

EXHAUST SYSTEM

for CI and SI engine

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NOTES

This document is applied for Kubota [CI and SI engines](#) for OEM.

This document is intend to provide installation guide for the engine to the application.

The information in this document subject to change without notice.

The latest document is available on the K-iSS website. Printed copies are for reference only.

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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 and keep clean exhaust gas emissions, 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 exhaust back pressure to a minimum.

2. EXHAUST BACK PRESSURE MEASUREMENT

See the Technical information document for the specific limitation value of each engine model.

Position to measure exhaust back pressure is at the outlet of exhaust manifold. Use a manometer to measure it. Refer to figure 1.

Note:

Exhaust back pressure to be measured at rated engine speed and load.

Generally speaking,

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

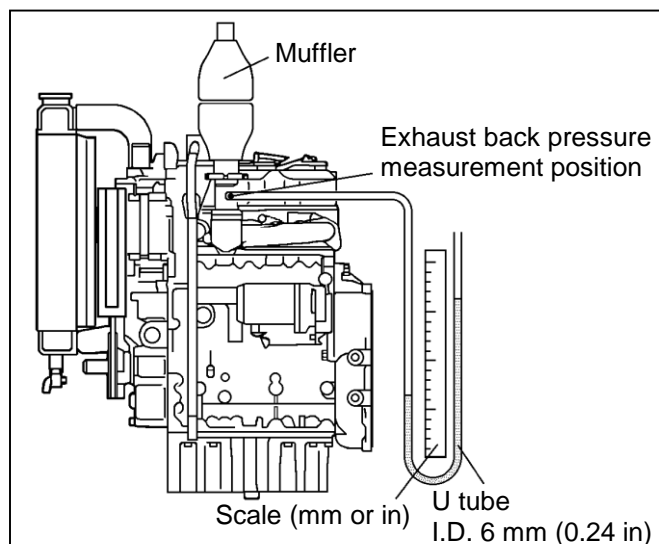


Figure 1 Exhaust back pressure measurement position

3. EXHAUST BACK PRESSURE CALCULATION

Exhaust back pressure is caused by resistance of muffler and exhaust pipe (length, pipe diameter, number of bend and bending radius) and gas volume. Exhaust back pressure can be determined by the following formula.

1) Gas volume and resistance

a) Gas volume and speed

$$v = [VE / (\pi \times D^2 / 4)] / 60$$

VE: Gas volume (m³/min)

(See Technical information documents)

v : Gas speed (m/s)

D: Internal diameter of exhaust pipe (m)

b) Resistance

- Straight pipe (resistance per one meter) ΔP (kPa)

$$\Delta P = \lambda \times (L / D) \times (\gamma \times v^2) / 2000$$

L: Pipe length = 1 m

D: Inside diameter of pipe (m)

γ : Specific gravity of gas at 673 K {400 deg. C
(752 deg. F)}

0.5 (kg/m³)

v : Gas speed (m/s)

λ : Friction coefficient = 0.030

- Elbow (resistance per one elbow) $\Delta P'$ (kPa)

$$\Delta P' = \zeta \times \gamma \times v^2 / 2000$$

ζ : Short elbow = 0.51

Long elbow = 0.36

Result of calculations by the above formula are on next page (Figure 2)

2) Resistance of mufflers (PM)

3) Total resistance (P)

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

L: Pipe length (m)

