Investigation of blocking struts for changing the final nozzle area of a jet engine

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SECURITY CLASSIFICATION CONFIDENTIAL

SUBJECT INVESTIGATION OF BLOCKING STRUTS FOR CHANGING THE FINAL NOZZLE AREA OF A JET ENGINE.

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ISSUED TO INTERNAL

SUMMARY

A blocking strut principle was applied to obtain a variable-area final nozzle for a reheated engine. Three different strut profiles were tested using a specially designed balance for measuring the strut drag. The short profile with bluff trailing edge was found preferable to the aerodynamical profile with long chord.

INVESTIGATION OF BLOCKING STRUTS FOR CHANGING THE FINAL NOZZLE AREA OF A JET ENGINE

INTRODUCTION

A variable-area nozzle is desirable for a reheated jet engine. As one of many methods of changing the area of the final nozzle, a blocking strut can be employed which would be removed (for instance, pivoted on a hinge) during the run of the engine on reheat, thus increasing the area of the nozzle. Without reheat, the strut swung into position, would give the smaller nozzle area.

TEST APPARATUS

An Orenda Mk. 14 jet engine with reheat installation, mounted in Test Cell No. 2, was used for tests. The tailpipe diameter was 24 ins., the final nozzle diameter 21 ins. For strut tests the engine was run without reheat.

Three blocking struts of 20 in. length, made from 16-gauge Inconel, were tested. They are shown in Figure 4. The profiles were chosen, on the recommendation of High Speed Aerodynamics Laboratory, as follows:

Profile A: NACA 0024, maximum thickness 3.7 in., chord 11.1 in.
Profile B: NACA 66_2-015, maximum thickness 3.7 in.,chord 7 in.
Profile C: Profile B up to the maximum thickness 3.7 in., then cut to bluff trailing edge, mounted on the 20 x 3 x 1/2 in. bar.

During the tests the maximum thickness of the strut profile was held in the plane of minimum cross-section of the nozzle, thus giving the maximum blockage.

It was known from previous experience (Refs. 1 and 2) that small differences in drag cannot be accurately determined by measurements with the test bed thrustmeter. A specially designed balance was therefore used, which enabled direct measurements of the drag to be taken. This arrangement is shown in Figures 1, 2 and 3. The exposure of the crew to the engine noise and exhaust gases prevented the use of weights as described in Reference 1, and instead a 2000-lb. spring dynamometer was installed, as shown in Figure 1. The balance was levelled during the tests, using a hand winch (Fig. 1).

TEST RESULTS AND DISCUSSION

The drag depends on $p.M^2$, where p is the static pressure and M the Mach number (See, for instance, Ref. 3). The measured values were therefore reduced to standard ambient pressure and plotted against corrected engine speed.

The results of the tests were rather surprising, as may be seen from Figure 5. The expected behaviour of the struts was found only at lower engine speed. That is, the lowest drag was measured for strut A, and the highest for strut C. However, this speed is of minor practical importance. For higher engine speeds, especially at and over the critical pressure ratio 1.85 (choking condition, Fig. 6), the drag curves A and C are practically the same. Strut B shows, at these speeds, about 10% higher drag (Fig. 5).

Figure 7 shows the corresponding thrust figures obtained with the struts tested, and Figure 8 the fuel flows and turbine outlet temperatures.

CONCLUSIONS

At higher engine speeds of about 7200 r.p.m. and over, the blocking strut C with short profile and bluff trailing edge, showed the same drag as the strut A with long profile. It is easier, from the design point-of-view, to install and operate the strut C, than A, and therefore strut C is to be preferred.

