RESEARCH MEMORANDUM

for the

Air Material Command, U. S. Air Forces

PRELIMINARY TRANSIENT PERFORMANCE DATA

ON THE J73 TURBOJET ENGINE

II - ALTITUDE, 35,000 FEET

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
JUL 18 1955
A program was undertaken to determine the J73 turbojet engine compressor stall and surge characteristics and combustor blow-out limits encountered during transient engine operation. Data were obtained in the form of oscillograph traces showing the time history of several engine performance parameters with changes in engine fuel flow. The data presented in this report are for step changes in fuel flow at an altitude of 35,000 feet, at flight Mach numbers of 0.3, 0.8, and 1.2, and at several engine-inlet temperatures.

INTRODUCTION

One phase of the altitude-performance investigation of the J73 turbojet engine conducted at the NACA Lewis laboratory consisted in determining the compressor stall and surge characteristics and the combustor blow-out limits encountered during and immediately following rapid changes in engine fuel flow.

The data were obtained on oscillograph traces which showed the time history of several engine parameters following a change in fuel flow. The preliminary data presented herein were obtained at an altitude of 35,000 feet, at flight Mach numbers of 0.3, 0.8, and 1.2, and at several engine-inlet temperatures. Similar data are presented in preliminary form in references 1 and 2 for altitudes of sea level, 15,000, and 45,000 feet at several flight Mach numbers.

The preliminary data which appear in this report consist of reproductions of oscillograph traces obtained at actual operating conditions. A check on the accuracy of the calibration values listed on the oscillograph traces has been made by a catalyst of the data is presented.
APPARATUS

Engine and Installation

The J73 turbojet engine used in this investigation has a thrust of approximately 9000 pounds, a rated engine speed of 7950 rpm, and an exhaust-gas temperature of 1185°F (1645° R). The engine is normally equipped with an hydraulic control system which was inoperative during this phase of the investigation. For these tests, the fuel system was so modified that fuel flow was a function of fuel-valve position only. Other engine components are a 12-stage axial-flow compressor with variable inlet guide vanes, an annular-type combustor with 10-cannular-type chambers, a two-stage axial-flow turbine, and a fixed-area exhaust nozzle.

The engine was mounted in a 14-foot diameter altitude chamber. A group of automatic throttle valves was incorporated at both inlet and exhaust ends of the test chamber to provide control of simulated altitude and ram-pressure ratio.

Instrumentation

The transient responses of the engine variables were recorded on a multiple channel, direct-inking, magnetic motor oscillograph. The oscillograph chart speed was 5 units per second.

The location of the measuring stations are shown in figure 1. The sensing devices used for indicating variations in the performance parameters are given in table I. Inasmuch as the total-pressure profile at the engine inlet was flat, it was possible to select almost any total- or static-pressure sensor to record on an oscillograph trace or its corresponding calibration gage without introducing errors. In the case of compressor-outlet total pressure, the sensor selected for both the oscillograph and the calibration gage was approximately the average total pressure at that station, as indicated from earlier steady-state data. Appropriate correction factors were employed where necessary for gage error and sensor location.

PROCEDURE

The oscillograph traces were calibrated by operating the engine at several widely different engine operating points and recording the corresponding pen deflections on the oscillograph trace. Fuel step changes were introduced over a range of initial engine speeds at the conditions shown in the following table:
The variable inlet guide vanes, which normally moved from closed to open position at an engine speed of 6800 rpm as speed was increased, were maintained in a fixed closed or open position during all transients of this phase of the investigation.

The size of the fuel step change was increased until limited by either compressor surge or combustor blow-out or until it was felt that large steps in fuel flow would expose the engine to excessively high temperature. Only the traces which were considered pertinent in determining an operating limit are presented. Thus, in general, at any given initial engine speed two traces are shown. One gives the maximum step change in fuel flow obtained without encountering compressor surge or stall. The other gives the minimum step change in fuel flow which produced compressor surge or stall.

During the period of transient engine operation, both the engine-inlet total pressure and the exhaust pressure varied from the initial value. However, the engine operating limit usually occurred before the engine-inlet total pressure or the exhaust pressure changed appreciably. The time history of the behavior of the engine-inlet total pressure during transient engine operation is shown on the oscillograph traces, but the variation of exhaust pressure is not shown. In general, the maximum increase in exhaust pressure was 7 percent of the initial value.

