KUBOTA ENGINES

APPLICATION MANUAL

(OC, EA ENGINE)

First Edition

May, 2010

KUBOTA

KiSS issued 05, 2010 A

INTRODUCTION

This application manual describes the technical information and data for installation and technical service of the OC and EA engines of the following concerned models.
Pay attention to the following points when using the manual.

1. Concerned models

Model name	Model code	Remarks
OC60-E3-D1-Q	1G197-00000	OC60-E3 standard export model, Q shaft, fully-equipped exterior
OC60-E3-D1-QX-L1	1G197-14000	Stop solenoid, high capacity charging dynamo, fully-equipped exterior
OC95-E3-D1-Q	1G198-00000	OC95-E3 standard export model, Q shaft, fully-equipped exterior
OC95-E3-D1-QX-L1	1G198-14000	Stop solenoid, high capacity charging dynamo, fully-equipped exterior
EA330-E3-NB1	1G194-00000	EA330-E3 standard export model, fully-equipped exterior
EA330-E3-NB1-APU-1	1G194-11000	Equipped with a radiator and a cooling fan; without air cleaners, mufflers, and fuel tanks.
EA330-E3-NB1-APU-2	1G195-00000	Without any of the radiators, cooling fans, air cleaners, mufflers, and fuel tanks.

2. OC is an oil-cooling and air-cooling diesel engine and EA is a water-cooling diesel engine.
   This manual is edited to cover information of both engines with different cooling systems. If you have any questions, please contact our corresponding section.

3. Both of the standard-model OC and EA engines are equipped with all necessary accessories to operate the engines.
   - OC are fully equipped with an air cleaner, a muffler, an fuel tank, an oil cooler, a cooling fan, and all other accessories.
     The cooling fan of OC is a flywheel-integrated type installed in the spiral case.
   - EA is fully equipped with an air cleaner, a muffler, a fuel tank, a radiator, a cooling fan, and all other accessories.

4. QX-L1 Model of OC is equipped with the exterior equal to the standard models, a stop solenoid, and a high capacity charging dynamo.
   - The assortment symbol Q of the model name indicates kinds of PTO shafts, X indicates the stop solenoid, and L indicates being equipped with a high capacity charging dynamo.
   - For the PTO shafts of OC, not only Q shaft but also D, G, and P shafts are available.
     For reference : For the above concerned models, it is possible to select the models with modified PTO shafts and equipment content.
     Example 1) OC60-E3-D1-G (Without stop solenoids, with a G shaft and all other accessories.)
     Example 2) OC95-E3-D1-QX (With a stop solenoid, a Q shaft, and all other accessories.)

5. Please pay attention to the difference in equipment for three types of EA330-E3-NB1 series.
   - The standard type and APU-1 are equipped with a radiator and a cooling fan, but APU-2 is not equipped with those.
     For APU-2 , the installing party is requested to prepare such equipment as a radiator, an electric cooling fan, a magnetic pump for cooling water, and piping.
   - APU-1 and APU-2 are not equipped with the flywheel cover, so the installing party is requested to install the safety cover.

6. The standards and general codes are listed for reference without limiting to those concerning to OC and EA engines.
   Information exclusively regarding each engine model such as conformity conditions to the emission regulation of each country is regularly revised; therefore please contact our corresponding section for the latest information.

GENERAL INFORMATION
(OC, EA Engine)

0. GENERAL

CONTENTS

1. SPECIFICATIONS

Item	Model	OC60-E3-D1-Q
Type		Vertical liquid-cooled, 4-cycle diesel engine
Number of Cylinders		1
Bore x Stroke	mm (in.)	72 x 68 (2.8 x 2.7)
Displacement	cm^3 (cu.in.)	276 (16.8)
Rated Output	kW (HP) / min^{-1} (rpm)	4.1 (5.5) / 3600
Maximum Output	kW (HP) / min^{-1} (rpm)	4.5 (6.0) / 3600
Maximum Torque	N·m (kgf·m) / min^{-1} (rpm)	13.2 (1.35) / 2000 to 2600
No Load Maximum rpm	min^{-1} (rpm)	3800
No Load Minimum rpm	min^{-1} (rpm)	1300 max.
Direction of Revolution		Counterclockwise viewed from PTO shaft side
Compression ratio		24.5
Type of Combustion Chamber		Spherical type (T.V.C.S : Three Vortex Combustion System)
Type of Injection Nozzle		Throttle type
Type of Injection Pump		PFR
Injection Pressure	MPa (kgf/cm^2)	14.3 (146)
Injection Timing (p : High Pressure Overflow Method)		T.D.C.-16 ° (T.D.C.-17 ° p)
Fuel		Diesel Fuel No. 2-D S500 or S15 (See page 4-10)
Fuel Tank Capacity	lit (USgal)	3.5 (0.92)
Governor Type		Centrifugal flyweight type mechanical governor
Lubricating System		Forced lubrication with trochoid pump
Lubricating Oil		CF or other applicable grade (See page 5-4)
Crankcase Oil Capacity	lit (USgal)	1.3 (0.34)
Effective Quantity Lubricating Oil	lit (USgal)	0.8 (0.2)
Cooling System		ACTV system (Oil and air cooling)
Cooling Device		Oil cooler, Air cooling cylinder
Dimensions (L x W x H)	mm (in.)	403 x 461 x 458 (15.87 x 18.1 x 18.03)
Dry Weight	kg (lbs)	38 (84)
Starting System		Electric starter
Starter Capacity	V-kW	12-0.7
Charging Dynamo	AC V-W	12-48
Recommended Battery Capacity	V-Ah	12-27 to 32 (5hr Ratio)

1) Specifications are subject to change without notice.
2) Dry weight is according to KUBOTA's standard specification.
When specification varies, the weight will vary accordingly.
3) Lubricating oil capacity : With oil filter cartridge.

Item \ Model		OC60-E3-D1-QX-L1
Type		Vertical liquid-cooled, 4-cycle diesel engine
Number of Cylinders		1
Bore x Stroke	mm (in.)	72 x 68 (2.8 x 2.7)
Displacement	cm^3 (cu.in.)	276 (16.8)
Rated Output	kW (HP) / min^{-1} (rpm)	4.1 (5.5) / 3600
Maximum Output	kW (HP) / min^{-1} (rpm)	4.5 (6.0) / 3600
Maximum Torque	N·m (kgf·m) / min^{-1} (rpm)	13.2 (1.35) / 2000 to 2600
No Load Maximum rpm	min^{-1} (rpm)	3800
No Load Minimum rpm	min^{-1} (rpm)	1300 max.
Direction of Revolution		Counterclockwise viewed from PTO shaft side
Compression ratio		24.5
Type of Combustion Chamber		Spherical type (T.V.C.S : Three Vortex Combustion System)
Type of Injection Nozzle		Throttle type
Type of Injection Pump		PFR
Injection Pressure	MPa (kgf/cm^2)	14.3 (146)
Injection Timing (p : High Pressure Overflow Method)		T.D.C.-16 ° (T.D.C.-17 ° p)
Fuel		Diesel Fuel No. 2-D S500 or S15 (See page 4-10)
Fuel Tank Capacity	lit (USgal)	3.5 (0.92)
Governor Type		Centrifugal weight mechanical governor
Lubricating System		Forced lubrication with trochoid pump
Lubricating Oil		CF or other applicable grade (See page 5-4)
Crankcase Oil Capacity	lit (USgal)	1.3 (0.34)
Effective Quantity Lubricating Oil	lit (USgal)	0.8 (0.2)
Cooling System		ACTV system (Oil and air cooling)
Cooling Device		Oil cooler, Air cooling cylinder
Dimensions (L x W x H)	mm (in.)	403 x 461 x 458 (15.87 x 18.1 x 18.03)
Dry Weight	kg (lbs)	38 (84)
Starting System		Electric starter
Starter Capacity	V-kW	12-0.7
Stop Solenoid	V-A	12-12
Charging Dynamo	AC V-W	12-170
Recommended Battery Capacity	V-Ah	12-27 to 32 (5hr Ratio)

1) Specifications are subject to change without notice.
2) Dry weight is according to KUBOTA's standard specification.
When specification varies, the weight will vary accordingly.
3) Lubricating oil capacity : With oil filter cartridge.

Item		Model: OC95-E3-D1-Q
Type		Vertical liquid-cooled, 4-cycle diesel engine
Number of Cylinders		1
Bore x Stroke	mm (in.)	83 x 77 (3.3 x 3.0)
Displacement	cm^3 (cu.in.)	416 (25.4)
Rated Output	kW (HP) / min^{-1} (rpm)	6.25 (8.4) / 3600
Maximum Output	kW (HP) / min^{-1} (rpm)	7.0 (9.4) / 3600
Maximum Torque	N·m (kgf·m) / min^{-1} (rpm)	21.6 (2.20) / 2300
No Load Maximum rpm	min^{-1} (rpm)	3800
No Load Minimum rpm	min^{-1} (rpm)	1300 max.
Rotation Direction		Counterclockwise viewed from PTO shaft side
Compression ratio		24.0
Type of Combustion Chamber		Spherical type (T.V.C.S : Three Vortex Combustion System)
Type of Injection Nozzle		Throttle type
Type of Injection Pump		PFR
Injection Pressure	MPa (kgf/cm^2)	14.3 (146)
Injection Timing		T.D.C.-14 ° (T.D.C.-15 ° p)
Fuel		Diesel Fuel No. 2-D S500 or S15 (See page 4-10)
Fuel Tank Capacity	lit (USgal)	5.5 (1.5)
Governor Type		Centrifugal weight mechanical governor
Lubricating System		Forced lubrication with trochoid pump
Lubricating Oil		CF or other applicable grade (See page 5-4)
Crankcase Oil Capacity	lit (USgal)	1.7 (0.45)
Effective Quantity Lubricating Oil	lit (USgal)	1.0 (0.26)
Cooling System		ACTV system (Oil and air cooling)
Cooling Device		Oil cooler, Air cooling cylinder
Dimensions (L x W x H)	mm (in.)	451 x 503 x 501 (17.8 x 19.7 x 19.7)
Dry Weight	kg (lbs)	56 (120)
Starting System		Electric starter
Starter Capacity	V-kW	12-1.2
Charging Dynamo	AC V-W	12-48
Recommended Battery Capacity	V-Ah	12-36 (5hr Ratio)

1) Specifications are subject to change without notice.
2) Dry weight is according to KUBOTA's standard specification.
When specification varies, the weight will vary accordingly.
3) Lubricating oil capacity : With oil filter cartridge.

Item / Model		OC95-E3-D1-QX-L1
Type		Vertical liquid-cooled, 4-cycle diesel engine
Number of Cylinders		1
Bore x Stroke	mm (in.)	83 x 77 (3.3 x 3.0)
Displacement	cm^3 (cu.in.)	416 (25.4)
Rated Output	kW (HP) / min^{-1} (rpm)	6.25 (8.4) / 3600
Maximum Output	kW (HP) / min^{-1} (rpm)	7.0 (9.4) / 3600
Maximum Torque	N·m (kgf·m) / min^{-1} (rpm)	21.6 (2.20) / 2300
No Load Maximum rpm	min^{-1} (rpm)	3800
No Load Minimum rpm	min^{-1} (rpm)	1300 max.
Rotation Direction		Counterclockwise viewed from PTO shaft side
Compression ratio		24.0
Type of Combustion Chamber		Spherical type (T.V.C.S : Three Vortex Combustion System)
Type of Injection Nozzle		Throttle type
Type of Injection Pump		PFR
Injection Pressure	MPa (kgf/cm^2)	14.3 (146)
Injection Timing		T.D.C.-14 ° (T.D.C.-15 ° p)
Fuel		Diesel Fuel No. 2-D S500 or S15 (See page 4-10)
Fuel Tank Capacity	lit (USgal)	5.5 (1.5)
Governor Type		Centrifugal weight mechanical governor
Lubricating System		Forced lubrication with trochoid pump
Lubricating Oil		CF or other applicable grade (See page 5-4)
Crankcase Oil Capacity	lit (USgal)	1.7 (0.45)
Effective Quantity Lubricating Oil	lit (USgal)	1.0 (0.26)
Cooling System		ACTV system (Oil and air cooling)
Cooling Device		Oil cooler, Air cooling cylinder
Dimensions (L x W x H)	mm (in.)	451 x 503 x 501 (17.8 x 19.7 x 19.7)
Dry Weight	kg (lbs)	56 (120)
Starting System		Electric starter
Starter Capacity	V-kW	12-1.2
Stop Solenoid	V-A	12-12
Charging Dynamo	AC V-W	12-170
Recommended Battery Capacity	V-Ah	12-36 (5hr Ratio)

1) Specifications are subject to change without notice.
2) Dry weight is according to KUBOTA's standard specification.
When specification varies, the weight will vary accordingly.
3) Lubricating oil capacity : With oil filter cartridge.

Item \ Model		EA330-E3-NB1
Type		Horizontal, water-cooled, 4-cycle diesel engine
Number of Cylinders		1
Bore x Stroke	mm (in.)	77 x 70 (3.0 x 2.8)
Displacement	cm^3(cu.in.)	325 (19.8)
Rated Output	kW (HP) / min^{-1} (rpm)	4.4 (5.9) / 3000
Maximum Output	kW (HP) / min^{-1} (rpm)	5.15 (6.9) / 3000
Maximum Torque	N·m (kgf·m) / min^{-1} (rpm)	17.65 (1.80) / 2000
No Load Maximum rpm	min^{-1} (rpm)	3220
No Load Minimum rpm	min^{-1} (rpm)	1000 max.
Rotational Direction		Counterclockwise viewed from flywheel side
Compression ratio		24.5
Type of Combustion Chamber		Spherical type (T.V.C.S : Three Vortex Combustion System)
Type of Injection Nozzle		Throttle type
Type of Injection Pump		PFR
Injection Pressure	MPa (kgf/cm^2)	14.3 (146)
Injection Timing (p : High Pressure Overflow Method)		T.D.C.-25.5 ° (T.D.C.-27 ° p)
Fuel		Diesel Fuel No. 2-D S500 or S15 (See page 4-10)
Fuel Tank Capacity	lit (USgal)	4.8 (1.3)
Governor Type		Centrifugal flyweight type mechanical governor
Lubricating System		Forced lubrication with trochoid pump
Lubricating Oil		CF or other applicable grade (See page 5-4)
Crankcase Oil Capacity	lit (USgal)	1.3 (0.34)
Effective Quantity Lubricating Oil	lit (USgal)	0.6 (0.2)
Cooling System		Radiator
Cooling Water Capacity	lit (USgal)	1.2 (0.32)
Dimensions (L x W x H)	mm (in.)	566 x 312 x 457 (22.3 x 12.3 x 18.0)
Dry Weight	kg (lbs)	54 (120)
Starting System		Electric starter
Starter Capacity	V-kW	12-1.1
Charging Dynamo	AC V-W	12-40
Glow Plug	DC V-Ω	11-1.5
Recommended Battery Capacity	V-Ah	12-28 (5hr Ratio)

1) Specifications are subject to change without notice.
2) Dry weight is according to KUBOTA's standard specification.
When specification varies, the weight will vary accordingly.
3) Recommended Coolant Capacity : With radiator.
4) Lubricating oil capacity : With oil filter cartridge.

Item	Model	EA330-E3-NB1-APU-1
Type		Horizontal, water-cooled, 4-cycle diesel engine
Number of Cylinders		1
Bore x Stroke	mm (in.)	77 x 70 (3.0 x 2.8)
Displacement	cm^3(cu.in.)	325 (19.8)
Rated Output	kW (HP) / min^{-1} (rpm)	4.4 (5.9) / 3000
Maximum Output	kW (HP) / min^{-1} (rpm)	5.15 (6.9) / 3000
Maximum Torque	N·m (kgf·m) / min^{-1} (rpm)	17.65 (1.80) / 2000
No Load Maximum rpm	min^{-1} (rpm)	3220
No Load Minimum rpm	min^{-1} (rpm)	1000 max.
Rotational Direction		Counterclockwise viewed from flywheel side
Compression ratio		24.5
Type of Combustion Chamber		Spherical type (T.V.C.S : Three Vortex Combustion System)
Type of Injection Nozzle		Throttle type
Type of Injection Pump		PFR
Injection Pressure	MPa (kgf/cm^2)	14.3 (146)
Injection Timing (p : High Pressure Overflow Method)		T.D.C.-25.5 ° (T.D.C.-27 ° p)
Fuel		Diesel Fuel No. 2-D S500 or S15 (See page 4-10)
Fuel Tank Capacity	lit (USgal)	4.8 (1.3)
Governor Type		Centrifugal flyweight type mechanical governor
Lubricating System		Forced lubrication with trochoid pump
Lubricating Oil		CF or other applicable grade (See page 5-4)
Crankcase Oil Capacity	lit (USgal)	1.3 (0.34)
Effective Quantity Lubricating Oil	lit (USgal)	0.6 (0.2)
Cooling System		Radiator
Cooling Water Capacity	lit (USgal)	1.2 (0.32)
Dimensions (L x W x H)	mm (in.)	485 x 304 x 429 (19.1 x 12.0 x 16.9)
Dry Weight	kg (lbs)	43 (95)
Starting System		Electric starter
Starter Capacity	V-kW	12-1.1
Charging Dynamo	AC V-W	12-40
Glow Plug	DC V-Ω	11-1.5
Recommended Battery Capacity	V-Ah	12-28 (5hr Ratio)

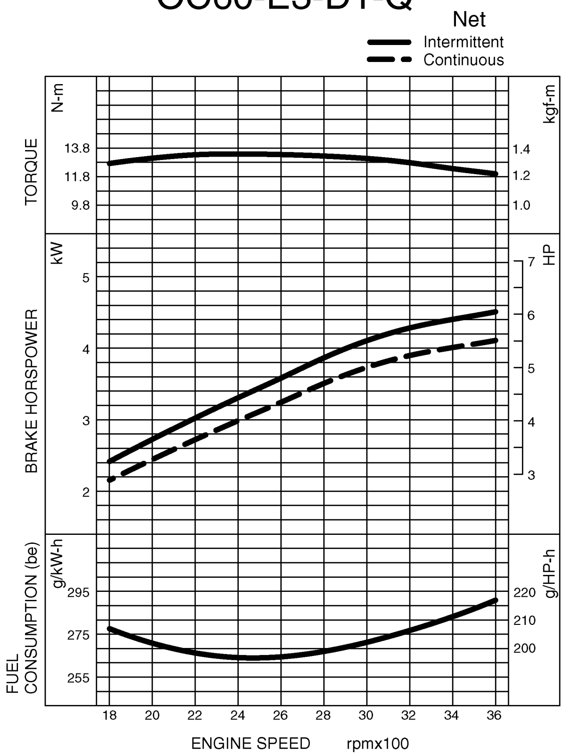
1) Specifications are subject to change without notice.
2) Dry weight is according to KUBOTA's standard specification.
   When specification varies, the weight will vary accordingly.
3) Recommended Coolant Capacity : With radiator.
4) Lubricating oil capacity : With oil filter cartridge.

Item		Model: EA330-E3-NB1-APU-2
Type		Horizontal, water-cooled, 4-cycle diesel engine
Number of Cylinders		1
Bore x Stroke	mm (in.)	77 x 70 (3.0 x 2.8)
Displacement	cm^3(cu.in.)	325 (19.8)
Rated Output	kW (HP) / min^{-1} (rpm)	4.8 (6.4) / 3000
Maximum Output	kW (HP) / min^{-1} (rpm)	5.9 (7.9) / 3000
Maximum Torque	N·m (kgf·m) / min^{-1} (rpm)	18.2 (1.86) / 2000
No Load Maximum rpm	min^{-1} (rpm)	3220
No Load Minimum rpm	min^{-1} (rpm)	1000 max.
Rotational Direction		Counterclockwise viewed from flywheel side
Compression ratio		24.5
Type of Combustion Chamber		Spherical type (T.V.C.S : Three Vortex Combustion System)
Type of Injection Nozzle		Throttle type
Type of Injection Pump		PFR
Injection Pressure	MPa (kgf/cm^2)	14.3 (146)
Injection Timing (p : High Pressure Overflow Method)		T.D.C.-25.5 ° (T.D.C.-27 ° p)
Fuel		Diesel Fuel No. 2-D S500 or S15 (See page 4-10)
Fuel Tank Capacity	lit (USgal)	4.8 (1.3)
Governor Type		Centrifugal flyweight type mechanical governor
Lubricating System		Forced lubrication with trochoid pump
Lubricating Oil		CF or other applicable grade (See page 5-4)
Crankcase Oil Capacity	lit (USgal)	1.3 (0.34)
Effective Quantity Lubricating Oil	lit (USgal)	0.6 (0.2)
Cooling System		Pressurized radiator, force circulation with water pump (not included in the basic engine)
Dimensions (L x W x H)	mm (in.)	485 x 304 x 342 (19.1 x 12.0 x 13.5)
Dry Weight	kg (lbs)	39 (86)
Starting System		Electric starter
Starter Capacity	V-kW	12-1.1
Glow Plug	DC V-Ω	11-1.5
Recommended Battery Capacity	V-Ah	12-28 (5hr Ratio)

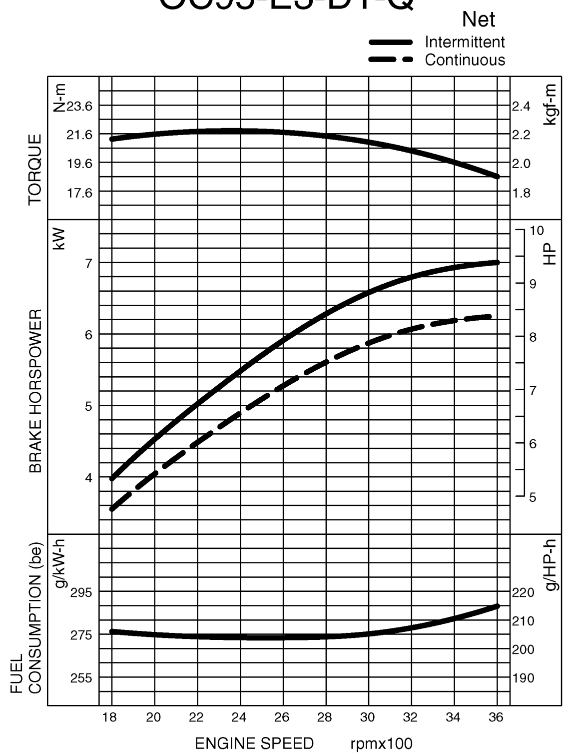
1) Specifications are subject to change without notice.
2) Dry weight is according to KUBOTA's standard specification.
When specification varies, the weight will vary accordingly.
3) Lubricating oil capacity : With oil filter cartridge.

2. PERFORMANCE CURVES

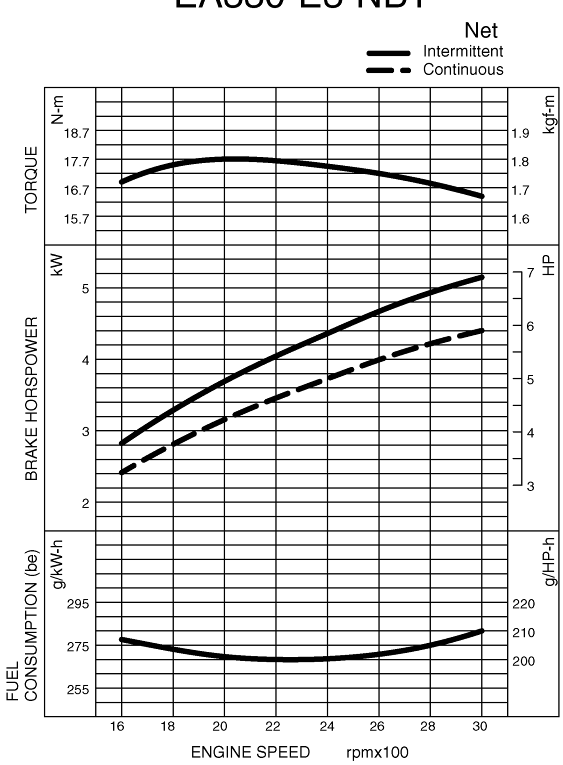
OC60-E3-D1-Q



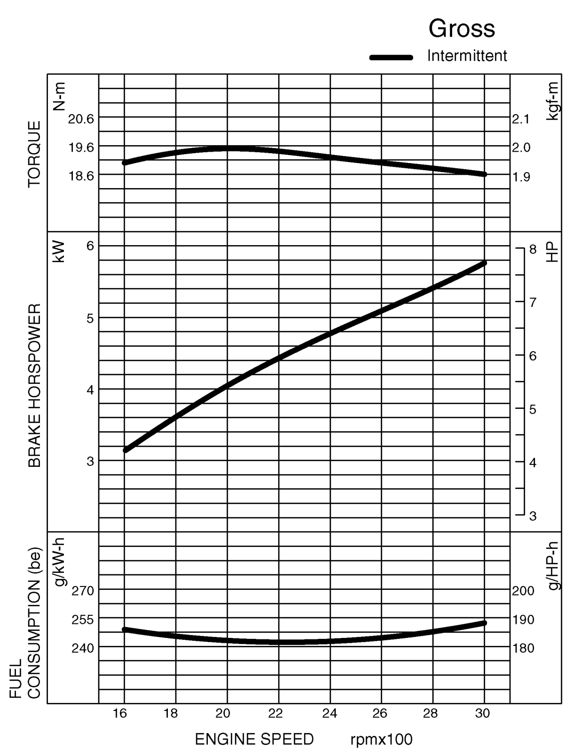
OC95-E3-D1-Q



EA330-E3-NB1



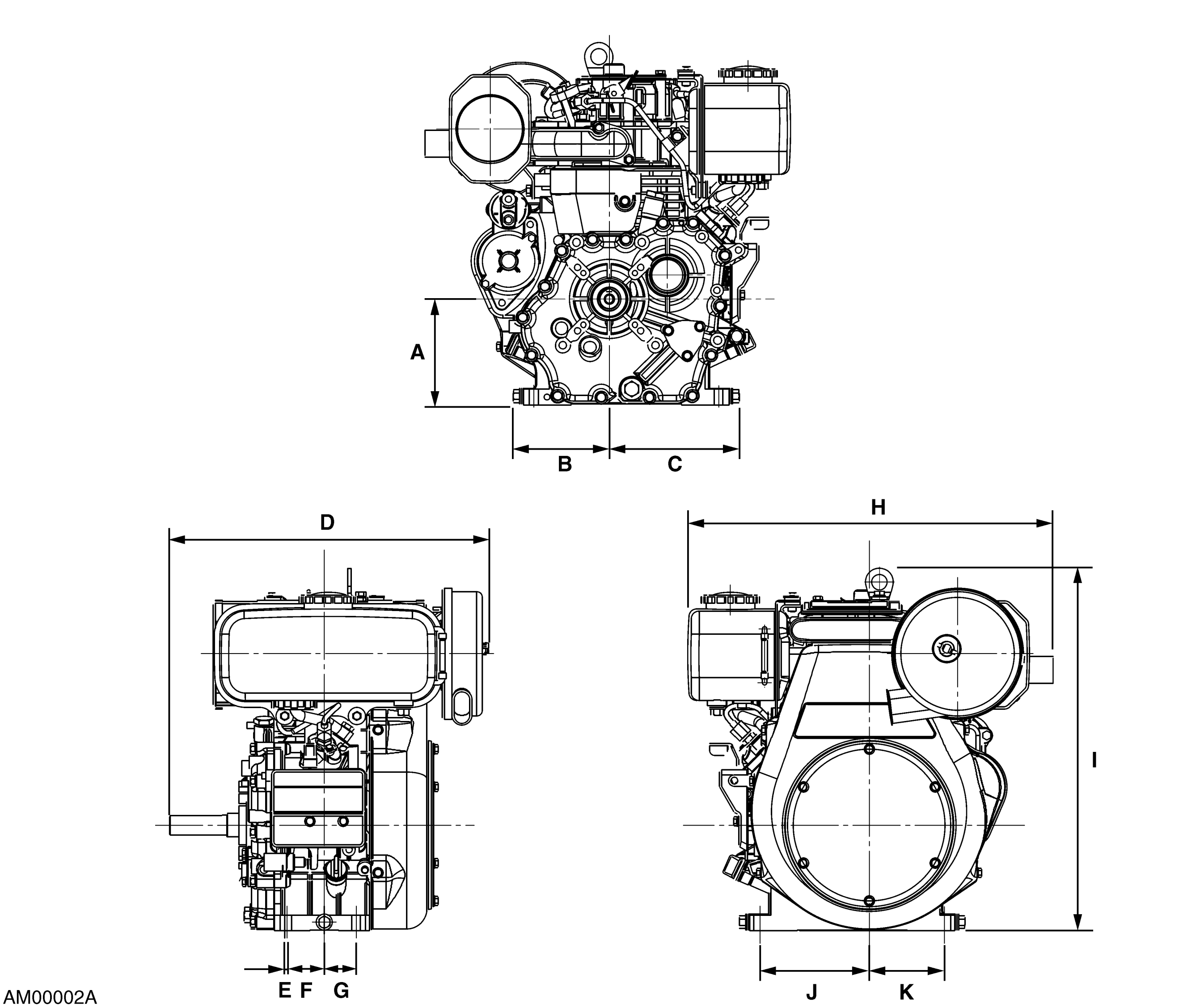
EA330-E3-NB1-APU-2



AM00001A

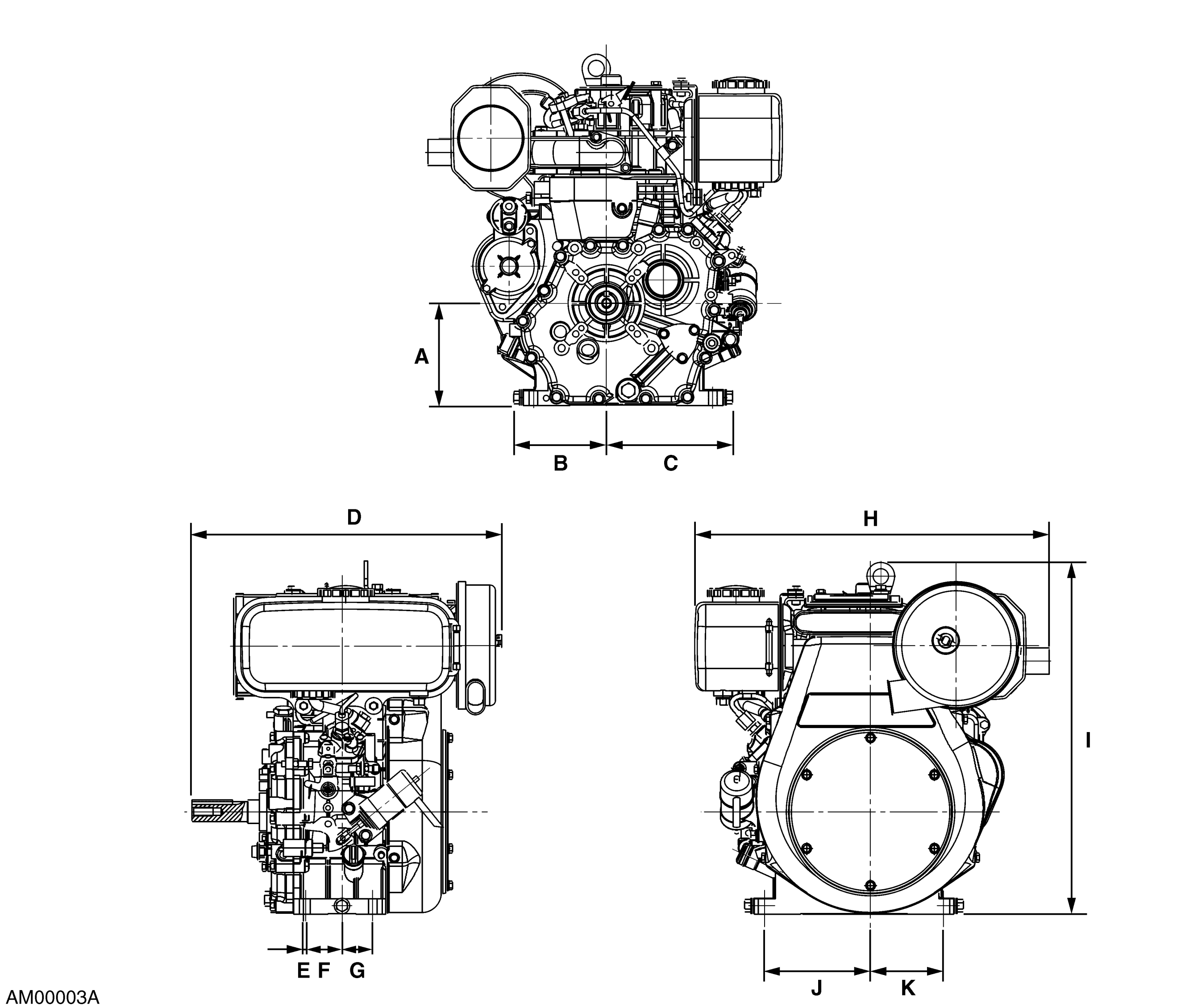
3. DIMENSIONS

STADARD TYPE [OC60-E3]



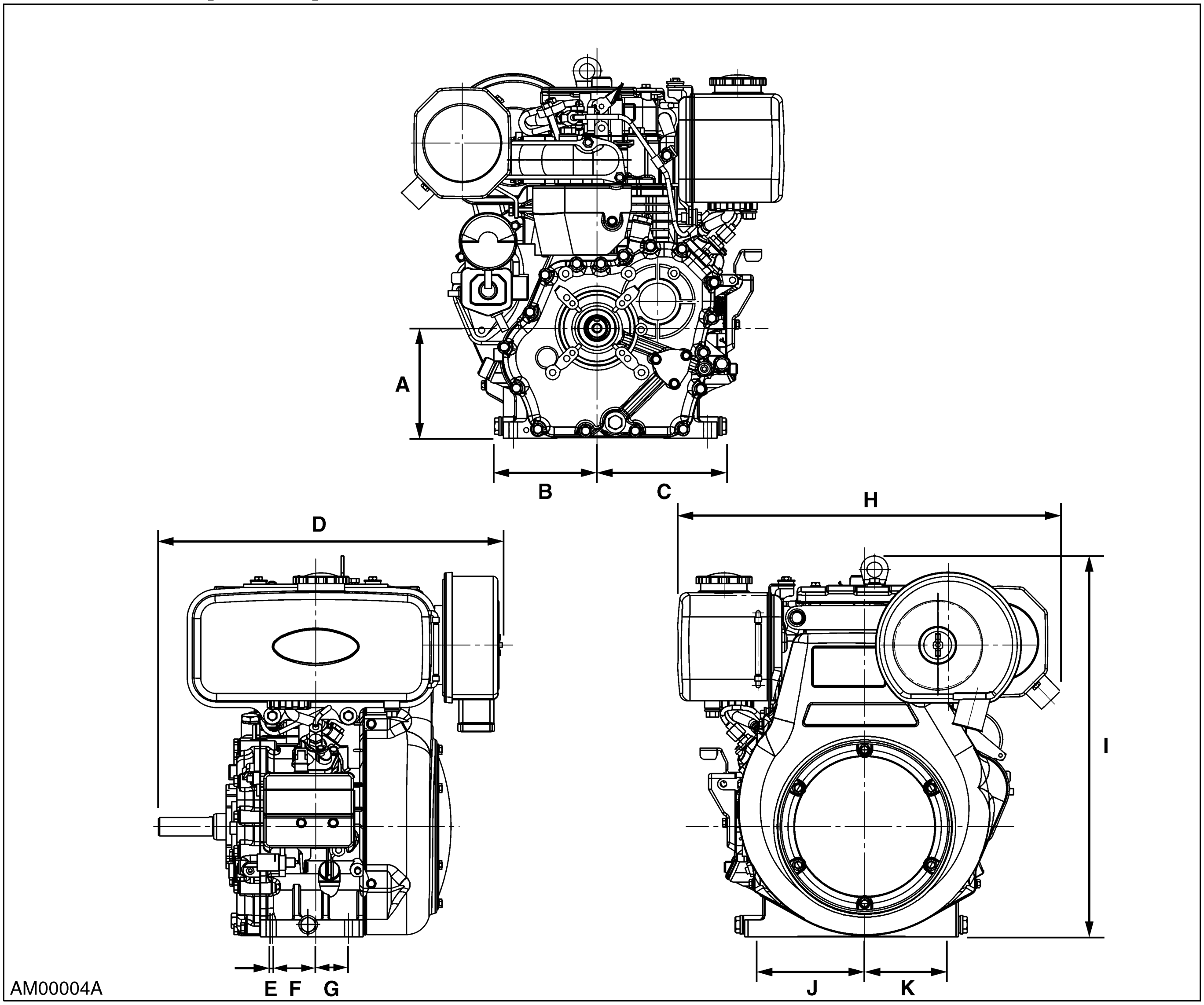
	STANDARD TYPE
A	133.5 mm (5.256 in.)
B	121 mm (4.76 in.)
C	164 mm (6.46 in.)
D	403.0 mm (15.87 in.)
E	3.0 mm (0.12 in.)
F	47.0 mm (1.85 in.)
G	40.0 mm (1.57 in.)
H	461.0 mm (18.15 in.)
I	458.0 mm (18.03 in.)
J	138 mm (5.43 in.)
K	95.0 mm (3.74 in.)

X TYPE (WITH STOP SOLENOID) [OC60-E3]



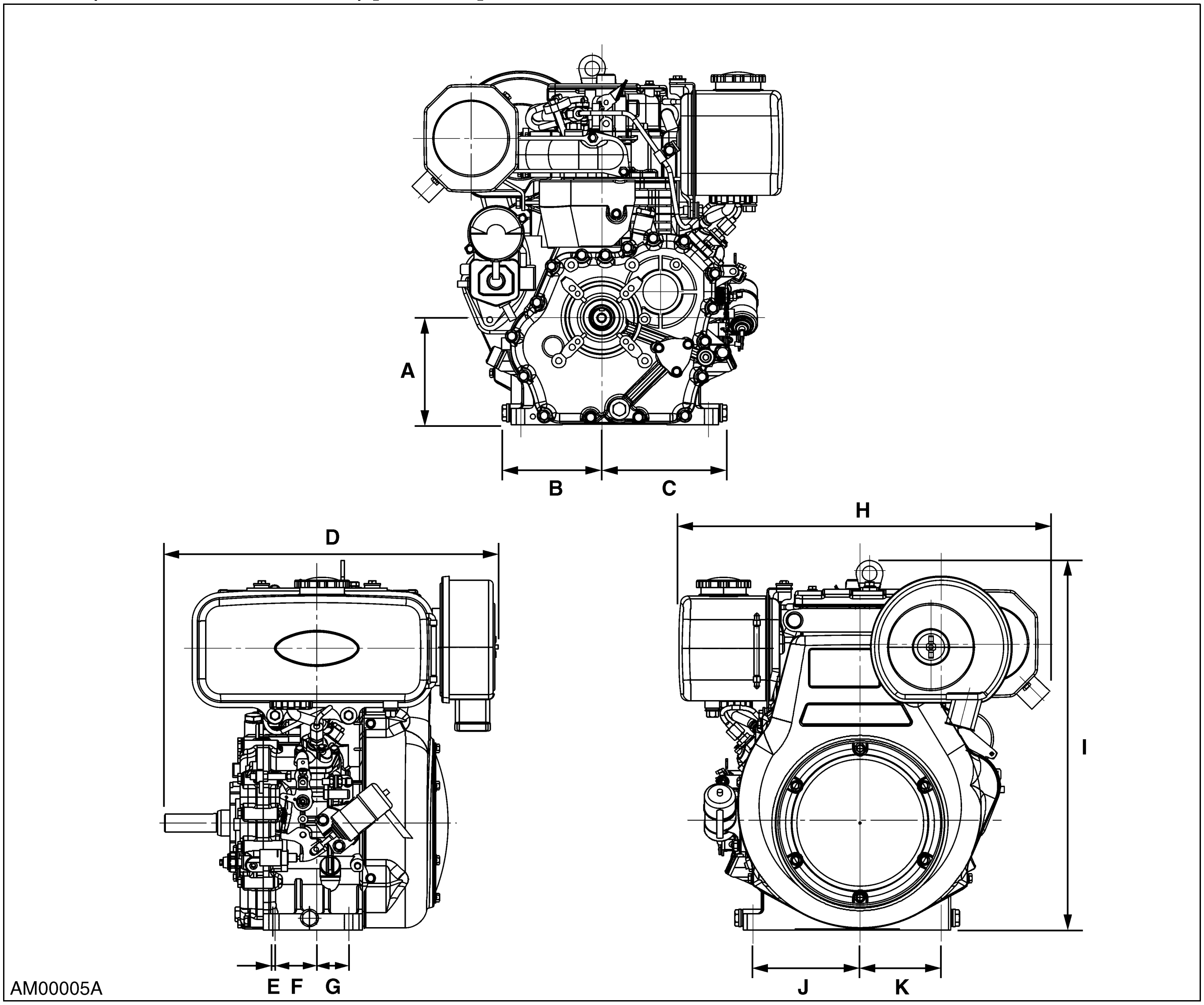
	X TYPE
A	133.5 mm (5.256 in.)
B	121 mm (4.76 in.)
C	164 mm (6.46 in.)
D	403.0 mm (15.87 in.)
E	3.0 mm (0.12 in.)
F	47.0 mm (1.85 in.)
G	40.0 mm (1.57 in.)
H	461.0 mm (18.15 in.)
I	458.0 mm (18.03 in.)
J	138 mm (5.43 in.)
K	95.0 mm (3.74 in.)

STANDARD TYPE [OC95-E3]



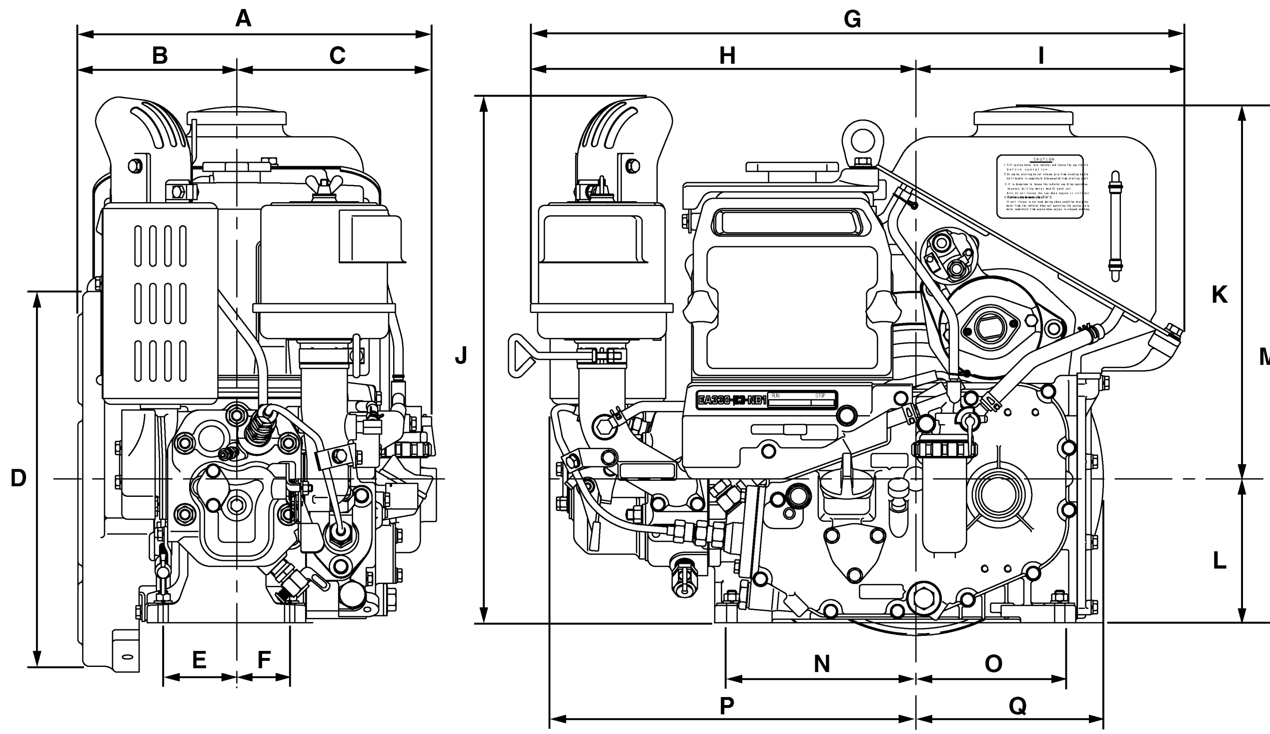
	STANDARD TYPE
A	145 mm (5.71 in.)
B	135 mm (5.31 in.)
C	170 mm (6.69 in.)
D	451 mm (17.80 in.)
E	3.0 mm (0.12 in.)
F	57.0 mm (2.24 in.)
G	43.0 mm (1.69 in.)
H	503.0 mm (19.80 in.)
I	501.0 mm (19.72 in.)
J	145 mm (5.71 in.)
K	110 mm (4.33 in.)

X TYPE (WITH STOP SOLENOID) [OC95-E3]



	X TYPE
A	145 mm (5.71 in.)
B	135 mm (5.31 in.)
C	170 mm (6.69 in.)
D	451 mm (17.80 in.)
E	3.0 mm (0.12 in.)
F	57.0 mm (2.24 in.)
G	43.0 mm (1.69 in.)
H	503.0 mm (19.80 in.)
I	501.0 mm (19.72 in.)
J	145 mm (5.71 in.)
K	110 mm (4.33 in.)

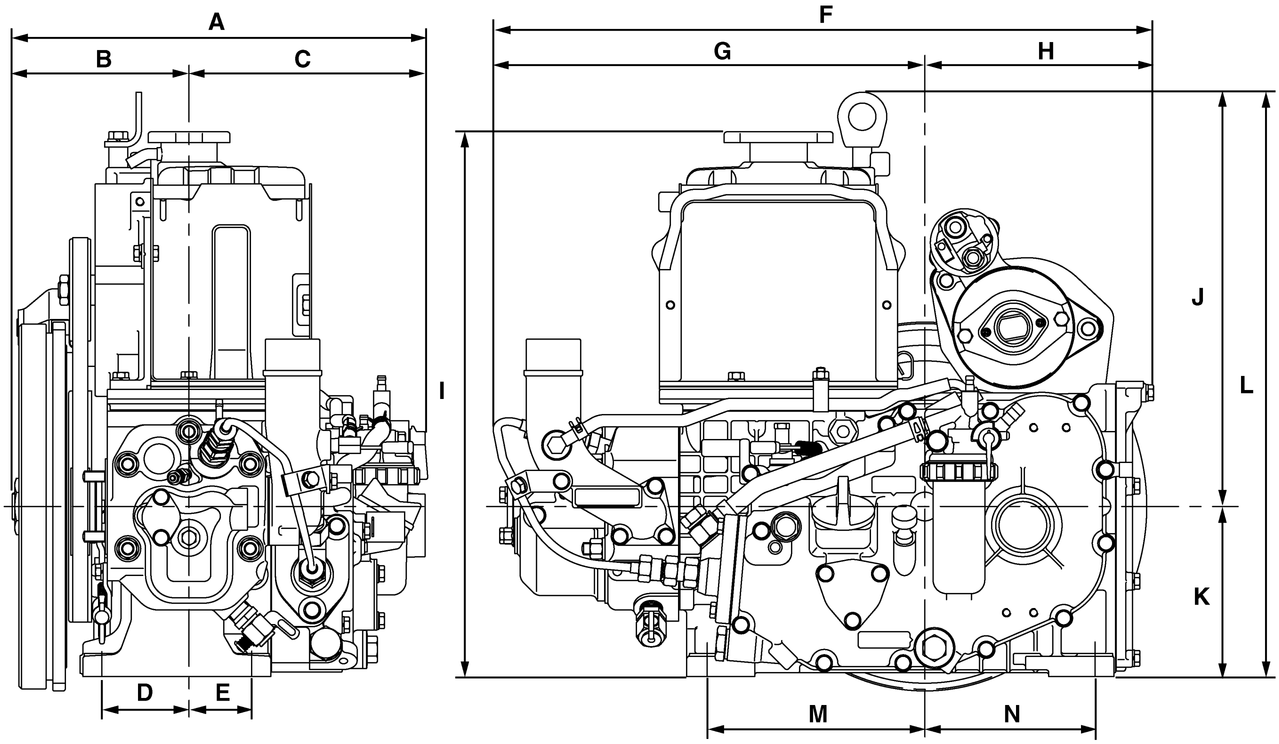
EA330-E3-NB1



AM00006A

	EA330-E3-NB1
A	312 mm (12.3 in.)
B	138 mm (5.43 in.)
C	174 mm (6.85 in.)
D	326 mm dia. (12.8 in. dia.)
E	64 mm (2.5 in.)
F	46 mm (1.8 in.)
G	566 mm (22.3 in.)
H	335 mm (13.2 in.)
I	231 mm (9.09 in.)
J	457 mm (18.0 in.)
K	326 mm (12.8 in.)
L	125 mm (4.92 in.)
M	451 mm (17.8 in.)
N	160 mm (6.30 in.)
O	125 mm (4.92 in.)
P	317 mm (12.5 in.)
Q	163 mm (6.42 in.)

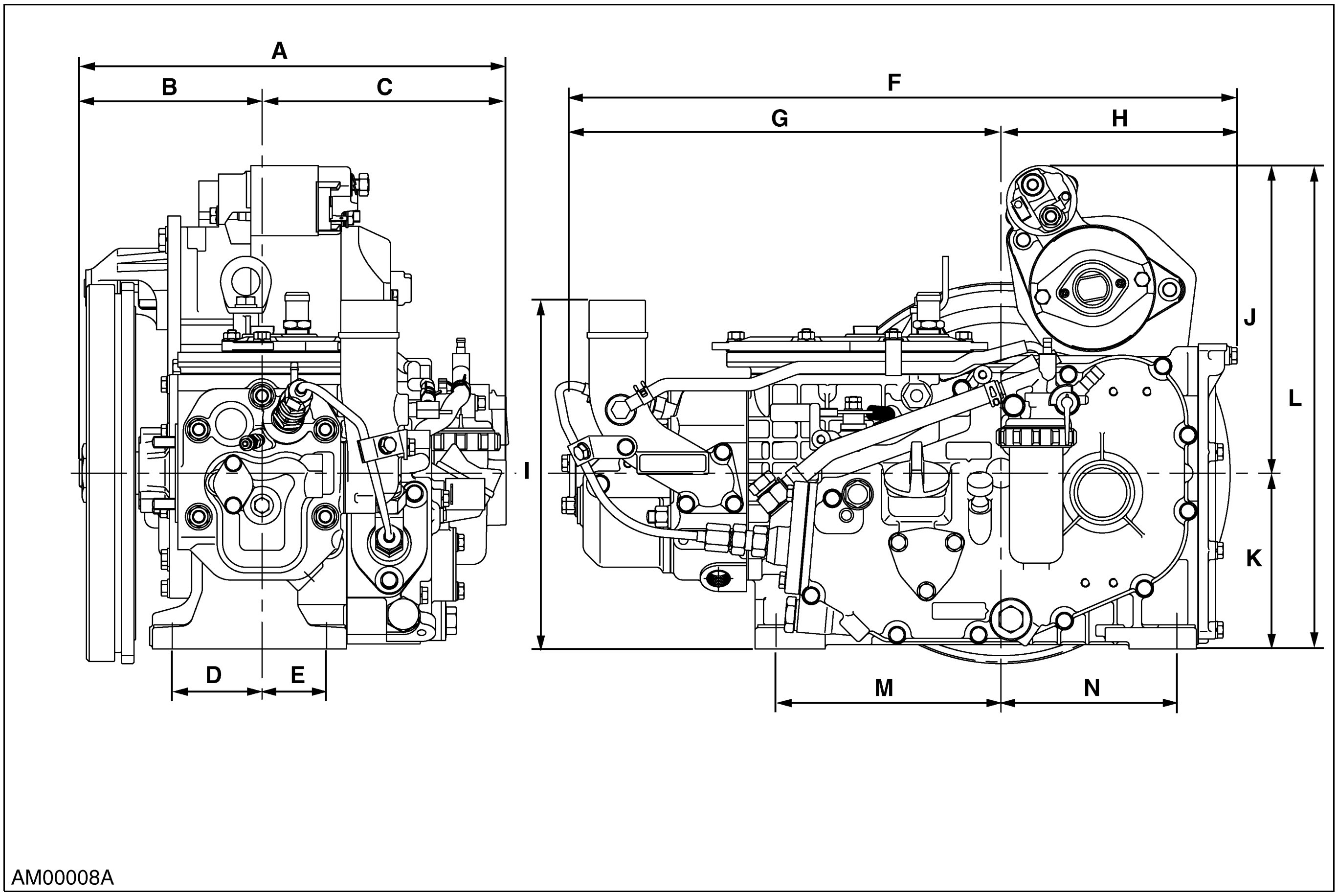
EA330-E3-NB1-APU-1



AM00007A

	EA330-E3-NB1-APU-1
A	304 mm (12.0 in.)
B	130 mm (5.12 in.)
C	174 mm (6.85 in.)
D	64 mm (2.5 in.)
E	46 mm (1.8 in.)
F	485 mm (19.1 in.)
G	317 mm (12.5 in.)
H	168 mm (6.61 in.)
I	400 mm (15.7 in.)
J	304 mm (12.0 in.)
K	125 mm (4.92 in.)
L	429 mm (16.9 in.)
M	160 mm (6.30 in.)
N	125 mm (4.92 in.)

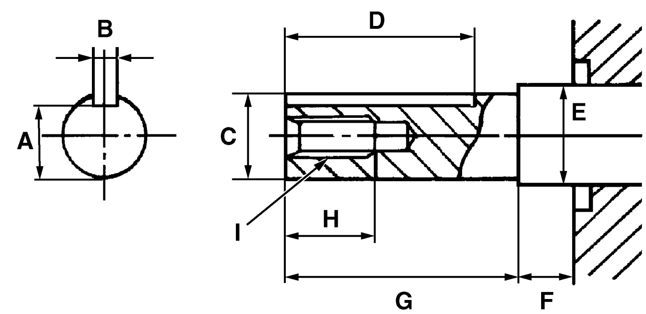
EA330-E3-NB1-APU-2



	EA330-E3-NB1-APU-2
A	304 mm (12.0 in.)
B	130 mm (5.12 in.)
C	174 mm (6.85 in.)
D	64 mm (2.5 in.)
E	46 mm (1.8 in.)
F	485 mm (19.1 in.)
G	317 mm (12.5 in.)
H	168 mm (6.61 in.)
I	248 mm (9.76 in.)
J	219 mm (8.62 in.)
K	125 mm (4.92 in.)
L	342 mm (13.5 in.)
M	160 mm (6.30 in.)
N	125 mm (4.92 in.)

