INACTIVE

~~RESTRICTED~~

UNCLASSIFIED

RESTRICTED

RM E50J17

CASE FILE COPY

NACA RM E50J17

NACA

RESEARCH MEMORANDUM

* Contains obsolete or proprietary info.

* PERFORMANCE OF J35-A-23 COMPRESSOR

I - OVER-ALL PERFORMANCE CHARACTERISTICS AT EQUIVALENT SPEEDS FROM 20 TO 100 PERCENT OF DESIGN

By Arthur A. Medeiros, Donald C. Guentert, and James E. Hatch

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

Classification Changed
To UNCLASSIFIED
By Authority of P.A. #7* Date 5-29-59

CLASSIFIED DOCUMENT

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
October 1, 1951

UNCLASSIFIED

RESTRICTED

UNCLASSIFIED

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

PERFORMANCE OF J35-A-23 COMPRESSOR

I - OVER-ALL PERFORMANCE CHARACTERISTICS AT EQUIVALENT SPEEDS FROM 20 TO 100 PERCENT OF DESIGN

By Arthur A. Medeiros, Donald C. Guentert, and James E. Hatch

SUMMARY

An investigation of the over-all performance of the J35-A-23 compressor was conducted as the preliminary step in an investigation of surging and off-design performance of high-pressure-ratio axial-flow compressors. The J35-A-23 compressor is a 16-stage compressor designed to produce a total-pressure ratio of 8.75 at an equivalent flow of 155 pounds per second and an equivalent speed of 6100 rpm.

Tests were run over a range of flows at speeds from 20 to 100 percent design speed. The maximum calculated total-pressure ratio obtained was 9.50 at an efficiency of 0.792 at an equivalent flow of 157.7 pounds per second. The measured total-pressure ratio at this point was 9.78. Because the compressor was not operated to surge at design speed, this value may not represent the maximum obtainable. At the design pressure ratio of 8.75, the equivalent weight flow was 158.4 pounds per second with an efficiency of 0.802 as compared with a design equivalent flow of 155 pounds per second and an assumed efficiency of 0.830. The maximum efficiency obtained was 0.835 at 85 percent of design speed at an equivalent flow of 123.2 pounds per second.

INTRODUCTION

Improvement in the altitude performance and the economy of turbojet engines can be realized through the use of compressors producing pressure ratios higher than those currently in use. Serious problems have been encountered, however, in surging and off-design performance of high-pressure-ratio compressors. As a preliminary step in an investigation of these problems, over-all performance tests have been made, with the cooperation of the U. S. Air Force and the Allison Division of General Motors Corporation, on a J35-A-23 axial-flow compressor of 16 stages designed to produce a total-pressure ratio of 8.75 at an equivalent flow of 155 pounds per second and equivalent speed of 6100 rpm.

Tests were run over a range of flows at speeds from 20 to 100 percent of design. Because of power limitations, tests at design speed were run at an inlet pressure of 5.7 inches of mercury absolute. At speeds below design speed, the inlet pressure was adjusted so that the average Reynolds number relative to the first rotor-blade row was approximately 230,000 at all speeds. Speeds from 20 to 50 percent of design were run with room-air inlet temperature; speeds above 50 percent of design were run with refrigerated air at a temperature of -55° F.

APPARATUS AND INSTRUMENTATION

Compressor

Type	Axial-flow
Number of stages	16
Design equivalent weight flow, pounds per second	155
Design total-pressure ratio	8.75
Design efficiency	0.830
Design equivalent speed, rpm	6100
Tip diameter, inches	33.5
Diameter ratio at first rotor inlet	0.55
Diameter ratio at compressor discharge	0.90

Driving Power

Drive motor	9000-horsepower synchronous motor
Speed control	Variable frequency
Gear box	5.016 ratio double-helical speed increaser
Power available at 6100 rpm	6100 horsepower
Compressor power required at design point with sea-level inlet conditions	28,220 horsepower