N: Number of elbow

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

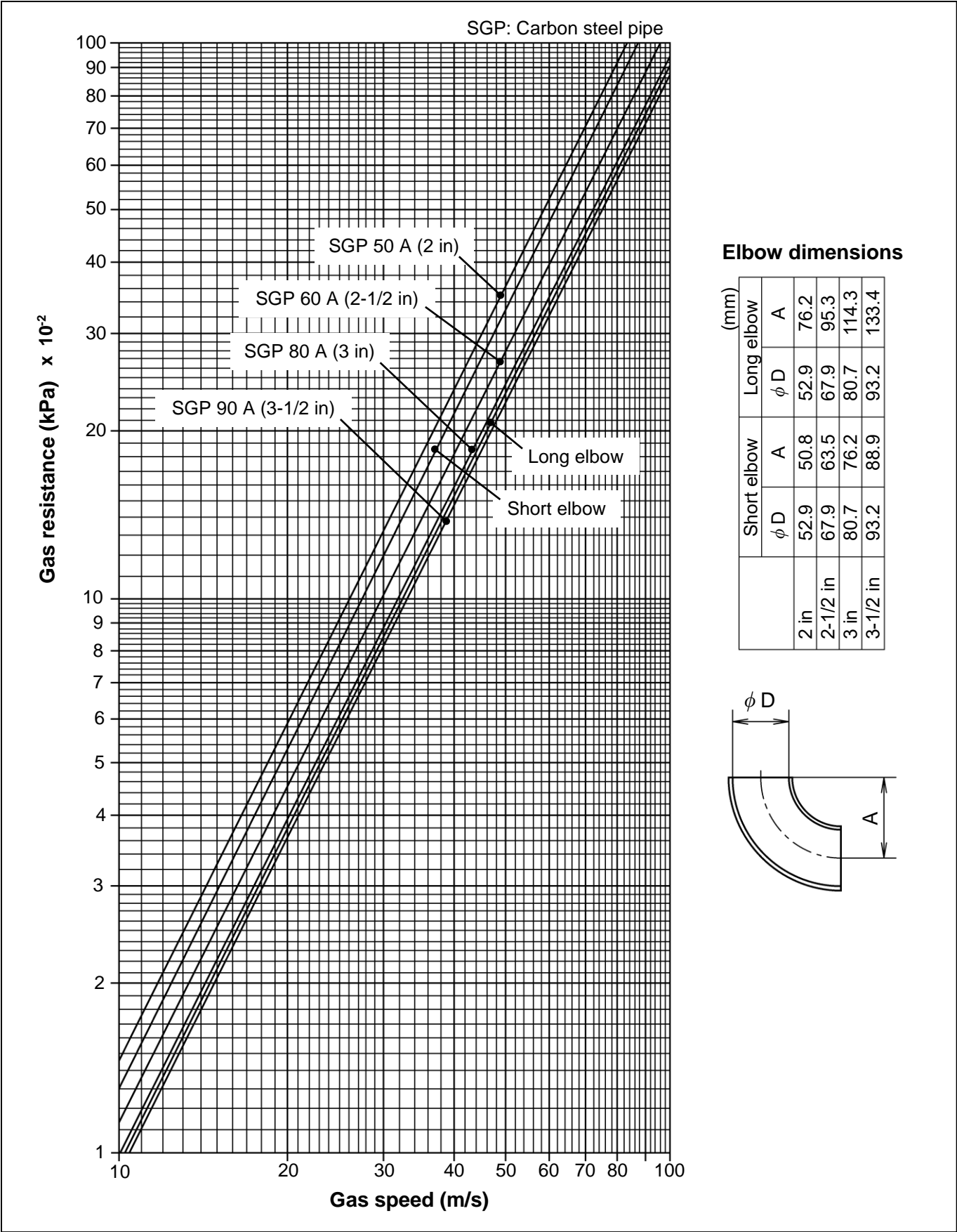


Figure 2

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.

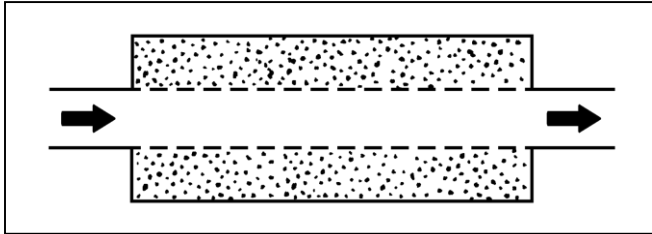


Figure 3 Absorption type

- 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.

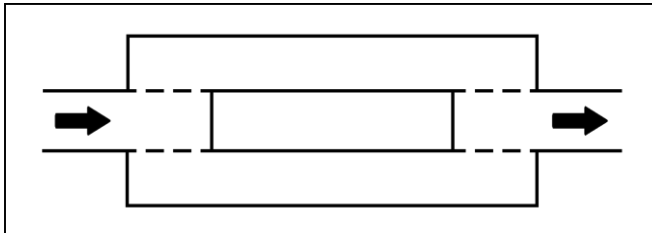


Figure 4 Expansion type

- Dispersion type

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

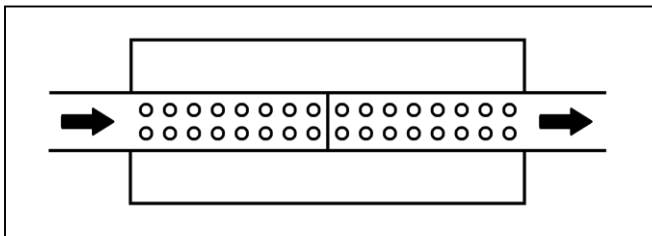


Figure 5 Dispersion type

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 SOS to arrange exhaust manifold outlets and directions of discharge.