4. PTO SHAFT DIMENSIONS

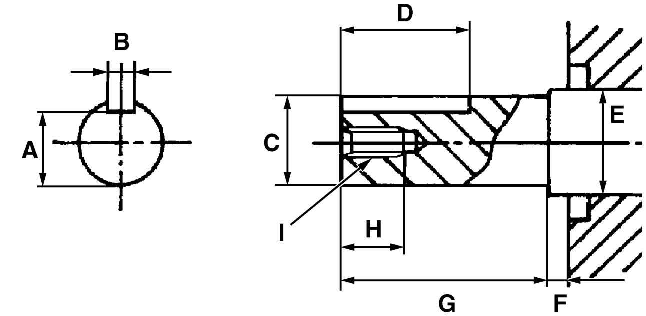
D1-Q



AM00009A

	OC60	OC95
A	21.619 to 21.819 mm (0.85115 to 0.85901 in.)	
B	6.312 to 6.342 mm (0.2485 to 0.2496 in.)	
C	25.379 to 25.400 mm dia. (0.99918 to 1.0000 in. dia.)	
D	56.0 mm (2.20 in.)	
E	30.0 mm dia. (1.18 in. dia.)	35.0 mm dia. (1.38 in. dia.)
F	15.7 mm (0.618 in.)	16.3 mm (0.642 in.)
G	72.2 mm (2.84 in.)	
H	28.0 mm (1.10 in.)	
I	7 / 16 - 20 UNF	

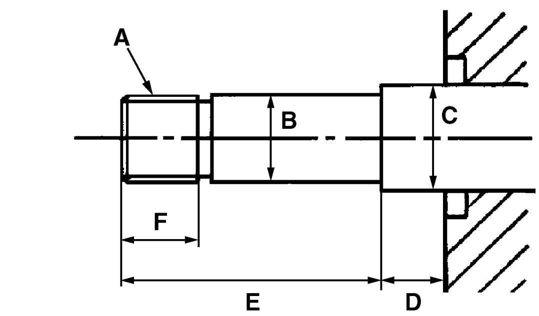
D1-D



AM00010A

	OC60	OC95
A	20.800 to 21.000 mm (0.81890 to 0.82677 in.)	
B	7.000 to 7.022 mm (0.2756 to 0.2764 in.)	
C	24.979 to 25.000 mm dia. (0.98343 to 0.98425 in. dia.)	
D	38.0 mm (1.50 in.)	
E	30.0 mm dia. (1.18 in. dia.)	35 mm dia. (1.38 in. dia.)
F	3.0 mm (0.12 in.)	
G	60.0 mm (2.36 in.)	
H	22 mm (0.87 in.)	
I	M8 x 1.25 mm (M0.31 x 0.05 in.)	

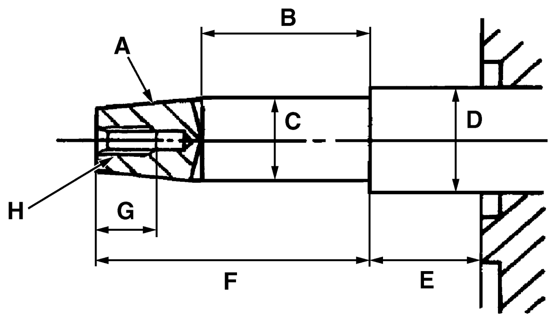
D1-P



AM00011A

	OC60	OC95
A	1 - 14 UNS	
B	25.379 to 25.400 mm dia. (0.99918 to 1.0000 in. dia.)	
C	30.0 mm dia. (1.18 in. dia.)	35.0 mm dia. (1.38 in. dia.)
D	16.5 mm (0.650 in.)	
E	72.2 mm (2.84 in.)	
F	25 mm (0.984 in.)	

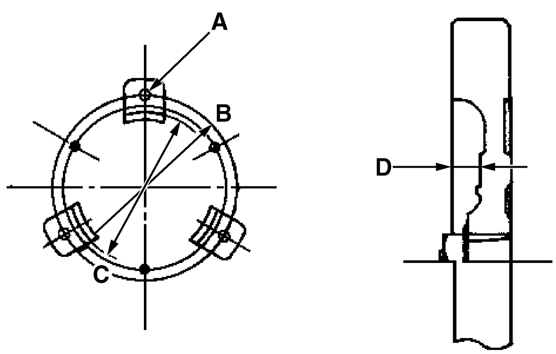
D1-G



AM00012A

	OC60	OC95
A	Taper 2 - 1 / 4 per foot	
B	46.5 mm (1.83 in.)	
C	22.14 to 22.16 mm dia. (0.8717 to 0.8724 in. dia.)	
D	30.0 mm dia. (1.18 in. dia.)	35.0 mm dia. (1.38 in. dia.)
E	30.5 mm (1.20 in.)	
F	75.5 mm (2.97 in.)	
G	18 mm (0.71 in.)	
H	5 / 16 - 24 UNF	

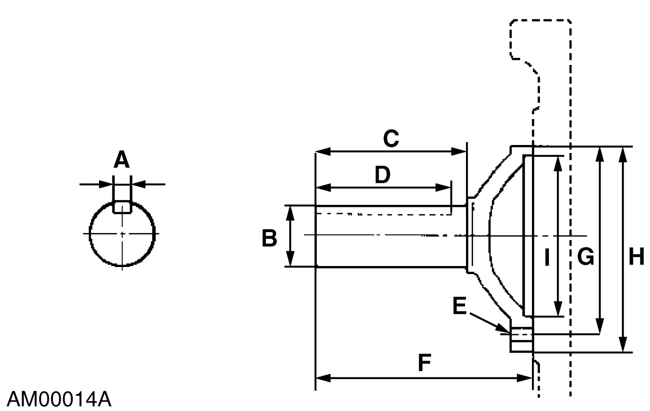
Flywheel



AM00013A

	EA330
A	3 Screw holes - Screw dia. size M 8.0 mm (M 0.31 in.)
B	116 mm dia. (4.57 in. dia.)
C	96.978 to 97.000 mm dia. (3.8180 to 3.8189 in. dia.)
D	16.8 to 17.2 mm (0.662 to 0.677 in.)

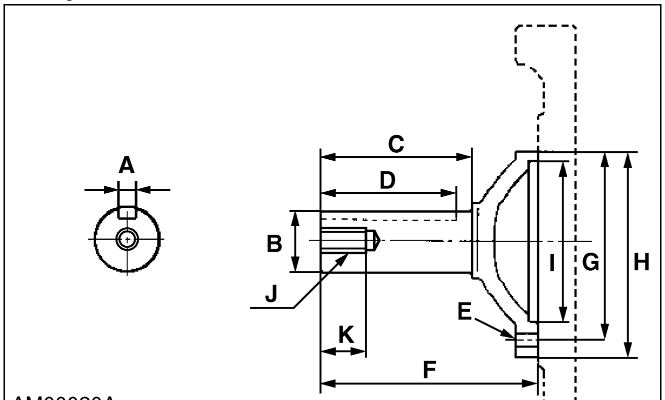
Pulley Shaft



AM00014A

	EA330
No.	19501-8451-0
A	9.525 to 9.575 mm (0.3750 to 0.3769 in.)
B	36.487 to 36.512 mm dia. (1.4365 to 1.4374 in. dia.)
C	88.9 mm (3.50 in.)
D	66.60 to 66.90 mm (2.622 to 2.633 in.)
E	3 Through holes-9.0 mm dia. (0.35 in. dia.)
F	128.9 mm (5.075 in.)
G	116 mm dia. (4.57 in. dia.)
H	138 mm dia. (5.43 in. dia.)
I	97.000 to 97.035 mm dia. (3.819 to 3.820 in. dia.)

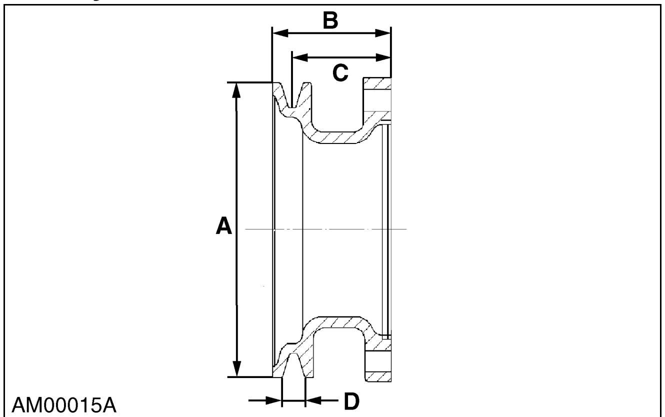
Pulley Shaft



AM00020A

	EA330 (OPTION)	
No.	14659-8451-0	14972-8451-0
A	7.000 to 7.022 mm (0.2756 to 0.2765 in.)	
B	30.008 to 30.021 mm dia. (1.1814 to 1.1819 in. dia.)	
C	55.0 mm (2.17 in.)	
D	46.50 to 47.00 mm (1.8307 to 1.8504 in.)	
E	3 Through holes-11.0 mm dia. (0.43 in. dia.)	
F	95.0 mm (3.7402 in.)	
G	116 mm dia. (4.57 in. dia.)	
H	138 mm dia. (5.43 in. dia.)	
I	97.000 to 97.035 mm dia. (3.819 to 3.820 in. dia.)	
J	M10 x 1.5 mm (M 0.39 x 0.06 in.)	(Without screw)
K	30 mm	-

V-Pulley



AM00015A

	EA330
No.	19704-8401-0
A	134 mm dia. (5.28 in. dia.)
B	53 mm (2.1 in.)
C	44 mm (1.7 in.)
D	10 mm (0.39 in.)

5. ENGINE SELECTION

	Check Items	Detail of Check
1	Check the required horsepower.	1) Check whether continuous or intermittent horsepower is required.
		2) Check that the engine horsepower is acceptable. (Check the engine speed at the same time.)
		3) If an old engine is to be replaced. Compare the displacement (cc), horsepower (kW) and speed (rpm) with those of the new engine. If there is a substantial difference between the old and new engines, discussion will be required.
		4) Remember that engine power loss is caused by high temperature or low atmospheric pressure.
2	Check the temperature requirement for cold starting. (Check that the cold start limit is acceptable.)	1) Check the minimum expected temperature.
		2) Check the battery capacity and wire size.
		3) Check whether or not the hydraulic pump and other devices apply a load when the engine starts.
3	Check the maximum required operating temperature. (Check the cooling capacity.)	1) Check the maximum expected temperature.
		2) Check that the engine cooling capacity is adequate for the above temperature. (Request the customer to conduct a test under the most unfavorable operating conditions.)
		3) Check the following engine installation condition; ☆Check that the engine is enclosed. ☆Check for heat sources (Such as the oil cooler and exhaust silencer) around the radiator.
		4) If the cooling capacity is insufficient, correct the cooling air flow. Further, devise countermeasures, such as employment of large radiator or large fan, and increasing of fan speed. However, there is a case that changing the specification of the fan may not necessarily result in the improvement of cooling performance, since it will increase the load of the engine. Note : The cooling capacity checking methods are shown below. (1) Air-to-boil test (2) Temperature measuring test
4	Check the inclination	Check the maximum inclination.
5	Application check of emission regulations	1) Is it required to use the engine that has cleared the emission regulation?
		2) In case that a conforming engine is required, confirm the kind of the applicable emission regulation, and that the relevant engine is the type that has complied with the applicable emission regulation.

1. EMISSION REGULATION

CONTENTS

EMISSION REGULATION

1. GENERAL

This version of Application Manual is edited for the purpose of performing the application with KUBOTA E3 Diesel Engines, which are designed for the compliance of the current emission regulations implemented in the North America and/or Europe. For the selection of Engines to comply with the emission regulation in the area other than North America or Europe, please refer the following information.

<The current Emission Regulation implemented in each region/country> P : Power

Region / Country	kW	Regulation
North America	$0 \leq P < 19$	Tier 4
	$19 \leq P < 56$	Interim Tier 4
	$56 \leq P < 75$	Tier 3
EU	$19 \leq P < 75$	Stage IIIA
JPN (MOT and MOE)	$19 \leq P < 75$	2007 / 2008 Regulation
JPN (MILT)	$8 \leq P < 75$	3rd Step
JPN (LEMA)	$0 \leq P < 19$	Tier 2
China	$0 \leq P < 75$	Tier 1
KOREA	$19 \leq P < 75$	Tier 3
INDIA (Gen Set)	$0 \leq P < 75$	Stage 2
INDIA (Construction)	$0 \leq P < 75$	Bharat Stage II

*As for the actual certification acquisition, please confirm with KUBOTA of the applicable Engine Model, especially in the area other than North America or EU.

Along with E3 models, E2 models are yet available to be used in the following countries per output category.

kW	Type	North America	Europe	Japan	China
$P < 19$	E3	Y	Y	Y	Y
	E2	N	Y	N	Y
$19 \leq P < 37$	E3	Y(-2012)	Y	Y(-2012)	Y
	E2	N	Y	N	Y
$37 \leq P < 56$	E3	Y(-2012)	Y(-2012)	Y(-2012)	Y/N
	E2	N	N	N	Y
$56 \leq P < 75$	E3	Y(-2011)	Y(-2011)	Y(-2011)	Y/N
	E2	N	N	N	Y

kW	Type	Korea	India	
			Gen Set	Construction
$P < 19$	E3	Y	(Y)	Y
	E2	Y	N	Y
$19 \leq P < 37$	E3	Y	Y	Y
	E2	N	N	Y
$37 \leq P < 56$	E3	Y	Y	Y
	E2	N	N	N
$56 \leq P < 75$	E3	Y	(Y)	Y
	E2	N	N	N

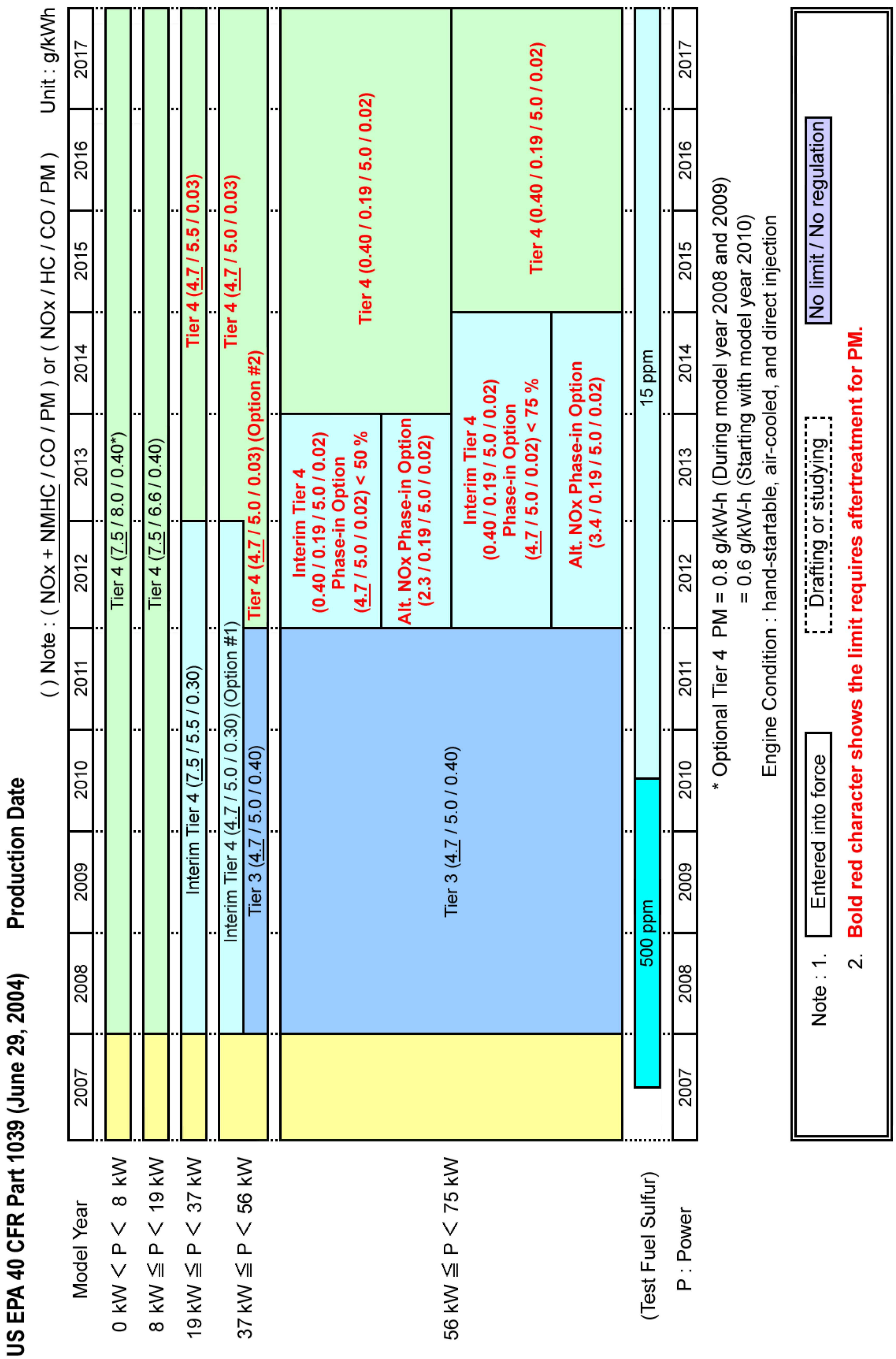
*As for the actual certification acquisition with E2 / E3 Models, again, please confirm with KUBOTA of the applicable Engine Model, especially in the area other than North America or EU.

*Y/N in China means that KUBOTA has acquired the certification for the limited E3 Models. Please consult with KUBOTA for more detailed information.

*(Y) in Gen Set of India means that the emission performance will be changes by output setting of this range. Please consult with KUBOTA for more detailed information.

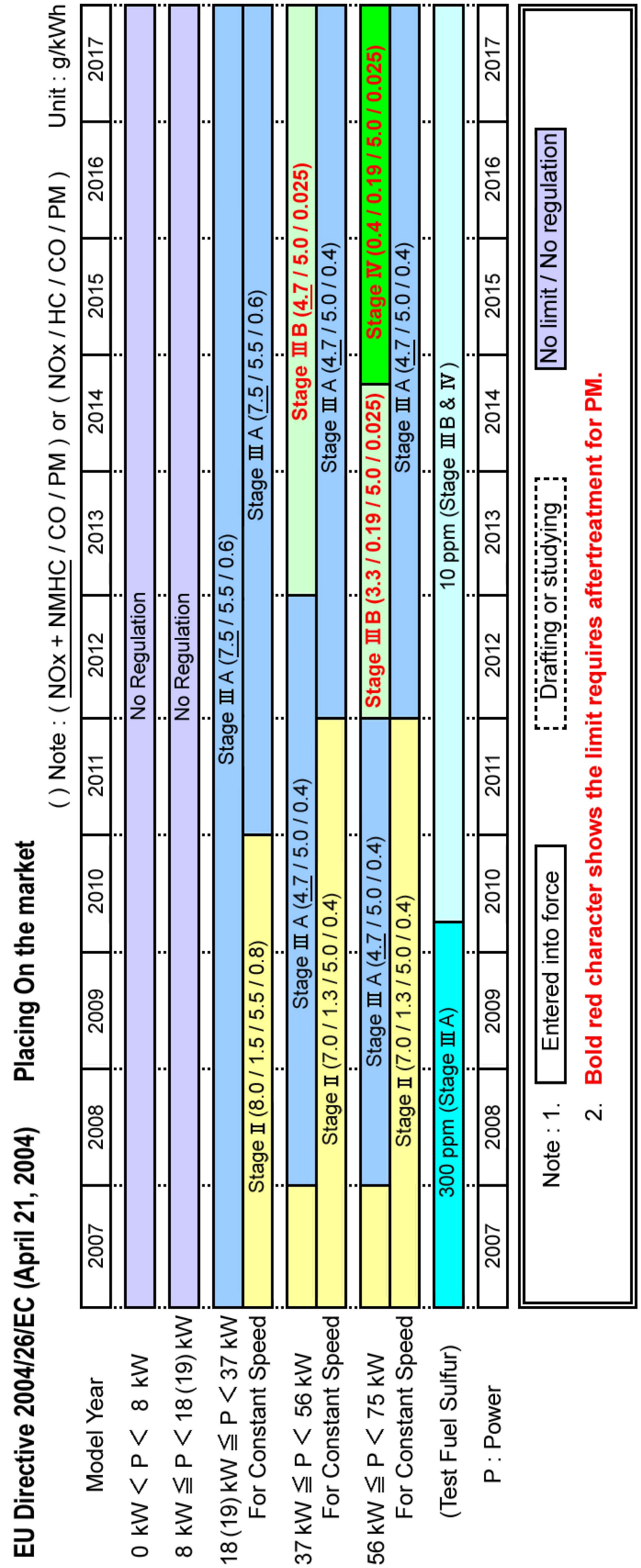
2. CURRENT AND FUTURE EMISSION REGULATIONS

[1] CURRENT AND FUTURE EMISSION REGULATIONS ON USA



AM01001A

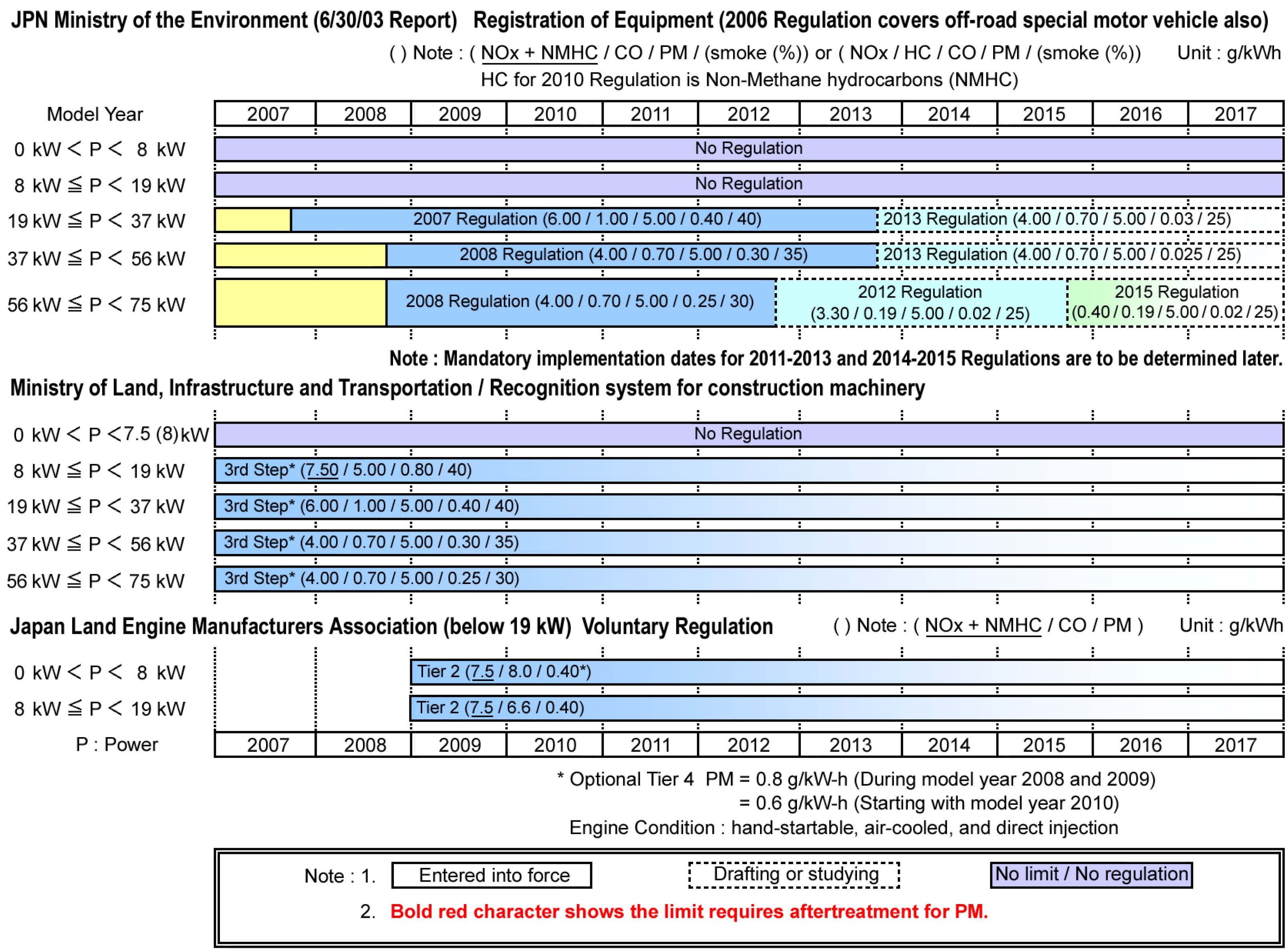
[2] CURRENT AND FUTURE EMISSION REGULATIONS ON EU



AM01002A

[3] CURRENT AND FUTURE EMISSION REGULATIONS ON JAPAN

AM01003A



[4] CURRENT AND FUTURE EMISSION REGULATIONS ON CHINA

Chinese National Environment Protection Agency (April 3, 2007) **Sales Date**

( ) Note : (NOx + NMHC / CO / PM) or (NOx / HC / CO / PM) Unit : g/kWh

Model Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0 kW < P < 8 kW			Stage 1 (18.4 / 12.3 / —)		Stage 2 (10.5 / 8.0 / 1.0)						
8 kW ≦ P < 18 kW			Stage 1 (12.9 / 8.4 / —)		Stage 2 (9.5 / 6.6 / 0.8)						
18 kW ≦ P < 37 kW			Stage 1 (10.8 / 2.1 / 8.4 / 1.0)		Stage 2 (8.0 / 1.5 / 5.5 / 0.8)						
37 kW ≦ P < 75 kW			Stage 1 (9.2 / 1.3 / 6.5 / 0.85)		Stage 2 (7.0 / 1.3 / 5.0 / 0.4)						
P : Power	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017

Note : 1. Entered into force / Drafting or studying / No limit / No regulation

2. **Bold red character shows the limit requires aftertreatment for PM.**

AM01004A

[5] CURRENT AND FUTURE EMISSION REGULATIONS ON KOREA

Korean Ministry of Environment (KMOE)
Equipment Production Date (Custom Clearance for Import) (Proposed Tier 3 to be regulation on engines)

( ) Note : (NOx + NMHC / CO / PM) Unit : g/kWh

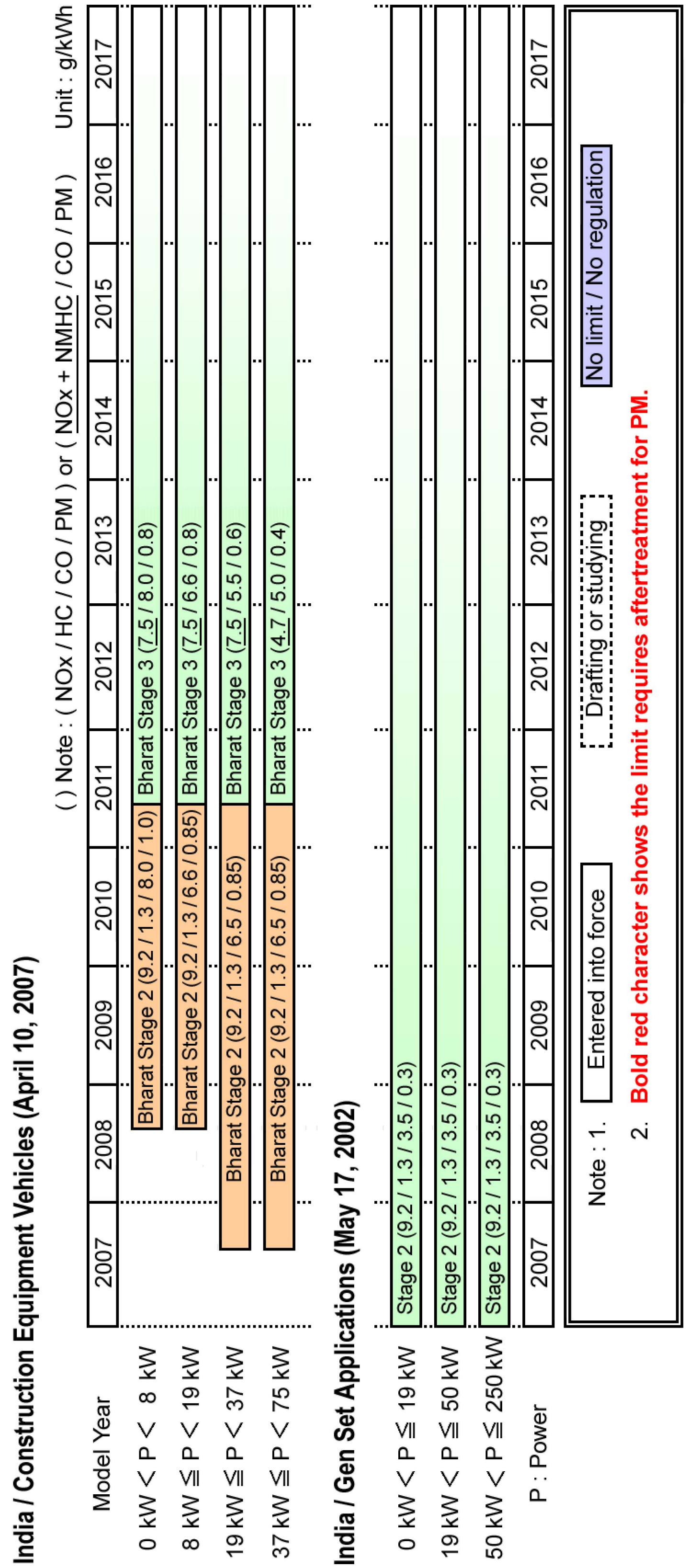
Model Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0 kW ＜ P ＜ 8 kW	No Regulation										
8 kW ≦ P ＜ 19 kW	No Regulation										
19 kW ≦ P ＜ 37 kW	Tier 2 (7.5 / 5.5 / 0.6)			Tier 3 (7.5 / 5.5 / 0.3)							
37 kW ≦ P ＜ 75 kW	Tier 2 (7.5 / 5.0 / 0.4)			Tier 3 (4.7 / 5.0 / 0.4)							
P : Power	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017

Note : 1. Entered into force Drafting or studying No limit / No regulation

2. **Bold red character shows the limit requires aftertreatment for PM.**

AM01005A

[6] CURRENT AND FUTURE EMISSION REGULATIONS ON INDIA



AM01006A

2. RATING

CONTENTS

RATING

Engine output indications are standardized in accordance with engine application and type in each country and test methods specified accordingly.
Indications for KUBOTA engine ratings conform to the Japan Industrial Standards (JIS), SAE and ISO.

1. ENGINE TESTING METHODS

Normally, testing methods for engine performance vary according to use. These methods also vary by countries, although in most major respects they are the same.
Engine performance is determined by the following factors and the presence of accessories.

1) Fixed factors -
   Piston displacement, compression ratio, cam timing and other factors that cannot be changed during operation.
2) Variable factors -
   Revolution speed and other factors that can be changed during operation.
3) Environmental factors -
   Atmospheric pressure, temperature, humidity and others.
4) Accessories -
   Fan, muffler, air cleaner and other auxiliary equipment and accessories.

Therefor, engine performance can be determined only after taking into account the setting of variable factors, atmospheric conditions, and use of optional accessories.
It is a common practice to select the annual mean value of the atmospheric conditions of the country in which the engine is used to minimize the error which must be corrected.
Engine performance is usually tested with the minimum number of accessories required for operation only.

There are two kinds of engine output notation. The output that is obtained in a test with the minimum fittings for driving is called *gross output*; and the output obtained in a test with the standard fittings is called *net output*. The standard specifications of OC and EA engines are in net output and the APU-2 specification of EA engine is in gross output.

Major standards for diesel engines are described below

2. STANDARD OF JAPAN, USA AND EUROPE

[1] PERFORMANCE TESTING METHODS

Country	Code number	Title
JAPAN	JIS B8002-1	Reciprocating internal combustion engines - Performance - Part 1 : Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods Part 3 : Test measurements Part 4 : Speed governing Part 5 : Torsional vibrations Part 6 : Overspeed protection Part 7 : Codes for engine power
	JIS B8014	Performance test method for constant revolution diesel engines
U.S.A.	SAE J1349	ENGINE POWER TEST CODE - SPARK IGNITION AND COMPRESSION IGNITION - NET POWER RATING
	SAE J1995	ENGINE POWER TEST CODE - SPARK IGNITION AND COMPRESSION IGNITION - GROSS POWER RATING
EUROPE	ISO 3046-1	Reciprocating internal combustion engines - Performance - Part 1 : Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods Part 3 : Test measurements Part 4 : Speed governing Part 5 : Torsional vibrations Part 6 : Overspeed protection Part 7 : Codes for engine power

[2] SCOPE, DECLARATIONS OF POWER AND STANDARD REFERENCE CONDITIONS

<table>
<tr><th></th><th>JIS B8002-1, ISO 3046-1</th><th>SAE J1995</th><th>SAE J1349</th></tr>
<tr><td rowspan="2">Scope</td><td>JIS B8002 :
All reciprocating internal combustion (R.I.C.) engines excluding engines used to aircraft.</td><td colspan="2" rowspan="2">1) 4 or 2 cycle engine.
2) Spark ignition or compression ignition engine.
3) N/A engine or engine with T/C or S/C and I/C.
4) Excluding engines used to aircraft or marine.</td></tr>
<tr><td>ISO 3046 :
R.I.C engines for land, rail - traction and marine use, excluding engines used to propel agricultural tractors, road vehicles and aircraft.</td></tr>
<tr><td rowspan="3">Declarations of power</td><td>1) Types of statement of power
ISO power :
The power determined under the operating conditions of the manufacturer’ s test bed and adjusted or corrected as determined by the manufacturer to the standard reference conditions.
Service power :
The power delivered under the ambient and operating conditions of an engine application.</td><td rowspan="3">Gross</td><td rowspan="3">Net</td></tr>
<tr><td>2) Types of power application
a) Continuous power
b) Overload power
c) Fuel stop power</td></tr>
<tr><td>3) Types of power
• Indicated power
• Brake power with
a) essential dependent auxiliaries.
b) essential independent auxiliaries.
c) non - essential dependent auxiliaries.</td></tr>
<tr><td rowspan="4">Standard reference conditions</td><td>Total barometric pressure :
Pr=100 kPa</td><td colspan="2">Inlet Air Supply Pressure (absolute) :
Pr=100 kPa</td></tr>
<tr><td>Ambient air temperature :
Tr=25 °C (77 °F)</td><td colspan="2">Inlet Air Supply Temperature :
Tr=25 °C (77 °F)</td></tr>
<tr><td rowspan="2">Relative humidity :
ϕr=30%
Relative humidity of 30% at a temperature of 25 °C (77 °F) corresponds to a water vapour pressure of 1 kPa.</td><td colspan="2">Dry Air Pressure (absolute)
Pb dry=99 kPa</td></tr>
<tr><td colspan="2" rowspan="2">REFERENCE CI FUEL SPECIFICATIONS
Fuel Density at 15 °C (59 °F) =0.850 kg/L
Fuel Kinematic Viscosity at 40 °C (104 °F) =2.6 mm^2/s
Fuel Inlet Temperature=40 °C (104 °F)</td></tr>
<tr><td></td><td>Charge air coolant temperature :
Tcr=25 °C (77 °F)</td></tr>
</table>

[3] METHOD OF POWER CORRECTION

	JIS B8002-1, ISO 3046-1	SAE J1995	SAE J1349
Formula of power correction	Standard power = α × Text power ≒ α × Test power	Standard power = (CA × CF) × Test power CA ; Air correction factor CF ; Fuel correction factor	
Correction factor	$\alpha = (fa)^{fm}$	$CA = (fa)^{fm}$ $CF = fd \times fv$	
Effective scope	0.9 < α <1.1 10 °C (50 °F) ≦ Intake air temperature ≦ 40 °C (104 °F) 80 kPa ≦ Dry air pressure ≦ 110 kPa	15 °C (59 °F) ≦ Intake air temperature ≦ 40 °C (104 °F) 90 kPa ≦ Dry air pressure ≦ 105 kPa	
Coefficient	Atmospheric factor : fa [For naturally aspirated engines mechanically pressure - charged engines and turbocharged engines with waste - gates operating] $fa = \left(\frac{99}{Pbdry}\right) \times \left(\frac{Tai + 273}{298}\right)^{0.7}$ [For turbocharged engines without charge air cooling or with charge cooling by air/air cooler] $fa = \left(\frac{99}{Pbdry}\right)^{0.7} \times \left(\frac{Tai + 273}{298}\right)^{1.2}$ [For turbocharged engines with charge air cooling by engine coolant] $fa = \left(\frac{99}{Pbdry}\right)^{0.7} \times \left(\frac{Tai + 273}{298}\right)^{0.7}$	1. Calculation of CA Atmospheric factor : fa [For naturally aspirated engines mechanically pressure - charged engines.] $fa = \left(\frac{99}{Pbdry}\right) \times \left(\frac{Tai + 273}{298}\right)^{0.7}$ [For turbocharged engines without charge air cooling or with charge cooling by air/air cooler] $fa = \left(\frac{99}{Pbdry}\right)^{0.7} \times \left(\frac{Tai + 273}{298}\right)^{1.2}$ [For turbocharged engines with charge air cooling by engine coolant] $fa = \left(\frac{99}{Pbdry}\right)^{0.7} \times \left(\frac{Tai + 273}{298}\right)^{0.7}$	
	Engine factor : fm $fm = 0.036 \times \frac{q}{R} - 1.14$ $(37.2 < q/R < 65)$ $fm = 0.2$ $(q/R \leqq 37.2)$ $fm = 1.2$ $(65 \leqq q/R)$	Engine factor : fm $fm = 0.036 \times \frac{q}{R} - 1.14$ $(37.2 < q/R < 65)$ $fm = 0.2$ $(q/R \leqq 37.2)$ $fm = 1.2$ $(65 \leqq q/R)$	
	Boost pressure ratio $R = \frac{PB + Pbc}{PB}$ (NA ; R=1)	Boost pressure ratio $R = \frac{PB + Pbc}{PB}$ (NA ; R=1)	
	Fuel mass per cycle per litre of engine swept volume $q = \frac{10^2 \times Be}{3 \times Ne \times Ve}$ mg/cyl.l	Fuel mass per cycle per litre of engine swept volume $q = \frac{10^2 \times Be}{3 \times Ne \times Ve}$ mg/cyl.l	
		2. Calculation of CF $fd = 1 + 0.70 \times \frac{0.850 - Sgo}{Sgo}$ $fv = \frac{1 + S/Vo}{1 + S/2.6} = \frac{1 + 0.15/Vo}{1 + 0.15/2.6}$ Sgo : Fuel density at testing (kg/L) Vo : Fuel viscosity at testing (mm^2/s)	

	JIS B8002-1, ISO 3046-1	SAE J1995	SAE J1349
Engine equipments	ISO standard power With essential dependent auxiliaries	Gross	Net
Intake air system	○	Option Minimum level restriction	○
Intake pipe	○		○
Air cleaner	○		○
Air heater		×	×
Charge air system Boost control settings	○	○	○
		○: In-use settings	○: In-use settings
Charge air cooling system	○	○	○
Charge air cooler	○	○	○
Fuel supply system	○	○	○
Fuel filter	○	Option	Option
Fuel feed pump	○	○	○
Fuel injection pump	○	○: In-use settings	○: In-use settings
Cooling system	○	○	○
Cooling water pump	○	○	○
Cooling fan	○	×	○
Thermostat		Option	Option
Lubricating system	○	○	○
Lubricating pump	○	○	○
Exhaust system	○	Option Minimum level restriction	○
Muffler	○		
			○
Emission control system	○	Option	○
Oil pump	×	×	×
Compressor for engine start	×	×	×
Ventilation fan	×	×	×

3. ENGINE PERFORMANCE

CONTENTS

ENGINE PERFORMANCE

1. OUTPUT

[1] GENERAL

The engine output depends upon the designed technical data (number of revolutions and displacement) and combustion efficiency (ups and downs of brake mean effective pressure, good and bad combustion performance) of engine.
It is calculated by the following formula.

Output (PS) = (Bmep x N x V) / 900

Bmep : Mean effective pressure (kg/cm^2)
N : Number of revolutions (min^{-1} (rpm))
V : Displacement (liter)

The mean effective pressure depends upon various internal factors (combustion method, type of nozzle and fuel pump, and adjustment of each section such as fuel injection timing).

Energy obtained by combusting fuel in the engine is not completely utilized for engine output.
Although diesel engines are more efficient than gasoline engines, only 30 to 35% of the energy generated by the diesel engines is effectively utilized (See Fig. 3-1). The residual 65 to 70% is not utilized (heat loss). Supposing that the gross heating value of combusted fuel is 100%, its distribution is called the "heat balance".

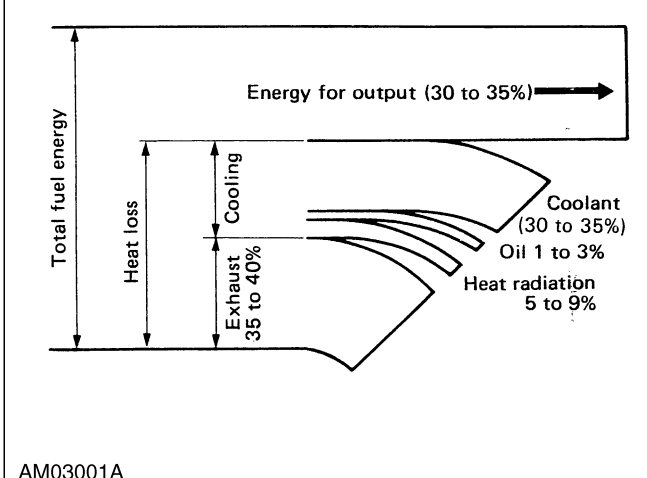


Fig. 3-1 Example of heat balance of diesel engine

In the above mentioned drawing, the ratio of the gross heating value (Qo) and the energy (heating value) (Qe) effectively utilized as the output is called the "thermal efficiency" (η e) and calculated by the following formula.

η e = Qe / Qo (%)

= Output (kW) x 3600 (kJ/hr) / 42700 x B

42700 : Lower calorific value of fuel (kJ/kg)
B : Fuel consumption (kg/hr)

[2] ACTUAL EFFECTIVE OUTPUT

The final output (actual effective output) of engine varies with various external factors such as horsepower loss due to the power consumed for driving the cooling fan and water pump, resistance of muffler and air cleaner, environmental conditions such as temperature, humidity, and altitude, type of applied fuel, and horsepower loss and transmission efficiency of equipment driven by the engine.
Thus the final output mainly depends upon the horsepower loss. Also the output varies with the time factors such as "aging and wear" and "maintenance", which depend upon the operating time. (See Fig. 3-2).

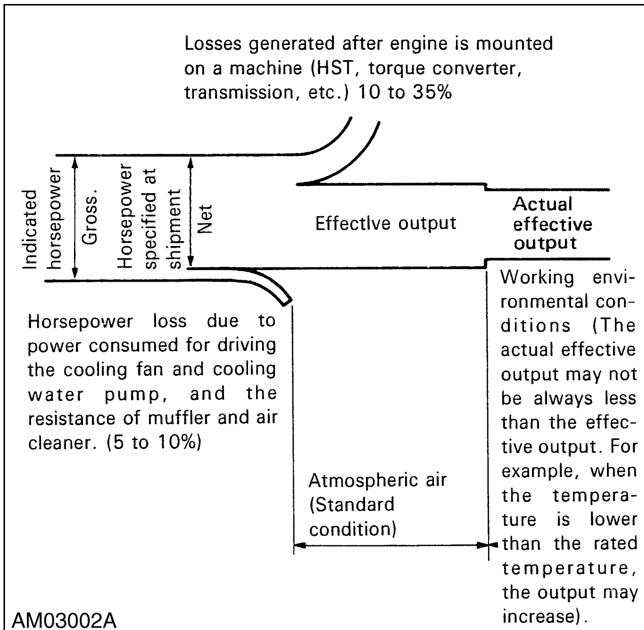


Fig. 3-2 Engine power loss

Fuel supply adjustment and governor setting are adjusted by KUBOTA according to each destination country in conformity with "JIS", "SAE" and "ISO" standards before shipment.
They may be adjusted to the output characteristic discussed with the Technical Department in case of special OEM requirements.
Engine performance is normally indicated by the output, torque and fuel consumption curves, which are closely related to each other.

[3] OUTPUT CHARACTERISTICS

When mounting an engine on a machine, it is risky to select an engine by its standard output alone (as shown in catalog and other literatures) and comparing it with the required power of the machine. The following factors must be carefully considered when making a selection.

(1) For large load variations

Engines with large torque backup are suitable for frequent use with varying loads which require a broad torque range.
The amount of torque backup is indicated by torque rise (%).

Torque rise
= (Max. torque / Torque at rated output) × 100 - 100 (%)

As shown in the torque curve, KUBOTA engines have a high torque rise.

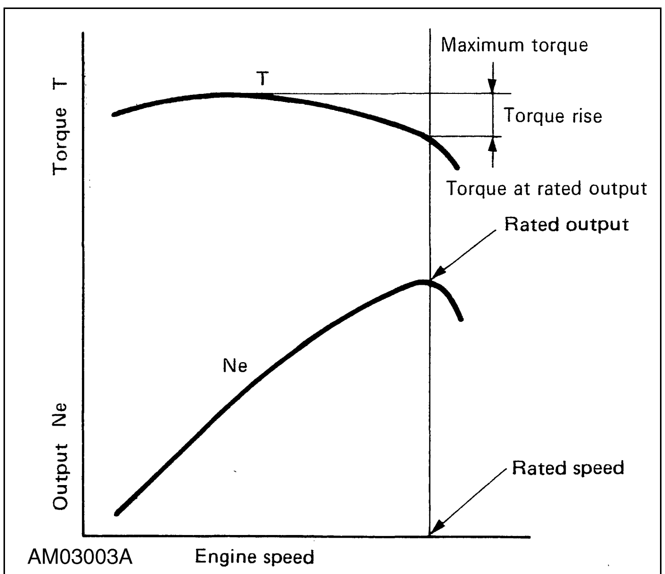


Fig. 3-3 Torque backup

(2) For constant speed applications

When an engine is to be used with a generator, for example, for which stable revolution characteristics are required, governor adjustment and inertia effect are needed to maintain the coefficient of revolution fluctuation at a minimum level. Unless these actions are taken, the generator voltage or frequency will vary largely with variation of engine revolution speed, preventing proper operation.

(3) For reduced engine speed applications

When an engine is to be operated slower than the rated speed in order to reduce the noise level below that of the rating, or due to the transmission unit to which the engine is connected, an optimum adjustment (including fan, pump and other equipment performance check) at that engine speed and output check is necessary.
Conditions for selection further vary with priority factors of the machine to which the engine is mounted. (e.g. emphasis on reduced fuel consumption, or larger output margin due to extremely long periods of operation.) There are many cases in which these factors are combined. It is suggested that careful review be given when determining the correct selection of an engine.

(4) Precautions for specifying engine output

When specifying the engine output characteristics it is necessary to consider the output decrease due to changes of ambient conditions, especially the temperature rise (rise of engine intake-air temperature as well as atmospheric temperature), power consumed by accessories and horsepower loss in the power transmission unit.

[4] FUEL CONSUMPTION

Whether the fuel consumption is efficient or not depends upon the specifications inherent to each engine such as combustion method (direct injection, swirl chamber, etc.), shape of combustion chamber, fuel injection timing, valve timing, type of nozzle, fuel pump, etc., and revolution speed.
The matching of engine and machine directly influences efficiency of fuel consumption.
Therefore sufficient consideration is required to select an engine to be mounted on each machine.

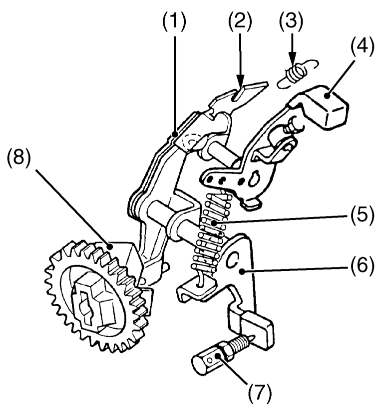
[5] GOVERNOR PERFORMANCE

In most machine including construction machines and industrial vehicles for cycle work involving starting -running -stop, -work, engine are used at varying loads.
Therefore the engine governor must have a speed control function that allows fast fuel supply control over the entire range.
KUBOTA engine use an all speed governor with an automatic fuel control mechanism that detects even small changes in rpm.
This allows optimum fuel supply at all times under various conditions such as the maximum engines speed, maximum load, low speed load, idling, starting and acceleration.
KUBOTA engine uses two kinds of mechanical governor.

1. Steel Ball Type
2. Weight Type

OC and EA engine uses weight type governor.

.OC engine

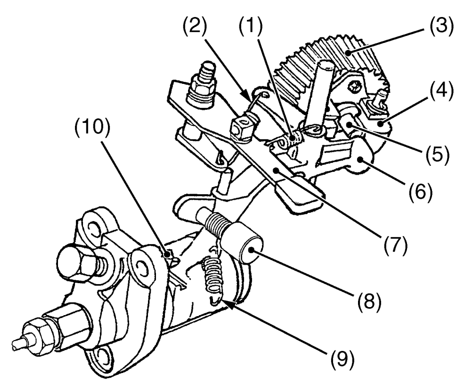


AM03004A

(1) Governor lever
(2) Control rack
(3) Idle spring
(4) Speed control lever
(5) Governor spring
(6) Governor lever
(7) Fuel limiter
(8) Governor weight

Fig. 3-4 Governor

EA engine



AM03005A

(1) Governor spring
(2) Stop spring
(3) Crank gear
(4) Governor weight
(5) Governor shaft
(6) Governor lever
(7) Speed control lever
(8) Fuel limiter
(9) Idle spring
(10) Control rack

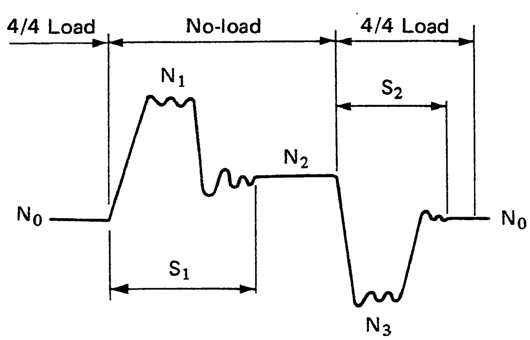
Fig. 3-5 Governor

【Governor regulation】
Generator governor should be regulated as small as possible when load is changed, and recovered to normal level as quick as possible.
This is especially important when the engine is used for constant speed applications such as with generators.
Coefficient of regulation and stabilization period are defined as follow.

● Instant governor droop
  = $(N_1 - N_0) / N_0 \times 100\%$
or = $(N_3 - N_0) / N_0 \times 100\%$

● Stabilized governor droop
  = $(N_2 - N_0) / N_0 \times 100\%$

● Stabilization period
  No load stabilization period = S_1 (sec)
  Load stabilization period = S_2 (sec)



AM03006A

Fig. 3-6

1) For variable speed use (2000 ~ 3000 min^{-1} (rpm))

Instant governor droop (%)	: 10
Stabilized governor droop (%)	: 6～10
Stabilization period (sec)	: 5
Low idling (min^{-1} (rpm))	: OC 1200 to 1300
	: EA 900 to 1000

2) For constant speed use
  OC : 3000, 3600 min^{-1} (rpm)
  EA : 2500, 3000 min^{-1} (rpm)

Instant governor droop (%)	: 10
Stabilized governor droop (%)	: 5
Stabilization period (sec)	: 5

※ Rate of governor regulation differ with the engine margin against load.
※ Consult when utmost precision is required.

[6] NOISE

Often they are subject to government regulation. One of the major development objectives for KUBOTA engines is a substantial reduction of noise and vibration.

(1) KUBOTA's T.V.C.S (Three Vortex Combustion System) originally developed.

By offsetting the direction of fuel injection into the swirl chamber and designing the throat of the swirl chamber to match the concave recess on the piston head, TVCS activates diffusive combustion in the main combustion chamber.

The injection pump and nozzle designs are optimized to match the combustion chamber.

The E-series is a well balanced engine series with improved power output, fuel economy, engine start ups, reduced noise and cleaner emission.

(2) Crank case and cylinder liner

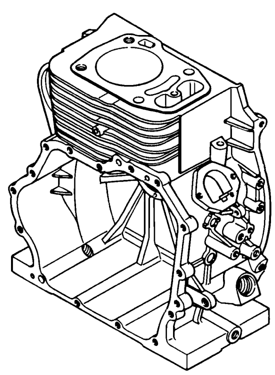
OC engine

The crank case is made of aluminium die-cast.

The crank case is provided with oil galleries to lubricate the crankshaft, crank pin metal. Another oil passage is provided at the side of the cylinder liner. This passage, also, serves to keep the cylinder liner cool and to suppress the explosive sound for lower noise.

The cylinder liner made of special cast iron having excellent wear resistance, is cast into crank case.

OC engine



AM03007A

Fig. 3-7 Crank case

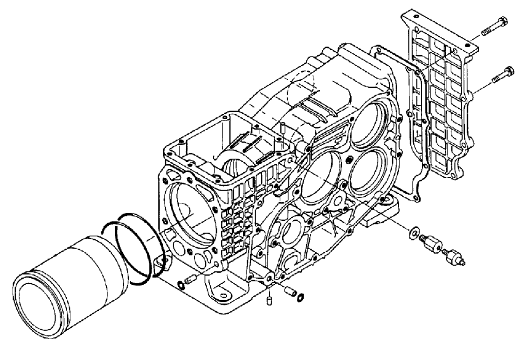
EA engine

The crank case is made of aluminium die-cast.

The crank case is provided with oil galleries to lubricate the crankshaft, main bearing case and rocker arm bracket. The cylinder liner made of special cast iron having excellent wear resistance, is pressfitted into the cylinder block.

The engine adopt a wet type cylinder liner which periphery comes into direct contact with cooling water. To prevent water leakage, O-rings are installed at the lower part of cylinder liner periphery. To prevent gas leakage, the upper part of the liner slightly protrudes from the cylinder block. This is because the gasket at this part is tightened strongly between the cylinder head and the liner.

EA engine



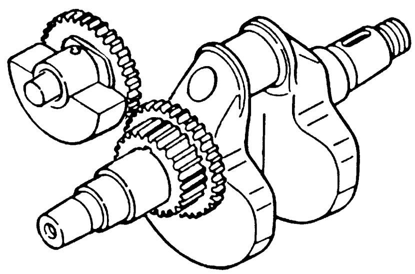
AM03008A

Fig. 3-8 Crank case

[7] VIBRATION

In order to reduce the vibration level as much as possible, special consideration has been taken in designing the engine.
There are two major vibration sources in a single-cylinder engine. One is the inertia force which is generated when the piston and the small end of the connecting rod are reciprocating. The other is the centrifugal force (kind of inertia force) generated when the large end of the connecting rod is turning.
The resultant force of these two inertial forces can be directed freely by adjusting the weight, but the force itself remains unchanged. The balancer shaft is provided in order to offset these inertial forces.
OC series engine is adopted a uniaxial balancer system and EA engine is adopted a dynamic balancer system to reduce engine vibrations.

