NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

# WARTIME REPORT

ORIGINALLY ISSUED
December 1942 as
Memorandum Report

## FLIGHT TESTS OF NACA JET-PROPULSION EXHAUST STACKS ON THE SUPERMARINE SPITFIRE AIRPLANE

By L. Richard Turner and Maurice D. White

Langley Memorial Aeronautical Laboratory
Langley Field, Va.



WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command
and the
Bureau of Aeronautics, Navy Department

# FLIGHT TESTS OF NACA JET-PROPULSION EXHAUST STACKS ON THE SUPERMARINE SPITFIRE AIRPLANE

By L. Richard Turner and Maurice D. White

## SUMMARY

The Supermarine Spitfire airplane was equipped with exhaust stacks designed according to the jet-propulsion exhaust-stack system developed by the NACA. An increase in the high speed of the airplane of 6 miles per hour at constant propeller thrust horsepower was obtained as compared with the airplane equipped with the Rolls Royce exhaust system.

No differentiation between the effects of reduced drag and increased exhaust jet thrust was possible.

The exhaust flame produced with the NACA exhaust stacks was greater than that with the Rolls Royce stacks under some conditions. Neither system is believed to be satisfactory as regards flame damping.

## INSTALLATION AND TESTS

An exhaust-stack system having a separate nozzle with an exit area of 1.8 square inches for each exhaust port was fitted to the Supermarine Spitfire airplane, number W-3119 equipped with a Rolls Royce Merlin XLV engine, number 37147, (figs. 1, 2, and 3). These stacks were designed by the method of reference 1 except that the nozzle exit area was increased by 10 percent; this modification was indicated by later tests on similarly shaped exhaust pipes at the NACA.

The airplane equipped with Rolls Royce exhaust stacks is shown in figures 4 and 5.

The relative performance of the airplane with the two exhaust systems was determined by measuring the high speed of the airplane with each installation. The runs were made at a constant density altitude several thousand feet higher than the critical altitude of the engine; in this region the true airspeed of the airplane at a constant engine speed and full throttle is essentially independent of altitude and air temperature.

In order to establish the high speed more accurately, measurements were made in level flight not only with full throttle but also with several partial throttle settings, maintaining constant altitude and engine speed for all runs.

## INSTRUMENTS

To determine airspeeds a swiveling pitot-static head was mounted on a boom ahead of the wing and connected to a standard NACA airspeed recorder. Position errors for the installation were not established since they are generally small for the location used and appeared to be an unnecessary refinement for the present comparative tests.

The static-pressure element of the airspeed head was connected to an indicating altimeter to determine pressure altitudes. An indicating bimetallic thermometer mounted on the wing was read at about 120 miles per hour at the test altitude to establish free-air temperatures.

An indication of the propeller thrust was obtained by determining the increment in total head above the free-stream value of a point a short distance behind the propeller. Previous tests on another airplane equipped with a torque dynamometer had shown this difference to be an accurate index of propeller thrust.

## RESULTS AND DISCUSSION

Performance. - The results of the performance tests are presented in figure 6 where the difference in total head (thrust indication) is plotted against true airspeed, all values being corrected for compressibility. Comparing results on the basis of equal propeller thrust horsepower, it is apparent that the NACA exhaust stacks effected a speed increase over the original stacks of 6 miles per hour.

For reference purposes the flight data corresponding to the points obtained are tabulated in table I.

In figure 6 the designation "calculated contour of equal propeller thrust horsepower," which applies to the curve representing a constant product of true airspeed and total-head difference, is probably not exact. The total-head difference used in this calculation may not actually have varied linearly with thrust, but may have merely varied consistently with thrust. The error involved in utilizing the total-head difference in this manner for the range indicated, however, does not appear great, as shown by the adherence of the two full-throttle points to the calculated curve.

Available data on power characteristics of the two arrangements are shown in figure 7, where the propeller thrust horsepower index, computed in terms of the thrust indication, is plotted against manifold pressure as indicated on the airplane gage. The results indicate that for a given manifold pressure there was no loss in propeller thrust horsepower due to the NACA stacks.

It should be noted, however, that the test program did not contemplate power measurements and that the precision of the manifold pressure readings was accordingly low. No attempt to draw precise conclusions from the plotted data should, therefore, be made.

Also, it is not possible from these tests to distinguish between the effects of form drag and exhaust jet thrust of the two installations.

