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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 242

IMPROVING THE PERFORMANCE OF A COMPRESSION IGNITION ENGINE BY DIRECTING FLOW OF THE INLET AIR

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Summary

The object of this report is to present the results of tests performed by the National Advisory Committee for Aeronautics to determine the effect on engine performance of directing the flow of the inlet air to a 5-inch by 7-inch single cylinder, solid injection, compression ignition engine. After a few preliminary tests, comparative runs were made at a speed of 1500 R.P.M. with and without directed air flow. It was found that directing the flow of the inlet air toward the fuel injection valve gave steadier engine operation, and an appreciable increase in power, and decreased fuel consumption. The results indicate the possibility of improving the performance of a given type of combustion chamber without changing its shape and with no change in valve timing. They would also seem to prove that directional turbulence, set up before the inlet valve of a four-stroke cycle engine, continues in the engine cylinder throughout the compression stroke.

Introduction

During the inlet stroke of a compression ignition engine, the air flow into the combustion chamber is given a turbulent motion, due primarily to its passage through the inlet valves. This turbulence persists throughout the compression stroke of the engine and is of use in bringing about an intimate mixing of the air and the injected fuel. For any given engine speed and volumetric efficiency, increasing the turbulence within a given combustion chamber usually leads to increased power and decreased fuel consumption.

The great disadvantage of a solid injection, compression ignition type of engine at high speeds is the failure to obtain complete burning of the fuel charge in the short time available; any factor, therefore, tending to improve the completeness of combustion should be investigated. In the design of a compression ignition engine using airless injection turbulence is usually obtained by the shape of the combustion chamber and location of the fuel valve. Little information is available on the research work which has been done to determine the effect on engine performance of directing the flow of the inlet air of a compression ignition engine before its passage through the inlet valve. The usual supposition has been that any attempt to maintain directional turbulence within the engine cylinder, by directing the flow of the inlet air before the inlet valve, would be destroyed by the passage of the air around the inlet valve and the compression of the charge. A recently designed oil engine, however, has used shielded inlet valves to produce rotation of the inlet air tangential to the circumference of the cylinder (Reference 1).

The tests referred to in this report were undertaken in an effort toward improving the performance of a given type of combustion chamber.

Description of Apparatus and Methods of Testing

These tests were performed on a 5-inch by 7-inch single cylinder, four-stroke cycle, compression ignition, test engine, coupled to a 50-75 HP. cradle type dynamometer. The cylinder and cylinder head were designed for fuel injection work by the staff of the National Advisory Committee for Aeronautics. The standard Navy Liberty type of piston was used with a special cylinder to give a compression ratio of 12.7. A balanced-valve type of pressure gauge was used to measure maximum cylinder pressure. The location of this gauge in the cylinder head is shown in Fig. 3.

The shape of the combustion chamber and location of the fuel valve are shown in Figs. 2 and 3. Due to the construction of the test engine, the fuel valve could not be placed centrally in the combustion chamber. The only suitable fuel valve that could be fitted to the combustion space was one having an impact lip which gave a flat sheet of fuel traveling across the combustion chamber.

The fuel used in the tests was a good grade of Diesel engine oil having a specific gravity of 0.847 at 80°F. The fuel was delivered to the cam-actuated fuel injection pump at a pressure of 85 lb. per sq.in. by a primary gear pump. A complete description of the fuel injection system is given in a National Advisory Committee for Aeronautics report (Reference 2).

The arrangement of vanes shown in Fig. 4 was inserted in the inlet stack and directed the flow of the inlet air into the engine cylinder. The position of the vanes in relation to the inlet valve is shown in Fig. 3.

The following procedure was observed in making all tests. The engine was run long enough to stabilize oil and water temperatures. At the beginning of a test run, the pump stroke (fuel quantity) was adjusted to give the required amount of fuel and the pump timing was advanced until the maximum pressure gauge indicated a pressure of 800 lb. per sq.in.

Previous work carried out at the Laboratory had shown that it was impossible to run standard Liberty aluminum pistons with maximum pressures of 1000 lb. per sq.in. without cracking the piston pin bosses. In order to avoid this difficulty, all runs were made with a maximum pressure of 800 lb. gauge, under which condition reasonable piston life was obtained.

The engine power was determined by means of a torque scale graduated at 0.2 lb. intervals and a magnetically operated stop watch and counter. Fuel consumption was obtained by timing with a stop watch the flow of 200 c.c. of fuel. From the total number of revolutions made during the fuel time, it was possible to calculate the quantity of fuel delivered per stroke by the pump for any given setting. Water and oil temperatures (out) were recorded by mercury thermometers and maintained at 140°F and 110°F, respectively. During the tests the temperature of the inlet air did not vary more than 5°F.