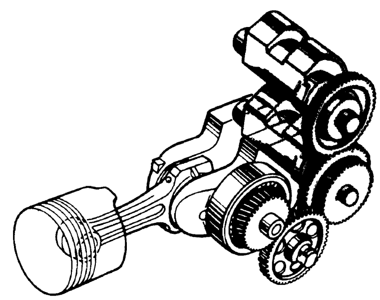
OC engine



AM03009A

Fig. 3-9

EA engine



AM03010A

Fig. 3-10

2. OPERATING ENVIRONMENT

[1] GENERAL

For the standard engine output performance, the values measured under the standard conditions specified by the world principle standards such as JIS, SAE and ISO are used as the standard. However since engines are used all over the world, their output performance varies with the operating conditions and ambient conditions (altitude, humidity and temperature). If the ambient temperature varies largely, the environment is dusty, or the engine is operated at an unusual installation altitude, the engine performance is directly or indirectly influenced.

It is necessary to consider the balance between the output compensation in accordance with the ambient conditions, and actions to adapt the engine to the operating conditions.

[2] COLD ENVIRONMENTS

In cold environments starting is a major problem. Once the engine is started, the air density becomes larger and the intake efficiency also becomes higher. More output can be expected in cold areas. When the temperature is very low, extra care must be taken regarding fuel and oil changes in their viscosity, freezing of water contained in the piping, or of water adhering on the filter.

At an extremely cold temperature, the viscosity of hydraulic fluid and lubrication oil may increase and the torque of starter may exceed its permissible value, hindering proper starting.

Requirements for cold starting

Item \ Cold intensity			Low temperatures more than 263 K {-10 °C (14 °F)}
Combustion	Fuel	For cold weather	No.1-D (ASTM D975-94)
	Preheating	Combustion chamber	Glow 10 sec
Turning force	Starter		Standard
	Battery		Standard
Lubrication	Oil	For cold weather	SAE #10W or SAE #10W30
Cooling	Coolant (EA only)		Antifreeze

1) Above table may be changed by application due to the drag torque of various machines.
2) Material of all pipes, resins and rubbers must be cold resistant material in extreme cold condition.

[3] HIGH TEMPERATURES

High compartment temperatures can be caused by high ambient temperatures, small engine room, soundproof cases and other reasons.
Among these the most important factor is the temperature of the intake and cooling air.
Even if the engine is contained in a soundproof case, its output is not affected as long as sufficient cold air is taken in from the outdoor atmosphere. In order to prevent overheating, it is necessary to measure and check the temperature of intake air and exhaust gas. At an extremely hot temperature it is necessary to control the viscosity of fuel and lubrication oil, to maintain the cooling performance (prevent overheat) and to care about the temperature rise of electric equipment.

※ Output reduction
Output decreases as ambient temperature increases.
※ Radiation of cooling water
Care must be taken regarding the amount of radiation reduction, when an all seasons antifreeze is used for continuous operation at high temperature, or when a high density antifreeze is used.

Requirements for operation at high temperature

Item \ Temperature			**High 30 to 40 °C (86 to 104 °F)**	**Extremely high 40 °C (104 °F) or higher**
Combustion	Fuel	Type	No.2-D (ASTM D975-94)	No.2-D (ASTM D975-94)
		Temperature		
Lubrication	Oil	Type	SAE #30, 10W30,15W40	SAE #40 or 20W50
		Temperature	120 °C (248 °F) or lower	
Cooling	Reserve tank		If necessary	
	Radiator, fan		When necessary, use larger radiator and fan. (For EA330-APU-2)	
Accessories	Permissible temperature		Starter, regulator, alternator, relay, timer : 80 °C (176 °F) or lower Emergency relay : 65 °C (149 °F) or lower	

[4] DUST

When the engine is to be used in extremely dusty areas or used continuously in a dusty environment, special care must be taken with air cleaner and radiator. The intake air must be cleaned with the air cleaner. Lowering of the radiator cooling capacity due to clogging dust must be prevented.

【Dust density】
A degree of dustiness is hard to express in numbers. Comparative indication of amount of dust contained per 1m^3 of air is one way to express dustiness.
Below are some examples :

1) Pavement : 0.0002 to 0.0004 g/m^3
2) Unpaved road : 0.005 to 0.01 g/m^3
3) Dusty road (after passing of a car on unpaved road 2) above) : 0.3 to 0.4 g/m^3
4) Construction site : 0.5 to 1.0 g/m^3
5) Extremely dusty operation : Over 1.0 g/m^3

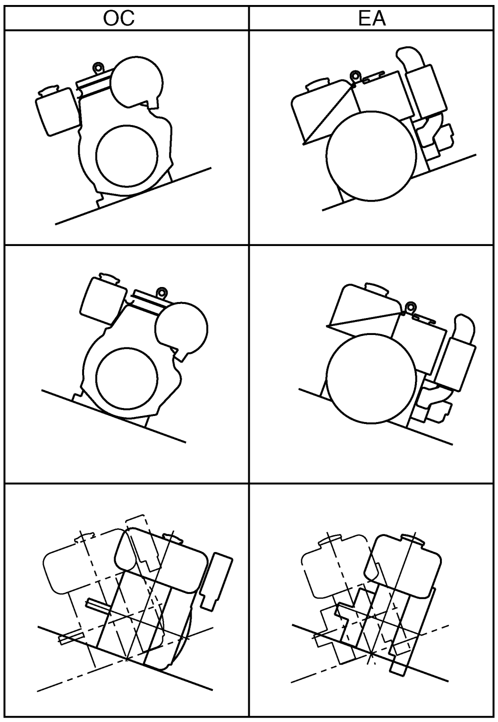
【Air cleaner】
Air cleaner type and capacity must be chosen according to the dust level in the operating environment and conditions for maintenance.
If an improper selection is made, especially when the capacity is less than needed, intake air resistance becomes higher, resulting in reduced output.
In order to maintain air tighten seals at the joining sections of intake system component parts and thus to prevent foreign matter from entering, it is necessary to ensure the security of the air intake system to prevent the component parts from being damaged.

[5] INCLINATION AND CENTER OF GRAVITY

Engine may be used inclined when it is used in a machine for working on slopes, during oscillation and when the engine is mounted at an angle. The tilted posture may be either momentary or continuous. Mounting the engine at an angle, even a small angle, should be avoided. When using an engine in a tilted posture continuously, the following points must be remembered.

1) If the engine is tilted to the front there is a possibility of an air pocket being created at the back of the cylinder head.
2) The effective volume of the oil pan becomes less, so air suction must be prevented.

Allowable angles for tilted operation are given below for engines with standard specifications.



AM03011A

	Less than 10 minutes continuous operation		Continuous operation	
	OC	EA	OC	EA
Front down	0.52 rad (30°)		0.35 rad (20°)	0.17 rad (10°)
Rear down	0.52 rad (30°)		0.35 rad (20°)	0.17 rad (10°)
Left or right side down	0.52 rad (30°)		0.35 rad (20°)	0.17 rad (10°)

Fig. 3-11

Note : The engine for generator should be mounted level.
When the engine is mounted at an angle, the governor droop may worsen.

【Center of gravity】

With reference to tilted engines during operation, it is necessary to know the center of gravity position when checking for machine stability.

[6] DERATION OF ENGINE OUTPUT

Engine output is affected by atmospheric pressure, temperature and humidity.
An engine should be selected with sufficient power to meet the load demands under all operating conditions.
KUBOTA diesel engine performance curves are corrected to standard conditions explained in standards such as JIS, SAE an ISO.
Provided output should be corrected for various atmospheric conditions by above standards.
Deration coefficient table is shown in next page.
Deration of engine output is very important when selecting the proper engine model when using at high ambient temperature and in high altitude location.

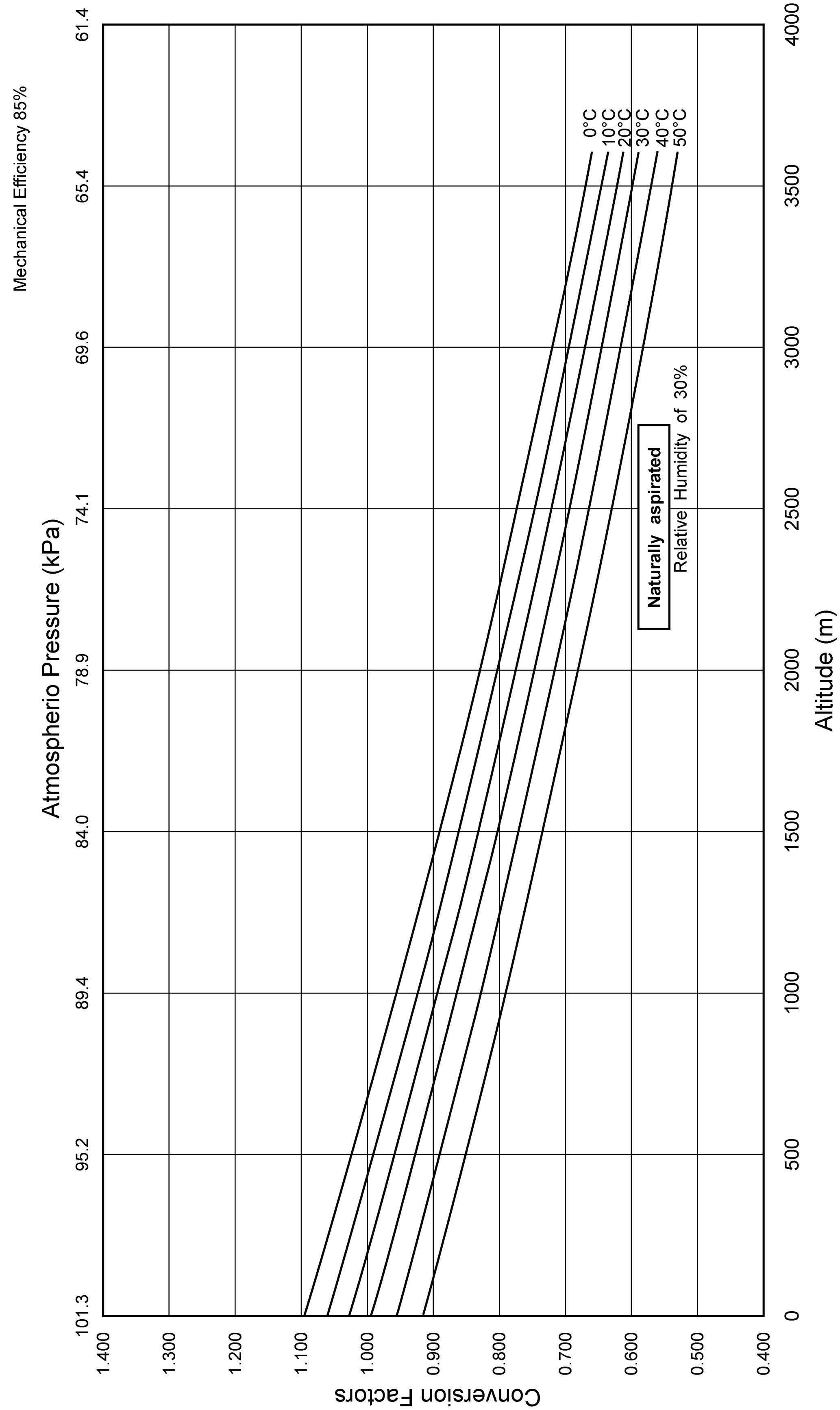
Table of Factors Used to Convert Output Obtained under Standard Conditions to that under Specific Environmental Conditions.

Note 1. This table shows the factors used for modifying the output under the standard conditions (atmospheric pressure 100 kPa {750 mmHg} : atmospheric temperature 25 °C (77 °F) relative humidity 30% to that under specific environmental conditions.
The applicable standards are ISO 3046-1, JIS 8002. The factors are calculated according to the expressions specified in the standards.
2. This table is applicable to the naturally aspirated diesel engine.
3. The output under relative humidity other than 30% can be obtained by calculation.

Table 1 Conversion Factors under Relative Humidity of 30% and Mechanical Efficiency of 85% — Naturally aspirated diesel engine

			Upper : Intake air temperature (℃) / Lower : Saturation vapor pressure (kPa)										
Altitude	**Atmospheric pressure**		**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
m	**mmHg**	**kPa**	**0.61**	**0.87**	**1.23**	**1.71**	**2.34**	**3.17**	**4.25**	**5.63**	**7.38**	**9.59**	**12.34**
0	760	101.3	1.102	1.085	1.067	1.050	1.033	1.016	0.998	0.980	0.961	0.941	0.919
100	751	100.1	1.087	1.070	1.053	1.036	1.019	1.001	0.984	0.966	0.947	0.927	0.906
200	741	98.8	1.072	1.055	1.038	1.021	1.004	0.987	0.970	0.952	0.933	0.914	0.893
300	732	97.6	1.057	1.040	1.023	1.007	0.990	0.973	0.956	0.938	0.920	0.900	0.880
400	723	96.4	1.042	1.026	1.009	0.993	0.976	0.959	0.942	0.925	0.906	0.887	0.867
500	714	95.2	1.028	1.011	0.995	0.979	0.962	0.946	0.929	0.912	0.893	0.874	0.854
600	705	94.0	1.013	0.997	0.981	0.965	0.949	0.932	0916	0.898	0.880	0.861	0.841
700	696	92.8	0.999	0.983	0.967	0.951	0.935	0.919	0.903	0.886	0.868	0.849	0.829
800	688	91.7	0.985	0.969	0.954	0.938	0.922	0.906	0.890	0.873	0.855	0.836	0.816
900	679	90.5	0.972	0.956	0.940	0.925	0.909	0.893	0.877	0.860	0.843	0.824	0.804
1000	671	89.4	0.958	0.942	0.927	0.912	0.896	0.880	0.864	0.848	0.830	0.812	0.792
1100	662	88.3	0.944	0.929	0.914	0.899	0.883	0.868	0.852	0.835	0.818	0.800	0.780
1200	654	87.2	0.931	0.916	0.901	0.886	0.871	0.855	0.840	0.823	0.806	0.788	0.769
1300	646	86.1	0.918	0.903	0.888	0.873	0.858	0.843	0.827	0.811	0.794	0.776	0.757
1400	638	85.0	0.905	0.890	0.875	0.861	0.846	0.831	0.815	0.799	0.783	0.765	0.746
1500	630	84.0	0.892	0.878	0.863	0.848	0.834	0.819	0.804	0.788	0.771	0.753	0.734
1600	622	82.9	0.880	0.865	0.851	0.836	0.822	0.807	0.792	0.776	0.760	0.742	0.723
1700	614	81.9	0.867	0.853	0.839	0.824	0.810	0.795	0.780	0.765	0.748	0.731	0.712
1800	607	80.9	0.855	0.841	0.826	0.812	0.798	0.784	0.769	0.753	0.737	0.720	0.701
1900	599	79.9	0.843	0.829	0.815	0.801	0.787	0.772	0.758	0.742	0.726	0.709	0.690
2000	592	78.9	0.830	0.817	0.803	0.789	0.775	0.761	0.747	0.731	0.715	0.698	0.680
2100	584	77.9	0.819	0.805	0.791	0.778	0.764	0.750	0.736	0.720	0.705	0.688	0.669
2200	577	77.0	0.807	0.793	0.780	0.766	0.753	0.739	0.725	0.710	0.694	0.677	0.659
2300	570	76.0	0.795	0.782	0.769	0.755	0.742	0.728	0.714	0.699	0.684	0.667	0.649
2400	563	75.1	0.784	0.771	0.757	0.744	0.731	0.717	0.703	0.689	0.673	0.657	0.639
2500	556	74.1	0.773	0.759	0.746	0.733	0.720	0.707	0.693	0.678	0.663	0.647	0.629
2600	549	73.2	0.761	0.748	0.736	0.723	0.710	0.696	0.683	0.668	0.653	0.637	0.619
2700	542	72.3	0.750	0.738	0.725	0.712	0.699	0.686	0.672	0.658	0.643	0.627	0.609
2800	535	71.4	0.739	0.727	0.714	0.702	0.689	0.676	0.662	0.648	0.633	0.617	0.600
2900	529	70.5	0.729	0.716	0.704	0.691	0.679	0.666	0.652	0.638	0.623	0.607	0.590
3000	522	69.6	0.718	0.706	0.693	0.681	0.669	0.656	0.643	0.629	0.614	0.598	0.581
3100	516	68.8	0.708	0.695	0.683	0.671	0.659	0.646	0.633	0.619	0.604	0.589	0.571
3200	509	67.9	0.697	0.685	0.673	0.661	0.649	0.636	0.623	0.610	0.595	0.579	0.562
3300	503	67.1	0.687	0.675	0.663	0.651	0.639	0.627	0.614	0.600	0.586	0.570	0.553
3400	497	66.2	0.677	0.665	0.653	0.642	0.630	0.617	0.604	0.591	0.577	0.561	0.544
3500	491	65.4	0.667	0.655	0.644	0.632	0.620	0.608	0.595	0.582	0.568	0.552	0.536
3600	484	64.6	0.657	0.646	0.634	0.623	0.611	0.599	0.586	0.573	0.559	0.544	0.527

Conversion Factors of Output



AM03012A

3. COLD STARTING AND OPERATION

[1] GENERAL

As explained in the preceding section regarding engines used in cold weather, OC and EA engines without external load can be started in temperatures as low as -10 °C (14 °F).
When the engine is mounted on a machine, cold starting performance is subject to various conditions, so very careful checks are necessary.
Points regarding fuel, lubricating oil, cooling water, starter, battery and glow plug are covered below.

[2] FUEL

The fuels of a high fluid point (viscosity) do not flow smoothly at an extremely cold temperature.
Such fuels should not be used. The table below shows the recommended fuels.

Standard / Temp. range	JAPAN	U.S.A.
	JIS K2204	ASTM D975-94
-5 °C (23 °F) and over	Diesel Fuel No.2 (or its equivalent)	No.2-D
-5 °C to -15 °C (23 °F to 5 °F)	Diesel Fuel No.3 (or its equivalent) or Diesel Fuel Special No.3 (or its equivalent)	No.1-D
Under -15 °C (5 °F)	Diesel Fuel Special No.3 (or its equivalent)	

For the diesel fuels, each nation has used a standard specified by a nationally authorized organization. In accordance with such a standard, a diesel fuel suitable to each season or region is selected to use.
This is in addition to the standards of JAPAN and U.S.A. shown in the above table.

Note :
Do not allow water to be mixed with the fuel.
Water in the fuel may freeze and prevent fuel flow.

[3] LUBRICANT

Oil viscosity changes in cold temperature as crystallization of the wax element contained in oil proceeds, and fluidity is finally lost. Wrong selection of oil cannot only increase resistance for cold starting but also affect lubrication of each part. Oils for low temperature, containing additives for lowering the pour point, should be used.

Note :
The use of synthetic oil is not recommended.

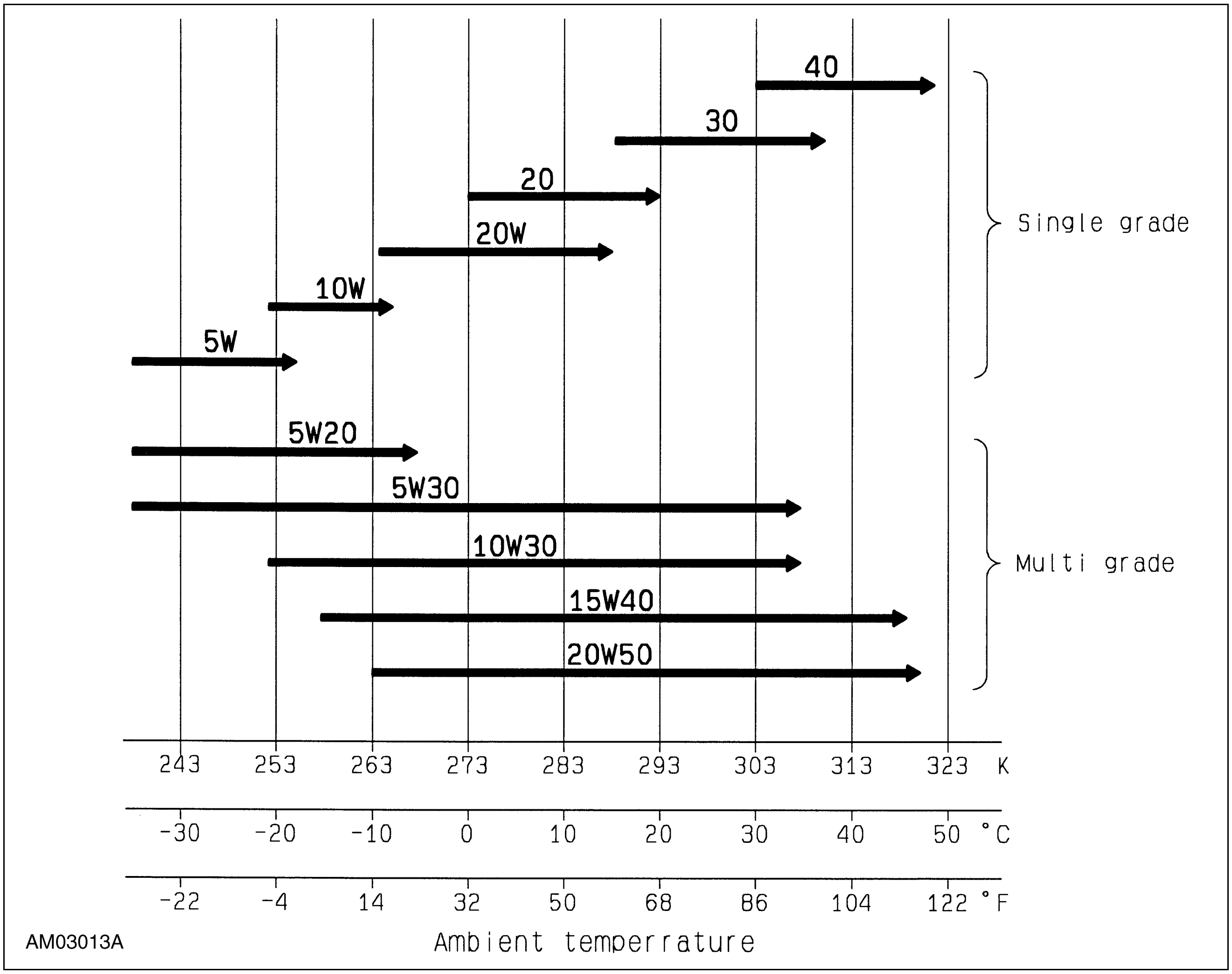


Fig. 3-12 Suitable oil viscosity chart

[4] COOLANT

High quality antifreeze must be used at all times.

1) Mix antifreeze with soft distilled water to use.
2) Premix the H_2O and antifreeze thoroughly before adding to the engine
3) Use only a 50/50 mix of H_2O and ethylene glycol (antifreeze) at all times.
4) Change antifreeze mix once a year.

[5] STARTER

Starters used in OC and EA engines have the following standard capacities ;

Model	Starter capacity (kW) [More than -10 °C (14 °F) Standerd Spec.]
OC60	0.7
OC95	1.2
EA330	1.1

Cold starting difficulty depends on the ambient temperature (intense cold or extreme cold) and resistance of transmission.

1) When an ON/OFF clutch is used between the engine and the power transmission, it can be set to OFF during starting and engine can be started as if starting an isolated engine.
2) Even though an ON/OFF clutch is not used, when resistance of the transmission is small, or when resistance is not small but the ambient temperature is not very cold, a standard starter may be sufficient.
3) On the contrary, as resistance increases, or as the ambient temperature becomes extremely cold, a large capacity starter and battery must be used.
4) As the displacement per cylinder increases, a larger capacity starter and battery must be used.

[6] BATTERY

From the viewpoint of startability, the battery capacity should be as high as possible. The capacity however is regulated by the assigned installation space and the balance between battery capacity and charging capacity. The table below is used as the standard in accordance with the description in the starter section.
Too much battery capacity imposes too much load on the starter. In the worst case, the starter may be burned up. Therefore, it is necessary to sufficiently examine and decide the battery capacity in accordance with the ambient conditions at starting.
As a principle, however, the battery is prepared and set by the manufacturer of machine to which the battery will be installed.

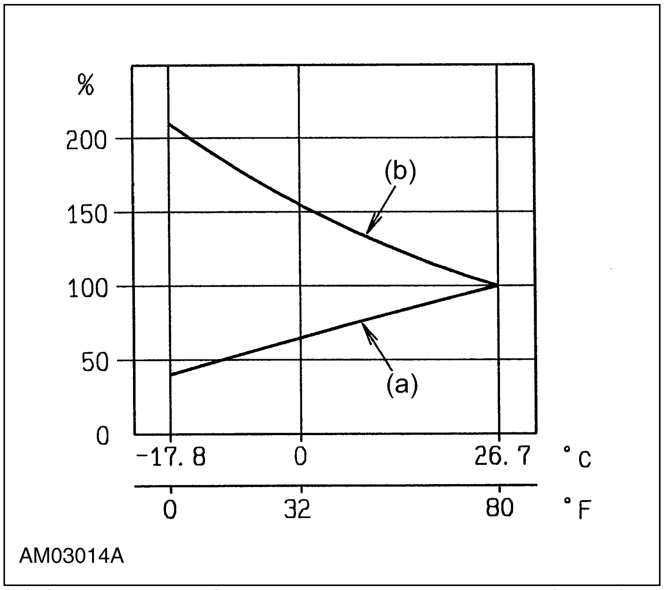
Battery capacity (AH)

Model	Battery capacity (AH) 5hr Ratio
OC60	27 to 32
OC95	36 to 48
EA330	28 to 36

Cold Cranking Amperage

Model	Cold Cranking Amperage [C.C.A (A)]
OC60	350 to 410
OC95	390 to 450
EA330	380 to 440

Discharging capacity is reduced by temperature change. The battery discharging capacity varies with the ambient temperature change.
Especially at a low temperature, the decrease of discharging capacity poses a problem. As for the equipment used at an extremely cold temperature, if the load of its hydraulic pump, torque converter, etc. is estimated to increase, it is necessary to increase the battery capacity together with that of the starter.



(a) Comparison of cranking power available from fully charged battery at various temperature.
(b) Comparison of power required to crank engine with S.A.E. 10W-30 oil at various temperature.

Fig. 3-13

[7] BATTERY CABLE

The battery cable size (cross-sectional area) largely influences the starting performance of engine (especially at an extremely cold temperature).
It is necessary to select a cable of appropriate size. The following summarizes the procedures for specifying the battery cable size area.

Current (A)	Cable size (mm^2)	AWG size
380	15	6
440	20	4
550	30	2
630	40	1
710	50	0

[Ambient temperature : 40 °C (104 °F)]

Procedures for specifying battery cable size

1. Obtain the rated current of starter.
   To obtain the rated current (A), divide the rated output of starter (kW) by the battery voltage (V).

   Ex.
   When a 2.2 kW starter is driven by a
   12 V battery : 2200 (W) / 12 (V) = 183.3 (A)

2. Multiply the obtained rated current by three (since the current flow at starting is about three times the rated current).

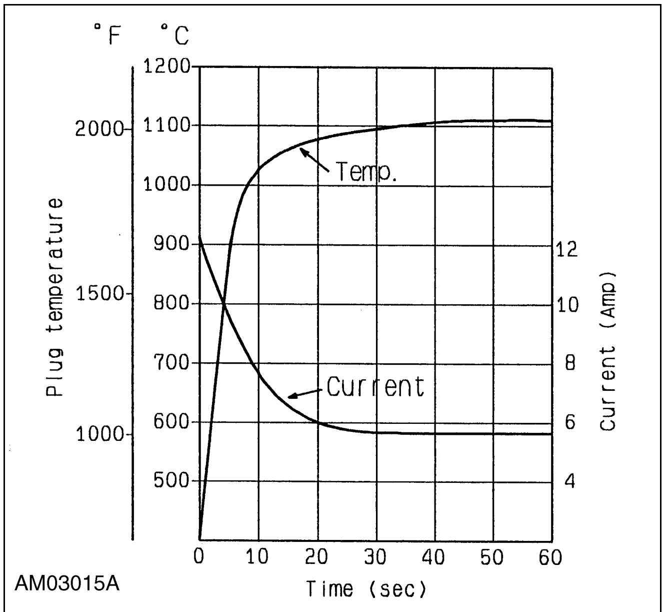
   Rated current × 3
   Ex. 183.3 × 3 = 549.9 (A)

3. In accordance with the obtained starting current value and above table (Table of maximum current for each cable size in short time operation), select the minimum cable size to withstand the starting current value.

   Ex.
   The above table shows a cable of 30 or 40 mm^2 cross sectional area (low voltage cable for automobiles) must be used.

[8] GLOW PLUG

The temperature and current and period of time of glowing plug are as shown in Fig. 3-14.
With OC and EA engines, the Super Glow Plug (Quick Glow Plug) system is supplied as a standard component to reduce the preheating period. When preheating is too short, the combustion chamber does not become sufficiently warm and the operator must repeat starting operation.
In this case the battery is also discharged.
Note : Refer to 9-8, “[4] GLOW PLUG”.



Glowing current time period and glow plug surface temperature and current.

Fig. 3-14

Atmospheric temperature °C (°F)	Time required * for red heat sec	Time required ** for preheating sec
Above 10 (50)	—	NO NEED
10 (50) to -5 (23)	Approx. 6	Approx. 5
Below -5 (23)		Approx. 10

* The above values are shown only as reference values and vary with engine types.
* Time required for red heat:
Time required for (raising the tube surface temperature to approx. 800 °C (1472 °F) at the glow terminal voltage of 12 V.
**Limit of continuous use is 20 seconds.

4. FUEL SYSTEM

CONTENTS

FUEL SYSTE

1. GENERAL

The fuel system feeds fuel from the fuel tank to the combustion chamber.
It contains a precision injection pump and injection system that greatly affects combustion performance.
A continuous supply of good quality filtered fuel is needed for these parts to function properly.
To make the exhaust gas emissions of engines meet regulations in each nation or region, the fuel injection system must be carefully controlled. Use of the poor fuel, inadequate maintenance of the fuel injection system, and replacement of the injection system with any other one than those recommended by KUBOTA may significantly affect the emissions.
The engine may discharge excessive bad levels of controlled constituents exhaust gas, consequently resulting in non-conformance with applicable emission standards.

【Fuel System】
The general fuel system of OC and EA diesel engines shown in the diagram below. Fuel from the tank flows in the passage and is injected from the nozzle via the fuel injection pump.
Overflow fuel returns to the tank. The system includes filters to protect it from entrance of air, water and dust.

OC engine
Fuel from the fuel tank passes through the fuel filter, and then enters the injection pump after impurities such as dirt, water, etc. are removed.
The fuel pressurized by the injection pump to the opening pressure (13.93 to 14.71 MPa, 142.0 to 150.0 kgf/cm^2, 2020 to 2133 psi), of the injection nozzle is injected into the combustion chamber.
Part of the fuel fed to the injection nozzle lubricates the moving parts of the plunger inside the nozzle, then returns to the fuel tank through the fuel overflow pipe from the upper part of the nozzle holder.

OC engine

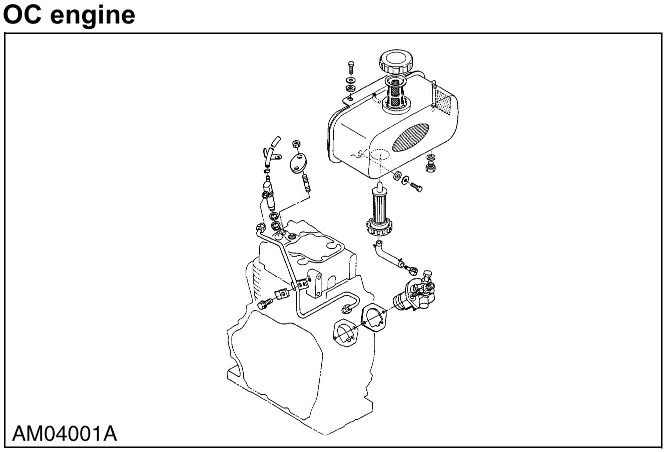


Fig. 4-1 Fuel system

EA engine
Fuel from the fuel tank passes through the fuel filter, and then enters the injection pump after impurities such as dirt, water, etc. are removed.
The fuel pressurized by the injection pump to the opening pressure (13.93 to 14.71 MPa, 142.0 to 150.0 kgf/cm^2, 2020 to 2133 psi), of the injection nozzle is injected into the combustion chamber.
Part of the fuel fed to the injection nozzle lubricates the moving parts of the plunger inside the nozzle, then returns to the fuel tank through the fuel overflow pipe from the upper part of the nozzle holder.

EA engine

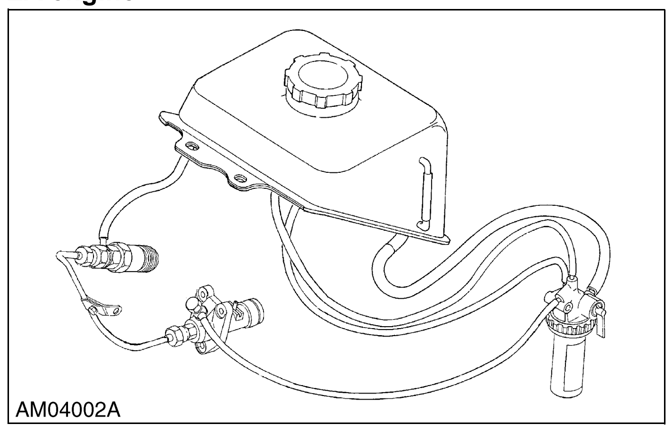


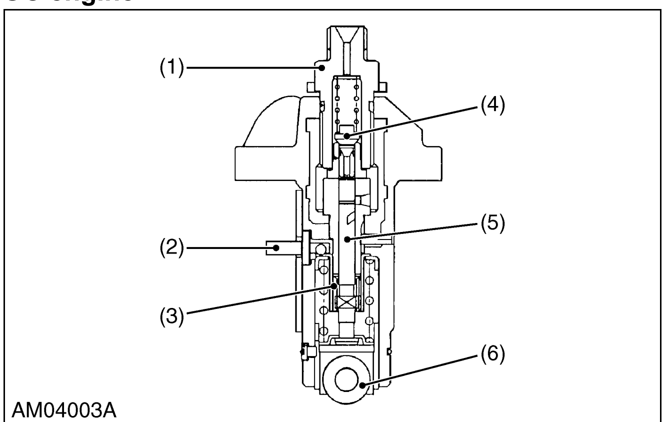
Fig. 4-2 Fuel system

2. FUEL INJECTION PUMP

The fuel injection pump is modified to fit KUBOTA engines.
The fuel injection pump is an extremely precise unit, so it must be handled very carefully.
Water entering in the fuel system will cause seizure, rusting or early wear of the injection pump plunger, cylinder, nozzle, needle valve, etc. Normal fuel has an appropriate viscosity to maintain good lubrication.

OC engine
In the fuel pump of OC engine, MD type mini pump is used for the injection pump. It is small, lightweight and easy to handle.
The plunger (5) with a right-hand lead reciprocates via the tappet roller (6) by means of the camshaft fuel cam, causing the fuel to be delivered into the injection nozzle.

OC engine

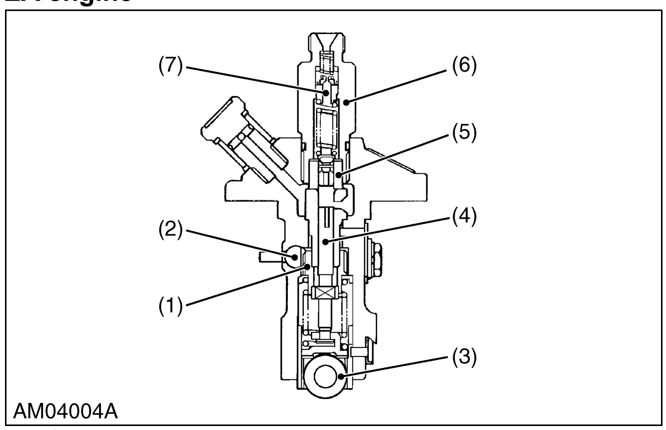


(1) Delivery valve holder
(2) Control rack
(3) Control sleeve
(4) Delivery valve
(5) Plunger
(6) Tappet roller

Fig. 4-3 Fuel injection pump

EA engine
In the fuel pump of EA engine, a Bosch KD type mini pump is used for the injection pump. It is small, lightweight and easy to handle.
The plunger (4) with a left-hand lead reciprocates via the tappet roller (3) by means of the camshaft fuel cam, causing the fuel to be delivered into the injection nozzle.
The fuel in the fuel chamber is drawn into the delivery chamber when the plunger lowers. When the plunger rises, delivery valve (5) is pushed open to force into the injection nozzle.
The control rack (2) is actuated by the governor, and the control rack movement is transmitted to the control sleeve (1). As a result, the plunger rotates to vary the amount of fuel fed into the injection nozzle.
When the speed control lever is set to the stop position, the fuel is not pressurized, and is not injected since the feed hole meets with the control groove.

EA engine



(1) Control sleeve
(2) Control rack
(3) Tappet roller
(4) Plunger
(5) Delivery valve
(6) Delivery valve holder
(7) Dumping valve

Fig. 4-4 Fuel injection pump

3. FUEL INJECTION NOZZLE

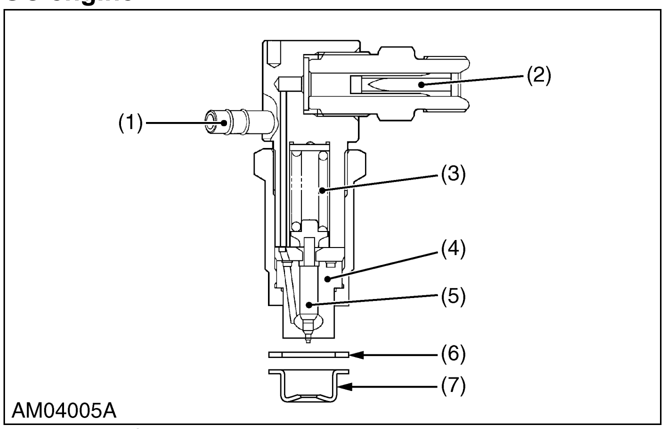
There are two types of the Pin type nozzle, Pintle type one and Throttle type one, among which OC and EA engines employs the Throttle type.

Throttle type of nozzle is designed to control the injection quantity when the lift rate is low at start of the injection, and to cut down on the knocking sound caused by excessive fuel injection by giving the needle valve section more taper than before to prevent the rapid increase in the injection quantity when the initial injection turns into the full-force injection.

The injection pressure is adjusted in the range of 13.9 to 14.7 MPa (142 to 150 kgf/m^2, 2020 to 2133 psi), in which the injection pressure can be adjusted by changing the shim thickness, if necessary.

The heat seal is employed to improve the durability and reliability of the nozzle.

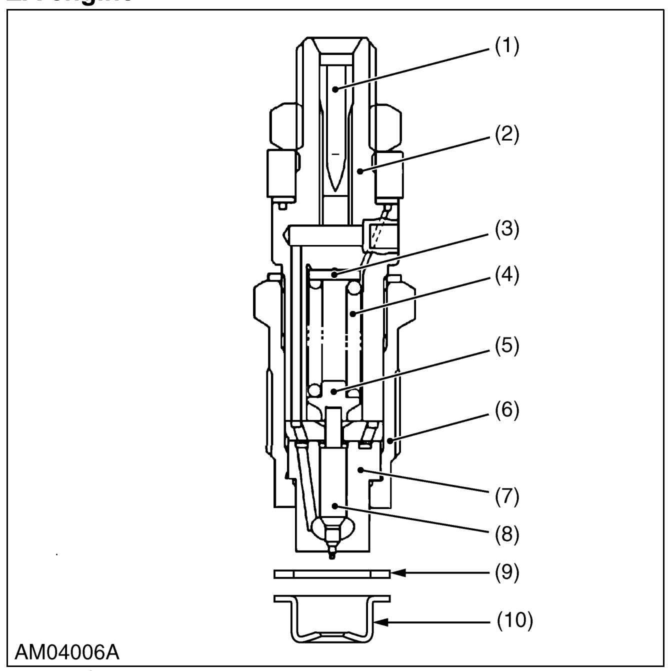
OC engine



(1) Fuel overflow pipe
(2) Bar filter
(3) Nozzle spring
(4) Nozzle body
(5) Needle valve
(6) Gasket
(7) Heat seal

Fig. 4-5 Throttle nozzle

EA engine

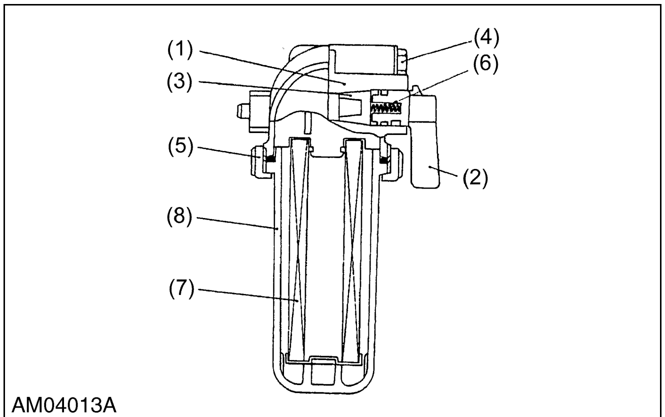


(1) Bar filter
(2) Nozzle holder body
(3) Adjusting washer
(4) Nozzle spring
(5) Push rod
(6) Retaining nut
(7) Nozzle piece
(8) Needle valve
(9) Gasket
(10) Heat seal

Fig. 4-6 Throttle nozzle

4. FUEL FILTER

The fuel filter located between the tank and the injection pump prevents foreign matter from entering the injection pump. A standard KUBOTA filter uses a paper element (filtration diameter less than 15 μ). Filtration surface areas available in KUBOTA filter is 250 cm^2 (38.75 sq.in.).
Normally filter elements or cartridges must be changed every 400 hours.
Three types of filters are shown.
This type filter is ordinary type. Air traped in the filter is purged by the vent plug (4).



(1) Body	(5) Ring nut
(2) Lever	(6) Spring
(3) Valve	(7) Filter element
(4) Vent plug	(8) Cup

Fig. 4-7 Fuel filter

Note :
In the standard specifications, the OC and EA engines are equipped with the standard fuel filter; however, when the fuel tank is located separately, select and install another proper fuel filter.

OC engine

The fuel filter is fitted inside the fuel tank with a ring nut. High-quality filter paper is used to filter out fine particles as small as 30 μm.

Air may enter the filter when it is washed clean or replaced with a new one or when the tank is refueled. To cope with the trouble of discharging the air, the filter has an air vent at the end to allow automatic air removal.

OC engine

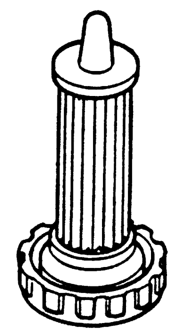


Fig. 4-8 Fuel filter

EA engine

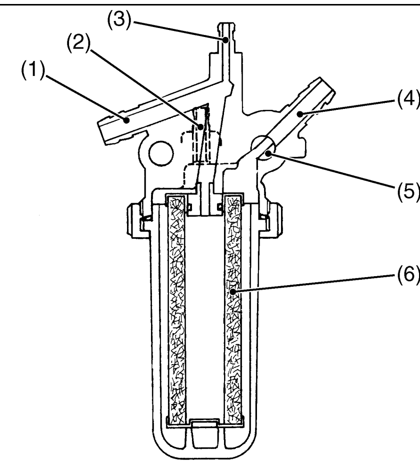
Each moving part of the injection pump and nozzle is extremely precision machined, and clearances of their sliding parts are extremely small. Fuel itself serves as lubricating oil. For this reason, it is extremely important to completely remove water and dirt contained in fuel.

This fuel filter, which uses very fine filter paper, serves to separate and filter dirt in fuel and water accumulated in the tank.

After passing through the filter element (6) from outside to the center of the filter, the fuel flows to the injection pump from the fuel outlet port (1).

When the filter element (6) is replaced, or the pipe is removed, or air enters together with fuel, air is automatically bled from the air vent port (2), (3).

EA engine



(1) Fuel outlet port
(2) Air vent port
(3) Air vent port
(4) Fuel inlet
(5) Fuel cock
(6) Fuel element

Fig. 4-9 Fuel filter

5. FUEL FEED PUMP

In the standard specifications of OC and EA engines, fuel is supplied to the fuel pump by fuel gravity-fall from the fuel tank mounted above the fuel pump. However, in the case that the fuel tank is located separately (located below the fuel pump or located distantly from the fuel pump), an electric fuel feed pump is required. The electric fuel feed pump should be selected after sufficiently considering the flow rate, lift amount, and others.

● **Electric fuel feed pump**

An electric fuel feed pump is used when a fuel tank is positioned below the fuel pump of the engine. The pump starts when the starter switch is switched on. Fuel is supplied to the injection pump regardless of engine speed, even in cold conditions.

e.g. Specifications Discharge 400 cc (2.44 cu.in.)/min. at 12 V voltage and 1.5 A current, suction head, 400 mm (15.7 in.)

This pump is driven by the battery. It can therefore be operated even with the engine stopped. The feed pump should be located near the fuel tank, to "PUSH" the fuel through the feed system.
Ensure that the electric pump is protected from dirt by using a strainer or sedimentor.

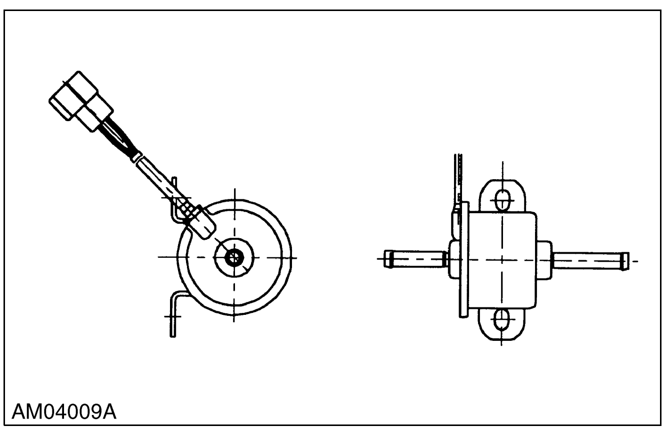


Fig. 4-10 Electric fuel feed pump

6. FUEL TANK

Note :
When using it other than in the standard specifications, take care of the following points.
The size, shape and position of fuel tank vary with the size and type of machine and application. Care should be taken with the following items.

(1) Capacity of fuel tank

The capacity of fuel tank varies with the application of machine to which the engine is installed. Generally the fuel tank capacity of mobile vehicles is small and that of stationary machines is large. To roughly estimate the required capacity, use the following formula.

Fuel tank sizing formula

$$Qt = Be \times Pr \times Hr$$

Qt : Approximate tank capacity (liter)
Be : Fuel consumption at the rated output (liter/kW•hr)

$$Be = be / (Fg \times 1000)$$

be : Fuel consumption (g/kW•hr)
Fg : Fuel specific gravity
Pr : Applicable power (rated output) (kW)
Hr : Running hours between fill-up (desired holding hours) (hr)

To obtain an approximate value, you may assume the fuel consumption per hour is 285 g/kW•hr and the fuel specific gravity is 0.84.

Fuel consumption by engine model is shown in TECHNICAL INFORMATION.

(2) Prevention of internal rusting

Since the tank is not always filled with fuel, its internal surface should be protected from rusting or for long term storage.
The surface should be treated by a reliable rust prevention method.

(3) Drain cock

It is very effective for maintenance of each equipment of the fuel system to provide a drain cock at the bottom of fuel tank for discharging water and substances other than fuel contents.

(4) Cap and filter of fuel tank

The fuel inlet port requires a filter (# 60 mesh) and a cap having a breather function. If a drum has been left outdoors, water or dirt may have entered it. A filter must be used for supplying fuel into the tank, and fuel at the bottom of drum must not be supplied to the tank. Fuel pickup should be above the tank bottom about 12 mm (1/2 in.). The cap must be sufficiently sealed so as to prevent fuel from leaking during operation. An air vent for maintaining the air pressure in the tank to atmospheric pressure must be provided.

(5) Position of fuel tank

The position of fuel tank varies with the distance from the engine, the inclination during operation of the engine, etc. When the gravity feed system is employed, the bottom of fuel tank must be at a 150 mm (6 in.) or more higher position than the top of fuel injection pump. Otherwise the fuel in the tank cannot be completely fed.
If the bottom of fuel tank is extremely close to the top of fuel injection pump, the fuel feed pressure and amount of fuel may become insufficient, thus reducing or fluctuating output and rpm. Range of distance between the bottom of fuel tank and the top of fuel injection pump :
150 mm (6 in.) to 2000 mm (78 in.)
For further details of other fuel systems, refer to fuel piping item.

7. FUEL PIPE

Fuel pipe must be made of a material that will withstand the vibration expected during operation and remain durable for several years. Since it contains flammable oil, piping must be arranged carefully.

● **Material**

Since fuel pipe carries a flammable liquid, high quality oil resistant multi-layer rubber for fuel with a temperature resistance of 373 K {100 °C (212 °F)} or higher must be used. Low quality piping can expand or break which cause accidents.

● **Piping precautions**

1) Piping should not be positioned close to any rotating parts or intense vibration.
2) Piping should be routed to avoid extremely high and low temperature.
3) Sharp turning, tapers and unnecessary bending must be avoided, since they will increase flow resistance which may cause decrease in output or fluctuation of rpm.
4) The number of joints must be as small as possible to prevent leakage, and joints must be made as rigid as possible.
5) Flexible pipes must be used between parts that have different vibration sources.
6) Sags or dips in piping must be eliminated since water will collect in them.
7) Fuel pipe must not contact or cross with electric wire.

8. FUEL PIPING

The types of fuel piping used depends upon the application. The fuel tank and fuel injection pump, the position of fuel filter and feed pump and length of piping may make air bleeding difficult and also may cause air to be entrapped after long-term storage.
Before making the final decision, carry out sufficient checks by installing the piping on the actual machine.

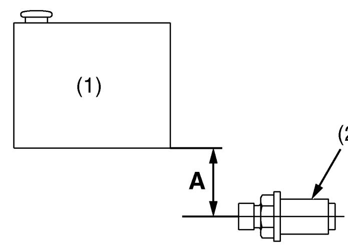
Piping reference are shown page 4-9.

Even in case that the fuel piping recommended by KUBOTA is adopted, it is still required to check the system for the following points after installing the engine on the equipment. The location of the fuel tank, the specifications of the mounted equipment, the length of the pipes and the location of each component will affect the flow and the inclusion and bleeding of air.

1) Make sure that air bleeding can easily be done when the fuel tank is being replenished with fuel.
2) Make sure that the engine can be operated normally when the various dynamic inclined conditions (e.g., at a horizontal position, at a maximally inclined position, and at a maximally swinging condition) are combined with the fuel levels (the upper limit and lower limit levels) in the tank.
3) Check the restarting ability when a certain time has elapsed after the engine was stopped.
4) Check the temperature in the fuel tank when the engine is operating and check decrease of the engine output and the engine workability when the fuel temperature is rising.
5) Check the starting ability in cold condition.
6) Print the following cautionary points in the instruction manual.

a) Use a high-quality fuel applicable to ambient and local conditions.
b) In the cold weather, change the fuel to the one exclusively recommended for cold season so that the sedimentor and the filter can be prevented from being blocked by precipitated wax of the fuel.
c) Periodically discharge the drain in the sedimenter.

7) Minimum distance for gravity feed.



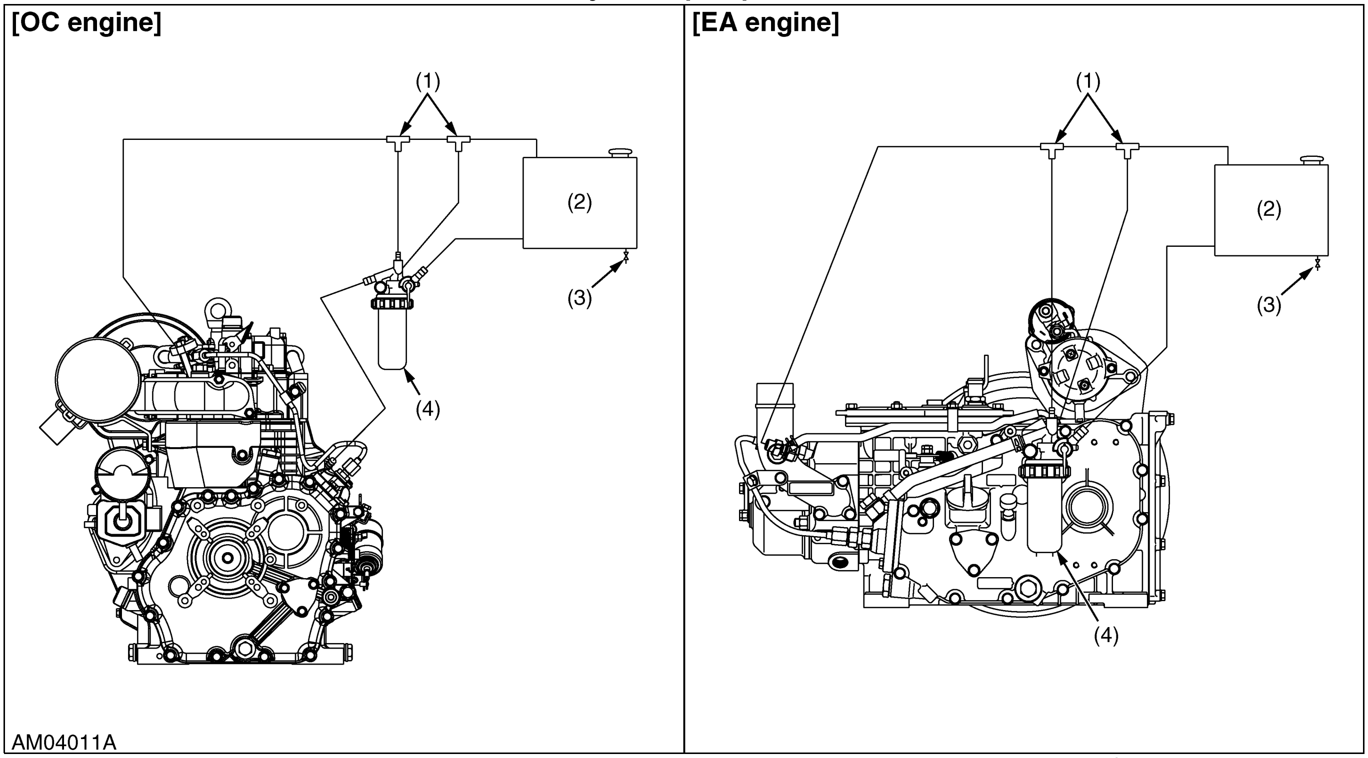
AM04010A

(1) Fuel tank
(2) Fuel pump

A : 150 mm (6 in.)

