State of Efflux of Scavenging Air through the Scavenging Ports

Yukio KASHIWADA, Koichi AKIYAMA

Department of Mechanical Engineering, School of Engineering, Okayama University, Okayama, Japan.

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In order to make clear how the efflux angle changes in a small crankcase scavenged engine cylinder and in a large loop scavenged engine cylinder, the inlet flow pattern in the single cycle model cylinder has been observed by a high speed motion camera.

In general, the scavenging air stream is not effluent in the designed direction of the scavenging port at comparatively slight opening, and the efflux angle changes in proportion to port opening advance. In a small crankcase scavenged engine cylinder, to keep the scavenging air stream in the direction of the scavenging port it is effective to incline the scavenging air passage between the crankcase and the cylinder, and to make thicker the cylinder wall where located scavenging port. In a large loop scavenged engine cylinder to coincide the scavenging air stream with the direction of the scavenging port in the early stage of the scavenging, it has an effect to set the guide plate the position of 1/2 at port height.

§ 1. Introduction

State of efflux of scavenging air stream is an influential factor on scavenging process, and up to the present, to find the direction of air stream into the two stroke cycle engine cylinder through the scavenging ports, the static investigations under the simplified conditions of steady flow[1)~6)] and the theoretical calculations on assumption of 2 dimensional potentioal flow [7)~9)] were carried out by many investigators.

According to these paper reports, the scavenging air stream changes with the piston travel. However, the question arises as to whether the flow pattern under such a steady flow or potential flow conditions is same as in running engine, especially as in high speed rotating engine.

The state of changeable efflux angle can be judged by the studies of the scavenging process in the cylinder having various scavenging port arrangements, which were carried out using the dielectric properties of gases by the authors.

In order to make clear how the efflux angle changes under the condition of moving piston, the authors have made a new single cycle model engine and have taken photographs of the scavenging air stream by the high speed motion camera and analyzed scavenging air stream in a small crankcase scavenged engine cylinder and in a large loop scavenged engine cylinder.

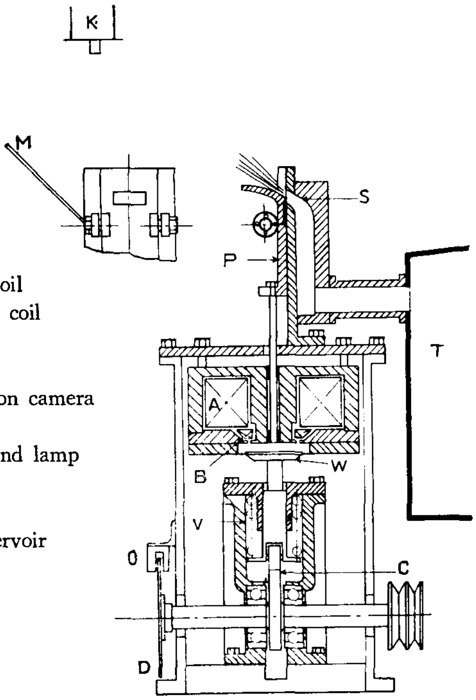
§ 2. Small SCHNÜRLE Scavenged Engine

2. 1 Apparatus and Method

The 2 dimensional single model port and the piston were used. The original engine is a small crankcase scavenged engine (SCHNÜRLE scavenging type, bore stroke; 52$\phi \times$58 mm), this model port has a port similar to that in the engine had been published on the scavenging process.[6)]

Analysis of the scavenging air stream were performed by taking high speed photographs of flowing states of white smoke which produced by the reaction $SiCl_4$ with NH_3 in the scavenging reservoir.

The test arrangement is shown in Fig. 1. The profile of cam C was designed as coincide with an actual engine piston movement while the scavenging period. A steady exciting current is supplied into the fixed magnetic coil A, and the flange W is fixed to magnetic seat against a spring force. Thereby, the follower leaves off the cam profile and the cam shaft can be free running, at the same time scavenging port is closed by the piston. At the time when the piston is to be moved an instantaneous heavy current is discharge into the inverse magnetic coil B, then the follower is dropped on the cam profile by a spring force and the piston travels the planed stroke. When the piston returns to the former position by the cam C, the flange W is



A: fixed magnetic coil
B: inverse magnetic coil
C: cam
D: disk
K: high speed motion camera
M: plane mirror
O: phototransistor and lamp
P: piston
S: scavenging port
T: fresh charge reservoir
V: spring
W: flange

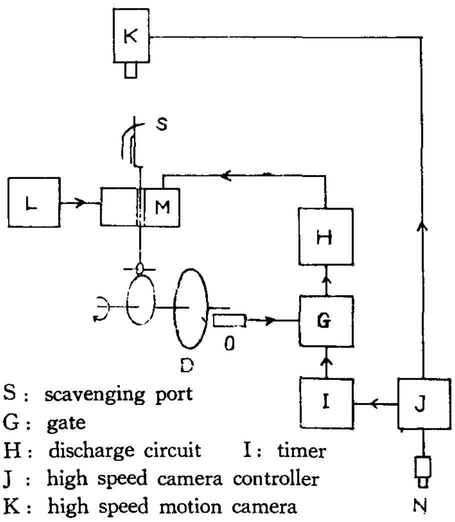
Fig. 1

side view by a plane mirror having the inclination of 45^0 as shown in Fig. 1.

