TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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HIGH THERMAL EFFICIENCY IN AIRPLANE SERVICE.

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To make higher engine efficiencies possible without making every effort to insure the attainment of this higher efficiency in actual service can seldom be justified. In most cases the wide difference between the average performance of an engine and that in the laboratory may be attributed to the difficulty of the problem rather than to failure to appreciate its importance. Instances where this difficulty appears to have been surmounted are thus deserving of careful study.

In this regard, the details of design of certain foreign engines, whose high average efficiency has received much publicity are of particular interest. In an examination of these engines at the Bureau of Standards, the unusual type of air-fuel ratio control suggested itself as a possible source of the high efficiency. Fig. 2 shows this type diagrammatically, while Fig. 1 is typical of a construction common on American engines. In the latter type, the rate of fuel flow is altered to produce the mixture ratio changes. This may be accomplished by restricting the fuel passage or, as shown in the figure, by changing the head producing flow through the agency of a valve in the passage connecting the float chamber with the carburetor throat. Similar results are frequently obtained by a type similar to that shown in Fig. 2, but so proportioned that the mixture ratio change is unaccompanied by any appreciable change in the quantity of charge supplied. In contrast, Fig. 2, to typify the foreign construction, is assumed to be so designed that the leaning of the mixture is always accompanied by an increase in the amount of charge supplied. This may be effected by interconnecting the throttle with a device for altering the size of the fuel orifice or, as shown in the figure, by an auxiliary throttle which admits a very lean mixture or pure air. For this auxiliary throttle to be effective, the carburetor throat must offer a considerable restriction to air flow. The important difference between the two types is that in the one shown in Fig. 1, the change in power produced by a mixture change is due almost entirely to the change in power producing ability of a unit weight of the mixture while in the other type, there is always the additional effect of the quantity change necessary to bring about the change in mixture quality.

Fig. 3 indicates something of the economy that is possible with the type shown in Fig. 1. The curves (shown in full lines) are based on tests of an 8-cylinder aviation engine at an altitude of 5000 feet and a speed of 1600 r.p.m.

It will be noted that a decrease in the specific fuel consumption of over 15 per cent is secured when the mixture is leaned until there is a decrease of 10 horsepower in 150, i.e., 7 per cent. Unquestionably then, so long as this type of control has sufficient range, its proper handling will result in a marked fuel saving. Will it receive such handling? To realize how unlikely this is, it must be remembered that continuing the mixture impoverishment will ultimately result in a blowback in the carburetor, a likely cause of fire. Knowing that safety depends on not reaching this condition and lacking knowledge as to how close to it a given carburetor setting is, the pilot has every incentive to adjust away from, rather than toward, maximum efficiency. Even were it possible to eliminate the fire hazard, the problem would be far from solved. In flight, the only measure of performance ordinarily available is that of power as indicated by the engine speed. In spite of all evidence as to the benefit of the lean mixture from the standpoint of efficiency, such an adjustment, inasmuch as it results in lower power, the only gauge of performance available to the pilot, is bound to be unnatural.

