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AVIATION FUELS

(With Especial Reference to "White Spirit")

By P. Dumanois

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Among the questions which concern aviation, the various problems presented by the fuels are of prime importance. Gasoline, the fuel now used, is an extremely volatile and inflammable liquid capable of forming explosive mixtures, the cause of many catastrophes in aviation.

It would obviously be very advantageous to employ less volatile fuels, so as to diminish the fire hazard, but it seems probable that, for a long time to come, only the explosion engine will be capable of keeping its weight per horsepower low enough for aviation purposes.

It is therefore of special interest to investigate the possibility of using fuels which, while being less volatile than gasoline, would nevertheless enable this engine to function satisfactorily.

Let us first consider the various dangers resulting from the use of gasoline.

1. From the storage viewpoint, gasoline presents an undeniable danger. The handling of the fuel in filling the tanks and the keeping of airplanes in flying order in the same locality

* "Au sujet des combustibles d'aviation" from "La Technique Aéronautique," April 15, 1927, pp. 105-109.

favor the formation of dangerous mixtures susceptible of producing fires which almost instantly become conflagrations. The evaporation resulting from its volatility is therefore not only the cause of a useless waste but also a constant source of danger.

2. From the viewpoint of functioning in flight, in the case of backfiring to the carburetor, there is danger of the gasoline taking fire and starting a conflagration. However, when the backfiring is not due to any organic defect of the engine or to a leak in the intake pipe, this danger is much less serious than might be supposed. The risk from this source is very slight, when the engine is well cared for and no gasoline is allowed to collect inside the hood, when the air intake is outside and when pipes opening outside the fuselage are provided to carry off any gasoline which may collect.

3. In the case of a large leak in the pipe conducting the gasoline to the carburetor and in the vicinity of the latter, the danger is considerable, because this fuel evaporates and fills the hood with an explosive mixture, which is liable to ignite in case of backfiring or even from contact with the exhaust pipe. What is then to be feared is not so much the fire itself, which can be localized by the judicious use of fire extinguishers, but the damage to the hood and the extinguisher pipes caused by the explosion. For the results of this explosion to be serious, however, the carbureted mixture must evidently have the right composition at the precise instant that a source of igni-

tion is produced. This danger cannot be disregarded, however, as accidents are generally caused by unfortunate coincidences. Moreover, a large leak in the carburetor or in the fuel pipe may result in the production of too poor a mixture and thus cause backfiring.

4. In case of a capsize, the tanks are generally broken open and the gasoline scattered in all directions. It is liable to come in contact with hot objects, such as the exhaust pipe or valves, whose temperature may exceed 700°C (1292°F.). The fire hazard is therefore great. The danger is of the same order when the engine is seriously damaged in flight, as, for example, by the breaking of the piston, which generally sets fire to the oil in the crank case, a fire which is then communicated to the fuel, if the carburetor or fuel pipe is damaged.

From the above considerations it follows that the great volatility of gasoline is a prime cause of accidents in cases 1 and 2. In case 3 the volatility of the gasoline is liable to cause a catastrophe by an explosion damaging the engine itself. Lastly, in case 4, it seems probable that, whatever fuel is used, there is always a fire hazard when parts of the engine or the exhaust pipe reach a temperature above the minimum ignition temperature of the fuel. In this connection, let us bear in mind that the heavy petroleum oils ignite at a lower temperature than gasoline and that benzol ignites at a higher temperature.

In fact, it may be considered that all the fuels are liable to ignite on contact with an object above 650°C (1202°F.). It is obvious, therefore, that the volatility of gasoline is a cause of danger and we are naturally led to investigate the possibility of using a less volatile fuel in aviation engines.

The specifications for aviation fuels were made after a large number of endurance tests on engines of all powers. The experiments demonstrated that two qualities were essential for satisfactory functioning, namely, homogeneity and volatility. When less volatile fuels were tested on the ground, it was found that, after a longer or shorter time, carbon deposits were formed, premature ignitions, and sometimes explosions occurred due to the fact that the more or less oily carbon deposits formed a sort of insulating layer on the inside of the combustion chamber. This seemed to demonstrate the necessity of using very volatile fuels. After awhile our attention was called to the fact that, when one examines the barograms of climbs, made by test pilots having the technical knowledge necessary for making a climb under the best conditions and sufficient professional skill to handle their airplanes to the best advantage, it is found that, in nearly all the barograms, above a certain altitude, generally comprised between 9500 and 10,000 meters (31,167 and 32,808 feet), the curve of ascent presents a sharp curve corresponding to a limitation of the ceiling much below the one which would result from the consistent prolongation of the barometric curve.