A block diagram of the control system is shown in Fig. 2. As the said, the cam shaft has free running by a motor. The manual trigger switch N is pushed on, in now case high speed motion camera starts, and the gate G is set ON by the timer I when arrived the prearranged photographing speed, so trigger pulse for moving piston flows into the gate G and an instantaneous current to generate an inverse magnetic field is fed by discharging the capacitor through a strobo discharge tube. Dropping time of the follower is chosen time at the beginning of downward stroke of the cam profile, accordingly the piston is traveled the prearranged stroke. The trigger pulse for moving piston was produced by a phototransistor and a lamp which setting the both side of a slitted rotating disk with cam shaft.

fixed to the magnetic seat again, and the piston is stopped, the scavenging port has opening and closing only once.

The high speed motion camera is interlocking with the phenomena, therefore the state of efflux is taken photographs. Moreover, the flow pattern is observed at the same time over look and



S: scavenging port
G: gate
H: discharge circuit I: timer
J: high speed camera controller
K: high speed motion camera
L: magnetic power supply
M: magnet N: manual trigger swich
O: phototransistor and lamp D: disk

Fig. 2

The model scavenging port and piston form are shown in Fig. 3. The port timing is as

A-A Section

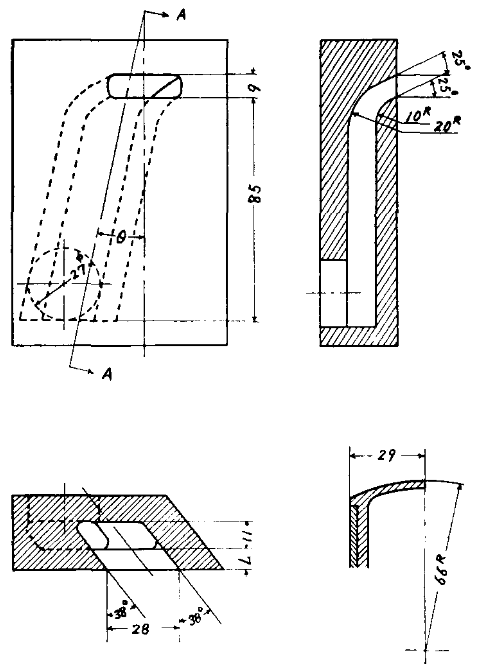


Fig. 3 Piston

follows:

Scavenging port opening……52^0 20′ before B. D. C.

Fig. 4. shows the piston displacement and the opening area of the scavenging port, the full line in the diagram shows the model piston movement which is measured on a record of photograph and the dotted line shows that of the actual engine. The model piston movement agrees well with that of the actual engine.

The tests were made at the scavenging pressures of 100, 200, 300 mmHg and at rotational frequencies of 600, 1000, and 2000 rpm respectively.

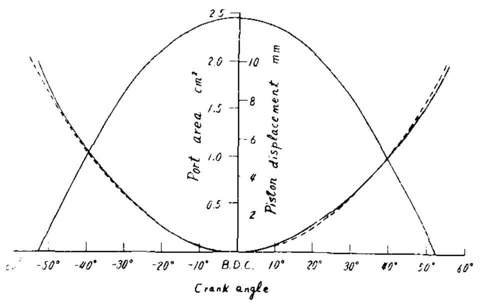


Fig. 4

2. 2 Test Result

2. 2. 1 General characters of scavenging air stream

In general, the scavenging air stream is not effluent in the designed direction of the scavenging port at comparatively slight opening. As shown in Fig. 3, the scavenging port has an upward inclination of 25° and has an inclination of 38° to radial direction, however, the scavenging air efflux angle does not coincide with the both angles, and when the port opening advances the efflux angle approaches the designed direction.

Fig. 5 shows the high speed photographs of the efflux state. The efflux angle changes with the piston movement, that is, the scavenging air stream flows out in a large upward angle than the designed angle from the beginning of sca venging to 35° before B. D. C., thereafter, it flows out in the nearly designed angle of the scavenging port till the scavenging port is closed. And while the comparatively slight opening, with all the port inclination of 38° to the radial direction, the scavenging air flows out perpendicularly to the cylinder wall, and in proportion to the port opening advance flows out having an inclination, However, it does not coincide with the designed angle of 38°, and flows out in a small angle than the designed angle. Since about 35° before B. D. C. it flows out in a constant direction. Namely, the efflux angle changes from the port opening time to 35° before B. D. C. and deviates from the designed angle of the scavenging port.

