PRESSURE INJECTION

A Description of the Stromberg System Widely Used on American Aircraft

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IN a previous article on fuel injection (*Flight*, August 21st) mention was made of the pressure injection system developed by Bendix Aviation Corporation, South Bend, Ind., U.S.A., and embodied in the Stromberg injection carburettor now fitted to large numbers of American aircraft-of-war. In the article referred to the pros and cons of the various injection systems were compared with those of the orthodox aircraft carburettor, and the reader who is sufficiently interested is advised to refer to that issue. Space considerations preclude the recapitulation of the various factors involved, and the present discussion is intended to deal only with the layout and operation of the Stromberg injection system. We should, however, preface our remarks with a few notes on the operative characteristics of the design. Together with cylinder injection systems, such as that employed on German aircraft, the Stromberg possesses the following qualities:—

(1) Freedom from icing-up, since no fuel whatever passes the throttles.

(2) Freedom from cutting-out during any manœuvre of the aircraft, including negative G, owing to the fuel system from fuel pump to injection nozzle being always full and under pressure.

(3) Freedom from vapour lock to higher altitudes for the same reason as (2).

(4) Efficient atomisation of the fuel, owing to pressure discharge.

In addition, the injection carburettor can claim the following:—

(5) Lower airflow loss through carburettor (venturis may be larger since no fuel metering suction is necessary), while the presence of fuel in the supercharger obviously maintains normal pressure ratio of the latter.

(6) Ease and simplicity of maintenance service testing.

Although a newcomer to the European field of carburation, the Bendix-Stromberg has been in large-scale production in the United States for about three years, and is standardised on a large proportion of the American aircraft now arriving in this country.

If there is one fact more than another which intrigues us in the review of fuel injection in general it is that, although the problem in all its branches (including cylinder injection *à la* the Germans) has been the subject of considerable research by various concerns in the States, it is fuel injection into the supercharger entry and not into the cylinder which has emerged successfully and passed into production.

Briefly, the Stromberg system consists of metering the air alone through a fairly orthodox arrangement of double venturi, and imposing the resulting pressure differential across a diaphragm assembly which controls the flow of fuel into the carburettor. From the fuel pump to the carburettor the fuel is under the initial pressure of 15 lb. per sq. in., and after being metered by the jet system it is injected into any chosen position in the blower entry through a discharge nozzle or nozzles of any chosen shape or type, at a constant pressure of about 5 lb. per sq. in. In some cases the point of injection chosen is directly into the eye of the blower, while in others a diffuser bar bearing a number of holes is arranged across the airstream tract between carburettor and blower. In all cases the nozzle location and type is worked out experimentally to suit the distribution characteristics of the engine concerned, and the ability to do this is a most valuable feature.

The carburettor embodies automatic correction for altitude, together with automatic mixture enrichment for high power, and the usual manual mixture controls, i.e., *Idle Cut-Off*, *Auto-Lean*, *Auto-Rich* and *Full Emergency Rich*.

Thus the system is one of pressure injection pure and simple, and although, for want of a better name, the assembly is known as the pressure or injection carburettor, it is quite unlike the orthodox aeroplane carburettor in its method of functioning. Another point of interest is that the mixture ratio demanded at any moment is completely unaffected by throttle position, since the carburettor responds only to changes in mass airflow. Similarly, the carburettor could be flown upside down all day without any change in functioning (if the fuel supply system could be arranged to deliver fuel satisfactorily). In other words, the carburettor does not know what the throttle is doing or whether the aircraft is right-side-up or not.

