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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

INVESTIGATION OF X24C-2 10-STAGE AXIAL-FLOW COMPRESSOR

II - EFFECT OF INLET-AIR PRESSURE AND TEMPERATURE ON PERFORMANCE

By Harold B. Finger, Harold J. Schum, and Howard A. Buckner, Jr.

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INVESTIGATION OF X24C-2 10-STAGE AXIAL-FLOW COMPRESSOR

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SUMMARY

An investigation was made to determine the effects of inlet-air pressure and temperature on the performance of the 10-stage axial-flow compressor from the X24C-2 turbojet engine. The investigation was conducted for speeds of 80, 89, and 100 percent of equivalent design speed with inlet-air pressures of 6 and 12 inches of mercury absolute (424 and 849 lb/sq ft) and inlet-air temperatures of approximately 538°, 459°, and 419° R (79°, 0°, and -40° F). The results of the investigation of the effect of inlet-air pressure were compared with the results of the previous performance investigation at a nominal inlet-air pressure of 21 inches of mercury absolute (1485 lb/sq ft) and an inlet-air temperature of approximately 538° R to give a larger range of inlet-air pressures.

The peak values of adiabatic temperature-rise efficiency and pressure ratio were found to decrease as the inlet-air pressure was reduced at constant inlet-air temperature. The effect of inlet-air pressure on equivalent weight flow was small, the relative deviation reaching a maximum of about 1 percent. Variations in inlet-air temperature had only a slight effect on the same performance parameters. All data obtained at various inlet-air pressures and inlet-air temperatures correlated on two curves when the polytropic efficiency was plotted as a function of the polytropic loss factor. The only effect of inlet-air pressure was to increase the minimum loss factor and to decrease the maximum polytropic efficiency as the inlet-air pressure was reduced. The corresponding effect of temperature was negligible. Peak adiabatic temperature-rise efficiency and pressure ratio increased with increasing Reynolds number. The fact that the range of Reynolds number covered in varying the inlet-air pressure was considerably

larger than that obtained by varying the inlet-air temperature, shows that the largest effect of a change in altitude will be due to the change in pressure. A study of the interstage static-pressure data, obtained during this investigation, was made to determine the performance of each compressor component.

INTRODUCTION

The performance of the 10-stage axial-flow compressor from the X24C-2 turbojet engine is being investigated at the NACA Cleveland laboratory at the request of the Bureau of Aeronautics, Navy Department. This compressor was designed to deliver 54.6 pounds of air per second at a pressure ratio of 4, sea-level inlet conditions, and a rotor speed of 12,000 rpm.

The results of an investigation at an inlet-air pressure of 21 inches of mercury absolute (1485 lb/sq ft) and an ambient inlet-air temperature of approximately 538° R are reported in reference 1. One run of this investigation was made at the design speed when losses through the inlet piping reduced the maximum inlet-air pressure obtainable to 19.5 inches of mercury absolute (1374 lb/sq ft).

In order to determine the effect of inlet-air pressure on the performance of the compressor, runs at 80, 89, and 100 percent of equivalent design speed were made at inlet-air pressures of 6 and 12 inches of mercury absolute (424 and 849 lb/sq ft, respectively) at an inlet-air temperature of approximately 538° R. Ambient-air temperature was used so that a comparison could be made with the results obtained in reference 1 at corresponding speeds. Runs at inlet-air temperatures of 538°, 459°, and 419° R at an inlet-air pressure of 6 inches of mercury absolute were made to determine the effect of inlet-air temperature on the performance of the compressor. Because data in the high-flow or choking range of operation were not obtained in reference 1, a study of the interstage wall static-pressure measurements was made.

During investigations of effects of inlet-air conditions on the performance of other axial-flow compressors, (references 2 to 4), unmeasured amounts of air leaked into and out of the compressor and an unknown degree of heat transfer was present. For the present investigation, the setup was therefore designed to eliminate any source of appreciable air leakage and provisions were made to evaluate any leakage that might exist. Because elimination of heat transfer was impractical, calculations were made to determine the errors introduced by the heat-transfer processes.

APPARATUS AND INSTRUMENTATION

Apparatus

The 10-stage axial-flow X24C-2 compressor was designed to deliver 54.6 pounds of air per second at a pressure ratio of 4, sea-level inlet conditions, and a rotor speed of 12,000 rpm. The compressor and the setup used for this investigation were the same as those completely described in reference 1. A photograph of the over-all experimental setup is shown in figure 1. The compressor was driven by a 9000-horsepower variable-frequency induction motor rated at 1793 rpm through a gear box with a step-up ratio of 8.974:1.

Room air was used for the runs made to determine the effect of inlet-air pressure on compressor performance; for the determination of the effect of inlet-air temperature, air was supplied to the compressor by the laboratory refrigerated-air system. In both cases, the air passed through a submerged adjustable orifice in the inlet piping and into a depression tank, which was approximately 10 feet in length and 6 feet in diameter. A wooden bellmouth was fitted between the depression tank and the compressor-inlet section to insure smooth air entry into the compressor. Discharge air passed through a screen in the compressor-outlet passage into a collector and was removed by two radial outlet pipes into a common outlet pipe connected to the laboratory altitude-exhaust system.

In the investigation reported in reference 1, the screen in the outlet passage of the compressor limited the maximum air-weight flow through the unit. In order to alleviate this situation, the original 47-percent opening screen was replaced with a screen of 87-percent opening. This change was the only alteration made to the compressor setup used for the investigation of reference 1.

The inlet piping, the depression tank, the compressor, and part of the outlet piping were lagged to minimize heat transfer to or from the room. The compressor was lagged outside the protective steel shield, which allowed a dead-air space of approximately $3\frac{1}{2}$ inches to act as an additional insulator. The shield was covered with approximately 4 inches of 85-percent magnesia insulation.

Instrumentation

The instrumentation required for the determination of compressor performance was the same as that described in detail in reference 1; the methods used were those recommended in reference 5. Compressor air flow was metered by the submerged adjustable orifice located in the inlet piping. Compressor inlet-air measurements were made in the depression tank. Because the cross-sectional area of the tank was large, the velocity pressure in the tank was negligible and the static-pressure wall taps were used for measuring the inlet-air total pressure. Inlet-air temperature was measured in approximately the same plane as the pressure measurements, using two thermocouple rakes. Each rake consisted of three thermocouples, each thermocouple being located at the radius of gyration of equal annular areas. The outlet-air conditions were determined by eight static-pressure taps and six thermocouples located in the compressor-outlet section, which was made annular by inserts, as recommended in reference 5. Static pressures were also measured along the compressor casing between each rotor and stator row in order to obtain the pressure gradient through the compressor at the casing.

Air pressures were indicated on mercury manometers with the exception of the orifice pressure differential, which was indicated on a water manometer. Temperatures were measured with calibrated iron-constantan thermocouples in conjunction with a highly sensitive potentiometer. The cold junctions of these thermocouples were located in an ice bath. The speed of the compressor was measured with an electrical chronometric tachometer. The air used in the air-oil mist lubrication system was metered by a submerged orifice plate and passed through sonic nozzles to maintain a constant air supply to the bearings.

Precision

The precision of the measurements taken to determine the performance of the X24C-2 10-stage axial-flow compressor is estimated to be within the following limits:

Temperature, °R . . . . ±0.5
Pressure, in. Hg . . . . ±0.05
Compressor speed, percent . . . . ±0.5
Air-weight flow, percent . . . . ±1.0

The air-weight flow through the compressor, as measured by the submerged adjustable orifice in the inlet piping, was checked by a velocity head traverse in the outlet piping. Both methods of determining air-weight flow were previously calibrated simultaneously using a flat-plate orifice as a standard. The outlet measuring system was used solely as a check of the leakage. During the investigation, the two measurements of air-weight flow always agreed to within ±2 percent and the assumption was made that a negligible amount of air leakage existed.

Although the temperature of the air in the depression tank was measured within ±0.5° R, the temperature of the air at the inlet to the compressor proper was affected by heat conduction along the compressor casing and the rotor from the outlet of the compressor to the inlet section. Another source of heat transfer was the heat introduced by the leakage air used in the lubrication of the compressor front bearing. Consequently, in addition to inherent errors incurred by the inaccuracy of the measurements, a small additional error was caused by heat transfer. The maximum errors caused by the combined heat-transfer effects on the peak pressure ratio P_2/P_1 (ratio of total pressure at compressor outlet to total pressure at compressor inlet) and adiabatic temperature-rise efficiency η_T were estimated to be 0.5 and 0.25 percent, respectively. The following table gives the maximum percentage of deviation in the peak pressure ratio and efficiency caused by the inherent inaccuracy of measurements at each speed and inlet condition:

Inlet conditions		Equivalent design speed (percent)					
		80		89		100	
Pressure (in. Hg abs.)	Temperature (°R)	Peak pressure ratio P_2/P_1	Peak adiabatic temperature-rise efficiency η_T	Peak pressure ratio P_2/P_1	Peak adiabatic temperature-rise efficiency η_T	Peak pressure ratio P_2/P_1	Peak adiabatic temperature-rise efficiency η_T
21[a]	538	±0.34	±0.97	±0.32	±0.50	±0.19	±0.49
12	538	±.60	±1.24	±.57	±1.05	±.52	±1.03
6	538	±1.20	±2.54	±1.16	±1.54	±1.09	±1.61
6	459	±.99	±2.47	±.95	±2.13	±.89	±1.62
6	419	±1.02	±2.65	±.95	±2.22	±.89	±2.23

[a]Nominal value.

From this table it can be seen that the maximum deviation in temperature-rise efficiency and pressure ratio incurred by the precision of measurements varies considerably with a decrease in inlet-air pressure but varies only slightly with inlet-air temperature. From the succession of points obtained at a given speed and inlet condition, it appears that the actual deviation incurred for each point was relatively constant, the deviation varying with speed and inlet condition as noted from the preceding table.

SYMBOLS

The following symbols are used in the calculations:

c_p	specific heat at constant pressure, (Btu/(lb)(°F))
c_v	specific heat at constant volume, (Btu/(lb)(°F))
D	inside diameter of compressor casing, (ft)
M_2	outlet Mach number
m	polytropic exponent
n	number of stages
P	absolute total pressure, (lb/sq ft)
$(P_2/P_1)^{1/n}$	root-mean-pressure ratio per stage
p_x	absolute static pressure at various points along compressor casing, (lb/sq ft)
R	Reynolds number at compressor inlet, $\rho VD/\mu$
R'	Reynolds number index at compressor inlet, $W/T_1^{0.77}$
T	absolute total temperature, °R
V	axial inlet-air velocity, (ft/sec)
W	weight flow, (lb/sec)
$W\sqrt{\theta}/\delta$	equivalent weight flow corrected to NACA standard sea-level conditions, (lb/sec)
$W\sqrt{\theta}/\delta D^2$	specific equivalent weight flow corrected to NACA standard sea-level conditions, (lb/(sec)(sq ft))
γ	ratio of specific heats, c_p/c_v

δ	ratio of inlet-air total pressure to NACA standard sea-level pressure
η_p	polytropic efficiency, $\left(\frac{\gamma-1}{\gamma}\right) \Big/ \left(\frac{m-1}{m}\right)$
η_T	adiabatic temperature-rise efficiency
θ	ratio of inlet-air total temperature to NACA standard sea-level temperature
λ_p	polytropic loss factor, $\frac{\psi_m}{\eta_T}(1-\eta_p) = \frac{\psi_p}{\eta_p}(1 - \eta_p)$
ρ	density of air at compressor inlet, (lb/cu ft)
μ	absolute viscosity of air at compressor inlet, (lb / (ft)(sec))
ψ_m	mean pressure coefficient per stage
ψ_m/η_T	work input factor based on adiabatic temperature-rise efficiency
ψ_p	polytropic pressure coefficient per stage

Subscripts:

1	inlet
2	outlet

METHODS

In order to determine the effect of inlet-air pressure on the performance of the X24C-2 compressor, runs were made at inlet pressures of 6 and 12 inches of mercury absolute and ambient-air temperature (approximately 538° R or 79° F) so that a comparison could be made with the results of reference 1, which were obtained at a corresponding inlet-air temperature and a nominal inlet pressure of 21 inches of mercury absolute.

At the beginning of the investigation at reduced inlet-air temperatures, failure of one of the setup parts damaged the two rows of outlet-guide vanes and also caused the rotor blade tips to rub and wear slightly. These blade tips were designed with grooves extending to a radial depth of 7/64 inch in order to minimize damage in the event of blade-casing interference. The burrs at the rotor blade tips and in the compressor casing were removed and the two rows of outlet-guide vanes were replaced.

A run was then made at an inlet-air pressure of 6 inches of mercury absolute and ambient-air temperature to determine the change in performance resulting from these modifications; the difference was found to be within the accuracy of measurement. Additional runs were then made at an inlet-air pressure of 6 inches of mercury absolute and inlet-air temperatures of 459° and 419° R (0° and -40° F) to determine the effect of inlet-air temperature on compressor performance. It was necessary to make these runs at an inlet-air pressure of 6 inches of mercury absolute because of the limited quantity of refrigerated air available. At each inlet condition, the speeds investigated were confined to 80, 89, and 100 percent of the equivalent design speed. Lower speeds were considered unessential for these investigations because they are not within the normal operating range of the compressor.

All the runs reported were made in the same manner as the runs of reference 1 and in accordance with the recommendations of reference 5. At each speed investigated, the inlet-air temperature and pressure were maintained constant and the air flow was varied from the maximum obtainable with the laboratory air system to the point just preceding incipient surge. Surging was detected audibly and by observing fluctuations on the manometers.

The methods of calculating the performance parameters are discussed in references 1 and 5 except for the inlet Reynolds number index, which is introduced herein.

Inlet Reynolds number is defined as

$$R = \frac{\rho V D}{\mu}$$

For the determination of the Reynolds number at a given blade element of the compressor, the velocity term should be taken as the velocity of the air relative to the blade element being considered and the length should be that which is characteristic of the particular blade element. Consequently, the numerical value of the Reynolds number will vary from hub to tip in a given blade row and from one row of blades to another. When dynamic similarity is obtained, the Reynolds number at any blade element is proportional to the inlet Reynolds number; and, except for the possible effects of viscosity and heat transfer, dynamic similarity is determined by equivalent speed and equivalent weight flow.