2. 2. 2 Influence of the scavenging air guide for efflux angle

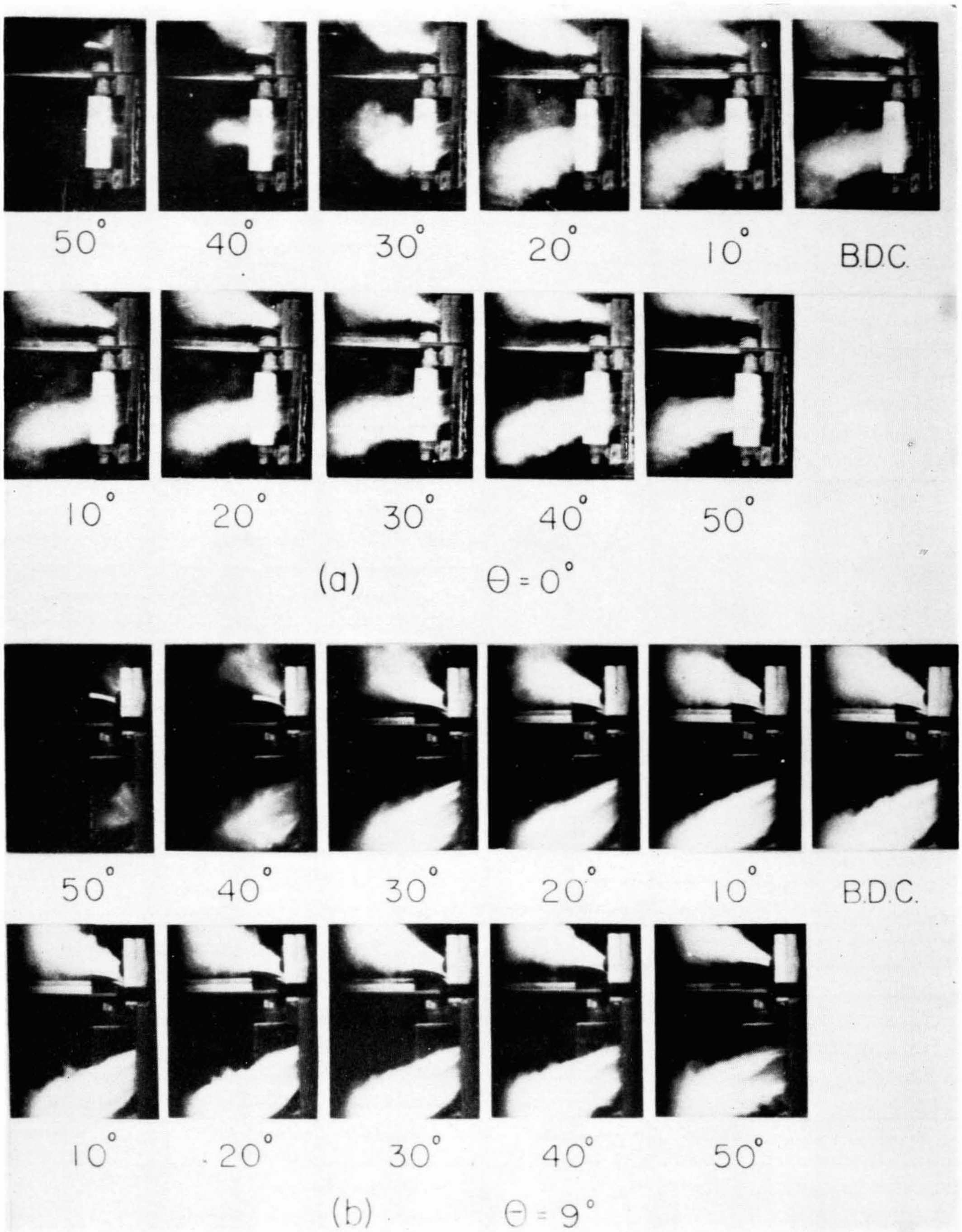
In loop scavenging system, upward flow into the cylinder occurred in the early stage of the scavenging process may be one of the cause of a short circuiting. Therefore, it is desirable to determine the form or the inclination of the scavenging air guide so as to flow out for the designed direction of the port in the early stage.

In order to examine the effects on the length of the scavenging air guide, the scavenging air guide length L was changed variously. The results are shown in Fig. 6. Time area of the scavenging port has an original engine timing. To keep near the scavenging air stream in the direction of the scavenging port, it is effective to draw long the scavenging air guide. However, to coincide the scavenging air flow with the direction of the scavenging port at B. D. C. perfectly, the scavenging air guide length must be 23 mm long, but in the small crankcase scavenged type engine cylinder, it is difficult on the engine structure to have the scavenging air guide of length of 23 mm.

2. 2. 3 Influence of the inclination of scavenging air passage between the crankcase and the cylinder

The photographs (b) in Fig. 5 show the typical photographs of air stream under the condition having the inclination of $\theta=9^0$, compared with photographs (a) under the condition of $\theta=0°$, scavenging air stream has a large inclination. The effects of inclination of the scavenging air passage is shown in Fig. 7.