Fig. 4-11

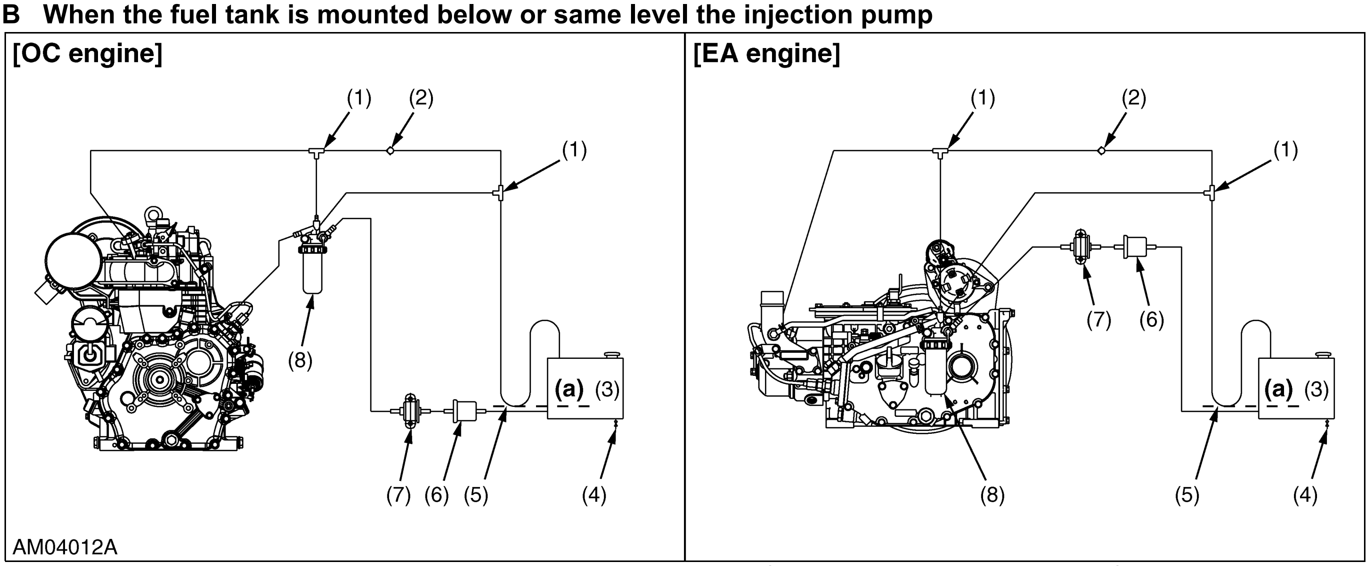
A When the fuel tank is mounted above the injection pump



(1) T joint (2) Fuel tank (3) Drain cock (4) Fuel filter

Fig. 4-11 Fuel piping

B When the fuel tank is mounted below or same level the injection pump



(1) T joint
(2) Check valve
(3) Fuel tank
(4) Drain cock
(5) U-return
(6) Pre-filter
(7) Electric Fuel feed pump
(8) Fuel filter
(a) Low level

Fig. 4-12 Fuel piping

If the fuel tank is installed at a lower level than the injection pump or at the same level, the electric fuel feed pump should be used to improve air bleeding the fuel in the fuel system, starting failure, the output decrease and the fluctuation of rotation, all of which occur due to such installation positions can be prevented.

KUBOTA recommends the above piping.

It is desirable that the fuel filter is installed at higher position than the injection pump.

9. FUEL

Fuel standards, grades and recommendations

Diesel fuels specified to EN590 or ASTM D975 are recommended.

- Since KUBOTA diesel engines of less than 56 kW (75 hp) utilize EPA Tier 4 and Interim Tier 4 standards, the use of low sulfur fuel or ultra low sulfur fuel is mandatory for these engines, when operated in US EPA regulated areas. Therefore, please use No.2-D S500 or S15 diesel fuel as an alternative to No.2-D, and use No.1-D S500 or S15 diesel fuel as an alternative to No.1-D for ambient temperatures below -10 °C (14 °F).
- No.2-D is a distillate fuel of lower voltility for engines in industrial and heavy mobile service. (SAE J313 JUN87)

Major fuel standards of the world

1) ASTM : American Society of Testing and Materials
2) US EPA : United States Environmental Protection Agency

Note :
Don't use kerosene in KUBOTA diesel engines.

(1) Requirements for diesel fuel

The following properties are required of diesel fuel.

1) Good ignitability
2) Appropriate viscosity
3) Low sulfur content
4) Low pour point
5) Good volatility
6) Low residual carbon
7) Free of water and foreign matter

These are described in detail below :

1) Good ignitability

Fuel with good ignitability burns quickly as it is atomized into the combustion chamber, allowing easy starting and smooth running with a minimum of smoke and noise.

Therefore, fuel with good ignitability must be used. Ignitability is indicated by the cetane number.

Recommended fuel cetane rating

Cetane Rating : The minimum recommended Fuel Cetane Rating is 45. A cetane rating greater than 50 is preferred, especially for ambient temperatures below -20 °C (-4 °F) or elevations above 1500 m (5000 ft).

2) Appropriate viscosity

Combustion is the engine begins with atomization of fuel, which requires a low viscosity.

However, penetration of injection is required of the atomized fuel to distribute the atomized particles throughout the combustion chamber, this requires certain amount of viscosity.

Since fuel is also used to lubricate the plunger and nozzle sliding in the fuel injection subsystem, fuel must have a viscosity sufficient enough to prevent wear and seizure of parts.

It must not be too viscous, because volatility of the atomized fuel will be reduced and distribution throughout the combustion chamber will be uneven.

3) Low sulfur content

The sulfur content of fuel must be as low as possible since it contributes to wear of parts and deterioration of oil.

When a sulfuric compound is burned, it changes to sulfurous acid gas (SO_2) and sulfuric anhydride (SO_3).

A large amount of water is also generated in the form of condensation within the engine crankcase. All of these by-products turn into sulfuric acid, which is strongly corrosive. Corrosion in a diesel engine is the result.

Fuel sulfur content and notes on use

Diesel Fuel Specification Type and Sulfur Content % (ppm) used, must be compliant with all applicable emission regulations for the area in which the engine is operated.

- Use of diesel fuel with sulfur content less than 0.10 % (1000 ppm) is strongly recommended.
- If high-sulfur (sulfur content 0.50 % (5000 ppm) to 1.0 % (10000 ppm)) is used as a diesel fuel, change the engine oil and filter at shorter intervals. (approximately half)
- DO NOT USE Fuels that have sulfur content greater than 1.0 % (10000 ppm).

Note :

- **No.1-D or No.2-D, S500 : Low Sulfur (LSD) less than 500 ppm or 0.05 wt.%**
- **No.1-D or No.2-D, S15 : Ultra Low Sulfur Diesel**

4) Low pour point
Fuel must have a low pour point to run smoothly from the fuel tank to the filter and through the fuel pipe of the fuel pump in cold weather.
A low pour point and a good ignitability have contradicting effects since low pour point fuel generally has low cetane number.

5) Good volatility
Fuel is atomized, vaporized and mixed with air before ignition at the combustion of diesel engine. Fuel must have a good volatility to become vaporized and burn quickly.
Any unvaporized oil will cause soot and smoke, and eventually contaminate the oil. Fuel with good volatility burns more completely, minimizing fuel combustion, lowering the exhaust gas temperature and does not generate black smoke.

6) Low residual carbon
Residual carbon is the carbonic residue that is generated during vaporization and decomposition of oil.
Although residual carbon and carbon accumulation in the engine have no direct relationship, they should be minimized.

7) Free of water and foreign matter
The fuel pump in a diesel engine is extremely precise, even the smallest trace of foreign matter can critically affect the fuel injection mechanism. Dust or dirt in the air or a solid matter such as iron rust in the fuel must be eliminated. Water may become mixed with fuel during storage or transportation. Most of it is removed as it settles in storage. Colloidal water floating or dissolved in water (0.1 to 0.5%) can enter the combustion chamber. Diesel fuel containing water loses its ignitability, adversely affecting combustion performance. Water must also be eliminated since it will freeze in cold temperature and block filtration.

(2) Cetane number

Cetane numbers indicate the anti-diesel knocking characteristics of fuel. The cetane number is measured in a similar way as an octane number using standard CFR testing engines.

A standard fuel is a mixture of n-cetane and αmethylnaphthalene. The former indicates the lowest knocking point, its cetane number is defined as 100. The latter has the greatest knocking points, its cetane number is defined as 0. Knocking of the standard fuel and the sample fuel is compared on testing engines by changing the mixing ratio of the two components in the standard fuel until both engines show equal knocking characteristics. The percentage of n-cetane at this point in a standard fuel is then taken as the cetane number of the sample fuel. Anti-knocking characteristics of fuel oil can also be indicated by diesel indexes and cetane indexes, which are derived from results of characteristics tests without using testing engines.

The cetane number for KUBOTA diesel engines must not be less than 45.

(3) Fuel ratings

Fuel ratings vary in different countries. Fuel must be chosen according to the operating temperature and emission regulations. Fuel feed will be adversely affected if a fuel is used in a temperature below its pour point.

Japan (JIS K2204)

1) Applicable range : This regulation specifies the diesel fuel to be used for diesel engines (mainly for automobiles).
2) Type : Diesel fuel is classified into five types, i.e., Special No.1, No.1, No.2, No.3, and Special No.3, according to each pour point.
3) Requirements

★ General matters
Diesel fuel is mainly composed of refined mineral oil having proper quality as the fuel oil for diesel engines (mainly those for automobiles), and it shall not include water and sediments.

★ Required quality

The property of diesel fuel should be within the range specified in the table below
.

Property Class of fuel	Flash point °C (°F)	Distillation (90% distillation temperature in °C (°F)	Pour point °C (°F)	Mass % of residual carbon in 10% residual oil	Cetane (2)	Kinematic viscosity 30 °C (86 °F) mm^2/s (cSt) (3)	Sulfuric mass %
Special No.1	Over 50 (122)	Below 360 (680)	Below +5 (41)	Below 0.1	Over 50	Over 2.7	Below 0.05
No.1	Over 50 (122)	Below 360 (680)	Below -2.5 (27.5)	Below 0.1	Over 50	Over 2.7	Below 0.05
No.2	Over 50 (122)	Below 350 (662)	Below -7.5 (18.5)	Below 0.1	Over 45	Over 2.5	Below 0.05
No.3	Over 45 (113)	Below 330 (626) (1)	Below -20 (-4)	Below 0.1	Over 45	Over 2.0	Below 0.05
Special No.3	Over 45 (113)	Below 330 (626)	Below -30 (-22)	Below 0.1	Over 45	Over 1.7	Below 0.05

Note :
(1) It is below 350 °C (662 °F) in case of Kinematic viscosit 30 °C (86 °F) is below 4.7 mm^2/c (4.4 cSt).
(2) It is possible to use cetane number.
(3) 1 mm^2/s = 1 cSt

U.S.A. (SAE J313)

Abstract :
Automotive and railroad diesel fuels, in general, are derived from petroleum refinery products which are commonly referred to as middle distillates. Middle distillates represent products which have a higher boiling range than gasoline and are obtained from fractional distillation of the crude oil or from streams from other refining processes. Finished diesel fuels represent blends of middle distillates. The properties of commercial distillate diesel fuels depend on the refinery practices employed and depend on the refinery practices employed and the nature of the crude oils from which they are derived.
Thus, they may differ both with and within the region in which they are manufactured. Such fuels generally boil over a range between 163 and 371 °C (325 and 700 °F). Their makeup can represent various combinations of volatility, ignition quality, viscosity, sulfur level, gravity, and other characteristics.
Additives may be used to impart special properties to the finished diesel fuel.

Grade of Diesel fuel oil	Flash point °C (°F)	Distillation Temperatures °C (°F) 90% Point	Viscosity Kinematic cSt or mm^2/s at 40 °C (104 °F)	Cetane Number
No.1-D	38 (100)	Below 288 (550)	1.3 to 2.4	Over 40
No.1-DLS	38 (100)	Below 288 (550)	1.3 to 2.4	Over 40
No.2-D	52 (125)	282 to 338 (540 to 640)	1.9 to 4.1	Over 40
No.2-DLS	52 (125)	282 to 338 (540 to 640)	1.9 to 4.1	Over 40

(4) Biodiesel fuel (B5)

Kubota only permits to use the biofuel (BDF) that satisfies the following conditions 1) - 4).
In using the biofuel (BDF), pay enough attention to the storing methods, using methods, and maintenance methods of the engine described in the following clauses of 5) to 14) while understanding the characteristics of the biofuel.

Conditions for the biofuel

1) Only the fuel that contains 5 % or lower volume mixing ratio of 100 % BDF (B100) in the mineral diesel fuel can be used. (B5)
2) The mineral diesel fuel shall be according to the newest edition of EN590 (Europe) or ASTMD975 (USA), while the B100 to be mixed shall be according to the newest edition of EN14214 (Europe) or ASTMD6751 (USA) standards. The final mixture fuel B5 shall, also, be according to the newest edition of E590 (Europe). Raw expressed vegetable oil cannot be used.
3) B100 or the mixed fuel B5 shall be purchased from the reliable manufacturers or dealers (in USA, the one accredited by BQ-9000). (Because on-the-site mixing tends to cause uneven mixing, it is recommendable to purchase the B5 that has been mixed at the manufacturer's factory in advance.)
4) Uses of Kubota Emission Certified Engines are responsible for obtaining any appropriate local, state and national exemptions required for the use of BDF.

Characteristics, storing procedures, and maintenance cautions of the biofuel

5) To prevent accumulation of moisture in the fuel tank, keep the fuel tank full as much as possible. Also, surely tighten the cap of the fuel tank to prevent moisture intrusion.
6) Confirm the engine oil level before starting the engine every day. Also, keep strictly the engine oil change interval because the delay in the engine oil change causes damages to the engine.
7) In the cold weather, take special care because clogging of the fuel lines can cause such problems as starting failures.
8) Be careful that BDF tends to aggravate multiplication of and contamination by microorganisms, which can causes such malfunctions like corrosion of the fuel system or too early clogging of the fuel filter.
9) Pay careful attention to the following cautions, because the fuel (BDF) during refueling and in the fuel tank tends to deteriorate by oxygen, water, heat, and foreign matters.
   a) Do not store the fuel in the fuel tank or in drums for longer than 3 months.
   b) In the case of the prolonged parking or storage of the vehicle, wash the engine by idling it using the conventional mineral diesel oil for at least 30 minutes.

10)BDF is hygroscopic and, therefore, tends to contain higher moisture content than the conventional diesel fuel. Accordingly, the intervals of the fuel filter cleaning and exchange, the fuel pipe check and exchange, the nozzle check and exchange, and the fuel system maintenance and check shall be shorter than those for the conventional mineral diesel fuel.
In addition, use of a sedimenter is strongly recommended.
11)When the biodiesel fuel is spilled on a painted surface, immediately wipe it off because it can damage the painting.
12)If the biodiesel fuel of higher concentration than B5 is used, it is possible to deteriorate the output and fuel consumption. Also, the higher concentration biodiesel fuel than B5 can corrode the brass/zinc parts and rubber/resin products of the fuel system. Therefore, never use the higher concentration biodiesel fuel than B5.
13)The adjustment of the tamper parts (fuel confinement) of the engine under the use of the biodiesel fuel is deemed to be an illegal activity to the emission regulation and punished. Never execute such adjustments.
14)The BDF of palm-oil-base has lower low-temperature fluidity than the BDF of soybean/rape seed-oil-base. Therefore, pay special attention to the fact that it can cause the fuel filter clogging during the cold season.

5. LUBRICATION SYSTEM

CONTENTS

LUBRICATION SYSTEM

1. GENERAL

All moving parts of the engine must be lubricated to function properly. For this purpose, the lubricating oil circulating through the engine has a number of functions.
In addition to reducing friction, the oil cools down the engine, controls expansion and dispersion of bearing areas, provides a sealing action, prevents rusting, seals out dust, and purifies products generated in the cylinders by incomplete combustion.

[1] LUBRICATION SYSTEM

OC and EA engine lubrication systems are shown in Fig. 5-1 and Fig.5-2. Lubricating oil in the oil pan is circulated by a pump.
Oil pressure is controlled in the range of proper pressure and it is delivered to each section of the engine before returning to the oil pan.

OC engine

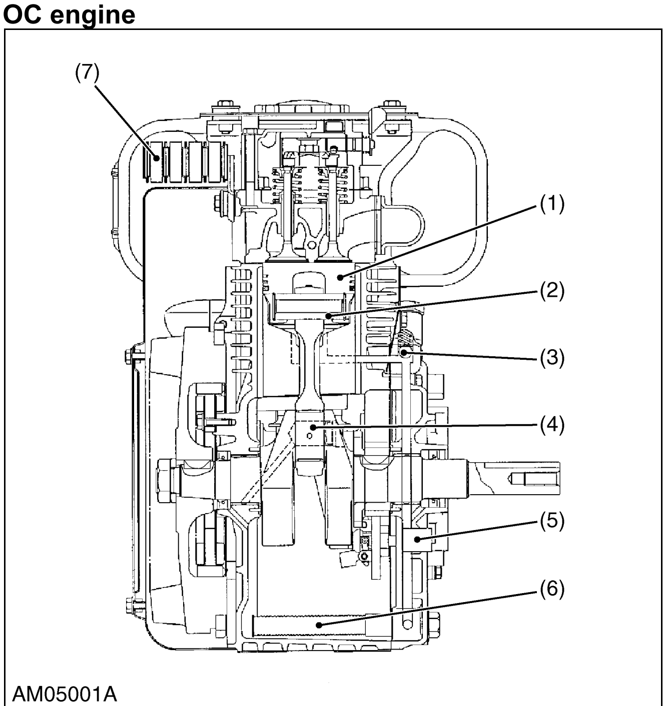
Lubrication is forced on with a trochoid pump. Lubrication oil is sucked in by the trochoid pump (5) via an oil strainer (6) mounted on the side of the gear case. The pressure of lubricating oil discharged from the trochoid pump is regulated by a relief valve (3) to 98 to 490 kPa (1.0 to 5.0 kgf/cm^2 , 14 to 70 psi) (at the rated revolution speed of the engine) and the pressure-regulated oil then fed to the various portions through the oil gallery in the cylinder block.

Lubricating oil sent to the oil gallery in the crankshaft lubricates the crank pin portion (4).

The oil passes along the cylinder liner and reaches the cylinder head to cool it down. The oil then flows into the oil cooler (7). The oil cooled there passes through the relief valve opening of the cylinder head and returns into the crankcase.

Other items such as the piston (1), piston pin (2), camshaft, tappet, bearing and rocker arm are lubricated by splash of the crankshaft, etc.

OC engine



(1) Piston
(2) Piston pin
(3) Relief valve
(4) Crank pin portion
(5) Trochoid pump
(6) Oil strainer
(7) Oil cooler

Fig. 5-1 Lubrication system

EA engine

Lubrication is forced on with a trochoid pump.

Lubrication oil is sucked in by the trochoid pump (7) via an oil strainer (8) mounted on the side of the gear case. The pressure of lubricating oil discharged from the trochoid pump is regulated by a relief valve (6) to 98 to 440 kPa (1.0 to 4.5 kgf/cm^2, 14 to 63 psi) (at the rated revolution speed of the engine), and the pressure-regulated oil is then fed to various portions through the oil gallery in the cylinder block.

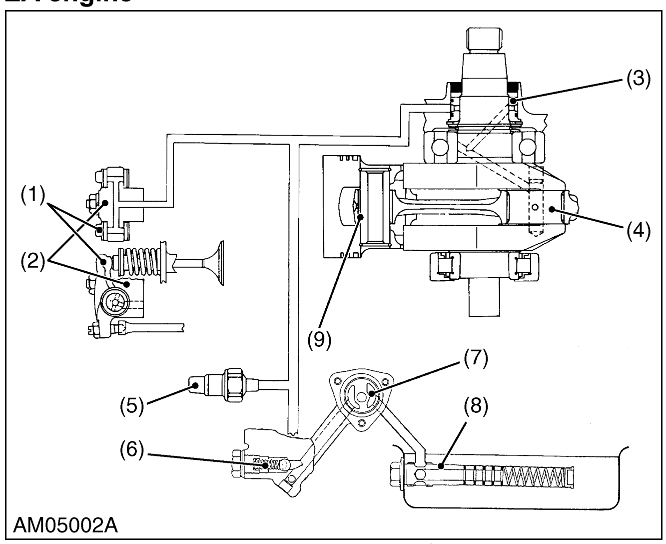
Lubricating oil sent to the oil gallery in the crankshaft lubricates the crank pin portion (4).

Oil sent to the cylinder head via the oil gallery in the cylinder block lubricates rocker arms (1) via a rocker arm bracket (2).

Other items such as the piston, piston pin bushing (9), cam shaft journal portion, tappet, timing gear and bearings are lubricated by splash of the crankshaft, etc.

An oil signal (5) is provided to enable the judgement whether the oil pressure is 50 kPa (0.5 kgf/cm^2, 7 psi) or more.

EA engine



(1) Rocker arm
(2) Rocker arm bracket
(3) Oil filler ring
(4) Crank pin portion
(5) Oil signal
(6) Relief valve
(7) Trochoid pump
(8) Oil strainer
(9) Piston pin bushing

Fig. 5-2 Lubrication system

2. LUBRICATING OIL

Note :
- **The use of synthetic oil is not recommended.**
- **Poor quality oil will shorten engine life.**
- **Use only the specified lubricating oils.**

[1] FUNCTIONS OF ENGINE OIL

(1) Anti-wear action

The most important role of engine oil is prevention of seizures and to reduce frictional forces to minimize the wear between moving parts and contact surfaces depending on the reduction of friction force. (Such as cylinder walls and piston rings and both ends of connecting rods, crankshaft bearings, camshaft, tappets, etc.).

(2) Cooling action

The combustion chamber becomes extremely hot. Oil not only lubricates friction parts of piston but also cools the engine by acting as a heat exchange medium. This prevents seizures and high temperature oxidation of the oil itself. This cooling action is an extremely critical function. Extremely high viscosity or insufficient supply will result in seizures due to inadequate cooling.

(3) Sealing action

Cylinder walls and compression rings seal the combustion chamber to allow build-up of compression. Oil seals the clearance between the cylinder walls and rings to provide more complete sealing and prevent leakage of the compressed air to maintain the compression pressure. It also prevents combustion gas from blowing back into the crankcase.
The prevents reduction of engine output and contamination of oil by unburned fuel.

(4) Engine cleaning action

Oil removes deposits inside the engine to prevent wear due to build-up of deposits.

(5) Corrosion preventive action

Oil prevents acid corrosion of metal parts, such as bearing metals, etc.

(6) Rust prevention action

Engine oil prevents rusting caused by condensation of acidic gases.

[2] CLASSIFICATION OF ENGINE OIL

(1) Classification by viscosity

SAE (Society of Automotive Engineers) Standards are generally used to classify engine oil viscosities. Viscosity is a principal property of oil, the higher the viscosity, the thicker the oil film formed over the metal surface will be and the lower the viscosity, the thinner the film thickness becomes.
Viscosity varies with temperature. The higher the temperature, the lower the viscosity and vice versa. Engine oil should have the appropriate viscosity and have properties which are not affected by viscosity changes caused by temperature changes. In other words, engine oil must have a high viscosity index. Multi-grade oils having relatively low viscosity (SAE 10W-30) can provide superior lubrication at both low temperature and high temperatures. Such oils are available commercially for all-season use.

*"High viscosity index" means less viscosity change by temperature fluctuation.

SAE J-300

Vis-cosity No.	*Max. viscosity at each temp. (CP)	**Max.temp. expressing tolerable pump discharge performance °C (°F)	Viscosity at 100 °C (212 °F)	
			Min.	Max.
0W	3250 at -30 °C (-22 °F)	238 (-35)	3.8	
5W	3500 at -25 °C (-13 °F)	243 (-30)	3.8	
10W	3500 at -20 °C (-4 °F)	248 (-25)	4.1	
15W	3500 at -15 °C (5 °F)	253 (-20)	5.6	
20W	4500 at -10 °C (14 °F)	258 (-15)	5.6	
25W	6000 at -5 °C (23 °F)	263 (-10)	9.3	
20	–	–	5.6	< 9.3
30	–	–	9.3	< 12.5
40	–	–	12.5	< 16.3
50	–	–	16.3	< 21.9

* Measured by CCS viscometer (ASTM D-2602).
** Measured by mini rotary viscometer (ASTM D-3829). When the viscosity is less than 30000 CP, the maximum temperature is measured.

(2) Recommended oil for E3 engine

• **Refer to the following table for the suitable American Petroleum Institute (API) classification of engine oil and the Fuel Type Used : LowSulfur, Ultra LowSulfur or High Sulfur Fuels**.

Fuel Type	Engine oil classification (API classification)
High Sulfur Fuel [0.05 % (500 ppm) ≤ Sulfur Content < 0.50 % (5000 ppm)]	**CF** (If the "CF-4, CG-4, CH-4, or CI-4" engine oil is used with a high-sulfur fuel, change the engine oil at shorter intervals. (approximately half))
Low Sulfur Fuel [Sulfur Content < 0.05 % (500 ppm)] or Ultra Low Sulful Fuel [Sulfur Content < 0.0015 % (15 ppm)]	**CF, CF-4, CG-4, CH-4** or **CI-4**

- **Oil used in the engine should have API classification and Proper SAE Engine Oil Viscosity according to the ambient temperatures where the engine is operated.**
- **With strict emission control regulations now in effect, the CF-4 and CG-4 engine oils have been developed for use with low sulfur fuels, for On-Highway vehicle engines. When a Non-Road engine runs on high sulfur fuel, it is advisable to use a "CF or better" classification engine oil with a high Total Base Number (a minimum TBN of 10 is recommended).**

[3] DEGRADATION OF ENGINE OIL

Engine oil is subjected to extremely harsh conditions. Since it is used at high temperatures and in situations where combustible compounds and soot become mixed, then degradation inevitably occurs. Cause and effect of oil degradation are described below.

(1) Effect of oxidation due to temperature changes

Oxidation of engine oil accelerates when oil is exposed to oxygen in the air at high temperatures. The speed of oxidation is faster with increase of temperature. Generally the speed of oxidation is doubled at each increase of 10 °C (50 °F) and the speed of oxidation accelerated further after the temperature reaches 150 °C (302 °F). The speed of oxidation is also affected by the metal which contacts engine oil and is the fastest when exposed copper-based metals.
Oil oxidation differs in low temperature sections, in the bearing system and in high temperature sections such as the ring grooves.
Specific oxidation conditions are described briefly below.

Oil temperature & oxidation process

★ Below 125 °C (257 °F)

Engine parts	Engine oil oxidation process
Main bearing, crank pin, oil pan, etc.	Gradual oil oxidation - peroxide generated - acid, (rich in extreme pressure) property) hydroxy acid-sludge generated Polymerization, Rate of wear

★ 125 to 200 °C (257 to 392 °F)

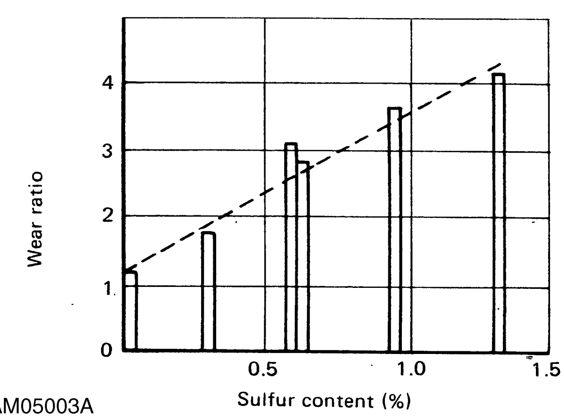
Engine parts	Engine oil oxidation process
Piston skirt, piston ring	Substantial oil oxidation - Gluey deposits generated Polymerization, Rate of wear

★ Above 200 °C (392 °F)

Engine parts	Engine oil oxidation process
Piston ring, piston head	Thermal cracking of oil and sludge light substance-combustion heavy substance-soot and hard carbon

(2) Effect of oxidation due to combustion

Oxidation of oil is not only affected by the oxidation of the oil itself but by entrance of aldehyde, peroxide, etc. which is produced by combustion. Gas with these substances blow back and is mixed with engine oil. Thus oxidation of oil is accelerated. With diesel engines, which used diesel fuel with higher sulfur content than gasoline, sulfur dioxide produced by combustion goes through the ring belt area as blow-by gas, changes into SO_3 after contacting the metal oxide. The absorbs water and becomes sulfuric acid it oxidizes the oil and accelerates cylinder wear.



AM05003A

Fig. 5-3 Effect of sulfur on wear

[4] ANALYSIS RESULTS AND ENGINE OIL CHANGE INTERVALS

To determine proper engine oil change intervals, it is necessary to study the results of engine oil analysis and internal smear characteristics and wear of engine parts. It is not practical to over-haul an engine every time an inspection is necessary. Generally judgement of oil change is based on the result of oil analysis and experience.

(1) Viscosity

Viscosity of oil increases as the oil oxidizes and as it mixes with incompletely burnt fuel by-products (soot etc.). Since pressure loss is greater as oil volume decreases improper or insufficient lubrication can result. High viscosity of oil causes greater frictional resistance which generates more heat. This can eventually cause seizure of major parts such as cylinders, bearings etc. and lead to serious problems.
Oil must be changed before viscosity increase is too great.

(2) Total acid value

Oils in which additives are used have a certain acid value even when new. The acid value increases as the oil itself becomes oxidized and contaminated by combustion by-products. The acid value must be controlled to a 2 mg/KOH/g increase from the value when new.
Oil must be changed before acid number becomes too high.

(3) Alkalinity

Detergent and dispersing agents contained in engine oil have a weak alkalinity to neutralize combustion by-products (especially sulfuric acid in diesel engines) and oil oxides. This alkalinity decreases gradually with use term. By checking this decrease of alkalinity, you can check the remaining level of detergent and dispersing agents in the oil, which in turn is an accurate indication of when to replace oil.
Generally certain allowances are made for exact replacement intervals but minimum alkalinity is usually considered to be approximately 1.0 mg/KOH/g.

(4) Insoluble matter of solvent

The amount of sludge in engine oil is measured by the percent of insoluble matter of solvent (weight %)
As shown in figure, N-pentane insoluble matter includes oxidized compounds of fuel or oil, inorganic matter such as dust and metal powder and soot. Oxidized compounds of fuel or oil are considered the reminder of N-pentane insoluble matter without insoluble benzene content, which is called the resin matter.

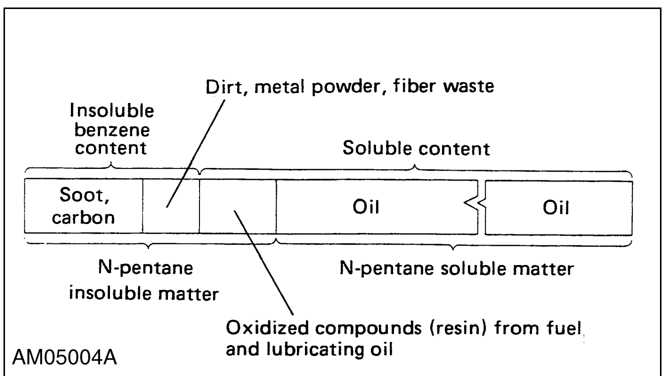


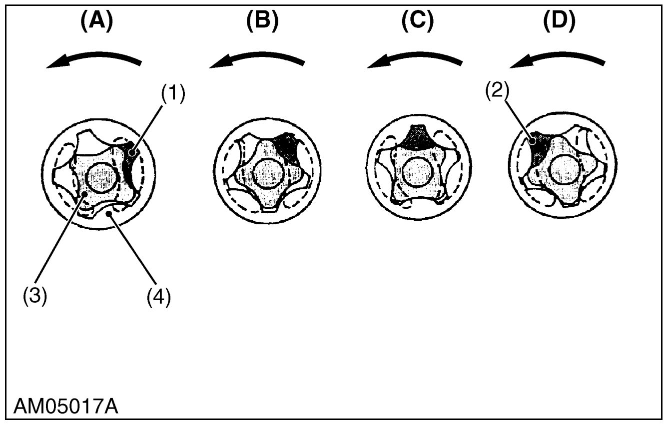
Fig. 5-4

Generally the limit of N-pentane insoluble matter should be within 2.0% and insoluble benzene content within 1.5%.
Oil must be changed before sludge amount is too great.
See “Operator’s Manual” for oil change intervals.

3. LUBRICATING OIL PUMP

(1) Oil pump

The oil pump is of trochoid pump type, whose rotors have trochoid lobes. The inner rotor (3) has 4 lobes and the outer rotor (4) has 5 lobes, and they are eccentrically engaged with each other.
In OC engine, the inner rotor is driven by the governor gear, which in turn rotates the outer rotor and in EA engine, the inner rotor is driven by the camshaft, rotates the outer rotor in the same direction, varying the spaces between the lobes.
While the rotors rotates from **A** to **B**, the space leading to the inlet port increases, which causes the oil to flow through the inlet lobes.
When the rotors rotates to **C**, the port to which the space leads is changed from inlet to outlet.
At **D**, the space decreases and sucked oil is discharged from the outlet port.



(1) Inner
(2) Outer
(3) Inner rotor
(4) Outer rotor

Fig. 5-5 Oil pump

The rotor has a precise clearance of 0.1 mm (0.0039 in.) which requires very careful attention. Make absolutely sure that no dirt or other foreign matter enters into oil pump through the oil filter.

Oil pump specifications

For OC series

Type	Trochoid pump
Inner rotor delivery volume (3500 min^{-1} (rpm))	4 lobes 9.1 L/min 2.40 USgals/min
Delivery pressure (3500 min^{-1} (rpm)) (Regulator valve pressure)	98 to 490 kPa 1.0 to 5.0 kgf/cm^2 14.0 to 70.0 psi

For EA series

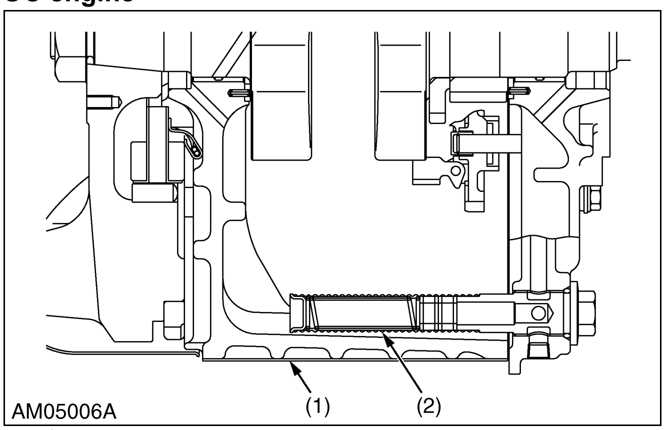
Type	Trochoid pump
Inner rotor delivery volume (1500 min^{-1} (rpm))	4 lobes 3.9 L/min 1.03 USgals/min
Delivery pressure (1500 min^{-1} (rpm)) (Regulator valve pressure)	98 to 440 kPa 1.0 to 4.5 kgf/cm^2 14.0 to 63.0 psi

4. LUBRICATING OIL FILTER

Oil in the crank case first passes through filter and is then suctioned by the oil pump and the oil lubricates the various parts.

Oil filter is installed near the bottom of the crank case and removes dirt and foreign matter.

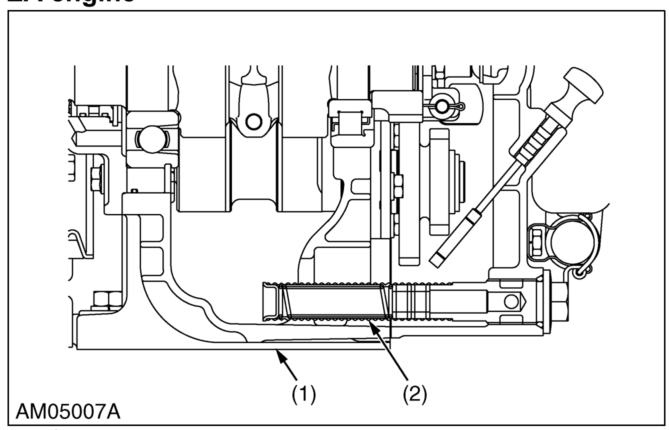
OC engine



(1) Crank case (2) Filter

Fig. 5-6 Filter

EA engine



(1) Crank case (2) Filter

Fig. 5-7 Filter

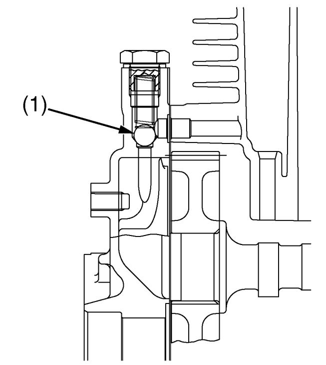
5. OTHERS

Relief valve

Maintains lubricating oil pressure at constant value adjusted to maintain the pressure below.

OC engine : 98 to 490 kPa
1.0 to 5.0 kgf/cm^2
EA engine : 98 to 440 kPa
1.0 to 4.5 kgf/cm^2

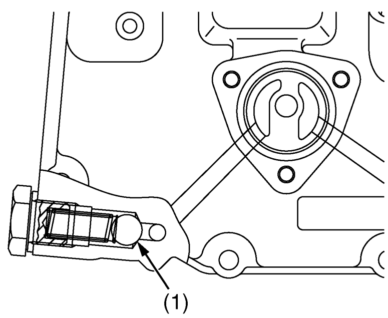
OC engine



AM05008A
(1) Relief valve

Fig. 5-8 Relief valve

EA engine



AM05009A
(1) Relief valve

Fig. 5-9 Relief valve

Oil switch

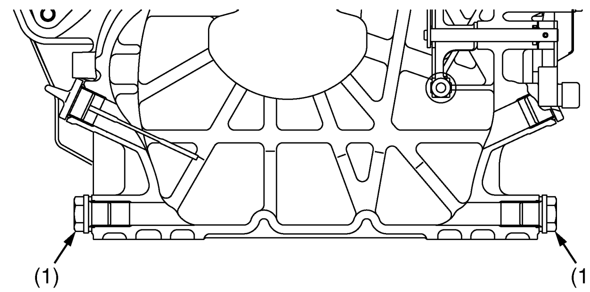
In OC engine, oil switch is fitted at side cover.
In EA engine, oil switch is fitted at crank case.
If oil pressure drops below 49.0 to 98.1 kPa (0.5 to 1.0 kgf/cm^2, 7.11 to 14.22 psi) ∗ a lamp connected to the switch lights up, advising the operator to stop engine and investigate the cause of the pressure drop.

∗ These will vary slightly according to model.

6. DRAIN PLUG

While the OC engine is equipped with an oil drain plug at each of the two crank-case feet, oil can be also drained by removing the oil-filter main body. The EA engine is not equipped with oil drain plugs, therefore, drain the oil by removing the oil-filter main body.

OC engine



AM05010A
(1) Drain plug

Fig. 5-10

7. OIL GAUGE AND SUPPLY PORT

Oil gauge

The standard oil gauge of OC engine is installed on the side of crankcase. The part is composed of plastic oil plug, gauge and O-ring. The end of the gauge indicates lower limits. And upper level is limitted by the height of supply port. And standard oil gauge of EA engine is installed on the front of gear case. The part which is inserted is made of rubber, which is grooved to release internal pressure during insertion. The oil gauge is stamped with lines indicating upper and lower limits. If oil is supplied far above the top limit, engine output will be reduced and oil temperature will be increased, so watch this point carefully.

Proper oil level is not indicated for a few minutes after the engine is stopped because of the time required for oil to return to the oil pan. Oil level must be measured in level position.

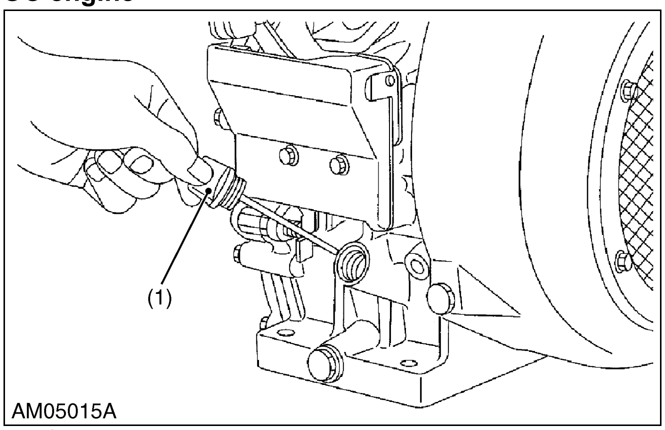
Oil supply port

Oil is supplied to the engine through the oil supply port located on top of the cylinder head cover the gear case or crankcase.

This oil supply port should be easily accessible for servicing, even after the engine has been installed.

Care must be taken to decide the position of oil supply port so that the oil can be easily supplied to the piping installed on the machine.

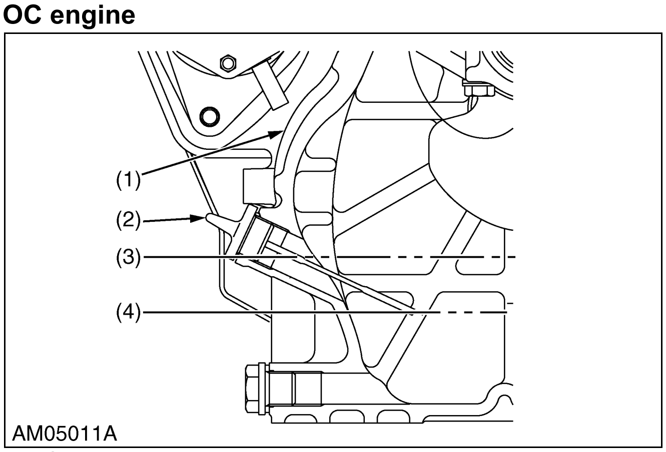
OC engine



(1) Oil plug

Fig. 5-11

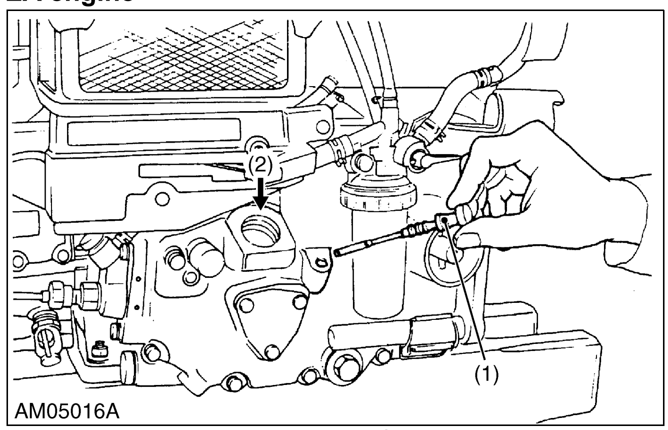
OC engine



(1) Crank case (3) Upper
(2) Oil gauge (4) Lower

Fig. 5-12

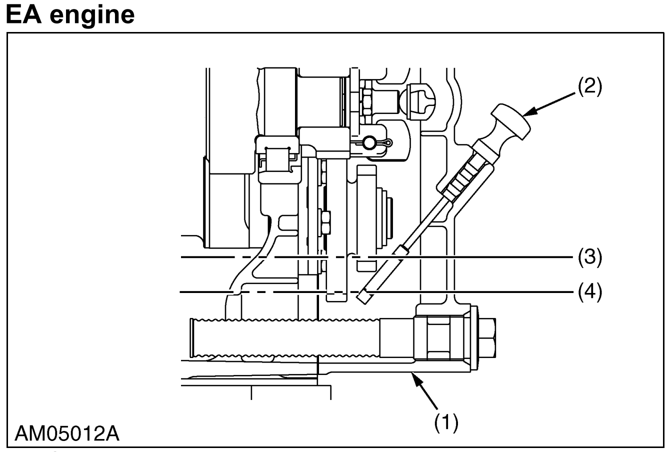
EA engine



(1) Dipstick (2) Oil inlet

Fig. 5-13

EA engine



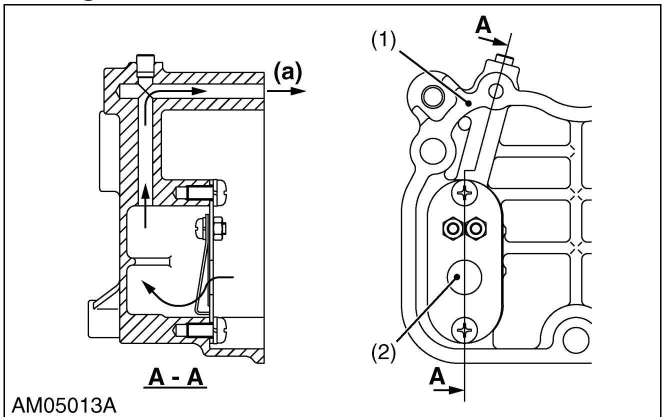
(1) Crank case (3) Upper
(2) Oil gauge (4) Lower

Fig. 5-14

8. CLOSED BREATHER

Closed breather system has been adopted to prevent the release of blow-by gas into the atmosphere.
After its oil content is filtered by oil shield, the blow-by gas is fed back to the intake manifold through breather valve to be used for re-combustion.

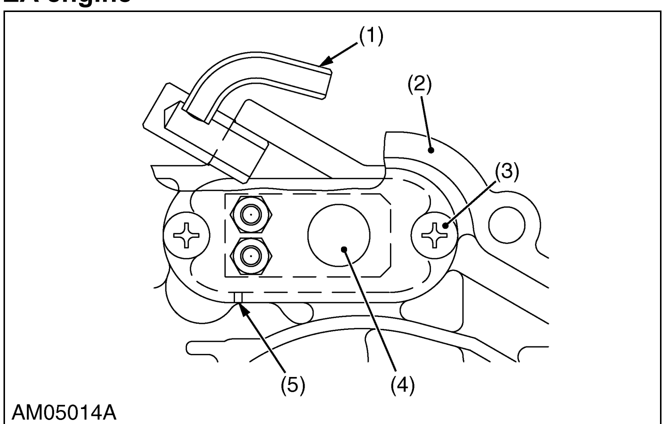
OC engine



(1) Head cover
(2) Valve hole
(a) To air cleaner

Fig. 5-15

EA engine



(1) Breather joint
(2) Gear case
(3) Mounting screw
(4) Valve hole
(5) Oil escape groove

Fig. 5-16

6. AIR INTAKE SYSTEM

CONTENTS

AIR INTAKE SYSTEM

1. GENERAL

The intake and exhaust system is very important for engines.
In order to operate an engine smoothly, the intake and exhaust system must be efficient enough for maximizing the functions of highly reliable valve mechanism. It is best to feed clean, low temperature (i.e. high density) air to the engine intake.
The intake system supplies the air required for combustion. Insufficient air intake decreases engine output. If air is not clean, wear increases on the piston, rings and cylinder and lubricating oil smear will tend to shorten engine life.

2. AIR CLEANER

(1) General

The air cleaner, of which purpose is to purify intake air, has two types, ; the dry type and wet type. The dry-type air cleaner, which is generally used in most cases, uses a filter paper element and therefore dust removing efficiency is very high regardless of the engine speed. (99.5-99.8%)
In OC and EA diesel engines, the dry-type air cleaner are employed as standard part for all models.

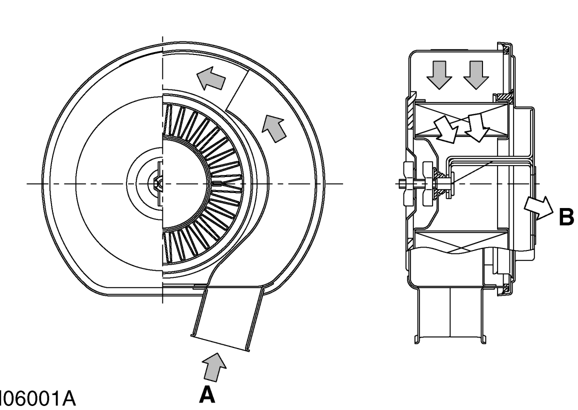
Note :
OC and EA are equipped with a standard air cleaner.

(2) Structure of dry type air cleaner

OC engine

For OC engine's air cleaner, dust or air containing moisture will infiltrate into air cleaner through the inlet installed perpendicularly on the bodies outer circumference and direct vortex flow along the guide is created inside the body.
After this, the air passes through the element and will further be purified.
The element is made of high-quality paper filter and can inhibit infiltration of very fine dust.

OC engine



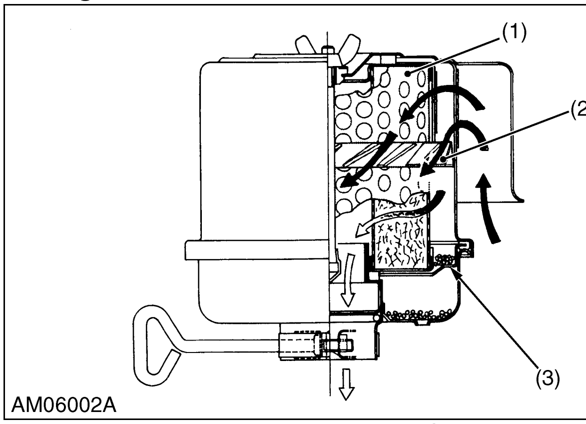
A : Contaminated air **B : Cleaned air**

Fig. 6-1 Standard cleaner

EA engine

For EA engine's air cleaner, the air enters it from the periphery of the element (1), and the air is turned into a cyclone swirl by the impeller (2) to separate coarse dust particles centrifugally from the air. As the air passes the element, remaining dust is removed from the air, and the clean air is sucked into the cylinder from the center.

EA engine



(1) Element (3) Dust Guide
(2) Impeller

Fig. 6-2 Standard cleaner

Note :
When using it other than in the standard specifications, take care of the following points.
The size, shape and position of air cleaner vary with the size and type of machine and application. Care should be taken with the following items.

1) Structure of single element air cleaner

This air cleaner is the most popularly used type for the small-size general purpose diesel engine and is composed of the air cleaner body, outer element, rear-side end cover, dust-evacuator valves, etc. The outline of the structure is shown in the Fig. 6-3.

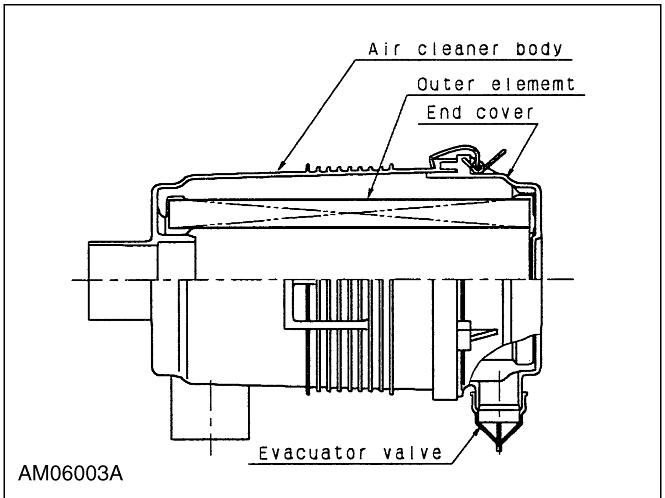


Fig. 6-3 Structure of single element air cleaner

2) Structure of double element air cleaner

The air cleaner of double element structure is used for the engine to be used in more severe environmental conditions such as the case of construction machinery and sweeper where the amount of dust is large. This type is made by adding the inner element to the previously-described single element air cleaner and the structure is shown in the following figure.

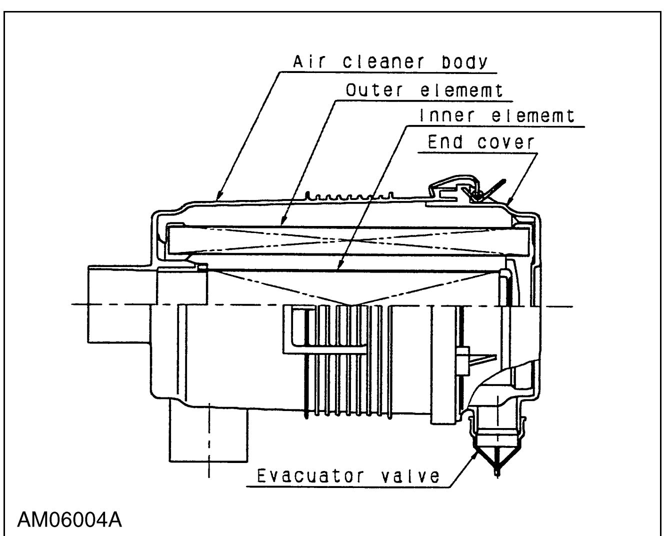


Fig. 6-4 Structure of double element air cleaner

(3) Selection of air cleaner

1) Conditions for selection

a) Amount of suction air
b) Environmental conditions of dust
- Small-amount dust conditions :
  Generator, forklift, carrier, etc.
- Large-amount dust conditions :
  Agricultural machinery, construction machinery

c) Mounting conditions
Mounting to engine, or mounting to machine
d) Destination
Use in advanced countries, or to developing countries
e) Use conditions
Operating hours and quality of maintenance
f) Cost
Initial cost and maintenance cost

2) Selection of air cleaner and the cautionary items

a) Cautionary items for environment
- In case that an air cleaner is used in high dust concentration areas (high-temperature or high-humidity area), a model of sufficient capacity should be used. (It is required to use the air cleaner of one size higher capacity than those to be used in ordinary areas.)
  The air cleaner should be the double element type.
- Reduction in the life of the air cleaner element (clogging) is often caused by comparatively small-sized dust. However, in the case that there is a possibility that the suction port (air intake) of air cleaner may be clogged by large-size dust (such as fallen leaves and straw dust), it is required to move the suction port to a location with less dust or to install a pre-filter to remove such large-size dust.
- In the case that there is a possibility that the air cleaner may suck in water, a water drain hole or water-separating device should be installed. Be very careful to prevent the water entering engine when washing the machine.

b) Caution items when mounting to engines
- Vibration of air cleaner should not exceed the rated value verified in the field operation of the actual machinery.
  Large vibration will cause damage to various parts or allow dust leakage of the element (including the element gasket section).

- Be careful so that the suction port of air cleaner is not subjected to the detrimental conditions such as the followings :
  a) Air cleaner should not inhale hot air, such as the hot side cooling air of radiator.
  b) Air cleaner should not inhale exhaust gas. Particularly fine carbon will cause to early clogging.
  c) Air cleaner should not inhale the material having viscosity such as mist of crankcase.
- Cautionary items when piping to the air cleaner
  a) Is the inner diameter, length, or bending of pipe appropriate ? Be careful so that the intake air resistance should not be too great.
  b) Is the dust seal of piping system complete ? If there is even the least gap in the suction air system, it will result in the early wear of the moving parts of engine.

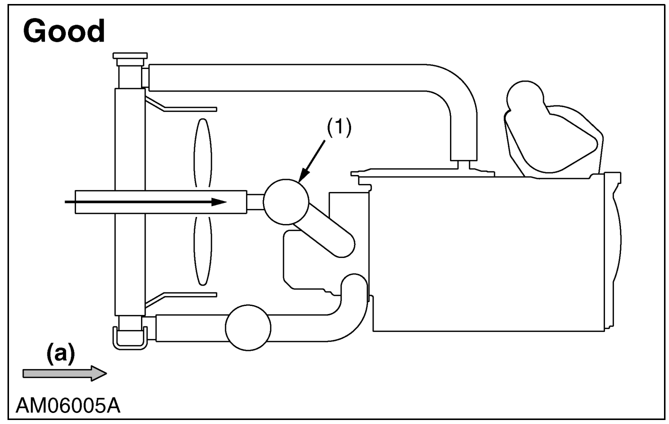
Therefore, checking of the following items is required.

