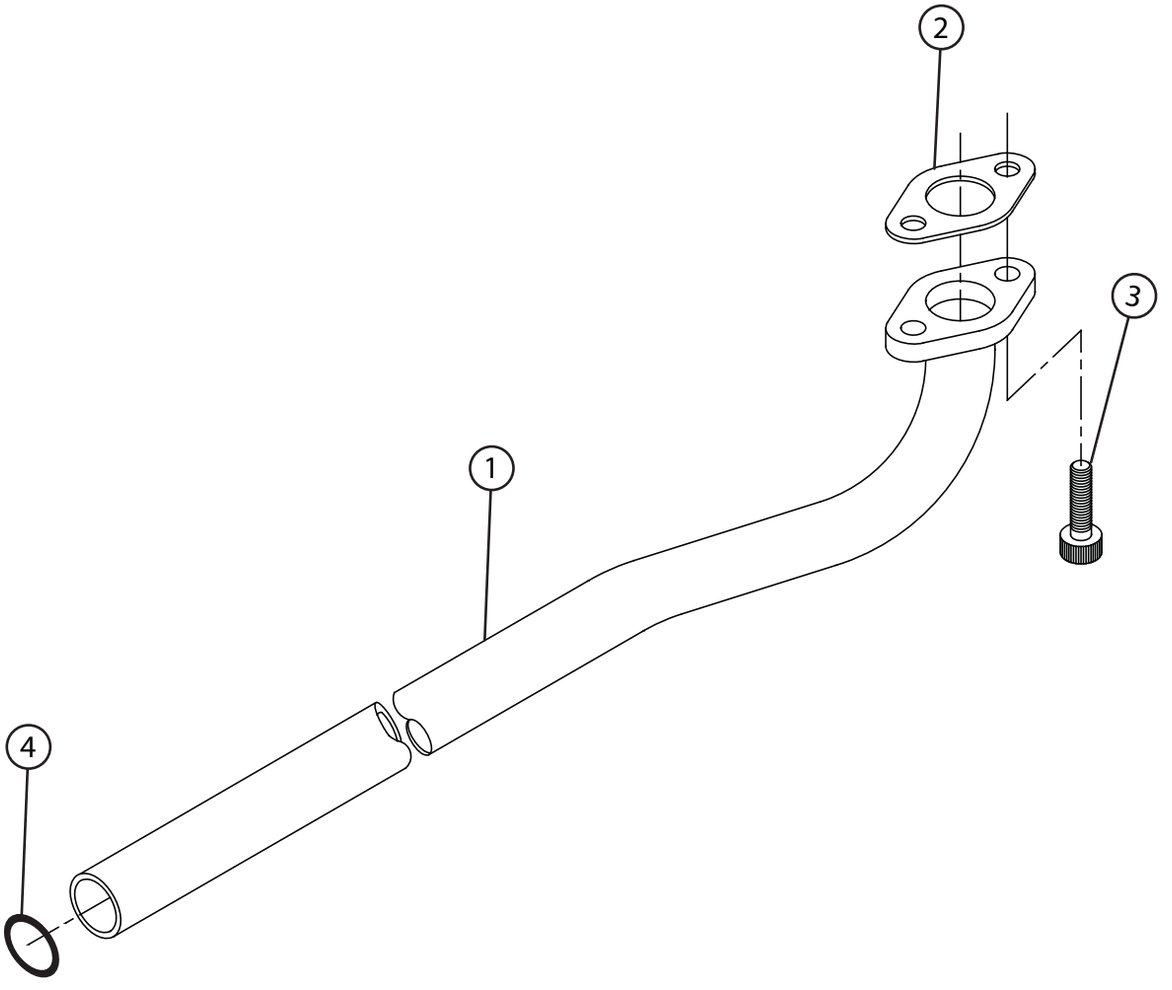
Piston and Connecting Rod Assembly			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50359	PISTON RING SET	6
2	KA50594	PISTON, COMPRESSION 9.0:1	6
3	KA50352	PISTON PIN	6
4	KA50383	CLIP, PISTON PIN	12
5A	KA50387	BEARINGS, BIG END (STD)	6
5B	KA50614	BEARINGS, BIG END (.020)	6
6	KA50384	BUSHING, SMALL END	6
7	KA50472	CONNECTING ROD ASSY (WITHOUT BEARING)	6
8	KA50300	CONNECTING ROD BOLT	12
9	KA03038	TOP O-RING	6
10	KA50385	CYLINDER LINER, ASSEMBLY	6
11	KA03037	LOWER O-RING	12

10.9 Oil Pan & Lube Pump



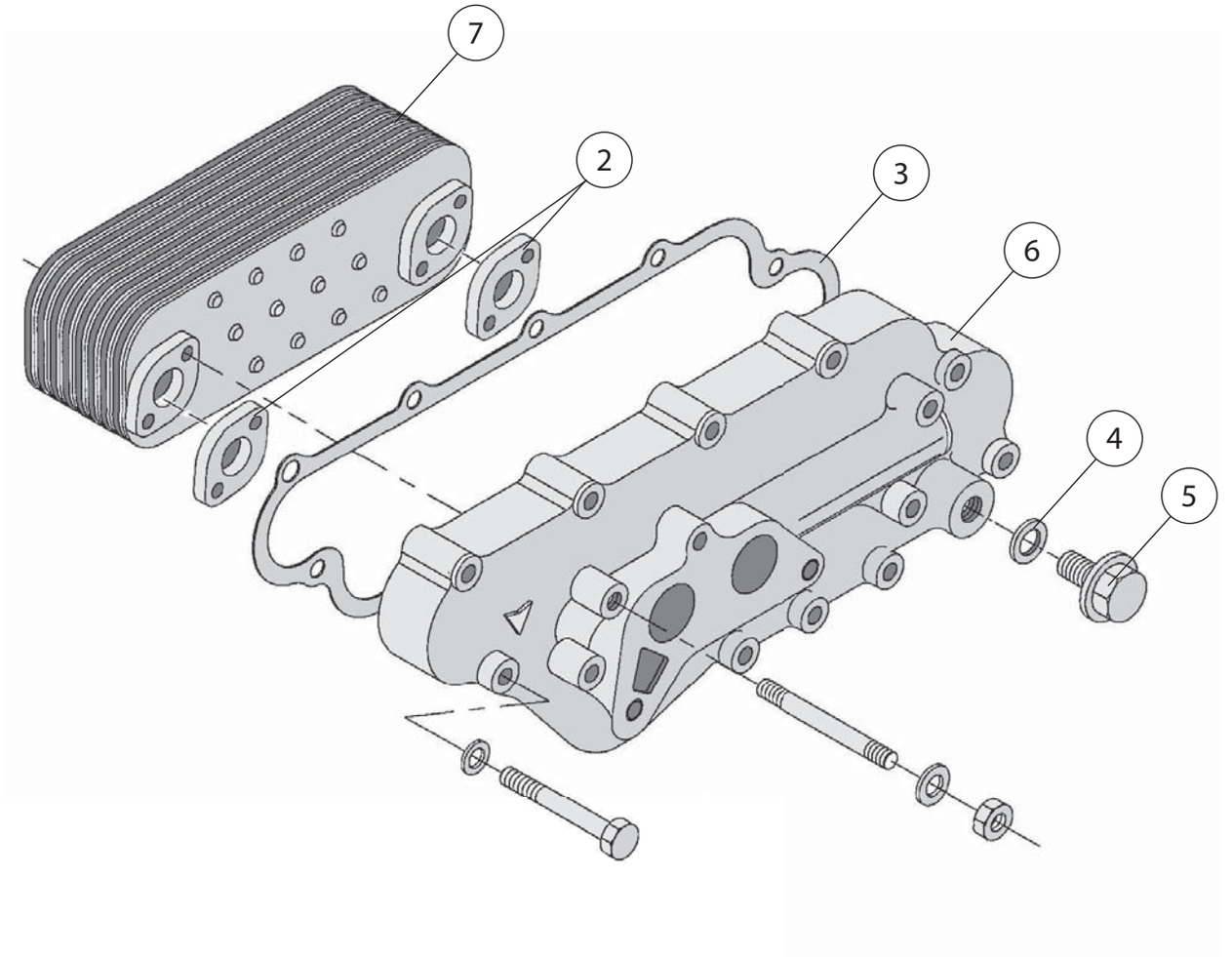
Oil Pan & Lube Pump			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA03003	GASKET, OIL PAN	1
2	KA50260	PAN, OIL (ASSEMBLY)	1
3	KA50388	LUBE OIL PUMP, HIGH DISCHARGE	1
4	KA03020	GASKET, OIL PICK-UP TUBE	1
5	KA50476	SCREEN, OIL PUMP	1
6	KA50374	DIPSTICK (DOES NOT INCLUDE O-RING)	1
7	KA19018	COPPER WASHER	1
8	KA17004	DRAIN PLUG	1
9	M08FW	PLAIN WASHER	33
10	M08WS	SPRING WASHER	33
11	M8X25	SET SCREW	33
12	KA18004	FITTING, OIL LVL TO OIL PAN (NOT SHOWN)	1
13	5020-A90	OIL REGULATOR (NOT SHOWN)	1
14	KA03005	O-RING, DIP STICK	1

10.10 Oil Delivery Pipe



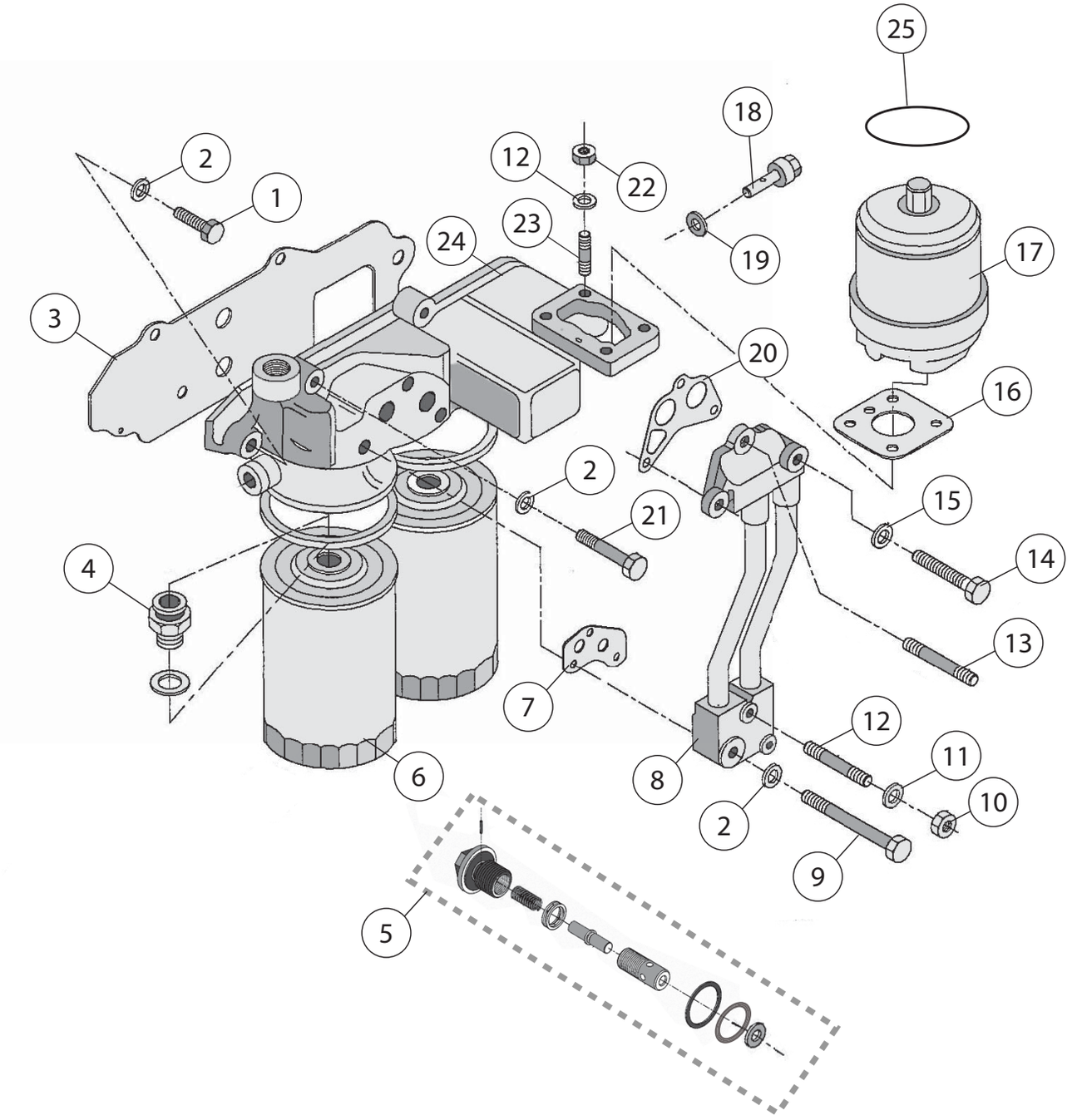
Oil Delivery Pipe			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50607	DELIVERY PIPE	5
2	KA03036	GASKET FOR DELIVERY PIPE	1
3	KA00022	SOCKET HEAD CAP SCREW-M8X20-12.9	2
4	KA03040	OIL PUMP SEALING RING	1

10.11 Lube Oil Cooler



Lube Oil Cooler			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	KA50471	COOLER, SUB ASSEMBLY (parts 2-5)	1
2	KA03013	GASKET, COOLER BOX	2
3	KA03014	GASKET, OIL COOLER	1
4	KA19017	WASHER, DRAIN	1
5	KA17003	PLUG, DRAIN	1
6	KA50637	COVER, OIL COOLER	1
7	KA50636	ELEMENT, OIL COOLER	1

