Chapter 2

AIR/FUEL RATIO CONTROLS, TYPES AFC SERIES

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LIST OF ILLUSTRATIONS

1. Dependent upon engine requirements some versions of the flow type fuel/air ratio control operate in conjunction with a pressure ratio (P2/P1) switch. This may be integral with the unit or, for installation convenience, fitted elsewhere in the system; a description of the pressure ratio switches are given in supplements at the end of the chapter.

2. To identify a unit by its type number and, using A.F.C. 24/30X as an example, the prefix 24 is the basic type of the unit, the suffix 30 identifies the installation standard, and the letter X identifies the calibration code. Later type units use only the basic number, e.g. A.F.C.100, this identifies also both installation standard and calibration code. Comparisons of various types in the A.F.C. series of controls are given in para. 19.

General

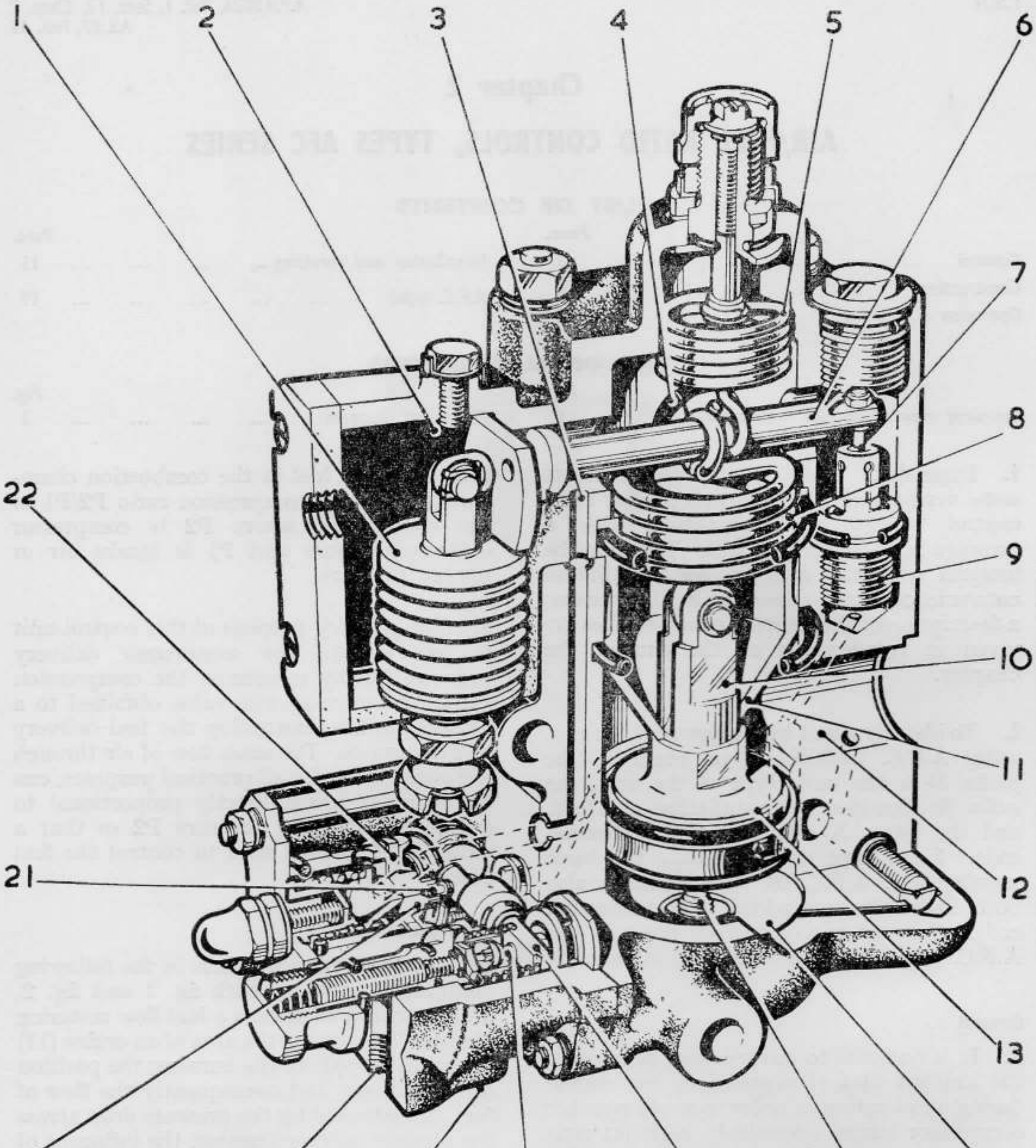
3. It is essential to control very accurately the amount of fuel supplied to the engine during acceleration in order to avoid possible compressor surge, excessively high jet pipe temperature and rich mixture extinction due to overfuelling.

