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FLOW QUALITY IMPROVEMENTS IN THE NASA LEWIS RESEARCH CENTER 9- BY 15-FOOT LOW SPEED WIND TUNNEL

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Summary

The NASA Lewis Research Center 9- by 15-Ft Low Speed Wind Tunnel (LSWT) was recently upgraded with the addition of several flow quality improvement devices: four 10-mesh turbulence reduction screens and a flow straightening honeycomb (3/8-in. cell, length to diameter ratio, L/D = 16) in the settling chamber upstream of the test section, and a diffuser extension fairing downstream of the test section. Test section flow quality was measured prior to and following the tunnel modifications. Comparison of the pre- (baseline) to post-tunnel modification flow quality data will provide a gage of the effectiveness of the flow quality devices.

An instrumented rake was used to provide both calibration and flow-field survey data at several stations in the test section. The flow-field parameters measured included total and static pressure, total temperature, pitch and yaw components of flow angle and turbulence; boundary layer total pressure surveys were also made.

The data indicated very good flow quality in the test section at all survey stations in terms of total pressure, total temperature, Mach number and flow angularity distributions, and turbulence levels. The data compared with that collected before facility flow quality additions indicate improvement in the test section Mach number distribution, flow angle distribution, and turbulence levels as well as an increase in the usable test section width. The temperature distributions can be further improved by increasing the cooling water flow into the facility heat exchanger.

Introduction

As part of a program to continually improve the flow quality in the NASA Lewis aeropropulsion facilities, several modifications were made to the 8- by 6-Ft Supersonic/9- by 15-Ft Low Speed Wind Tunnel complex in 1992. The improvements that affect the 9- by 15-ft test section were the installation of flow conditioning devices in the settling chamber upstream of the test section, installation of acoustic treatment on the downstream face of the facility heat exchanger (cooler), and the addition of diffuser fairings downstream of the test section. The flow conditioning devices installed in the settling chamber include a honeycomb flow straightener (length to diameter ratio L/D = 16) and four 10-mesh turbulence reduction screens. The flow manipulators were designed to attain specific test section flow quality goals. These goals were based on information from the 1989 Wind Tunnel Calibration Workshop held at NASA Langley Research Center.[1] The output of the workshop defined the guidelines for desired wind tunnel test section flow quality. The flow quality goals for the 9- by 15-ft test section are listed in Table 1. Earlier works which documented the test section flow quality indicated that the Mach number variation was already less than the goal of 0.005.[2,3] The primary goals for flow quality improvement concerned reducing the test section flow angularity and turbulence levels (shown to be on the order of 2 percent) without adversely affecting the Mach number distribution.

The purpose of this report is to document the improvement in test section flow quality as a result of the facility modifications. Flow-field surveys were conducted in the 9- by 15-ft test section prior to[4] and following the installation of the flow conditioning devices;[5] additional data collected prior to the modifications are described in earlier works.[2,3]

Description of Facility

The 8- by 6-Ft Supersonic/9- by 15-Ft Low Speed Wind Tunnel complex, shown in Fig. 1, is an atmospheric pressure, continuous flow propulsion wind tunnel. The airflow is driven through the facility by a 7-stage axial compressor (18-ft inlet diameter) that is powered by three 29,000-hp electric motors. The 8- by 6-ft test section is a porous wall type transonic test section with a Mach number range of 0.36 to 2.0. The 9- by 15-ft test section is located in the return leg of the 8- by 6-ft wind tunnel loop. This test section is of slotted wall construction resulting in an 11 percent open area and has a Mach number range of 0.0 to 0.2. Conditions in the 9- by 15-ft test section are controlled by the large flow control doors

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located upstream of the test section (Figs. 1 and 2). The test section is 28.6 ft long. The walls of the test section diverge 0.25°; the floor and ceiling do not diverge. The walls, floor, and ceiling of the 9- by 15-ft test section are equipped with removable acoustic panels. The acoustic treatment begins 4 in. downstream of the test section inlet and extends for 27.5 ft. The acoustic panels reduce the inside height and width of the test section by approximately 4 in.

Instrumentation, Test Hardware, and Test Setup

A 15-ft survey rake was used to measure the test section flow parameters (Figs. 3 and 4). The instrumentation mounted on the rake included 20 flow angularity probes, 15 thermocouples, and 3 hot film/wire anemometry probes (1-component sensors were used during the baseline tests, while 1-, 2-, and 3-component probes were used following the tunnel modifications). The flow angle probes are five-hole hemispherical head types which allow resolution of two flow angle components (pitch and yaw). The flow angle probes have been calibrated for the Mach number range of 0.05 to 0.20 (the Mach number range of the 9- by 15-ft test section is 0.00 to 0.20). Total pressure is sensed by a port at the center of the probe tip. Four independent static pressure measurements are made using taps on the probe body; these four measurements are then averaged to indicate the static pressure at each probe. These probes extend 21.5 in. ahead of the leading edge of the rake. Aspirated thermocouples with Chromel-Alumel (type K) sensing elements were used. The thermocouples are mounted to the bottom surface of the survey rake, with the heads of the thermocouples approximately even with rake leading edge. The hot film and hot wire anemometry probes are mounted to the upper surface of the rake. Figure 5 shows the survey stations used during the flow-field surveys. Eight boundary layer rakes were used to survey the flow field near each of the test section surfaces. These rakes were 18 in. in height and had 25 total pressure probes. Figure 6 shows a typical boundary layer rake; the typical test configuration is shown in Fig. 7. The axial stations at which the boundary layer profiles were measured are shown in Fig. 5. Additional details of the test hardware and test procedures used during each test entry are provided in Refs. 4 and 5.

The standard tunnel data system was used for the aerodynamic calibration test. Steady-state pressure data for the aerodynamic calibration was acquired with an Electronically Scanned Pressure (ESP) system. The ESP system uses plug-in modules, each containing 32 individual transducers, which are addressed and scanned at a rate of 10,000 ports per second. On-line calibration of all ESP transducers can be performed automatically every 20 min or at the test engineer's discretion. The transducer calibration is controlled by a pneumatic valve in each module which allows three calibration pressures to be applied to each transducer; these calibration pressures are measured with precision digital quartz transducers. During the calibration tests, the ESP transducers were calibrated at each Mach number setting. For these tests, ±5-psid modules were used.

Real-time data acquisition and display was provided by ESCORT D+, the standard data system used in the large test facilities at the NASA Lewis Research Center. This system accommodates the ESP inputs, plus all steady-state analog and digital signals used including survey rake and tunnel facility thermocouples and pertinent tunnel control parameters such as compressor speed and positions of flow control doors 1 and 2. The ESCORT D+ facility microcomputer acquires the data, converts it to engineering units, executes performance calculations, checks limits on selected channels, and displays the information in alpha-numeric and graphical form at a 1-sec update rate. For this test, each collected data reading was the average of 20 scans (20 sec) of data.

For turbulence measurements, commercially available hot wire and hot film probes, constant temperature anemometers, signal conditioners, and 12-bit analog to digital converters were used. Sampling rates and low pass filter frequencies were nominally set at 20 and 10 kHz, respectively. The nominal number of data points acquired was 20,000 (1 sec of data). A personal computer with commercially available software was used to control the data acquisition process and to carry out subsequent data reduction.

Measurement Accuracy

The accuracy of the pressure measuring system used was ±0.0022 psi for absolute pressure levels and ±0.0009 psi for transducer to transducer accuracy (probe to probe delta pressure). An error analysis was performed to determine the accuracy of the Mach number and flow angularity data. The analysis showed that the Mach number measurement accuracy improved from ±0.0016 at Mach 0.05 to ±0.0004 at Mach 0.20. The accuracy for the flow angularity measurements is 0.05° at Mach 0.20, 0.09° at Mach 0.15, 0.12° at Mach 0.10, and 0.8° at Mach 0.05. The accuracy in the total temperature measurements is 0.5 °F for absolute readings and 0.25 °F for temperature gradients (probe to probe variation). The estimated turbulence intensity accuracy is ±0.05 percent.

Discussion of Results

The discussion will focus on comparisons between data collected before and after the facility modifications and will emphasize changes in the test section flow quality.

There was a tremendous amount of data collected during both the baseline and post-modification (post-mod) tests; the data from both of these tests are described in detail in Refs. 4 and 5, as are the details of the data reduction and analysis procedures. In order to keep the amount of graphical data presented in this report to a minimum, only data from axial station 198 (a typical model test plane) will be shown for the 15-ft rake surveys. The data presented are representative of the results seen throughout the test section. Total and static pressure and total temperature data measured using the 15-ft survey rake were nondimensionalized by the corresponding parameter measured by the aft test section rake or aft rake. The aft rake is the standard facility rake used to set test conditions in the tunnel.

Spanwise total pressure distributions at each station surveyed for both the baseline and post-mod tests show variations on the order of 0.003 psia, neglecting areas of the survey in the boundary layer (Fig. 8). However, data collected following the facility modifications show that usable test section width based on total pressure distribution increased on the order of 1 to 2 ft at Mach 0.20. Similar trends were found in the static pressure data, where spanwise variations were on the order of 0.003 psia at each rake position both before and after the tunnel modifications (Fig. 9). Mach number data show that, at all positions surveyed for both the baseline and post-mod data, the flow quality goal of 0.005 Mach number variation was met or surpassed (Fig. 10). There was slight improvement in the Mach number distributions recorded in the post-mod data. Both baseline and post-mod data show that in the core of the test section the Mach number variation is much less than the 0.005 goal. For Mach 0.10 and above, the variation is on the order of 0.001; at the Mach 0.05 setting, the variation was about 0.003. The Mach number data also showed that the usable test section width had increased when compared with baseline results. The post-mod data show that the usable test section width has increased (boundary layer thickness decreased) as seen in the data near the test section walls. The effect is more pronounced at the north test section wall than at the south wall.

