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RESEARCH MEMORANDUM

for the

Bureau of Ordnance, Department of the Navy

EFFECT OF FIRST-STAGE BLADE DESIGN ON PERFORMANCE OF MARK 25 TORPEDO POWER PLANT

By Harold J. Schum and Jack W. Hoyt

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REVIEWED BUT NOT EDITED

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SUMMARY

The effect of rotor-blade length, inlet angle, and shrouding was investigated with four different nozzles in a single-stage modification of the Mark 25 aerial-torpedo power plant. The results obtained with the five special rotor configurations are compared with those of the standard first-stage rotor with each nozzle. Each nozzle-rotor combination was operated at nominal pressure ratios of 8, 15 (design), and 20 over a range of speeds from 6000 rpm to the design speed of 18,000 rpm. Inlet temperature and pressure conditions of 1000° F and 95 pounds per square inch gage, respectively, were maintained constant for all runs.

The increase in annular flow area, either through greater blade length or wider inlet angle, apparently resulted in the greatest increase in efficiency. The rotor having longer blades showed slightly greater efficiency than the blades with wider inlet angles with each nozzle at the high pressure ratios. Removal of the blade shroud caused a decrease in efficiency as expected. Only part of this decrease in efficiency was recovered when a close-fitting stationary shroud cap was placed over the active part of the blading.

The maximum brake efficiency of 0.54 was obtained when the longest blades (0.45 in.) were used with a cast sharp-edged-inlet nozzle (H). When this configuration was run as a two-stage unit with a standard second-stage rotor, however, the resulting efficiency was less than that observed when both standard rotors were used. This decrease in efficiency was probably caused by less favorable outlet velocities from the 0.45-inch first-stage rotor due to the increase in flow area, thereby reducing the effectiveness of the second stage.

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A water-channel investigation of X5-scale models of the standard 17°-inlet-angle blade and the special 20°-inlet-angle blade indicated the presence of a normal shock at the blade inlet, causing both subsonic flow through the blade passages and a loss in total pressure.

INTRODUCTION

At the request of the Bureau of Ordnance, Department of the Navy, the performance of a turbine from the Mark 25 aerial-torpedo power plant is being investigated at the NACA Lewis laboratory. Although the gas turbine is composed of two counterrotating stages, the second rotor is used primarily for balance. For possible application of high-pressure single-stage turbines to rocket accessory drive, a Mark 25 turbine with the second-stage blading removed was investigated. The over-all performance of the standard two-stage turbine and the first-stage turbine with five nozzles is reported in references 1 and 2, respectively, and a study of axial nozzle-rotor clearance in reference 3.

Because of the geometry of the turbine installation in the Mark 25 torpedo, no precise survey measurements could be made near the nozzles and the blades during these previous investigations. Only the over-all performance of various combinations of nozzles and blades could be used to obtain information leading to performance improvements.

The investigation reported herein was undertaken to obtain information regarding the variation of the over-all efficiency of turbines of this type with nozzles designed to vary the weight-flow rate and blades designed to change the effective flow area through the passages.

Four different turbine nozzles were investigated in conjunction with modifications to the first-stage blade design. These modifications included special blade heights of 0.35 and 0.45 inch as compared with the standard blade height of 0.40 inch. A third special first-stage rotor was fabricated with a blade-inlet angle of 20° instead of the standard 17°, the blade height being the same as that of the standard blade. When the results obtained with these three rotors are compared with the results previously obtained with the standard rotor, the effect of varying the effective flow area through the blading can be determined. The use of unshrouded blading facilitates turbine manufacture and hence the extent of the change in over-all performance was ascertained with the shroud removed from the 0.35-inch rotor blading. Turbine performance was also determined with a close-fitting stationary shroud cap installed around the active portion of the blading to reduce the air leakage around the blade tips. Finally, the most efficient combination of nozzle and first-stage rotor was investigated in a two-stage Mark 25 turbine with use of the standard second-stage rotor.

All nozzle-rotor configurations were investigated at pressure ratios of 8, 15 (design), and 20 and a range of turbine speeds from approximately 6000 to 18,000 rpm at inlet temperature and pressure conditions of 1000° F and 95 pounds per square inch gage, respectively. In order to evaluate the actual output of the nozzle-rotor combinations, the windage losses of each blade design were determined.

Water-channel investigations applying the hydraulic analogy to supersonic air flow in order to study the flow through the first-stage blades at simulated operating velocities were made of both the 20°- and the standard 17°-inlet-angle blades.

TURBINE MODIFICATIONS AND SETUP

The standard Mark 25 torpedo power plant is a two-stage counter-rotating turbine with partial gas admission. The two stages operate at the same rotative speed but in opposite directions in order to eliminate gyroscopic action. Design speed is 18,000 rpm. A description of the turbine and the modifications necessary to convert this unit into a single-stage turbine are described in references 1 and 2.

Blades. - The standard first-stage turbine has an outer diameter of 11.00 inches and 0.40-inch shrouded blades with an inlet angle of 17°. The blades of a standard first-stage rotor were machined to 0.35 inch and a steel shroud was shrunk around the wheel to make one special turbine rotor. The second special rotor had blades 0.45 inch high and was designed so that the pitch diameter was not changed from that of the standard rotor; that is, the tip diameter was increased and the hub diameter was decreased 0.025 inch. The third special rotor used had a 20° inlet angle and the standard blade height of 0.40 inch.

Shrouds. - The effect of shrouding was determined by removing the steel shroud band around the 0.35-inch blades. Because unshrouded turbine wheels are more easily fabricated, determination of the aerodynamic penalty involved in the use of such wheels was considered desirable. A close-fitting stationary shroud cap was installed around the active part of the unshrouded 0.35-inch blades. The stationary shroud cap is shown with the unshrouded rotor in figure 1.

Nozzles. - The alphabetical notation of the nozzles used in the investigation was arbitrarily selected to distinguish nozzle design. Nozzles A, E, and H are discussed in references 1 and 2. Nozzle A has rounded inlets to the rectangular converging-diverging nozzle ports. Nozzle E has reamed ports with rounded inlets. These ports are cylindrical with no divergence in the nozzle, completed gas expansion occurring in the clearance space between the nozzle and the blades. Nozzle H has rectangular ports with sharp-edge inlets to the throats cast by a different technique from that used for nozzle A. Nozzle I (not previously investigated) is similar to nozzle H in design but has smaller inlets and greater wall divergence in the ports. Both nozzles H and I utilize the gas-jet contraction effect caused by the sharp inlet edges, producing the equivalent of converging-diverging flow. The throat of the two nozzles is thus at the vena contracta, from which the gas expands to the nozzle outlet. All four nozzles have nine ports with 90°-arc admission. Additional characteristics of the nozzles are given in the following table:

Nozzle	Total measured throat area (sq in.)	Observed air weight flow (lb/hr)
A	0.183	955
E	.193	972
H	.226	1132
I	.217	995

The nozzle-throat area and the air-weight flow are not proportional, probably because of variance in vena contracta with different nozzle designs.

The axial nozzle-rotor clearances were set to give a running clearance of 0.030 inch at operating temperature. Radial nozzle settings as well as the proper allowances for thermal changes in axial clearances were made to conform with the recommendations of reference 1.

In order to determine what gains in a two-stage Mark 25 torpedo turbine could be realized by using the most efficient single-stage nozzle-rotor configuration, a turbine was assembled to operate with a standard second-stage rotor in combination with the 0.45-inch blading and nozzle H.

The shock pattern and the possible flow separation through the standard 17°-inlet-angle blades and the special 20°-inlet-angle blades were studied by placing X5-scale models of the two pitch-line sections in a water channel similar to that described in reference 4. The water channel essentially consists of a trough of shallow water flowing at the velocity necessary to simulate a given air-flow Mach number. The surface waves caused by the blades in the water channel represent shock waves in air. The waves are photographed by illuminating the channel from underneath and focusing the shadows of the waves on a ground glass. The theory of the hydraulic analogy to compressible air flow is given in references 4 and 5.

PROCEDURE

For each nozzle-rotor combination, the effect of pressure ratio and blade-jet speed ratio on turbine efficiency was investigated. These investigations were made at pressure ratios of 8, 15 (design), and 20 over a speed range from 6000 to 18,000 rpm with a constant inlet temperature of 1000° F and a constant inlet pressure of 95 pounds per square inch gage. Because of flow limitations of the outlet ducting, the maximum pressure ratio obtained with nozzle H was 19.

The rotation losses of the single-stage turbine with the standard rotor are presented in references 1 and 2 and include an individual evaluation of the mechanical friction losses, the disk windage losses, and the losses incurred by the air-pumping effect with partial admission. Rotation losses of the 0.35-inch unshrouded blade were determined by measuring the power required to motor the rotor at speeds from 6000 to 18,000 rpm and at various air densities in the turbine case. Because of stress limitations acquired when the outer shroud was shrunk onto the blades, motoring the shrouded 0.35-inch blades under cold-air conditions for which there would be no compensating thermal effects was considered unsafe. The windage losses for this rotor were therefore calculated from previous data.

CALCULATIONS

The brake, the rotor, and the blade efficiencies were computed according to the method given in reference 1. Brake efficiency is the ratio of the brake power calculated from the torque and the speed at the dynamometer shaft to the available isentropic power based on inlet total temperature and pressure and outlet static pressure; rotor efficiency is the ratio of the brake power plus the mechanical losses in the gears and the bearings to the isentropic power; and blade efficiency is the ratio of the brake power plus the mechanical losses and the disk and blade windage losses to the isentropic power. Blade-jet speed ratio is defined as the ratio of the blade speed at the pitch diameter of the rotor to the ideal nozzle-jet velocity based on isentropic expansion from the inlet total temperature and pressure to the outlet static pressure. Pressure ratio is defined as the ratio of the inlet total pressure to the outlet static pressure.

Charts of the windage and mechanical losses of the single-stage unit prepared from motoring studies of a disk (reference 2) and the complete rotor are based on the analysis and the calculation procedure described in reference 1 for the two-stage turbine. The power required to motor the unshrouded 0.35-inch blades at various turbine speeds and temperatures and pressures in the turbine case is given in table I. Because of stress limitations, the power necessary to motor the 0.35-inch shrouded blades was necessarily computed from data for the 0.40-inch-blade-height rotor (reference 2) by assuming that the blade windage loss was proportional to $l^{1.5}$, where l is the length of the turbine blade (reference 6). Data obtained with the shrouded 0.35-inch blades were calculated both with and without this correction and the agreement with the basic data obtained with the 0.40-inch standard rotor was found to be within experimental accuracy. On this basis and because the pitch diameters and the outside diameters of the rotors with the 0.45-inch and the 0.40-inch blades described in reference 2 are almost the same, the two rotors were assumed to have the same windage losses. Because the nozzles had 90°-nozzle-arc gas admission, one-fourth of the rotor blades are active and hence not subject to windage or pumping loss. Because windage loss of the unit is the total disk windage (reference 2) plus three-fourths of the windage due to the inactive rotor blades, figure 2 was prepared with the additional loss due to the inactive 0.35-inch shrouded and unshrouded blades considered. This figure may be used directly to find the windage and mechanical losses in the 0.35-inch-blade turbine if the gas density in the turbine case is known. A similar chart for the rotor with 0.40-inch blades is presented in reference 2.

For the water-channel studies of the blade shapes, the inlet Mach number to the blade under turbine operating conditions was calculated for the design pressure ratio of 15 through the nozzle, assuming a nozzle velocity coefficient of 0.96, an inlet temperature of 1000° F, and design turbine speed of 18,000 rpm. This Mach number and the design inlet angle of flow were simulated in the water channel.

RESULTS AND DISCUSSION

Single-Stage Performance with Various Nozzle-Rotor Combinations

Efficiency data for the rotors having 0.35-inch unshrouded blades, 0.35-inch unshrouded blades with a stationary shroud cap, 0.35-inch shrouded blades, standard 0.40-inch blades and nozzle I, 0.45-inch shrouded blades, and for the runs with the 20°-inlet blades are presented in tables II to VII.

