Exhaust Emission Distributions in the Exhaust Pipe of an Industrial Gasoline Engine

(Part II The Observation of Dilution Phenomena of Exhaust Gases in an Exhaust Pipe)

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Abstract

The dilution phenomenon of exhaust gases in the exhaust pipe of a small, single-cylinder industrial gasoline engine was investigated.

An engine blows out periodically burnt gases at the entrance of the exhaust pipe, and then a pressure wave occurs and progresses to the open end of the exhaust pipe.

Progressive waves (positive pressure) reflect at the open end of the exhaust pipe and become reflective waves (negative pressure) which come back through the exhaust pipe. It was found that when these reflective waves return through the exhaust pipe, the surrounding air is sucked into the exhaust pipe, diluting the exhaust gases.

The length of the region in which this dilution phenomenon occurred changed according to the total length of the exhaust pipe and the load fraction.

It is interesting to note that the maximum length for the dilution phenomenon of exhaust gases in an exhaust pipe is about 50 cm in all cases for single-cylinder gasoline engines.

It is believed that the dilution phenomenon of exhaust gases near the open end of the exhaust pipe is a kind of end effect.

1 *Introduction*

Many papers[1)~7)] have been published regarding the dynamic effects of pipe systems of internal combustion engines.

However, most of these deal with the pipe suction effect with very few[8)~9)] giving any consideration to the exhaust pipe effect.

Some reports[10)] on emission distributions and sampling procedures of exhaust gases in the exhaust pipe of small, single-cylinder gasoline engines have been published. In addition some reports[11)~16)] on the dilution phenomena of exhaust emissions in the exhaust pipe near the open end for small, single-cyinder gasoline engines have been published, for example, the Japanese Industrial Standards (JIS D1029, 1030) regarding sampling procedures of exhaust gases in the exhaust pipe of automotive internal combustion engines have been published.

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In a previous report[17] we considered the pulsation phenomenon in the exhaust pipe of a small, single-cylinder gasoline engine. In this paper, we have investigated the dilution phenomenon of exhaust gases near the open end of the exhaust pipe of a small, single-cylinder gasoline engine.

In this report, only observations of the dilution phenomenon are described.

2 *Experimental Technique*

2.1 Apparatus

The engine used to obtain experimental data was a four-stroke-cycle, single-cylinder, air-cooled gasoline engine designed for general use. Table 1 shows the specifications of this engine.

Figure 1 shows an illustrative drawing of the experimental apparatus and Photo. 1 shows the experimental apparatus.

Photo. 2 shows the apparatus for drawing and delivering exhaust gases and the air surrounding the sampling device of a CO analyzer. A Froude hydraulic dynamometer, various water gauge manometers, a CO analyzer, several thermocouple thermometers, a pressure inspectation device along with various other equipments were used.

Cycle		4 stroke-cycle
Bore X Stroke mm		75∅×62
Stroke Volume cc		252
Compression ratio		6.0
Rated horsepower		5PS/3600rpm
Combustion chamber type		Side valve type
Suction	SO	BT 43°
	SC	AB 53°
Exhaust	EO	BB 86°
	EC	AT 48°

Table 1. Engine Specifications

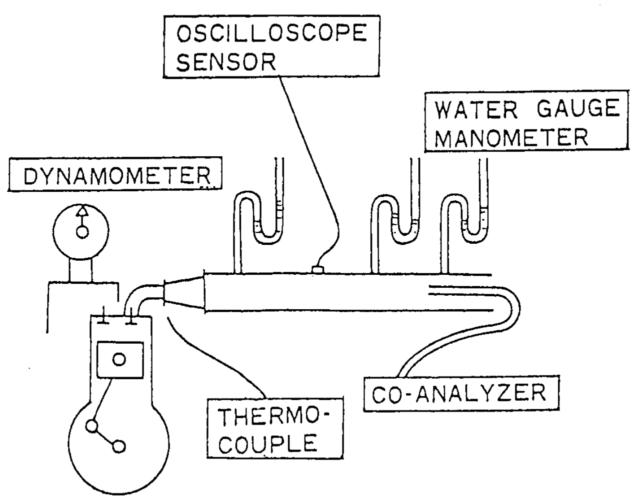

Fig. 1. Illustrative drawing of the experimental apparatus.