REFERENCES

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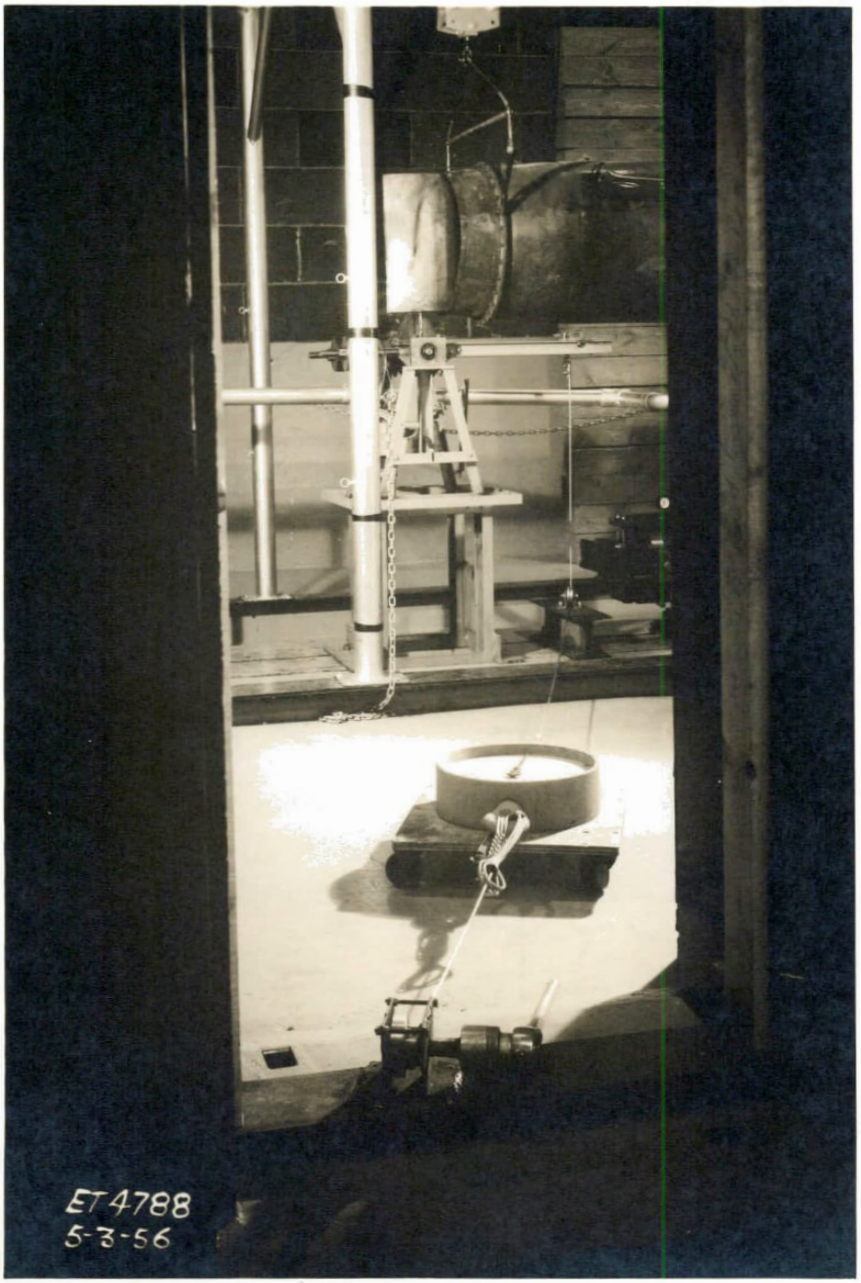


