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RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

PERFORMANCE OF J33-A-23 TURBOJET-ENGINE COMPRESSOR

II - OVER-ALL PERFORMANCE CHARACTERISTICS OF COMPRESSOR WITH 34-BLADE IMPELLER AT EQUIVALENT IMPELLER SPEEDS FROM 6000 TO 11,750 RPM

By William L. Beede and Karl Kovach

Flight Propulsion Research Laboratory
Cleveland, Ohio

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II - OVER-ALL PERFORMANCE CHARACTERISTICS OF COMPRESSOR WITH 34-BLADE IMPELLER AT EQUIVALENT IMPELLER SPEEDS FROM 6000 TO 11,750 RPM

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SUMMARY

The J33-A-23 compressor with a 34-blade impeller was operated at ambient inlet temperature and an inlet pressure of 14 inches mercury absolute over a range of equivalent impeller speeds from 6000 to 11,750 rpm. Additional runs at equivalent speeds of 7,000, 10,000, and 11,750 rpm and ambient inlet temperature were made at inlet pressures of 5 and 10 inches mercury absolute. The results of this investigation are compared with those of the J33-A-23 compressor with a 17-blade impeller.

At the design equivalent speed of 11,750 rpm the J33-A-23 compressor with a 34-blade impeller had a peak pressure ratio of 4.49 at an equivalent weight flow of 82.4 pounds per second and an adiabatic temperature-rise efficiency of 0.740. The maximum equivalent flow at design speed was 91.8 pounds per second. The peak efficiency at design speed (0.757) occurred at an equivalent weight flow of 85.5 pounds per second. The maximum adiabatic temperature-rise efficiency of 0.773 was obtained at an equivalent impeller speed of 10,000 rpm, an equivalent weight flow of 65.8 pounds per second, and a pressure ratio of 3.27.

At equivalent impeller speeds of 10,000 and 11,750 rpm a decrease in inlet pressure resulted in a decrease in maximum equivalent weight flow, peak pressure ratio, and peak adiabatic temperature-rise efficiency.

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Over the range of equivalent impeller speeds investigated, the J33-A-23 compressor with a 34-blade impeller showed an increase in peak pressure ratio and maximum equivalent weight flow over the J33-A-23 compressor with a 17-blade impeller. At the design equivalent speed of 11,750 rpm the two compressors had the same peak adiabatic temperature-rise efficiency; however, at lower equivalent impeller speeds the J33-A-23 compressor with a 17-blade impeller had a higher efficiency than the J33-A-23 compressor with 34-blade impeller.

INTRODUCTION

At the request of the Air Materiel Command, U. S. Air Force, an investigation is being conducted at the NACA Cleveland laboratory to determine the performance characteristics of a series of J33 turbojet-engine compressors. A J33-A-23 compressor with a 34-blade impeller was operated over a range of equivalent impeller speeds from 6000 to 11,750 rpm with an inlet pressure of 14 inches mercury absolute and ambient inlet temperature. Additional runs at equivalent speeds of 7000, 10,000, and 11,750 rpm and ambient inlet temperature were made at inlet pressures of 5 and 10 inches mercury absolute. The over-all performance characteristics of the compressor are presented and these data are compared with those of the J33-A-23 compressor with a 17-blade impeller (reference 1).

APPARATUS AND METHODS

The apparatus and instrumentation are the same as those described in reference 2 with the exception that this impeller has 34 blades per side and the diffuser inlet-vane diameter is 33.76 inches.

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

Temperature, °F	±0.5
Pressure, inches mercury absolute	±0.04
Air weight flow, percent	±1.0
Speed, percent	±0.3

All runs were made at ambient inlet temperature which varied from 62° to 76° F. A summary of the operating conditions is given in the following table:

Equivalent impeller speed, $N/\sqrt{\theta}$ (rpm)	Equivalent tip speed, $U/\sqrt{\theta}$ (ft/sec)	Inlet pressure (in. Hg absolute)	Determine effect of
6,000	786	14.0	Speed
7,000	916	14.0	
8,500	1113	14.0	
9,000	1178	14.0	
10,000	1309	14.0	
11,000	1440	14.0	
11,750	1538	14.0	
7,000	916	5.0	Inlet pressure
7,000	916	10.0	
10,000	1309	5.0	
10,000	1309	10.0	
11,750	1538	5.0	
11,750	1538	10.0	