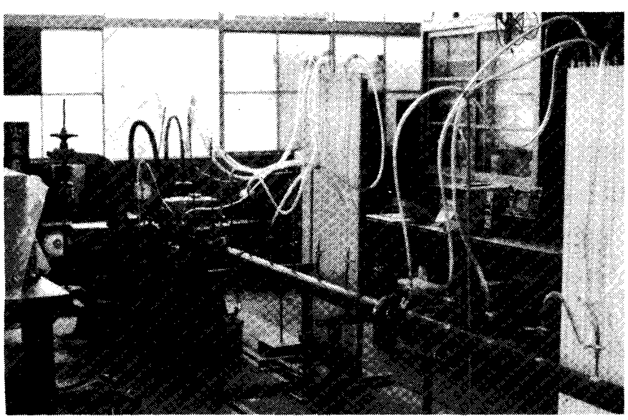

Photo. 1. Photograph of a general view of the experimental apparatus

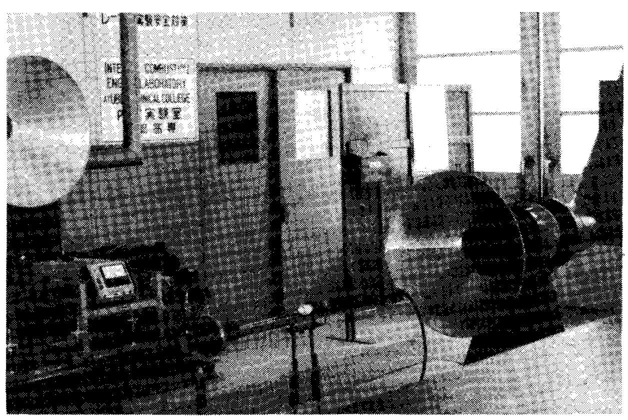

Photo. 2. An installation to draw and deliver exhaust gases.

Very long pipes were used in accordance with the requirements of this experiment. Taking into consideration the flow resistances caused by friction in the pipe and in order to enable sampling of exhaust gases at various locations on a cross-section of the right angle direction for the pipe axis, both 52 mm (inside diameter ID) and 68 mm (ID) steel pipes were used.

2.2 Measurement and Procedure

In this experiment, mainly CO concenration distributions in the exhaust pipe were measured. CO concentration values were measured at various locations described above and as shown in the figures. A HORIBA CO analyzer (MEXA 200) was used for measuring the CO concentrations. The sampling of gases was carried out by inserting various stainless-steel sampling tubes (6 mm OD, 4 mm ID), 1.5 m in length, into the open end of the exhaust pipe. For the direction of the pipe axis, the distances of the samppling locations from the open end of the exhaust pipe were 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 30, 40, 50, . . . centimeters. The response time (indicating speed) of the CO analyzer including the sampling system was about 5 sec.

Gas temperatures were measured at the distances of 0.5, 1.0, 1.5, 2.0, 2.5, . . . meters from the engine's cylinder.

Thermometers having an AC sheath thermocouple were used for measuring exhaust gas temperatures at the

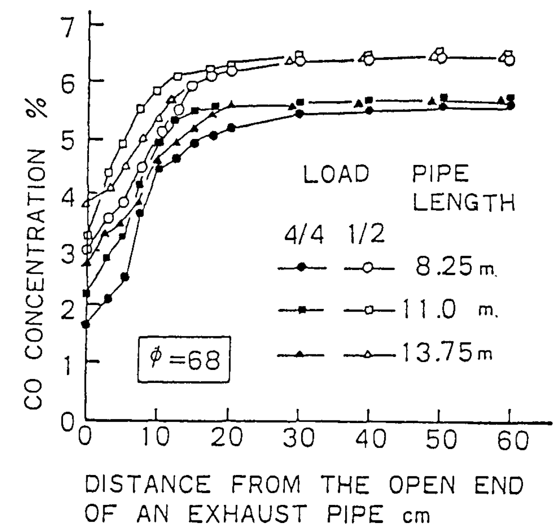

Fig. 2. Exhaust CO concentration distributions.

