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CHECK CALIBRATION OF THE AEDC 16-FT TRANSONIC TUNNEL

J. A. Gunn
ARO, Inc.

May 1966

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NOTICES

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FOREWORD

The work reported herein was sponsored by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 65402234.

The results of this calibration were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of AEDC, AFSC, Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The calibration was conducted from May 5 to 14, 1965, under ARO Project No. PB9340, and the results of this calibration program were incorporated into the data reduction program for subsequent tests. The organization of this final report was accomplished under ARO Project No. PB3642. The manuscript was submitted for publication on March 23, 1966.

This technical report has been reviewed and is approved.

Francis M. Williams Major, USAF AF Representative, PWT DCS/Test	Jean A. Jack Colonel, USAF DCS/Test

ABSTRACT

Tests were conducted in the Propulsion Wind Tunnel, Transonic (16T) of the Propulsion Wind Tunnel Facility (PWT) to determine the test section Mach number calibration and Mach number distributions. During the test, Mach number was varied from 0.50 to 1.60, and the wall angle from -1.00 to +1.00 deg, while holding tunnel total pressure at 1000 psfa and tunnel temperature at 120°F. At all Mach numbers the region from Station 1 to Station 20 was considered the test region. The results show that the tunnel calibration is a function of test section wall angle, and that all wall angles in the calibrated Mach number range produce Mach number distributions acceptable for testing. This was the first calibration after the installation of the modified main compressor utilizing fiber glass rotor blades.

CONTENTS

ILLUSTRATIONS

NOMENCLATURE

b, b_θ, k, k_θ	Defined in Appendix I
M_c	Mach number as computed from p_c/p_t
$M_c(\ell, m)$, $M_c(m, h)$	Defined in Appendix I
M_{TP}	Mach number as computed from the average of Mach number measurements along the perforated plate from station 1 to 20
M_{TS}	Mach number as computed from the average of Mach number measurements along the solid plate from station 1 to 20
M_∞	Free-stream Mach number
$M_\infty(\ell, m)$, $M_\infty(m, h)$	Defined in Appendix I
p_c	Plenum chamber static pressure, psf
p_i	Compressor inlet static pressure, psf
p_P	Static pressure measured on perforated plate, psf
p_S	Static pressure measured on solid plate, psf
p_t	Stilling chamber total pressure, psf
p_∞	Free-stream static pressure, psf
θ_w	Test cart wall angle, deg (positive when walls are diverged)
$\theta_w{}^*$	Optimum wall angle, deg
$\lambda_t{}^*$	Optimum tunnel pressure ratio, p_t/p_i

SUBSCRIPTS

h	High transonic Mach number range
ℓ	Low transonic Mach number range
m	Mid transonic Mach number range
x	Axial station number, ft

SECTION I
INTRODUCTION

The Propulsion Wind Tunnel, Transonic (16T) began shakedown and operation in July of 1956. In August 1961 Tunnel 16T was removed from service by a main compressor failure. The compressor rotor has been redesigned and installed with fiber glass reinforced plastic blades. The results of the test section calibration with the plastic bladed compressor are presented in this report. This calibration was initiated to determine empty test section Mach number distribution and Mach number calibration over a wide range of test section wall angles.

SECTION II
APPARATUS

2.1 BASIC TUNNEL AND SUPPORT EQUIPMENT

Tunnel 16T is a continuous flow, closed-circuit tunnel capable of operation at Mach numbers from 0.50 to 1.60 and stagnation pressures from approximately 100 to 4000 psf. The location of Tunnel 16T and its relationship to the rest of the PWT facility are shown in Fig. 1. The compressor drive system consists of four electric motors with a maximum power rating of 216,000 hp. The main compressor is a constant speed, three-stage, axial flow compressor with variable stator blades for inlet volume flow control. The calibration of the compressor with fiber glass blades is given in Ref. 1. Temperature control is provided by an air-to-water heat exchanger located just upstream of the stagnation region. The stagnation temperature control is automatic and will maintain the average temperature to ±1°F of the set temperature through the normal temperature range from 90 to 125°F with estimated deviations across the stagnation region of no more than ±5°F.

Supersonic Mach numbers are generated by a flexible, two-dimensional Laval nozzle. Fifty contours are available for supersonic Mach numbers from 1.00 to 1.65. A 10-ft variable porosity flow stabilization region, shown in Fig. 2, connects the solid plate nozzle and the porous test section. The removable test section is 40 ft long and 16 ft square with 6-percent porosity walls. Figure 3 is a sketch of a portion of the wall showing the hole pattern and cross-section details. The test section sidewalls can be converged to 2 deg and diverged to 1 deg. A scavenging scoop is located in the diffuser to remove the products of combustion during propulsion tests. A closed tip is installed on the scoop during aerodynamic tests.

Plenum suction is required for removal of air through the test section walls to prevent choking in the transonic range. For initial operation plenum suction was provided by opening the diffuser flaps. As its units became operational, auxiliary suction was provided by the Plenum Evacuation System (PES). The PES consists of two increments of compressors which can operate independently. All or a portion of the air removed from the plenum may be energized by the PES and returned to the tunnel in the diffuser. Pressure level control and drying are maintained by removing air from the tunnel (either from the plenum or from ports in the scavenging scoop support strut) and exhausting it to the atmosphere. Dry make-up air is returned to the tunnel downstream of the scavenging scoop from the PWT dryer building which uses silica gel as a desiccant. The Rocket Test Facility (RTF) exhauster plant may be used to supplement the PES in removing air for drying and pressure control.

2.2 CALIBRATION EQUIPMENT

The test section Mach number distributions were obtained from static pressure orifices 0.090 in. in diameter. These orifices were installed on 1-ft centers in the test section floor on lines 1 ft either side of the tunnel centerline. The orifices on the east side of the centerline were set in a 2-ft-wide solid plate extending from station 0 to station 30, whereas the orifices on the west side of the centerline were positioned in the perforated test section liner plates with an orientation to the perforations as exhibited in Fig. 3. The location of the solid plates in the empty test section is shown in Fig. 4.

In addition to the orifices in the test section, other orifices in the tunnel floor, placed nominally on the centerline, extend from station -80 to station 39. These orifices were used to determine flow development and decay. Most orifices were connected to both transducers and unity oil manometers.

SECTION III
PROCEDURE

3.1 CALIBRATION PROCEDURE

Variables during this empty test section calibration were Mach number and wall angle. The general procedure followed was to set a chosen wall angle and vary Mach number through the desired range. Nominal Mach number was set by adjusting plenum pressure using tables from previous calibration data, and tunnel pressure ratio was regulated to give the best test section Mach number distribution. This was determined visually from a 100-in. manometer board in the control room. For Mach numbers up to and including 1.05, the nozzle was set on the sonic contour. Above Mach number 1.05 supersonic contours were used.

Throughout this calibration a stagnation pressure of 1000 psf was maintained. Most of the test was conducted at a stagnation temperature of 120°F; however, some data were obtained at a stagnation temperature of 100°F. Check points showed that there was no noticeable difference in data at 120 and 100°F. A tunnel humidity level of 0.001 lb of water per pound of mixture or less was maintained for Mach numbers greater than 1.2.

3.2 DATA REDUCTION PROCEDURE

The on-line printout consisted of basic tunnel conditions (stagnation temperature, stagnation pressure, and plenum pressure) and calibration data. Several on-line plots were used to observe data which were not tabulated on-line, and an off-line printout supplied the ratio, p/p_t, for all orifices.

Since most model testing is done in the test section region from station 1 to station 20, the calibration data were based on that length. The on-line program printed out the average Mach number on the solid plates, M_{TS}, and the average Mach number on the perforated walls, M_{TP}, for stations 1 to 20.

The following relations were computed to determine tunnel calibration:

$$M_c = \sqrt{5\left[\left(\frac{p_c}{p_t}\right)^{-2/7} - 1\right]} \qquad (1)$$

$$M_{TS_x} = \sqrt{5\left[\left(\frac{p_{S_x}}{p_t}\right)^{-\frac{2}{7}} - 1\right]} \quad (2)$$

$$M_{TP_x} = \sqrt{5\left[\left(\frac{p_{P_x}}{p_t}\right)^{-\frac{2}{7}} - 1\right]} \quad (3)$$

$$M_{TS} = \frac{\sum_{x=1}^{20} M_{TS_x}}{20} \quad (4)$$

$$M_{TP} = \frac{\sum_{x=1}^{20} M_{TP_x}}{20} \quad (5)$$

The procedure used to reduce the results of this calibration to a form which is employed for on-line data reduction is given in Appendix I.

SECTION IV
RESULTS AND DISCUSSION

Previous calibrations (Ref. 2) have established parameters for optimum shock cancellation and minimum base pressure interference for certain bodies of revolution. These parameters are θ_w* for optimum cart wall angle (Fig. 5) and λ* for optimum tunnel pressure ratio (Fig. 6, which was corrected according to Appendix II). However, facility limitations, different test requirements, and a variety of model sizes and shapes frequently dictate that the tunnel should be operated at test section wall angles other than θ_w*. The main objective of this test, therefore, was to obtain empty test section Mach number distributions and calibrations for a range of wall angles from +1.00 to -1.00 deg. This "complete" calibration will allow tests to be conducted within this wall angle range with a high degree of certainty in the Mach number settings.

Other previous calibrations (Ref. 3) have shown that the ratio of plenum chamber pressure, p_c, to stagnation pressure, p_t, can be used as a reference to set test section Mach number. The calibration of M_{TS} and M_{TP} for various wall angles is presented in Figs. 7 and 8. In these figures the calibration reference, p_c/p_t, is given in the form M_c. Comparison of these plots raised the question of which Mach number, M_{TS} or M_{TP} represented the free-stream Mach number, M_∞. The PWT 1-ft Transonic Tunnel (1T) calibration data obtained from a long centerline probe and given in the plenum coefficient form, $(p_\infty - p_c)/p_t$, is shown in Fig. 9 (Ref. 4). A comparison of the Tunnel 1T data with the Tunnel 16T data (Figs. 10 and 11) indicates that results obtained from the solid plates in Tunnel 16T exhibit the same general trend as the data from the long centerline probe. Tunnel 16T calibration data (Ref. 3) from a short static pipe are compared with the solid plate data in Fig. 10. The agreement of the data is excellent and points out conclusively that the calibration data obtained from orifices in solid plates on the tunnel floor represent the free-stream Mach number.

The Mach number distributions measured on the solid plates from station 1 to station 20, free-stream Mach number, M_∞, and the reference Mach number, M_C, are presented in Fig. 12. It will be shown in the following discussion that in general the best empty test section distributions are obtained at $\theta_W = 0.25$ deg.

Although the data in Fig. 12 can be used to determine model positioning, it is difficult to resolve from these data which wall angle gives the best overall distribution at a given Mach number. A more complete analysis of the distribution was obtained by using the standard deviation method (explained in Appendix III) based on a 95-percent, 2σ confidence level. The data acquired from this statistical approach should be used primarily to compare one set of data with another, but it is probably indicative of absolute values of deviation.

Figure 13, which is a plot of the 2σ Mach number deviation versus θ_W for constant nominal Mach numbers, indicates that in almost all cases the lowest Mach number deviation occurs at $\theta_W = 0.25$ deg. This result is most pronounced in the supersonic range where very distinct minimum points or "buckets" appear. This phenomenon may be explained by the physical fact that the angle made by a nozzle side wall and the tunnel centerline at the nozzle exit (station -10) ranges from 0.22 to 0.32 deg in the Mach number range above 1.10. If the nozzle exit angle does not match the test section wall angle then flow disturbances, which extend through the test region, will be generated at the nozzle-test section intersection point. The 2σ deviation throughout the Mach number range for $\theta_W = 0$ deg, $\theta_W = 0.25$ deg, and $\theta_W = \theta_W^*$ is given in Fig. 14.

For all Mach number and wall angle combinations tested, the region between stations 1 and 20 is suitable for model testing. However, Fig. 12 shows that flow disturbances are prevalent for negative wall angles in the supersonic range especially in the front of the test cart. Proper model positioning can minimize this problem. It is shown in Figs. 13 and 14 that the (*) conditions mentioned previously are not necessarily synonymous with the best empty test section Mach number distribution. As explained in Ref. 2, θ_W* and λ* represent optimum conditions for minimizing test section wall interference with models of a particular type and size.

Development of flow in Tunnel 16T is illustrated in Fig. 15. The flow characteristics of this plot are: a gradual acceleration of flow in the contraction region, a smooth development of flow in the nozzle, and a flat distribution in the test section. The distribution in the bulge region may have little meaning since the calculations assumed isentropic flow.

SECTION V
CONCLUSIONS

The following conclusions were reached as a result of the calibration of Tunnel 16T:

1. The Mach number obtained from the average of 20 Mach number measurements along the solid plate represents the free-stream Mach number, and agrees well with the calibration from a short static pipe.
2. All Mach number and wall angle combinations tested were found to be suitable for model testing, but, in general, the best empty tunnel Mach number distributions were obtained at θ_W = 0.25.

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3. Chevalier, H. L. "Calibration of the PWT 16-FT Transonic Circuit with a Modified Model Support System and Test Section." AEDC-TN-60-164 (AD241785), August 1960.

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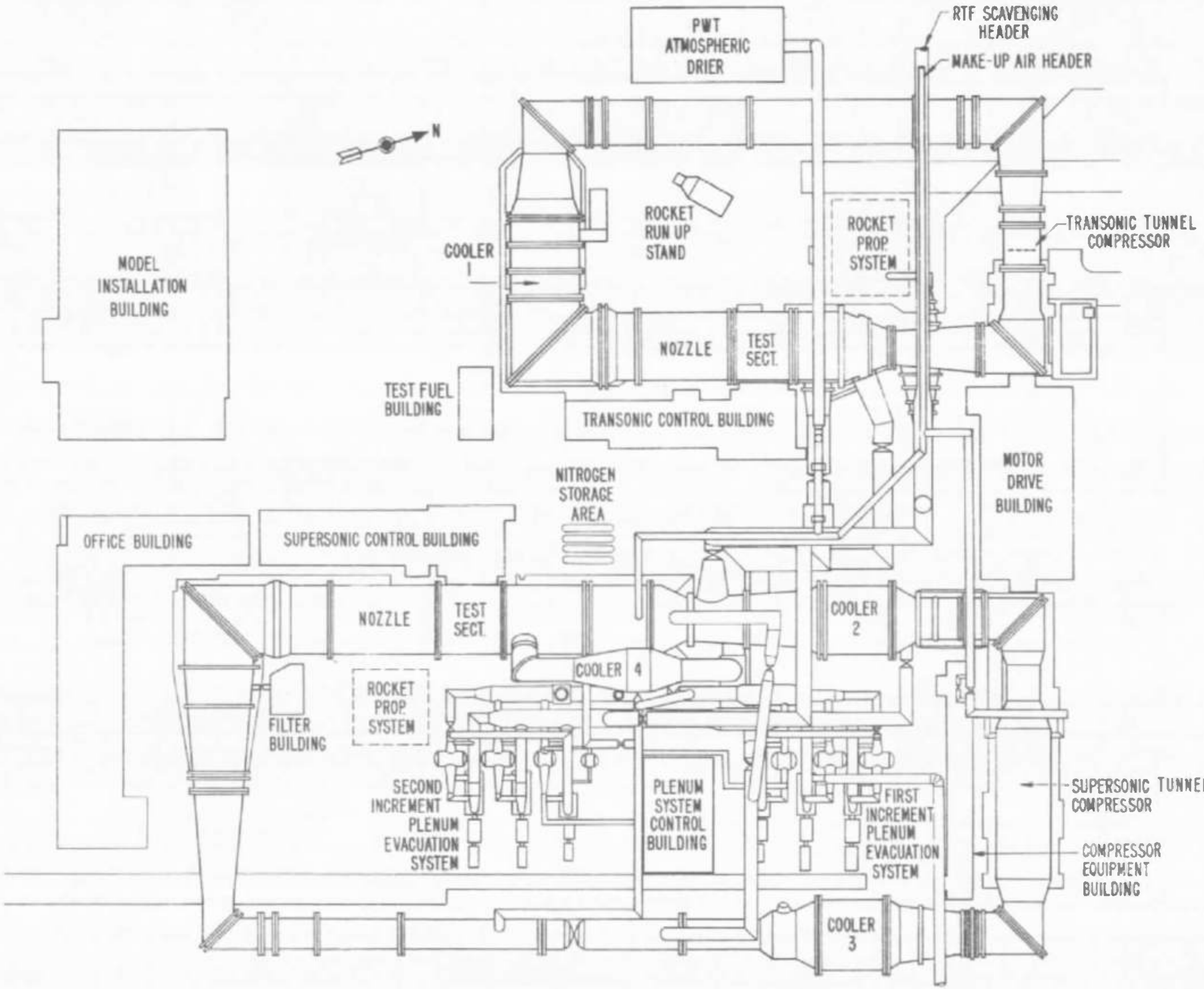