In order to explain this peculiar phenomenon, it would appear necessary to introduce an important variation in the physical properties which affect the functioning of the airplane. Now, neither the air, nor the cell, nor the engine, nor the propeller, nor the barograph seems, a priori, to depend on any discontinuous parameter for a certain value of the altitude. There remains nothing but the fuel, which seems capable of accounting for this phenomenon. In fact, at the abovementioned altitudes, the atmospheric pressure is only about 200 mm (7.87 in.) of mercury. Moreover, as a result of the warming of the carburetor due to the fact that the fuel is contained in a tank protected by the fuselage, the fuel has a considerably higher temperature than that of the surrounding air. In a climb to 9500 m (31,167 ft.), Adjutant Moutonnier found that the temperature of the tank was still 15°C (59°F.), while the outside temperature was below -40°C (-40°F.). It is obvious therefore that the atmospheric pressure is of the order of magnitude of the vapor tension of aviation gasoline. If we take into account, moreover, the natural enrichment of the carbureted mixture with increase in altitude, it is reasonable to suppose that, with the usual fuels, there is a certain limit at which, by reason of the excessive relative value of the vapor tension of the gasoline with respect to the external pressure, the carburetor no longer furnishes a mixture with the requisite qualities for obtaining a good carburetion.

We have therefore been led to make the following hypothesis. Given a fuel having a vapor tension h which produces on the ground, at the atmospheric pressure H, a satisfactory functioning in an aviation engine, other things being equal, a fuel having the same qualities of homogeneity but a vapor tension equal to a h will produce a functioning equivalent to an altitude at which the atmospheric pressure is a H. It is very evident that a law conceived in such an absolute form cannot be strictly verified, because the vapor tension is not the only physical characteristic which affects the formation of the carbureted mixture. The nature of the fuel, its composition and viscosity, the mechanism of the carburetor and the degree of atomization have a bearing which is not negligible. It is nevertheless true that, with the automatic carburetor devices used, the importance of the vapor tension is primordial from the viewpoints of the atomization of the fuel and of the homogeneity of the mixture. This hypothesis seems, moreover, to accord very well with the results obtained some 15 years ago by Bellem and Grageras in the carburetion of kerosene in explosion engines. Instead of using an automatic carburetor, they employed a pump which delivered at each cycle the requisite quantity of fuel. This fuel was drawn in at the beginning of the intake period, the intake valve remaining closed during a certain portion of the stroke. The partial vacuum thus obtained was favorable to the vaporization of the fuel. We believe, moreover, that the device employed had some effect on the results obtained.

Since it follows from the foregoing considerations that the volatility of the aviation gasoline was accurately determined by the condition of obtaining on the ground a satisfactory functioning of the engine, it is very evident that fuels with a lower vapor tension would give poorer results on the ground and would be liable to produce incrustations or fouling. This point is important, for it is obviously desirable to have, at the altitude of utilization, a not very volatile fuel, in order to insure proper functioning, but it is also necessary to be able to reach this altitude without the engine becoming foul. It is, in fact, of no avail to eliminate the fire hazard at the expense of infinitely more probable engine failure in taking off or while climbing. This disadvantage can be overcome by using gasoline to start with, which we have done, but we deem this solution unsatisfactory and one to be regarded only as a makeshift.

On the other hand, we have had the opportunity to demonstrate the possibility of using, in automobile engines, fuels heavier than gasoline, provided they contain a sufficient proportion of volatile substances capable of playing the part of solvents and vaporizers of the heavier components. By preventing detonation, it is thus possible to obtain very satisfactory functioning. We have successfully used ethyl alcohol carbureted with 30% kerosene, as also mixtures of gasoline and kerosene.* We have thus been led to infer that, reciprocally, if we can take a certain gasoline and remove the heavy constituents, it should also be possible to remove from it the light constituents without disturbing the functioning. We were thus led to experiment with "white spirit," a petroleum product distilling entirely between 130° and 180°. The first tests made on a vehicle having a 10 HP. engine of 68 mm (2.68 in.) bore and 100 mm (3.94 in.) stroke, produced a very satisfactory functioning without altering the engine and without other modification than the adjustment of the spraying nozzles and a slight heating obtained by simply leading the fuel pipe over the exhaust manifold, which gave the fuel a temperature of about 25°C (77°F.). The start was made by injecting a few cubic centimeters of gasoline into the fuel pipe, or by heating the float chamber by electricity. With this fuel we traveled over 3000 km (1864 miles), mostly in Paris, without any kind of accident. In comparison with gasoline the maximum speed diminished from 80 to 75 km (49.7 to 46.6 miles) per hour, the fuel consumption increased about 10% and the fouling was a little more pronounced. Otherwise the functioning was excellent.

