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# RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

## PERFORMANCE OF ALLISON MODEL 400-C6 TURBOJET-ENGINE COMPRESSOR

## I - OVER-ALL PERFORMANCE CHARACTERISTICS OF COMPRESSOR AT EQUIVALENT IMPELLER SPEEDS OF 6000, 7000, AND 8500 RPM

By Karl Kovach and Joseph R. Withee, Jr.



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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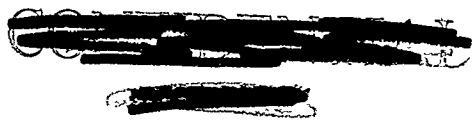
## SUMMARY

The Allison model 400-C6 compressor was operated at an inlet pressure of 12 inches of mercury absolute and ambient inlet temperature at equivalent impeller speeds of 6000, 7000, and 8500 rpm. Additional runs at an equivalent speed of 7000 rpm and ambient inlet temperature were made at inlet pressures from 7 to 22 inches of mercury absolute. The results of this investigation are compared with those of the J33-A-23 compressors.

For the speeds investigated, the Allison model 400-C6 compressor had a maximum adiabatic temperature-rise efficiency of 0.768 at an equivalent speed of 7000 rpm; the corresponding equivalent weight flow was 45.0 pounds per second and the pressure ratio was 1.83. At an equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow was 61.6 pounds per second and the peak pressure ratio of 2.38 occurred at an equivalent weight flow of 52.2 pounds per second and an adiabatic temperature-rise efficiency of 0.714.

At an equivalent speed of 7000 rpm, increasing the compressor-inlet pressure increased the maximum equivalent weight flow and the pressure ratio.

At the maximum comparable equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow was approximately 6.5 percent



higher than the weight flow for the J33-A-23 compressor with a 34-blade impeller. The pressure ratio and the adiabatic temperature-rise efficiency were slightly lower than those of the J33-A-23 compressors; however, a comparison of pressure ratio and efficiency at low speeds is not necessarily indicative of a comparison at high speeds.

## INTRODUCTION

At the request of the Air Materiel Command, U. S. Air Force, an investigation is being conducted at the NACA Lewis laboratory to determine the performance characteristics of a series of turbojet-engine compressors. An investigation of an Allison model 400-C6 turbojet-engine compressor is presented. Runs were made over a range of equivalent impeller speeds from 6000 to 8500 rpm with an inlet pressure of 12 inches of mercury absolute and ambient inlet temperature. Additional runs were made at an equivalent impeller speed of 7000 rpm, ambient inlet temperature, and various inlet pressures to determine the effect of inlet pressure (Reynolds number) on compressor performance. The investigation was terminated by failure of the compressor unit.

## APPARATUS AND INSTRUMENTATION

Apparatus. - The Allison model 400-C6 compressor assembly consists of a double-entry centrifugal compressor, a vaned diffuser, and a compressor casing. The compressor dimensions are:

| | |
|---|---|
| Impeller-inlet diameter, inches | 19.48 |
| Impeller-outlet diameter, inches | 30.00 |
| Number of impeller blades, per side | 23 |
| Diffuser-inlet-vane diameter, inches | 33.24 |
| Number of diffuser passages | 14 |
| Mean diffuser-discharge diameter, inches | 42.88 |
| Diffuser-outlet passage area, square inches per passage | 10.41 |

The remainder of the apparatus is the same as that described in reference 1.

Instrumentation. - The instrumentation is also the same as that described in reference 1 with the exception that a submerged flat-plate orifice was used to measure the compressor air weight flow.