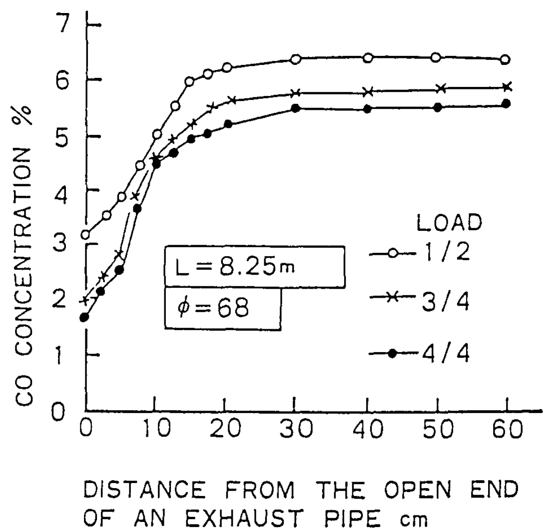

Fig. 3. Exhaust CO concentration distributions.

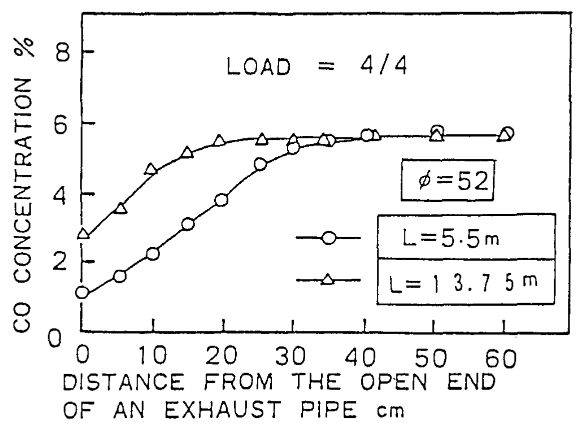

Fig. 4. Exhaust CO concentration distributions.

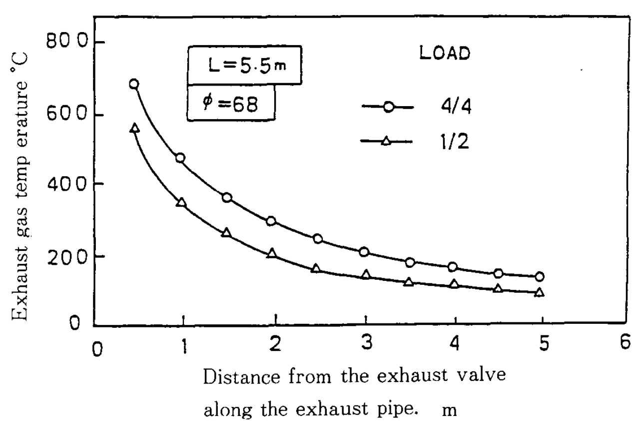

Fig. 7. Exhaust gas temperature distributions in an exhaust pipe.

above locations along the exhaust pipe.

The engine was driven at 3600 rpm. The exhaust pipe was carefully sealed to prevent the lekage of gas.

3 *Experimental Results*

3.1 CO concentration distributions in the exhaust pipe

Figures 2 and 3 show some of the experimental results for CO concentration distributions in the center of the exhaust pipe (68 mm ID; load fraction 4/4, 1/2; pipe length 8.25 m, 11.0 m, 13.75 m, and 68 mm ID; load fraction 1/2, 3/4, 4/4; pipe length 8.25 m, respectively).

Figure 4 (Exhaust CO Concentrations) shows the distance at which CO concentrations settle to constant values for two different total pipe lengths. Figures 5 and 6 show CO concentration profiles for the same pipe length and two different loads.

Figure 7 shows an example of the exhaust gas temperature distributions in the exhaust pipe.

4 *Discussion*

Depending upon the exhaust opening, pressure waves (positive waves) progress down an exhaust pipe and then reflect at the open end of the exhaust pipe and come back down the exhaust pipe.