4. An acceleration control must allow the engine to accelerate in the shortest possible time and it must also make it impossible to overfuel the engine and stall the compressor. To satisfy these two conflicting requirements at all altitudes and atmospheric conditions, it is necessary to limit the fuel supply to the engine by using functions which are in themselves independent of altitude and atmospheric variation. These are (a) the ratio of air to fuel in the combustion chambers and (b) the compression ratio P2/P1 of the compressor, where P2 is compressor delivery pressure and P1 is intake air or nacelle pressure.

5. The primary purpose of this control unit is to evaluate the compressor delivery pressure P2, by measuring the compression ratio, and to relate the value obtained to a variable orifice controlling the fuel delivery to the burners. The mass flow of air through the compressor, for all practical purposes, can be taken as being directly proportional to compressor delivery pressure P2 so that a value of P2 can be used to control the fuel flow.

Construction

6. The annotation numbers in the following paragraphs apply to both fig. 1 and fig. 2. The basic unit comprises a fuel flow metering plunger (10) varying the area of an orifice (11) in the fuel supply to the burners; the position of the plunger, and consequently the flow of fuel, is controlled by the pressure drop across the plunger balanced against the influence of a capsule (1) sensing compressor delivery pressure (2). A servo piston (13) attached to the metering plunger is moved by a change in a servo pressure balance (12/14), which is modified by the control capsule, through a rocker lever (6) carrying the piston servo system valve (7), whilst the pressure drop across the plunger orifice is sensed by the piston (20); this, through a push rod (21), rocker lever (16) and valve (17) acts upon the fuel pump servo system and so regulates pump delivery to the value required for any given air mass flow condition.



KEY TO FIG. 1 and 2

1 FLOW CONTROL CAPSULE
2 COMPRESSOR DELIVERY PRESSURE P2
3 DRILLING TO PRESSURE CONTROL PISTON
4 BURNER PRESSURE
5 CONTROL DATUM TRIMMING SPRING
6 FLOW CONTROL CANTILEVER
7 METERING PLUNGER SERVO VALVE
8 CONTROL SPRING
9 METERING PLUNGER SERVO PRESSURE STRAINER
10 METERING PLUNGER
11 METERING ORIFICE
12 FUEL INLET
13 METERING PLUNGER SERVO PISTON
14 METERING PLUNGER SERVO CYLINDER
15 SERVO PISTON STOP SCREW
16 PRESSURE CONTROL LEVER
17 PRESSURE CONTROL VALVE
18 RETURN TO PUMP SUCTION
19 CONNECTION TO PUMP SERVO CYLINDER
20 PRESSURE CONTROL PISTON
21 PRESSURE CONTROL NEEDLE
22 PRESSURE CONTROL CYLINDER