Thus, when the equivalent speed and the equivalent weight flow are held constant, the true variations of Reynolds number throughout the compressor will be approximately proportional to the variation of inlet Reynolds number if the accumulated effects of Reynolds number are actually small.

From the equation of continuity

$$\rho V = \frac{4W}{\pi D^2}$$

The viscosity μ is proportional to the inlet-air temperature raised to the 0.77 power for the range of temperatures encountered in this investigation. Substitution in the original equation for inlet Reynolds number yields

$$R \sim \frac{4W}{DT_1^{0.77}} \sim \frac{W}{T_1^{0.77}} = R'$$

For facility in discussion, the Reynolds number index R' is used as an exact indication of inlet Reynolds number.

RESULTS AND DISCUSSION

All performance parameters presented in the discussion have been corrected to NACA standard sea-level conditions of 29.92 inches of mercury absolute and 518.4° R, as prescribed in reference 5. The results of the investigation are divided into five parts: (1) general performance, (2) effect of inlet-air pressure, (3) effect of inlet-air temperature, (4) effect of Reynolds number, and (5) interstage measurements.

General Performance

The variation of over-all pressure ratio P_2/P_1 and root-mean-pressure ratio per stage $(P_2/P_1)^{1/n}$ with equivalent weight flow $W\sqrt{\theta}/\delta$ and specific equivalent weight flow $W\sqrt{\theta}/\delta D^2$ is shown in figure 2 for compressor speeds of 80, 89, and 100 percent of the design speed (12,000 rpm) with an ambient inlet-air temperature of approximately 538° R and inlet-air pressures of 12 and 6 inches of mercury absolute. Adiabatic temperature-rise efficiency contours and the surge limit are also shown. The general performance for the three speeds investigated with an inlet pressure of 6 inches of mercury absolute and inlet-air temperatures of approximately 538°, 459°, and 419° R is presented in figure 3. The results of figure 3 were obtained after the compressor blade tips had rubbed and the damage had been repaired. Table I presents all compressor parameters determined in accordance with reference 5.

Effect of Inlet-Air Pressure on Performance

The effect of varying inlet-air pressure on compressor performance was found to be difficult to evaluate in references 2 to 4 because of unmeasured amounts of air leakage into and out of the compressors. The setup for the present investigation was therefore designed to reduce leakage as much as possible; and if any leakage did occur, precautions were made for measuring the air-weight flow both upstream and downstream of the compressor. Because these two weight-flow measurements agreed within ±2 percent, the assumption was made that the amount of air leakage was negligible. The only known source of leakage was the air spray used in conjunction with the oil-air-mist lubrication system for the compressor front bearing. This air leakage was constant at 0.024 pound per second for all operating conditions and resulted in a maximum error of 0.3 percent in the actual air flow through the compressor. This error was well within the precision of measurement and was less than the difference between the inlet and outlet flow measurements.

In order to show the effect of inlet-air pressure on compressor-performance characteristics, results obtained at inlet-air pressures of 6 and 12 inches of mercury absolute are compared with corresponding results at the higher inlet-air pressures (reference 1) for 80, 89, and 100 percent of design speed. Adiabatic temperature-rise efficiency η_T and pressure ratio P_2/P_1 as functions of equivalent weight flow are presented in figures 4 and 5, respectively, for the inlet-air pressures investigated. The effect of inlet-air pressure on the variation of polytropic efficiency with polytropic loss factor is shown in figure 6.

Adiabatic temperature-rise efficiency. - The effect of inlet-air pressure on the adiabatic temperature-rise efficiency at an inlet-air temperature of 538° R is presented in figure 4. At each of the three speeds investigated, the peak efficiency decreased with decreasing inlet-air pressure. The difference between peak efficiencies decreased from 0.07 at 80 percent of design speed to 0.05 at design speed. These results are in general agreement with those of references 2 and 3. The trend of decreasing efficiency with decreasing inlet-air pressure is in the direction that would be expected from a Reynolds number effect; that is, lower inlet

Reynolds numbers result in lower efficiencies. An indication of the range of Reynolds number covered by varying inlet-air pressure may be obtained from the fact that the inlet Reynolds number at the highest inlet-air pressure was approximately $3\frac{1}{2}$ times that for for the lowest inlet pressure.

Maximum efficiency at an inlet-air pressure of 21 inches of mercury absolute was observed at 89 percent of the design speed; at an inlet-air pressure of 12 inches of mercury absolute, maximum efficiency was observed at 80 percent of design speed; with an inlet-air pressure of 6 inches of mercury absolute, however, maximum efficiency was observed at design speed. The maximum difference between the peak efficiencies for a given inlet-air pressure was approximately 0.02. For the inlet-air pressure of 6 inches of mercury absolute, the entire variation of peak efficiency with speed is within experimental error; for inlet-air pressures of 21 and 12 inches of mercury absolute, however, only one-half of the variation of peak efficiency with speed may be attributed to experimental error. From these results, inlet-air pressure apparently changed the speed at which maximum efficiency occurred.

Pressure ratio and equivalent weight flow. - The effect of inlet-air pressure on pressure ratio and equivalent weight flow is presented in figure 5. At all the speeds investigated, the peak pressure ratio obtained with the maximum inlet-air pressure was greater than that obtained with an inlet-air pressure of 6 inches of mercury absolute. The difference in peak pressure ratio obtained at the highest and lowest inlet-air pressures reached a maximum of 0.17 (approximately 6 percent) at 89 percent of design speed. Peak pressure ratio at an inlet-air pressure of 12 inches of mercury absolute was, in all cases, less than or equal to the peak pressure ratio at an inlet-air pressure of 21 inches of mercury absolute and greater than or equal to that obtained at 6 inches of mercury absolute. The difference in peak pressure ratio obtained at the two low inlet-air pressures decreased from 0.06 to practically 0 as the speed was increased from 80 to 100 percent of design speed. In general, a decrease in inlet-air pressure with constant inlet-air temperature therefore decreases the peak pressure ratio. The differences in peak pressure ratio at each speed were approximately equivalent to the differences in peak adiabatic temperature-rise efficiency.

The effect of inlet-air pressure on equivalent weight flow can be determined by examining the high-flow range of operation for each speed in figure 5. The maximum equivalent weight flow was the same for the two higher inlet-air pressures at all speeds. At design speed, the curves for all three inlet-air pressures are coincident in the high-flow range. At 80 and 89 percent of design speed, the weight flows for an inlet-air pressure of 6 inches of mercury absolute are slightly less than those for inlet-air pressures of 12 and 21 inches of mercury absolute. The maximum deviation at high flows was only 2 percent, at least one-half of which can be attributed to experimental error. Inlet-air pressure apparently has a maximum effect of about 1 percent on equivalent weight flow. The discrepancy between the effect of inlet-air pressure on equivalent weight flow as shown in references 2 to 4 and that shown herein may be chiefly attributed to leakage effects in the reference investigations.

The results presented in figure 4 indicate that the surge-free range of operation was increased as the inlet-air pressure was reduced. At 80 and 89 percent of design speed, the surge limit of operation consistently occurred at lower values of weight flow as inlet-air pressure decreased. At the low inlet-air pressures, detection of surging was difficult because the pulsations were much milder than at the high inlet-air pressures. The milder pulsations at the low inlet-air pressures may have been due either to the decreased air density or to changes in the resistance-volume characteristics of the inlet and outlet ducts resulting from different inlet and outlet throttle settings. Inasmuch as the surging characteristics encountered in this investigation would very probably be different from those encountered during the operation of a jet engine, the observed extension of the surge-free range of operation accompanying a decrease in inlet-air pressure was regarded only as a possible trend.

Polytropic loss factor. - The use of a polytropic loss factor proved satisfactory in obtaining an accurate correlation of the effect of inlet-air pressure upon compressor performance independent of speed. The polytropic loss factor λ_p, which is a function of all the losses of compression such as heat transfer, blade drag, tip clearance, and wall friction, is defined as the difference between the work input factor ψ_p/η_p and the pressure coefficient ψ_p, which are measures of the actual and useful work, respectively, performed on a gas during the compression process. In addition, presenting this polytropic loss factor as a function of polytropic efficiency, which serves as an indication of mean stage efficiency, gave a satisfactory correlation. This polytropic efficiency is equal to the ratio of the polytropic to the actual work of compression. The derivations of polytropic efficiency and polytropic loss factor are presented in reference 1.

The variation of polytropic efficiency with the polytropic loss factor for the various speeds and inlet-air pressures investigated is shown in figure 6. The compressor performance for all speeds and inlet conditions can be presented by two converging curves as found in reference 1. Points for low flows at each speed fall on the upper curve of figure 6 and those for high flows fall on the lower curve. All the data correlate on the same two curves within about 2 percent regardless of inlet-air pressure and speed. The data for each inlet-air pressure are shown on a separate plot only for the sake of simplicity. The chief effects of inlet-air pressure were to increase the minimum loss factor and decrease the maximum polytropic efficiency as the inlet-air pressure was reduced. In going from the maximum inlet-air pressure of 21 inches of mercury absolute to 6 inches of mercury absolute, the polytropic loss factor increased from 0.056 to 0.082 and the polytropic efficiency decreased from 0.87 to 0.81. It must be remembered, however, that efficiency is a function of the ratio of losses to input and that a decrease in losses alone does not necessitate an increase in efficiency. From the data of figure 6 it appears that inlet-air pressure has little effect on the correlation except in the region of the minimum loss factor.

Effect of Inlet-Air Temperature on Performance

Heat transfer. - Because other investigators have found it difficult to evaluate the effect of inlet-air temperature on compressor performance due to heat-transfer effects (references 2 and 3), calculations were made to estimate the extent of these effects for the present investigation. The following processes were considered:

(a) Heat transferred by conduction from the outlet air to the inlet air through the casing and the rotor, which would cause a difference between the observed and the actual inlet-air temperatures

(b) Heat transferred by convection from the front bearing air-oil lubrication spray entering the air stream at the compressor inlet to the inlet air, which would cause a difference between the observed and the actual inlet-air temperatures

(c) Heat transfer between the working fluid and the ambient air, which would not only cause a deviation between the observed and the actual temperature rises through the compressor but would also change the relative velocity diagram of the individual stages

(d) Heat transfer from the working fluid through the turbine shaft to the balance piston (see fig. 5, reference 1), which would cause an error in the measured outlet-air temperature

(e) Heat transferred between the compressor and its supports

These calculations indicated that the maximum error in efficiency due to these heat-transfer effects was 0.25 percent for the condition that seemed to be affected most. The magnitude of the calculated effect is less than the accuracy of the measurements for an inlet-air pressure of 6 inches of mercury absolute. Consequently, the effect of heat transfer was neglected in evaluating the results of this investigation.

Adiabatic temperature-rise efficiency. - The effect of inlet-air temperature on adiabatic temperature-rise efficiency is presented in figure 7 for 80, 89, and 100 percent of design speed at an inlet-air pressure of 6 inches of mercury absolute. Inlet-air temperatures of 538°, 459°, and 419° R were investigated. The differences in the peak efficiencies obtained with the various inlet-air temperatures are very small, reaching a maximum of about 0.03 at 80 percent of design speed. In the low-flow range of the curves at 80 percent of design speed, the efficiency with an inlet-air temperature of 419° R is considerably lower than the efficiencies with either of the two other inlet-air temperatures. This variation is partly attributed to the light-surge condition over most of the low-flow region. For all speeds, the peak adiabatic temperature-rise efficiency at an inlet-air temperature of 459° R was greater than or equal to that for 538° R. Conversely, the peak value of adiabatic temperature-rise efficiency at an inlet-air temperature of 419° R was never greater than that obtained at the inlet-air temperature of 538° R. The peak efficiency for all speeds investigated was less for an inlet-air temperature of 419° R than for 459° R. Although the total variation of peak efficiency with the three inlet-air temperatures is within the absolute precision of measurements, most of the data indicate that the adiabatic temperature-rise efficiency does vary with inlet-air temperature. Between the temperatures of 538° and 459° R, the change in efficiency with temperature follows a trend which suggests that the effect of inlet-air temperature on adiabatic temperature-rise efficiency was nothing more than the effect of Reynolds number. Between the temperatures of 459° and 419° R, however, the apparent trend is just the opposite. Although the evidence is still inconclusive, the effect of inlet-air temperature on adiabatic temperature-rise efficiency apparently can not be completely explained by the effect of inlet-air temperature on Reynolds number.

The results of reference 2 indicate an effect of temperature comparable in magnitude to these results. The effect of temperature as presented in reference 3 was considerably greater than the effect obtained in the current investigation but the results of reference 3 were affected by air leakage of unknown magnitude. In this investigation, the variation of peak adiabatic temperature-rise efficiency with inlet-air temperature over the range of temperature that is of interest appears to be extremely small for the inlet-air pressure investigated (6 in. Hg absolute).

Pressure ratio and equivalent weight flow. - The variation of pressure ratio with equivalent weight flow is shown in figure 8 for the three speeds and inlet-air temperatures investigated. At all speeds, the maximum difference in peak pressure ratio obtained with the various inlet-air temperatures was less than 0.10. Because the differences in peak pressure ratio at 89 and 100 percent of design speed are only approximately 0.3 and 0.8 percent greater, respectively, than the inaccuracy introduced by the precision of measurements, the effect of inlet-air temperature on pressure ratio apparently is equivalent to the effect of inlet-air temperature on efficiency. In all cases investigated, the peak pressure ratio obtained with an inlet-air temperature of 459° R was greater than with either the inlet-air temperatures of 538° or 419° R with the exception of the 80 percent design speed where the peak pressure ratio was approximately the same at the inlet-air temperatures of 538° and 459° R. The peak pressure ratio obtained with the inlet-air at 419° R increased from 2.18 at 80 percent of design speed to 3.28 at design speed and was less than that obtained with ambient inlet-air temperature at all speeds investigated. The effect of inlet-air temperature on equivalent weight flow is relatively small when the precision of measurement is considered, but most of the data indicate that a decrease in inlet-air temperature from 538° to 459° R tends to increase the maximum air capacity of the compressor; whereas a decrease in inlet-air temperature from 459° to 419° R tends to diminish the air capacity. The maximum air capacity of the compressor is apparently a complex function of the inlet-air temperature, and is not completely explained by Reynolds number.