**DISCUSSION**

The conditions for each oscillograph trace (figs. 2 to 152) presented herein are given in table II. On each set of oscillograph traces the figure legend specifies the engine conditions at the beginning of the change in fuel flow. Each trace is identified by a label below which is given the calibration factor for the trace. As indicated by the calibration factor, all traces are considered linear except the fuel-flow trace which follows the square-law relation. On each trace is shown the initial value of the engine variable. In the case of fuel flow, one or more additional values are given. The arrows on each figure indicate the direction in which the variable is increasing.
Caution should be used in applying the calibration factors to the traces. Although the horizontal or time scale is linear, the vertical scale on all traces is a circular arc. In obtaining the rate of change of any variable or in calculating elapsed time, this curvature must be considered.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, July 1, 1953

REFERENCES


<table>
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**TABLE II - OSCILLOGRAPH-TRACE CONDITIONS**
Figure 1. - Side view of turbojet engine installation showing stations at which instrumentation was installed.
Exhaust-gas temperature, °F (compensated) Calibration 85.4 °F/mm

Engine-inlet total pressure, in. Hg abs Calibration 0.135 in. Hg/mm

Compressor-outlet total pressure, in. Hg abs Calibration 0.641 in. Hg/mm

Exhaust-gas temperature, °F (compensated) Calibration 85.4 °F/mm

Engine speed, rpm Calibration 71.4 rpm/mm

Figure 2
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -2 °F; inlet guide vanes position, open.
Figure 3
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -20°F; inlet guide vanes position, open.
Figure 4
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.5; engine-inlet air temperature, 0 °F; inlet guide vanes position, open.
Figure 5

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 0 °F; inlet guide vanes position, open.
Figure 6
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 2°F; inlet guide vane position, open.
Figure 7
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 20°F; inlet guide vane position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3: engine-inlet air temperature, 0 °F; inlet guide vanes position, open.
Engine speed, rpm
Calibration 71.4 rpm/mm

Dynamic pressure at engine inlet, lb/sq ft abs
Trace inoperative

Engine-inlet total pressure in. Hg abs
Calibration 0.135 in. Hg/mm

Compressor-outlet total pressure, in. Hg abs
Calibration 0.641 in. Hg/mm

Exhaust-gas temperature, °F (compensated)
Calibration 85.4 °F/mm

Engine speed, rpm
Calibration 71.4 rpm/mm

Figure 9
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 50°F; inlet guide vanes position, open.
Figure 10
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 30°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.5; engine-inlet air temperature, 10°F; inlet guide vane position, open.
Figure 12
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 380°F; inlet guide vane position, open.
Figure 13

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 350°F; inlet guide vane position, open.

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Figure 14
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.5; engine-inlet air temperature, 38°F; inlet guide vanes position, open.
Figure 15
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vanes position, open.
Figure 16
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vane position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 38°F; inlet guide vanes position, open.

Figure 17
Figure 18
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 38° F; inlet guide vanes position, open.
Figure 19
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vanes position, open.
Figure 20

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37 °F; inlet guide vanes position, open.

Dynamic pressure at engine inlet, lb/sq ft abs
Calibration 1.390 (lb/sq ft)/mm

Engine-inlet total pressure, in. Hg abs
Calibration 0.126 in. Hg/mm

Compressor-outlet total pressure, in. Hg abs
Calibration 0.647 in. Hg/mm

Exhaust-gas temperature, °F (compensated)
Calibration 71 °F/mm

Engine speed, rpm
Calibration 67.2 rpm/mm
Figure 21
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vane position, open.
Figure 22
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 35 °F; inlet guide vanes position, open.