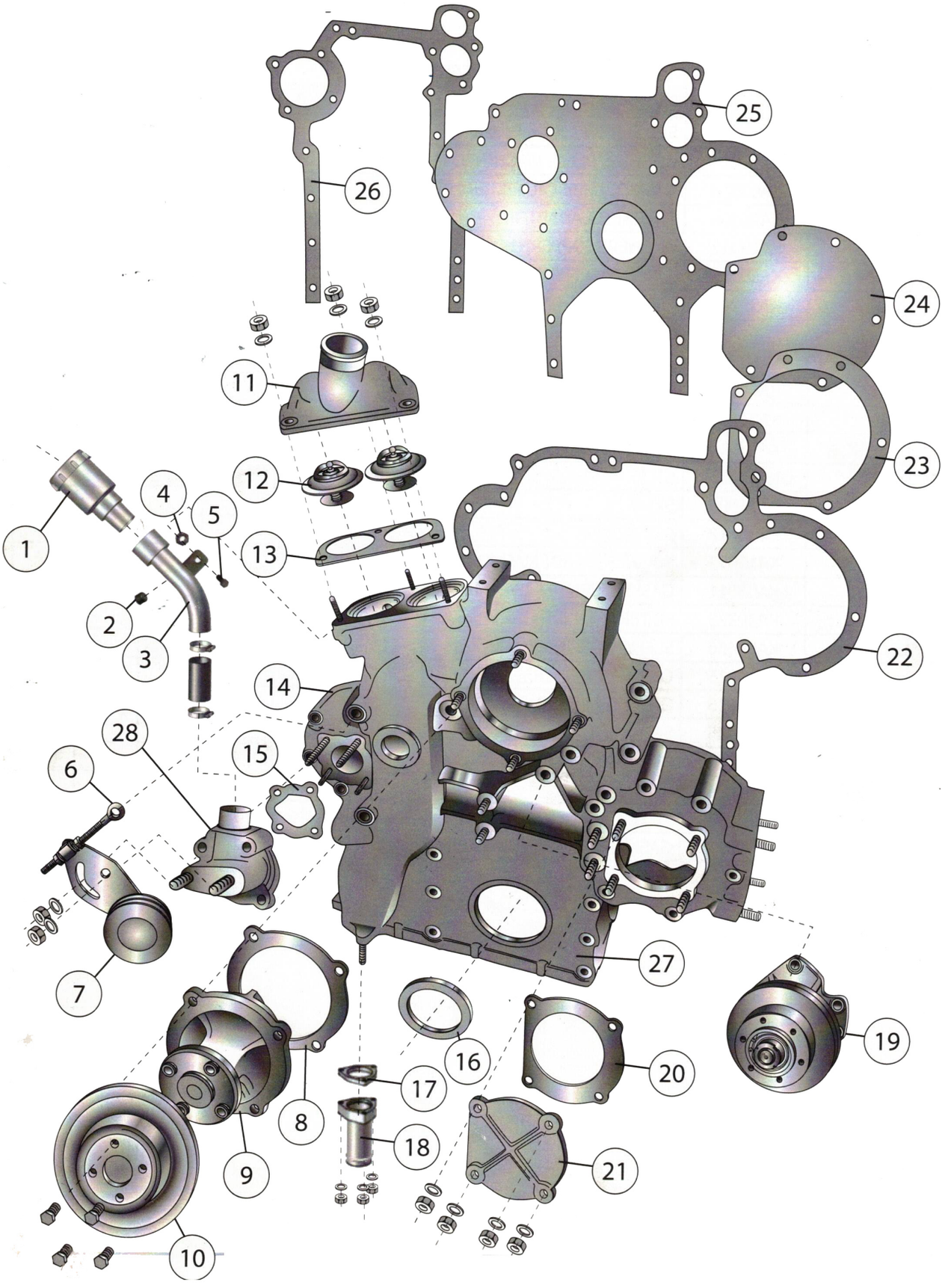
10.12 Oil Filter & Mounting



Oil Filter & Mounting			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
KA50451		FILTER & HEADER ASSEMBLY, LUBE OIL (COMPLETE ASSY)	
1	KA00014	SET SCREW	4
2	KA19014	WASHER, PLAIN MACHINED	5
3	KA03010	GASKET, LUBE OIL FILTER HEADER	1
4	KA16006	THREADED ADAPTOR	2
5A	KA50455	VALVE ASSEMBLY, RELIEF	1
5B	KA03019	O-RING	1
6	KA50060	FILTER, SPIN-ON	2
7	KA03012	GASKET, HEADER	1
8	KA50453	LUBE OIL PIPE ASSEMBLY	1
9	KA00016	SET BOLT	1
10	KA02003	NUT	6
11	KA19013	WASHER, PLAIN MACHINED	9
12	KA01005	STUD	2
13	KA01006	STUD	2
14	KA00017	SET SCREW	3
15	KA19013	WASHER, PLAIN MACHINED	4
16	KA03011	GASKET, CENTRIFUGE FILTER TO BLOCK	1
17	KA50375	FILTER, CENTRIFUGE	1
18	KA50456	RELIEF VALVE ASSEMBLY	1
19	KA19015	COPPER WASHER	1
20	KA03015	GASKET, PRESSURE RELIEF VALVE (30 X 38)	1
21	KA00015	SET BOLT	1
22	KA02003	NUT	4
23	KA01004	STUD	4
24	KA50452	FILTER HEADER, LUBE OIL	1
25	KA03023	GASKET, CENTRIFUGE CLEANER	1
26*	KA03039	O-RING ROTOR UNIT	1

*NOT SHOWN

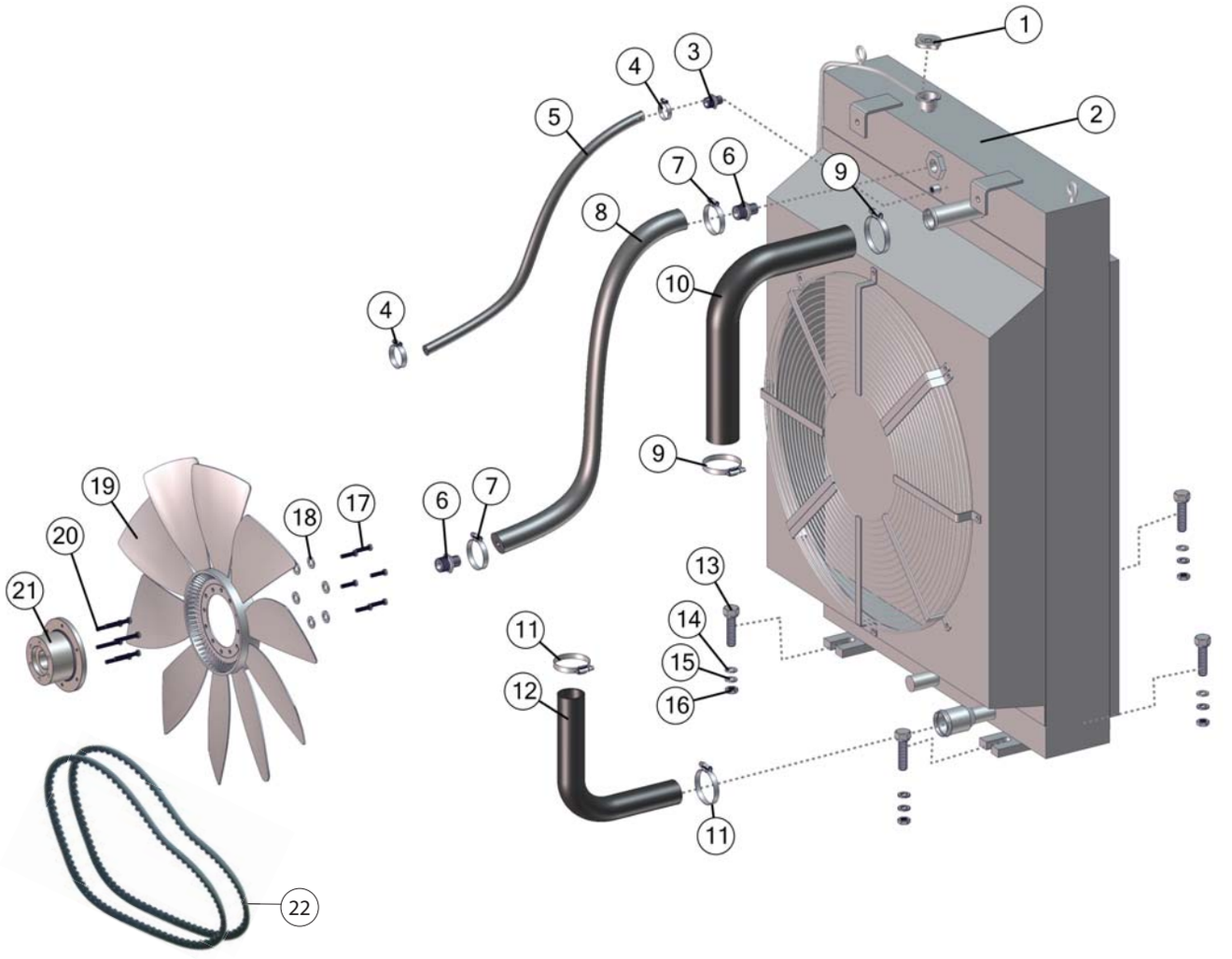
10.13 Front Cover Assembly



Front Cover Assembly			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	ASP-3-FM	OIL FILL	1
2	27411	PIPE PLUG FOR OIL FILL, 3/8”	1
3	KA50556	PIPE, OIL FILL	1
4	M8F2	HEX NUT	1
5	M8X20	HEX BOLT	1
6	KA50566	FAN BELT TENSIONING ADJUSTER	1
7A	KA50565	FAN BELT TENSIONING UNIT	1
7B	SKA50624	TENSIONING LONG BELT	1
8	KA03009	GASKET, WATER PUMP	1
9	KA50376	WATER PUMP SUB ASSEMBLY	1
10	KA50541	PULLEY, WATER PUMP	1
11	KA50567	THERMOSTAT HOUSING	1
12A	KA50357	THERMOSTAT, 165°F (STD)	2
12B	KA50555	THERMOSTAT, 180°F	2
12C	KA50562	THERMOSTAT, 195°F	2
13	KA03028	GASKET, THERMOSTAT HOUSING	1
14	KA03008	GASKET, BREATHER	1
15	KA50381	SEAL OIL, TEFLON	1
16	KA03002	GASKET, INLET	1
17A	KA18012	FLANGE, ENGINE WATER PUMP INLET	1
*17B	KA18001	FLANGE, NON COLD WEATHER KIT	1
18	SKA50564	FAN DRIVE ASSEMBLY	1
19	KA03035	GASKET, ACCESSORY FRONT COVER PLATE	1
20	KA50571	ACCESSORY FRONT COVER PLATE	1
21	KA03017	GASKET, GEAR CASING	1
22	KA03029	GASKET IGNITION HOUSING FACE	1
23	KA50070	PLATE COVER INJECTION PUMP	1
24	KA50477	FRONT PLATE	1
25	KA03016	GASKET, FRONT PLATE	1
26	KA50479	FRONT COVER, GEAR CASE HOUSING	1
27	SKA50573	BREATHER HOUSING ASSY	1
28	KA01010	STUD, 10MM	1
29	KA01011	STUD, 12MM	6
30	M12NF	NUT, 12MM	1
31	M12FW	FLAT WASHER, 12MM	1

*NOT SHOWN

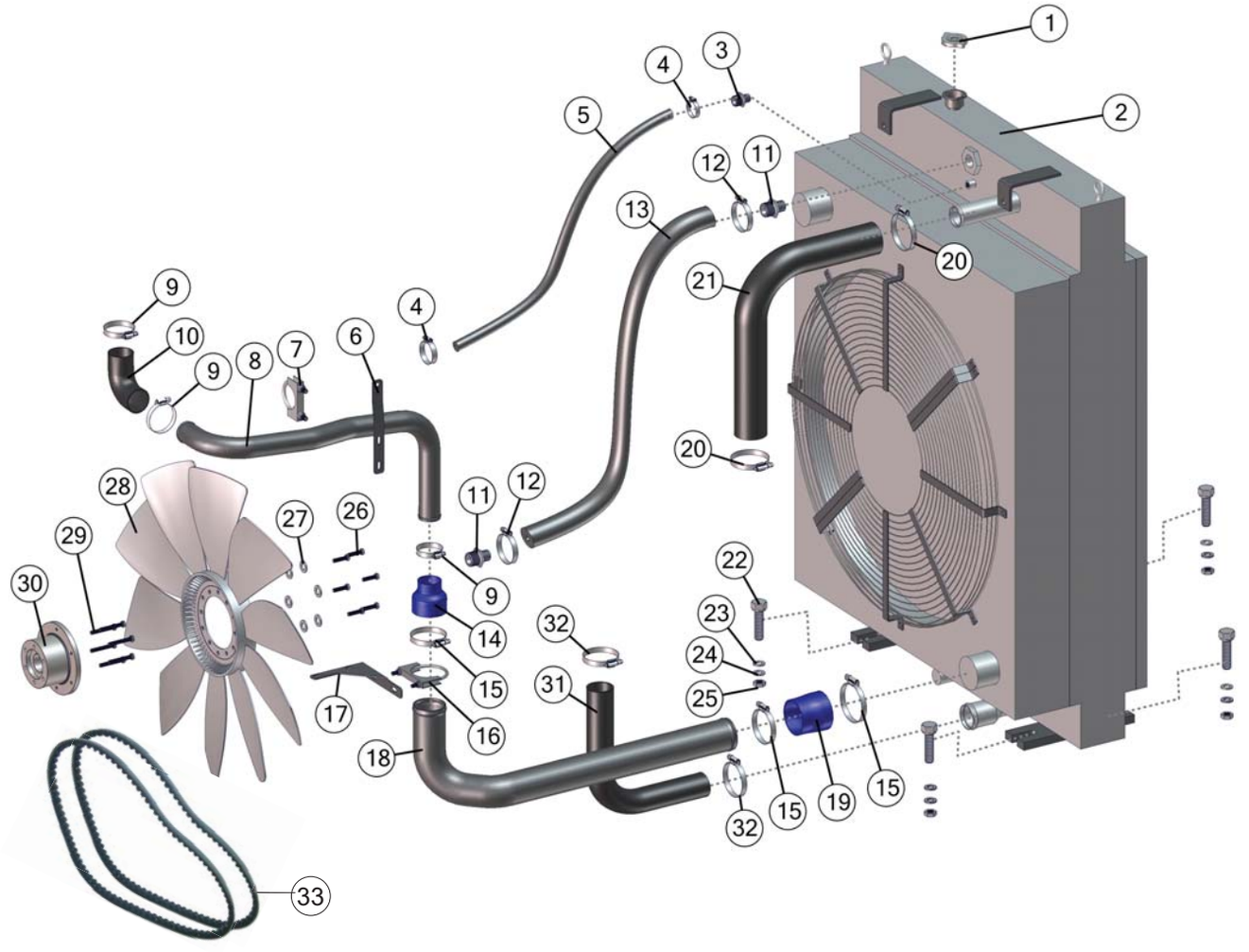
10.14 Radiator Assembly, A90NA (Naturally Aspirated)



Radiator Assembly			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	KA50542	RADIATOR CAP	1
2	KA50010	RADIATOR	1
3	PF5-3/8X1/4	3/8 x 1/4 KC NIPPLE	1
4	41236L	HOSE CLAMP	2
5	KA05004	HOSE, FRONT HEAD VENT TO RADIATOR	3
6	KCN-1	1” NIPPLE	2
7	41236G	HOSE CLAMP	2
8	KA05003	HOSE, FRONT LIQ COOLED MAN TO RAD	3
9	41236C	HOSE CLAMP	4
10	KA05000	HOSE, RADIATOR UPPER	1
11	41236D	HOSE CLAMP	4
12	KA05001	HOSE, RADIATOR LOWER	1
13	7A-3/410X3	SET BOLT	4
14	1B-3/4	WASHER	8
15	1A-3/4	LOCKWASHER	4
16	25A-3/410	NUT	4
17	M8X20	FAN MOUNTING BOLTS	6
18	M08WS	WASHER	6
19A	KA13000	RADIATOR FAN 30” PUSHER	1
19B*	KA13001	SUCTION FAN	1
20	M8X75S	ADAPTER MOUNTING BOLTS	6
21	KA50080	ADAPTER, FAN	1
22A	KA04001	FAN BELTS SHORT	2
22B	KA04002	FAN BELTS LONG	2
23**	1324409	RADIATOR DRAIN FITTING	1

*Suction fan not recommended for turbo charged models.
**Not shown.

