NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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THE USE OF MULTIPLIED PRESSURES FOR AUTOMATIC ALTITUDE ADJUSTMENTS.

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The efficient performance of an airplane requires that certain adjustments be made as the density of the air through which the airplane passes, becomes changed. Hence, there is the "altitude control" of the carburetor which enables the pilot to maintain the desired air-fuel ratio. Recent developments have increased both the number and importance of such adjustments. For example, the safety of the over-dimensioned engine depends upon careful manipulation of spark advance and throttle opening and a proper control of a variable pitch propeller, if the maximum performance of the supercharged engine is to be obtained. It is evident that there is a real need for satisfactory devices to make such adjustments automatically. The following discussion deals with a method of automatic compensation which deserves, but never to the writer's knowledge has received, consideration in the design of such devices.

Prior to this discussion a few remarks concerning existing schemes for automatic compensation seem desirable. The majority of these schemes depend upon some contrivance which functions primarily because of changes in atmospheric pressure. Though uninfluenced by temperature, these devices are usually arranged so that the adjustment effected by a change in pressure compensates also for the change in temperature by which it is normally accompanied. Hence the inability of these devices to alter an adjustment solely because of a change in temperature is of minor importance except in rare instances where the temperature is far removed from its normal value. Nearly all of these automatic controls are essentially the same in principle. Their chief element is a tight chamber containing a gas (usually air). When the atmospheric pressure changes, the resultant change in the difference between it and the pressure of the gas within the chamber causes motion of some wall of the chamber. This motion effects the desired adjustment.

In such devices a leak in the supposedly tight chamber means utter failure. The elimination of this source of danger is one of the aims of the method of altitude compensation about to be described. To this end the most important step is a change in the method of operating the automatic device. The change suggested is to make the source of operation the difference between atmospheric pressure and some multiple of atmospheric pressure instead of the difference between atmospheric pressure and that of a gas confined in a tight chamber. Following are tabulated values of the difference between atmospheric pressure and twice and ten times atmospheric pressure respectively.

Approximate Altitude. feet	Barometric Pressure Cm. Hg.	(2-1) Atmospheric Pressure. lb./ sq.in.	(10-1) Atmospheric Pressure. lb./ sq. in.
Sea level	76	14.7	132
5,000	63	12.2	110
10,000	52	10.1	91
15,000	44	8.5	77
20,000	36	7.0	63
25,000	30	5.8	52

Using 2 as the multiple gives a force for operating the adjustment equal to that which would be obtained in the conventional device if the sealed chamber were completely evacuated. With the higher multiples sufficient pressure is obtained to make it unnecessary either to provide a relay or to make the unit of large dimensions to care for adjustments whose operation requires considerable force.

The accompanying drawing shows a possible device based on this method of altitude compensation. The multiplication of pressure is obtained with a pump comparable in size to those now used for supplying pressure to fuel systems. For a pump of this type the following relation is true:

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^n$$

where

P_1 = absolute pressure at beginning of compression stroke.
V_1 = volume at beginning of compression stroke.
P_2 = absolute pressure at end of compression stroke.
n = exponent having a value between 1.3 and 1.4,
V_2 = volume at end of compression stroke,

V_1, V_2, and n are constant for any given pump and hence the quantity $\left(\frac{V_1}{V_2}\right)^n$ is also constant. This relation can be chosen to give any multiple of the initial pressure that is desired. Since, with adequate port opening, P_1 is very nearly atmospheric pressure it is evident that the compression pressure of a pump of this sort is a constant multiple of the pressure of the air which surrounds it. This is the condition sought.