Exhaust-flame visibility. - Ground observations to compare the exhaust-flame visibility of the two installations were made at night on two occasions. There appeared to be little choice between the two installations as regards flame-damping characteristics, although in some conditions the flame produced by the NACA stacks was greater; both were considered unsatisfactory.

Further, there was no noticeable difference in visibility, heat, or exhaust smell in the cockpit.

## CONCLUSIONS

1. A set of exhaust stacks, designed according to the NACA procedure, at constant propeller thrust horsepower increased the speed of the Spitfire airplane 6 miles per hour as compared with the Rolls Royce type exhaust stacks.

2. The visibility of the exhaust flame was not satisfactory for a night fighting airplane with either set of exhaust stacks.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 7, 1942.

## REFERENCE

1. Pinkel, Benjamin, Turner, L. Richard, and Voss, Fred: Design of Nozzles for the Individual Cylinder Exhaust Jet Propulsion System. NACA A C.R., April 1941.

TABLE I

PILOT'S FLIGHT NOTES

Flight condition: - original stacks. Date of test: - February 3, 1942. The free-air temperature at 120 miles per hour indicated airspeed at 21,780 feet indicated pressure altitude (corrected for scale error, 21,880 feet) was -31° C.

| Run no. | Indicated pressure altitude, ft | Engine rpm | Engine boost, lb/sq in. | |
|---|---|---|---|---|
| 1 | 21,750 | 2980 | 6 | Full throttle |
| 2 | 21,780 | 2980 | 4-1/2 | |
| 3 | 21,780 | 2980 | 3 | |
| 4 | 21,780 | 2980 | 1-1/2 | |

Flight condition: - NACA stacks. Date of test: - February 5, 1942. The free-air temperature at 120 miles per hour indicated airspeed at 21,400 feet indicated pressure altitude (corrected for scale error, 21,500 feet) was -27° C.

| Run no. | Indicated pressure altitude, ft | Engine rpm | Engine boost, lb/sq in. | |
|---|---|---|---|---|
| 5 | 21,380 | 2980 | 6 | Full throttle |
| 6 | 21,380 | 2980 | 4-1/2 | |
| 7 | 21,380 | 2980 | 2-3/4 | |
| 8 | 21,420 | 2980 | 1-1/2 | |
| 9 | 21,480 | 2980 | 0 | |

L-680

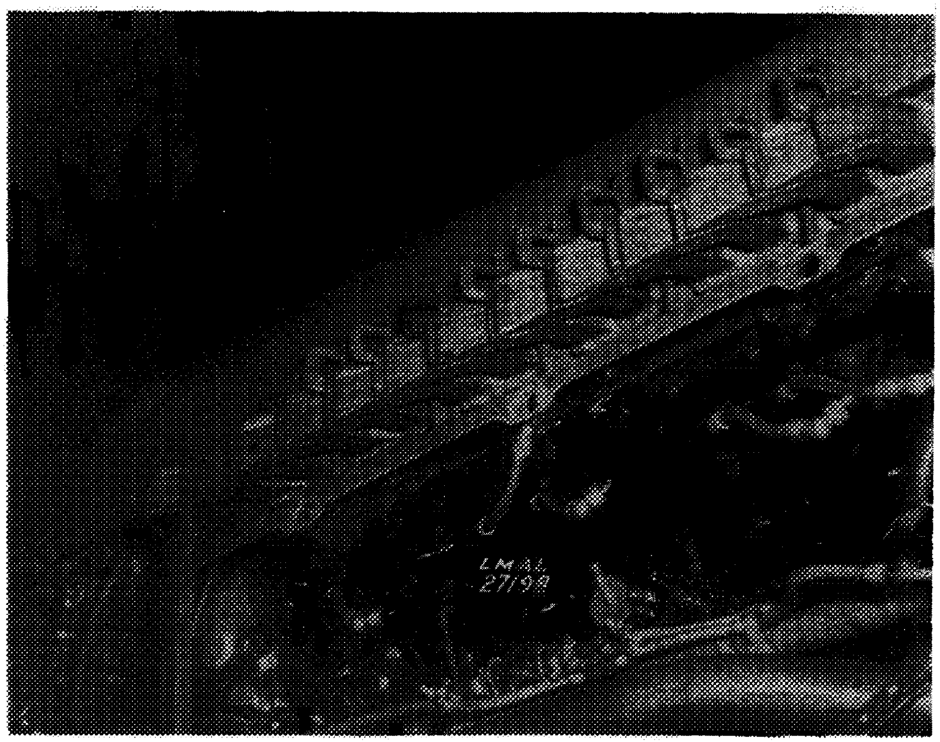



Figure 1.- View of NACA ejector stacks on Spitfire airplane.