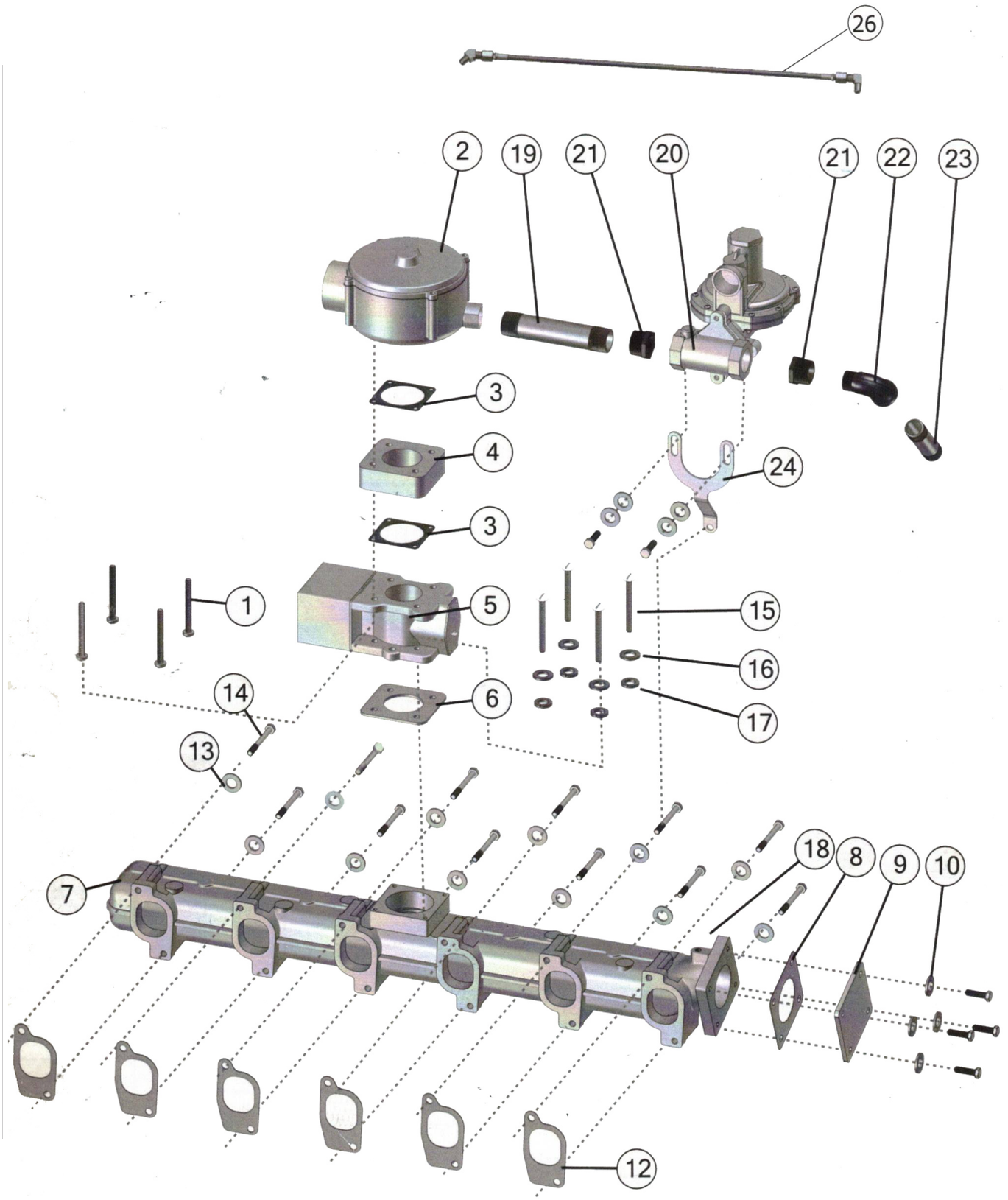
10.15 Radiator Assembly, Turbo



Radiator Assembly			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	KA50542	RADIATOR CAP	1
2	KA50488	RADIATOR, TURBO	1
3	PF5-3/8X1/4	3/8 x 1/4 KC NIPPLE	1
4	41236L	HOSE CLAMP	2
5	KA05004	HOSE, FRONT HEAD VENT TO RADIATOR	1
6	KA50525	SUPPORT, UPPER BOOST TUBE	1
7	KA07002	CLAMP, 2" EXHAUST	1
8	KA05016	TUBE, 2", TURBO TO BOOST PIPE	1
9	41236D	HOSE CLAMP, 2"	2
10	KA05015	HOSE, 2", 90 DEG, TURBO TO BOOST PIPE	1
11	KCN-1	1" NIPPLE	2
12	41236G	HOSE CLAMP	2
13	KA05003	HOSE, FRONT LIQ COOLED MAN TO RAD	3
14	KA05014	HOSE, 2"-3", TURBO TO BOOST TUBE	1
15	41236A	HOSE CLAMP, 3"	2
16	KA07001	CLAMP, BOOST TUBE	1
17	KA50524	SUPPORT, LOWER BOOST TUBE	
18	KA05009	TUBE, 3", TURBO TO RADIATOR BOOST	1
19	KA05024	HOSE, 3"-3.25", BOOST TUBE CONNECTOR	1
20	41236C	HOSE CLAMP	2
21	KA05000	HOSE, RADIATOR UPPER	1
22	7A-3/410X3	SET BOLT	4
23	1B-3/4	WASHER	4
24	1A-3/4	LOCKWASHER	4
25	25A-3/410	NUT	4
26	M8X20	FAN MOUNTING BOLTS	6
27	M08WS	WASHER	6
28*	KA13000	RADIATOR FAN 30" PUSHER	1
29	M8X75S	ADAPTER MOUNTING BOLTS	6
30	KA50080	ADAPTER, FAN	1
31	KA05001	HOSE, RADIATOR LOWER	4
32	41236D	HOSE CLAMP	2
33A	KA04001	FAN BELTS SHORT	2
33B	KA04002	FAN BELTS LONG	2
34	KA50632	REPLACEMENT AIR INTER COOLER (NOT SHOWN)	1

*Suction fan not recommended for turbo charged models.

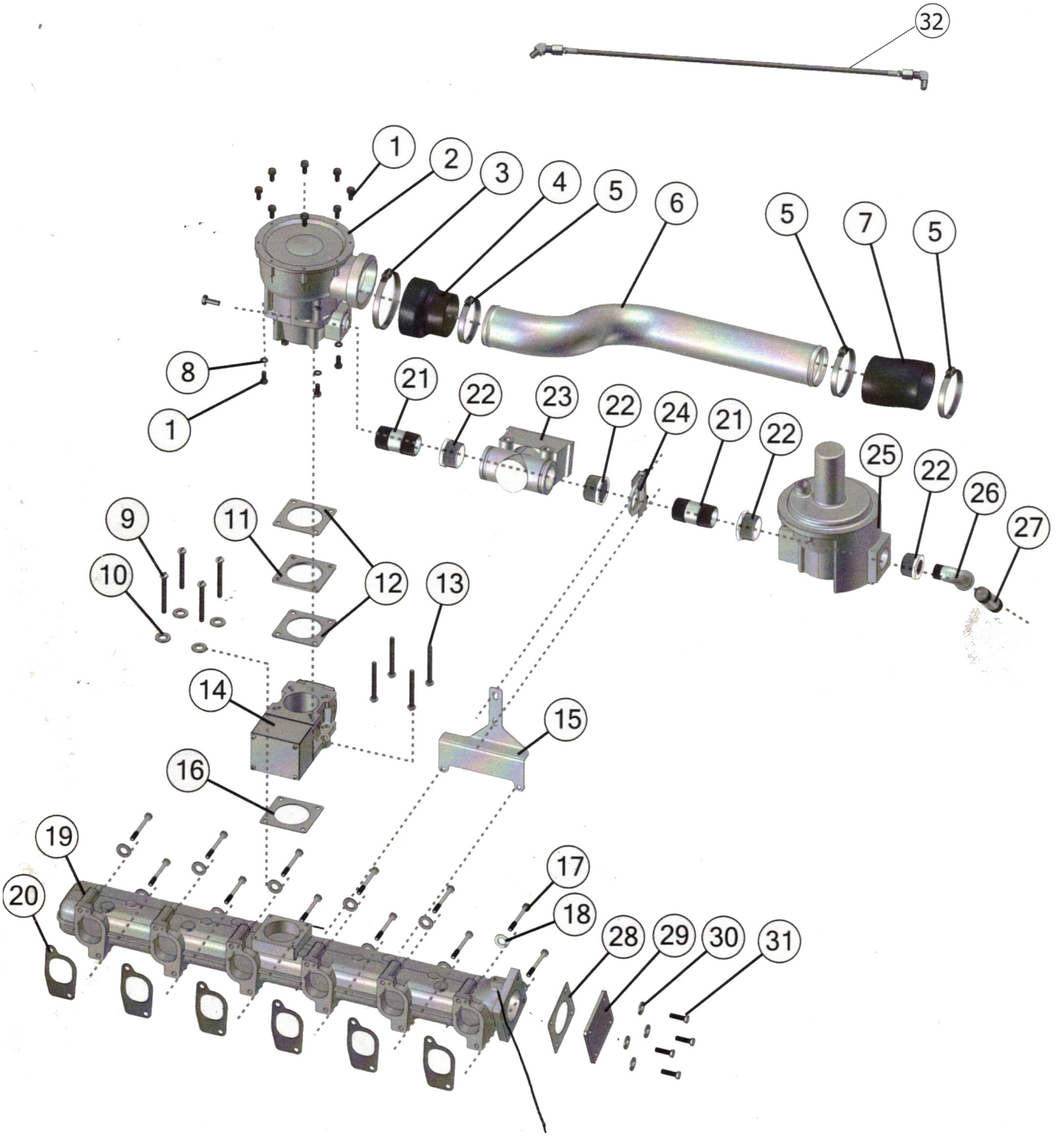
10.16 Intake Assembly



Intake Assembly

NUMBER	PART NUMBER	DESCRIPTION	PART QTY	RECOMMENDED SPARE PARTS		
				6 MO	1 YR	2 YR
1	S1-24	BOLT	4			
2	ASIC-7-C	200 CARB	1			
3	G1-21	GASKET, SPACER	2			
4	AS3-45	SPACER 200 13/16 INCH	1			
5a	KA50140	THROTTLE BODY, 12 VOLT OPTION	1			
5b	KA50515	THROTTLE BODY, 24 VOLT OPTION	1			
6	KA03001	GASKET (INCLUDED W/THROTTLE BODY)	1			
7	KA50130	MANIFOLD INTAKE	1			
8	KA00002	GASKET, BLOCK-OFF	1			
9	KA50090	PLATE, INTAKE MANIFOLD BLOCK-OFF	1			
10	M08FW	WASHER, FLAT	4			
11	M8X30	BOLT	4			
12	KA02000	GASKET, INTAKE MANIFOLD	6			
13	M8WS	PLAIN MACHINED WASHER	12			
14	M8X75S	METRIC ALLENHEAD SCREW	12			
15	M6X25	HEXHD CAPSCREW GRD 8.8 PLTD	4			
16	1A-1/4	LOCKWASHER, PLATED	4			
17	1N-1/4	WASHER ,FLAT SAE PLATED	4			
18	~~26411~~	SOCKET, PLUG PIPE HD 3/8 (NOT SHOWN)	1			
19	PF1-3/4-4	1.0 X 6.0 NIPPLE	1			
20	S-102-4	REGULATOR 3/8 ORF, 1" NPT	1			
21	PF9-1X3/4	BUSHING	2			
22	PF5-3/4	ELBOW	1			
23	PF2-3/4	.750X4.000_SCH40	1			
24	KA08010	BRACKET FUEL LINE SUPPORT	1			
25	465-106	VALVE, THROTTLE (GENSET ONLY, NOT SHOWN)	1			
26a	KA11001	FUEL LINE VENT ASSY	1			
26b	KA11002	FUEL LINE VENT ASSY (AFR ONLY)	1			