Results of Tests

Under actual running conditions the performance of the engine fitted with the impact lip type of fuel valve was very poor. The B.M.E.P. was low and the fuel consumption was excessive. A continuous heavy knock was noted even when limiting the maximum explosion pressures to 800 lb. per sq.in. It was found possible at all times, however, by varying the pump timing to maintain maximum explosion pressures of 800 lb. per sq.in. without having the engine detonate. An examination of the carbon formation on the piston (Fig. 5) at the end of seven hours running with varying load, showed that only a small percentage of the injected fuel was being burned.

After experimenting with various rates of fuel injection, obtained by varying the pump plunger diameter and the fuel valve opening pressure, without being able to reduce the fuel consumption to a reasonable value; the experiment was tried of directing the flow of the inlet air to obtain better combustion. Directing the flow of the inlet air toward the left of the inlet valve gave steadier engine operation, increased power, and decreased fuel consumption. When the inlet air was directed toward the right, however, the engine showed a marked decrease in performance.

The opening pressure of the fuel valve was found to influence the operation of the engine when the vanes were installed. The best results were obtained with a low static opening pressure of 1400 lb. gauge pressure. When running with the higher static opening pressures of the fuel valve, namely, 2300 and 3200 lb. per sq.in., directing the inlet air gave only a slight improvement in performance. Although the atomization of the fuel was better with the higher opening pressure, it was thought that the fuel tended to penetrate across the combustion chamber and did not mix with the air immediately surrounding the fuel valve.

Data for the tests made at 1500 R.P.M. with the vanes inserted was obtained with a fuel valve opening pressure of 1400 lb. gauge. With the air vanes removed, however, operation at this engine speed and with the low fuel valve opening pressure was very unsteady. The B.M.E.P. was low and it was necessary to make large variations in the engine load to maintain a constant speed. This unsteady running condition had not been experienced when using the higher fuel valve opening pressure without the vanes and was thought to be caused by the lack of penetration of the fuel spray. It was decided, therefore, to compare the performance of the engine with the best that had been obtained when using a higher fuel valve opening pressure. With the static opening pressure of the fuel valve raised to 2300 lb. per sq.in., the operation of the engine was steady. Increasing the opening pressure to 3200 lb. gauge, was found to give a slight increase in B.M.E.P., but the fuel consumption was greatly increased.

The results are presented in the form of curves and photographs (Figs. 1-6 inclusive). All curves are based on observed performance at sea level and are plotted on a basis of fuel quantity in pound per cycle. The best results obtained by directing the flow of the inlet air before the inlet valve were made with a fuel valve opening pressure of 1400 lb. per sq.in., and are shown in Fig. 1. The curves "Best Performance without Directed Air Flow" were obtained with a fuel valve opening pressure of 2300 lb. sq.in. It may be noted that it was possible by directing the flow of the inlet air, to increase the I.M.E.P. from 82.0 to 96.0 lb. per sq.in. with a corresponding decrease in fuel consumption from 0.60 to 0.51 lb./I.HP./hr.

The photograph (Fig. 6) shows the carbon formation of the piston after completing seventeen hours' running at 1500 R.P.M. The coating of carbon was very light and indicates that the combustion within the cylinder was greatly improved, over that shown in Fig. 5, by directing the flow of the inlet air. The clean area of the piston (Fig. 6) was originally covered with a very thin coating of soft carbon which was removed to indicate the area of the piston over which complete combustion occurred.

Although the degree of turbulence in the cylinder was the same, whether the air was directed toward the left or right, the increased performance was obtained only with the air directed toward the left or toward the fuel valve. Since fuel injection into the cylinder does not start until about 30 degrees B.T.D.C., it would seem that any gain in performance brought about by increased turbulence during the suction stroke should be the same, whether the air was directed toward the left or right. It is thought that directing the air toward the left, however, swept the products of combustion completely away from the fuel valve and left a charge of relatively pure air surrounding the injection valve.

Conclusions

The results of the tests indicate a simple means for improving the air flow in a given combustion chamber without changing its shape. They would also seem to prove that directional turbulence set up before the inlet valves of a four-stroke cycle engine continues in the engine cylinder throughout the compression stroke.