FIG. I GENERAL VIEW OF TEST INSTALLATION

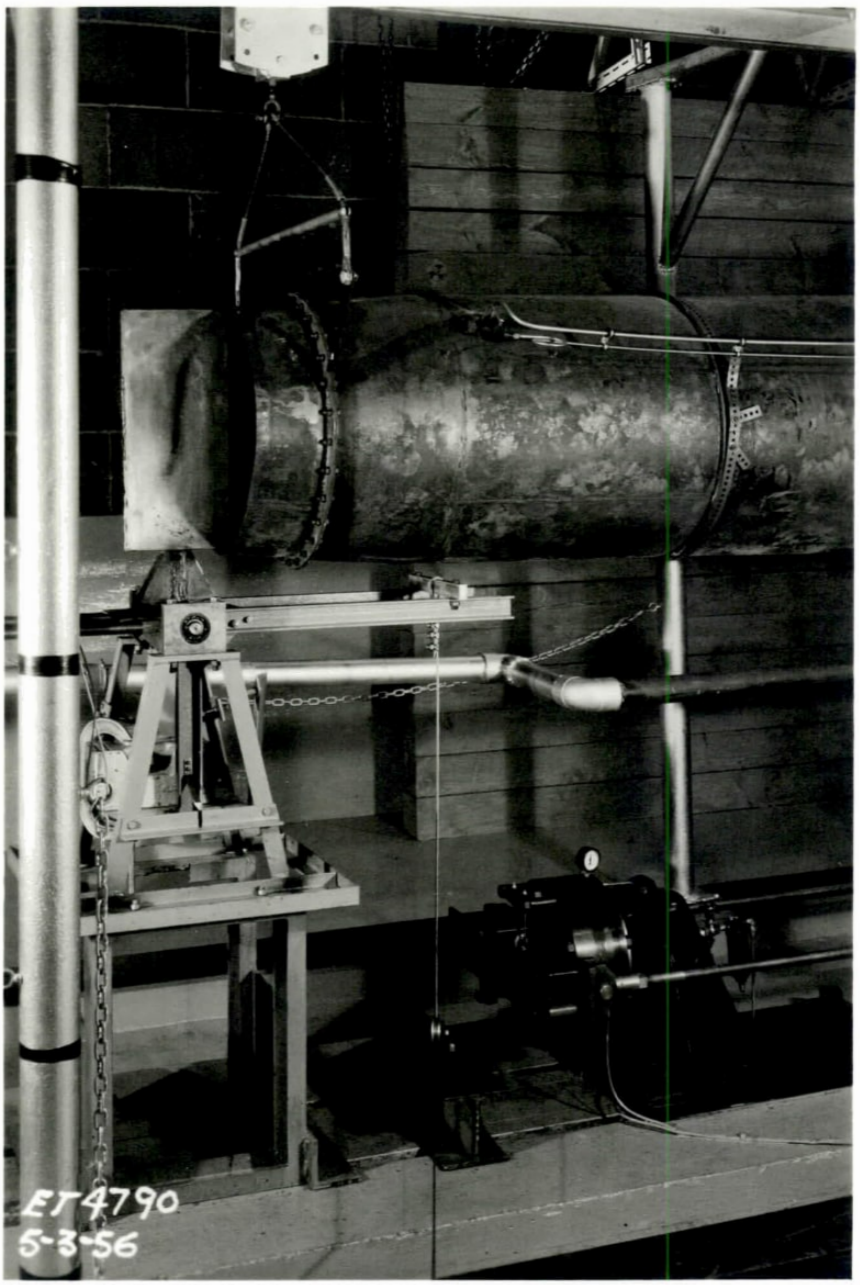


FIG. 2 DETAILS OF