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Cessna

MODEL: 309A & 319 REPORT NO. 4

APPLICATION OF CIRCULATION CONTROL TO AN AIRPLANE OF MILITARY LIAISON TYPE

NONR CONTRACTS 234(00) AND 856(00)

Cessna Aircraft Company
Wichita, Kansas

Cessna
Aircraft Company
Wichita, Kansas

PERIODIC PROGRESS REPORT

MODEL 309A & 319: REPORT NO. 4

APPLICATION OF CIRCULATION CONTROL TO AN AIRPLANE OF MILITARY LIAISON TYPE.

NONR CONTRACTS 234(00) AND 856(00)

REPORT DATE: 2 January 1953

PREPARED BY: E. O. Blosser

WITNESSED BY: J. W. Fisher

APPROVED BY: A. N. Petroff

APPLICATION OF CIRCULATION CONTROL TO AN AIRPLANE OF MILITARY LIAISON TYPE

This report covers the period from 2 November 1952 to 1 January 1953.

CESSNA MODEL 309-309A - CONTRACT NO. 234(00)

Analysis

Examination of data obtained during the flight test of the airplane with AirResearch Turbine as an injector pump for the BLC system revealed an error in the computation of C_{Q_B} and C_{Q_S}. This explains the poor performance of the Cessna installation as compared with German and French tests (which was previously attributed to low efficiency of the pumping system) and throws a different light on the performance of the AirResearch Turbine. Results of this study will be presented in the Report #1309-8: "Evaluation of Performance and Efficiency of the AirResearch Gas Turbine as an Injector Pump for the BLC System".

Meanwhile the corrected curves of C_Q vs C_L and true air speed are attached to this report and will be distributed to be inserted as page 16 of the report 1309-3.

Pumping performance of the axial fan system in flight has been evaluated and flow coefficients, horsepower input and output, and duct efficiency determined. Results and conclusions not already reported are as follows:

1. As airplane speed increases flow quantity is reduced, and C_Q falls off more rapidly than normally would be expected. This is caused by inability of the fans, presently installed, to operate at the same output, but against greater pressure losses. These losses increase with speed because the air entering the suction slot must be accelerated from rest to the velocity of the airplane.

2. Flow quantities also show an abrupt drop in the region of fan surge (blade stall). This occurs in both forward and aft ducts, but at lower indicated airspeeds in the forward duct. Losses in the forward duct were greater initially (static conditions) which accounts for the earlier surge in that duct. The effect of fan surge is to reduce BLC system output, but requires approximately the same power input.

3. Airplane power reduces the C_Q required to maintain a constant C_L (due to slip stream effect). This indicates the $\Delta C_{L_{max}}$ due to power is greater with BLC than without. Further results and conclusions pertaining to the BLC performance with axial fan system will be presented in report #1309-7: "Analysis of Boundary Layer Control Pumping Performance with Electrically Driven Fans".

Flight Tests

Tests to determine the reason for change in static longitudinal stability caused by the BLC system in action have been completed. In order to measure downwash angle and dynamic pressure at the tail, Kollsman angle of attack indicator was installed on the leading edge of the stabilizer. The results will be presented in report #1309-6: "Static Longitudinal Stability of the Model 309A with Axial Fans as BLC Pumping System".

Ground Tests

Several combinations of lead-acid batteries were tested at 360 amp. current discharge to obtain voltage drop vs time. Results of tests show promise for intermittent service of 30 seconds at 5 minute intervals. (See graph) The installation will consist of three or four 12 volt aircraft batteries of 60-90 ampere hour rating weighing approximately 230-310 lbs. Reading Batteries Company agreed to test several combinations of batteries at 360 amps. discharge rate. Meanwhile they will send us four T-38 aircraft batteries to be installed on the airplane for flight testing.