RESULTS AND DISCUSSION

Effect of speed. - Figure 1 presents the over-all performance of the J33-A-23 compressor with a 34-blade impeller. At the design equivalent speed of 11,750 rpm, the operating limits of the compressor lie between the surge point (82.4 lb/sec) at which the peak pressure ratio of 4.49 and the adiabatic temperature-rise efficiency of 0.740 occur and the choke flow of 91.8 pounds per second. At this speed, the peak efficiency of 0.757 occurred at an equivalent weight flow of 85.5 pounds per second and a pressure ratio of 4.40. The maximum adiabatic temperature-rise efficiency of 0.773 was obtained at an equivalent speed of 10,000 rpm, an equivalent weight flow of 65.8 pounds per second, and a pressure ratio of 3.27.

Effect of Reynolds number. - Figure 2 shows the effect of Reynolds number index $P_1/\mu\sqrt{T_1}$ on compressor performance for equivalent impeller speeds of 7000, 10,000, and 11,750 rpm. Because the inlet temperature was held as nearly constant as possible, changes in μ and $\sqrt{T_1}$ are very small and the principal variable is inlet pressure P_1. In the following table representative results are presented for a decrease in inlet pressure from 14 inches mercury absolute to 10 and 5 inches mercury absolute:

Inlet pressure (in. Hg absolute)	Equivalent speed (rpm)	Decrease in P_2/P_1 (percent)	Decrease in peak η_{ad} (percent)	Decrease in maximum $W\sqrt{\theta}/\delta$ (percent)
10 5	7,000	0 0	0 0	0 0
10 5	10,000	1.54 3.69	1.81 3.10	1.90 4.08
10 5	11,750	2.67 3.34	2.11 4.10	2.48 5.09

These variations indicate a Reynolds number effect which causes the performance to improve as the Reynolds number increases.

Comparison of performance of J33-A-23 compressor with 17-blade and 34-blade impeller. - A comparison of the performance of the J33-A-23 compressor with a 17-blade and a 34-blade impeller at design equivalent speed is shown in figure 3 and the following table:

Compressor	Peak η_{ad}	$W\sqrt{\theta}/\delta$ at peak η_{ad} (lb/sec)	Peak P_2/P_1	$W\sqrt{\theta}/\delta$ at peak P_2/P_1 (lb/sec)	Maximum $W\sqrt{\theta}/\delta$ (lb/sec)
17 blade	0.757	80.8	4.39	80.8	88.0
34 blade	0.757	85.5	4.49	82.4	91.8

The 34-blade compressor showed an improvement in performance over the 17-blade compressor except for the peak adiabatic temperature-rise efficiency, which was unaffected by the number of blades.

Figure 4 presents the variation in peak performance characteristics for the two compressors. The increase in weight-flow capacity of the 34-blade compressor over that of the 17-blade compressor varied from 1.6 percent at an equivalent speed of 6000 rpm to 4.3 percent at the equivalent design speed of 11,750 rpm. The peak efficiency of the 17-blade compressor is 1.8 to 3.5 percent higher than that of the 34-blade compressor except at the design equivalent speed where the efficiencies of the compressors are equal. The 34-blade compressor had a peak pressure ratio 0 to 2.3 percent greater than that of the 17-blade compressor.

SUMMARY OF RESULTS

1. At the design equivalent speed of 11,750 rpm, the J33-A-23 compressor with 34-blade impeller had a peak pressure ratio of 4.49 at an equivalent weight flow of 82.4 pounds per second and an adiabatic temperature-rise efficiency of 0.740. The maximum equivalent weight flow at this speed was 91.8 pounds per second. The peak efficiency at this speed (0.757) occurred at an equivalent weight flow of 85.5 pounds per second and a pressure ratio of 4.40.

2. The maximum adiabatic temperature-rise efficiency of 0.773 was obtained at an equivalent impeller speed of 10,000 rpm, an equivalent weight flow of 65.8 pounds per second, and a pressure ratio of 3.27.