L-680

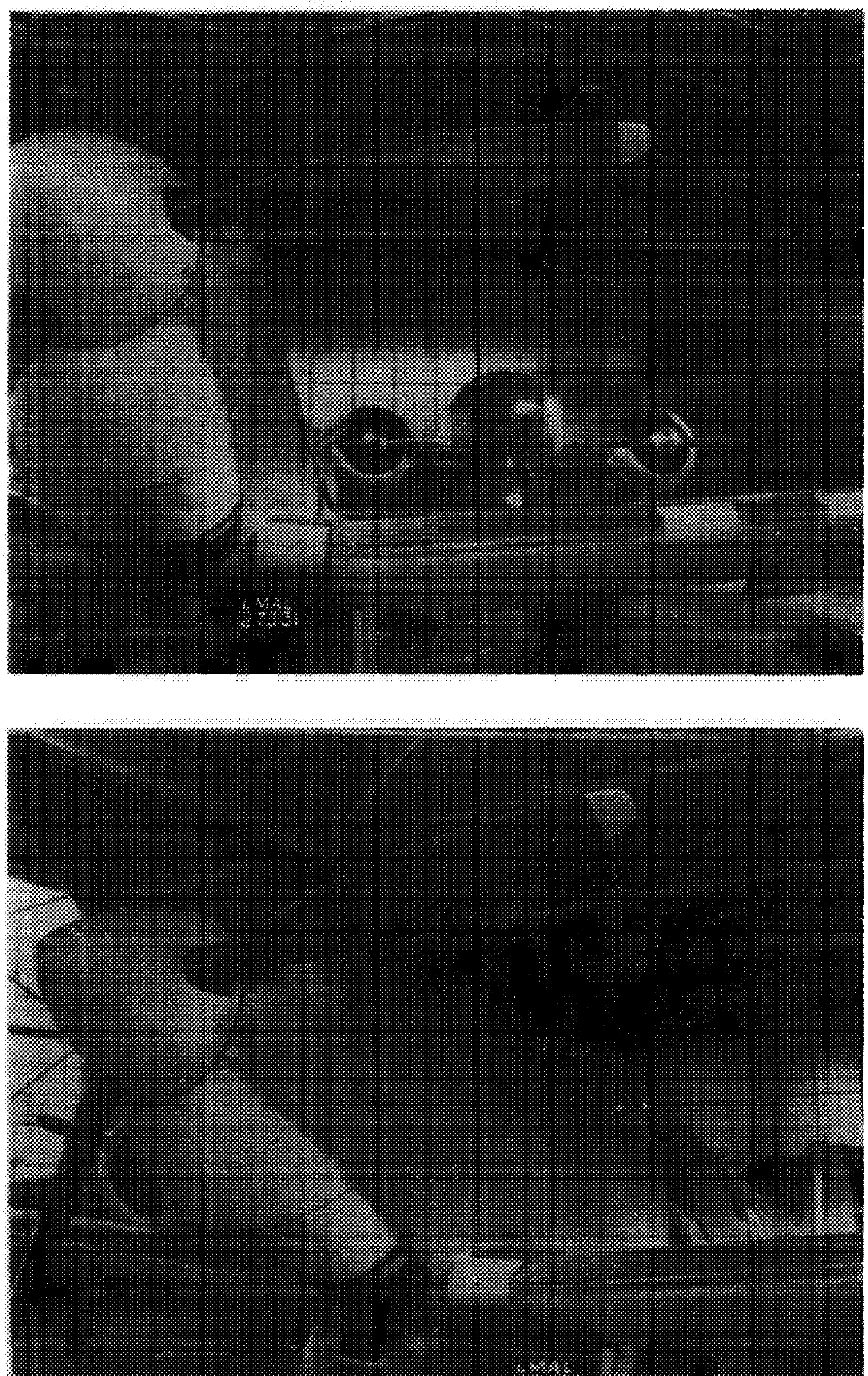


Figure 2.- Views of NACA ejector stacks on Spitfire airplane.