5. EXHAUST GAS RECIRCULATION (EGR) SYSTEM (for the specific model of CI engines)

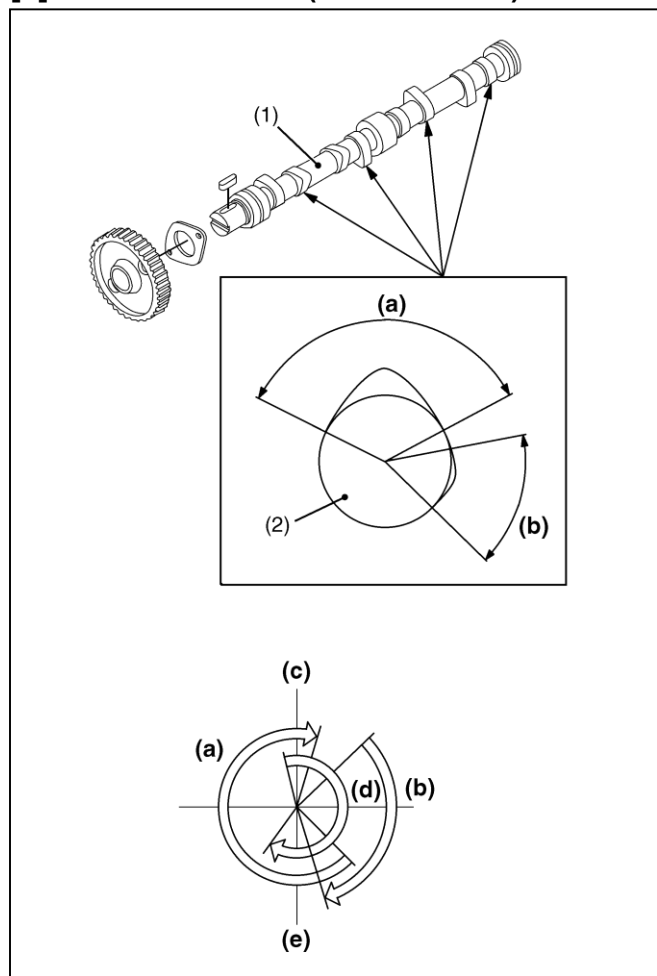
[1] GENERAL

In order to meet with the strict emission regulations, Kubota has adopted the EGR on the V3-E3B series and 07-E3B series. The nitrogen oxide (NO_x) which is a hazardous component in exhaust gas is generated by oxidation of nitrogen in the air, due to rise of the combustion temperature in cylinders. The EGR is a

system in which the exhaust gas with lean oxygen is cooled and returned to cylinders again in order to lower the combustion temperature. As a result, NO_x can be decreased.

And EGR has 2 types. One is an internal EGR, the other is an external EGR.

[2] INTERNAL EGR (V3600-T-E3B)



- (1) Camshaft
- (2) 2 Stage exhaust cam
- (a) Exhaust stage
- (b) EGR stage
- (c) T.D.C. (Top Dead Center)
- (d) Intake stage
- (e) B.D.C. (Bottom Dead Center)