Total temperature data collected throughout the test section indicated the presence of a spanwise temperature gradient at the higher Mach number settings (there were no indications of either axial or vertical temperature gradients). This gradient consistently showed an increase in the test section temperature across a survey plane; higher temperatures were recorded nearer to the south (outside) tunnel wall. Figure 11 shows typical temperature ratio data which give additional details concerning the thermal gradient. The data presented indicate that the gradient is a function of the test section velocity. The largest gradients were recorded at the higher test section Mach numbers and the gradient decreased as the Mach number decreased. The data presented show a gradient of 3.8 °F across the test section at Mach numbers M = 0.20 and 0.15 for both the pre- and post-modification data; the local temperature gradient across the portion of the test section where fan models are generally located is 1 °F or less. It was found that the full-span gradient could be decreased by increasing the supply of cooling water to the facility heat exchanger. At M = 0.20, the gradient was reduced to 2.2 °F by operating the heat exchanger at maximum water flow rate.

Figure 12 shows the comparison of the pitch angle data from the baseline and post-mod tests as measured by the 15-ft survey rake for the reference Mach numbers of 0.10, 0.15, and 0.20 (the Mach 0.05 data are omitted because of a high degree of data scatter). The average pitch flow angle over the center 9 ft of this survey is 0.10°, and the variations in flow angle from this average is generally ±0.25°. These results are typical for both the baseline and post-mod data, although the post-mod data tends to show less scatter in the data. Figure 13 shows the average pitch flow angle measured at axial station 198 at vertical positions of centerline and ±6, ±12, and ±18 in. from centerline. The data show that the mean pitch flow angle was not affected much by installation of the honeycomb. At M = 0.20, the mean flow angle was –0.03° for the baseline data and 0.06° for the post-mod data; at M = 0.15, the mean pitch flow angles were –0.02° and 0.11° for the baseline and post-mod, respectively. However, these data indicate that there is less variation in flow angle in this region of the test section following the installation of the flow quality devices; this is indicated by the tighter data band on the post-mod data. For example, at M = 0.20, the variation in the average pitch flow angle over the given vertical rake position range was –0.20° to 0.17° (0.37° spread) for the baseline data and –0.03° to 0.17° (0.20° spread) for the post-mod data. The yaw angle data, which are not presented in this document but are contained in Refs. 4 and 5, showed trends similar to those seen in the pitch angle data.

Turbulence data are given in Fig. 14. The baseline data were collected with a single element hot film. The post-mod data were measured using X-probe hot films that were run in two orientations to provide axial as well as vertical and horizontal (transverse) components of turbulence. The data show that there has been a large decrease in the freestream turbulence levels in the test section as a result of the installation of four turbulence reduction screens in the settling chamber. The axial turbulence levels from the baseline tests ranged from 1.8 to 2.4 percent; post-mod data show the axial turbulence levels as 0.1 percent. The post-mod data indicate that, for all components (axial, horizontal, and vertical), the turbulence levels are less than 0.4 percent and generally below the test section turbulence level goal of 0.25 percent. The data also indicate that the axial turbulence levels do not vary with Mach number, but the horizontal and vertical turbulence levels increase as the Mach number increased (Fig. 14).

Before the facility flow quality improvements, a limited amount of boundary layer data were obtained.[3] These data are directly compared with the post-mod data in Figs. 15 and 16. The bar charts in Fig. 15 show a decrease in the boundary layer thickness at the test section entrance and the model test plane following the flow quality improvements for M = 0.20 and 0.10 (data from M = 0.15 and 0.05 were similar and therefore omitted for brevity). This was also evident from the 15-ft rake data. At the test section exit, it appears that the boundary layer thicknesses are comparable and the post-mod boundary layers are sometimes thicker although the ceiling boundary layer is consistently thinner. Figure 16 directly compares boundary layer total pressure ratio profiles for M = 0.20 and 0.10. From the profiles at the test section entrance and the model test plane, the thinner boundary layers are evident for the post-mod data (particularly at higher test section Mach numbers). At the test section exit, the appearance of thicker boundary layers is apparent.

Summary of Results

Comparisons were made between data collected prior to and following facility flow quality modifications being made to the 9- by 15-Ft Low Speed Wind Tunnel. These comparisons were made to judge the effectiveness of the facility modifications.

The following are the results of the data comparison; the results are also summarized in Table 2:

1. There was little significant change in total and static pressure distributions between the baseline and post-mod data. Spanwise variations were generally 0.003 psia; vertical variations were 0.003 to 0.009 for the post-mod data.

2. Based on the spanwise total pressure distributions from the 15-ft rake surveys, the usable test section width has increased because of a reduction in the boundary layer thickness. The usable test section width at station 198 increased from about 11 to 13 ft at Mach 0.20.

3. For all conditions and all survey locations, the goal of 0.005 variation in Mach number was met or surpassed. There was slight improvement in the Mach number distributions seen in the post-mod data.

4. Data from both the baseline and post-mod tests indicate a thermal gradient across the test section on the order of 4 °F at M = 0.20; it decreased as the Mach number decreased. The magnitude of the gradient can be reduced by operating the facility heat exchanger at the maximum cooling water flow rate. The temperature gradient across the test section area where fan models are generally tested is 1 °F or less.

5. Comparison of the pitch flow angle data from the baseline and post-mod tests indicated that, while the average flow angle values were not greatly affected, the variation in flow angularity in the test section was reduced because of the modifications to the tunnel.

6. Axial turbulence levels decreased from the baseline level of approximately 2 percent to 0.1 percent following the installation of the screens and honeycomb. The 0.1 percent axial turbulence level surpasses the goal of 0.25 percent.

7. Turbulence levels in the vertical plane measured during the post-mod tests varied from 0.1 to 0.3 percent; horizontal plane turbulence levels were 0.1 to 0.4 percent. The turbulence levels in the vertical and horizontal planes generally met the goal of 0.25 percent.

8. The axial turbulence level was independent of Mach number, whereas the vertical and horizontal components increased as the Mach number increased.

9. The boundary layers along the tunnel surfaces decreased at the test section entrance and model test plane as a result of the installation of the flow quality improvement devices. Boundary layer thicknesses at the test section exit were comparable to those prior to the flow quality improvements and only the ceiling boundary exhibited a definite thinning. The significance of thinner boundary layers is that the usable test section area increases.

Concluding Remarks

Major modifications were made to the NASA Lewis 9- by 15-Ft Low Speed Wind Tunnel in order to improve its overall flow quality characteristics. Test section flow surveys made before and after the tunnel modifications have been used to ascertain the effectiveness of the flow quality improvements. Overall, there has been improvement in the test section flow quality, primarily in turbulence reduction, reducing flow angularity and increasing the usable test section area. The flow quality in the test section generally meets or exceeds the flow quality goals required for propulsion systems wind tunnel testing. Additional study to determine the source of the test section total temperature gradient is warranted, since this could lead to further enhancement of the test section flow quality.

References

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2. Clough, N.; Diedrich, J.H.; and Yuska, J.A.: Lewis 9- by 15-Foot V/STOL Wind Tunnel. NASA TM X–2305, 1971.

3. Hughes, C.E.: Flowfield Measurements in the NASA Lewis Research Center 9- by 15-Foot Low-Speed Wind Tunnel. NASA TM–100883, 1989.

4. Arrington, E.A.; Pickett, M.T.; and Soeder, R.H.: Calibration of the NASA Lewis Research Center 9- by 15-Foot Low Speed Wind Tunnel (1992 Test). NASA TM–106860, 1995.

5. Arrington, E.A.; and Gonsalez, J.C.: Calibration of the NASA Lewis Research Center 9- by 15-Foot Low Speed Wind Tunnel (1994 Test). NASA CR–195438, 1995.

TABLE 1.—SUMMARY OF TEST SECTION FLOW QUALITY GOALS FOR THE NASA LEWIS RESEARCH CENTER WIND TUNNEL FACILITIES

Flow quality parameter	NASA Lewis facility	
	8- by 6-ft SWT 9- by 15-ft LSWT 10- by 10-ft SWT[a]	Icing Research Tunnel
Mach number variation	0.005	0.005
Flow angularity, deg	0.25	0.25
Turbulence intensity, percent	0.25	0.50
Total temperature variation, °R	4	2

[a]SWT: Supersonic Wind Tunnel; LSWT: Low Speed Wind Tunnel.

TABLE 2.—OVERVIEW OF PRIMARY RESULTS FROM THE 1992 AND 1994 CALIBRATION OF THE 9- BY 15-FT LOW SPEED WIND TUNNEL

[The goals listed were derived from ref. 1.]

	Goal	1992 calibration results	1994 calibration results	Comment
Spanwise total and static pressure variation		0.003 psia	0.003 psia	Spanwise
Spanwise Mach number variation	0.005	0.002 to 0.003	0.002 to 0.003	Axial stations 40 through 279
Average flow angularity (pitch and yaw)	±0.25°	–0.2 to 0.17° at M = 0.20 –0.15 to 0.19° at M = 0.15 –0.12 to 0.6° at M = 0.10	–0.03 to 0.17° at M = 0.20 0.04 to 0.23° at M = 0.15 0.0 to 0.41° at M = 0.10	Average spanwise flow angle at station 198 (range indicates variation with vertical position)
Turbulence intensity	0.25 percent	Axial 1.5 to 2.5 percent	Axial: 0.10 percent Vertical: 0.10 to 0.30 percent Horizontal: 0.10 to 0.40 percent	Turbulence levels increase slightly as Mach number increases
Total temperature	4 °R	1.5 °R for M < 0.10 3.5 to 4.5 °R for M > 0.20	1.5 °R for M < 0.10 3.5 to 4.5 °R for M > 0.10	Gradient reduced to 2.2 °R at M = 0.2 using maximum heat exchanger capacity
Usable test section area		Width: 11 to 12 ft	8 by 13 ft (approximate)	Full area is 9 by 15 ft