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Figure 23
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vanes position, open.
Figure 24: Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 350°F; inlet guide vanes position, open.
Figure 25
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vanes position, open.
Figure 26
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 370°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 36°F; inlet guide vanes position, open.
Figure 28
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 56 °F; inlet guide vanes position, open.
Dynamic pressure at engine inlet, lb/sq ft abs = Calibration 6.890 (lb/sq ft)/mm

Engine-inlet total pressure, in. Hg abs = Calibration 0.260 in. Hg/mm

Compressor-outlet total pressure, in. Hg abs = Calibration 1.225 in. Hg/mm

Exhaust-gas temperature, °F

Engine speed, rpm = Calibration 103.5 rpm/mm

Figure 29
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vane position, open.

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Figure 30

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37°F; inlet guide vanes position, open.
Figure 31
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 36 °F; inlet guide vane position, open.
Figure 32

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 36°F; inlet guide vanes position, open.
Figure 33
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 36,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 37 °F; inlet guide vanes position, open.
Figure 34
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.5; engine-inlet air temperature, 56°F; inlet guide vanes position, open.
Figure 35
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 360°F; inlet guide vanes position, open.
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Figure 36
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, 65.4°F; inlet guide vane position, closed.
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Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -6 °F; inlet guide vanes position, closed.
Figure 38
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -5 °F; inlet guide vanes position, closed.
Figure 39

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -3 °F; inlet guide vane's position, closed.
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Figure 40

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -5° F; inlet guide vanes position, closed.
Figure 41
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, \(-5\) °F; inlet guide vanes position, closed.

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Figure 42

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -1 °F; inlet guide vanes position, closed.
Fuel flow, lb/hr

Dynamic pressure at engine inlet, lb/sq ft abs

Engine-inlet total pressure in. Hg abs
Calibration 0.135 in. Hg/mm

Compressor-outlet total pressure, in. Hg abs
Calibration 0.641 in. Hg/mm

Exhaust-gas temperature, °F (compensated)
Calibration 85.4 °F/mm

Engine speed, rpm
Calibration 71.4 rpm/mm

Figure 45

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -1 °F; inlet guide vane position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -2°F; inlet guide vanes position, closed.
Figure 45

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.3; engine-inlet air temperature, -20°F; inlet guide vanes position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -10°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude: 35,000 feet; Flight Mach number: 0.61; engine-inlet air temperature: -165°F; inlet-guide vane position: open.

CONFIDENTIAL
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Figure 48. Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -40°F; inlet guide vane position, open.

- Fuel flow, lb/hr
- Dynamic pressure at engine inlet, lbf/ft²
- Engine-inlet total pressure, in. Hg abs
- Calibration: 0.135 in. Hg/ft
- Compressor-outlet total pressure, in. Hg abs
- Calibration: 1.380 in. Hg/ft
- Exhaust-gas temperature, °F (compensated)
- Calibration: 55.6°F/ft
- Engine speed, rpm
- Calibration: 71.4 rpm/ft
Figure 49

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.6; engine-inlet air temperature, -8°F; inlet guide vane position, open.

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Figure 50
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -80 F; inlet guide vane position, open.
Figure 51: Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -6°F; inlet guide vanes position, open.
Figure 52

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -6°F; Inlet guide vanes position, open.
Figure 53
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -60°F; inlet guide vanes position, open.
Compressor-outlet total pressure, Calibration 1.460 in. Hg abs

Engine-inlet total pressure, in. Hg abs
Calibration 0.153 in. Hg/psig

Compressor-outlet total pressure, in. Hg abs
Calibration 1.460 in. Hg/psig

Engine speed, rpm
Calibration 68.5 rpm/psig

Exhaust-gas temperature, °F (compensated)
Calibration 80 °F/psig

Fuel flow, lb/hr

Figure 14
Oclograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -6 °F; inlet guide-plate position, open.
Figure 55
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -8°F; inlet guide vane position, open.
Figure 56
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 80°F; inlet guide vane position, open.
Figure 57
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -50°F; inlet guide vane position, open.