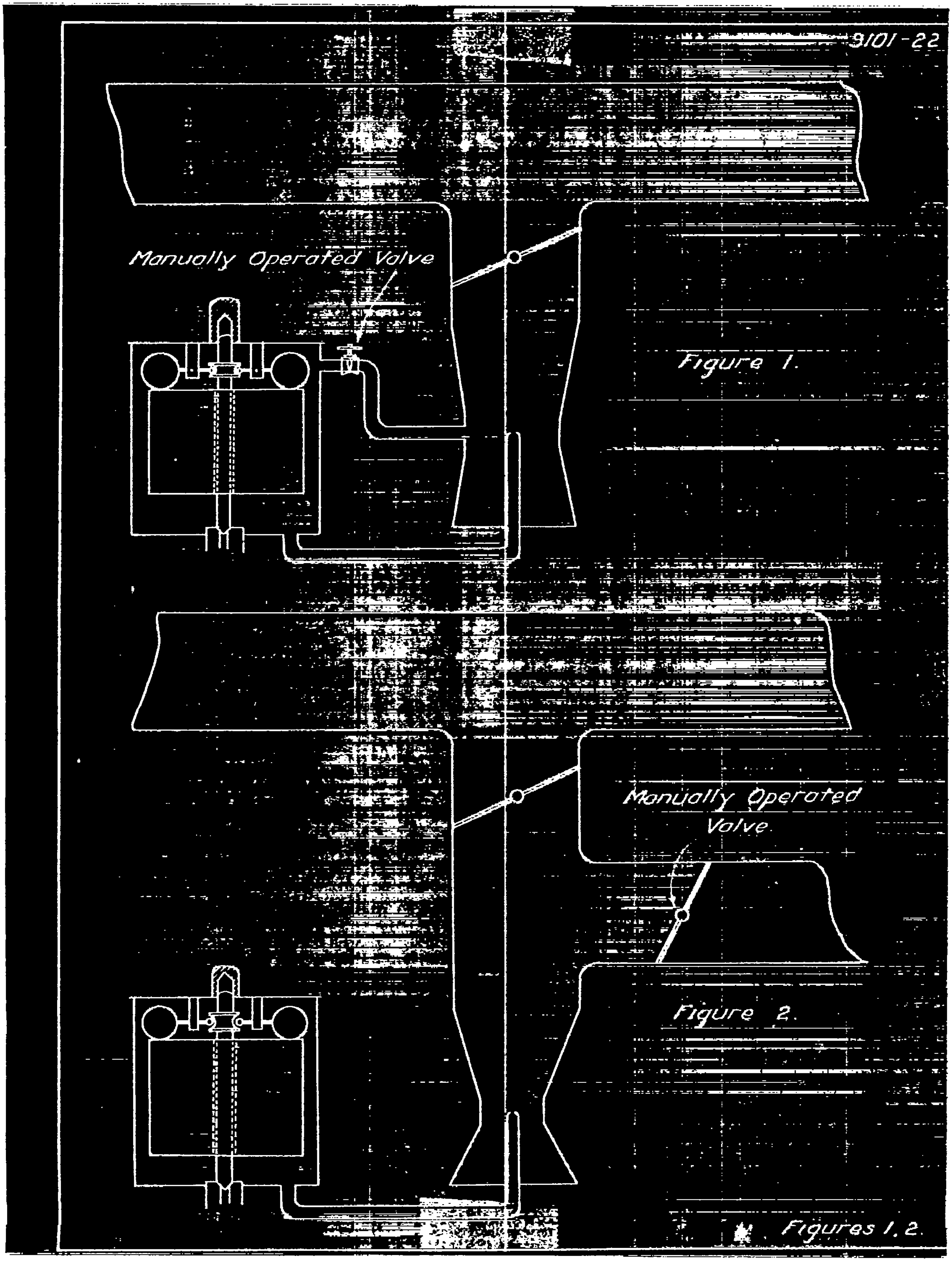
The explanation of the disadvantages of the first type makes clear the merits of the second. With this, as the mixture becomes of poorer quality, the amount supplied is increased. The natural adjustment, that for maximum power, will be the one at which the decrease in quality ceases to be overbalanced by the increase in quantity. If the design is such that this point is always reached before the mixture becomes lean enough to cause a blowback in the carburetor, there is a considerable safeguard against fire.

Since this type of control permits the maximum weight of charge to be supplied only when the mixture quality is such as to give a comparatively low power output per unit weight of charge, it is obvious that the greatest engine power will be slightly less than with types which permit the maximum power producing air-fuel ratio to be obtained when the maximum weight of charge is supplied. This constitutes the chief limitation of this construction. That the marked advantages of this control appear only at full throttle can scarcely be considered a fault, as most commercial flying may be expected to take a place under these conditions. An example of the variation of power that might be expected at different mixture ratios is given by the dotted lines of Fig. 3. Suppose the point O to indicate the desired mixture ratio for operation and hence the point at which the design permits the maximum charge to be supplied. The power at the other throttle positions has been estimated from the weight of air required to give the various mixture ratios and the indicated horsepower developed per pound of air at these mixture ratios as determined from the full line curves.*

* No consideration has been given to the change in fuel flow resulting from the different suctions produced at various throttle positions or to the change in the pumping loss element of the friction horsepower under these conditions. Such consideration is not needed in the general comparison here made but is of very real importance in a detailed design of either type.

In the over-dimensioned engine, parts are designed for the stresses of full throttle operation at a certain altitude and the throttle closed so as not to exceed this power at lower altitudes. The mixture ratio control described above forms an admirable safeguard against full throttle operation at these altitudes, inasmuch as, under these conditions, it supplies a mixture too lean for engine operation. Moreover, some of the previously mentioned power loss at full throttle may be offset by an increase in compression ratio. A throttled engine can employ a higher ratio with safety than one operating at full throttle.