Nozzle A. - The brake efficiency of the single-stage turbine with nozzle A and the various blade designs is shown in figure 3. The data of reference 2 for the standard 0.40-inch rotor are also shown for comparison. At a pressure ratio of 8, the standard rotor is the most efficient for this nozzle. When the pressure ratio is increased to the design value of 15 or to 20, the two rotors having a greater flow area (the 0.45-in. blade and the 20°-inlet blade) showed improved performance. Figure 3 also shows the reduction in performance when the blade height is reduced to 0.35 inch. The very substantial drop in efficiency when the shroud band is removed is only partly recovered when a close-fitting stationary shroud cap is placed over the active portion of the blading. Because the difference in windage losses in the shrouded and unshrouded 0.35-inch blades is small (fig. 2), the drop in efficiency of approximately 0.04 caused by the two rotor configurations at maximum blade-jet speed ratio and the design pressure ratio of 15 indicates high tip losses when the unshrouded wheel is used. The corresponding drop in efficiency at pressure ratios of 8 and 20 were approximately 0.08 and 0.05, respectively.

Nozzle E. - When nozzle E is used (fig. 4), there is little difference in performance between the standard 0.40-inch rotor, the 0.45-inch rotor, and the 20°-inlet-angle rotor, especially at the higher pressure ratios. The performance with the 0.35-inch rotor shows the same trends as those for nozzle A.

Nozzle H. - A gain in performance of approximately 0.03 over the standard 0.40-inch blade was obtained with nozzle H and the 0.45-inch blade (fig. 5). The maximum obtained brake efficiency of 0.54 occurred at a blade-jet speed ratio of 0.295 and a pressure ratio of 8. The peak brake efficiency, which would be at a higher blade-jet speed ratio, could not be determined because of the 18,000-rpm speed limitation of the turbine. The same limitation of peak efficiency occurs with all the nozzle-rotor configurations investigated. The 20°-inlet-angle rotor showed substantially the same performance as the standard rotor with nozzle H. This nozzle handled the largest air flow of the nozzles operated, indicating that a greater flow area through the turbine blade is advantageous for more extraction of power from the single-stage turbine.

Nozzle I. - The results of the various rotor configurations with nozzle I are presented in figure 6. At the higher pressure ratios, the 0.45-inch blade shows the most efficient performance. The unshrouded 0.35-inch blades again had the lowest performance.

In general, the rotor and blade efficiencies presented herein for the various nozzle-rotor configurations follow the same trends as the brake efficiencies.

Two-Stage Turbine with Most Efficient Nozzle-Rotor Combination

In general, experience with the various types of nozzle and blade in the single-stage turbine indicates that a somewhat larger flow area in the rotor is advantageous for the extraction of greater power from the first stage. Results have shown that the rotor having longer blades than that of the standard rotor had slightly greater efficiency than the blades with increased inlet angles with each nozzle. In the event that the flow leaving the rotor is subsonic, however, the greater area in the first stage may cause the velocity leaving this stage to be insufficient for developing as much useful work from the second stage as that observed during the investigation of the standard Mark 25 two-stage turbine. Study of the standard first-stage turbine blades indicated that the throat area was insufficient to swallow a supersonic air stream under operating conditions. Subsonic flow appeared likely to prevail at the blading outlet. Velocity diagrams based on this premise indicated both low outlet velocity from the first stage and unfavorable inlet angle for the second stage. In order to investigate the possible adverse effects of increasing the flow area of the first-stage rotor, the most efficient first-stage combination (0.45-in.-blade rotor and nozzle H) was therefore operated with the second stage. It should be noted, however, that at a blade-jet speed ratio of 0.20, which would be approximately the peak performance point for the two-stage turbine, the 0.45-inch-blade rotor gives only a slight gain in performance over the standard rotor.

In figure 7, the performance of the two-stage turbine with the 0.45-inch-blade first-stage rotor and nozzle H is compared with the standard Mark 25 blading with nozzle H. The lower efficiency of the unit with the higher blade-height first stage may be attributed to unfavorable inlet conditions of the second stage. Because the windage losses for the 0.40- and 0.45-inch blade-height first-stage rotors are considered the same, the windage losses for the two-stage units using these rotors are the same. The blade efficiencies therefore bear the same relation to each other as do the brake efficiencies for the two-stage units. The gain in first-stage output is apparently more than outweighed by the drop in second-stage performance. The data for the two-stage unit with the 0.45-inch blade-height first stage is presented in table VIII.

Water-Channel Studies

In order to ascertain if supersonic velocities are maintained through the turbine-blade passages, X5-scale models of the standard 17°- and special 20°-inlet blades were placed in a water channel to investigate the flow by the hydraulic analogy. Photographs of the flow through models of the turbine blades taken in the water channel at an analogous Mach number of approximately 1.6, corresponding to assumed turbine operating conditions at a speed of 18,000 rpm and an inlet temperature of 1000° F, are shown in figure 8. A nozzle pressure ratio of 15 and a nozzle-velocity coefficient of 0.96 were assumed for the Mach number calculations. The leading edge of the 17°-inlet-angle blades was placed at an angle of attack of 0° and the 20°-inlet-angle blades at an angle of attack of 3° in the water stream.

In each set of blades, a wave corresponding to a normal shock in air appears at the inlet to the passage between the blades. The wave appears to be somewhat farther inside the passage in the 20°-inlet-angle design. The occurrence of a normal shock in the inlet of the blade passage is indicative that the throat area is insufficient and that a rise in pressure together with substantial blade losses would result. That the analogous velocity inside the passage is subsonic is evidenced by the apparent inability of the blading to swallow the shock and by the lack of oblique waves inside the passage. For maximum blade performance in supersonic turbine passages, it would be more advantageous to allow the normal shock to be swallowed completely. This experiment also supports the conjecture that subsonic flow prevailed at the rotor outlet.

SUMMARY OF RESULTS

The performance of the first stage of a Mark 25 two-stage turbine with several blade designs was investigated with each of four nozzles. The most efficient first-stage blade and nozzle combination was operated with a standard second-stage rotor as a two-stage turbine. The first-stage blade designs were examined in a water channel for shock-wave formation. The following results were obtained:

1. A somewhat larger flow area in the first-stage blades than that provided in the standard Mark 25 turbine was found to be advantageous for more efficient extraction of power from the first stage. At the high pressure ratios, the rotor having longer blades than that of the standard rotor showed slightly greater efficiency than the blades with increased inlet angles with each nozzle.

2. The highest first-stage brake efficiency was obtained with a rotor having blades 0.45 inch high and a cast sharp-edged-inlet turbine nozzle (H). For a pressure ratio of 8 and blade-jet speed ratio of 0.295, the maximum brake efficiency of the combination was 0.54, a gain of 0.03 over the standard Mark 25 first stage under the same conditions.

3. Removing the shroud band from the outside of the turbine blades caused a substantial drop in efficiency. Only part of this decrease in efficiency was recovered when a close-fitting stationary shroud cap was placed over the active portion of the blading.

4. When the most efficient first-stage rotor and nozzle combination was assembled with a standard second-stage rotor to form a two-stage turbine, the resulting brake efficiency was less than when a standard Mark 25 first-stage rotor was used. This decrease was presumed to be caused by unfavorable outlet velocities from the first stage and inlet angles to the second stage due to the greater blade-height first-stage wheel, causing the second stage to be of reduced effectiveness.

5. Water-channel investigation of X5 models of the standard 17°- and the special 20°-inlet-angle Mark 25 first-stage blade

designs indicated the presence of a normal shock at the blade-passage inlet caused by insufficient passage area. Such a normal shock caused the flow in the blading to be subsonic and resulted in a loss in total pressure.

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TABLE I - DATA FOR WINDAGE AND MECHANICAL LOSSES OF SINGLE-STAGE TURBINE WITH 0.35-INCH UNSHROUDED BLADES

Turbine speed (rpm)	Horsepower to motor turbine	Air temperature in turbine case (°F)	Air pressure in turbine case (in. Hg abs.)
6069	0.84	129	27.55
	.82	132	22.59
	.78	133	15.65
	.68	132	9.36
8092	1.41	162	27.71
	1.36	165	22.96
	1.28	162	16.01
	1.09	154	9.21
10,115	2.16	195	27.51
	2.07	200	22.96
	1.93	196	15.77
	1.70	186	9.34
12,138	3.20	236	27.31
	2.96	242	22.74
	2.72	234	15.73
	2.40	215	9.24
14,161	4.34	284	27.05
	4.06	297	22.78
	3.68	286	15.81
	3.26	253	9.25
16,184	5.49	353	27.14
	5.17	351	22.76
	4.69	328	15.66
	4.21	286	9.43
18,207	7.32	381	26.81
	6.90	388	22.44
	6.30	351	15.71
	5.52	320	9.44

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TABLE II - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 0.35-INCH UNSHROUDED BLADES

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
A	8	957.4	0.0137	61.26	6,079	13.64	0.0985	0.0312	0.223	0.228	0.231
		956.4	.0137	61.20	8,092	17.07	.1311	.0317	.279	.289	.294
		957.4	.0137	61.26	10,135	19.87	.1643	.0321	.324	.339	.346
		958.4	.0136	61.30	12,178	22.15	.1974	.0327	.361	.381	.389
		958.4	.0136	61.30	14,161	23.75	.2295	.0330	.387	.412	.425
		957.4	.0137	61.26	16,174	24.73	.2621	.0333	.404	.433	.453
		957.4	.0137	61.26	18,187	24.87	.2947	.0335	.406	.440	.470
A	15	952.5	0.0137	73.56	6,099	14.95	0.0900	0.0183	0.203	0.207	0.209
		952.5	.0137	73.56	8,092	18.72	.1195	.0186	.255	.263	.266
		952.5	.0137	73.56	10,125	21.86	.1495	.0186	.297	.310	.314
		952.5	.0137	73.56	12,128	24.42	.1790	.0187	.332	.348	.352
		953.6	.0137	73.65	14,141	26.38	.2088	.0187	.358	.379	.384
		952.5	.0137	73.56	16,184	28.11	.2389	.0190	.382	.407	.415
		952.5	.0137	73.56	18,237	29.09	.2692	.0192	.396	.424	.438
A	20	953.6	0.0137	78.73	6,079	15.03	0.0868	0.0146	0.191	0.195	0.197
		953.6	.0137	78.73	8,102	18.93	.1157	.0153	.240	.248	.251
		953.6	.0137	78.73	10,125	22.12	.1446	.0155	.281	.293	.296
		953.6	.0137	78.73	12,158	24.76	.1736	.0154	.315	.330	.333
		953.6	.0137	78.73	14,141	26.70	.2019	.0157	.339	.358	.362
		953.6	.0137	78.73	16,194	28.18	.2313	.0159	.358	.381	.388
		953.6	.0137	78.73	18,227	29.25	.2603	.0162	.372	.399	.409
E	8	971.4	0.0139	62.17	6,079	12.36	0.0985	0.0312	0.199	0.204	0.207
		971.4	.0139	62.17	8,072	15.43	.1308	.0312	.248	.258	.263
		970.7	.0139	62.13	10,095	18.20	.1636	.0317	.293	.307	.315
		971.4	.0139	62.17	12,178	20.39	.1974	.0320	.328	.347	.355