TEST INSTALLATION

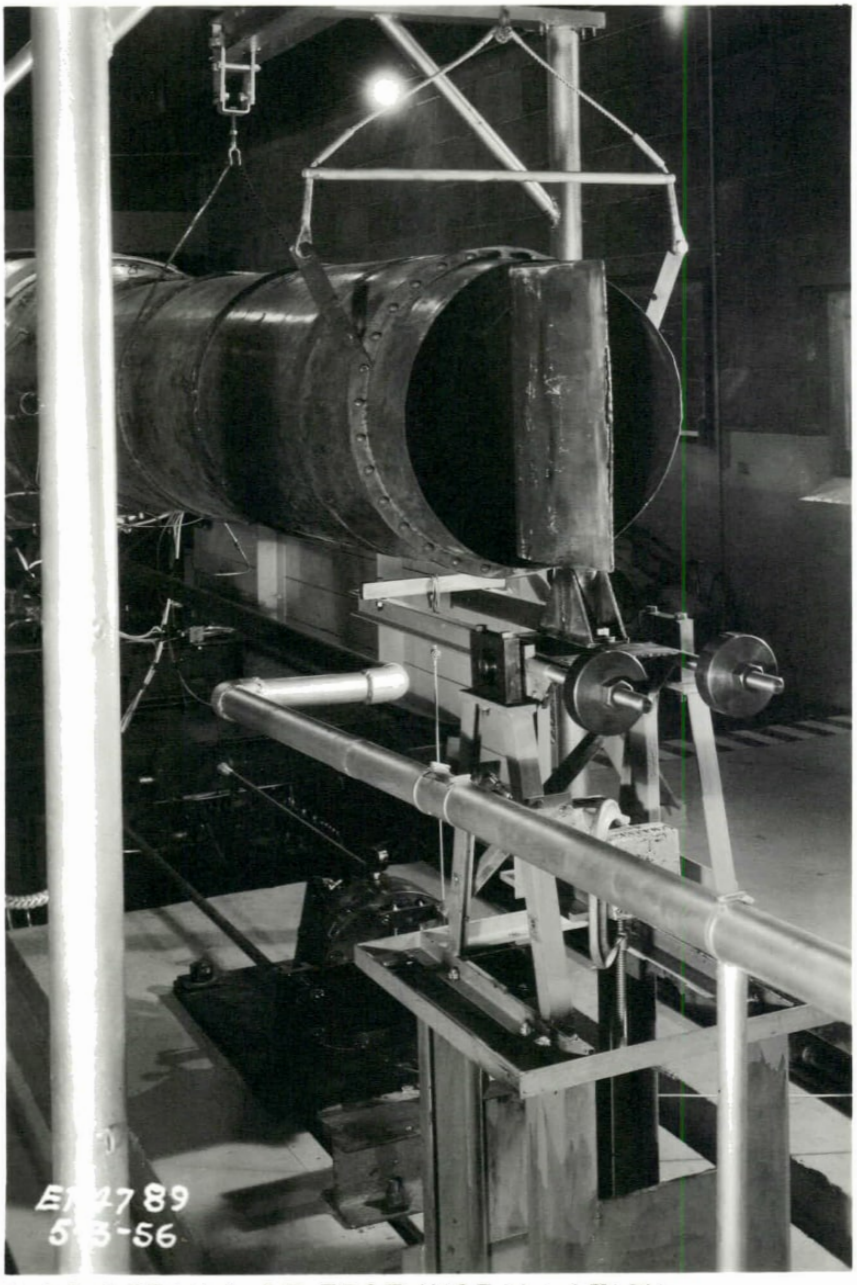
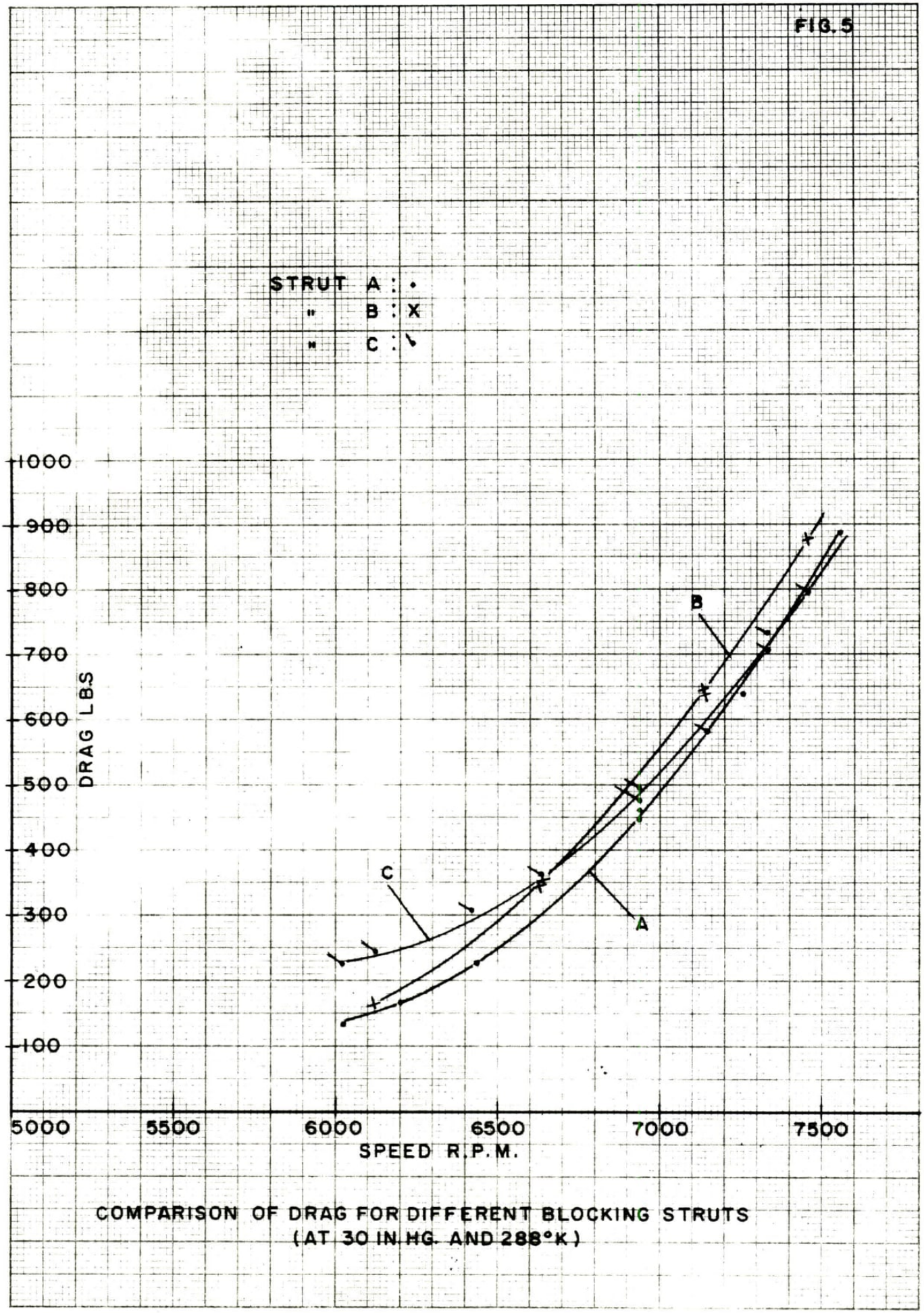