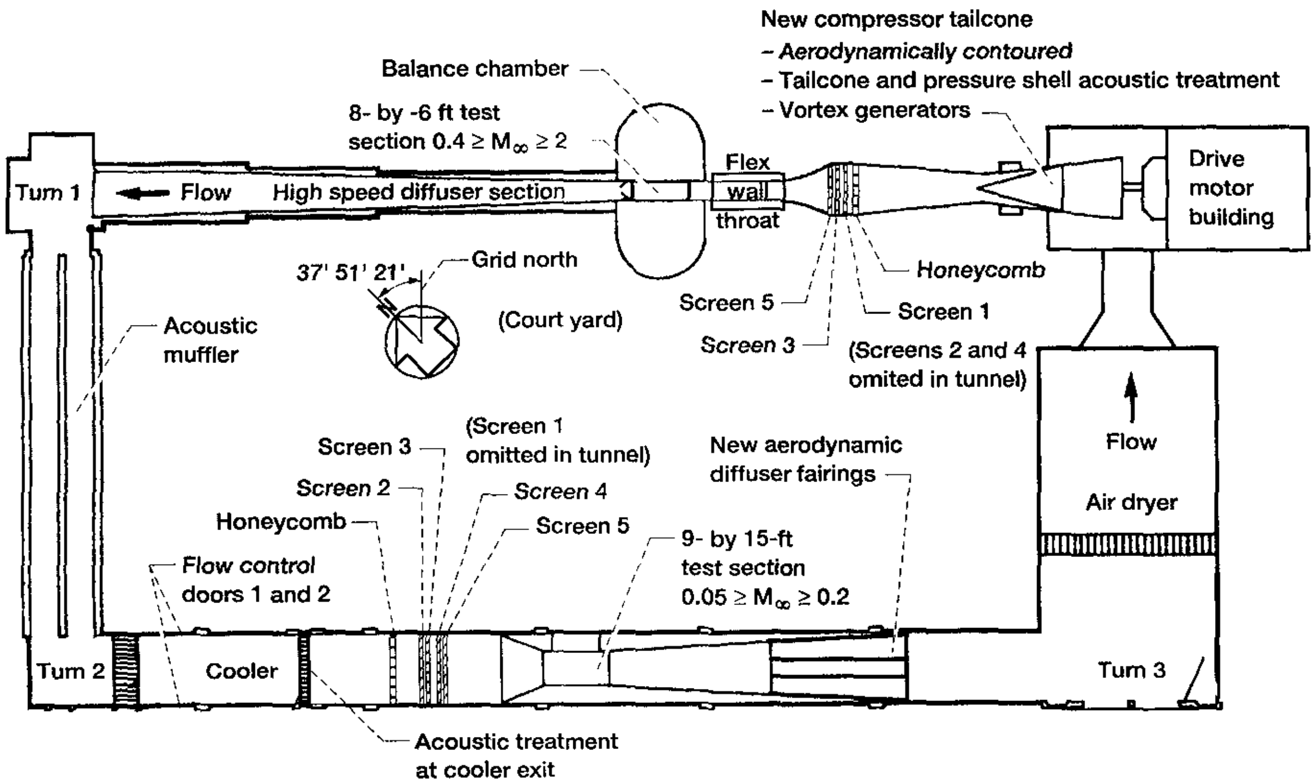


Figure 1.—Planview of 8- by 6-Ft Supersonic/9- by 15-Ft Low Speed Wind Tunnel facility showing locations of flow quality improvements.

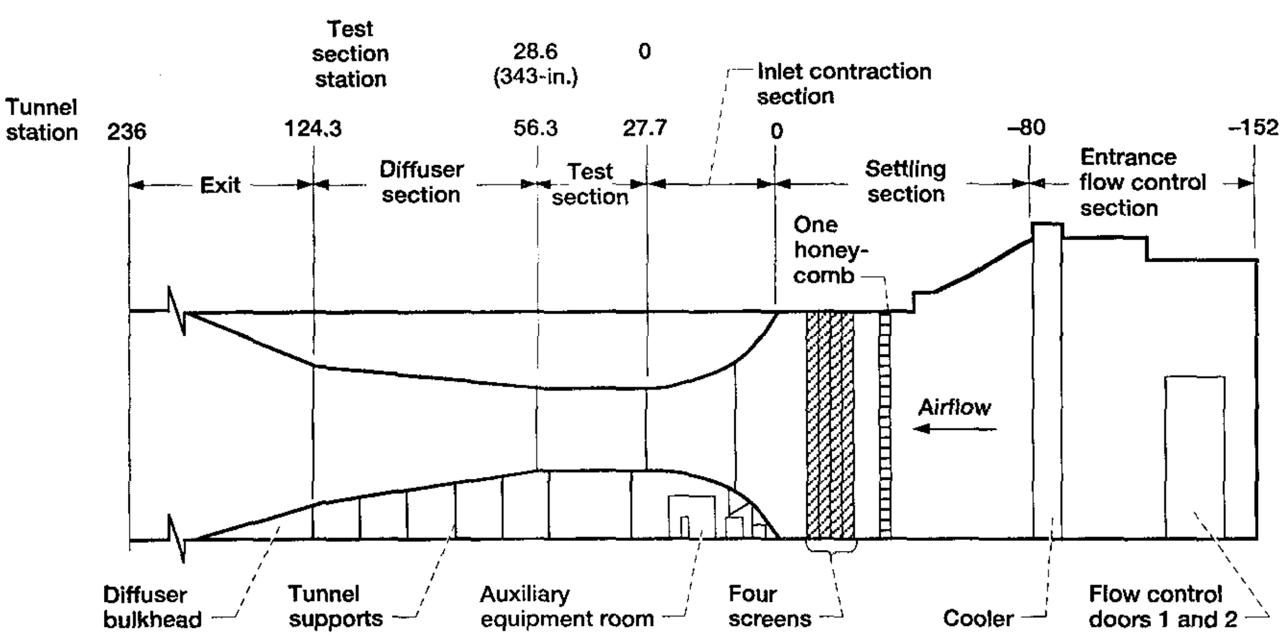
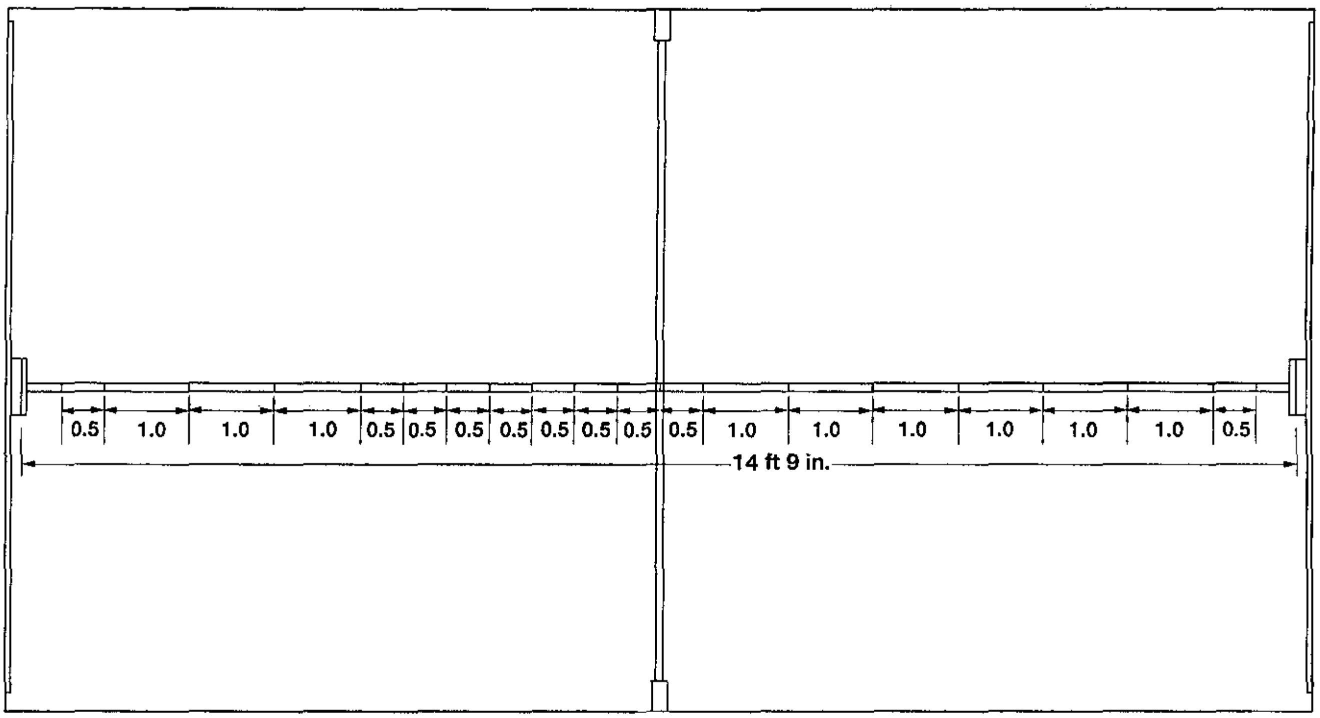
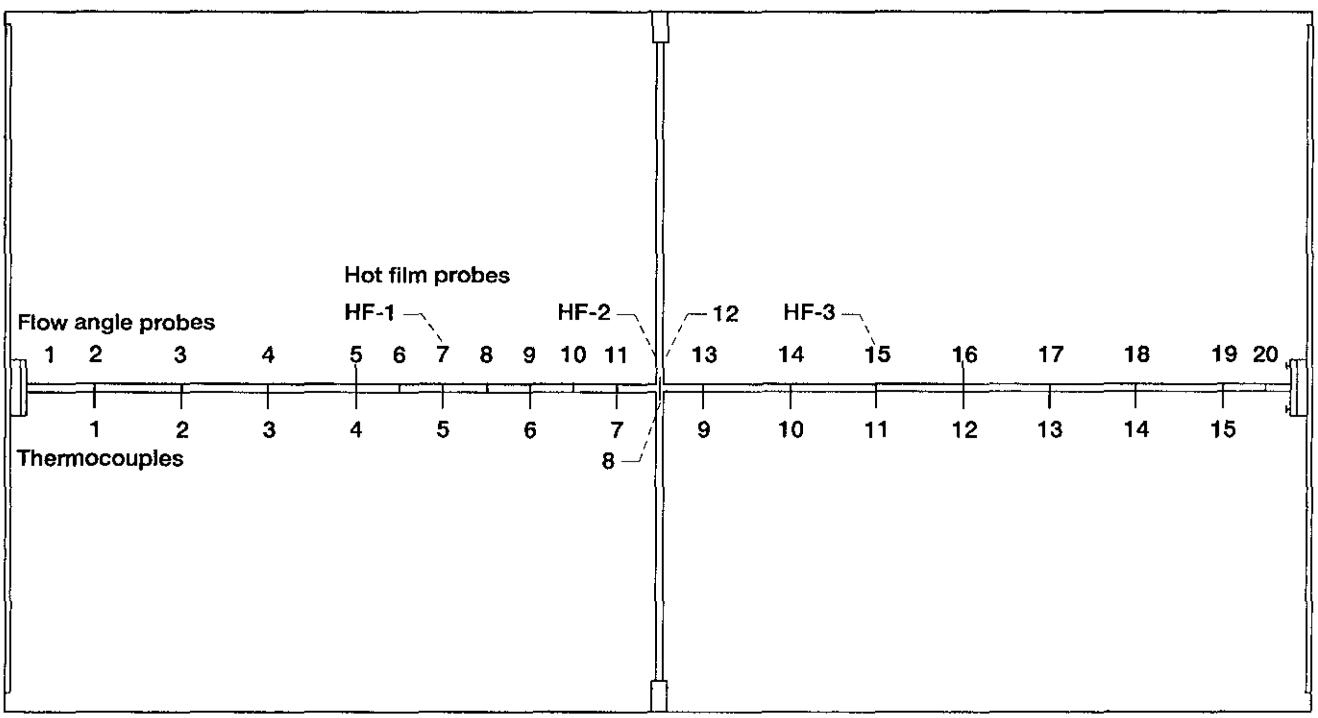