The inclination θ has a considerable effect to keep near the scavenging air stream in the designed direction of the scavenging port. To decrease the difference of the designed direction andthe effluent direction, it is useful to give some inclination in the scavenging air passage between the crankcase and the cylinder. The inclination of above $\theta=10°$ is not so effective as a little inclination of the first stage. But to keep the scavenging air stream in the direction of



n = 1200 rpm Scavenging pressure = 200 mmHg

Fig. 5

the scav- enging port, it is effective to incline the scavenging air passage between the crank case and the cylinder.

Besides, both the rotating frequency and the scavenging pressure have hardly any effects on the characters of the scavenging air flow.

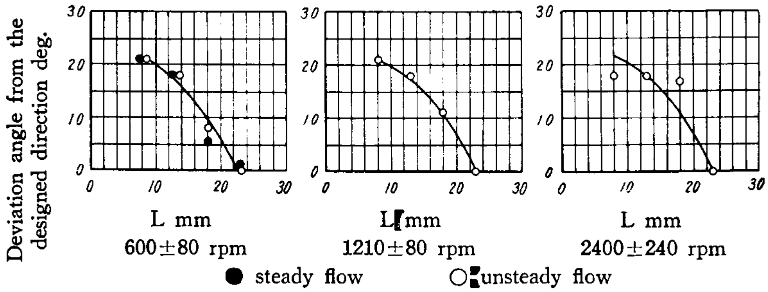


Fig. 6

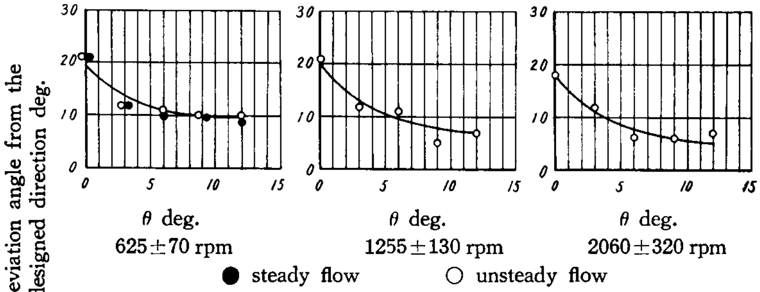
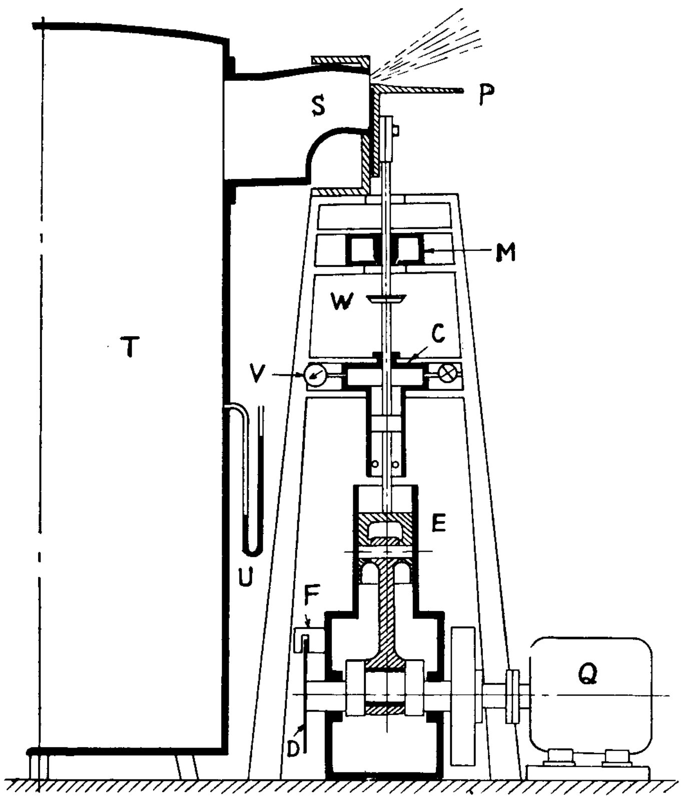


Fig. 7



C: air cylinder D: disk E: engine F: phototransistor and lamp M: magnet P: piston Q: motor S: scavenging port T: fresh change reservoir U: manometer V: pressure gage W: flange

Fig. 8

§ 3. Large Loop Scavenged Engine

3.1 Apparatus and Method

A schematic diagram of the model engine is shown in Fig. 8. An acting principle is the same as that in the previous investigation, however, the cam was not used because it has a long piston stroke. In stead of cam, the piston movement of the engine E which has a stroke of 200 mm and a connecting rod 4 times as long as its crank radius as shown in Fig. 8 was used. Free rotating speed 3 times as fast as actual engine speed so it will be noted that the piston movement is nearly the same as that in an actual engine as shown in Fig. 9.

