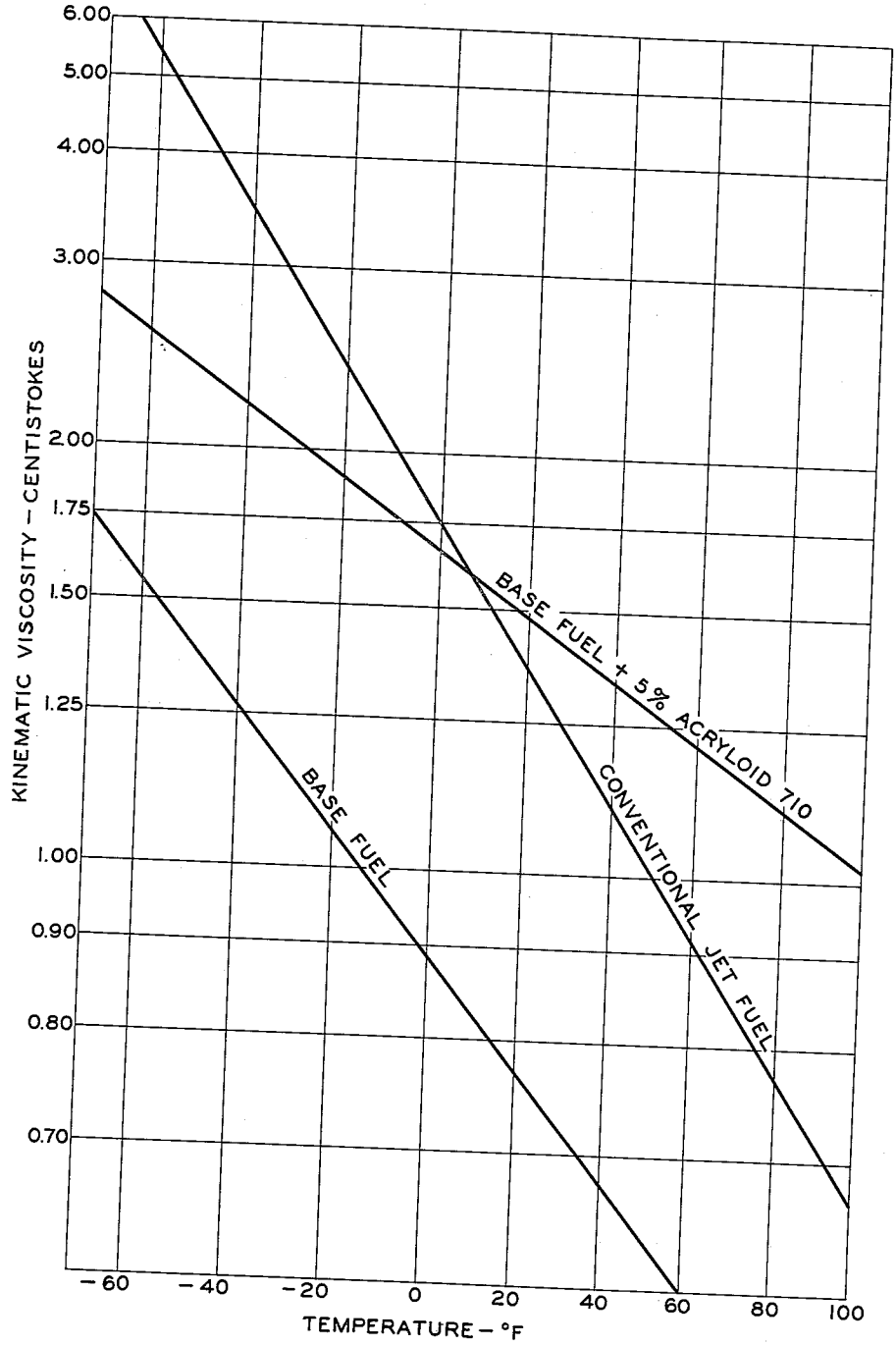
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2,712,726

METHOD OF OPERATING A JET ENGINE

Filed Sept. 20, 1951



RELATION BETWEEN KINEMATIC VISCOSITY AND TEMPERATURE FOR VARIOUS FUELS.

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METHOD OF OPERATING A JET ENGINE

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1 Claim. (Cl. 60—35.4)

This invention provides an improved hydrocarbon fuel mixture suitable for burning in jet combustion devices, said fuel being characterized by relatively small changes in viscosity with changes in temperature, and to an improved method of operating a jet engine over a wide range of atmospheric temperatures and altitudes.