A considerable scattering of points was observed in the process of measuring quantity flow of air in the ducting system. It was suspected that this could be due to excessive turbulence which was causing irregular reading of the manometer. In order to verify this a simple bench test was performed to study the effect of flow angularity upon the readings of total pressure tubes. Air for the test was blown through a two inch straight nozzle at a constant rate. The total pressure tubes were mounted one at a time six inches from the nozzle and rotated about the nose as shown on the sketch of Figure 1. The results indicate that round tubing with rounded nose is least susceptable to angular flow.

Design and Drafting

A drawing of the installation of the hydrogen peroxide injection pump in the 309C is now in progress. It will include the supply tanks, the injector pump, firewalls and fire control system.

The following drawings were released:

12309-65 - Rudder Bungee System
-66 - Pressure Pick-Up Installation (Model 309C)
-67 - Wiring Diagram - Battery Operated Fan System
-68 - Wiring Diagram - Compound Battery and Generator Operated Fan System

CESSNA MODEL 319 - CONTRACT NO. 856(00)

Analysis

In order to establish a specification for the design of the fan and the pumping system a study was initiated to determine the effect of wing loading, coefficient of ground friction and $C_{L_{max}}$ upon take-off distance. The results will determine a $C_{L_{max}}$ for the optimum take-off characteristics. Then, knowing duct losses and required values of C_Q, a curve of Δp across the fan vs quantity flow will be established. This, along with limiting physical dimensions and operating conditions, will govern the design of a pumping unit.

Preliminary analysis of take-off distance over 50 ft. obstacle indicated the following:

1. Substantial reduction of take-off distance at the same wing loading occurs with increased $C_{L_{max}}$ (due to BLC). The largest performance gain exists for take-off on a very soft turf (or sand) with smaller gains on a hard surface runway.
2. Proportionally larger gains can be expected with increased wing loading at the same $C_{L_{max}}$ (neglecting the weight of BLC system). If the airplane weight is increased, to take account of BLC apparatus, smaller gains would exist. A reasonable estimation of weight chargable to BLC awaits the results of a current survey of auxiliary power units as well as studies of electrical, hydraulic, and other systems.
3. Reduction of take-off distance for values of $C_{L_{max}}$ greater than 4.0 was found to be small, particularily for low wing loading and hard surfaced runways.

4. Power extracted from the engine to operate a BLC system reduced performance gain. An optimum $C_{L_{max}}$ (for take-off distance) of approximately 4.0 was found for all runway conditions and wing loadings in the range of 20 to 25. For wing loadings of 15 to 20 the optimum value was 4.5.

5. If an amount of power equivalent to that required by BLC is added, instead of subtracted, take-off performance still remains <u>inferior</u> to that with BLC up to wing loadings of 20. This is true for $C_{L_{max}}$ (due to BLC) up to 4.5 beyond which power required for BLC becomes quite large.

These conclusions are subject to verification by wind tunnel tests of the 0.6-scale model. Further results and conclusions will be presented at a later date.

Mock-Up of Suction Duct

Model 319 suction duct bench tests performed recently by the University of Wichita indicate that total pressure losses in the "vortex" type suction duct are very high - exceeding those of the ducts now installed in the Model 309A. In view of this the University has undertaken at their own expense, the design, construction (modification of present mock-up), and testing of another configuration which offers possibility of impoovement.

Design and Drafting

Since the Model 319 is expected to be flight tested over a range of wing loadings from 15 to 25 lb/sq.ft., it was necessary to increase the strength of the airplane in several critical points. Design work on the structural details of the wing are confined to areas forward of the front spar. This is due to the fact that the final duct design has not been confirmed by bench and wind tunnel tests (see section on suction duct mock-up tests).