L-680

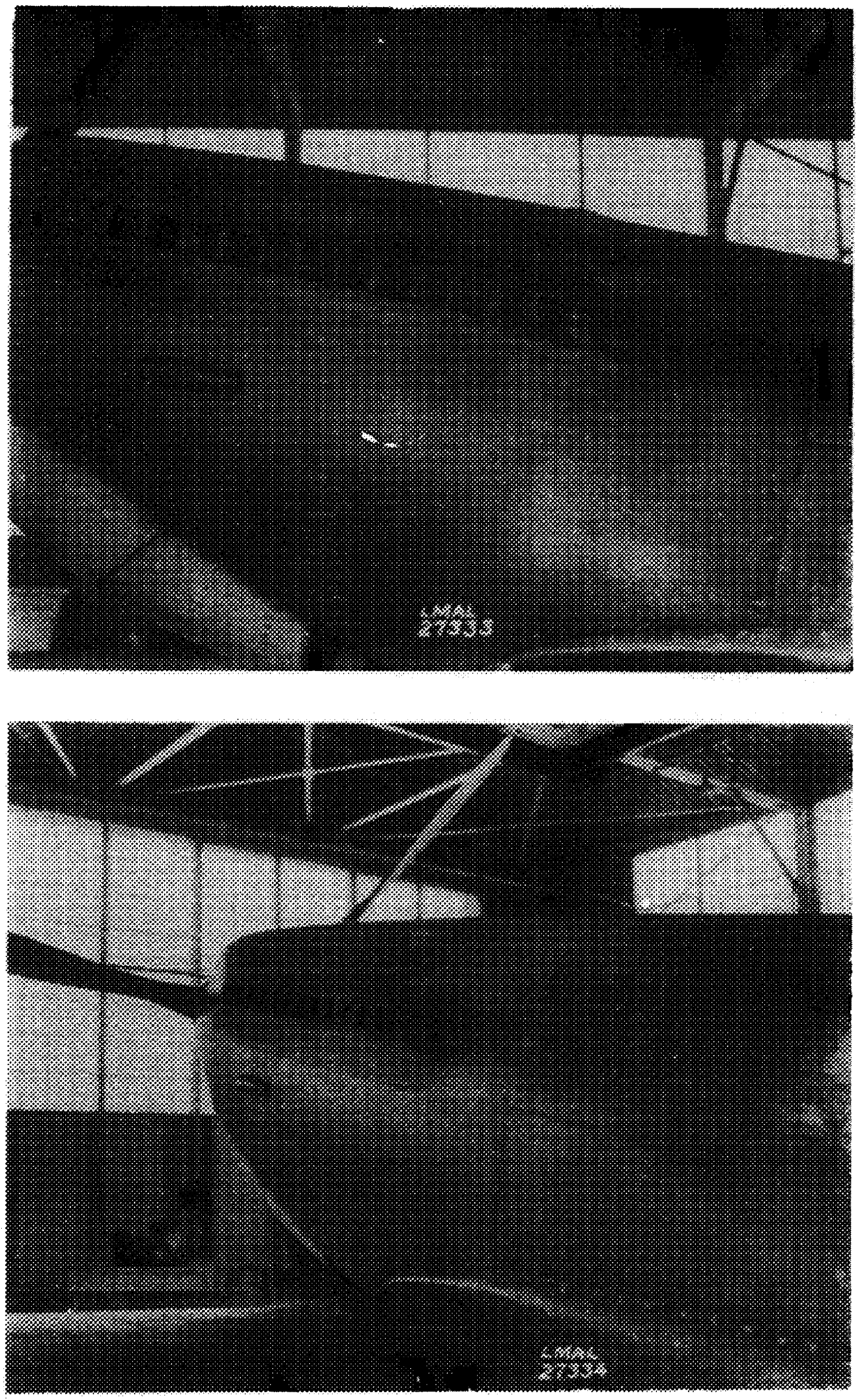



Figure 3.- Views of NACA ejector stacks on Spitfire airplane.