The original engine is a large loop scavenged engine: M. A. N. KZ 84/160 (bore stroke 840ϕ × 1600 mm), a center port and a side port were remade into the 2 dimensional model. The ports timing is as follows:

Center scavenging port opening……41°7′ before B. D. C.

Side scavenging port opening ……43°1′ before B. D. C.

Controlling method of the apparatus and analyzing method of the scavenging air flow have been used the same way in the previous investigations.

The tests were made at the scavenging pressures of 50, 100, 200, 300 mmHg and at rotating frequencies of 60, 75, 90, 105 and 120 rpm respectively.

3. 2 Test Result

3. 2. 1 State of efflux from the scavenging port located center of port arrangement

The model scavenging port form is shown in Fig. 10. High speed photographs are shown in Fig. 11. The efflux angle changes with the piston movement as in the small crank case scavenged engine, but in the large loop scavenged engine efflux angle leaves again from the designed direction of the scavenging port when the piston approaches near the end of scavenging.

On the assumption of the 2 dimensional potential flow, in Fig. 12, the constant velocity of the free stream line at the infinity point equals 1, the free stream width is π at this point, and the velocity at the infinity A is κ, the velocity at the point B is zero. Then, flowing direction is given by following relations[7)-9)];

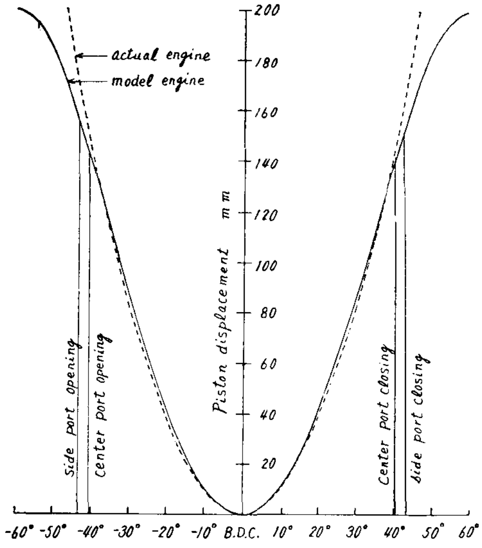
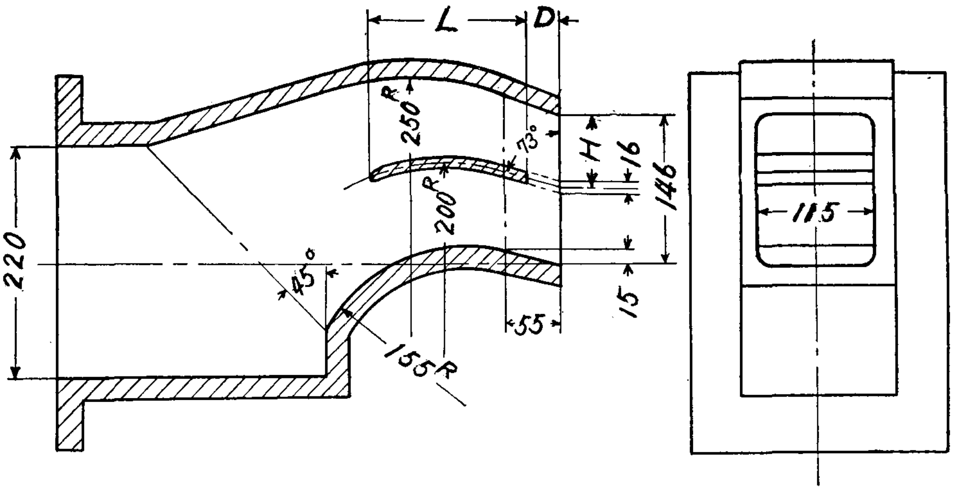


Fig. 9



$$m = -c/b = f_1(\kappa) + \kappa\varphi_1(\alpha)$$

$$n = e/b = f_2(\kappa) + \kappa\varphi_2(\alpha)$$

Where $f_1(\kappa)$, $f_2(\kappa)$ and $\varphi_1(\alpha)$, $\varphi_2(\alpha)$ are the functions κ and α which has different form by the values of ß, in the case of $ß = \pi/2$,

