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Revised Test Method for the Investigation of Aviation Fuels (Oppau Method).

Synopsis: The knock rating of modern aviation fuels according to octane number is supplemented by the results obtained in tests conducted according to the DVL supercharge method. In this process, however, the requirements as regards installations, personnel, quantity of testing fuel and time are decidedly a disadvantage.

By making slight alterations to the I.G. test engine and the experimental conditions, this engine will yield results comparable to those obtained with the supercharge method, as well as providing the usual octane numbers already in use. Thus the carrying out of measurements to supplement the usual method of obtaining octane numbers, is greatly simplified.

Object of Test

Previous trials made if possible to correlate tests on an I.G. experimental engine with results obtained on the full-scale single-cylinder built by the Technical Test Station.

In the meantime the DVL - supercharge method has been introduced at the "BM W/132 - Flugmotoren - Einzylinder-Prüfstand" and it was considered useful to carry out correlation tests with that engine.

At the Technical Test Station the gasoline samples are tested on a BMW 132 under the following conditions:-

Compression ratio	= 6.5:1
Boost air temperature	= 130° C
Excess air ratio	= approx. 0.7 to 1.2
Ignition advance	= 30°

The mean effective pressure and the boost pressure at excess load, respectively, are determined for each separate sample using about 6-8 different excess air fuel ratios (between 0.7 and 1.2). These values, on plotting, produce curves showing the relationship, at a particular engine temperature, between the excess air ratio and the mean effective pressure at incipient knock, (see figure 3). As is well known, engine fuels containing aromatics and olefines are more sensitive as regards knocking to changes in running conditions than paraffinic fuels, and hence steeper curves are obtained for aromatic than for paraffinic fuels.

In the classification of fuels both the minimum value of the mean effective pressure and the slope of the λ curve are considered and these factors are compared with the corresponding factors of a suitable fuel. The higher these two factors are the better is the fuel. However, if the curves intersect as in figures 2 and 3, complications arise in the application of test results to actual practice because fuel A (aromatic) is better at rich mixtures while fuel P (paraffinic) is better at normal mixture strength. It is therefore not always possible to classify the various fuels as categorically suitable or unsuitable.

As a rule, the investigations at boost air temperatures other than that of 130°, though provided for the DVL supercharge procedure, are not carried out at the Technical Test Station as they would lead to an increase in expenditure out of proportion to the information obtained.

The following are claimed to be the advantages of the DVL - supercharge method over the usual method of determining the octane number of a high performance fuel:

a) the knocking tendency of the fuels is tested directly in actual aero-engine cylinders.

b) the fuels are tested under conditions closely approaching those met with in actual practice.

c) the multipoint evaluation of a gasoline allows conclusions to be drawn for the further development of 100 - octane engines and their fuels.

Compared with the method of determining the octane number in the usual experimental engine, the adoption of the DVL supercharge method even when considerably modified as it was by the Technical Test Station, results in the following requirements:

1) Considerable expenditure in test apparatus sample quantities and personnel.

2) Increased requirements for training of personnel if they are intended to make the necessary calculations as well. This is desirable in case it is necessary to check the experimental points.

3) Time-consuming control tests must be made to guarantee constant engine conditions, especially as both piston and cylinder must be renewed comparatively often.

4) Construction of graphs, as easy comprehension of the knock-behaviour is only possible with the aid of curves. It is moreover necessary to plot a reference fuel curve in order to eliminate the effects of changes in engine condition.

In the experience of the Technical Test Station the accuracy of measurement in the DVL-supercharge method may be taken as with ± 0.5 at b.m.e.p.

It was attempted to incorporate all the advantages of the supercharge method for routine measurements without its disadvantages. By suitably altering the running conditions in the I.G. test engine this object was fulfilled to a large extent.

2. Test Procedure

The test installation described in Report No. 416 was taken over without any important alterations. For the sake of clarity the conditions and method of the test are briefly described again.

a) Test installation

In contrast to previous tests, a pressure reducing value was added in order to give a constant induction pressure. The bouncing-pin apparatus and the cathode ray tube previously employed were replaced by a piezo-electrically operated knock indicator. In accordance with the altered operating conditions, the octane number dial was re-calibrated. Figure 1 shows the test installation.

b) Conditions of Test

R.P.M.	600
Coolent temperature	100° C
Temperature of mixture	125° C
Ignition advance	22°
Inlet Air pressure	1000 m/m of mercury
Variable carburettor control	

λ varies from 0.8 to 1.2.
Variable compression ratio, arranged to produce the same impulse on the knock indicator, viz. 50.

c) Test Procedure

This is the same as that for the simplified octane number determination. That is to say, the sample fuel is made to knock by change of compression ratio to give an indicator reading of 50, with the carburettor needle adjusted to maximum knock, and the knock value is read directly off the octane number dial. The air fuel ratio is calculated as usual from the fuel and air consumptions.