L-680

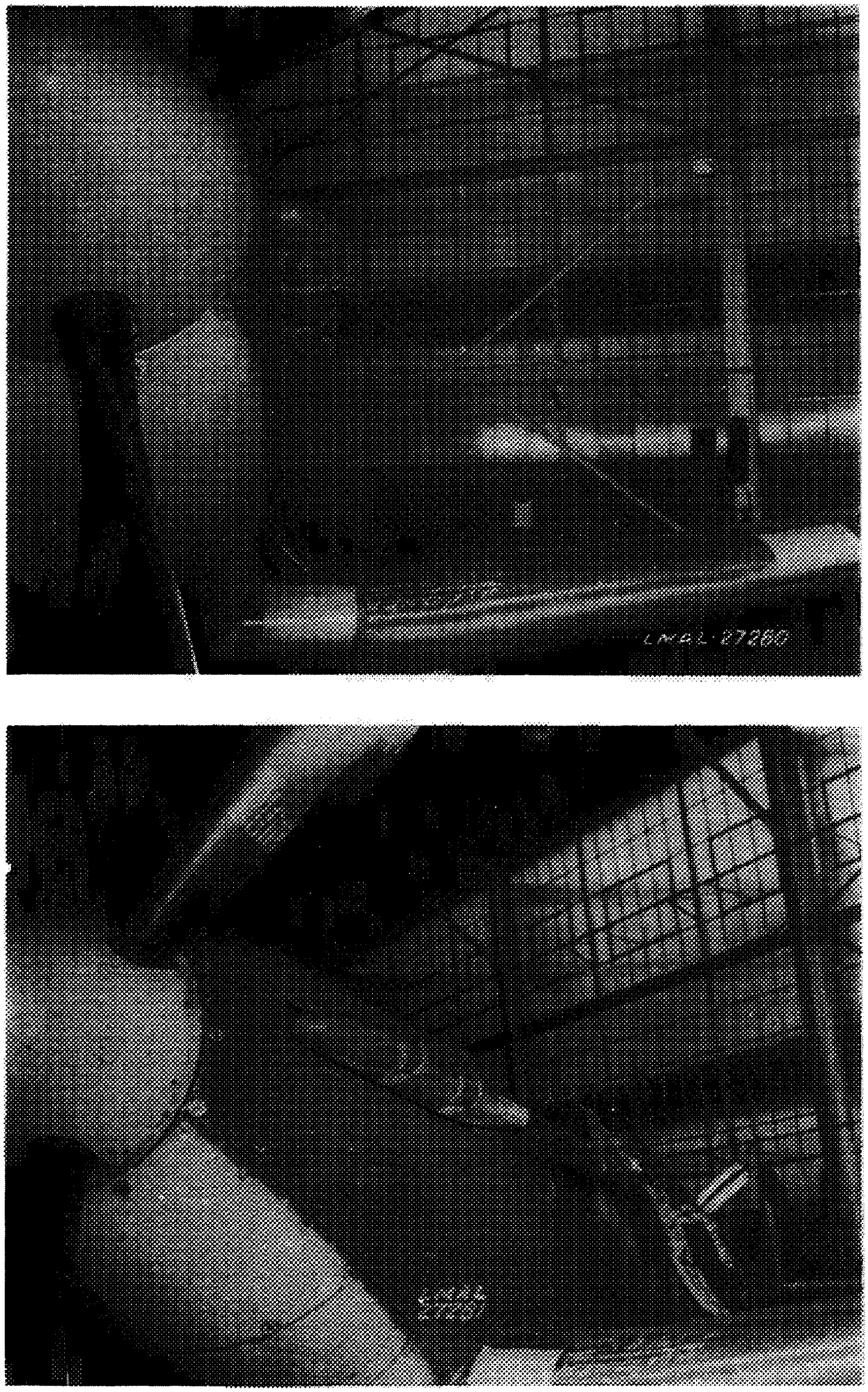
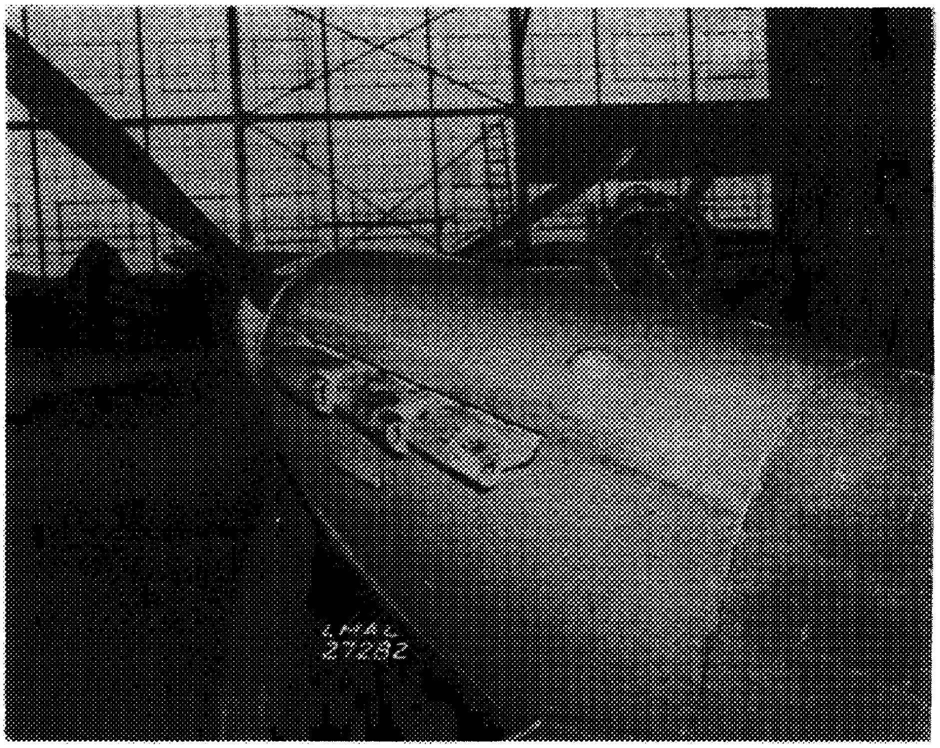