Fig. 1. Cut-away view of air/fuel ratio control

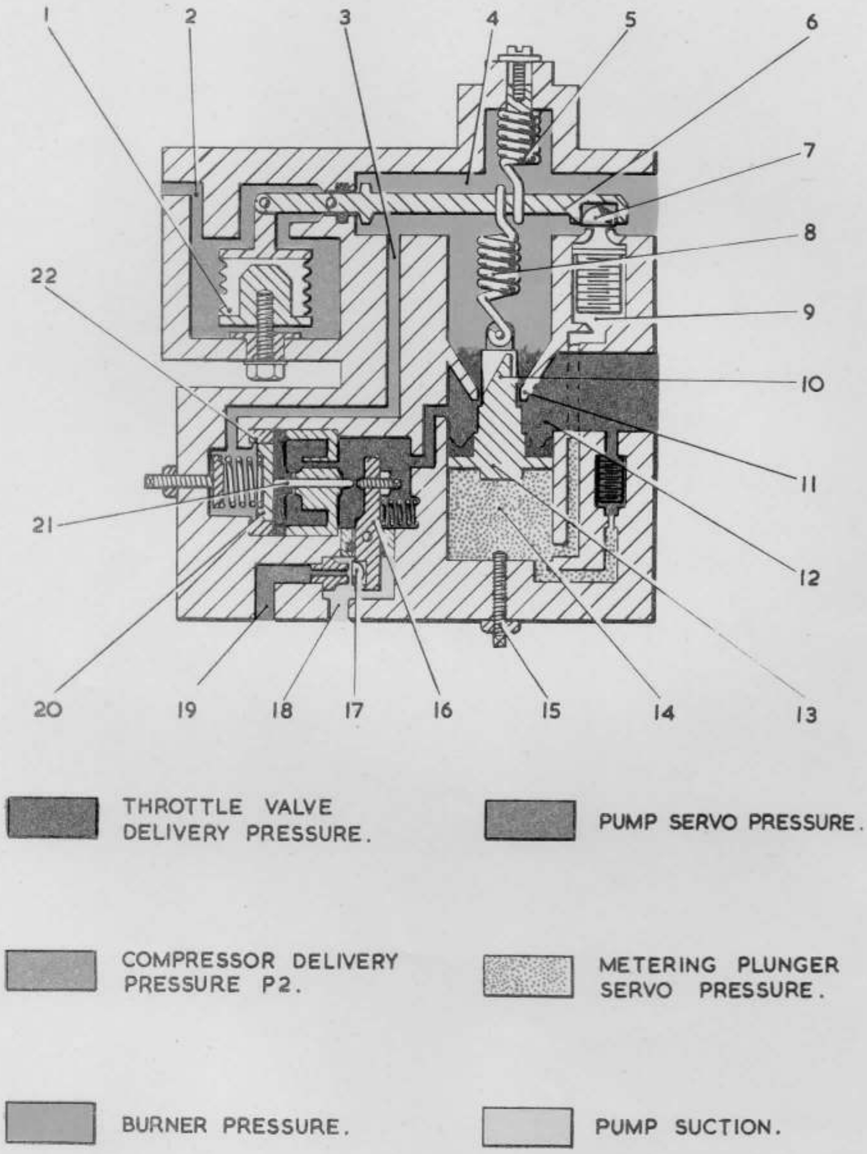


Fig. 2 Functional diagram

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7. Compressor stall characteristics on different engines vary however, and it is not always possible to find a single control line to keep the overfuelling curve below the compressor stall curve at low r.p.m. without adversely affecting the high r.p.m. range. In addition, to obtain the most rapid acceleration possible, it is necessary to limit the degree of overfuelling permissible at the lower end of the speed range whilst permitting a greater degree of overfuelling towards the upper end of the range.

8. To achieve these conditions the plunger fuel-metering profile is designed to limit the degree of overfuelling during mid-range acceleration, whilst a cut-out on the plunger permits a much greater degree of overfuelling beyond a pre-determined speed.

9. By this method a control is achieved that will permit the most rapid accelerations possible under all conditions, providing fully-automatic acceleration times that are faster than the best that can be obtained normally without an accompanying danger of rich mixture extinction, or the necessity for constant observation of the jet pipe temperature indicators. At the same time the risk of compressor stall during initial acceleration is avoided.

Operation

10. During normal operation, compressor delivery pressure P2 (2) is supplied to the control capsule chamber and compresses the control capsule (1) thereby influencing the position of the rocker lever (6). The rocker lever is balanced against the capsule by the control spring (8), which senses the position of the metering plunger according to the fuel flow, dependent upon the pressure balance across the plunger servo piston. It will be seen therefore, that the ratio of the lever balance between the control capsule influence and the control spring influence proportions the fuel flow in accordance with compressor pressure, the adjustment between the two being effected by the degree of spill from the plunger servo chamber (14) through valve (8), controlling the position of the plunger and consequently the flow area through the orifice.

11. On acceleration, the throttle valve is opened to provide an increased fuel flow to the engine; this demand is passed by the air/fuel ratio control up to the maximum permitted by the metering plunger setting for the prevailing compressor delivery pressure.