The following drawings have been released:

12319-8 - Tail Wheel Modification
-9 - Bulkhead Contour Sta. 214-375 (loft)
-10- Main Landing Gear Installation

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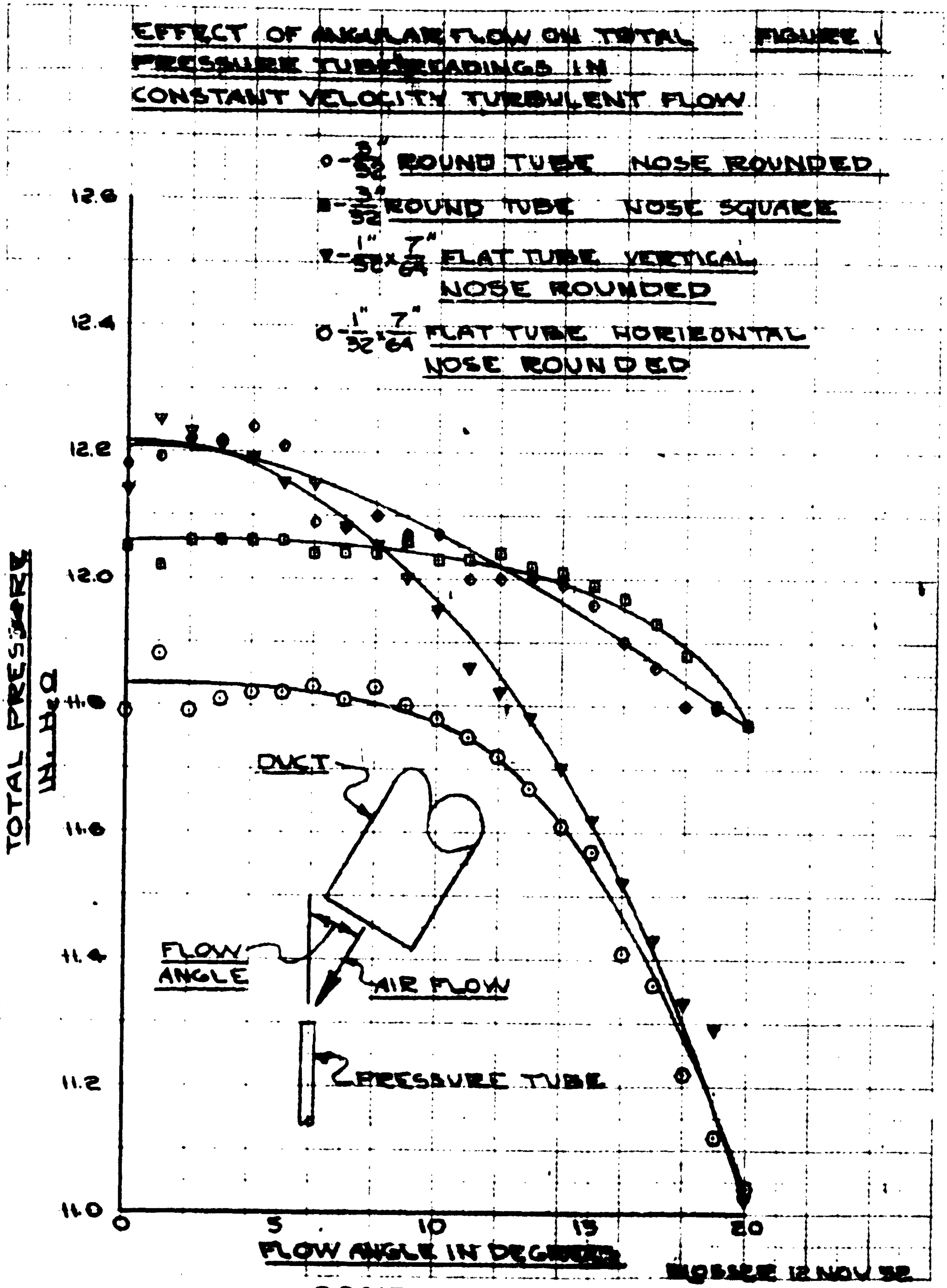

