USE OF ALTERNATIVE FUELS FOR AVIATION

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Abstract

The report contains the analysis of fuel balance development in the world and in Russia, the comparison of using the alternative fuels with their specific features for civil aviation. The main attention is paid to the introduction of liquefied natural gas (СПГ) and liquefied petroleum gas (aviation condenced fuel АСКТ) as fuels for civil aviation in the nearest future. The possibility to get significant benefits and reduce the dependence of civil aviation on conventional fuel supplies is shown.

Predicted estimates of fuel resources output, both on a world scale and in our country (Fig 1,2) show the tendency to the stabilization and subsequent diminution of petroleum extraction. At the same time these estimates show the increase of natural gas share in the whole energy balance.

These tendencies stem from the dep - letion of crude oil resources and complexity of its extraction on the one hand, and from the existence of sufficiently rich resources of natural gas on the other.

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THE WORLD POWER PRODUCTION

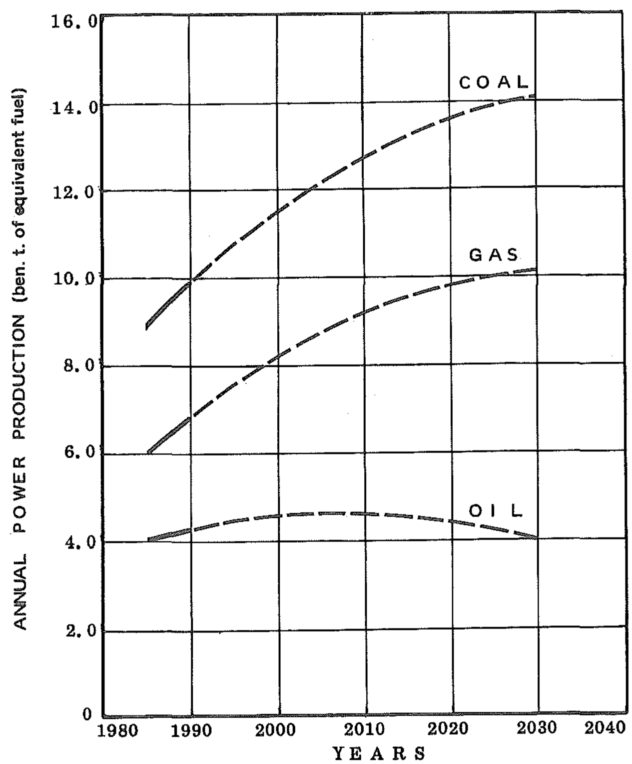


Fig.1

In particular, according to some estimates world resource of gas explored can provide a modern level of its consumption during 150 years. Evidently because of these reasons there appeared some publications mentioning of the advent of the period of the intensive use of gas in the world and in Russia.

The process of substitution of liquid fuel for gas will also be promoted by more severe ecology requirements to the emission of injurious substances of the engine combustion products.

It should be noted that with respect to the purity of combustion products natural gas occupies one of the first

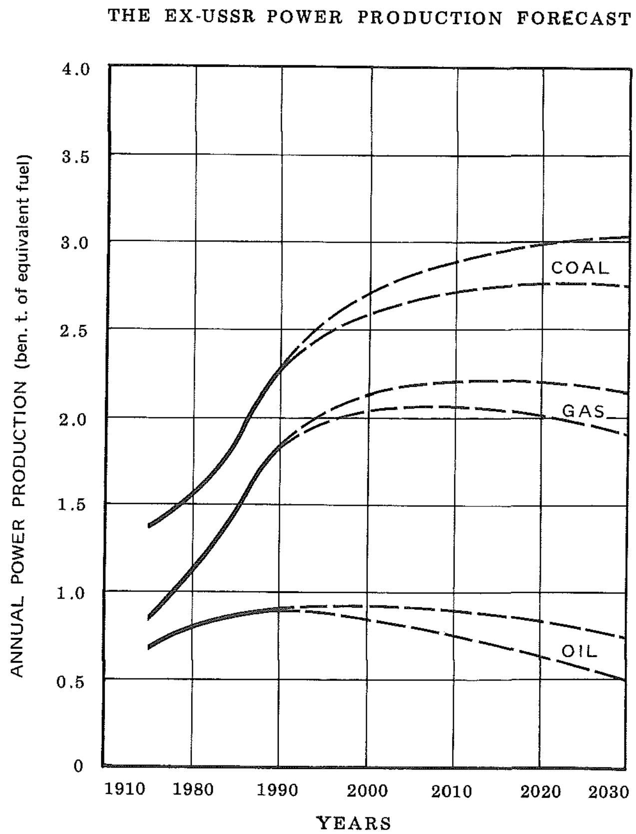


Fig. 2

places. The oxides of carbon and nitrogen ejection when the engine is operating at natural gas, is two times lower as compared with an engine operating at kerosene.