In the present day operation of jet-powered aircraft at altitudes up to and including 35,000 feet, a wide range of atmospheric temperatures are encountered. Although near the earth's surface, the temperature may be 100° F. or higher, the temperature at high altitudes may be as low as —67° F. Obviously, jet engines can not be expected to operate with the present fuels to give high performance and efficiency throughout this wide range of operating temperatures.

The effect of temperature changes on the viscosity of lubricating oils is well known; that is, the viscosity of an oil changes with temperature change. At high temperatures the oil has a "thinned out" appearance and at low temperatures the oil has a "thickened-up" appearance. The term used to express this viscosity-temperature relationship is "viscosity index." Oils with a large tendency to thin-out with the application of heat and to thicken-up with the application of cold indicate a very poor resistance to viscosity changes with temperature changes and are identified by a low viscosity index number. Oils which show only a small change in viscosity with changes in temperature are assigned a high viscosity index number.

Jet engine fuels, which generally comprise a distillate hydrocarbon petroleum oil boiling within the range of light gasoline to heavy gas oil inclusive, show the same general viscosity-temperature behavior of lubricating oils. In the figure is shown the relationship between the kinematic viscosity and temperature for a conventional jet fuel and a base fuel such as aviation gasoline of 81.2 octane number. It is obvious that temperature does have a substantial effect on the viscosity of jet fuels as these two fuels clearly exemplify.

In the usual jet engine, the fuel is forced under pressure through a nozzle to be atomized into a fine spray and burned in the combustion chamber of the engine, thereby furnishing thrust to the aircraft. Before combustion of the droplets of spray in the combustion chamber, the fuel must be substantially vaporized to form a combustible mixture of fuel and air and possible combustion difficulties are encountered if the fuels are vaporized either too slowly or too rapidly. For instance, if all the fuel were to be vaporized quickly and mixed rapidly with the air, zones of gas would be created where the fuel-air mixture would be too rich to support combustion. As these gases are swept toward the exhaust of the combustion chamber, some dilution of the mixture with air may occur to give a combustible mixture; however, there usually is insufficient time for complete combustion before the reaction is quenched by the cooling air and swept completely out of the combustion chamber. If vaporization is insufficient then the mixture will be too lean to support combustion.

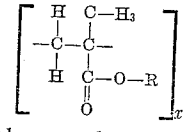
This invention relates to a method for improving the viscosity index of jet fuels by admixture with the conventional jet fuels of from 1 per cent to 12 per cent by weight, and preferably from 2 per cent to 7 per cent by weight, of an oil-soluble, high molecular weight polymeric material, such as one of the commercial viscosity index improvers, Acryloid 710, Paratone, or Santodex, to raise the viscosity index of the fuel, and thereby improve its spray characteristics, so that easier starting of the engine, improved flame-out performance, and improved combustion efficiencies may be achieved both on the ground and at high altitude and over a wide range of atmospheric temperatures.

The combustion of the fuel-air mixture depends upon the character of the spray introduced into the combustion chamber. Low-viscosity fuels require substantially lower fuel pressures than high-viscosity fuels to obtain a proper spray pattern, because spray quality is greatly influenced by fuel viscosity, to the detriment of the more viscous fuels.

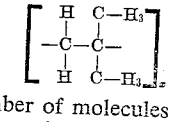
The performance of fuels in starting and flame-out tests declines in the order of increasing viscosity of the fuel to the extent that at low fuel pressures the high-viscosity fuel is discharged with little or no atomization.

I have found that small amounts of various polymeric substances of high molecular weight in admixture with standard types of hydrocarbon jet fuels substantially decreases the effect of temperature change on fuel viscosity and, therefore, cause an improvement in the viscosity index of the fuel. When the addition of a viscosity index improver to a fuel increases the viscosity of the fuel, nozzles designed for the use of higher viscosity fuels can be used.

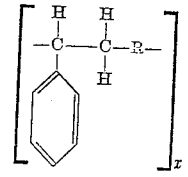
A considerable variety of oil-soluble materials have been found to have the property of increasing the viscosity index of lubricating oils and at least three of these additives exhibit this property when admixed with the conventional jet fuels, which, of course are not lubricating oils. "Acryloid 710" is a well known additive with the polymeric material having the chemical structure of



where R is an alkyl group derived from a fatty alcohol and x is the number of molecules of similar structure condensed together to form the polymer. This polymeric material is essentially an ester of methacrylic acid and higher fatty alcohols such as cetyl or lauryl alcohol. Another additive which I have found to increase the viscosity index of jet fuels is "Paratone." This additive contains a linear iso-butylene polymer which is typified by the structure



where x is the number of molecules of similar structures condensed together to form the polymer. Still another material which is useful as a viscosity index additive is "Santodex." The active ingredient of this additive is considered to be a co-polymer product of styrene and olefins of 8 to 12 carbon atoms. Its structure can be represented as



where R is an alkylene group and x is the number of molecules of similar structure condensed together to form the polymer.