FIG.3 DETAILS OF TEST INSTALLATION

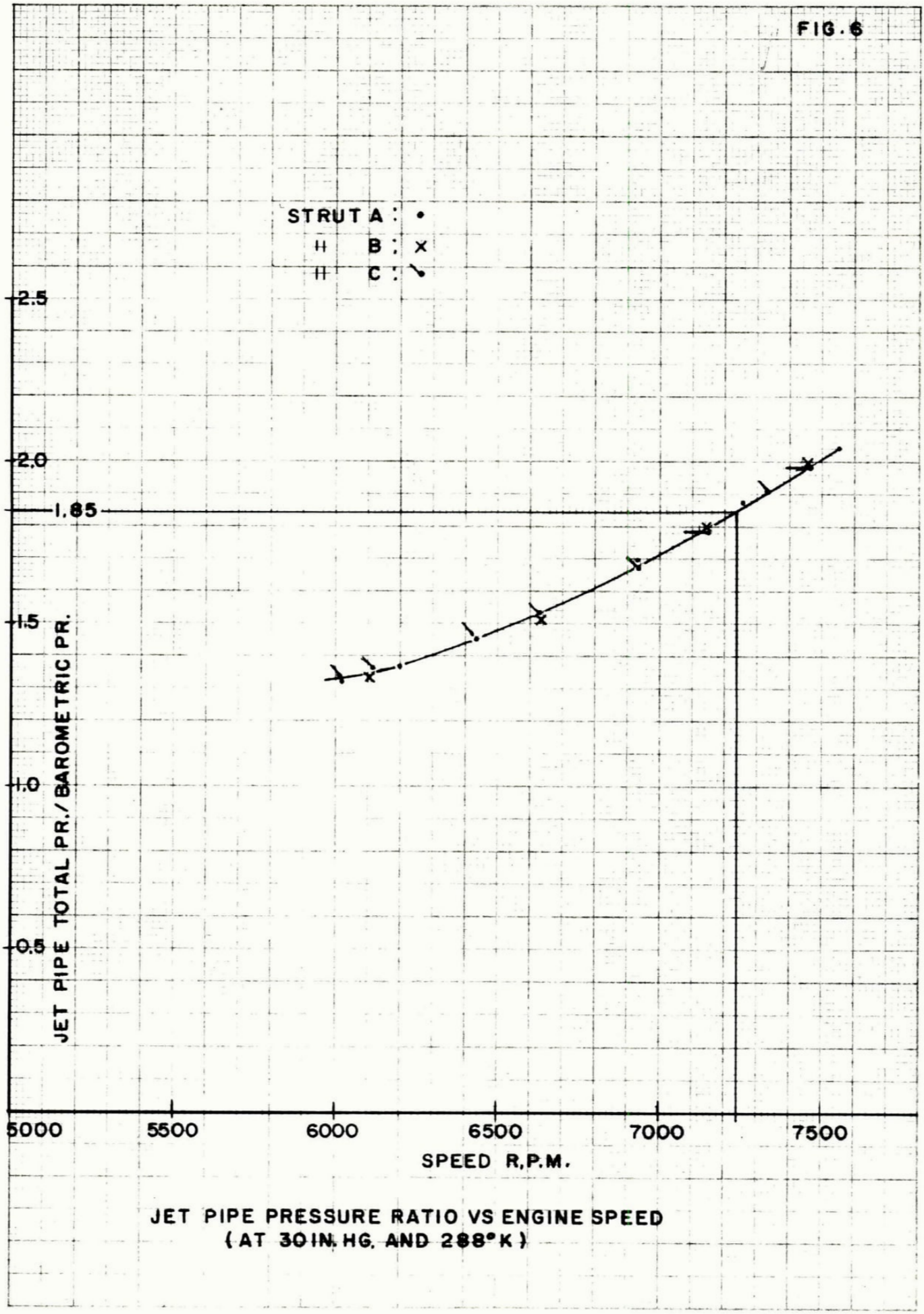
FIG. 4 BLOCKING STRUTS TESTED

FIG. 5