12. As engine speed increases the compressor speed and, therefore, pressure P2 increases; this is sensed by the control capsule (1), which is compressed further and causes the rocker lever (6) to open the half-ball valve and so increase the leak from the metering plunger servo cylinder (14). This will affect the pressure balance across the metering plunger piston (13) causing it to move and increase the flow through the orifice. At the same time, this will increase the tension in the control spring (8), and consequently the load on the rocker lever, causing the half-ball valve to be restored to the floating position, thereby re-establishing the pressure balance across the metering plunger piston. The piston will now become stabilized in its new position as determined by the increased compressor delivery pressure. This process is continuous, the plunger piston servo mechanism working always to maintain a pressure balance commensurate with the compressor delivery pressure P2.

13. During acceleration however, fuel delivery tends to rise considerably above the flow limit set by the compressor delivery pressure and causes an increased pressure drop across the unit which would result in overfuelling. This increased pressure drop however, is sensed by the pressure balance piston (20) controlling the bleed from the fuel pump servo line (19). In this case the piston moves against its spring loading and allows the rocker lever half-ball valve (17) to open and increase the bleed from the servo cylinder of the fuel pump, thereby causing the pump servo piston to move and reduce the pump delivery until the pressure drop across the control unit is restored to its desired value and the fuel flow to the proportion demanded by the air mass flow.

14. At the upper end of the speed range at low altitude a high degree of overfuelling is permissible. To provide this extra fuel a mechanical cut-out consisting of a step in either side of the metering plunger (10) permits a constant increase in flow through the metering orifice. The cut-out is drawn past the orifice when the compressor delivery pressure is compressing the control capsule (1) sufficiently to open the servo valve (7) to its maximum spill, permitting the metering plunger to be withdrawn from the orifice to allow a large un-metered flow to be passed under specific low altitude/high forward speed conditions. On deceleration, the operation is a direct reverse of the accelerating conditions.

Installing and servicing

15. The control unit is secured by three retaining bolts to a suitable mounting bracket on the engine.

16. Fuel system connections are as follows:—

Inlet from fuel pump delivery

Outlet to burners

Low pressure return to pump inlet

Servo connection to pump servo system

Air inlet connection from engine compressor delivery

17. No adjustments must be made on the unit when it is fitted to the engine, and the locking wire of the adjustment points must be examined to ensure that it is intact.

18. The unit must be inhibited prior to storage in accordance with A.P.4471A.

AFC. types

19. The differences in the AFC. series are as follows:—

AFC.

14 Integral pressure ratio switch and skirted piston.

18 No pressure ratio switch.

19 Integral pressure ratio switch and modified orifice bobbin.

20 As AFC.14 with wider calibration range, redesigned pressure drop lever and lever bush assembly, and introduction of $\frac{1}{2}$ in. UNF pump inlet connection.

24 Integral pressure ratio switch and increased range of adjustment.

25 No pressure ratio switch, differences in orifice, piston and operating levers.

100 As AFC.24 with different calibration details and addition of modification plate.

102 As AFC.100 with additional calibration points.

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Supplement 1

PRESSURE RATIO SWITCH (DOUBLE ORIFICE TYPE)

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LIST OF ILLUSTRATIONS

General

1. As previously stated the primary purpose of the air/fuel ratio control is to evaluate the compressor delivery pressure P2 by measuring the compression ratio and relating the value obtained to a variable orifice which controls the fuel delivery to the burners.

2. In order to match, as closely as possible the complex curve that represents the overfuel curve of an engine it may be necessary to use more than one ratio of fuel flow to P2. The change of ratio is affected by utilizing an intermediate value between P2 and P1 to close an air valve operated by a P2/P1 pressure ratio switch. This air valve is operated by the differential areas of an evacuated capsule and a differential bellows which measure the compression ratio P2/P1 and close the valve at the desired ratio. Whilst the valve is open a spill through the valve orifice reduces P2 pressure applied to the fuel flow capsule to a proportional value referred to as KP2. When the valve closes at the desired P2/P1 value, the spill is cut off and the full P2 value is applied to the fuel control capsule.

Construction

3. The unit consists of a light alloy casting which houses an evacuated capsule and differential bellows assembly. The pressure ratio valve is housed within and operated by the capsule and bellows assembly. The cover houses the P2/P1 pressure ratio orifice tube which contains the P2 inlet orifice and the end of which forms the seating for the pressure ratio valve. A drilling in the cover also houses the differential pressure orifice.