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 |
| Impeller speed, percent | ±0.3 |

## SYMBOLS

The following symbols are used in this report:

| | |
|---|---|
| $N$ | impeller speed, rpm |
| $P_1$ | inlet total pressure, inches mercury absolute |
| $P_2$ | outlet total pressure, inches mercury absolute |
| $Q$ | volume flow, cubic feet per second |
| $T_1$ | inlet total temperature, °R |
| $U$ | impeller tip speed, feet per second |
| $W$ | weight flow, pounds per second |
| $\delta$ | ratio of inlet total pressure to NACA standard sea-level pressure |
| $\eta_{ad}$ | adiabatic temperature-rise efficiency |
| $\theta$ | ratio of inlet total temperature to NACA standard sea-level temperature |
| $\mu$ | absolute viscosity, pounds per foot-second |

## METHODS

The runs to determine the over-all performance characteristics of the compressor were made at ambient inlet temperature, which varied from 78° to 86° F, and at the highest inlet pressure possible at design

speed as limited by the power and the gear ratio of the drive unit. 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 $P_1$ (in. Hg abs.) | Effect determined |
|---|---|---|---|
| 6000 | 786 | 12 | Speed and air-flow rate |
| 7000 | 916 | 12 | |
| 8500 | 1113 | 12 | |
| 7000 | 916 | 7 | Inlet pressure (Reynolds number) |
| 7000 | 916 | 9 | |
| 7000 | 916 | 17 | |
| 7000 | 916 | 22 | |

## RESULTS AND DISCUSSION

Effect of speed. - The performance of the Allison model 400-C6 compressor at equivalent impeller speeds of 6000, 7000, and 8500 rpm is presented in figure 1. For these speeds, the maximum adiabatic temperature-rise efficiency was 0.768 and occurred at an equivalent impeller speed of 7000 rpm, an equivalent weight flow of 45.0 pounds per second, and a pressure ratio of 1.83. At an equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow was 61.6 pounds per second, and the peak pressure ratio of 2.38 occurred at an equivalent weight flow of 52.2 pounds per second and an adiabatic temperature-rise efficiency of 0.714.

Effect of inlet pressure (Reynolds number). - The effect of inlet pressure (Reynolds number) on compressor performance for an equivalent impeller speed of 7000 rpm is shown in figure 2. For convenience, this effect is shown in terms of a Reynolds number index $P_1/(\mu\sqrt{T_1})$. Because the inlet temperature was held as nearly constant as possible, changes in $\mu$ and $\sqrt{T_1}$ are very small and the principal variable is inlet pressure $P_1$. Increasing the Reynolds number by increasing the inlet pressure resulted in higher maximum equivalent weight flow and pressure ratio.

Comparison of performance of J33-A-23 compressors with Allison model 400-C6 compressor. - Peak performance characteristics of the J33-A-23 compressors and the Allison model 400-C6 compressor are

compared in figure 3 for equivalent impeller speeds of 6000, 7000, and 8500 rpm. The comparison is not exact because of the difference in the operating conditions between the model 400-C6 compressor and the J33 compressors. The model 400-C6 compressor was run at an inlet pressure of 12 inches of mercury absolute and the J33 compressors were run at an inlet pressure of 14 inches of mercury absolute. It can be seen from figure 2 that a slight increase in compressor performance would be obtained if the model 400-C6 compressor were operated at an inlet pressure of 14 inches of mercury absolute.

The weight-flow capacity of the model 400-C6 compressor is greater than the weight-flow capacity of the J33-A-23 compressors (fig. 3(a)). At an equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow is approximately 6.5 percent higher than the weight flow for the J33-A-23 compressor with a 34-blade impeller. The peak pressure ratio for the model 400-C6 compressor is very slightly lower than the peak pressure ratio for the J33-A-23 compressors. At an equivalent impeller speed of 8500 rpm, the peak adiabatic temperature-rise efficiency for the model 400-C6 compressor was approximately 0.04 lower than the efficiency for the J33-A-23 compressor with a 17-blade impeller, and approximately 0.02 lower than the efficiency for the J33-A-23 compressor with a 34-blade impeller. This comparison of pressure ratio and efficiency at low speeds is not necessarily indicative of a comparison at high speeds. In fact, the better a unit is at the design point, the poorer it is likely to be at off-design points.