3. At equivalent impeller speeds of 10,000 and 11,750 rpm a decrease in inlet pressure from 14 to 5 inches mercury absolute resulted in a decrease in maximum equivalent weight flow, peak pressure ratio, and peak adiabatic temperature-rise efficiency. These variations with inlet pressure indicate a Reynolds number effect.

4. Over the range of equivalent impeller speeds investigated, the 34-blade compressor showed an increase in maximum pressure ratio and maximum equivalent weight flow over the 17-blade compressor. At the design equivalent speed of 11,750 rpm the two compressors had the same peak adiabatic temperature-rise efficiency; however, at lower equivalent impeller speeds the 17-blade compressor had a higher efficiency than the 34-blade compressor.

Flight Propulsion Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, August 13, 1948.

William L. Beede

William L. Beede,
Aeronautical Research Scientist.

Karl Kovach

Karl Kovach,
Aeronautical Research Scientist.

Approved:
Robert O. Bullock,
Aeronautical Research Scientist.

Oscar W. Schey,
Aeronautical Research Scientist.

jgm

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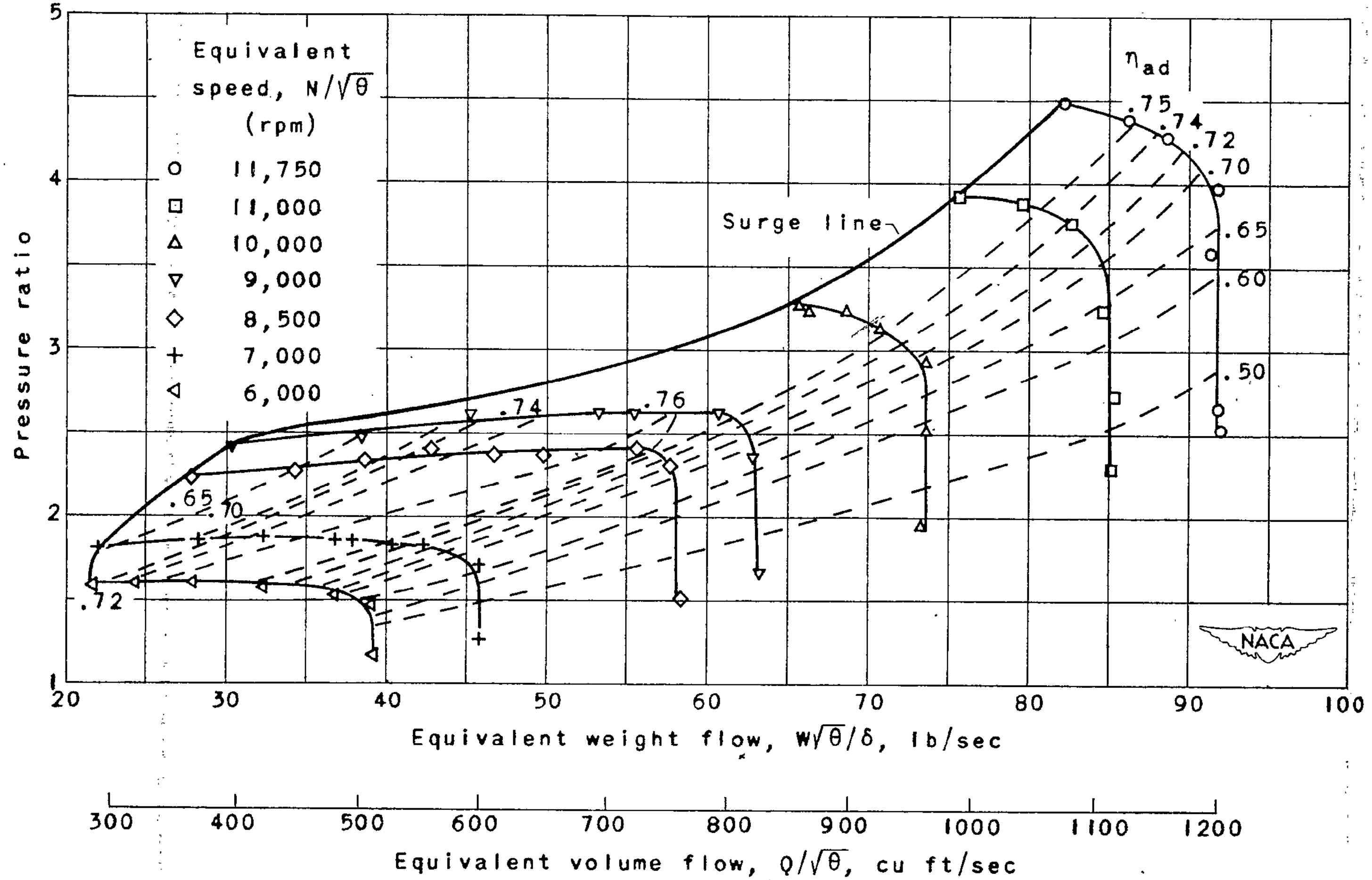
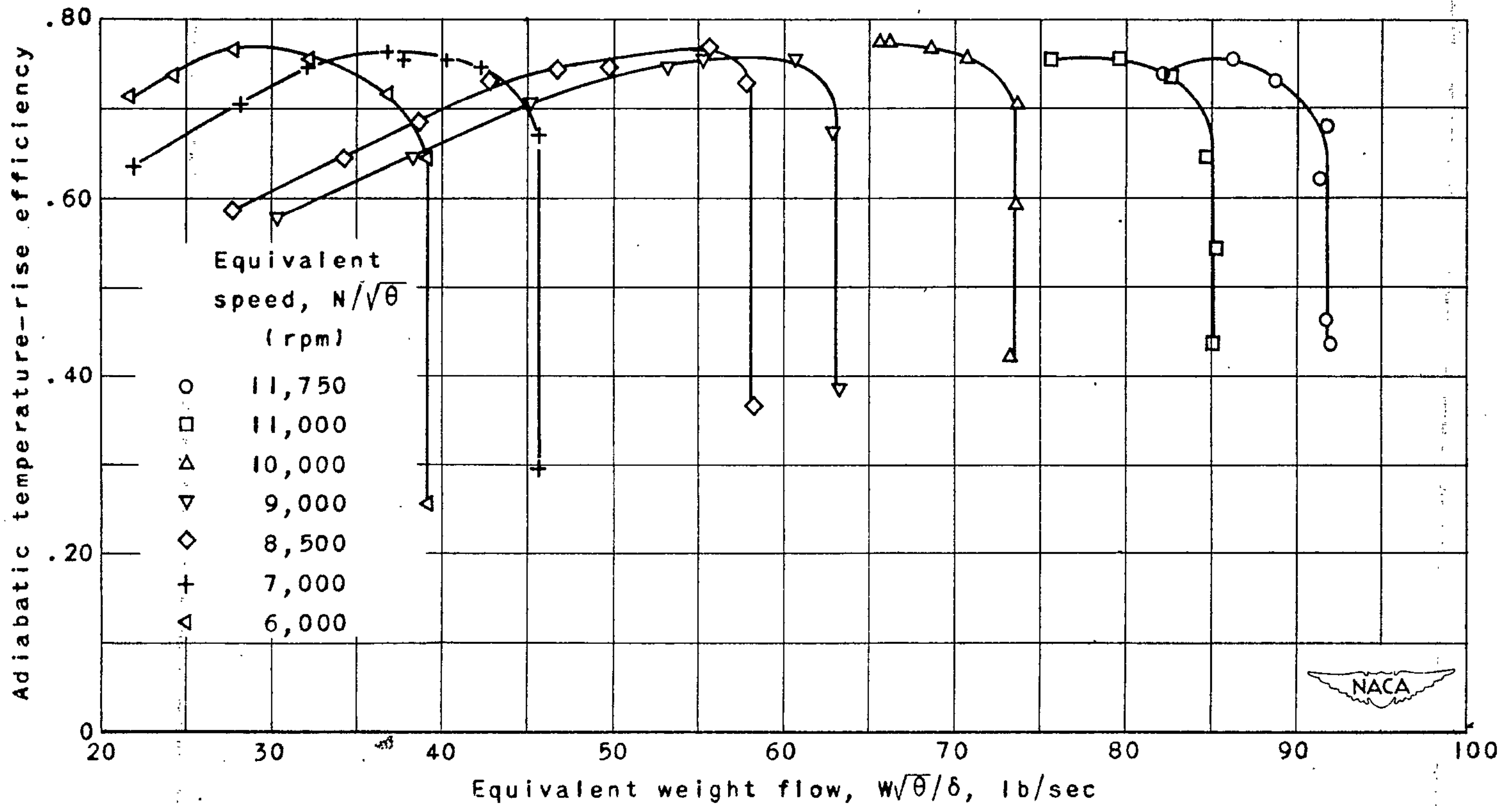


(a) Pressure ratio.

