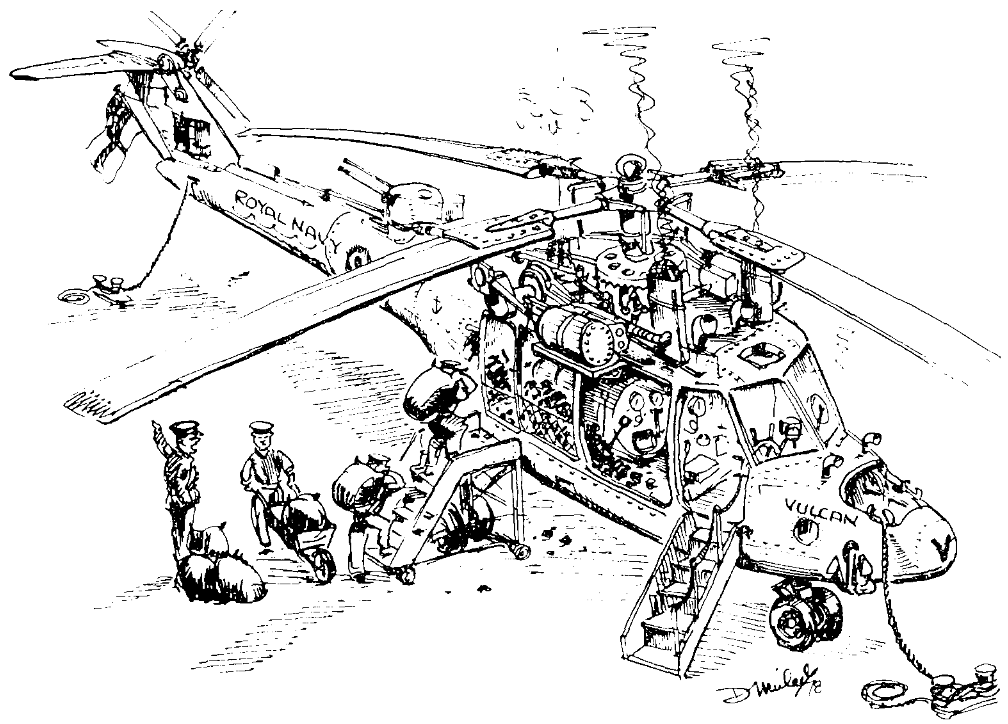

FIG. 1—RAS—RHONDDA ANTHRACITE SHIPMENT

FLY NAVY?—THEN DIG THIS

BY

LIEUTENANT S. D. RALPH, B.SC., R.N.
(*Aircraft Branch, R.E.M.E.*)

Power-driven aircraft can overcome gravity—a problem but not insurmountable. They refuse, however, to fly without petroleum fuel. That fuel is in short supply, and no amount of debate between environmentalists, theorists, and politicians will prevent its final disappearance. Of course, there are numerous alternative energy sources available to drive our predominantly oil-based economy, and conversion of this energy to drive existing plant is relatively straightforward. Unfortunately, the energy requirements of aviation transportation are unique in that aircraft are completely reliant on fluid hydrocarbon fuels within the boundaries of present technology.

There have been many studies to ascertain the quantity of oil remaining, and their conclusions have been based on various parameters. Perhaps the most important feature of these estimates is that they all project zero world production of oil by about AD 2025. To meet the anticipated shortages of oil production for the aviation industry before that date there are three fundamental options, namely: legal restriction of oil for premium uses (aviation based); development of new generations of low-fuel-use engines (turbo-fan/turbo-prop engines); and the development of synthetic fuels. The first two may put off the fateful day but the third option offers the only real solution to the problem.

Examples of synthetic fuels include liquid hydrogen and the liquefaction of coal (there are others). Liquid hydrogen is unacceptable, barring an unexpected technical breakthrough, because of, amongst other reasons, the dangers involved. However, considerable promise is offered by the use of coal to produce liquid hydrocarbon. Present economically recoverable World reserves of coal are estimated to be 40×10^9 tonnes; enough to last 300 years at present rates of consumption. In recent years, the coal industry has been in decline but the next two decades should see a rapid increase in production. This will be significantly affected by the continuing advances in mining technology and an envisaged rapid increase in World trade of coal at the turn of the century. Assuming therefore that there will be an adequate supply of coal, how is it converted to liquid hydrocarbons?

The ratio of hydrogen atoms to carbon atoms is 0·8:1, whereas in crude oil it is 1·75:1. Therefore, in most cases, the conversion of coal into oil requires the addition of hydrogen to the coal. This can be achieved by two processes, namely: gasification and hydrogenation.