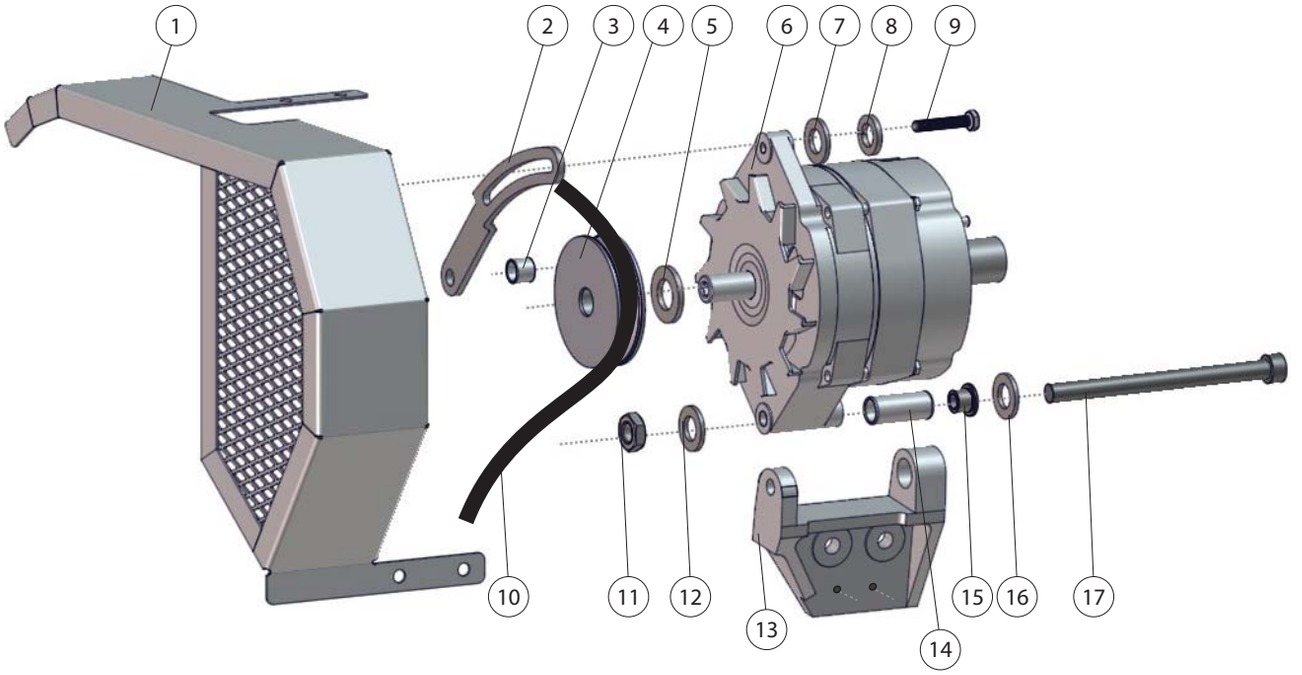
10.17 Intake Assembly, Turbo



Intake Assembly, Turbo

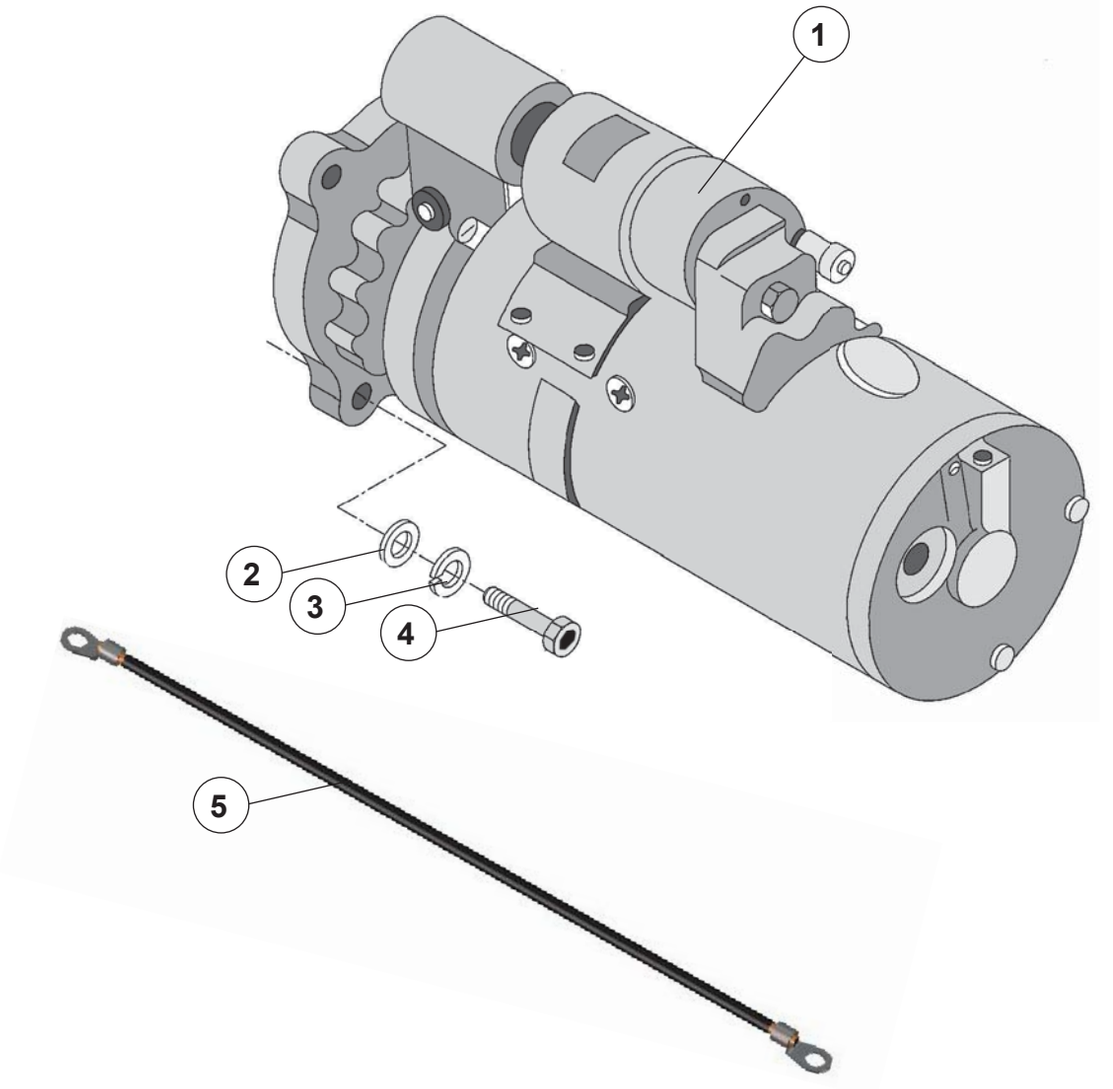
NUMBER	PART NUMBER	DESCRIPTION	PART QTY	RECOMMENDED SPARE PARTS		
				6 MO	1 YR	2 YR
1	7A-5/1618X3/4	CAPSCREW, HEX HEAD	12			
2	KA14000	CARBURETOR, 400	1			
3	41236B	CLAMP, HOSE	1			
4	KA05017	HOSE BOOST TUBE TO CARB 4" TO 3" ADAPTOR	1			
5	41236A	CLAMP, HOSE	3			
6	KA05010	BOOST TUBE, RADIATOR TO CARB	1			
7	KA05011	BOOST TUBE, UPPER	1			
8	1A-5/16	LOCKWASHER, PLATED	4			
9	M6X25	CAPSCREW, HEX HEAD	4			
10	1A-1/4	LOCKWASHER, PLATED	4			
11	KA16012	ADAPTER, CARB	1			
12	KA03026	GASKET, CRB ADAPTOR	2			
13	M10X25	CAPSCREW, HEXHEAD	4			
14a	KA50140	THROTTLE BODY, 12 VOLT OPTION	1			
14b	KA50515	THROTTLE BODY, 24 VOLT OPTION	1			
15	KA08016	BRACKET, FUEL LINE SUPPORT, TURBO	1			
16	KA03001	GASKET (INCLUDED W/THROTTLE BODY)	1			
17	MX75S	METRIC ALLENHEAD SCREW	12			
18	M8WS	PLAIN MACHINED WASHER	12			
19	KA50130	INTAKE MANIFOLD	1			
20	KA02000	GASKET, INTAKE MANIFOLD	6			
21	KA18005	NIPPLE 1.25 X 3 NPT	2			
22	PF9-11/2X11/4	BUSHING REDUCER, 1 1/2 X 1 1/4	4			
23	A690154-1	1-1/2" FUEL VALVE	1			
24	KA07003	CLAMP 1 3/4" EXHAUST	1			
25	KA50512	REGULATOR	1			
26	KA18007	FITTING	1			
27	KA18008	NIPPLE	1			
28	KA00002	GASKET, BLOCK-OFF	1			
29	KA50090	PLATE, INTAKE MANIFOLD BLOCK-OFF	1			
30	M08F2	WASHER, FLAT	4			
31	M8X30	BOLT	4			
32	KA05018	BALANCE TUBE ASSY	1			

10.18 Alternator & Mounting Bracket



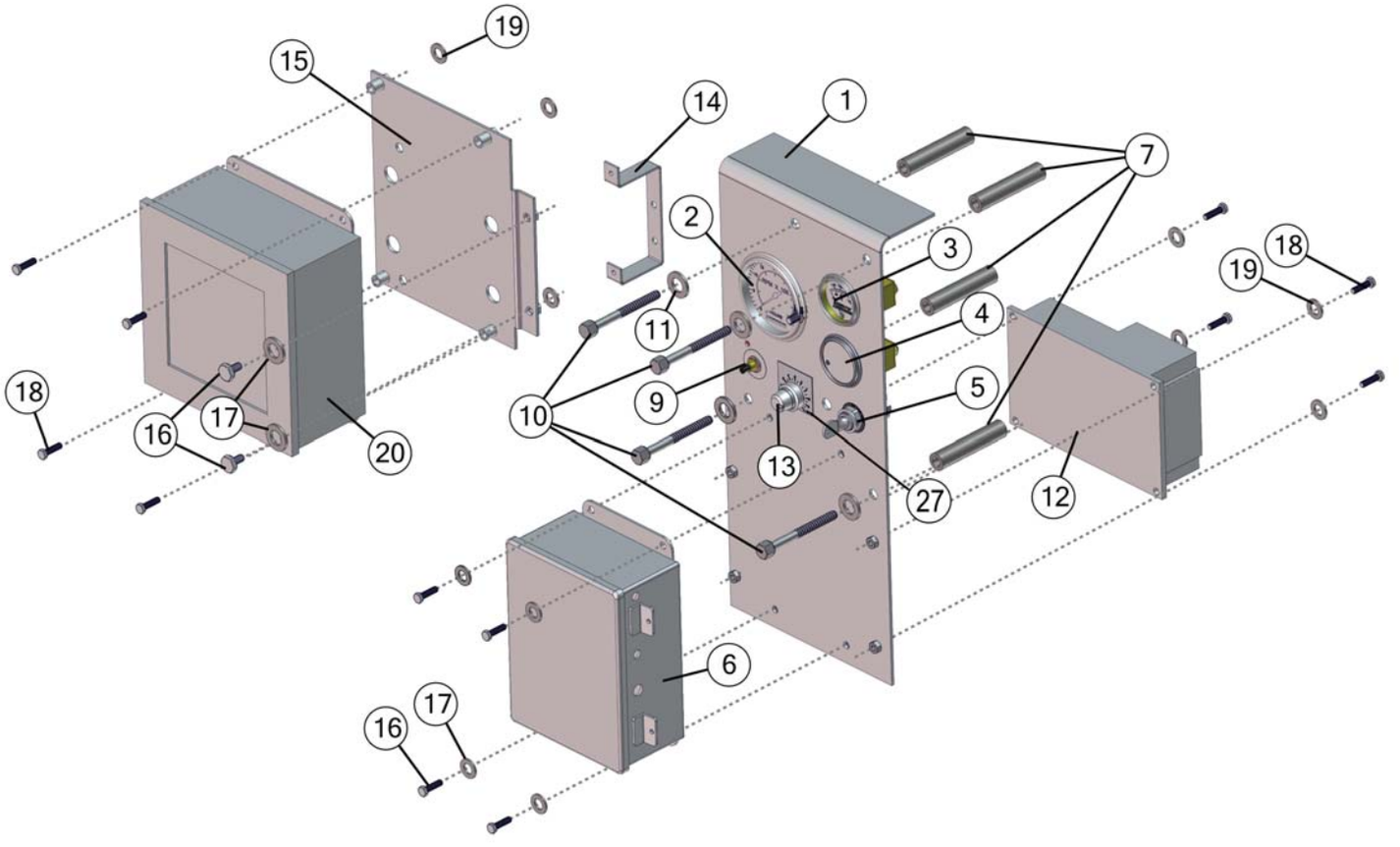
Alternator & Mounting Bracket			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50350	BELT GUARD, ALTERNATOR	1
2	KA08009	STRAP, ADJUSTING	1
3	KA16028	SPACER, FRONT LIFTING EYE STANDARD	1
4	216096E	PULLEY, ALTERNATOR	1
5	M16FW	WASHER, FLAT	1
6A	69753LV	12-V ALTERNATOR STANDARD	1
6B	24V ALT	24-V ALTERNATOR OPTION	1
7	M08FW	WASHER, FLAT	1
8	M08WS	WASHER, LOCK	1
9	M8X25	CAPSCREW, HEX HEAD	1
10	KA04000	BELT, ALTERNATOR	1
11	M10NF	NUT, HEX HEAD	1
12	M10FW	WASHER, FLAT	1
13	KA08000	BRACKET, ALTERNATOR, LOWER	1
14	KA16001	BUSHING, LOWER ALTERNATOR BRACKET	1
15	12190551	BUSHING, MOUNTING BOLT	1
16	1N-3/8	WASHER, FLAT	1
17	26241	DOWEL BOLT, ALTERNATOR MOUNTING	1
18*	KA50576	FRONT LIFTING EYE (NOT SHOWN)	1
19*	KA00025	HEX HD CAPSCREW M10X150 8.8	1

10.19 Starter



Starter			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1a	KA10000	STARTER MOTOR 12V	
1b	KA10001	STARTER MOTOR 24V	
2	M14FW	PLAIN MACHINED WASHER	3
3	M14WS	SPRING WASHER	3
4	M14X45S	SET BOLT	3
5	KA15004	STARTER GROUND CABLE	1
6	892-A90R	BATTERY WIRE + (NOT SHOWN)	1
7	892-A90B	BATTERY WIRE - (NOT SHOWN)	1

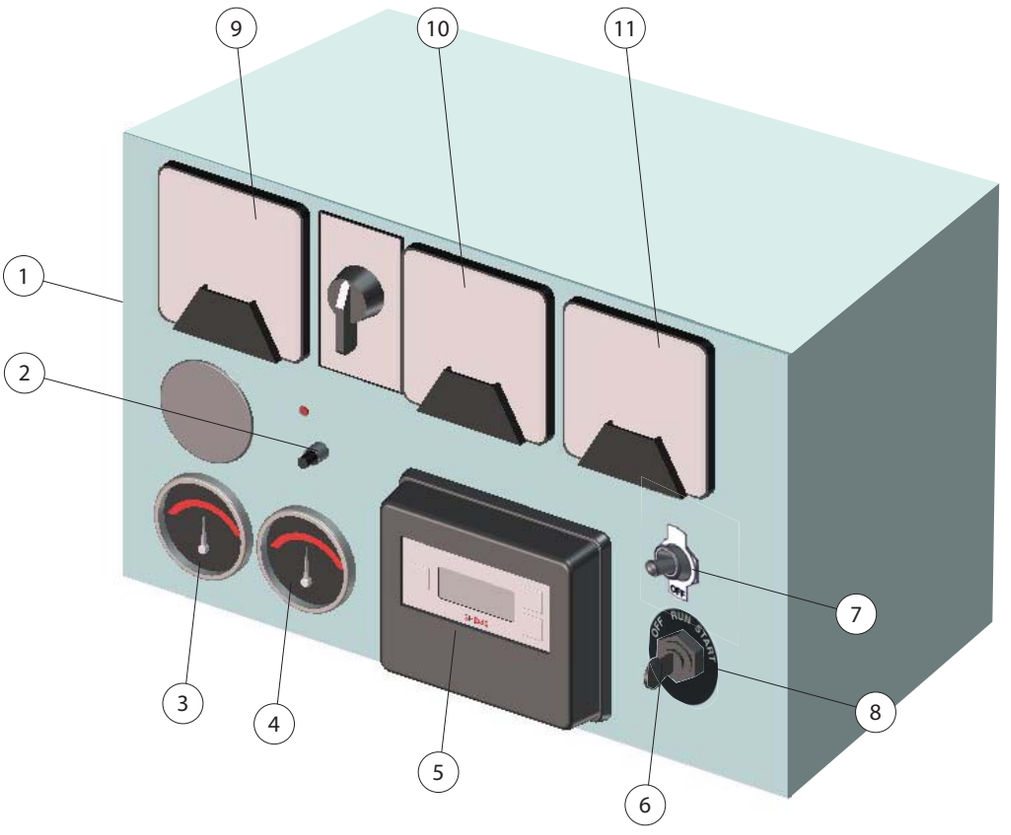
10.20 Control Panel & Governor Box for Power Unit