  1) Is clamping force of the hose clamp sufficient, and will not the hose clamp be loosened by vibration ? Are all hose connection “rubber to metal”? Are all rubber hose connections tight on metal connections?
  2) Is strength of the hose sufficient ? (Will not distortion or damage of the hose be incurred by negative suction pressure or positive suction air pressure ?)
  3) Will dust infiltrate through the screw holes ?
  c) If an extension pipe is installed to the suction port, or the hose between air cleaner and intake manifold is too long, it may result in an engine output decrease or smoke increase.

c) Cautionary items on maintenance

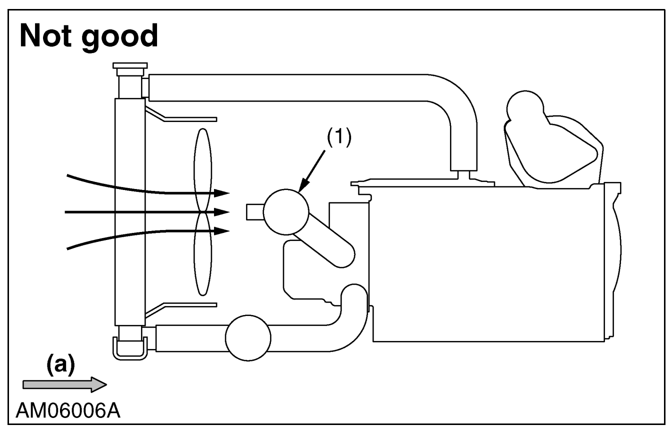
- Maintain the air cleaner within the time specified in the operators manual. (In the case of the air cleaner provided with a dust indicator, maintenance should be performed after the warning of clogging is indicated.) Unnecessary maintenance will be the cause of problems, such as the damage or deformed element.
- Be careful so that dust adhered on the element should not infiltrate to the outlet side of air cleaner when removing the element.
- When cleaning the element, it should be done by blown air or water washing. (Depending on the kind of the element, water washing is allowed, or specified detergent can be used.) In case of blown air remember to blow air from the inside toward the outside.
- When removing the element, stop the engine.
- In case that there is a pin hole on the element, replace it with new one.

Installation example of air cleaners are shown :



(1) Air cleaner **(a) Wind direction**

Fig. 6-5 Air cleaner installations



(1) Air cleaner **(a) Wind direction**

Fig. 6-6 Air cleaner installations

3. REQUIRED AIR VOLUME

The volume of air required during engine operation can be determined by the following formula.

$Q_1 = Vh \times N \times C \times \eta \times k\ 10^{-3}$

where as : Q_1 = Amount of intake air (m^3/min)

Vh = Total displacement (liter)

N = Engine speed (min^{-1} (rpm))

C = Coefficient 4 cycle ··· 0.5

η = Intake efficiency 0.85 to 0.87

k = Coefficient

Natural aspirated engine : 1.0

The intake efficiency of KUBOTA diesel engines shall be as follows :
Natural aspirated engine
Engines of 3000 min^{-1} (rpm) or less : 0.87
Engines of 3600 min^{-1} (rpm) or less : 0.85

The air volume required for KUBOTA diesel engine is referred to in section. (TECHNICAL INFORMATION)

Example Calculation

[Engine model : EA330,
Engine speed : 3000 min^{-1} (rpm)]

$Q_1 = Vh \times N \times C \times \eta \times k \times 10^{-3}$

Vh = 0.325 lit

N = 3000 min^{-1} (rpm)

C = 0.5

η = 0.87

k = 1.0

$Q_1 = 0.325 \times 3000 \times 0.5 \times 0.87 \times 1.0 \times 10^{-3}$

$= 0.424\ m^3/min$

4. INTAKE RESISTANCE

Resistance of the intake system is caused by the air cleaner and intake piping. This resistance must be kept below a certain point. To prevent decreases of engine output performance, this resistance must be held within the following reference sheet ;

.

Engine model series	Initial limit w/clean filter	Limit w/dirty filter
	(mmAq)	(mmAq)
	NA	NA
OC	150	300
EA		

Note :

1) The intake restriction is the total system limit.

2) The restriction must be measured as close to the intake manifold (or turbo inlet) as possible to properly measure the entire system restriction.

3) Intake restriction must be measured at the location that is not affected by pulsation.

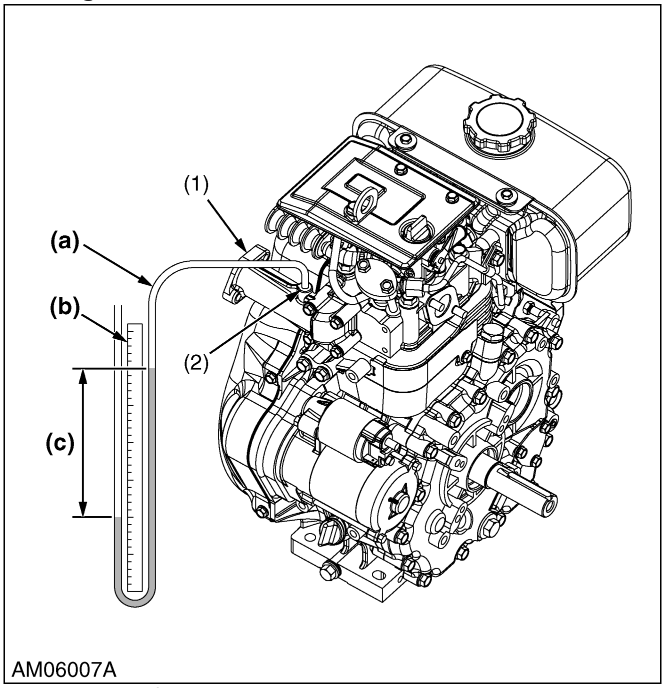
4) For naturally aspirated (NA) engines, conduct the restriction test at full throttle, high Idle condition no load.

5) The application check must be performed at the Initial limit with clean filter condition.

6) If OEMs mention the restriction values on their operator manuals for service interval, refer to the above sheet (Limit w/dirty filter).

The intake piping should be made of a high quality compounded rubber with exceptional resistance to aging, oil and cold to reduce chances of cracking during operation.

OC engine

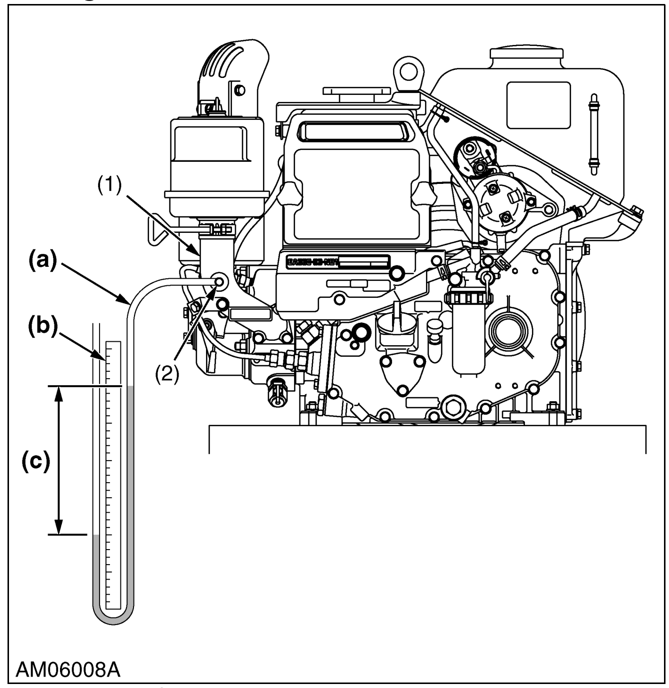


(1) Air cleaner flange
(2) Intake resistance measurement point

(a) U tube I.D. 6 mm (0.24 in.)
(b) Scale mm or in.
(c) Intake resistance measurement value

Fig. 6-7 Intake resistance measurement point

EA engine



(1) Air cleaner flange
(2) Intake resistance measurement point

(a) U tube I.D. 6 mm (0.24 in.)
(b) Scale mm or in.
(c) Intake resistance measurement value

Fig. 6-8 Intake resistance measurement point

Note :
Intake resistance measurement point should be close to intake manifold.

7. EXHAUST SYSTEM

CONTENTS

EXHAUST SYSTEM

1. GENERAL

An engine's exhaust system must be able to freely discharge all high temperature exhaust gas after combustion to the outside air.
Exhaust resistance must be as low as possible in order to prevent a decrease in power, however exhaust noise must be kept at an acceptable level. Careful design is required to reconcile these two conflicting factors.

Exhaust gas from the exhaust manifold can either be directly fed into the muffler or routed to a place which will not interfere with the operator by exhaust pipe. The most important point in all cases is to reduce back pressure to a minimum.

2. LIMITATION OF PERMISSIBLE BACK PRESSURE

If OEM uses their original muffler they should keep the following back pressure.
Position to measure back pressure is at the outlet of exhaust manifold. Use a manometer to measure it. Refer to Fig. 7-1 and Fig. 7-2

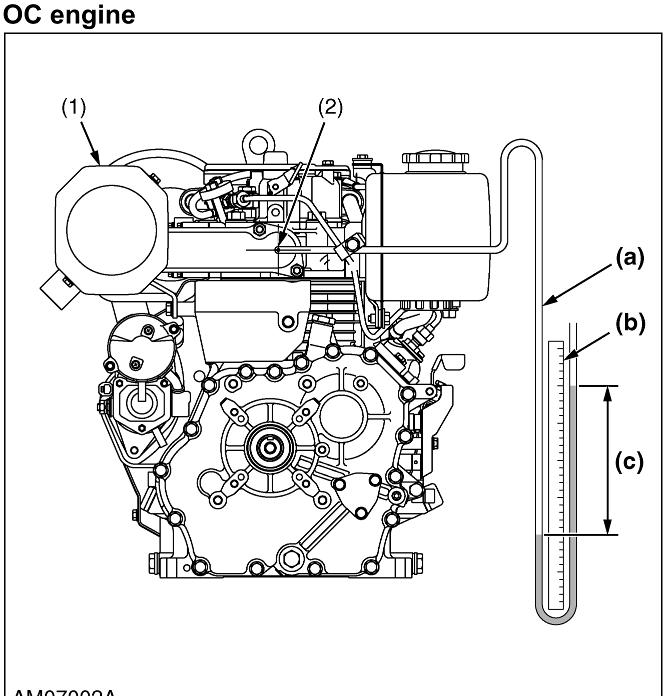
Unit : kPa (mmHg)

Back Pressure	
OC	4.7 (35) or less
EA	

Note :
Back pressure to be measured at rated rpm and load.
Generally speaking,

- Back pressure increases as engine speed increases. Increase in back pressure varies with muffler construction.
- Mufflers with higher back pressures have larger output loss. (approximately 5%)
- Back pressure increases as exhaust piping has many bends, longer length, many restrictions and smaller muffler volume.

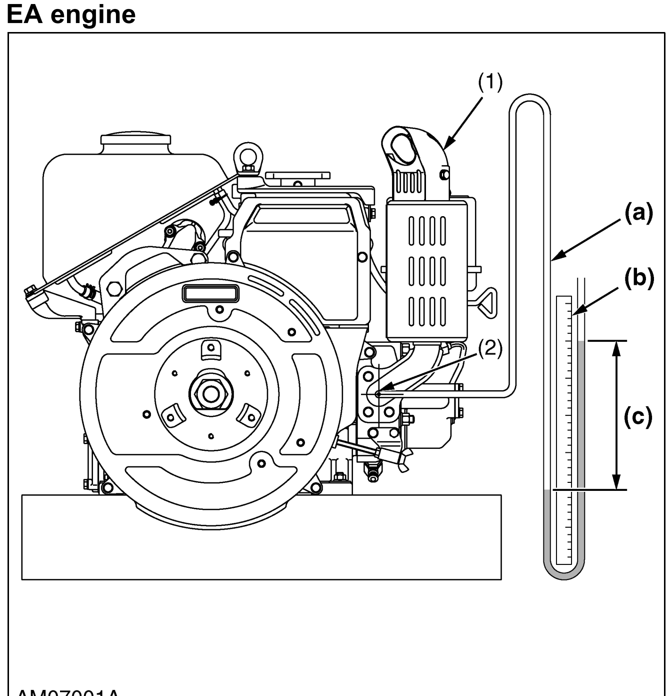
OC engine



(1) Muffler
(2) Back pressure measurement point
(a) U tube I.D. 6 mm (0.24 in.)
(b) Scale mm or in.
(c) Intake resistance measurement value

Fig. 7-1 Back pressure measurement point

EA engine



(1) Muffler
(2) Back pressure measurement point
(a) U tube I.D. 6 mm (0.24 in.)
(b) Scale mm or in.
(c) Intake resistance measurement value

Fig. 7-2 Back pressure measurement point

3. CALCULATION OF BACK PRESSURE

Back pressure is decided in accordance with resistance of muffler and exhaust pipe (length, pipe diameter, number of bend and bending radius) and gas volume. Back pressure can be determined by the following formula.

1) Gas volume and resistance

a) Gas volume and speed

$\nu = [VE / (\pi \times D^2/4)] \div 3600$

VE : Gas volume (m^3/hr)
(See attached TECHNICAL DATA)
ν : Gas speed (m/s)
D : Internal diameter of exhaust pipe (m)

b) Resistance

● Straight pipe (resistance per one meter)⊿P (mmAq)

$\triangle P = \lambda \times (L / D) \times (\gamma \times \nu^2) / (2 \cdot g)$

L : Pipe length = 1m
D : Inside diameter of pipe (m)
γ : Specific gravity of gas at 673 K { 400 °C (752 °F) } 0.5 (kg/m^3)
ν : Gas speed (m/sec)
g : 9.8
λ : Friction coefficient = 0.030

● Elbow (resistance per one elbow) ⊿P' (mmAq)

$\triangle P' = \zeta \times \gamma \times \nu^2 / 2 \cdot g$

ζ :Short elbow = 0.51
Long elbow = 0.36

Result of calculations by the above formula are on next page (Fig. 7-3)

2) Resistance of mufflers (PM)

3) Total resistance (P)

$P = \triangle P \times L + \triangle P' \times N + PM$

L : Pipe length (m)
N : Number of elbow

4. MUFFLER

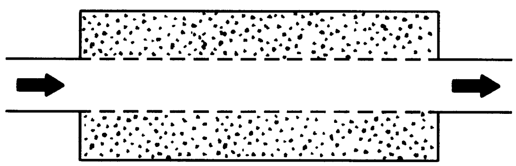
High temperature and high pressure exhaust gas is intermittently discharged by fuel combustion, generating pressure waves inside the exhaust pipe which results in noise.

Mufflers are used to reduce this noise. There are three major types of mufflers described.

Muffler types :

● Absorption type

A perforated pipe is surrounded by glass fiber and other noise absorbing materials.

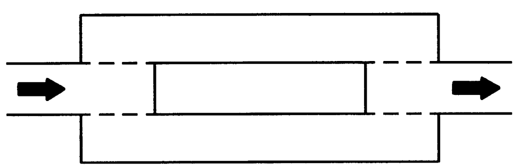


AM07003A

● Expansion type

Exhaust gas is discharged into an expansion chamber from the exhaust pipe to diffuse the noise.

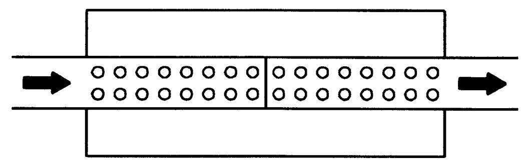
This type comes with either a single or multiple expansion chambers.



AM07004A

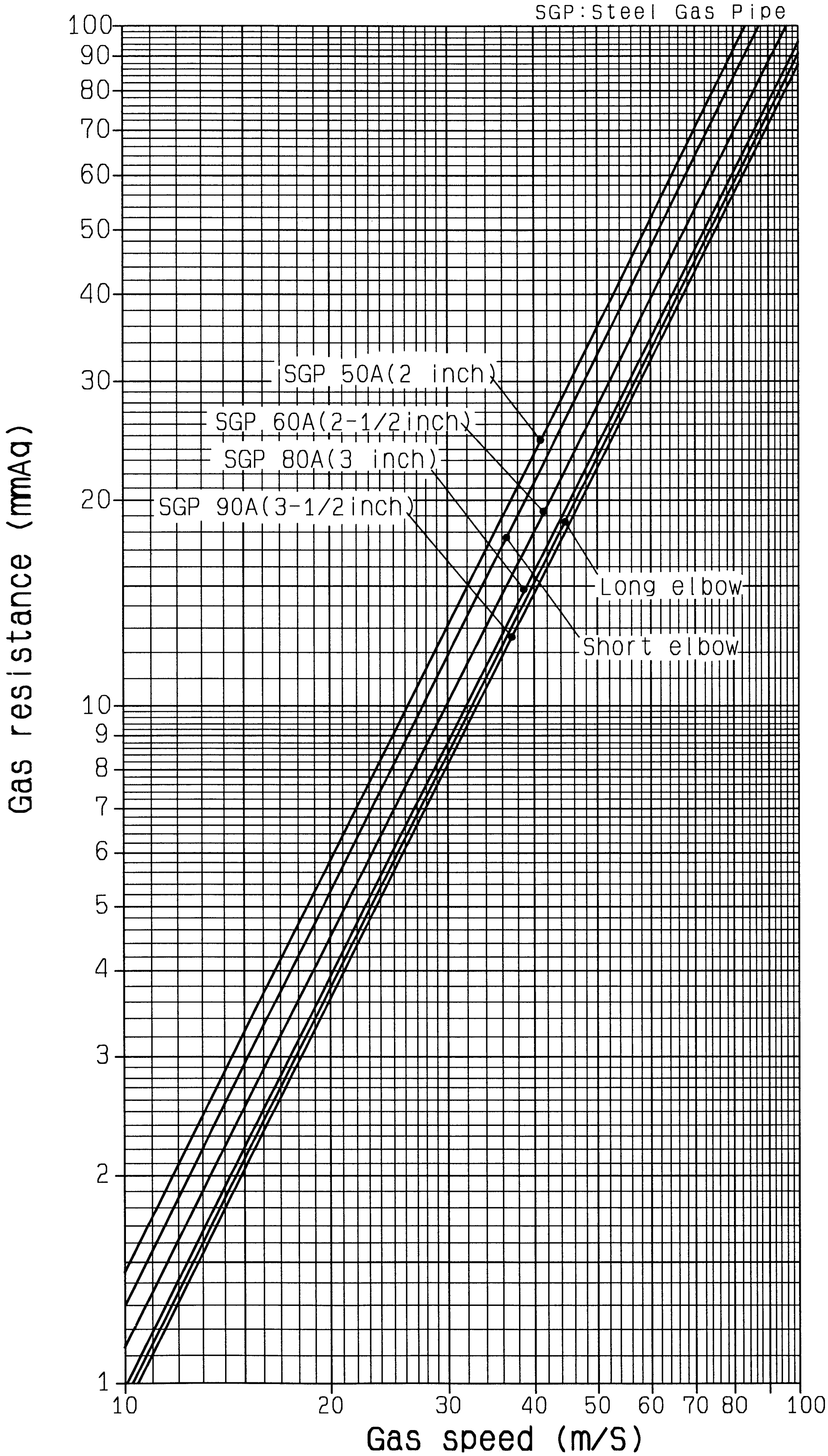
● Dispersion type

Noise is muffled by changing the direction of the gas flow.



AM07005A

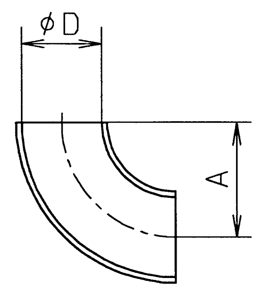
Rough estimate chart of exhaust gas resistance on straight pipe and elbow



Elbow dimensions

(mm)

	Short elbow φD	Short elbow A	Long elbow φD	Long elbow A
2 inch	52.9	50.8	52.9	76.2
2-1/2 inch	67.9	63.5	67.9	95.3
3 inch	80.7	76.2	80.7	114.3
3-1/2 inch	93.2	88.9	93.2	133.4



AM07006A

Fig. 7-3

There are many cases when combinations of these three kinds are used. The size of a muffler should generally be four or six times more than engine total displacement. This will vary according to length of exhaust pipe, type of muffler and purpose. Tests are required to determine the optimum arrangement.
When designing an exhaust system, exhaust direction and the high temperature of the pipes must be carefully considered for safety avoiding key engine parts, such as fuel piping and wiring are necessary when enclosing a muffler in an engine room or soundproof case. Air flow must be taken into consideration to keep the temperature inside as low as possible.

Other precautions

1) When directing the exhaust port upwards, rain will enter. Therefore, a snap-open cap at the top or a small drainage hole on the bottom of manifold must be provided.
2) If the muffler and exhaust piping are mounted on the machine body itself, a heatproof flexible pipe must be installed between the engine and the muffler. External piping must be isolated from vibration.
   Muffler must be held by additional stay from the engine in order to prevent a crack or break in the exhaust manifold or muffler itself.
3) Refer to the list of optional parts to arrange exhaust manifold outlets and directions of discharge.

8. COOLING SYSTEM

CONTENTS

COOLING SYSTEM

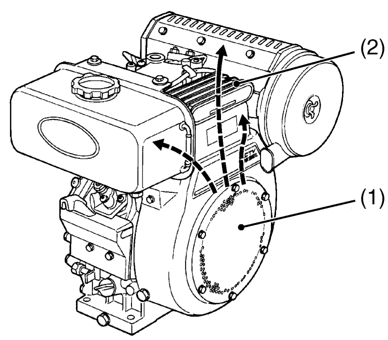
1. GENERAL

Heat generated inside the combustion chamber during combustion and heat generated by friction of moving parts is removed by the cooling system to allow continuous operation in the proper range.

OC engine

OC engine cooling system comes in two way. The cylinder block is air-cooled, whereas the combustion area of the cylinder head is oil-cooled. Air sucked by the flywheel fan is accelerated in the spiral casing (2) to cool down the cylinder liner as well as the oil cooler (1) located atop the spiral casing. The lubricant cooled by the oil cooler, on the other hand, flows through the return opening of the cylinder head and back to the crankcase. The trochoid pump works to force the lubricant to the cylinder head again to cool the combustion system around. The lubricant finally comes back to the oil cooler. This series of actions is repeated while the engine is running.

OC engine



AM08002A

(1) Oil cooler (4) Spiral casing

Fig. 8-1

EA engine

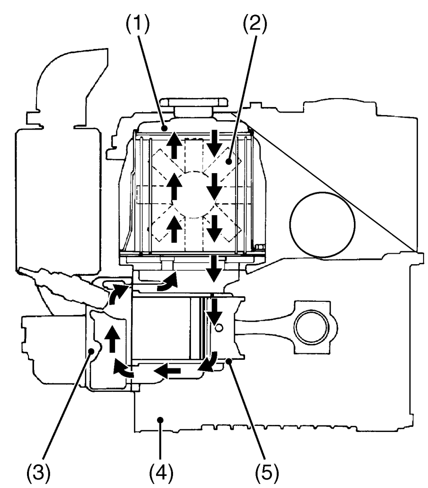
EA engine employ a pressurized radiator natural convection cooling system.

Cooling by the radiator (1) and radiator fan (2) increases in specific gravity. And it absorbs combustion heat of the cylinder liner (5) and cylinder head (3) and friction heat generated from moving parts to cool them.

Then, cooling water moves upward, as the water absorbs heat and decreases in specific gravity.

The heated water is cooled again by the radiator. Thus, the cooling water circulates naturally to cool the engine.

EA engine



AM08001A

(1) Radiator (4) Cylinder block
(2) Radiator fan (5) Cylinder liner
(3) Cylinder head

Fig. 8-2

2. RADIATOR (EA only)

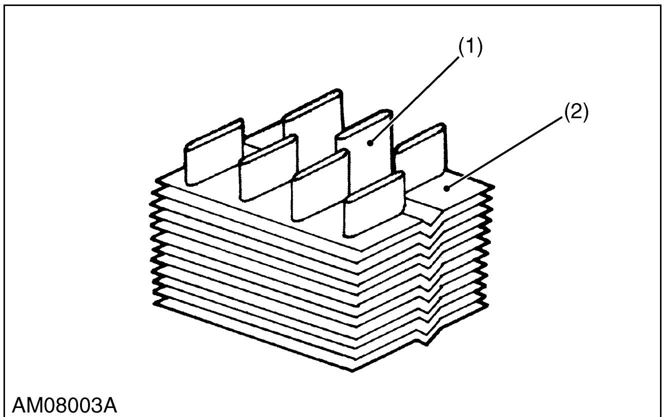
[1] GENERAL

EA engine radiator adopted is of a plate find type which is durable and resistant to pressure, and has good heat transfer proper ties. As it passes through the radiator core, it is cooled by air from outside, and is again circulated to the engine body.

The radiator core is composed of a tube (1), through which water flow, and cooling fins (2). Both of the components are formed of thin copper plate, etc. which gives good heat transfer. Cooling air passing between the fins helps cooling water in the tube to give off heat.

EA engine's standard radiator, pressurized cooling water inside the radiator is kept less than 108 kPa (1.1 kgf/cm^2, 15.6 psi) by the radiator cap.

This radiator cap has no gasket for coolant recovery tank, so coolant recovery tank can not be installed in EA engine's standard radiator without change of radiator cap. In case of using recovery tank, radiator cap must be changed to the type of opening pressure 88 kPa (0.9 kgf/cm^2, 12.8 psi) with gasket for coolant recovery tank.



(1) Tube (2) Cooling fin (Waved plate fin)

Fig. 8-3

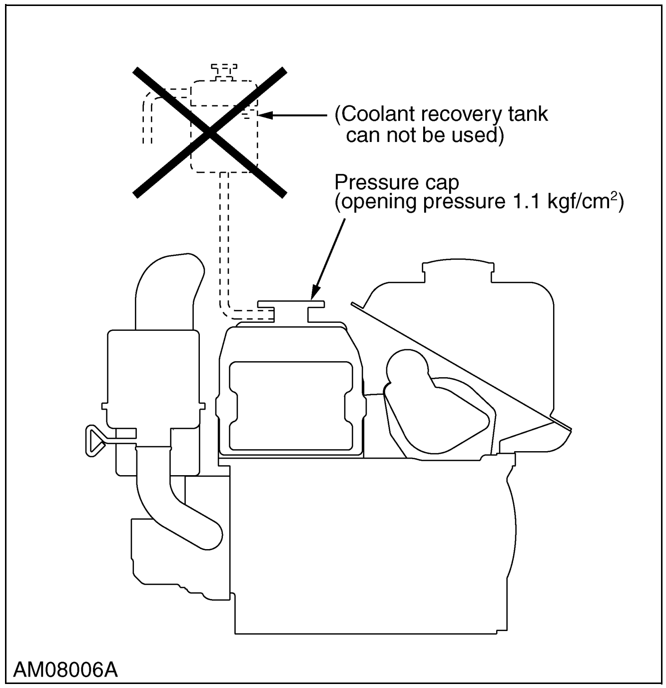


Fig. 8-4

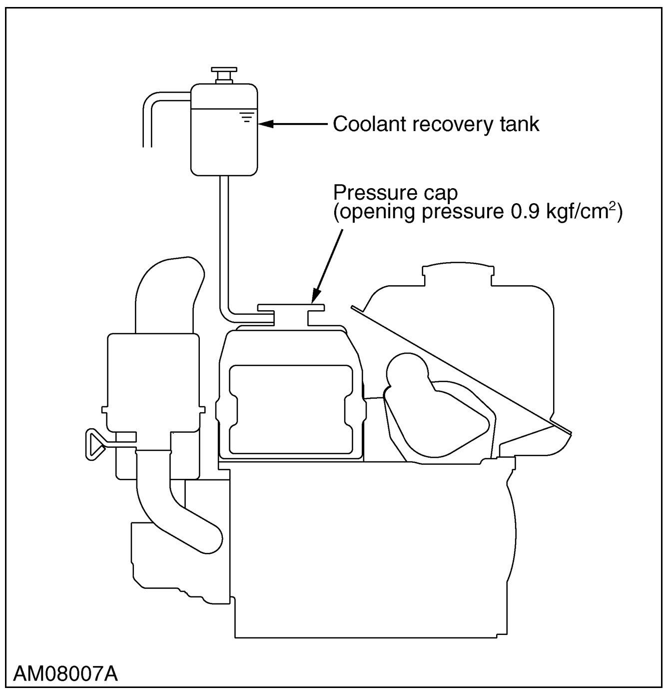


Fig. 8-5

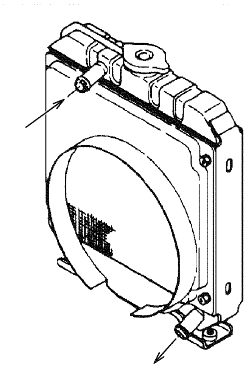
[2] WHEN USEING RADIATOR SEPARATELY FROM THE ENGINE

Customer will need to procure a commercially available radiator for EA330-E3-NB1-APU-2.
Please pay attention to the following directions for the radiator choice and installation to ensure serious damage is not caused to the engine.

1) Choose a radiator that has the sufficient performance to cool the engine.
2) Choose a radiator that is appropriate for the environment that the engine is to work in.
3) Install a radiator in an appropriate place and in a way as not to be effected by vibration.

The following information is the radiator characteristics.

★ **Down flow radiator (Conventional)**



AM08004A

Fig. 8-6

★ **Cross-flow radiator**

In a cross-flow radiator the coolant passageways travel horizontally rather than vertically. Another feature of the cross-flow radiator is that the inlet and outlet tanks are located on the sides of the radiator, rather than on top and bottom. This allows for a "low profile" cooling system.

These radiators offer a compact cooling system, but special attention must be given to key issues associated with a cross-flow radiator.

[3] PIPING

(1) Cooling system fill

a) A cooling system should be designed to provide complete filling of the engine, piping, and radiator without air pockets in the system. Due to the nature of the cross-flow radiator design, this can be very difficult.
b) Even with a standard coolant recovery bottle, removing this air can require several warm-up and cool-down cycles.
c) Only cooling system with a pressurized recovery tank will allow proper and quick de-aeration.

(2) De-aeration capability

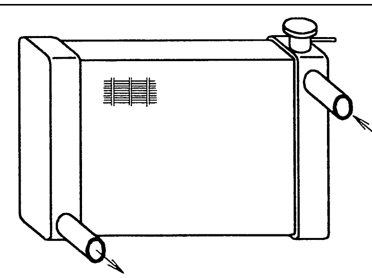
a) De-aeration capability is the ability of a cooling system to get rid of air and gasses entrapped in the cooling system. Air can be introduced into the system during fill or during normal operation.
b) A properly designed down-flow radiator has a top tank with a baffle. The area above the baffle serves as space to isolate entrapped air from the coolant.
c) A cross-flow radiator has no method of separating the entrapped air from the coolant causing the air to constantly be drawn back into the system. Constant splashing as coolant enters the tank causes air and coolant to mix, allowing the cooling system to draw the air in.

* Air retained in the cooling system can cause "hot spots" in the engine, particularly the cylinder head. It can also reduce cooling capacity and possibly cause cavitations of the water pump.

(3) Drawdown capability

a) Drawdown capability is the ability of a cooling system to correctly function with a given amount of coolant loss.
b) Cross-flow radiators do not provide drawdown capability during operation, Even With A Standard Coolant Recovery Bottle.

* Only at cool-down will coolant from the recovery bottle be allowed back into the radiator.



AM08005A

Fig. 8-7

[4] RADIATOR POSITION

(1) Basic type

The standard specifications of EA employ the radiator of pressurized radiator natural convection type, therefore the radiator position cannot be changed. Accordingly, when the radiator position needs to be changed, an electric-fan type radiator must be used.

(2) EA330-APU-2

When mounting EA330-APU-2, use an electric fan.
EA engine's standard radiator position is shown below.

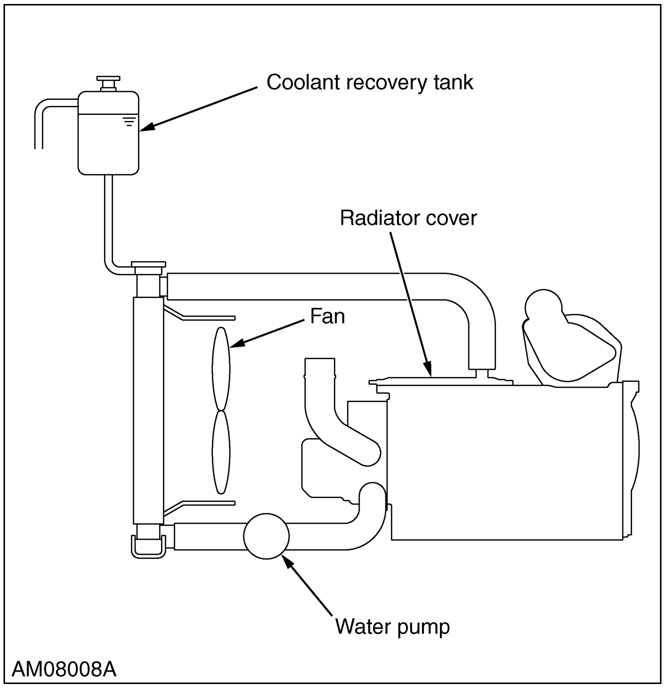


Fig. 8-8

(3) Distance between fan and radiator core

Clearance between fan and radiator core should be kept as far as possible, within the space limitation in radiator mounting.
If the clearance between fan and radiator core cannot be maximized due to lack of space, it should be more than 25 mm (1 in.).

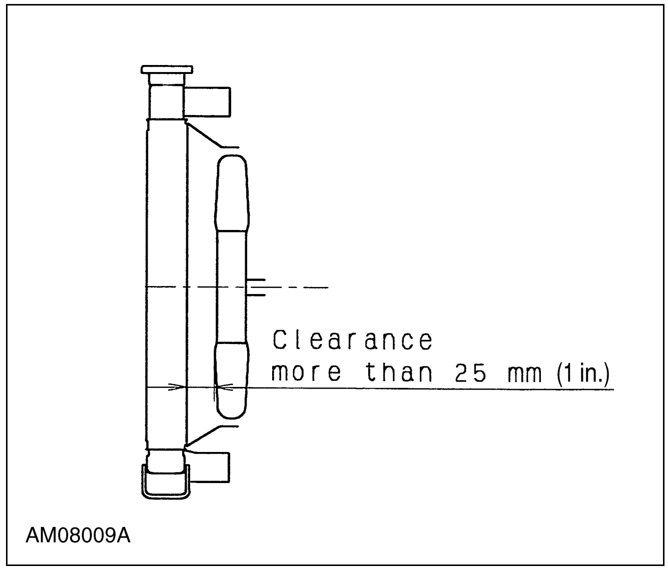
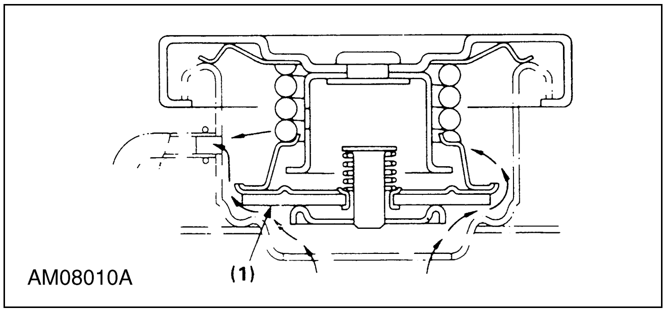


Fig. 8-9

[5] RADIATOR CAP

Pressure inside a radiator is slightly higher than atmospheric pressure and is regulated by the radiator cap.
[EA engine's radiator cap opening pressure is less than 108 kPa (1.1 kgf/cm^2,15.6 psi)]

【Function of Radiator Cap】
(1) When internal pressure is high

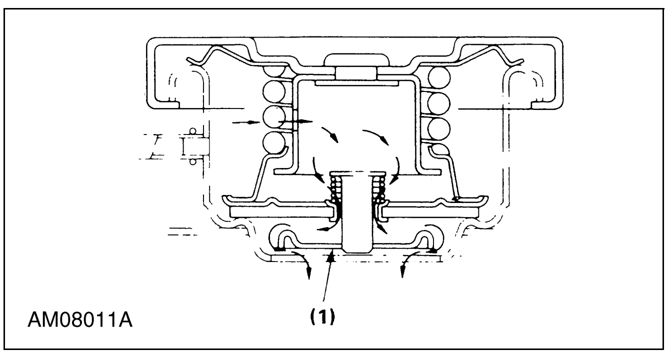


(1) Pressure valve

Fig. 8-10 When radiator internal pressure is greater than 108 kPa (1.1 kgf/cm^2, 15.6 psi)

When temperature in the radiator increases, the coolant volume increases proportionally. This, combined with steam generation, may cause the internal pressure to rise up to 108 kPa (1.1 kgf/cm^2, 15.6 psi). The pressure valve opens, allowing coolant to escape and preventing rise in pressure. This protects the radiator.

(2) When radiator internal pressure is lower than atmospheric pressure



(1) Vacuum valve

Fig. 8-11 When radiator internal pressure is lower than atmospheric pressure

When coolant temperature drops, coolant volume decreases, reducing internal radiator pressure to below atmospheric pressure.
The vacuum valve opens, equalizing radiator internal pressure and atmospheric pressure, protecting the deformation of radiator.

(3) Electric fan

Use of electric fans on vehicles for radiator cooling has been increasing recently.
These fans turn at a constant speed regardless of engine speed.
However, in cases where cooling air is not enough due to insufficient vehicle velocity, the cooling effect on engine body, oil pan, etc is sometimes less than that of a direct-driving fan.
For this reason, cooling capacity and air flow around the engine must be examined and thorough tests conducted after the engine is installed.
Also, care must be taken to the capacity of alternator since the DC motor drives the fan.

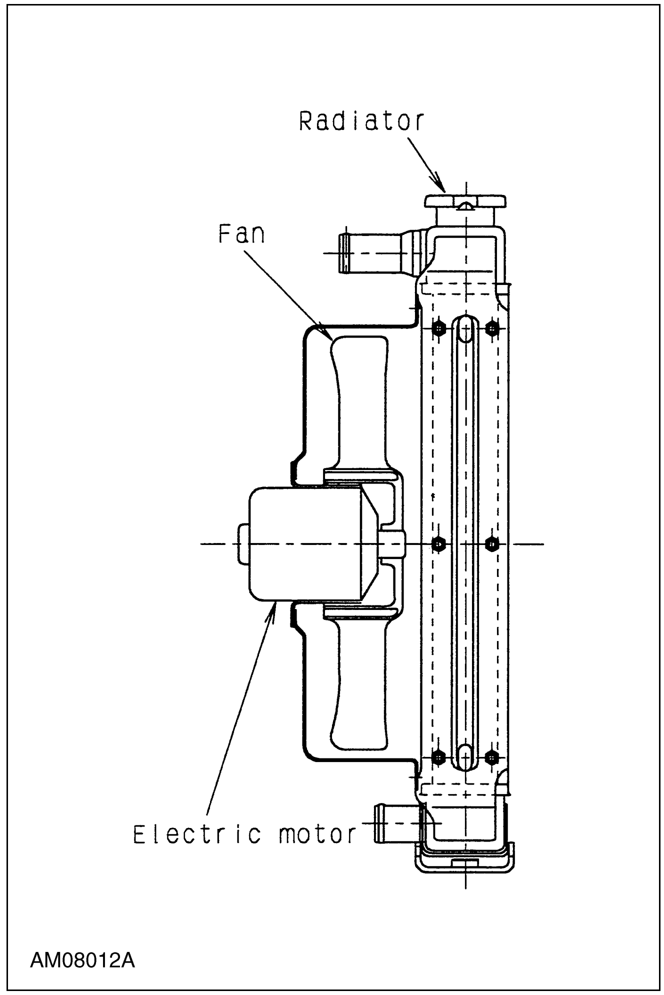


Fig. 8-12

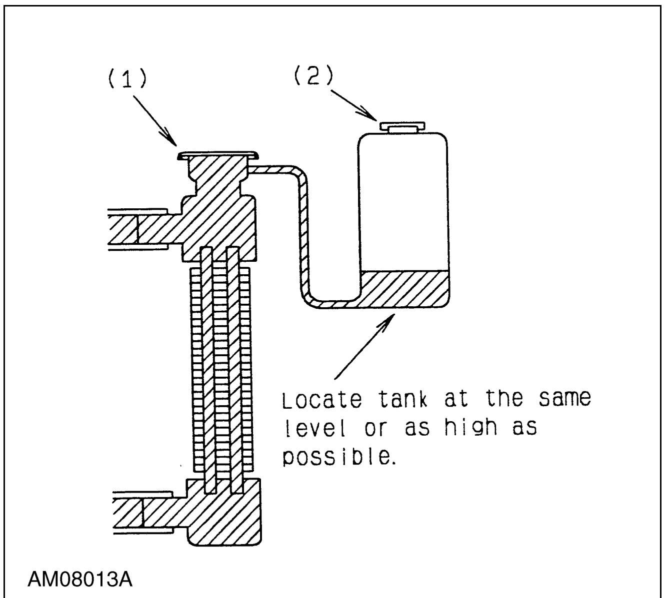
Great care should be taken in the selection of temperature switches and the use of fan relay switches to ensure positive switch relay function.

3. COOLANT RECOVERY TANK

The following benefits are provided by installing a coolant recovery tank independently to the radiator.

1) The radiator is always completely full which prevents entrance of air into the cooling system.
2) Any coolant overflow due to heat expansion is transferred to the coolant recovery tank and returns to the radiator when the temperature lowers. This eliminates coolant waste and the need to add coolant periodically.
3) Coolant is replenished to the coolant recovery tank only. Maintenance can be done easily if coolant level is visible.

【Types of coolant recovery tanks】
1) Semi-sealed type : An open-air type with slight natural evaporation of coolant, but low cost.
2) Actual capacity of a coolant recovery tank should be sized more than about 10% of total cooling system capacity.



(1) Cap with pressure valve (2) Cap with air bleed

Fig. 8-13 Semi-sealed type

4. OIL COOLER

OC engine's oil cooler consist of oil carrying tubes and fins. Heat of heated oil in the tubes is radiated from the tube walls and fins. Kubota's engines are of louvered corrugated fin type, featuring light weight and better cooling/radiating effect.

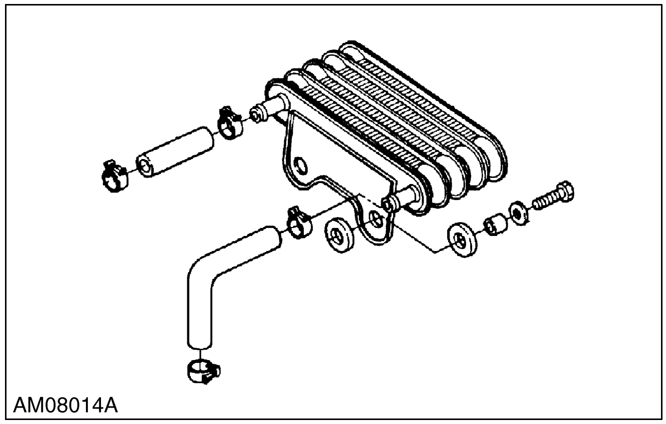


Fig. 8-14

5. HEAT REJECTION TO COOLANT (EA only)

The amount of cooling loss, which can be dispersed by coolant in an engine is expressed as follows :

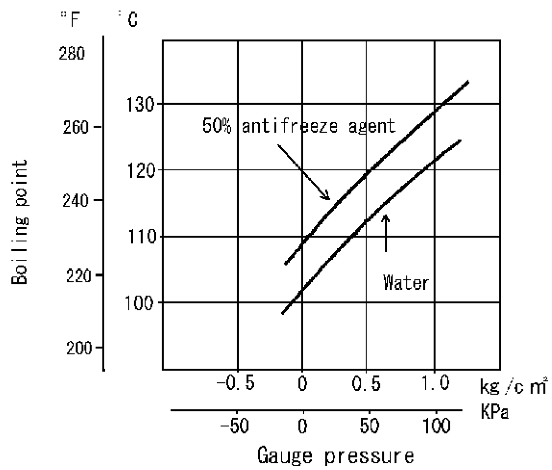
Ho = Hu × Ne × be × i/1000
The amount of heat dispersion by coolant of each engine is in accordance with attached TECHNICAL INFORMATON.
where as ; Ho : Amount of heat dispersion by cooling water (cooling loss) kJ/hr (kcal/hr) be : Specific fuel consumption (gr/kW•hr) i : Dispersion ratio to cooling water (%) Hu : Diesel fuel low caloric value 43074 kJ/kg (10290 kcal/kg) Ne : Engine output (kW)

6. RADIATOR CAPACITY

(1) General

Generally, water at atmospheric pressure boils at 100 °C (212 °F).

As the pressure inside the radiator is raised higher than the atmospheric pressure, the boiling point is also raised, and thereby the coolant temperature in the radiator can be kept lower than the boiling point, thus preventing eventual cavitation inside the pump.



AM08015A

Fig. 8-15 A boiling point of water at different pressures

Boiling point of coolant

Rad. cap pressure	% of water /antifreeze	Boiling point	
		°C	°F
0 kPa {0 kgf/cm^2 (0 psi) }	100% water	100	212
	50/50	108	226
88.2 kPa {0.9 kgf/cm^2 (13 psi) }	100% water	118	244
	50/50	126	259

(2) Determination of a radiator size

The final determination of a radiator size is dependent on the load, ambient temperature and whether the engine is in a compartment or not, always select a larger radiator if a severe condition exists.

1) Factors of radiator size determination

[Operating condition]

Ambient temperature ⇒ Will the engine be open to the air or enclosed ?
Ambient pressure ⇒ Will the engine be used at high altitudes ?
Ambient humidity ⇒ Will the engine be used in extremely dry areas ?
Dust conditions ⇒ Will dust adhere to radiator surface ?
Movement of vehicle ⇒ Will the engine be installed in a moving vehicle ?
Load pattern ⇒ Will overloads be applied frequently ?
Cooling ⇒ Will the oil and/or hydraulic system also be cooled ?

[Construction]

Cooling water ⇒ How is it sufficient ?
Air flow ⇒ Is surrounding air normally still ?
Type of radiator ⇒ Is it readily available ?
Space ⇒ How much space is available for radiator installation ?

2) Step of radiator specification determination

1) Determine heat load.
2) Determine overheating limit
3) Determine specifications of cooling system.

7. COOLANT (EA only)

Quality of coolant is an important factor.
Cooling is adversely affected by corrosion of engine parts. This can reduce engine output and shorten engine life.

(1) Nature of water

Water is used for cooling since it absorbs heat well and is readily available. Coolant boils at 100 °C (212 °F) freezes at 0 °C (32 °F) and has other disadvantages such as a tendency to leave deposits and corrode metal parts.
These disadvantages can cause cooling system problems. Special measures, such as those listed below, are required :

a) Raising of the boiling point by pressurizing the cooling system (Radiator cap) and using antifreeze.
b) Lowering the freezing point by using antifreeze.
c) Selecting water carefully and using a rust preventive.
d) Don't use hard water.

(2) Deposits and rust

Deposits (scale) can be generated wherever water exists and can accumulate easily in the cylinder block and cylinder head where temperature is consistently high and where the radiator temperature varies greatly. Deposits will take the form of brown and sticky tar, and have very poor thermal conductivity. Accumulated deposits restrict water circulation and reduce the overall cooling effect.
Rust, on the other hand, is gathered on metal parts and restricts water circulation if left untreated.
Rust also lowers the overall cooling effect (like deposits), because it has poor thermal conductivity. Rusted metal surfaces become rough and pitted. Metal pieces can become scaled and thick and lose their strength, causing cracks or fatigue failure.

(3) Grade of water

Clean soft water should be used for the cooling system. Distilled water, tap water, and pure rain are especially recommended. Natural water generally contains minerals and sometimes salt, which can oxidize metal and accelerate corrosion. On the other hand, hard water is liable to create deposits more quickly. If impure water has to be used for cooling, completely flush the cooling system and add a rust preventive.

8. FREEZING AND ANTIFREEZE COOLANT (EA only)

(1) Freezing of coolant

Water freezes at 0 °C (32 °F), and its volume expands approximately 9%. This expansion force is so great that water loses its fluidity. When the cooling water freezes in the cooling system, expansion can crack the engine and radiator or lead to other damage.

(2) Major components of antifreeze coolant

Freezing temperature is lowered to prevent the freezing of coolant by adding ethylene glycol, etc..

★ Ethylene glycol
Ethylene glycol has no odor, will not evaporate and will not affect paints and coatings. It has a high boiling point, and can be used along with an anti-corrosive agent in the summer.

(3) Types and characteristics of antifreeze coolant

KUBOTA recommends the use of ethylene glycol base antifreeze coolant of permanent type which is most commonly used.

★ Characteristics of permanent type antifreeze coolant

【Characteristics of antifreeze】

Main components	Ethylene glycol
Specific gravity 20 °C (68 °F)	Above 1.12
Boiling point	145 °C (293 °F)
Flash point	Flame retardant but burns
Hygroscopicity	Very easily absorbs humidity
Freezing of undiluted solution or mixture	Freezes sometimes below -20 °C (-4 °F)

【Characteristics during use】

Boiling point	100 to 113 °C (212 to 235.4 °F)
Evaporation of main components	Small evaporation
Boiling of during operation	No

(4) Caution in using antifreeze coolant

1) Never use poor quality antifreeze coolant

The main components of the antifreeze coolant can corrode metal, gathering rust in the cooling system over an extended period. Corrosion is caused by acids and various kinds of additives which are used to neutralize them. Some additives give the cooling water alkaline properties that can rapidly corrode light metal.
Poor quality antifreeze has poor content of corrosion preventive. The content further becomes less potent with the dilution of water.
For this reason, poor quality antifreeze accelerates metal corrosion.

2) Do not use antifreeze for extended periods

Except for quality permanent antifreeze coolant which does not require replacement for a long time. Drain the antifreeze coolant mixture when it is not in use and flush the cooling system.
Use of antifreeze coolant for an extended time can result in increased corrosion within the cooling system.

3) Use permanent type ethylene glycol antifreeze coolant when temperature of coolant exceeds 100 °C (212 °F).

4) Completely cover the container since the undiluted solution is hygroscopic.

5) Undiluted solutions of permanent type can freeze below -20 °C (-4 °F) in some cases, so watch the temperature carefully.

6) Never drink antifreeze coolant, because they are poisonous.

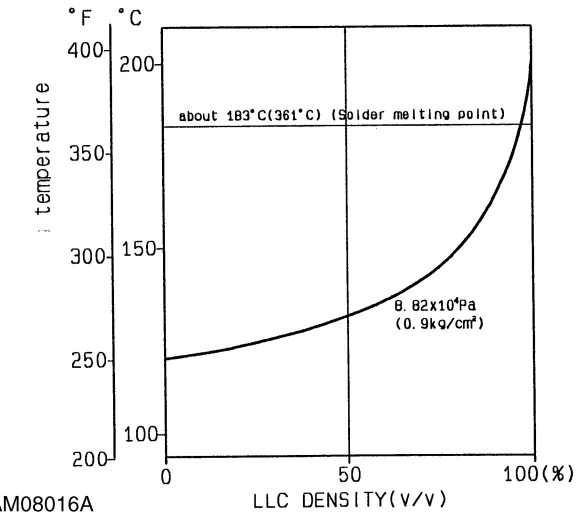
7) Do not spill antifreeze coolant over painted surfaces since they may dissolve paint.

(5) Dilution rations

Always use a 50/50 mix of ethylene glycol coolant in KUBOTA engines.
Contact KUBOTA concerning coolant for extreme conditions.

When the density becomes too high, the boiling point rises and the solder strength lowers, resulting in a dangerous situation. The following drawing shows the relation between the boiling point and density.

★LLC Density and Boiling Point



AM08016A

L.L.C : Long Life Coolant

(6) Adding antifreeze coolant

1) Completely drain the cooling water and flush the cooling system.

2) Check for leaks or loose connections at the radiator, cylinder head gasket, drain cock, etc..

3) Mix antifreeze coolant and water at the specified ratio before pouring into engine.

4) For replenishment, add 50/50 mix to cooling system for permanent types.

Note :
If antifreeze and water are not mixed thoroughly, before putting into the engine, hot spots may develop leading to engine overheating.

9. ELECTRICAL SYSTEM

CONTENTS

ELECTRICAL SYSTEM

1. GENERAL

A typical electrical system is shown in Fig.9-1.

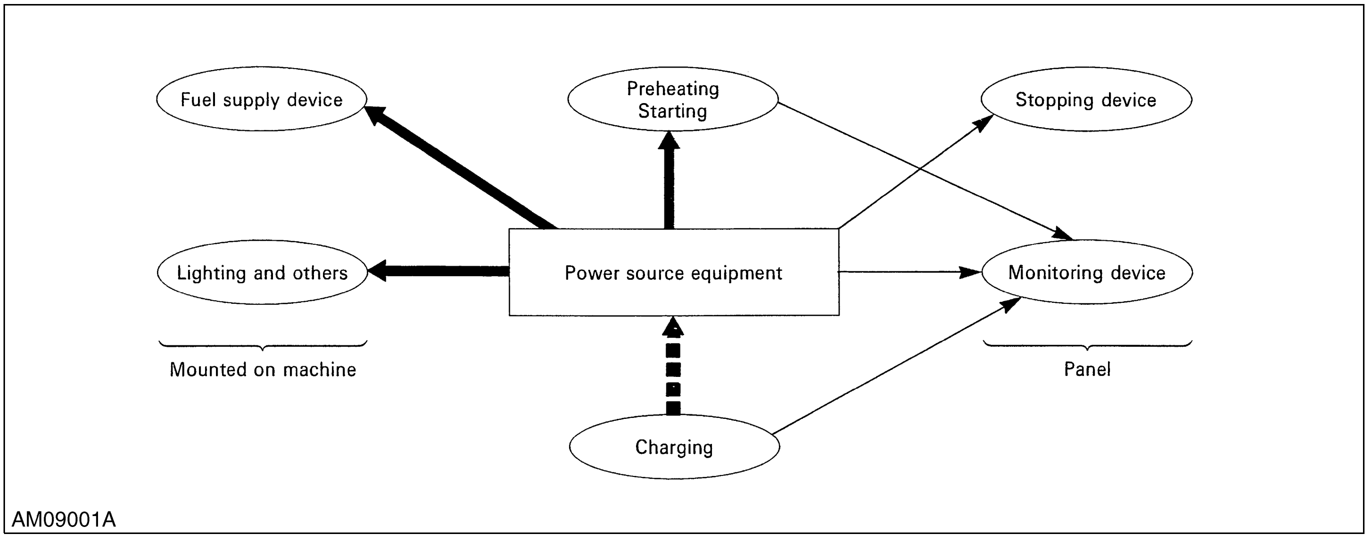


Fig. 9-1

An electrical system consists of starting equipment, such as a starter and glow plug ; charging devices, such as an alternator, regulator, and battery ; and indication and control equipment, such as an oil switch, water temperature switch, glow plug indicator, timer and starter switch.