These viscosity index improvers are all characterized by molecules of large size and long chain lengths. For instance, the molecular weight is apparently in the order of 5,000 to as high as 20,000 for the Acryloid improvers, 10,000 to 15,000 for the Paratone improvers, and several thousand for the Santodex improver. These additives are composed of some 20 to 50 per cent of the actual polymeric material dispersed in light mineral oil to facilitate handling and blending. The specification tests on these viscosity index improvers is given below

	Paratone	Acryloid 710	Santodex
Gravity, °A. P. I.	28.3	27.0	25.9
Saybolt Viscosity at 100° F., S. U. S.	55,600	24,000	30,000
Saybolt Viscosity at 210° F., S. U. S.	3,180	3,200	1,900
Flash point, ° F	435	400	350
Pour Point, ° F	30	20	25
Color, A. S. T. M.	2	2	2.5

In my invention, the additives are utilized in rather small amounts, ranging say from 1 per cent to 12 per cent of additive, the preferred amounts being 2 to 7 per cent, by weight of the fuel. In the figure is shown the reduction of the effect of temperature changes on fuel viscosity of a base fuel of aviation gasoline, the specifications of which are given below.

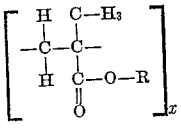
Norwood bromine No., gm. Br/100 gm	1.1
Gravity, °A. P. I	70.2
A. S. T. M. distillation,° F.:	
I. B. P	109
10% rec	144
50% rec	182
90% rec	208
E. P.	262
Reid vapor pressure, p. s. i	6.65
Aviation octane No	81.2
T. E. L., ml./gal	0.42
Aniline No., ° C	61
Viscosity @ 100° F., cs	0.49

In this example, 5 per cent by weight of fuel of Acryloid 710 was admixed with the aviation gasoline and the viscosity of the base fuel plus additive compared with the viscosity of the base fuel. The figure shows that the value of the slope of the fuel plus additive is smaller than the slope of the base fuel alone and, therefore, the viscosity index of the base fuel plus additive has been improved. It should also be noted that although the viscosity of the base fuel has been increased by the incorporation of the additive, the viscosity of the improved fuel near the middle of the temperature range is still comparable to the viscosity of the conventional jet fuel. Furthermore, the viscosity index of the improved fuel, prepared according to my invention, is also higher than the viscosity index of the conventional jet fuels, since in the higher range of temperatures the viscosity of the improved fuel is greater than the conventional fuel and in the lower range of temperatures the viscosity of the improved fuel is lower than the viscosity of the conventional fuel. It is evident, therefore, that the effect of temperature changes on the viscosity of jet engine fuels can be reduced by the addition of viscosity index improvers, in accordance with my invention, to obtain improved jet engine performance throughout a wide range of altitude conditions.

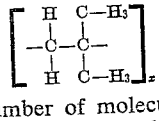
Reasonable variation and modification are possible within the scope of the foregoing disclosure and the appended claims to the invention, the essence of which is that an improved method of operation for jet engines has been provided as set forth, comprising the addition of a lubricating oil viscosity-index improver type of substance to the said jet fuel and operating a jet engine therewith. It will be noted especially that jet fuels are not lubricating oils.

I claim:

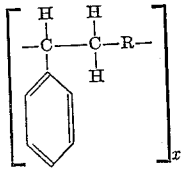
A method of operating a jet engine with a liquid hydrocarbon fuel which comprises incorporating into said fuel supplied to said engine a viscosity index improver selected from the group consisting of high molecular weight polymers which are represented by the following formulae:



wherein R is an alkyl group derived from a fatty alcohol and x is the number of molecules of a similar structure condensed together to form the polymer and is of a value to impart to the said polymer a molecular weight in the range 5000–20,000;



wherein x is the number of molecules of similar structure condensed together to form the polymer and is of a value to impart to the said polymer a molecular weight in the range 10,000–15,000; and



wherein R is an alkylene group containing 8–12 carbon atoms and x is the number of molecules of similar structure condensed together to form the polymer and is of a value such that the polymer will have a Saybolt viscosity at 100° F. of the order of 30,000 and at 210° F. of the order of 1,900.

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