Control Panel & Governor Box for Power Unit			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	KA08003	PANEL, GAUGE	1
2	103684	TACHOMETER	1
3	120843H	TEMPERATURE GAUGE	1
4	120844	OIL PRESSURE GAUGE	1
5	868-A-255	ROTARY KEY SWITCH	1
6	AS1-A42	GOVERNOR BOX	1
7	KA16003	GAUGE PANEL SPACERS	4
8	ANP-58	STARTER PLATE OFF-RUN	1
9	152934	MAGNETIC SWITCH	1
10	KA00001	BOLT (M10X110)	4
11	M10FW	WASHER	4
12	7910106	CD-1 IGNITION MODULE	1
13	100KT-105B	POTENTIOMETER	1
14	KA08013	PANEL BRACKET (AFR ONLY)	1
15	KA08011	INSTRUMENT PANEL (AFR ONLY)	1
16	M8X20	CAPSCREW, HEX HEAD (AFR ONLY)	10
17	M08WS	WASHER, SPLIT, LOCK (AFR ONLY)	10
18	M6X25	CAPSCREW, HEX HEAD (AFR ONLY)	4
19	M06WS	WASHER, SPLIT, LOCK (AFR ONLY)	4
20	AFR-2	AFR KIT (AFR ONLY)	1
21*	KA18002	FITTING OIL PRESS GAUGE BLK ADPT	1
22*	119-RG-46	TEE MALE BRANCH 1/8	1
23*	60356	OIL PRESSURE SWITCH	1
24*	OL-A62	OIL LINE	1
25*	7930486	CD1, HARNESS	1
26*	KA08022	BRACKET, INSTRUMENT PANEL SUPPORT	1
27	SK-615562-88	LEGEND PLATE	1
28*	217067-A42	PLATE, IGNITION, GENSET	

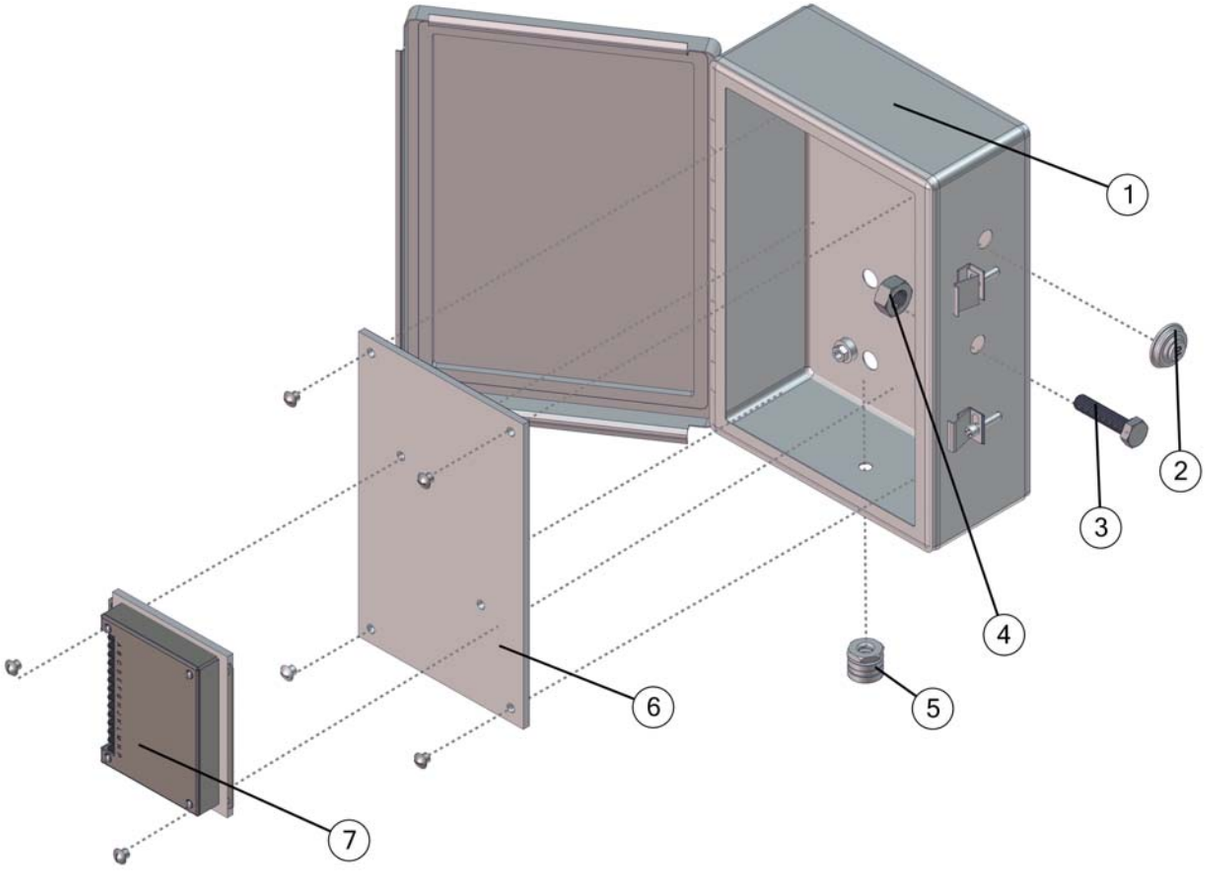
* Not Shown

10.21 Control Panel & Governor Box for Genset



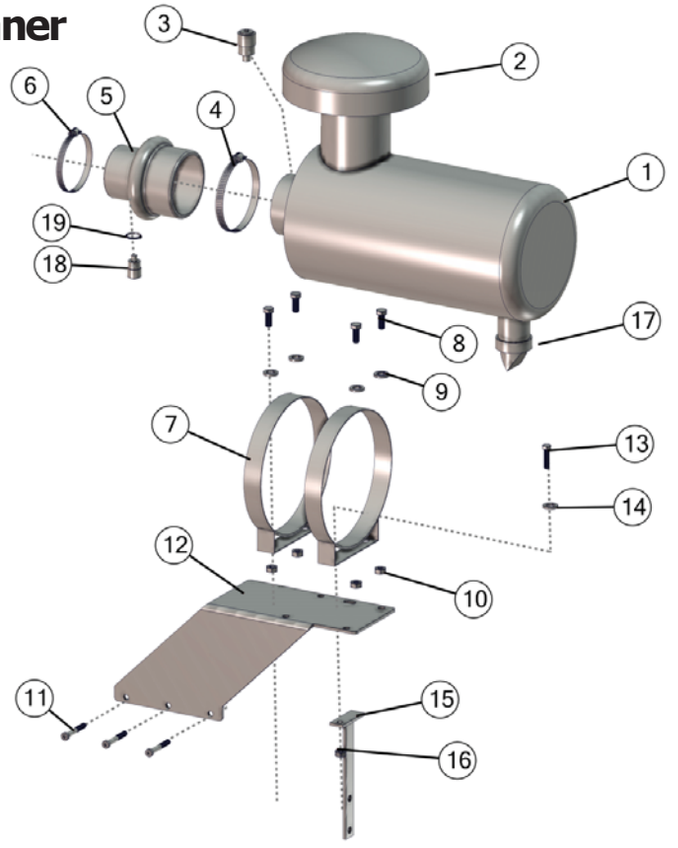
Control Panel & Governor Box for Genset			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	GEN-PANEL-3-PHASE-NS	PANEL, GENERATOR	1
2	152934	MAGNETIC SWITCH	1
3	KA06004	GAUGE, ELEC OIL PRESS SWITCH	1
4	KA06002	GAUGE, ELEC TEMP SWITCH	1
5	SHD30	TACH/HOURMETER	1
6	868-A-255	ROTARY KEY SWITCH	1
7	208435-1	TOGGLE SWITCH	1
8	ANP-58	NAMEPLATE, START PLATE OFF/RUN	1
9	GEN-PANEL-VOLTMETER	GENERATOR PANEL VOLTMETER	1
10	GEN-PANEL AMMETER	GENERATOR PANEL AMMETER	1
11	GEN-PANEL FREQ METER	GENERATOR PANEL FREQUENCY METER	1
not shown	KA06001	ELECTRICAL TEMP SENDER	1
	KA06003	SENDING UNIT, ELECTRICAL OIL PRESSURE	1

10.22 Governor Box



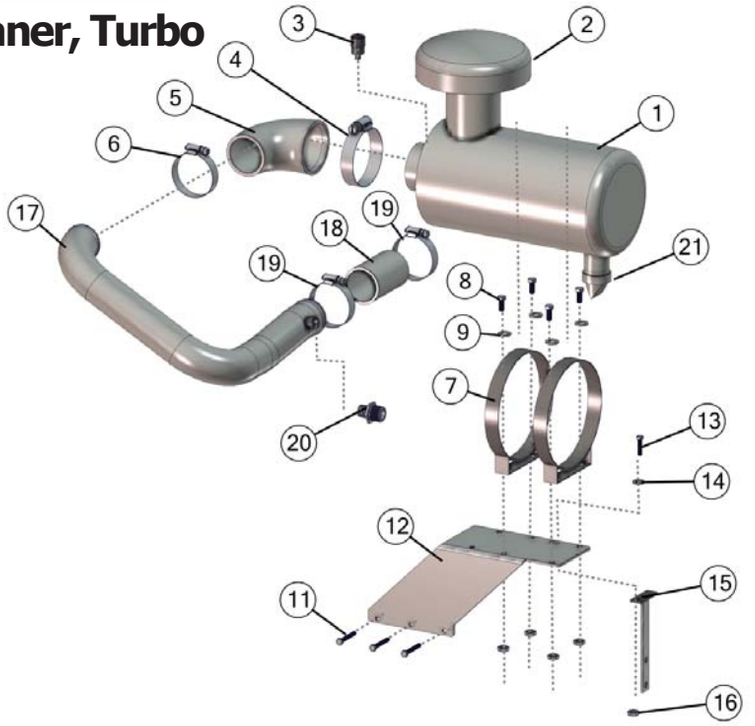
Governor Box			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	AS1-A42	BOX FOR GOVERNOR	1
2	6321-CB	CIRCUIT BREAKER, GAC GOVERNOR	1
3	M10X20	CAPSCREW, HEX HEAD	1
4	M10NF	NUT, HEX HEAD	1
5	PF-5090	FITTING FOR WIRING	1
6	AS1-1-P	PLATE	1
7a	ESD-5131	SPEED CONTROL, 12/24 VOLT	1
8	MSP675	SPEED SENSOR MAGNETIC (NOT SHOWN)	1
9	7910151	MAGNETIC PICKUP (NOT SHOWN)	1

10.23 Air Cleaner



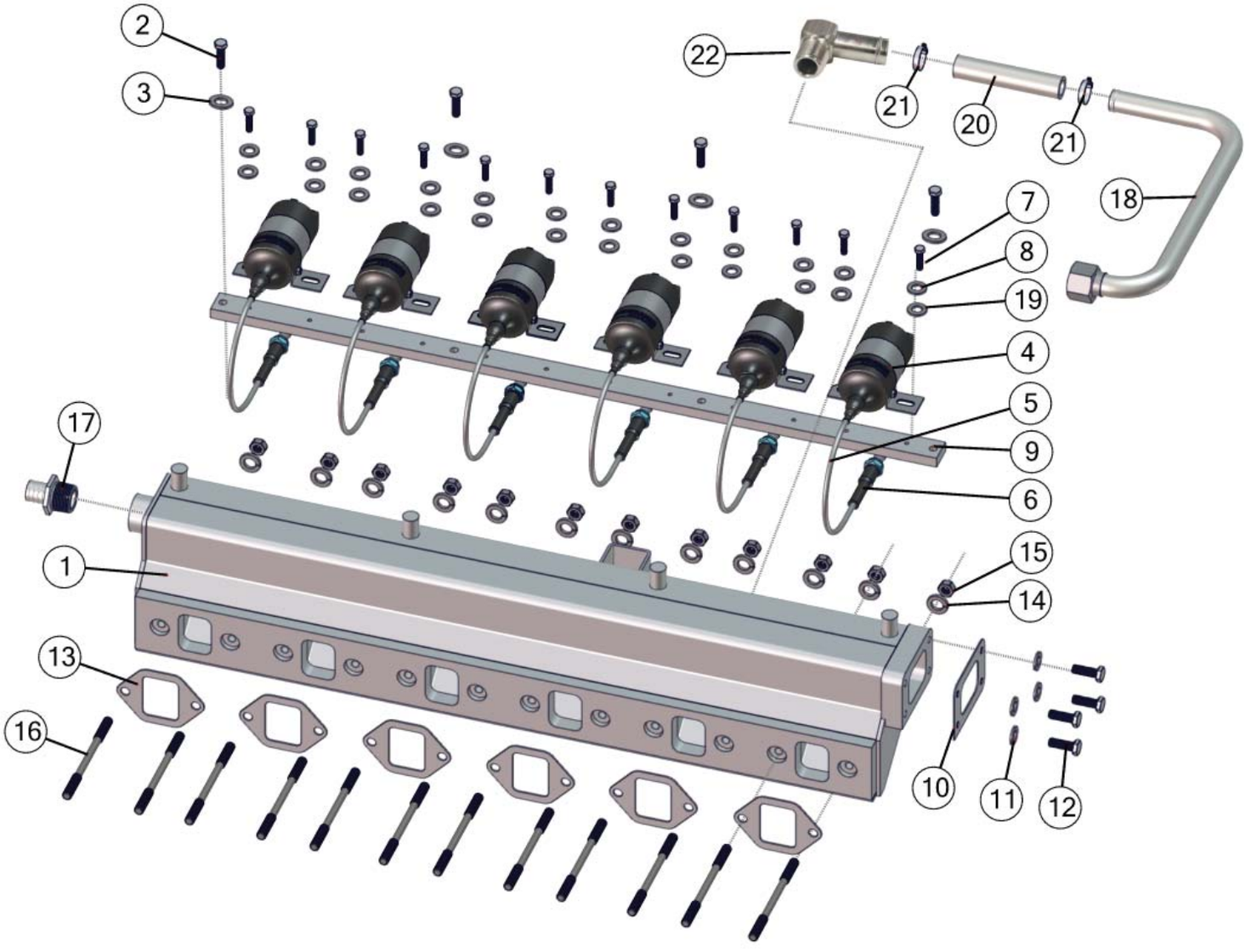
Air Cleaner			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50100	AIR CLEANER ASSEMBLY	1
2	KA50220	CAP, AIR STACK	1
3	153789	AMERICAN AIR FILTER GAUGE	1
4	41236B	HOSE CLAMP, 4"	1
5	KA16002	ADAPTOR, AIR CLEANER HOSE	1
6	41236	HOSE CLAMP, 3"	1
7	KA07000	CLAMP, AIR CLEANER MOUNTING	2
8	M10X20	SET SCREW - M10X1.5- 8.8	4
9	M10FW	PLAIN MACHINED WASHER - M10	4
10	M10NF	10MM HEX NUT ZINC PLTD	4
11	M8X1.25X60	SOCKET HEAD BOLT	3
12	KA08008	BRACKET, MOUNTING, AIR CLEANER	1
13	M8X30	HEX BOLT	1
14	M08WS	LOCK WASHER, SPLIT	1
15	KA08004	BRACKET, AIR CLEANER SUPPORT	1
16	M08NF	NUT	1
17	WF50165	RUBBER DRAIN	1
18	KA17009	3/4” CAP	1
19	118224	3/4” HOSE CLAMP	1
NOT SHOWN	KA50101	REPLACEMENT AIR CLEANER ELEMENT	1