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Figure 58
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 55,800 feet; flight Mach number, 0.08; engine-inlet air temperature, -10°F; inlet guide vane position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -10 °F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 30°F; inlet guide vane position, open.
Figure 6.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 20°F; inlet guide vane position, open.
Figure 61

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.6; engine-inlet air temperature, 30°F; inlet guide vane position, open.
Figure 63
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 300°F; inlet guide vanes position, open.
Figure 64
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 28 °F; inlet guide vanes position, open.
Figure 65
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 280°F; inlet guide vanes position, open.
Figure 66
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 30°C; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 300°F; inlet guide vanes position, open.
Figure 68
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 30°F; inlet guide vanes position, open.
Dynamic pressure at engine inlet, lb/sq ft abs
Calibration 1.095 (lb/sq ft)/in

Engine-inlet total pressure, in. Hg abs
Calibration 0.11 in. Hg/mm

Compress-outlet total pressure, in. Hg abs
Calibration 1.14 in. Hg/mm

Exhaust-gas temperature, °F

Engine speed, rpm

Figure 69
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 30 °F; inlet guide vanes position, open.
Figure 70
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 30°F; inlet guide vanes position, open.
Figure 71
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 33°F; inlet guide vanes position, open.
Figure 72
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 55,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 360°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 30°F; inlet guide vanes position, open.
Figure 74
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 39°F; inlet guide vanes position, open.
Figure 75
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 35° F; inlet guide vanes position, open.
Figure 76
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 300°F; inlet guide vane position, open.
Figure 77
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 39 °F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 39°F; inlet guide vanes position, open.
Fuel flow, lb/hr
48.5
Dynamic pressure at engine inlet, lb/sq ft abs
Calibration 2.09 (lb/sq ft)/mm
Time ~- 1 sec ~-
Engine-inlet total pressure in. Hg abs
Calibration 0.128 in. Hg/mm
Compressor-outlet total pressure, in. Hg abs
Calibration 1.245 in. Hg/mm
Exhaust-gas temperature, °F (uncompensated)
Calibration 20.5°F/mm
Engine speed, rpm
Calibration 101 rpm/mm

Figure 79
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 35°F; inlet guide vanes position, open.
Figure 80
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 39°F; inlet guide vanes position, open.
Figure 81
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 39°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 39° F; inlet guide vane position, open.
Figure 83
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow, Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 39°F; intake guide vane position, open.
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Figure 52
Oscillograph tracings showing variations of different engine parameters during a step-change in fuel flow. Altitude, 30,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 100°F; inlet guide vane position, open.
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Figure 8b

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 55,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 14°F; inlet guide vane position, open.

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Figure 66

Semiautographic tracings showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 100°F; fuel inlet guide vane position, open.

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Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 152°F; inlet guide vanes position, open.
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Figure 88
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 152°F; inlet guide vanes position, open.

- Fuel flow, lb/hr
- Dynamic pressure at engine inlet, lb/sq ft abs
  Calibration 2.74 (lb/sq ft)/mm
- Engine-inlet total pressure, in. Hg abs
  Calibration 0.047 in. Hg/mm
- Compressor-outlet total pressure, in. Hg abs
  Calibration 0.660 in. Hg/mm
- Exhaust-gas temperature, °F (compensated)
  Calibration 33.6 °F/mm
- Engine speed, rpm
  Calibration 67.2 rpm/mm
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 1500°F; inlet guide vanes position, open.
Figure 90
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; Flight Mach number, 0.8; Engine-inlet air temperature, 161°F; Inlet guide vanes position, open.
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Figure 91
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 161°F; inlet guide vanes position, open.
Figure 92
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 161°F; inlet guide vane position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 161°F; inlet guide vane position, open.
Figure 94

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 163°F; inlet guide vanes position, open.
Figure 95

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 163°F; inlet guide vanes position, open.
Figure 96
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; Flight Mach number, 0.8; engine-inlet air temperature, 184°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude: 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 1650 °F; inlet guide vanes position, open.

**Figure 27**

**Engine speed, rpm**
- Calibration: 67.5 rpm/sec

**Exhaust-gas temperature, °F (compensated)**
- Calibration: 72.8 °F/sec

**Compressor-outlet total pressure, in. Hg abs**
- Calibration: 0.660 in. Hg/sec

**Engine-inlet total pressure, in. Hg abs**
- Calibration: 0.047 in. Hg/sec

**Dynamic pressure at engine inlet, lb/sq ft abs**
- Calibration: 2.74 (lb/sq ft)/sec

**Fuel flow, lb/hr**

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Figure 98

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 165°F; inlet guide vanes position, open.
Figure 99
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 6640 °F; inlet guide vanes position, open.
Figure 100
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 164°F; inlet guide vanes position, open.