Figure 4.- Views of original exhaust stacks on Spitfire airplane.

L-680



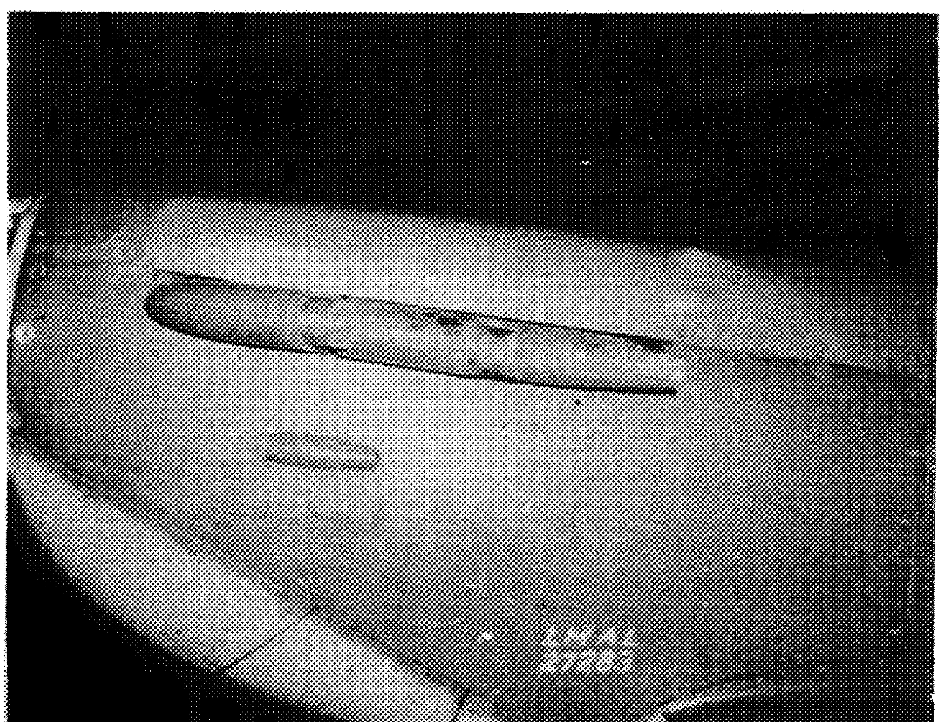




Figure 5.- Views of original exhaust stacks on Spitfire airplane.