Intensive introduction of more efficient aircraft (Fig 3), as well as the possibility for using synthetic liquid fuels can somewhat weaken the fuel problem but hardly solve it completely.

An alternate solution is the use of liquefied gases as aviation fuels: propane, butane, methane and hydrogen (Fig 4). As it was mentioned above the main preconditions for the transition to gas fuel are:

1. Intensive output of gas fuel.
2. More lower rate of expenditure growth of gas output.
3. Ecological benifit of natural gas use as compared with aviation kerosene.

At present Design Bureaux and research institutes of aviation industry have carried out a large amount of R&D works

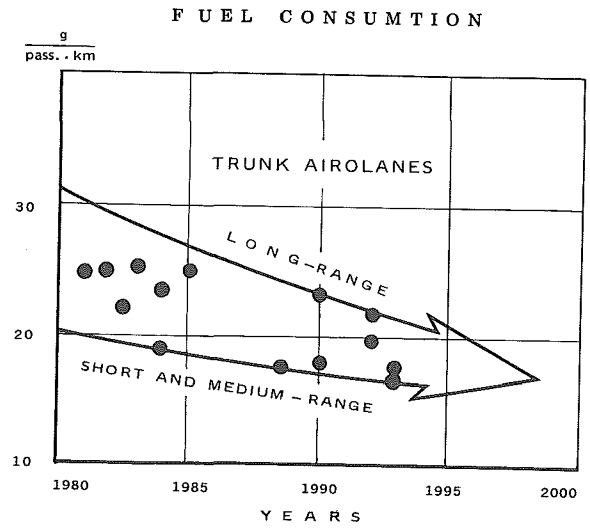


Fig.3

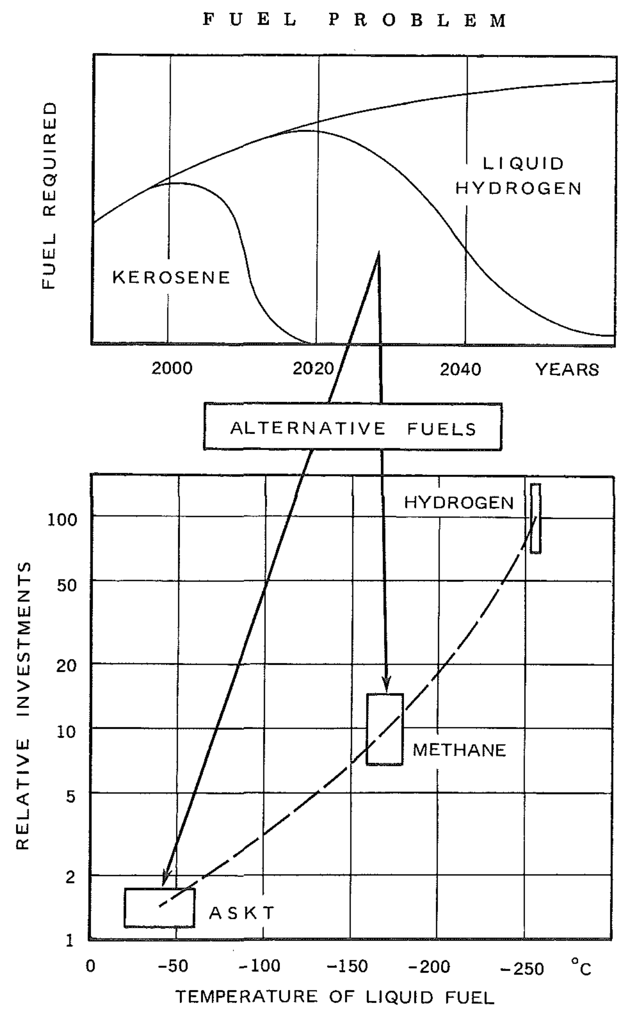


Fig.4

oriented to the development and operational tests of gas-fueled aircraft

In particular, Tupolev Design Bureau together with other organizations have tested hydrogen and methane-fueled Tu-155 aircraft in flight and continue to develop versions of Tu-154 and Tu-204 aircraft operating at liquefied gas.