2. STARTING DEVICE

[1] GENERAL

The starting device is composed of the starter, starter switch, glow plug, slow blow fuse, battery, glow lamp timer, etc., and the outline of the basic operation is as the followings ;

1) Voltage from battery is added to the B terminal of starter switch through the slow blow fuse.
2) If the starter switch is turned on, B terminal will be connected to AC, and the electrical current will flow to each load.
3) If the starter switch is turned to preheating, B terminal will be connected to AC and 19, making the glow plug heat, and at the same time lighting the glow lamp, and the lamp will be turned off by activation of the lamp timer after 5 seconds.
   Even if glow lamp is turned off, when the starter switch is either in the preheating position or starting position, the glow plugs will remain heating.
4) If the starter switch is turned to the starting position, B terminal will be connected to AC, 19, and 50 will be connected to the ST terminal of starter to start the engine.
5) After the engine is started, if you have let your hand off the starter switch, it automatically returns to ON position.

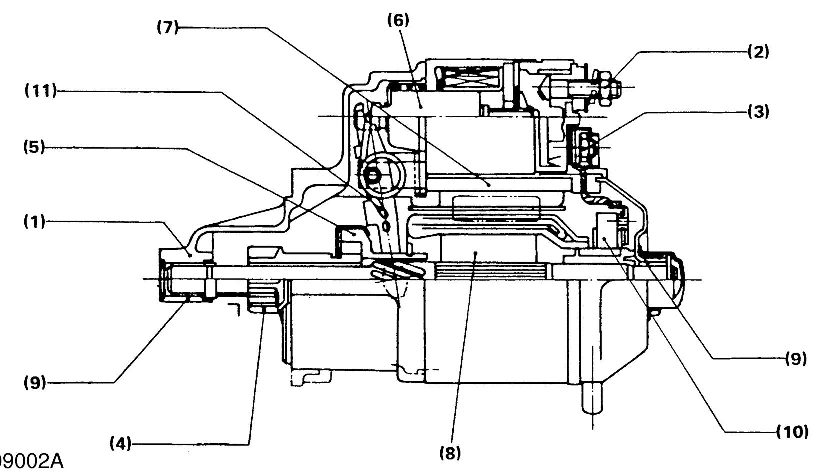
[2] STARTER

The function of starter is to rotate the engine with the speed higher than the minimum rotation speed required to start the engine.
Particularly in the diesel engine of which compression ratio is high, small-sized and powerful starters are required, and for this purpose, the direct-current / direct-winding type, which can produce powerful rotation force when the rotation speed is still low, is suitable.
However, compared with other electric motors the size of this type is small and the weight is light, in proportion to its large output resulting in a short usage time (rated time : 31 sec.).

(1) Types of starter

1) Conventional type (OC60, EA330)

This type is provided with the magnet switch with terminal, and the pinion made of carbonized materials and the overrunning clutch (roller clutch) to prevent overrun of the armature after starting.

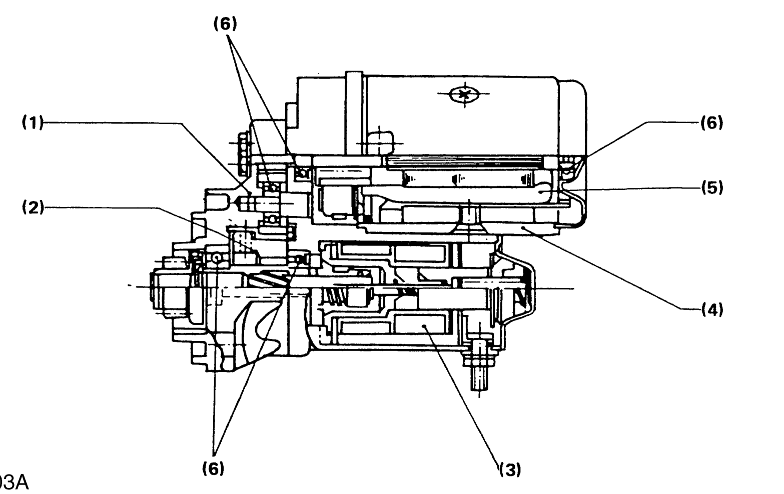


(1) Drive side housing
(2) B terminal
(3) S terminal
(4) Pinion
(5) Overrunning clutch
(6) Solenoid
(7) Yoke
(8) Armature
(9) Bearing
(10) Brush
(11) Drive lever

Fig. 9-2 Conventional type

2) Reduction type (OC95)

This type drives the pinion reducing the speed of the small-sized high-speed large-output motor by 1/3 to 1/5, so that the motor can be made smaller and lighter. The starter is made lighter by using aluminum die cast metal, and in addition, there is no exposure of the pinion sliding surface and waterproofing is improved.



(1) Drive side housing
(2) Overrunning clutch
(3) Solenoid
(4) Yoke
(5) Armature
(6) Bearing

Fig. 9-3 Reduction type

(2) Circuit of the starter

1) When the starter switch is turned to start position:

a) If the starter switch is turned to start position, electrical current will flow to holding coil (H.C) and pulling coil (P.C), and it will excite the 3 coils, and suck the plunger.
Consequently, the pinion gear will move out to the fly wheel side, and the ring gear and pinion gear will be intermeshed.

b) Electrical current will also flow to the armature from P.C, and it will remove the load in the initial stage of armature rotation.
(If the armature is slightly rotated, it will facilitate intermesh of the pinion gear and ring gear.)

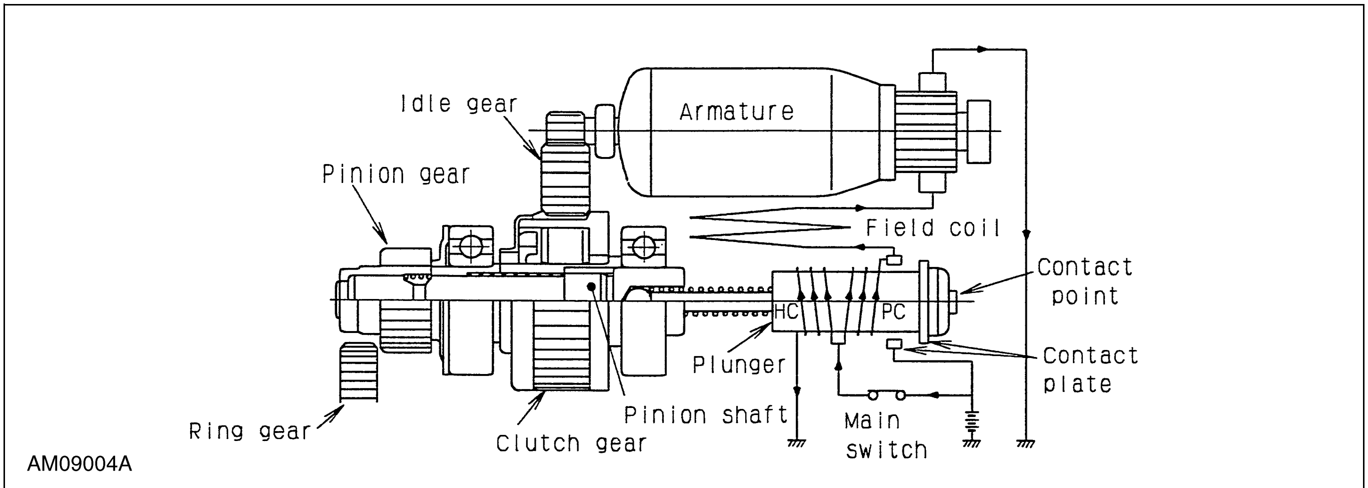


Fig. 9-4

2) During cranking of the engine :

a) If the pinion gear and ring gear are fully intermeshed, the main contact point will be closed, and the field coil and armature coil will be directly connected from the battery so that a large amount of electrical current flows and the pinion gear rotates.

b) Potential difference of P.C will become zero by the voltage from the main switch and the voltage from the main contact point, making the magnetic force nonexistent.

c) Therefore, the plunger is supported by H.C alone while the pinion is intermeshed with the ring gear.

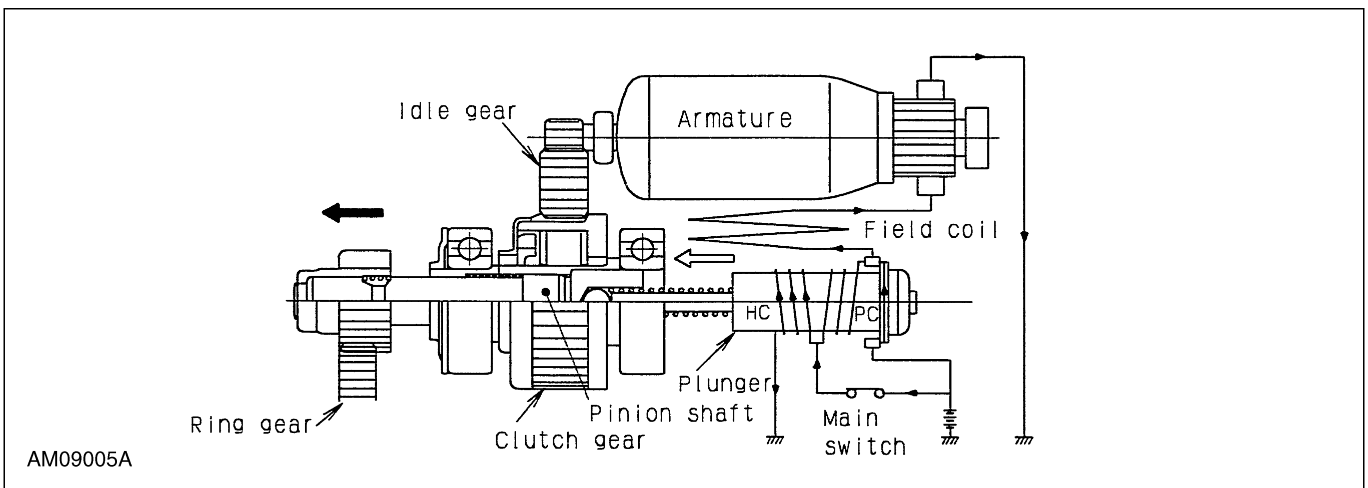


Fig. 9-5

3) When the engine is started :

a) When the engine is started, rotation of the gear will become faster than rotation of the pinion gear. (If such a state is left as it is, rotation of the engine will be driven directly into the armature, and may damage it.)

b) In case that rotation faster than that of the armature is transmitted to the pinion gear, the overrunning clutch will begin to race, and will protect the armature from abnormal rotation.

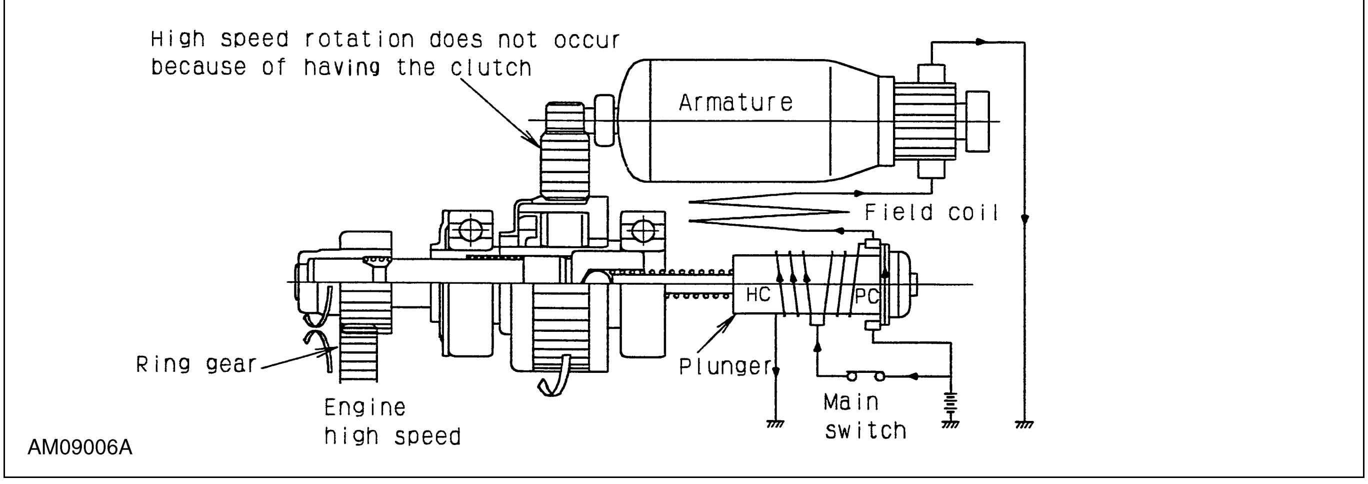


Fig. 9-6

4) When the starter switch is returned to AC :

a) If the starter switch is returned to AC, energizing to H.C will be shut off.

b) The force on the plunger will cease and the pinion gear will be returned by the return spring. At the same time, the main contact point will be opened as well, and rotation of the armature will be stopped. Braking of the armature is performed by abrasion force of the brush and commutator.

∗ For an instance, potential difference of the C terminal becomes higher than that of the S terminal, and electrical current flows from the main contact point to the direction of P.C and H.C so that engaging force of the plunger will be offset each other, and the plunger will be returned quickly.

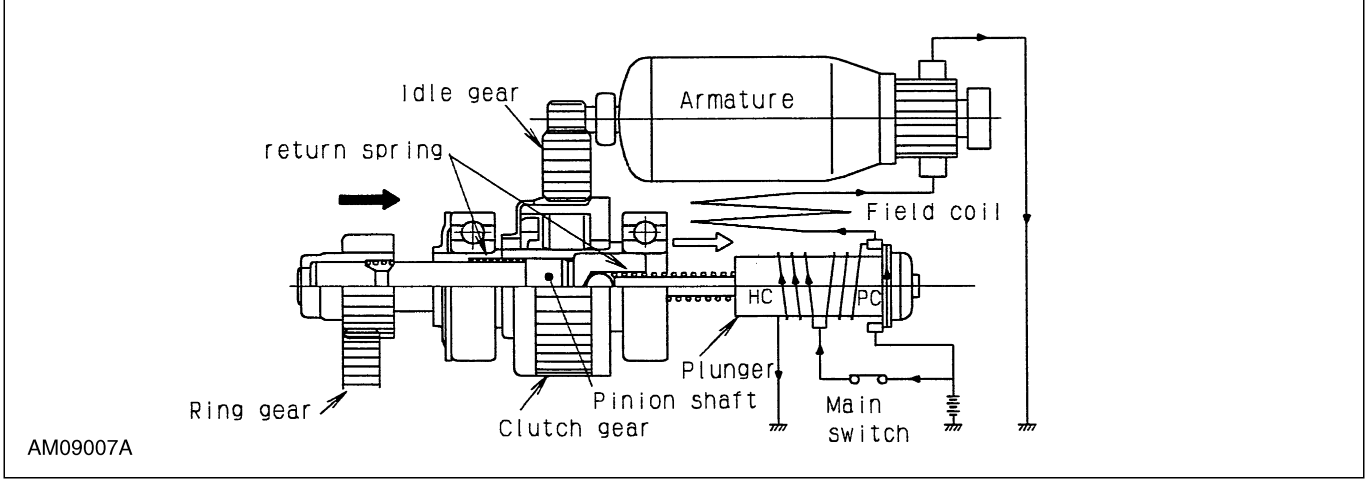


Fig. 9-7

5) The check method for the starter wiring connection

Terminal	The measuring method	The judging standard and countermeasure
S terminal	1. Remove the wiring to the starter B terminal and connect the S terminal wiring alone. 2. Remove the wiring connection of other parts connected to the battery (+) terminal. 3. Connect a voltmeter to the battery (+) terminal and starter S terminal. 4. Connect an ammeter to the S terminal wiring. 5. Connect a voltmeter to the battery (-) terminal and the starter body. 6. Turn the key switch to the starting position, wait 3 seconds, and measure each value of the ammeter and voltmeters. 7. Calculate the wiring resistances from the measured current and voltages and sum up them.	The total sum of resistance shall satisfy the following standard. KBT Standard Starter for; OC, EA : 50 to 70 mΩ or lower When the above standard is not satisfied, the wiring diameter shall be increased.
B terminal	1. By the stop solenoid and stop lever, keep the engine in the condition where start up is not possible. 2. Connect the S terminal wiring. 3. Connect the starter B terminal wiring. 4. Remove the wiring connection of other parts connected to the battery (+) terminal. 5. Connect a voltmeter to the battery (+) terminal and starter B terminal. 6. Connect a voltmeter to the battery (-) terminal and starter body. 7. Connect a clamp-on ammeter to the starter B terminal wiring. 8. Turn the key switch to the starting position, wait 3 seconds, and measure each value of the ammeter and voltmeters. 9. Calculate the wiring resistances from the measured current and voltages and sum up them.	The total sum of resistance shall satisfy the following standard. KBT Standard Starter for; OC, EA : 50 to 70 mΩ or lower When the above standard is not satisfied, the wiring diameter shall be increased.

Note :
The starter type must be checked before application review.

(3) Overrunning clutch

1) Function

In case that the pinion gear and ring gear are still intermeshed even when the engine is started, the motor will be forced to run in abnormal rotation, and the armature, brush, etc. will be damaged.

In order to prevent such an error, the overrunning clutch will function as the device to let the pinion race against the armature shaft when the engine is started, and to shut off transmission of rotation of the engine to the motor.

2) Action

a) When starting :

If the outer is rotated in the arrow mark direction receiving rotation of the armature, the clutch roller will be pushed toward the narrower side of clearance between the outer concave side and the inner so that the outer and inner will be locked. The roller will function as a wedge between the inner and outer, and will transmit the rotation of the outer to the inner, and both will rotate in the same speed.

b) After the engine is started :

When the pinion is forced to rotate by the ring gear, rotation of the inner (rotation of engine x gear ratio) will become faster than that of the outer (a number of rotation of armature), and the clutch roller will move toward the direction that compresses the spring.

Consequently, clearance between the outer concave side and the inner becomes wide to prevent overrunning of the armature.

(It is required to decrease the contact pressure of the pinion gear and ring gear to realize smooth separation of the pinion gear, and for the sake of this, the pinion gear must be in the state of racing.)

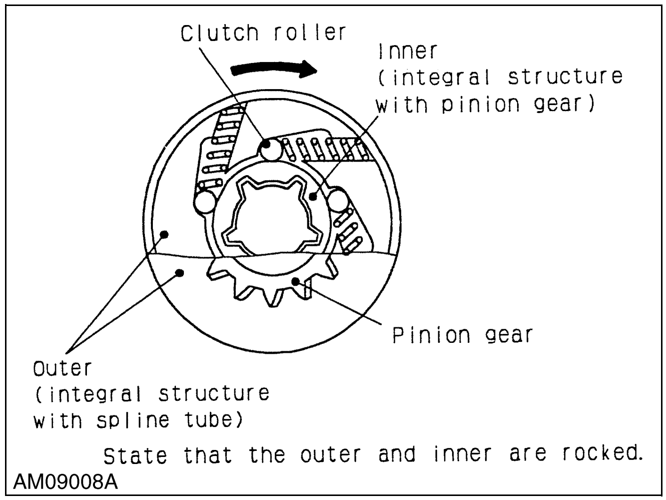


Fig. 9-8

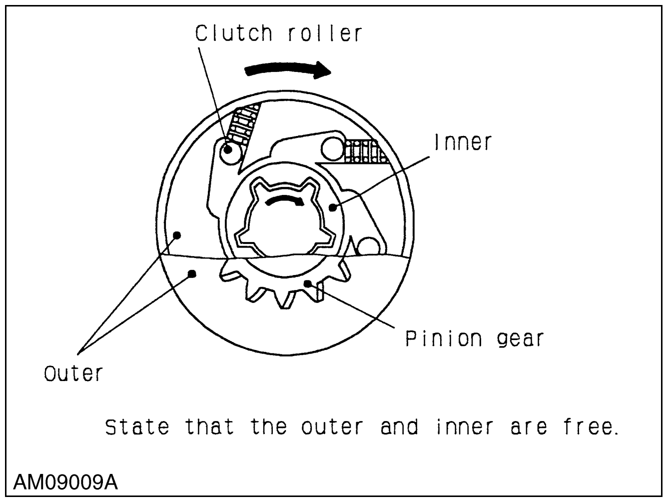


Fig. 9-9

[3] STARTER SWITCH

Starter switch is an important part comprising of the starting device of engine. Particularly, as seizing of the starter and solenoid may be incurred due to failure of the starter switch, careful consideration is required for the installation position, place, and direction, so that rain or cleaning water should not directly splash on the starter switch.
As the standard part of OC, EA engine, the starter switch in below figure is recommended.
(Part No. : 15248 - 63593) or (Part No. : 37410-59113)

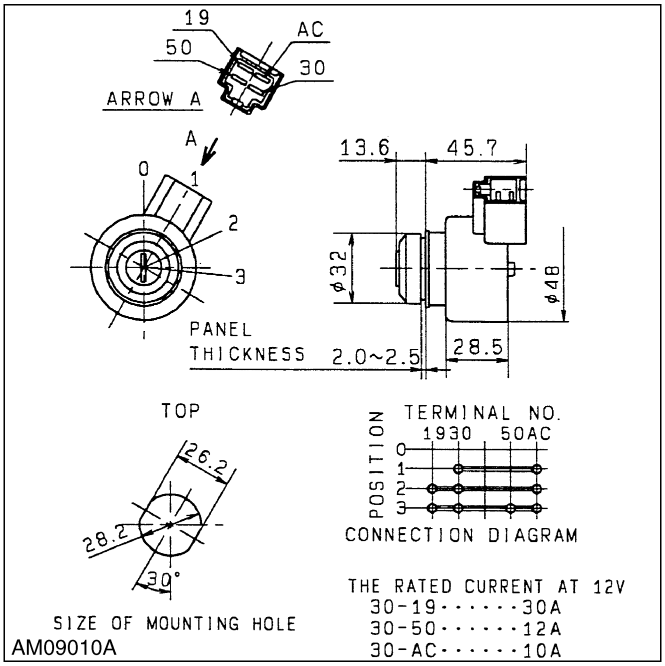


Fig. 9-10 - (1) Starter switch (15248 - 63593)

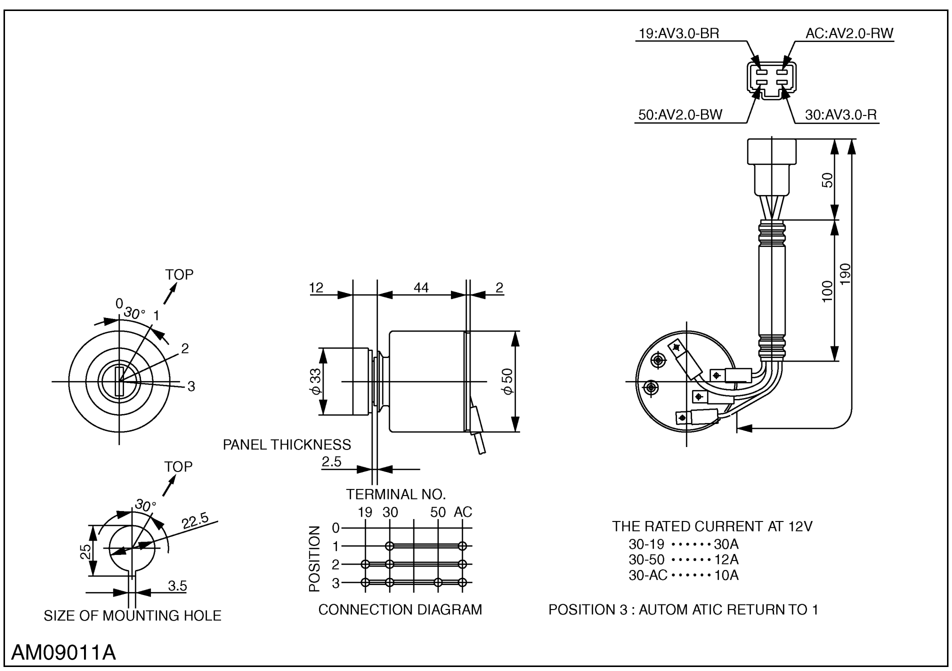


Fig. 9-11 - (2) Starter switch (37410-59113)

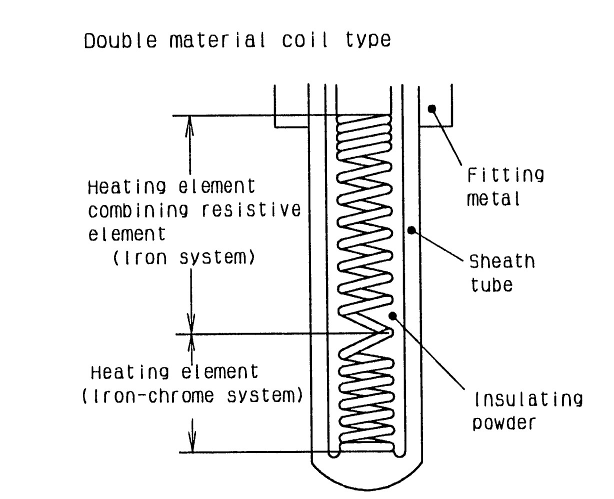
[4] GLOW PLUG

(1) General

Pressed heat of air, and if the cylinder and head is cold when the engine is to be started, the glow plug will be used to supplement this compressed heat.
On the OC and EA of KUBOTA diesel engine, the QGS type plug of double-material type and high reliability, of which temperature is increase is fast, is employed. The outline specifications are as shown in the below. (Q.G.S : Quick Glow System)

(2) Structure and function

In case of the conventional sheathed-type glow plug, the heating element is only incorporated in the sheathed tube, however, in case of this quick glow type, the heating element that combines a heating element and resistive element is connected in series.
As for the temperature increase property, when the temperature at the initial stage of power supply is low due to activation of the resistive element, resistance is small and enough electrical current flows into the heating element so that the temperature will increase quickly.
If power supply is continued, the amount of electrical current decreases and overheating is prevented, this is because temperature of the resistive element will increase and the resistance will become large (about 10 times).

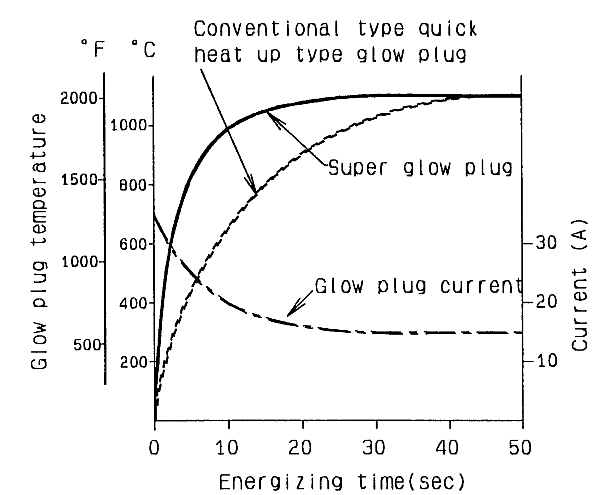


AM09012A

Fig. 9-12 Structure of glow plug

Further, the heat point is at 2 to 3 mm (0.08 to 0.12 in.) from the tip, and protrusion into the combustion chamber is short.

KUBOTA's standard starter switch has the function that the glow plug will be energized as well when energizing the starter.
In case that starter switch is prepared by an OEM, it should also be designed so that the glow plug will also be energized when energizing to the starter.



AM09013A

Fig. 9-13 Comparison of the temperature increase

[5] GLOW LAMP AND LAMP TIMER

(1) General

The purpose of glow lamp is to time the activating conditions of the glow plug located in the combustion chamber of engine.

When the starter switch is turned to preheating position, the lamp timer will activate the glow plug lamp, and when the timer has activated after 5 seconds, the lamp will be turned off.

Even if the lamp is turned off by the lamp timer, the glow plug will still be kept turned ON, if the starter switch is in preheating position, or the starter is in the state of being turned ON.

(2) Activation circuit

a) If the starter switch is turned to preheating, energizing will be made to No.6 terminal of the lamp timer from No.19 terminal through the glow lamp.
   Then, the lamp timer is grounded, and it will light the glow lamp for 5 seconds.
   At the same time, energizing will also be made to the glow plug directly from No.19 terminal, and the glow plug will be heated.

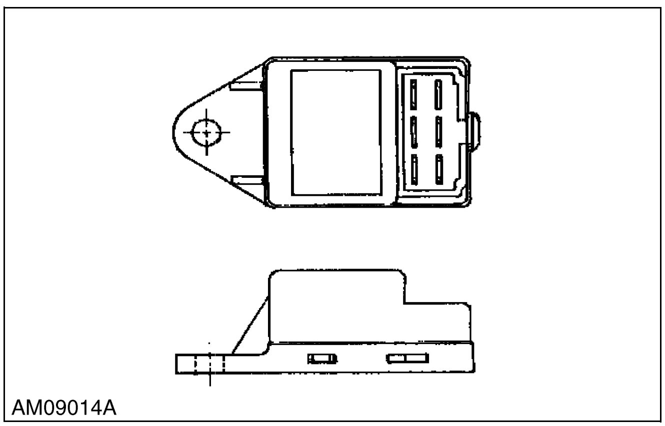


Fig. 9-14 Glow lamp timer

b) If the starter switch is turned to starting, energizing will be made to No.5 terminal of the lamp timer so that electrical power of the glow lamp cannot be grounded, and the glow lamp will not be on. Energizing will be made to the glow plug directly from No.19 terminal of the starter switch, and the glow plug will be heated.

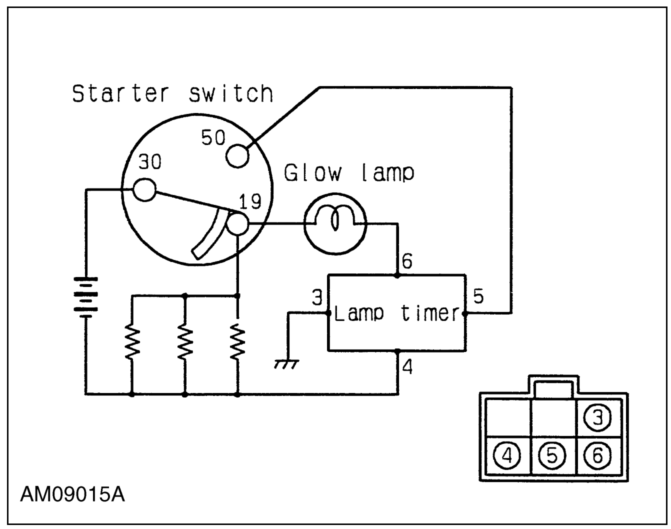


Fig. 9-15

3. CHARGING DEVICE

[1] GENERAL

The function of the charging device is to charge batteries.
EA engine's charging device is built-in fan assy..
OC engine's charging device is composed of flywheel and stator assy..

[2] AC DYNAMO AND REGULATOR

(1) AC dynamo

OC engine

This dynamo is 12 pole rotating magnet type generator. It is simple in construction, consisting of a stator and permanent magnet.
A permanent magnet is attached on the inner face of the flywheel, which is connected with the engine's crankshaft. As the flywheel turns, the magnet induces electromotive force to each coil of the stator.
*Figure shows the flywheel, the arrangement of the stator poles, and the magnetized state of the magnet.

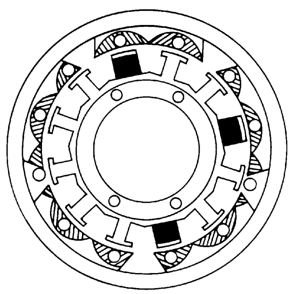

AM09016A

Fig. 9-16 Standard type

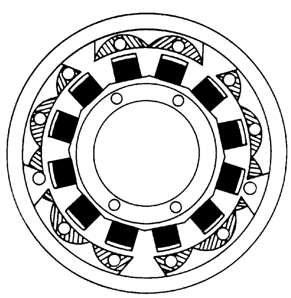
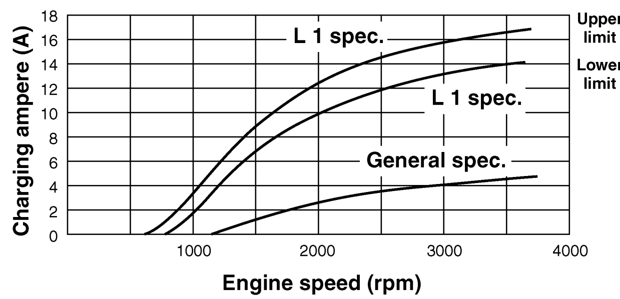

AM09017A

Fig. 9-17 L type



AM09018A

Fig. 9-18

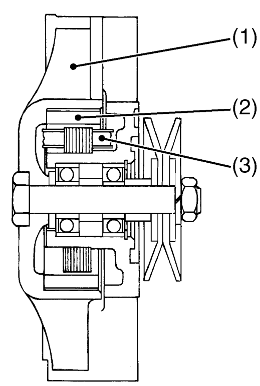
(2) Fan dynamo

EA engine

The fan dynamo generates a single-phase alternating current as the permanent magnet (2) which is an integral part of the fan (1) rotates outside the dynamo coil (3) which is fixed.

Power Generating Performance

EA330-E3-NB1 EA330-E3-NB1-APU-1	13V 1.6 to 2.6 A (Fan speed: 6950 min^{-1} (rpm))



AM09019A

(1) Fan
(2) Permanent magnet
(3) Dynamo coil

Fig. 9-19

(3) Thyristor type regulator

Thyristor-type regulator is composed of the diode, resistor, thyristor, zener diode, and transistor.

When the battery voltage is low, the thyristor will be turned on, and complete the charging circuit to the battery.

Further, if the battery voltage is increased to be more than the specified value of the zener diode (14.5 ± 0.5 V), thyristor will be turned off, and the charging circuit to battery is shut off.

As the standard part of OC and EA engine, the regulator in below figure is recommended.

(Part No. : PN201-68562) (Part No. : 11520-64602)
(Part No. : 14428-64602)

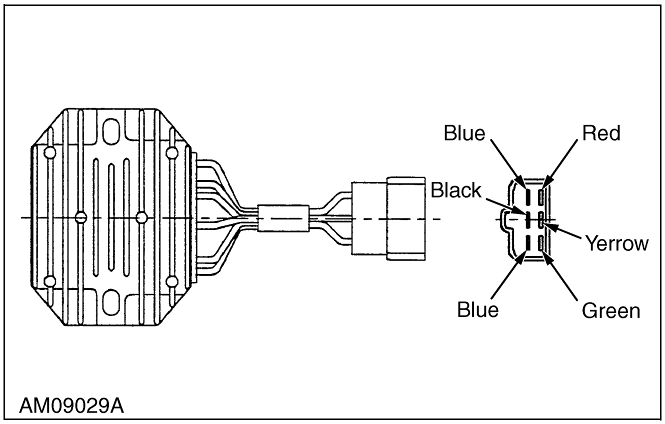


Fig. 9-20 Regulator for OC engine L type (PN201-68562)

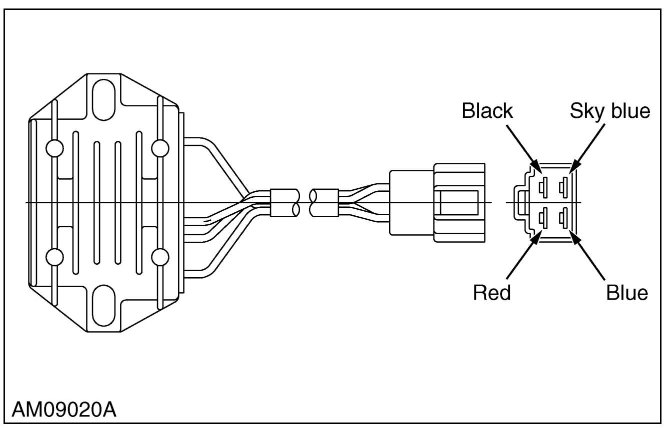


Fig. 9-21 Regulator for OC engine standard type (11520-64602)

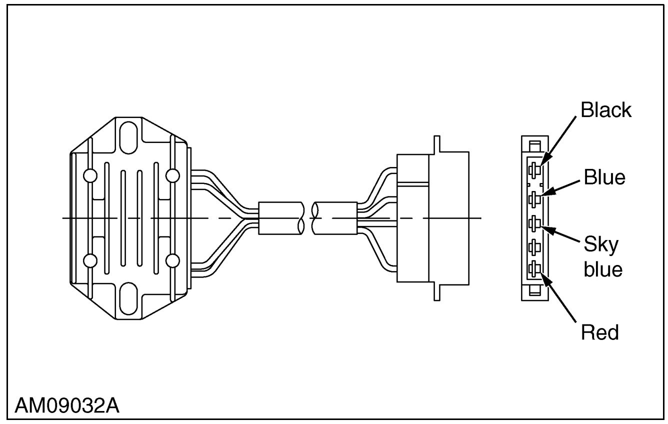


Fig. 9-22 Regulator for EA engine (14428-64602)

4. STOPPING DEVICE (OC only)

[1] GENERAL

To stop diesel engine, normally, the operator will operate the stop lever, and reduce the injection amount of fuel to zero.

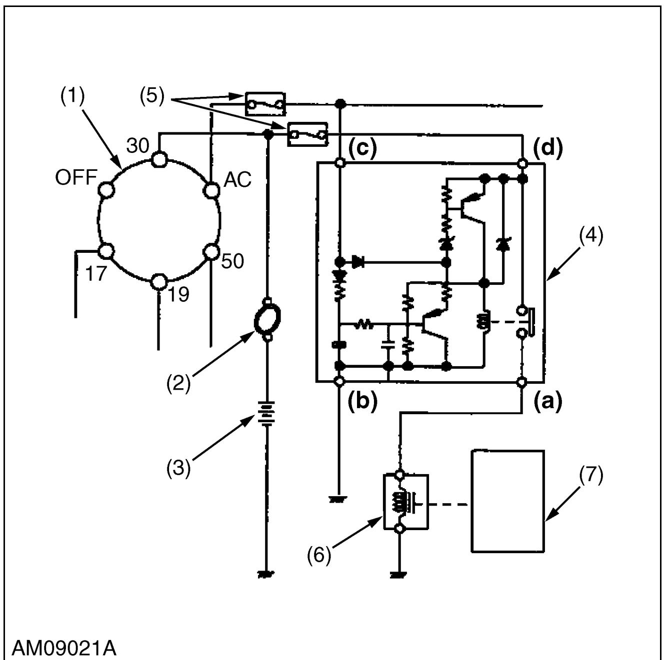
However, this operation of stopping the engine can be performed in such a way that the engine solenoid is excited by turning starter switch to the off position, and the stop solenoid plunger is pulled in to stop the fuel and the engine.

This system uses the engine key to operate the stop device, and facilitates easy operation, in addition, manual operation is also possible.

[2] SOLENOID

(1) Energize to stop type solenoid

This stopping device is composed of the solenoid and timer relay, and will keep activating the solenoid for about 10 seconds after the starter switch is turned to off position so that the control rack is pushed to the non-injection position, and the engine is stopped.



(1) Starter switch
(2) Fusible ring
(3) Battery
(4) Timer relay
(5) Fuse
(6) Solenoid
(7) Injection pump

Fig. 9-23 Energize to stop device

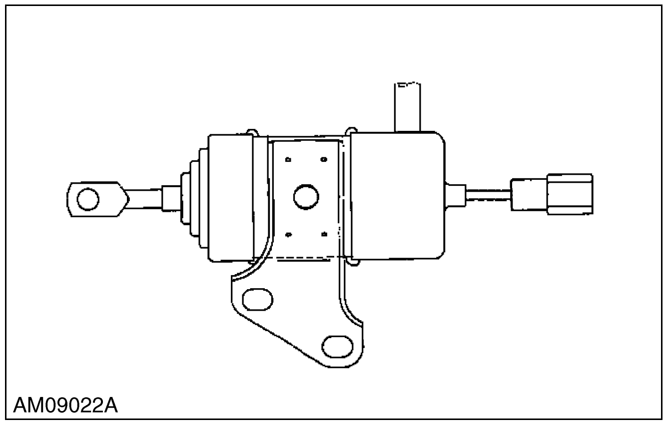


Fig. 9-24 Energize to stop device

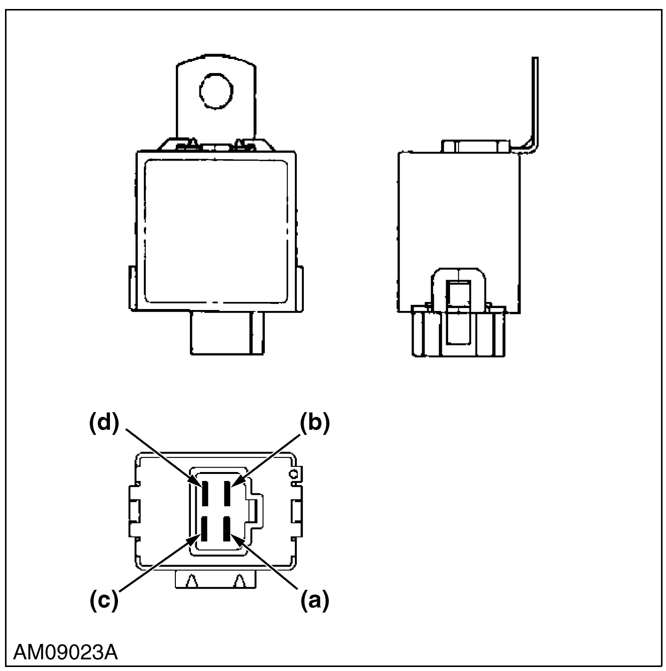


Fig. 9-25 Timer relay

5. MONITORING DEVICE

[1] GENERAL

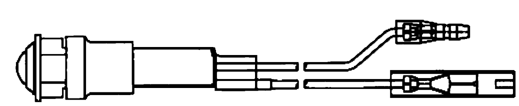
Minimum limit monitoring is required to maintain the normal operation of the engine.
Operating and monitoring devices include parts and instruments as follows

a) Glow lamp
b) Oil pressure lamp
c) Water temperature lamp
d) Charging lamp
e) Water temperature meter
f) Oil pressure gauge
g) Fuel gauge
h) Pilot lamp

Which equipment is employed shall be determined by taking into consideration the factors such as the types of engines, use condition (temperature, time, load, etc.), and design.

[2] LAMP

There is a lamp which indicate abnormality of oil pressure, coolant temperature, and one which indicates heated condition of the glow plug.



AM09031A

Fig. 9-26 Indicator lamp (Kubota standard)

6. WIRING

[1] STANDARD WIRING (KUBOTA Recommendation)

Wiring type is different in OC and EA engines.
starter without safety device / engine to stop solenoid for OC engine.
Starter without safety device / without stop solenoid for EA engine.
In case that a particular request is not presented, the KUBOTA standard specification or similar wiring to the specifications are recommended.

[2] CAUTIONARY ITEMS FOR WIRING

1) Equipment should be grounded securely.

When the grounding is not properly done, necessary amount of electrical current will not flow, and function of electrical equipment will not be exhibited fully. For example, it is possible that insufficient grounding of the starter will cause failure to start, and in addition, after repeating the starting many times, the starter will seize.
Therefore, select a clean metal surface for the grounding wire attachment (on the main machine side as well as engine side), and completely remove the paint to make the contact resistance as low as possible.

2) The wire diameter of wiring and the electrical current capacity of each fuse are shown in the wiring diagram.

However, these are only recommended values, and therefore when applying to the actual case, be careful to use the correct sites taking into consideration the length of wiring and the connection form.
Note that the wire diameters not specified in the wiring diagram shall be 0.8 to 1.25 mm^2.

3) Wiring should be routed and secured, be careful so that the insulation will not be worn off due to contact with other parts during operation, and short circulating will not occur.
Further, it recommended to protect wiring with corrugated protective covers.

4) In case that wiring is made mistaking the polarity, wiring materials may be burned and damaged, or it may result in personal injury.
It is important that any mistaken wiring never be made, and in addition, attention and care (by changing the colors and length of wire) should be taken not to let workers perform incorrect wiring.

5) Use low-voltage wires for automobile (AV SS wire, etc.) for wiring. However, in case that the ambient temperature is more than 75 °C (167 °F), use heat-resistant wires (AVX wire, etc.).
Example :
A V 0.5 RW

Color code
Sectional area
Insulation material : Vinyl
Low-voltage wire for automobile

6) To protect wiring, use a fuse or slow-blow fuse. Note that slow-blow fuses should be located near to the battery, and fuse box to the starter switch.

7) As for the load that may incur when unexpected current comes into the circuit, such as the case of motors, be careful not to directly connect to ACC and any wires connected directly to battery ‘+’.

8) Attach covers to the terminal on the terminal on the positive side of the battery to prevent sparks due to accidental contact.

[3] SIZE OF WIRING

(1) General

a) The size of wiring shall be determined taking into consideration the various factors such as the length of cable, electrical current value, allowable voltage drop, etc.

b) When electrical current 'A' (Amperes) flows in the circuit, the resistance 'ohms' always exists as the result of electrical power loss in the cable, and the voltage will be decreased.
The difference between the voltage of electrical power source and the voltage at the connection end of the cable of each equipment is the voltage drop leading to poor performance.

c) Excessive electrical power loss in the cable will cause overheating of the cable and drastic voltage drop.
To resolve such a problem, it is important to take into consideration that the cable resistance is the accumulated value of complete circuit and to correctly use the specified cables.

d) The rated value of the cable shall be determined according to the allowable electrical current value.
Electrical resistance depends on the total sectional area of the conductive material (wire).
It is possible to minimize the electrical power loss and voltage drop by using correct cables.
It is important to restrain the temperature increase of the cable for the cables that are used together in a harness.

e) All of the voltage drop in the circuit should not exceed 10% of the regular voltage. (For example, 1.2 V in case of 12 V circuit.)
The voltage drop expected to occur in the circuit can be measured by using the simple formula as shown below :

Voltage drop = Current value × Total cable resistance

f) For the cables in which electrical current will flow continuously for a long period of time, attention and care must be taken for both the temperature increase and voltage drop, and on the other hand, as for the circuit to be used for a short time (for example, preheating circuit), care must be taken for the voltage drop.
Voltage drop of the glow plug circuit, is should be minimized so that necessary level to heat the glow plug can be maintained.

(2) Connector and terminal

After selecting the correct cables, it is required to select the connectors and terminals that can match each electrical part.
The connectors and terminals of major electrical parts that are employed in KUBOTA engines are shown in the SOS.

(3) Battery cable

The battery cable is the first 'connection' in the electric system of engine. Attention and care should be taken so that this cable should be of the sufficient size matching the electrical current required, and the length should be as short as possible.
Take care to securely install the battery terminals, and tightly clamp the cables.

Voltage drop against each battery cable should not exceed 0.6 V DC – 0.8 V DC.

Recommended minimum battery cable :

Engine	Cable size (mm^2)	AWG size
OC series	20	4
EA series		

7. BATTERY

The battery makes it possible to store electric energy as chemical energy, and to take it out as electric energy as needed.
Further, a battery is the device that can repeatedly charge and discharge.

(1) Formula of discharging amount
Discharging amount (Ah) = Rated capacity (Ah) × (S.G. when fully charged - S.G. when measuring) / (S.G. when fully charged - S.G. when fully discharged)

In general case :
S.G. when fully charged : 1.26 {20 °C (68 °F)}
S.G. when fully discharged : 1.06 {20 °C (68 °F)}

S.G. : Specific Gravity

Battery capacity is indicated by the electricity amount that can be taken out before the voltage reaches the discharging end voltage, after the fully charged battery is continuously discharged with a electrical current.

Capacity (Ah) = Discharging current (A) × Time until discharging end voltage (Hr)

[Meaning of 28 Ah / 5 Hr]
28 Ah / 5 Hr = 5.6 A ··· 5 hour rate current

Capacity is determined when the battery voltage becomes the discharging end voltage, when the battery is discharged for 5 hours at 5.6 A.

(2) Temperature rectification
Temperature compensation should be made for the specific gravity measured by a gravimeter.
This specific gravity value will indicate that “it is low when the temperature is high”, and “it becomes high when the temperature becomes low”.
Generally, the specific gravity of the electrolyte of battery shall be taken using the temperature of 20 °C (68 °F) as the standard, and as for the rate of the change, the specific gravity decreases by 0.0007 against a temperature increase of 1 °C (34 °F), and the specific gravity increases by 0.0007 against the temperature of 1 °C (34 °F).
It is convenient to use the following formula to convert the specific gravity measured at a certain temperature into the standard temperature of 20 °C (68 °F).

S20 = St + 0.0007 (t - 20)
S20 : S.G. at the temperature of 20 °C (68 °F)
St : S.G. at the temperature of t °C

[Example : In case of electrolyte temperature of 40 °C (104 °F)]
Reading of gravimeter : 1.240
S20 = 1.240 + 0.0007 (40 - 20) = 1.254

Consequently, the S.G. converted into 20 °C (68 °F) is 1.254. If looked at on the gravimeter, it appears that it is discharged by about 10%, however, if converted into the standard temperature, it is practically near to the state of full charge.
The charged or discharged state of battery can be known by measuring the S.G. of the electrolyte.
When measuring S.G., it can easily be performed comparatively by using a suction gravimeter.