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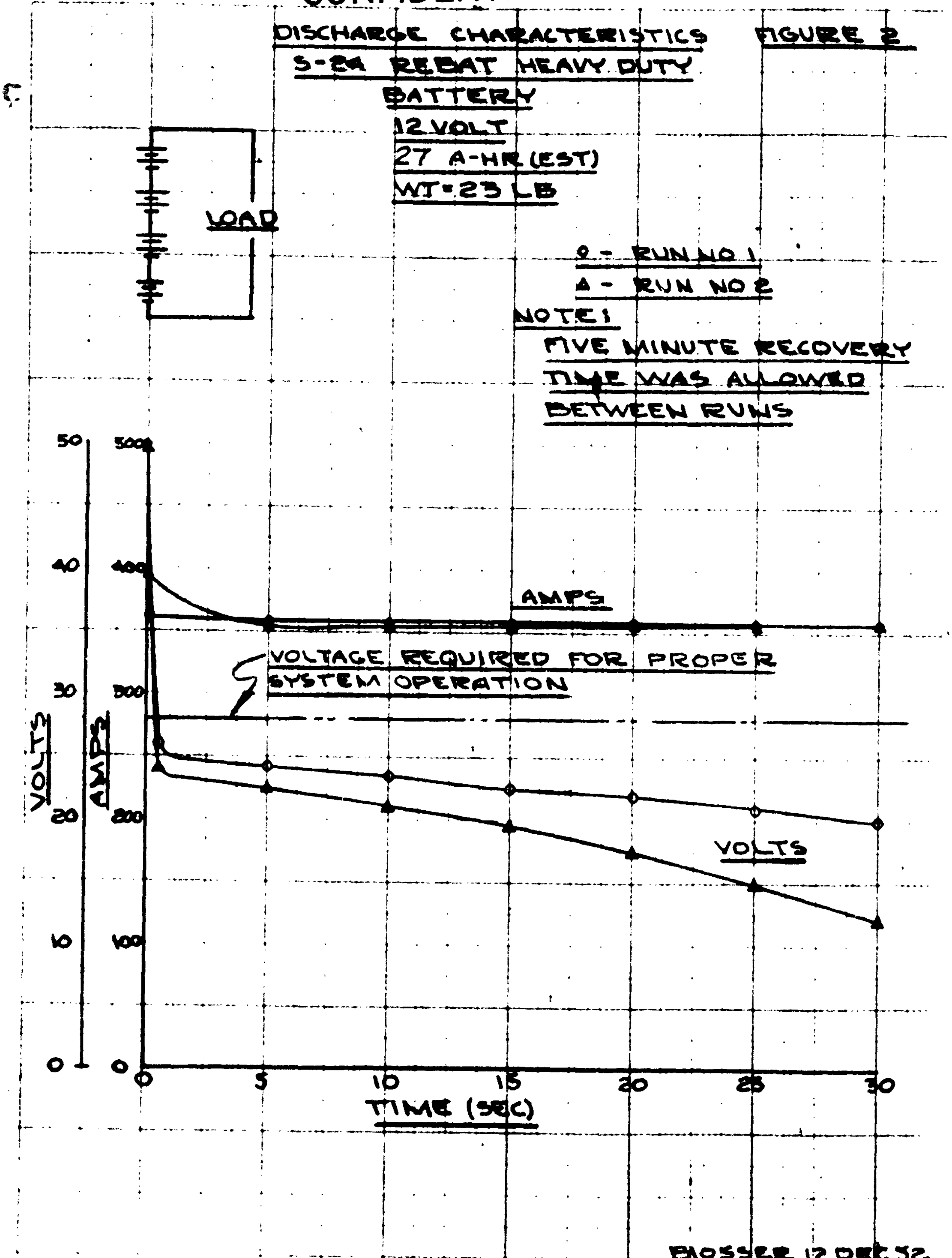