Fig. 1 Propulsion Wind Tunnel Facility

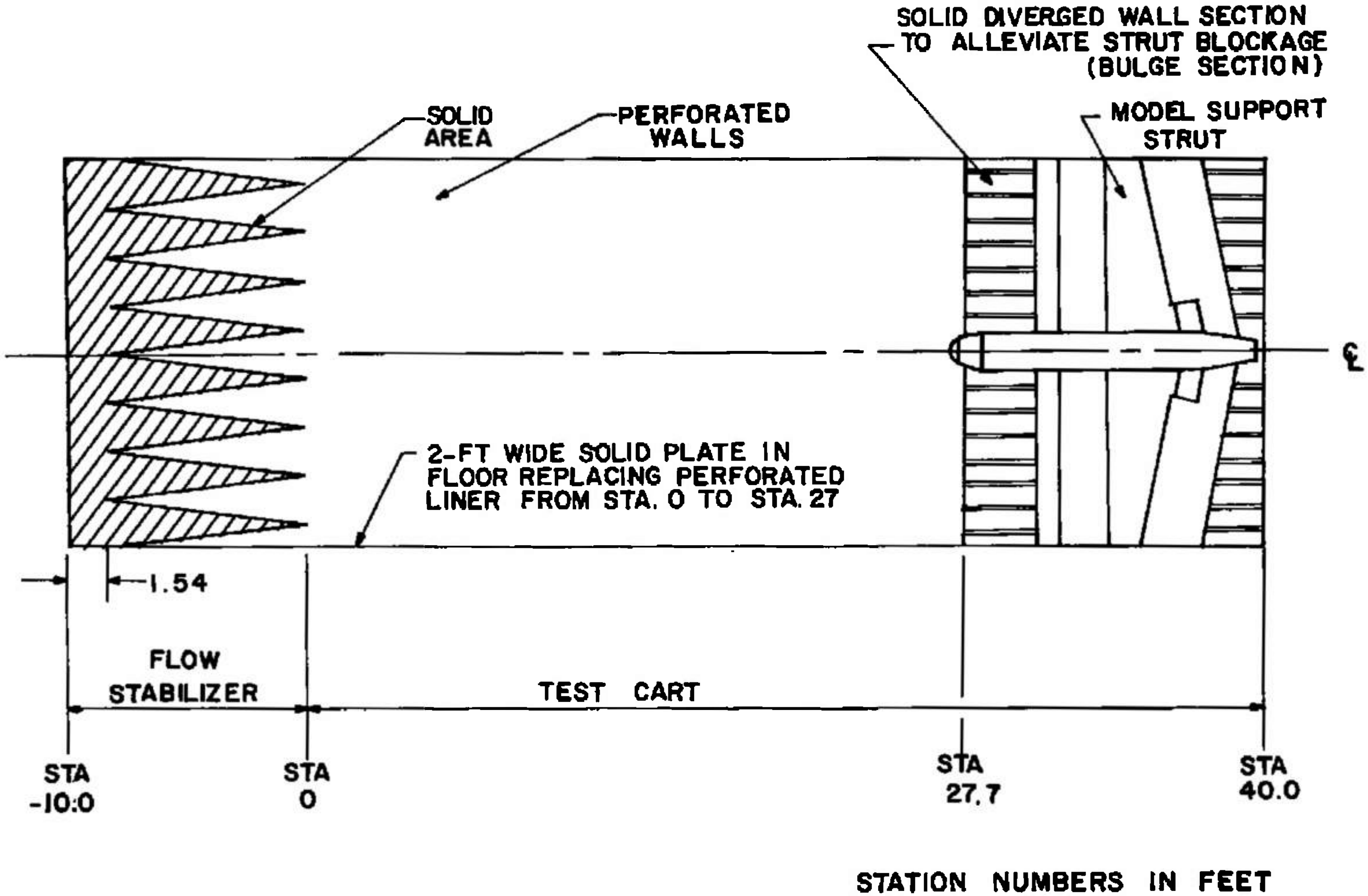
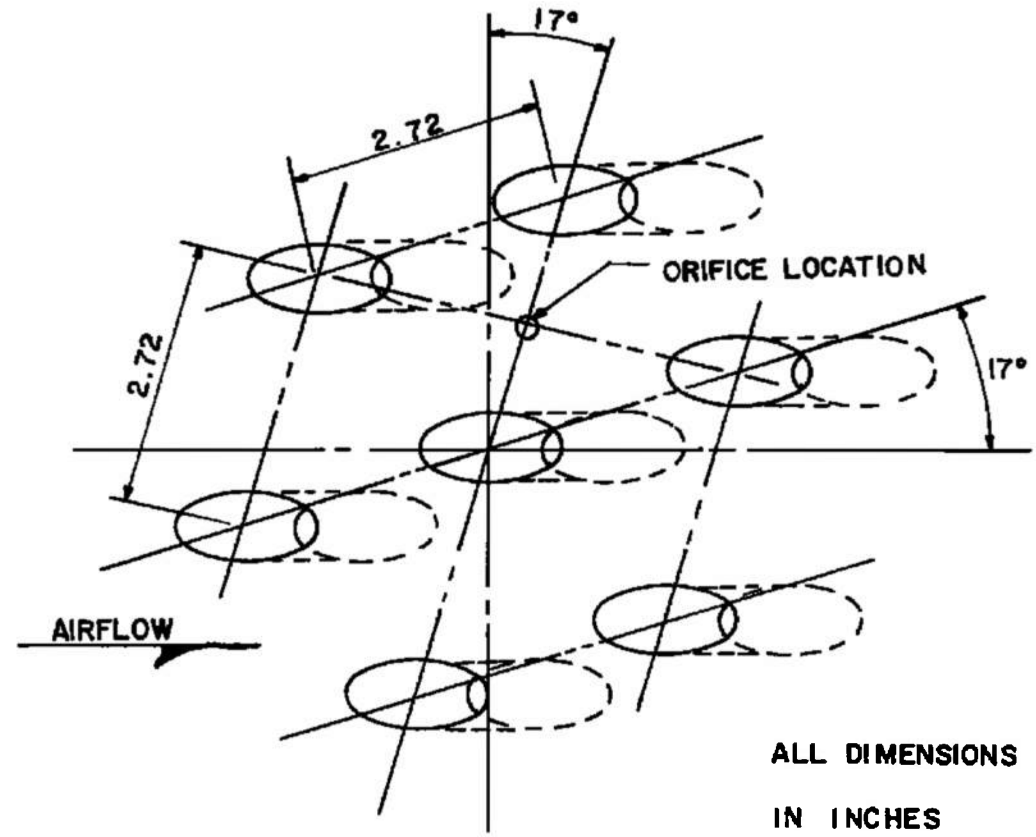
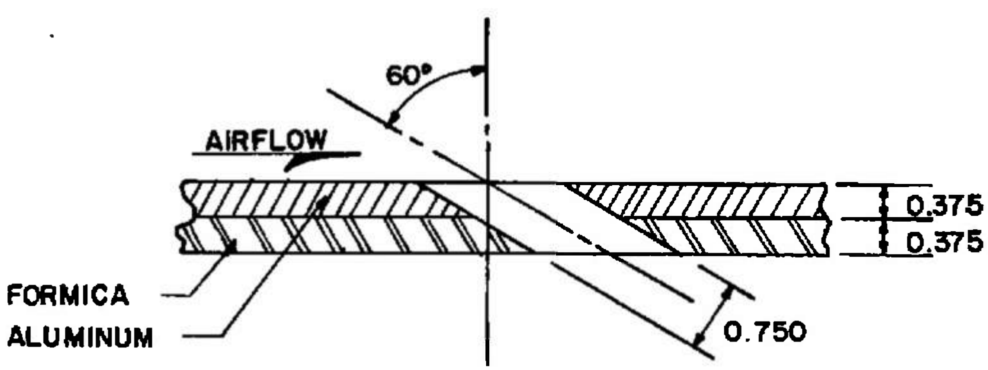


Fig. 2 16-ft Transonic Tunnel Test Section





SECTION THROUGH TYPICAL HOLE

Fig. 3 Typical Hole Pattern in the 6-Percent-Open Inclined-Hole Walls

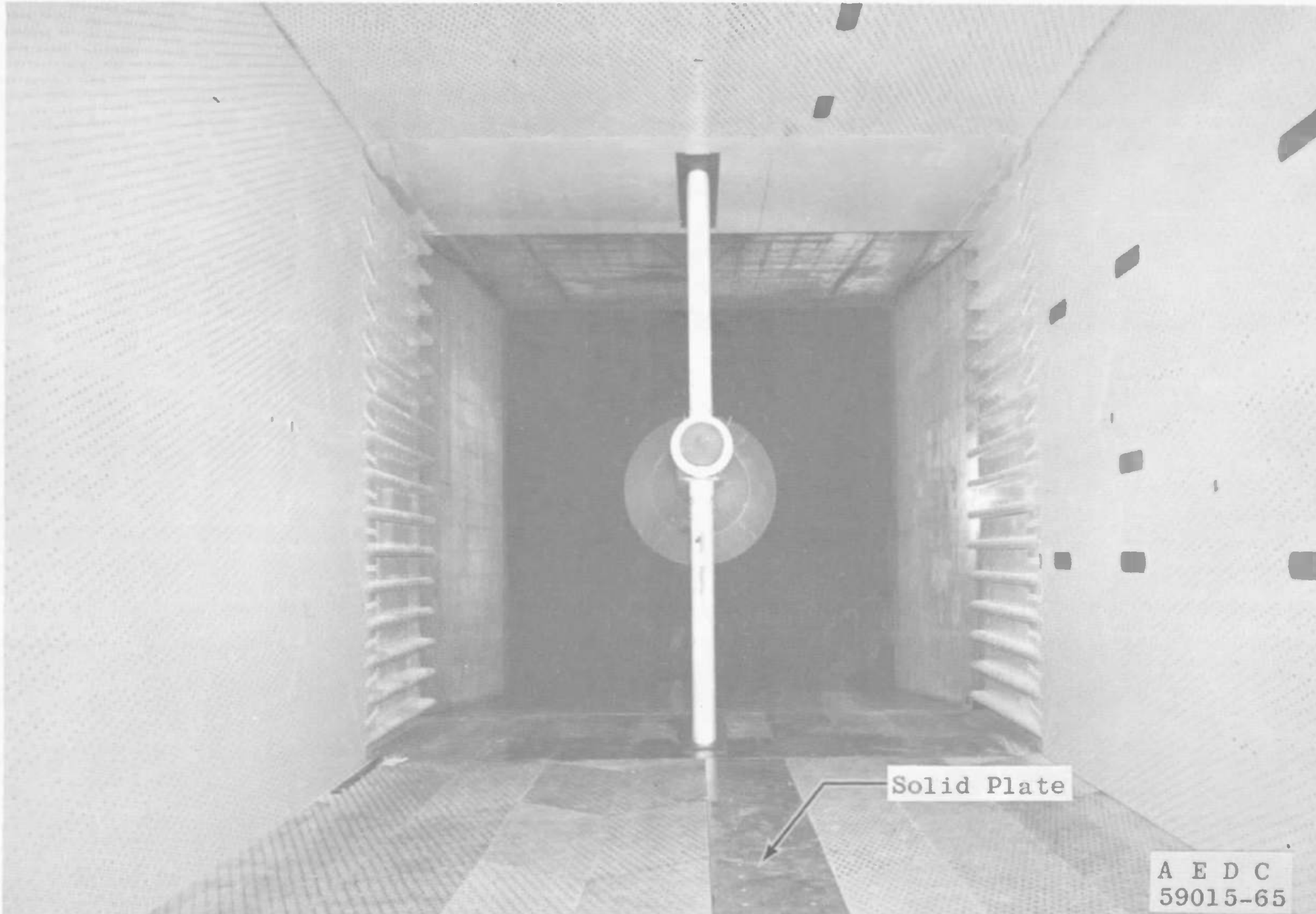


Fig. 4 Photograph of Empty Test Section Showing Solid Plates

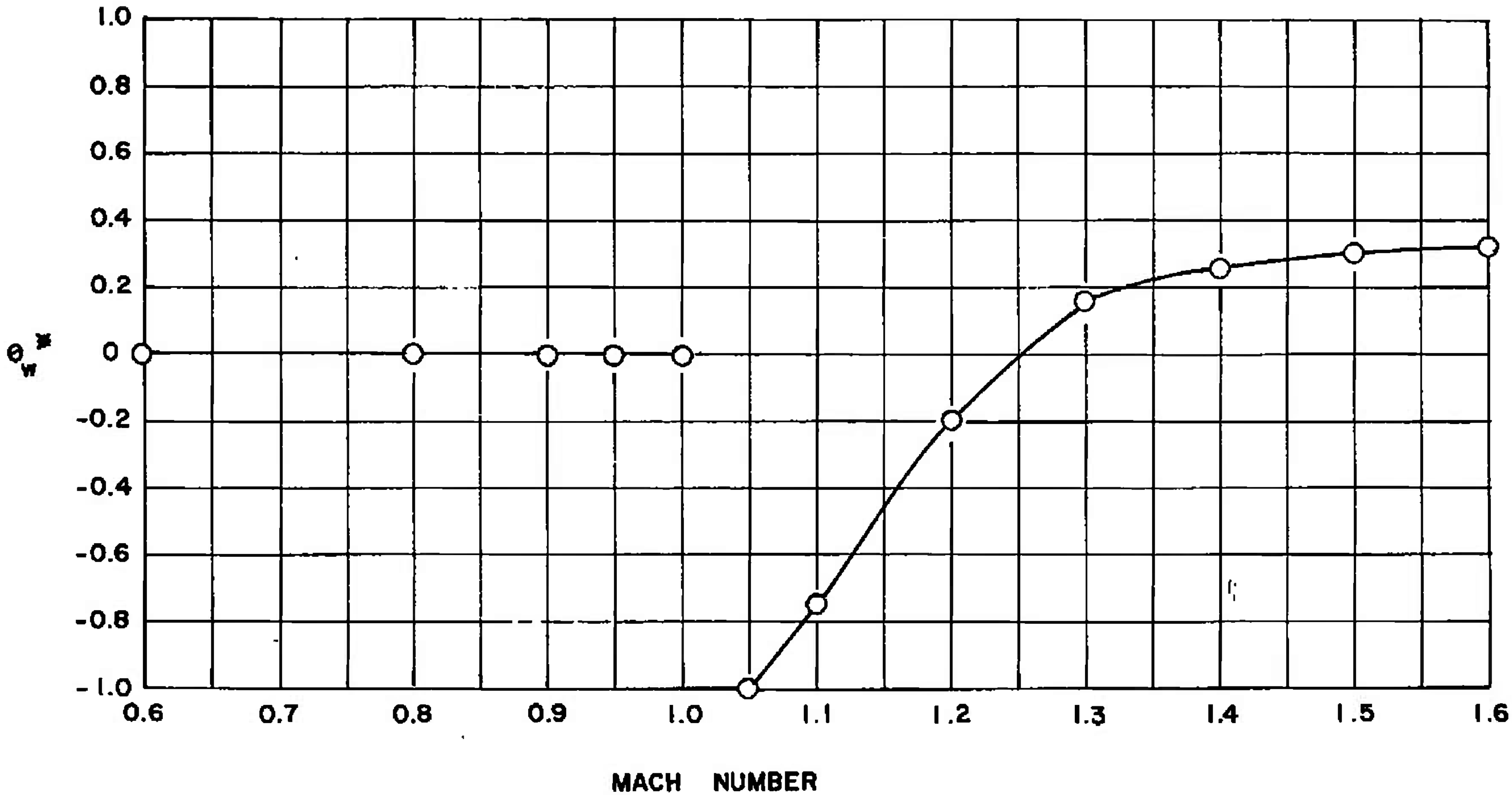


Fig. 5 Variation of Optimum Test Section Wall Angle, θ_w^*, with Mach Number (From Ref. 2)

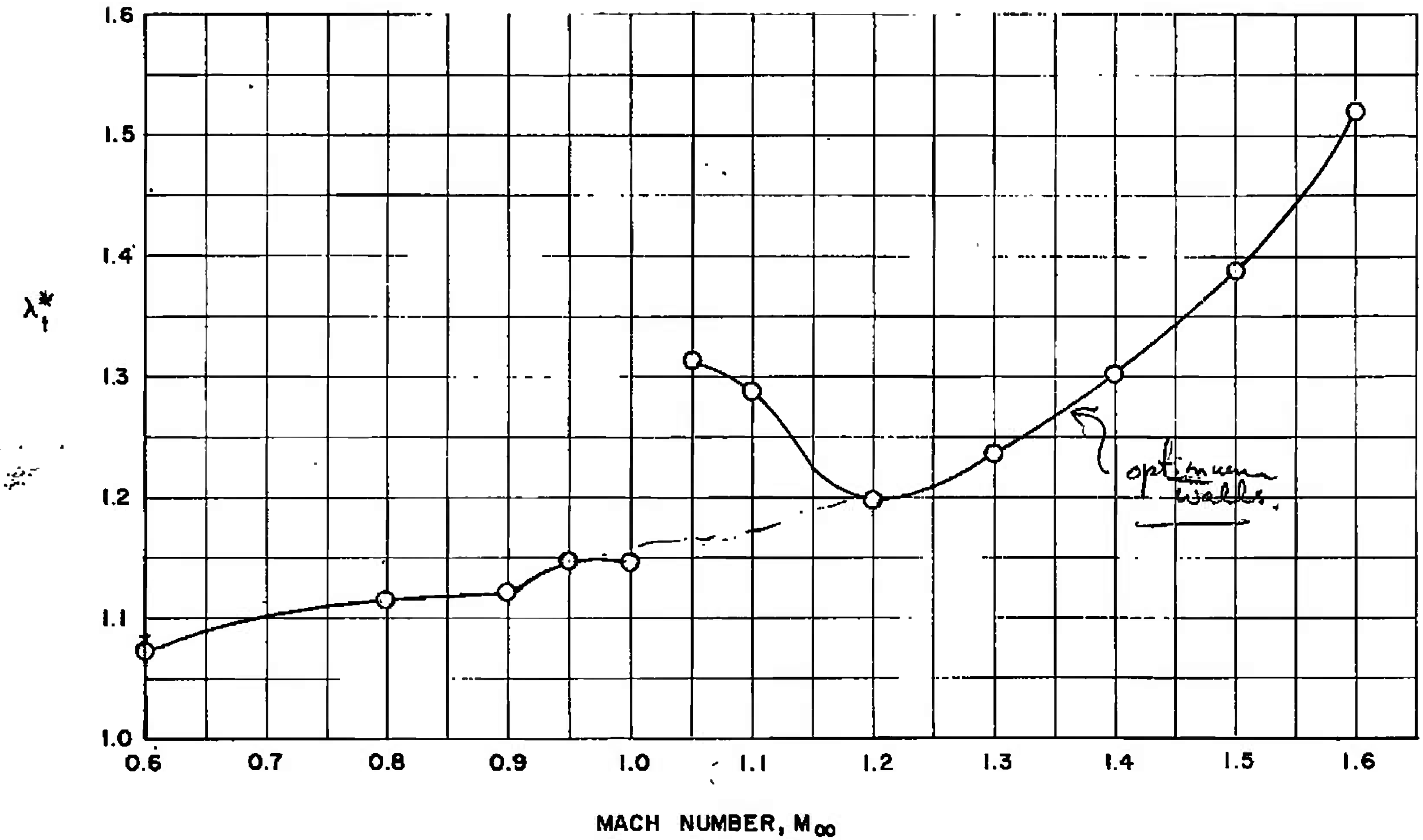


Fig. 6 Variation of Optimum Test Leg Pressure Ratio, $\lambda_T{}^*$, with Mach Number (From Ref. 2 – Corrected by Fig. II-1)

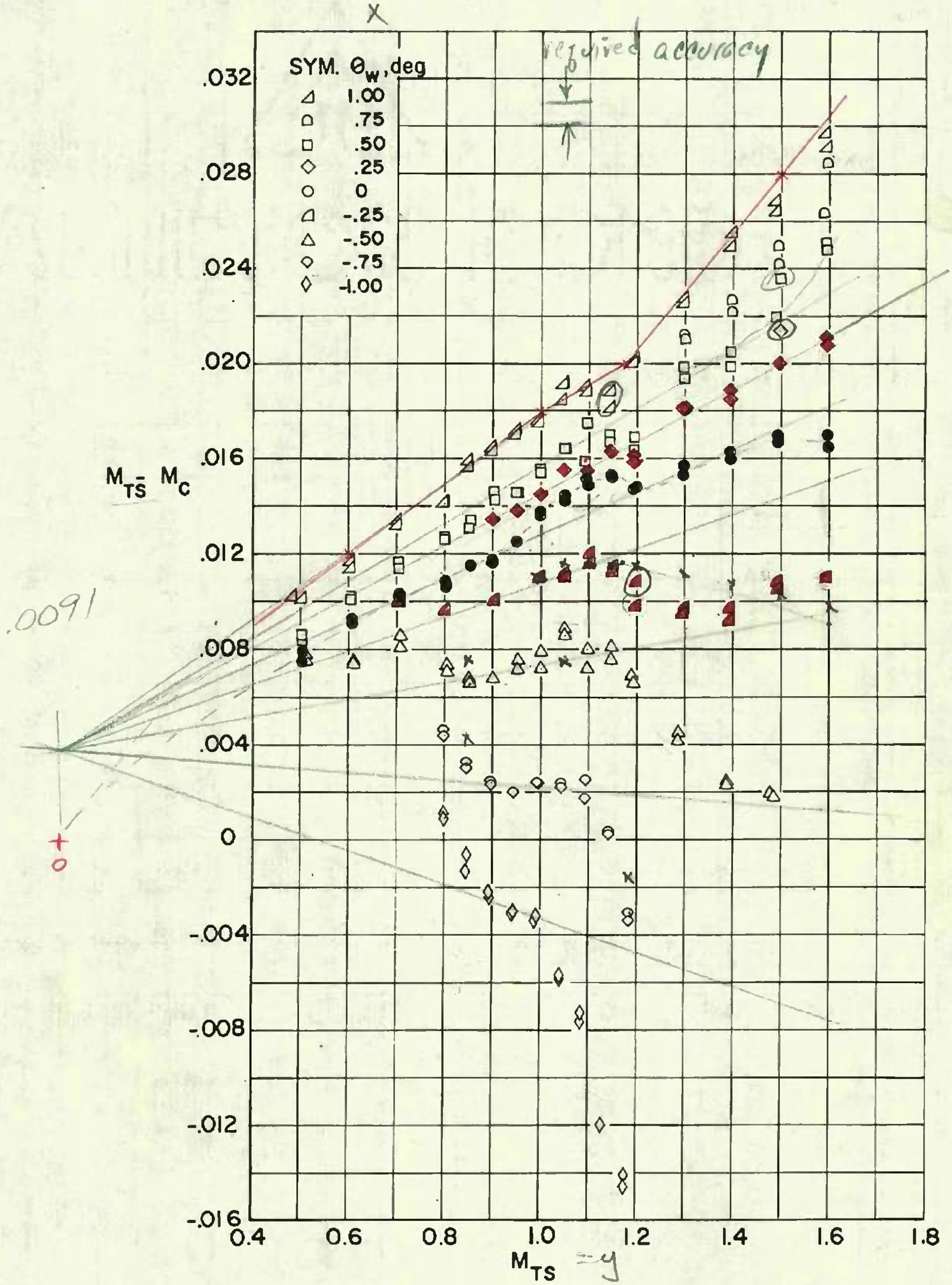


Fig. 7 Tunnel Calibration Based on Solid Plate Orifices

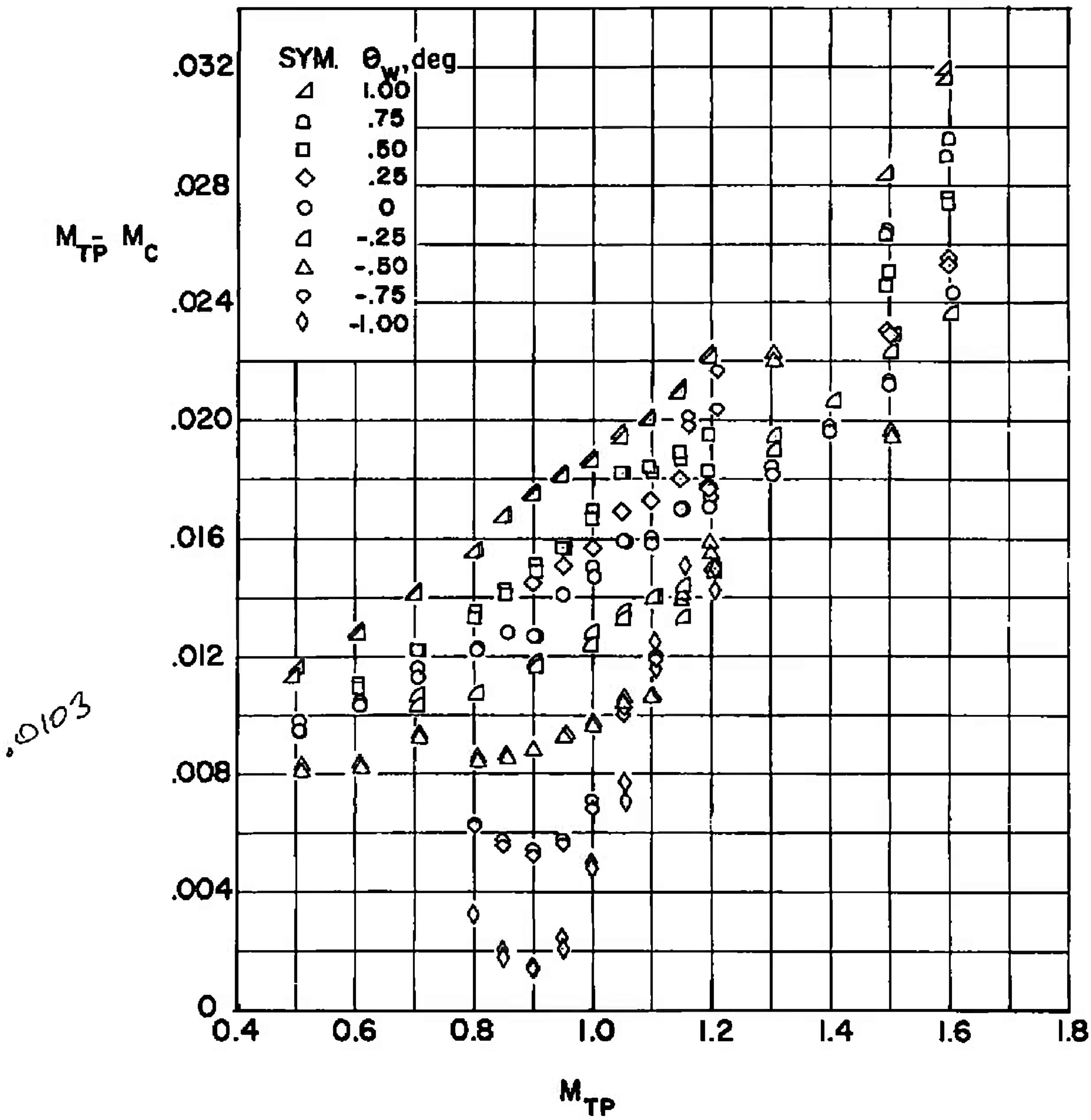


Fig. 8 Tunnel Calibration Based on Perforated Plate Orifices

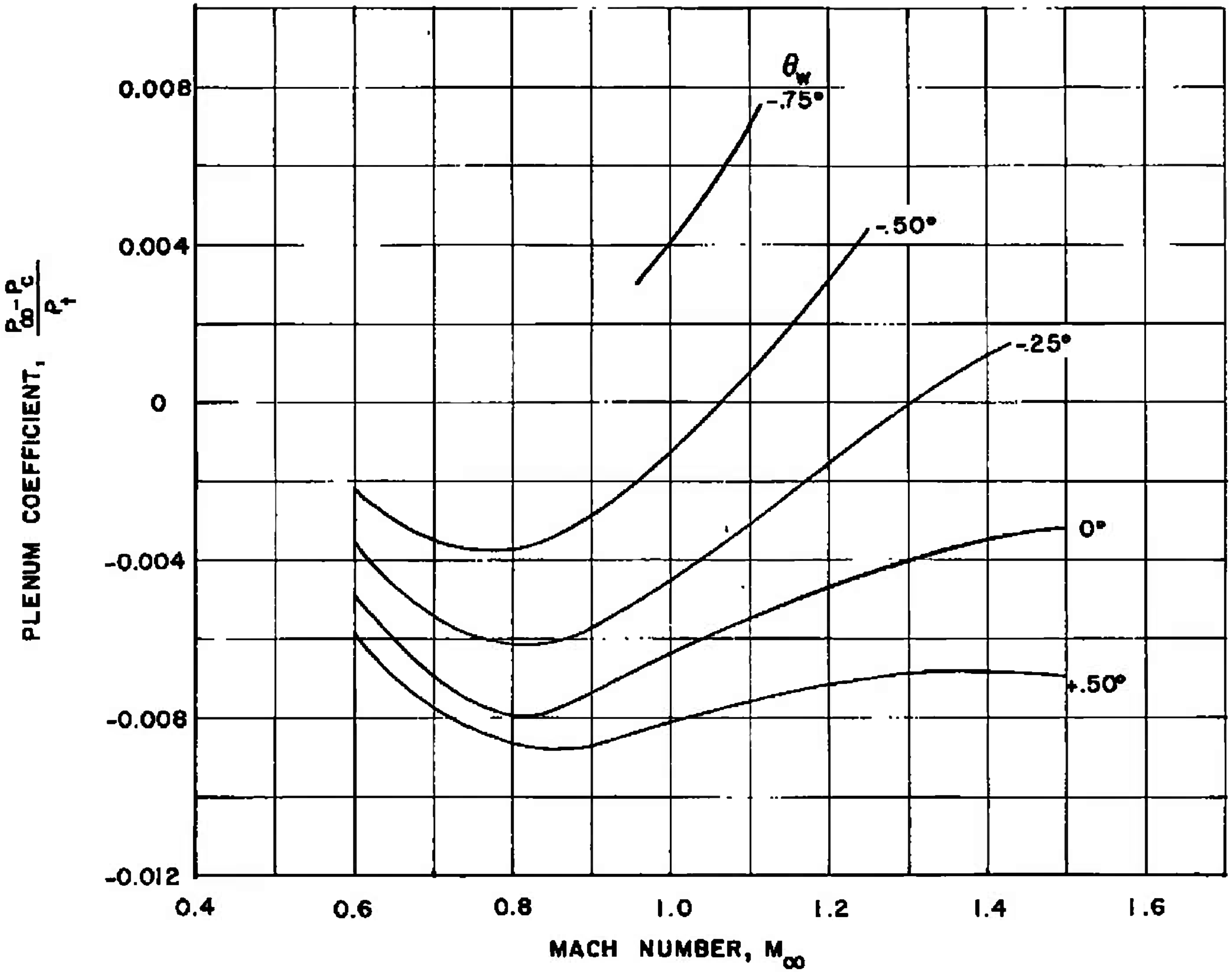


Fig. 9 Effect of Wall Angle on the Test Section Calibration – Data Obtained from Tunnel 1T Using Long Static Probe (From Ref. 4)

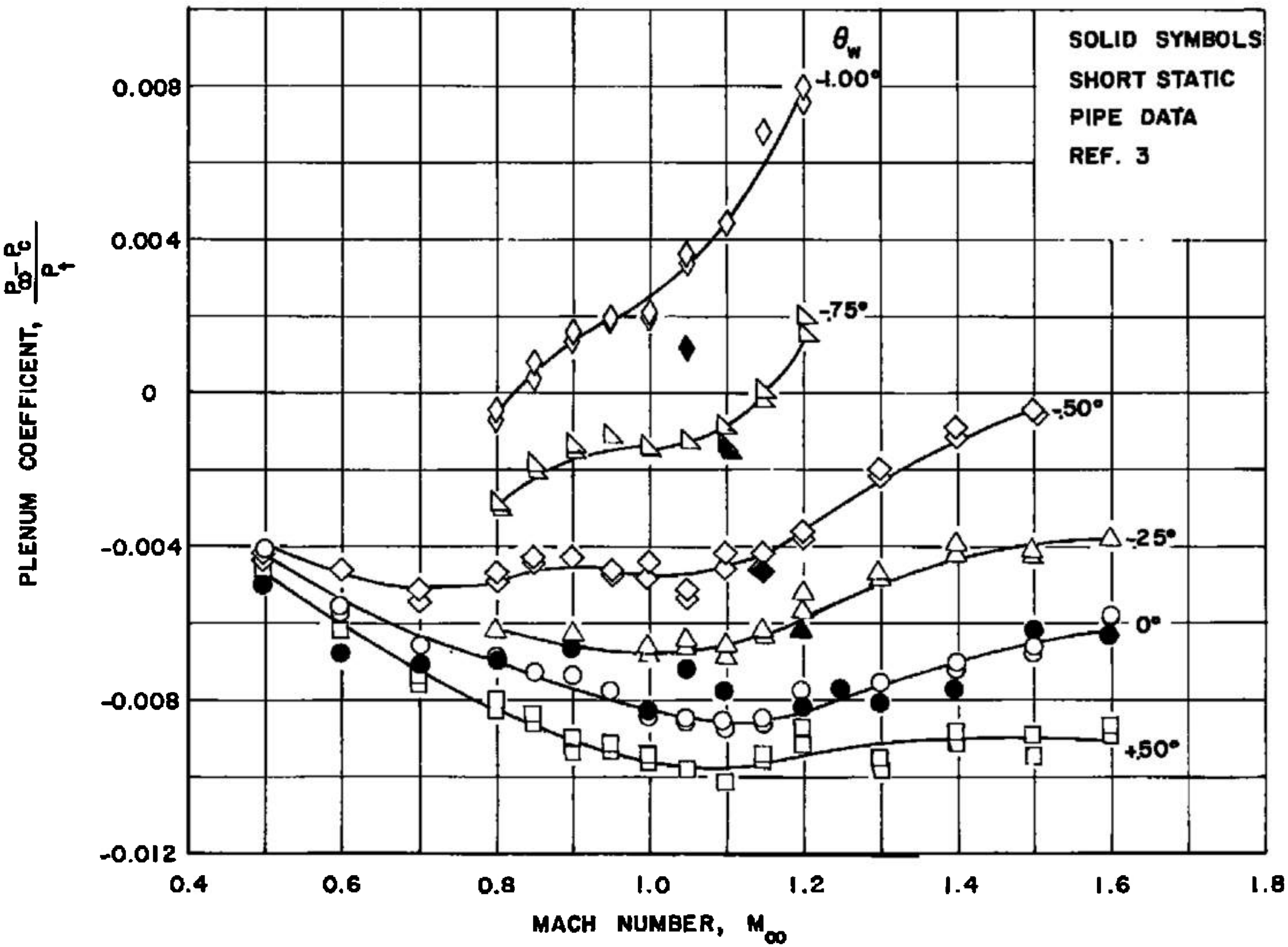


Fig. 10 Effect of Wall Angle on the Test Section Calibration – Tunnel 16T Data from Solid Plates Compared with Earlier Short Static Probe Data

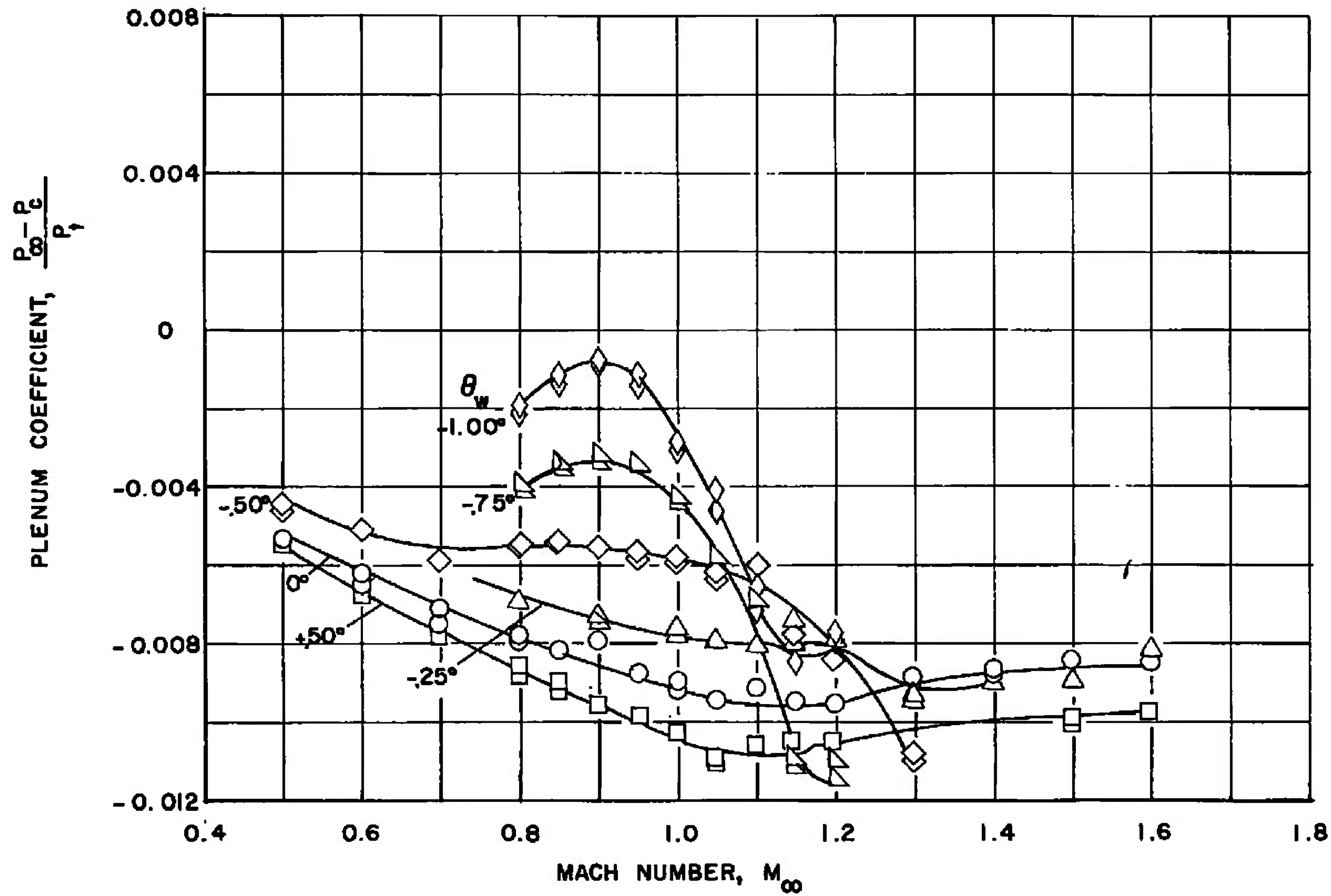
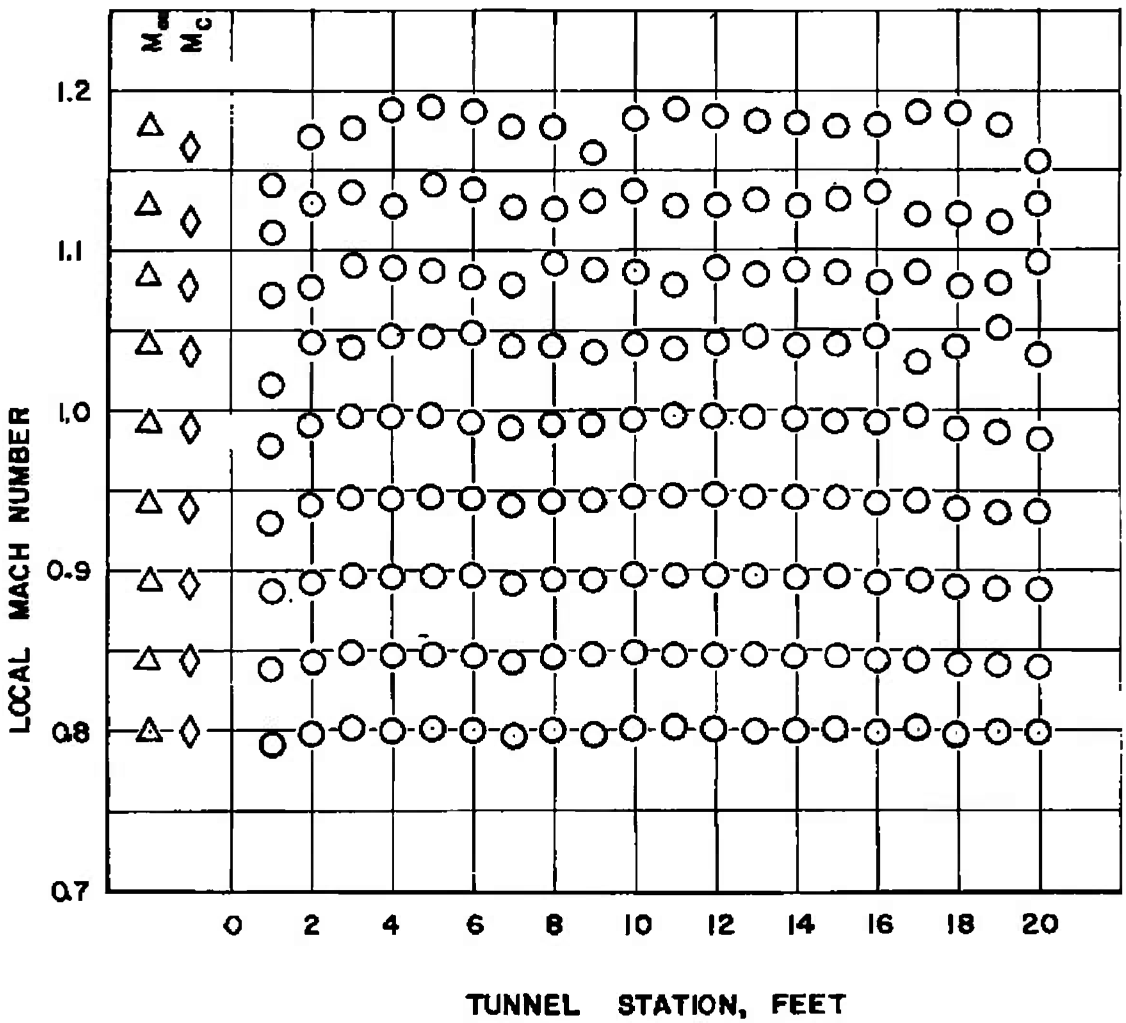
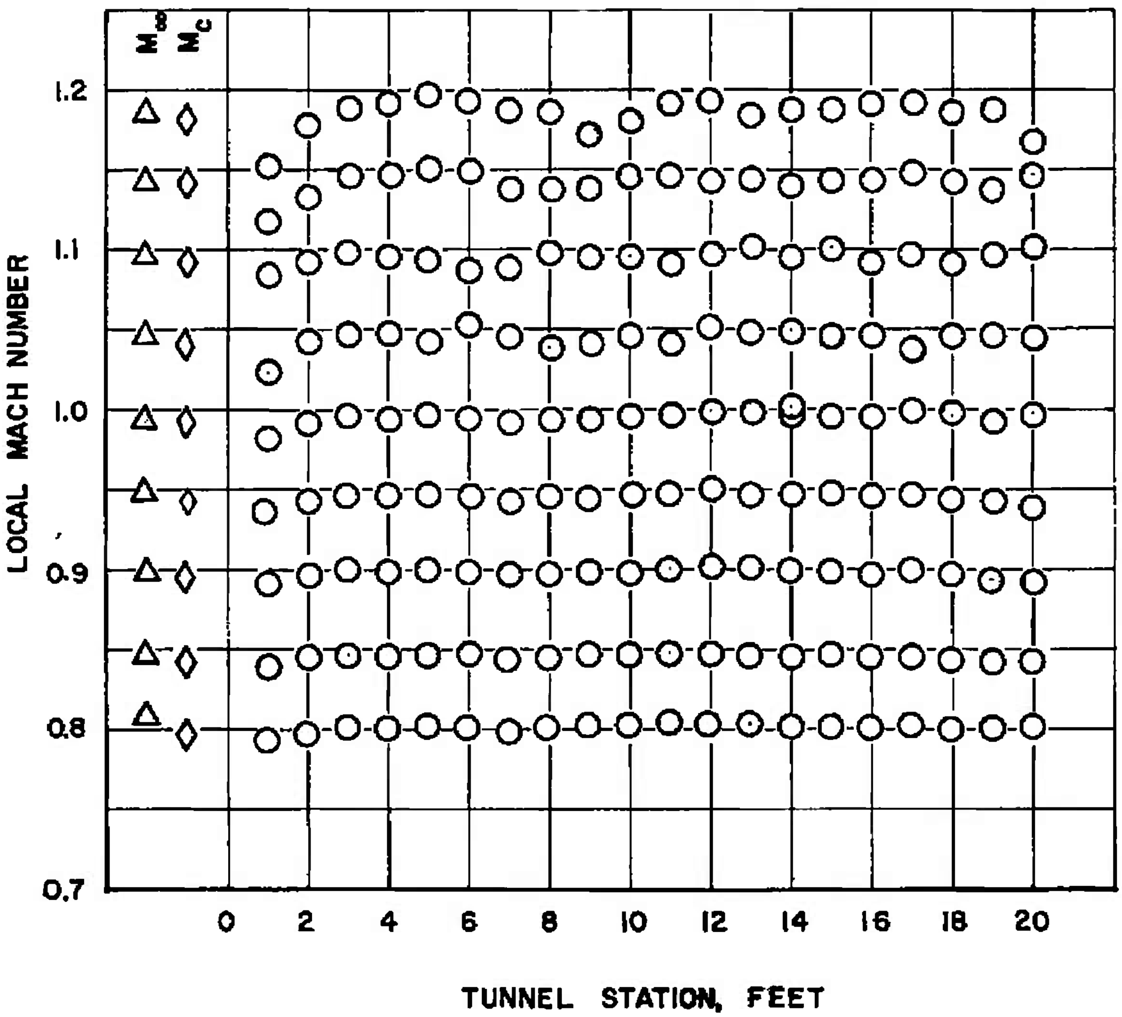


Fig. 11 Effect of Wall Angle on the Test Section Calibration – Tunnel 16T Data from Orifices on Perforated Walls



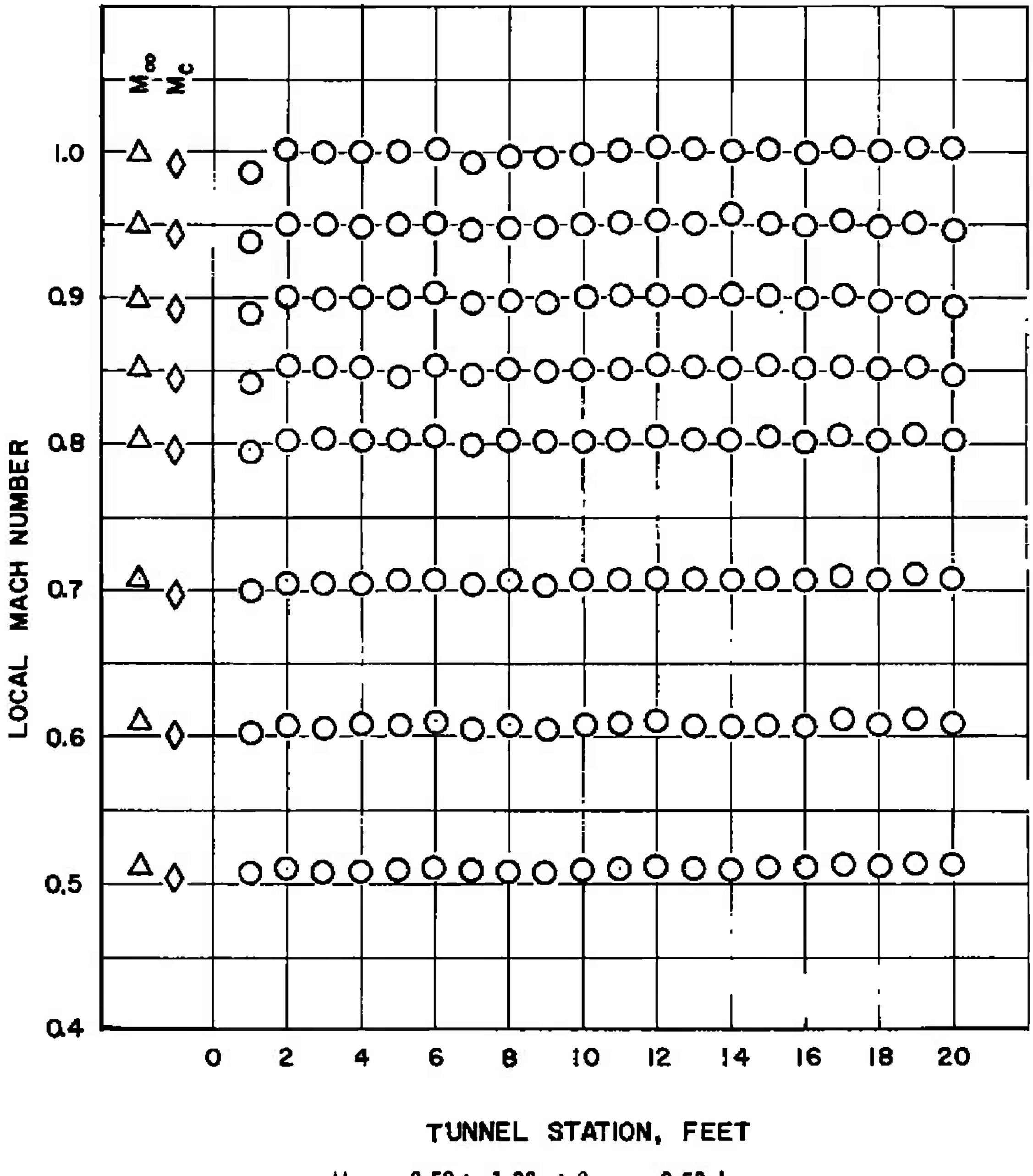
a. M_{∞} = 0.80 to 1.20 at θ_w = −1.00 deg

Fig. 12 Mach Number Distribution on Solid Plates at Various Wall Angles



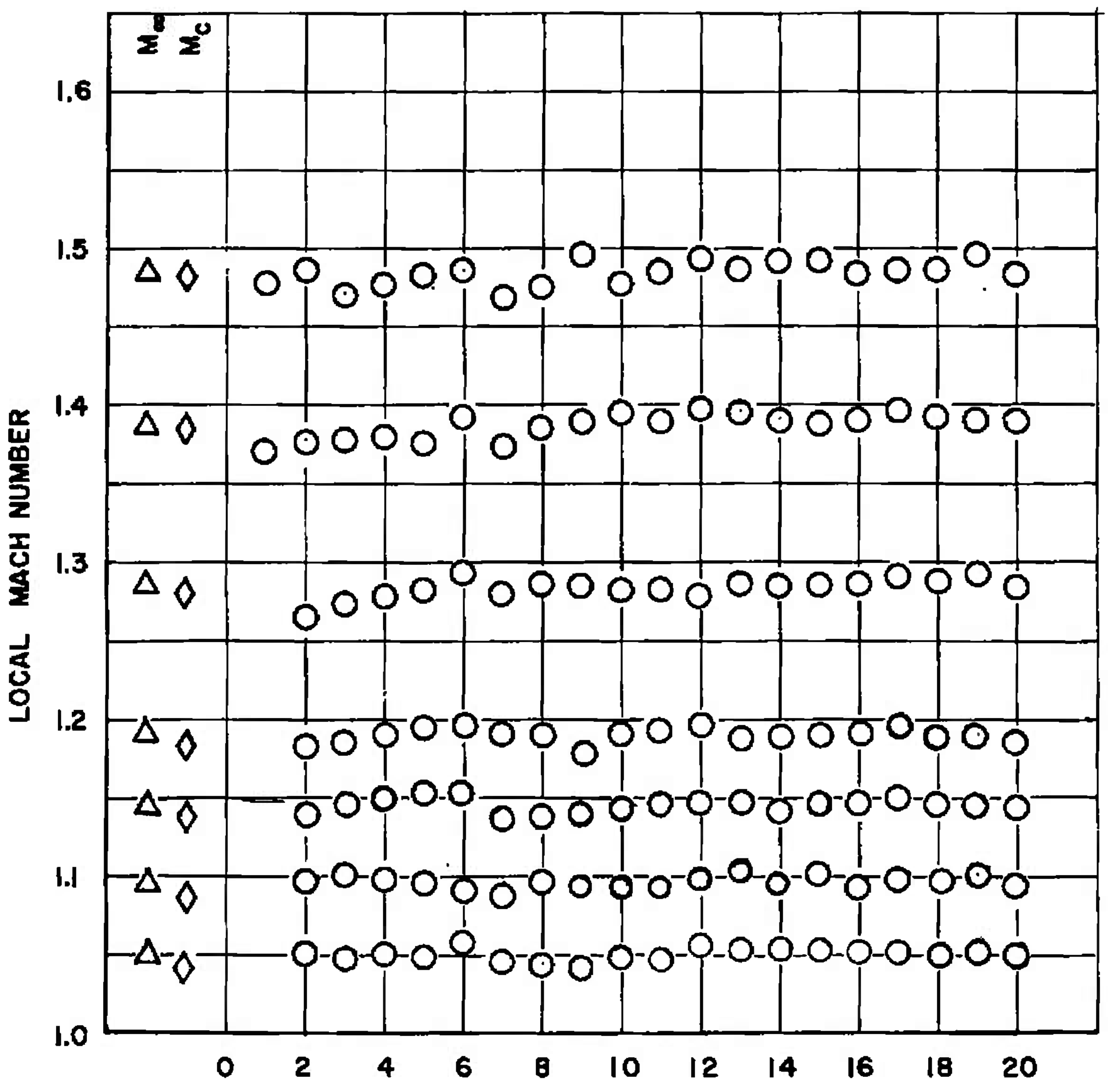
b. M_∞ = 0.80 to 1.20 at θ_w = −0.75 deg

Fig. 12 Continued



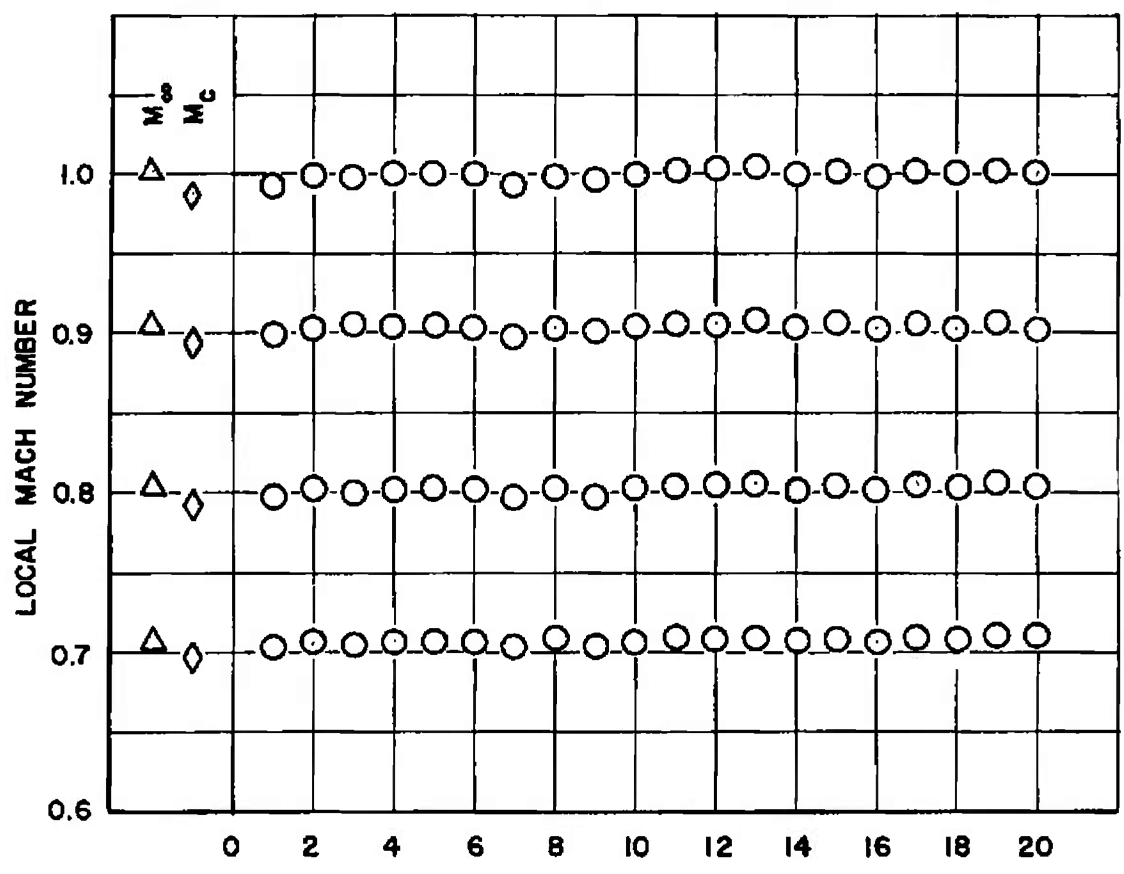
c. M_∞ = 0.50 to 1.00 at θ_w = ~0.50 deg

Fig. 12 Continued



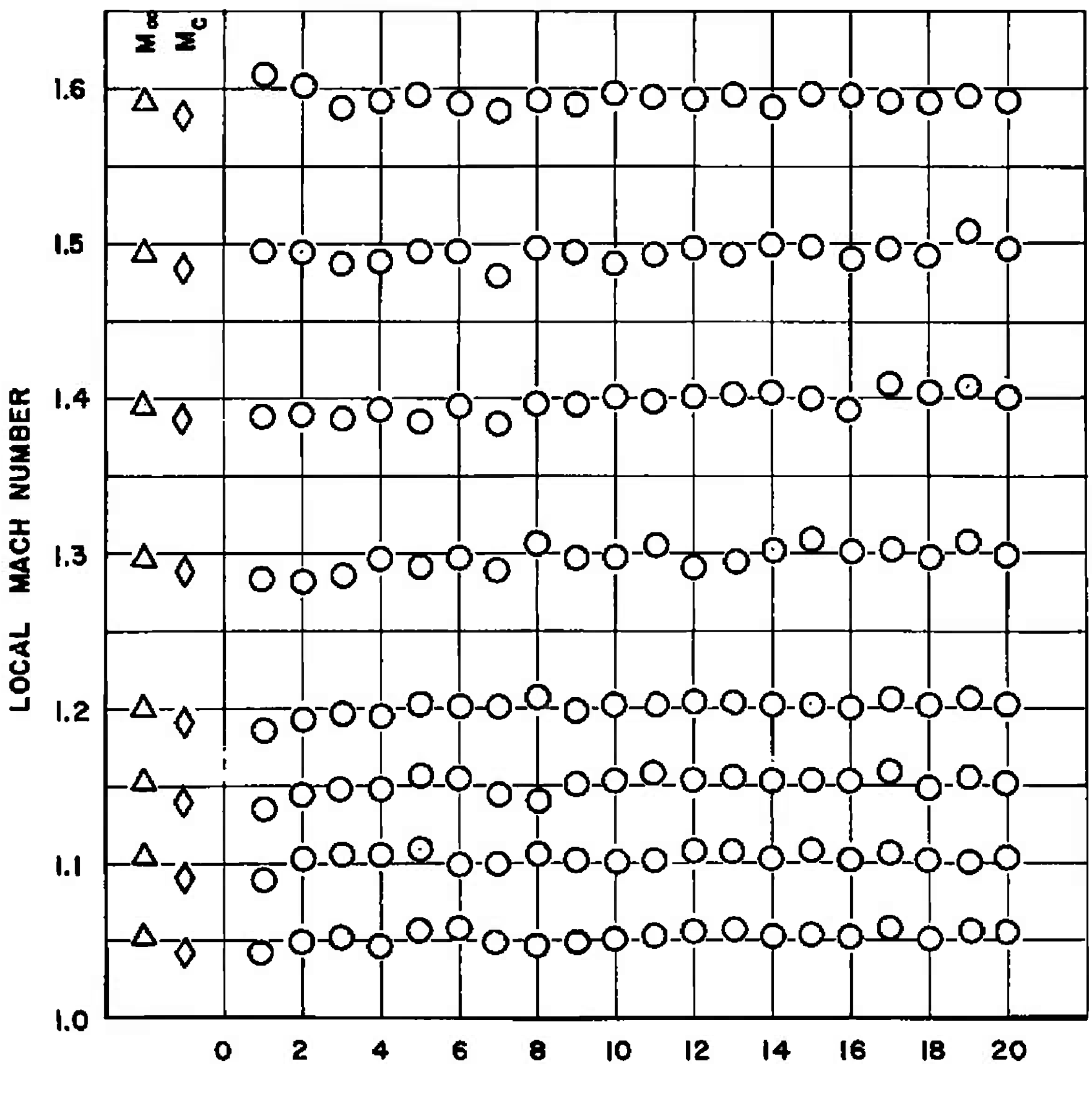
d. M_∞ = 1.05 to 1.50 at θ_w = − 0.50 deg

Fig. 12 Continued



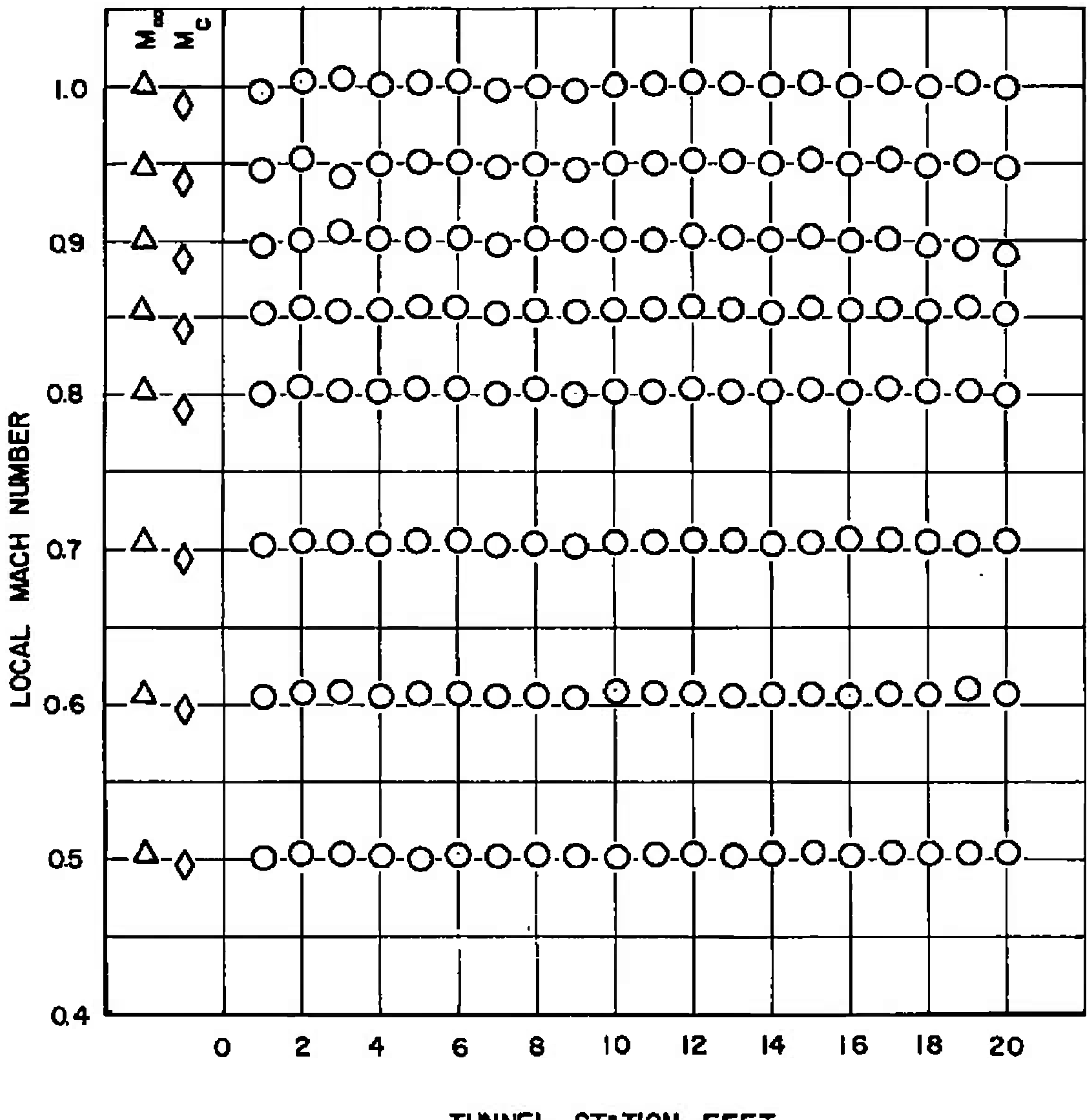
e. M_∞ = 0.70 to 1.00 at θ_w = −0.25 deg

Fig. 12 Continued



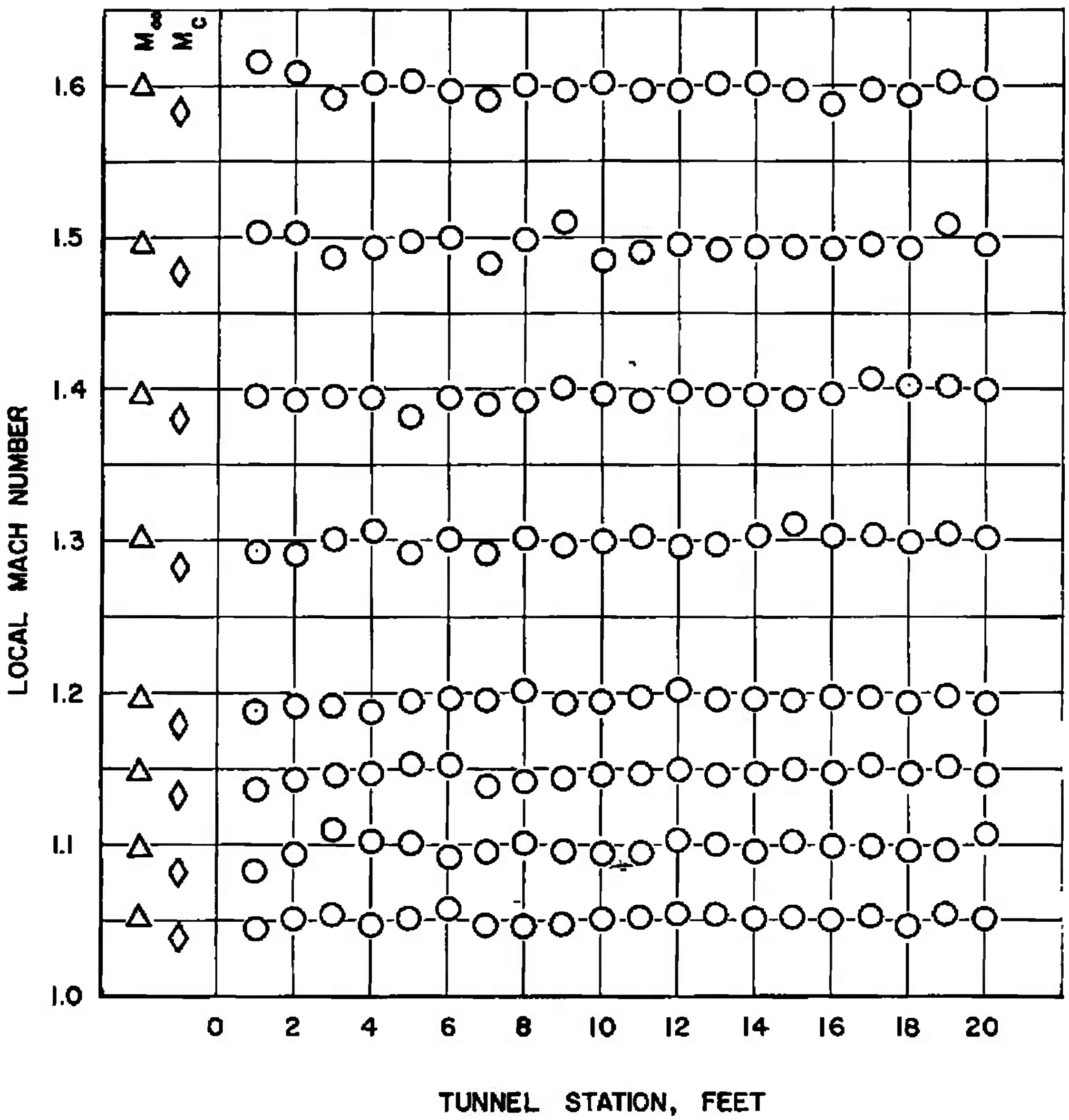
f. M_∞ = 1.05 to 1.60 at θ_w = −0.25 deg

Fig. 12 Continued



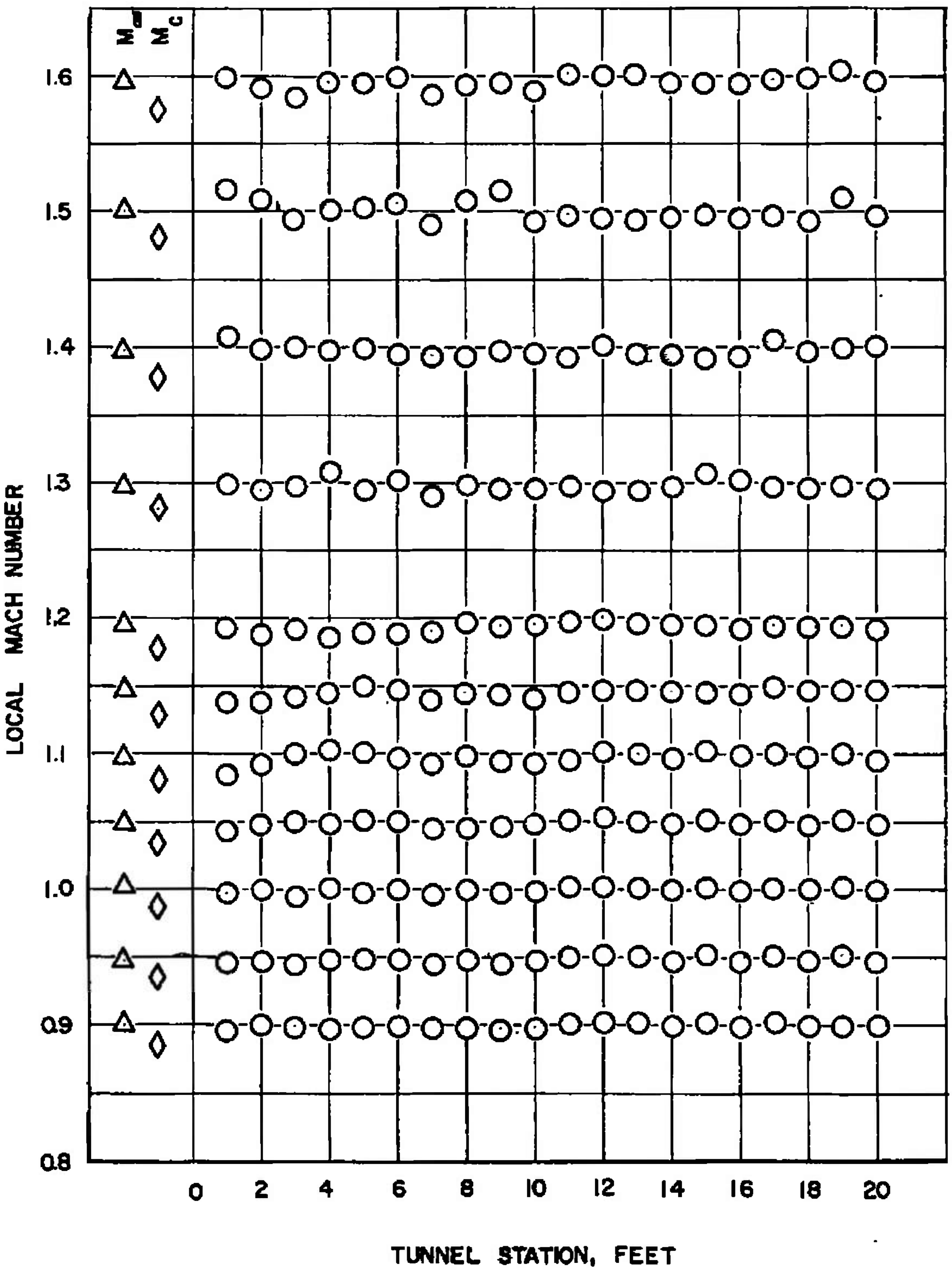
g. M_∞ = 0.50 to 1.00 at θ_w = 0 deg

Fig. 12 Continued



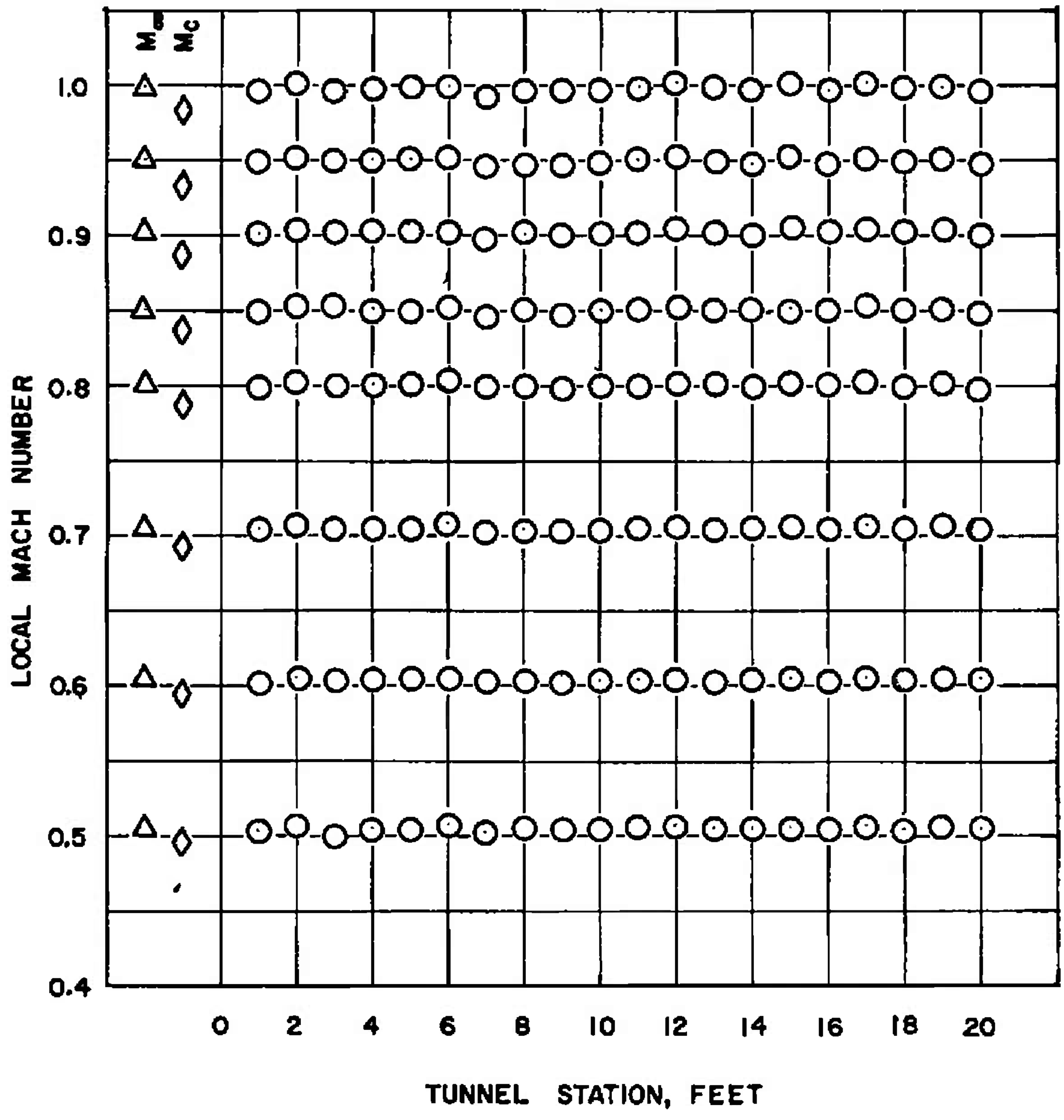
h. M_∞ = 1.05 to 1.60 at θ_w = 0 deg

Fig. 12 Continued



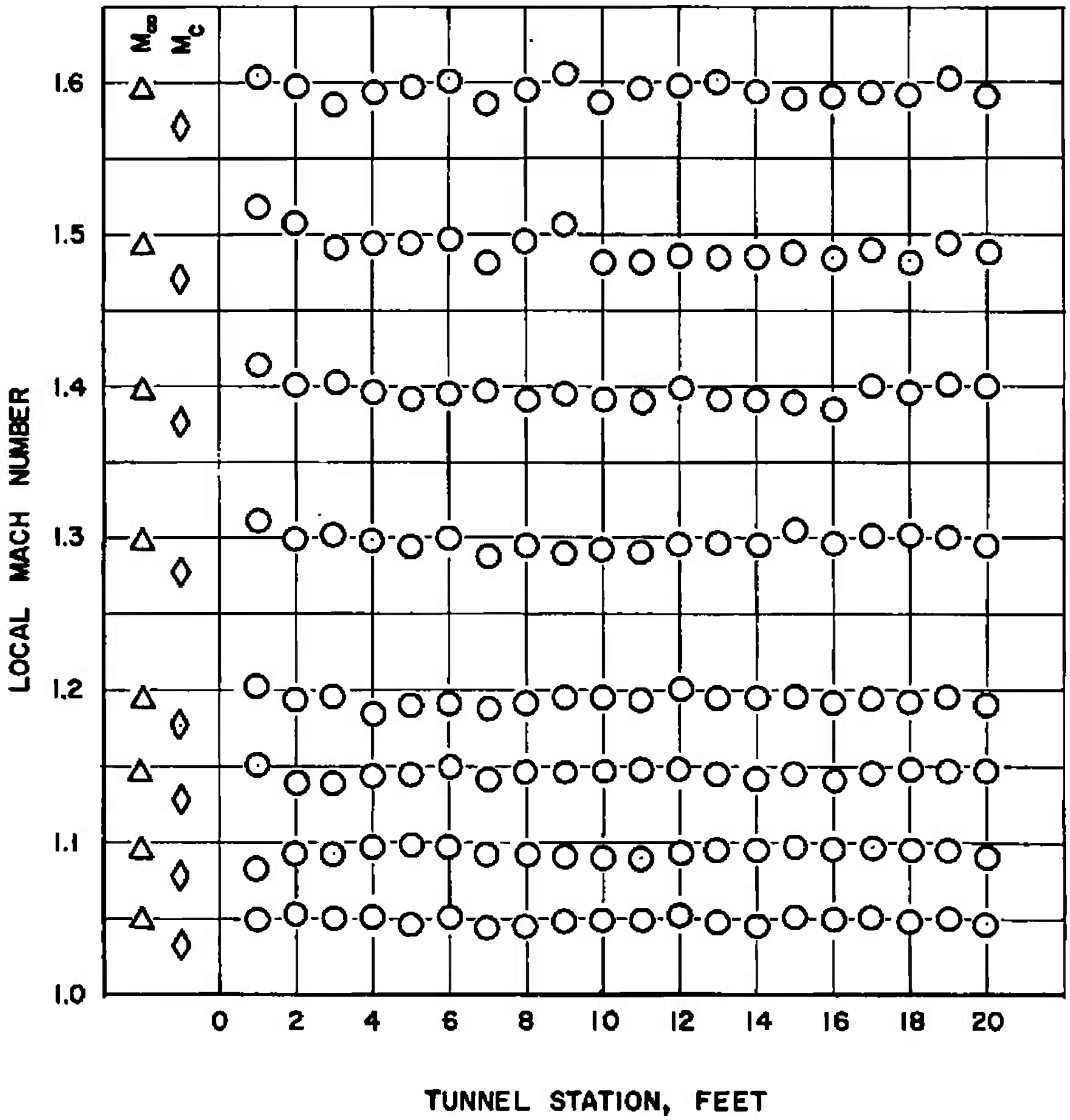
i. M_∞ = 0.90 to 1.60 at θ_w = + 0.25 deg

Fig. 12 Continued



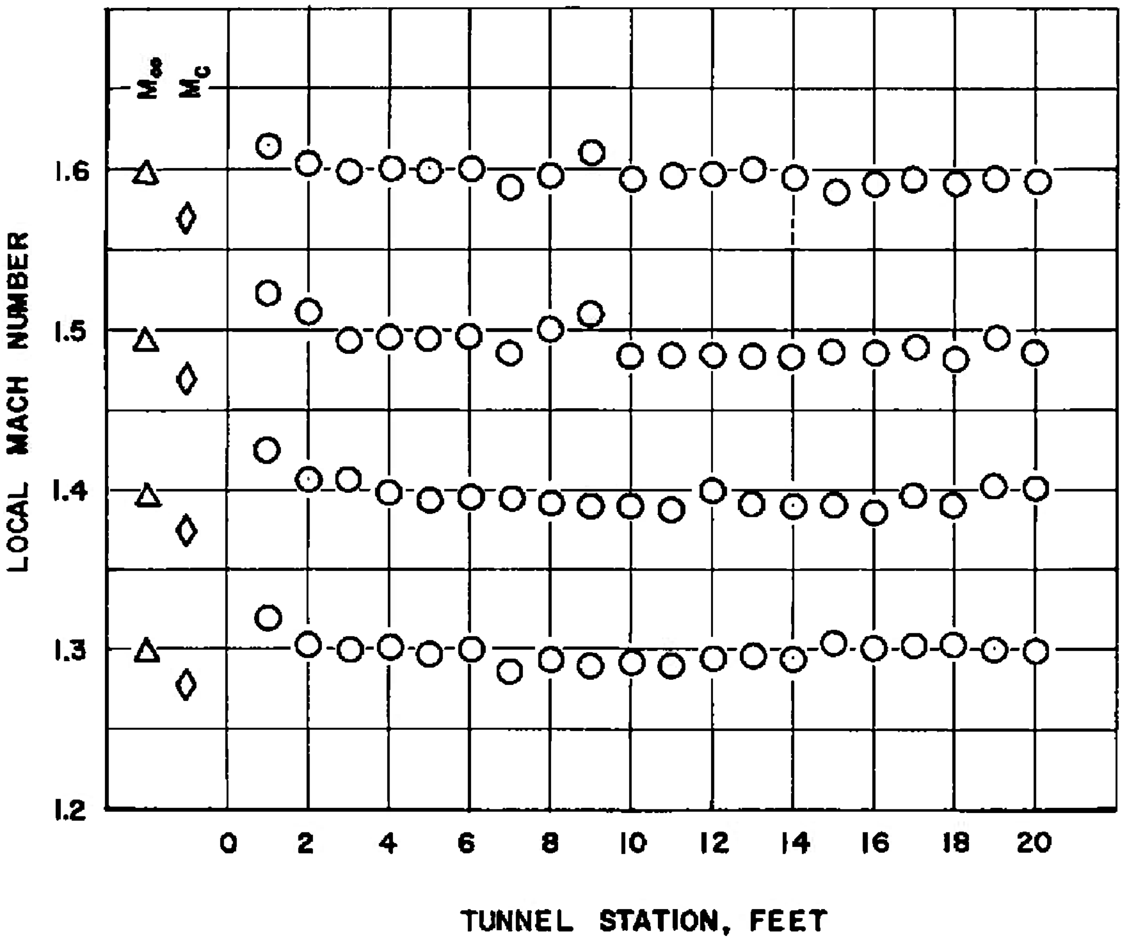
j. M_∞ = 0.50 to 1.00 at θ_w = + 0.50 deg

Fig. 12 Continued



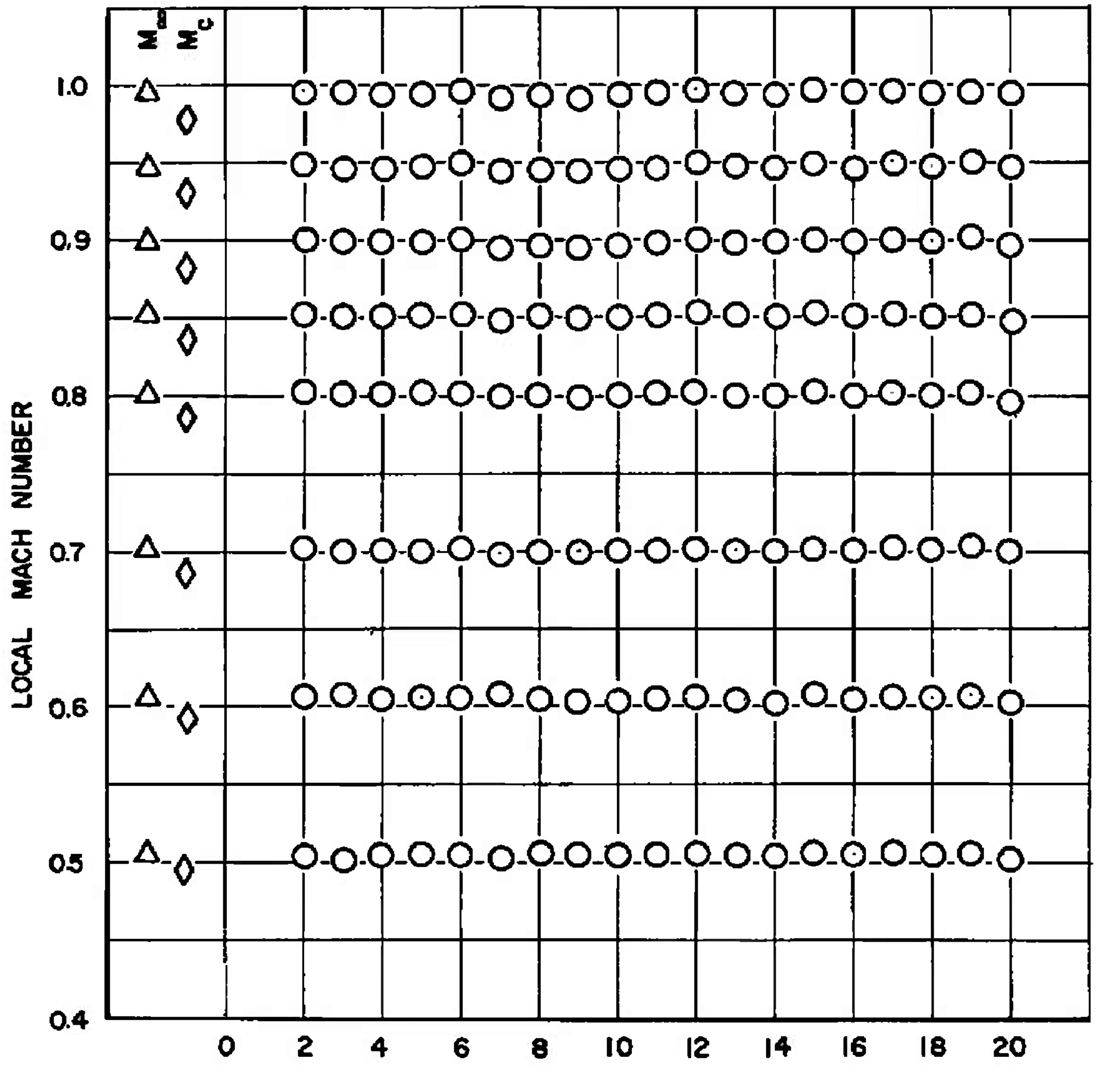
k. M_∞ = 1.00 to 1.60 at θ_w = +0.50 deg

Fig. 12 Continued



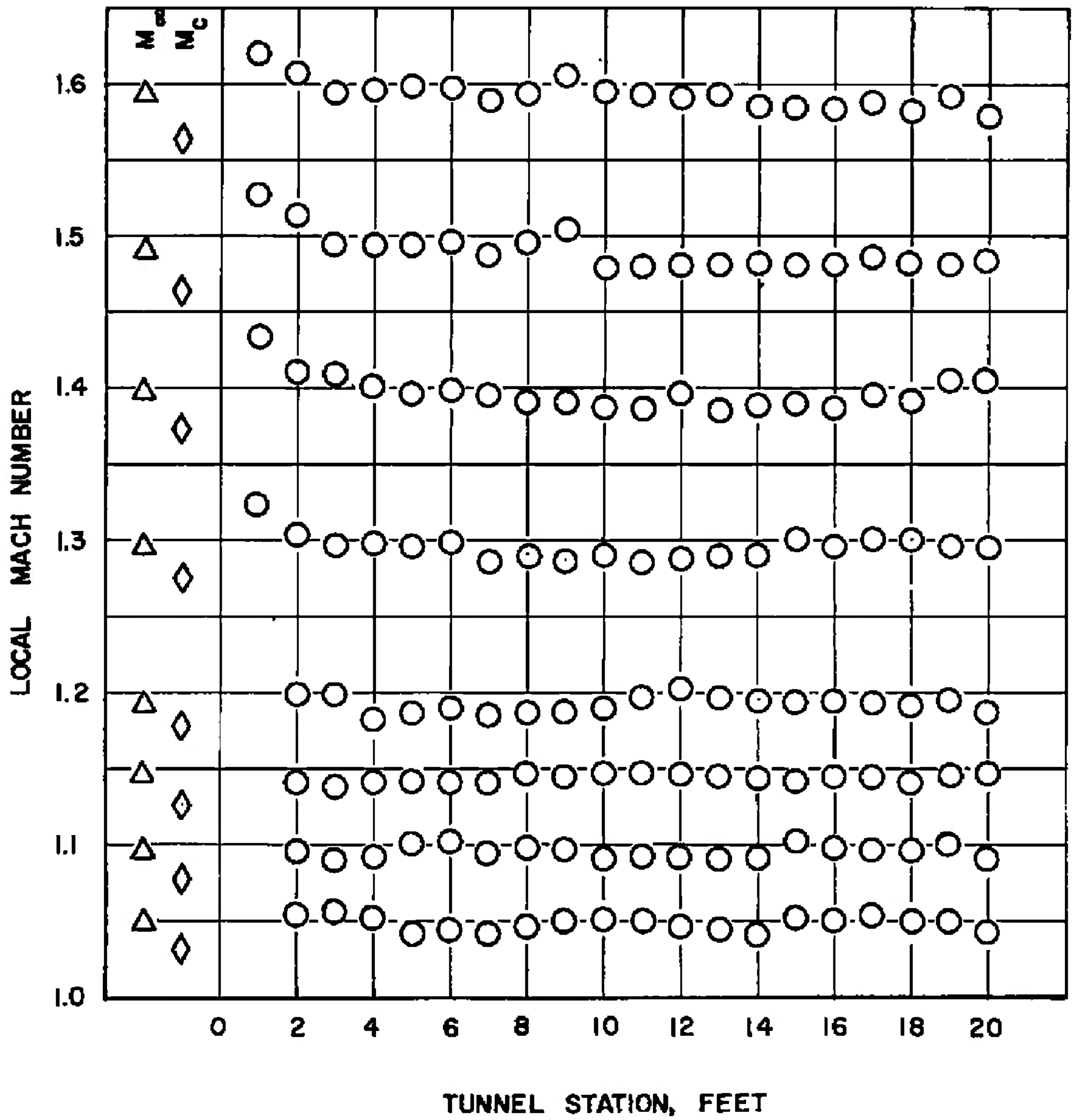
l. M_∞ = 1.30 to 1.60 at θ_w = +0.75 deg

Fig. 12 Continued



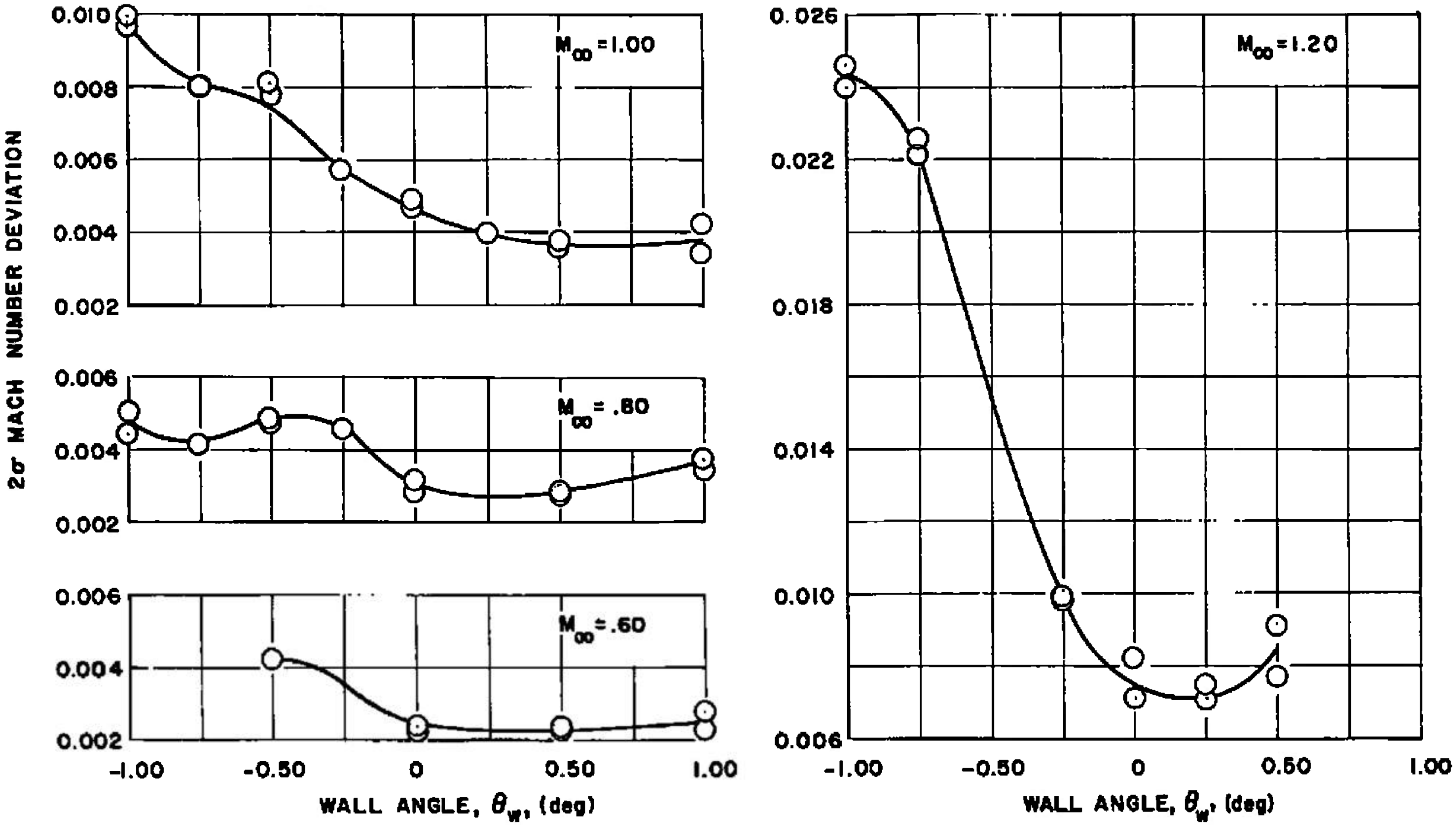
m. M_∞ = 0.50 to 1.00 at θ_w = + 1.00 deg

Fig. 12 Continued



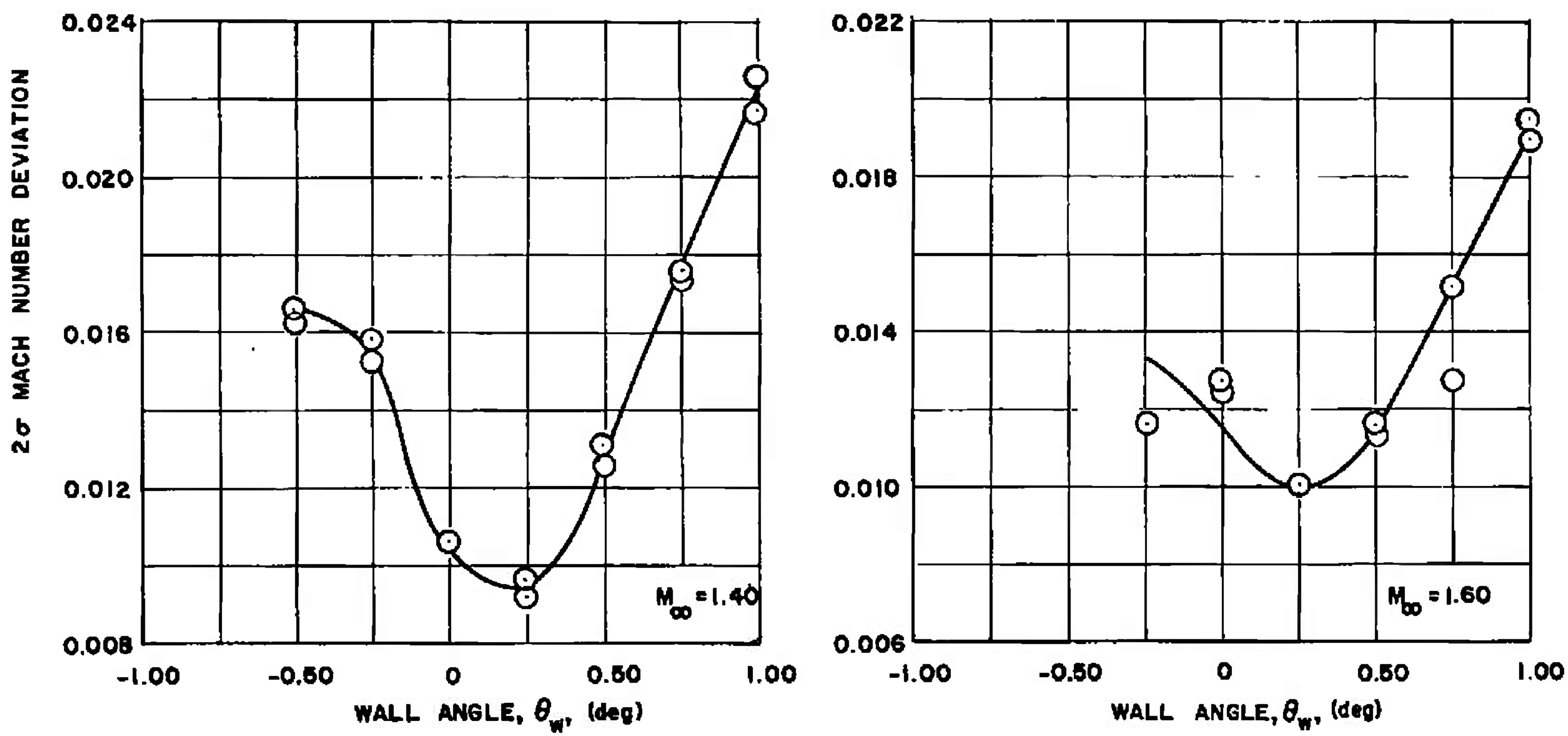
n. M_∞ = 1.05 to 1.60 at θ_w = + 1.00 deg