It was found from the CO concentration distributions that when these reflective waves return down the exhaust port (exhaust valve), surrounding air was sucked into the exhaust pipe through the open end.

Generally speaking, when the exhaust pipe is longer, the pressure wave (progressive wave) decreases gradually and accordingly the reflective wave becomes weaker. As a result, the sucking power of the surrounding air decreases and the CO concentration at the open end of the exhaust pipe becomes larger and also the distance in which CO concentration settles to constant value becomes shorter.

When the load fraction is larger, the strength of the pressure wave (progressive wave) increases, and in accordance, the reflective pressure becomes larger. As a result, the sucking power of surrounding air increases and the CO concentration at the open end of the exhaust pipe is smaller and also the distance in which the CO concentration settles to constant value is longer.

From the different standpoint, considering the dilution phenomena, it is concerned that the pulsation phenomenon is whether near or far from the synchronism condition of that.

Accordingly the dilution phenomena are rather complicated.

In addition, we plan experiments using the Laser Doppler Method in order to investigate the velocity field near the open end of the exhaust pipe and to clarify the dilution phenomena.

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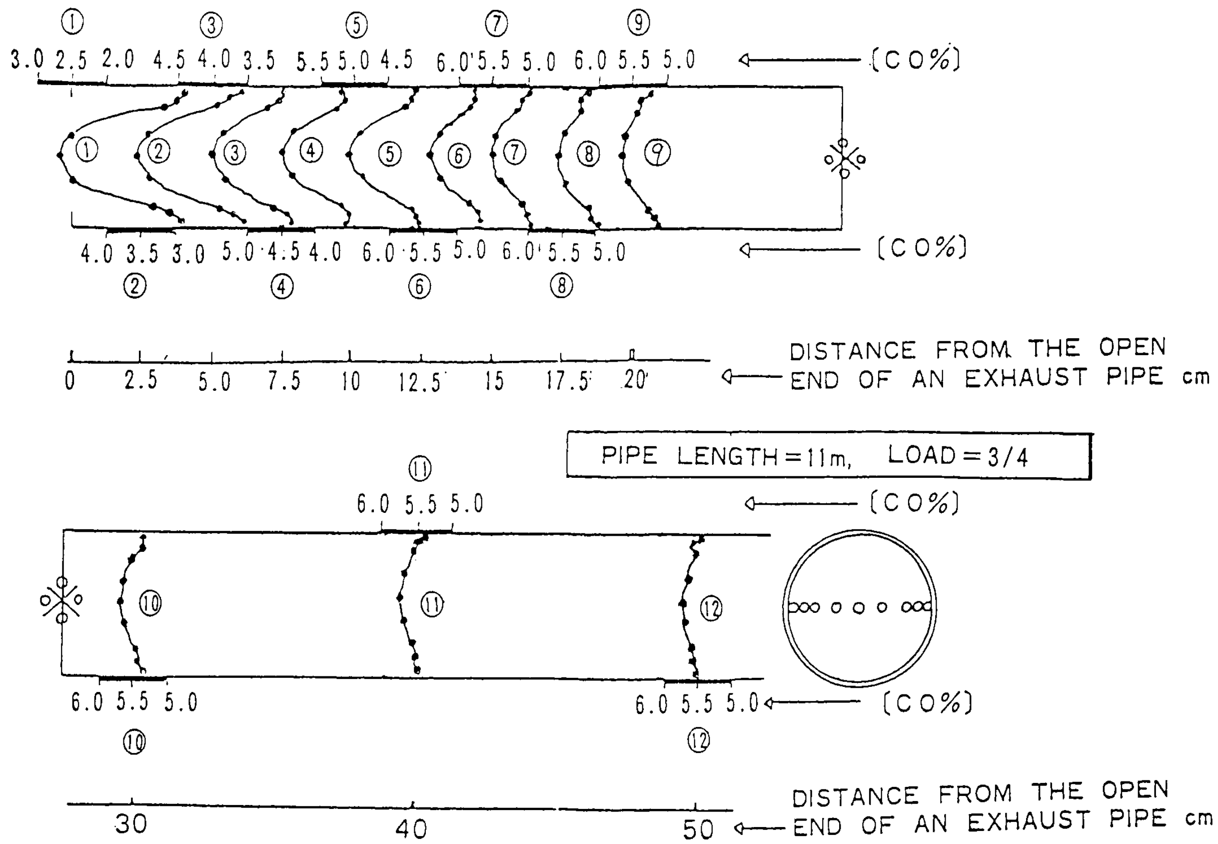

Fig. 5. Exhaust CO concentration profiles.