Installation and Instrumentation

Air supply	Atmospheric air or refrigerated air at pressure of 50 inches mercury absolute
Exhaust	Altitude exhaust at 10 inches mercury absolute
Air Control	Butterfly throttles in inlet and outlet ducting
Air metering	Calibrated, adjustable, submerged orifice
Compressor inlet	Depression tank 6 feet in diameter and approximately 10 feet long
Compressor inlet pressure	Two wall static-pressure taps 180° apart and six total-pressure tubes located at area center of equal areas in depression tank
Compressor inlet temperature	Six shielded total-temperature probes located at area center of equal areas in depression tank
Compressor discharge pressure	Eight wall static-pressure taps spaced around circumference, and 16-tube circumferential total-pressure rake surveyed over five equispaced radial positions 1 inch downstream of discharge guide vanes
Compressor discharge temperature	Four double stagnation-chamber thermocouple rakes spaced around the circumference with five equally-spaced radial measuring stations located 1 inch downstream of discharge guide vanes
Compressor insulation	At speeds above 50 percent of design, compressor insulated with 2 inches of glass wool. No insulation used below 50 percent of design speed
Pressure measurement	Water and mercury manometers
Temperature measurement	Calibrated potentiometer in conjunction with spotlight galvanometer
Motor-speed measurement	Electric chronometric tachometer

The precision of measurements is estimated to be within the following limits:

Temperature, °R	±1.0
Pressure, inches mercury	±0.05
Weight flow, percent	±1.5
Speed, percent	±0.3

RESULTS AND DISCUSSION

The total-pressure ratio and the efficiency are presented in figure 1 as functions of equivalent weight flow at equivalent speeds of 20 to 100 percent of design. Figures 2 and 3 are larger scale plots of the pressure ratio, with efficiency contours, as a function of equivalent weight flow. At each flow point the discharge total pressure was obtained by two methods. The measured total pressure is the arithmetic average of the circumferential-rake measurements at five radial positions. The calculated total pressure was obtained by the method presented in reference 1. Adiabatic temperature-rise efficiencies were calculated using both pressures for the isentropic power input and the arithmetic average of the 20 discharge temperatures for the actual power input. The differences in the total-pressure ratios and efficiencies obtained by the two methods are largest at the high-flow end of the curves and are probably due to losses at the walls and in the blade wakes.

At the design pressure ratio of 8.75, the equivalent weight flow was 158.4 pounds per second at an efficiency of 0.802 as compared with a design equivalent weight flow of 155 pounds per second and an assumed efficiency of 0.830. The maximum calculated pressure ratio obtained was 9.50 at an efficiency of 0.792 and an equivalent weight flow of 157.7 pounds per second. The measured total-pressure ratio at this point was 9.78. This value does not represent the maximum obtainable pressure ratio because the compressor was not surged at design speed. The maximum efficiency of 0.835 occurred at 85 percent of design speed at an equivalent weight flow of 123.2 pounds per second and a pressure ratio of 5.80. The peak efficiency dropped sharply at speeds below 82 percent of design to a value of 0.495 at 20 percent of design speed.

Surge was encountered at all speeds above 20 percent of design with the exception of design speed where it was not thought advisable to surge the compressor and risk mechanical failure. At speeds from 30 to 85 percent of design, the flow was decreased until the compressor surged. A point was then taken at the flow and pressure ratio closest to surge at which stable compressor operation could be obtained. At 85 percent of design speed incomplete data were obtained at the surge point because the flow conditions changed enough while data were being taken to cause surge. The pressure ratio at this point is therefore based on the total pressure at the mean radius of the diffuser discharge instead of the average compressor-discharge pressure. The surge-limit line has two distinct slopes - one for speeds up to 80 percent of design and a steeper slope for speeds above 80 percent of design.

SUMMARY OF RESULTS

The following results were obtained from an investigation of the over-all performance of a J35-A-23 16-stage axial-flow compressor:

1. At the design pressure ratio of 8.75, the equivalent weight flow was 158.4 pounds per second with an efficiency of 0.802 as compared with the design equivalent weight flow of 155 pounds per second and an assumed efficiency of 0.830.

2. The maximum calculated total-pressure ratio was 9.50 at an efficiency of 0.792 and an equivalent weight flow of 157.7 pounds per second. The measured total-pressure ratio at this point was 9.78.