Fig. 12 Concluded



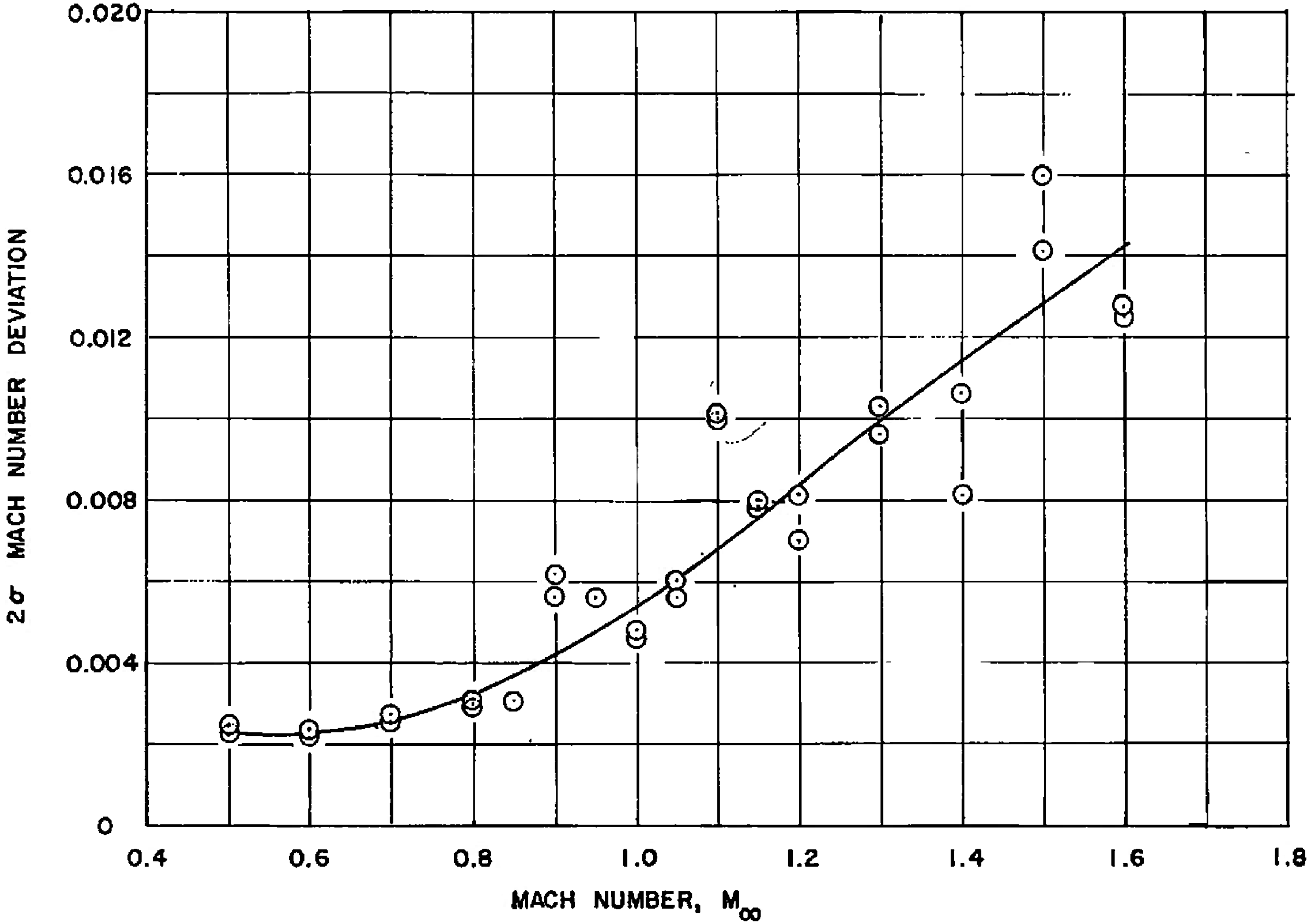
a. M_∞ ~ 0.60, 0.80, 1.00, and 1.20

Fig. 13 Statistical Evaluation of Empty Test Section Mach Number Deviations at Various Nominal Mach Numbers



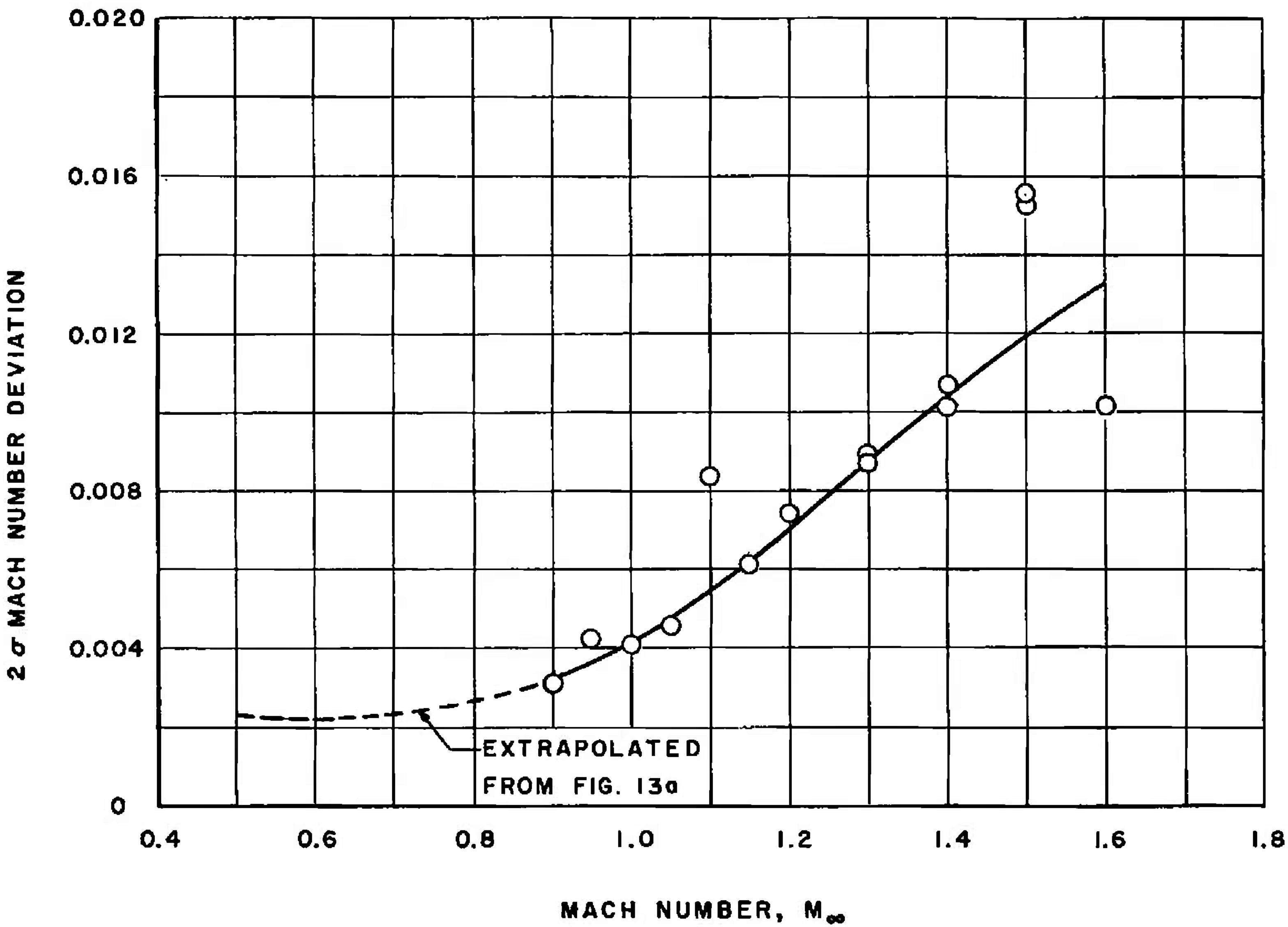
b. M_∞ = 1.40 and 1.60

Fig. 13 Concluded



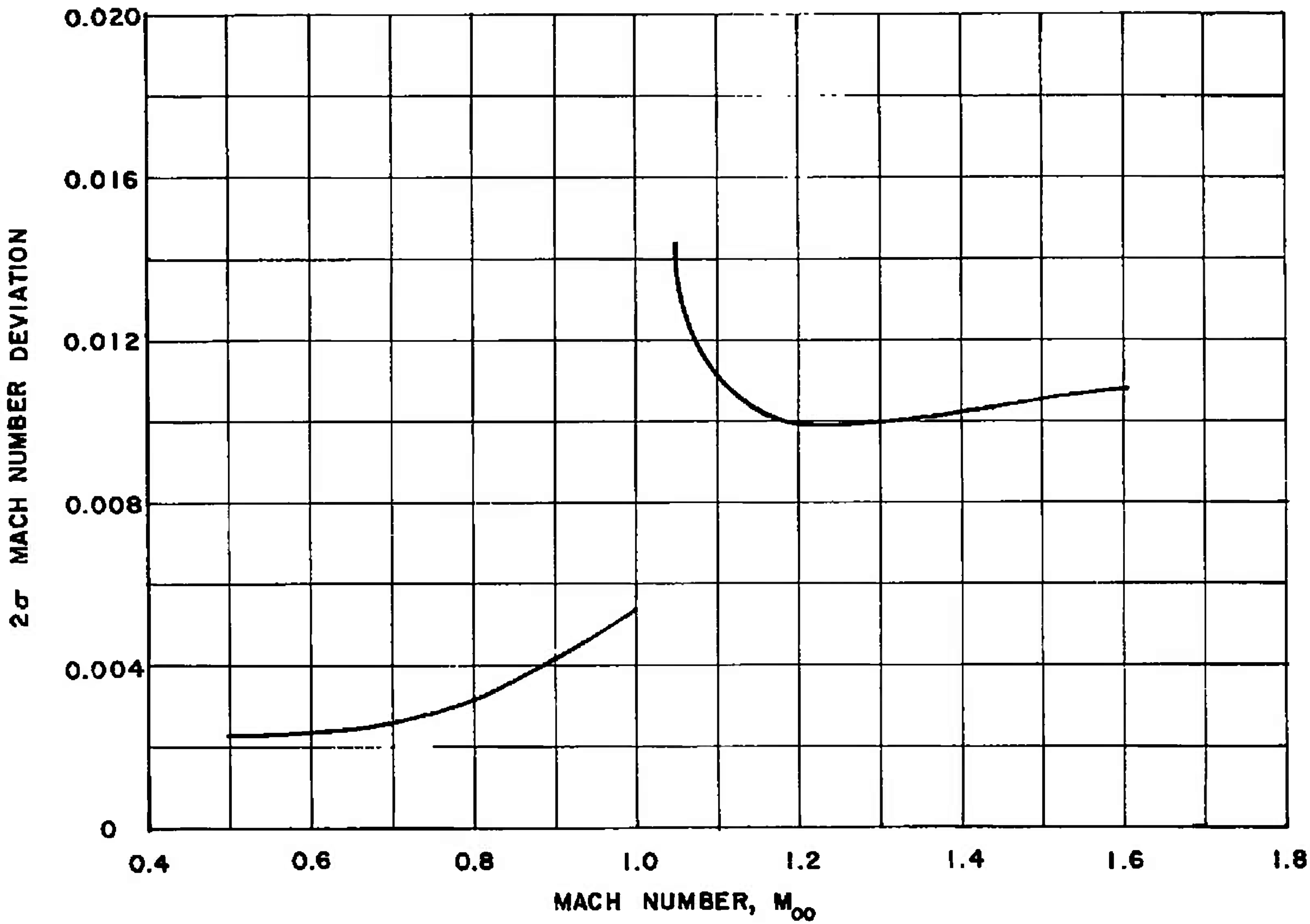
a. θ_w = 0 deg

Fig. 14 Local Mach Number Variation at θ_w = 0 deg, θ_w = 0.25 deg, and θ_w = θ_w* Based on 95-percent Confidence Level



b. θ_w = 0.25 deg

Fig. 14 Continued



c. $\theta_w = \theta_w^*$

Fig. 14 Concluded

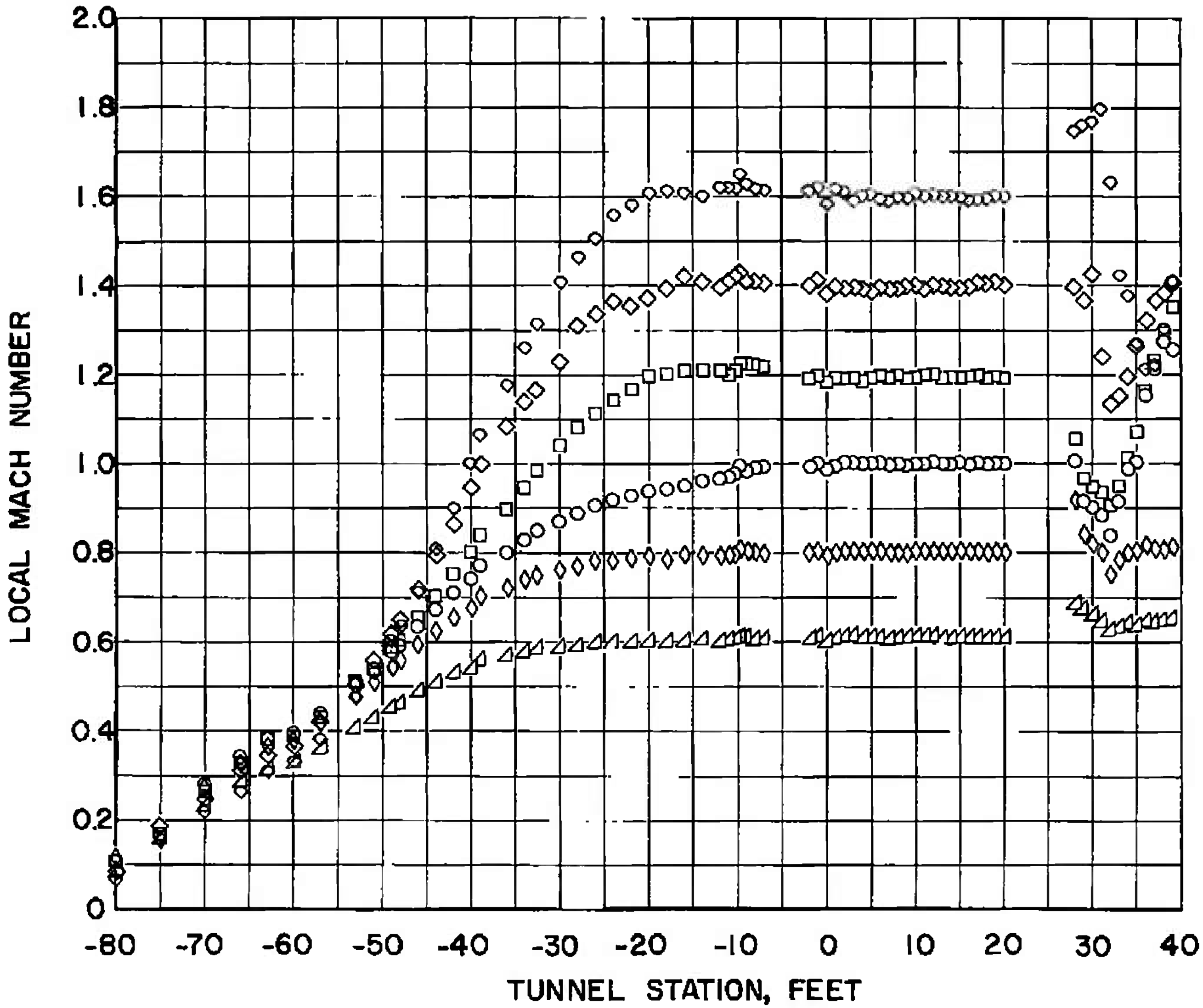


Fig. 15 Lower Wall Mach Number Distribution through Contraction, Nozzle, and Test Section for Various Test Section Mach Numbers at θ_w = 0 deg

APPENDIX I
LINEARIZED CALIBRATION EQUATIONS

A goal of this test program was to reduce the calibration to a form which could be easily stored in the computer for on-line data reduction. This goal was achieved in the following manner:

The relation between (M_{TS} - M_c) and M_{TS}, Fig. 7, for a constant wall angle was approximated graphically by three straight-line segments. These segments formed the low, mid, and high transonic Mach number ranges. It should be noted that the parameters (M_{TS} - M_c) and M_{TS} were used instead of the more straightforward approach of M_{TS} and M_c to give more resolution to the data and, therefore, facilitate the graphical means of obtaining the calibration relations.