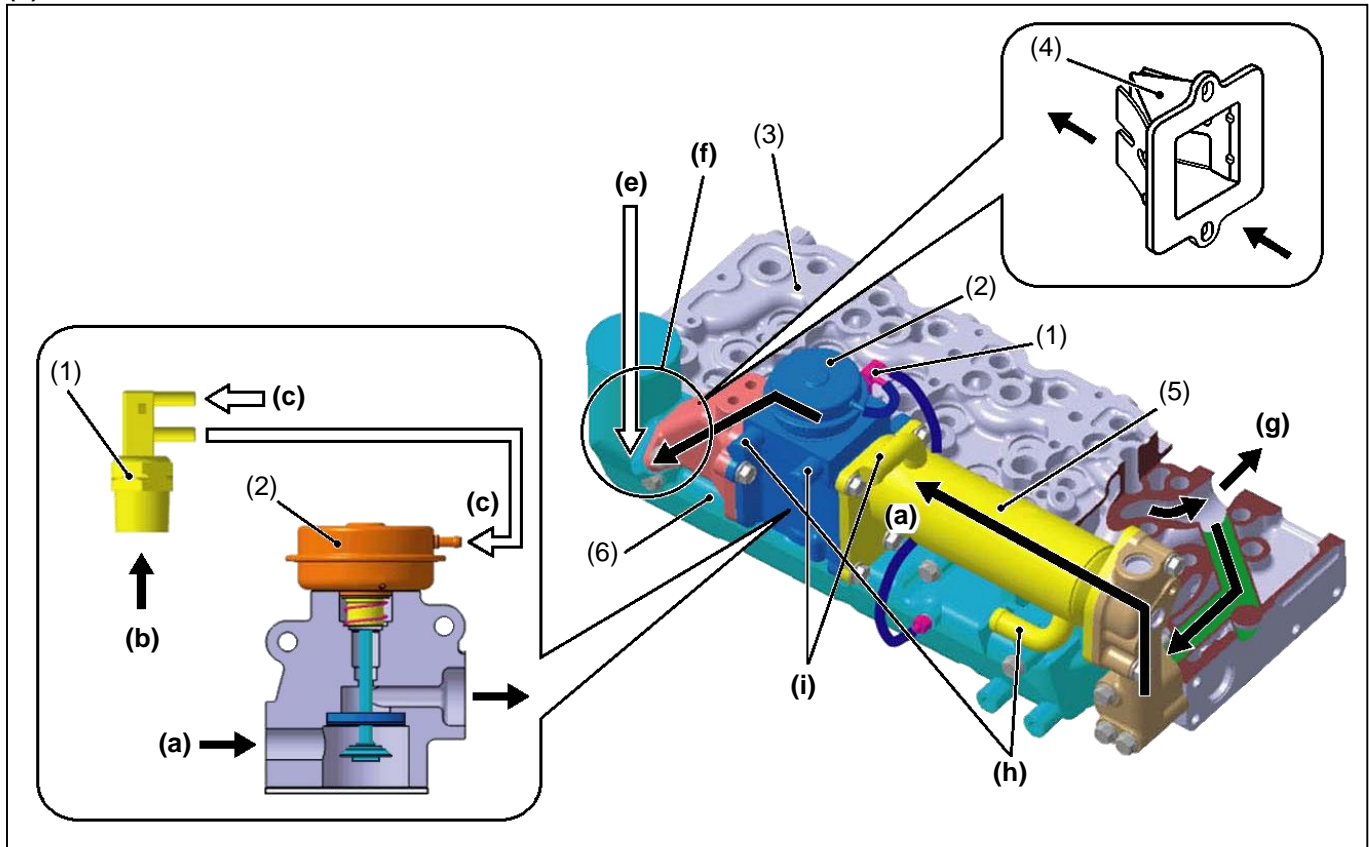
Figure 6 2 stage exhaust camshaft

Internal EGR consists of 2 stage exhaust camshaft.

At the exhaust stroke, 1st stage exhaust cam opens the exhaust valve, and exhaust gas flows into the exhaust manifold. At the suction stroke, intake valve is open and fresh air flows into the cylinder, and also, 2nd stage exhaust cam opens the exhaust valve, and exhaust gas in the exhaust manifold is sucked back into the cylinder.