Polytropic loss factor. - The variation of polytropic efficiency with polytropic loss factor is presented in figure 9 for inlet-air pressure of 6 inches of mercury absolute and inlet-air temperatures of 538°, 459°, and 419° R. Comparison of the curves indicates that inlet-air temperature has no appreciable effect on the location of the two curves on which the data fall. The only effect of temperature occurred at the point of minimum loss factor but this effect was practically negligible.

Effect of Reynolds Number on Performance

The results of this investigation have indicated a noticeable effect of inlet-air pressure on performance but only a slight effect of inlet-air temperature. Both adiabatic temperature-rise efficiency and pressure ratio increased appreciably as the inlet-air pressure was increased from 6 to 21 inches of mercury absolute. This trend is in agreement with the results of previous investigations (references 2 to 4) and indicates a Reynolds number effect. As an indication of the effect of Reynolds number, figure 10 presents peak adiabatic temperature-rise efficiency and peak pressure ratio as functions of the Reynolds number index, based upon the actual air flow and the inlet-air temperature. The results are shown for all inlet conditions investigated at speeds of 80, 89, and 100 percent of design speed. From the rather meager data presented in figure 10 and considering the experimental accuracy, the efficiency appears to increase uniformly with increasing Reynolds number index and the variation of peak pressure ratio with Reynolds number is similar to that for peak adiabatic temperature-rise efficiency. The range of Reynolds number covered in varying the inlet-air pressure from 6 to 21 inches of mercury absolute was approximately seven times as great as the range covered in varying the inlet-air temperature from 538° to 419° R. As far as the Reynolds number effect is concerned the effect of inlet-air temperature is therefore small and the greatest effect of a change in altitude will be due to the change in pressure.

Interstage Measurements

The interstage static pressures measured at the compressor casing are presented in figure 11 as the ratio of the static pressure at each station to the total pressure as measured in the depression tank. The results are presented for the design speed runs at inlet-air pressures of 6 and 12 inches of mercury absolute and ambient inlet-air temperature of 538° R for the complete flow range. For both inlet-air pressures, the data show that a choking condition existed in the first row of outlet-guide vanes in the region of maximum flow. This phenomenon is indicated by the continual decrease in downstream pressure without a corresponding decrease in upstream pressure. The maximum flow obtained was approximately 89 percent of the total flow required to give sonic velocity at the outlet of the inlet-guide vanes and the inlet-guide vanes were approaching a choked condition. The static-pressure drop incurred in the inlet-guide vanes is recovered in the first two stages of compression. The existence of separation in the second row of outlet-guide vanes is indicated by the drop in pressure through this row of blades at the peak adiabatic temperature-rise efficiency and surge points. Also, the tenth rotor row appears to be approaching a turbining condition in the high flow region, similar to the condition found in reference 1.

The effect of speed on interstage static pressures is presented in figure 12 for the points of maximum weight flow, peak adiabatic temperature-rise efficiency, and surge for inlet conditions of 12 inches of mercury absolute and ambient inlet-air temperature. As would be expected, because of the reduced weight flow, the drop in pressure through the inlet-guide vanes is reduced as the speed is reduced. Evidence of stalling conditions in the second row of outlet-guide vanes can again be noted for the peak adiabatic temperature-rise efficiency and surge points at design speed. In addition, a similar stalling condition occurs at the surge point at 89 percent of design speed. It also appears that the first stator row is stalling at 80 percent of design speed at all flow conditions presented.

SUMMARY OF RESULTS

An investigation of the performance of the 10-stage X24C-2 axial-flow compressor at various inlet-air pressures and temperatures produced the following results:

1. With a decrease in inlet-air pressure at constant inlet-air temperature, a corresponding decrease in peak values of adiabatic temperature-rise efficiency and pressure ratio was obtained. The variation in inlet-air pressure, however, had little effect (a maximum of about 1 percent) on the equivalent weight flow at any particular speed investigated.

2. Although the total variation of peak adiabatic temperature-rise efficiency at each speed for all three inlet-air temperatures was within the precision of the experiment for the low inlet-air pressure of 6 inches of mercury absolute, the trend of the curves at each speed investigated demonstrated that the peak adiabatic temperature-rise efficiency varied with a change in the inlet-air temperature. The effect of inlet-air temperature on equivalent weight flow and peak pressure ratio was small.

3. All data obtained at various inlet-air pressures and inlet-air temperatures correlated within 2 percent on two curves when the polytropic efficiency was plotted as a function of the polytropic loss factor. The only effect of inlet-air pressure was to

increase the minimum loss factor and to decrease the maximum polytropic efficiency as the inlet-air pressure was reduced. The effect of inlet-air temperature was negligible.

4. Peak adiabatic temperature-rise efficiency and pressure ratio increased with increasing Reynolds number. Because the range of Reynolds number covered in varying the inlet-air pressure from 6 to 21 inches of mercury absolute was approximately seven times as great as the range covered in varying the inlet-air temperature from 538° to 419° R, the greatest effect of a change in altitude will be due to the change in pressure.

5. The results of the interstage static-pressure measurements indicated a stalled condition in the second row of outlet-guide vanes in the region of peak adiabatic temperature-rise efficiency at design speed and in the first stator row of blades at 80 percent of design speed. The first row of outlet-guide vanes were shown to be choking in the region of maximum flow.

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TABLE I - PERFORMANCE OF X24C-2 10-STAGE AXIAL-FLOW COMPRESSOR

(a) Inlet pressure, 12 inches mercury absolute (849 lb/sq ft); inlet-air temperature, 538° R.

Percentage of design speed	Equivalent air-weight flow $W\sqrt{\theta}/\delta$	Over-all pressure ratio P_2/P_1	Over-all temperature ratio T_2/T_1	Adiabatic temperature-rise efficiency η_T	Polytropic efficiency η_p	Mean pressure coefficient ψ_m	Adiabatic work-input factor ψ_m/η_T	Polytropic pressure coefficient ψ_p	Polytropic loss factor λ_p	Outlet Mach number M_2
80	43.00	1.362	1.231	0.398	0.424	0.131	0.329	0.140	0.190	0.452
	42.87	1.673	1.243	.648	.674	.226	.348	.235	.114	.352
	42.83	1.785	1.271	.711	.687	.256	.360	.247	.114	.328
	42.35	1.903	1.265	.755	.791	.288	.381	.301	.080	.300
	41.75	2.032	1.282	.791	.813	.320	.405	.329	.076	.279
	41.08	2.137	1.298	.807	.829	.345	.428	.355	.073	.261
	40.79	2.194	1.307	.813	.836	.358	.440	.368	.072	.253
	39.89	2.245	1.320	.807	.830	.369	.457	.379	.078	.243
	39.05	2.253	1.327	.793	.817	.372	.469	.384	.088	.237
	38.37	2.255	1.331	.784	.810	.372	.475	.385	.090	.233
	36.92	2.244	1.346	.745	.775	.369	.496	.384	.112	.225
	35.37	2.222	1.357	.713	.745	.364	.511	.380	.130	.218
	33.73	2.157	1.366	.666	.702	.350	.525	.369	.157	.216
	32.23	2.105	1.373	.630	.668	.339	.537	.359	.178	.211
	31.72	2.113	1.386	.613	.653	.341	.557	.363	.193	.209
	30.19	2.061	1.400	.568	.612	.328	.577	.353	.224	.204
89	49.62	1.604	1.289	0.496	0.529	0.166	0.335	0.177	0.157	0.455
	49.58	1.682	1.288	.548	.583	.184	.336	.196	.140	.427
	49.39	2.068	1.309	.741	.768	.265	.356	.275	.083	.335
	49.30	2.149	1.320	.757	.784	.281	.371	.291	.080	.322
	49.28	1.898	1.297	.671	.701	.231	.345	.242	.103	.367
	48.98	2.243	1.332	.776	.802	.298	.385	.308	.076	.306
	48.77	2.385	1.353	.792	.818	.324	.409	.335	.075	.287
	48.16	2.437	1.363	.791	.817	.333	.421	.344	.077	.277
	47.97	2.490	1.370	.797	.825	.343	.430	.355	.075	.270
	47.10	2.586	1.394	.784	.814	.359	.458	.373	.085	.256
	46.58	2.642	1.406	.780	.810	.368	.471	.382	.090	.250
	46.44	2.656	1.407	.782	.814	.370	.473	.385	.088	.248
	46.18	2.657	1.412	.774	.805	.370	.478	.385	.093	.246
100	56.61	2.009	1.358	0.613	0.648	0.200	0.327	0.212	0.115	0.417
	56.56	2.083	1.360	.643	.679	.212	.330	.224	.106	.399
	56.35	2.226	1.360	.707	.740	.233	.330	.244	.086	.367
	56.25	2.306	1.372	.717	.751	.245	.341	.256	.085	.353
	56.17	2.553	1.402	.756	.789	.279	.368	.291	.078	.317
	55.79	2.855	1.445	.777	.811	.317	.408	.331	.077	.283
	55.68	3.052	1.472	.788	.822	.340	.432	.355	.077	.265
	55.46	3.175	1.490	.790	.825	.355	.450	.371	.079	.254
	54.71	3.232	1.503	.783	.820	.361	.461	.378	.083	.247
	53.83	3.299	1.521	.772	.810	.370	.479	.388	.091	.239

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TABLE I - CONTINUED. PERFORMANCE OF X24C-2 10-STAGE AXIAL-FLOW COMPRESSOR

(b) Inlet pressure, 6 inches mercury absolute (424 lb/sq ft); inlet-air temperature, 538° R.

Percentage of design speed	Equivalent air-weight flow $W\sqrt{\theta}/\delta$	Over-all pressure ratio P_2/P_1	Over-all temperature ratio T_2/T_1	Adiabatic temperature-rise efficiency η_T	Polytropic efficiency η_p	Mean pressure coefficient ψ_m	Adiabatic work-input factor ψ_m/η_T	Polytropic pressure coefficient ψ_p	Polytropic loss factor λ_p	Outlet Mach number M_2
80	42.41	1.610	1.243	0.595	0.622	0.206	0.346	0.216	0.131	0.364
	41.89	1.679	1.243	.652	.678	.226	.347	.235	.112	.342
	41.77	1.795	1.243	.742	.765	.258	.347	.266	.082	.316
	40.20	2.093	1.310	.751	.778	.333	.444	.345	.099	.263
	39.29	2.162	1.328	.744	.773	.349	.469	.363	.107	.249
	38.53	2.197	1.338	.742	.770	.359	.484	.373	.111	.240
	38.20	2.202	1.342	.734	.764	.358	.488	.373	.115	.238
	37.06	2.195	1.348	.716	.748	.357	.498	.373	.126	.233
	35.91	2.178	1.351	.702	.736	.354	.504	.371	.133	.226
	34.51	2.168	1.365	.671	.707	.352	.524	.370	.154	.220
	33.95	2.215	1.376	.670	.708	.362	.541	.383	.158	.213
	31.04	2.102	1.404	.580	.623	.336	.579	.361	.218	.207
	29.22	2.058	1.419	.541	.586	.325	.600	.352	.248	.199
	25.98	1.975	1.443	.480	.528	.305	.636	.336	.300	.186
89	48.74	2.088	1.325	0.719	0.749	0.270	0.376	0.282	0.095	0.327
	48.49	2.255	1.345	.753	.782	.300	.398	.311	.087	.301
	47.61	2.432	1.375	.764	.794	.332	.435	.345	.090	.275
	45.83	2.623	1.416	.755	.790	.364	.481	.380	.101	.247
	45.82	2.618	1.416	.754	.789	.362	.481	.379	.102	.247
	45.45	2.624	1.417	.754	.788	.363	.481	.379	.102	.245
	44.76	2.611	1.427	.733	.769	.361	.493	.379	.114	.243
100	56.64	2.220	1.379	0.670	0.708	0.232	0.346	0.245	0.101	0.374
	56.57	2.060	1.367	.619	.649	.208	.337	.218	.118	.407
	56.54	2.624	1.419	.751	.785	.288	.384	.301	.083	.311
	56.20	2.412	1.396	.716	.752	.259	.363	.273	.090	.337
	56.12	2.265	1.383	.680	.718	.238	.351	.252	.099	.356
	56.03	2.136	1.373	.645	.682	.220	.341	.232	.109	.384
	55.96	2.731	1.437	.754	.788	.302	.401	.316	.085	.296
	55.67	3.125	1.492	.776	.811	.350	.451	.366	.085	.259
	55.56	2.957	1.467	.770	.805	.331	.430	.346	.084	.273
	54.10	3.281	1.524	.764	.804	.367	.481	.387	.095	.241

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TABLE I - CONTINUED. PERFORMANCE OF X24C-2 10-STAGE AXIAL-FLOW COMPRESSOR

(c) Inlet pressure, 6 inches mercury absolute (424 lb/sq ft); inlet-air temperature, 538° R. (Rerun)