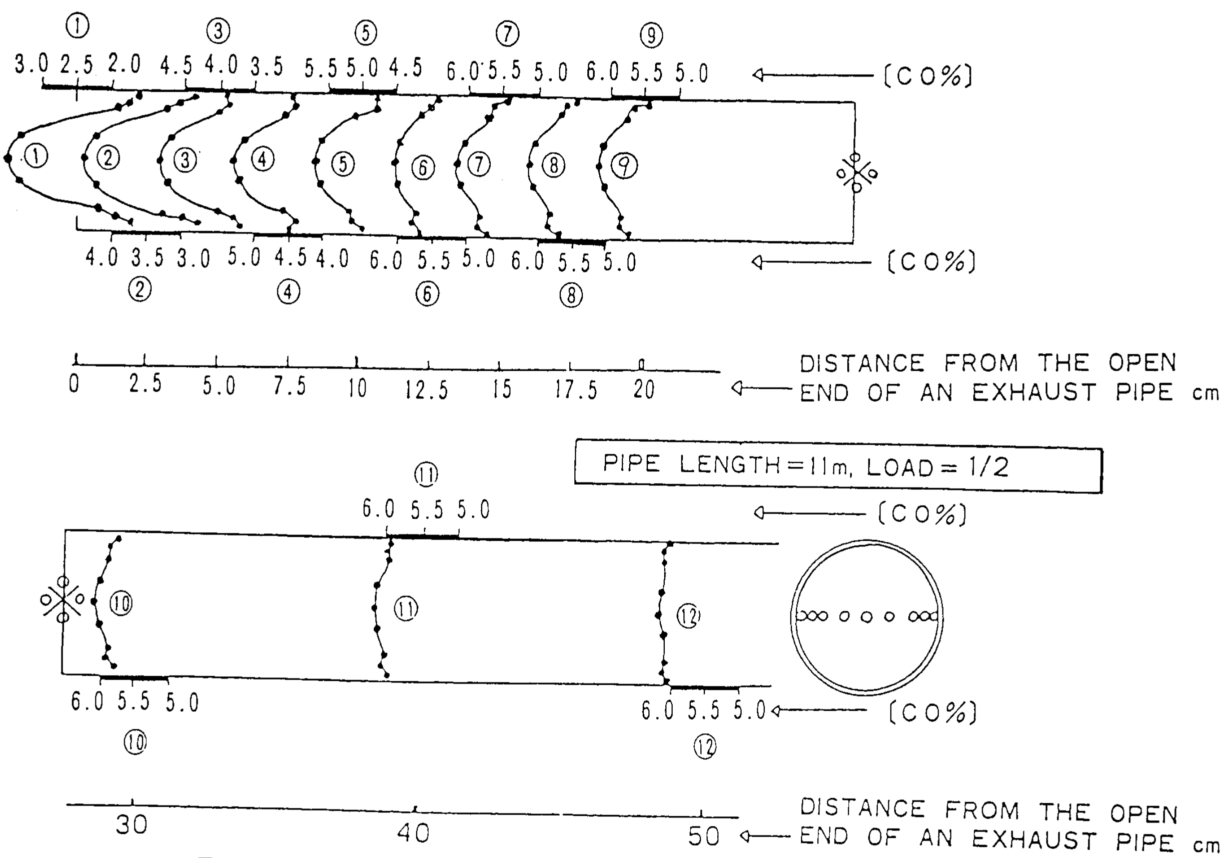

Fig. 6. Exhaust CO concentration profiles.

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