A study of the drawing will make the action of the device clear. When the piston is at lower center, air enters the cylinder through Port A. On its upward stroke the piston first closes this port and then compresses the air above it. This air as soon as its pressure is sufficiently high opens check valve C and passes into reservoir B. The process continues until the pressure in B is approximately the same as that in the cylinder at the end of the compression stroke. From then on, the piston merely compresses and re-expands the same charge and its operation requires an amount of power only slightly in excess of that necessary to overcome the piston friction. If the pump were exactly as described it would function satisfactorily only when the airplane was descending, that is to say, when the compression pressure was increasing. With the compression pressure decreasing, as in passing from a lower to a higher altitude, check valve C would fail to open and the pressure in B would cease to be a constant multiple of the pressure of the surrounding atmosphere. The remedy is to open positively a passage between the pump and reservoir for a short time during each cycle. This permits an equalization of reservoir and cylinder pressures regardless of whether the atmospheric pressure is increasing or decreasing. To secure this positive opening check valve C, as shown in the drawing, is provided with a boss which comes in contact with the piston head causing the valve to be lifted from its seat by about one thirty second of an inch at each revolution. When the pressure in reservoir B changes, D, one of its confining walls, moves until the spring pressure on one side balances the difference in pressure between the gas inside and that outside of this cylinder. It is the movement of D which actually effects the desired adjustment.

A device very similar to that shown in the drawing was con-constructed at the Bureau of Standards and subjected to a few tests to demonstrate that it would operate essentially as expected. These tests showed that with a pump of small dimensions care should be taken to ensure that piston and rings fit nicely or that the piston be equipped with leather or some equally satisfactory type of packing. With a loosely fitting piston the compression pressure decreases with decrease of speed presumably because of the longer time allowed for the gas to leak by the piston at the slower speed. This point is of importance because a device of this sort can be driven most conveniently directly from the engine and this means that it must operate at variable speeds. Increasing the pump size does much to minimize the difficulty from leakage in that it increases the amount of air handled more than it increases the circumferential area through which leakage can take place. In fact if the increase in pump size is obtained by lengthening the stroke the circumferential area is not increased at all. Stress has been placed on this leakage problem not because it is considered a trouble very difficult to overcome, but one that it is very necessary to overcome. Forwarned of its existence the designer will adopt the sane policy of at first building units of somewhat greater capacity than appears necessary and then decreasing their size as better methods of piston packing are developed.

The mechanical features of the device can be altered in countless ways without changing its basic principle of operation. One interesting possibility, particularly in view of the leakage problem, is to use a "sylphon" type of pump and to replace the reservoir movable wall D by a "sylphon". The "sylphon" which is a trade name for a type of copper bellows, has an advantage over the conventional type of piston in that it requires no packing gland.*

There remains to be considered what advantages this method of automatic adjustment may possess. The most important of these