Figure 2.—Elevation view of 9- by 15-ft test section and settling chamber. (All station numbers in feet except as noted; view from courtyard.)



(a)



(b)

Figure 3.—Instrumentation layout of 15-ft survey rake. (a) Spacing between flow angularity probes shown. (All dimensions in feet except as noted.) (b) Flow angle probe, hot film probe, and thermocouple positions shown.

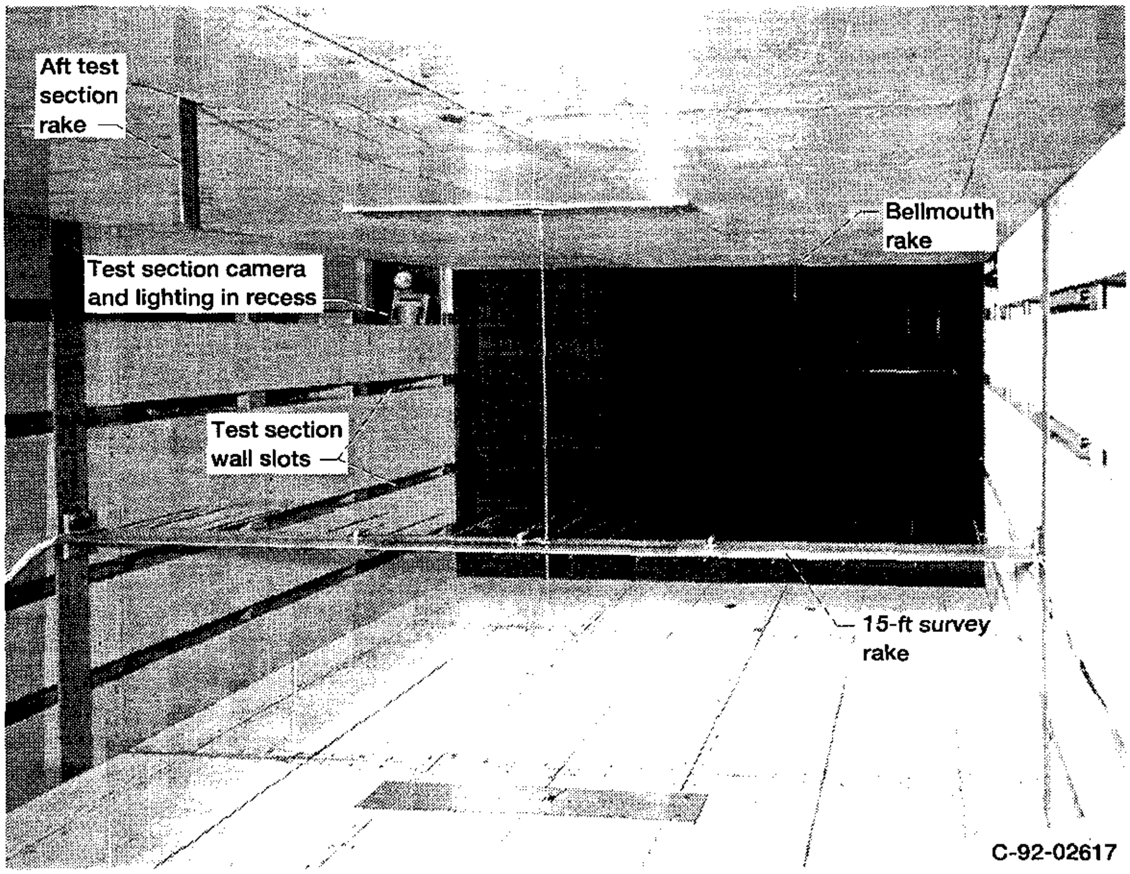


Figure 4.—Typical test set up using 15-ft survey rake in 9- by 15-Ft Low Speed Wind Tunnel. Rake shown at axial station 118 and vertical position 6 in. below test section centerline. (View looking upstream).

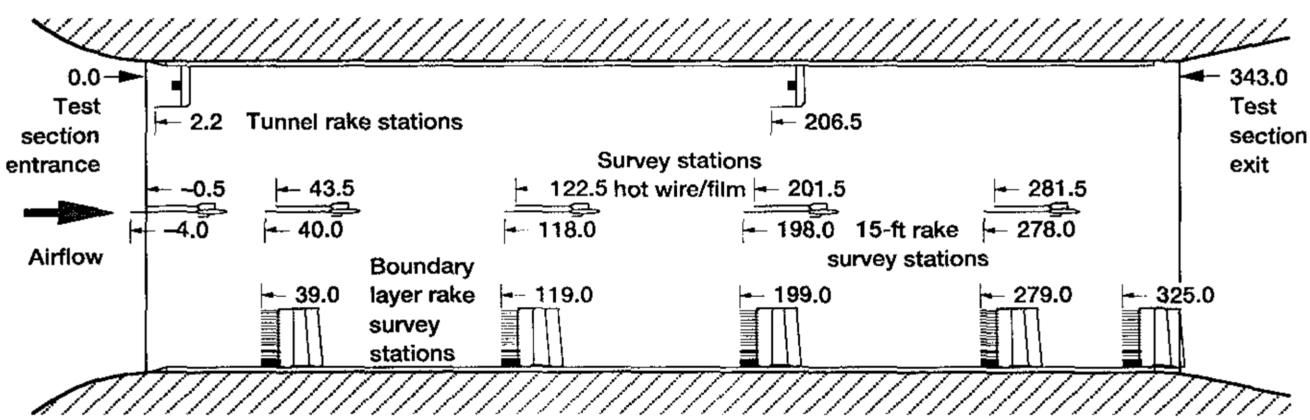


Figure 5.—Location of wind tunnel and boundary layer survey rake instrumentation and axial flow-field surveys in test section. (Test section stations in inches.)

Probe No.	Distance from tunnel surface, Z, in.
1 (Base)	0.250
2	0.500
3	0.750
4	1.000
5	1.250
6	1.500
7	2.000
8	2.250
9	3.000
10	3.500
11	4.000
12	4.500
13	5.500

Probe No.	Distance from tunnel surface, Z, in.
14	6.500
15	7.500
16	8.500
17	9.500
18	10.500
19	11.500
20	12.500
21	13.500
22	14.500
23	15.500
24	16.500
25 (Tip)	17.500