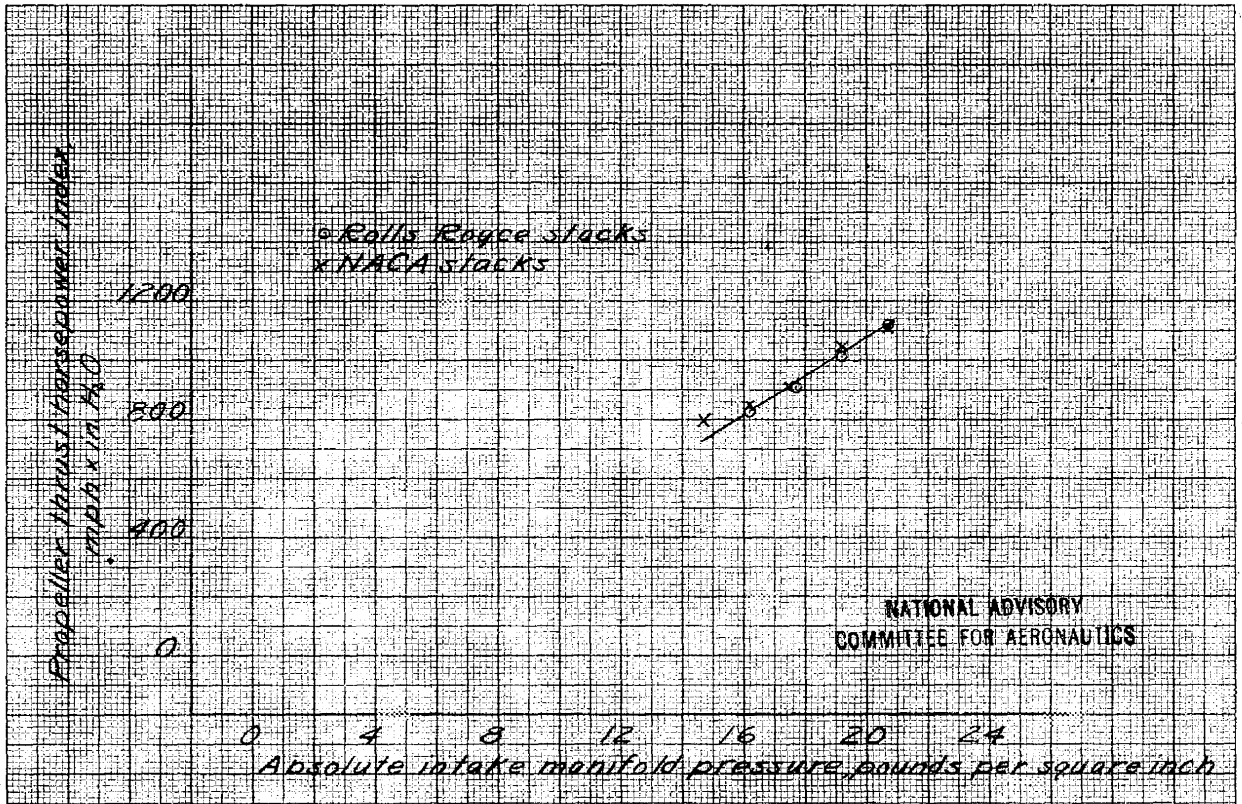



Figure 7.- Power-boost characteristics of the Rolls Royce Merlin XLV engine as determined from flight tests of the Spitfire airplane.