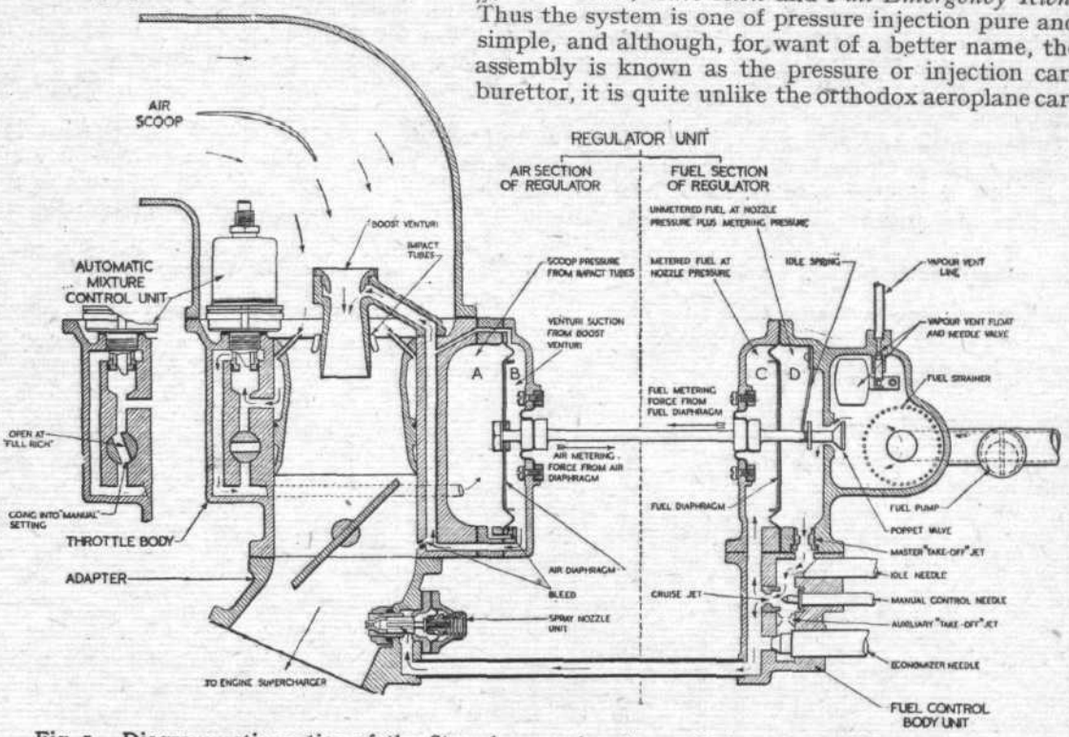


Fig. 1. Diagrammatic section of the Stromberg carburettor, which comprises four main parts: the throttle body, the altitude control unit, the regulator unit, and the fuel control body.

The elementary functioning of the carburettor will best be understood by study of the illustration in Fig. 1. The assembly may be divided broadly into four parts:—

The Throttle Body, which comprises the venturi system and throttles. Attached to the throttle body is

The Altitude Control Unit. This is a self-contained assembly comprising a capsule and needle valve, and may easily be unscrewed and withdrawn for inspection.

The Regulator Unit. This assembly contains the air and fuel diaphragms, which are the chief sources of fuel control within the carburettor.

The Fuel Control Body, which contains the jet system

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which meters the fuel, together with the mechanism of the manual mixture control.

Let us first examine the airflow side of the diagram, Fig. 1. On the left we have the throttle body, which contains the venturis and orthodox-type throttles. These throttles do nothing except control the airflow, and there are no critical "throttle-edge" idle or progression devices, since the idle control is incorporated in the main carburettor. Those familiar with Stromberg carburettors will recognise the arrangement of double venturi, but here the venturis meter air only. *No fuel passes through the venturi or throttle body.* The pressure of the incoming air through the airscoop is recorded by a number of small impact tubes, so arranged on the upstream end of the large venturi that they face the airstream. The suction in the small or "boost" venturis is taken from an annular channel round the neck of the latter, the edge of this pointing downstream. This arrangement is, in effect, an airflow meter, recording mass airflow; and, since there is no discharge of fuel at this point to upset the venturi action, its calibration is extremely accurate. In the research work on the carburettor during development it was found that this layout permits more than twice as large a metering head per unit of resistance as could be obtained in previous carburettor systems.

Turning again to the diagram, the suction from the small venturi is taken through the passage shown to the right-hand side of the air diaphragm, known as chamber B. The airscoop pressure from the impact tubes is likewise carried (via the altitude control needle valve) to the left-hand chamber, called chamber A. The air diaphragm is thus subject to the pressure differential across the venturi system, and so will be pulled to the right as the airflow is increased, and vice versa.

Turning now to the fuel section of the regulator (on the right of the illustration) there is another diaphragm chamber, the fuel diaphragm being connected to the air diaphragm by a rod, so that both must move together. At the extreme right-hand end of this coupling rod is one of the most important items in the carburettor, the poppet valve which controls the main flow of fuel into the carburettor.