$$f_1(\kappa) = -\frac{2(1-\kappa^2)}{\pi}\, tan^{-1}\kappa$$

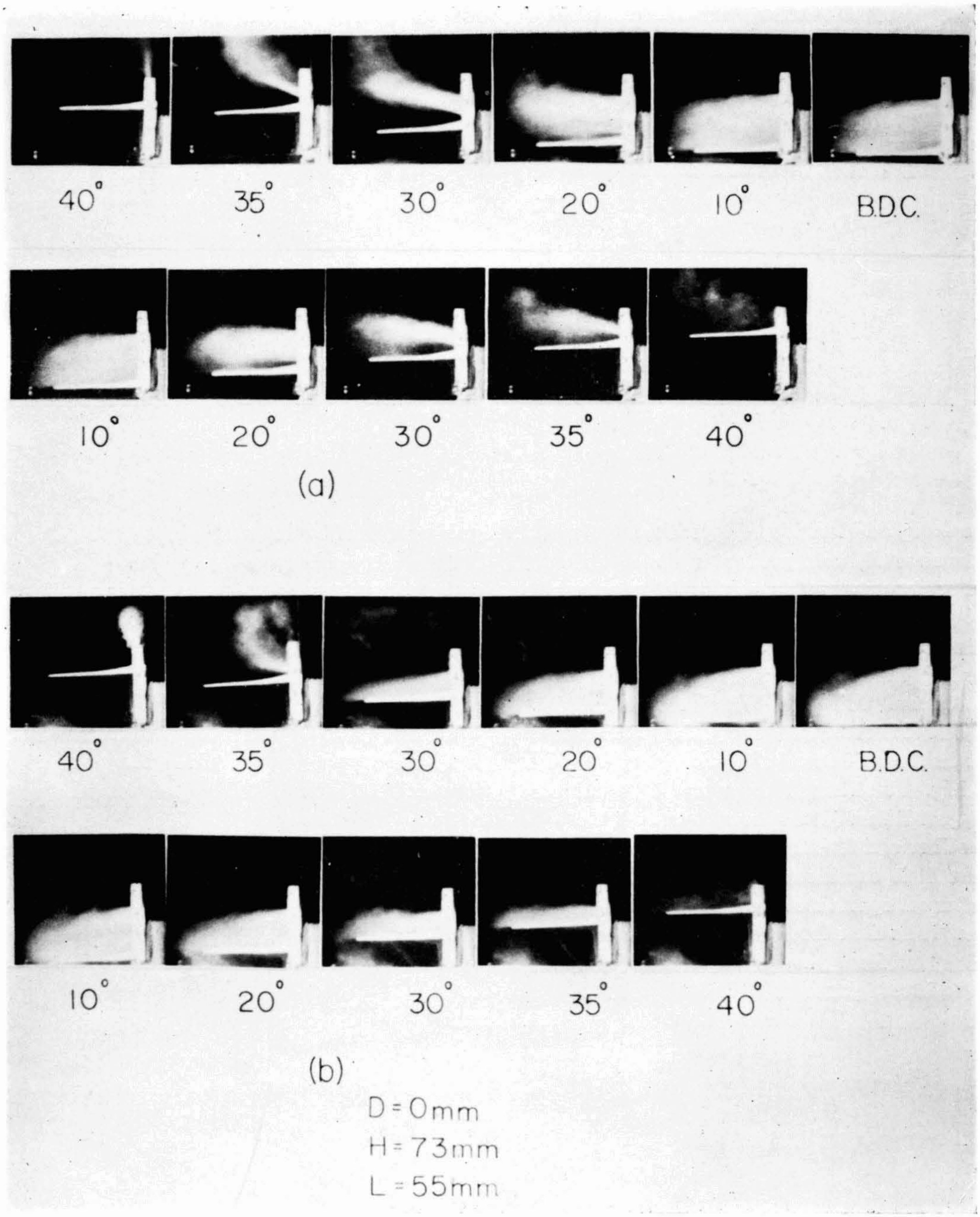
$$f_2(\kappa) = \frac{1+\kappa^2}{\pi} ln \frac{1+\kappa}{1-\kappa}$$

$$\varphi_1(\alpha) = \frac{cos\,\alpha}{\pi} ln \frac{1 \div cos\,\alpha}{1 - cos\,\alpha} - sin\,\alpha$$

$$\varphi_2(\alpha) = cos\,\alpha - \frac{sin\,\alpha}{\pi} ln \frac{1 \div sin\,\alpha}{1 - sin\,\alpha}$$

From these relations, effluent direction of the scavenging air stream is related to only the scavenging port opening ratio. Therefore, the change of efflux is down in a short time at the lower port height compared with higher port height. Accordingly, on a method to keep near the effluent direction of the scavenging air stream in the designed direction setting the guide plate in the scavenging port as shown in Fig. 10 is considered.

If it is considered that the port is divided up and down by a guide plate, when the upper port was opened scavenging air stream coincides with the designed direction in a little while. When the lower port where located under the guide plate was opened, in this port too, efflux



n=62 rpm Scavenging pressure=50 mmHg

Fig. 11

angle changes with the piston movement, and efflux pattern is formed to complicated pattern withthe previous stream flowing out from the upper port. But it seems to reduce the intreferences of the two stream from the upper and lower ports by the setting position of the guide plate is chosen properly.