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
E	8	971.4	0.0139	62.17	14,161	21.84	0.2295	0.0325	0.351	0.376	0.388
		971.4	.0139	62.17	16,194	22.84	.2625	.0325	.367	.397	.415
		971.4	.0139	62.17	18,197	23.09	.2949	.0326	.371	.405	.433
E	15	971.4	0.0139	75.04	6,059	12.54	0.0894	0.0178	0.167	0.171	0.173
		972.3	.0139	75.11	8,041	15.69	.1187	.0181	.209	.217	.220
		972.3	.0139	75.11	10,145	18.59	.1497	.0181	.248	.260	.264
		972.3	.0139	75.11	12,148	20.86	.1793	.0183	.278	.294	.297
		972.3	.0139	75.11	14,201	22.51	.2096	.0184	.300	.320	.325
		972.3	.0139	75.11	16,184	23.84	.2389	.0188	.317	.342	.350
		972.3	.0139	75.11	18,217	24.25	.2689	.0188	.323	.351	.364
E	20	973.1	0.0139	80.37	6,059	12.42	0.0865	0.0149	0.155	0.158	0.160
		972.1	.0139	80.28	8,082	15.47	.1154	.0148	.193	.200	.203
		972.1	.0139	80.28	10,115	18.43	.1445	.0147	.230	.241	.244
		973.1	.0139	80.37	12,118	20.85	.1731	.0155	.259	.274	.277
		973.1	.0139	80.37	14,161	22.54	.2022	.0149	.281	.299	.303
		973.1	.0139	80.37	16,184	23.63	.2311	.0150	.294	.317	.323
		973.1	.0139	80.37	18,227	24.33	.2603	.0153	.303	.329	.339
H	8	1131.8	0.0142	72.47	6,079	16.13	0.0985	0.0317	0.223	0.227	0.229
		1131.8	.0142	72.47	8,092	20.19	.1311	.0320	.279	.287	.292
		1131.8	.0142	72.47	10,115	23.60	.1639	.0323	.326	.338	.344
		1131.8	.0142	72.47	12,158	26.64	.1970	.0329	.368	.384	.391
		1131.8	.0142	72.47	14,151	28.82	.2293	.0336	.398	.419	.430
		1131.8	.0142	72.47	16,144	30.11	.2616	.0335	.416	.440	.457
		1131.8	.0142	72.47	18,247	30.79	.2957	.0336	.425	.454	.479

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TABLE II - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 0.35-INCH UNSHROUDED BLADES - Concluded

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
H	15	1131.8	0.0142	87.47	6,049	16.62	0.0893	0.0189	0.190	0.194	0.195
		1131.8	.0142	87.47	8,092	20.93	.1194	.0190	.239	.246	.249
		1131.8	.0142	87.47	10,115	24.50	.1493	.0193	.280	.291	.294
		1133.2	.0142	87.58	12,138	27.40	.1792	.0198	.313	.327	.330
		1131.8	.0142	87.47	14,171	29.42	.2092	.0198	.336	.354	.358
		1131.8	.0142	87.47	16,204	31.08	.2392	.0194	.355	.376	.384
		1131.8	.0142	87.47	18,207	31.92	.2687	.0199	.365	.389	.401
H	19	1131.4	0.0142	92.45	6,089	16.66	0.0875	0.0166	0.180	0.184	0.185
		1131.4	.0142	92.45	8,132	20.82	.1168	.0165	.225	.232	.234
		1131.4	.0142	92.45	10,145	24.34	.1457	.0169	.263	.273	.276
		1131.4	.0142	92.45	12,138	27.20	.1743	.0169	.294	.307	.310
		1132.6	.0142	92.54	14,161	29.31	.2034	.0171	.317	.333	.337
		1132.6	.0142	92.54	16,194	30.85	.2326	.0171	.333	.353	.359
		1132.6	.0142	92.54	18,167	31.79	.2609	.0171	.344	.366	.376
I	8	994.8	0.0140	63.68	6,079	13.50	0.0985	0.0315	0.212	0.217	0.220
		994.8	.0140	63.68	8,072	16.89	.1308	.0320	.265	.275	.280
		994.1	.0140	62.63	10,155	19.85	.1646	.0322	.312	.326	.333
		994.8	.0140	63.68	12,098	22.09	.1961	.0324	.347	.366	.374
		994.8	.0140	63.68	14,121	23.78	.2289	.0327	.373	.397	.409
		994.8	.0140	63.68	16,174	25.10	.2621	.0329	.394	.423	.441
		994.8	.0140	63.68	18,187	25.35	.2947	.0329	.398	.431	.459
I	15	994.8	0.0140	76.86	6,099	15.38	0.0900	0.0181	0.200	0.204	0.206
		994.8	.0140	76.86	8,072	19.29	.1192	.0180	.251	.259	.262
		994.8	.0140	76.86	10,125	22.56	.1495	.0184	.294	.305	.309

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
I	15	994.1	0.0140	76.81	12,138	25.28	0.1792	0.0188	0.329	0.345	0.348
		994.8	.0140	76.86	14,161	27.35	.2090	.0192	.356	.376	.381
		994.8	.0140	76.86	16,224	28.98	.2395	.0195	.377	.401	.409
		994.8	.0140	76.86	18,227	29.79	.2691	.0198	.388	.415	.428
I	20	994.8	0.0140	82.17	6,099	15.52	0.0871	0.0151	0.189	0.193	0.194
		994.8	.0140	82.17	8,062	19.42	.1151	.0151	.236	.244	.246
		994.8	.0140	82.17	10,135	22.91	.1447	.0152	.279	.290	.293
		994.8	.0140	82.17	12,118	25.56	.1730	.0153	.311	.326	.328
		994.8	.0140	82.17	14,151	27.56	.2021	.0156	.335	.354	.357
		994.8	.0140	82.17	16,184	29.23	.2311	.0159	.356	.378	.384
		994.8	.0140	82.17	18,187	30.27	.2597	.0161	.368	.394	.404

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TABLE III - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 0.35-INCH UNSHROUDED BLADES AND SHROUD CAP

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
A	8	952.5	0.0138	60.92	6,089	13.83	0.0987	0.0328	0.227	0.232	0.235
		953.2	.0138	60.97	8,072	17.16	.1308	.0334	.281	.291	.297
		953.2	.0138	60.97	10,135	20.21	.1643	.0345	.332	.346	.354
		953.2	.0138	60.97	12,189	22.61	.1976	.0343	.371	.391	.399
		954.0	.0138	61.02	14,191	24.37	.2300	.0342	.399	.424	.438
		953.3	.0138	60.98	16,174	25.53	.2621	.0341	.419	.448	.469
		954.0	.0138	61.02	18,207	26.16	.2951	.0339	.429	.463	.493
A	15	954.0	0.0138	73.63	6,069	15.06	0.0896	0.0181	0.205	0.209	0.211
		955.0	.0138	73.70	8,072	18.99	.1191	.0184	.258	.266	.269
		955.0	.0138	73.70	10,115	22.50	.1493	.0191	.305	.318	.322
		955.0	.0138	73.70	12,178	25.44	.1798	.0190	.345	.362	.365
		955.0	.0138	73.70	14,151	27.51	.2089	.0192	.373	.394	.399
		955.0	.0138	73.70	16,184	29.17	.2389	.0192	.396	.420	.429
		955.0	.0138	73.70	18,187	30.27	.2684	.0194	.411	.439	.453
A	20	953.2	0.0138	78.68	6,089	15.17	0.0870	0.0148	0.193	0.197	0.198
		953.2	.0138	78.68	8,102	19.22	.1157	.0151	.244	.252	.255
		952.5	.0138	78.63	10,115	22.50	.1445	.0155	.286	.298	.301
		954.0	.0138	78.75	12,087	25.53	.1726	.0157	.324	.339	.342
		954.0	.0138	78.75	14,110	27.85	.2015	.0156	.354	.373	.377
		954.0	.0138	78.75	16,184	29.65	.2311	.0159	.377	.400	.406
		954.0	.0138	78.75	18,207	30.90	.2600	.0160	.392	.419	.430
E	8	973.5	0.0139	62.27	6,089	12.58	0.0987	0.0323	0.202	0.207	0.210
		973.5	.0139	62.27	8,092	15.68	.1311	.0325	.252	.262	.267
		973.5	.0139	62.27	10,095	18.43	.1636	.0337	.296	.310	.318

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
E	8	973.5	0.0139	62.27	12,168	20.53	0.1972	0.0331	0.330	0.349	0.357
		973.5	.0139	62.27	14,161	22.07	.2295	.0329	.354	.379	.391
		973.5	.0139	62.27	16,184	23.04	.2623	.0330	.370	.399	.418
		973.5	.0139	62.27	18,187	23.31	.2948	.0329	.374	.408	.437
E	15	972.8	0.0139	75.16	6,059	12.96	0.0895	0.0188	0.172	0.176	0.178
		971.8	.0139	75.07	8,112	16.17	.1198	.0186	.215	.224	.227
		971.8	.0139	75.07	10,095	18.86	.1491	.0186	.251	.263	.267
		971.8	.0139	75.07	12,138	21.24	.1792	.0187	.283	.299	.303
		971.8	.0139	75.07	14,141	22.93	.2088	.0190	.305	.325	.331
		971.8	.0139	75.07	16,224	24.22	.2396	.0190	.323	.347	.355
		971.8	.0139	75.07	18,187	24.45	.2685	.0193	.326	.354	.367
E	20	971.0	0.0139	80.15	6,099	12.86	0.0871	0.0152	0.160	0.164	0.166
		971.0	.0139	80.15	8,092	16.00	.1156	.0153	.200	.207	.210
		970.1	.0139	80.08	10,115	18.77	.1445	.0152	.234	.246	.249
		971.0	.0139	80.15	12,189	21.13	.1741	.0153	.264	.279	.281
		971.0	.0139	80.15	14,171	22.65	.2024	.0153	.283	.301	.305
		971.0	.0139	80.15	16,214	23.83	.2316	.0156	.297	.320	.326
		971.0	.0139	80.15	18,187	24.45	.2597	.0158	.305	.331	.341
H	8	1140.6	0.0141	73.02	6,089	16.66	0.0987	0.0315	0.228	0.232	0.235
		1140.6	.0141	73.02	8,092	20.99	.1312	.0321	.288	.296	.300
		1140.6	.0141	73.02	10,145	24.47	.1645	.0327	.335	.348	.354
		1140.6	.0141	73.02	12,148	27.26	.1970	.0328	.373	.390	.397
		1140.6	.0141	73.02	14,161	29.21	.2296	.0330	.400	.421	.432
		1140.6	.0141	73.02	16,194	30.63	.2625	.0330	.420	.444	.461
		1140.6	.0141	73.02	18,237	31.31	.2957	.0333	.429	.458	.482

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TABLE III - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 0.35-INCH UNSHROUDED BLADES AND SHROUD CAP - Concluded

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
H	15	1134.0	0.0142	87.64	6,109	17.40	0.0902	0.0187	0.199	0.202	0.204
		1134.0	.0142	87.64	8,092	21.87	.1194	.0192	.250	.257	.259
		1134.0	.0142	87.64	10,034	25.59	.1481	.0194	.292	.302	.306
		1135.1	.0142	87.72	12,138	28.92	.1791	.0202	.330	.343	.347
		1134.0	.0142	87.64	14,171	31.29	.2092	.0205	.357	.374	.379
		1134.0	.0142	87.64	16,194	33.30	.2390	.0208	.380	.401	.409
		1134.0	.0142	87.64	18,207	34.44	.2687	.0211	.393	.417	.430
H	19	1137.5	0.0142	92.94	6,109	17.68	0.0877	0.0175	0.190	0.194	0.195
		1137.5	.0142	92.94	8,092	22.24	.1162	.0178	.239	.246	.248
		1137.5	.0142	92.94	10,135	26.22	.1455	.0183	.282	.292	.295
		1139.3	.0141	93.08	12,158	29.49	.1745	.0184	.317	.330	.333
		1138.5	.0141	93.00	14,171	31.94	.2034	.0186	.343	.360	.364
		1138.5	.0141	93.00	16,224	34.11	.2329	.0190	.367	.386	.393
		1138.5	.0141	93.00	18,187	35.48	.2611	.0192	.382	.404	.415
I	8	999.6	0.0140	63.99	6,069	14.38	0.0984	0.0318	0.225	0.230	0.232
		999.6	.0140	63.99	8,072	18.11	.1308	.0321	.283	.292	.298
		999.6	.0140	63.99	10,145	21.30	.1644	.0332	.333	.347	.354
		999.6	.0140	63.99	12,138	23.64	.1967	.0333	.369	.388	.396
		999.6	.0140	63.99	14,181	25.47	.2298	.0332	.398	.422	.434
		999.6	.0140	63.99	16,214	26.56	.2628	.0332	.415	.444	.462
		999.6	.0140	63.99	18,167	26.88	.2944	.0331	.420	.453	.481
I	15	999.6	0.0140	77.23	6,109	15.95	0.0902	0.0179	0.207	0.211	0.212
		999.6	.0140	77.23	8,112	20.21	.1197	.0181	.262	.270	.273
		999.6	.0140	77.23	10,145	23.70	.1497	.0184	.307	.319	.322