Operation

4. Where the most rapid acceleration possible is desired the P2/P1 pressure ratio switch comes into operation. Initially the KP2 proportional control pressure (switch open) is applied to the control capsule; this is calibrated to limit the fuel supply curve to a line which is low enough to prevent interference with the compressor stall curve as indicated in fig. 2. By this means the air/fuel ratio is maintained low enough to prevent the tendency to overfuel during the early portion of the engine acceleration curve, thereby avoiding compressor stall due to too rapid an initial acceleration. The P2/P1 switch enables the air/fuel ratio control characteristics to be changed from the initial setting (switch open) to a high setting (switch closed) and thus permit the fuel flow to be increased to a greater proportion at the higher r.p.m. end of the acceleration curve.

5. When the P2/P1 switch is open there is a constant bleed from the lower orifice through the interior of the differential bellows communicating with nacelle pressure P1 and the control capsule which senses a proportion KP2 of compressor delivery pressure P2. At

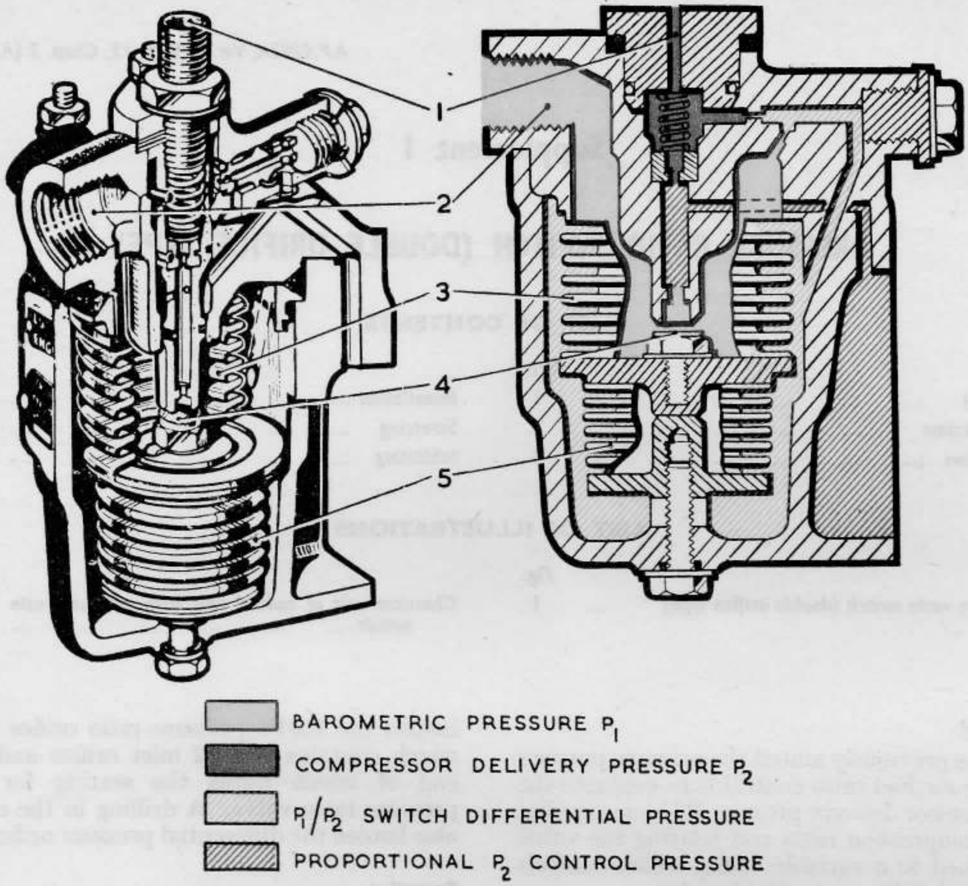

Fig. 1. Pressure ratio switch (double orifice type)

a given ratio of P2/P1 as shown in fig. 3. it is permissible to increase the proportion of fuel to air mass flow. The increase in compressor delivery pressure, which is being applied also through a drilling and orifice to the outside of the differential bellows and evacuated capsule reacts on their differential areas to cause the plate valve between them to rise and close the lower orifice, sealing it from nacelle pressure, thus changing KP2 to full P2.