The photographs (b) in Fig. 11 show the typical photographs of the air stream having the guide plate which is set on the middle position in the scavenging port as shown in Fig. 10. The driving conditions are same to the photographs (a). The effects of the guide plate are shown in Fig. 13. The scavenging air stream flows out to

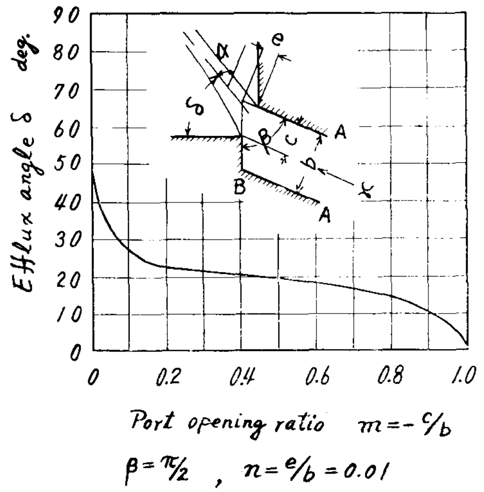


Fig. 12

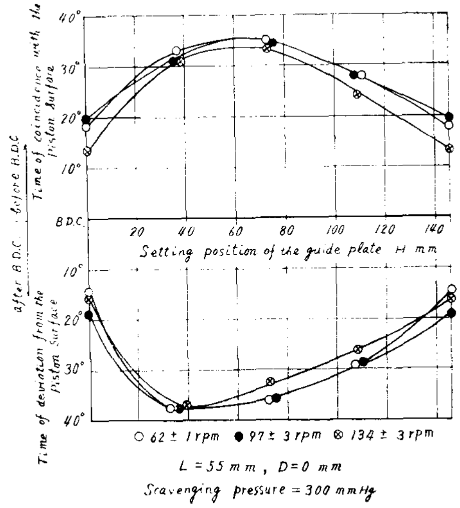


Fig. 13

the designed direction in speedily, as might has been expcted, compared with photographs (a).

For the scavenging port which was used in this experiments, the scavenging air stream coincides with the scavenging port direction exceedingly long while when the guide plate was set on the position of 1/2 of the port height.

On the above experiments, the guide plate was set on the inside wall of the cylinder (D = 0 mm in Fig. 10) although in an actual engine it may happen difficulties on the structure of the cylinder liner and on the acting of the piston, therefore, it is considered that the guide plate had better set apart from the inside wall of the cylinder. Then the effects of the guide plate which is set apart from the inside wall of the cylinder were investigated. The setting position of the guide plate is H = 73mm of a best setting height and is arranged from the inside wall of the cylinder for the scavenging reservoir.

Fig. 14, Fig. 15 show the results in this case. The scavenging air stream coincides with the scavenging port direction a long while when the guide plate was set to inside wall of the cylinder. When the guide plate is set apart from the inside wall, the scavenging air under the guide plate flows out from the space between the guide plate and the piston, so that this effluent has influence upon the scavenging air stream and coincident time with the designed direction of the scaveng-

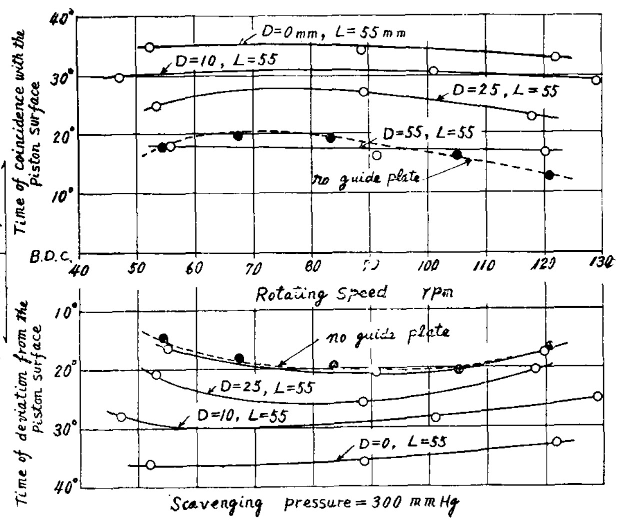


Fig. 14

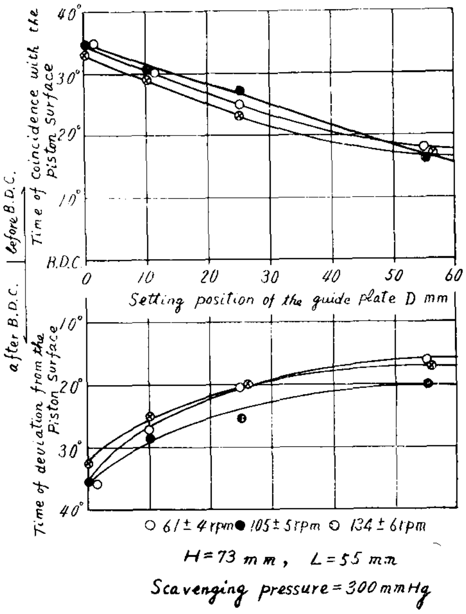


Fig. 15

ing port is delayed.

The influence of the guide plate length is shown in Fig. 16. The setting position of the guide plate is D = 55 mm and H = 73 mm. When the guide plate is set apart from the inside wall, even if the long guide is used, the remarkable influence was not observed, therefore, it is effective to set the inside wall of the cylinder as near as possible.