10.24 Air Cleaner, Turbo



Air Cleaner, Turbo			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50100	AIR CLEANER ASSEMBLY	1
2	KA50220	CAP, AIR STACK	1
3	153789	AMERICAN AIR FILTER GAUGE	1
4	41236B	HOSE CLAMP, 4"	1
5	KA05021	ADAPTOR, AIR CLEANER HOSE	1
6	41236	HOSE CLAMP, 3"	1
7	KA07000	CLAMP, AIR CLEANER MOUNTING	2
8	M10X20	SET SCREW - M10X1.5- 8.8	4
9	M10FW	PLAIN MACHINED WASHER - M10	4
10	M10NF	10MM HEX NUT ZINC PLTD	4
11	M8X1.25X60	SOCKET HEAD BOLT	3
12	KA08008	BRACKET, MOUNTING, AIR CLEANER	1
13	M8X30	HEX BOLT	1
14	M08WS	LOCK WASHER, SPLIT	1
15	KA08004	BRACKET, AIR CLEANER SUPPORT	1
16	M08NF	NUT	1
17	KA50545	BOOST TUBE, TURBO TO AIR CLEANER	1
18	KA05022	HOSE, SILICON, 3” X 3”	1
19	41236	HOSE CLAMP, 3”	2
20	78283A	PLUG	1
21	WF50165	RUBBER DRAIN PLUG	1
NOT SHOWN	KA50101	REPLACEMENT AIR CLEANER ELEMENT	1

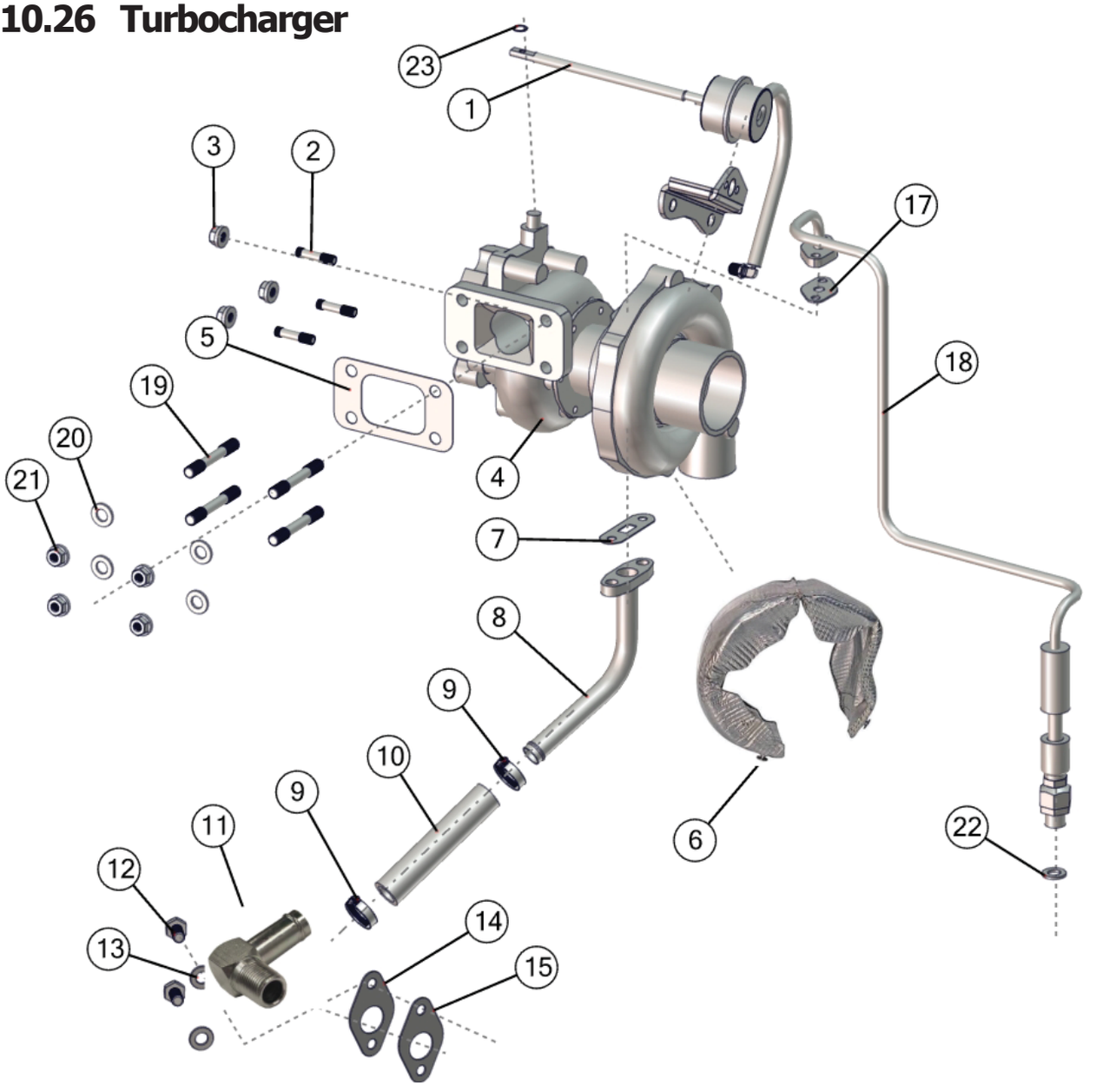
10.25 Liquid Cooled Exhaust Manifold



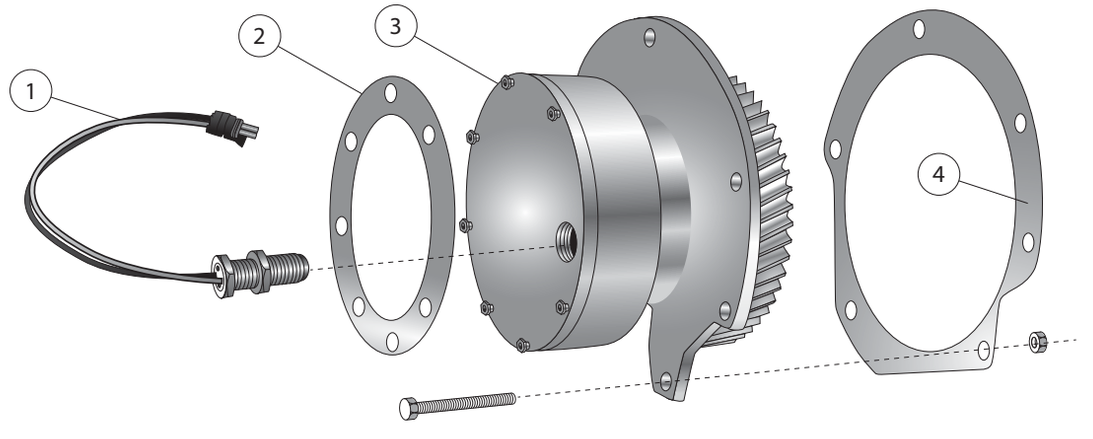
Liquid Cooled Exhaust Manifold			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	KA50529	EXHAUST MANIFOLD, LIQUID COOLED	1
2	M8X30	HEX HEAD BOLT	4
3	M08WS	LOCK WASHER	4
4	330-2-AI-46	COIL, IGNITION	6
5	KA50595	SPARK PLUG WIRES	6
6	KA17000	SPARK PLUG	6
7	M6X20	HEX HEAD BOLT	12
8	1A-1/4	WASHER	12
9	KA08006	BRACKET, COIL	1
10	208594A	GASKET, TURBO CONNECTION	1
11	M10WS	LOCK WASHER	4
12	M10X30S	ALLEN HEAD BOLT	4
13	SL0001	GASKETS	6
14	M10WS	LOCK WASHER	12
15	M10NF	10MM HEX NUT ZINC PLTD	12
16A	KA01008	STUD, M10X1.5X165	12
16B	KA01000	STUD MANIFOLD FOR TA WIRING	1
17	KCN-1	1” NIPPLE	1
18A	KA05012	MANIFOLD FEED PIPE, TURBO UNIT	1
18B	KA05006*	MANIFOLD FEED HOSE EARLY NA MODELS	1
19	1N-1/4	WASHER FLAT SAE PLATED	12
20	KA05013	HOSE	1
21	41236G	HOSE CLAMP	2
22	KA18010	90 DEG ELBOW	1
23	7930486*	COIL HARNESS	1

*Not Shown

10.26 Turbocharger



10.27 Single Fire Ignition



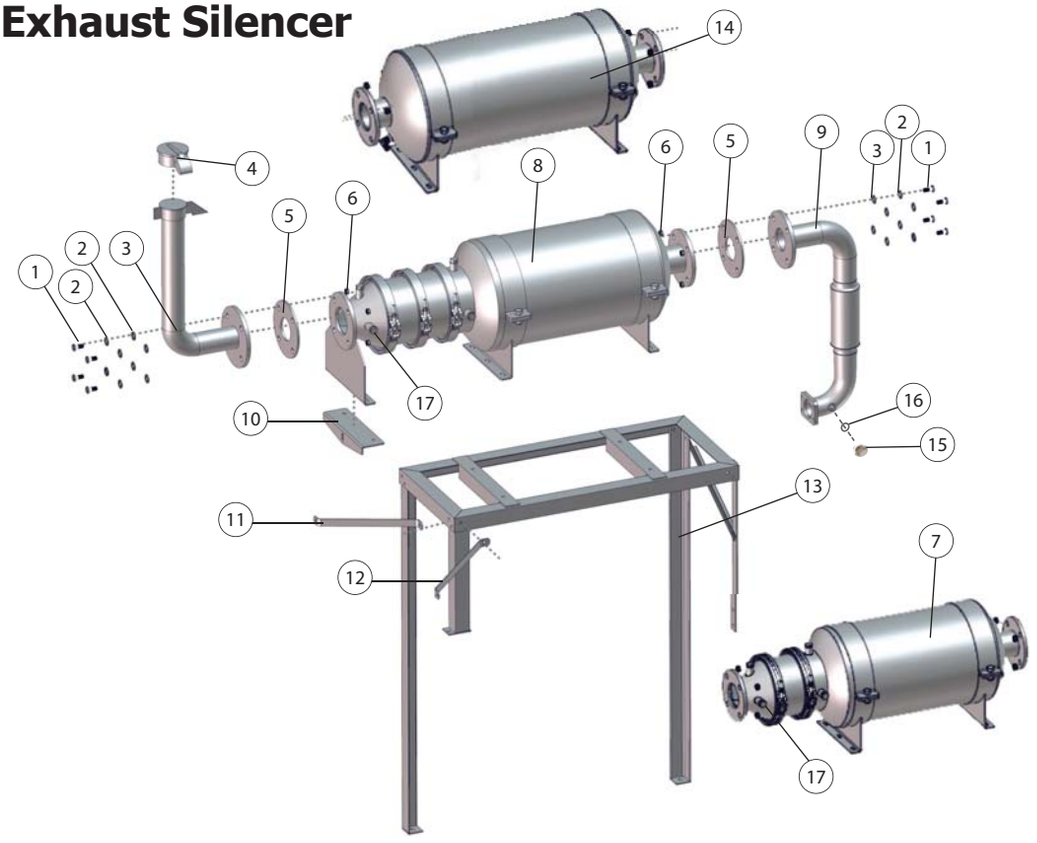
TURBOCHARGER			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**QTY**
1	KA50559	ACTUATOR	1
2	KA01007	STUD, TURBO	3
3	KA02006	NUT	3
4	KA50498	TURBOCHARGER	1
5	208594A	INLET GASKET	1
6	KA50527	HEAT SHIELD	1
7	12161798	GASKET, OIL RETURN	1
8	KA12001	OIL LINE RETURN	1
9	118224	HOSE CLAMP	2
10	KA05019	HOSE	1
11	KA18006	FITTING, 90 DEG, TURBO OIL DRAIN	1
12	M8X30	BOLT	2
13	M8WF	FLAT WASHER	2
14	KA06016	FLANGE TURBO OIL LINE RETURN TO BLK	1
15	KA03027	GASKET, TURBO OIL LINE RETURN TO BLK	1
16	KA08019	BRACKET, BOOST ACTUATOR	1
17	12161797	OIL LINE GASKET	1
18	KA12000	OIL LINE FEED	1
19	01143285	MOUNTING STUD, TURBO	4
20	M10WS	WASHER	4
21	M10NF	NUT, TURBO MOUNTING	4
22	KA19018	BRASS SEALING RING	1
23	KA50605	CLIP RETAINER (NOT SHOWN)	1
24*	KA50629	TURBO RESTRICTOR	1

*NOT SHOWN

SINGLE FIRE IGNITION			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**QTY**
1	7910151	MAGNETIC PICKUP	1
2	KA03025	GASKET IGNITION HOUSING	1
3	KA50496	SINGLE FIRE IGNITION ASSY	1
4	KA03029	GASKET, IGNITION HOUSING FACE	1
5	7930486	COIL HARNESS (NOT SHOWN)	1
6*	M4X12S	4MM BOLT	8