6. When the valve closes, a much larger value of compressor delivery pressure is applied to the control capsule. This will lift the rocker lever to open the servo valve and affect the servo pressure balance across the full metering plunger piston causing it to move to a new datum, at which it will become stabilized again. The plunger will now control the flow as before but permit a greater fuel flow for so long as the compressor valve maintains the P2/P1 switch in the closed position.

Installation

7. The pressure ratio switch is usually mounted on a flange on the main housing of the air/fuel ratio control which is otherwise fitted with a cover plate and union. It is located on four studs with a gasket interposed and is secured with four 2 B.A. nuts, grover washers and plain washers. Connections to the switch are P2 compressor delivery pressure and P1 nacelle pressure by means of the appropriate unions. The pressure ratio switch may be mounted separately on the engine, in which instance a third connection is necessary, i.e. from the switch to the air/fuel ratio control unit.

Servicing

8. When installed on an engine no inspection nor servicing is necessary except to ensure that all connections are tight.

Inhibiting

9. The unit must be inhibited prior to storage in accordance with the detailed instructions contained in A.P.4471A.

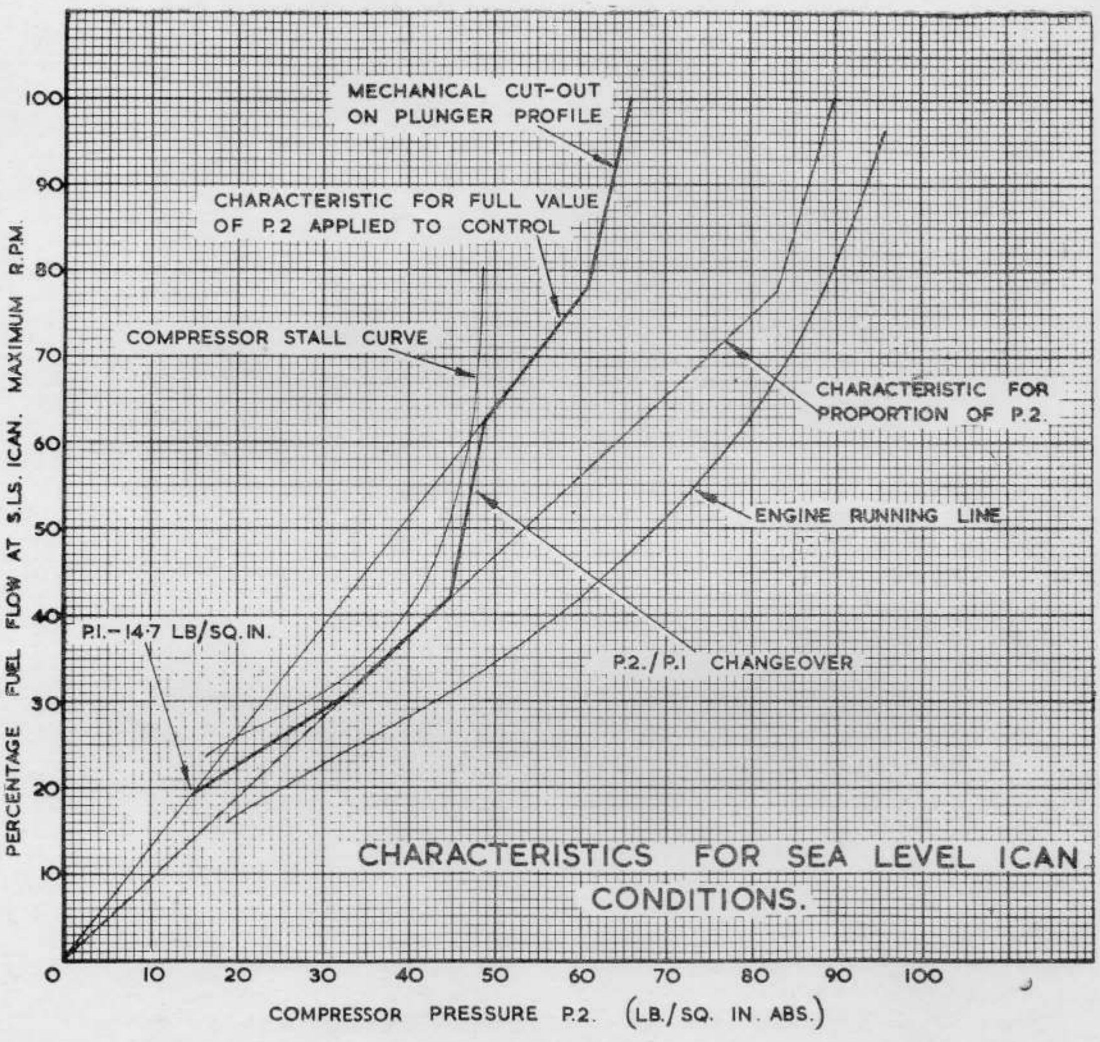

Fig. 2. Characteristics of control unit with double orifice type pressure ratio switch

Supplement 2

PRESSURE RATIO SWITCH (VENTURI TYPE)

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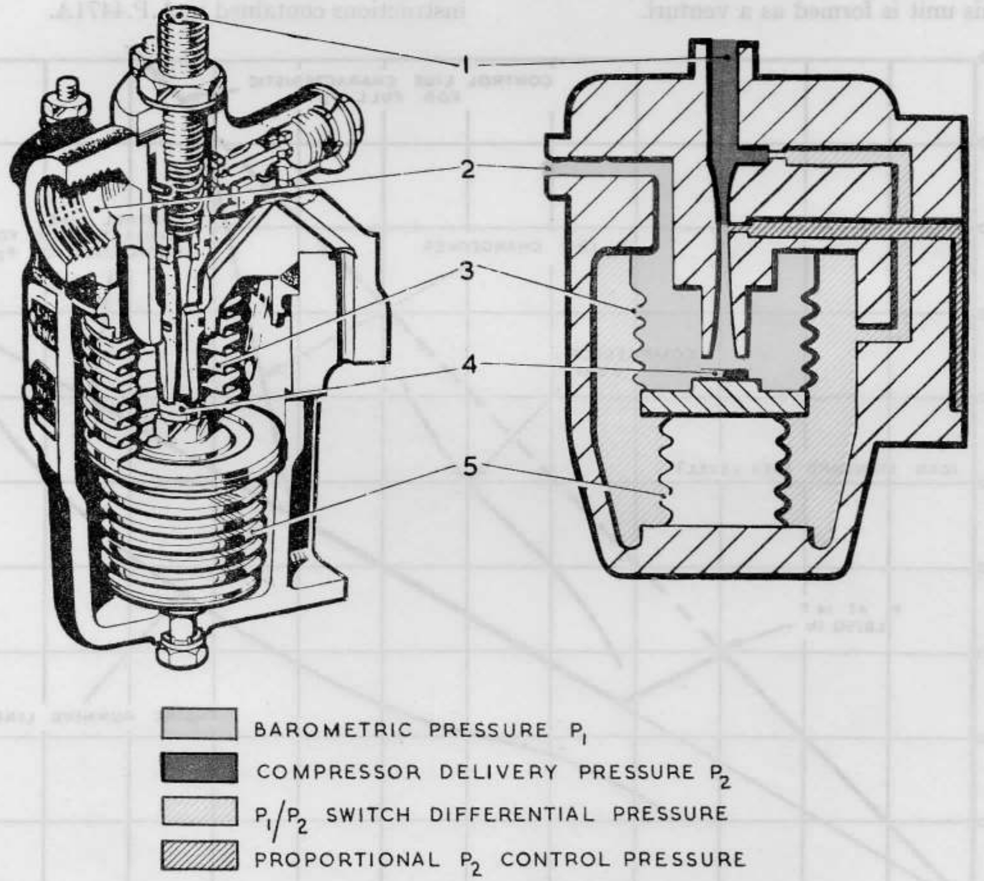

1 COMPRESSOR DELIVERY PRESSURE P_2
2 BAROMETRIC PRESSURE P_1
3 DIFFERENTIAL BELLOWS
4 PLATE VALVE
5 EVACUATED CAPSULE

Fig. 1. Pressure ratio switch (venturi type)

General

1. The general remarks on the pressure ratio switch (double orifice type) Supplement 1, para. 1 are equally applicable to the venturi type the only difference being in the actual switch which enables a wider ratio of control to be applied than is possible with the double orifice type where the pressures are always positive.

2. The venturi type therefore is used where a large change in the ratio of P2/P1 is required and is achieved by applying a depression to the control capsule when the switch is open and full P2 pressure when the switch is closed.