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Figure 101

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 165°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 186°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 166°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 166°F; inlet guide vane position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 185°F; inlet guide vanes position, open.
Figure 106
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temp., 165°F; inlet guide vanes position, open.
Figure 107

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 17°C; inlet guide vanes position, closed.

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Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 17 °F; inlet guide vane position, closed.
Figure 109
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 17 °F; inlet guide vanes position, closed.
Exhaust-gas temperature, OF (compensated)
Calibration 80°F/mm

Engine-inlet total pressure in. Hg
Calibration 0.153 in. Hg/mm

Compressor-outlet total pressure, in. Hg
Calibration 1.460 in. Hg/mm

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Internal oscillations showing variations of different engine parameters during a step-change in fuel flow.

Altitude: 35,000 feet; flight Mach number: 0.8; engine-inlet air temperature: -20°F; inlet guide vane position: closed.
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Figure 111

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, -3°F; inlet guide vanes position, closed.
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Figure 12
Oscillograph traces showing variations of different engine parameters during a step-change in Fuel flow. Attitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 140 °F; inlet guide vane position, closed.

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Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 14 °F; inlet guide vanes position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 55,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 140°F; inlet guide vanes position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; Flight Mach number, .08; engine-inlet air temperature, 110°F; inlet guide vanes position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 14 °F; inlet guide vanes position, closed.
Figure 117
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 9 °F; inlet guide vane position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.6; engine-inlet air temperature, 9 °F; inlet guide vanes position, closed.
Figure 129: Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 167°F; inlet guide vane position, closed.
Figure 120

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 157 °F; inlet guide vanes position, closed.
Figure 123
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 50,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 1670°F; inlet guide vane position, closed.

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Figure 122
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 165°F; inlet guide vanes position, closed.
Figure 123
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 163°F; inlet guide vanes position, closed.
Figure 124
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 164°F; inlet guide vanes position, closed.
Figure 125
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 164°F; inlet guide vane position, closed.
Figure 126
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.5; engine-inlet air temperature, 160°F; inlet guide vanes position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 163°F; inlet guide vane position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 163°F; inlet guide vanes position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 0.8; engine-inlet air temperature, 163°F; inlet guide vanes position, closed.
Figure 150
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 320°F; inlet guide vanes position, open.
Figure 131
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 32°F; inlet guide vanes position, open.
Figure 132
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 54°F; inlet guide vanes position, open.
Figure 133

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 420°F; inlet guide vanes position, open.

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Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 54°F; inlet guide vanes position, open.

Figure 234
Figure 135

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 42 °F; inlet guide vanes position, open.

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Figure 126

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.8; engine-inlet air temperature, 350°F; inlet guide vanes position, open.
Figure 137
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 350°F; inlet guide vane position, open.
Figure 138
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 420°F; inlet guide vane position, open.
Figure 139
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 45°F; inlet guide vanes position, open.
Figure 140

Oscillograph traces showing variations of different engine parameters during a step change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 35°F; inlet guide vane position, open.
Figure 141
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 38°F; inlet guide vanes position, open.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 30°F; inlet guide vanes position, closed.

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Figure 143
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 30°C; inlet guide vanes position, closed.

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Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 300°F; inlet guide vane position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 29°F; inlet guide vanes position, closed.
Figure 146

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 50°F; inlet guide vanes position, closed.
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 50°F; inlet guide vane position, closed.
Figure 148
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 480°F; inlet guide vanes' position, closed.
Figure 149
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 300 °F; inlet guide vane position, closed.
Figure 150

Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 40°F; inlet guide vanes position, closed.
Figure 15
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 35,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 30°F; inlet guide vanes position, closed.
Figure 132
Oscillograph traces showing variations of different engine parameters during a step-change in fuel flow. Altitude, 25,000 feet; flight Mach number, 1.2; engine-inlet air temperature, 30°F; inlet guide vane position, closed.
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

PRELIMINARY TRANSIENT PERFORMANCE DATA ON THE J73 TURBOJET ENGINE

II - ALTITUDE, 35,000 FEET

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lsp - 7/2/53