ENCLOSURE (B) 17

ALCOHOL FUEL UTILITY TEST AS AEROENGINE FUEL

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LIST OF TABLES AND ILLUSTRATIONS

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SUMMARY

Alcohol (99%) could be used for small power engines; that is, 300 to 500 hp aero-engines with full power rating. For large power engines it could be used only with reduced power.

Alcohol (94%) had many troubles when used in carburettor engines, but could be used in injection engines at reduced power.

Alcohol-gasoline fuel [Alcohol(99%) 50% + Aviation gasoline 50% (by vol.)] with the same octane number as the base gasoline could be used for low power range.

It was necessary to increase the fuel consumption by 20-40% for alcohol fuels.

In winter, it was necessary to cover engine heads to prevent the misfiring of spark plugs.

Aluminium material was corroded by alcohol fuel. Anodic oxidation of aluminium and addition of sodium arsenite in fuel were necessary.

I. INTRODUCTION

A. History of Project

Owing to the shortage of aviation gasoline, tests with alcohol as aviation fuel were started in May, 1944, in compliance with the request of the First Naval Fuel Depot, and after about one year the test was finished and the above-mentioned conclusions were obtained.

B. Key Research Personnel Working on Project

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II. DETAILED DESCRIPTION

A. Description of Test Apparatus

Various practical aviation engines were used for bench tests.

Various practical aeroplanes were used for flight tests.

B. Test Procedure and Experimental Results

1. Alcohol-gasoline mixed fuel testing. First, aviation gasoline and alcohol were mixed in the following proportion.

Aviation gaso. 87 octane 50% & alcohol(purity 99%) 50% (spec. 87 Hoi)
Aviation gaso. 85 octane 50% & alcohol(purity 99%) 50% (spec. 85 Hoi)
Aviation gaso. 80 octane 50% & alcohol(purity 99%) 50% (spec. 80 Hoi)
Aviation gaso. 70 octane 50% & alcohol(purity 99%) 50% (spec. 70 Hoi)

Several practical aero-engines were operated with these fuels.

Tempuu 10 type 9 cyls.single row aircooled 300hp max.boost -50mm Hg.
Tempuu 20 type 9 cyls.single row aircooled 500hp max.boost+130mm Hg.
Kotobuki2 type 9 cyls.single row aircooled 500hp max.boost+150mm Hg.
Sakae 10 type 14 cyls.double row aircooled 940hp max.boost+250mm Hg.
Kinsei 40 type14 cyls.double row aircooled1000hp max.boost+200mm Hg.

It was found that the engines could be operated under the following conditions. (See Table I(B)17)

These performances were confirmed by flight tests with the following aeroplanes; that is.

93 type medium training plane(with Tempuu 10 type engine)
Shiragiku(training plane with tempuu 20 type engine)
90 type training plane(with Kotobuki 2 type engine)
Zero-fighter (with Sakae 10 type engine)
96 type torpedo-bombing aeroplane(with Kinsei 40 type engine)

Increasing the fuel consumption in these tests was performed by enlarging the fuel nozzle area of the engine carburettor. The power to boost pressure was the same as gasoline. During the tests, corrosion of aluminium materials in the fuel pass was discovered, and 0.005 gm/liter of sodium-arsenite was added to the mixed fuel to prevent corrosion by orders of the First Naval Fuel Depot.

2. Alcohol Fuel Testing. Immediately after the engine test with the alcohol-gasoline mixed fuel was finished, the fuel was changed to a 94% alcohol (spec. No. 2 alcohol) alone, and experiments made with the following engines.

Homare 20 type 18 cyls.double row aircooled 2000hp max.boost+500mmHg.
Kasei 20 type 14 cyls. double row aircooled 1750hp max.boost+450mmHg.
Atsuta 30 type 12 cyls.inverted Vee watercooled1400hp max." +325mmHg.
Sakae 30 type 14 cyls. double row aircooled 1150hp max.boost+300mmHg.
Tempuu 10 type
Tempuu 20 type
Kotobuki 2 type
Sakae 10 type
Kinsei 40 type
} same as before

Using No. 2 alcohol, trouble occurred in acceleration in all engines except Kasei, 20 type and the Atsuta 30 type (solid injection), when the power was varied from dead slow to medium power. Then 99% alcohol (No. 1 alcohol) was applied to the above carburettor engines, and it was found that the engines could be operated under the following conditions: (See Table II(B)17)

(These performances were confirmed by flight tests using the following aeroplanes.)