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
I	15	999.6	0.0140	77.23	12,158	26.72	0.1794	0.0188	0.346	0.362	0.365
		999.6	.0140	77.23	14,161	28.98	.2090	.0189	.375	.395	.400
		999.6	.0140	77.23	16,174	30.59	.2387	.0192	.396	.419	.428
		999.6	.0140	77.23	18,167	31.43	.2681	.0195	.407	.434	.447
I	20	1000.5	0.0140	82.64	6,089	16.11	0.0869	0.0151	0.195	0.199	0.200
		1000.5	.0140	82.64	8,112	20.48	.1158	.0154	.248	.255	.258
		1000.5	.0140	82.64	10,115	24.07	.1444	.0155	.291	.302	.305
		1000.5	.0140	82.64	12,138	27.24	.1733	.0157	.330	.344	.347
		1000.5	.0140	82.64	14,171	29.89	.2023	.0158	.362	.380	.384
		1000.5	.0140	82.64	16,235	31.78	.2318	.0160	.385	.407	.413
		999.6	.0140	82.57	18,177	32.95	.2595	.0161	.399	.425	.435

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TABLE IV - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 0.35-INCH SHROUDED BLADES

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
A	8	953.6	0.0138	61.02	6,089	15.87	0.0987	0.0323	0.260	0.265	0.267
		953.3	.0138	61.01	8,143	19.99	.1320	.0333	.328	.338	.341
		953.3	.0138	61.01	10,115	23.26	.1640	.0346	.381	.396	.401
		953.6	.0138	61.02	12,189	26.11	.1976	.0340	.428	.448	.455
		953.6	.0138	61.02	14,171	27.50	.2297	.0343	.451	.475	.487
		953.6	.0138	61.02	16,214	28.90	.2628	.0340	.474	.503	.522
		953.6	.0138	61.02	18,187	29.36	.2948	.0338	.481	.516	.544
A	15	953.6	0.0138	73.66	6,049	16.08	0.0893	0.0185	0.218	0.223	0.224
		953.6	.0138	73.66	8,143	20.58	.1202	.0186	.279	.288	.290
		953.6	.0138	73.66	10,135	23.98	.1496	.0182	.326	.338	.341
		953.6	.0138	73.66	12,138	27.32	.1792	.0182	.371	.387	.390
		953.6	.0138	73.66	14,161	29.16	.2091	.0183	.396	.416	.421
		953.6	.0138	73.66	16,224	31.22	.2395	.0187	.424	.448	.456
		953.6	.0138	73.66	18,227	32.31	.2691	.0191	.439	.467	.480
A	20	959.3	0.0137	79.21	6,109	15.96	0.0872	0.0149	0.202	0.206	0.207
		959.7	.0137	79.24	8,092	20.24	.1156	.0149	.255	.263	.265
		959.7	.0137	79.24	10,085	23.96	.1440	.0148	.302	.314	.316
		959.7	.0137	79.24	12,148	27.34	.1735	.0147	.345	.360	.362
		959.7	.0137	79.24	14,191	29.79	.2027	.0153	.376	.395	.398
		958.8	.0137	79.16	16,194	31.86	.2313	.0154	.403	.425	.431
		959.7	.0137	79.24	18,207	33.30	.2600	.0155	.420	.447	.456
E	8	977.4	0.0139	62.56	6,059	15.39	0.0982	0.0326	0.246	0.251	0.253
		977.1	.0139	62.54	8,052	19.34	.1305	.0331	.309	.319	.322
		977.4	.0139	62.56	10,125	22.99	.1641	.0339	.368	.382	.387

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
E	8	977.4	0.0139	62.56	12,138	26.04	0.1967	0.0343	0.416	0.436	0.442
		977.4	.0139	62.56	14,161	27.67	.2295	.0341	.442	.466	.478
		977.4	.0139	62.56	16,194	29.51	.2625	.0338	.472	.501	.519
		977.4	.0139	62.56	18,167	30.17	.2944	.0336	.482	.516	.543
E	15	977.4	0.0139	75.51	6,039	15.84	0.0892	0.0178	0.210	0.214	0.215
		978.3	.0139	75.57	8,092	20.32	.1195	.0178	.269	.277	.279
		978.3	.0139	75.57	10,135	24.18	.1496	.0179	.320	.332	.335
		978.3	.0139	75.57	12,138	27.48	.1792	.0181	.364	.380	.382
		978.3	.0139	75.57	14,212	29.64	.2098	.0186	.392	.412	.416
		978.3	.0139	75.57	16,154	31.67	.2385	.0186	.419	.443	.451
		978.3	.0139	75.57	18,187	32.66	.2685	.0190	.432	.460	.472
E	20	978.3	0.0139	80.80	6,109	15.94	0.0872	0.0143	0.197	0.201	0.202
		978.3	.0139	80.80	8,092	20.21	.1156	.0143	.250	.258	.259
		978.3	.0139	80.80	10,115	24.13	.1445	.0143	.299	.310	.312
		978.3	.0139	80.80	12,148	27.58	.1735	.0144	.341	.356	.358
		978.3	.0139	80.80	14,161	30.05	.2022	.0147	.372	.391	.393
		978.3	.0139	80.80	16,204	32.25	.2314	.0150	.399	.422	.427
		978.3	.0139	80.80	18,197	33.46	.2599	.0152	.414	.440	.449
H	8	1131.6	0.0143	72.47	6,079	18.91	0.0985	0.0320	0.261	0.265	0.267
		1132.7	.0143	72.53	8,112	23.82	.1315	.0322	.328	.337	.339
		1131.6	.0143	72.47	10,125	27.59	.1641	.0320	.381	.393	.397
		1135.1	.0143	72.68	12,189	30.76	.1976	.0332	.423	.440	.446
		1135.1	.0143	72.68	14,161	32.76	.2295	.0327	.451	.472	.481
		1134.0	.0143	72.62	16,184	33.86	.2623	.0328	.466	.491	.507
		1134.0	.0143	72.62	18,207	34.26	.2951	.0329	.472	.501	.524

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TABLE IV - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 0.35-INCH SHROUDED BLADES - Concluded

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
H	15	1135.4	0.0143	87.76	6,069	18.70	0.0896	0.0186	0.213	0.217	0.218
		1132.0	.0143	87.49	8,122	23.61	.1199	.0191	.270	.277	.279
		1132.0	.0143	87.49	10,105	27.94	.1492	.0191	.319	.330	.332
		1133.4	.0143	87.61	12,148	31.70	.1793	.0192	.362	.376	.378
		1133.4	.0143	87.61	14,171	34.69	.2092	.0197	.396	.413	.417
		1133.4	.0143	87.61	16,184	36.69	.2389	.0196	.419	.439	.447
		1133.4	.0143	87.61	18,197	38.02	.2686	.0203	.434	.458	.470
H	19	1133.4	0.0143	92.62	6,079	18.53	0.0873	0.0173	0.200	0.203	0.205
		1133.4	.0143	92.62	8,041	23.26	.1155	.0171	.251	.258	.259
		1133.4	.0143	92.62	10,135	27.72	.1456	.0170	.299	.309	.311
		1133.4	.0143	92.62	12,138	31.64	.1743	.0170	.342	.355	.357
		1133.4	.0143	92.62	14,151	34.74	.2032	.0174	.375	.391	.395
		1133.4	.0143	92.62	16,133	36.79	.2317	.0175	.397	.417	.423
		1133.4	.0143	92.62	18,187	38.47	.2612	.0178	.415	.438	.448
I	8	988.1	0.0139	63.24	6,109	16.65	0.0990	0.0336	0.263	0.268	0.270
		988.1	.0139	63.24	8,112	20.90	.1315	.0336	.331	.340	.343
		992.5	.0139	63.52	10,085	24.22	.1635	.0331	.381	.396	.401
		992.5	.0139	63.52	12,168	27.27	.1972	.0327	.429	.448	.455
		992.5	.0139	63.52	14,181	29.30	.2298	.0332	.461	.485	.496
		992.5	.0139	63.52	16,184	30.34	.2623	.0330	.478	.506	.524
		992.5	.0139	63.52	18,237	30.89	.2956	.0334	.486	.520	.546
I	15	988.1	0.0139	76.33	6,069	16.74	0.0896	0.0186	0.219	0.223	0.225
		988.1	.0139	76.33	8,072	21.36	.1192	.0191	.280	.288	.290
		988.1	.0139	76.33	10,115	25.16	.1493	.0189	.330	.342	.344

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
I	15	988.1	0.0139	76.33	12,178	28.49	0.1798	0.0189	0.373	0.389	0.392
		988.1	.0139	76.33	14,141	30.99	.2088	.0190	.406	.426	.430
		988.1	.0139	76.33	16,235	33.22	.2397	.0191	.435	.459	.467
		988.1	.0139	76.33	18,207	34.26	.2688	.0194	.449	.477	.489
I	20	992.2	0.0139	81.94	6,069	16.80	0.0867	0.0154	0.205	0.209	0.210
		992.2	.0139	81.94	8,102	21.38	.1157	.0158	.261	.268	.270
		992.2	.0139	81.94	10,155	25.33	.1450	.0158	.309	.320	.323
		992.2	.0139	81.94	12,168	28.75	.1738	.0157	.351	.366	.368
		992.2	.0139	81.94	14,181	31.21	.2025	.0156	.381	.399	.402
		992.2	.0139	81.94	16,184	33.01	.2311	.0158	.403	.425	.431
		992.2	.0139	81.94	18,237	34.01	.2605	.0161	.415	.441	.450

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TABLE V - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH STANDARD SHROUDED 0.40-INCH BLADES AND NOZZLE I

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
8	1007.5	0.0140	64.49	6,029	16.95	0.0977	0.0320	0.263	0.268	0.270
	1007.5	.0140	64.49	8,112	21.44	.1315	.0329	.333	.342	.345
	1007.5	.0140	64.49	10,085	25.32	.1635	.0334	.393	.406	.412
	1007.5	.0140	64.49	12,158	28.81	.1955	.0335	.447	.465	.473
	1007.5	.0140	64.49	14,161	31.31	.2296	.0335	.486	.509	.522
	1007.5	.0140	64.49	16,174	33.10	.2622	.0334	.513	.541	.562
	1007.5	.0140	64.49	18,177	33.84	.2947	.0334	.525	.558	.588
15	1005.5	0.0140	77.69	6,079	17.65	0.0897	0.0179	0.227	0.231	0.233
	1005.5	.0140	77.69	8,102	22.56	.1196	.0177	.290	.298	.300
	1005.5	.0140	77.69	10,115	26.87	.1493	.0178	.346	.357	.361
	1005.5	.0140	77.69	12,168	30.64	.1796	.0177	.394	.410	.413
	1005.5	.0140	77.69	14,181	33.46	.2093	.0179	.431	.450	.455
	1005.5	.0140	77.69	16,184	35.73	.2389	.0180	.460	.483	.492
	1004.6	.0140	77.62	18,187	37.46	.2684	.0183	.483	.510	.523
20	1001.5	0.0140	82.73	6,099	17.63	0.0871	0.0158	0.213	0.217	0.218
	1001.5	.0140	82.73	8,072	22.21	.1152	.0152	.269	.276	.278
	1002.5	.0140	82.81	10,145	26.71	.1448	.0149	.323	.334	.336
	1002.5	.0140	82.81	12,118	30.55	.1730	.0150	.369	.383	.386
	1004.3	.0140	82.96	14,161	33.74	.2022	.0149	.407	.425	.428
	1004.3	.0140	82.96	16,235	36.27	.2318	.0148	.437	.459	.465
	1004.3	.0140	82.96	18,237	38.22	.2604	.0148	.461	.486	.496