[3] EXTERNAL / MECHANICAL EGR

(1) V2607-DI-T-E3B / V3307-DI-T-E3B



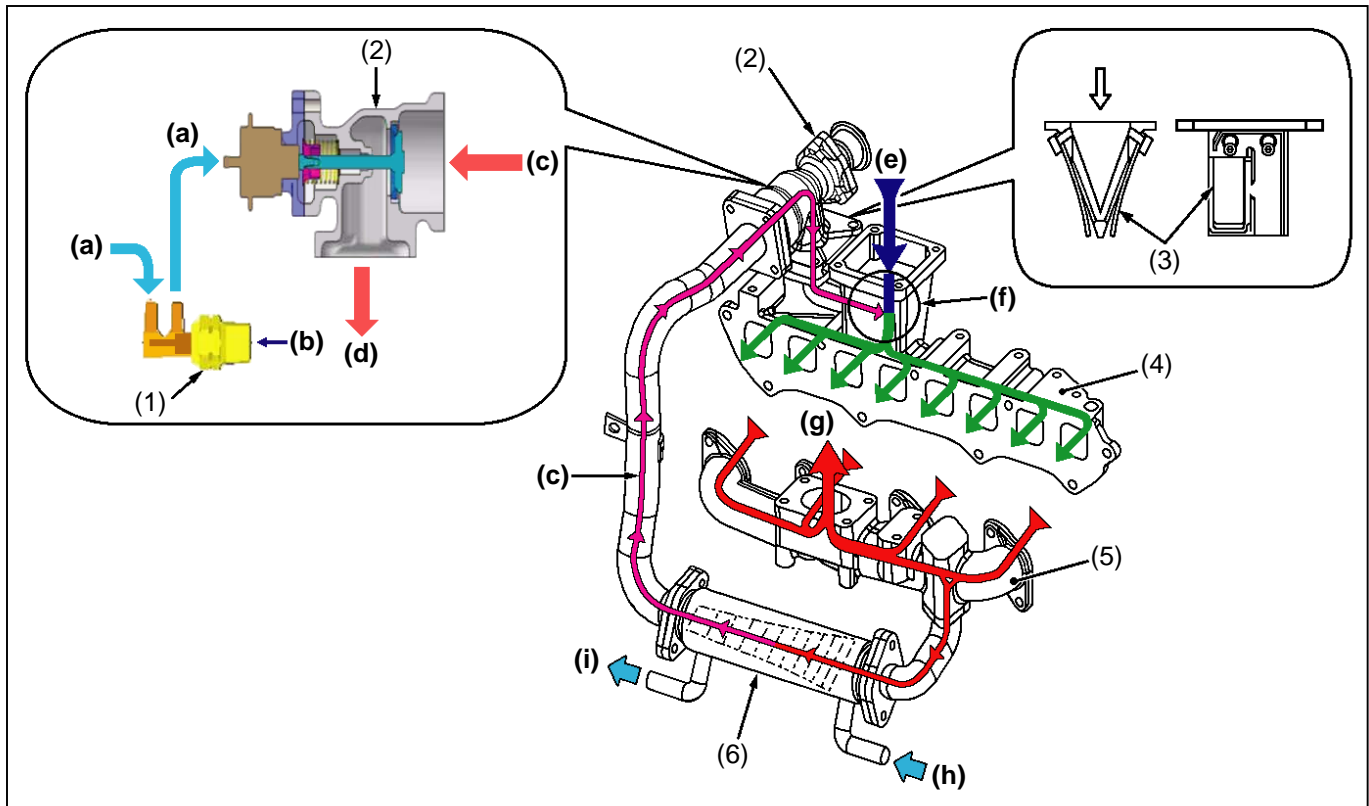
- | | | | |
|--------------------------|---------------------|----------------------------|------------------------------------------|
| (1) Thermo valve | (4) Reed valve | (a) Cooled EGR gas | (f) Cooled EGR gas merges with fresh air |
| (2) Mechanical EGR valve | (5) EGR cooler | (b) Coolant temperature | (g) Exhaust gas |
| (3) Cylinder head | (6) Intake manifold | (c) Boost pressure | (h) Coolant inlet |
| | | (d) To the intake manifold | (i) Coolant outlet |
- Figure 7**

External mechanical EGR consists of water cooled EGR cooler (5), mechanical EGR valve (2), reed valve (4) and thermo valve (1).

When the coolant temperature **(b)** is getting higher, thermo valve (1) is open and the boost pressure of intake manifold (6) gets to reach the diaphragm of mechanical EGR valve (2).

If the coolant temperature **(b)** is high, but the boost pressure is low, the EGR valve (2) does not open. If coolant temperature **(b)** is high, boost pressure is also high, EGR valve (2) is open and cooled EGR gas **(a)** through the water cooled EGR cooler (5) flows into the intake manifold (6). And the reed valve (4) between EGR valve (2) and intake manifold (6) prevents the fresh air flowing into EGR system.

(2) V3800DI-T-E3B



- | | | | |
|--------------------------|----------------------|----------------------------|------------------------------------------|
| (1) Thermo valve | (4) Intake manifold | (a) Boost pressure | (f) Cooled EGR gas merges with fresh air |
| (2) Mechanical EGR valve | (5) Exhaust manifold | (b) Coolant temperature | (g) Exhaust gas |
| (3) Reed valve | (6) EGR cooler | (c) Cooled EGR gas | (h) Coolant inlet |
| | | (d) To the intake manifold | (i) Coolant outlet |
| | | (e) Fresh air | |
- Figure 8**

External / Mechanical EGR consists of water cooled EGR cooler, mechanical EGR valve, reed valve and thermo valve.

When the coolant temperature is getting higher, thermos valve is open and the boost pressure of intake manifold gets to reach the diaphragm of mechanical EGR valve.

If the coolant temperature is high, but the boost pressure is low, the EGR valve does not open. If coolant temperature is high, boost pressure is also high, EGR valve is open and cooled EGR gas through the water cooled EGR cooler flows into the intake manifold. And the reed valve between EGR valve and intake manifold prevents the fresh air flowing into EGR system.

REVISION HISTORY

File Name	Remarks	Date
KORD3_16-191_7_exhaust_system.pdf	Exhaust back pressure correction	Oct. 20, 2016
KORD3_21-177_ Exhaust_system_for_CI_and_SI_engine.pdf	Document style standardization	Aug. 23, 2021