93 type training plane (with Tempuu 10 type engines)
Shiragiku (training plane with Tempuu 20 type engine)
90 type training plane (with Kotobuki 2 type engine)
Zero fighter (with Sakae 10 type engine)
96 type torpedo-bombing aeroplane(with Kinsei 40 type engine)
Shiden (fighter with Homare 20 type engine)
Raiden (fighter with Kasei 20 type engine)
Suisei (diving bomber with Atsuta 30 type engine)
Zero fighter (with Sakae 30 type engine)

~~In these tests, fuel consumption was increased by enlarging the fuel~~ nozzle area of the engine carburettor.

To prevent the corrosion of aluminium materials in the fuel pass, sodium arsenite was added to the alcohol, but the effect was not sufficient, so the materials were coated with an electric oxidation oxide film.

When high power flights were made, vibration occurred, but there was no time to investigate these troubles. Moreover, when a relatively lean mixture ratio was taken to avoid this vibration, because of the bad distribution of alcohol to each cylinder, (this was thought to be one of the chief reasons causing the vibration), a very high exhaust gas temperature was reached; that is, over 800°C. This tendency was very severe in flight tests, because of the use of long exhaust passes, Zero fighters with Sakae 30 type engine and also with 10 type engine could not fly with a boost over zero mm Hg.

Other marked troubles caused by alcohol were bad starting and bad acceleration. It was thought that these were caused by the high latent heat of alcohol as well as bad distribution. Normal aviation gasoline was used only for starting, and was contained in one of the gasoline tanks or a special starting gasoline tank of 5 liters. No good counter-measure was devised to prevent bad acceleration, but adjustment of slow nozzle or slow vernier nozzle was somewhat effective. Moreover, careful attention was necessary during quick acceleration. Even in small power engines, such as Tempuu 10 type, 20 type, and Kotobuki 2 type, starting and acceleration were not satisfactory, so that 3% of ethyl ether was added to No. 1 alcohol with good results.

In winter, misfire of ignition plugs in these low power engines occurred, and as a counter-measure the cylinder heads were covered with asbestos cords.

III. CONCLUSIONS

This test was started only about a year before the war ended. Alcohol was used in training the air corp, only about two or three months before the war ended. The research period was too short to obtain good conclusions. Moreover, even a sufficient amount of alcohol for these tests could not be obtained.

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Table I(B)17
OPERATIONAL CONDITIONS FOR AEROENGINES

Engines	Fuel	Consumption increase (by vol.)	Allowable max. boost with alcohol-gasoline mixed fuel	Allowable max. boost with the ordinary gasoline	Power rate
Tempuu 10 type	70 Hoi	nothing	-50mm Hg	-50mm Hg	full power
Tempuu 20 type	85 Hoi	25%	130mm Hg	130mm Hg	full power
Kotobuki 2 type	80 Hoi	10%	150mm Hg	150mm Hg	full power
Sakae 10 type	87 Hoi	30%	50mm Hg	250mm Hg	80% power
Kinsei 10 type	87 Hoi	30%	60mm Hg	200mm Hg	85% power

Table II(B)17
ALCOHOL FUEL UTILITY TEST DATA

Engines	Alcohol	Consumption Increase	Allowable max. boost with the Alcohol	Allowable max. boost with the Ordinary Gasoline	Power Rate
Homare 20 type	No. 1	65 %	150 mm Hg (over +90 mm with supplementary fuel)	500 mm Hg (over +125mm with supplementary fuel)	70% power
Kasei 20 type	No. 2	70 %	200 mm Hg (over +50 mm Hg with supplementary fuel)	450 mm Hg (over +160 mm Hg with supplementary fuel	85% power
Atsuta 30 type	No. 2	70 %	250 mm Hg	325 mm Hg	95% power
Sakae 30 type	No. 1	65 %	120 mm Hg	300 mm Hg	85% power
Tempuu 10 type	No. 1	70 %	− 50 mm Hg	50 mm Hg	full power
Tempuu 20 type	No. 1	70 %	130 mm Hg	130 mm Hg	full power
Kotobuki 20 type	No. 1	70 %	150 mm Hg	150 mm Hg	full power
Sakae 10 type	No. 1	70 %	50 mm Hg	250 mm Hg	80% power
Kinsei 40 type	No. 1	70 %	60 mm Hg	200 mm Hg	85% power