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TABLE VI - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH SHROUDED 0.45-INCH BLADES

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
A	8	958.1	0.0137	61.30	6,089	15.19	0.0987	0.0330	0.248	0.253	0.255
		957.2	.0137	61.25	8,112	19.30	.1315	.0344	.315	.325	.328
		958.1	.0137	61.30	10,145	22.90	.1644	.0352	.374	.388	.394
		958.1	.0137	61.30	12,098	25.75	.1961	.0360	.420	.440	.449
		958.1	.0137	61.30	14,212	28.24	.2304	.0358	.461	.486	.500
		957.2	.0137	61.25	16,133	29.88	.2615	.0350	.488	.517	.540
		957.2	.0137	61.25	18,177	30.61	.2947	.0340	.500	.534	.567
A	15	957.2	0.0137	73.92	6,069	16.60	0.0896	0.0172	0.225	0.229	0.230
		956.4	.0137	73.86	8,072	21.14	.1192	.0173	.286	.294	.296
		958.1	.0137	73.99	10,135	25.25	.1496	.0183	.341	.354	.357
		957.2	.0137	73.92	12,178	28.81	.1798	.0183	.390	.406	.409
		957.2	.0137	73.92	14,171	31.57	.2092	.0185	.427	.448	.453
		957.2	.0137	73.92	16,184	34.02	.2389	.0185	.460	.485	.494
		957.2	.0137	73.92	18,167	35.68	.2682	.0184	.483	.511	.525
A	20	957.2	0.0137	79.03	6,069	17.00	0.0867	0.0133	0.215	0.219	0.220
		957.2	.0137	79.03	8,072	21.73	.1152	.0134	.275	.283	.284
		956.4	.0137	78.96	10,075	25.89	.1438	.0135	.328	.339	.342
		956.4	.0137	78.96	12,199	29.54	.1742	.0139	.374	.390	.392
		956.4	.0137	78.96	14,161	32.71	.2022	.0139	.414	.433	.436
		956.4	.0137	78.96	16,214	35.37	.2315	.0139	.448	.471	.477
		956.4	.0137	78.96	18,207	37.44	.2600	.0139	.474	.501	.511
E	8	971.9	0.0138	62.19	6,109	14.98	0.0990	0.0330	0.241	0.246	0.248
		972.7	.0138	62.24	8,122	18.98	.1317	.0348	.305	.315	.318
		973.6	.0138	62.30	10,145	22.37	.1645	.0349	.359	.374	.379

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
E	8	972.7	0.0138	62.24	12,178	25.24	0.1975	0.0349	0.406	0.425	0.433
		971.9	.0138	62.19	14,121	27.31	.2289	.0343	.439	.463	.477
		971.9	.0138	62.19	16,144	29.15	.2617	.0339	.469	.498	.519
		971.9	.0138	62.19	18,197	30.28	.2950	.0332	.487	.521	.552
E	15	972.7	0.0139	75.14	6,109	15.93	0.0902	0.0170	0.212	0.216	0.218
		971.9	.0139	75.08	8,143	20.34	.1202	.0172	.271	.279	.281
		971.9	.0139	75.08	10,155	24.16	.1499	.0179	.322	.334	.337
		971.9	.0139	75.08	12,118	27.55	.1789	.0179	.367	.383	.386
		971.9	.0139	75.08	14,161	30.57	.2090	.0179	.407	.427	.432
		971.9	.0139	75.08	16,154	32.90	.2384	.0180	.438	.462	.471
		971.9	.0139	75.08	18,237	34.98	.2692	.0178	.466	.494	.508
E	20	971.0	0.0139	80.18	6,120	16.23	0.0874	0.0138	0.202	0.207	0.208
		970.1	.0139	80.11	8,102	20.61	.1157	.0137	.257	.265	.267
		971.0	.0139	80.18	10,145	24.74	.1448	.0140	.309	.320	.322
		971.0	.0139	80.18	12,189	28.36	.1740	.0141	.354	.369	.371
		971.0	.0139	80.18	14,191	31.47	.2026	.0139	.393	.411	.414
		971.0	.0139	80.18	16,164	34.04	.2308	.0138	.425	.447	.453
		971.0	.0139	80.18	18,197	36.10	.2598	.0138	.450	.477	.486
H	8	1129.6	0.0142	72.33	6,089	19.36	0.0987	0.0328	0.268	0.272	0.274
		1128.6	.0143	72.27	8,122	24.60	.1317	.0347	.340	.349	.352
		1129.6	.0142	72.33	10,075	28.98	.1633	.0342	.401	.413	.418
		1128.6	.0143	72.27	12,138	32.92	.1968	.0333	.456	.472	.479
		1127.6	.0143	72.20	14,161	35.88	.2296	.0334	.497	.518	.529
		1127.6	.0143	72.20	16,184	37.92	.2623	.0328	.525	.550	.568
		1127.6	.0143	72.20	18,187	39.13	.2948	.0322	.542	.571	.597

TABLE VI - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH SHROUDED 0.45-INCH BLADES - Concluded

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
H	15	1127.6	0.0143	87.16	6,069	20.46	0.0896	0.0173	0.235	0.238	0.240
		1127.6	.0143	87.16	8,092	26.02	.1194	.0172	.299	.306	.307
		1127.6	.0143	87.16	10,125	30.76	.1495	.0177	.353	.363	.366
		1127.6	.0143	87.16	12,118	34.94	.1789	.0177	.401	.415	.418
		1127.6	.0143	87.16	14,131	38.32	.2086	.0179	.440	.457	.461
		1128.6	.0143	87.23	16,214	41.46	.2393	.0178	.475	.496	.504
		1127.6	.0143	87.16	18,247	43.65	.2693	.0177	.501	.525	.537
H	19	1126.6	0.0143	92.07	6,109	20.69	0.0877	0.0148	0.225	0.228	0.229
		1127.6	.0143	92.15	8,052	26.05	.1156	.0147	.283	.289	.291
		1127.6	.0143	92.15	10,115	31.16	.1452	.0150	.338	.348	.350
		1126.6	.0143	92.07	12,178	35.67	.1749	.0152	.387	.401	.403
		1126.6	.0143	92.07	14,121	39.08	.2027	.0150	.425	.441	.444
		1127.6	.0143	92.15	16,154	42.37	.2319	.0147	.460	.479	.485
		1127.6	.0143	92.15	18,207	44.88	.2614	.0149	.487	.510	.519
I	8	995.8	0.0141	63.75	6,069	16.48	0.0984	0.0325	0.259	0.263	0.266
		995.8	.0141	63.75	8,143	21.09	.1320	.0336	.331	.341	.343
		995.8	.0141	63.75	10,125	24.86	.1641	.0341	.390	.404	.410
		995.8	.0141	63.75	12,158	28.05	.1970	.0339	.440	.459	.467
		994.8	.0142	63.69	14,121	30.20	.2288	.0340	.474	.498	.511
		994.8	.0142	63.69	16,204	32.09	.2626	.0336	.504	.532	.553
		994.8	.0142	63.69	18,227	32.98	.2954	.0333	.518	.551	.581
I	15	994.8	0.0142	76.88	6,069	17.74	0.0896	0.0168	0.231	0.235	0.236
		995.8	.0141	76.96	8,072	22.72	.1191	.0171	.295	.303	.305
		994.8	.0142	76.88	10,105	27.14	.1491	.0183	.353	.365	.368
		995.8	.0141	76.96	12,118	30.83	.1789	.0182	.401	.416	.419

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horse-power	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
I	15	995.8	0.0141	76.96	14,171	34.18	0.2092	0.0185	0.444	0.464	0.469
		995.8	.0141	76.96	16,174	36.78	.2387	.0187	.478	.501	.510
		995.8	.0141	76.96	18,156	38.29	.2680	.0186	.498	.525	.539
I	20	1000.3	0.0141	82.64	6,059	17.95	0.0865	0.0137	0.217	0.221	0.222
		1000.3	.0141	82.64	8,153	23.32	.1164	.0138	.282	.290	.291
		999.4	.0141	82.56	10,135	27.72	.1447	.0138	.336	.347	.349
		999.4	.0141	82.56	12,108	31.68	.1729	.0146	.384	.398	.401
		998.5	.0141	82.49	14,161	35.19	.2022	.0143	.427	.445	.448
		998.5	.0141	82.49	16,204	37.91	.2314	.0147	.460	.482	.488
		998.5	.0141	82.49	18,156	40.15	.2593	.0146	.487	.512	.522

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TABLE VII - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 20°-INLET BLADES

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
A	8	950.1	0.0138	60.79	6,099	15.68	0.0988	0.0349	0.258	0.263	0.265
		950.1	.0138	60.79	8,153	19.94	.1321	.0349	.328	.338	.341
		949.2	.0138	60.74	10,145	23.20	.1644	.0345	.382	.397	.403
		949.2	.0138	60.74	12,138	26.16	.1967	.0344	.431	.450	.459
		949.2	.0138	60.74	14,161	28.23	.2295	.0335	.465	.490	.503
		949.2	.0138	60.74	16,204	30.01	.2626	.0331	.494	.524	.545
		949.2	.0138	60.74	18,187	30.99	.2948	.0326	.510	.545	.576
A	15	949.2	0.0138	73.31	6,089	16.49	0.0899	0.0168	0.225	0.229	0.231
		949.2	.0138	73.31	8,052	20.86	.1189	.0172	.285	.293	.295
		949.2	.0138	73.31	10,135	24.78	.1496	.0179	.338	.350	.354
		949.2	.0138	73.31	12,138	28.24	.1792	.0175	.385	.402	.405
		948.4	.0138	73.25	14,161	30.94	.2091	.0173	.422	.443	.448
		948.4	.0138	73.25	16,133	33.02	.2382	.0171	.451	.475	.484
		948.4	.0138	73.25	18,247	35.00	.2694	.0169	.478	.507	.520
A	20	949.2	0.0138	78.38	6,099	16.50	0.0871	0.0135	0.211	0.215	0.216
		948.4	.0138	78.32	8,112	21.17	.1158	.0137	.270	.278	.280
		949.2	.0138	78.38	10,115	25.20	.1445	.0143	.322	.333	.336
		949.2	.0138	78.38	12,178	28.74	.1739	.0142	.367	.382	.384
		948.4	.0138	78.32	14,110	31.62	.2015	.0142	.404	.423	.426
		948.4	.0138	78.32	16,184	34.35	.2311	.0137	.439	.462	.468
		948.4	.0138	78.32	18,207	36.36	.2600	.0137	.464	.491	.501
E	8	967.1	0.0138	61.89	6,069	15.24	0.0984	0.0329	0.246	0.251	0.254
		967.1	.0138	61.89	8,143	19.29	.1320	.0344	.312	.322	.325
		967.1	.0138	61.89	10,115	22.67	.1639	.0345	.366	.381	.387
		967.1	.0138	61.89	12,158	25.84	.1970	.0341	.418	.437	.445