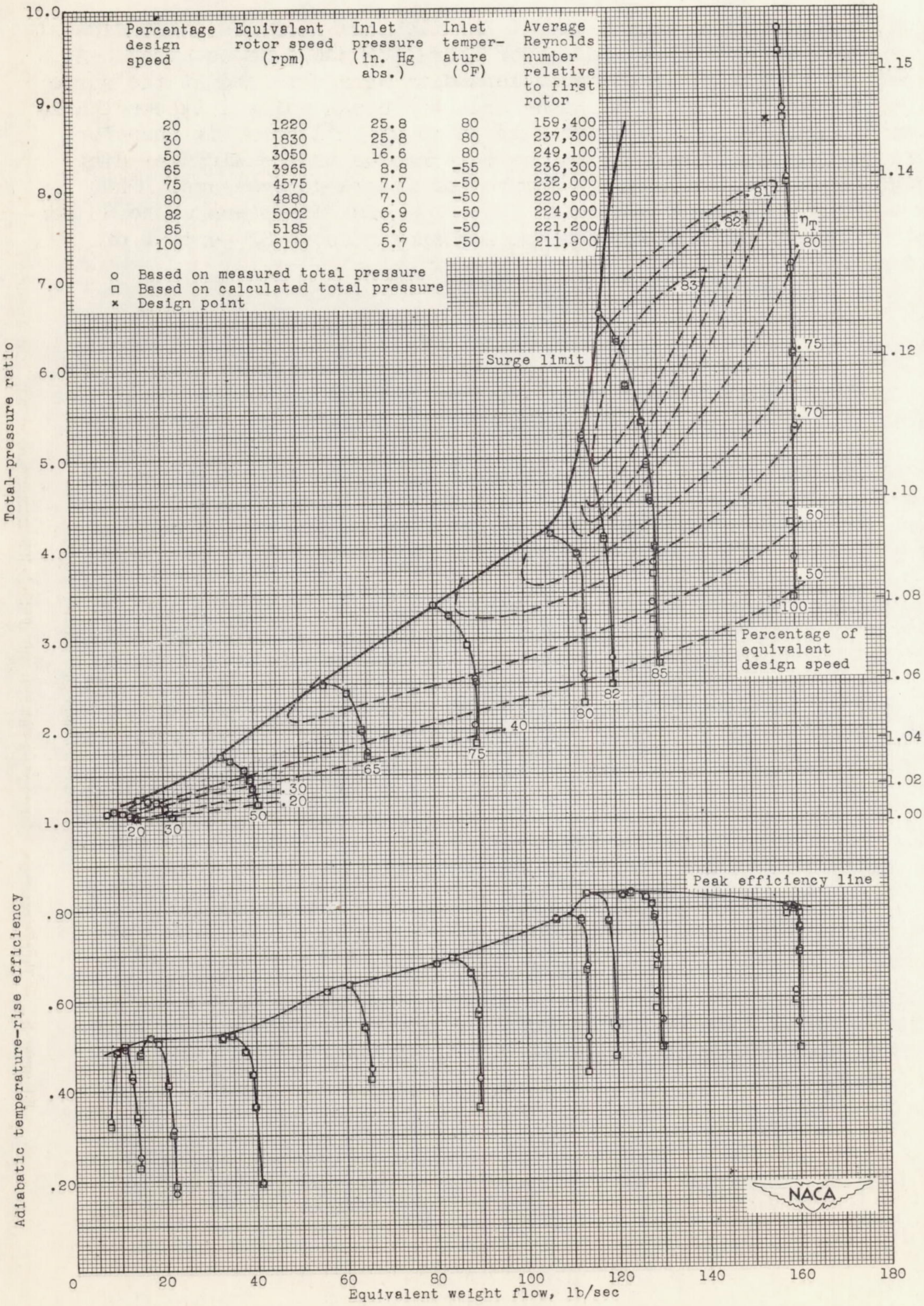
3. The maximum efficiency of 0.835 occurred at 85 percent of design speed at an equivalent weight flow of 123.2 pounds per second and a pressure ratio of 5.80.

Lewis Flight Propulsion Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio.

REFERENCE

1. NACA Subcommittee on Compressors: Standard Procedures for Rating and Testing Multistage Axial-Flow Compressors. NACA TN 1138, September 1946.

