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Miniature Diesel Fuels

The diesel fuels used in road transport vehicles are fairly high-boiling fractions from natural petroleum consisting mainly of certain types of "paraffinic" hydrocarbons. Such a "gas oil" has a Spontaneous Ignition Temperature around 250°C. and when forced into the cylinders in finely atomised form will fire satisfactorily under the high-temperature conditions prevailing in these very high-compression full-scale engines. But they will not ignite in a model "Diesel" unless it is hot, and to enable miniature compression-ignition two-stroke engines to be started it is customary to add a proportion of Ethyl Ether, which combines the phenomenally low S.I.T. of 188°C with very wide Explosive Limits.

Since the miniature "Diesel" is a two-stroke engine, lubricant must also be incorporated in the fuel. Finally, to ensure smooth even running it is often advantageous to include a small proportion of a further component, the "dope". It is worth while to study in some detail the functions and properties of these *four vital compounds*.

(1) The Paraffinic Base-Fuel.

This is the main ingredient of the fuel. Its function is to provide most of the energy of the fuel, and it should therefore possess high Calorific Value and low S.I.T. Reference to TABLE III will show that, with the exception of certain ethers. The only readily available substances with relatively low S.I.T.'s are the *paraffin* hydrocarbons—which fortunately also possess very high Calorific Values. Ruling out individual pure hydrocarbons like pentane, hexane, heptane, etc., on the grounds of expense, this virtually narrows down our choice of base fuel to PARAFFIN OIL, COMMERCIAL DIESEL OIL and special HIGH CETANE GAS OIL FRACTIONS, if available.

There is little to choose between paraffin and diesel oil, the latter having its higher viscosity and greater "oiliness" to recommend it. It can be seen, partly by reference to TABLE III, that the addition of petrol, benzene, toluene, naphthalene, turpentine, white spirit, or in fact any of the fantastic materials that have from time to time been recommended, must of necessity make the fuel worse, because of the high S.I.T.'s of these substances. Their use to "deadend down" the detonation of the ether is a case of two wrongs failing to make a right: a fuel that needs deadening down has got far too much ether in it.

(2) The Lubricant.

The lubricating component of the fuel may be any good quality lubricating oil, either mineral or vegetable. The only limitation imposed by vegetable oils like Castor Oil is that, alone, they will not blend with paraffin base fuels; castor oil can be used only in a fuel ready-mixed with ether, which will keep all the components in solution. There is scope for experimenting with different grades and qualities of oil.

With regard to the *quantity* of oil to incorporate in the fuel, this again is a matter for experiment. Many miniature engine fuels are grossly over-lubricated, with the result that they are unnecessarily messy in use, and also require more ether than they otherwise would. In designing a diesel fuel it should be borne in mind that the oil has one function only—to provide adequate lubrication—and that it should not be expected to burn, to moderate the explosive tendencies of excess ether, or to do anything else.

A two-stroke motorcycle engine runs on the road for long periods at a time under much greater (and varying) load than any model engine, and with considerably greater bearing and piston speeds, yet seldom does the percentage of lubricant in the fuel exceed 7.5%. It is desirable in formulating a model diesel fuel to increase this proportion for the following reasons:

1. A new engine may be tight and require excessive lubrication till it is run-in.
2. In a very old, or badly made engine, the piston may be a poor fit in the bore, so that a fairly thick viscous fuel is needed in order to seal the compression, and
3. The manufacturer must allow a reasonable safety factor.

Point 2 normally affects only the ease of starting: once the engine has been started it will usually continue to run perfectly satisfactorily even on a very thin fuel. With old engines starting can usually be facilitated by injecting a drop or two of lubricating oil through the ports.

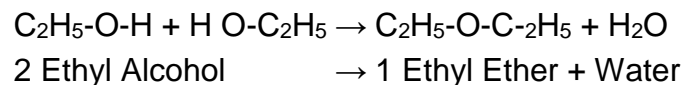
For a normal fuel for use in a run-in engine in good condition, oil percentages in the region 30% to 50% are unnecessarily high. If the aeromodeller experiments with proportions of oil in the range 12%-20% for racing blends and 20%-30% for general-purpose and running-in fuels, he will not go far wrong. Diesel oil based fuels tend to require rather less than those blended with paraffin.

(3) Ether.

Apart from its low S.I.T., which enables it to start easily, and its wide Explosive Limits which ensure that throttle settings are not critical, *ether is a bad diesel fuel*. It has a considerably lower Calorific Value than the paraffinic base fuel and it detonates or "knocks" badly. Excess of ether means correspondingly less base-fuel in the formulation, and hence a fuel of lower calorific value than need be, whilst its detonating propensities when present in excess cause diesel knock and impose undue strains on the con-rod.

Ether should, therefore, be added to a diesel fuel for one purpose only, namely to make the engine start. Just enough for this purpose should be added—and *no more*. 30%-35% is excessive, and modellers are recommended to experiment in the range 20%-30%. It cannot be overstressed that the function of the ether is solely to bring about easy starting; it should not be expected to usurp the function of the base-fuel.

There seems to be some confusion regarding the grades of ether suitable for use in fuels. Ether is manufactured from ordinary ethyl alcohol, two molecules of which join together, with the elimination of water, thus:-



The process is usually carried out by heating the alcohol with concentrated sulphuric acid, which absorbs the water formed—which is why the product is sometimes called "sulphuric ether". The ether which distils over is washed free from acid, purified, dried and re-distilled. It therefore contains no acid whether it is sold as "Anaesthetic Ether", "Ether '720", "Ether B.S.S. 759", "Sulphuric Ether" or "Ether Meth."