In the same way further octane numbers are determined, using richer and weaker mixtures. Since the carburettor adjustment at the start of the test must give maximum knock, the fuel gives higher octane n mbers in the subsequent measurements. When plotted, these measurements result in a curve such as that in fig. 2, showing how the octane number thus obtained is dependent on the amount of excess air. In order to forestall confusion with results obtained by test methods already in existence (Motor and Research), this new process was called the "Oppau Method."

About 500 ccs. are required per test, each test lasting about ¾ hour, and the accuracy of measurement lies within ± ½%. Naturally the accuracy of the dial recording the octane number must be checked from time to time, but this is possible without an appreciable loss of time.

d) Comparison of the Methods of Evaluation

In the Oppau Method the fuels are evaluated according to the compression ratio obtainable with moderate Knock intensity, while the value adopted in the DVL method is the brake horse power of the engine when knocking begins. Even when the air fuel ratio is constant, the relationship between compression ratio and brake horse power is not linear; the present investigation, using a variable air fuel ratio, results in a change in the combustion process itself which affects differently the power and the permissible compression ratio. Within the range of measurement investigated it is therefore clear why the supercharge method should yield a falling curve in the rich mixture region while the Oppau Method does not. (cf. figs. 1and 2.).

e) Comparison of the Methods of Measurement

In the supercharge method the investigation is based on a constant compression ratio and the sample tested is judged on its ability to withstand supercharging. The Oppau Method employs a constant boost and gauges the sample according to the useful compression ratio. Within the limits of investigation, however, the difference of principle underlying the test methods has no effect on the resulting measurements. Earlier on, a similar switch-over was made from the Delco-engine (boost method) to the test engine (compression method) for determining the octane number, without great difficulties in the assessment being encountered.

3. Test Results

A large number of fuels were evaluated simultaneously, according to both the supercharge and the Oppau methods. The tests were carried out on different aviation spirits, supplied to the Technical Test Station for routine investigation.

The result arrived at, using both processes, is based on tests made on 51 different fuels and is illustrated in figures 4-15 the curves on the left hand side of the page are those obtained with the I.G. engine, those on the right are the corresponding graphs obtained with the BMW engine. Thus, the results obtained with the same fuel but by different methods, may be compared at a glance. On the whole, both methods classify the fuels in much the same manner; the observed differences lie within the limits of permissible experimental error inherent in the two engines. Using the Oppau method, the slope of the characteristics of various fuels is somewhat smaller than when the DVL process is employed. With the I.G. engine the position of the minimum points on the characteristics show some spread because during some of the tests the air temperature, and thus the air fuel ratio, was not always recorded correctly owing to a fault in the temperature indicator which was noticed too late. As this had no bearing on the results it was decided not to repeat the tests concerned.

The detailed results are as follows:-

Figure 4 shows that mixtures of reference fuel with pure benzene and reference fuel Z, respectively, are rated in the same order in both processes. It is noticed that the Bi/Bo 100 mixture can still be made to knock in the experimental engine but no longer in the BMW engine; evidently because in this case the BI/Bo 94- mixture has already been shown to have a high knock resistance in comparison with the values in fig. 4.a.

Figure 5 shows curves for various types of gasoline. Both processes evaluate the fuels in the same manner both as regards the order of precedence and of the slope of the part of the curve in the weak mixtures region.

Figure 6 deals with the effect of adding various aromatics to VT 702. Again, both processes yield similar positions for minima and slopes on the region of rich mixtures; - in the weak mixture region mesitylene and toluene show divergences.

Figure 7 shows a similar improvement in both engines with additions of ET 100 and cyclohexane, the differences in both cases being close to the limits of experimental error.

Figure 8 proves that the test methods give similar values when isopropyl ether and ET 100 are added to VT 702, VT 705 being used as standard of comparison.

Figure 9 shows a greater effect than figure 9b, in the case of methanol but the position and sequence of the other fuels is the same for both methods.

Figure 10 includes fuels exhibiting practically the same knocking tendency indicating satisfactory agreement between both processes.

Figure 11 shows the effect of adding various aromatics to the same basic fuel, VT 702. Again the discrepancies between the two processes lie within the limits of experimental error. In these tests there was no confirmation of the suggestion from figure 6 that the toluene blend curve rises more steeply in the weak mixture region.

Figure 12 shows that both methods rate fuels of different composition in the same order.

Figure 13 shows satisfactory correlation between the test results for a similar series of fuels

Figure 14 ~~empasises the~~ difference existing between fuels of the same nature but of different manufacture both processes giving the same order of rating.

4. Interpretation of the Tests

The results obtained with both processes (supercharge and Oppau Methods) are represented as characteristic curves. In the case of the DVL supercharge process the curves obtained for the fuel samples tested are compared with the graph for a suitable reference fuel, from a purely pictorial point of view. An evaluation of the knock behaviour, therefore, can only be determined if an appropriate series of curves is available.

Doubtless the allotment of numerical factors to denote knocking tendency in different fuels,, would make the whole question much more easily intelligible Hence, a special report will deal with the numerical classification of the results obtained with the Oppau process.