Leaded Aircraft Fuels

A Study of the Response of Aircraft Fuels to the Admixture of Tetraethyl Lead: Gains from Isooctane Plus Tetraethyl Lead

Except for a small quantity of special-purpose fuel, all aviation petrols used to-day contain some tetraethyl lead. The susceptibility of the various petrol constituents to tetraethyl lead is, therefore, an integral part of the characteristics which determine the limits of performance.

An interesting contribution to the study of the response of aircraft fuels to tetraethyl lead has recently been made by A. G. Cattaneo and A. L. Stanly, of the Shell Development Co., in a discussion before the American Chemical Society.

As Cattaneo and Stanly point out, to this fact justice is only rarely done. After considerable effort on the part of all industries concerned, it has become possible to measure the anti-knock value of petrol within a few tenths of an octane number, but the susceptibility of a petrol to tetraethyl lead is still expressed by such vague terms as "poor," "fair," or "good." Thus the interpretation is left to the individual, and comparison of results is impossible.

The reason for this situation lies in the complexity of the response to lead. The rise in octane number on any one fuel is different for each cubic centimetre of tetraethyl lead added. Also, the shape of the curve is different for fuels of the same octane number and different lead response as well as for fuels of different octane number but equal lead response. Fig. 1, in which conventional lead-response curves are plotted for a number of common fuels, shows these effects clearly.

By far the most confusing element, however, is the non-uniformity of the octane scale. An 85-octane fuel, showing an increase of 15 octane numbers from the addition of 3 c.c. of tetraethyl lead, is considered to have a good lead susceptibility, but a 50-octane fuel, showing an equal increase in octane number, is not. This is because an increase from 85 to 100 octane number is more than twice as effective in terms of engine performance as an increase from 50 to 65 octane number.

The Ethyl Blending Chart

In 1933, Hebl, Rendel, and Garton (In. Eng. Chem., 25, 187, 91) first showed an empirical way to deal with this situation. On the ethyl blending chart which they proposed, the horizontal scale of c.c. tetraethyl lead per gallon and the vertical scale of octane number were so chosen that a lead response curve becomes a straight line. This was later revised for A.S.T.M.-C.F.R. motor method octane numbers, and also to take better account (by the use of slanting ordinates) of the effect of the anti-knock value of the base stock upon the relation between lead concentration and increase in compression ratio. Fig. 2 shows the data of Fig. 1 entered upon the revised chart.

This chart has been in use for several years, and has been found reliable for lead concentrations up to 3 c.c. per gallon. For higher concentrations of tetraethyl lead the chart is useful but is not so well established, partly owing to lack of sufficient data and partly to the large influence which small variations in the sulphur content may have, particularly in the region above 50 octane number. Below 3 c.c. of tetraethyl lead the chart can be considered more reliable than any one individual octane number determination.

The slope of the lines representing two petrols can easily be compared on this chart, either visually or by use of the scale of lead susceptibility marked along the right-hand side. A given slope—i.e., lead susceptibility—represents a greater increase in octane number for a given addition of lead when the unleaded fuel is of low octane number.

Although the chart has been developed empirically, and its scales do not suggest any obvious relations, reference to its derivation will show that the relation between lead concentration and octane number was obtained by elimination from expressions relating both to compression ratio. While the relative size of octane numbers used in the ethyl blending chart is thus linked to a specific engine factor, further confirmation of its significance should be looked for.

One such source of confirmation, say Cattaneo and Stanly, is found in the rating of fuels on a supercharged C.F.R. engine operated at a fixed compression ratio. The anti-knock value of a fuel is found by increasing the intake manifold pressure under constant operating conditions of speed, temperature, and air fuel ratio, until incipient detonation occurs. The rating of the fuel could be expressed in terms of permissible manifold pressure, or indicated mean effective pressure, but it is preferable to refer in some way to a reference fuel in order to eliminate engine, atmospheric, and personal variations.

A convenient expression proposed by Boerlage, Pelletier, and Tops (Aircraft Eng. 7, 306, 8) is "allowable boost ratio," defined as

A.B. ratio = manifold pressure (abs.) at incipient detonation for test fuel/manifold pressure (abs.) at incipient detonation for reference isoctane.

The centre of lead susceptibility scale...