Let us now follow the passage of fuel through the carburettor. Fuel enters the strainer chamber at a pressure of approximately 15 lb. per sq. in. from the fuel pump. It then passes the poppet valve (which is never quite closed, as will be explained later), and so into the chamber on the right, called chamber D. Before passing into the next chamber (chamber C) the fuel must first pass through the Fuel Control Body, where it is metered by the jet system as shown. Chamber C, it will be observed, is in direct communication with the discharge nozzle, and the fuel therein is *metered* fuel, as against the *unmetered* fuel in chamber D.

We have seen that the pressure differential across the venturi, acting upon the air diaphragm, exerts a force to the right, and this is known as the *air metering force*. The greater the airflow through the carburettor the greater this

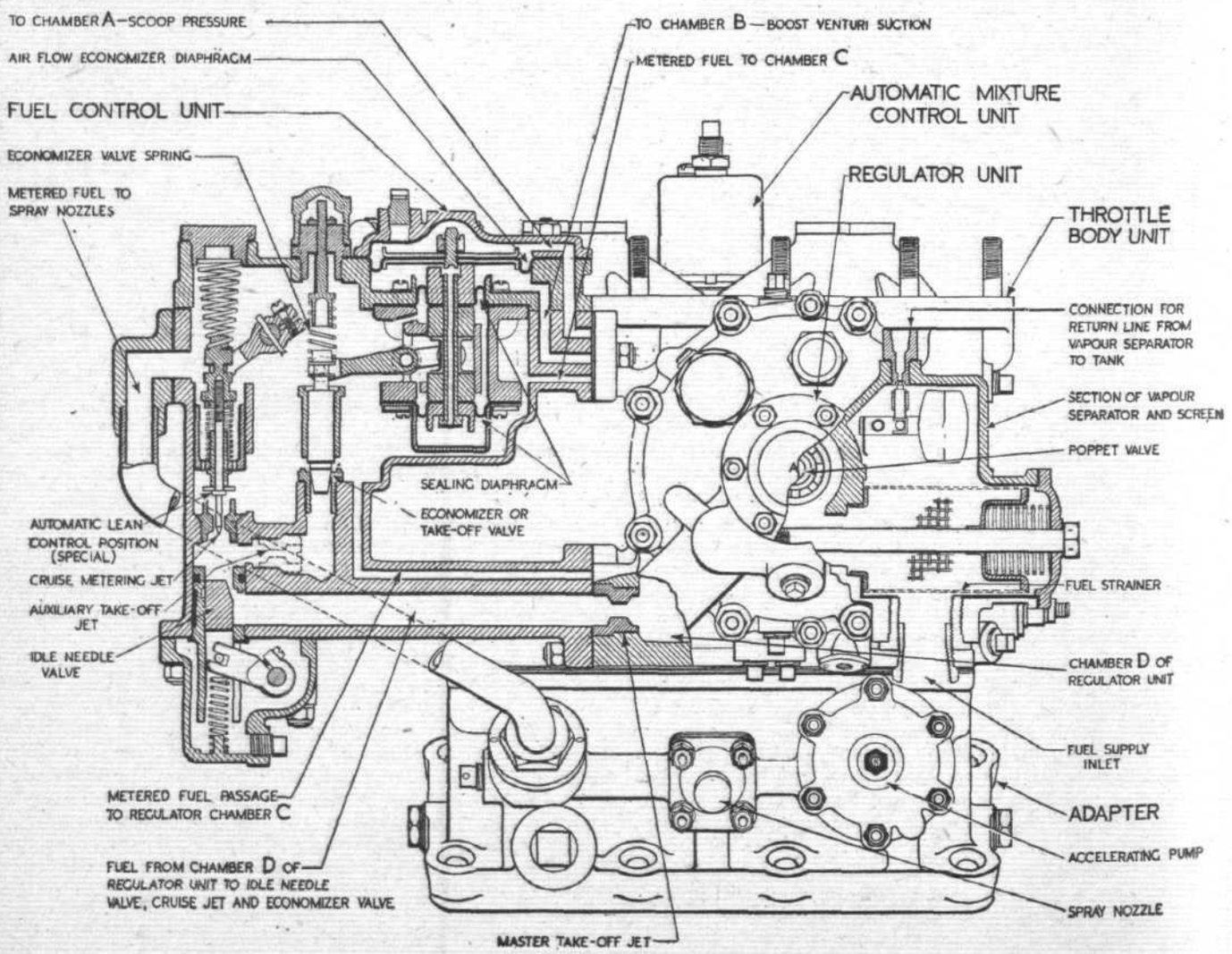


Fig. 2. In this model the enrichment diaphragm is controlled by the air differential. The illustration shows the practical form of the arrangement.