3. 2. 2 State of efflux from the scavenging port located side of port arrangement

The scavenging port of a M.A.N. loop scavenged engine has a upward angle and at the same time inclines for the radial direction similarly in the small crankcase scavenged engine. Besides, according to circumstance, the scavenging port upper wedge has a inclination. Then the states of the efflux from such a port were observed. The scavenging port form is shown in Fig. 17.

The state of efflux is very complicated pattern because it has a complex geometrical form compared with the center port. In this scavenging port too, several guide plates are set as shown in Fig. 17, and the investigations were carried out, but it seems that improvement of the characters of the scavenging air stream by utilizing the guide plate is difficult.

§ 4. Summary

By using the 2 dimensional single model port, the characters of the scavenging air stream through the scavenging ports in a small crank case scavenged engine cylinder and in a large loop scavenged engine cylinder were investigated. It may be summarized as follows ;

1. In general, the scavenging

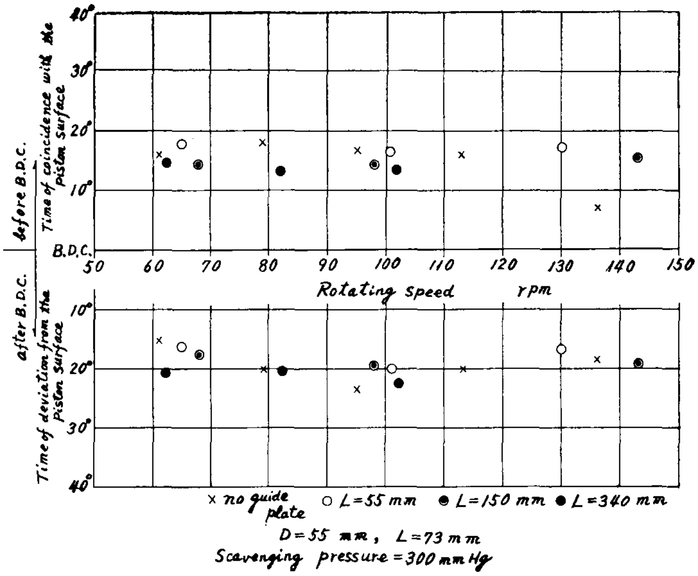
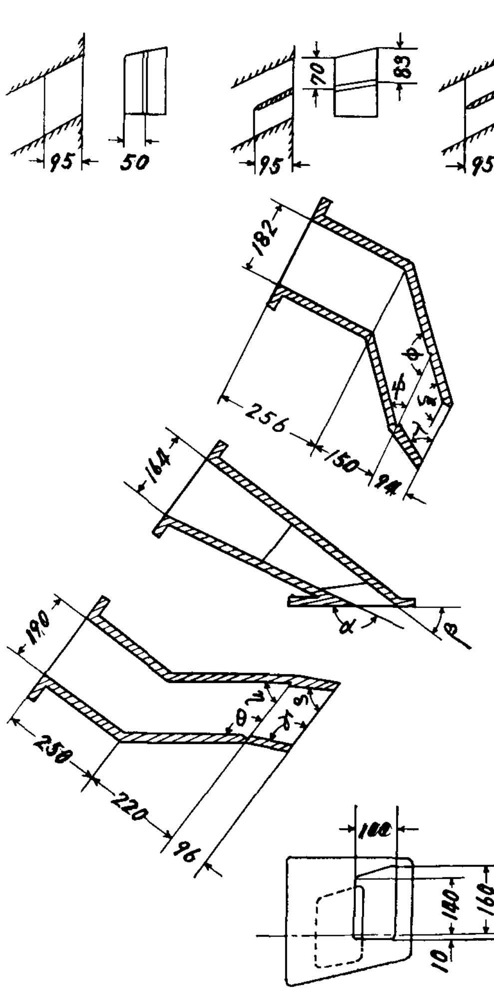


Fig. 16



Angle	
α	37°
β	155°
γ	115.5°
δ	63.5°
η	54°
θ	126°
λ	59°
ξ	135°
φ	138.5°
ψ	41.5°

Fig. 17

air stream does not effluent in the designed direction of the scavenging port at comparatively slight opening and the efflux angle changes with the piston movement.

2. In the small crankcase scavenged engine cylinder, to keep the scavenging air stream in the direction of the scavenging port, it is effective to incline the scavenging air passage between the crankcase and the cylinder and to make thicker the cylinder wall where located the scavenging port.

3. In the scavenging port located near the center of a large loop scavenged engine cylinder, to coincide the scavenging air stream with the direction of the scavenging port in the early stage of the scavenging, it has an effect to set the guide plate the position of 1/2 at port height moreover from the inside wall of the cylinder. But in the side port, the guide plate has no effect as regards the coincident time with the scavenging port direction and the effluent direction.

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