## SUMMARY OF RESULTS

An investigation of the over-all performance characteristics of the Allison model 400-C6 compressor gave the following results:

1. When operated at equivalent impeller speeds of 6000, 7000, and 8500 rpm, the compressor had its maximum adiabatic temperature-rise efficiency of 0.768 at an equivalent impeller speed of 7000 rpm with an equivalent weight flow of 45.0 pounds per second and a pressure ratio of 1.83. At an equivalent impeller speed of 8500 rpm the maximum equivalent weight flow was 61.6 pounds per second and the peak pressure ratio of 2.38 occurred at an equivalent weight flow of 52.2 pounds per second and an adiabatic temperature-rise efficiency of 0.714.

2. At an equivalent impeller speed of 7000 rpm, increasing the compressor-inlet pressure resulted in higher maximum equivalent weight flow and pressure ratio. This variation of compressor performance with inlet pressure indicates a Reynolds number effect.

3. At the maximum comparable equivalent impeller speed of 8500 rpm, the maximum equivalent weight flow was approximately 6.5 percent higher than the weight flow for the J33-A-23 compressor with a 34-blade impeller. The pressure ratio and the adiabatic temperature-rise efficiency were slightly lower than those of the J33-A-23 compressors; however, a comparison of pressure ratio and efficiency at low speeds is not necessarily indicative of a comparison at high speeds.

Lewis Flight Propulsion Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, December 15, 1948.

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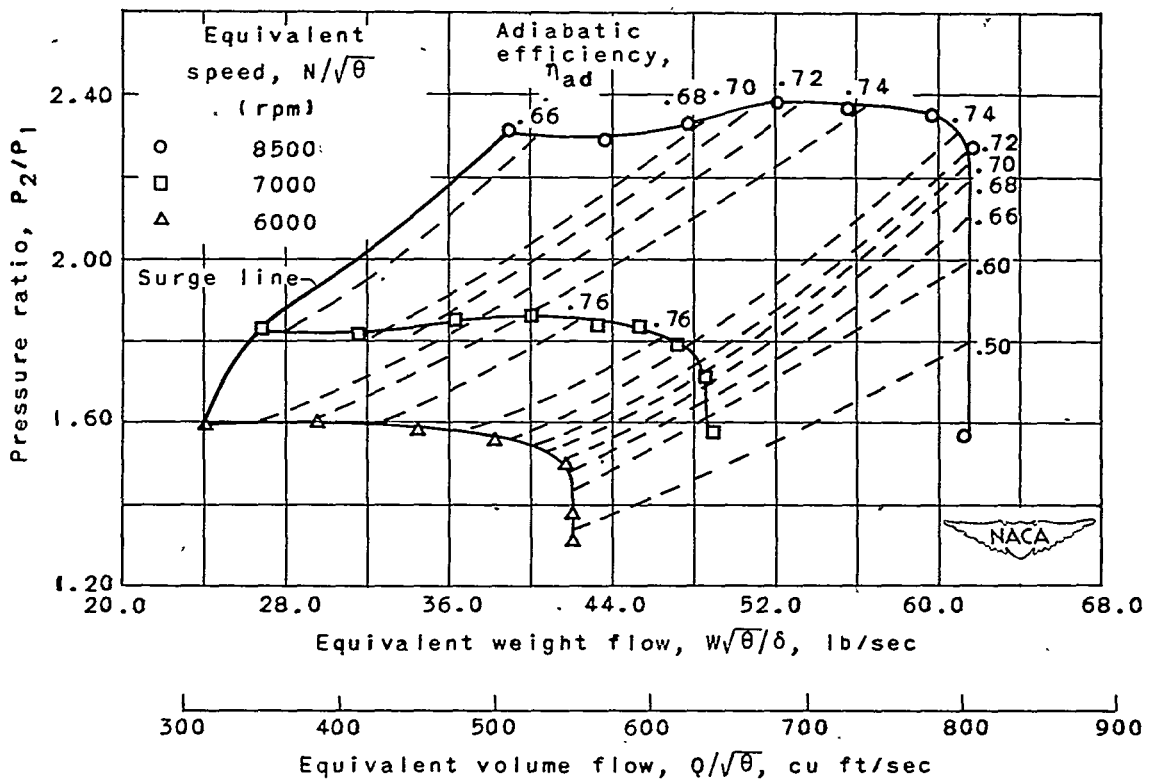
REFERENCES