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
E	8	967.1	0.0138	61.89	14,141	28.05	0.2292	0.0335	0.453	0.478	0.491
		967.1	.0138	61.89	16,204	30.28	.2626	.0329	.489	.519	.539
		967.1	.0138	61.89	18,167	31.43	.2944	.0327	.508	.542	.573
E	15	967.1	0.0138	74.70	6,130	16.16	0.0905	0.0167	0.216	0.221	0.222
		967.1	.0138	74.70	8,143	20.63	.1202	.0171	.276	.285	.286
		967.1	.0138	74.70	10,145	24.54	.1498	.0173	.329	.341	.344
		967.1	.0138	74.70	12,128	28.02	.1791	.0174	.375	.391	.394
		967.1	.0138	74.70	14,161	30.94	.2091	.0177	.414	.435	.439
		967.1	.0138	74.70	16,133	32.80	.2382	.0178	.439	.463	.472
		967.1	.0138	74.70	18,187	35.36	.2685	.0176	.473	.502	.515
E	20	967.1	0.0138	79.87	6,069	16.00	0.0867	0.0133	0.200	0.204	0.206
		967.1	.0138	79.87	8,143	20.72	.1163	.0132	.259	.267	.269
		966.3	.0138	79.80	10,125	24.52	.1446	.0131	.307	.319	.321
		966.3	.0138	79.80	12,158	28.13	.1736	.0131	.353	.368	.370
		966.3	.0138	79.80	14,161	31.22	.2022	.0132	.391	.410	.413
		967.1	.0138	79.87	16,204	34.02	.2314	.0132	.426	.449	.454
		966.3	.0138	79.80	18,227	36.16	.2603	.0133	.453	.480	.489
H	8	1132.0	0.0142	72.48	6,069	19.02	0.0984	0.0301	0.262	0.267	0.269
		1132.0	.0142	72.48	8,072	23.99	.1308	.0306	.331	.339	.342
		1132.0	.0142	72.48	10,085	28.05	.1634	.0316	.387	.399	.404
		1132.0	.0142	72.48	12,138	31.52	.1967	.0314	.435	.451	.458
		1132.0	.0142	72.48	14,161	33.93	.2295	.0314	.468	.489	.499
		1131.0	.0142	72.42	16,164	36.01	.2620	.0313	.497	.522	.539
		1131.0	.0142	72.42	18,207	37.02	.2951	.0311	.511	.540	.565

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TABLE VII - EFFICIENCY DATA FOR SINGLE-STAGE TURBINE WITH 20°-INLET BLADES - Concluded

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
H	15	1131.0	0.0142	87.40	6,089	19.32	0.0899	0.0175	0.221	0.225	0.226
		1131.0	.0142	87.40	8,112	24.59	.1198	.0178	.281	.288	.290
		1131.0	.0142	87.40	10,085	29.11	.1489	.0188	.333	.343	.346
		1130.0	.0142	87.34	12,118	33.02	.1789	.0186	.378	.392	.395
		1130.0	.0142	87.34	14,191	36.43	.2095	.0187	.417	.434	.439
		1130.0	.0142	87.34	16,184	39.04	.2389	.0188	.447	.468	.476
		1131.0	.0142	87.40	18,227	41.33	.2691	.0190	.473	.497	.509
H	19	1131.0	0.0142	92.41	6,120	19.36	0.0879	0.0160	0.210	0.213	0.214
		1130.0	.0142	92.34	8,102	24.46	.1164	.0159	.265	.272	.273
		1130.0	.0142	92.34	10,145	29.49	.1457	.0158	.319	.329	.332
		1131.0	.0142	92.41	12,138	33.60	.1743	.0158	.364	.377	.379
		1131.0	.0142	92.41	14,212	37.28	.2041	.0158	.403	.420	.423
		1131.0	.0142	92.41	16,154	40.24	.2320	.0159	.436	.455	.461
		1131.0	.0142	92.41	18,156	42.42	.2607	.0158	.459	.482	.492
I	8	993.2	0.0141	63.59	6,049	16.50	0.0980	0.0308	0.260	0.264	0.267
		993.2	.0141	63.59	8,092	21.20	.1311	.0333	.333	.343	.346
		993.2	.0141	63.59	10,115	24.87	.1639	.0332	.391	.405	.411
		993.2	.0141	63.59	12,189	27.80	.1976	.0328	.437	.456	.464
		993.2	.0141	63.59	14,212	30.16	.2303	.0324	.474	.498	.510
		993.2	.0141	63.59	16,224	32.08	.2630	.0324	.505	.533	.553
		993.2	.0141	63.59	18,227	32.92	.2954	.0321	.518	.551	.580
I	15	994.1	0.0141	76.81	6,059	16.83	0.0895	0.0180	0.219	0.223	0.225
		993.2	.0141	76.74	8,122	21.63	.1199	.0192	.282	.290	.292
		994.1	.0141	76.81	10,115	25.67	.1494	.0190	.334	.346	.349
		993.2	.0141	76.74	12,128	28.90	.1791	.0185	.377	.392	.396

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Nozzle	Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
I	15	993.2	0.0141	76.74	14,161	31.69	0.2091	0.0183	0.413	0.433	0.438
		992.3	.0141	76.67	16,204	34.12	.2392	.0183	.445	.469	.477
		992.3	.0141	76.67	18,217	35.54	.2690	.0184	.464	.491	.505
I	20	992.3	0.0141	81.98	6,089	16.74	0.0870	0.0149	0.204	0.208	0.209
		991.4	.0141	81.90	8,122	21.52	.1160	.0147	.263	.270	.272
		992.3	.0141	81.98	10,135	25.48	.1447	.0146	.311	.322	.324
		991.4	.0141	81.90	12,138	29.24	.1733	.0145	.357	.372	.374
		991.4	.0141	81.90	14,212	32.46	.2030	.0149	.396	.415	.418
		992.3	.0141	81.98	16,184	34.77	.2311	.0146	.424	.446	.452
		992.3	.0141	81.98	18,187	36.56	.2597	.0147	.446	.472	.482

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TABLE VIII - EFFICIENCY DATA FOR TWO-STAGE TURBINE WITH NOZZLE H

FIRST STAGE, 0.45-INCH BLADES; SECOND STAGE, STANDARD TURBINE

[Inlet temperature, 1000° F; inlet pressure, 95 lb/sq in. gage]

Pressure ratio	Air weight flow (lb/hr)	Fuel-air ratio	Horsepower available from isentropic expansion	Turbine speed (rpm)	Brake horsepower	Blade-jet speed ratio	Gas density in turbine case (lb/cu ft)	Brake efficiency	Rotor efficiency	Blade efficiency
8	1131.2	0.0141	72.42	6,109	27.02	0.0990	0.0335	0.373	0.384	0.387
	1130.2	.0141	72.36	8,092	32.08	.1311	.0340	.443	.459	.468
	1130.2	.0141	72.36	10,155	34.97	.1646	.0338	.483	.504	.521
	1130.2	.0141	72.36	12,138	36.44	.1967	.0340	.504	.530	.560
	1130.2	.0141	72.36	14,161	35.70	.2295	.0346	.493	.528	.575
	1130.2	.0141	72.36	16,194	33.46	.2625	.0354	.462	.506	.582
	1130.2	.0141	72.36	18,167	29.99	.2944	.0356	.415	.470	.602
15	1132.5	0.0141	87.52	6,130	30.78	0.0905	0.0203	0.352	0.361	0.362
	1131.6	.0141	87.45	8,052	37.12	.1189	.0202	.425	.437	.443
	1131.6	.0141	87.45	10,135	41.32	.1496	.0203	.473	.490	.499
	1131.6	.0141	87.45	12,138	43.56	.1792	.0202	.498	.520	.535
	1131.6	.0141	87.45	14,161	43.68	.2091	.0203	.500	.528	.550
	1131.6	.0141	87.45	16,184	43.04	.2389	.0211	.492	.529	.566
	1131.6	.0141	87.45	18,227	40.54	.2691	.0214	.464	.510	.575
19	1130.6	0.0141	92.37	6,079	31.49	0.0873	0.0174	0.341	0.350	0.350
	1130.6	.0141	92.37	8,122	38.09	.1167	.0173	.412	.425	.429
	1130.6	.0141	92.37	10,125	42.51	.1454	.0172	.460	.476	.484
	1130.6	.0141	92.37	12,189	45.19	.1751	.0172	.489	.510	.522
	1130.6	.0141	92.37	14,181	45.75	.2037	.0174	.495	.522	.540
	1131.6	.0141	92.44	16,184	45.60	.2324	.0178	.493	.528	.558
	1131.6	.0141	92.44	18,237	43.81	.2619	.0182	.474	.518	.570

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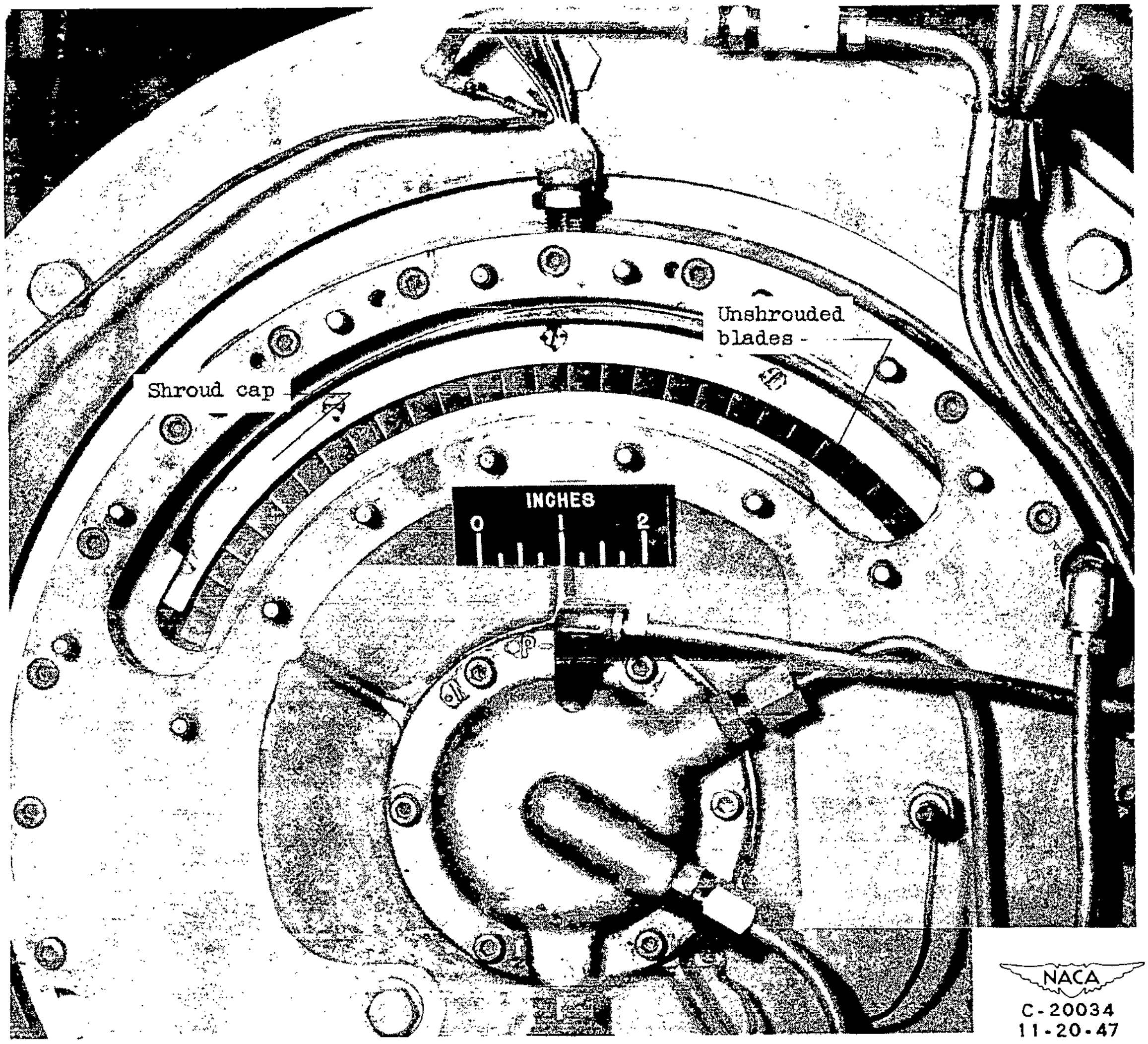


Figure 1. - Front view of first-stage turbine of Mark 25 power plant with nozzle removed to show unshrouded 0.35-inch rotor blade and shroud cap.

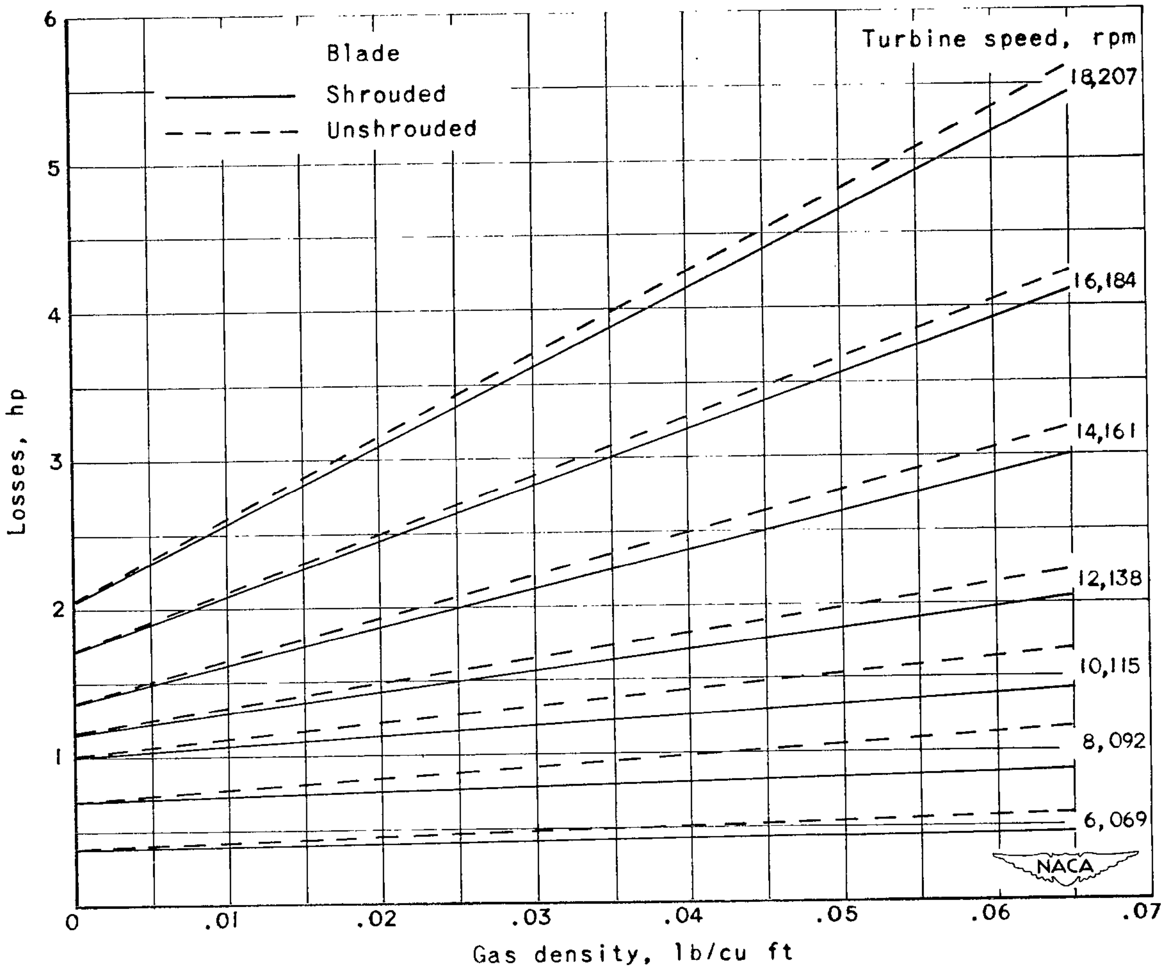


Figure 2. - Windage and mechanical losses of first-stage turbine with 90°-arc admission and 0.35-inch shrouded and unshrouded rotor blades.

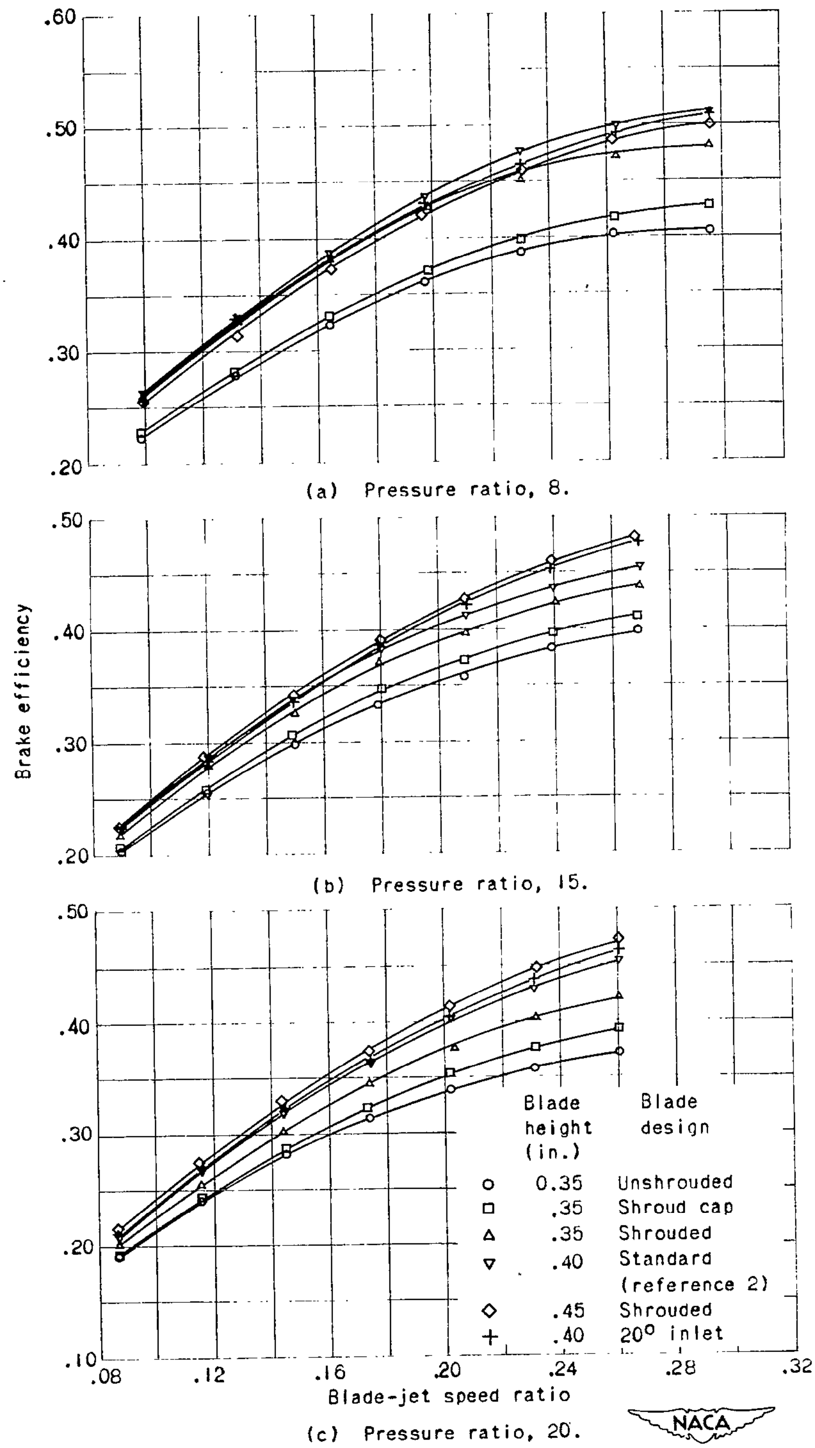


Figure 3. - Effect of blade design on performance of single-stage turbine with nozzle A.

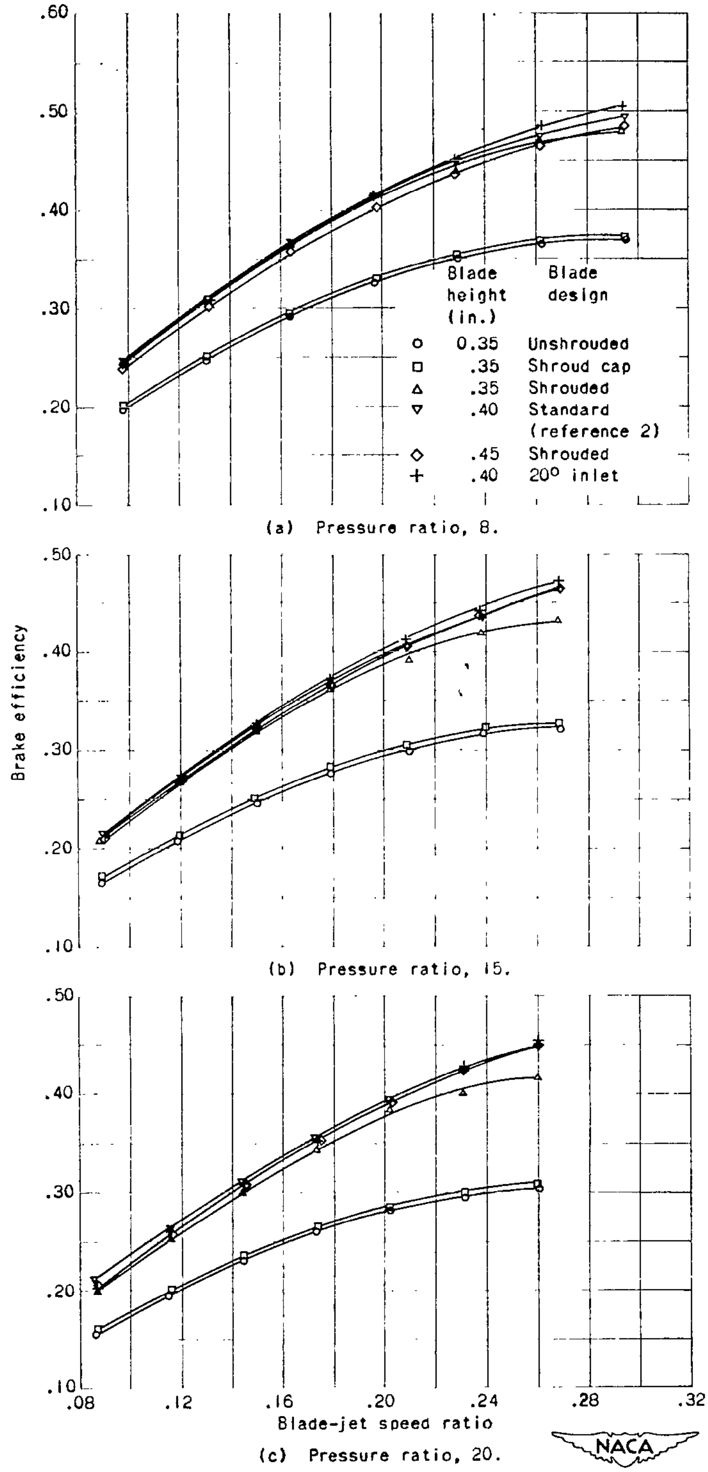


Figure 4. - Effect of blade design on performance of single-stage turbine with nozzle E.

