REPORT NO. 0-2298

DATE 24 May 1944

FR-2298

SECRET

Report on

INFLUENCE OF ELECTRIC FIELD ON AERODYNAMIC DRAG COEFFICIENT

by

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WASHINGTON, D. C.

DECLASSIFIED

SERIAL No. 33

26 May 1944 [redacted] NRL Report No. 0-2298

FR-2298

Classification changed from Unclassified by authority of Lab. Memo 117-46 ltr. Dated 2-1-46 File No.

UNCLASSIFIED

NAVY DEPARTMENT

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[redacted]

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

No. of Pages:	Text 3	Table 1
Authorization:	BuAero Project Order 832/44 of 30 June 1943	
Date of Tests:	April, May, 1944	

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Distribution:

BuAero	(10)
Joint A-N Committee	(1)
BuShips	(2)
BCSO	(2)
OSRD	(2)
Coord. R & D	(2)
NACA	(3)
Minn. Branch	(1)

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TABLE OF CONTENTS

ABSTRACT

In experiments on a B-25 at Minneapolis under carefully controlled conditions of flight, the application of a free electrical charge to the airplane, approximately equivalent to 100,000 volts impressed thereon, had a less than 1% influence on the total drag. It is concluded that an electric field has no appreciable effect on the drag coefficient.

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INFLUENCE OF ELECTRIC FIELD ON AERODYNAMIC DRAG COEFFICIENT

INTRODUCTION

1. This study was specially authorized by the Director of the Naval Research Laboratory.

STATEMENT OF THE PROBLEM

2. The object of the investigation was to test, in flight, if an electric field on a metallic airplane would modify in an appreciable manner the drag on the airplane airfoils.

KNOWN FACTS BEARING ON THE PROBLEM

3. It is a well known fact that the drag coefficient for a sample airfoil can not be exactly calculated from physical data such as the density of air and its viscosity. In a discussion of the subject matter, with competent aerodynamicists, it was suggested that an electric field acting at the surface of the wing might selectively attract ions to the surface and thereby modify the streamline flow or possibly deposit disturbing momentum in such a way that the resistance of the wing was increased. It is easy to make calculations of the latter hypothesis and the effect turns out to be small. No way is known for estimating the influence of bombarding ions upon the thin turbulent layer of skin adjacent to the airfoil and a crucial experiment seemed to be indicated.

4. Operations of the airplane assigned to the precipitation static work at Minneapolis have shown that the flight of an airplane through even very light snow sometimes results in the conversion of the forward mechanical energy of the airplane into electrical energy approximating 400 watts. This generation of electrical energy from the motion of the airplane through the snow necessarily constitutes a drag on its motion and its effective drag coefficient will be slightly increased.

5. In a recent series of papers by H. B. Barakan *, it is suggested that electrification of an airplane might play an important part in accelerating or reducing airplane icing under certain conditions. Without passing judgments on to the merits or weaknesses of Barakan's contentions, it does seem of interest to consider rather critically the influences of an electric field superimposed upon a wing section in modifying its drag coefficient.

6. At first sight it might be supposed that the influence of electric field on drag and upon icing could be determined from wind tunnel measurements. However, it is well established that the ionization distribution in the earth's atmosphere is always severely

* One of the Possible Causes of Airplane Icing
H. B. Barakan, Leningrad Institute of Meteorology

[redacted]

modified inside a cavity having conducting walls. In view of this fact, it is highly improbable that wind tunnel measurements on the subject problem would be a sufficiently close approximation to actual conditions in flight.

7. Measurements conducted by the Naval Research Laboratory on the U.S.S. Los Angeles and similar measurements made by the Germans have shown that lighter-than-air craft built up electrical potentials of the order of 1500 volts. This voltage and its associated free electrical charge is small, indeed, compared to the electric charge acquired by an aircraft flying through precipitation-static conditions. For example, in certain measurements this laboratory has observed potentials up to 400,000 volts on a B-24 flying in very dry snow in the Alaskan areas. In view of these facts and because the reporting group had special facilities available, it was decided to make an actual determination in flight of the drag coefficient of an airplane wing both with and without a superimposed electric field.