Percentage of design speed	Equivalent air-weight flow $W\sqrt{\theta}/\delta$	Over-all pressure ratio P_2/P_1	Over-all temperature ratio T_2/T_1	Adiabatic temperature-rise efficiency η_T	Polytropic efficiency η_p	Mean pressure coefficient ψ_m	Adiabatic work-input factor ψ_m/η_T	Polytropic pressure coefficient ψ_p	Polytropic loss factor λ_p	Outlet Mach number M_2
80	42.40	1.369	1.259	0.361	0.389	0.133	0.368	0.143	0.225	0.447
	41.79	1.627	1.264	.682	.613	.211	.363	.222	.141	.355
	41.36	1.813	1.274	.673	.700	.262	.390	.273	.117	.313
	40.68	2.008	1.285	.740	.767	.312	.421	.323	.098	.277
	40.09	2.131	1.312	.768	.793	.342	.444	.353	.092	.257
	39.54	2.201	1.324	.775	.801	.358	.462	.370	.092	.245
	38.41	2.268	1.342	.764	.793	.373	.488	.387	.101	.233
	38.06	2.253	1.344	.754	.783	.370	.491	.385	.106	.232
	37.10	2.284	1.353	.740	.770	.373	.503	.388	.116	.225
	36.11	2.281	1.360	.724	.756	.372	.514	.389	.125	.219
	34.02	2.206	1.371	.678	.718	.359	.530	.379	.151	.212
89	49.00	1.601	1.307	0.467	0.501	0.166	0.355	0.178	0.177	0.452
	48.93	1.629	1.309	.480	.516	.171	.356	.184	.173	.441
	48.89	1.715	1.310	.534	.569	.191	.358	.204	.154	.413
	48.43	2.390	1.361	.776	.805	.325	.419	.337	.081	.283
	48.21	2.292	1.351	.757	.788	.307	.405	.318	.087	.295
	48.18	1.937	1.321	.644	.677	.238	.370	.251	.120	.352
	47.93	2.332	1.364	.768	.796	.315	.410	.326	.084	.288
	47.16	2.489	1.377	.784	.812	.342	.437	.355	.082	.265
	46.77	2.668	1.392	.782	.812	.356	.456	.370	.086	.256
	46.69	2.669	1.421	.768	.795	.375	.488	.388	.100	.247
	46.00	2.697	1.423	.767	.801	.377	.492	.394	.098	.242
100	55.92	2.013	1.375	0.585	0.626	0.201	0.344	0.215	0.129	0.412
	55.90	2.696	1.416	.779	.811	.298	.382	.310	.072	.299
	55.86	2.164	1.378	.647	.685	.225	.347	.238	.109	.378
	55.63	2.536	1.402	.750	.784	.277	.370	.290	.080	.316
	55.61	1.890	1.370	.534	.575	.181	.339	.195	.144	.443
	55.57	2.921	1.446	.795	.827	.327	.411	.340	.071	.274
	55.47	2.326	1.388	.695	.733	.248	.357	.262	.095	.346
	55.24	3.095	1.477	.790	.825	.348	.440	.363	.077	.259
	54.52	3.171	1.508	.781	.800	.355	.467	.373	.093	.252
	53.97	3.305	1.515	.781	.819	.371	.475	.389	.086	.238

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TABLE I - CONTINUED. PERFORMANCE OF X24C-2 10-STAGE AXIAL-FLOW COMPRESSOR

(d) Inlet pressure, 6 inches mercury absolute (424 lb/sq ft); inlet-air temperature, 459° R.

Percentage of design speed	Equivalent air-weight flow $W\sqrt{\theta}/\delta$	Over-all pressure ratio P_2/P_1	Over-all temperature ratio T_2/T_1	Adiabatic temperature-rise efficiency η_T	Polytropic efficiency η_p	Mean pressure coefficient ψ_m	Adiabatic work-input factor ψ_m/η_T	Polytropic pressure coefficient ψ_p	Polytropic loss factor λ_p	Outlet Mach number M_2
80	42.16	1.352	1.244	0.369	0.395	0.128	0.346	0.137	0.209	0.446
	42.10	1.568	1.252	.545	.573	.193	.355	.204	.152	.362
	41.99	1.450	1.248	.451	.480	.158	.351	.168	.182	.408
	41.76	1.701	1.261	.628	.655	.233	.371	.243	.128	.336
	41.74	1.859	1.276	.699	.727	.274	.395	.287	.108	.308
	41.25	1.965	1.288	.739	.764	.300	.406	.310	.096	.285
	40.91	2.018	1.296	.750	.775	.313	.418	.323	.095	.276
	40.61	2.092	1.305	.768	.793	.332	.432	.343	.089	.263
	39.91	2.193	1.321	.784	.808	.355	.452	.366	.087	.248
	39.80	2.190	1.318	.790	.812	.357	.452	.367	.085	.247
	39.40	2.218	1.327	.780	.804	.365	.469	.393	.092	.243
	38.46	2.262	1.343	.767	.793	.374	.487	.386	.101	.232
	37.44	2.264	1.347	.756	.784	.373	.494	.387	.107	.226
	36.28	2.230	1.357	.722	.752	.365	.505	.380	.125	.224
	32.25	2.148	1.387	.630	.668	.345	.548	.366	.182	.207
89	49.61	1.611	1.310	0.477	0.506	0.168	0.351	0.178	0.174	0.453
	49.48	2.032	1.330	.685	.711	.258	.376	.267	.108	.343
	49.47	1.685	1.309	.521	.555	.185	.354	.197	.158	.426
	48.95	1.864	1.319	.617	.643	.223	.362	.233	.129	.373
	48.53	2.232	1.343	.751	.778	.297	.395	.307	.088	.304
	48.11	2.382	1.358	.785	.812	.325	.414	.336	.078	.282
	47.66	2.502	1.373	.805	.828	.343	.426	.353	.073	.265
	47.08	2.665	1.406	.796	.823	.368	.463	.381	.082	.248
	46.11	2.727	1.423	.787	.813	.382	.486	.395	.091	.239
100	56.46	2.169	1.389	0.638	0.674	0.225	0.353	0.237	0.116	0.381
	56.28	2.326	1.401	.677	.716	.247	.365	.261	.104	.352
	56.19	2.035	1.381	.590	.629	.204	.346	.218	.128	.408
	56.04	2.586	1.421	.741	.773	.282	.381	.295	.067	.312
	56.02	2.948	1.473	.763	.799	.329	.431	.345	.087	.276
	55.99	2.741	1.438	.760	.794	.303	.399	.316	.082	.294
	55.46	3.075	1.486	.777	.812	.343	.441	.358	.083	.262
	55.33	3.257	1.514	.779	.814	.366	.469	.382	.087	.248
	54.93	3.240	1.503	.791	.825	.363	.459	.379	.080	.246
	54.04	3.363	1.532	.775	.814	.376	.485	.394	.090	.234

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TABLE I - CONCLUDED. PERFORMANCE OF X24C-2 10-STAGE AXIAL-FLOW COMPRESSOR

(e) Inlet pressure, 6 inches mercury absolute (424 lb/sq ft); inlet-air temperature, 419° R.

Percentage of design speed	Equivalent air-weight flow $W\sqrt{\theta}/\delta$	Over-all pressure ratio P_2/P_1	Over-all temperature ratio T_2/T_1	Adiabatic temperature-rise efficiency η_T	Polytropic efficiency η_p	Mean pressure coefficient Ψ_m	Adiabatic work-input factor Ψ_m/η_T	Polytropic pressure coefficient Ψ_p	Polytropic loss factor λ_p	Outlet Mach number M_2
80	41.49	1.458	1.246	0.460	0.490	0.160	0.349	0.171	0.178	0.398
	41.19	1.682	1.261	.612	.642	.226	.369	.237	.132	.336
	40.96	2.122	1.313	.763	.791	.334	.443	.350	.093	.263
	40.87	1.906	1.281	.718	.745	.286	.398	.297	.102	.291
	41.40	1.456	1.239	.475	.508	.161	.338	.172	.167	.396
	40.00	2.150	1.320	.763	.788	.347	.455	.359	.098	.254
	38.63	2.167	1.338	.731	.760	.351	.480	.365	.115	.244
	37.12	2.176	1.357	.696	.729	.353	.507	.370	.138	.234
	35.76	2.159	1.367	.670	.705	.349	.520	.367	.154	.228
	34.76	2.145	1.378	.642	.681	.343	.534	.363	.170	.224
	32.81	2.099	1.401	.586	.629	.333	.567	.357	.211	.217
89	49.00	1.633	1.303	0.496	0.530	0.172	0.347	0.184	0.163	0.438
	48.69	2.177	1.333	.747	.775	.286	.383	.296	.086	.312
	48.63	1.884	1.313	.633	.666	.228	.360	.240	.121	.366
	48.19	2.396	1.358	.791	.817	.325	.411	.336	.075	.280
	48.03	2.304	1.348	.776	.800	.310	.399	.319	.080	.291
	48.02	2.333	1.352	.780	.804	.315	.403	.324	.079	.287
	47.59	2.464	1.369	.796	.821	.337	.424	.348	.076	.269
	47.39	2.451	1.368	.792	.819	.335	.424	.347	.077	.270
	47.36	2.457	1.369	.793	.819	.336	.424	.347	.077	.268
	46.25	2.569	1.392	.786	.813	.353	.450	.365	.084	.253
	46.03	2.659	1.409	.787	.816	.369	.469	.383	.086	.243
	44.89	2.661	1.420	.766	.799	.369	.482	.386	.097	.238
100	56.24	1.854	1.372	0.517	0.559	0.174	0.336	0.188	0.148	0.460
	55.40	2.000	1.377	.590	.620	.198	.340	.211	.129	.408
	55.31	2.211	1.386	.659	.696	.231	.350	.244	.107	.363
	55.26	2.535	1.404	.752	.784	.277	.369	.289	.080	.311
	55.25	2.776	1.432	.784	.813	.307	.392	.319	.073	.285
	54.82	3.118	1.497	.772	.807	.348	.450	.363	.087	.255
	54.18	3.309	1.526	.774	.810	.369	.477	.397	.091	.238
	53.87	3.222	1.511	.777	.811	.360	.464	.376	.087	.242
	53.85	3.279	1.535	.753	.793	.365	.485	.385	.101	.241