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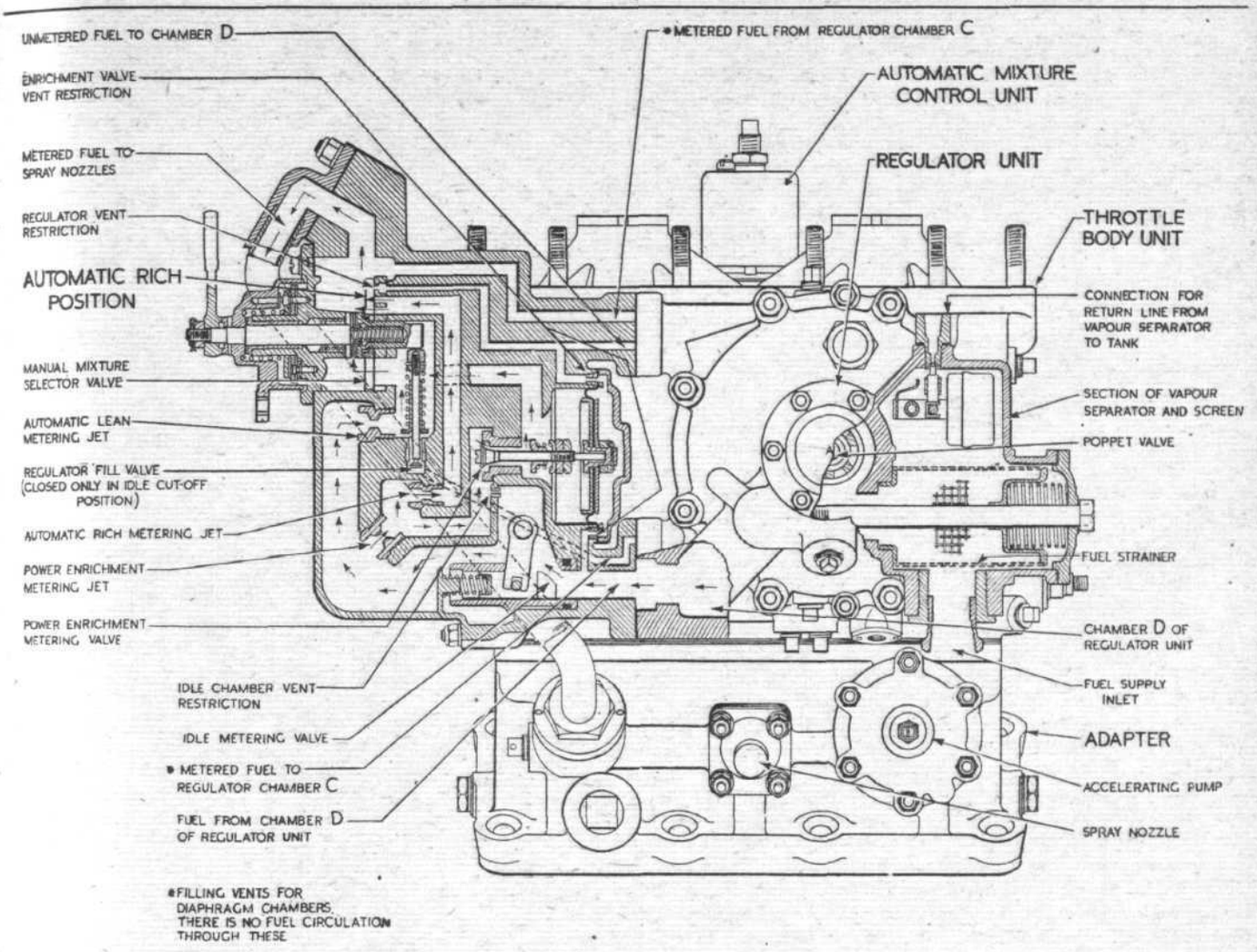


Fig. 3. **A different model from that shown in Fig. 2. The enrichment diaphragm is controlled by the fuel differential. The valve which gives the manual mixture positions is of the rotary disc type.**

force becomes, and the more the air diaphragm will move to the right, so opening the fuel poppet valve still farther and admitting more fuel. The system is kept in balance by the fuel diaphragm, which exerts a force in the opposite direction, known as the *fuel metering force*. This force is the difference between the unmetered and the metered fuel. The pressure of the metered fuel being kept constant at 5 lb. per sq. in., the pressure differential across the air and fuel diaphragms is always the same, but acting in opposite directions, since the air metering force will always be balanced by the fuel metering force. Additional small diaphragms are used in both chambers for sealing and balancing.