L-680

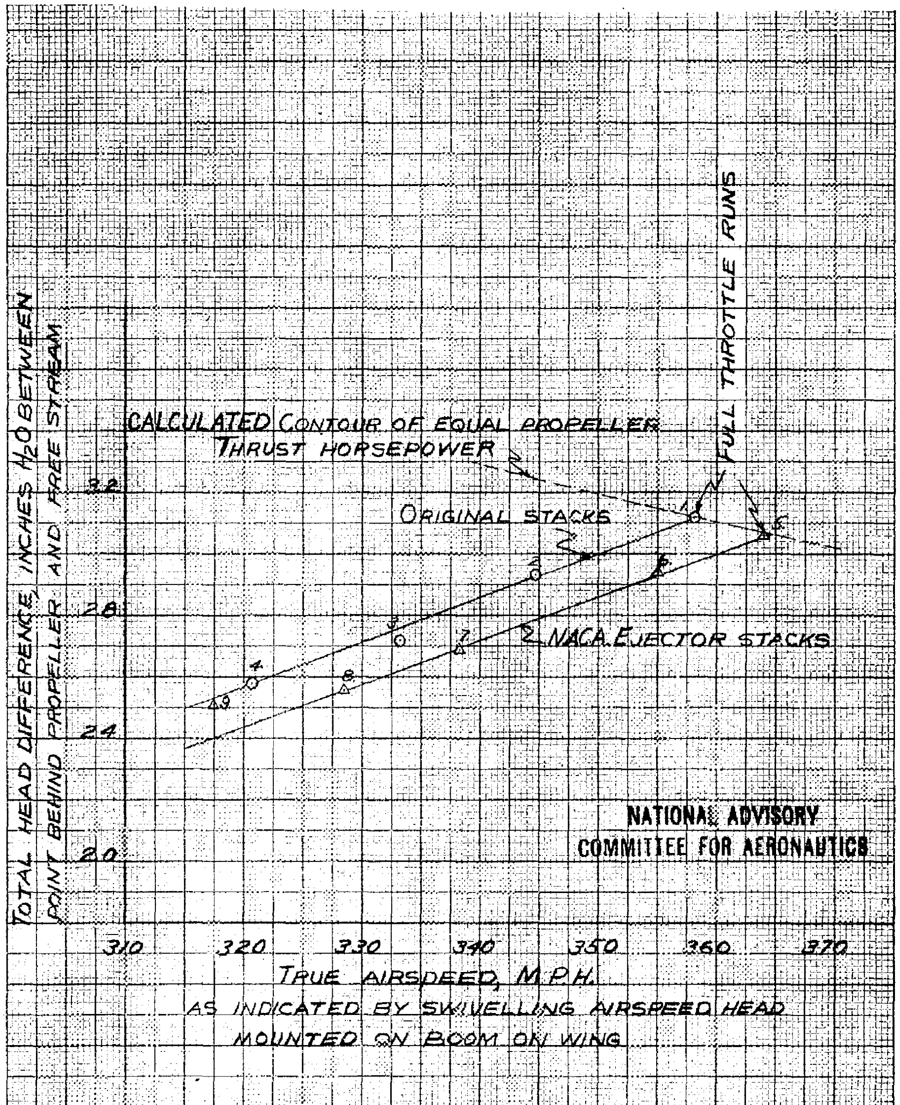



FIGURE 6.- RESULTS OF TESTS OF ORIGINAL EXHAUST STACKS AND NACA EJECTOR STACKS ON SPITFIRE AIRPLANE

RESTRICTED

TITLE: Flight Tests of NACA Jet-Propulsion Exhaust Stacks on the Supermarine Spitfire Airplane

AUTHOR(S): Turner, L. R.; White, Maurice D.

ORIGINATING AGENCY: National Advisory Committee for Aeronautics, Washington, D. C.
PUBLISHED BY: (Same)

ATI- 15625
REVISION (None)
ORIG. AGENCY NO. (None)
PUBLISHING AGENCY NO.

U

| DATE | DOC. CLASS. | COUNTRY | LANGUAGE | PAGES | ILLUSTRATIONS |
|---|---|---|---|---|---|
| Dec '42 | Restr. | U. S. | Eng. | 14 | photos, table, graphs |

ABSTRACT:

Airplane was equipped with exhaust stacks designed according to the NACA system. An increase in speed of the airplane of 6 mph at constant propeller thrust hp was obtained as compared to the airplane equipped with the Rolls-Royce exhaust system. No differentiation between effects of reduced drag and increased exhaust jet thrust was possible. The exhaust flame produced with the NACA exhaust stacks was greater than that produced with the Rolls-Royce stacks under some conditions. Neither system is believed to be satisfactory in regard to flame damping.

EO 10501 dd 5 NOV 1953

DISTRIBUTION: Request copies of this report only from Originating Agency

DIVISION: Flight Testing (13)
SECTION: Propulsion Group (7)

30
5

ATI SHEET NO.: R-13-7-2

SUBJECT HEADINGS: Spitfire - Flight tests (88435); Airplanes, Fighter - Flight tests (08553); Exhaust stacks - Flame damping (34413); Spitfire (88430)

| | | | |
|---|---|---|---|
| | ATI No: | US Classification: | OA No: |
| 9-1-1261 | 16169 | Unclass. | MR-L-680 |

TITLE:
Flight Tests of NACA Jet-Propulsion Exhaust Stacks on The Supermarine Spitfire Airplane 15625

AUTHOR(S):
Turner, L. R.; White, Maurice D.

OA:
National Advisory Committee for Aeronautics

Foreign Title:

CANCELLED - DUPE OF 15625

Previously cataloged under No:

Translation No:

Subject Division:

Section: