AD NUMBER

AD848796

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Critical technology; 24 Oct 1968. Other requests shall be referred to US Naval Ordnance Laboratory, White Oak, MD, 20910.

AUTHORITY

NOL ltr, dtd 15 Nov 1971

AD848796

NOLTR 68-187

(1)

cb

PERFORMANCE CAPABILITY OF THE NOL HYPERSONIC TUNNEL

24 OCTOBER 1968

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND. 20910

NOLTR 68-187

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of NOL.

119

NOLTR 68-187

PERFORMANCE CAPABILITY OF THE NOL HYPERSONIC TUNNEL

Prepared by:
Frank P. Baltakis

ABSTRACT: This report summarizes the performance capability data of the U. S. Naval Ordnance Laboratory's Hypersonic Tunnel. The report includes a brief description of the facility, overall performance capability data, nozzle calibration data, and some nozzle boundary-layer thickness and temperature variation data. The nozzle aerodynamic design method is indicated and its adequacy in the range of the supply and test flow conditions of the Hypersonic Tunnel is briefly discussed.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND. 20910

The following notice applies to any unclassified (including originally classified and now declassified) technical reports released to "qualified U.S. contractors" under the provisions of DOD Directive 5230.25, Withholding of Unclassified Technical Data From Public Disclosure.

NOTICE TO ACCOMPANY THE DISSEMINATION OF EXPORT-CONTROLED TECHNICAL DATA

1. Export of information contained herein, which includes, in some circumstances, release to foreign nationals within the United States, without first obtaining approval or license form the Department of State for items controlled by the International Traffic in Arms Regulations (ITAR), or the Department of Commerce for items controlled by the Export Administration Regulations (EAR), may constitute a violation of law.

2. Under 22 U.S.C. 2778 the penalty for unlawful export of items or information controlled under the ITAR is up to two years imprisonment, or a fine of $100,000, or both. Under 50 U.S.C., Appendix 2410, the penalty for unlawful export of items or information controlled under the EAR is a fine of up to $1,000,000, or five times the value of the exports, whichever is greater; or for an individual, imprisonment of up to 10 years, or a fine of up to 10 years, or a fine of up to $250,000, or both.

3. In accordance with your certification that establishes you as a "qualified U.S. Contractor", unauthorized dissemination of this information is prohibited and may result in disqualification as a qualified U.S. contractor, and may be considered in determining your eligibility for future contracts with the Department of Defense.

4. The U.S. Government assumes no liability for direct patent infringement, or contributory patent infringement or misuse of technical data.

5. The U.S. Government does not warrant the adequacy, accuracy, currency, or completeness of the technical data.

6. The U.S. Government assumes no liability for loss, damage. Or injury resulting form manufacture or use for any purpose of any product, article, system, or material involving reliance upon any or all technical data furnished in response to the request for technical data.

7. If the technical data furnished by the Government will be used for commercial manufacturing or other profit potential, a license for such use may be necessary. Any payments made in support of the request for data do not include or involve any license rights.

8. A copy of this notice shall be provided with any partial or complete reproduction of these data that are provided to qualified U.S. contractors.

DESTRUCTION NOTICE

For classified documents, follow the procedures in DOD 5200.22-M, Industrial Security Manual, Section II-19 or DOD 5200.1-R, Information Security Program Regulation, Chapter IX. For unclassified, limited documents, destroy by any method that will prevent disclosure of contents or reconstruction of the document.

NOLTR 68-187 24 October 1968

PERFORMANCE CAPABILITY OF THE NOL HYPERSONIC TUNNEL

This report summarizes the performance capability data of the U. S. Naval Ordnance Laboratory's Hypersonic Tunnel. Preparation of this report was prompted by numerous requests for performance data which are needed in test program planning and also in development of new wind tunnel facilities.

The tunnel performance data have been obtained through a number of partial calibrations, some of which had been performed earlier by different staff members of the Applied Aerodynamics and Wind Tunnel Design and Operations Divisions. The author wishes to express particular appreciation to Ray Cornett for permission to reproduce a number of the overall performance figures from reference (1) and to Lawrence A. Mason for his assistance in preparation of the figures.

E. F. SCHREITER
Captain, USN
Commander

L. H. SCHINDEL
By direction

CONTENTS

TABLES

ILLUSTRATIONS

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

ILLUSTRATIONS (Cont'd)

INTRODUCTION

The present complement of nozzles for the Hypersonic Tunnel has been acquired gradually over a period of several years. Calibrations of these nozzles were performed individually as new nozzles became available. Calibration data have been documented in individual internal memos which to date have not been summarized or published.

The need for a single publication, containing the Hypersonic Tunnel performance data, has been well recognized. Such publication was not undertaken earlier in order that the information could be made more complete and up to date.

At present, refinements in nozzle calibrations, as well as further development of tunnel components, are continuing and additional data are being acquired. However, the growing need for the Hypersonic Tunnel performance information, as indicated by the increasing number of requests, makes further postponement unwarranted.

Information relating to flow uniformity in the test rhombus was considered to be of particular importance. Such data have been obtained for a wide range of nozzle supply conditions and constitute the bulk of this report. Flow angularity and some boundary-layer thickness and temperature variation data have also been obtained and the available data are included.

The physical components of the Hypersonic Tunnel and the associated instrumentation have been described previously and may be found in references (1) to (3). The overall performance capability has also been described in reference (1). This information, however, is considered essential for interpretation of the calibration data and is included in this report.

SYMBOLS

M	Mach number
P_o	supply pressure
T_o	supply temperature
α	flow deviation angle in vertical centerplane
β	flow deviation angle in horizontal centerplane

GENERAL DESCRIPTION OF THE TUNNEL

The Hypersonic Tunnel is an intermittent blowdown type facility in which heated air is used as the working medium. The air is first compressed and stored in high pressure bottles and it is heated on its way to the nozzle.

The heating system consists of a pebble bed heater and an electric resistance heater. The latter is used in addition to the pebble bed heater when the required air temperature exceeds 1150°F.

The tunnel has an open jet test section and a constant geometry diffuser. Recompression of air to the atmospheric pressure during the starting process, or during operation at low supply pressures, is accomplished by means of vacuum pumps.

NOZZLES

The nozzles are contoured and are of fixed geometry. Consequently, a separate nozzle is required for each Mach number. Table 1 lists the available nozzles and gives some of the geometry and design data. The aerodynamic design method of these nozzles is described in reference (4). Nozzle construction details are given in reference (1).

PERFORMANCE CAPABILITY

Overall Performance Capability

The overall performance capability of the Hypersonic Tunnel is summarized in Table 2. This table shows the nominal test Mach numbers, the maximum available supply pressures and temperatures, the maximum test Reynolds numbers, and the permissible flow durations at maximum pressures.

The range of Reynolds numbers, attainable at each Mach number, is shown in figure 3. The upper limit in Reynolds number here is imposed by the maximum supply pressure of the nozzle and by the minimum supply temperature at which the flow is free of liquefaction effects.* The lower Reynolds number limit is indicated by the 10 atmosphere supply pressure line.**

*The liquefaction temperatures were determined from reference (5) and, where applicable, include supersaturated conditions.

**This line is somewhat arbitrary as the tunnel can be operated at considerably lower pressures, particularly at lower Mach numbers.

The available run times at various supply pressures are shown in figure 3.

Flow Calibration Method

The quality of the flow was determined through Pitot pressure, angularity, and total temperature surveys. Pitot surveys were made by axially traversing a seven-probe rake in the horizontal and in the vertical centerplanes of the test jet.* Flow angularity measurements were made with a truncated 20-degree half-angle cone. This cone was provided with two sets of orifices for measuring differential pressures in two mutually perpendicular planes. During nozzle calibration, the cone was traversed axially along the centerline of the test jet. The temperature data were obtained with a fast-response, well-shielded thermocouple. The Mach number values were computed from the measured Pitot-to-supply pressure ratios, the flow angularities, from pressure differentials measured across two diametrically opposite orifices on the cone.

Calibration Data

The Mach number and flow angularity data are shown in figures 4 to 14. The tunnel air supply pressures and temperatures are indicated as P_o and T_o respectively. The positions of individual Pitot probes are indicated in terms of distances from the nozzle centerline.

The nozzle calibration data are not quite complete and in some cases are not final. The Mach 9 and Mach 10 nozzle data, for example, contain some scatter. These data were taken at supply temperatures slightly below the minimum required for liquefaction-free flow,** because full capacity of the heater was not available during these calibrations. The upwash angle in the flow angularity data may be in some error due to deflection of the probe. This possibility is currently being investigated and measurements with a modified probe support mechanism are being conducted.

*In some cases 45-degree planes were also used.

**The theoretical air liquefaction temperature is indicated in figure 2. In practice a slightly higher supply temperature is required because of temperature fluctuations with time. The magnitude of these fluctuations is indicated elsewhere in this report.

Mach number variation with the supply pressure is shown in figure 15. This figure was prepared by crossplotting average test section Mach numbers (from figs. 4 to 14) versus the supply pressure.

Boundary-layer thickness data are shown in figure 16. Only a limited number of measurements have been made to date. The data shown were obtained with a Pitot tube at the nozzle exit plane.

Variation in the stagnation temperature across the test jet is illustrated in figure 17. The data shown were obtained by traversing a total temperature probe across the test jet of the Mach 7 and Mach 9 nozzles.

Variation in the stagnation temperature with time is shown in figure 18. These measurements were obtained with a fast response thermocouple, located in the test section near the centerline.

CONCLUSIONS

The Hypersonic Tunnel is an intermittent blowdown type facility capable of producing test Mach numbers of 5, 6, 7, 8, 9 and 10 at supply pressures ranging from 5 to 150 atm (1 to 100 atm at Mach 5).

The tunnel is equipped with contoured nozzles of approximately 2-foot exit diameter. The aerodynamic design method for these nozzles was derived at NOL. Calibration results indicate that the nozzles have good performance over a wide range of supply conditions.

Nozzle calibrations included detailed flow Mach number surveys in the test rhombus, flow angularity surveys along the test jet centerline, and some bounday layer and air temperature measurements at the nozzle exit. The data show the following:

1. The maximum flow Mach number deviations, from the average value for a given supply pressure, are of the order of $\pm\frac{1}{2}$ percent. At supply pressures near the design,these deviations are of the order of $\pm\frac{1}{4}$ percent.

2. The maximum flow angularity is of the order of 1 degree.

3. The radial temperature gradient within the test jet core is very small, of the order of $\frac{1}{4}$ percent of the total temperature per inch. The total temperature fluctuations with time are of the order of ± 2 percent.

4. The boundary-layer thickness at the nozzle exit is about 2 inches at Mach 5 and about 4.5 inches at Mach 9. The effect of the supply pressure on the boundary-layer thickness is small.

REFERENCES

(1) Geineder, F., Schlesinger, M. I., Baum, G. and Cornett, R., "The U. S. Naval Ordnance Laboratory Hypersonic Tunnel," NOLTR 67-27, Apr 1967

(2) Risher, D. B., "Multiple Pressure Transducer Banks and Their Application," NOLTR 67-148, Sep 1967

(3) Willis, J. W., "Data Acquisition and Recording Equipment for the Naval Ordnance Laboratory's Hypersonic Tunnel No. 8," NOLTR 63-281, Jan 1964

(4) Enkenhus, K. R., Maher, E. F., "The Aerodynamic Design of Axisymmetric Nozzles for High-Temperature Air," NAVWEPS Report 7395, Feb 1962

(5) Daum, F. L. and Gyarmathy, G., "Condensation of Air and Nitrogen in Hypersonic Wind Tunnels," AIAA Journal, Vol 6, Mar 1968

TABLE 1

NOZZLE GEOMETRY DATA

Mach No.	Cross-section	Throat Dimensions in.	Overall Length in.	Exit Dimensions in.	Design Pressure PSIA	Design Temperature °F
5	Rectangular	0.6398 x 16.00	123.5	17.37 x 16.97	1100	500
6	Rectangular	0.300 x 16.00	131.4	17.90 x 17.44	1100	500
7	Circular	1.962 dia.	144.5	21.78 dia.	1175	710
8	Rectangular	0.084 x 16.00	147.5	19.47 x 18.40	1470	1000
9	Circular	1.061 dia.	163.0	22.40 dia.	1470	1200
10	Circular	0.868 dia.	145.0	24.21 dia.	1470	1350

TABLE 2

OVERALL PERFORMANCE CAPABILITY

Mach No.	Maximum Supply Pressure atm	Maximum Supply Temperature °F	Maximum Reynolds Number Million per ft	Blowing Time at Maximum Pressure Min.	Blowing Time at 25 atm Supply Pressure Min.
5	100	700	54	½	10
6	150	700	36	½	20
7	150	1000	18	1	40
8	150	1100	10	3	80
9	150	1250	6	6	200
10	150	1450	3	12	400

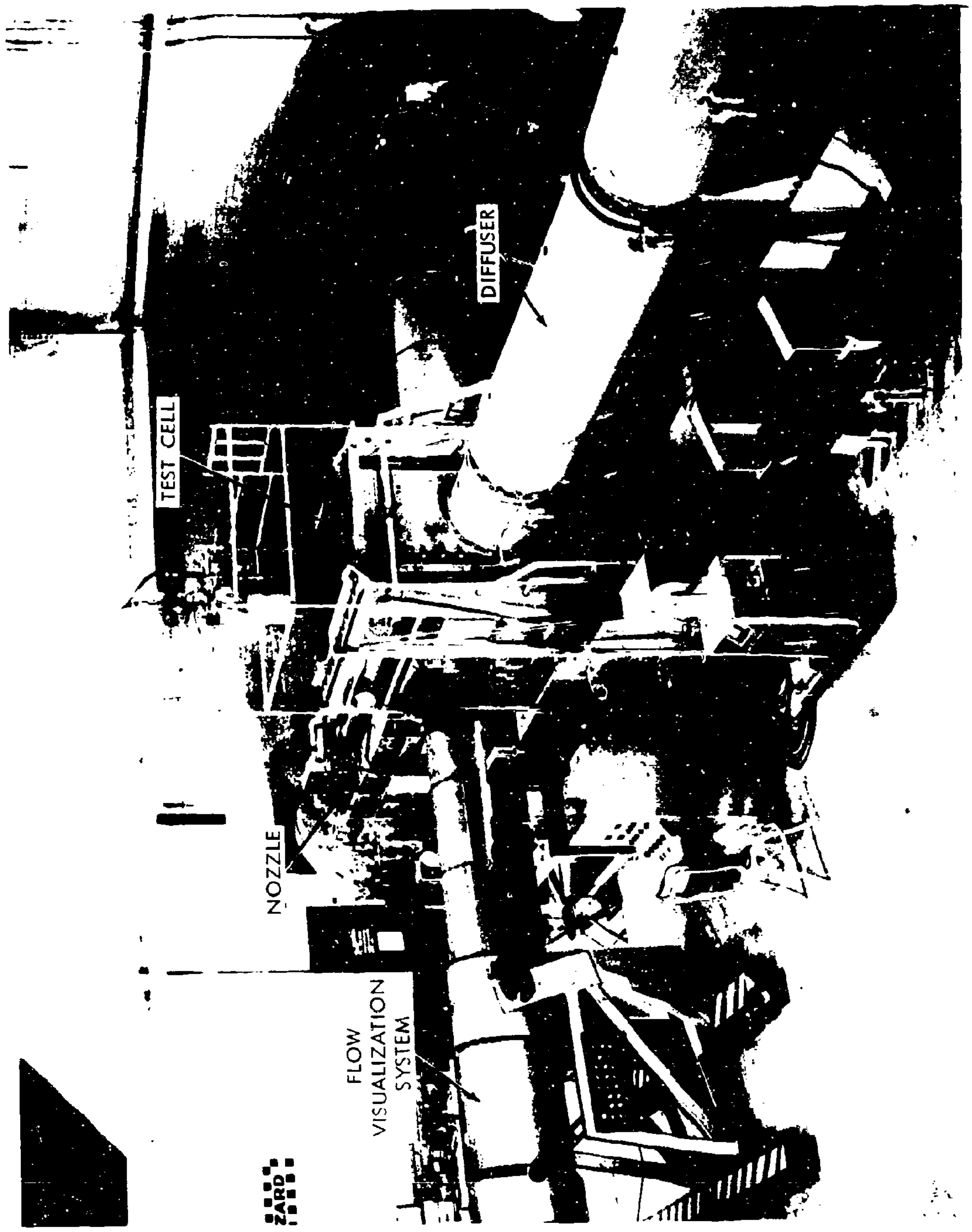

FIG. 1 TUNNEL WORKING SECTION

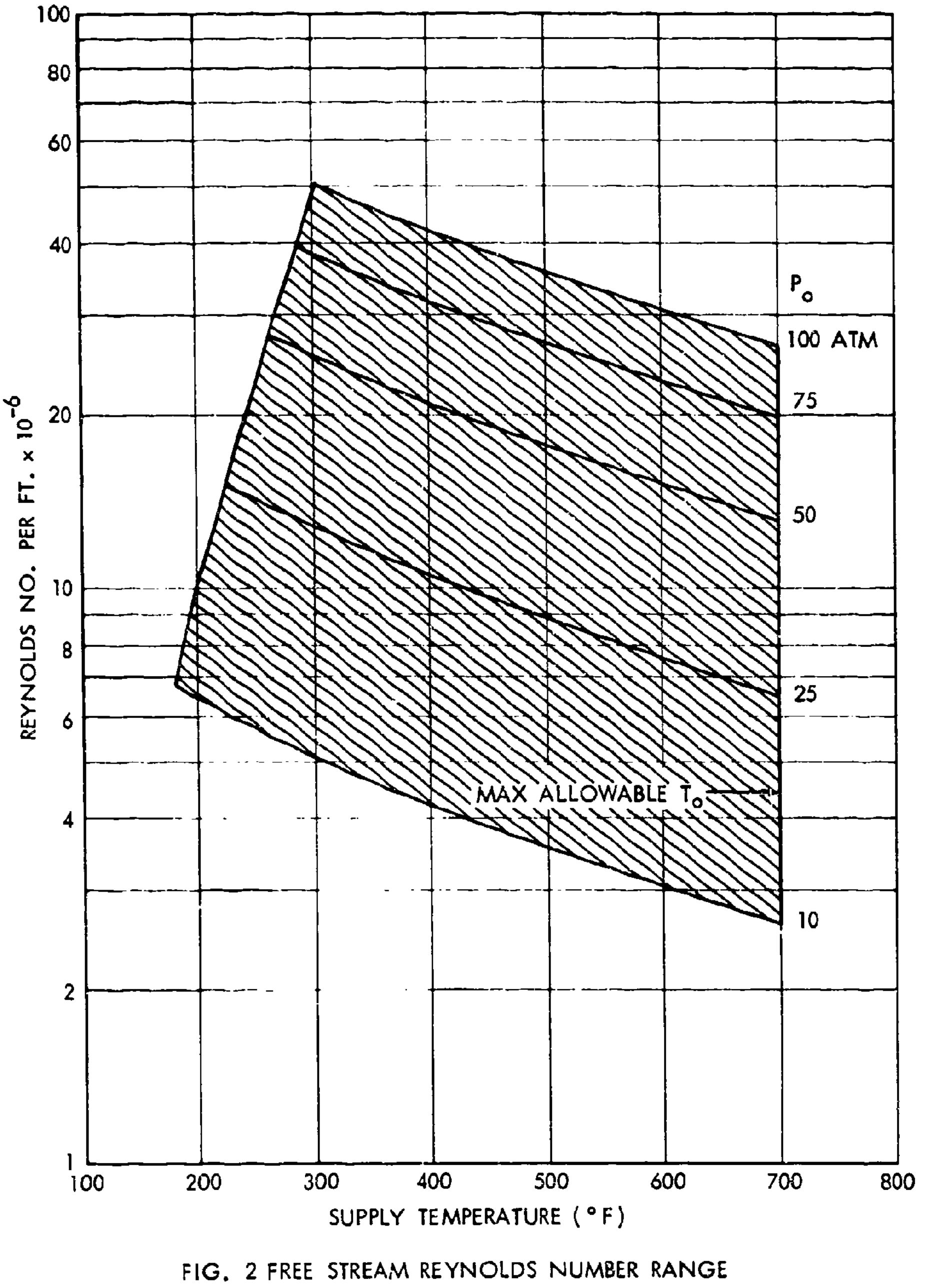

FIG. 2 FREE STREAM REYNOLDS NUMBER RANGE
A. MACH 5 NOZZLE

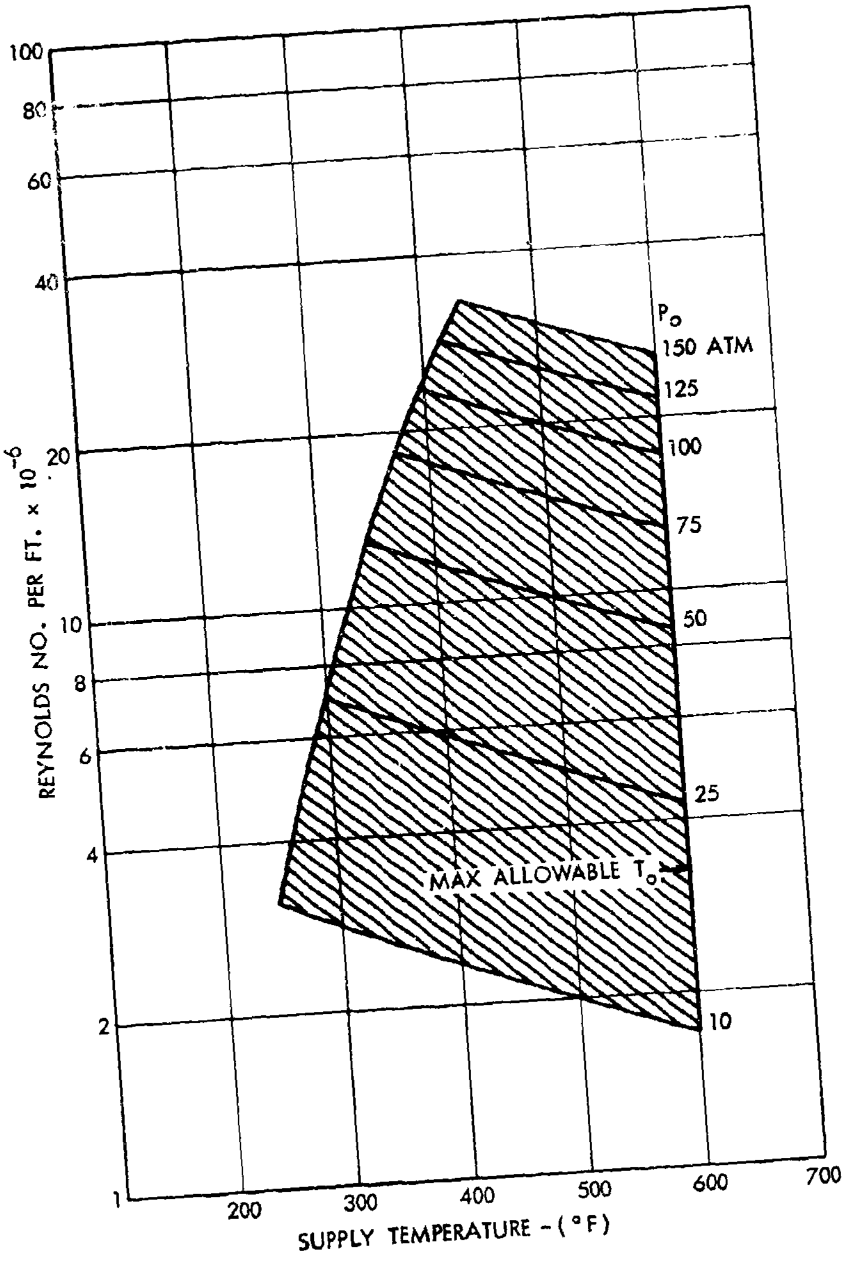

FIG. 2 CONTINUED
B. MACH 6 NOZZLE

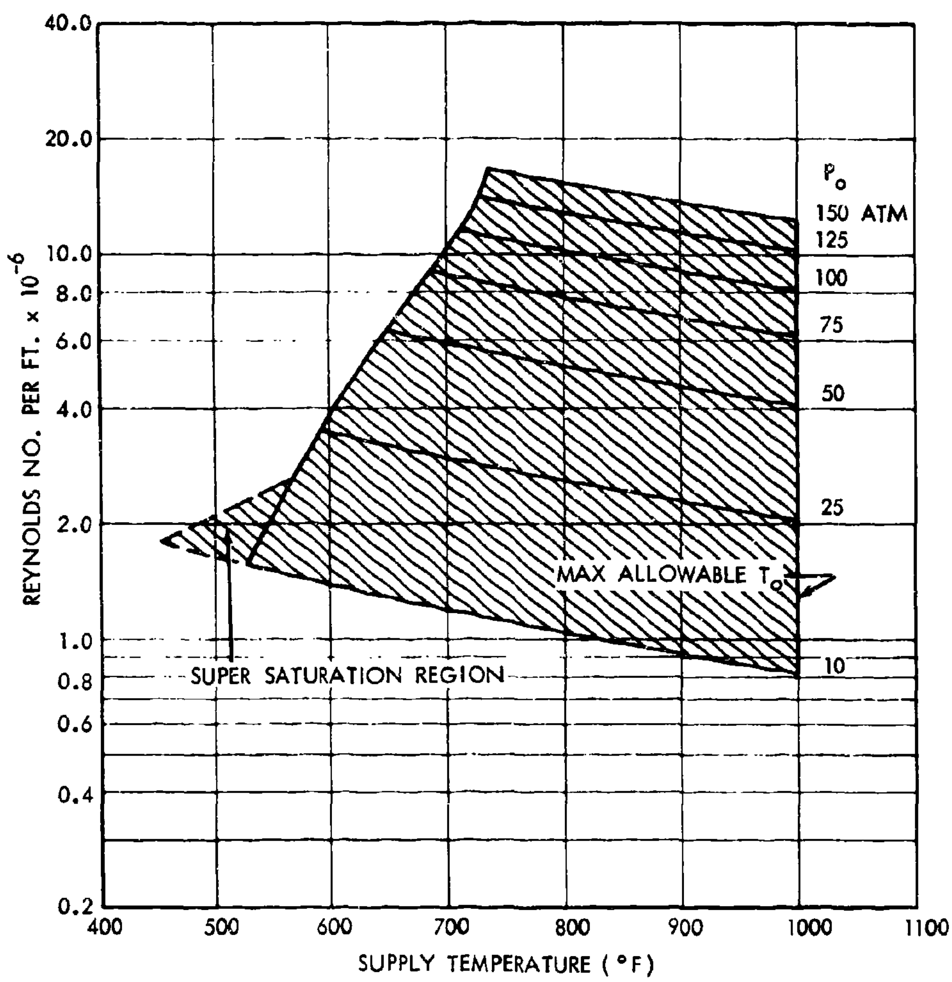

FIG. 2 CONTINUED
C. MACH 7 NOZZLE

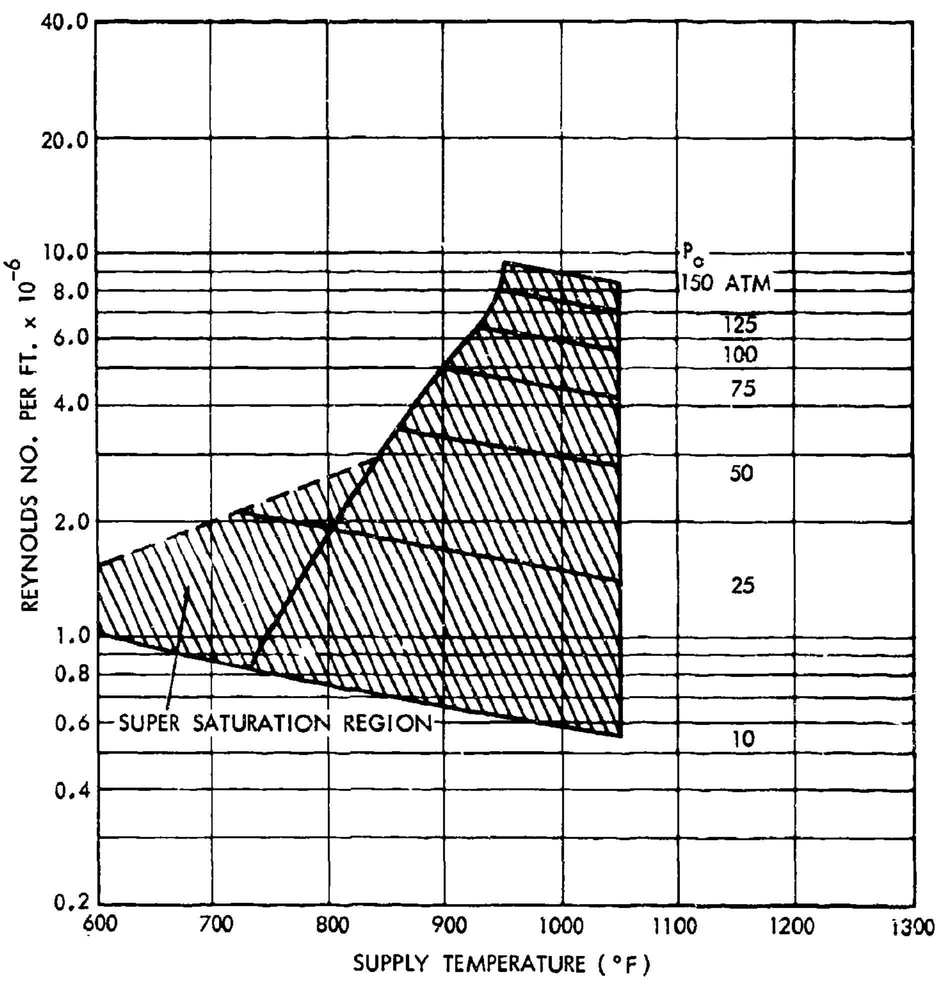

FIG. 2 CONTINUED
D. MACH 8 NOZZLE

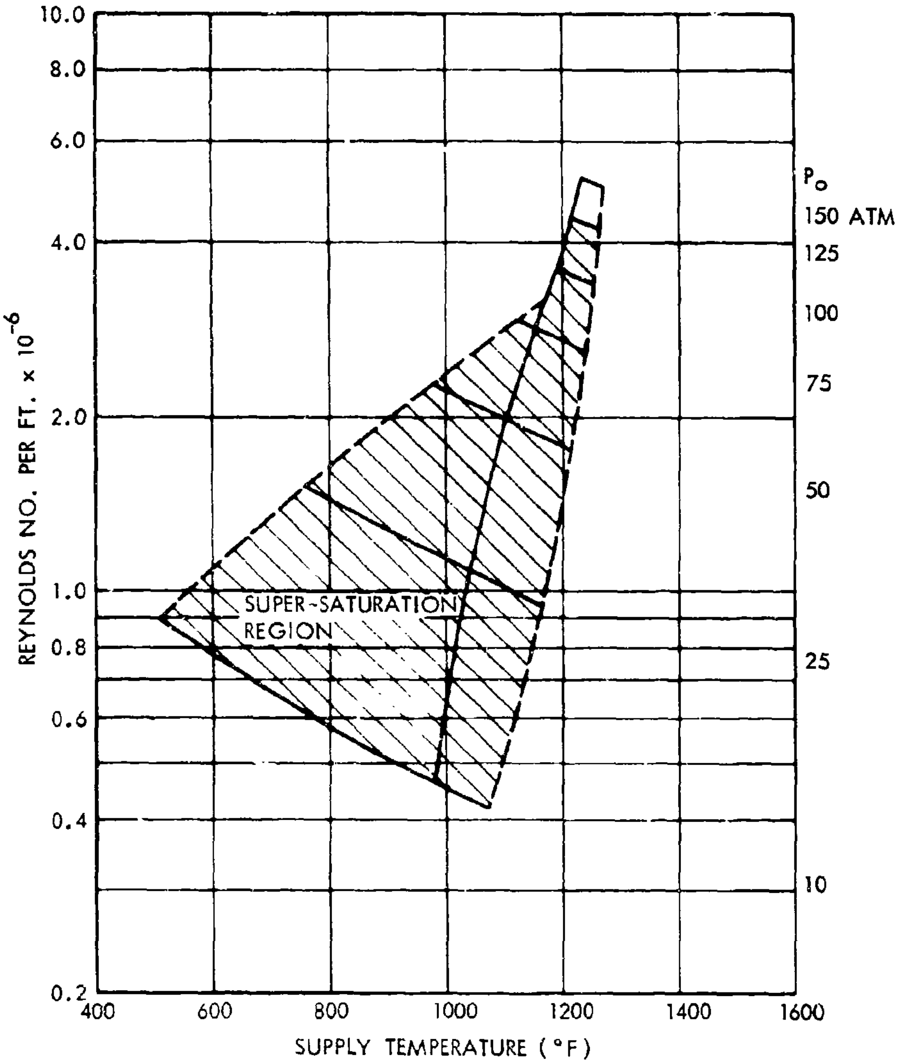

FIG. 2 CONTINUED
E. MACH 9 NOZZLE

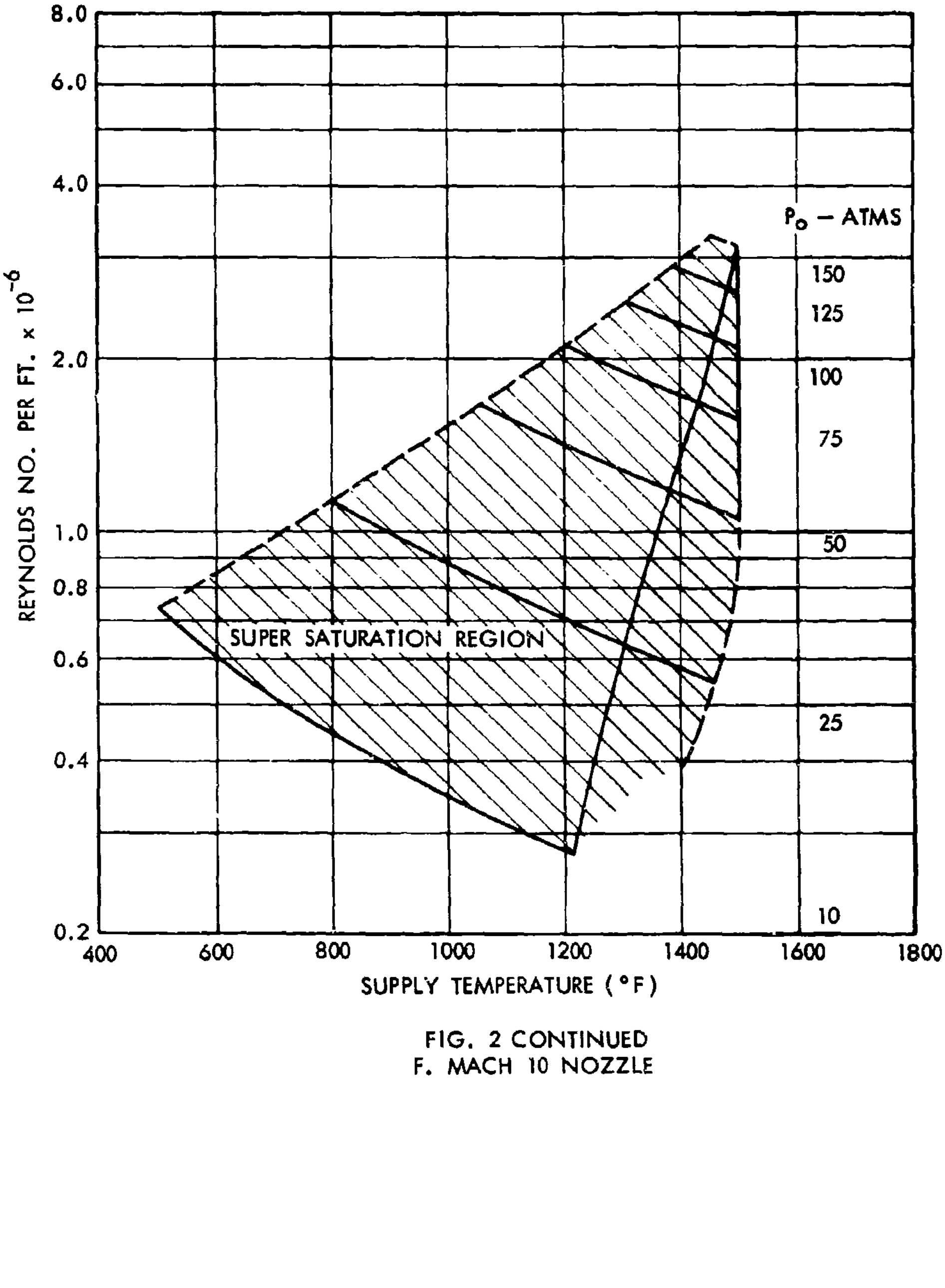

FIG. 2 CONTINUED
F. MACH 10 NOZZLE

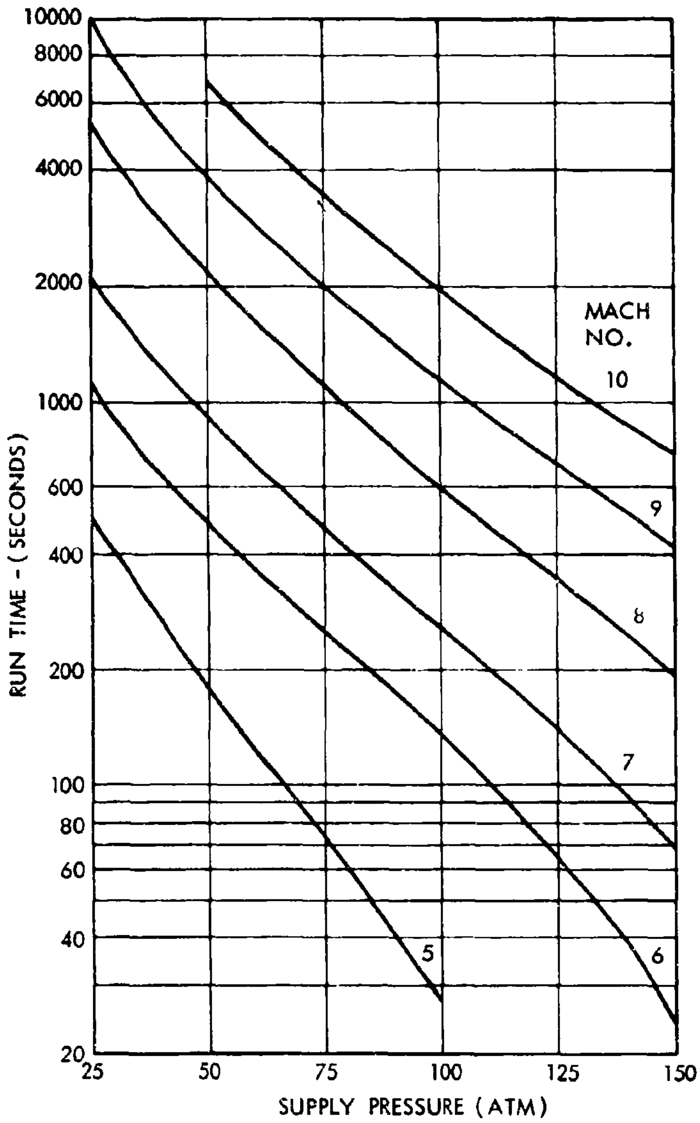

FIG. 3 RUN TIME vs SUPPLY PRESSURE

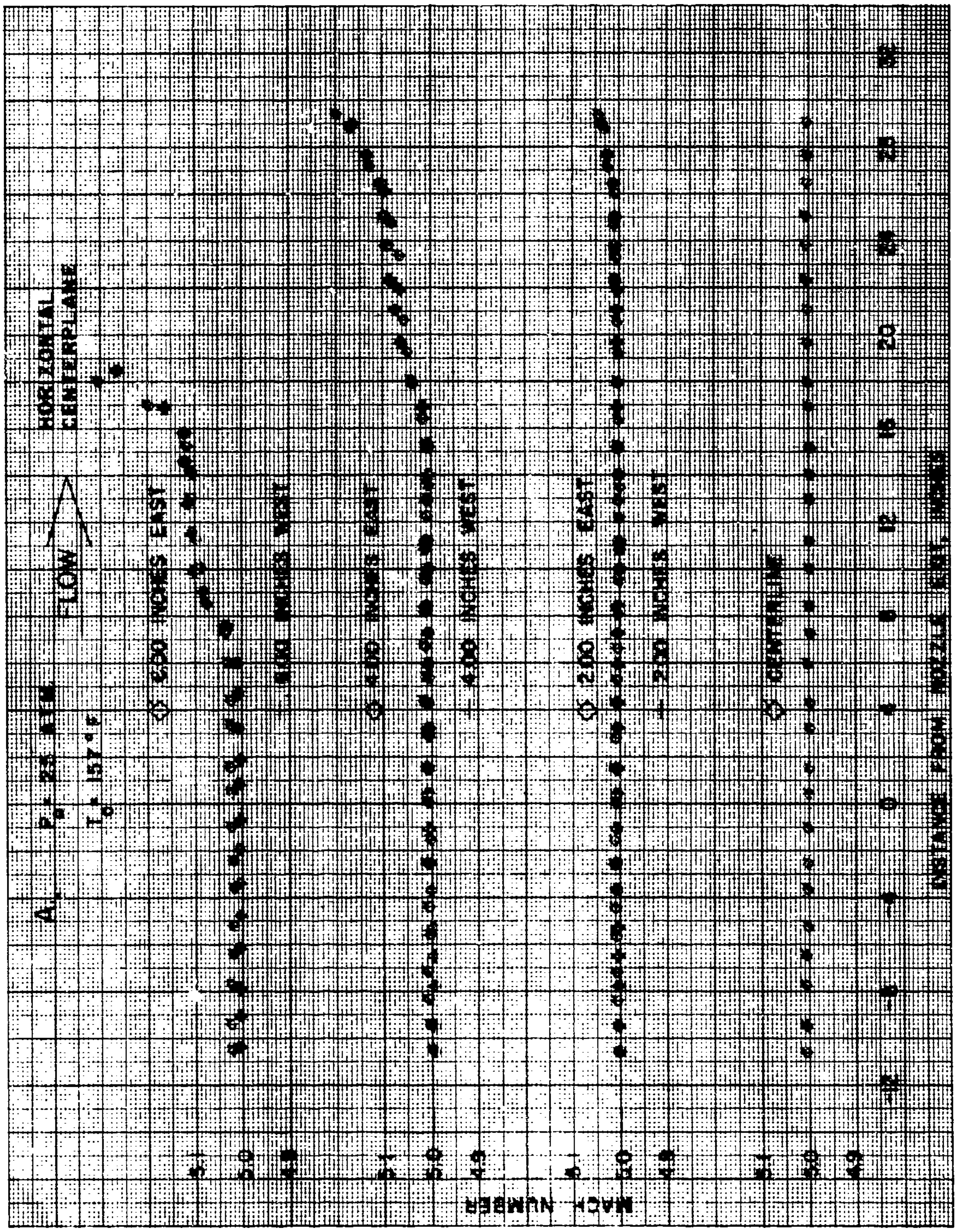

FIG. 4-A MACH 5 NOZZLE FLOW MACH NUMBER

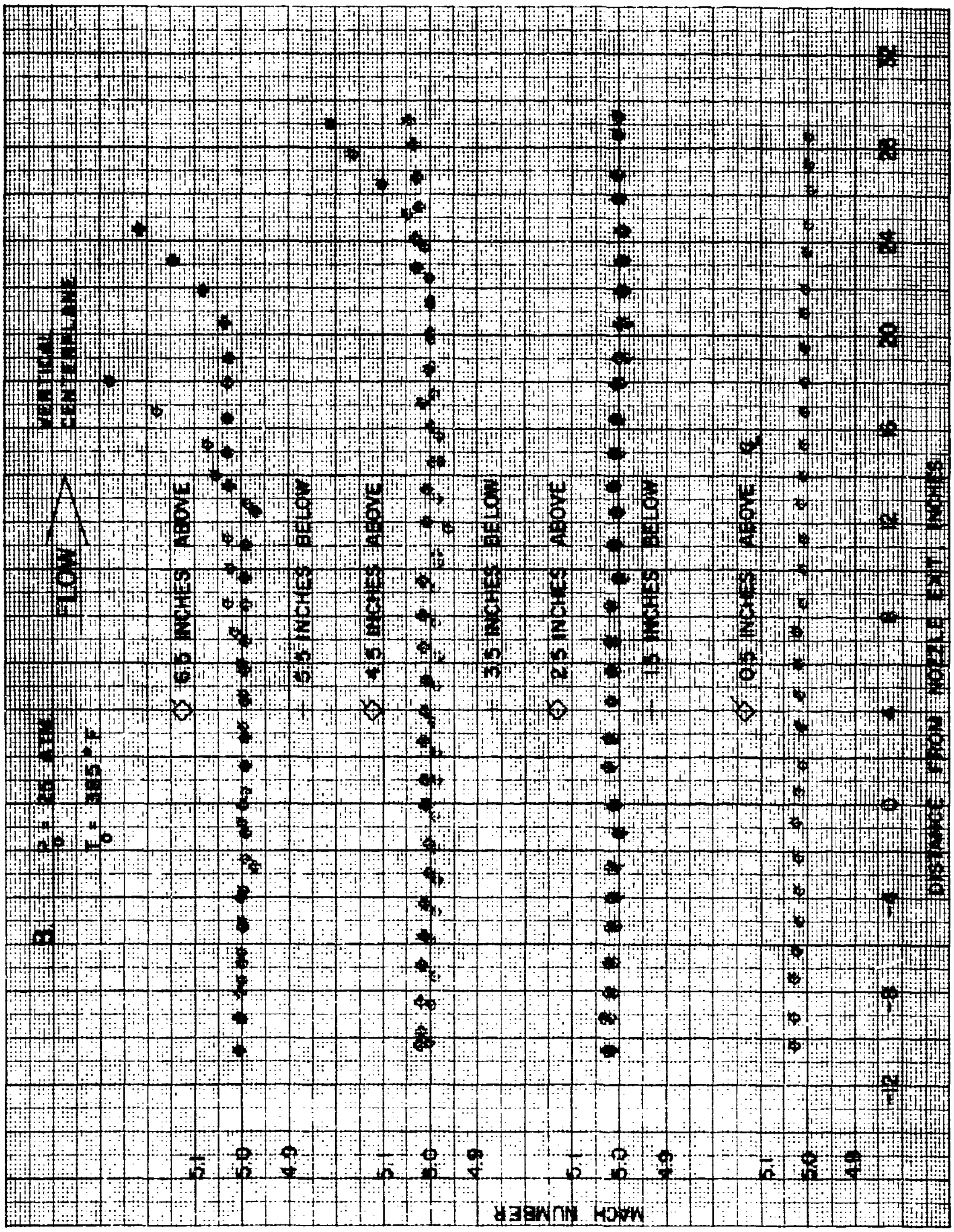

FIG. 4-B MACH 5 NOZZLE FLOW MACH NUMBER

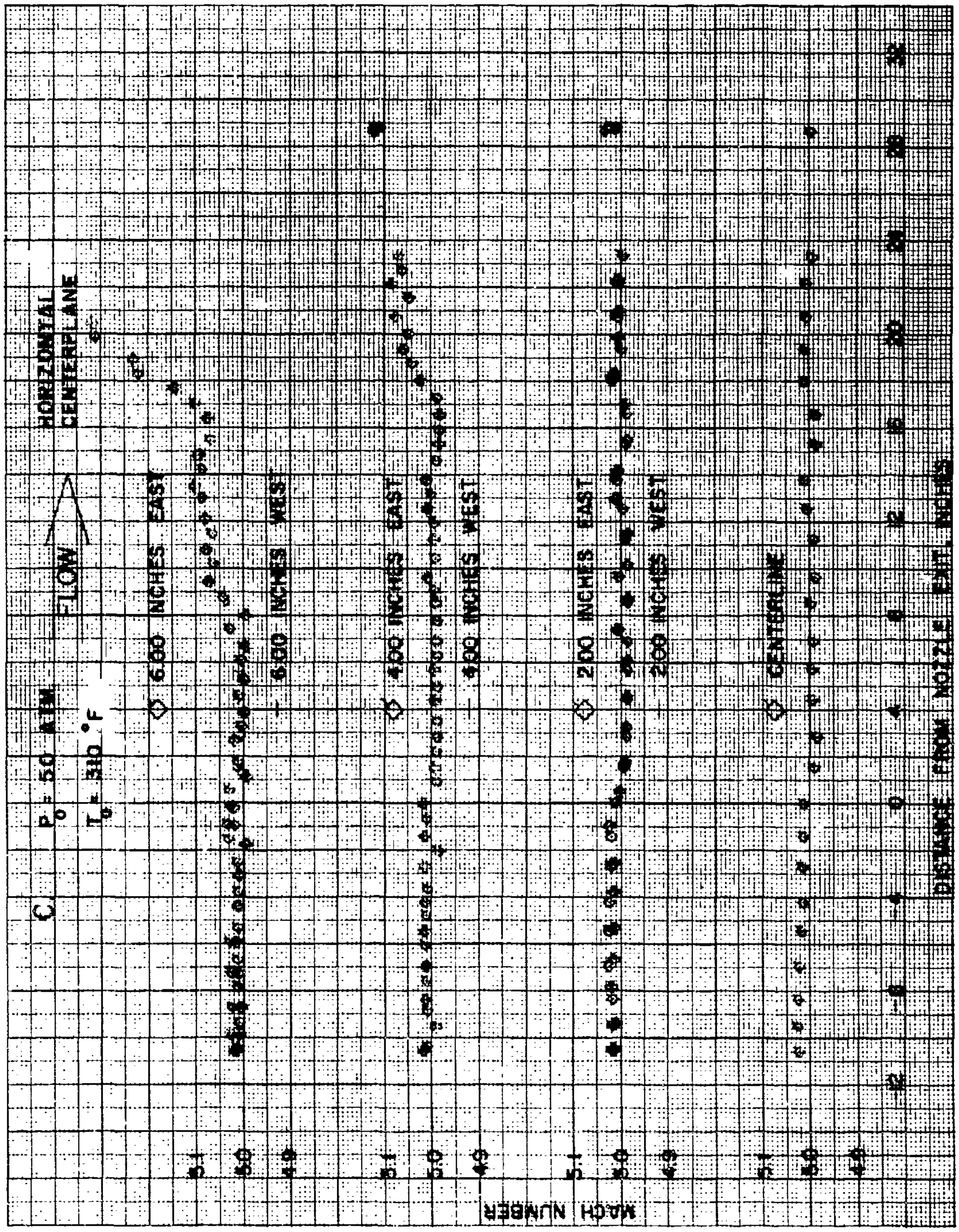

FIG. 4-C MACH 5 NOZZLE FLOW MACH NUMBER

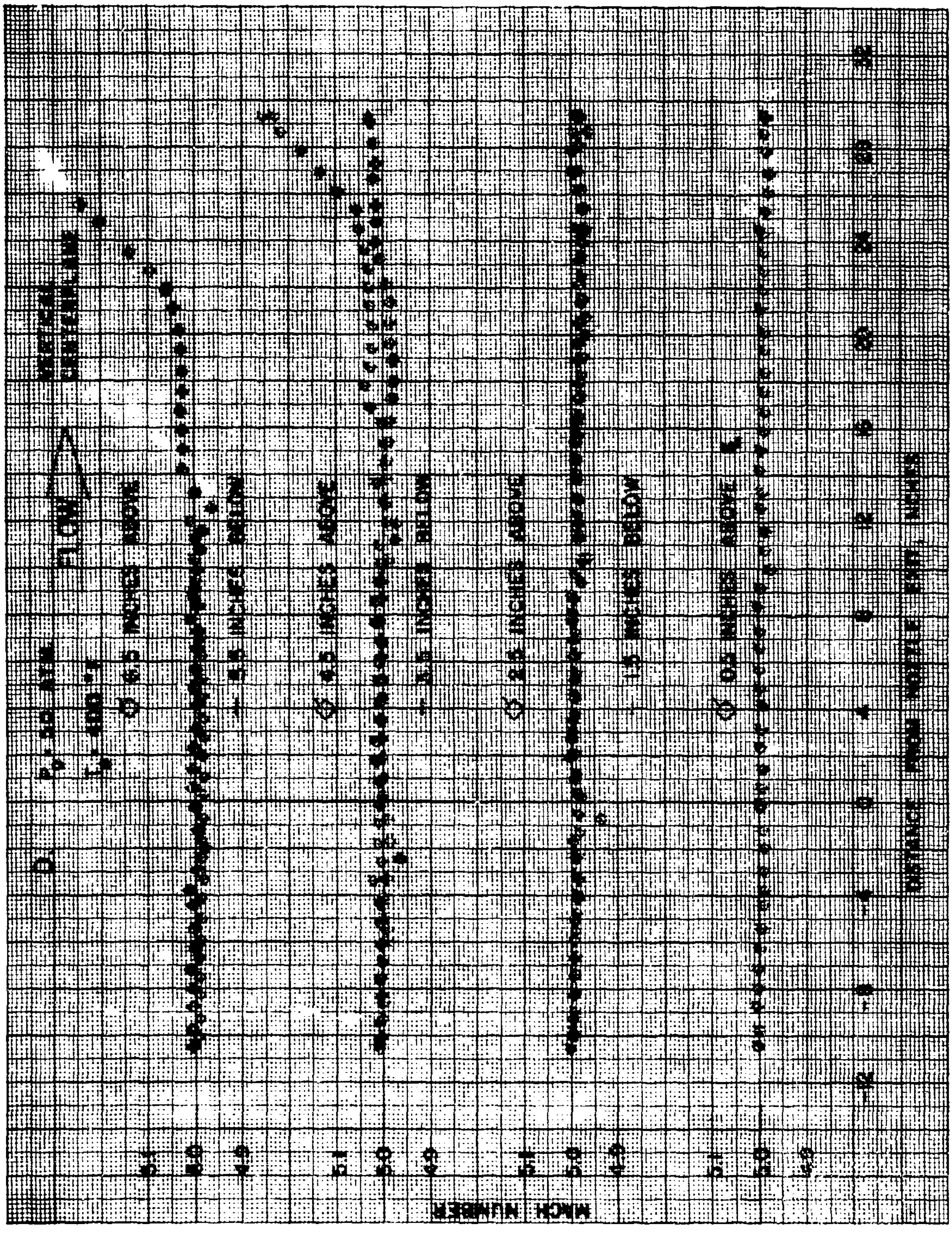

FIG. 4-D MACH 5 NOZZLE FLOW MACH NUMBER

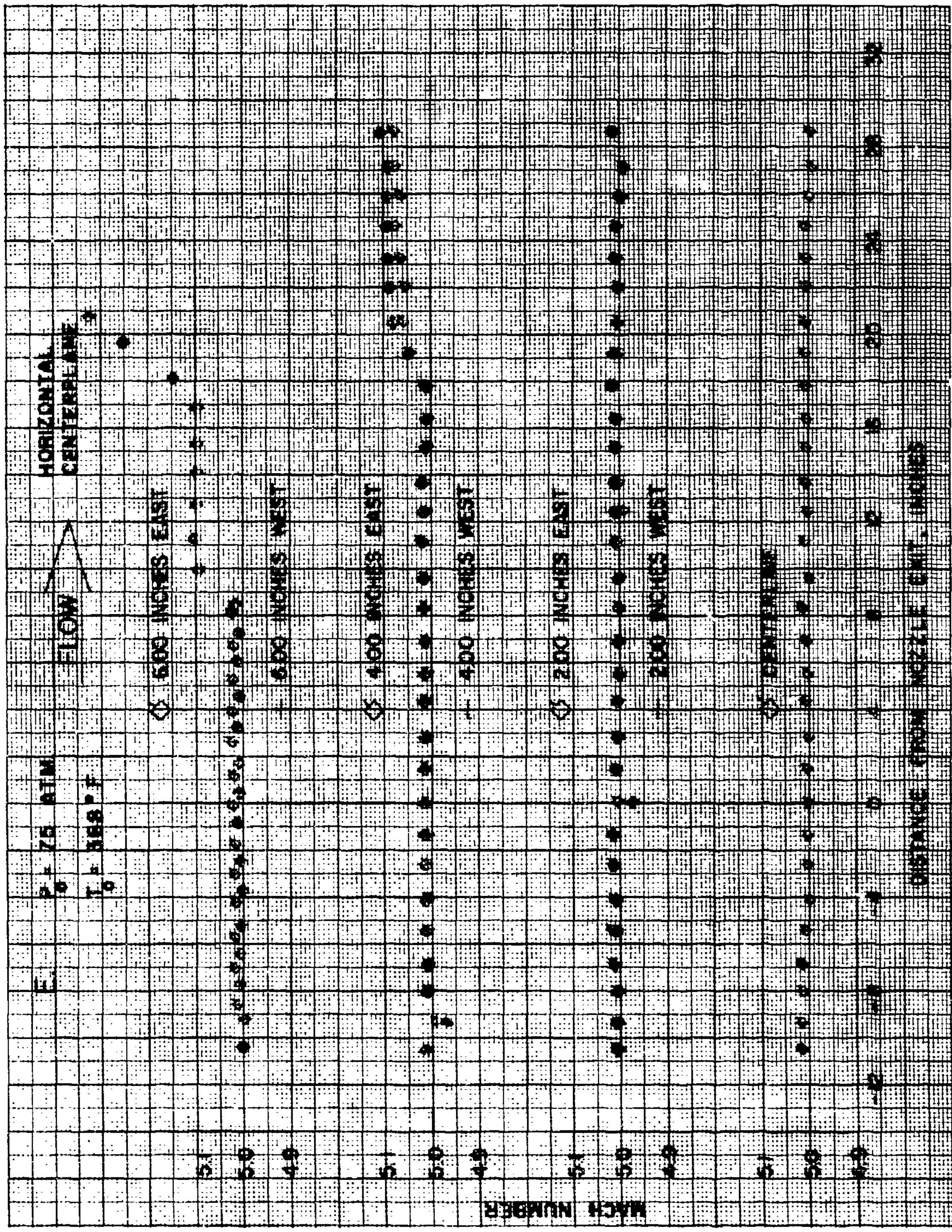

FIG. 4-E MACH 5 NOZZLE FLOW MACH NUMBER

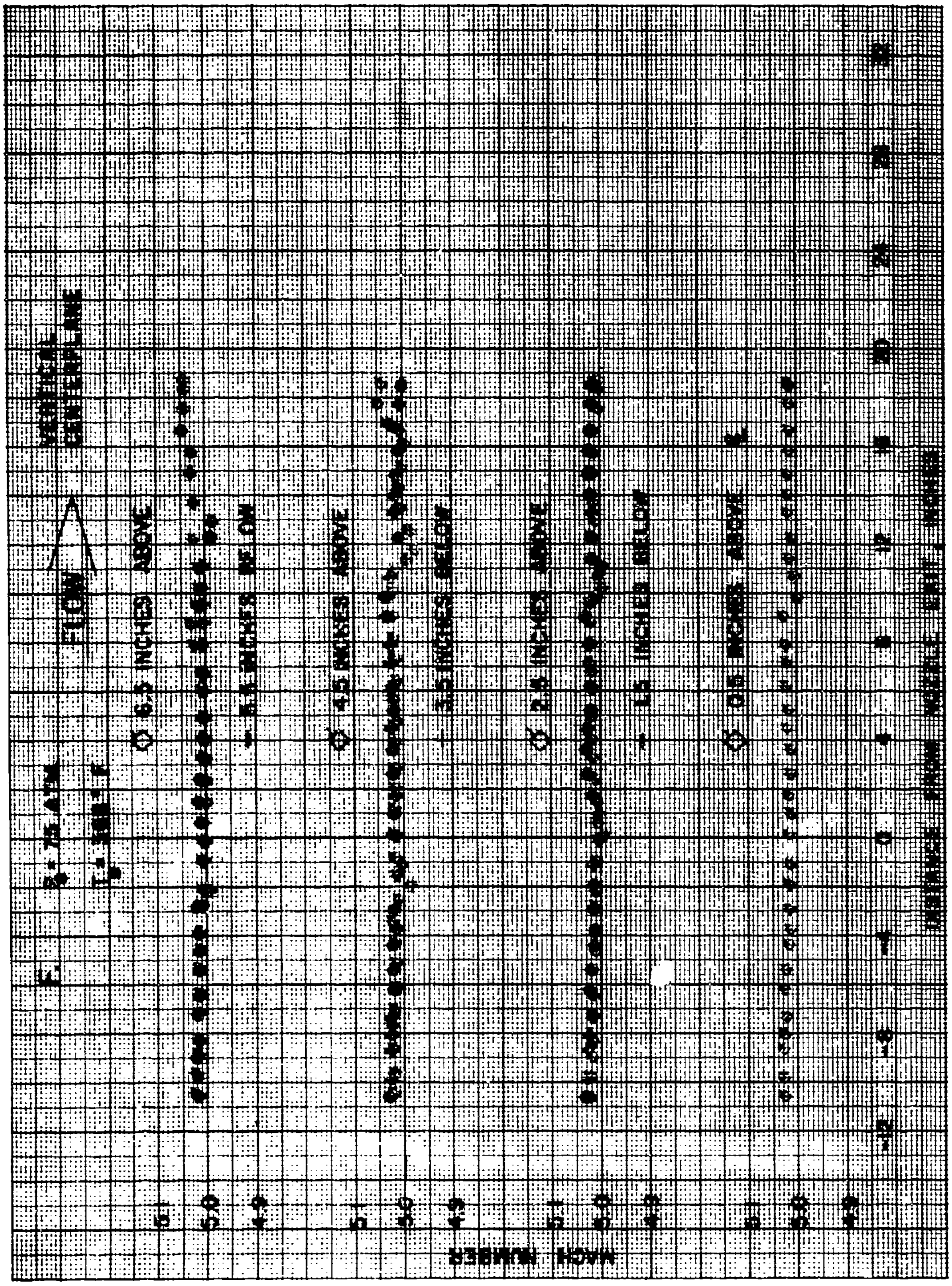

FIG. 4-F MACH 5 NOZZLE FLOW MACH NUMBER

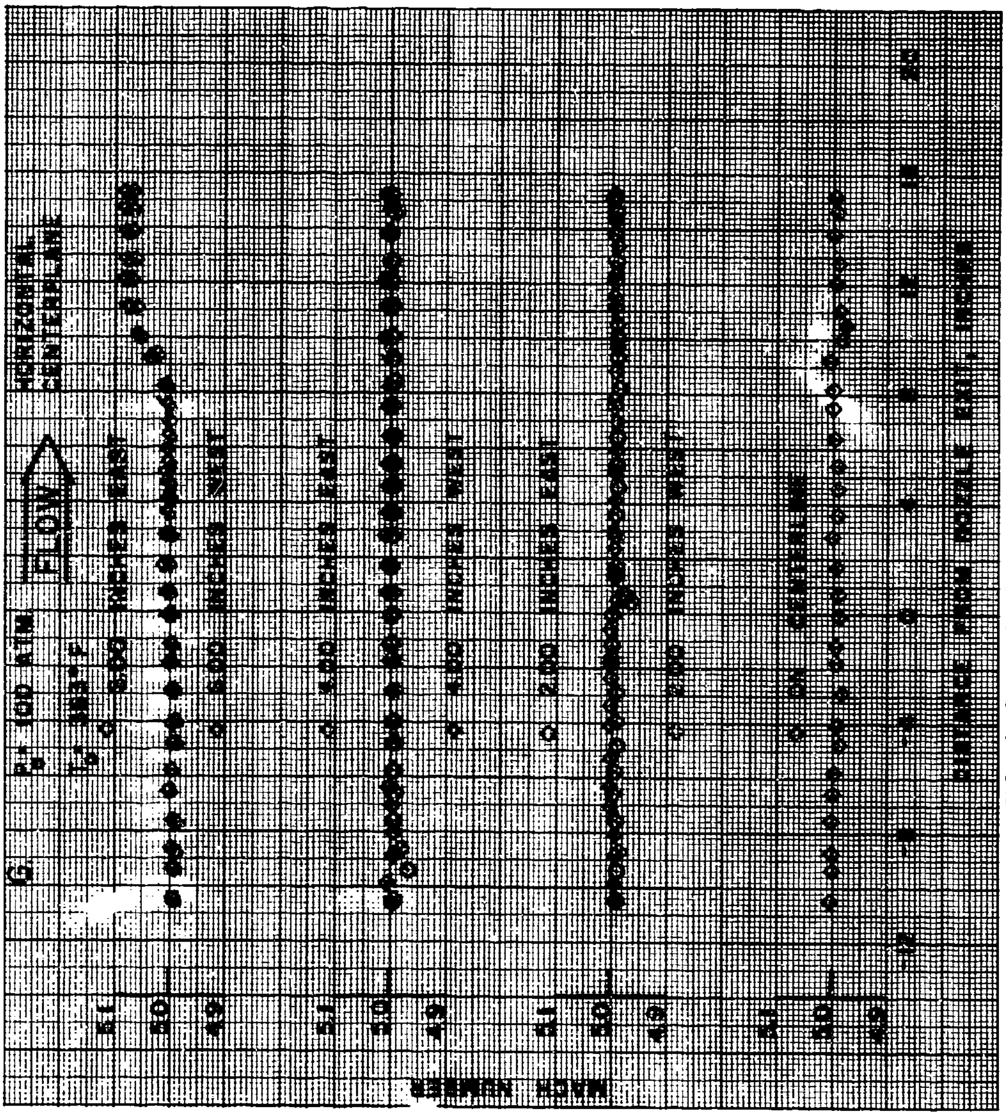

FIG. 4-G MACH 5 NOZZLE FLOW MACH NUMBER

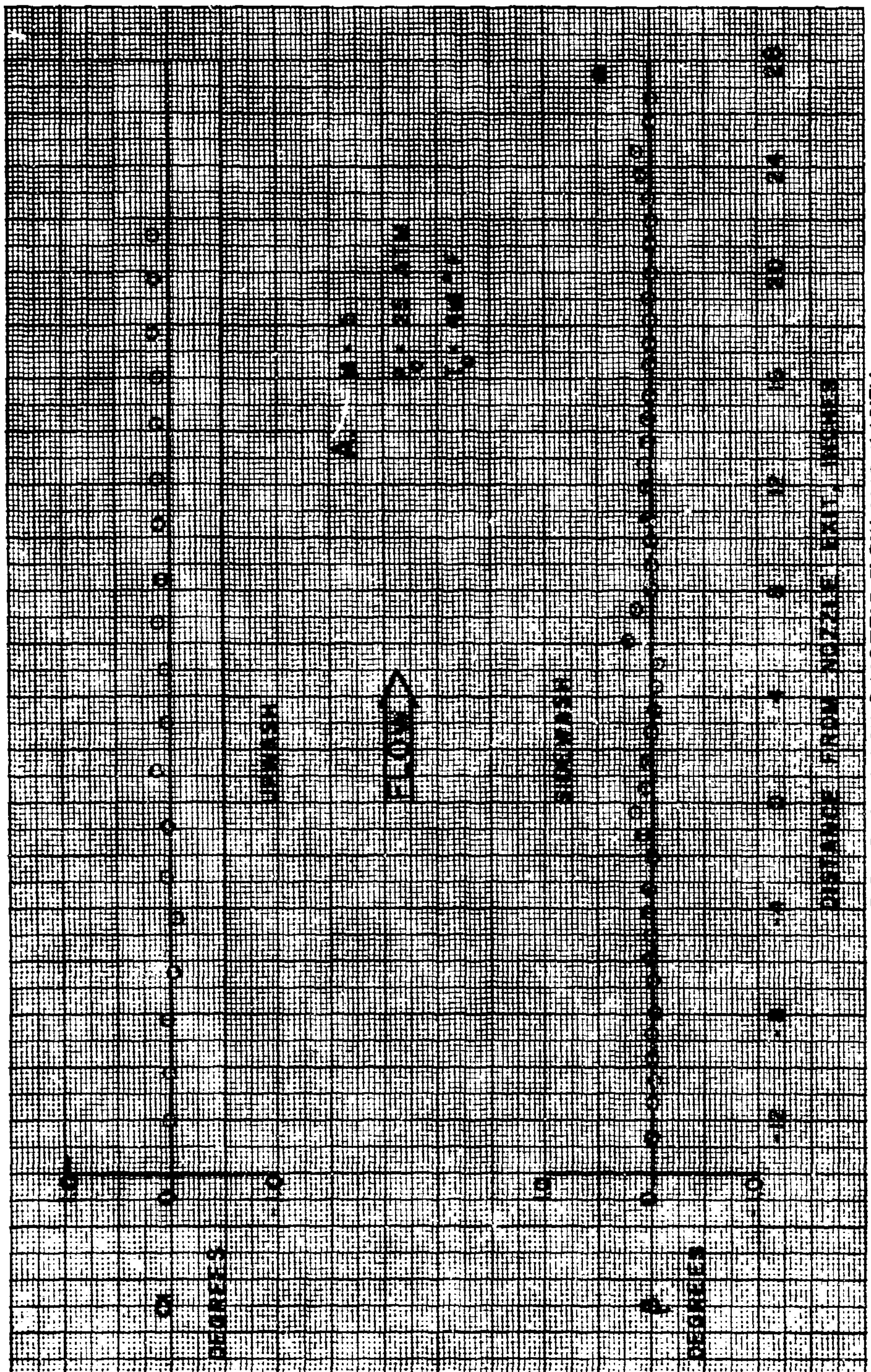

FIG. 5-A MACH 5 NOZZLE FLOW ANGULARITY

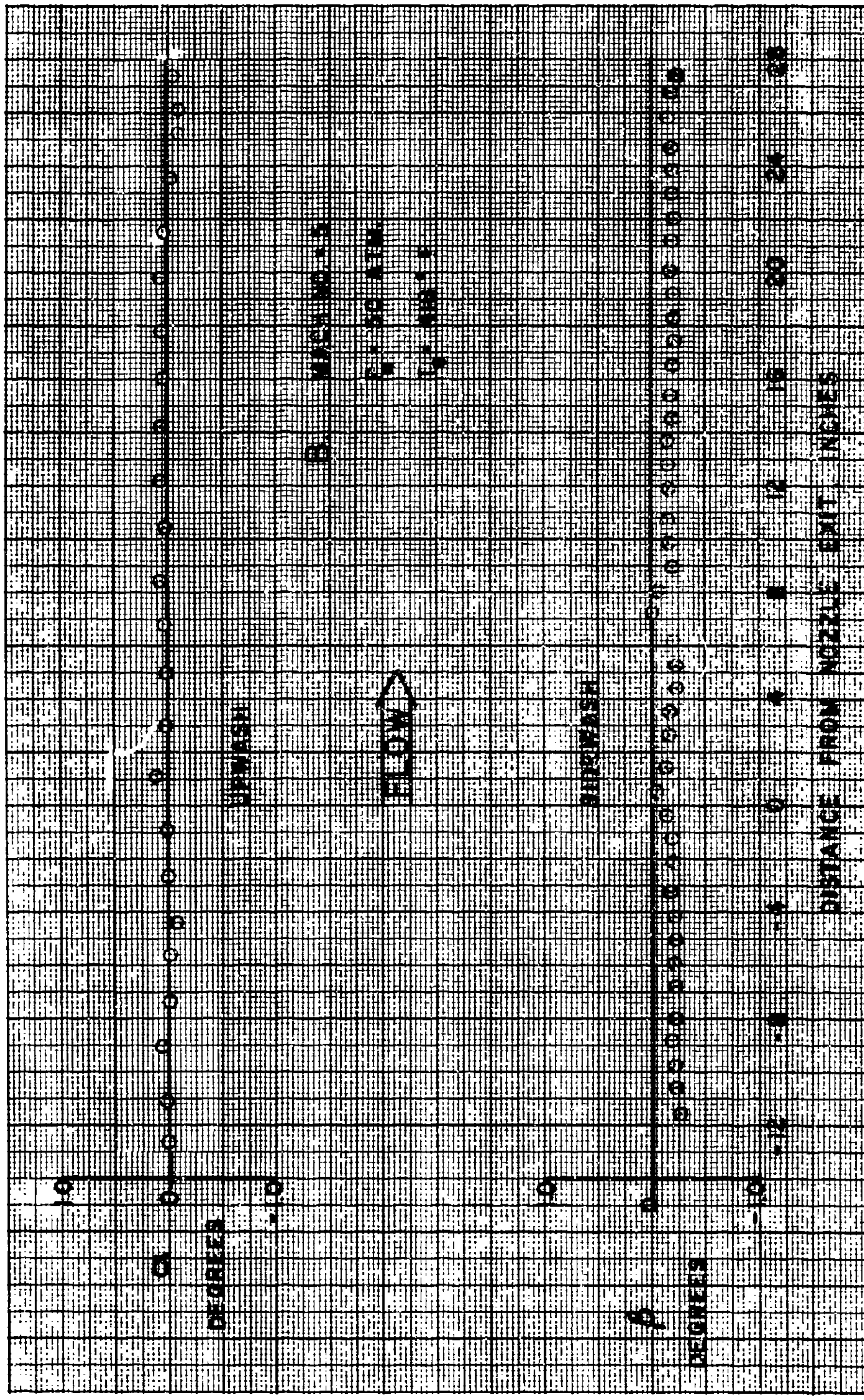

FIG. 5-B MACH 5 NOZZLE FLOW ANGULARITY

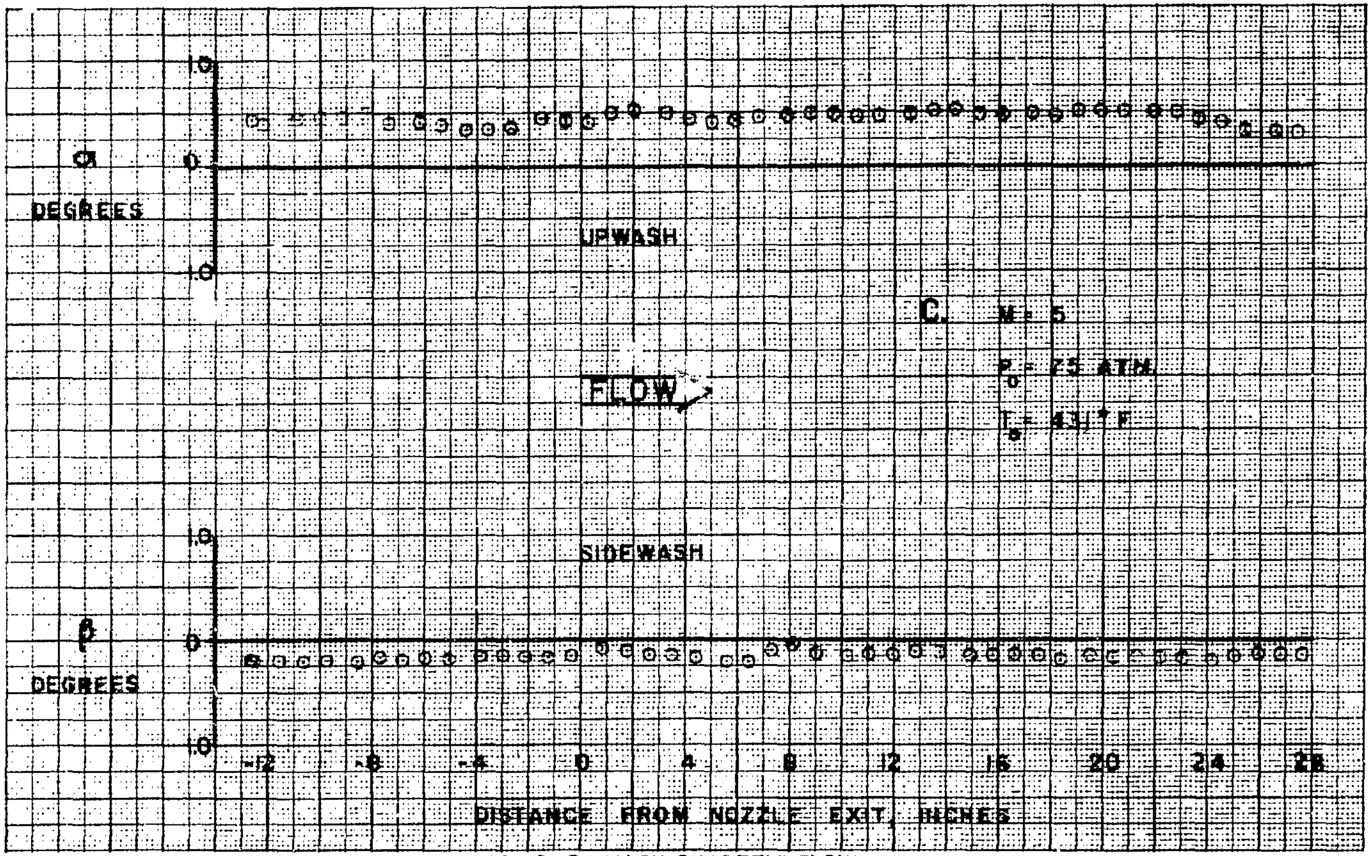

FIG. 5-C MACH 5 NOZZLE FLOW ANGULARITY

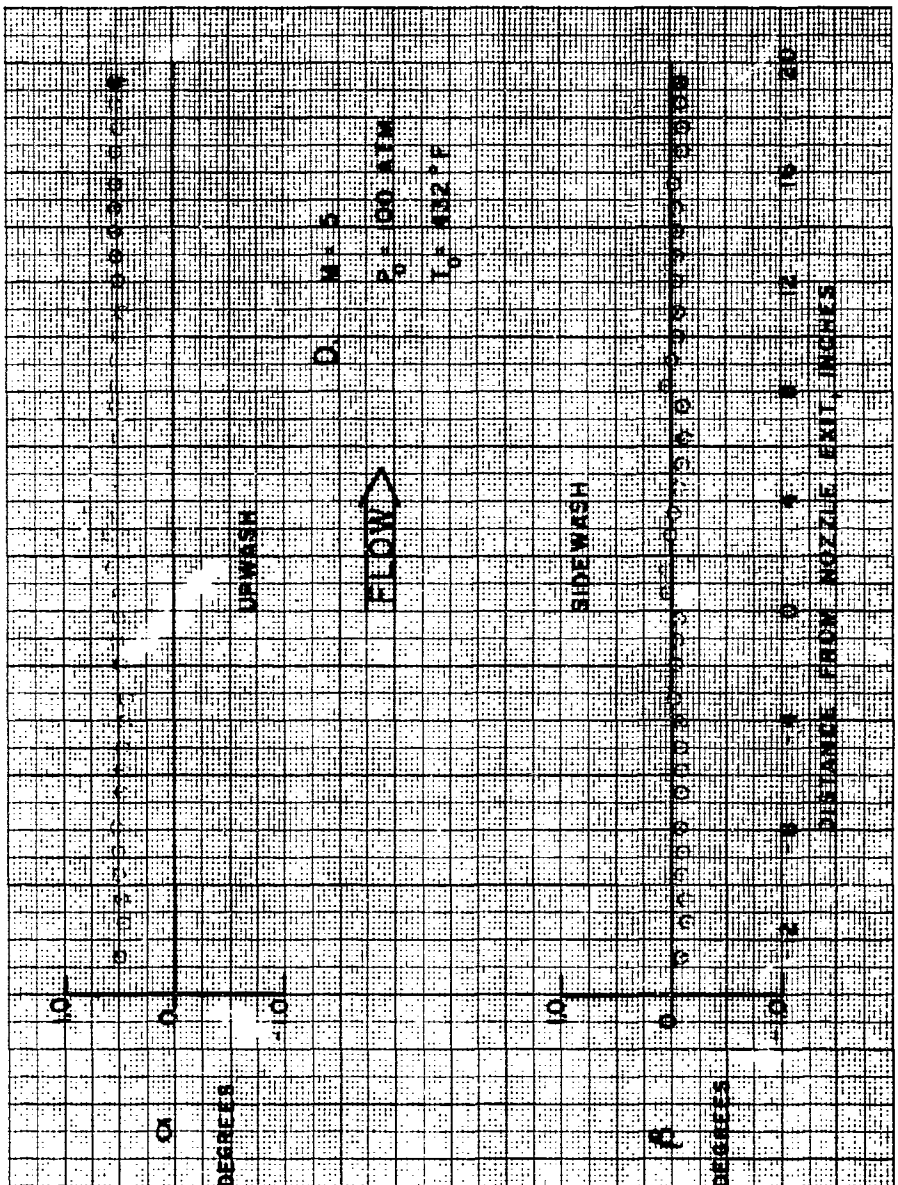

FIG. 5-D MACH 5 NOZZLE FLOW ANGULARITY

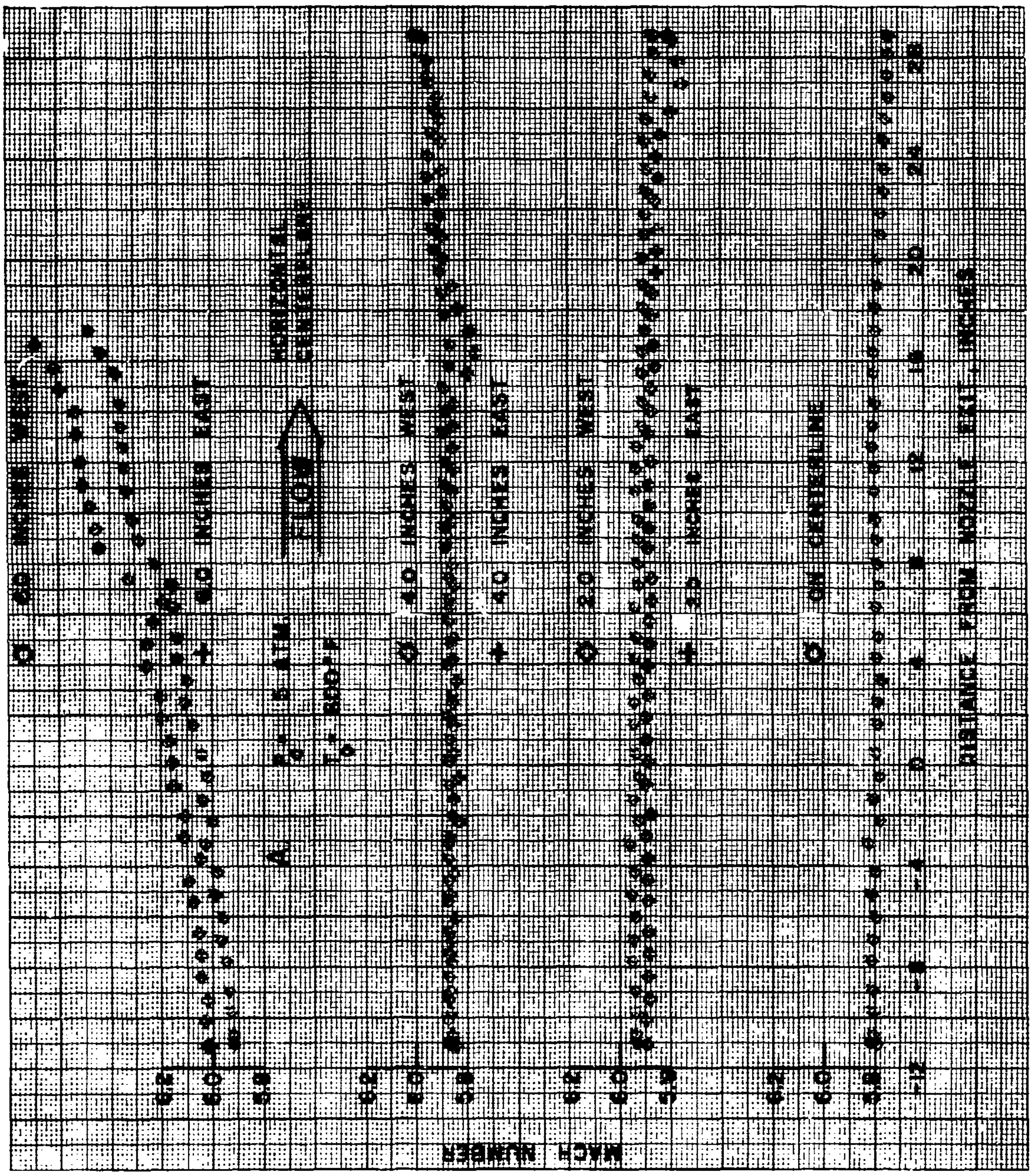

FIG. 6-A MACH 6 NOZZLE FLOW MACH NUMBER

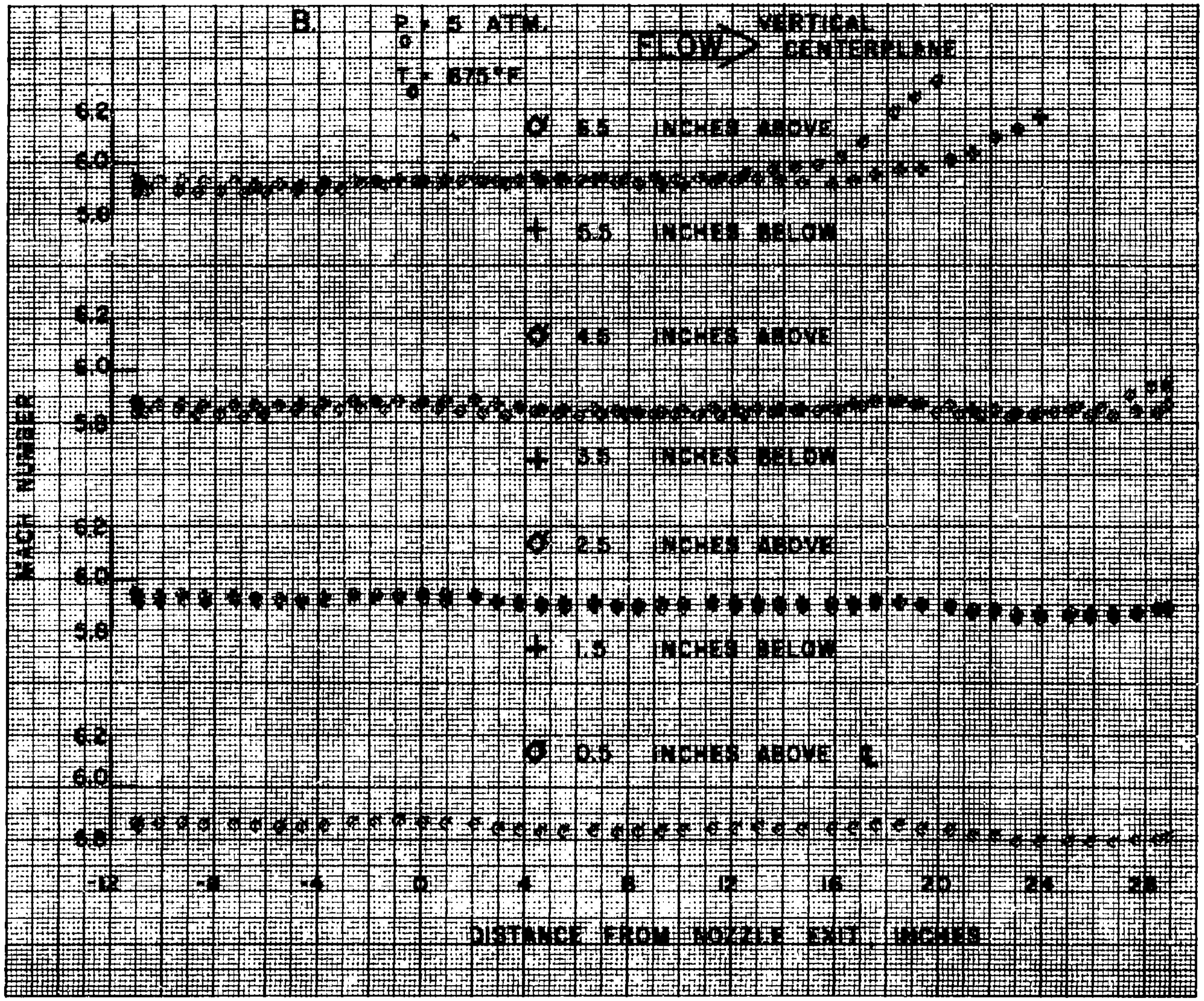

FIG. 6-B MACH 6 NOZZLE FLOW MACH NUMBER

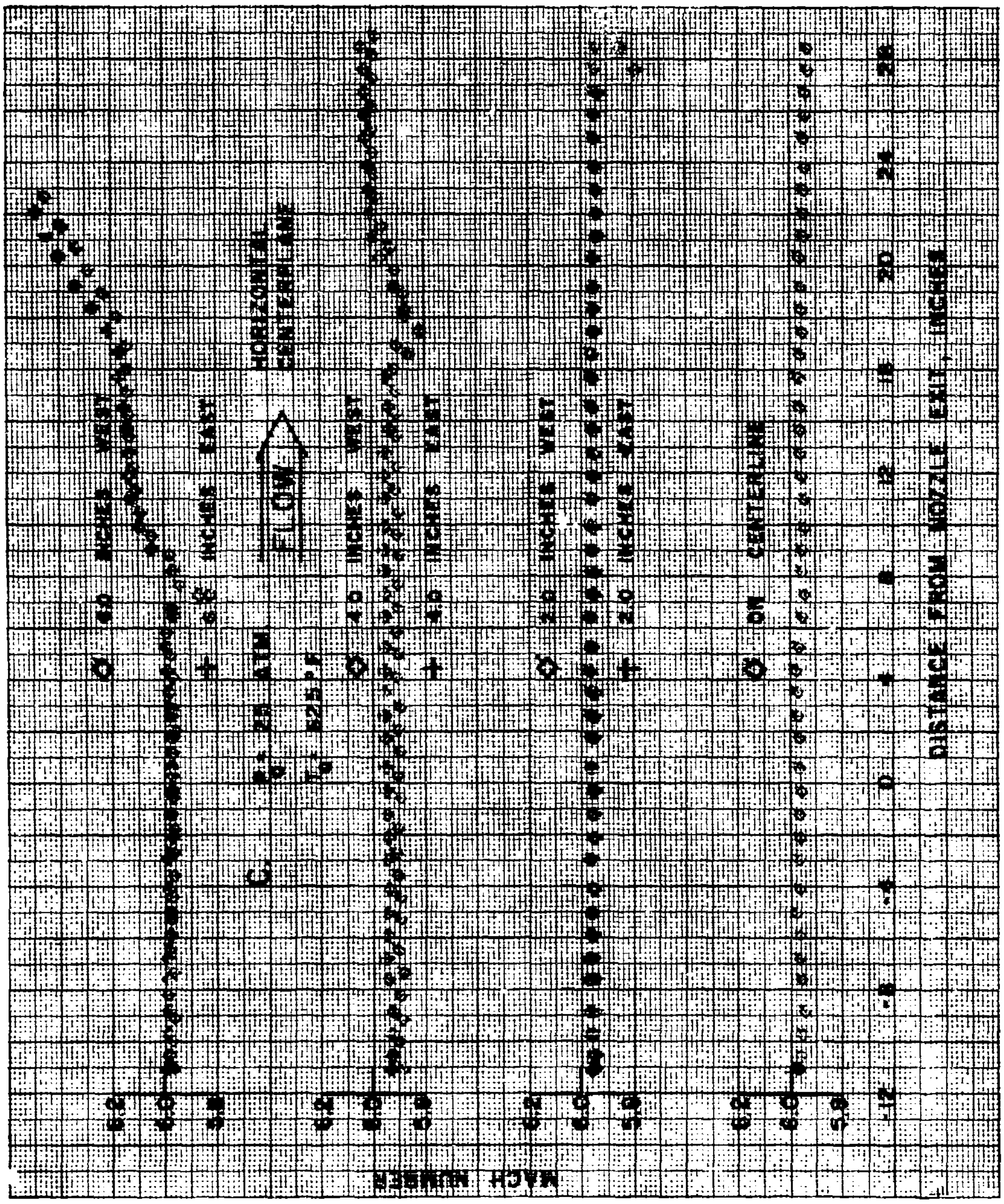

FIG. 6-C MACH 6 NOZZLE FLOW MACH NUMBER

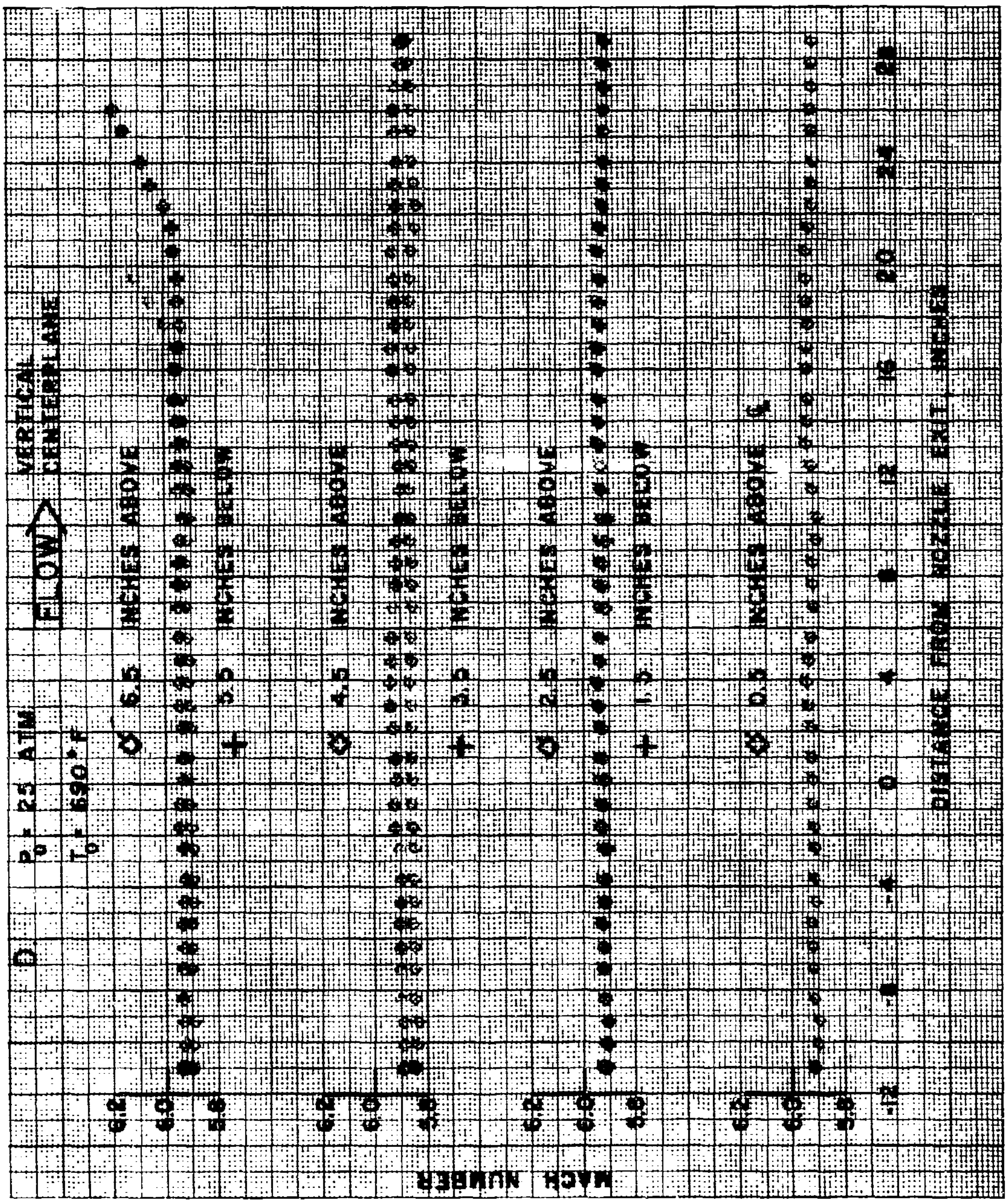

FIG. 6-D MACH 6 NOZZLE FLOW MACH NUMBER

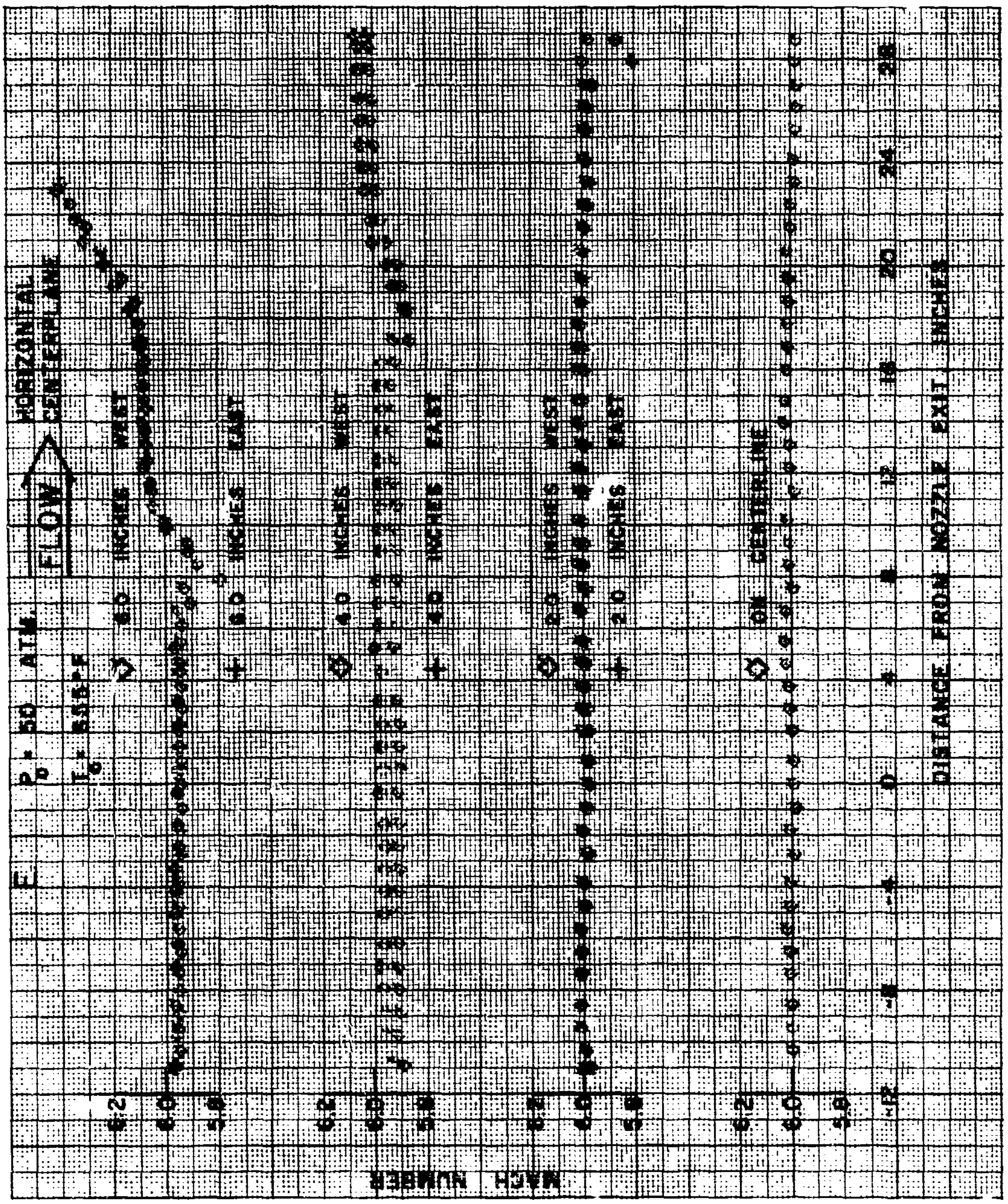