Mil Design Bureau has carried out a large amount of flight tests of Mi-8TГ helicopter, operating at liquefied petroleum gas(АСКТ). Propane and butane are the main components of this fuel. Proposed also is the development of liquefied petroleum gas-fueled versions of Yak-40 and Il-114. The main characteristics according to which gas fuels differ from kerosene are:

- density,
- boiling point,
- liquid phase temperature range,
- combustion heat related both to mass and volume unit,
- cooling capacity,
- emission products.

Essential distinctions exist also in explosive fire risk characteristics of fuels

Propane and butane(АСКТ) are characterized by the highest density and boiling point among gases considered. They can be stored on-board in a cooled state or under low pressure. Combustion heat of these gases is 5-7% above that for kerosene.

Combustion heat of methane(the main component of liquefied natural gas)is 14% above that for kerosene. However, because of the relatively low density of liquefied methane(1,7-1,8 times lower as compared with kerosene) methane tank volume at equal energy capacity will exceed kerosene tank volume by 1,5-1,6 times. Besides, low cryogenic boiling point of methane(-162°C) and its small liquid phase temperature range(20°C)necessitate to use new cold-resistant structural and sealing materials and high-quality low temperature heat insulation for fuel tanks and their fittings

From the standpoint of providing the energy the use of hydrogen is the most efficient, its combustion heat is almost 3 times above that for kerosene. However a very low density of hydrogen, its boiling point close to absolute zero(-253°C) and a narrow liquid phase temperature range (6°C) require to solve more complex structural and production problems.

Fuel tank accomodation on aircraft may be various:

- under or above the wing,
- in the fuselage or above it,
- in the wing.

According to the investigations conducted at TsAGI it should be noted that fuel tank installation above the upper wing surface can cause a significant reduction of cruise lift-to-drag ratio. Wing box accomodation seems to be not acceptable for cryogenic fuels because for this type of tanks a maximum allowable internal excess pressure of fuel vapours is significantly limited and besides there exist problems of providing efficient tank insulation.

Fuselage fuel accomodation can be considered as one of the variants admissible for aircraft being designed.

While modifying the existing operational aircraft or already designed it is more reasonable to accomodate fuel tank under wing or above fuselage if it is permitted by the general aircraft layout. Such a variant provides a minimum change in the aircraft structure.

Aviation firms, in particular MBB, are studying an interesting variant of positioning the cryogenic fuel tank between two spaced fuselages.

The highest penalties due to the accomodation of gas fuel on-board, i.e. additional structural mass(Fig 5), lift-to-drag ratio losses occur when liquid hydrogen is used. СПГ and especially АСКТ application can provide the lesser penalties.

At the same time a complex analysis of

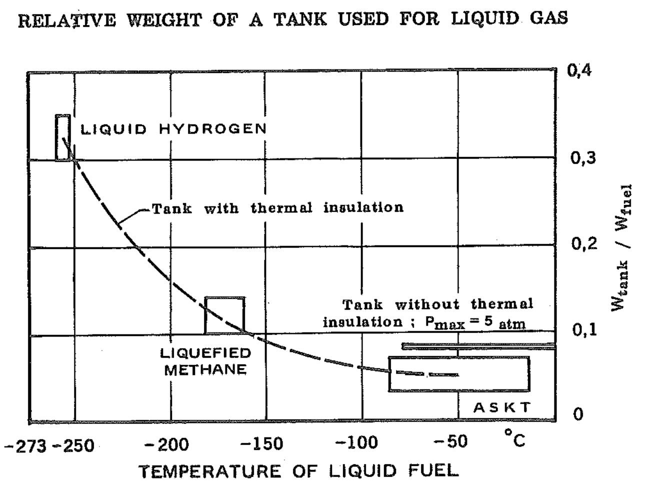


Fig. 5

characteristics of a hypothetic long-range passenger aircraft using various types of fuel (Fig 6) has shown that:

- when liquefied propane and methane are used structural mass increase and aerodynamic efficiency losses are more than offset by a higher combustion heat of these fuels. As a result the reduction of aircraft take-off mass and fuel consumption(approximately by 9-10%) may occur as compared with the conventional fuel use;
- in the case of application of liquid hydrogen which combustion heat is 2,7 times than that for a conventional fuel, more significant reduction of take-off mass (by 25-30%) and fuel consumption (by 3 times) can be reached.