Figure 1. - Over-all performance of J33-A-23 compressor with 34-blade impeller at inlet pressure of 14 inches mercury absolute.



(b) Adiabatic temperature-rise efficiency.

Figure 1. - Concluded. Over-all performance of J33-A-23 compressor with 34-blade impeller at inlet pressure of 14 inches mercury absolute.

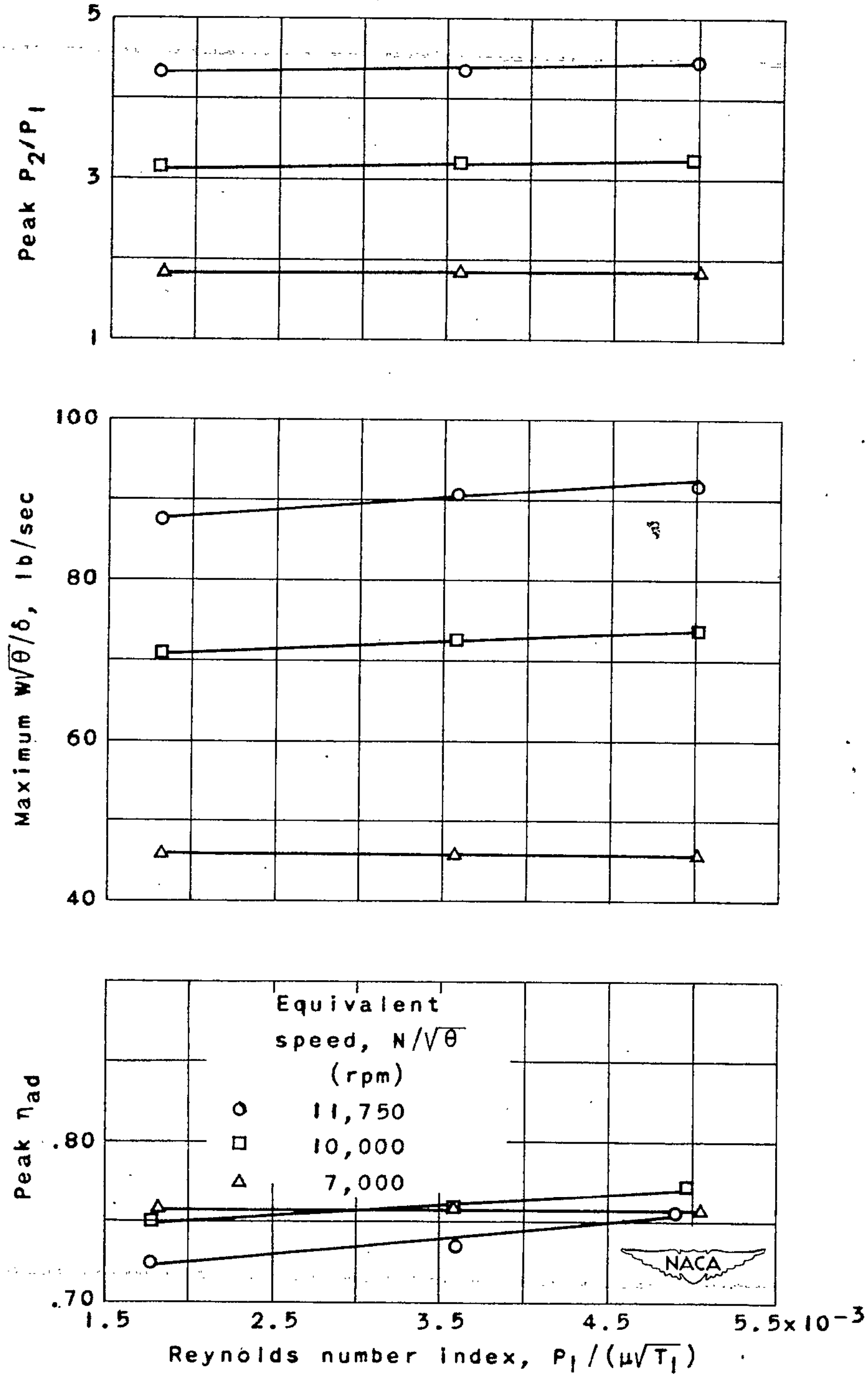


Figure 2. - Effect of Reynolds number on compressor performance.