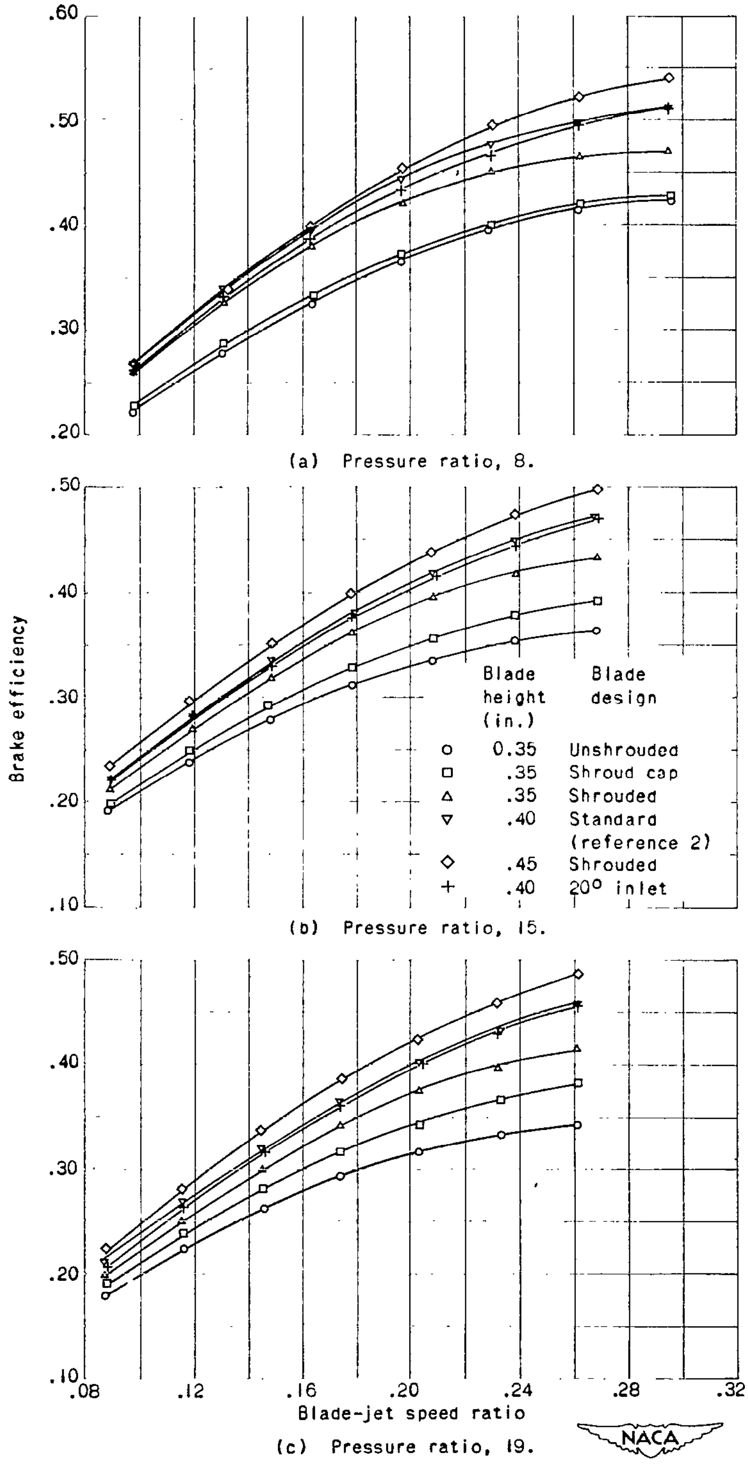


Figure 5. - Effect of blade design on performance of single-stage turbine with nozzle H.

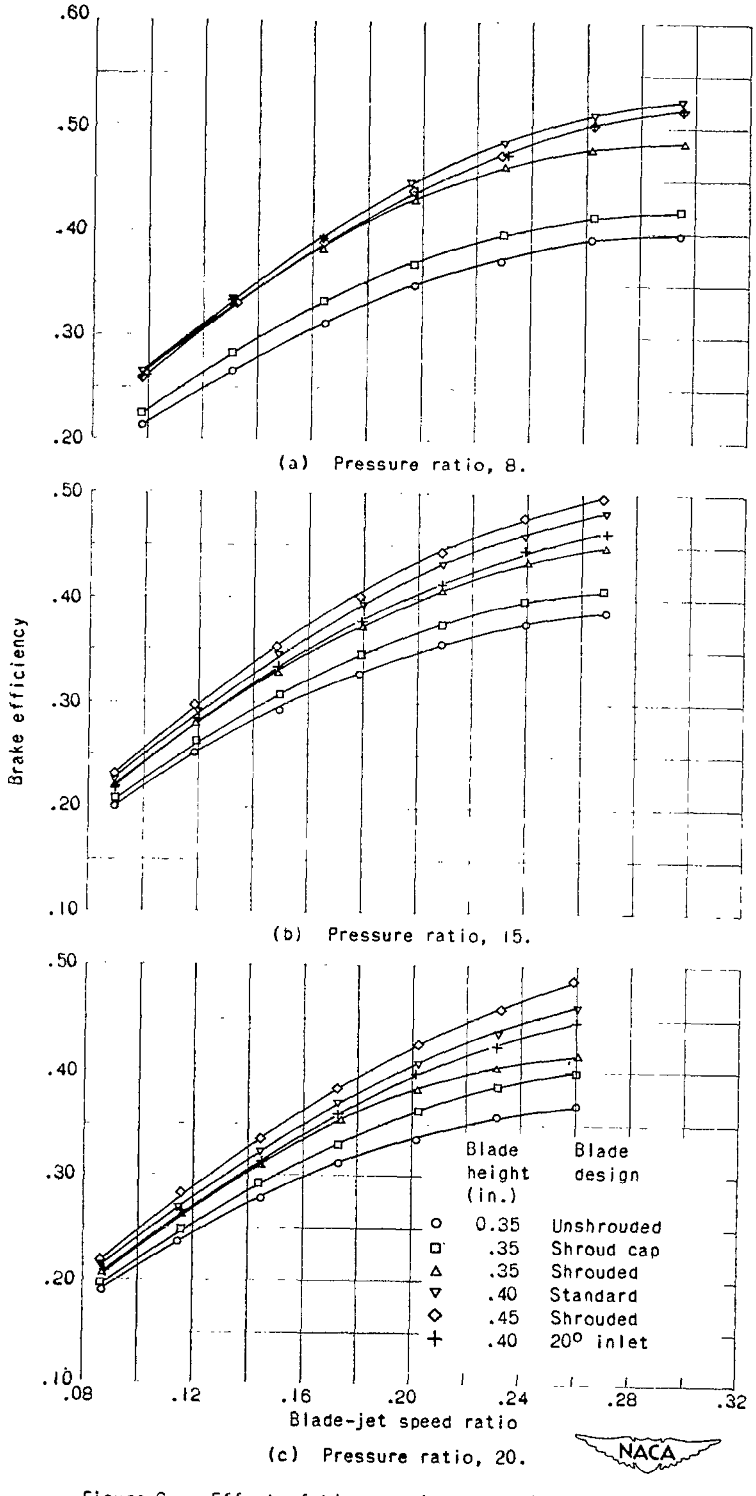


Figure 6. - Effect of blade design on performance of single-stage turbine with nozzle I.

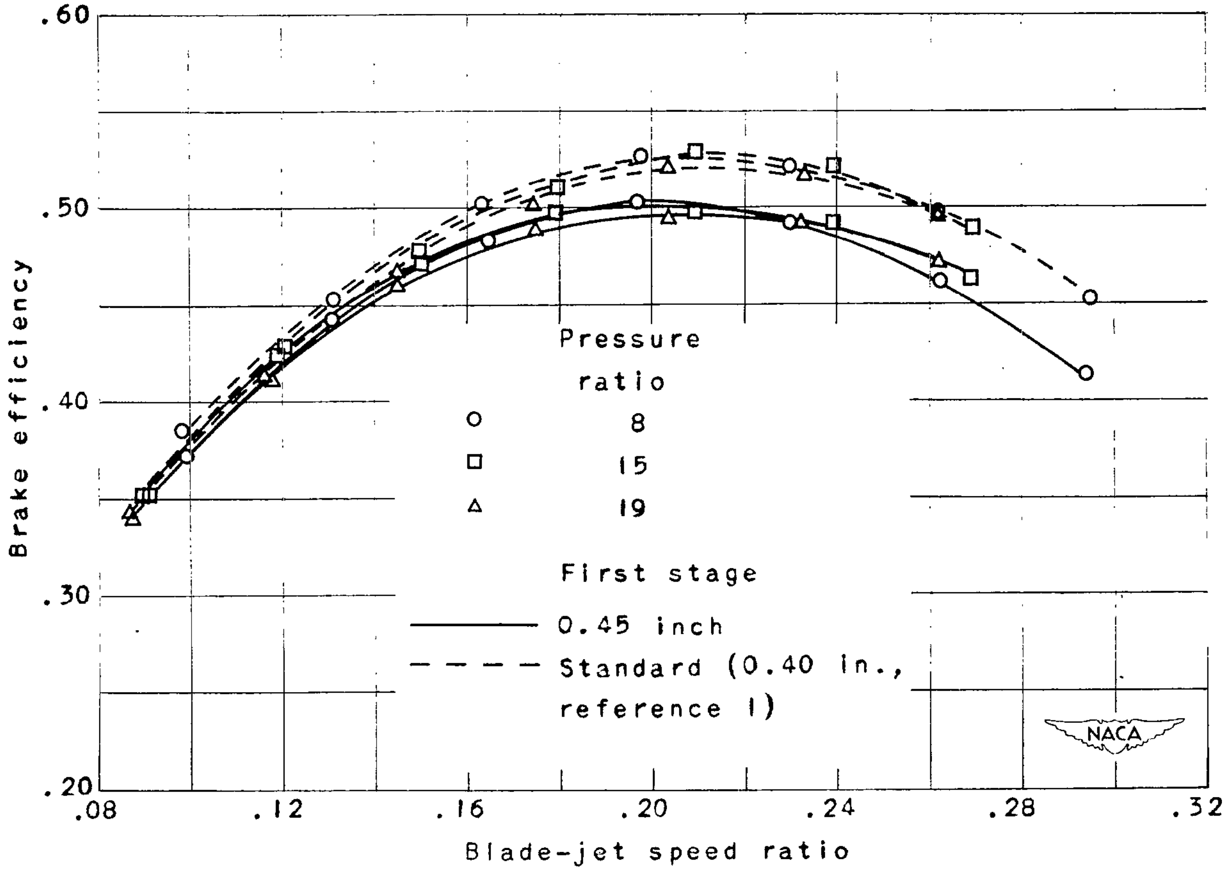
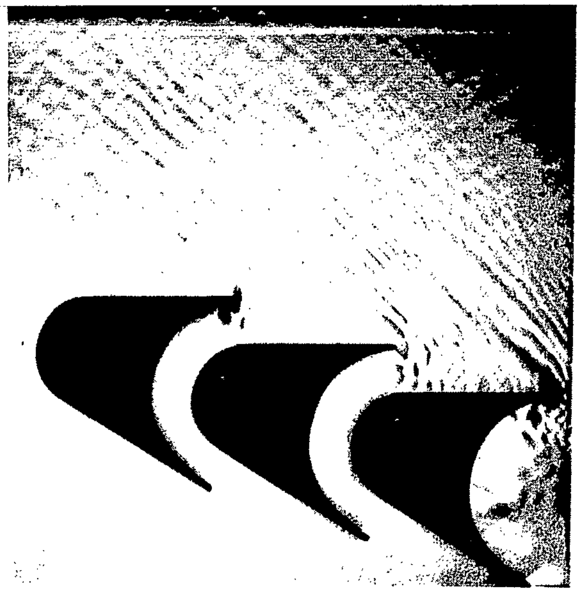
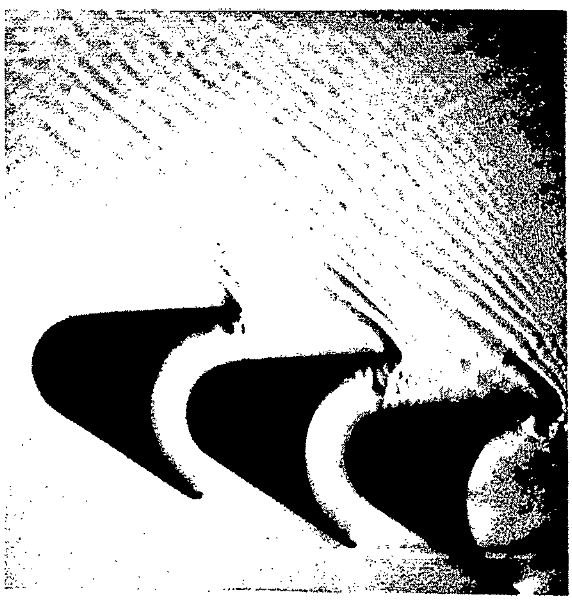


Figure 7. - Performance of two-stage turbine with standard first-stage rotor and with rotor having 0.45-inch blades in combination with nozzle H.



(a) Standard blades with 17° inlet angle.



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(b) Special blades with 20° inlet angle.

Figure 8. - Water-channel photographs of flow through pitch section of blades at analogous Mach number of 1.6.