Construction

3. The construction of the unit is similar to that of the double orifice type (Supplement 1) with the exception of the orifice tube which in this unit is formed as a venturi.

Operation

4. When the P2/P1 switch is open there is a constant flow from P2 to P1 through the venturi and the control capsule pressure KP2 is subject to the depression in the throat of the venturi. The raising of the plate valve under the influence of differential pressure closes the end of the venturi; the depression in the throat therefore changes to full P2 pressure and this is applied to the control capsule. The effect upon the control unit may be seen by comparing the curve (*fig.* 2) with that in Supplement 1.

Installation and servicing

5. Installation details are the same as for the double orifice type, Supplement 1. When installed on an engine no servicing is necessary.

Inhibiting

6. The unit must be inhibited prior to storage in accordance with the detailed instructions contained in A.P.4471A.

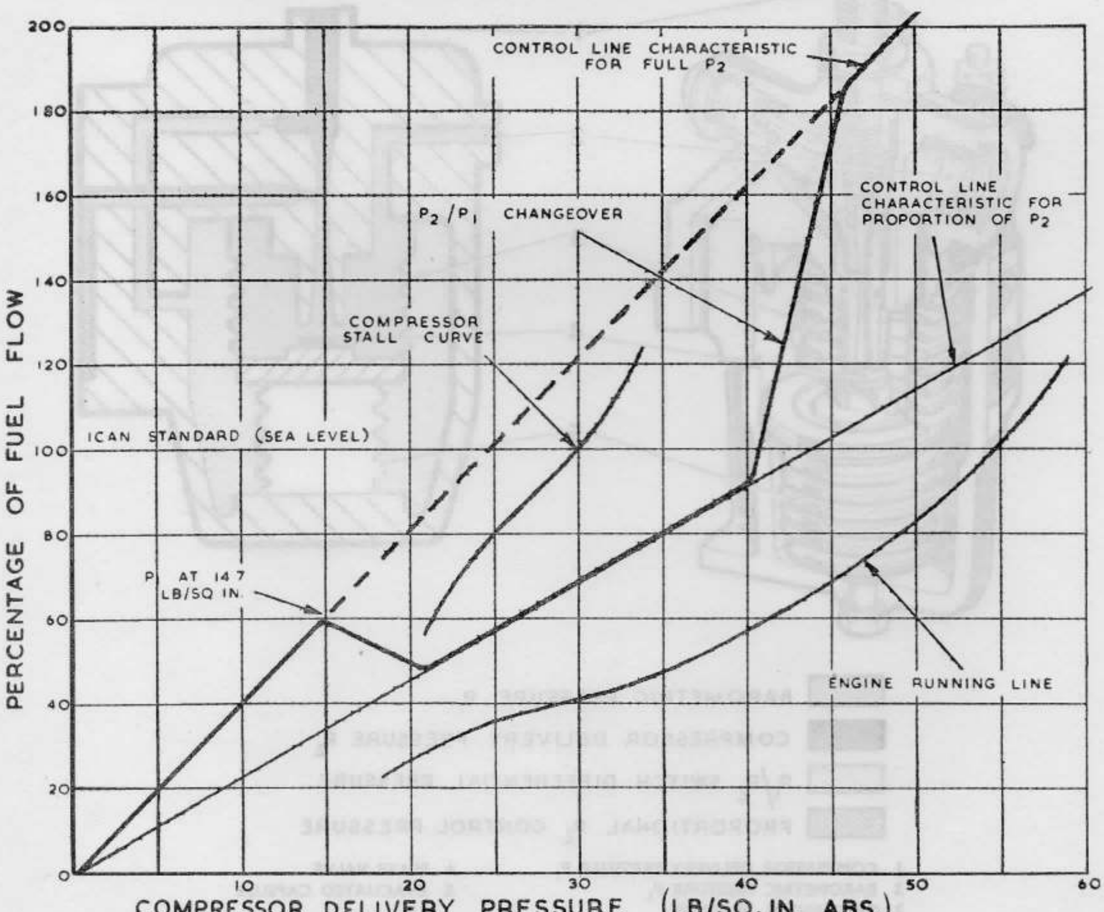

Fig. 2. Characteristics of control unit with pressure ratio switch

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