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No. 136

IS THERE ANY AVAILABLE SOURCE OF HEAT ENERGY LIGHTER THAN GASOLINE?

By P. Meyer.

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The weight of gasoline consumed, plus the weight of the tanks, reaches the weight of the engine itself inabout five hours' flight with a fixed engine, or in a much shorter period with a rotary engine. Any reduction in the weight of the fuel is, therefore, bound to prove advantageous. The possibility of reducing the consumption per HP-hour will not be considered, but merely the possibility of finding lighter sources of heat energy.

Of the hitherto exclusively employed fuels, which burn by combining with atmospheric oxygen, gasoline appears to be the best, since benzol has a lower calorific value. From the technical point of view, the chemical composition of gasoline is about 85% C and 15% H. This gives, as a conservative estimate of the heat value, 81 x 85 + 287 x 15 = 11190 kilocalories. The composition of refined petroleum (kerosine) does not differ much from that of gasoline. Benzol is 92% C and 8% H, which gives a heat value of

$$81 \times 92 + 287 \times 8 = 9748 \text{ kilocalories.}$$

The heat values of both, as determined by calorimetry, are somewhat lower; for gasoline about 10000, for kerosine about 10200, and for benzol about 9590 (kilocalories or greater calories). This difference, in comparison with the heat values calculated on the basis of the chemical combination of the elements, permits the

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* From Technische Berichte, Vol. III, No. 3, pp. 74-75. (1918).

conclusion that there are exothermic compounds in these hydrocarbons.

From the details of the calculation, it is seen that hydrogen with 387 k-cal per 0.01 kg is of greater significance than carbon with 81 k-cal, suggesting at once that we must adhere to compounds rich in hydrogen, or look for endothermic compounds in which, when the atoms are separated by combustion, the heat absorbed in combination is given off at the same time. The possible effect of the latter circumstance is illustrated by acetylene (C_2H_2) which, with the same proportional composition as benzol (C_6H_6), has a heat value of 11600 cal. It is in fact, a compound capable of disrupting explosively.

Ethylene (C_2H_4), propylene (C_3H_6) and butylene (C_4H_8) have each twice as many hydrogen as carbon atoms. Their carbon content is therefore about 86% and their hydrogen content about 14%. In this respect they are somewhat lower in the scale than gasoline. In spite of this, their heat value is rather higher, the cause lying in differences in their heat of combination. The difference in comparison with gasoline, is too small, however, to offer any prospects.

Methane (CH_4) with 75% C and 25% H is disappointing, since its actual heat value is only 11900 k-cal, as against 13250 given by the combination of its elements, without taking into account the heat of combination.

The search for substances rich in hydrogen must finally lead to pure hydrogen itself, which, in fact, with 28700 k-cal, is by far ahead of all other known fuels. The requisite weight of fuel, with equal utilization of the heat energy, would be only 0.35 that of gasoline. In the engine itself, the use of pure hydrogen could give rise to no insuperable difficulties. Unfortunately, it is a gas under ordinary conditions and occupies a large volume. To keep it in a condensed form, strong containers are required, whose weight is many times that of the enclosed gas, so that all the advantages of this admirable fuel are more than counterbalanced.

There remains only the question of carrying it in a liquid state, as has been done with oxygen for breathing at high altitudes. Although, in fact, the liquefaction of hydrogen is much more difficult than that of oxygen, it cannot be regarded as impossible. Moreover, liquid hydrogen has the very low density of 0.033, which is only 1/30 that of water and about 1/20 that of gasoline. It would therefore occupy 20 x .35 = 7 times the volume of its heat equivalent in gasoline. Naturally, this would have an extremely unfavorable effect on the weight of the containers, which, in any case, would be heavier than gasoline tanks, on account of the heat insulation. Hence, it is very doubtful whether the utilization of hydrogen as a fuel lies within the bounds of possibility.

Far less is this the case with acetylene and methane. Both must be liquified, if pressure containers are to be dispensed with. In the liquid condition, acetylene has a specific gravity of 0.23 and has about three times the volume of gasoline. The specific gravity of methane, unfortunately, could not be found. In any case, it would be much lighter than gasoline, so that the small superiority in heat energy could not make up for the greater size and weight of the heat-insulated containers. This reconnoitering in the domain of the hydrocarbons, including hydrogen itself, reveals no prospect of a reduction in the weight of the fuel. Whether better proposals can be made remains an open question.

Explosive substances will now be submitted to examination, although they offer no prospect of success.* To the layman they appear, naturally, as an enormous source of energy, and stimulate him to invention. The nature of an explosive lies in the fact that the elements which combine with release of heat, are entirely contained in it, while other fuels take oxygen from the air. The significance of this is due to the fact that the 85% of C in gasoline requires about 226% of O for combustion and the 15% of H about 120% of O, so that gasoline requires 346% or, in round numbers, 3.5 times its weight of oxygen. One kg of the combustion products of gasoline and oxygen has therefore a heat value of only $\frac{10600}{1+3.5}$ = 2350 k-cal. Most explosives likewise depend on the combustion of a substance with oxygen contained in some other compound, e.g., in the form NO_2. As N takes no part in the combustion, we must add 14 N to 32 O, so that the weight of the oxygen is increased by its carrier in the ratio $\frac{32 + 14}{32}$ = 1.44 times.

For the combustion of gasoline, the oxygen with its carrier would increase the weight of the gasoline about five times, so that a hypothetical explosive consisting of gasoline, oxygen and the indispensable oxygen carrier, could have a calorific value of only

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* The part dealing with explosive substances is the result of a conference with my colleague, H. W. Fischer.

10000/(1 + 5) = 1770 k-cal. An increase of 885 k-cal would in fact be added, since NO_2 is an endothermic compound, and gives off, on disruption, 177 k-cal per kg.

The known explosives are in no way superior to this hypothetical explosive, as is shown by the following table of calorific values per kg, as determined by calorimetry.

Blasting gelatine	1640	k-cal	per kg
Nitro-glycerine	1580	"	"
Dynamite (75%)	1290	"	"
Gun cotton with 13% N	1100	"	"
Collodion	730	"	"
Picric acid	810	"	"
Irinitrotoluene	730	"	"
Black powder	685	"	"
Fulminate of Mercury	415	"	"

While explosives, without any reference to the possibility of their use in engines, are already seen to be entirely unsuitable, on account of their limited supply of energy per unit mass, for use as fuels throughout the whole duration of flight, we must not exclude the possibility of their use to increase the power output for brief periods.

Their efficacy rests on the possibility of their being admitted into the cylinder in liquid form, without crowding out the atmospheric oxygen, thus affording a second source of energy without impairing the efficiency of the original source and without the necessity of carrying any considerable weight of the explosive, on account of the brief duration of the power increase.

The tactical advantages, resulting from the possibility of an occasional increase of power, need not here be discussed.

Translated by the National Advisory Committee for Aeronautics.