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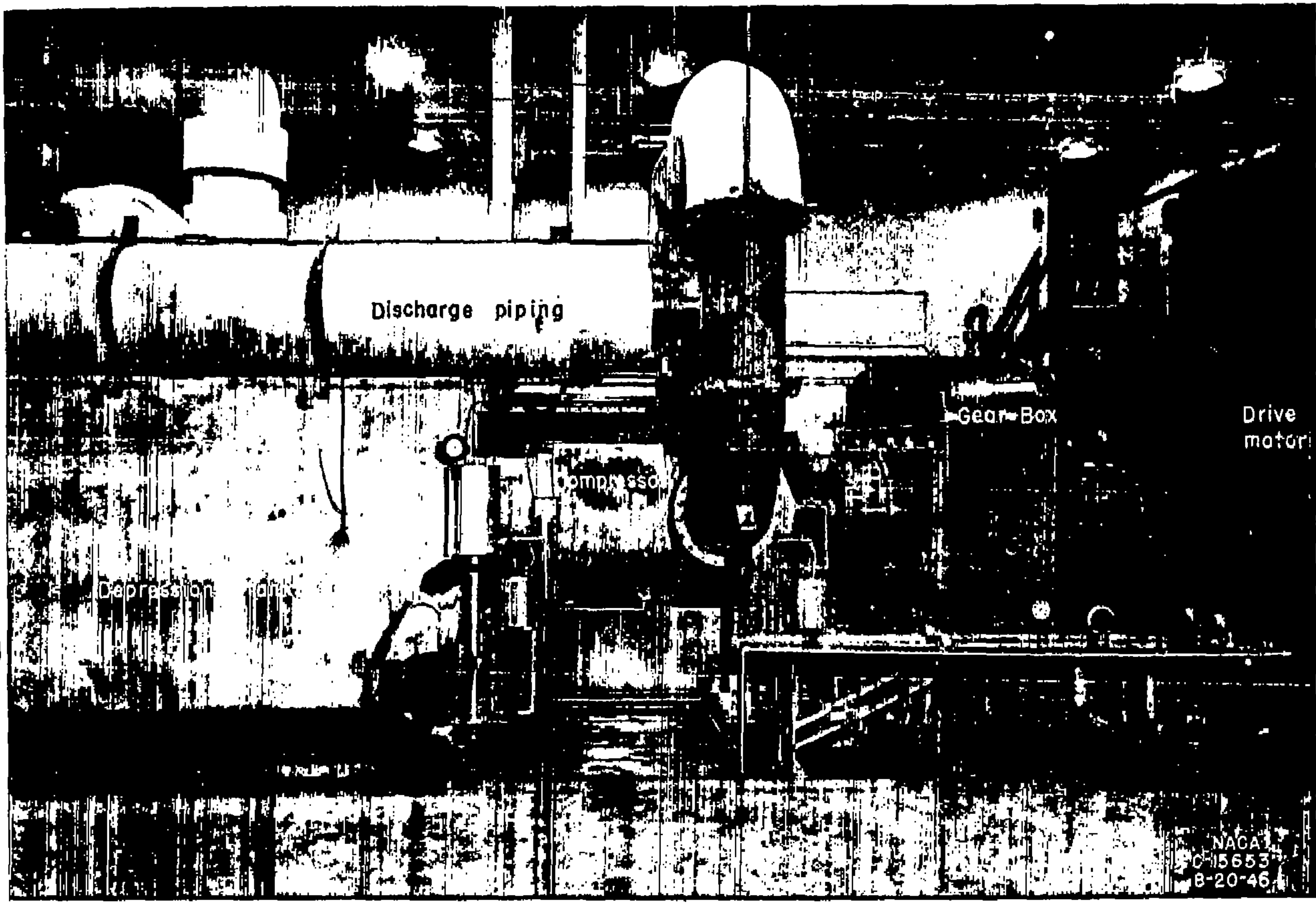
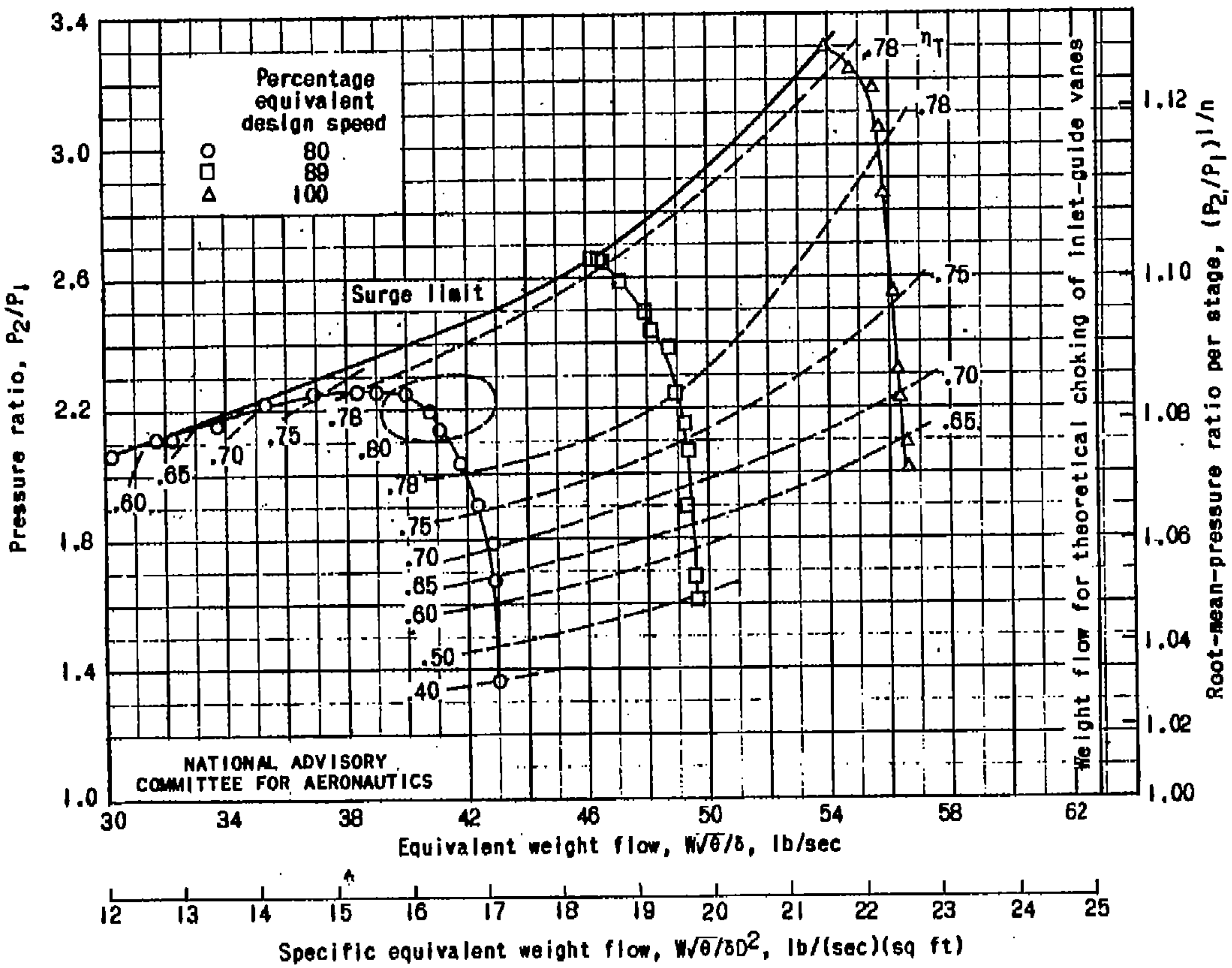
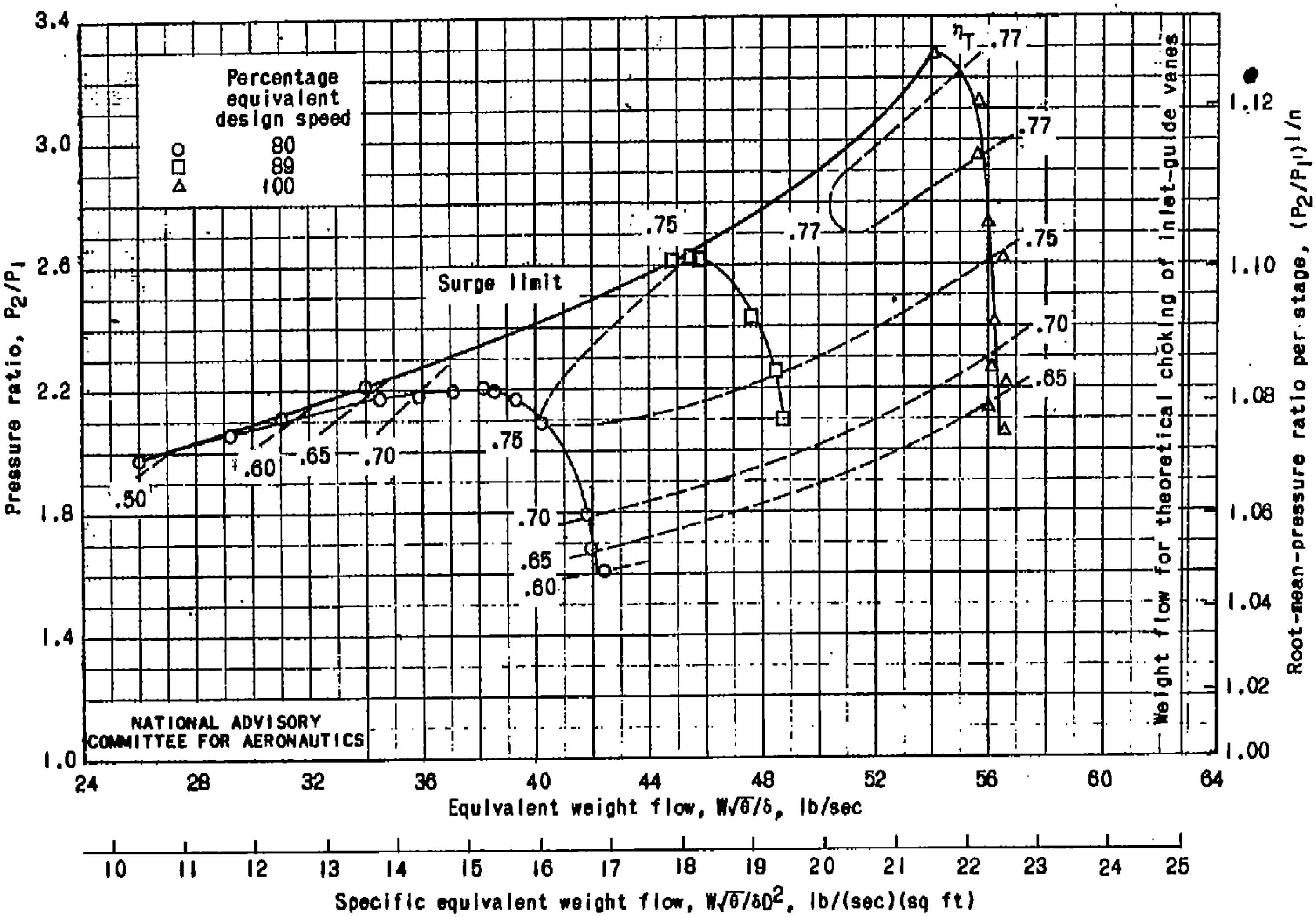


Figure 1. - Setup for investigating performance of X24C-2 axial-flow compressor.



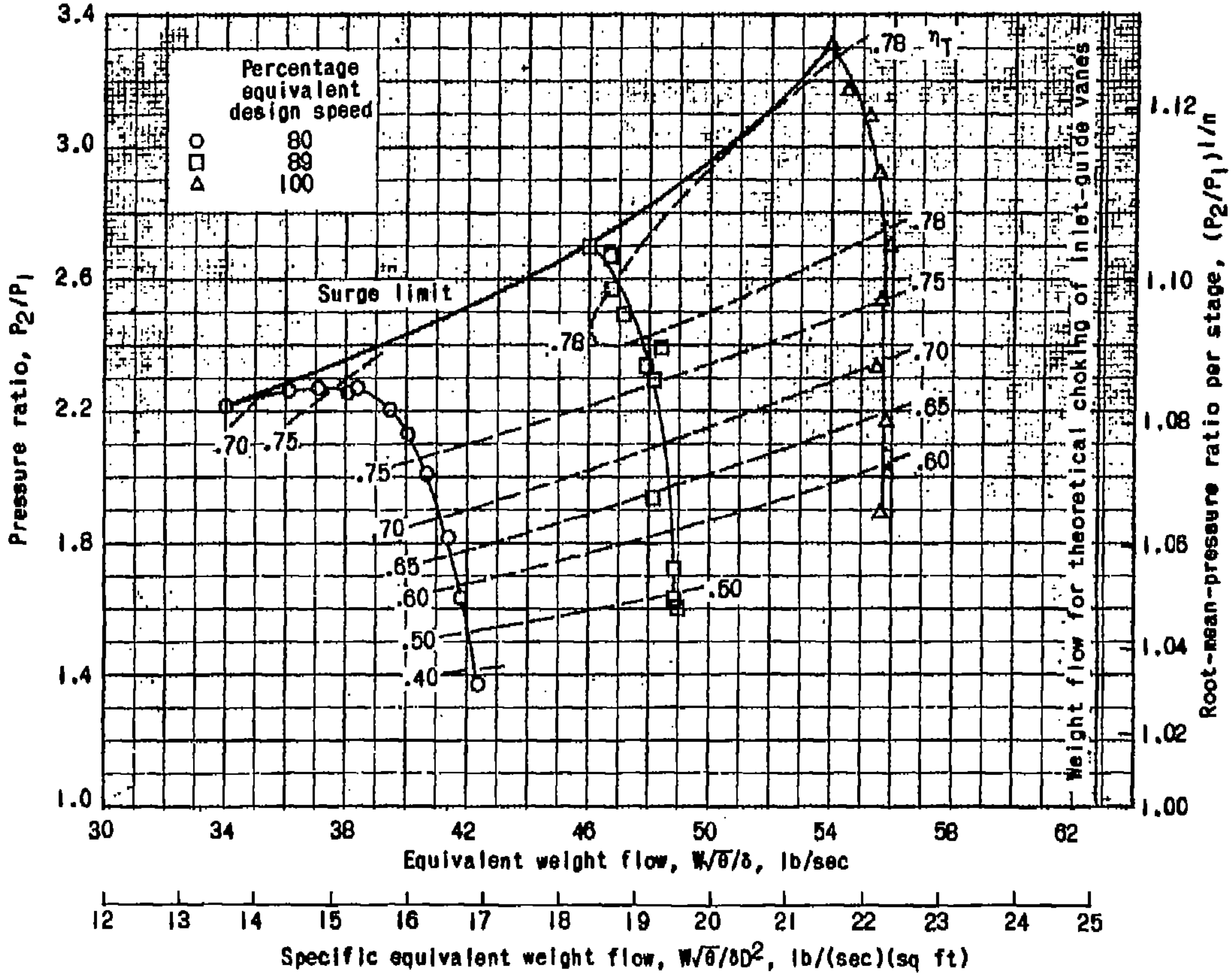
(a) Inlet total pressure, 12 inches mercury absolute (849 lb/sq ft).

Figure 2. - Performance of X24C-2 axial-flow compressor at various inlet pressures. No diffuser; inlet-air temperature, 538° R.



(b) Inlet total pressure, 6 inches mercury absolute (424 lb/sq ft).

Figure 2. - Concluded. Performance of X24C-2 axial-flow compressor at various inlet pressures. No diffuser; inlet-air temperature, 538° R.



(a) Inlet-air temperature, 538° R.

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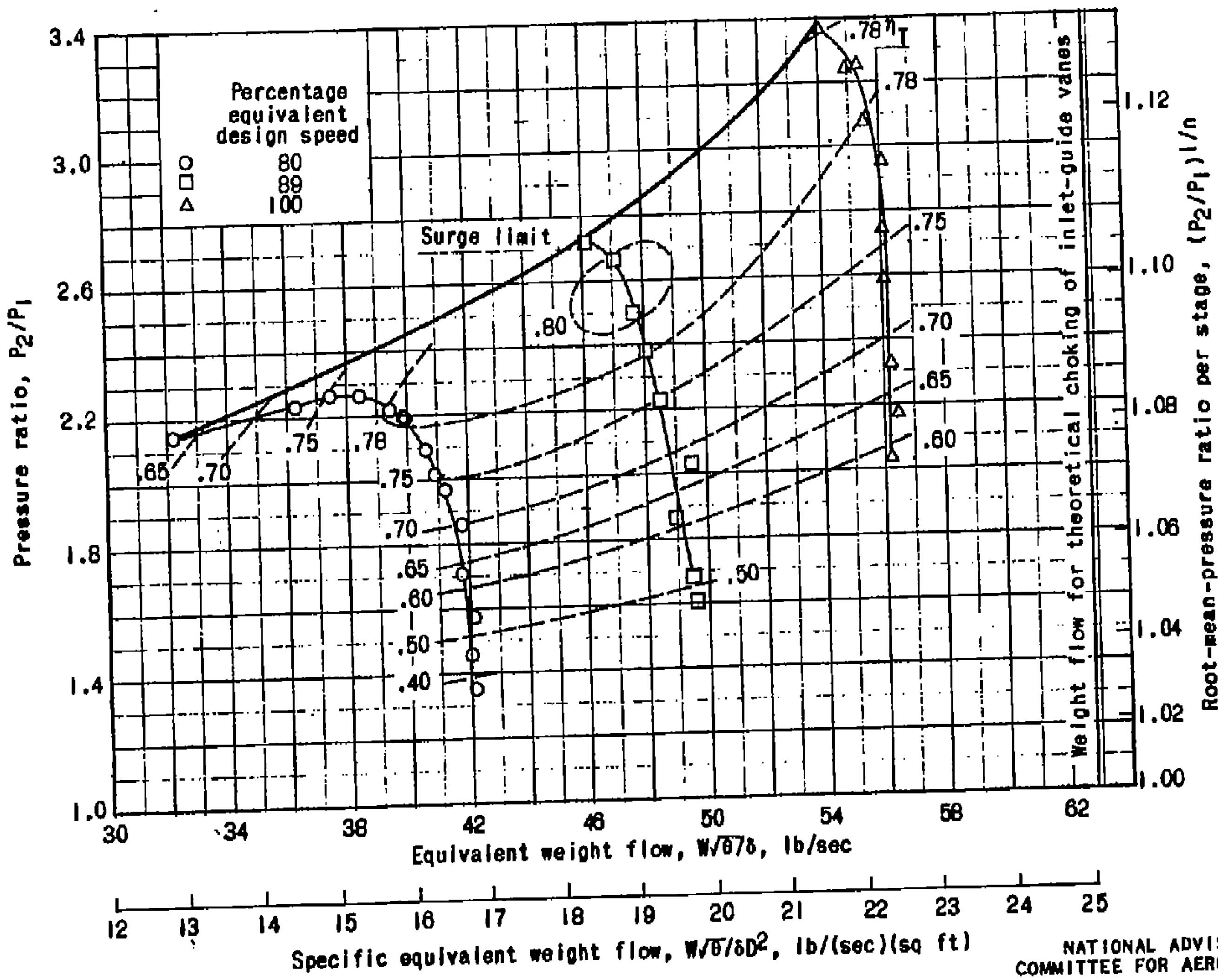
Figure 3. - Performance of X24C-2 axial-flow compressor at various inlet-air temperatures. No diffuser; inlet pressure, 6 inches mercury absolute (424 lb/sq ft).



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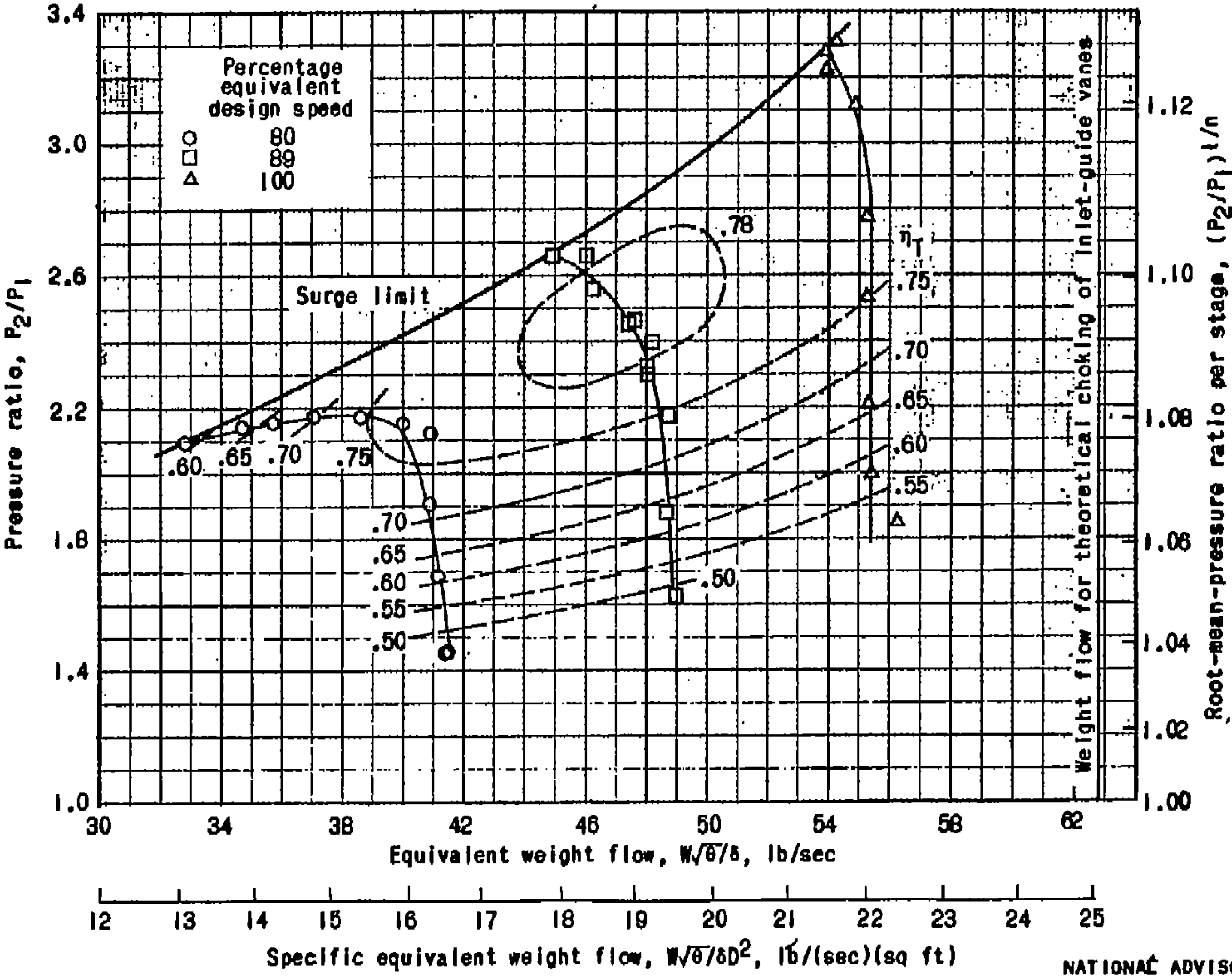
(b) Inlet-air temperature, 459° R.

Figure 3. - Continued. Performance of X24C-2 axial-flow compressor at various inlet-air temperatures. No diffuser; inlet pressure, 6 inches mercury absolute (424 lb/sq ft).



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(c) Inlet-air temperature, 419° R.

Figure 3. - Concluded. Performance of X24C-2 axial-flow compressor at various inlet-air temperatures. No diffuser; inlet pressure, 6 inches mercury absolute (424 lb/sq ft).

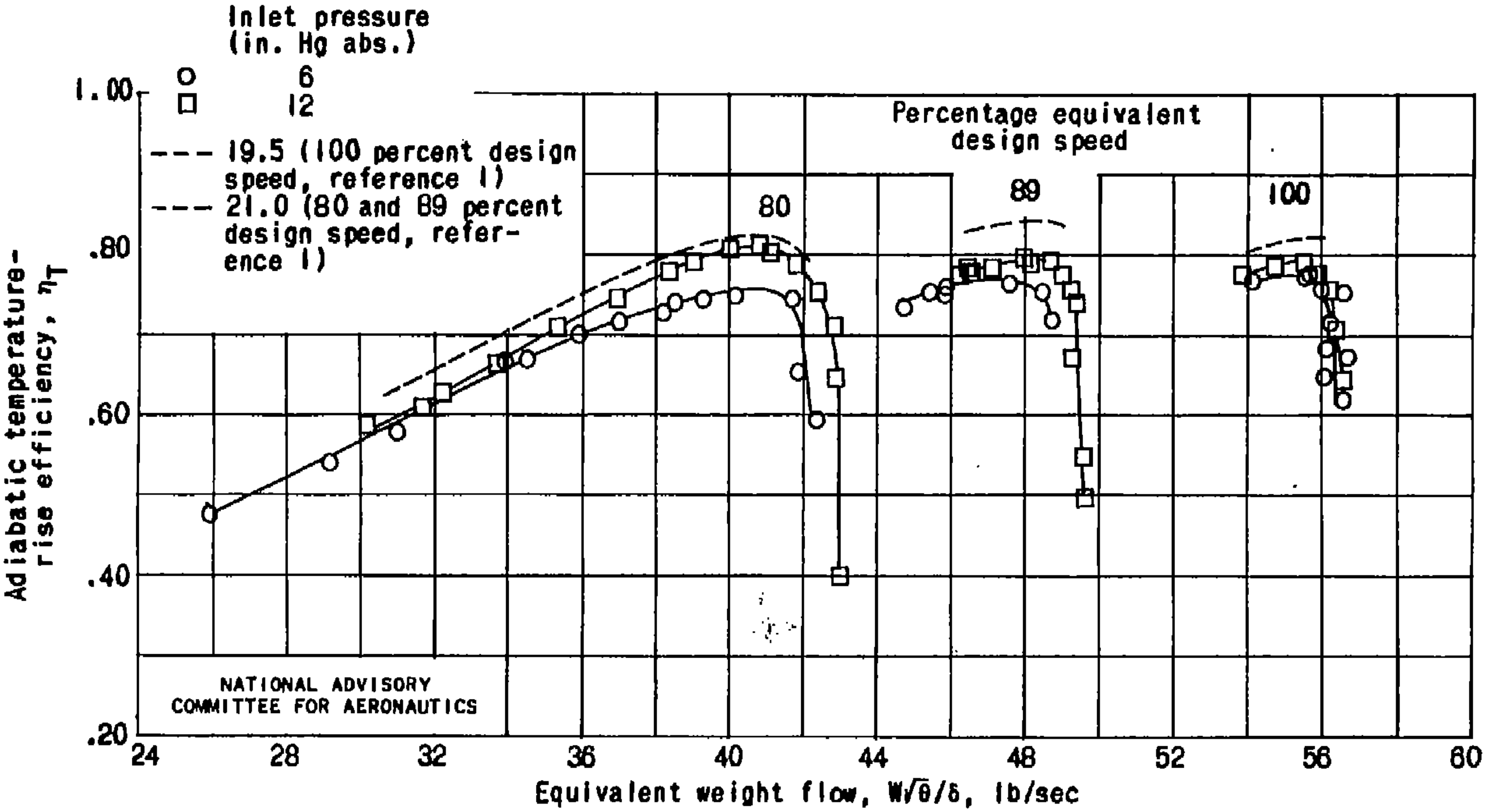


Figure 4. - Effect of inlet pressure on adiabatic temperature-rise efficiency. No diffuser; inlet-air temperature, 538° R.

815

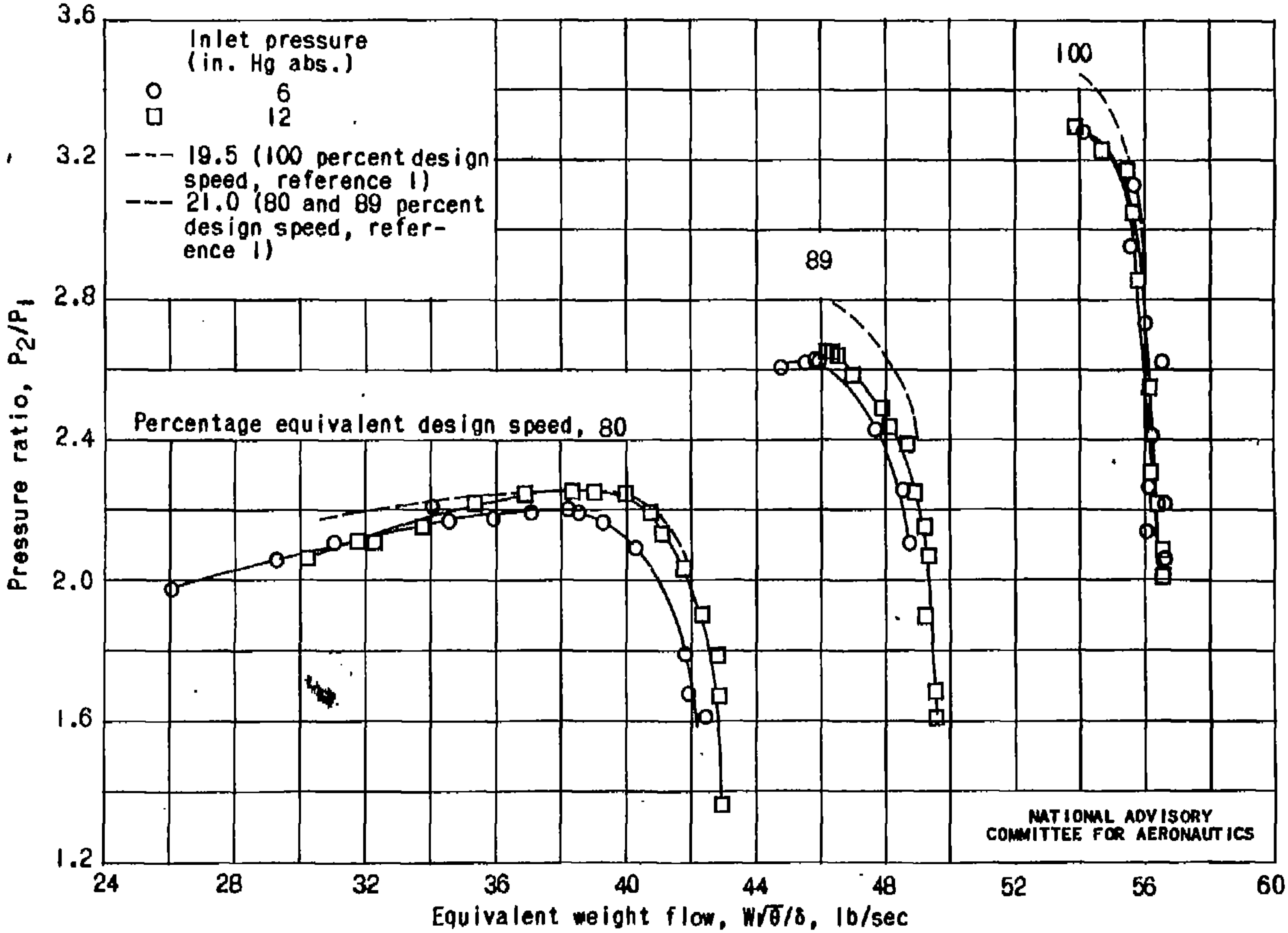
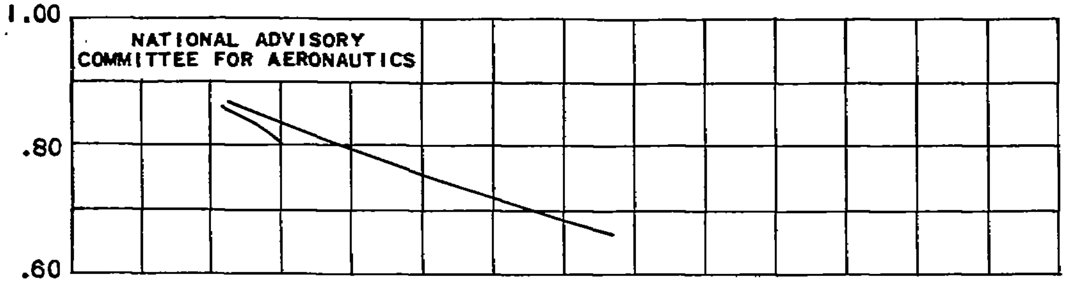
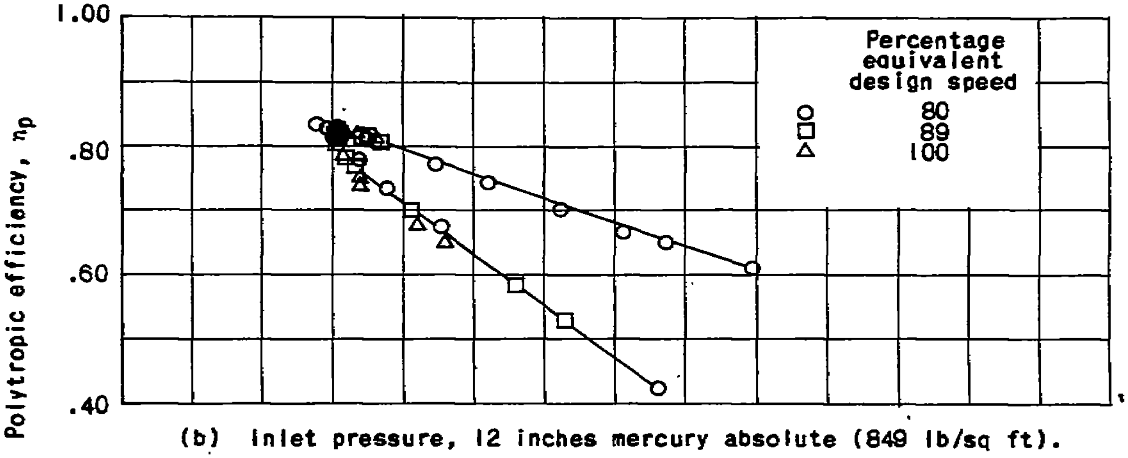