FIG. 6-E MACH 6 NOZZLE FLOW MACH NUMBER

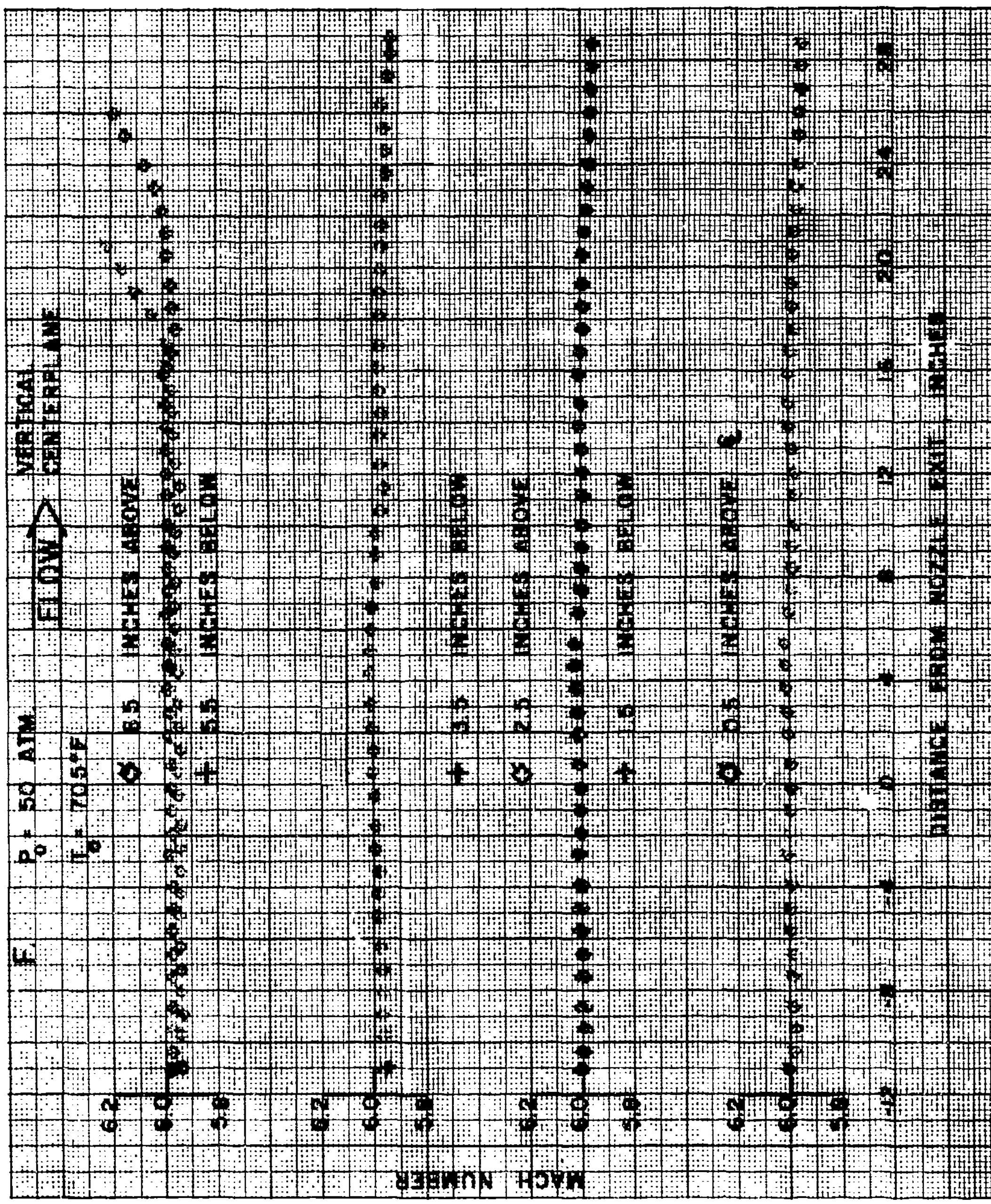

FIG. 6-F MACH 6 NOZZLE FLOW MACH NUMBER

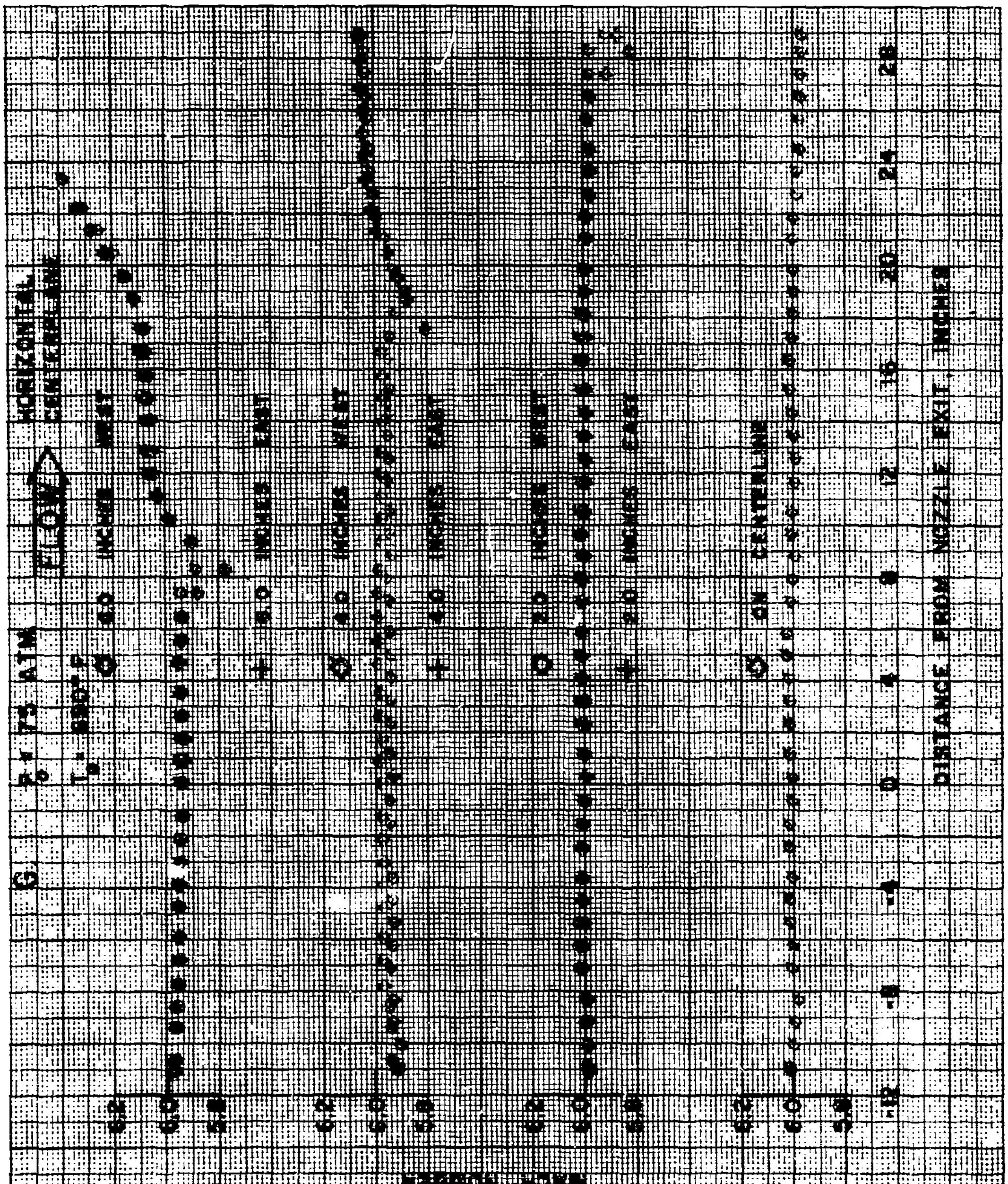

FIG. 6-G MACH 6 NOZZLE FLOW MACH NUMBER

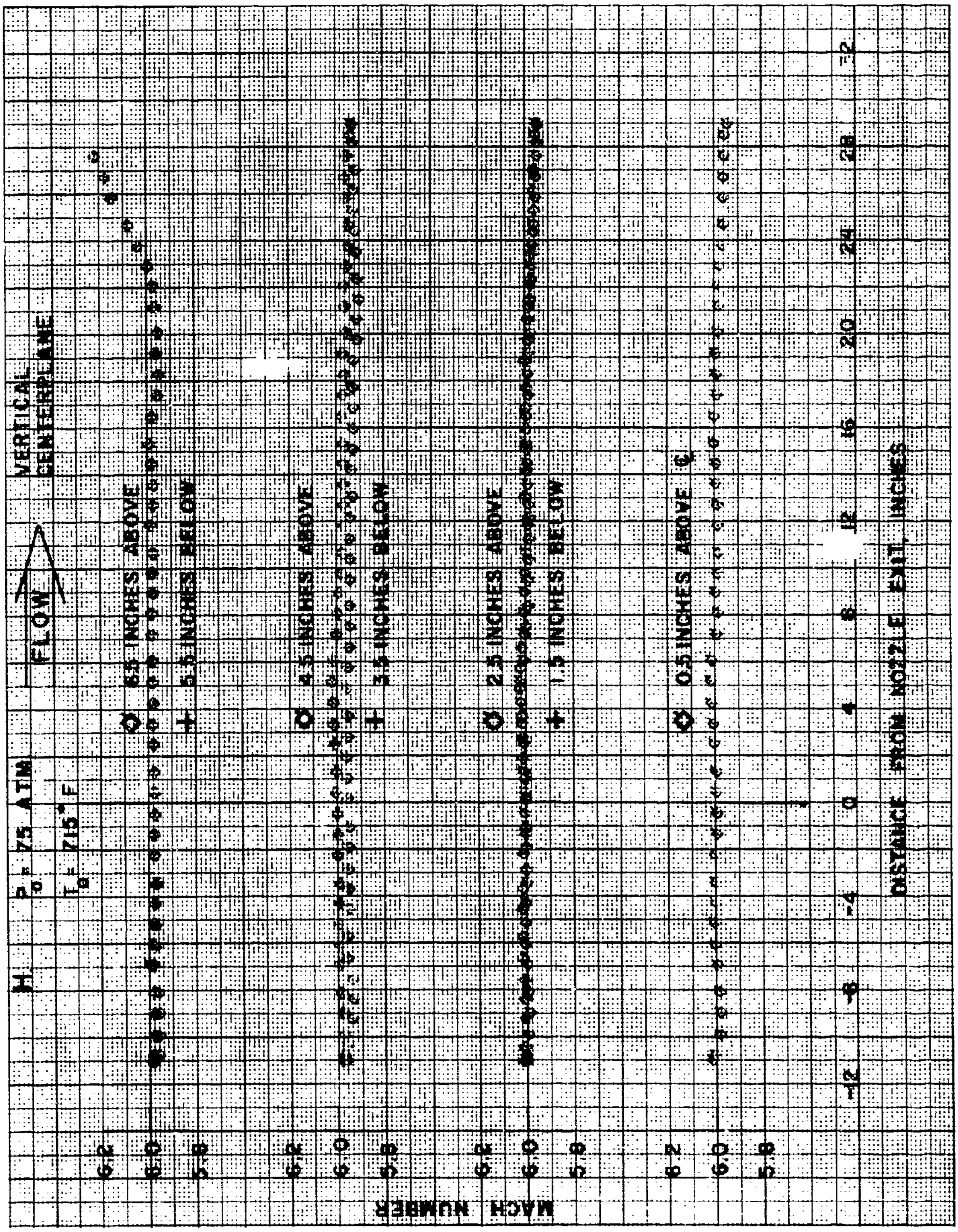

FIG. 6-H MACH 6 NOZZLE FLOW MACH NUMBER

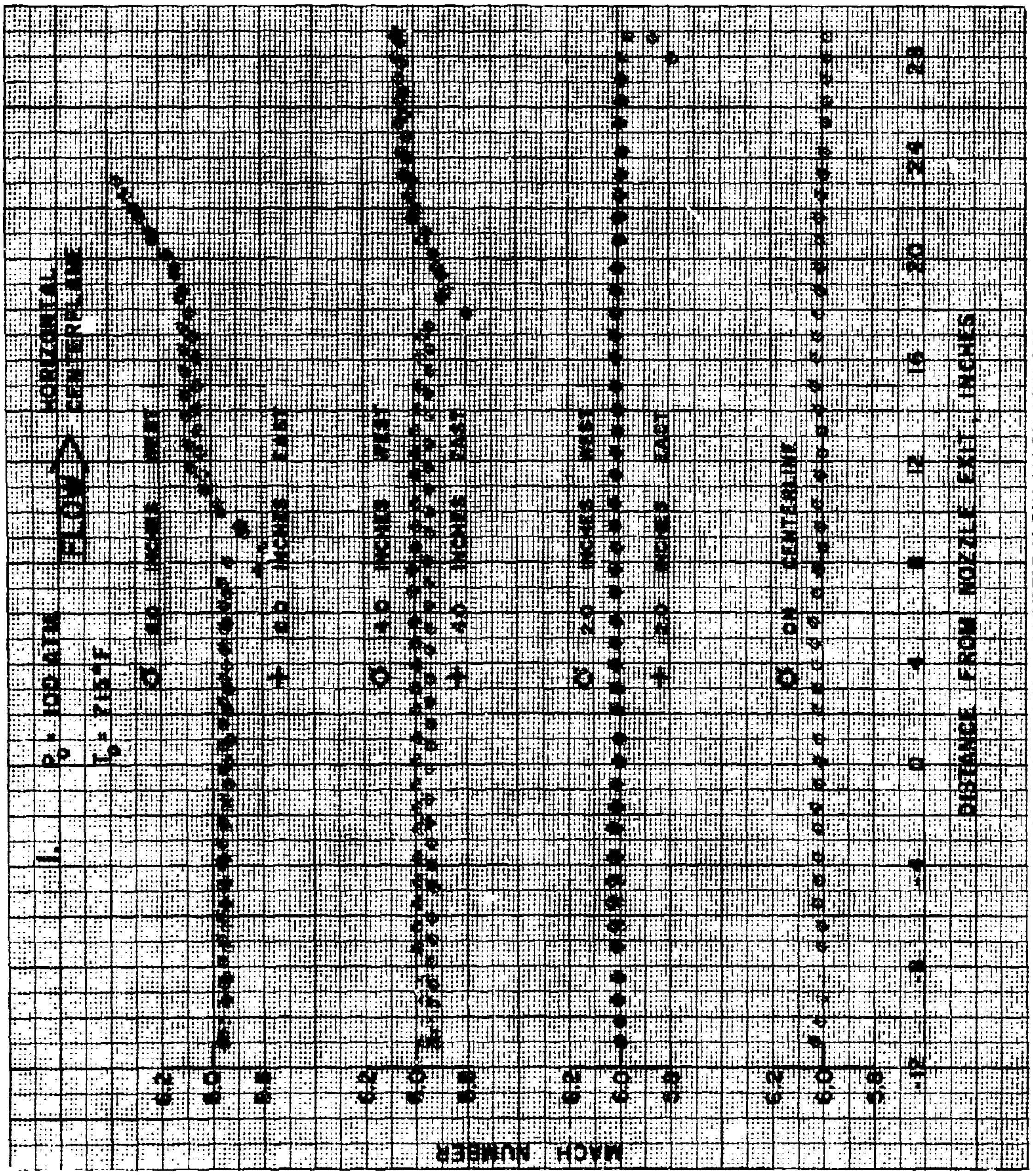

FIG. 6-1 MACH 6 NOZZLE FLOW MACH NUMBER

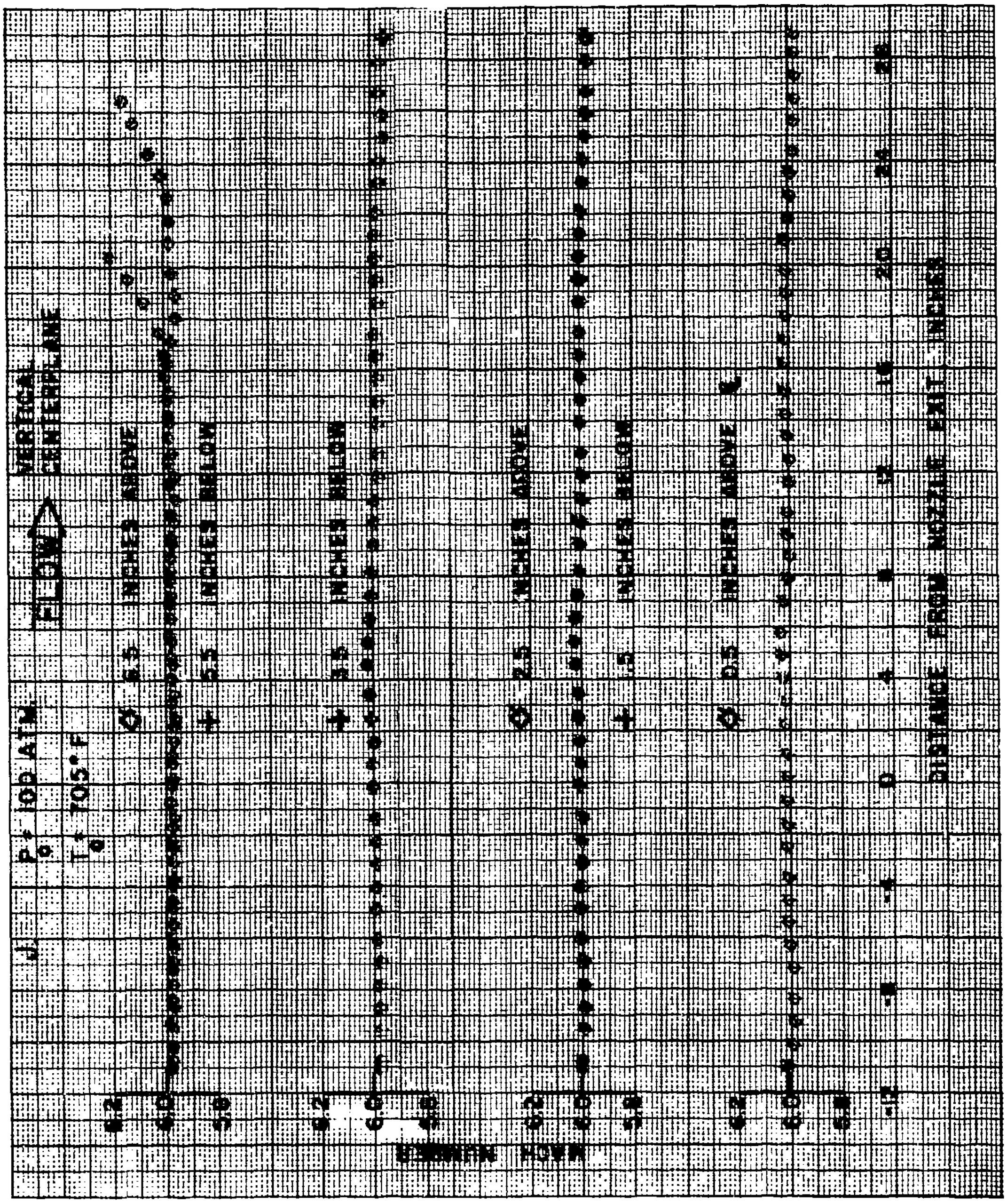