1. Beede, William L., Kovach, Karl, and Creagh, John W. R.: Performance of J-33-A-21 Turbojet-Engine Compressor. I - Over-All Performance Characteristics at Equivalent Impeller Speeds from 6000 to 13,400 rpm. NACA RM No. SE8C15, U.S. Air Force, 1948.

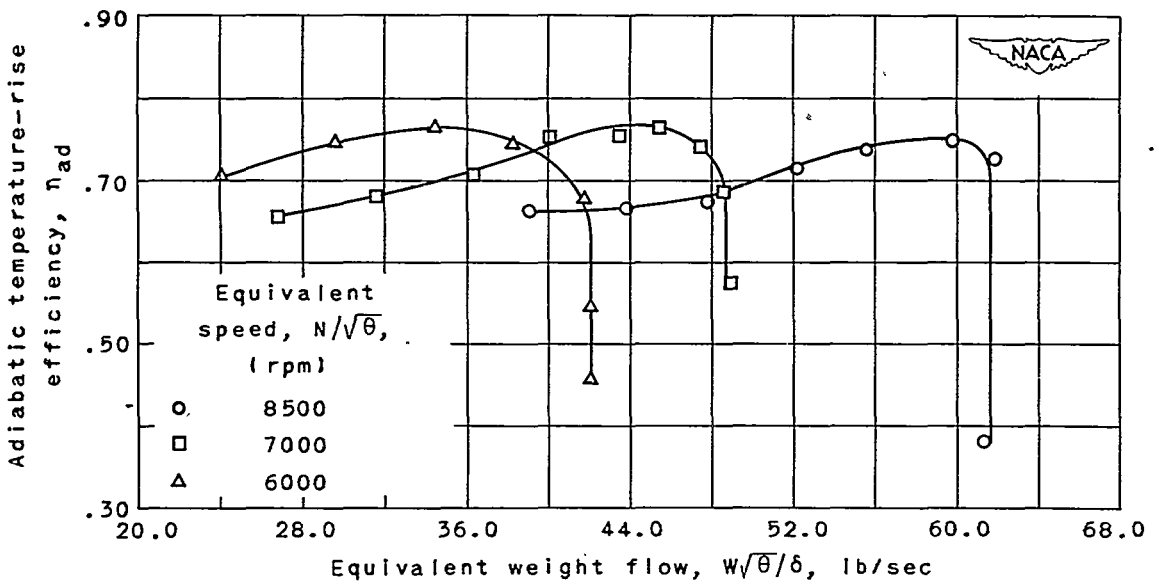
2. Beede, William L., and Kottas, Harry: Performance of J33-A-23 Turbojet-Engine Compressor. I - Over-All Performance Characteristics of Compressor with 17-Blade Impeller. NACA RM No. SE8F15, U.S. Air Force, 1948.

3. Beede, William L., and Kovach, Karl: 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. NACA RM No. SE8H13, U.S. Air Force, 1948.