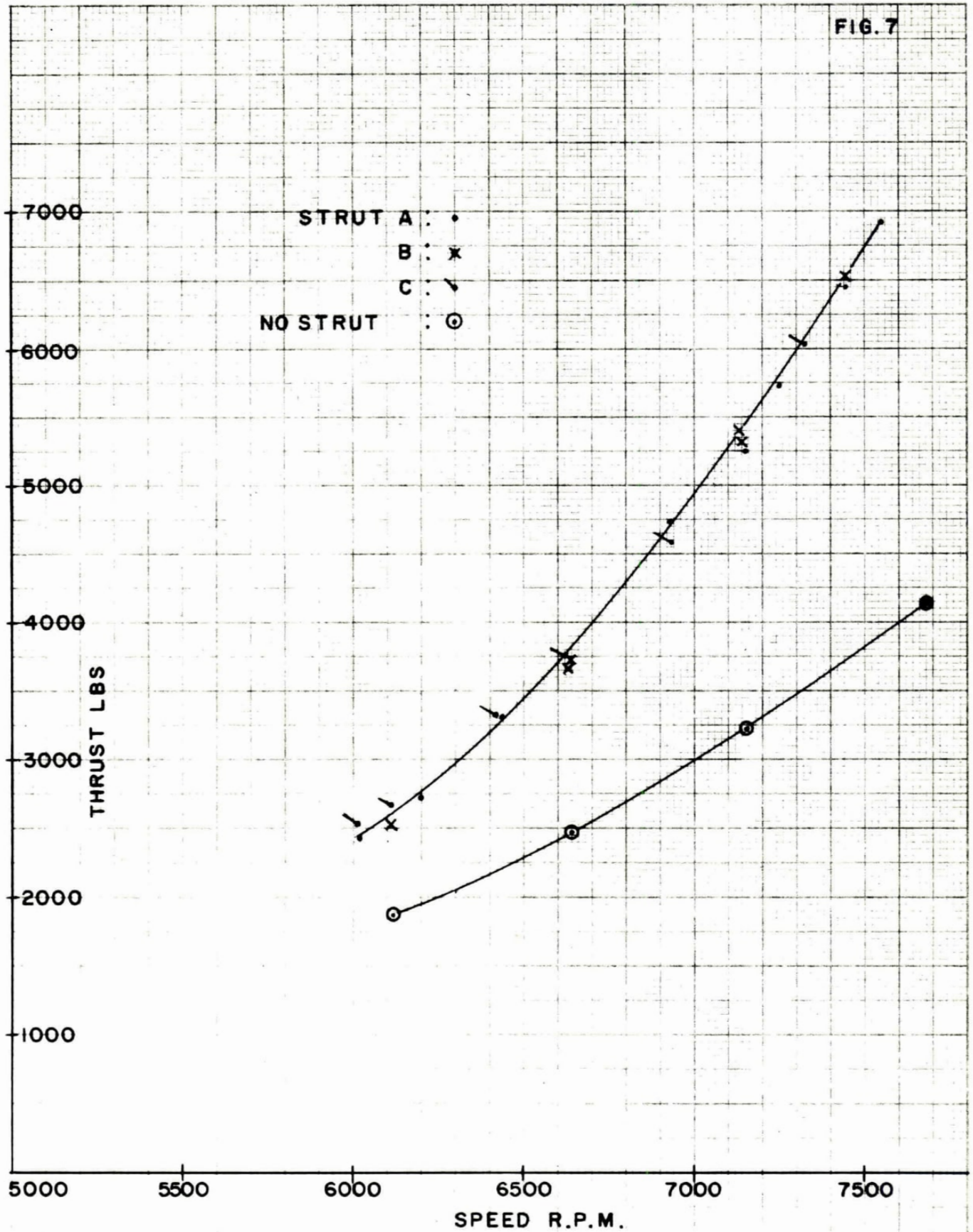
COMPARISON OF DRAG FOR DIFFERENT BLOCKING STRUTS
(AT 30 IN. HG. AND 288°K)