8. A joint Army-Navy precipitation static investigation has been set up under the technical guidance of the Naval Research Laboratory and a research group has been established at Minneapolis, Minnesota, to investigate problems connected with atmospheric electricity and flight. The Minneapolis Group now has a B-25 medium bomber and a Vega Ventura bomber that are fully equipped with all types of electrostatic measuring devices necessary to evaluate the electrical condition of the airplane in flight. In addition to measuring equipment, the B-25 is equipped with an artificial charging device that is capable of applying potentials to the plane, in flight, up to about 200,000 volts. Either sign of charge may be applied at will and the voltage adjusted to any predetermined value. Details of the artificial charger and pictures showing method of installation and circuits for it are given in NRL Report No. 0-2243, dated 23 February 1944, being the Third Partial Report on the Precipitation-Static Problem. Because the electric field or voltage on the airplane can be quickly and immediately changed and controlled, it is evident that a direct comparison can be made of the performance of the airplane wing section in flight; first, with the airplane uncharged and immediately thereafter in a highly charged condition.

9. On May 8, 1944, a check run was made with the B-25 to secure a comparison of performance between a charged and an uncharged airplane. Weather conditions were stable but with a broken cloud layer. At 9,000 feet, which was chosen as the operating altitude, the air was solid except for a very occasional thermal of moderate intensity. The temperature was -3° C and the average indicated air speed 188 mile-per-hour. A sensitive altimeter was installed where the pilot could easily see it and he was instructed to fly the airplane at a constant level. The pilot was experienced in this type of work and was disconnected from the interphone system so there could be no subjective connection between his piloting and any instructions that might be passed over the interphone.

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The pilot estimated that he flew the plane at a constant altitude subject to an error of ± 15 feet. Available to the observer in charge of air operations was a sensitive airspeed meter, produced by the Pioneer Instrument Company, and known as the type F1. A single division on this airspeed meter corresponds to 1 mile-per-hour covered a space of about 1/16-inch. It is estimated that a change in air speed of 1 mile-per-hour could be easily measured. Operating under steady conditions an artificial electric charge was put on the airplane. This free charge was adjusted so that it raised the electric field on the belly of the plane to about 200 volts per cm. This is estimated to be equivalent to a voltage on the plane of something less than 150,000 volts. The charge placed on the plane was negative, corresponding to the charge usually acquired by an aircraft in flight. Arrangements were made so that the artificial charge could be applied or suddenly removed. Simultaneously, the airspeed of the sensitive airspeed meter was recorded. A cyclical application of the charge and discharge resulted in a set of data as given in Table 1.

10. It may be seen from the data of Table 1 that the influence of the electric charge on the plane was less than the fluctuations of airspeed that normally exist during stable flight conditions. It is difficult to assign definite values to the experiment, but from the data it seems safe to conclude that a very strong electric field averaging perhaps 100 volts per cm over the entire wing surface had less than a 1% influence on the drag coefficient of the B-25's airfoils. If there were any special reason for more detailed data, it is possible to determine the distribution of the electric field over the airplane wing with the electric field on the belly of the ship adjusted to the employed 200 volts per cm.

[redacted]

DRAG EXPERIMENT MAY 8, 1944

BROKEN CLOUDS ALTITUDE 9000 FT.
TEMP. -3 °C AIRCRAFT NEGATIVE
CHARGING CURRENT 45 MICROAMPERES
ELECTRIC FIELD ON BELLY = 200 $\frac{\text{VOLTS}}{\text{CM.}}$

AIRSPEED MILES PER HOUR

ELECTRIC FIELD

ON	OFF
INITIAL	188
189	188
188	188
190	195
187	190
194	193
	189
188	187
188	189

LEAST COUNT PIONEER SENSITIVE
AIRSPEED METER = 1 MILE PER HOUR

TYPE F 1