The use of cooling capacity of liquefied gases for the laminar-flow control and the improvement of the characteristics of the airborne conditioning system is an additional reserve to increase technical and economical performances of aircraft.

Considered peculiarities of new fuels application are valid for the helicopters as well. However helicopters may have some additional advantages as compared with aircraft. This is because the helicopter fuel capacity, as a rule, is relatively lower and consequently the increase of fuel tank volume required for transition to gas fuel is less. Besides the increase in aerodynamic drag due to the

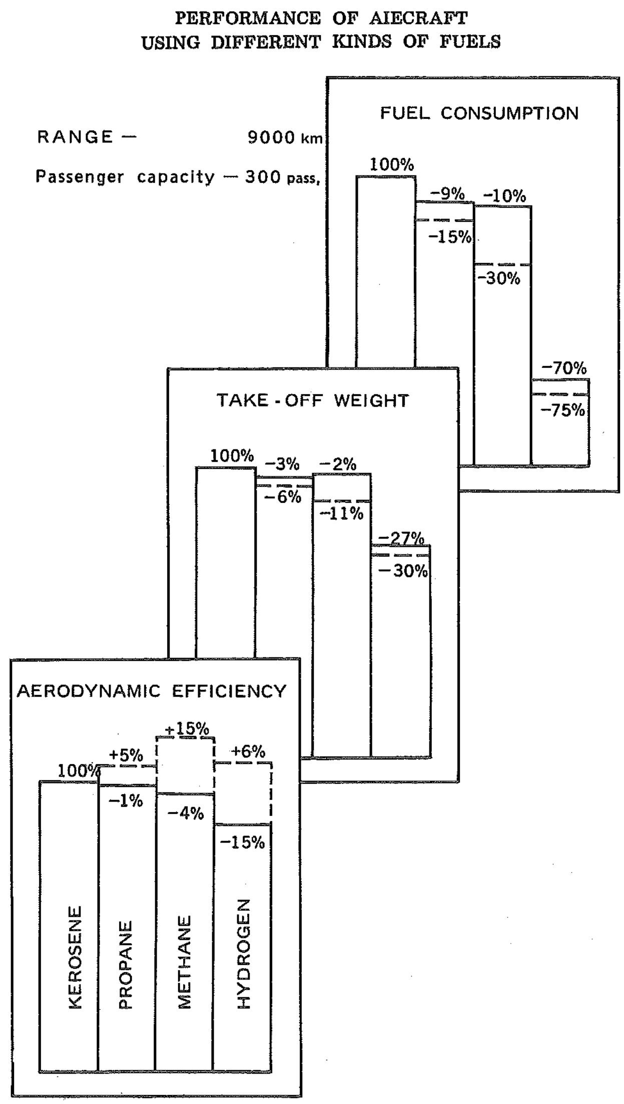


Fig. 6

accomodation of liquefied gas tanks will influence the helicopter energetics to a less degree because the flights of helicopters are usually performed at lower speeds.

Fuel cost and its relation to the cost of conventional fuel is an important factor when making decision about the transition to liquefied gas. It was revealed that liquid hydrogen application for civil aviation is not reasonable from the economy point of view in the nearest future. As for СПГ or АСКТ application they might appear economically efficient, especially under the conditions of increase in conventional fuel cost.

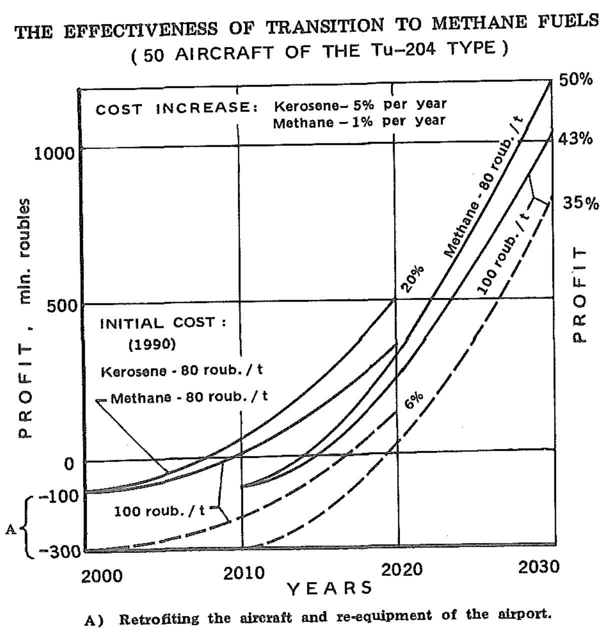
The list of problems needed to be solved during the introduction of such fuels into civil aviation can be shown by the example of ACKT use.

While estimating economic efficiency of new fuels application it is necessary to take into account not only the costs of retrofitting the aircraft, helicopter or other vehicles, but also significant costs needed to equip the airports with additional means of fuel transportation, storage and refuelling.
Also needed are significant changes in technology and preflight and postflight maintenance of such vehicles.

Nevertheless, calculations show that even with the account for these circumstances it is possible to return the investments into the introduction of СПГ and ACKT in the nearest future. And significant benefits might be reached during the operation of C   and ACKT-fueled aircraft (Fig 7,8).

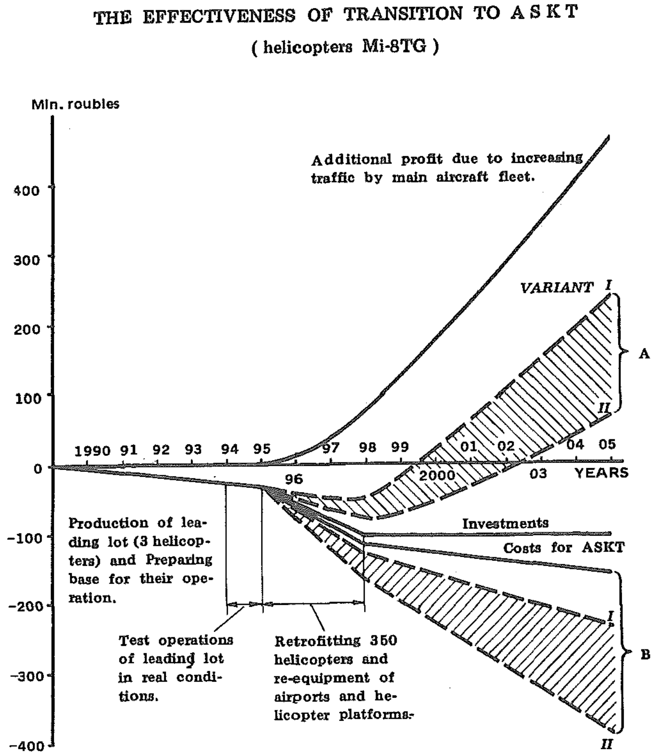
Besides the dependence of civil aviation on problems of conventional fuel supplies might be also weakened.

Test commercial operation of some civil vehicles using new fuels is planned to carry out in our country These vehicles include:



A) Retrofiting the aircraft and re-equipment of the airport.

Fig 7



A) Economical benefit due to ASKT application (353 helicopters).
B) Additional costs for maintenance of 353 helicopters.

Fig 8

- Tu-154 airplane retrofitted for liquefied natural gas to be used on one or some domestic routes;
- Mi-8TГ helicopter (Jak-40CIC, IL-114I and others) using ACKT and intended for operation in Tumen region and other oil production regions.

As it was shown above, the use of new fuels on various types of air vehicles for civil aviation is a complex task It has some general problems and necessitates to unite efforts of Design Bureaux, research institutes, organizations that operate these vehicles and enterprises of petroleum-gas industry.

At present new forms of cooperation are realizing. In particular, a joint-stock company "INTRAVIAGAS" has been created in our country. It will assist in effective transition to new fuels in civil aviation. Taking into account that the solution of this problem has a large significance for the world association, it is also necessary to develop international cooperation in this direction.