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# LEXINGTON PROJECT REPORT

## No. 20

## RELATION BETWEEN ENGINE AND AIRPLANE CHARACTERISTICS

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Lexington Project Report # 20

Subject: Relation Between Engine and Airplane Characteristics
Lecturer: Benjamin Pinkel (NACA)
Notes by: Charles Marion
Date: June 10, 1948
Place: Lexington

Summary: Mr. Pinkel states that the characteristic numbers in the subject relation are thrust/unit frontal area; thrust/unit engine weight; and pounds fuel/hour/pound thrust. He develops a relation between range, gross weight, engine weight, structural load and disposable load. A tabulation is made of the performances of various supersonic and subsonic airplanes; and the thrusts of turbojets and turboprops are compared.

## Military Aircraft

Various types require different characteristics -- bombers, fighters, etc. We shall consider long-range airplane types.

## Power Plant

1. Power plant is designed for cruise conditions.
2. Take-off conditions are different from those in cruising -- assisted take-off is used if necessary.
3. Three numbers are characteristic of engine,
   a. Thrust/unit frontal area of engine, F/A -- use because net thrust is performance criterion -- drag proportional to frontal area.
   b. Thrust/unit engine, $F/W_e$ -- weight affects lift requirement. Engine weight distinguished from fuel and useful loads.
   c. Pounds fuel/hour/pound thrust.

Using conventional aerodynamic relations and present-day knowledge, NACA has obtained predicted performance characteristics for several types of aircraft. These are shown in the following table where:

$V$ = Velocity of flight (m.p.h.)
$F$ = Thrust (lb.)
$A$ = Frontal Area (sq. ft.)
$W_e$ = Engine Weight (lb.)
$W_f$ = Fuel Consumption (lb./hr.)
$W_d$ = Useful load (lb.)
$W_g$ = Gross Weight (lb.)

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| | V | Alt. (feet) | F/A | $F/W_e$ | $\frac{W_f}{F}$ | $\frac{W_d}{W_g}$ | $\frac{W_f}{W_g}$ | Range (miles) |
|---|---|---|---|---|---|---|---|---|
| | 200 | 0 | 180 | .61 | .265 | .51 | .156 | 6000 |
| Reciprocating | 200 | 30,000 | 230 | .58 | .220 | .50 | .122 | 7000 |
| | 500 | 30,000 | 92 | .275 | .56 | .34 | .158 | 3900 |
| Turbojet | 200 | 0 | 385 | 1.20 | .285 | .56 | .16 | 6200 |
| not best | 200 | 30,000 | 180 | .55 | .247 | .50 | .14 | 6500 |
| but current | 500 | 30,000 | 80 | .30 | .644 | .36 | .182 | 3600 |
| | 200 | 0 | 780 | 2.40 | 1.21 | .58 | .55 | 1920 |
| | 200 | 30,000 | 300 | .85 | .92 | .54 | .52 | 2220 |
| Turbojet | 500 | 30,000 | 320 | .99 | 1.10 | .54 | .26 | 3700 |
| | 1400 | 30,000 | 950 | 5.30 | 1.63 | .60 | 1.20 | 910 |
| | 2000 | 30,000 | 5000 | 11.5 | 2.00 | .67 | 1.10 | 1100 |
| Ramjet | 2000 | 50,000 | 2000 | 8.5 | 1.94 | .68 | .62 | 2000 |

The calculations for the supersonic airplane were made on the assumption of $L/D = 7$ for wing only. It was then necessary to resort to trial and error for the required fuselage and nacelles.

Considering a turboprop versus a turbojet:

For turboprops

$$S.H.P. \simeq \frac{F\,V}{375}$$

$$N_p S.H.P. = \frac{F\,V}{375}$$

where

S.H.P. = shaft horsepower
F = thrust
V = velocity of flight
N = efficiency
M = mass of air

if it be assumed that $N_p$ and S.H.P. are approximately independent of V, then F varies inversely with V.

For turbojets

$$N_j = \frac{2V}{V_j + V} = \frac{2}{\frac{V_j}{V} + 1} \quad ; \quad F = M(V_j + V)$$

It turns out that F is almost independent of V.

Calculations have also been made for a nuclear steam power plant driving a plane 500 m.p.h. at 30,000 ft. $W_d/W_g$ was found to be 0.41 with turbine inlet pressure of 1400 psia and temperature 866°F. This means 0.41 of $W_g$ was available for the nuclear reactor and useful load. Turbine exhaust pressure was 50 psia for optimum conditions. Heat may be rejected in exchangers which act as jets to partially overcome their drag. The steam condenser was hung in a nacelle below the plane.

Additional References: NACA RM. No. E 7 J01
RM. No. E 8

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