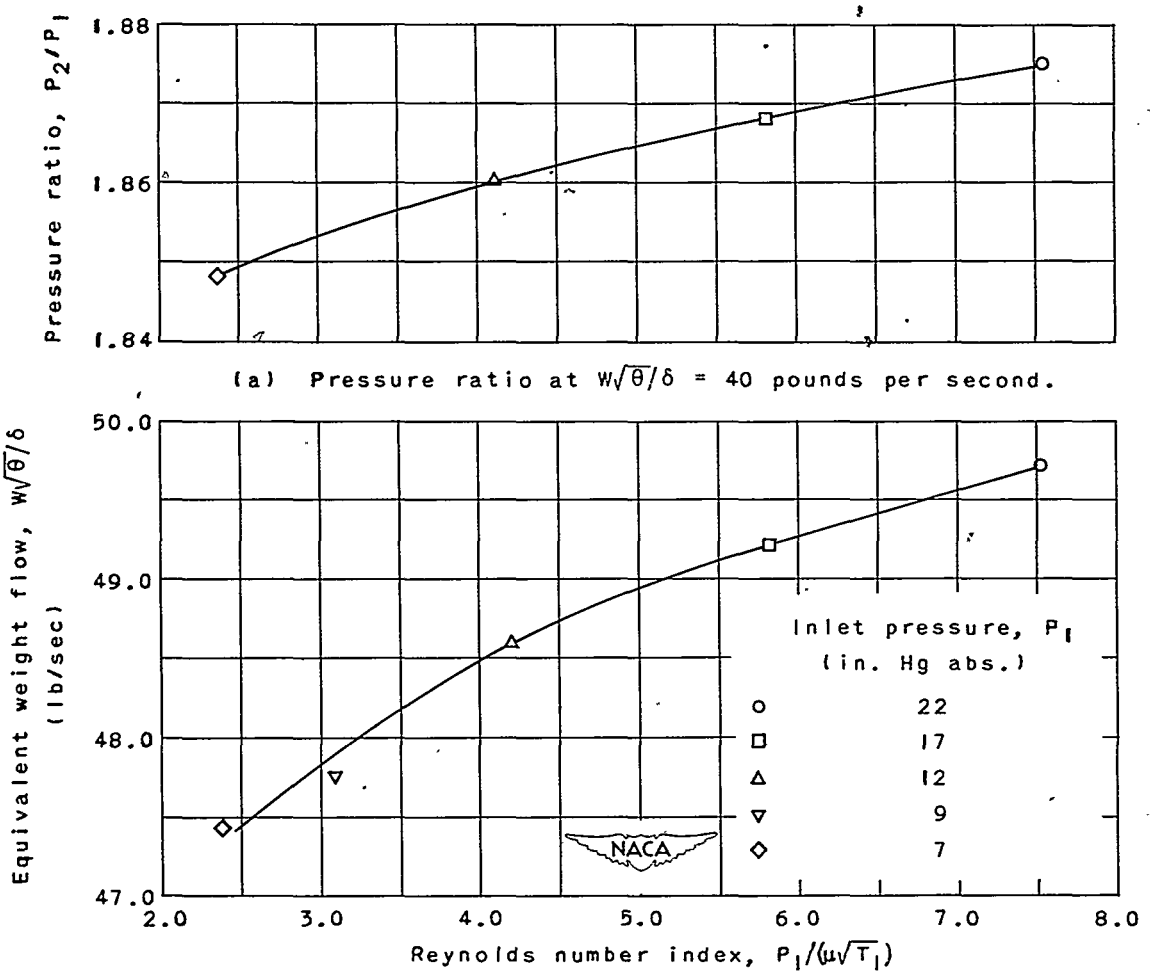

(a) Pressure ratio.

Figure 1. – Performance of 400-C6 compressor at inlet pressure of 12 inches mercury absolute and ambient inlet temperature.




(b) Adiabatic temperature-rise efficiency.

Figure 1. - Concluded. Performance of 400-C6 compressor at inlet pressure of 12 inches mercury absolute and ambient inlet temperature.




(a) Pressure ratio at $W\sqrt{\theta}/\delta$ = 40 pounds per second.

(b) Maximum equivalent weight flow.

Figure 2. – Effect of Reynolds number on 400-C6 compressor performance at equivalent impeller speed of 7000 rpm and ambient inlet temperature.

