TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 133

DISTURBING EFFECT OF FREE HYDROGEN ON FUEL COMBUSTION IN INTERNAL COMBUSTION ENGINES.

By A. Riedler.

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Experiments with fuel mixtures of varying composition, have recently been conducted by the Motor Vehicle and Airplane Engine Testing Laboratories of the Royal Technical High School in Berlin and at Fort Hahneberg, as well as at numerous private engine works. The behavior of hydrogen during combustion in engines and its harmful effect under certain conditions, on the combustion in the engine cylinder are of general interest. Some of the results of these experiments are given here, in order to elucidate the main facts and explain much that is already a matter of experience with chauffers and pilots.

1. Fuel Mixtures with "Secret" Additions.

Immediately after the mobilization of the army, in 1914, a shortage of gasoline was experienced, but it was believed that possibly the situation could be met by intensifying the production of benzol throughout the country. The military authorities were offered various fuel mixtures which, at first, were not designated as "substitutes," but as "improved" and "enriched" fuels. These were mostly 1 : 1 benzol-alcohol mixtures, with a "secret addition," which was to be introduced in powder form and dissolved immediately before use.

Preliminary investigation showed that these so-called "enrichers" were carriers of oxygen or hydrogen. In engine tests,

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however, it was found, without exception, that both the power output and fuel consumption were more unfavorable with these added substances than without them, and that, therefore, the "enriching mediums" had no practical value.

The reason for decreased output and increased fuel consumption, in so far as it was affected by the presence of the oxygen carriers, was not investigated, as it was considered too trivial to warrant extensive research, apart from the fact that the quantity of "secret" substances available was also insignificant. These substances were generally found to consist of permanganate of potash combined with various other substances. The exhaust gases from engines burning fuels containing these enrichers usually contained nitric acid compounds which detrimentally affected various parts of the engine and the valve gear.

It may be remembered that it was frequently asserted that successful racing drivers used these fuel "enrichers," in order to increase the power developed by the engines with the weight of fuel allowed under the racing stipulations. It might indeed be of value for aviators, even at the cost of some disadvantages such as excessive corrosion of engine parts, to increase their speed, if only for short periods of time. But all these claims have been proved by experiment to be without foundation. Concerning the hydrogen carrying additions, the explanation is the same as that given below for fuels containing free hydrogen.

2. Mechanically Hydrogenized Benzol.

Ordinary commercial benzol with added hydrogen, though only mechanically mixed and not chemically combined, was very skilfully prepared. The additional hydrogen did not separate at ordinary temperatures and elementary chemical analysis showed, in fact, a composition similar to gasoline, as did calorimetric determinations, so that the equality of this fuel with gasoline was assumed as a matter of course.

On the other hand, it must be remembered that chemical tests and calorific values are not the determining factors, but only the behavior of the fuel mixture while burning under pressure, during the extremely small periods of time necessitated by the high revolution speeds of automobile and airplane engines.

The experiments were conducted in the Motor Vehicle Testing Laboratory of the Berlin Technical High School. The results of comparative trials with unmixed benzol and with hydrogenized benzol showed that the engine output with the latter decreased approximately in proportion to the amount of hydrogen introduced, while the fuel consumption increased in a yet higher ratio, and that the addition of hydrogen caused irregularities in combustion. In particular, it appeared to delay combustion, causing long visible flames to issue from the exhaust.

The proportion of hydrogen in the fuel is, however, the determining factor in considering its suitability for use in internal combustion engines, since this element is the lightest in weight, possesses the highest calorific value and, with the oxygen of the air, forms a mixture which burns rapidly under compression. An excess of hydrogen is, therefore, harmful, though a sufficient quantity of it is desirable, for the acceleration of combustion in the engine.

Gasoline contains about 15 parts by weight of hydrogen, and about 85 parts of carbon, in the form of easily disintegrated aliphatic hydrocarbons. This proportion of hydrogen is approximately, under the usual compression pressures employed, the maximum needed for complete combustion. If the compression is increased, then, owing to premature ignition, irregularity in running may soon occur, as shown by the reduced output, and the increase in the specific fuel consumption. The lighter petroleum hydrocarbons and hydrogenized benzol, owing to their hydrogen surplus, cause a reduction in the thermal efficiency and risk of premature ignition, even under ordinary compression, thus necessitating the reduction of the compression pressure. Similar results have been obtained from water-gas, heavily charged with hydrogen. Engines that ran perfectly on poorer gases, showed irregularities, such as result from premature ignition, when run on water-gas. Benzol, which contains more stable hydrocarbons, has 5 to 10 parts by weight less of hydrogen than gasoline has. Benzol mixtures, therefore, are capable of far higher compression, thus giving a thermal efficiency equal to that of gasoline.

Hydrogen in a liquid fuel is in chemical combination, is liberated during decomposition simultaneously with carbon, and both can then take the necessary oxygen from the air and burn completely. If, on the other hand, hydrogen is only mechanically combined, it ignites prematurely, burns rapidly, detrimentally affects the mixture, and hinders the carbon of the fuel from combining sufficiently rapidly with the oxygen necessary for its complete combustion. The carbon is then consumed slowly, with delayed ignition, or separates unconsumed as soot, forming a hard scale with the lubricating oil; causing irregular running, and increased fuel consumption, in spite of the increased heat value due to the added hydrogen. Owing to this incomplete combustion, the output of the engine decreases.

The results, although surprising at first, are therefore easily explained. The added hydrogen burns first and the benzol, less easy of decomposition, follows, only after the hydrogen has already taken part of the oxygen. Retarded combustion, or sooting of the engine, is the result, according to whether the carburetor has been adjusted for a poorer (extra air) or normal mixture. Fuels mixed with hydrogen are therefore unsuitable and from a practical point of view, are only adulterated benzol.

Translated by the National Advisory Committee for Aeronautics.