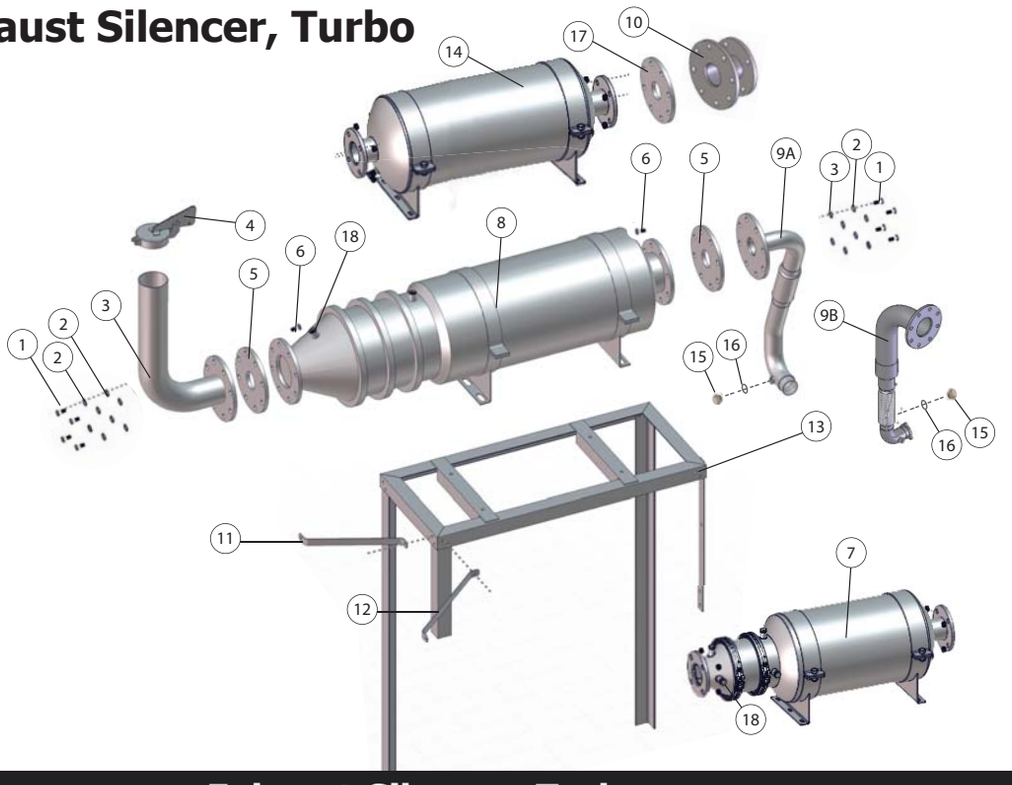
*NOT SHOWN

10.28 Exhaust Silencer



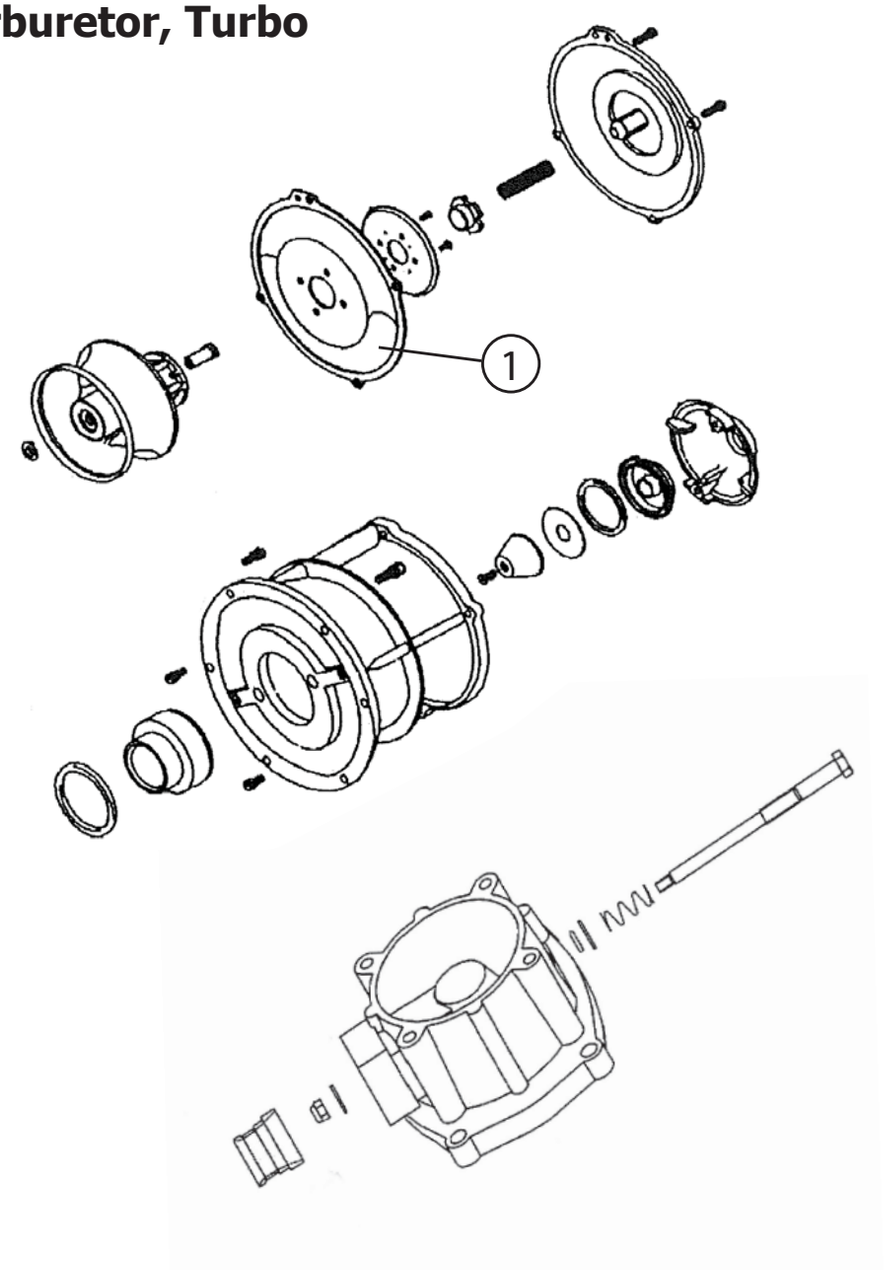
Exhaust Silencer			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	7A-5/811x21/2	BOLT	8
2	1N-5/8	PLAIN MACHINED WASHER	8
3	CAT OUTLET	TAIL PIPE	1
4	155938	RAIN CAP	1
5	AFR-GASKET	FLANGE GASKET FOR AFR/CATALYST/MUFFLER	2
6	1A-5/8	NUT	8
7	CAT 10 CCC	EXHAUST SILENCER/CAT SINGLE ELEMENT	1
8	CAT 10 CCC PJ	EXHAUST SILENCER/CAT DUAL ELEMENT	1
9	KA16000	EXHAUST PIPE TO CAT/MUFFLER	1
10	KA08007	BRACKET, FRONT (AFR ONLY)	1
11	KA08002	BRACKET, RADIATOR TO CATALYST, RIGHT	1
12	KA08001	BRACKET, RADIATOR TO CATALYST, LEFT	1
13	KA50020	FRAME CATALYST SUPPORT	1
14	KA50240	MUFFLER	1
15	KA19004	WASHER, O2 SENSOR DELETE PLUG	1
16	KA17001	O2 SENSOR DELETE PLUG (NON AFR)	1
17	610862	THERMOCOUPLE ADAPTER	2
18	O2-SENSOR-2WIR	O2 SENSOR (AFR ONLY) (NOT SHOWN)	1

10.29 Exhaust Silencer, Turbo



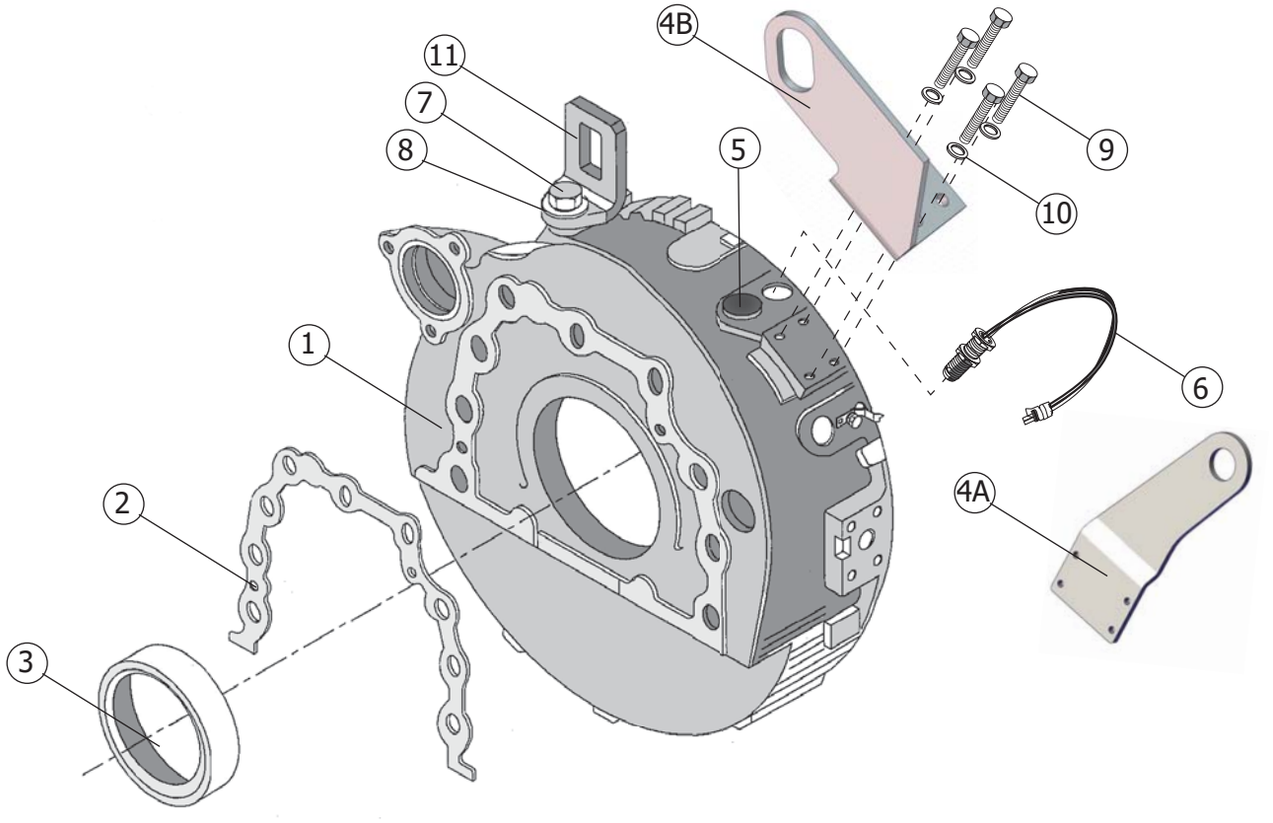
Exhaust Silencer, Turbo			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	7A-5/811x21/2	BOLT	8
2	1N-5/8	PLAIN MACHINED WASHER	8
3	KA50523	OUTLET, TAIL PIPE, 4" FLANGE	1
4	KA50526	RAIN CAP, 4"	1
5	GSKT-4-150-SW	FLANGE GASKET FOR AFR/CATALYST	2
6	1A-5/8	NUT	8
7	CAT 12 CCC	EXHAUST SILENCER/CAT SINGLE ELEMENT	1
8	CAT 12 CCC PJ	EXHAUST SILENCER/CAT DUAL ELEMENT	1
9A	KA50499	EXHAUST PIPE, OPEN UNIT	1
9B	KA50510	EXHAUST PIPE, ENCLOSURE, 4"	1
10	KA50245	FLANGE, PIPE ADAPTOR 4" - 3"	1
11	KA08002	BRACKET, RADIATOR TO CATALYST, RIGHT	1
12	KA08001	BRACKET, RADIATOR TO CATALYST, LEFT	1
13	KA50020	FRAME CATALYST SUPPORT	1
14	KA50240	MUFFLER	1
15	KA17001	O2 SENSOR DELETE PLUG (NON AFR)	1
16	KA19004	WASHER, O2 SENSOR DELETE PLUG	1
17	AFR-GASKET	GASKET, 3"	2
18	610862	THERMOCOUPLE ADAPTER	2
19	O2-SENSOR-2WIR	O2 SENSOR (AFR ONLY) (NOT SHOWN)	1

10.30 Carburetor, Turbo



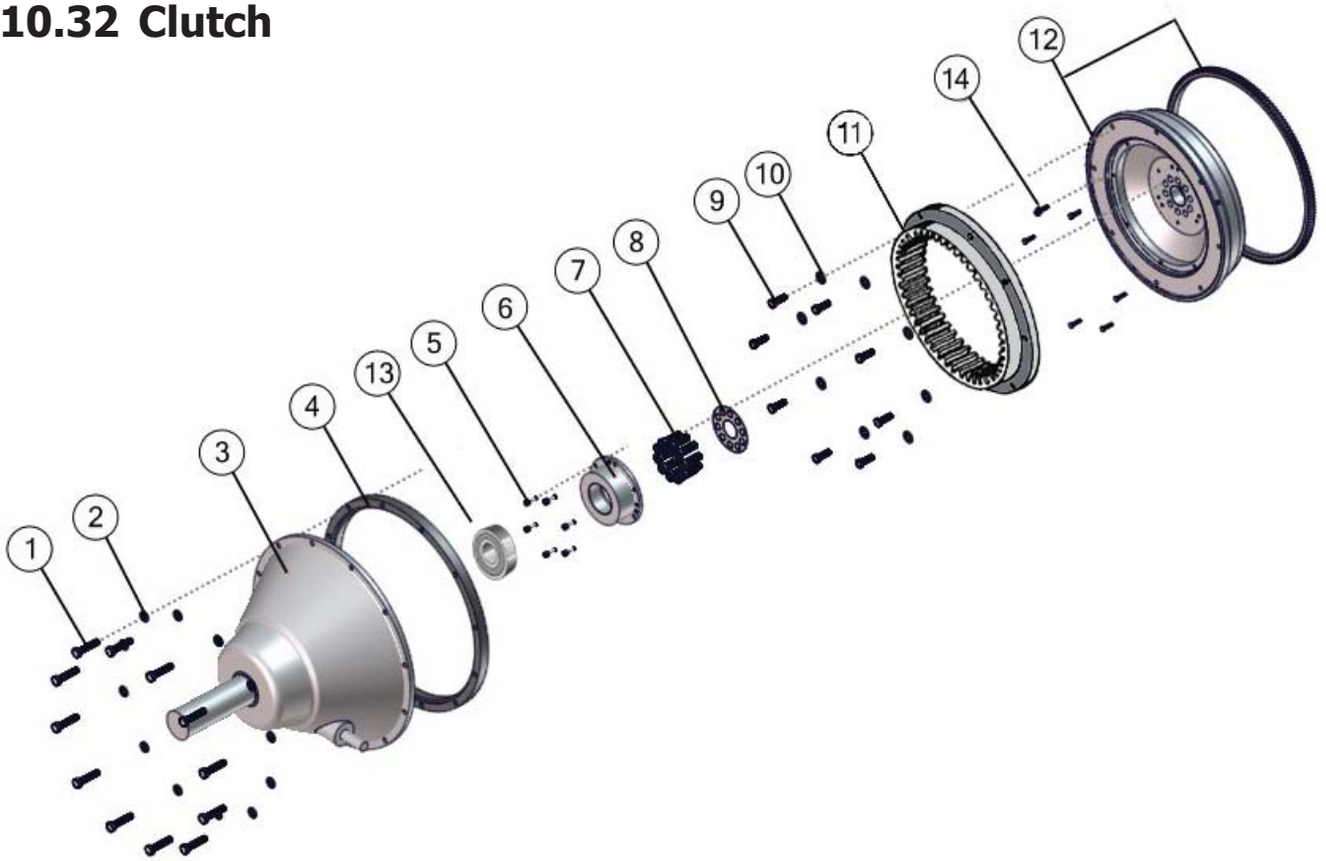
Carburetor, Turbo			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	KA50563	DIAPHRAGM, 400 KIT	1