With a knowledge of the faults and merits of the various types of mixture ratio control, choice is dependent upon reliable information as to the service to which the plane is to be subjected. As commercial aviation develops, economy is more likely to be of paramount importance than maximum power. It is to point out one method by which high average fuel economy has been realized and to again emphasize the wide gulf separating maximum economy and maximum power adjustments that this discussion has been prepared.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Manually Operated Valve
Figure 1.
Manually Operated Valve
Figure 2.

Figures 1, 2.

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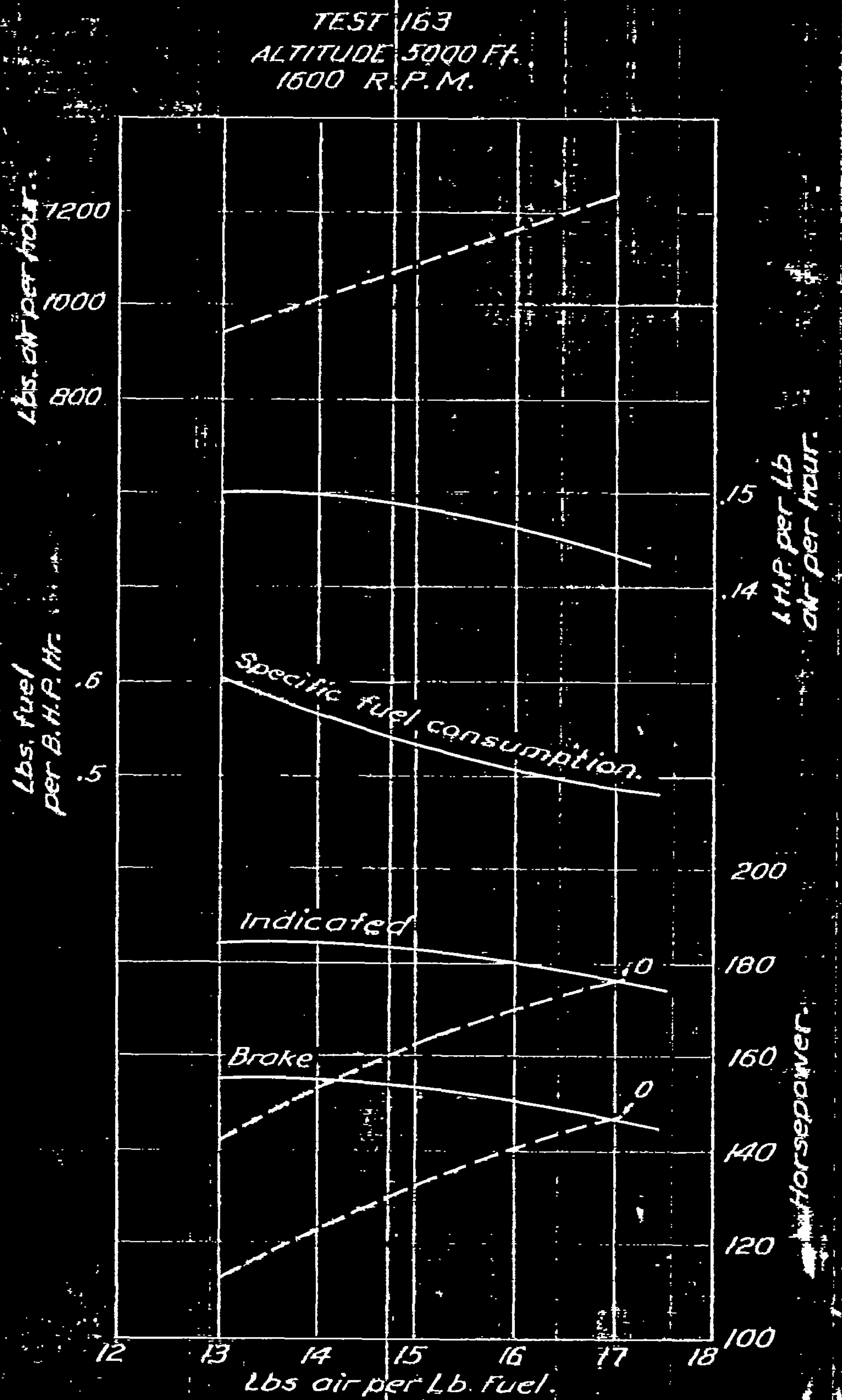

Bureau of Standards Aeronautic Power Plant. Fig. 3.