These results led us to experiment with an airplane engine. October 29, 1926, we obtained authorization from the General Di-

* The results were exhibited to the "Société de Navigation Aérienne," May 20, 1925, at a session where Mr. Painlevé, Minister of War, wished to have them presented. Since then different S.T.Aé. vehicles have functioned satisfactorily with a fuel containing 50% kerosene.

rector of Aeronautics, on putting the results of our experiments at his disposal. The engine employed was a 180 HP. Hispano, chosen because of the shortness of the intake pipe, a favorable condition for preventing condensation.

The first tests, made on the bench, demonstrated that it was necessary, on the ground, to have a little richer adjustment than for gasoline, in order to make up for the greater viscosity of the fuel, that the flow velocity had to be slightly diminished and that the fuel in the float chamber had to be kept at a temperature of about 25°C (77°F.). Under these conditions the maximum number of revolutions per minute obtained on the bench was 1770, in place of 1800, with gasoline.

The engine was mounted on an airplane and, on December 16, 1926, the first test was made by the engineer Ceccaldi. The take-off was made with gasoline, "white spirit" being substituted at an altitude of 500 m (1640 ft.). The climb was continued to 3000 m (9842 ft.), at which altitude a horizontal stretch was flown. The total time of functioning with the "white spirit" was 28 minutes. The functioning was satisfactory at both high and low speed, but the pick-ups were very troublesome.

It was demonstrated during this flight test that the engine which lost, on the ground, about 80 R.P.M., as compared with gasoline, made 1700 R.P.M. in horizontal flight at 3000 m (9842 ft.), as against a maximum of 1630 R.P.M. with gasoline under the same conditions.

The results have no other value than to demonstrate the possibilities. These seem to confirm the hypotheses which led to the experiments and which should not be considered final. They were obtained with an ordinary engine and an ordinary carburetor. Doubtless the carburetor, which was designed especially for gasoline, is not equally well adapted for "white spirit" and should be altered, in order to effect a better evaporation. It is also probable that the intake pipes should be modified in certain engines, where their length tends to cause condensation. It nevertheless seems, in view of the results obtained, that the investigation should be continued.

Lastly, fire hazards cannot be entirely eliminated by the use of fuels having properties similar to those of "white spirit." It must not be forgotten that all fuels are made to burn. Whatever its flashing point, if a fuel is brought in contact with objects above its ignition temperature, it is liable to take fire. It is none the less true that, from the viewpoint of the safety of handling and storing and especially of the danger of explosion in case of a leak in the carburetor or fuel pipe, the fire hazards would be greatly reduced. It would therefore constitute a decided improvement from the standpoint of safety.

In concluding, let us note that the idea of employing safety fuels is not a new one. The first researches were made in 1917 on the initiative of Mr. Breton, with reference to "tank" engines. Mr. Ferrié, a naval engineer of hydraulics made bench tests in

1921-1922, which led him to consider the use of non-volatile fuels in explosion engines. Unfortunately, the experiments of Mr. Ferrié remained unknown until recently. We first learned of them through a letter received from him, after we had begun our investigation.

Mr. Ferrié considers that the limit of the volatility of the fuels is determined by the condition that they must exist only in the state of vapor at the end of the compression period, taking into account the elevation in temperature produced by the compression. He also thinks that the chances of condensation on the walls are inversely proportional to the final volume and directly proportional to the duration of contact with the walls, i.e., higher compression and lower engine speed. We agree with Mr. Ferrié in this view. We think, however, that the abovementioned conditions, while being necessary, are not sufficient. Thus, with kerosene, a compression ratio of 6 suffices to obtain a temperature of over 300°C (572°F.), at which the kerosene is converted into vapor.

Under these conditions, functioning is not possible, however, due to detonation and premature ignition. In the last analysis, these phenomena limit both the proportion of heavy constituents and the admissible maximum compression pressure.

Finally, the experiments with "white spirit" seem to indicate that, due to its viscosity being greater than that of gasoline, it will be necessary to improve the atomization. It is probable, moreover, that the improvement of the atomization, in producing a more homogeneous mixture, would, at the same time, make it possible to function at a higher compression pressure without danger of detonation.

Translation by Dwight M. Miner,
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