All these materials are, effectively, the same thing; and if properly manufactured are all harmless to model engines. The '720 refers to the specific gravity of the product and shows the substantial absence of water; B.S.S. 579 refers to the appropriate British Standards Specification laying down the standard of purity; "Ether Meth." indicates that the ether was not manufactured from pure ethyl alcohol but from methylated spirits, which contain a few percent of methanol—this will give traces of methylethyl and dimethyl ethers in the product, which are not harmful.

Anaesthetic ether is made from pure alcohol and usually contains a proportion of deliberately added alcohol, and sometimes other additives, to prevent peroxide formation on storage. It is more expensive than other grades and, if anything, is slightly less suitable for fuel work.

The di-ether, Methylal, with the chemical formula $\text{CH}_3\text{O}-\text{CH}_2-\text{O}-\text{CH}_3$, may be used partly or wholly to replace ethyl ether in certain specialised fuel formulations. The higher ethers Amyl Ether and Butyl Ether are too high boiling to be valuable alone, but may be used mixed with ethyl ether. Isopropyl Ether, unlike the straight-chain ethers above, has a very high S.I.T. and is not suitable for use in diesel fuels. It is a possible ingredient of glo-fuels.

(4) Dopes.

There are a number of well recognised "dopes" which may be added to diesel fuels, best known of which are

- Ethyl and Amyl Nitrites
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- β -Chloro-ethyl Nitrate
- Paraldehyde
- Various organic peroxides like Tertiary Butyl Hydro-Peroxide, Di-Tertiary Butyl Peroxide, etc.

The choice of dope is usually determined by price and availability.

The function of the dope is to reduce "Ignition Lag" and thereby give smooth powerful running. Very little dope is needed for this purpose, the precise amount depending on the particular fuel formulation, and is a matter for experiment in each case. Seldom is more than 3% required, and modellers would be well advised to start with about 1% of dope and gradually increase, by not more than 0.5% at a time up to a maximum of about 2.5%, until smooth even running is obtained—and then to STOP. This is a case of "a little of what you fancy does you good"—but a little bit more can play hell.

Dopes should be used solely for the purpose described above and should under no circumstances be used in excess to assist starting. They do, indeed, lower S.I.T. somewhat, but their effect in this direction is most marked with the first few per cent and then falls off very rapidly. It should be remembered that nitrate dopes are, in effect, high explosives and that when they burn they generate nitrous fumes. An over-doped fuel requires the compression setting of the engine to be drastically reduced as the engine warms up it sets up unnecessary strains in the engine, and it is corrosive.

A proprietary brand of fuel will be a carefully balanced blend of ingredients with the correct amount of dope; no attempt should be made to "improve" it by further dope additions.

Following the basic principles discussed above, and bearing in mind that each component of the mixture has its own specialised part to play in the performance of the final fuel, it is now possible to set about designing a good diesel fuel for a particular engine or for a specific purpose. A good running-in fuel for new engines and for general purpose flying would look something like this:

PARAFFINIC BASE FUEL	45-60%
LUBRICANT	20-30%
DOPE	1-2.5%
ETHER	20-25%

Whilst a Racing or Competition fuel might well be :

PARAFFINIC BASE FUEL	55-65%
LUBRICANT	12.5-20%
DOPE	1-3%
ETHER	20%

If the fuel is of the ready-mixed variety all the ingredients are mixed together, and the lubricant may be castor oil. But if the fuel is to have its ether added immediately before use, only the first three components are mixed in each case; in which event mineral lubricant must be employed.

Starting with either of the above basic formulations as a guide, the ideal fuel for a particular purpose and individual engine can readily be worked out on the test bench by modifying the components of the appropriate formula a very few per cent at a time until optimum performance is obtained.

It should be borne in mind that the perfect fuel for one engine may not be ideal for another with totally different design characteristics and the really scientific flying enthusiast will study the individual fuel requirements of all the more important engines in his "armoury". It should also, of course, be appreciated that different fuels may require different starting and running settings—and the careful experimenter has to develop a considerable amount of patience.

RUNNING-IN ENGINE TEMPERATURE.

It follows from the increased proportion of base-fuel and the reduced proportion of ether that a "racing" fuel will run hotter than a running-in or general-purpose fuel, because of its higher Calorific Value. This relatively high-temperature running has been known to worry some modellers, who sometimes attribute it to frictional heat arising from under-lubrication.

Any well-formulated racing fuel is, by its very nature, bound to run hot—and it is advantageous that it should do. The efficiency of operation of the internal combustion engine increases, within reasonable limits, with increase in temperature of running, hence the modern practice of cooling full-scale aero engines with ethylene glycol (b.p. 198°C), instead of with water (b.p. 100°C).

It is clearly not the wish of the reputable fuel manufacturer to ruin his customers' engines, and his branded fuels will have undergone extensive tests on a range of engines before being launched on the market. There should, therefore, be no cause for uneasiness in using well known proprietary brand fuel. But if the modeller is still anxious, it is suggested that he feel, not the cylinder head where combustion of powerful fuel is taking place, but the crankshaft main-bearing. If this remains moderately cool he need have no fear of a seizure.

WARNING. In fairness to the manufacturer, as well as in his own interests, the modeller should. Of course, be careful only to use a fuel for the purpose for which it is intended. A "Competition" or "Racing" mixture is, as its name implies, intended for high-speed work, and the manufacturer assumes his customer will not be expecting to develop maximum power and revs with a new engine straight out of its box. A "Standard" or "Running-In" fuel should always be used with new engines, which should first be run on the bench for some time with an oversize propeller.

After the engine has loosened up it should be run for another half-hour or more with a standard prop., still on the same type of fuel. Only after proper running in, and after a fair amount of work, should peak output with racing fuels be attempted.