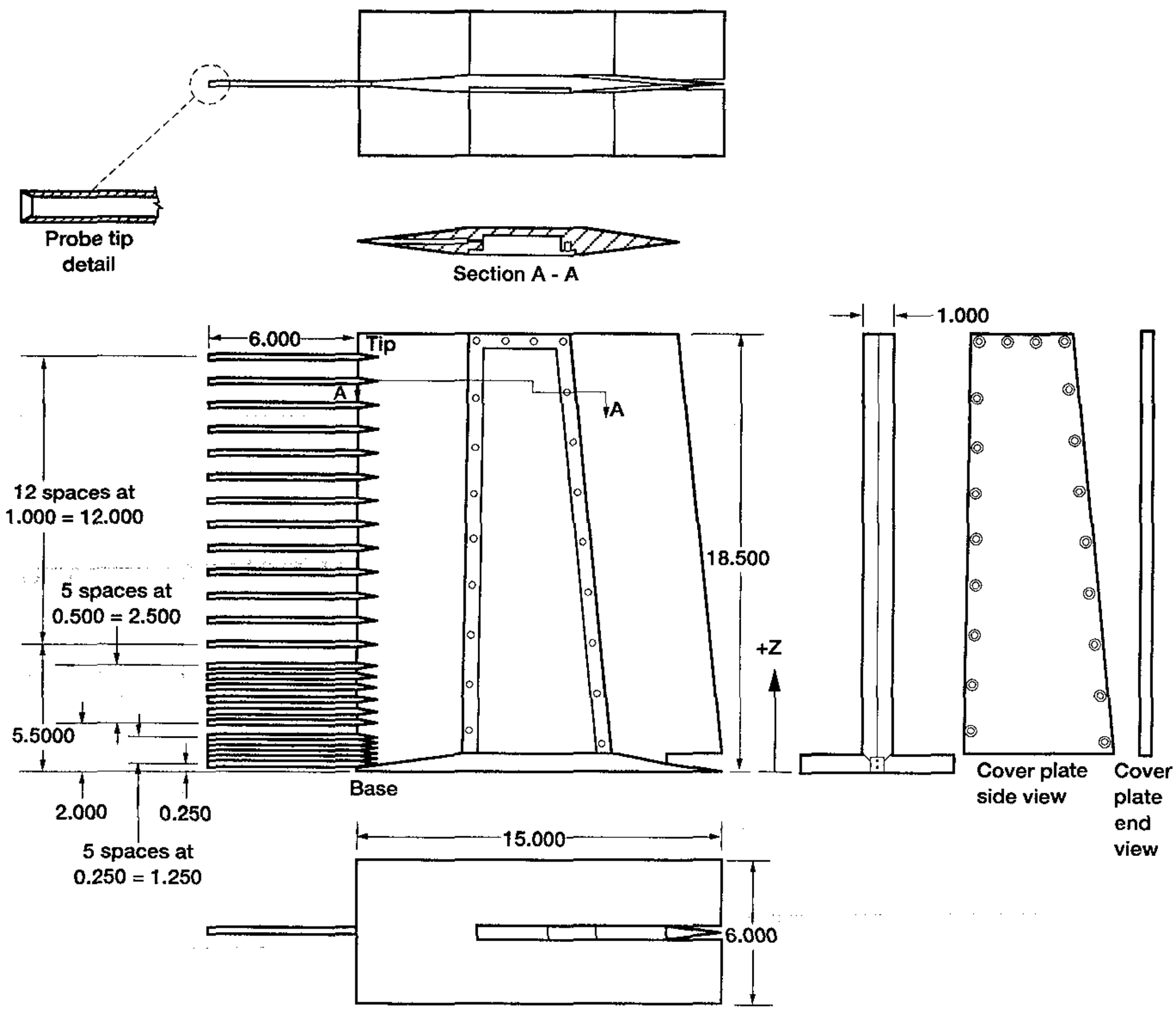
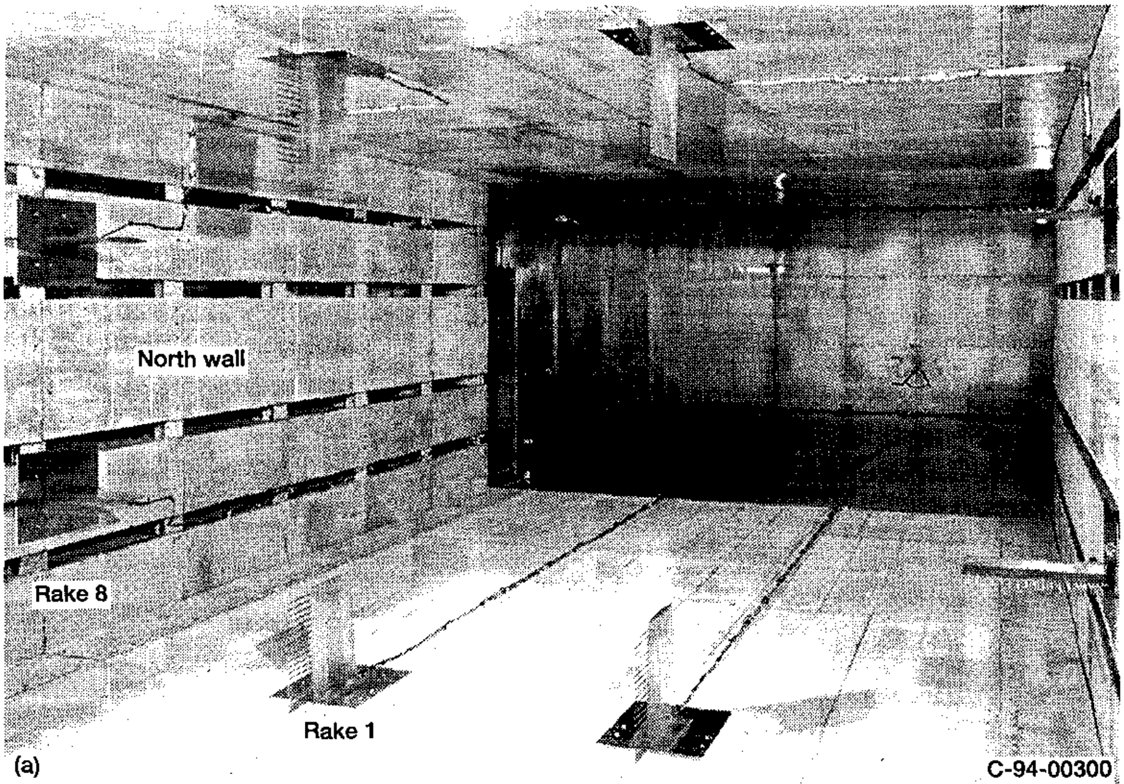
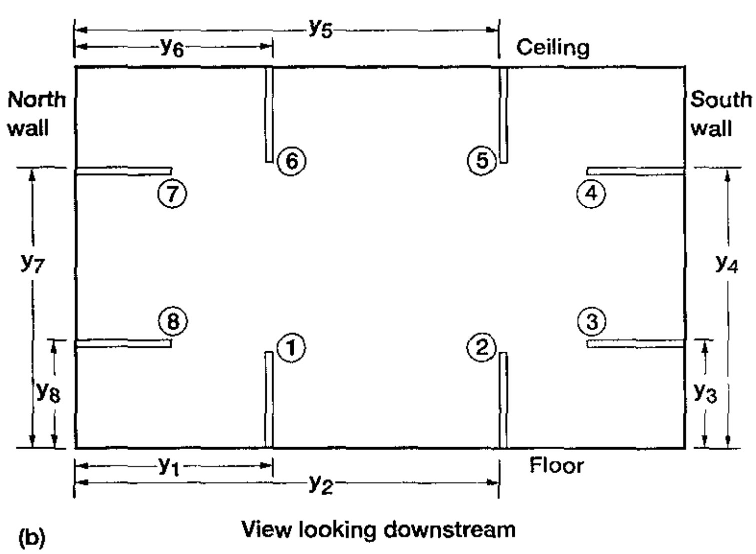


Figure 6.—Boundary layer rake details, layout, and dimensions. (All dimensions in inches.)





Reference position	Post mod, 1994	Hughes, 1989		
	Typical, all axial stations	Entrance	Model test plane	Exit
y_1	61± 2	69	—	56
y_2	116± 2	—	—	124
y_3	28± 2	29	—	25
y_4	76± 2	79	—	83
y_5	113± 2	111	115	124
y_6	63± 2	69	—	56
y_7	75± 2	79	—	83
y_8	29± 2	29	—	25

Figure 7.—Boundary layer rake installation details. (a) Typical test setup using eight boundary layer rakes at one axial station (i.e., station 119; view looking downstream.) (b) Boundary layer rake locations. (All dimensions in inches.)

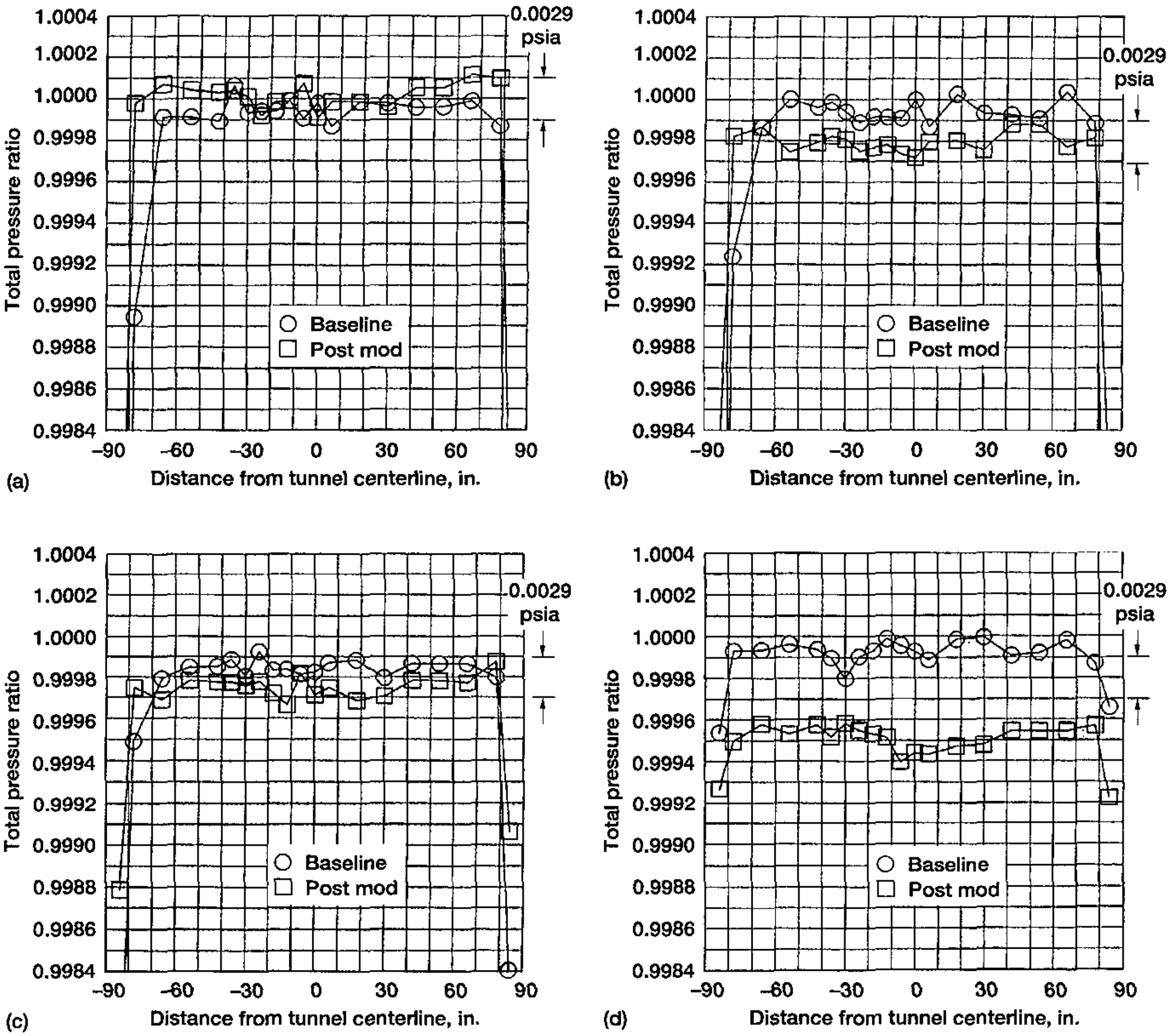


Figure 8.—Spanwise total pressure ratio distribution at station 198, vertical centerline for each reference Mach number. Total pressure measured by 15-ft survey rake was nondimensionalized by total pressure measured using aft test section rake. Absolute pressure variation indicated on plots is based on typical test conditions. Some data near tunnel walls has been omitted in order to provide greater resolution of data from center of test section. (a) M = 0.20. (b) M = 0.15. (c) M = 0.10. (d) M = 0.05.

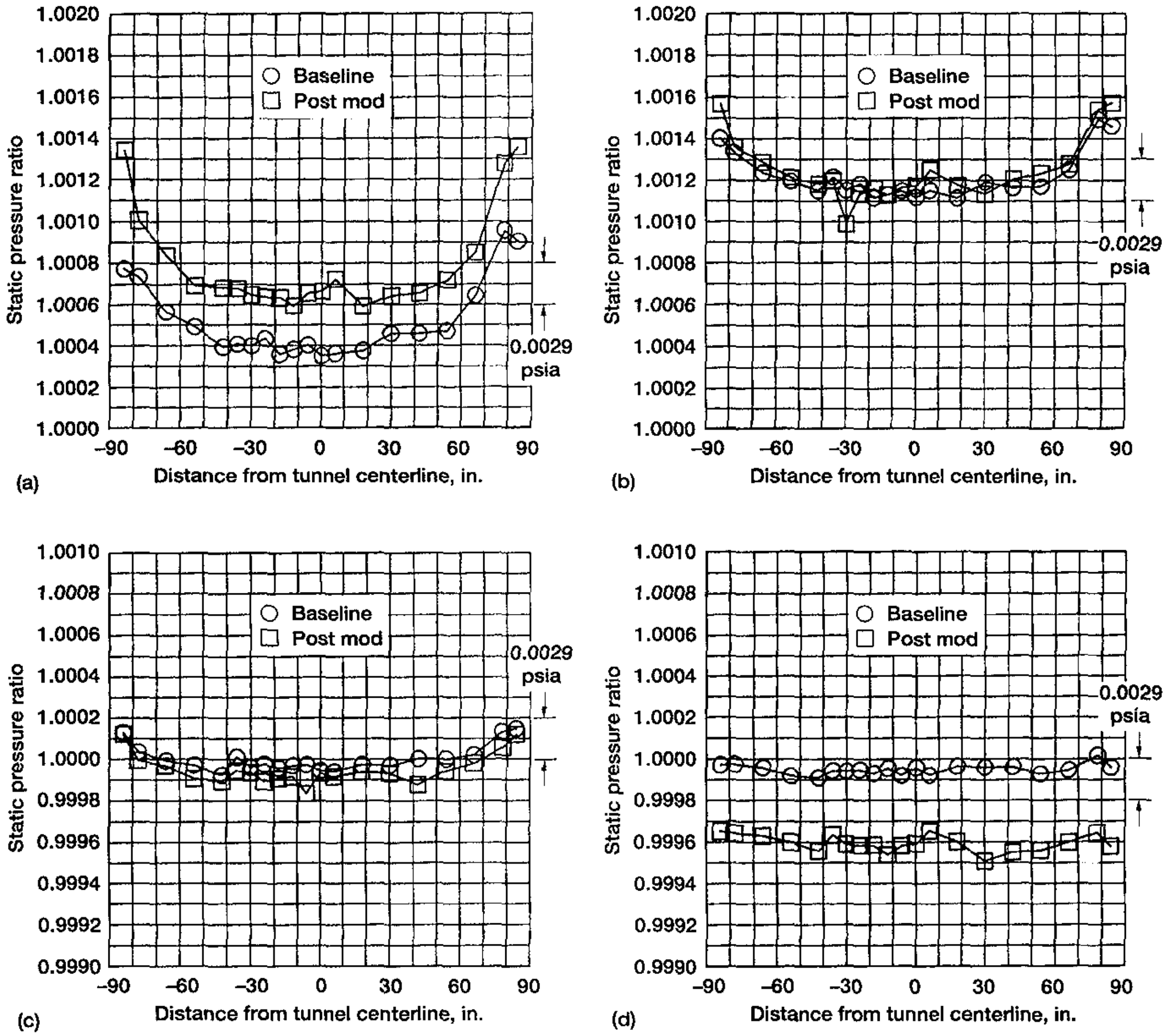


Figure 9.—Spanwise static pressure ratio distribution at station 198, vertical centerline for each reference Mach number. Static pressure measured by 15-ft survey rake was nondimensionalized by static pressure measured using aft test section rake. Absolute pressure variation indicated on plots is based on typical test conditions. (a) M = 0.20. (b) M = 0.15. (c) M = 0.10. (d) M = 0.05.

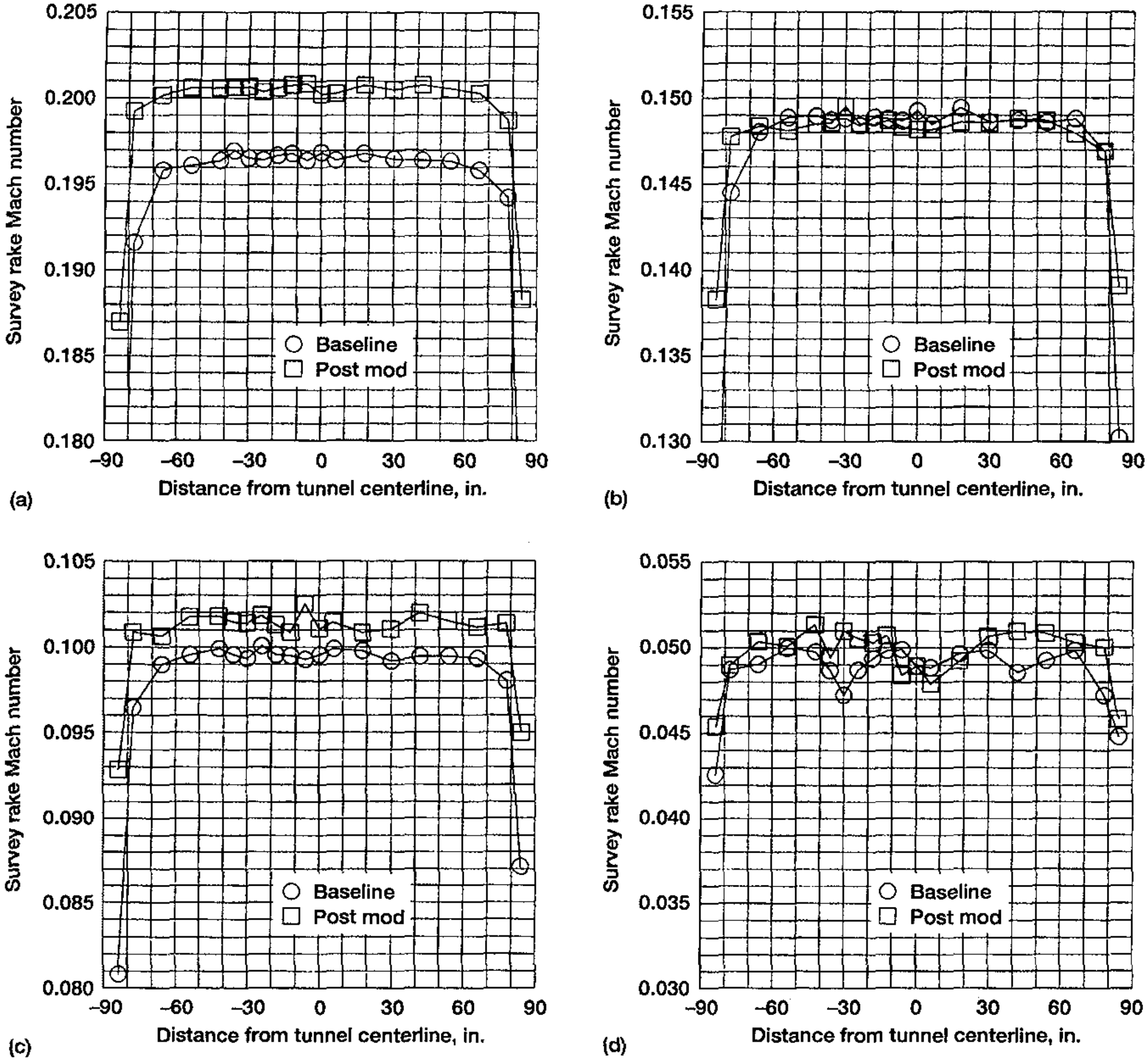


Figure 10.—Mach number distribution across test section at station 198, vertical centerline. Small differences in absolute Mach number setting apparent in some cases (M = 0.20 and 0.10) are of no importance since setting can be tweaked to repeat nominal conditions to within ± 0.001. Some data near tunnel walls has been omitted to provide greater resolution of data from center of test section. (a) M = 0.20. (b) M = 0.15. (c) M = 0.10. (d) M = 0.05.