Directing the flow of the inlet air toward the fuel valve gave steadier running, increased power, and decreased fuel consumption. It was found possible by this means to increase the I.M.E.P. of a 5-inch by 7-inch single cylinder engine, having compression ignition, solid injection and running at a speed of 1500 R.P.M. from 82.0 to 96.0 lb. per sq.in. The corresponding fuel consumptions were respectively, 0.60 and 0.51 lb./I.HP./hr. The lowest fuel consumption obtained with these operating conditions was 0.38 lb./I.HP./hr. at 73.0 I.M.E.P. Supercharging the engine with the inlet vanes in place should give even better improvement.

References

1. Hesselman, K. J. E. : Hesselman Heavy Oil High-Compression Engine. N.A.C.A. Technical Memorandum No. 312 - 1925.

2. Paton, C. R. and Kemper, Carlton : Power Output and Air Requirements of a Two-Stroke Cycle Engine for Aeronautical Use. N.A.C.A. Technical Report No. 239 - 1926.

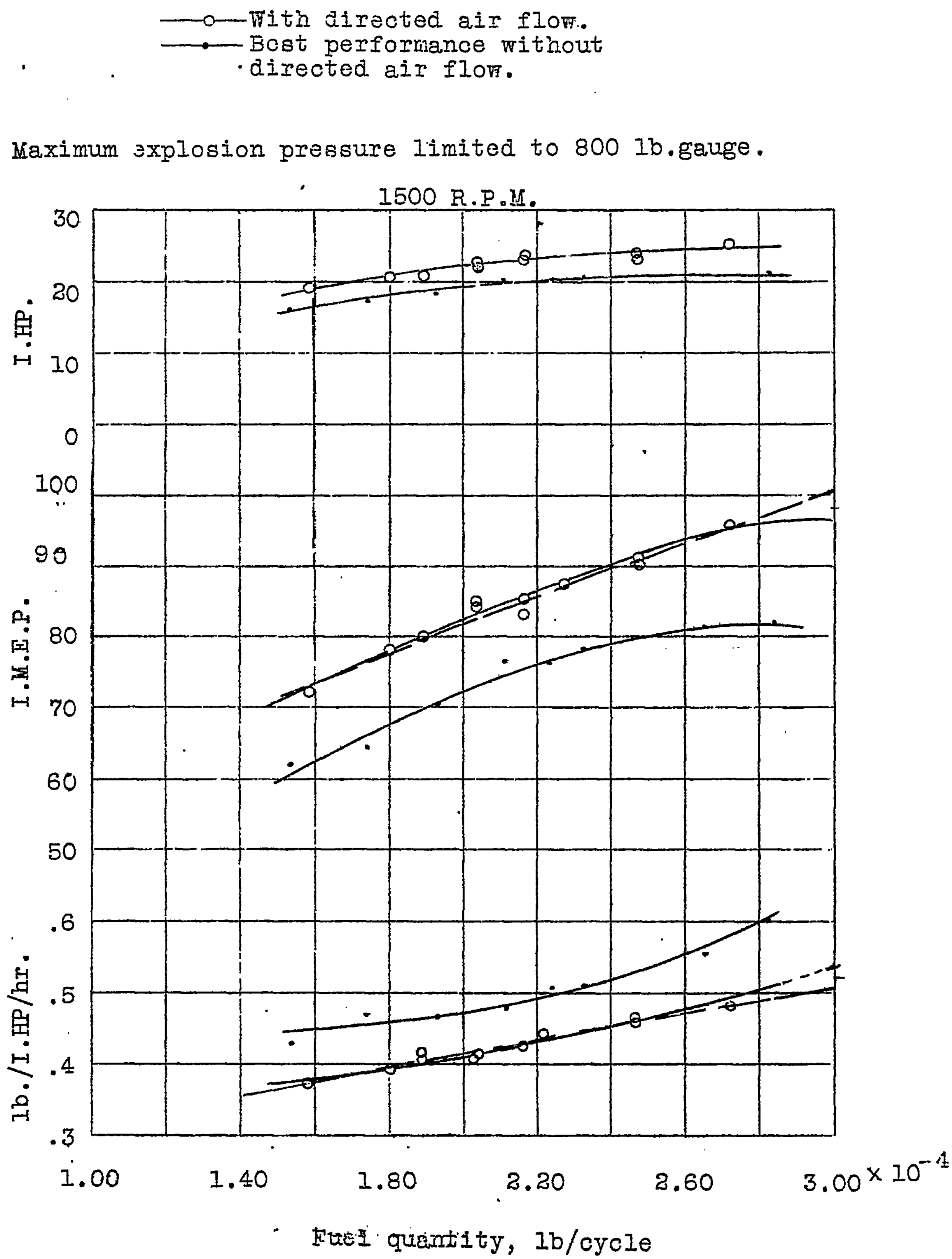

Fig.1 Test of compression ignition engine having directed flow of inlet air.