Owing to the possibility of inertia in the diaphragm assembly at very small airflow, a light spring is arranged to hold the poppet valve from seating on idle. This introduces a rich bias when idling, which is corrected as required by an external idle mixture adjustment.

The constant-pressure discharge nozzle is a simple arrangement, and its operation will be readily grasped from the illustration. The spring permits the valve to open at approximately 5 lb. per sq. in., and when the pressure tends to increase as the flow becomes greater, the diaphragm compresses the spring and opens the valve farther, maintaining the pressure constant.

The fuel-control body and jet system assembly are shown diagrammatically at the bottom right-hand corner of Fig. 1. There are actually several arrangements of jet system which differ only slightly, but for the purposes of this description we will deal only with that illustrated in the diagram. From chamber D the fuel passes through the *master take-off jet*, past the idle needle and so through the *cruise jet* into chamber C. The idle needle is of large diameter and is linked with the throttle spindle in such a manner that from the nearly closed or idling position it is withdrawn completely in the first ten degrees of throttle travel.

Mixture regulation on idle is effected by moving the idle needle in or out from its seat by an external adjustment. Since the needle is located directly in the main fuel circuit in the carburettor there can be no flat spot on opening the throttle. When the throttle is opened to enter the cruise range the needle is withdrawn, and the fuel flows past it and so to the cruise and economiser jets. On this model (known as the "Airflow Economiser") the manual control takes the form of a movable needle which can be pushed forward so as to restrict slightly the orifice of the cruise jet. This gives the auto-lean cruising mixture position. Withdrawing the needle completely gives the auto-rich mixture position, while moving the needle right forward so that the flange seats on the jet itself gives the idle cut-off position. The operation of the full rich position will be described in connection with the Altitude Control.

Enrichment for take-off and high power is effected by the economiser needle, which by its contour and movement permits the required amount of fuel to pass through into chamber C. In this model the economiser is governed by another and smaller diaphragm, one side of which is in communication with chamber A, the other side with chamber B. When the pressure differential reaches a certain predetermined figure the diaphragm will move suffi-

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ciently to withdraw the needle and allow fuel to pass. The rate of the spring loading and the contour of the needle itself give the necessary graduation of mixture enrichment as power increases.

The practical form of this arrangement is shown in Fig. 2. On other models the enrichment diaphragm is controlled by the fuel differential instead of the air differential. This is known as the "Fuel Head Enrichment Valve," the details of which are clearly shown in Fig. 3. It will be observed that here the valve giving the manual mixture positions is of the rotary disc type, but the general scheme of operation remains the same.

The Altitude Control

The Altitude Control is a self-contained unit which screws into the air intake of the throttle body (Fig. 4). Within the outer casing is a sylphon filled to about 80 per cent. of its capacity with inert oil. The remaining space being filled at a given pressure with nitrogen. The oil is used to dampen out vibration and hysteresis, and is a special inert fluid having a low viscosity change with temperature. The needle is attached directly to the sylphon, so eliminating levers and other linkages, and callibration is arranged by the rate of spring loading and the shape of the needle.

Referring to Fig. 1, it will be observed that the impact pressure to chamber A passes the altitude needle valve, so that the position of the needle will govern the pressure in chamber A. Thus, as the aircraft climbs the sylphon will expand, pushing down the needle and restricting the pressure in chamber A. This will, of course, lower the pressure differential across the air diaphragm and restrict the fuel supply, so weakening the mixture. It will be noted that the reduction of fuel takes place at the source of fuel entry into the carburettor, so that the basic shape of the sea-level mixture ratio curve should be unaffected.

Located in the vertical channel below the altitude needle will be seen a disc valve, which opens or closes a passage by-passing the needle valve. The disc valve is linked with the manual mixture control, and when closed as shown in the diagram the altitude control functions in the normal manner. When the valve is rotated to the open position, the altitude control is by-passed and has no effect on the mixture strength. This is the full rich position of the mixture control.

A vacuum-operated accelerating pump is incorporated in the system, and is generally located in the flange adaptor between the throttle body and the blower casing. It is a simple single or double diaphragm pump with engine suction on one side and fuel on the other, and takes its feed from the C chamber fuel.