2022



Percentage design speed	Equivalent rotor speed (rpm)	Inlet pressure (in. Hg abs.)	Inlet temperature (°F)	Average Reynolds number relative to first rotor
20	1220	25.8	80	159,400
30	1830	25.8	80	237,300
50	3050	16.6	80	249,100
65	3965	8.8	-55	236,300
75	4575	7.7	-50	232,000
80	4880	7.0	-50	220,900
82	5002	6.9	-50	224,000
85	5185	6.6	-50	221,200
100	6100	5.7	-50	211,900

○ Based on measured total pressure
□ Based on calculated total pressure
× Design point

Figure 1. - Over-all performance of J35-A-23 compressor.

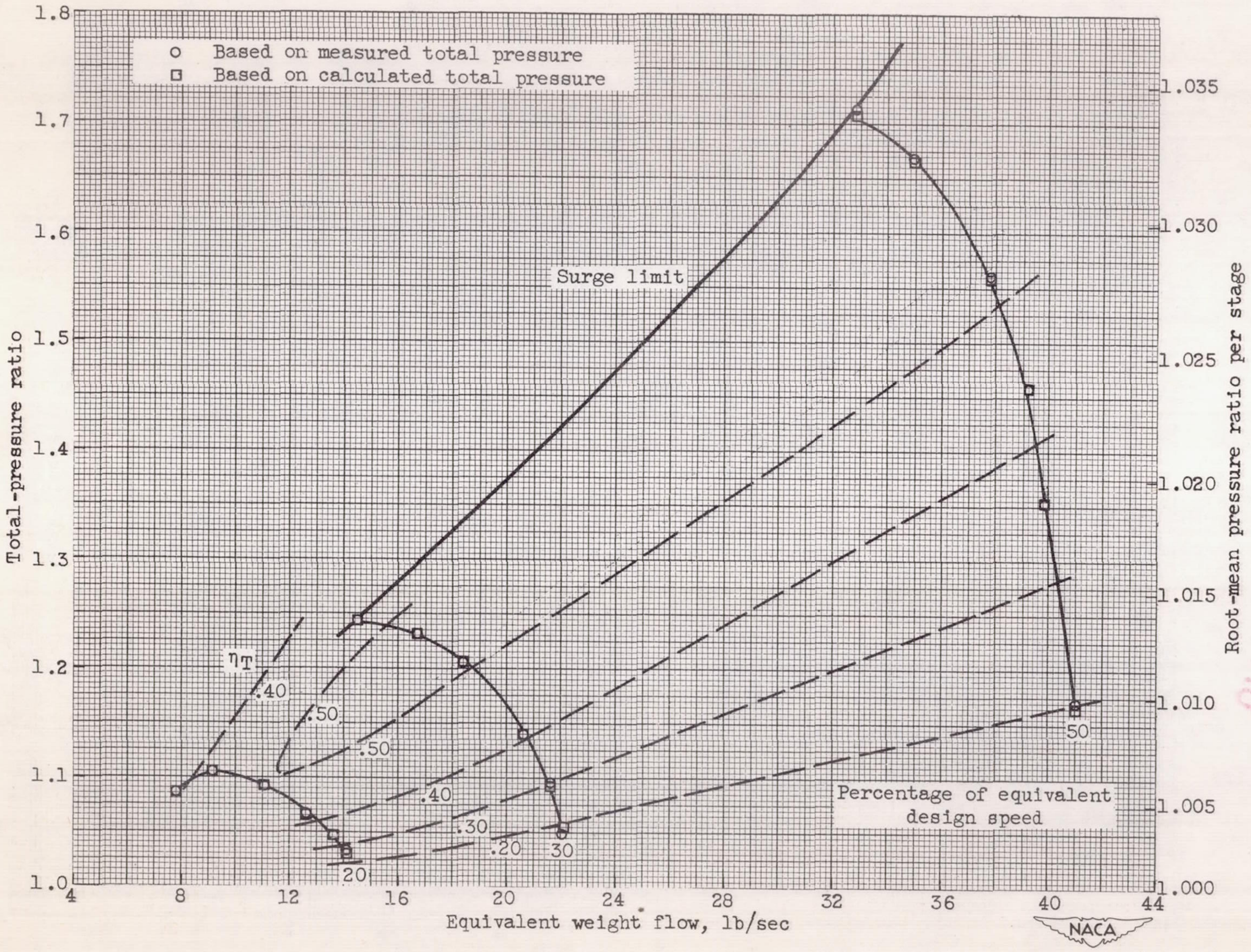


Figure 2. - Performance characteristics of J35-A-23 compressor at low speeds.