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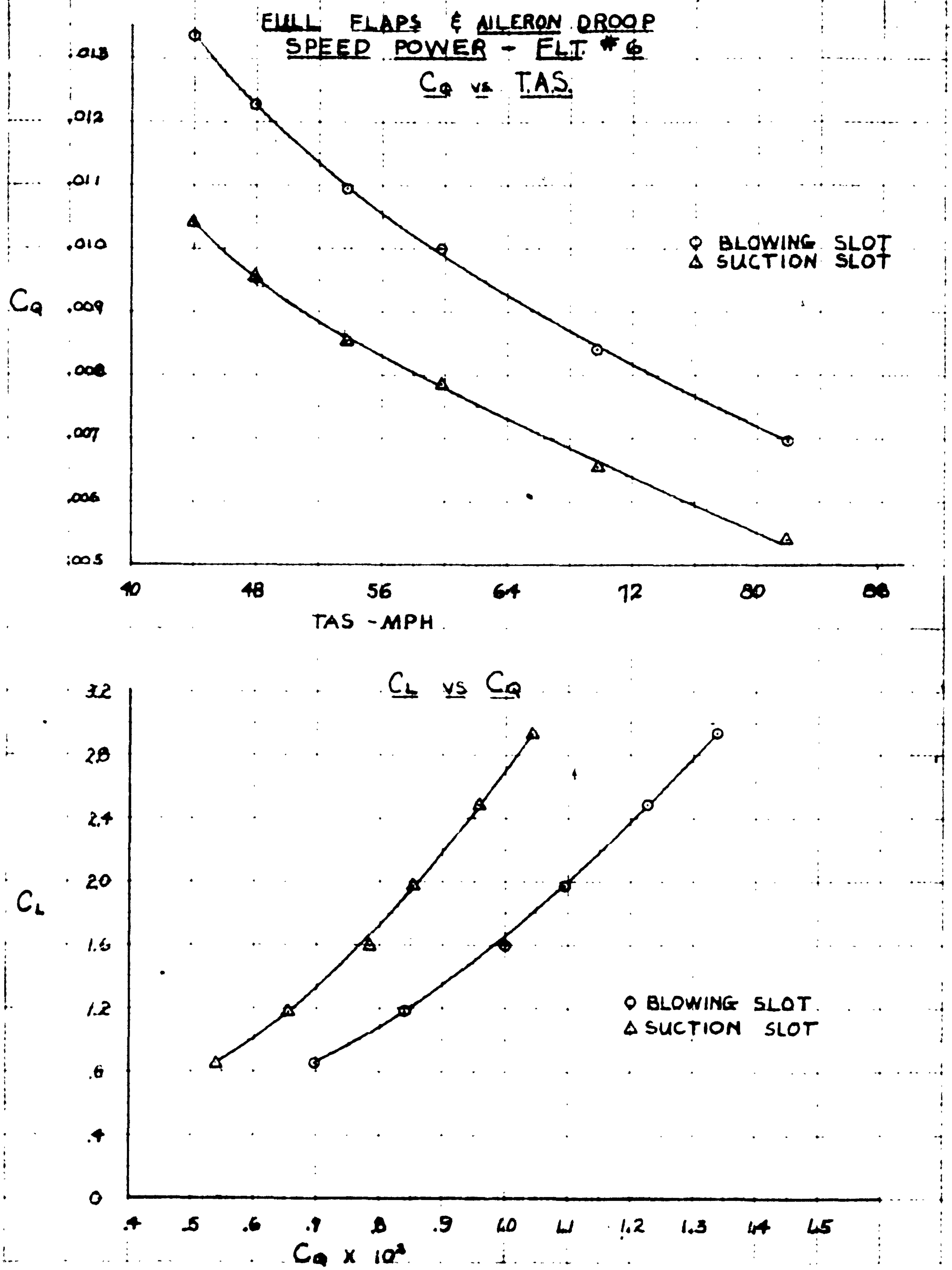
FULL FLAPS & AILERON DROOP
SPEED POWER - FLT #6
C_Q vs. T.A.S.
.013
.012
.011
.010
.009
.008
.007
.006
.005
C_Q
40
48
56
64
72
80
88
TAS - MPH
BLOWING SLOT
SUCTION SLOT
C_L vs C_Q
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
0
C_L
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
$C_Q \times 10^2$
BLOWING SLOT
SUCTION SLOT