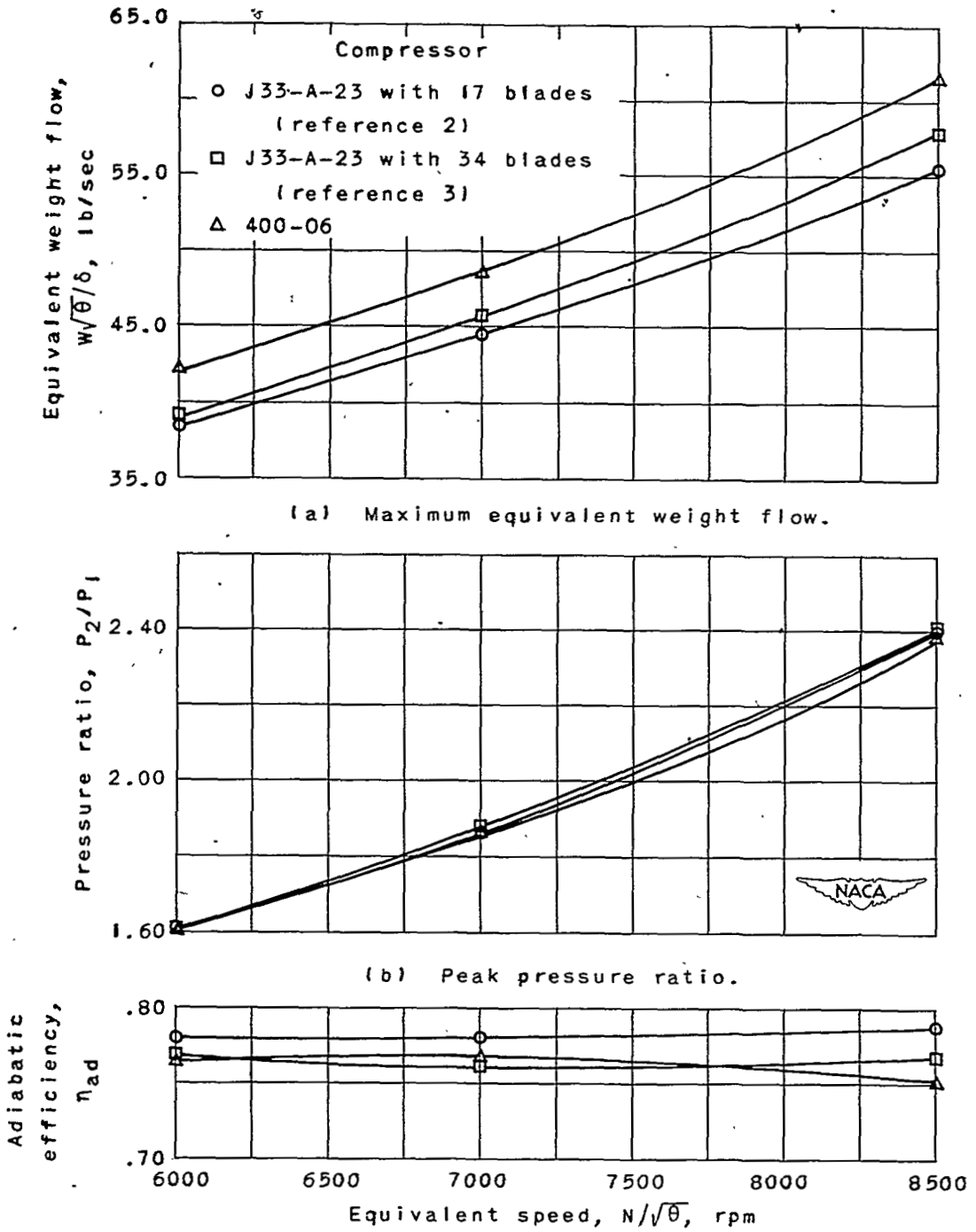



Figure 3. - Comparison of 400-C6 compressor with J33-A-23 compressors.