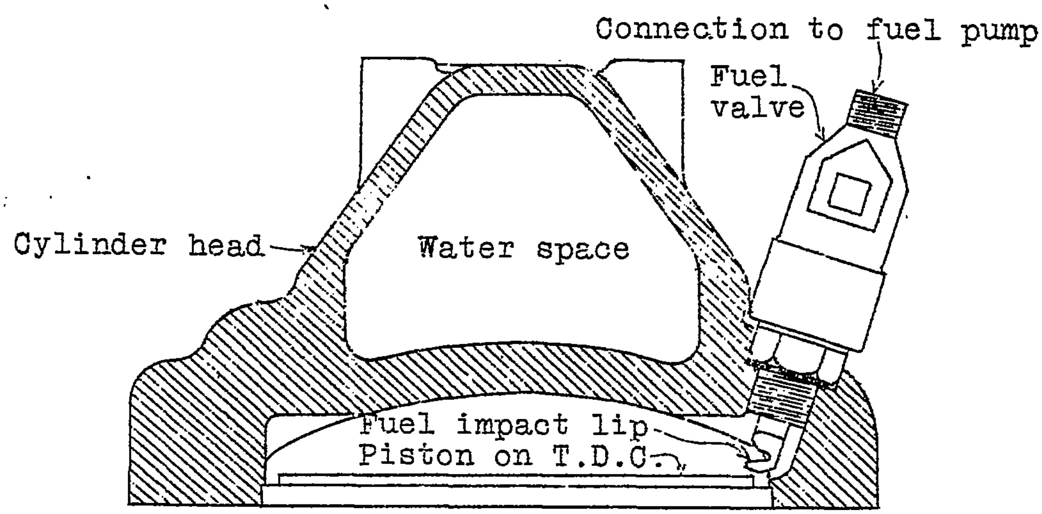

Fig.2 Location of fuel valve in cylinder head.

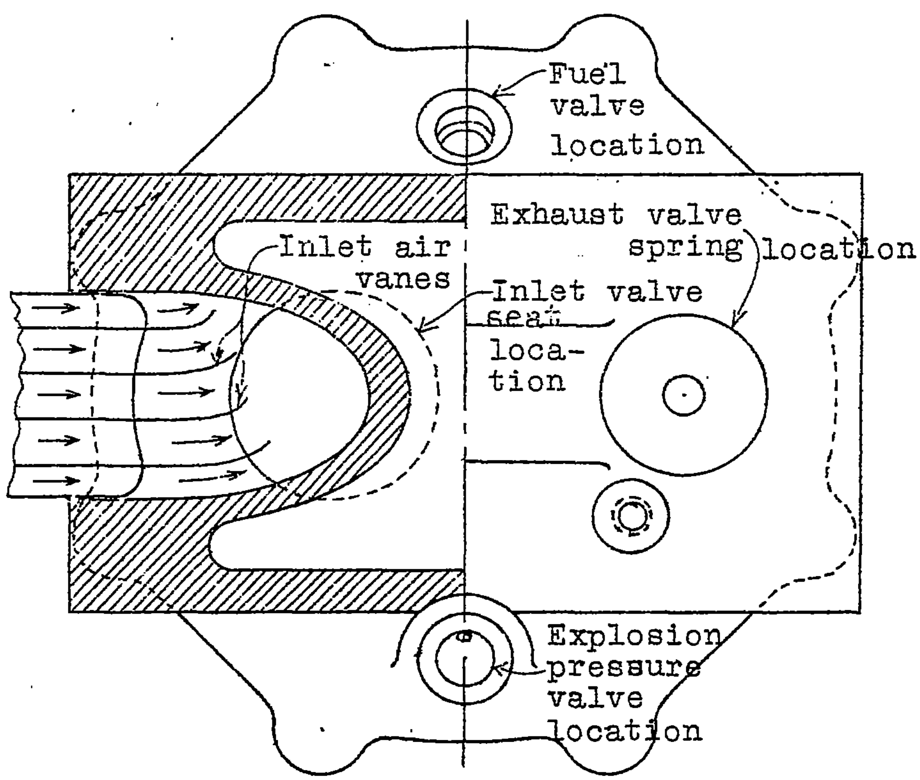

Fig.3 Position of inlet air vanes.

