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PROPOSED FUELS DISCUSSION

FOR THE SECOND ANNUAL MANUFACTURERS' CONFERENCE

Our research is directed toward improved performance of fuels in turbojet, ram jet, rocket and reciprocating aircraft engines. The present discussion will be confined largely to the topic of turbojet fuels. Careful consideration of the problems associated with the establishment of an optimum fuel for turbojet engines indicates that among the important problems those listed on the first chart are important. We shall consider each of these topics in turn: maximum availability, influence of fuels on engine performance (the three topics under this heading which we wish to discuss today are combustion efficiency, altitude limits and carbon formation). The last item for discussion is the influence of the fuel on flight range.

Going back to item one on the list it is important that our turbojet aircraft be designed to use a fuel which is available in large quantities. Our jet aircraft today operate on high-octane gasoline or on a kerosene type fuel which is available in only very small quantities.

Because of the increasing numbers of turbojet aircraft being employed for military purposes and probably for commercial applications in the near future it is apparent that turbojet engines should be designed to use a fuel of greater availability than that now in use.

Representatives of the petroleum industry have indicated the type of fuel which will be available from domestic petroleum in the maximum quantity. The next chart shows a comparison of the quantities of fuels available from a barrel of crude oil. On the left is shown the relative quantity of the present fuel available from a barrel of crude oil -- about 5 percent. On the right is shown the relative quantity of fuel which can be produced from a barrel of crude if the fuel is specified in accordance with the recommendations of the petroleum industry. In this case about 50 percent of each barrel of crude oil would be available as jet fuel. It is obviously desirable to use such a fuel if turbojet engines can be operated satisfactorily on it.

The Air Force, Bureau of Aeronautics, Navy Department, and the NACA are cooperating in a program to evaluate the performance of this available fuel in turbojet engines and in single combustors from jet engines.

One of the parameters under investigation by the NACA is combustion efficiency. Our previous investigations have shown that the boiling point of the fuel and the molecular structure of the fuel both have a marked effect on turbojet combustor efficiency at high altitude conditions. The next chart shows an illustration of differences in combustion efficiency encountered with fuels of different molecular structure. The examples chosen are the well-known hydrocarbons, normal heptane and isooctane. These constitute the components of the octane scale used as a measure of the knock-limited performance of reciprocating engine fuels. The knock rating of heptane is arbitrarily stated to be zero. If 20 percent isooctane is added to the heptane the octane rating is 20 and so on up the scale. Pure isooctane has an octane rating of 100. Here are molecular models of the two fuels. This fuel, heptane, has the zero octane number and this fuel, isooctane, has an octane number of 100. Now if we consider the combustion efficiencies of these two fuels at a severe operating condition we find that the trend observed with the reciprocating engine is reversed. On a relative basis the pure heptane gives a 16 percent higher combustion efficiency than the pure isooctane.

A second parameter under investigation by the NACA is the altitude operational limits of combustors encountered with different fuels. Previous investigations have shown differences as large as 13,000 feet in altitude operational limits as indicated on this chart. To illustrate different burning characteristics of fuels we have under this bell jar two burners containing oil would be available as jet fuel. It is obviously desirable to use such a fuel if turbojet engines can be operated satisfactorily on it.

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This experiment, of course, does not simulate the conditions encountered in jet engines at altitude conditions but does serve to show differences in the combustion characteristics of two fuels at the low air pressures encountered at high altitudes.

A third parameter that has been investigated here is the quantity of carbon that will be deposited in a turbojet combustion chamber by different fuels. The fact that fuels vary markedly in their tendencies toward carbon deposition is illustrated by the carbon deposited in these combustion chamber liners. Here we have a very small quantity of carbon deposited by one fuel and here we have the carbon deposited by another fuel. Here a large part of the liner cross-sectional area is blocked. Such a deposit would be expected to seriously alter the normal combustion process. Our investigations have shown that carbon deposition can be predicted if the boiling point and the hydrogen and carbon content of the fuel are known. The next chart illustrates how the correlation may be applied. One first selects the boiling point of the fuel and the correct H/C ratio. Then by traveling vertically to the diagonal line one can predict the quantity of carbon that will be deposited at a given operating condition in a given engine.

The third point which we wish to mention briefly is the matter of range. High speed aircraft are built with thin wings and a small fuselage. Consequently the space available for fuel tanks is very limited. Therefore it is desirable to use a fuel which will deliver the maximum amount of energy per unit volume.

The burning of metals will yield more energy per unit volume than anything known except nuclear energy. To indicate some advantages one could expect from burning metals we have the next chart which shows the relative thrust per unit combustor cross-sectional area to be expected from gasoline, aluminum and beryllium. These calculations assumed that the aircraft was flying at a Mach number of 3.5.

To indicate to you the intensity with which aluminum burns we have here in a small wind tunnel an experimental ram jet model in which we shall burn aluminum. You can observe the intense white flame and the solid products of combustion. It is necessary to use a colored glass shield in order to protect your eyes from the brilliant light.

(At this point burn aluminum)

The temperature of the flame which you observed is estimated to be above 4000° F.

The burning of metals presents several problems, one of which is the matter of the solid products of combustion. For that reason it would be extremely difficult to adapt metals to use in turbojet engines. However, there are hydrocarbon fuels that will give appreciably more energy per unit volume than aviation gasoline. Here there are three containers in which we have equal volumes of fuels. The significant difference between the three fuels is that this quantity of gasoline will deliver 225,000 Btu's of thermal energy whereas the kerosene will deliver 258,000 Btu's (a 14 percent increase over gasoline) and the high-density hydrocarbon will deliver 304,000 Btu's or a 35 percent increase over aviation gasoline.

We are engaged in the evaluation of these high-density hydrocarbons here at the laboratory. Certain quantities of these materials are found in crude oils and are also produced in refinery operations. They are usually not isolated in experimental quantities so we have installed distillation equipment for that purpose. You will see the distillation columns at your next stop. Here we have a glass model of a distillation column to show how such equipment can be operated. Here the heated liquid is introduced into the column and the lowest boiling fractions go to the top of the column. The higher boiling fractions go down the column -- flowing over the ceramic packing so that these hydrocarbons intimately contact the gases caused by boiling the liquid in the reboiler. The hydrocarbon vapors give up heat to the descending liquid and the lower boiling components boil. As this heat exchange process continues the low boiling components tend to concentrate at the top of the column where it is taken off and the high boiling liquid will be concentrated at the bottom and taken off from the reboiler. You will see a larger scale column in operation but it is of steel and insulated so you cannot observe the operation.

In summary -- we are conducting research that will contribute markedly toward increasing the fuel supply ten-fold and we are conducting research which will eventually allow extended flight range for aircraft.