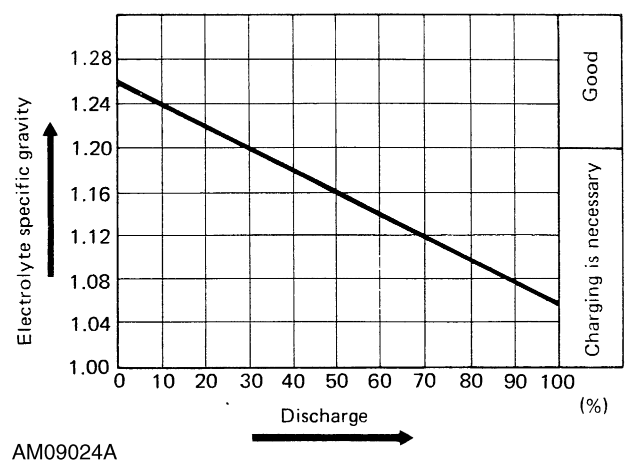


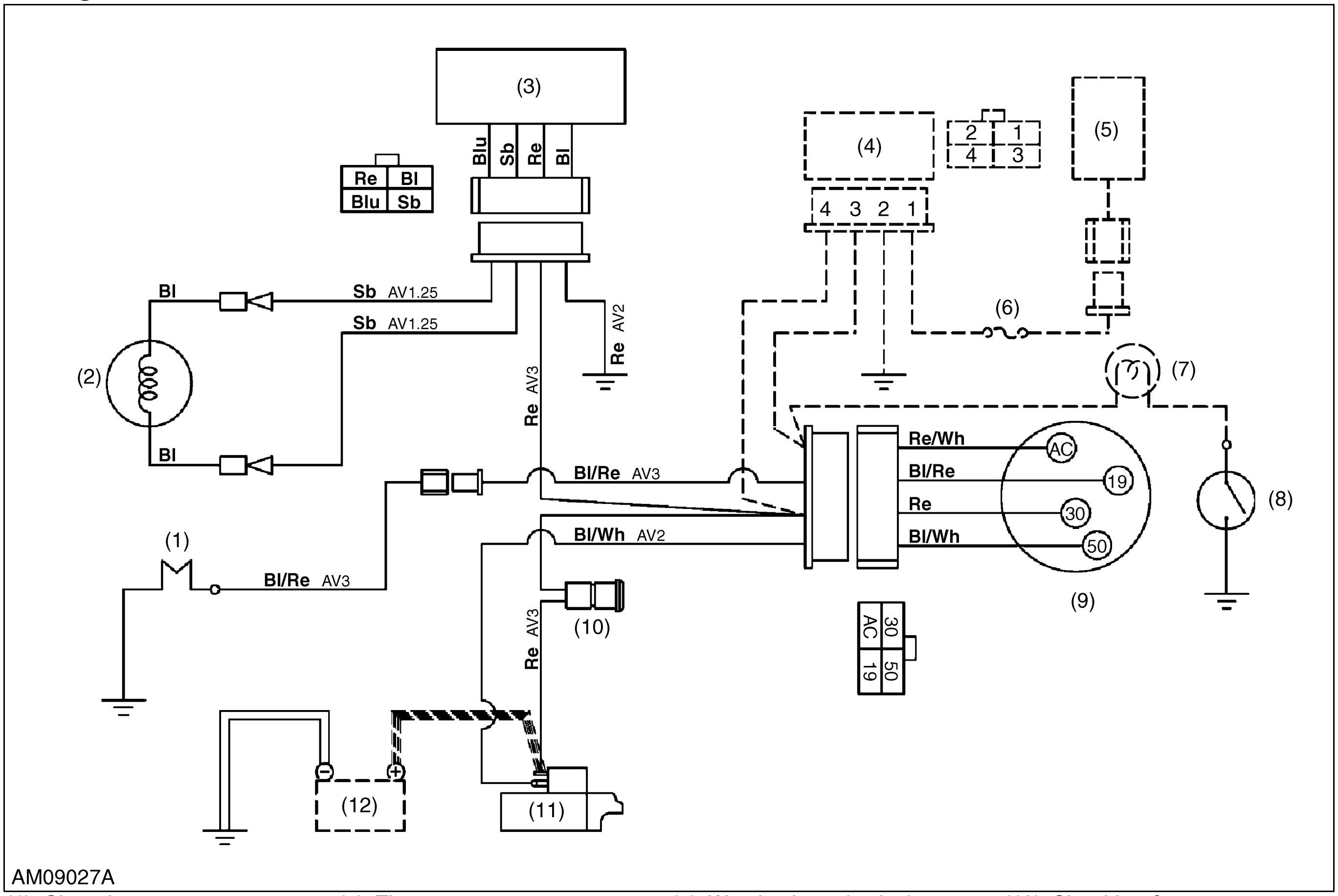
Fig. 9-27 Relation between specific gravity of electrolyte and discharging amount

Gravity of electrolyte 20 °C (68 °F)	State of discharging
1.260	100
1.210	75
1.160	50
1.110	25
1.060	Totally discharged

Fig. 9-28 Specific gravity indication varies with discharging amount

8. WIRING DIAGRAM

OC engine



(1) Glow plug	(4) Timer	(7) Warning lamp (option)	(10) Slow blow fuse
(2) Dynamo (48 W)	(5) Stop solenoid	(8) Oil pressure switch	(11) Starter
(3) Regulator	(6) Fuse (15A)	(9) Key switch	(12) Battery (12V)

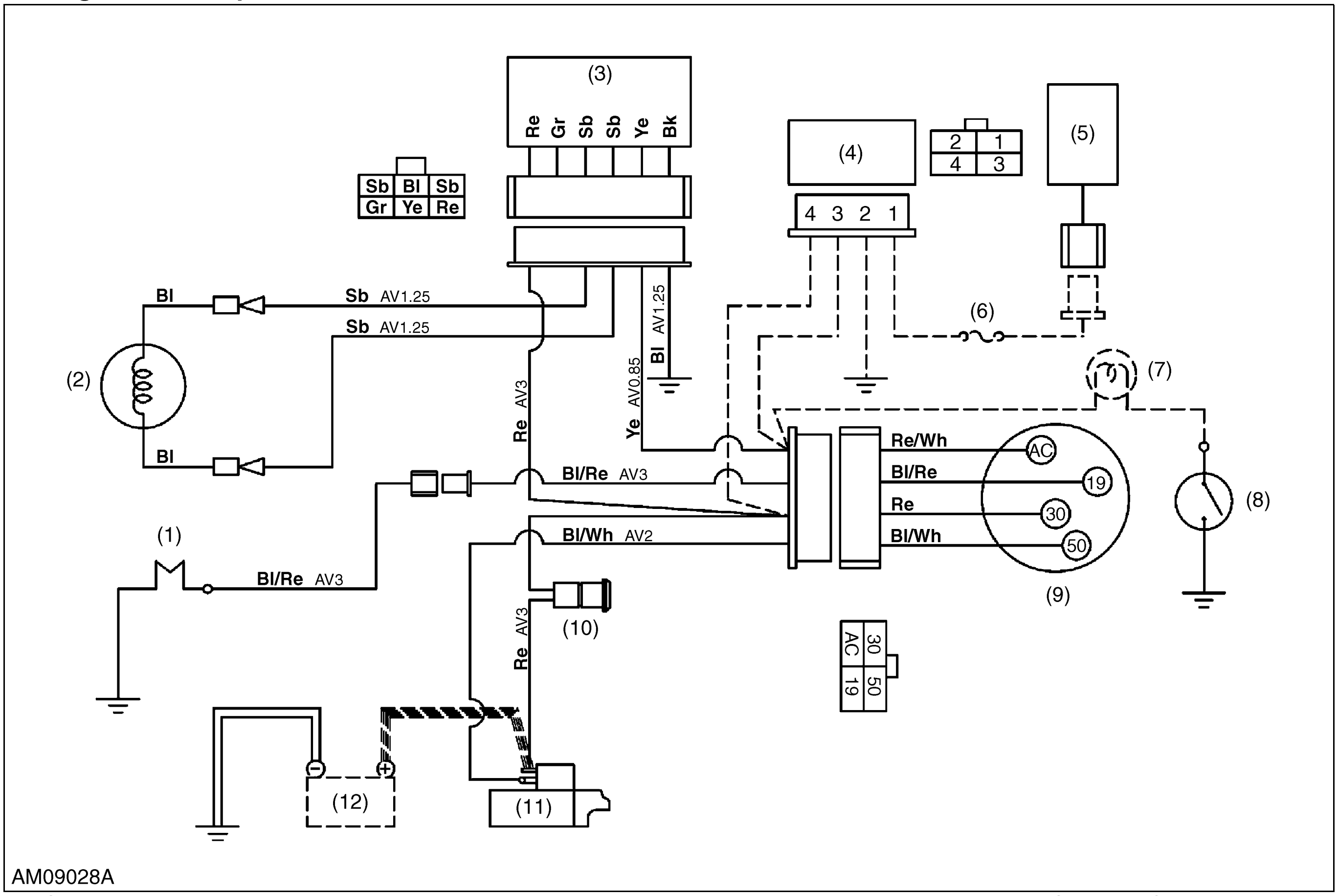
Fig. 9-29

Note :
The dot lines indicate option parts.
The following model is with stop solenoid.
OC60-E3-D1-QX
OC95-E3-D1-GX

Color of Wiring

Bl .... Black	Blu .... Blue	Re .... Red
Re / Wh .... Red / White	Bl / Wh .... Black / White	Bl / Re .... Black / Red

OC engine with stop solenoid



(1) Glow plug
(2) Dynamo (170 W)
(3) Regulator
(4) Timer
(5) Stop solenoid
(6) Fuse (15A)
(7) Warning lamp (option)
(8) Oil pressure switch
(9) Key switch
(10) Slow blow fuse
(11) Starter
(12) Battery (12V)

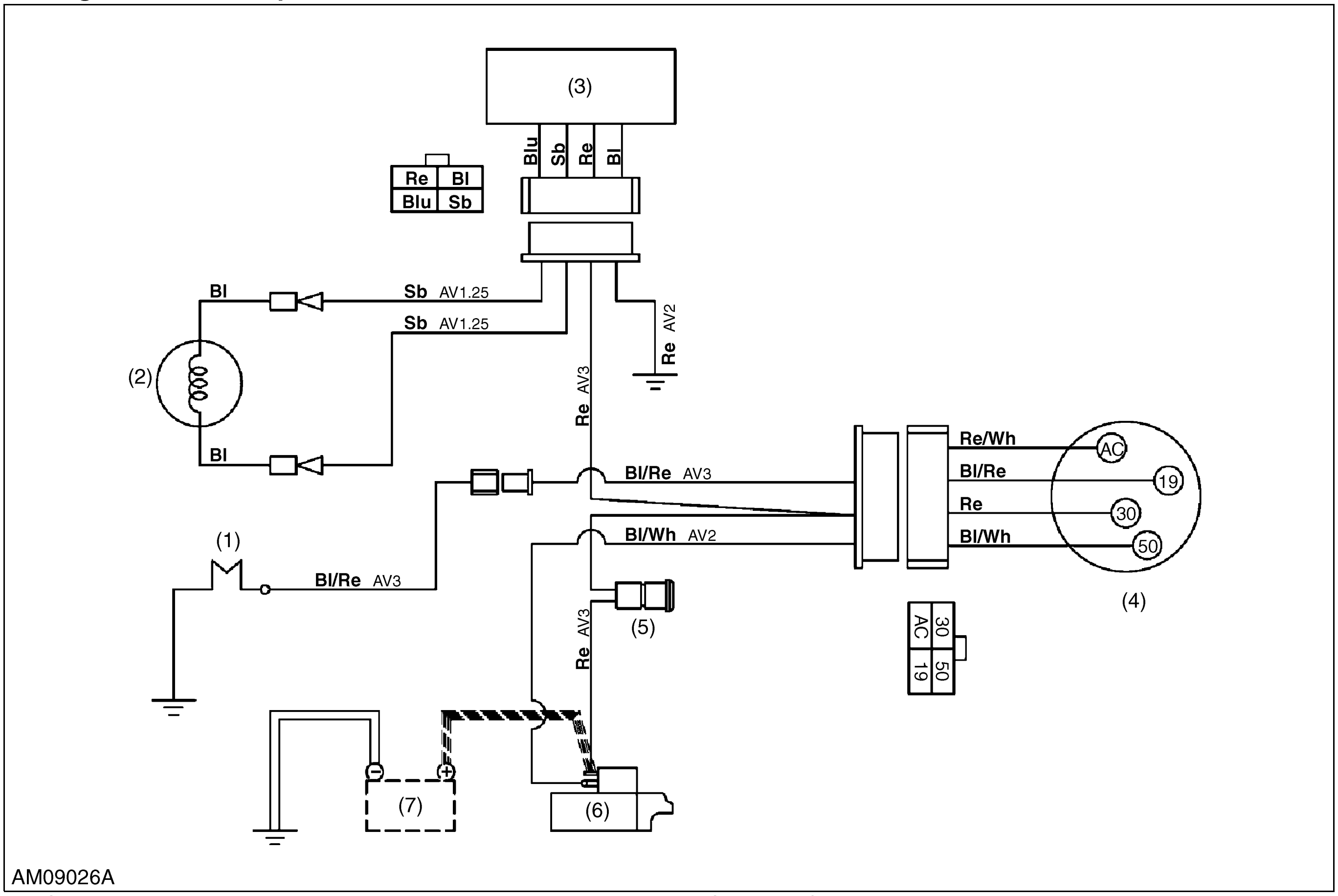
Fig. 9-30

Note :
The dot lines indicate option parts.
The following model is with stop solenoid.
OC60-E3-D1-QX-L1
OC95-E3-D1-QX-L1

Color of Wiring

Bl .... Black	Ye .... Yellow	Re .... Red
Blu .... Blue	Bl / Wh .... Black / White	Bl / Re .... Black / Red
Re / Wh .... Red / White	Gr .... Green	Sb .... Sky blue

OC engine without stop solenoid



(1) Glow Plug
(2) Dynamo (48 W)
(3) Regulator
(4) Key switch
(5) Slow blow fuse
(6) Starter
(7) Battery (12V)

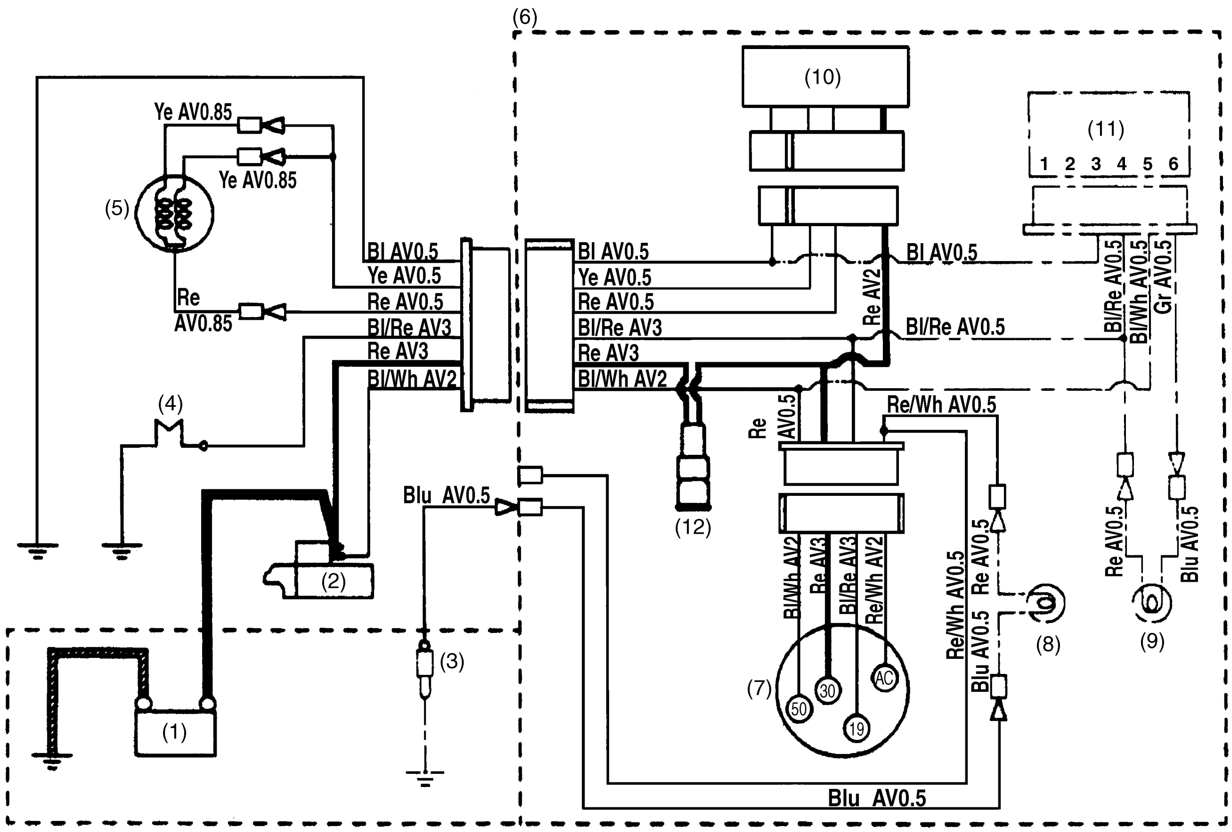
Fig. 9-31

Note :
The following model is without stop solenoid.
OC60-E3-D1-Q

Color of Wiring

Bl .... Black	Blu .... Blue	Re .... Red
Re / Wh .... Red / White	Bl / Wh .... Black / White	Bl / Re .... Black / Red

EA engine



AM09025A

(1) Battery (option)	(4) Glow plug	(7) Starter switch	(10) Regulator
(2) Starter	(5) Fan dynamo	(8) Oil lamp	(11) Glow lamp timer
(3) Oil switch (option)	(6) Switch box	(9) Glow lamp	(12) Fuse

Fig. 9-32

Note :
The parts shown in the dashed-dotted-line are optional extras.

Color of Wiring

Bl .... Black	Ye .... Yellow	Re .... Red
Blu .... Blue	Bl / Wh .... Black / White	Bl / Re .... Black / Red
Re / Wh .... Red / White	Gr .... Green	

10. PTO SYSTEM

CONTENTS

PTO SYSTEM

1. GENERAL

Power can be taken off a OC and EA engine from the following points within a certain range dictated by total engine output.
To ensure proper engine performance and long life the drive system must be carefully designed.A review by KUBOTA is recommended.

Series	PTO Position	Connecting method
OC	Side-cover side	Belt drive by pulley
		Flange direct-coupling
EA	Flywheel side	Belt drive by pulley

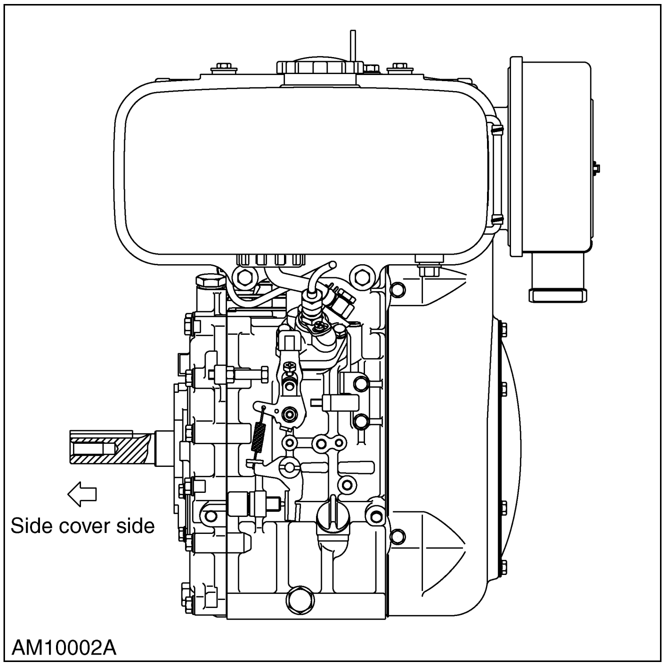


Fig. 10-1

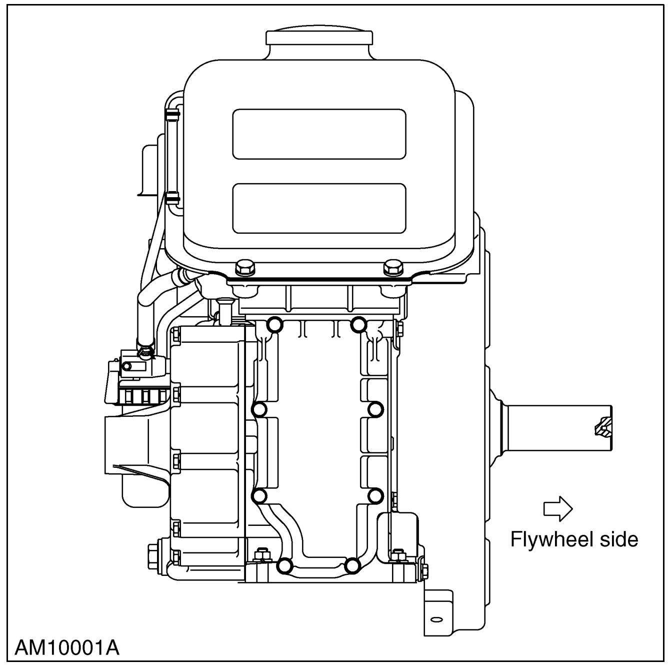


Fig. 10-2

2. FLANGE DIRECT COUPLING (OC only)

(1) PTO shaft selection

For flange direct coupling, there are some PTO shaft types for OC engine.
They are shown page 0-16 to 0-17

(2) Precision of rotating body

Rigid connection of the PTO, make the system compact. Special attention should be paid to the assembly precision for this type of connection.
Improper assembly will result in excessive power loss premature parts failure.

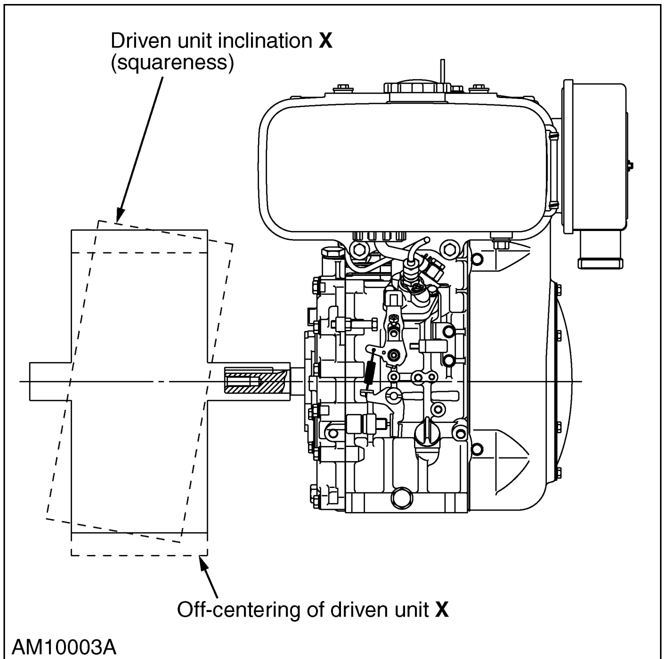


Fig. 10-3

3. BELT DRIVE BY PULLEY

[Power Take-off Recommendations]

1. If PTO shaft length are too long, an outboard bearing must be added.
2. Flexible couplings allow a little miss alignment between engine and drive device.
   They also dampen inertial loads, they must be used, along with outboard bearing, for front PTO drives.
3. Power disconnects (Clutches, Hydraulic unloader valve, etc.) reduce the load on the engine when being started.
   Using them may eliminate the cost of adding a heavy duty starter.
4. To reduce overhang, belt drive pulleys must be as close to the engine as possible.

(1) Side load calculation for V-belt drive application

When V-belt pulley is used for PTO according to the following procedure, confirm that the position of the pulley is within the allowable limit.
Even if it is located within the limit, minimize the overhang as much as possible to avoid any side load problems.
Also, tension of the belt is very important for the life of the bearing of the engine and the belt.
Follow the recommendation of the belt manufacture for tensioning the belt.
The following calculation method is only a reference for designing. Therefore, it is important to eventually carry out the actual operation test or the endurance test using the actual machine to check for problems.

(2) Procedure to determine the allowable side load

1) Find the design horsepower Pd

a) Select the service factor Ks from Table No.1 depending on the type of the driven machine and the service cycle.
If can not find you machine on Table No.1 use 1.3 as the service factor.

b) Calculate the Design Horsepower according to Formula No.1.

$Pd = Ks \times Pr$ ··· (Formula No.1)
Pd : Design Horsepower (kW)
Pr : Required Horsepower for the machine (kW)
Ks : Service Factor

2) Find the shaft load

a) Calculate Ψ or (D-d) / c

$\Psi = 180 - 57\,(D-d)/c$ ··· (Formula No.2)
Ψ : Arc of contact on small sheave (deg)
D : Diameter of large sheave (mm or in.)
d : Diameter of small sheave (mm or in.)
c : Center distance between both sheave (mm or in.)

b) Calculate the primal belt speed

$$V = \frac{\pi \times Dp \times nd}{60 \times 1000}$$

V : Belt speed (m/s)
Dp : Large or small pulley pitch circle diameter (mm)
nd : Large or small pulley speed (rpm)

c) Calculate the primal belt tension

$$T_0 = 0.9\left\{51 \times \frac{(2.5 - K\Psi)\,Pd}{K\Psi \times nb \times V} + \frac{W \times V^2}{g}\right\}$$

T_0 : Primal belt tension (kgf)
$K\Psi$: Contact angle correction factor - shown fig 10-9
nb : Belt setting number
W : Belt unit weight (kg/m) - shown table No.2
g : Gravity acceleration (9.8 m/s^2)

Table No.2

Belt	W (kg/m)
M	0.05
A	0.12
B	0.20
C	0.30

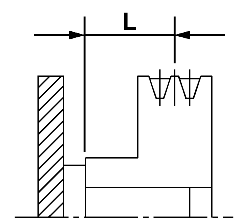
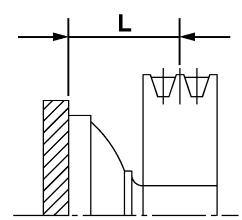
d) Calculate the shaft load Fs

$$Fs = \left\{2 \times nb \times T_0 \times \sin\frac{\Psi}{2}\right\} \times 1.5$$

Fs : Shaft load (kgf)

(3) Find the allowable from engine

According to Fig. 10-5 and design the position within the allowable limit.
For reference OC and EA engine overhang L are defined as follow.

	Image	Definition
OC	 AM10004A	Distance between the stepped section of PTO and the belt loading center.
EA	 AM10005A	Distance between the mounting surface of the flywheel and the belt loading center.

ARC CORRECTION FACTOR KΨ

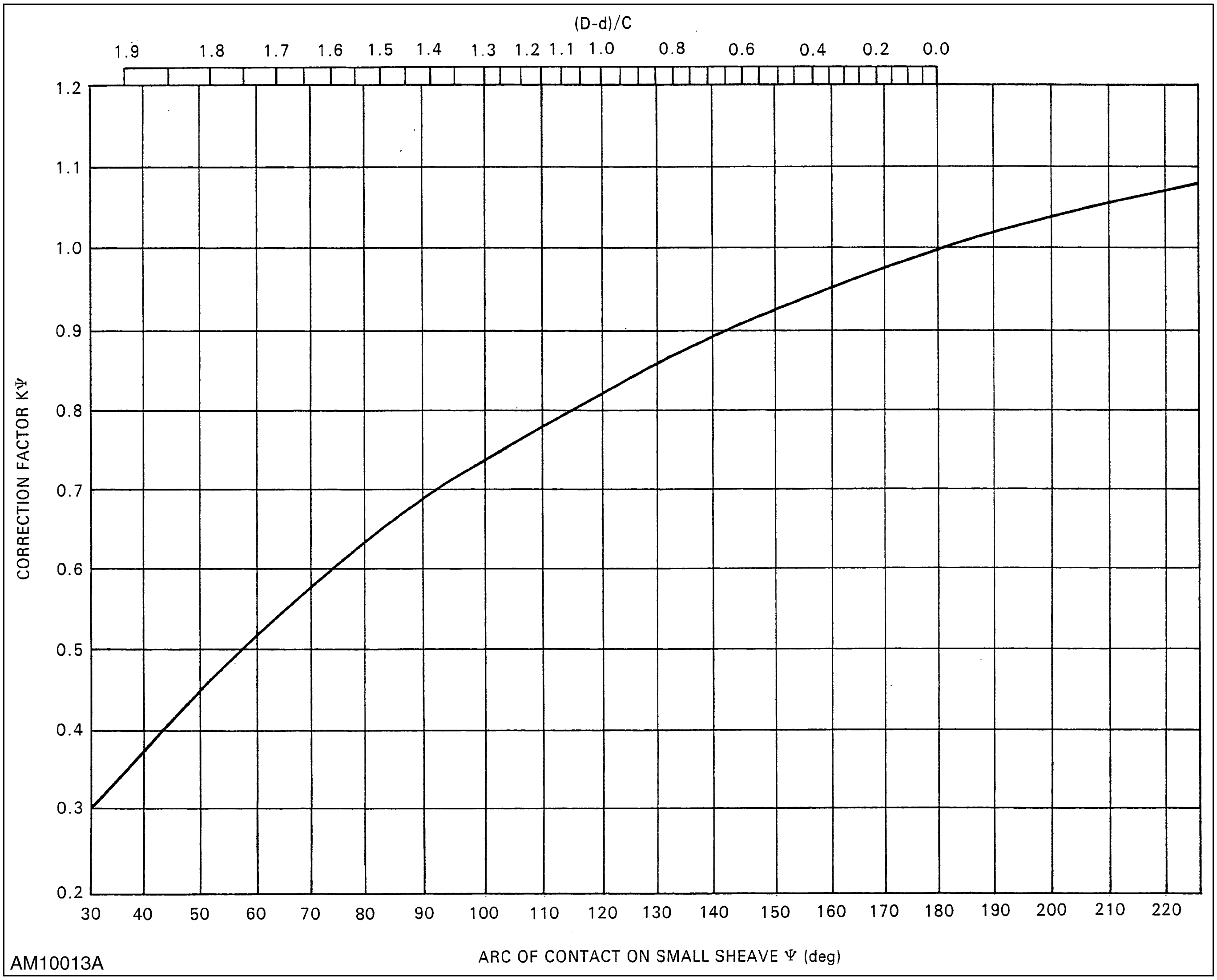


Fig. 10-4

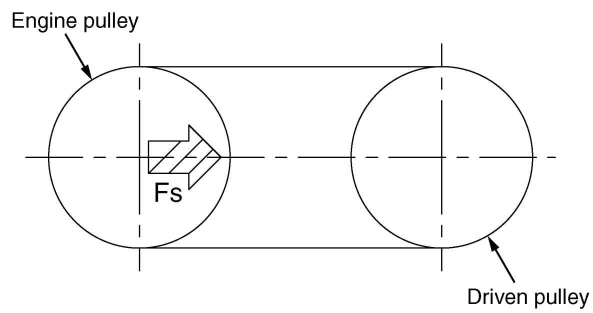
TABLE NO.1 SERVICE FACTORS

Driven Machine	Type of Service		
	Ⅰ	Ⅱ	Ⅲ
Agitators for Liquids	1.0	1.1	1.2
Blowers and Exhausters			
Centrifugal Pumps & Compressors			
Fans up to 10 Horsepower			
Light Duty Conveyors			
Belt Conveyors for Sand, Grain, etc	1.1	1.2	1.3
Dough Mixers			
Fan Over 10 Horsepower			
Generators			
Line Shafts			
Laundy Machinery			
Machine Tools			
Punches - Presses - Shears			
Printing Machinery			
Positive Displacement Rotary Pumps			
Removing and Vibrating Screens			
Brick Machinery	1.2	1.3	1.4
Bucket Elevators			
Exciters			
Piston Compressors			
Conveyors (Drag - Pan - Screw)			
Hammer Mills			
Paper Mill Beaters			
Piston Rumps			
Positive Displacement Blowers			
Pulverizers			
Saw Mill and Woodworking Machinery			
Textile Machinery			
Crushers (Syratory - Jaw - Roll)	1.3	1.4	1.5
Mills (Ball - Rod - Tube)			
Hoists			
Rubber - Extruders - Mills			

TYPE OF SERVICE

Ⅰ : Intermittent Service	3-5 Hours Daily or Seasonal
Ⅱ : Normal Service	8-10 Hours Daily
Ⅲ : Continuous Service	16-24 Hours Daily

Available load vs. overhang for using belt



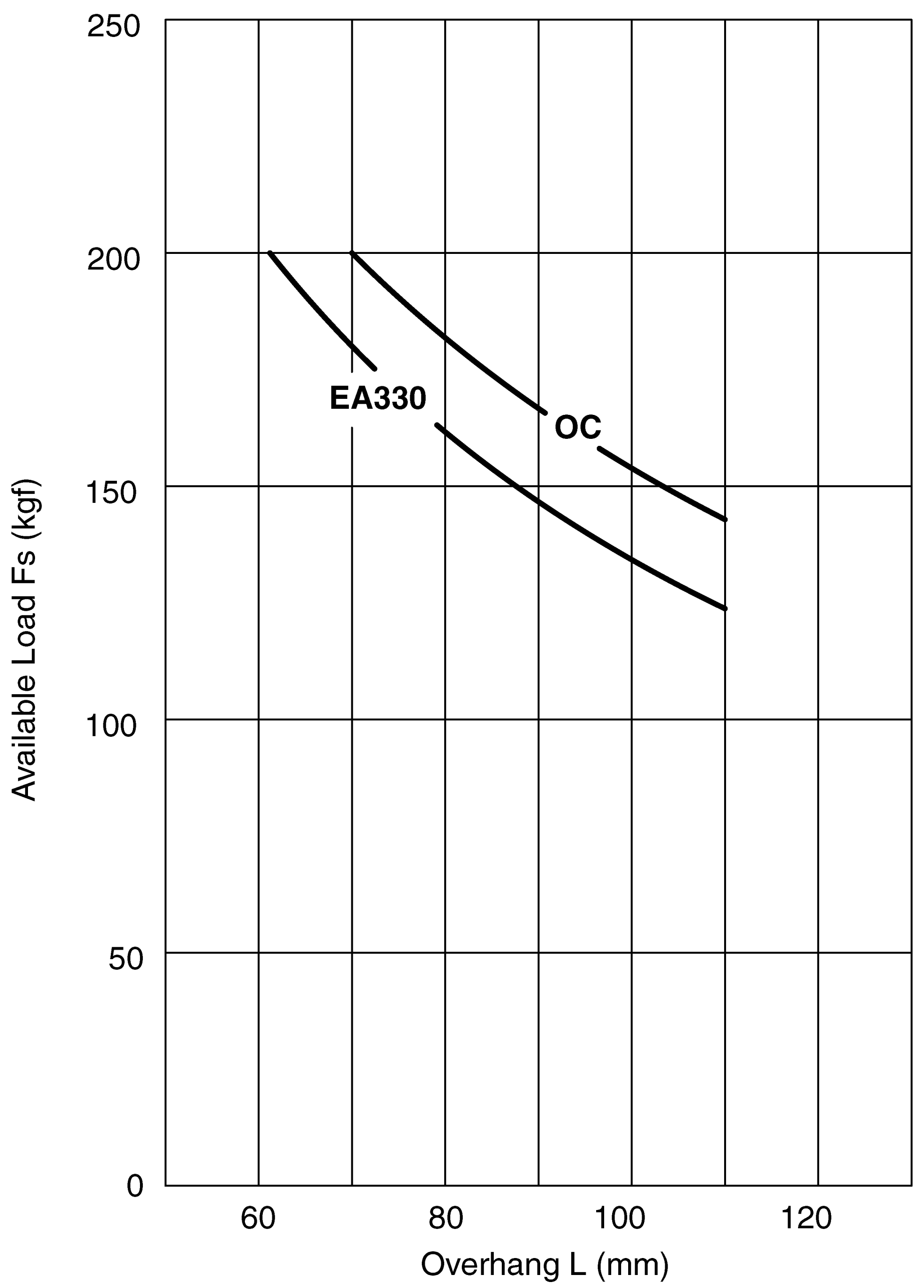


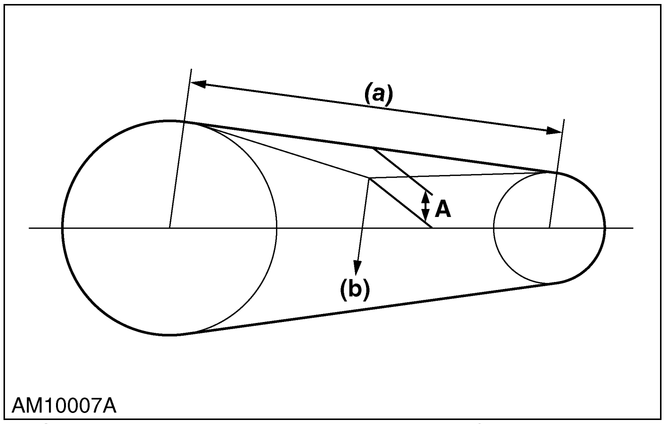
Fig. 10-5

4. HOW TO SET THE BELT

(1) Set the belt according to the following procedures.

1) Calculate the belt span length.

The belt span length is the length of the belt that does not contact with the pulleys, which is equal to the shaft center distance when the diameters of the drive and driven pulleys are the same.



(a) Span length
(b) Load
A : 1.6 mm deflection amount per 100 mm span length

Fig. 10-6

2) Apply load to the center of the belt span length and obtain the deflection loading.

Apply load to the center of the belt span length using a spring balance or something, perpendicularly to the belt. Apply the load in such a way as the deflection amount per 100 mm span length comes to be 1.6 mm. (For example, the deflection amount comes to be 8 mm when the span length is 500 mm.) And measure the load at the time.

3) Adjust the tension of the belt so as to make the load acquired by the procedure 2 between the maximum and minimum values shown in the following table.

The deflection loads that give the belts proper tensions and the axial loads at the time.

Belt shape	Range of the small pulley diameters (mm)	Minimum deflection loading		For setting a new belt		For resetting a belt	
		Deflection loading $F\delta$ (kgf/piece)	Axial load (kgf/piece)	Deflection loading $F\delta$ (new) (kgf/piece)	Axial load (kgf/piece)	Deflection loading $F\delta$ (R) (kgf/piece)	Axial load (kgf/piece)
M	38 to 50	0.5	14	0.7	20	0.6	17
A	65 to 80	0.8	23	1.2	34	1.0	29
	81 to 90	0.9	26	1.4	39	1.2	34
	91 to 105	1.1	31	1.7	46	1.4	40
	over 106	1.2	35	1.8	53	1.6	46
B	115 to 135	1.4	45	2.1	68	1.8	59
	136 to 160	1.8	54	2.7	81	2.3	70
	over 161	1.9	58	2.9	86	2.5	75
C	175 to 205	2.8	84	4.2	126	3.6	109
	206 to 255	3.3	102	5.0	153	4.3	132
	over 256	3.9	119	5.9	178	5.1	154

11. MOUNTING SYSTEM

CONTENTS

MOUNTING SYSTEM

1. GENERAL

When setting an engine on a machine, major importance should be given to assembling with precision the parts connected to flywheels, and crank shafts which rotate at high speeds.
The following points must be carefully observed.

1) Do not apply excessive force to the engine during assembly. (For prevention of off-centering surface deflection, excessive, clearance and thrust)
2) Minimize bending moment to rotating shaft. (For extended life of shafts and bearings)
3) Avoid resonance around the engine mounting frame. (Use of appropriate supporting method and rigid mounting frame).
4) Avoid torsional vibration between the engine and driven components. (Connection with a rotating body)
5) Take air flow into consideration when enclosed cover is used. (for proper cooling)
6) Provide access for easy maintenance when covering engine or parts. (for easy maintenance)
7) Take maintenance and reliability into consideration for remote control. (for positive operation)

2. SUPPORTING METHOD

Vibrations from a machine mounted with an engine depend on the vibration of the engine itself, rigidity of the mounting frame, weight of engine with equipment connected, vibromotive force and the supporting method between the engine and equipment.
Improper mounting and support will create resonant vibration in the engine system, which will cause noise and can result in major problems. The supporting method must be carefully designed.

Typical connection and supporting methods

1) Direct-connection, stationary

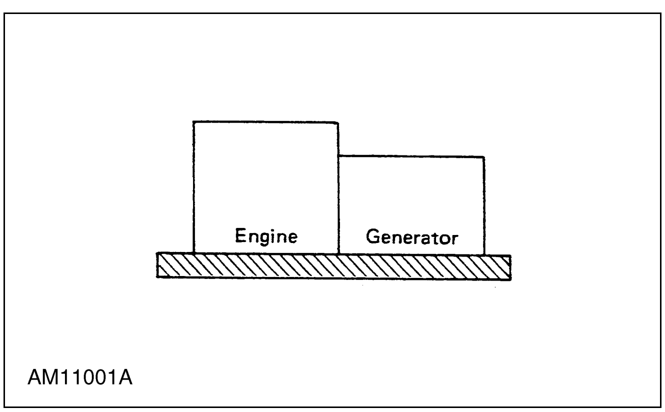


Fig. 11-1

2) Direct-connection, anti-vibration support

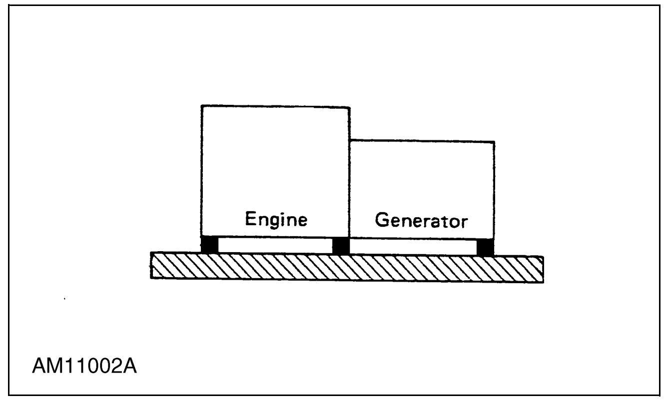


Fig. 11-2

3) Direct-connection, movable (tire)

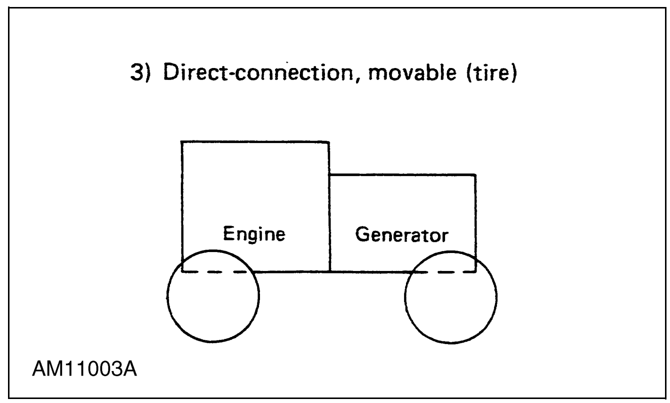
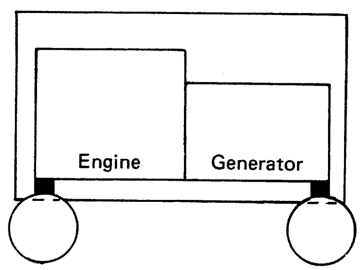


Fig. 11-3

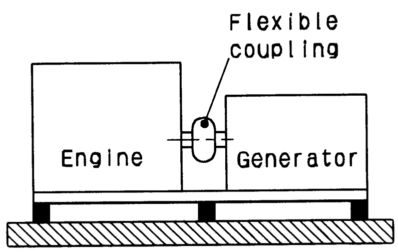
4) Direct-connection, anti-vibration support, movable



AM11004A

Fig. 11-4

5) Separate transmission, anti-vibration engine support



AM11005A

Fig. 11-5

Determine the best supporting method considering the above vibration conditions and the characteristics of the machine on which the engine is to be mounted.
Vibration acceleration and amplitude should be below the allowable levels.
Many types of anti-vibration support are being adopted recently.

Explain the determination method of anti-vibration support specifications next.

What is the goal for engine mounting ?

a) If machine has an operator and noise / vibration reduction are very important, then maximum vibration isolation is required.
   However, this usually means that the isolators are very "soft" and have larger movement, so any accessory attached to the engine should have their "mass" as closely centralized to the engines / transmissions natural "roll center" as possible or very high displacement, acceleration type vibration can occur.
   e.g. : The further away from engine / transmissions natural "roll" center the end of the muffler gets, the worse the movement.

b) If no operator, (e.g. : water pump) then isolation importance is not as great and "hard" mounts with less movement can be used.
   This will make it much easier to mount the engines accessories to the engine (less "wobble").
   However a high frequency, high acceleration, low displacement vibration can occur.

c) Is machine subjected to heavy bouncing ?
   Either moving by itself or when being carried by another vehicle.
   Mounts that may have to withstand up to 6G (6X) engine transmission weight may be required with strong overload in the vertical +/- and lateral movements.

d) Is mounting base rigid enough ?
   That the base does not have an interfering natural frequency / displacement that coincides with the engine / attachment / transmission isolators and engine rotational frequency.

   This is when a vibration reading on the machines chassis is important and may require the use of a strobe to point to the problem area.

[REQUIREMENTS IN MOUNTING THE ENGINE]

- Keep the chassis isolated from engine vibration as much as possible.
- Support the engine with the operating condition safely.

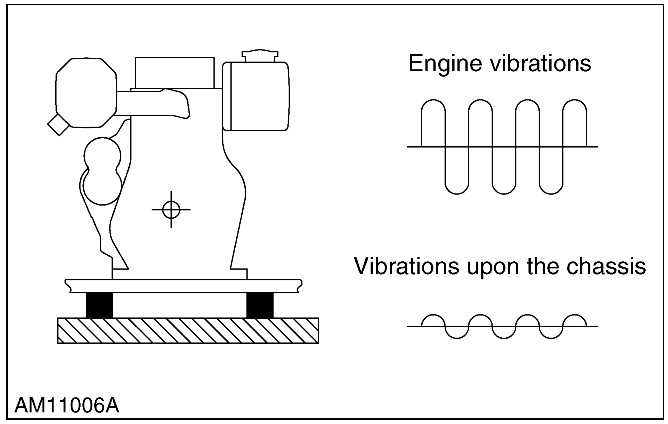


Fig. 11-6 Engine mount

(1) How to isolate the chassis from engine vibration

Elastic materials such as vibration-insulating rubber products (VIRP) are used to support an engine mount to isolate the chassis from engine vibration as much as possible.
A flexible supported engine mount has its specific natural frequency.When the engine runs near or at rpm that corresponds to that frequency, resonance occurs, which adversely amplifies the vibrations. To cope with this problem, the following points are important. :
First, support the engine with an elastic material such as VIRP.
Second, keep the engine mount's natural frequency away enough from the engine's operating speed range. (See Fig. 11-7)
Vibration-insulating rubber products (VIRP), commonly used for engine mounts, are discussed.

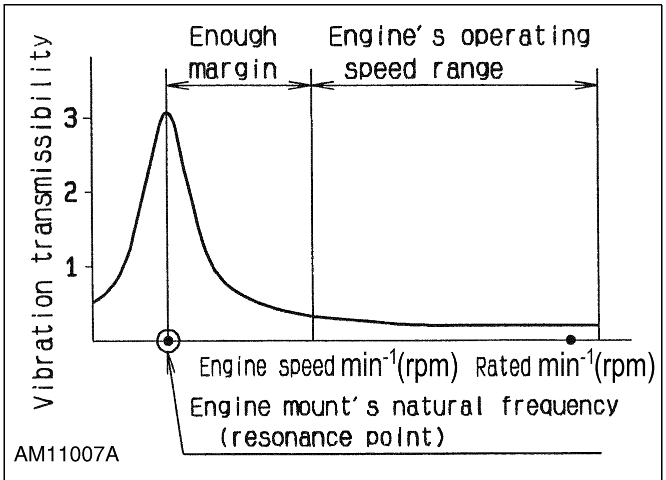


Fig. 11-7 Engine's operating speed range versus engine mount's natural frequency

(2) Conditions for safety supporting with vibration-insulating rubber products (VIRP)

Unlike rigid support with metallic stays, stiffness is a key factor in supporting an engine with VIRP in an elastic way. The VIRP helps reduce the effect of vibration upon the chassis, but the engine tends to shake more.

The softer the rubber is, the smaller the vibration transmissibility becomes, and the lower the resonance point drops. If a strong external force comes from the chassis, however, the engine will move, possibly causing an interference around the radiator or damaging the engine-related equipment. Keep engine mounting base very rigid. If the VIRP, with the rubber's deflection too large, easily gets cracked. For reliable engine mounting, therefore, keep the following point in mind :

Select VIRP that has small deflection with respect to various loads and that is durable enough.

Here are major loads that are exerted on an engine-mounting VIRP.

- Engine's own weight
- Engine's vibromotive force
- External force coming from the chassis

A VIRP to be applied must have a spring constant appropriate to support all these loads.

Now let's discuss some precautions on the loads in mounting an engine.

1) Engine's own weight

An engine's own weight cannot be avoided. Suppose that a load is equally applied on each piece of VIRP. Divide the engine's weight by the number of the VIRP pieces. The result must be below the permissible load of each VIRP piece. When the deflection of the VIRP is high, it is advisable to have a somewhat higher spring constant even within the permissible load. The permissible load P and the deflection H of VIRP are expressed as follow :

Permissible load of VIRP : $P > W/n$
Deflection of VIRP : $H = W / (K \times n)$

Where W : Engine weight
K : Spring constant of VIRP
n : Number of VIRP pieces

It is clear that the engine weight divided by the VIRP pieces must be smaller than the permissible load and that the deflection H must be kept low.

2) Engine's vibromotive force

The VIRP is exposed to the vibromotive force of an engine while it is running. An appropriately selected spring constant does not give the VIRP much deflection due to the vibromotive force. It should be noted, however, that generally there is a resonance point in the operating speed range of a rubber-mounted engine.

By resonance, the vibromotive force becomes multiplied by several times, which deflects the VIRP greatly. To allow no resonance point in the engine's operating speed range, the natural frequency must be kept out of this range.

Often, the engines low idle speed will have to be increased.

But when the engine STARTS and STOPS, the resonance point is experienced along the way of speeding up and slowing down.

The VIRP must withstand such vibrations that occur during the start and stop the engine.

These vibrations generally roll the engine. To reduce the deflection in such direction, increase the spring constant in the rolling direction or modify the support structure.

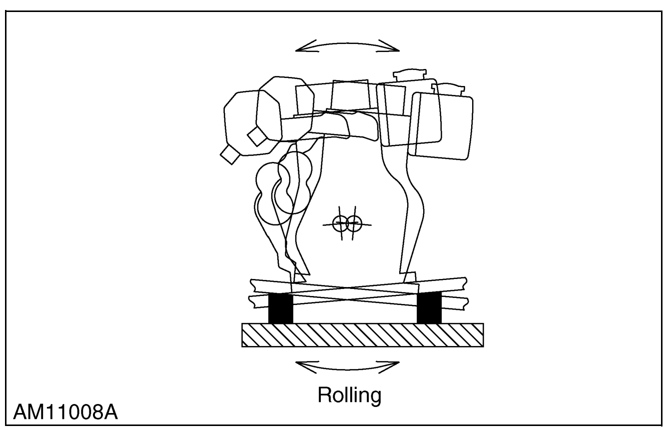


Fig. 11-8 Vibration at engine start and stop

[VIBRATION INSULATING RUBBER PRODUCTS (VIRP)]

(1) Selecting VIRP

Please consult KUBOTA Engineering or VIRP manufacturer for proper selection of VIRP.

(2) VIRP characteristics

VIRP have the following main features.

- Damping force available
- Spring constants presettable in three axes
- VIRP shaped in a relatively flexible way

For use of VIRP, the following points must be kept in mind.

- Creep phenomenon
- Temperature characteristic
- Oil resistance

1) Creep phenomenon

Since the VIRP has been applied, it gradually suffers from permanent deformation.
Initial deflection comes after the first 2 weeks, and slight, gradual deformation continues thereafter.
This problem must be considered in advance.

2) Temperature characteristics

The VIRP is greatly affected by temperature fluctuations. The higher the temperature, the smaller the spring constant, and vice versa.
The temperature characteristics depend on the types of rubber, but their spring constants suddenly get higher. This means that temperature changes must be understood well. It is also important to adjust test-run temperatures to the practical application.

3) Oil resistance

Some VIRP materials are not resistant to oil and grease. Pick up the appropriate VIRP material that sufficiently withstands oil and grease for engine-supporting applications.

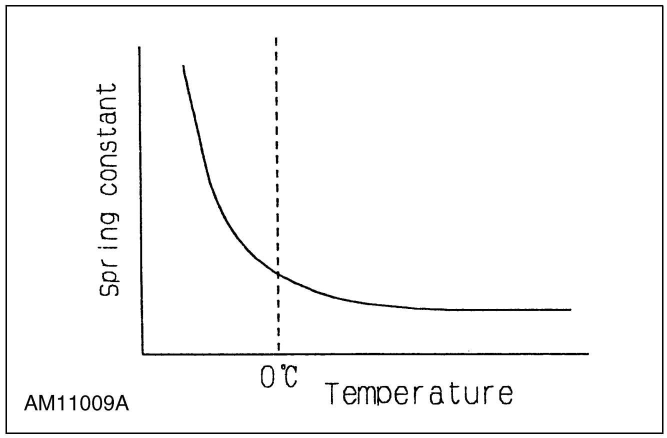


Fig. 11-9 VIRP spring constants versus temperatures

[SUPPORTING PROCEDURE]

(1) Supporting points

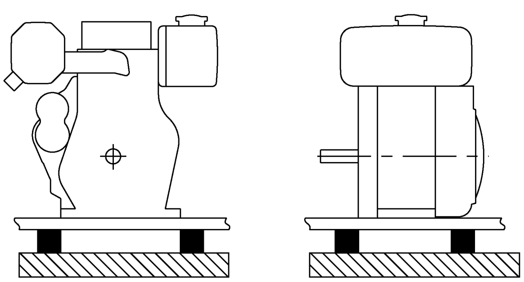
In cases of using VIRP, all the VIRP points must be arranged to be equally loaded. If any of the VIRP pieces is under unequally heavy load, not just its durability is affected, but also unusual vibrations may occur. The load upon each of the VIRP pieces is determined by its center of gravity and supporting position. If the support positions cannot be changed and the load cannot be equally distributed, preferably modify the spring constant of each VIRP piece and allow the same level of deflection to all the pieces.

Supporting methods

A typical supporting methods is shown in Fig. 11-10 and Fig. 11-11 In this design.

The engine is installed on the common bedplate whose bottom is supported by the VIRP.

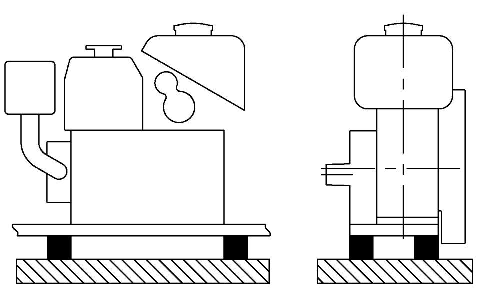
OC engine



AM11010A

Fig. 11-10

EA engine

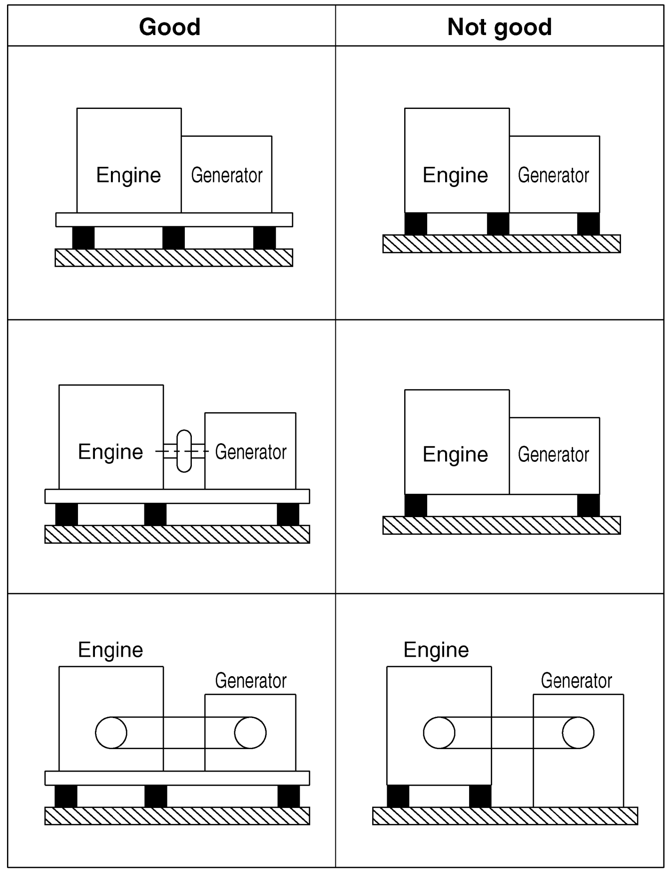


AM11011A

Fig. 11-11

CAUTION

- When using VIRP, the engine and the driven unit shall be installed on a common bedplate whose bottom shall be supported by the VIRP. Directly supporting the engine with the VIRP might cause vibration generation, which can cause eventual breakage of the PTO shaft and shortening of the life of the engine drive unit.



AM11012A

Fig. 11-12

CAUTION

● Regarding the EA engine

If engine feet are supported directly with the VIRP or the front and rear engine feet are separately supported in a vibration-proof way on the different bedplates, the crank case might be cracked because of its natural vibration.

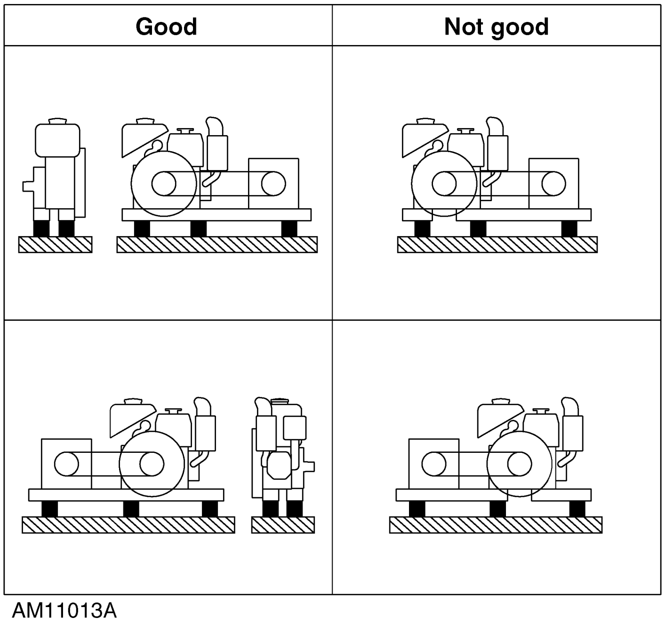


Fig. 11-13

(2) Support stay configurations

Most general-purpose engines are supported at 4 points. There are two common ways to support them : horizontal stays and slanted stays.

1) Horizontal stays

The horizontal stays are shown in Fig. 11-13.
This is the simplest method in a compact way.
To keep the natural frequency low in this arrangement, have the stays as close to the center of gravity of the engine as possible. Because the vibrations occur vertically or horizontally depending on the support positions, it is equally important to find the best support positions.

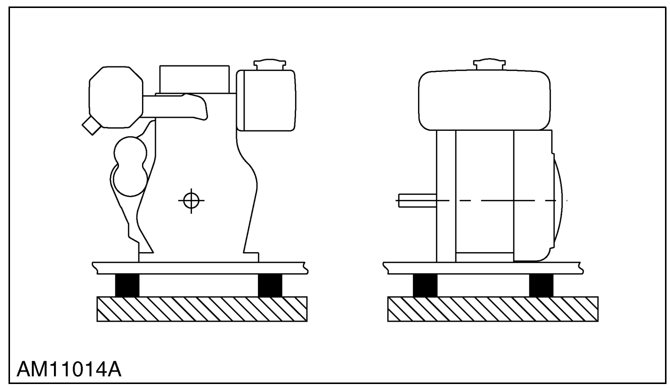


Fig. 11-14 Horizontal stays

2) Slanted (angled) stays

The slanted stays are shown in Fig. 11-15. This method is commonly used when the rolling vibration's natural frequency needs to be lower. Such natural frequency is kept smaller by aligning the shearing direction (softest portion) of VIRP with the rolling direction. The tilt angle θ is determined by the following factors among others.

- Principal axis of inertia
- Direction of external force
- Durability of VIRP

The above factors are discussed one by one next.