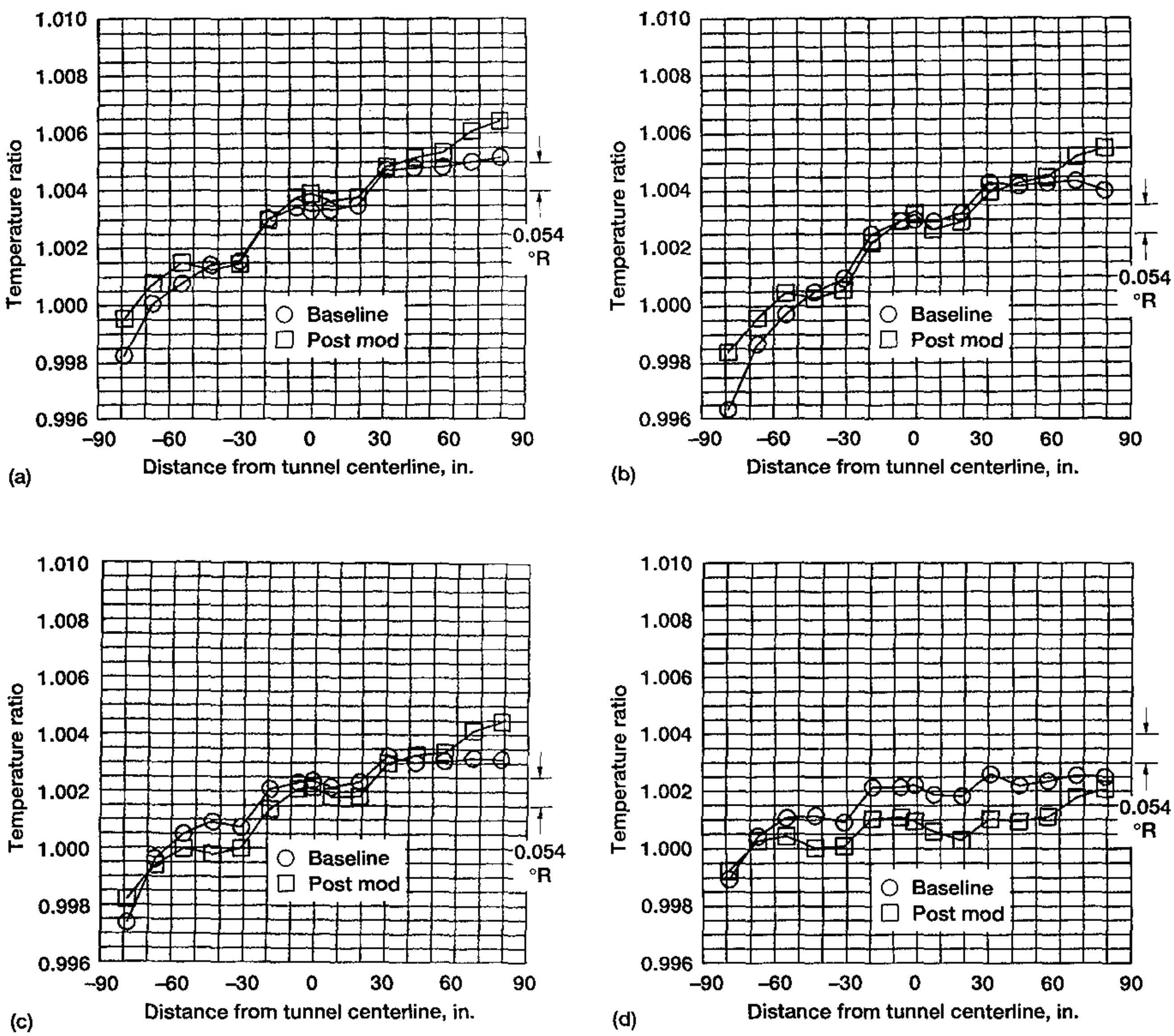


Figure 11.—Spanwise total temperature ratio distribution at axial station 198, vertical centerline. Total temperature measured by 15-ft survey rake was nondimensionalized by total temperature measured by aft test section rake. Absolute temperature variation indicated on plots is based on typical test conditions. (a) M = 0.20. (b) M = 0.15. (c) M = 0.10. (d) M = 0.05.

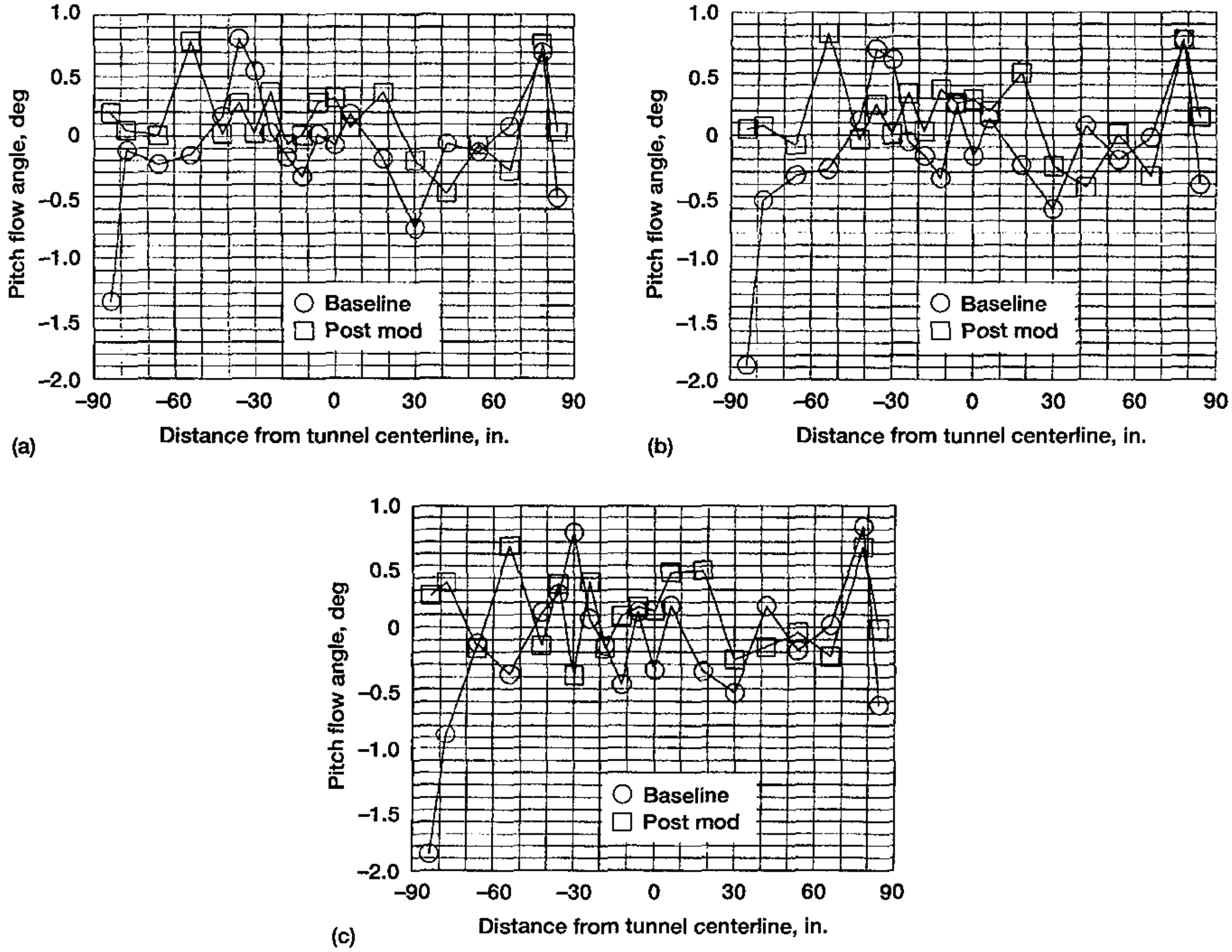


Figure 12.—Pitch flow angle distribution across test section at station 198, vertical centerline. (a) M = 0.20. (b) M = 0.15. (c) M = 0.10.

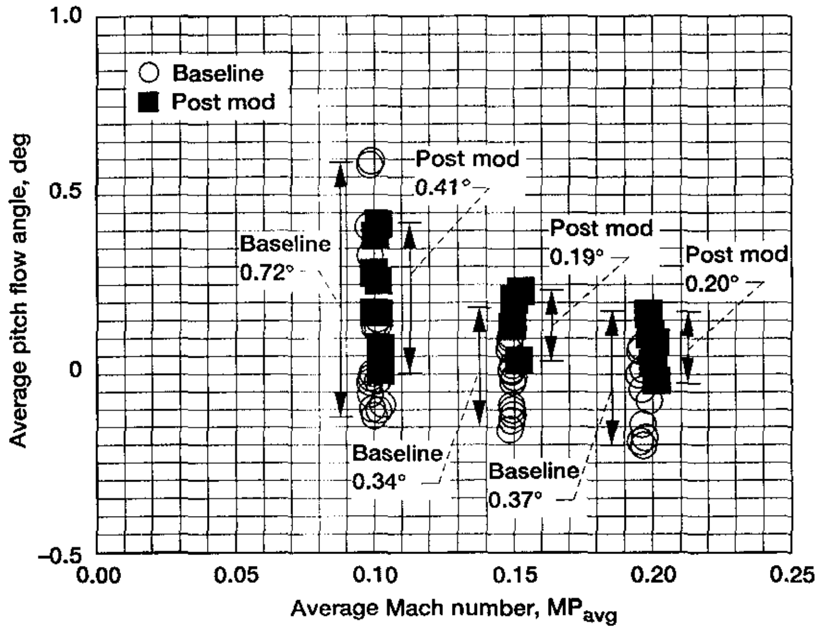


Figure 13.—Comparison of average pitch flow angle data at station 198 and vertical positions –18, –12, –6, 0 (centerline), 6, 12, and 18 in. for three reference Mach numbers.

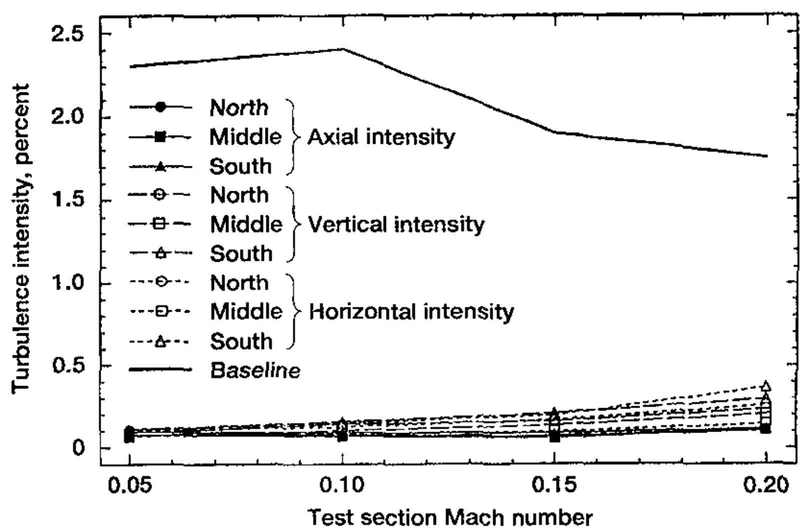


Figure 14.—Turbulence intensity levels in 9- by 15-ft test section at axial station 204 and test section centerline.