The Vapour Separator is an interesting device. It will be seen at the top of the strainer chamber in Fig. 1. It is, in effect, a small float assembly, the needle of which seals a vent which is piped back to the fuel tank. Any vapour either forming or being fed into the carburettor rises to the top when the float falls, so opening the vent orifice and permitting the vapour to escape.

A manifold injection system such as this is seen to possess most of the advantages of cylinder injection without the chief disadvantages of the latter, i.e., high cost of manufacture, high weight and complication. In addition to the characteristics of non-icing, etc., outlined at the beginning of this article, the Stromberg system possesses yet another most important advantage. This is the fact that the design of the carburettor permits it to be tested after manufacture or overhaul on a comparatively cheap and simple rig that will reproduce complete test results comparable with the full-scale airbox blower tests necessary in the case of the orthodox aeroplane carburettor. Space forbids the elaboration of this aspect of the system, but it is one that has far-reaching effects upon the service of aircraft carburettors. It should be added that the carburettor is handled in this country by the Zenith Carburettor Co., Stanmore, Middlesex, to whom service enquiries should be addressed.

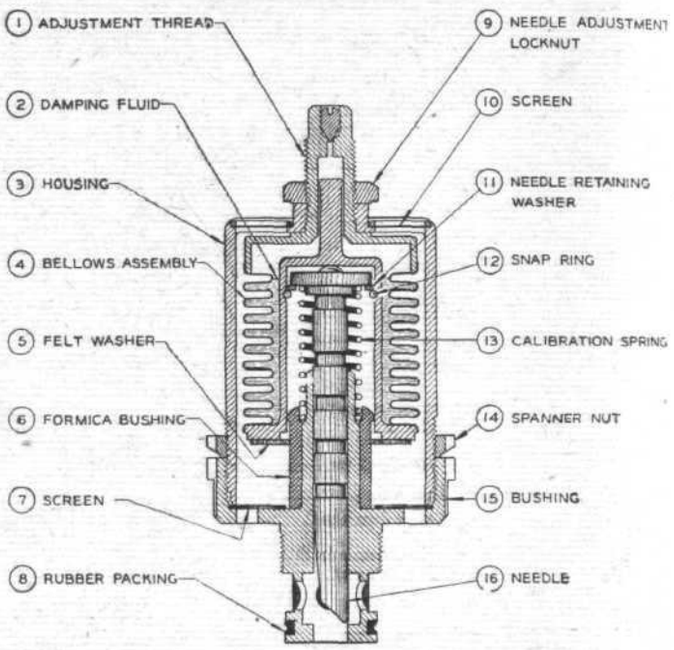


Fig. 4. The altitude control unit.

THE FORD AERO ENGINE

Further Details Show it to be in the 2,000 h.p. Class

THROUGH the courtesy of *Intava World*, it is possible to give further particulars about the Ford V-12 aero engine, the illustration of whose mock-up was published in *Flight* for August 21st. Its displacement is 1,650 cu. in., and the company aims to produce an engine developing between 1,800 and 2,000 h.p. at 3,600 r.p.m. at take-off. Layout was started in July, 1940, and three months later a two-cylinder experimental unit was running. This gave 250 h.p. at 3,000 r.p.m.

Air intake to the exhaust-driven turbo-supercharger and the exhaust from the turbine are both in the direction of flight, so reducing drag from the intake and getting some propulsive effect from the exhaust. Fuel is injected directly into each cylinder. By increasing the overlap of exhaust and inlet valves, a small quantity of compressed air enters the combustion space at the top of the stroke just before the injection of fuel and so ensures better scavenging and cooling of exhaust valve and piston head. The crankshaft is cast, and there is liberal overlap between crankpin and main bearing. Cylinders and upper half of the crankcase are an integral aluminium alloy casting with water jackets the full length of the cylinder barrels. The cylinder liners are of the "dry" type made of centrifugally cast oil-hardened steel.

The connecting rods are side-by-side, which makes them identical; bearings are floating. Length and diameter of piston are approximately equal. Cruising revs will be between 2,700 and 3,000, and it is expected that the engine will develop 1,500 h.p. at the latter speed. The supercharging is designed to maintain power up to 32,500ft. Supercharger, exhaust turbine, and intercooler are all integral with the engine, which weighs complete 1,600 lb. The supercharger and turbine are designed as a result of the company's own researches into the many problems involved in a new engine.