In any range the general equation of a line segment for a constant wall angle is:

$$(M_{TS} - M_c) = k M_{TS} + b \qquad \text{(I-1)}$$

where k and b are the slope and intercept, respectively. Rearranging Eq. (I-1) gives

$$M_{TS} = \left(\frac{1}{1-k}\right) M_c + \left(\frac{b}{1-k}\right) \qquad \text{(I-2)}$$

and defining the parameters

$$k_\theta = \left(\frac{1}{1-k}\right) \qquad \text{(I-3)}$$

$$b_\theta = \left(\frac{b}{1-k}\right) \qquad \text{(I-4)}$$

results in the equation

$$M_{TS} = k_\theta M_c + b_\theta \qquad \text{(I-5)}$$

From the text it was concluded that

$$M_\infty = M_{TS} \qquad \text{(I-6)}$$

and therefore

$$M_\infty = k_\theta M_c + b_\theta \qquad \text{(I-7)}$$

It was assumed that k_θ and b_θ are functions of θ_w, and therefore a family of line segments can be defined in each range. The graphically measured values of k and b were used to calculate k_θ and b_θ, which were reduced by a computer to a "sum-of-the-least-squares" curve fit for each range. The six equations formed are as follows: (Note the subscripts ℓ, m, and h denote low, medium, and high Mach number ranges)

$$k_{\theta_\ell} = (4.68349 \times 10^{-3})\,\theta_w^5 + (-8.94881 \times 10^{-3})\,\theta_w^4 + (1.04264 \times 10^{-2})\,\theta_w^3 + (-1.29942 \times 10^{-2})\,\theta_w^2 + (9.51048 \times 10^{-3})\,\theta_w + (1.01274) \quad \text{(I-8)}$$

$$b_{\theta_\ell} = (-4.82642 \times 10^{-3})\,\theta_w^5 + (9.38471 \times 10^{-3})\,\theta_w^4 + (-5.37987 \times 10^{-3})\,\theta_w^3 + (4.35438 \times 10^{-3})\,\theta_w^2 + (-2.03608 \times 10^{-3})\,\theta_w + (1.37811 \times 10^{-3}) \quad \text{(I-9)}$$

$$k_{\theta_m} = (-2.75364 \times 10^{-3})\,\theta_w^5 + (2.80392 \times 10^{-3})\,\theta_w^4 + (5.77389 \times 10^{-3})\,\theta_w^3 + (-3.42326 \times 10^{-3})\,\theta_w^2 + (6.00905 \times 10^{-3})\,\theta_w + (1.00268) \quad \text{(I-10)}$$

$$b_{\theta_m} = (2.77071 \times 10^{-4})\,\theta_w^5 + (-9.56196 \times 10^{-5})\,\theta_w^4 + (-2.66601 \times 10^{-4})\,\theta_w^3 + (-5.66745 \times 10^{-3})\,\theta_w^2 + (1.54495 \times 10^{-3})\,\theta_w + (1.12929 \times 10^{-2}) \quad \text{(I-11)}$$

$$k_{\theta_h} = (-1.19467 \times 10^{-3})\,\theta_w^5 + (3.21790 \times 10^{-3})\,\theta_w^4 + (5.42545 \times 10^{-3})\,\theta_w^3 + (-2.48307 \times 10^{-2})\,\theta_w^2 + (3.78741 \times 10^{-2})\,\theta_w + (1.00519) \quad \text{(I-12)}$$

$$b_{\theta_h} = (-2.68307 \times 10^{-3})\,\theta_w^5 + (-3.23442 \times 10^{-3})\,\theta_w^4 + (5.51800 \times 10^{-3})\,\theta_w^3 + (1.85721 \times 10^{-2})\,\theta_w^2 + (-3.62867 \times 10^{-2})\,\theta_w + (8.25986 \times 10^{-3}) \quad \text{(I-13)}$$

Values of θ_W from -1.00 to +1.00 deg in increments of 0.10 deg were used to evaluate the intersection points of the straight line segments between adjoining regions. These intersection points were fitted to fifth-order polynomials for M_C and M_∞ as functions of θ_W. The resulting four equations are:

$$M_{c(\ell,m)} = (-1.07567 \times 10^{-1})\,\theta_w^5 + (4.54862 \times 10^{-3})\,\theta_w^4 + (1.67529 \times 10^{-1})\,\theta_w^3 + (-5.74300 \times 10^{-2})\,\theta_w^2 + (3.12362 \times 10^{-3})\,\theta_w + (9.85932 \times 10^{-1}) \quad \text{(I-14)}$$

$$M_{c(m,h)} = (5.01108 \times 10^{-2})\,\theta_w^5 + (8.42477 \times 10^{-2})\,\theta_w^4 + (-4.36116 \times 10^{-2})\,\theta_w^3 + (-1.80925 \times 10^{-1})\,\theta_w^2 + 5.92472 \times 10^{-2})\,\theta_w + (1.19274) \quad \text{(I-15)}$$

$$M_{\infty(\ell,m)} = (-1.22475 \times 10^{-1})\,\theta_w^5 + (1.12770 \times 10^{-2})\,\theta_w^4 + (1.88121 \times 10^{-1})\,\theta_w^3 + (-7.07909 \times 10^{-2})\,\theta_w^2 + (7.66990 \times 10^{-3})\,\theta_w + (1.00029) \qquad \text{(I-16)}$$

$$M_{\infty(m,h)} = (3.08744 \times 10^{-2})\,\theta_w^5 + (1.20774 \times 10^{-1})\,\theta_w^4 + (-2.02932 \times 10^{-2})\,\theta_w^3 + (-2.27465 \times 10^{-1})\,\theta_w^2 + (6.55277 \times 10^{-2})\,\theta_w + (1.21393) \qquad \text{(I-17)}$$

The equations $M_{\infty(\ell,\,m)}$ and $M_{\infty(m,\,h)}$ are used in the program which compiles the table for setting Mach number in Tunnel 16T while $M_{c(\ell,\,m)}$ and $M_{c(m,\,h)}$ are used in the on-line data reduction program which evaluates M_∞.

A plot of the linearized calibration equations for θ_W = -1.00 to +1.00 deg in increments of 0.25 deg is shown in Fig. I-1. The region in which linearization produced a deviation of ±0.001 or less in M_∞ from the calibration data is given in Fig. I-2.

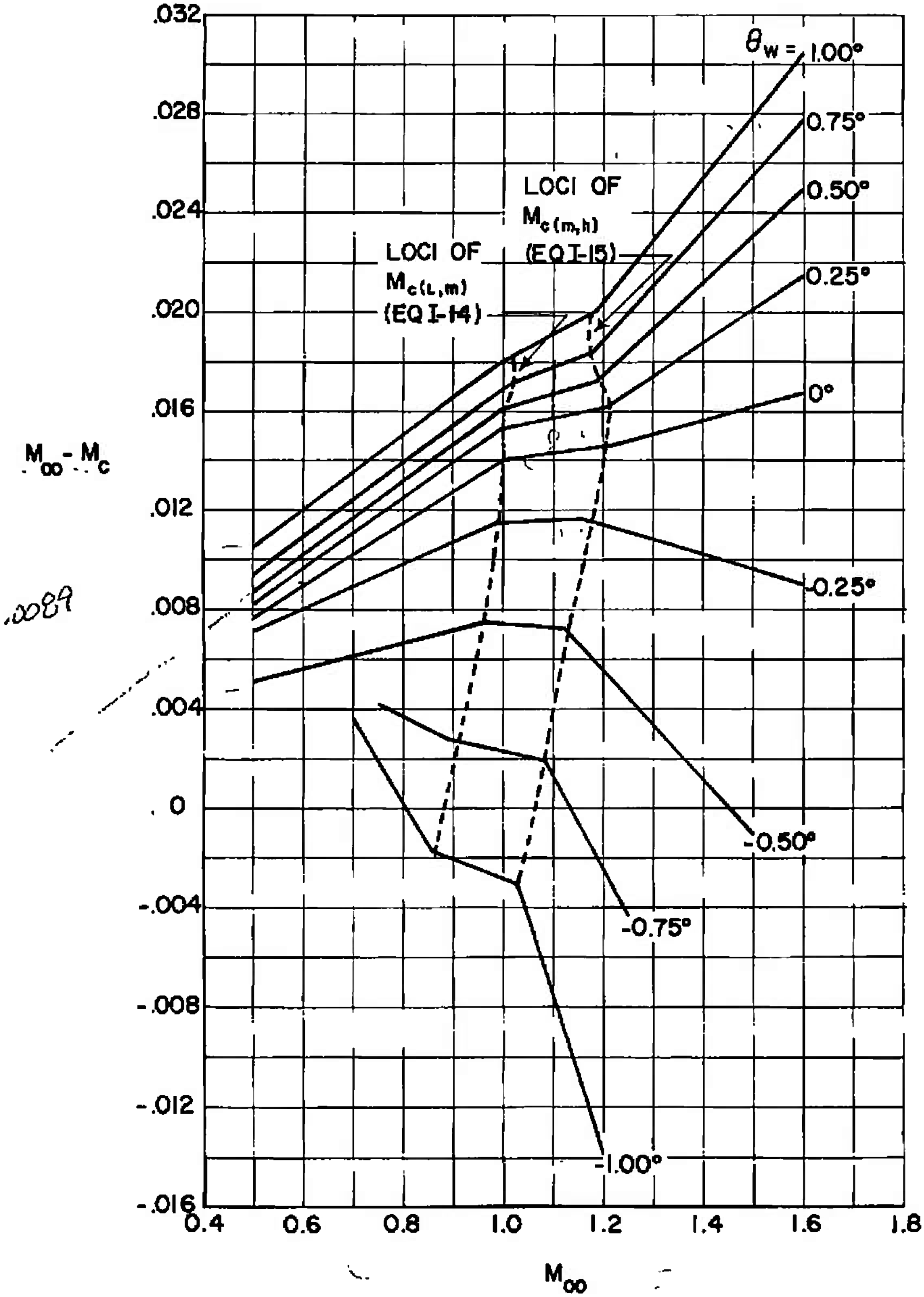


Fig. I-1 Calibration Reduced to Linear Functions

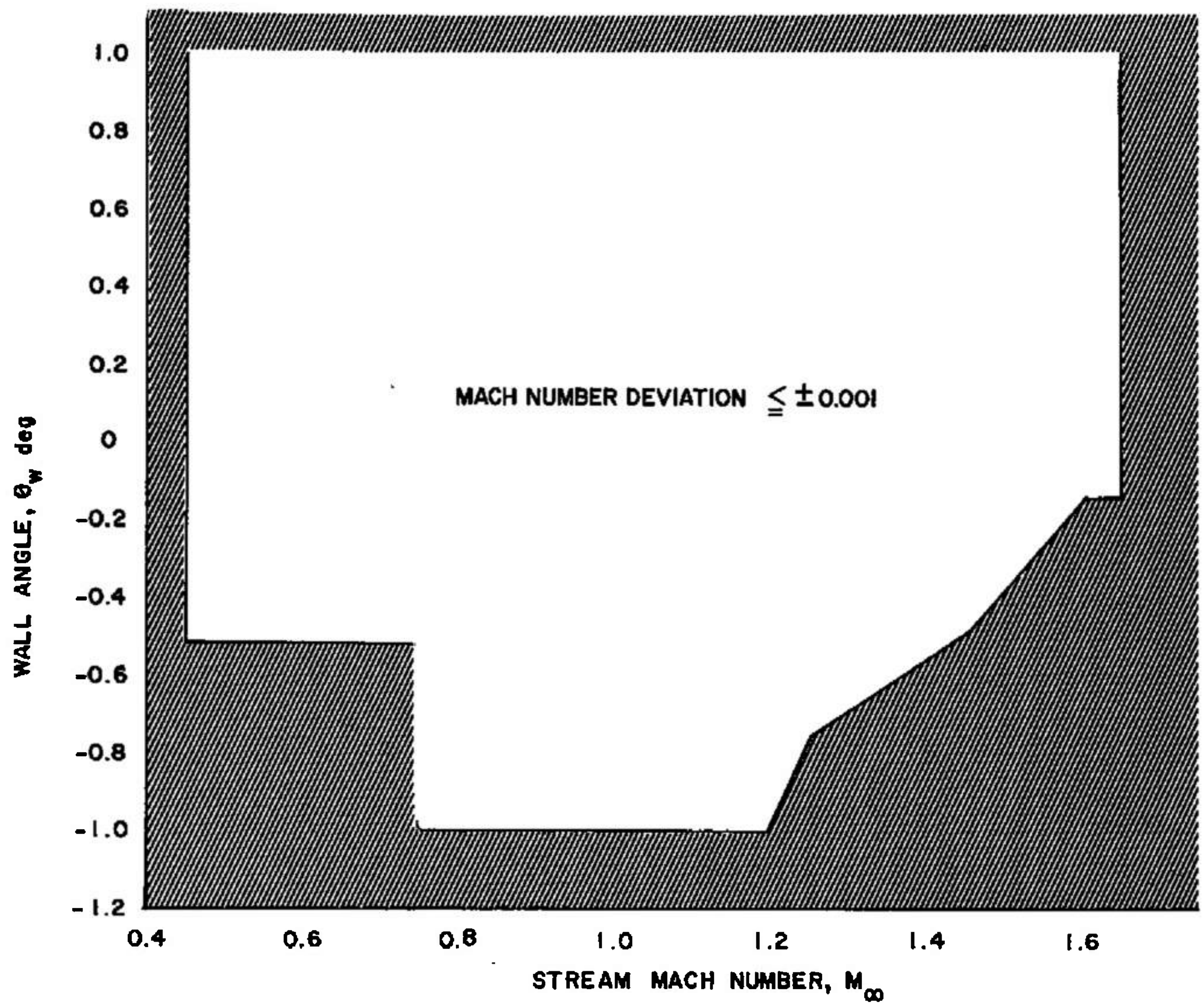


Fig. I-2 Operating Region in which Linearized Calibration Resulted in a Maximum Deviation of ±0.001 in Mach Number from Calibration Data

APPENDIX II
SUPPLEMENTAL CALIBRATION INFORMATION

In previous calibration reports, such as Refs. 2 and 3, the tunnel pressure ratio has been defined as the ratio of tunnel total pressure to the static pressure at the downstream end of the diffuser. This ratio has usually been given the symbols λ or λ_{210}. In April 1965 this definition was changed so that the tunnel pressure ratio, λ_T, is the ratio of tunnel total pressure to the compressor inlet static pressure. The correlation between λ_T and λ_{210} is given in Fig. II-1. This change is applicable to all Tunnel 16T calibration reports preceding April 1965.

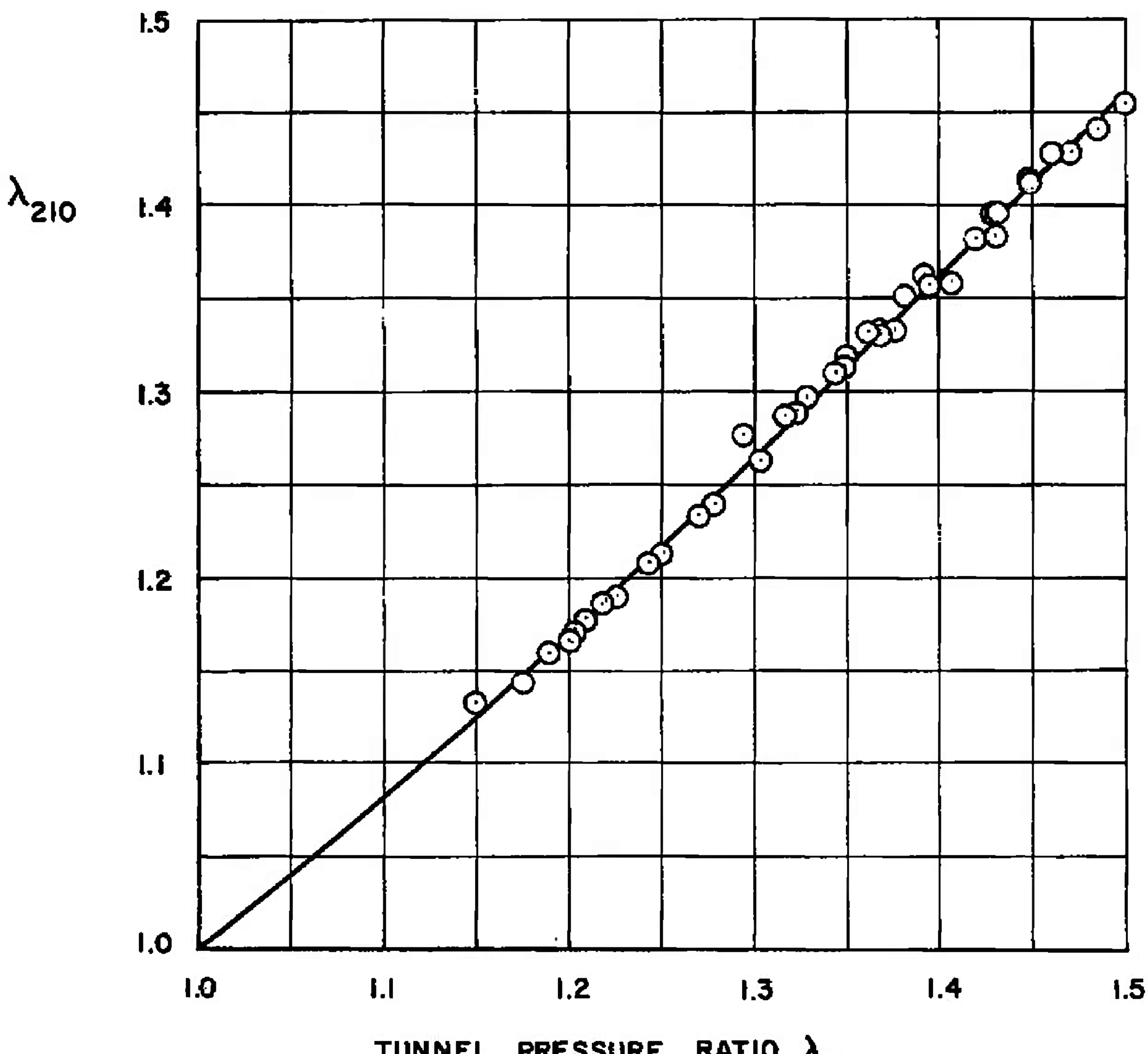


Fig. II-1 Relation between Previous Definition of Tunnel Pressure Ratio, λ_{210}, and Present Pressure Ratio, λ_T, Definition – Effective April 1965

APPENDIX III
STANDARD DEVIATION

The standard deviation, σ, of a set of n numbers, x_1, x_2, ... x_n, is approximately the root-mean-square (rms) deviation of the numbers from their average.

Even though the longitudinal deviations in Mach number from the geometric average may not be entirely a random function, the concept of random deviation may be applied to a large sample of data with some meaningful results. Mathematically applied to the Tunnel 16T Mach number data obtained from 20 orifices (n = 20) at a constant wall angle:

$$M_\infty = \frac{\sum_{i=1}^{n} M_{TS_i}}{n} \tag{III-1}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(M_{TS_i} - M_\infty\right)^2}{n-1}} \tag{III-2}$$

The standard deviation is an extremely useful distribution function since it is a measure of the distribution band. For example, 95.4 percent of all numbers of a data set which has a normal distribution will fall between -2σ and $+2\sigma$.

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13 ABSTRACT

Tests were conducted in the Propulsion Wind Tunnel, Transonic (16T) of the Propulsion Wind Tunnel Facility (PWT) to determine the test section Mach number calibration and Mach number distributions. During the test, Mach number was varied from 0.50 to 1.60, and the wall angle from -1.00 to +1.00 deg, while holding tunnel total pressure at 1000 psfa and tunnel temperature at 120°F. At all Mach numbers the region from Station 1 to Station 20 was considered the test region. The results show that the tunnel calibration is a function of test section wall angle, and that all wall angles in the calibrated Mach number range produce Mach number distributions acceptable for testing. This was the first calibration after the installation of the modified main compressor utilizing fiber glass rotor blades.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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