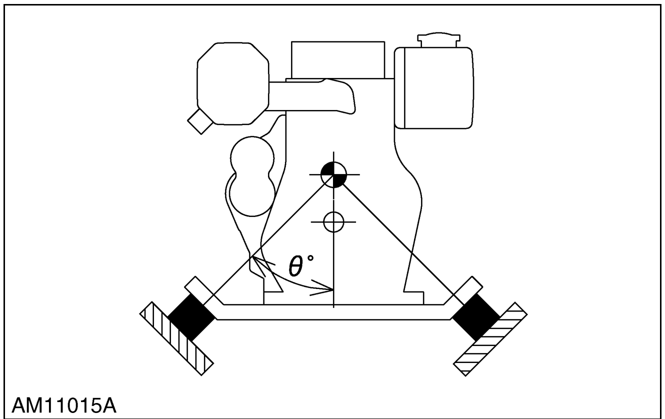


Fig. 11-15 Slanted stays (A)

a) Principal axis of inertia

With the support positions fixed, the natural frequency can be lowered by setting the tilt angle θ along the principal axis of inertia (see Fig. 11-15). Tilt angles of 30～60° are commonly adopted.

b) Direction of external force

The slanted support system is weak against the vertical external force coming from the chassis.
The tilt angle therefore must be determined by the type of machine. If the vertical external force is applied, narrow the tilt angle θ or raise the spring constant. It should also be noted that the slanted support has a smaller spring constant in the rolling direction and that the vibrations become noticeable at start and stop of the engine.

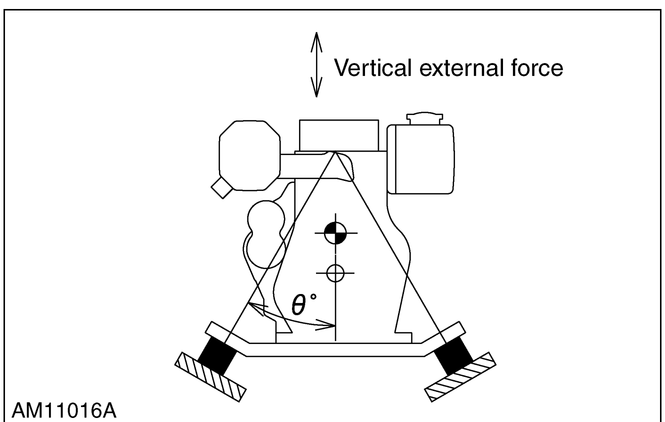


Fig. 11-16 Slanted stays (B)

c) Durability of VIRP

The slanted stays support the engine in the shearing direction, in which the VIRP is most affected, and help reduce the natural frequency.

An extreme tilt angle of θ = 90° must be avoided.
The permissible load of VIRP is generally small in the shearing direction, which may affect its durability. The tilt angle θ must therefore be determined to keep the shearing load low.

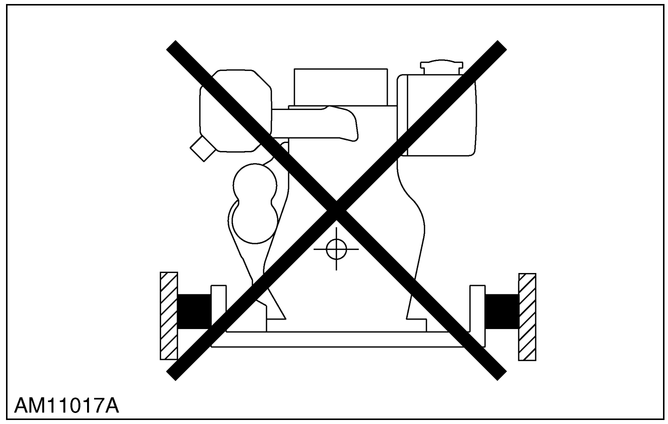


Fig. 11-17 Tilt angle θ =90°

3) Support stays

The support stays should be designed with a sufficient strength margin. The support stays must also be free from resonance with the engine's vibrations because the stays themselves have their own natural frequency.
The thickness of the stays vary from machine to machine. To cope with a great external force as construction machinery, the stays must be designed to be stiff. It is a advisable to have the stays relatively short and place them near the engine.

[ATTACHING EQUIPMENT ON THE ENGINE]

Generally speaking, it is better to place a silencer, air cleaner and other equipment separate from the engine. In many cases, stays for air cleaner, silencer, fuel filter and others are affected much by vibrations, and such equipment is set up easy to resonate. Resonance may damage the equipment and their stays much earlier than expected.
Preferably place those equipment on the chassis and connect them with the engine using flexible pipes or the like. When placed directly on the engine, proper measures must be taken against vibrations.
Regarding the OC engine.
The OC engine is equipped with a standard muffler and a fuel tank. If the engine is operated at high revolution while it is supported with the anti-vibration rubbers, the mounting positions of the muffler and fuel tank might be damaged because of the vibration. When operating at 3000 rpm or higher revolution, it is recommended that the muffler and the fuel tank are installed separately from the main body.
And carry out a durability test with the equipment on the engine to make sure there is no problem. It is important to check related water, fuel and other pipes that are vulnerable to vibrations.

[NATURAL FREQUENCY VERSUS RESONANCE]

When an engine is mounted, there surely is a natural frequency. The natural frequency depends on the following factors :
Weight, moment of inertia, center of gravity, support positions, spring constant of VIRP, and principal axis inertia.
In using rubber for the engine mount, the natural frequency must be strictly considered. If the engine runs around the natural-frequency rpm, resonance occurs and the vibromotive force gets amplified up to several times. This may damage the equipment, stays or VIRP pieces, or invite an innterference with the chassis.
The natural frequency can be calculated. In a practical test, however, run the engine in its entire speed range and find an rpm at which the vibration reaches a peak (resonance point) : the natural frequency stands at this rpm. If the natural frequency is within the engine's operating speed range, it is necessary to keep the natural frequency below the operating speed range or the lowest operating speed above the natural frequency.
The following measures could be taken in order to reduce the natural frequency.

- Lowering the spring constant of VIRP
- Increasing the moment of inertia (for rotary motion)
- Decreasing the distance from the center of gravity to the support positions (for translational motion)
- Increasing the weight (for translational motion)
- Reducing the number of supporting points (VIRP pieces)

The above ways help reduce the natural frequency and keep the resonance point away from the engine's operating speed range. But the entire amplitude and acceleration may remain the same.
When the spring constant of VIRP is made smaller, for example, the natural frequency becomes lower too. The smaller the spring constant, however, the less the VIRP can with stand the vibromotive force.
This means that the VIRP may be affected much more by the same level of vibromotive force.
The durability is also degraded accordingly.
The same is true with a smaller number of VIRP pieces.
Just lowering the natural frequency is not sufficient.
Other points that would be adversely affected must be kept. In mind, too.
The engine mount may also resonate by an external force. This is called engine shake.
If the resonance point lies at low frequencies of 5～20 Hz, the external force from the chassis gets the engine resonating. In such case, VIRP with great damping force must be used.

[PRECAUTIONS IN SWITCHING TO DIFFERENT-TYPE ENGINE]

Suppose the VIRP is used for an engine of different type from the previous one.
It is essential to consider a quite different design of engine mount.
This is because a different-type engine requires a different set of VIRP factors. Here are the points to remember in selecting the appropriate VIRP.

- Physical properties of the engine (weight, moment of inertia, center of gravity, etc.)
- Specifications of the engine (number of cylinders, speed range, etc.)
- Supporting method of the engine (support positions, number of supporting points, etc.)

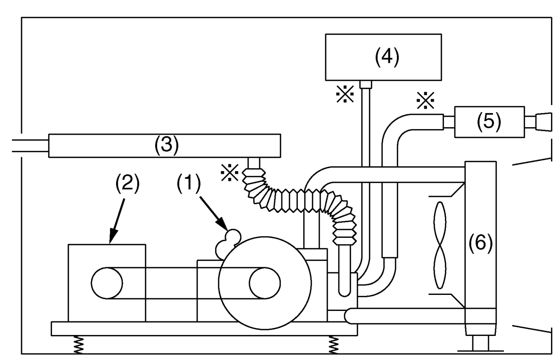
According to these data, the following factors will be different, also, causing a different mode of vibration.

- Natural frequency
- Vibration characteristics of the engine

Take an example of an engine that has nearly the same specifications, except the weight, as those of the previously mounted engine.
The smaller the weight, the greater the natural frequency. This causes the resonance-point rpm to go higher and adversely affects the vibration in the low rpm range. There may be cases in which the engine mount must be redesigned or the idling speed must be changed.

[PRECAUTIONS IN PIPING WHEN USE RUBBER MOUNT]

If engine and related equipment are supported on different frames, flexible piping must be used.



AM11018A

(1) Engine (2) Generator (3) Muffler (4) Tank (5) Air cleaner (6) Radiator

Fig. 11-18 Example

3. POWER TRANSMISSION DEVICE

[FLEXIBLE COUPLING]

Torsional vibration and impact of the drive shaft can be absorbed by a flexible coupling which prevents them from being transmitted to the driven shaft. Installation of such a coupling between the engine and driven shaft is limited by available space. A flexible coupling also prevents torsional vibrations and impacts generated at driven shaft from being transmitted to the engine. There are many types available, such as rubber types, resin types, chain types, tire types and fluid types.
Select according to specific load and use condition.

[POWER CUTOFF DEVICE (Clutches / Disconnects)]

Power cutoff devices (clutches) allow engines to be warmed-up at no load. It is a general practice to install clutches on such as products vehicles, tractors, pump sets ; etc. which can encounter sudden loads.
The following kinds of clutches are available.

Mechanical type	Dry type	● Engagement ● Friction plate loaded type (spring) ··· ∗1 ● Centrifugal clutch
	Wet type	● Friction plate loaded type (spring) ··· ∗2
Electric type		● Electromagnetic clutch ··· ∗3

Note 1 :
The spring loaded type clutches (∗1, 2) are always "IN" and a clutch pedal or lever is used to cut off power against spring force. For this reason, thrust force is applied to the crankshaft and care must be given to prevent use at a load exceeding the allowable limit.

Note 2 :
The electromagnetic clutch (∗3), must be grounded to prevent an electric current from flowing to the crankshaft. Otherwise, bearing metals will be electrically corroded, resulting in possible bearing and crankshaft failure.
Detailed consultations should be held with the engine maker to determine the most appropriate clutch for a particular engine and purpose.

[TORSIONAL VIBRATION]

When an output shaft is directly connected to the crankshaft, it is necessary to examine stresses caused by torsional vibration of the shaft system depending on rigidity and inertia force of connecting shaft system. When connecting the engine directly to generator, compressor, pump, air blower, etc., contact KUBOTA.

4. SPEED CHANGE DEVICES

The following kinds of speed change devices are available.

1) Mechanical type : Gear speed change devices
2) Fluid type : Torque converter
3) Fluid type : Hydrostatic transmission (HST)

Efficiency is a common factor of an engine regarding load characteristics against engine characteristics and adaptability to using conditions and its frequency.
Fluid types allow stepless variation of torque and speed. Efficiency is lower than a mechanical type and varies greatly depending on speed range, so that matching should be done carefully.
Fluid types also require special maintenance since oil is used as the transmission a medium.
Various factors, including oil temperature, heat dispersion, rising of starting temperature limit due to resistance increase at cold starting must be considered, along with oil viscosity for use in cold weather.
Oil viscosity, and increased viscosities due to low ambients are important considerations.

5. OPERATING MECHANISM

If an engine is covered ; starting, speed changing, and stopping must be controlled remotely via a mechanical (rod or wire) or an electrical system.
In this case, consider clearances of link mechanism, wear and aging factors carefully. Improper installation will adversely affect engine performance.
Provide special attention to frequency of use and force applied to levers.

6. OTHER PRECAUTIONS

1) When both the engine and transmission machine are directly connected and fixed, rigidity and strength of the mounting base must be considered carefully.
   i.e. Material, plate thickness, flatness, roughness, etc.
2) Engine mounting stands and fixing bolts must have sufficient rigidity and strength.

Application Check Sheet

for **OC / EA Engine**

Engine Model:		Base Engine Model:	
Cord No. -		Cord No. -	
Gross: ISO-2534,3046	kW(ps) / min^{-1} (rpm)	Gross: ISO-2534,3046	kW(ps) / min^{-1} (rpm)
Continuous: ISO-2534,3046	kW(ps) / min^{-1} (rpm)	Continuous: ISO-2534,3046	kW(ps) / min^{-1} (rpm)
Overload: ISO-2534,3046	kW(ps) / min^{-1} (rpm)	Overload: ISO-2534,3046	kW(ps) / min^{-1} (rpm)

Idling Speed: High/ ~ min^{-1} (rpm), Low/ ~ min^{-1} (rpm)

Application:

Engine Engineering Dept.

KUBOTA Corporation

Revision				Issued
Date: / /	Date: / /	Date: / /	Date: / /	Date: / /

confirmed

Issue No.

Reg.No.

Equipment Manufacturer (Customer)	→ ←	KUBOTA (Engine) Distributor	KUBOTA Corporation
Your signature Date: / /		Your signature Date: / /	Engine Engineering Dept.

↑ ↓ ↑ ↓

KUBOTA Corporation
Engine Export Dept.

KUBOTA Industrial Engine Application Check

1) Purpose :

Engine Division of Kubota Corporation (hereinafter referred to as Kubota) supports OEM through application check of the engines (hereinafter abbreviated as Application Check) in order to maintain and improve the quality and performance of the OEM products that have engines of Kubota.

Application Check is intended to check whether the engines of Kubota mounted on the OEM products are properly installed and deliver such performance as indicated, and instruct OEM to correct defects, if any; thus Application Check is extremely important for not only Kubota but also OEM.

Application Check must be implemented if any change is made in the development of new products and to the specification of products.

Whether Application Check is proper or not affects whether the entire products are good or bad as well as the performance of the engines. And if Application Check is not proper, this may lead to complaints and lower brand image; therefore Application Check shall be implemented by the engineers with a certain knowledge and skills who are certified by Kubota or a distributor of Kubota.

In Application Check, measurement instruments which are periodically calibrated and whose accuracy is ensured shall be used.

If Application Check is implemented by any related department other than Engineering Dept. or distributor of Kubota, the results shall be reported to such Engineering Dept. via Engine Export Dept. to seek their judgment on whether the results are acceptable or not and any improvement is required or not. In some cases, Application Check shall be implemented again.

The results of Application Check shall be stored without fail as they will be needed in subsequent services.

2) Application Review Forms :

Following forms are used for KUBOTA to review its Direct OEM product. KUBOTA Distributors are recommended to use the same forms for the review.

· Review Form - (a) :
- Engine Application Sheet 1/3 : required technical factors and environmental conditions in installation (A-1)
- Engine Application Sheet 2/3 : power requirement as per each PTO system and engine model recommendation (A-2)
- Engine Application Sheet 3/3 : product type, engine mounting system and other technical informations (A-3)
- Engine Performance, Maintenance and Safety Check Sheet (B-1)
- Engine Specification Sheet (B-2 --- 1/2, 2/2)

· Review Form - (b) :
- All of the "Review Form - (a)" sheets and
- Temperature Measuring Sheet (b-1)
- Vibration Measuring Sheet (b-2)

· New part of Modification Request and Part Change Information & Agreement Sheet (C-1), (C-2)

3) Supplement :

The purpose of this application check is, as mentioned in the paragraph 1), to assist equipment manufactures in the application of KUBOTA engines with the objective of improving overall equipment quality. In this object, KUBOTA and the KUBOTA distributors assume no and hereby disclaim any additional liability in undertaking this review, including but not limited to, any liability under any express or implied warranties, applicable national, state or local laws, regulations or ordinances, or otherwise. The customer is responsible for accurately and fully completing this engine application check and returning it to KUBOTA or the KUBOTA distributors, as the case maybe.

The customer is further responsible for confirming the suitability for different operating conditions or legal regulations and requirements at each delivery destination.

A-1 Engine Application Sheet (1/3)

(OC / EA)

(technical factors and environmental conditions in installation)

Date: / /

Customer :	Product Name :	Model Name :
Address : a person in charge :	Tel :	Fax :
start of production : -20 . units/1st lot (☐new product ☐minor change product)	**_Production quantity :_** units/year (at commercial base)	
Distributor : Address :	a person in charge : Tel :	Fax :

1. Requirements for engine *☐points to be marked by "x"

*Applicable output standard :
☐ ISO-3046, ☐ SAE-J1349,

(1)-1 Gross {Gross intermittent} :	(1)-2 Overload {Net intermittent} :	(1)-3 Continuous {Net continuous} :
(. HP) . kW (. ps) / min^{-1} (rpm)	(. HP) . kW (. ps) / min^{-1} (rpm)	(. HP) . kW (. ps) / min^{-1} (rpm)

(2) Displacement : L

(3) Max. torque : . N-m (. kgf-m) / min^{-1} (rpm)

(4) Dimensions :	[Total length]	[Total width]	[Total height]
	Max. mm (inch)	Max. mm (inch)	Max. mm (inch)

(5) ***Idling speed :*** (without load) min^{-1} (rpm)

(6) ***Max. speed :*** (without load) min^{-1} (rpm)

(7) ***Loading pattern :***
Please submit Kubota Japan the loading pattern data with its work description.

(8) **Regulation & standard requirements** (emission, materials, others) :

☐ EPA	☐ INDIA
☐ 97/68/EC	☐ R120
☐ KOREA	☐ R24
☐ CHINA	☐ JPN
☐ Others	

(9) Destination :

2. Operating condition *☐ points to be marked by "x"

(1) Operating hours :

****annual estimated usage :***	****seasonal characteristics :***
hr.	☐ No ☐ Yes (from : to :)

(2) Operator :
☐ private use ☐ rental use ☐ professional operator

(3) Atmosphere :

a) ***Cold starting temp. :***	b) Max. (or Highest) operating temp. :
°C (°F)	°C (°F)
c) Max. (Highest) operating altitude : m(ft)	d) Highest operating humidity : %

(4) Dust : Special consideration to be applied to air cleaner and radiator for dusty conditions.
☐ straw, grass, dry leaf, ash ☐ dust, sand (particle size : about μ)
*dust prevention : ☐ No ☐ Yes ( )

(5) Rust surrounding : Special countermeasure is necessary depending on the condition.
☐ Normal ☐ Peculiar (for ☐ salt ☐ chemical :)

(6) ***Inclined angle :***
☐ No ☐ Yes (Max. inclined angle : about degrees, Max. continuous operation : about minutes)

*** If there are specification or structural changes at Customer's product, application must be rechecked and reported.**

confirmed

Customer : ____________ Distributor : ____________ KUBOTA : ____________

reported by : ____________

A-2 Engine Application Sheet (2/3)

(OC / EA)

(technical factors and environmental conditions in installation)

3. Power requirement			*☐ points to be marked by "x"		
	*Applicable output standard : ☐ ISO-3046, ☐ SAE-J1349.				
	Use (unit)	PTO spec.	Power take off system	Load	concurrent drive : *mark
1	A : (1st drive)	1. system ☐mechanical ☐hydraulic ☐generator	1) clutch : ☐ Yes ☐ No (Type :)	1. rated output (. HP) . kW (. ps) / min^{-1} (rpm)	
			2) coupling : ☐ Yes ☐ No (Type :)	2. max. output (. HP) . kW (. ps) / min^{-1} (rpm)	
		2. PTO position ☐FW ☐Crank Shaft	3) torque converter : ☐ Yes ☐ No (Type :)	3. load pattern	
			4) belt or chain drive : ☐ Yes ☐ No (Type : , no. of :) *overhang : mm		
2	B : (2nd drive)	1. system ☐mechanical ☐hydraulic ☐generator	1) clutch : ☐ Yes ☐ No (Type :)	1. rated output (. HP) . kW (. ps) / min^{-1} (rpm)	
			2) coupling : ☐ Yes ☐ No (Type :)	2. max. output (. HP) . kW (. ps) / min^{-1} (rpm)	
		2. PTO position ☐FW ☐Crank Shaft	3) torque converter : ☐ Yes ☐ No (Type :)	3. load pattern	
			4) belt or chain drive : ☐ Yes ☐ No (Type : , no. of :) *overhang : mm		
3	***possible max. concurrent load to engine***		(SYS.A) + (SYS. B) = (total) (. HP) + = . kW (. ps) / min^{-1} (rpm)		
4	***frequency of max. load***		☐ intermittent max. load	☐ continuous rated load	☐ stand-by load (Generator etc.)
5	***starting resistance (load)***		***cold starting temperature :*** °C (°F)	☐ ***instant load at cold starting*** (dragged torque : . N-m or kgf-m) (surplus output is necessary in case of larger fluid resistance.)	☐ no load
6	(1) ***power requirement***		(max. power requirement) (surplus output ratio) - - - Atmosphere and others (. HP) . x = . kW (. ps) / min^{-1} (rpm)		
	(2) ***torque requirement*** (peak torque)		. x = . N-m or kgf-m / ∼ min^{-1} (rpm)		
4. Recommended KUBOTA standard engine			*☐ points to be marked by "x"		
	*Applicable output standard : ☐ ISO-3046, ☐ SAE-J1349.				
	KUBOTA standard engine model		- - - (cord no. -) (. HP) . kW (. ps) / min^{-1} (rpm)		

*** If there are specification or structural changes at Customer's product, application must be rechecked and reported.**

(technical factors and environmental conditions in installation)

5. Mounting & matching

*☐ points to be marked by "x"

(1) product type :
☐ vehicle ☐ transportable ☐ stationary

(2) Engine mount position : from whole product (body)
☐ front ☐ center ☐ rear

Engine mount direction :
(flywheel direction for product left direction)
☐ front ☐ rear ☐ left ☐ right

(3) Speed control lever
Operation : ☐ electric governor ☐ foot pedal ☐ manual ☐ others
Connection : ☐ rod ☐ wire

[Engine mounting position---sketch]

(4) **Engine mounting system**

A. mount base :
(material : , plate thickness : , flatness :)

B. rubber cushion :
☐ No ☐ Yes (material : , spring constant :)

C. mounting feet :
☐ No ☐ Yes (plate thickness : , no. of holding points :)

D. flywheel housing direct mounting :
☐ No ☐ Yes (☐ knock pin ☐ centering location)

E. engine support or common mount base :
☐ No ☐ Yes (material : , plate thickness :)

[Engine mounting system---sketch or photo]

* front view * side view * top view

* crankshaft center

6. Other technical information

*☐ points to be marked by "x"

(1) engine rpm at centrifugal clutch engagement : ______ min^{-1} (rpm)

(2) ***belt drive*** : tension force / direction of tension, overhung, belt type / no. of belt, diameter or pulley. etc.

(3) ***thrust force on crankshaft :*** ☐ No ☐ Yes

(4) in case it is necessary to check torsional vibration : ______

(5) ***fuel tank position*** : height difference between the bottom of fuel tank and the upper surface of injection pump.
* note : fuel feed pump, fuel filter and fuel piping must be checked and sketched in details.

[fuel line system - - - sketch]

* fuel injection pump fitting face

(unit = mm/inch)

(6) ***Safety shut down, warning system :***

Oil pressure : ☐ Gauge
kPa (kgf/cm^2, psi) switch,
setting pressure manufacturer

Water temperature : ☐ Gauge
°C (°F) switch,
setting pressure manufacturer

Radiator cap pres : ☐ 108 kPa (1.1 kgf/cm^2, 15.6 psi) (STD) ☐83 ~ 96 kPa (0.84 ~ 0.98 kgf/cm^2, 12 ~ 13 psi) ☐ Others

Warning system : ☐ Lamp ☐ Buzzer ☐ Gauge ☐ Automatic shut down

Shut down system : ☐ Operate the stop lever ☐ Shut off the fuel line ☐ By hand ☐ By solenoid
☐ By electromagnetic valve

(7) ***accessory parts supply***

* radiator : ☐ KBT (P/N : -) ☐ local (manufacturer :)
* muffler : ☐ KBT (P/N : -) ☐ local (manufacturer :)
* air cleaner : ☐ KBT (P/N : -) ☐ local (manufacturer :)
* fuel flter : ☐ KBT (P/N : -) ☐ local (manufacturer :)

(8) other unique specifications or technical information :
☐ No ☐ Yes

*** If there are specification or structural changes at Customer's product, application must be rechecked and reported.**

B-1 Performance & Maintenance and Safety Check Sheet (OC / EA)

Date: / /

Unit model / serial no. :	Product Name :
Engine Model :	***Engine serial no.*** :
Checked place at :	***Loadng condition*** :

checking items	judged
1. Engine oil :	
- ***Oil temp. (below 120 °C (248 °F) under max load and below 110 °C (230 °F) at continuous operation)***	
- oil level checking	
- oil supply	
- oil draining	
- oil filter replacement	
2. Cooling system	
- obstacles, radiator front and rear	
- clearance, fan and radiator core / shroud / bracket	
- prevention of re-circulation cooling air	
- prevention dust of radiator	
- checking, closed by dust on radiator	
- capacity (radiator locally supplied)	
- antifreeze coolant	
- reserve tank	
air to boil (ATB = above 49 °C (120 °F), at continuous operation) When using radiator separately from the engine.	
- water supply (add) and level checking	
- cooling system to fill water completely (to avoid aeration)	
- water draining	
- fan belt adjustment	
- fan belt replacement	
- danger of scald by overblown hot water	
- danger of scald by damages of radiator cap, hoses	
3. Inlet and Exhaust	
- entrance of rain, dust and hot air from air cleaner	
- capacity (locally supplied air cleaner)	
- back pressure of muffler (locally supplied muffler)	
- check, cleaning and replacement of air cleaner element	
- objects, easy burn, on or over muffler	
- exhaust direction (not toward human being, battery, fuel system)	
- cover to prevent a burn	
4. Fuel system	
- filter at fuel tank, supply port	
- devious fuel piping	
- fuel drop to fuel tank	
- air bleeding, after filter change or fuel empty	
- electric fuel feed pump for low positioned tank	
- fuel supply to fuel tank	

checking items	judged
- fuel draining from tank bottom	
- air bleeding from fuel line	
- check, cleaning, replacement of fuel filter	
- fuel pipe's do not contact with hot part	
- fuel pipe's do not contact with engine or machine	
- fuel type label	
- temperature of fuel system must not beyond 60 °C (140 °F)	
5. Electric parts	
- temp. (unexposed to elevated heat)	
- fixing direction of electrical components such as	
- protection from rain, vibration	
- key switch, prevented from rain, washing	
- earth (two grounding conductor necessary for rubber cushion mount)---Battery ⇔ Engine / Battery ⇔ Chassis	
- battery capacity	
- battery check, cleaning, replacement	
- battery cable not connected reversely structurally	
- battery cable not bundled other cords	
- contact parts, covered by corrugate tube	
- wiring clip, suitable for vibration	
- engine stop when electric system is disabled (e.g. Battery dropped out)	
- wirings do not contact with hot part	
6. Others	
- no excessive force on engine speed control lever	
- no resonance point between low and high engine speed	
- engine oil, specified oil is used	
cold starting ability, satisfactory for customer requirement	
- PTO system, proper	
- belt tension drive, durable	
- engine serial number, can be read	
- engine maintenance interval, clarified	
- cover protector against rotator	
- cover at high temp. Parts / area for burn prevention	
- visibility of emission label	

7. Special interference check between OEM parts and Kubota parts				
- evidence of interference check (ex. drawings) by OEM or Kubota engineering	Parts	Yes	Evidence	<OEM parts name>
				<KUBOTA parts name>
		No		

NOTE : judgment (evaluation) : O = good, OK, E = to be examined, X = No good, need modification.

*** If there are specification or structural changes at Customer's product, application must be rechecked and reported.**

confirmed

Customer : ____________________ Distributor : ____________________ KUBOTA : ____________________

reported by : ____________________

B-2 Engine Specification Sheet

(OC / EA)

Engine model :

ITEM	UNIT	SPECIFICATION
Type		Horizontal Water Cooled 4-stroke Diesel / Vertical Oil -air-cooled 4-stroke Diesel
Number of cylinder - Bore x Stroke	mm	- Φ x L
Total Displacement	L	
Power (Continuous)	kW [HP] (ps) / min^{-1} (rpm)	
Power (Overload)	kW [HP] (ps) / min^{-1} (rpm)	
High idling speed	min^{-1} (rpm)	
Low idling speed	min^{-1} (rpm)	
Combustion chamber type		
Fuel injection pump type		
Type of Governor		
Injection nozzle type		
Fuel injection timing	deg.	- ° Before Top Dead Center
Fuel injection pressure	MPa	
Fuel		
Compression ratio	ε	
Cooling system		
Starting system		
Lubricating oil quality		
Lubricating oil capacity	L	
Direction of rotation		
Dry weight	kg	
Injection (Fire) order		
Fuel tank capacity	L	
Fuel consumption	gr/kW [HP], (ps)/h	
Coolant capacity	L	
Regulator		
Starter	V-kW	
Starting aid device		
Dynamo / Alternator	V-W	
Dimension (L x W x H)	mm	
Recommended battery capacity	V-Ah	
Application		
Stop solenoid		
Air cleaner		
Muffler		
Fuel filter		
Fuel pump (feed)-electrical		
Pre-filter		
Radiator / Oil cooler		
Reserve tank		
Timer		
Coupler		
PTO shaft		

NOTE : 1) It is requested specify the exact parts NR. If possible please attach the contents of the Kit, or Comp. Parts.
2) When you have to ask KBT to adopt "New parts" you should be required to apply "Sheet C-1".

b-1 Temperature Measuring Sheet

(OC / EA)

Date : / /

Unit model / serial no. :	Product Name :	Checked place at :
Engine model :	**Engine serial no. :**	**Loading condition :**

	measuring	before E/G start	1st	2nd	3rd	4th	5th	6th	7th	8th	Allowance value	remarks
* measuring time :			:	:	:	:	:	:	:	:		
(unit = degrees ℃/℉)		℃/℉	℃/℉	℃/℉	℃/℉	℃/℉	℃/℉	℃/℉	℃/℉	℃/℉	℃/℉	
1. Ambient	AT											
2. **Engine room**	RT										<50/122	
3. **Exhaust gas (confluence)**	EXT											
4. **Engine oil** Grade ______ (API classification)	LOT										<110/230 <120/248	(at Continuous) (at Overload)
(at 40 °C (104 °F) Ambient)	△T											
5. **Intake air**	IAT										<45/113	
	△T										<5/9	(IAT)-(AT)
6. Cooling air inlet **(Radiator inlet)**	CAIT										<40/104	
7. Cooling air outlet	CAOT											
(Radiator outlet)	△T										<30/54	(CAOT)-(CAIT)
8. Overflow volume of cooling water	OFQ											
9. Fuel	FOT										<60/140	
	△T										<20/36	(FOT)-(AT)
10. Battery surface	BRT										<55/131	
11. Surface of starter alternator, regulator, etc.	STT ALT RET										<80/176	
12. **Engine speed** (min^{-1}(rpm))	N										**Low Idling** **High Idling**	

When using radiator separately from the engine

13. Cooling water inlet **(Radiator inlet)**	CWIT										<110/230	**radiator cap = 88.3 kPa (0.9 kgf/cm^2, 12.8 psi)
14. Cooling water outlet **(Radiator outlet)**	CWOT											
15. **Air To Boil** ***ATB=(x)-(CWIT)+(AT)	ATB										(>49/120)	

NOTE : 1) **Operating conditions : Cooling water / LLC 50%, Thermostat / jacked open.**

2) The above judgment (evaluation) standards is to be applied in the max. ambient condition of 40 °C (104 °F), in case that the ambient temperature is over 40 °C (104 °F), it must be judged adding the balance between the actual temperature and 40 °C (104 °F) to the judgment standard.

3) **Do not run a cooling test if the ambient temperature is below 24 °C (75 °F) because the large change in air density and radiation from non cooling system parts give false results.**

***Air To Boil (ATB) value must be calculated by using below max. temperature :

LLC 50 % with 88.3 kPa (0.9 kgf/cm^2, 12.8 psi) pressure cap : (x) = 110 °C (230 °F)

SPECIAL NOTE :

1) The judgment standard > 49 °C (120 °F) in the above formula { ***ATB = (x) - (CWIT) + (AT) } is KUBOTA's standard. It may change depending on applications, countries, locations, etc., therefor, it is better to judge under the discussion with OEM's referring their own experienced values.

Agreement :

____

____

*** If there are specification or structural changes at Customer's product, application must be rechecked and reported.**

confirmed

Customer :____________________ Distributor :____________________ KUBOTA :____________________

reported by :____________________

b-2 Vibration Measuring Sheet

(OC / EA)

Date : / /

Unit model / serial no. :	Product name :
Engine model :	Engine serial no. :
Checked place at :	Loading condition :

Confirmed	
OEM	KUBOTA

(unit)	vibrating acceleration RMS*** m/s^2 (int) [G (int)]					total amplitude (mm)					result	
place \ direction	limits		4/4 full load min^{-1}(rpm)	0/4 no load min^{-1}(rpm)	(resonance point) min^{-1}(rpm)	standard value of evaluation		4/4 full load min^{-1}(rpm)	0/4 no load min^{-1}(rpm)	(resonance point) min^{-1}(rpm)	good OK	no good needs to improve
	OC	EA				OC	EA					
1. Crank case												
up / down	6 (10)	6 (10)				0.7 (1)	0.7 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
2. Crank case stand												
up / down	3 (5)	2 (4)				0.5 (1)	0.5 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
3. Muffler												
up / down	10 (12)	10 (12)				0.7 (1)	0.7 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
4. Oil cooler (OC) / Radiator (EA)												
up / down	4 (5)	6 (10)				0.5 (1)	0.5 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
5. Air cleaner												
up / down	5 (10)	5 (10)				0.7 (1)	0.5 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
6. Starter												
up / down	5 (10)	5 (10)				0.7 (1)	0.7 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
7. Fuel tank												
up / down	8 (10)	8 (12)				0.5 (1)	0.5 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
8. Spiral case												
up / down	8 (10)	— (—)				0.7 (1)	— (—)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
9. Head cover												
up / down	6 (8)	6 (8)				0.5 (1)	0.5 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
10. Radiator cover												
up / down	— (—)	6 (10)				— (—)	0.5 (1)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					
11. Regulator												
up / down	2 (3)	2 (3)				— (—)	— (—)					
forward / rear	↑	↑				↑	↑					
left / right	↑	↑				↑	↑					

NOTE : 1) "forward / rear" is crankshaft direction and "left / right" is a right angle direction for crankshaft.
2) Figure ( ) in the judgment column shows max. value of resonance point where passed by temporally.
3) RMS*** : root mean square value.

SPECIAL NOTE :______________________________ reported by :____________________

(OC / EA)

Ref. No. :
Date :   /   /

C-1 ☐ New part Request of Engine specification

C-1 ☐ Modification Request of Engine specification

We would like to require following modification to our engine specification.

Equipment model : ______________________________

Engine model name :   Code number :

Contents of modification :

Reason of modification :

Attached documents :

Requirement of effective production :
From,   month   year.

We notify the above modification plan through KUBOTA Engine Distributor (____________________).
You are requested to return your confirmation in soonest possible.
If anything, your comment will be highly appreciated.

☐ Agreed	☐ Disagree
Comments :	Comments :
* Expected effective production :	
Engine : month year.	
(Related engine order number :)	

confirmed

KUBOTA Corporation	KUBOTA (Engine) Distributor	Equipment Manufacturer (Customer)
Engine Engineering dept.	Date : / /	Date : / /

KUBOTA Corporation

Engine Export Dept.

Attn. : ______________________
Equipment Maker (Customer)

(OC / EA)
Ref. No. : KEED.OS-
Date : / /

C-2 Part Change Information & Agreement Sheet

We would like to receive your agreement with following modification of engine components.

Engine model name :	Code number :
Contents of modification :	
Reason of modification :	
Attached documents :	
Effective production planned Engine production from : month year.	

We notify the above modification plan through KUBOTA Engine Distributor (______________________).
You are requested to return with your agreement in soonest possible.
If anything, your comment will be highly appreciated.

☐ Agreed	☐ Disagree
Comments :	

confirmed

Equipment Manufacturer (Customer)	KUBOTA (Engine) Distributor	KUBOTA Corporation
Your signature Date : / /	Your signature Date : / /	Engine Engineering dept.

KUBOTA Corporation
Engine Export Dept.

TECHNICAL INFORMATION
(OC, EA Engine)

OC60, OC95, EA330

CONTENTS

1. BRAKE HORSE POWER AND FUEL CONSUMPTION

a) ISO 3046, 2534

	Item	Unit	OC60-E3-D1-Q OC60-E3-D1-QX-L1		OC95-E3-D1-Q OC95-E3-D1-QX-L1		EA330-E3-NB1 EA330-E3-NB1-APU-1		EA330-E3-NB1-APU-2
	Engine Speed	min^{-1} (rpm)	3000	3600	3000	3600	2500	3000	3000
Gross	Brake Horse Power	kW	-	-	-	-	-	-	5.9
		PS	-	-	-	-	-	-	8.0
Overload	Brake Horse Power	kW	4.05	4.5	6.1	7.0	4.6	5.15	-
		PS	5.5	6.1	8.3	9.5	6.3	7.0	-
	Specific Fuel Consumption	kg/kW•hr	0.269	0.289	0.270	0.287	0.265	0.282	-
		kg/PS•hr	0.198	0.213	0.199	0.211	0.195	0.207	-
	Fuel Consumption	lit/hr	1.30	1.55	1.96	2.39	1.45	1.73	-
Continu-ous	Brake Horse Power	kW	3.7	4.1	5.2	6.25	4.05	4.4	4.8
		PS	5.0	5.6	7.1	8.5	5.5	6.0	6.5

b) SAE J1349

	Item	Unit	OC60-E3-D1-Q OC60-E3-D1-QX-L1		OC95-E3-D1-Q OC95-E3-D1-QX-L1		EA330-E3-NB1 EA330-E3-NB1-APU-1		EA330-E3-NB1-APU-2
	Engine Speed	min^{-1} (rpm)	3000	3600	3000	3600	2500	3000	3000
Gross Intermit-tent	Brake Horse Power	kW	-	-	-	-	-	-	5.9
		HP	-	-	-	-	-	-	7.9
Net Intermit-tent	Brake Horse Power	kW	4.05	4.5	6.1	7.0	4.6	5.15	-
		HP	5.4	6.0	8.2	9.4	6.2	6.9	-
	Specific Fuel Consumption	kg/kW•hr	0.269	0.289	0.270	0.287	0.265	0.282	-
		kg/HP•hr	0.201	0.216	0.201	0.214	0.198	0.210	-
		lb/HP•hr	0.442	0.475	0.444	0.472	0.436	0.464	-
	Fuel Consumption	Gal/hr	0.34	0.41	0.52	0.63	0.38	0.46	-
Net Con-tinuous	Brake Horse Power	kW	3.7	4.1	5.2	6.25	4.05	4.4	4.8
		HP	5.0	5.5	7.0	8.4	5.4	5.9	6.4

c) JIS D1005, B8014

	Item	Unit	OC60-E3-D1-Q OC60-E3-D1-QX-L1		OC95-E3-D1-Q OC95-E3-D1-QX-L1		EA330-E3-NB1 EA330-E3-NB1-APU-1		EA330-E3-NB1-APU-2
	Engine Speed	min^{-1} (rpm)	3000	3600	3000	3600	2500	3000	3000
Net Intermit-tent (D1005)	Brake Horse Power	kW	4.05	4.5	6.1	7.0	4.6	5.15	-
		PS	5.5	6.1	8.3	9.5	6.3	7.0	-
Continu-ous (B8014)	Brake Horse Power	kW	3.7	4.1	5.2	6.25	4.05	4.4	4.8
		PS	5.0	5.6	7.1	8.5	5.5	6.0	6.5

Note :
1. Above powers may be changed by emission regulations applied.
2. Conversion rates
☆ 1 kW = 1.35962 PS = 1.34048 HP
☆ 1 PS = 0.7355 kW = 0.985925 HP
☆ 1 HP = 0.7457 kW = 1.01428 PS

Fuel Consumption Calculating Formula

$$\text{Fuel Consumption (lit/hr)} = \frac{\text{Fuel Consumption (kg/kW•hr)} \times \text{Brake Horse Power (kW)}}{0.84}$$

0.84 (g/cc) : Gravity of Diesel Fuel

$$\text{Fuel Consumption (Gal/hr)} = \frac{\text{Fuel Consumption (lb/HP•hr)} \times \text{Brake Horse Power (HP)}}{7.01}$$

7.01 (lb/Gal) : Gravity of Diesel Fuel

2. NOISE LEVEL

Model	Engine Speed min^{-1}(rpm)	Unit	Sound Pressure at 1 m (3.3 ft)	
			at Full Load	at No Load
OC60	1200	dB (A)	-	80.4
	1300		-	81.2
	1500		-	82.3
	2000		-	85.3
	2500		88.5	87.6
	2700		-	88.2
	2800		89.7	88.8
	3000		90.7	89.6
	3200		91.1	89.8
	3400		92.0	90.8
	3600		92.3	92.7
	3800		-	92.6
OC95	1200	dB (A)	-	82.5
	1300		-	83.5
	1500		-	85.7
	2000		-	88.8
	2500		92.0	91.1
	2700		-	92.4
	2800		93.7	92.4
	3000		94.9	93.2
	3200		96.1	94.2
	3400		96.5	94.5
	3600		97.6	94.7
	3800		-	96.3

These data show the average noise level at four points.

Note :
[Measurement conditions]
☆ With oil cooler, cooling fan, air cleaner and muffler.

Model	Engine Speed min^{-1}(rpm)	Unit	Sound Pressure at 1 m (3.3 ft)	
			at Full Load	at No Load
EA330	800	dB (A)	-	75.0
	1000		-	77.6
	2000		87.0	84.6
	2250		-	86.0
	2500		90.3	86.8
	2700		-	87.7
	2800		91.5	88.4
	3000		92.6	89.7
	3200		-	90.5

These data show the average noise level at four points.

Note :
[Measurement conditions]
☆ With radiator, cooling fan, air cleaner and muffler.

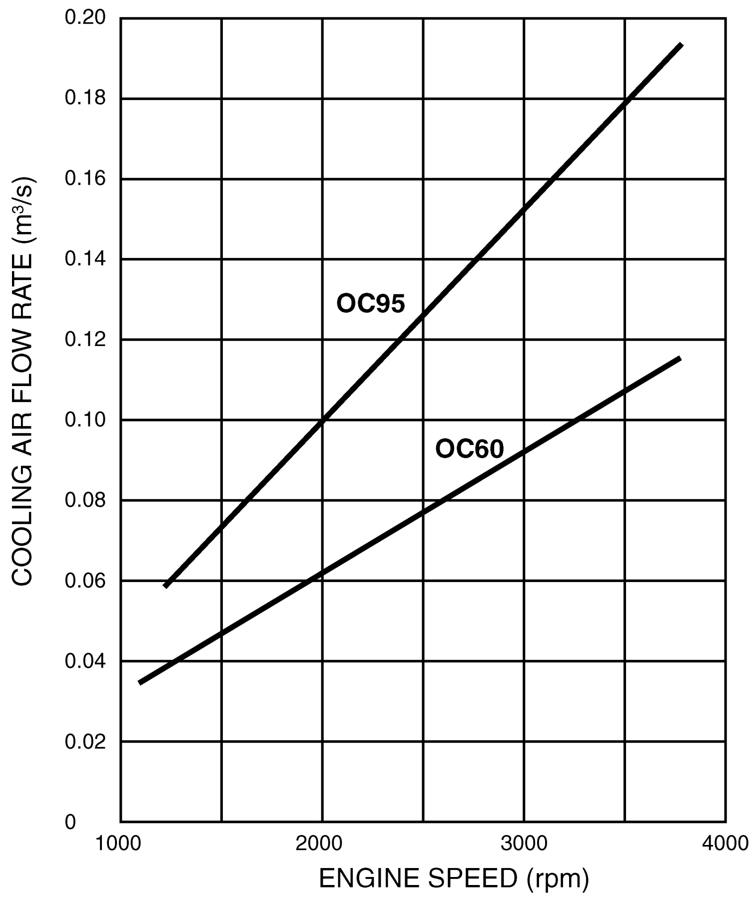
3. AIR REQUIREMENTS

(1) Intake Air Volume

Model	min^{-1} (rpm)	rpm	2500	3000	3600
OC60	Intake Air Volume	m^3/hr	-	20.5	24.6
		m^3/min	-	0.34	0.41
		lit/sec	-	5.69	6.83
		in^3/sec	-	347	417
		ft^3/min	-	12.1	14.5
OC95	Intake Air Volume	m^3/hr	-	29.9	34.9
		m^3/min	-	0.50	0.58
		lit/sec	-	8.31	9.69
		in^3/sec	-	507	592
		ft^3/min	-	17.6	20.5
EA330	Intake Air Volume	m^3/hr	20.3	24.9	-
		m^3/min	0.34	0.42	-
		lit/sec	5.64	6.92	-
		in^3/sec	344	422	-
		ft^3/min	11.9	14.7	-

Note :
[Measurement conditions]
☆ **Atmosphere : 750 mmHg**
☆ **Intake air temperature : 25 °C**
☆ With standard air cleaner

(2) Cooling Air Volume



AM12001A

Note :
[Measurement conditions]
☆ With standard oil cooler, oil cooler cover and standard cooling fan.

(3) Cooling Air Requirements

{Refer to 25 °C (77 °F) and 750 mmHg}

Engine Speed	min^{-1}(rpm)	2500	3000
EA330	kg/hr	675	804
	m^3/hr	570	679
	m^3/min	9	11
	lit/sec	158	189
	in^3/sec	9658	11507
	ft^3/min	335	400

Note :
Above data is decided by condition which engine is run as open unit.

[Conversion Rates]
☆ 1 lit = 61.0237 in^3 = 0.035315 ft^3
☆ 1 ft^3 = 28.3168 lit
☆ 1 lit/sec = 3.6 m^3/hr = 2.1189 ft^3/min

4. EXHAUST GAS VOLUME

{Refer to 25 °C (77 °F) and 750 mmHg}

Model	Engine Speed	rpm	2500	3000	3600
OC60	Intake Air Volume	m^3/min	-	0.34	0.41
	Brake Horse Power	kW	-	4.05	4.5
	Fuel Consumption	lit/hr	-	1.30	1.55
		g/hr	-	1089	1301
	Exhaust Gas Volume	m^3/hr	-	55.3	68.4
		m^3/min	-	0.92	1.14
		lit/sec	-	15.4	19.0
		in^3/sec	-	938	1160
		ft^3/min	-	32.6	40.3
OC95	Intake Air Volume	m^3/min	-	0.50	0.58
	Brake Horse Power	kW	-	6.1	7.0
	Fuel Consumption	lit/hr	-	1.96	2.39
		g/hr	-	1647	2009
	Exhaust Gas Volume	m^3/hr	-	77.1	102.7
		m^3/min	-	1.28	1.71
		lit/sec	-	21.4	28.5
		in^3/sec	-	1306	1741
		ft^3/min	-	45.4	60.5
EA330	Intake Air Volume	m^3/min	0.34	0.42	-
	Brake Horse Power	kW	4.6	5.15	-
	Fuel Consumption	lit/hr	1.45	1.73	-
		g/hr	1219	1452	-
	Exhaust Gas Volume	m^3/hr	54.1	67.4	-
		m^3/min	0.90	1.12	-
		lit/sec	15.0	18.7	-
		in^3/sec	918	1142	-
		ft^3/min	31.9	39.7	-

Note :

GL = (AL + 7.1 x Be/10000) x (298 + t) x 760 / 298 / (760 + Ps) (m^3/hr)

AL : Intake Air Volume (m^3/hr)
Be : Fuel Oil Consumption (g/hr)
t : Exhaust Gas Temperature (°C)
Ps : Exhaust Gas Back Pressure (mmHg)

[Conversion Rates]

☆ 1 lit = 61.0237 in^3 = 0.035315 ft^3
☆ 1 ft^3 = 28.3168 lit
☆ 1 lit/sec = 3.6 m^3/hr = 2.1189 ft^3/min

5. HEAT REJECTION TO COOLANT

a) ISO 3046 (Value at Overload)

Model	Engine Speed	rpm	2500	3000	3600
OC60	Brake Horse Power	kW	-	4.05	4.5
	Specific Fuel Consumption	kg/kW•hr	-	0.269	0.289
	Heat Rejection	kJ/hr	-	13140	15685
		kcal/hr	-	3139	3747
OC95	Brake Horse Power	kW	-	6.1	7.0
	Specific Fuel Consumption	kg/kW•hr	-	0.270	0.287
	Heat Rejection	kJ/hr	-	19864	24230
		kcal/hr	-	4745	5788
EA330	Brake Horse Power	kW	4.6	5.15	-
	Specific Fuel Consumption	kg/kW•hr	0.265	0.282	-
	Heat Rejection To Coolant	kJ/hr	16802	20018	-
		kcal/hr	4014	4782	-

b) SAE J1349 (Value at Net Intermittent)

Model	Engine Speed	rpm	2500	3000	3600
OC60	Brake Horse Power	kW	-	4.1	4.5
	Specific Fuel Consumption	kg/kWh	-	0.269	0.289
	Heat Rejection	kJ/hr	-	13140	15685
		Btu/hr	-	12458	14871
OC95	Brake Horse Power	kW	-	6.1	7.0
	Specific Fuel Consumption	kg/kWh	-	0.270	0.287
	Heat Rejection	kJ/hr	-	19864	24230
		Btu/hr	-	18833	22972
EA330	Brake Horse Power	kW	4.6	5.15	-
	Specific Fuel Consumption	kg/kWh	0.265	0.282	-
	Heat Rejection To Coolant	kJ/hr	16802	20018	-
		Btu/hr	15930	18979	-

Note :

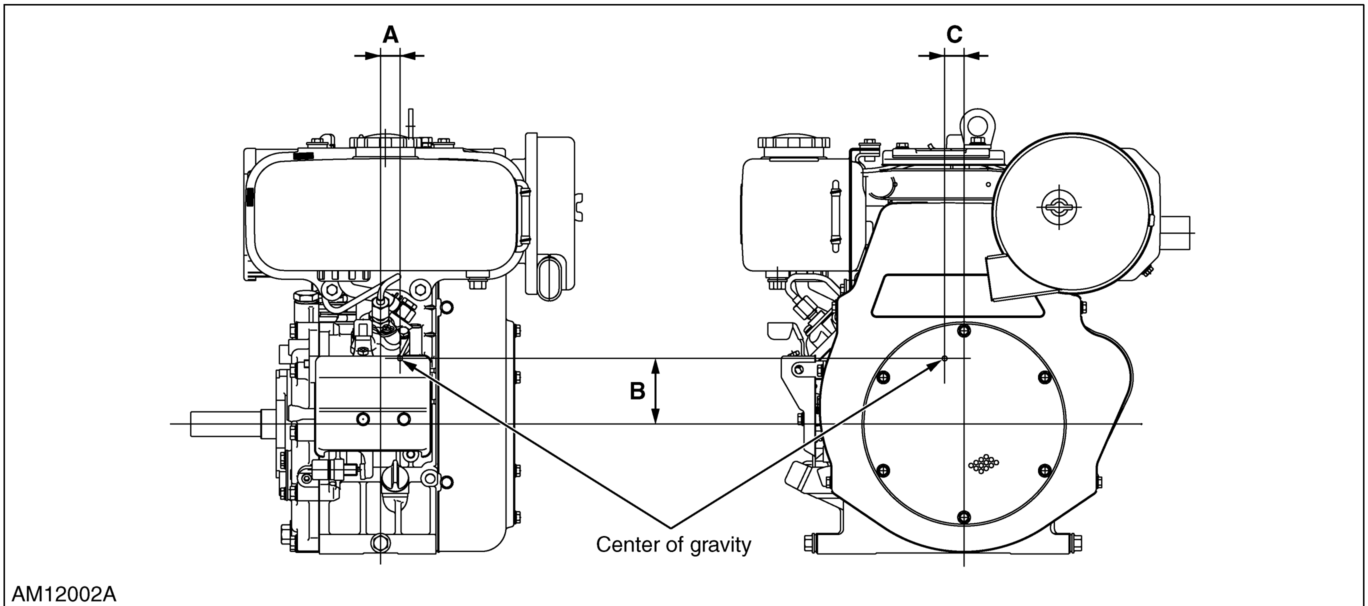
☆ Heat Rejection (to Coolant) Calculating Formula

Ho = Hu x Ne x be x i

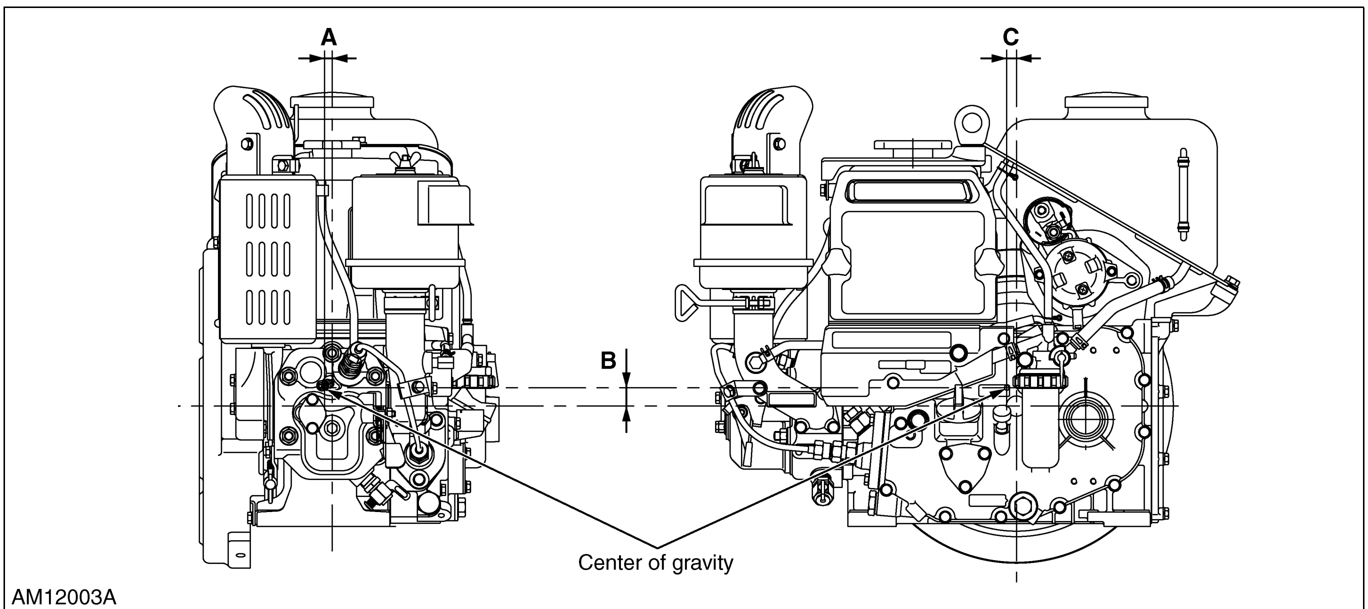
Ho : Heat Rejection (to Coolant)
Hu : Diesel Fuel Low Caloric Value
(43070 kJ/kg, 10290 kcal/kg)
Ne : Brake Horse Power (kW)
be : Specific Fuel Oil Consumption (g/kW•hr)
i : Dispersion Ratio (to Coolant) (%)

6. CENTER OF GRAVITY

OC60, OC95



EA330



MODEL	A	B	C
OC60	15.5	67.5	-3
OC95	20	83	4
EA330	8	19	19

Note :
[Measurement condition]
☆ Dry condition