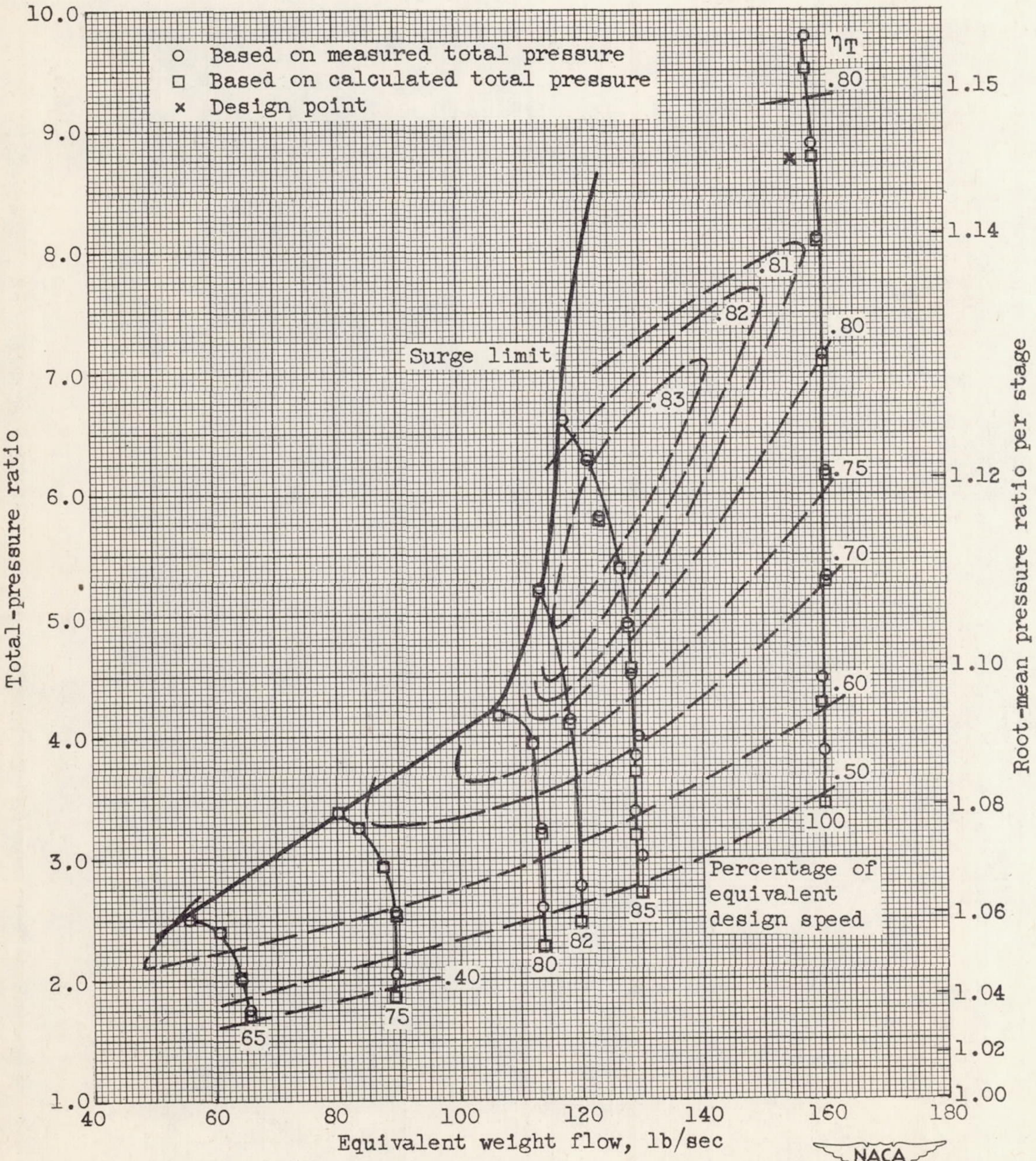


Figure 3. - Performance characteristics of J35-A-23 compressor at high speeds.