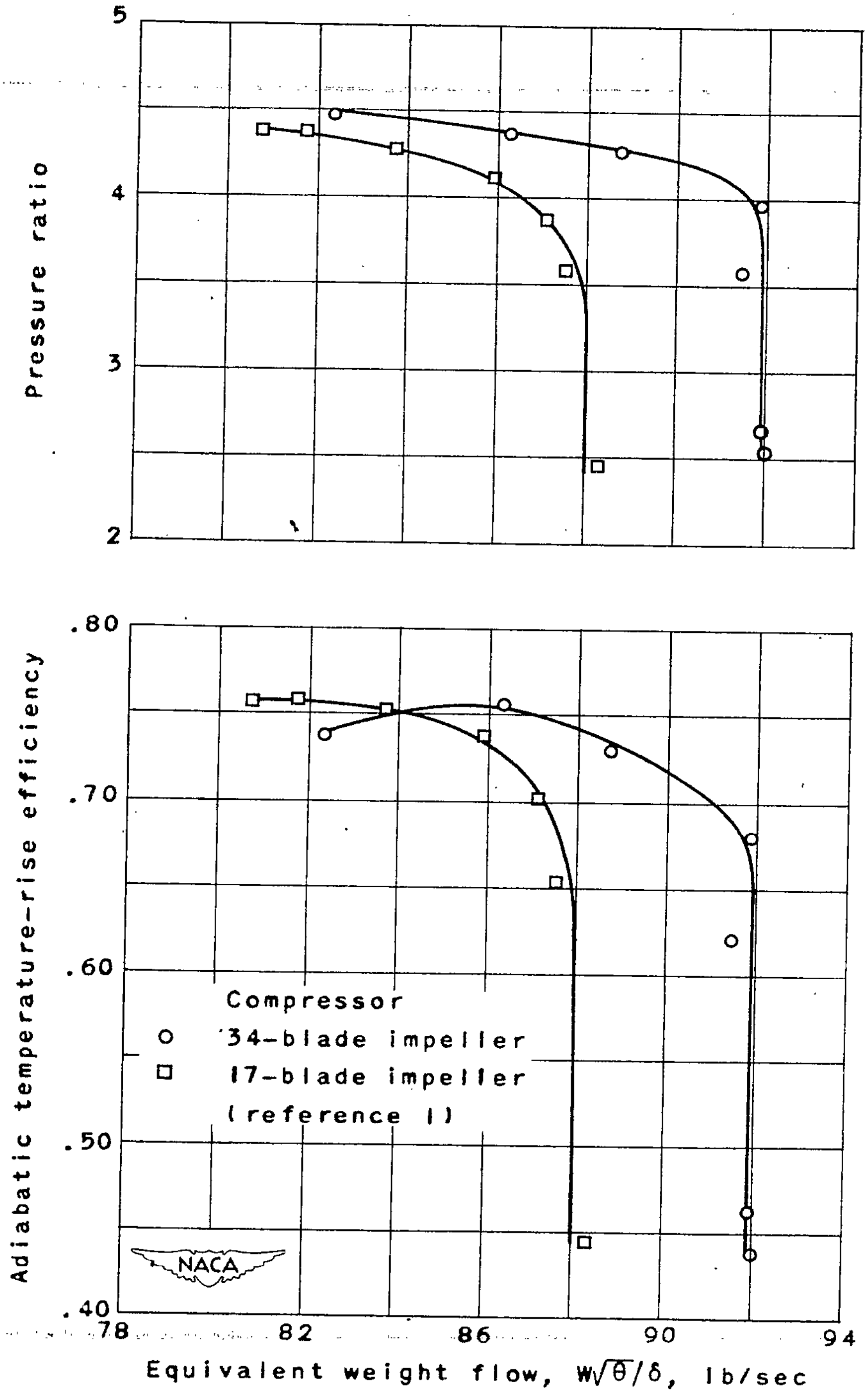
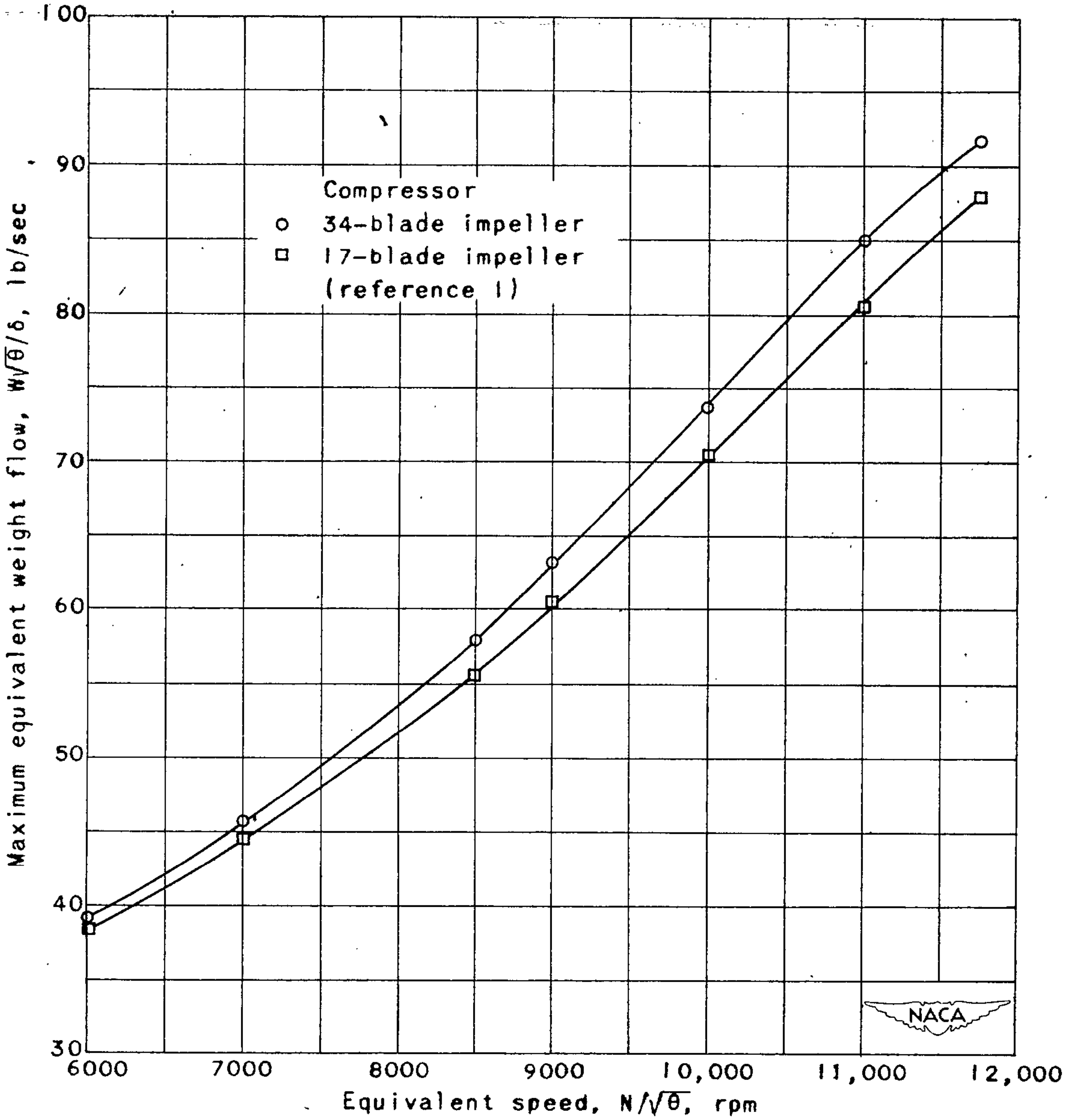
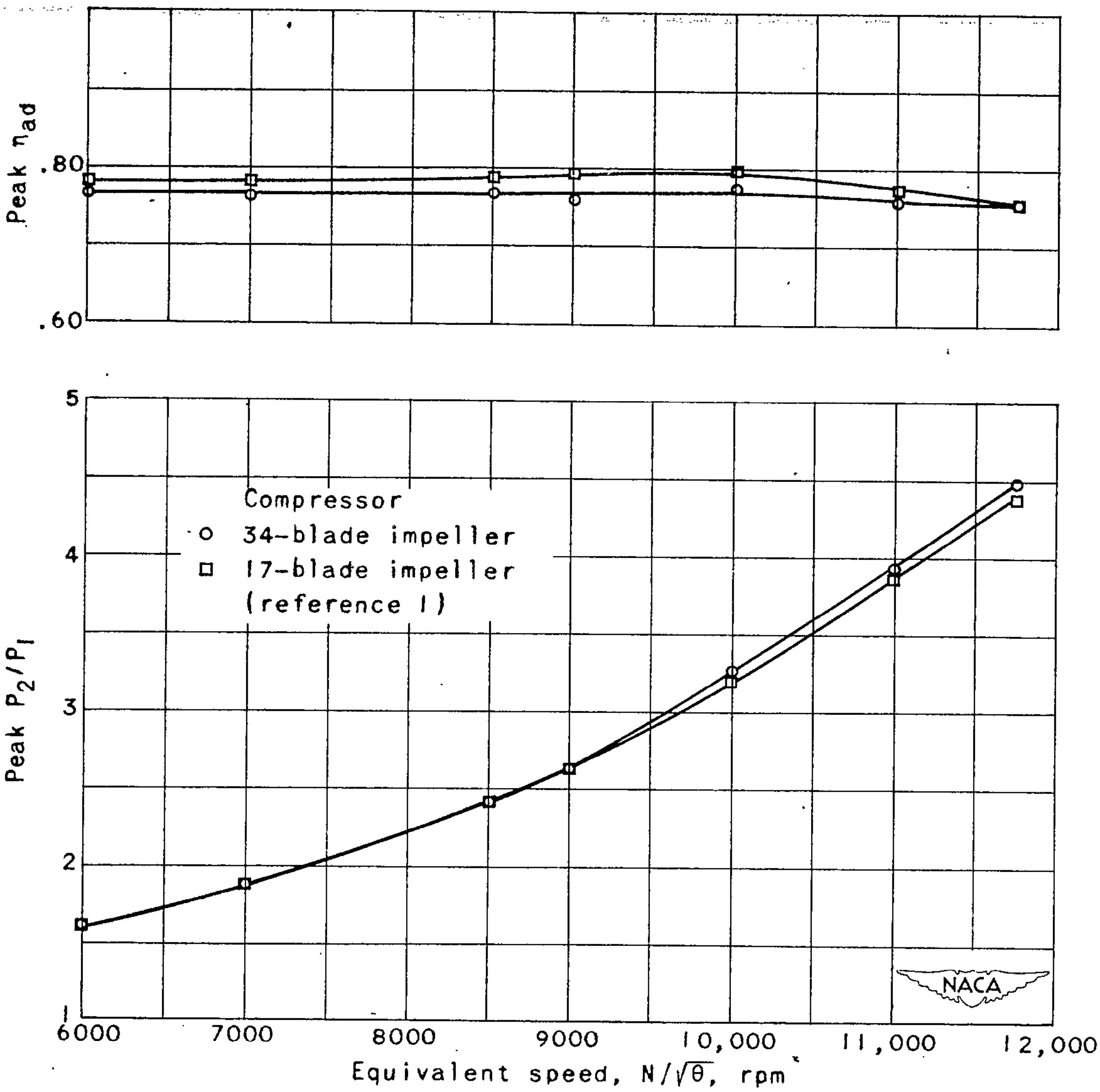


Figure 3. -Performance of J33-A-23 compressor with 17-blade and 34-blade impeller at equivalent design speed of 11,750 rpm.



(a) Maximum weight flow.

Figure 4. - Peak performance characteristics of J33-A-23 compressor with 17-blade and 34-blade impeller at inlet pressure of 14 inches mercury absolute.



(b) Peak pressure ratio and adiabatic efficiency.

Figure 4. - Concluded. Peak performance characteristics of J33-A-23 compressor with 17-blade and 34-blade impeller at inlet pressure of 14 inches mercury absolute.