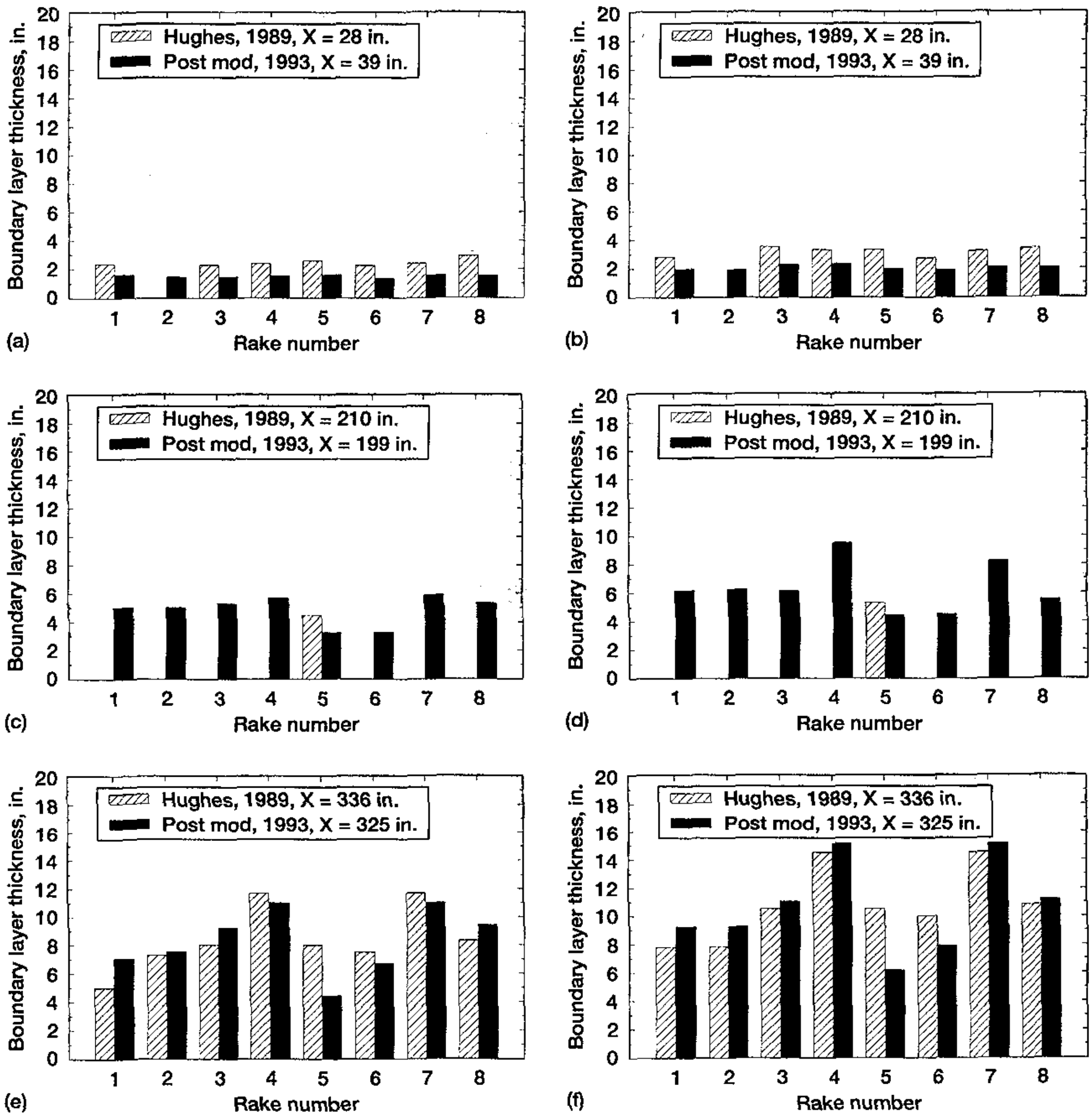


Figure 15.—Boundary layer thickness comparison before and after flow quality improvements. Boundary layer thickness computing using a total pressure ratio (boundary layer to freestream total pressure) of 0.999. (X denotes station.) (a) Test section entrance at M = 0.10. (b) Test section entrance at M = 0.20. (c) Model test plane at M = 0.10. (d) Model test plane at M = 0.20. (e) Test section exit at M = 0.10. (f) Test section exit at M = 0.20.

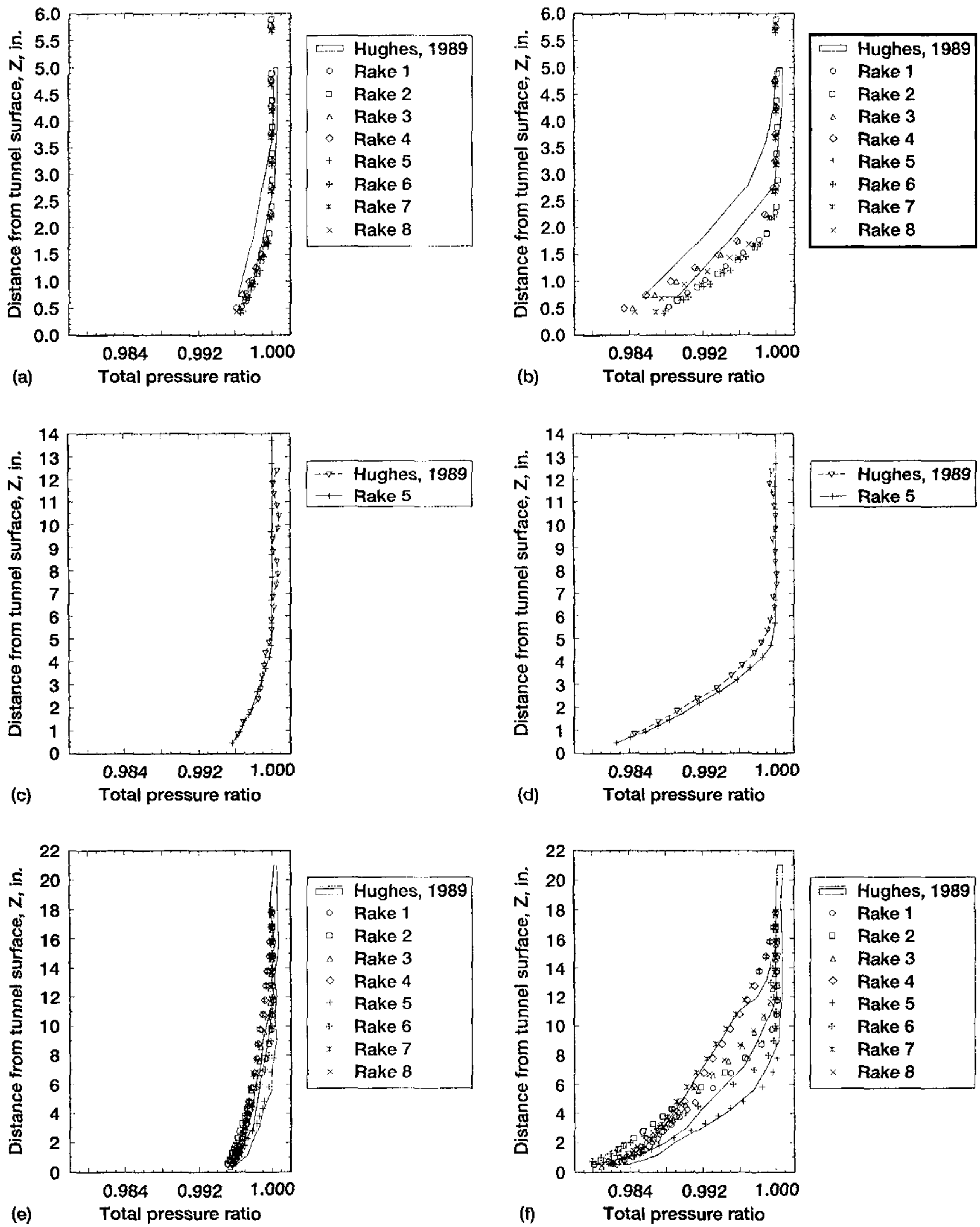


Figure 16.—Boundary layer to freestream total pressure ratio profile comparison before and after flow quality improvements. (a) Test section entrance at M = 0.10. (b) Test section entrance at M = 0.20. (c) Model test plane at M = 0.10. (d) Model test plane at M = 0.20. (e) Test section exit at M = 0.10. (f) Test section exit at M = 0.20.

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13. ABSTRACT ***(Maximum 200 words)***
The NASA Lewis Research Center 9- by 15-Ft Low Speed Wind Tunnel (LSWT) was recently upgraded with the addition of several flow quality improvement devices: four 10-mesh turbulence reduction screens and a flow straightening honeycomb (3/8-in. cell, length to diameter ratio, L/D = 16) in the settling chamber upstream of the test section, and a diffuser extension fairing downstream of the test section. Test section flow quality was measured prior to and following the tunnel modifications. Comparison of the pre- (baseline) to post-tunnel modification flow quality data will provide a gage of the effectiveness of the flow quality devices. An instrumented rake was used to provide both calibration and flow-field survey data at several stations in the test section. The flow-field parameters measured included total and static pressure, total temperature, pitch and yaw components of flow angle and turbulence; boundary layer total pressure surveys were also made. The data indicated very good flow quality in the test section at all survey stations in terms of total pressure, total temperature, Mach number and flow angularity distributions, and turbulence levels. The data compared with that collected before facility flow quality additions indicate improvement in the test section Mach number distribution, flow angle distribution, and turbulence levels as well as an increase in the usable test section width. The temperature distributions can be further improved by increasing the cooling water flow into the facility heat exchanger.

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