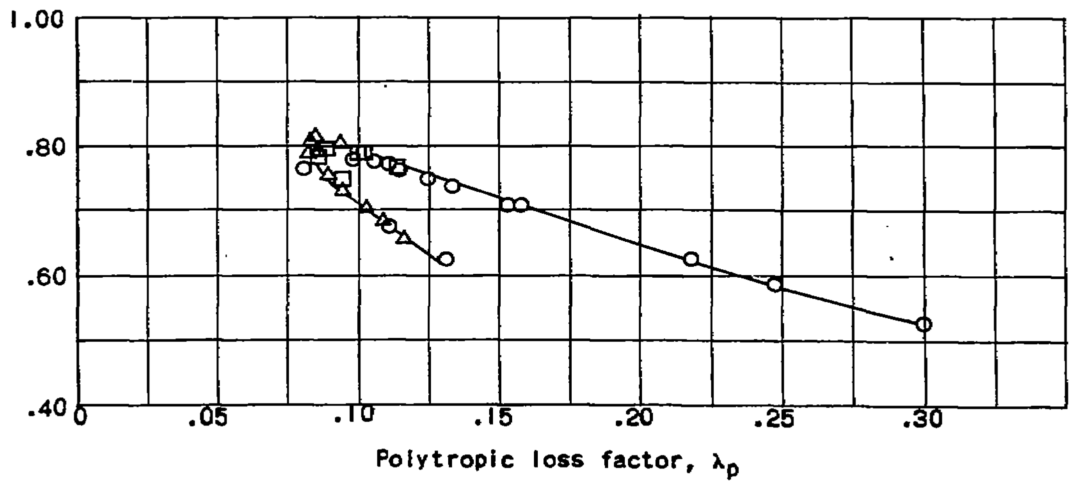
Figure 5. - Effect of inlet pressure on pressure ratio. Inlet-air temperature, 538° R.



(a) Inlet pressure, 21 inches mercury absolute (1485 lb/sq ft) for 80 and 89 percent of design speed and 19.5 inches mercury absolute (1374 lb/sq ft) for design speed. (Replotted from reference 1.)



(b) Inlet pressure, 12 inches mercury absolute (849 lb/sq ft).



(c) Inlet pressure, 6 inches mercury absolute (424 lb/sq ft).

Figure 6. – Variation of polytropic efficiency with polytropic loss factor at several inlet pressures and design speeds. No diffuser; inlet-air temperature, 538° R.

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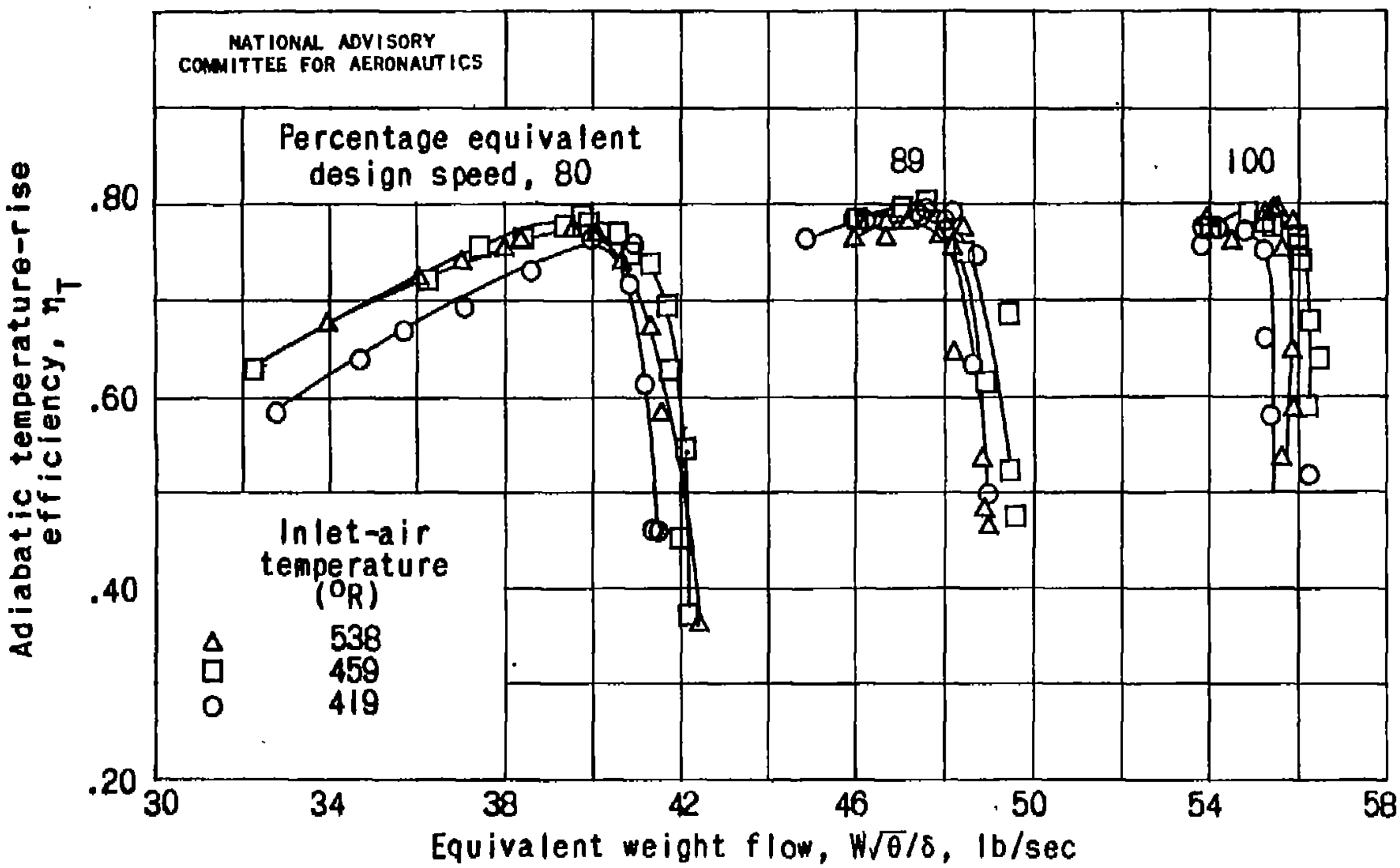


Figure 7. - Effect of inlet-air temperature on adiabatic temperature-rise efficiency. No diffuser; inlet pressure, 6 inches mercury absolute (424 lb/sq ft).

815

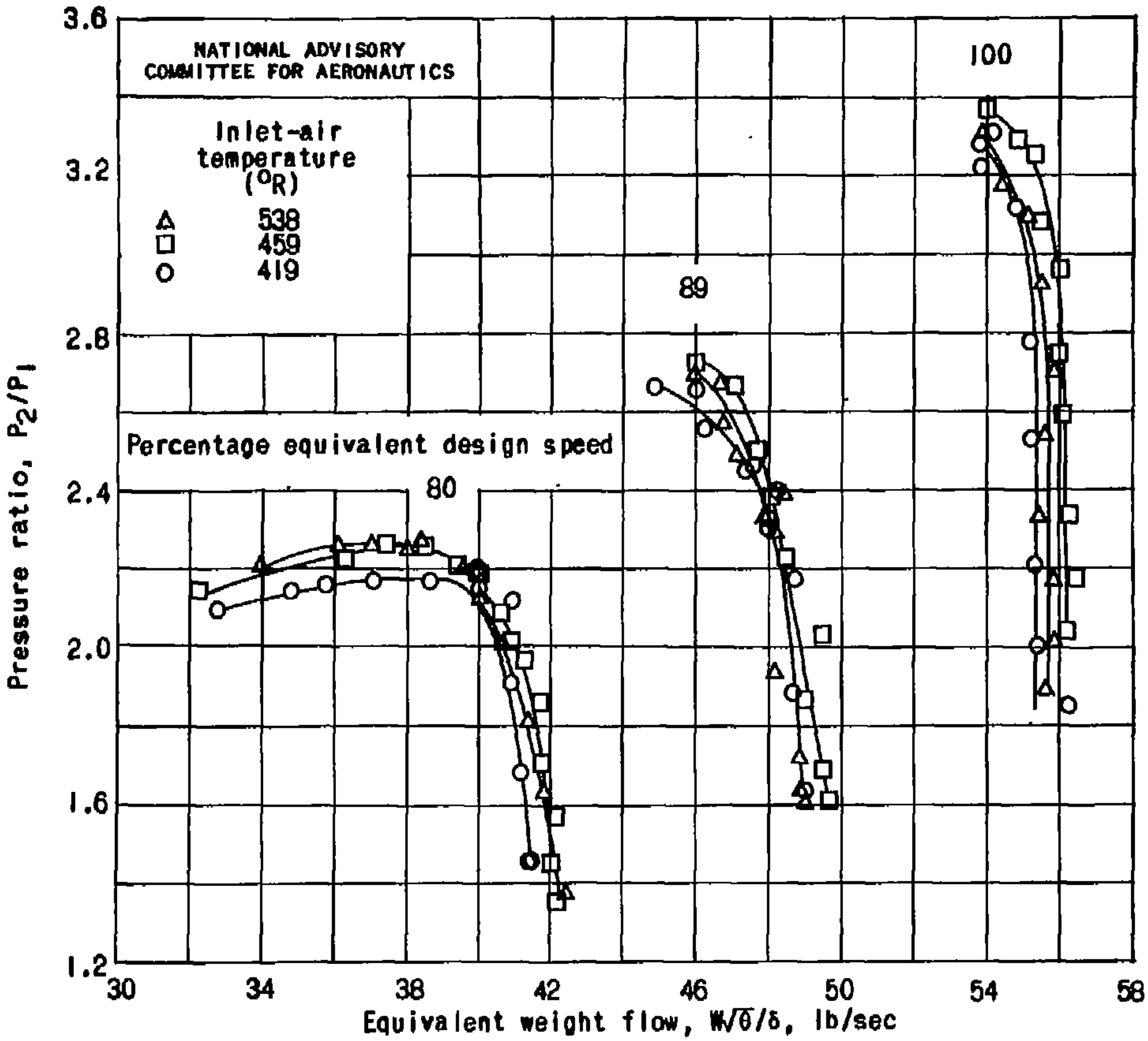
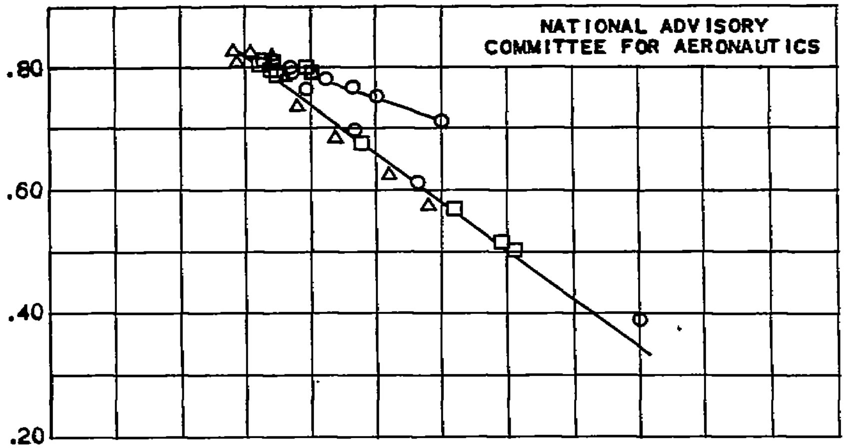
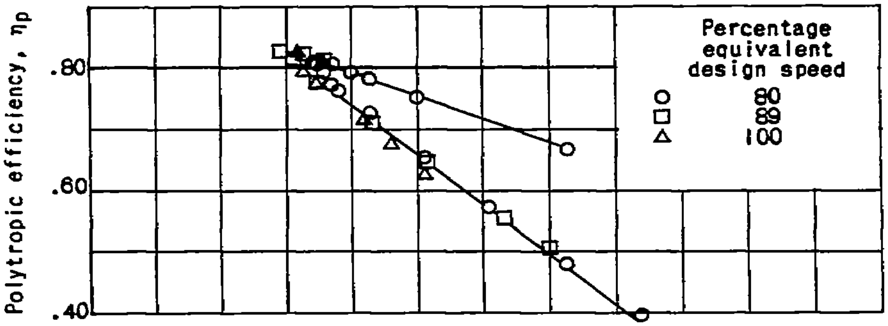


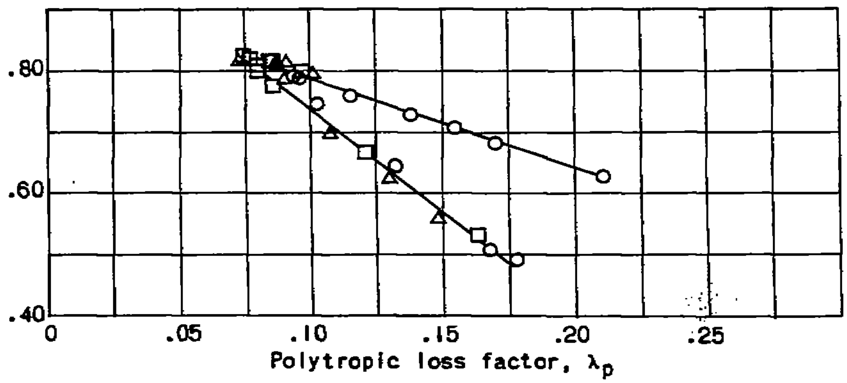
Figure 8. - Effect of inlet-air temperature on pressure ratio. No diffuser; inlet pressure, 6 inches mercury absolute (424 lb/sq ft).