FIG. 6



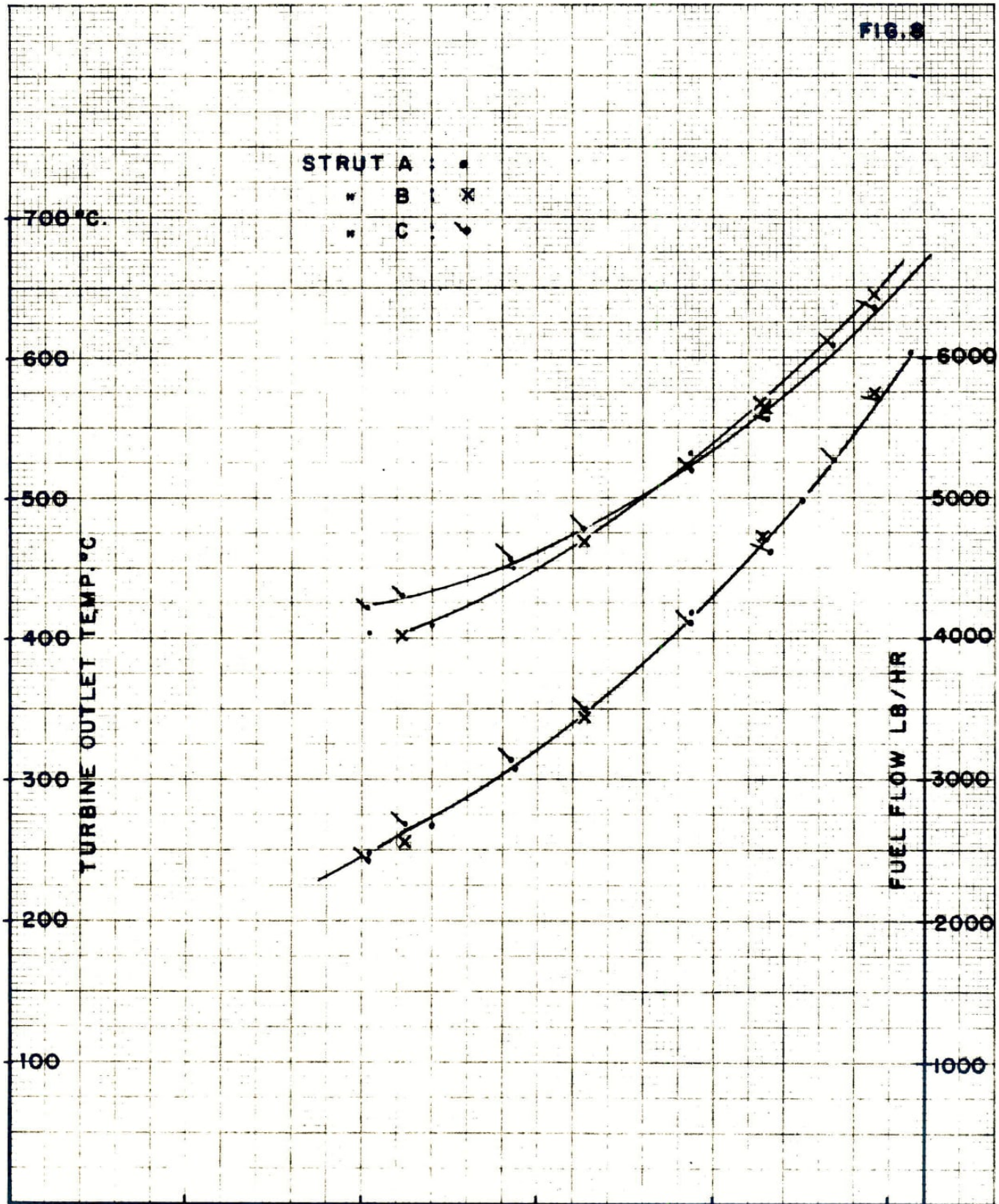
JET PIPE PRESSURE RATIO VS ENGINE SPEED
(AT 30 IN. HG. AND 288°K)

FIG. 7



ENGINE THRUST FOR DIFFERENT BLOCKING STRUTS
(AT 30 IN. HG. AND 288°K)

FIG. 8



FUEL FLOW AND TURBINE OUTLET TEMP. FOR DIFFERENT STRUTS

(AT 30 IN. HG. AND 288° K)