10.31 Flywheel Housing and Lifting Brackets



Flywheel Housing and Lifting Brackets			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	KA50507	HOUSING, FLYWHEEL	1
2	KA03031	GASKET, FLYWHEEL HOUSING	1
3	KA50380	SEAL OIL TFE, REAR, 150X120X13.5	1
4A	KA50552	REAR LIFTING EYE, NA ONLY	1
4B	KA50503	REAR LIFTING EYE, TURBO ONLY	1
5	KA17010	PLUG, FLYWHEEL HOUSING	1
6	7910151	MAGNETIC PICKUP	1
7	M16X45	SCREW	1
8	M16FW	FLAT WASHER	1
9	M12X40	SCREW, HEX HD	4
10	M12FW	WASHER	4
11	KA50633	LIFTING EYE, REAR STANDARD	1

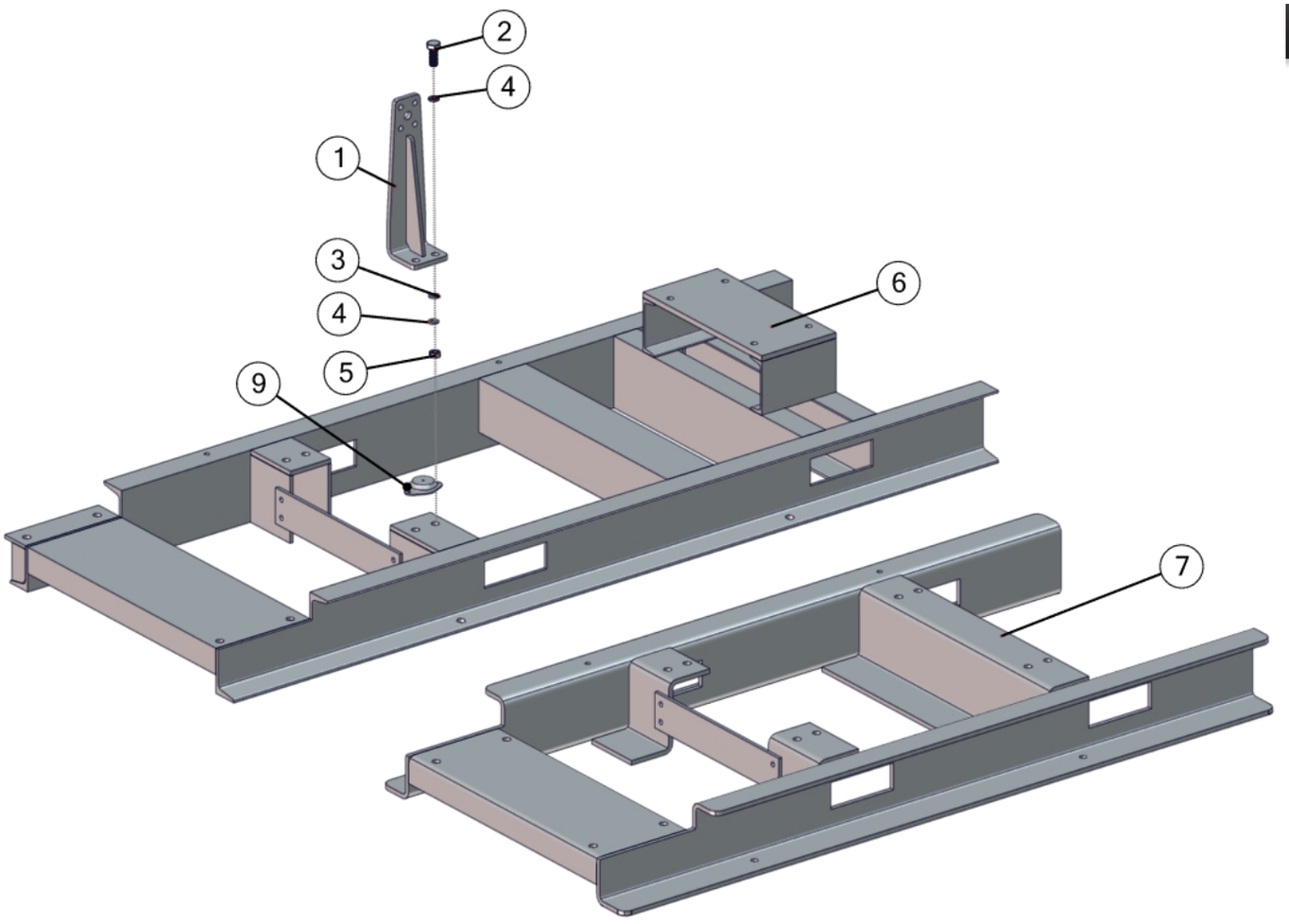
10.32 Clutch



Clutch			
NUMBER	**PART NUMBER**	**DESCRIPTION**	**PART QTY**
1	M10X60	BOLT, HEX HD	12
2	M10WS	10MM SPLIT LOCKWASHER ZINC PLTD	12
3	SPE-114-P1	CLUTCH, SINGLE DISC	1
4	KA50120	SPACER, 1" SAE 1 FLYWHEEL HOUSING	1
5	M8X30S	METRIC ALLENHEAD SCREW	6
6	KA50170	HOUSING, PILOT BEARING	1
7	KA00003	BOLT, FLY WHEEL	10
8	KA50478	PLATE, HOLDER	1
9	M12X30	CAPSCREW, HEXHD GRD 8.8 PLTD	8
10	M12WS	LOCKWASHER, 12MM SPLIT ZINC PLTD	8
11	5713	RING DRIVE GEAR, SINGLE DISC CLUTCH	1
12	KA50150	FLYWHEEL ASSY WITH STARTER RING GEAR	1
13	M-1985	BEARING, CLUTCH	1
14	M10X25	HEXHD CAPSCREW	6
15*	KA50635	DISC CLUTCH, HEAVY DUTY, OPTIONAL	6
16*	A-6518	RING DRIVE GEAR DUAL DISC CLUTCH, OPTIONAL	6
17*	M-2529	EASY SLIP BEARING, OPTIONAL	6

*Not shown.

10.33 Engine Mounting Bracket



Engine Mounting Bracket			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1A	SKA50620	ENGINE MOUNTING BRACKET (GENSET)	2
1B	SKA50620	ENGINE MOUNTING BRACKET (POWER UNIT)	4
2	7A-5/811X21/2	CAPSCREW HX HD	8
3	1A-5/8	LOCKWASHER, PLATED	8
4	M18FW	WASHER FLAT STD	16
5	25A-5/811	NUT HX HEAVY	8
6	KA50320	SKID (GENSET ONLY)	1
7	KA50310	SKID (POWER UNIT ONLY)	1
8	KA50470	ENCLOSURE W/INSULATION (NOT SHOWN)	1
9	KA50517	GENSET ISOLATORS (GENSET)	2

10.34 Tank

Tank			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
1	C6X52CX	COALESCENT FILTER FOR NA OR TA	1
2	KA50536	REGULATOR REQUIRED FOR TURBO	1

10.35 Sheet Metal

Sheet Metal			
NUMBER	PART NUMBER	DESCRIPTION	PART QTY
	KA08018	BRACKET SUPPORT LEFT HAND	
	KA0817	BRACKET SUPPORT RIGHT HAND	
	KA50551	PLATE, PATCH LOWER RADIATOR	
	KA50550	PLATE, PATCH TOP RADIATOR	
	KA50489	RADIATOR SHELL RIGHT HAND	
	KA50549	RADIATOR SHELL LEFT HAND	
	KA50494	DOORS SHEET METAL	
	KA50493	HOOD SHEET METAL PU	
	KA50491	PANEL LOWER REAR SHEET METAL	
	KA50490	PANEL UPPER REAR SHEET METAL	
	KA50552	LIFTING EYE SHEET METAL	
	KA50589	IGNITION & GOVERNOR PANEL	
	KA15007	HARNESS EXTENSION SHEET METAL NA	
	KA15005	CABLE 12” BLACK SHEET METAL	
	KA15006	CABLE 30” RED SHEET METAL	
	KA16024	SPACER REAR BRACKET SHEET METAL	
	KA01009	STUD A90 SHEET METAL	
	KA50597	PIPE INTAKE SHEET METAL NA	

A-90 Service Kits

G-979-A90	QTY	TOP END GASKET SET
12161797	1	GASKET, TURBO OIL FEED LINE
12161798	1	GASKET, TURBO OIL LINE RETURN
208594A	1	GASKET, TURBO CONNECTION
AFR-GASKET	2	GASKET, EXHAUST SILENCER FLANGE (3”)
G1-21	1	GASKET, THROTTLE BODY
GSKT-4-150-SW	2	GASKET, EXHAUST SILENCER FLANGE (4”)
KA02000	6	GASKET, INTAKE MANIFOLD
KA03001	1	GASKET, THROTTLE BODY BASE
KA03004	13	SEALING RING, 14MM BANJO FITTING
KA03006	6	GASKET, CYLINDER HEAD (1.25 MM)
KA03007	6	GASKET, ROCKER COVER
KA03008	1	GASKET, OIL FILL TO BLOCK
KA03025	1	GASKET, INJECTION HOUSING (SFI)
KA03026	2	GASKET, CARB ADAPTOR 65MM
KA03027	1	GASKET, TURBO OIL LINE RETURN TO BLOCK
KA03028	1	GASKET, THERMOSTAT HOUSING
KA03029	1	GASKET, IGNITION HOUSING FACE
KA03030	1	GASKET, OIL CAP
SL0001	6	GASKET, EXHAUST MANIFOLD
SL0002	1	GASKET, INTAKE BLOCK OFF

G-977-A90	QTY	SINGLE HEAD GASKET KIT
KA03007	1	VALVE COVER GASKET
KA03006	1	CYLINDER HEAD GASKET
KA03030	1	GASKET SEALING OIL CAP

G-900-A90	QTY	BOTTOM END GASKET SET
KA03002	1	GASKET, ENGINE WATER PUMP INLET
KA03003	1	GASKET, OIL PAN
KA03005	1	O-RING, DIP STICK
KA03009	1	GASKET, WATER PUMP
KA03010	1	GASKET, FILTER HEADER
KA03011	1	GASKET, CENTRIFUGE FILTER TO BLOCK
KA03012	1	GASKET, HEADER
KA03013	1	GASKET, COOLER BOX
KA03014	1	GASKET, LUB OIL COOLER
KA03015	1	GASKET, SPECIAL ADAPTOR PIECE
KA03016	1	GASKET, FRONT PLATE
KA03017	1	GASKET, GEAR CASING
KA03019	1	O-RING, PRESSURE RELIEF VALVE
KA03020	1	GASKET, OIL PICKUP TUBE
KA03021	1	GASKET, REAR CAM COVER
KA03023	1	GASKET, CENTRIFUGE CLEANER
KA03031	1	GASKET, FLYWHEEL HOUSING
KA03036	1	GASKET, UPPER OIL PICKUP TUBE
KA50380	1	OIL SEAL, REAR MAIN
KA50381	1	OIL SEAL, CRANKCASE
KA03022	1	GASKET, COVER
KA03040	1	OIL PUMP SEALING RING
KA19018	1	COPPER WASHER
KA03039	1	O-RING ROTOR UNIT
KA03029	1	GASKET, IGNITION HOUSING FACE
KA03027	1	GASKET, TURBO OIL LINE RETURN TO BLOCK
12161797	1	GASKET, TURBO OIL FEED
12161798	1	GASKET, OIL LINE RETURN TUBO
KA03035	1	GASKET, ACCESSORY COVER PLATE

G-936-A90	QTY	HEAD REPAIR KIT
KA19009	2	WASHER
KA19010	2	WASHER
KA50180	1	VALVE, EXHAUST
KA50351	1	VALVE, SEAT (INLET)
KA50370	2	VALVE, GUIDE
KA50371	2	VALVE, KEEPER
KA50372	2	VALVE, SEAL, STEM
KA50603	1	VALVE, SEAT, EXHAUST
KA50442	2	VALVE SPRING (INNER)
KA50443	2	VALVE SPRING (OUTER)
KA50444	2	VALVE, CUP, SPRING
KA50460	1	VALVE, INTAKE
KA17006	1	CORE PLUG 32MM
KA17008	2	CORE PLUG 36MM

G-932-A90	QTY	PISTON / SLEEVE KIT
SKA50594	1	PISTON COMPRESSION 9.0:1
KA50359	1	PISTON RING SET (STD)
KA50385	1	LINER CYL ASSY W/ O-RINGS

KA50483	QTY	WATER PUMP KIT
KA50376	1	WATER PUMP SUB. ASSY
KA03009	1	GASKET WATER PUMP

KA50401	QTY	CAM SHAFT
KA50401	1	CAM SHAFT WITH CAM GEAR ASSEMBLY

G-927-A90	QTY	CAMSHAFT BEARING KIT
G-927-A90	1	CAM BEARING KIT (NOT SOLD SEPARATELY)

G-907-A90	QTY	PISTON RING KIT
KA50359	6	PISTON RING SET (STD)

G-918-A90	QTY	MAIN BEARING KIT STANDARD
KA50386	7	MAIN BEARING PAIR (STD)

SKA50615	QTY	MAIN BEARING KIT OPTIONAL
KA50615	7	.020 MAIN BEARING PAIR

G-970-A90	QTY	OVERHAUL KIT
G-900-A90	1	BOTTOM END GASKET SET
G-932-A90	6	SINGLE SLEEVE KIT 9.0:1
G-979-A90	1	TOP END GASKET SET
G-918-A90	1	MAIN BEARINGS KIT STD
KA50483	1	WATER PUMP ASSY W/GASKET
SKA50387	1	ROD BEARING SET STD
G-936-A90	6	CYLINDER HEAD REPAIR KIT
KA50377	12	LIFTER
KA50418	1	OIL DEFLECTOR
G-927-A90	1	CAM BUSHING SET
KA16011	1	WASHER SET, THRUST BEARING

SKA50555	QTY	KIT, COLD WEATHER 180 DEGREE
KA50555	2	THERMOSTAT 180 DEGREE
KA18010	2	FITTING, 90° 1” MALE X 1” HOSE BARB
KA18012	1	FLANGE ENGINE WATER PUMP INLET W/1” BIB
PF18-1	1	PLUG, SOCKET HD PIPE
KA03028	1	THERMOSTAT HOUSING GASKET
KA03002	1	GASKET, ENGINE WATER PUMP INLET
KA05023	34”	1” HOSE

SKA50562	QTY	KIT, COLD WEATHER 195 DEGREE
KA50562	2	THERMOSTAT 195 DEGREE
KA18010	2	FITTING, 90° 1” MALE X 1” HOSE BARB
KA18012	1	FLANGE ENGINE WATER PUMP INLET W/1” BIB
PF18-1	1	PLUG, SOCKET HD PIPE
KA03028	1	THERMOSTAT HOUSING GASKET
KA03002	1	GASKET, ENGINE WATER PUMP INLET
KA05023	34”	1” HOSE

SES ARROW