(a) Inlet-air temperature, 538° R.



(b) Inlet-air temperature, 459° R.



(c) Inlet-air temperature, 419° R.

Figure 9. - Variation of polytropic efficiency with polytropic loss factor at several inlet-air temperatures. No diffuser; inlet pressure, 6 inches mercury absolute (424 lb/sq ft).

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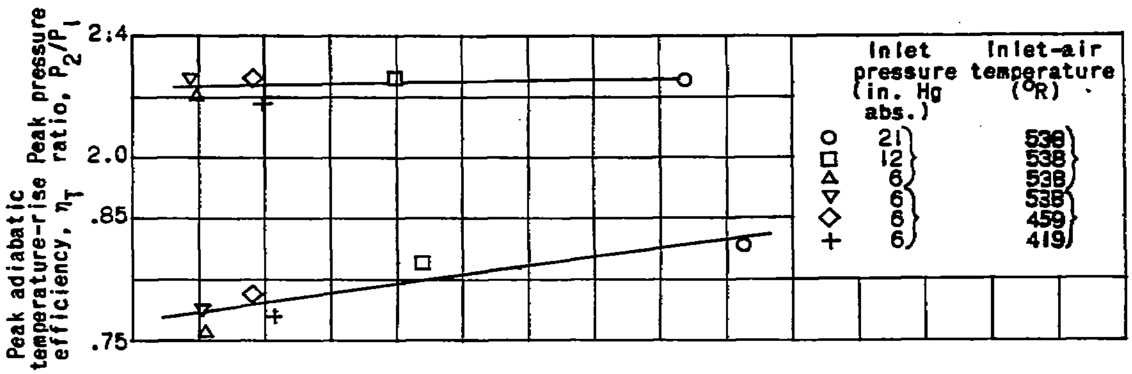
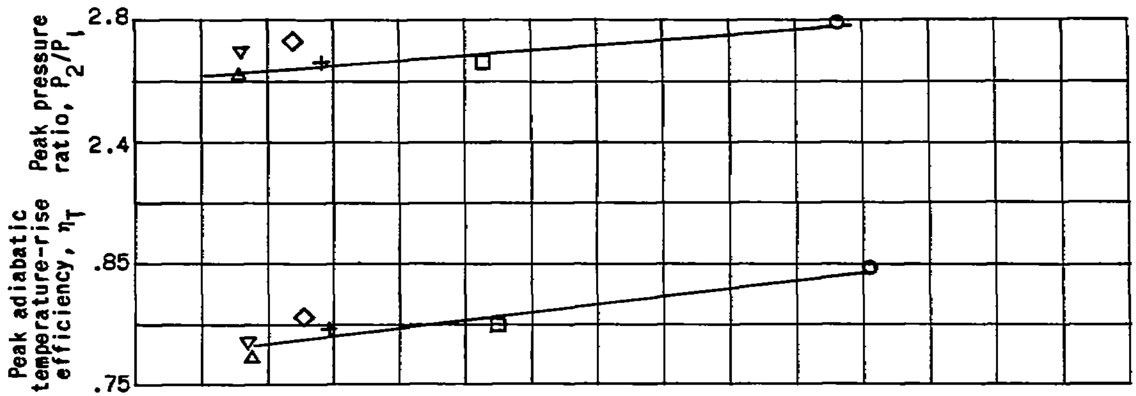
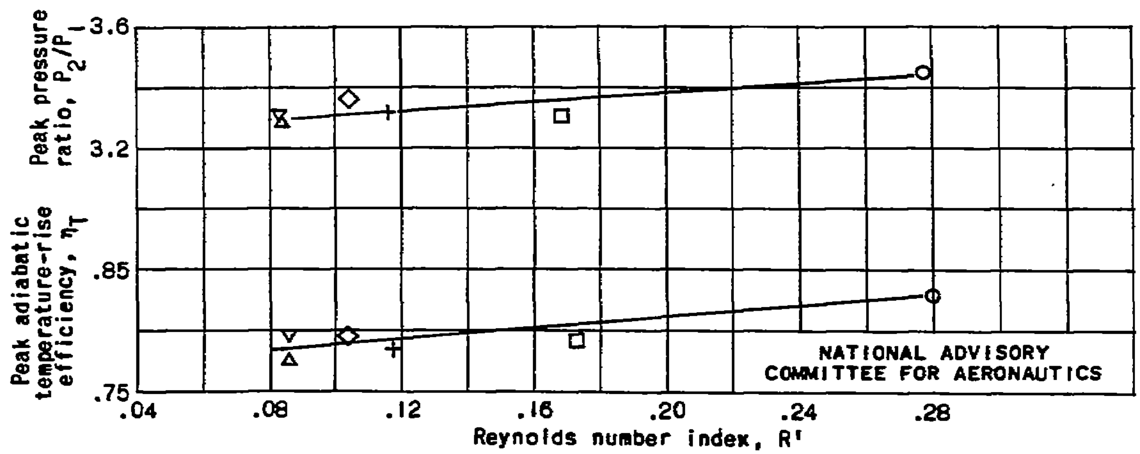


(a) Percentage of equivalent design speed, 80.



(b) Percentage of equivalent design speed, 89.



(c) Percentage of equivalent design speed, 100.

Figure 10. - Effect of Reynolds number index on peak adiabatic temperature-rise efficiency and peak pressure ratio.

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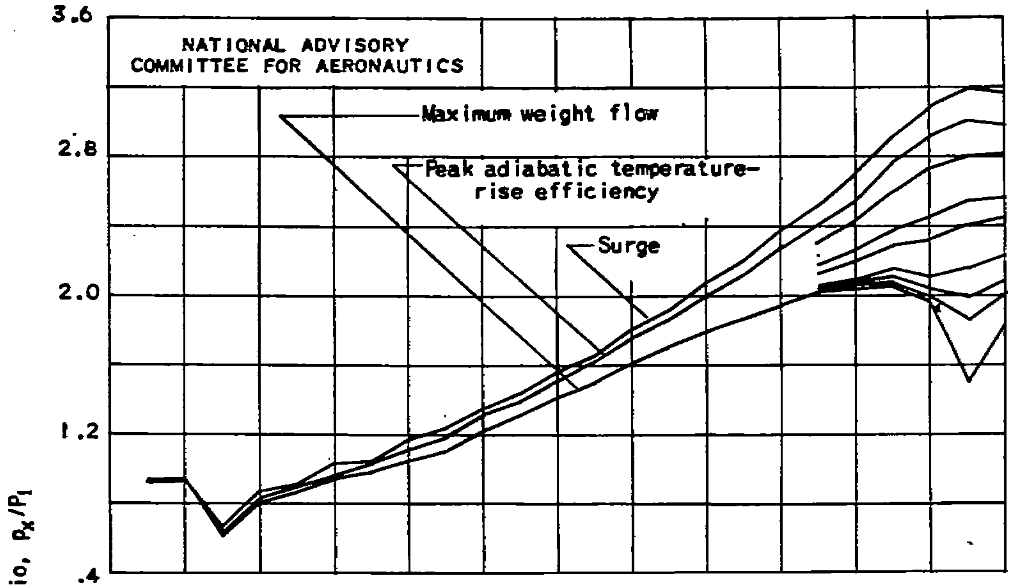
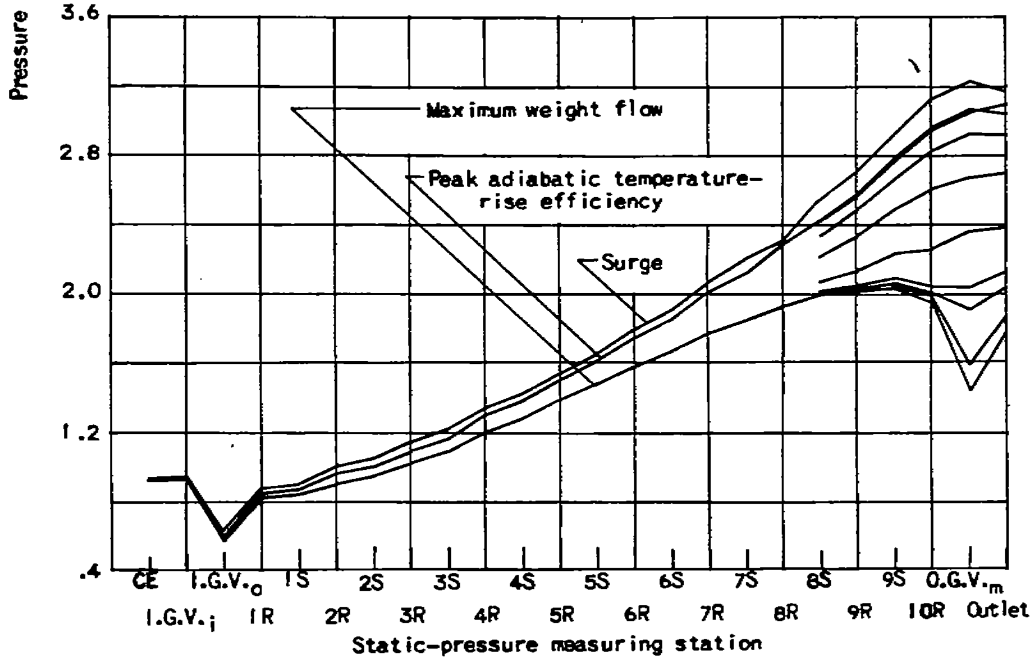


(a) Inlet pressure, 6 inches mercury absolute (424 lb/sq ft).



(b) Inlet pressure, 12 inches mercury absolute (849 lb/sq ft).

Figure 11. - Effect of weight flow on distribution of interstage static pressure along compressor casing for design speed. No diffuser; inlet-air temperature, 538° R; at compressor entrance, CE; inlet-guide vane inlet, I.G.V.$_i$; inlet-guide vane outlet, I.G.V.$_o$; rotor blades, R; stator blades, S; between two rows of outlet-guide vanes, O.G.V.$_m$.

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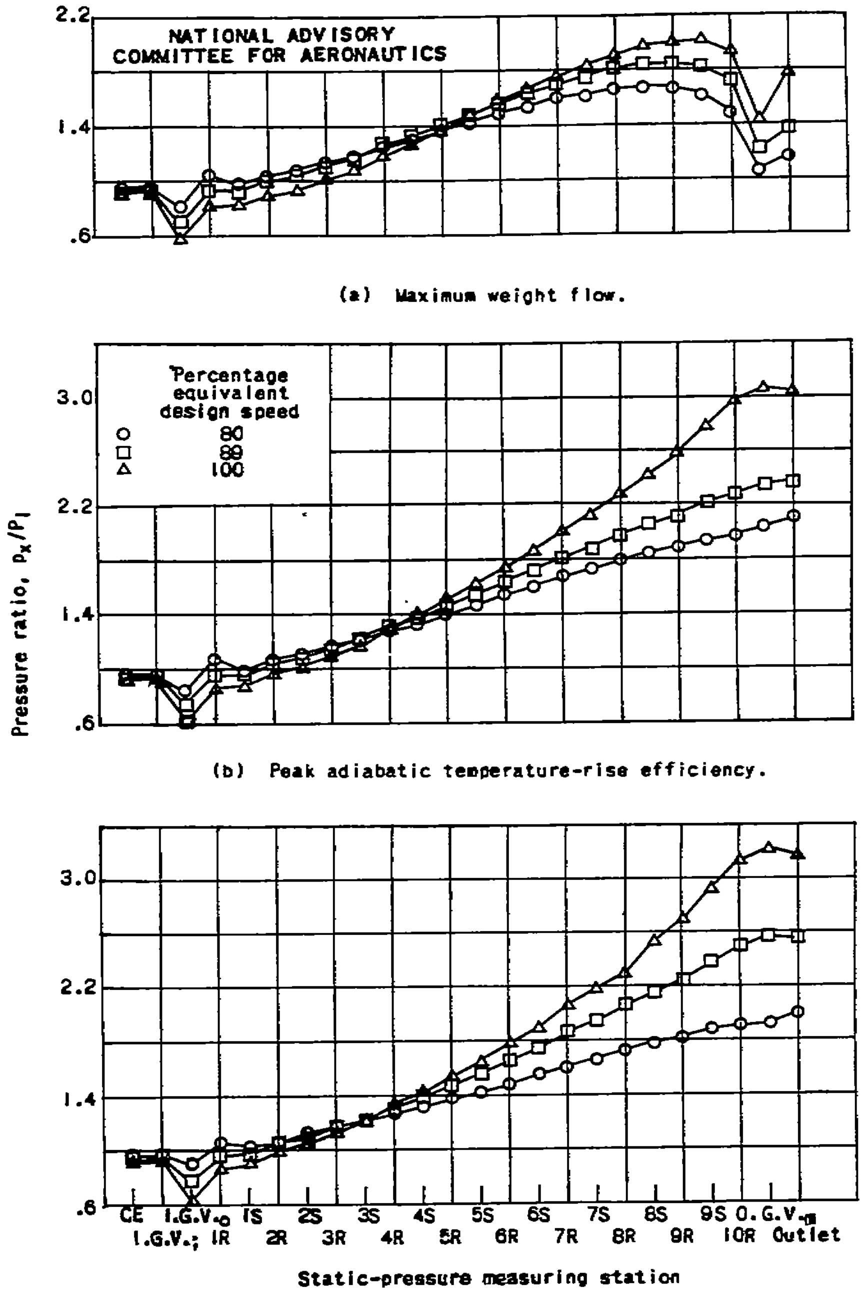

(a) Maximum weight flow.

(b) Peak adiabatic temperature-rise efficiency.

(c) Surge.

Figure 12. - Effect of various percentages of design speed on distribution of interstage static pressures along compressor casing. No diffuser; inlet-air temperature, 538° R; inlet pressure, 12 inches of mercury absolute (849 lb/sq ft); at compressor entrance, CE; inlet-guide vane inlet, I.G.V.$_i$; inlet-guide vane outlet, I.G.V.$_o$; rotor blades, R; stator blades, S; between two rows of outlet-guide vanes, O.G.V.$_m$.

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