When heated to very high temperatures, in the presence of steam, coal can be gasified to synthesis gas ($CO + H_2$). After purification and passage over a catalyst, liquid products are yielded ranging from methanol to hydrocarbons of high molecular weight. This is known as the Fischer Tropsch process and has been operated in South Africa for many years, where it is politically important to be independent of imported oils. This process is restricted by its dependence on a particular type of coal and is not very efficient or cheap. Hydrogenation is effected by three different methods. Direct hydrogenation involves the reaction of coal with hydrogen at high pressure and usually in the presence of a catalyst. These processes require a temperature of 450°C and pressures from 2000 to 4000 psi. A lower pressure and shorter reaction time limit the reaction between the coal and hydrogen, favouring the production of heavy fuel oil; a high pressure and longer reaction time favour the production of lighter fractions. Typical yields are 0·35 to 0·44 tons per ton of coal. The remaining two methods of hydrogenation involve the partial or complete solution of coal. In the former, coal is dissolved in an organic liquid in the presence of hydrogen gas under pressure (2500 psi). In the latter, coal is dissolved in a hydrogen-rich solvent at low pressure (300 psi). Being rich in hydrogen, it transfers hydrogen to the coal. Typical yields are 0·25 to 0·38 tons per ton of coal. A form of hydrogenation was employed on a large scale during World War II in Germany when 30–50 000 tons were produced per annum, but production was closed soon after the War because of immense practical difficulties and consequent expense.

The previously described processes all possess inherent problems and are expensive. However, a reappraisal of the traditional method of coke and coal gas production may provide an easier and cheaper method of coal conversion. The old method of coke production has always produced coal tar as a by-product which can be converted to petroleum replacements. Now that this method is free from the constraints of maximized coke/gas production, coal tar yields can be optimized. Coal tar can be produced by a process known as pyrolysis. As the name implies, it is based on the heating of coal (in the absence of air). Tar yields are determined as much by the rate of heating as by the final temperature attained; being greatest under conditions of 'shock heating'. Flash tube techniques, using powdered coals, have shown that tar yields as high as 30 per cent. by weight are possible. Unfortunately, tars are viscous and could be regarded as soft pitches. They are high in oxygen, sulphur, and nitrogen, but low in hydrogen compared with petroleum crude. Survival of the tar depends on how quickly it can be isolated and cooled.

The solution of this problem could be the use of supercritical extraction (SCE). SCE is based on the ability of substances to vaporize freely in the presence of compressed gas. The technique is well suited for the extraction of the liquids formed when coal is heated to about 750°F. These liquids will not distil to any great extent at this temperature, and are not stable at high temperatures. Gas extraction affords a means of recovering the liquids as they are formed at the lower temperature and thus avoids unnecessary degradation. The vaporized substance can be readily recovered by transferring the gas phase to a reducing chamber where the density of the solvent gas and its 'solvent power' is reduced. The solid will precipitate out and may be recovered, leaving the 'solvent' gas to be recycled.

The SCE process has a number of attractive features:

(*a*) It is relatively cheap.

(*b*) The gas solvent is easily separated from the extract.

(*c*) The extract is a low melting-point solid which represents the hydrogen rich fraction of coal.

(*d*) The char by-product is readily utilized for gasification or combustion.

(*e*) No hydrogenation is required.

At this time, the cost of crude petroleum is appreciably lower than synthetic petroleum. 1974 calculations showed that crude petroleum cost £40 per ton in comparison with hydrogenation-produced and SCE-manufactured fluid hydrocarbons costing £50 and £45 per ton respectively. In the intervening years, the cost of coal and of chemical plant has increased faster than that of crude petroleum, which makes oil manufactured from coal less attractive. This could lead to a sense of unimportance and some complacency. However, economic and production forecasts indicate that the cross-over point between crude and synthetic oil fuel prices is expected to occur sometime in the early 1990s. This date is important for it makes the timetable critical. If the SCE process is adopted as the best option for synthetic petroleum production, the design and development of such plants would take as long as fifteen years. The opportunity, therefore, of a smooth transition from crude oil to synthetic oil production becomes increasingly reduced from now onwards.

It is highly likely that, within the next thirty years, the dwindling supplies of crude oil may become inadequate to sustain the increased consumption by aviation transport. Such a situation could drastically affect the operability of our front-line military aircraft with a corresponding reduction of tactical training—the nation's air defence could be severely reduced. It is quite possible that a latter-day Government would be unsympathetic to the needs of the military when public and also international commerce is so dependent on civilian air travel.

It is rather ironic that one of the key objectives of the Fuel Research Station, on its foundation in 1919, was to devise processes for converting coal to oil to meet the growing demands of the Royal Navy's surface fleet. To what extent is the Navy, indeed the Army and Air Force, endeavouring to re-define that objective to ensure that plant is developed to manufacture adequate supplies for their air fleets towards the end of this century?