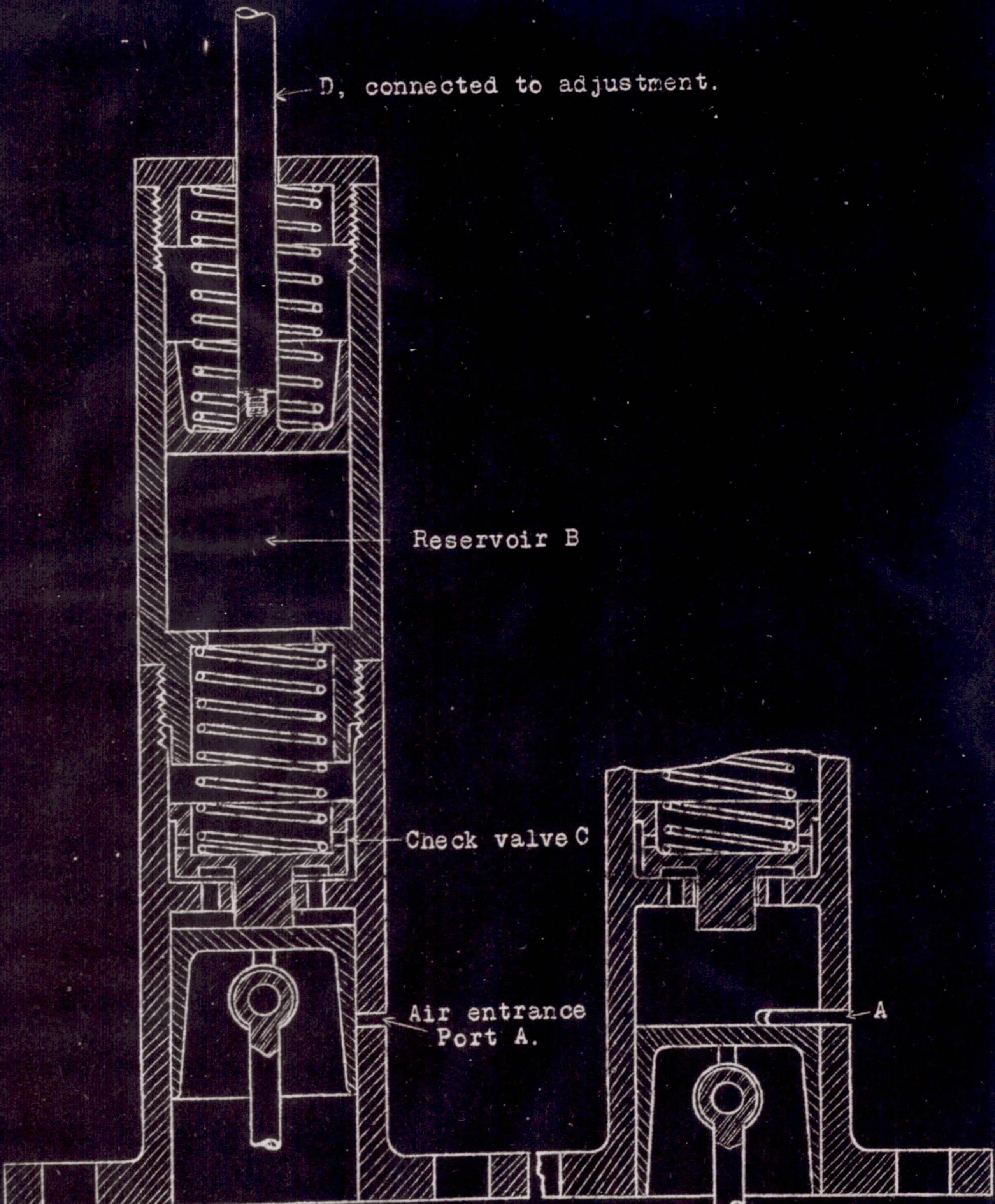
* A description of "The 'Sylphon' Fuel System for Liberty '12' and Wright Model 'H' Engines" as developed by the Engineering Division of the Air Service at McCook Field is given in "The Aerial Age Weekly" of January 16, 1922 and in "Air Service Information Circular", Vol. III, No. 281.

has already been stated, - the elimination of a chamber upon the absolute tightness of which the satisfactory operation of the device depends. To be sure the chamber still exists and functions much the same as in the conventional device. So long, however, as the rate of leakage from this chamber, storage reservoir B, does not exceed the rate at which air can be supplied by the pump, the adjustment will remain unchanged. Moreover a leak of any greater magnitude ought easily to be detected. Even in the improbable event of the leakage exceeding the rate of supply failure is likely to be partial rather than complete. The reason is two-fold. First, when excessive leakage reduces the pressure in storage reservoir B, it decreases the head producing flow through these leaks and hence the leakage rate. Secondly the amount of air supplied to the reservoir increases because of the reduction in the pressure against which the pump delivers its charge. From the combined influence of a lower rate of outflow and a higher rate of inflow a point of equilibrium is apt to be reached at a pressure only slightly below normal.

If desired these may be connected to reservoir B a pressure gauge by observing which the pilot can see whether or not the apparatus is functioning properly. Needless to say the danger of leakage precludes connecting a similar gauge to the air tight chamber of the conventional device. The operation of the latter may be checked by other methods but these often require installations so awkward as to be hardly feasible.

In sealed chamber devices of any except the completely evacuated type the range of motion of the movable wall is limited by the fact that by its motion the pressure in the chamber becomes changed. This limitation disappears when using the device described herein because the pump maintains the pressure constant regardless of the motion of the walls of the reservoir. Furthermore it would be possible to operate several devices from a single pump installation. This would require merely that each individual reservoir should have a movable wall similar to D in the drawing and that each should be connected by a pipe with the main reservoir.

Whatever merit the device under discussion may possess depends upon the overcoming of some of the faults of existing devices. For this reason it is extremely difficult to describe the device without seeming to unduly emphasize such faults. It is realized that the suggested method of adjustment may have faults equally grave and equally numerous. This note therefore should not be construed as an attempt to prove the superiority of any particular method of automatic adjustment, but as an endeavor to show the possibilities of a method which seems to have received no attention heretofore.



Piston at upper center

Piston at lower center.