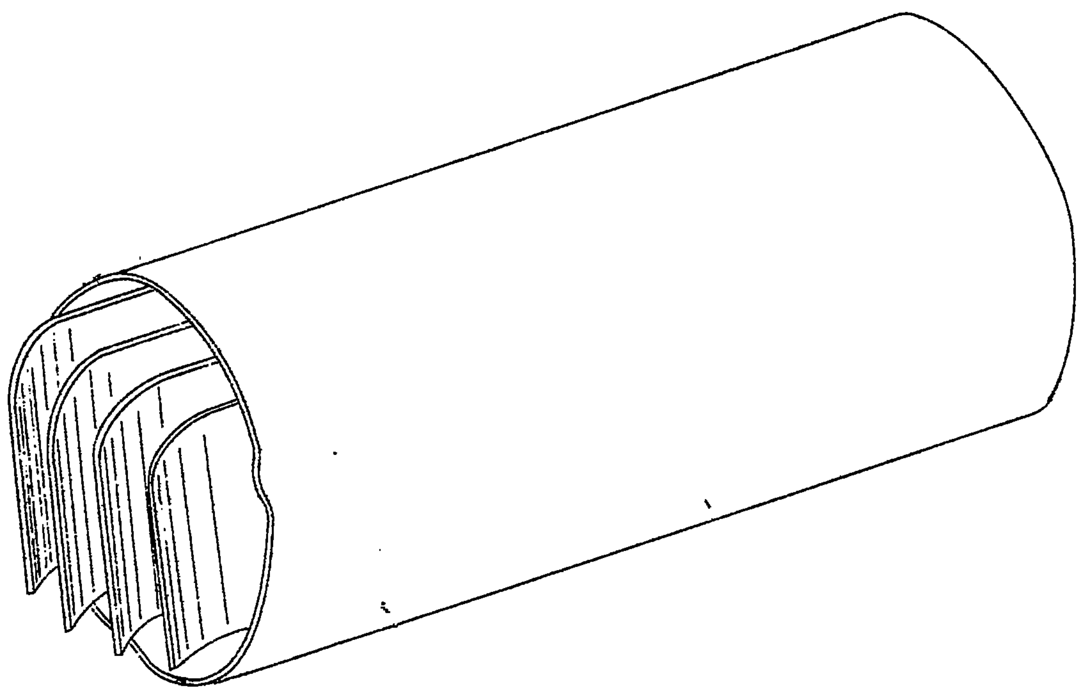

Fig.4 Arrangement of vanes for directing flow of the inlet air.

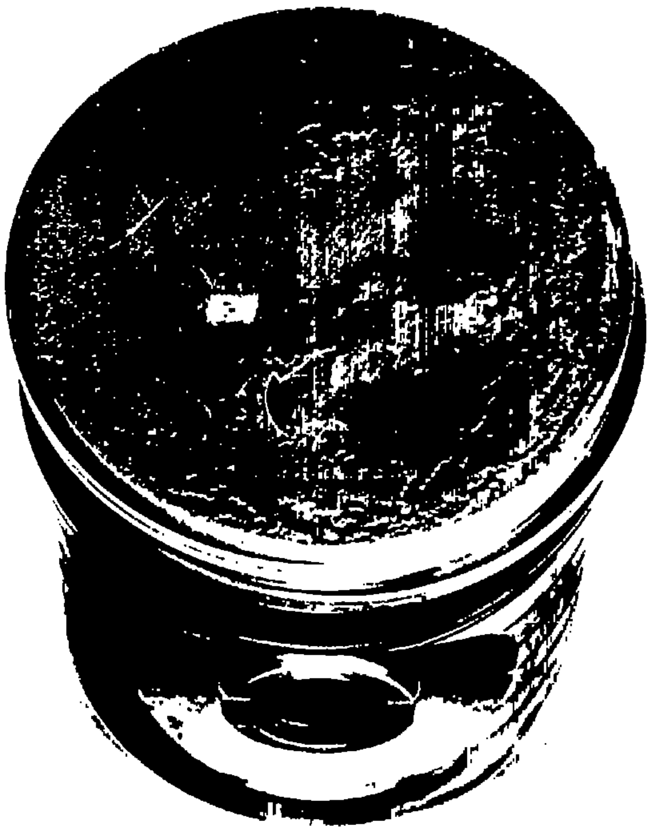

Fig.5 Piston after seven hours running without directed inlet air

Fig.6 Piston after seventeen hours running with directed inlet air

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