FIG. 6-J MACH 6 NOZZLE FLOW MACH NUMBER

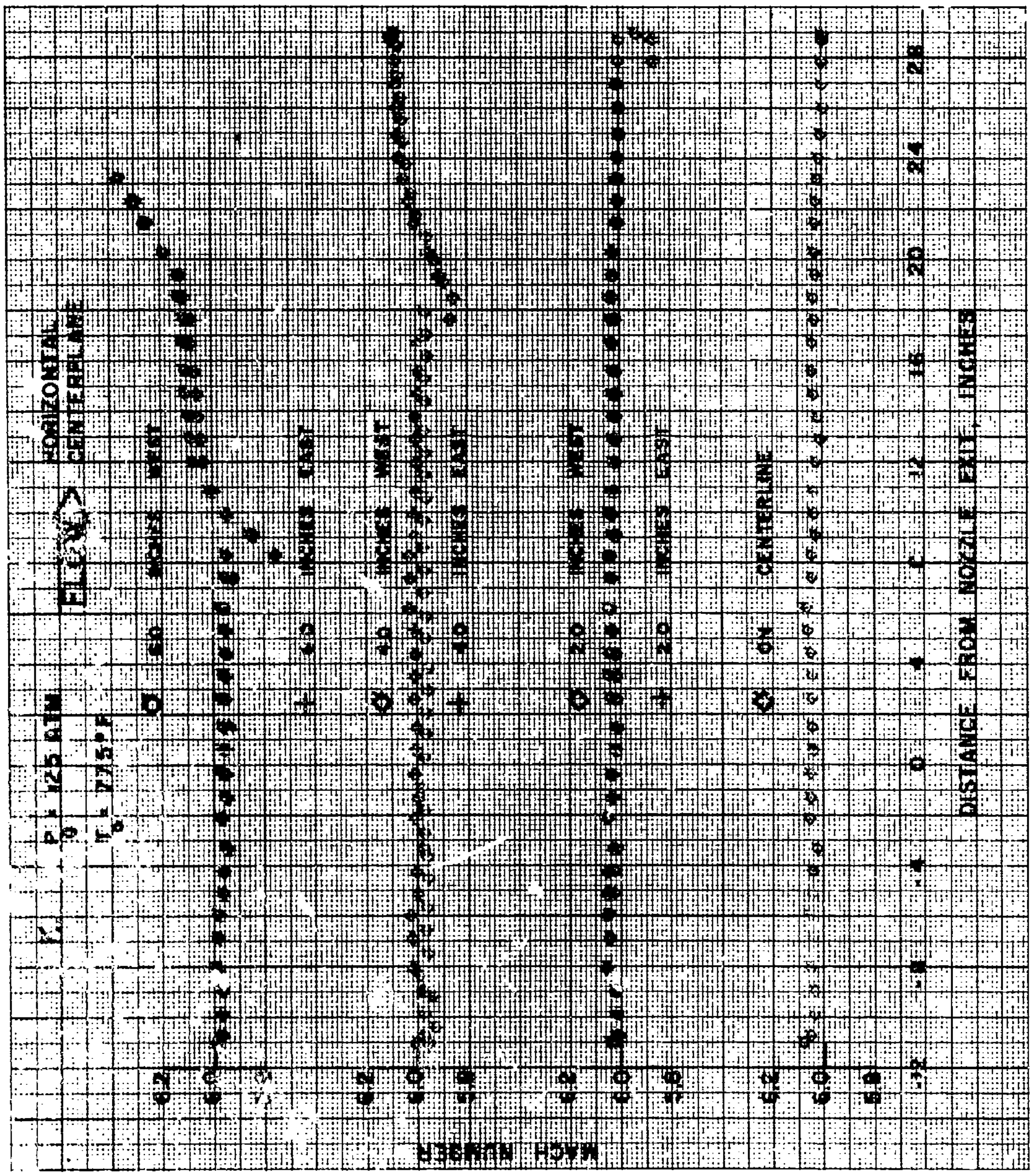

FIG. 6-K MACH 6 NOZZLE FLOW MACH NUMBER

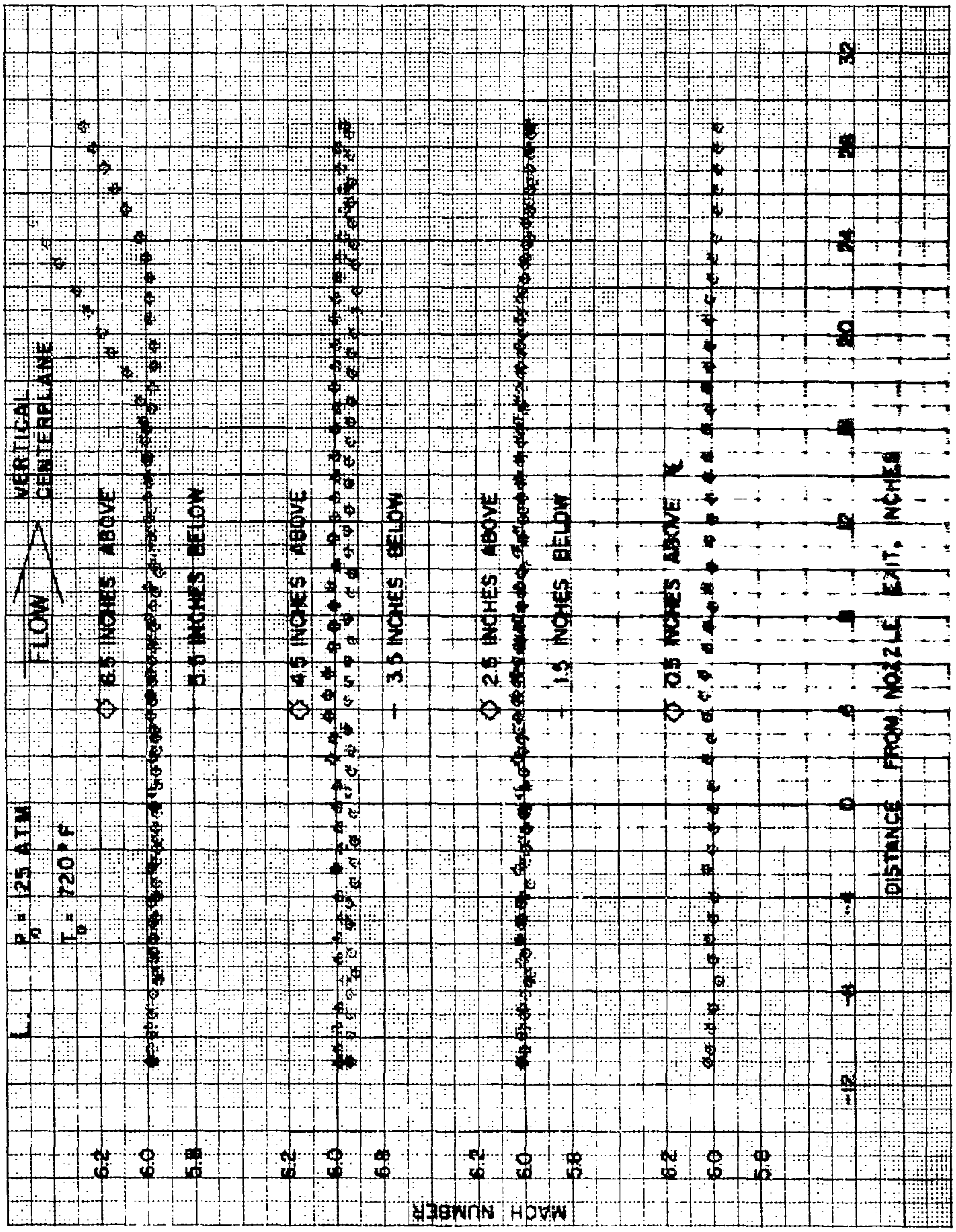

FIG. 6-1 MACH 6 NOZZLE FLOW MACH NUMBERS

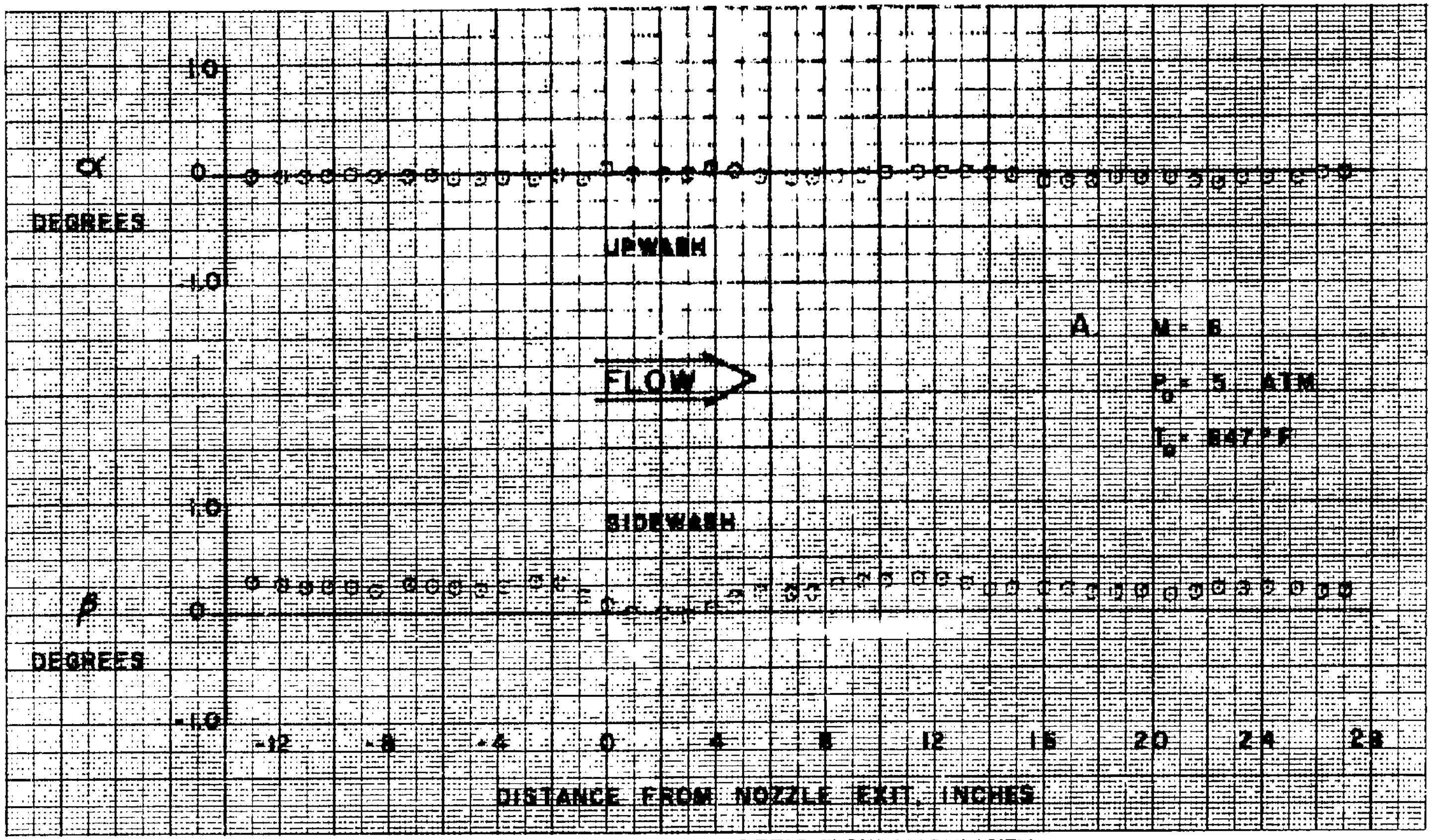

FIG. 7-A MACH 6 NOZZLE FLOW ANGULARITY

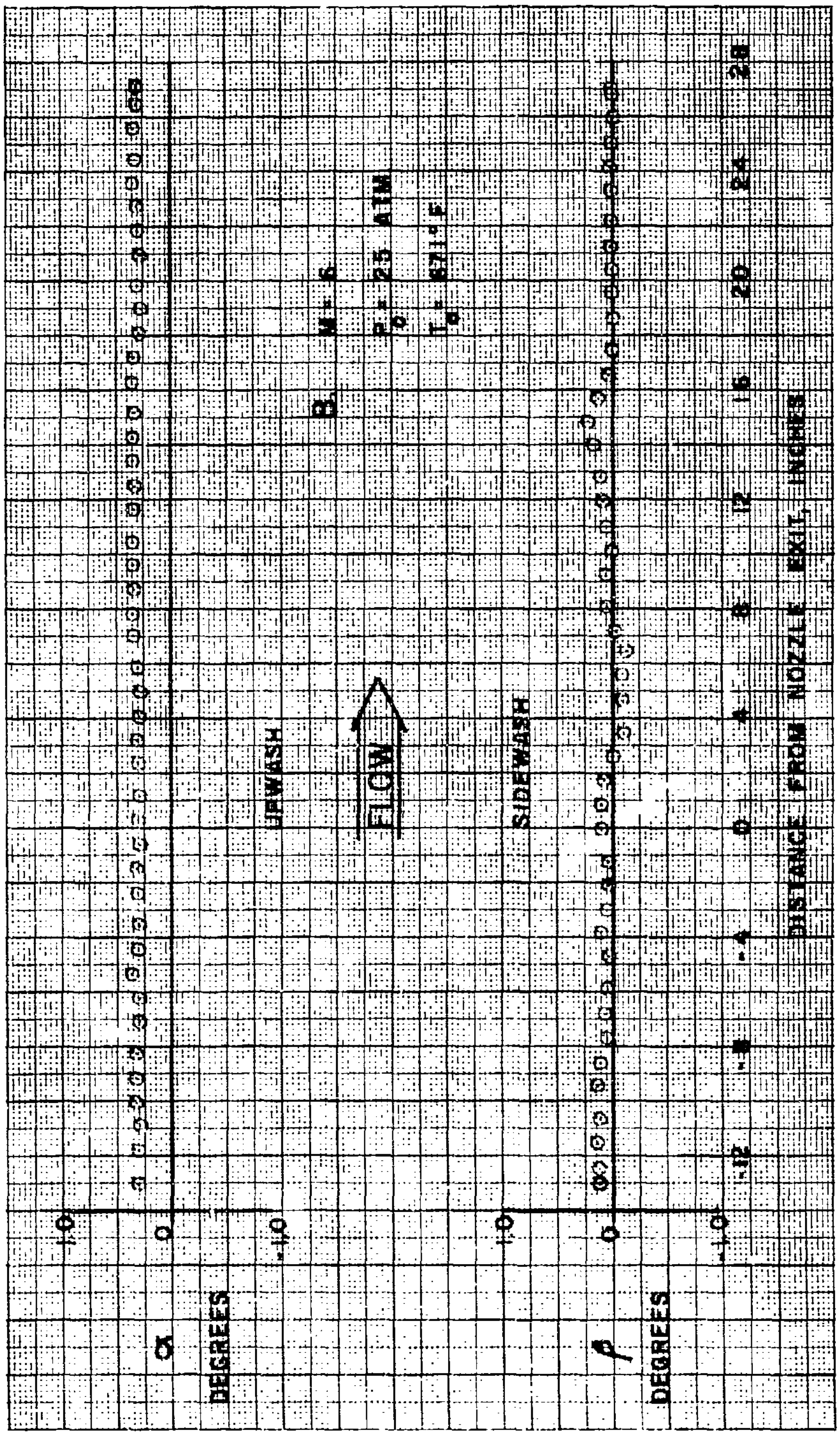

FIG. 7-8 MACH 6 NOZZLE FLOW ANGULARITY

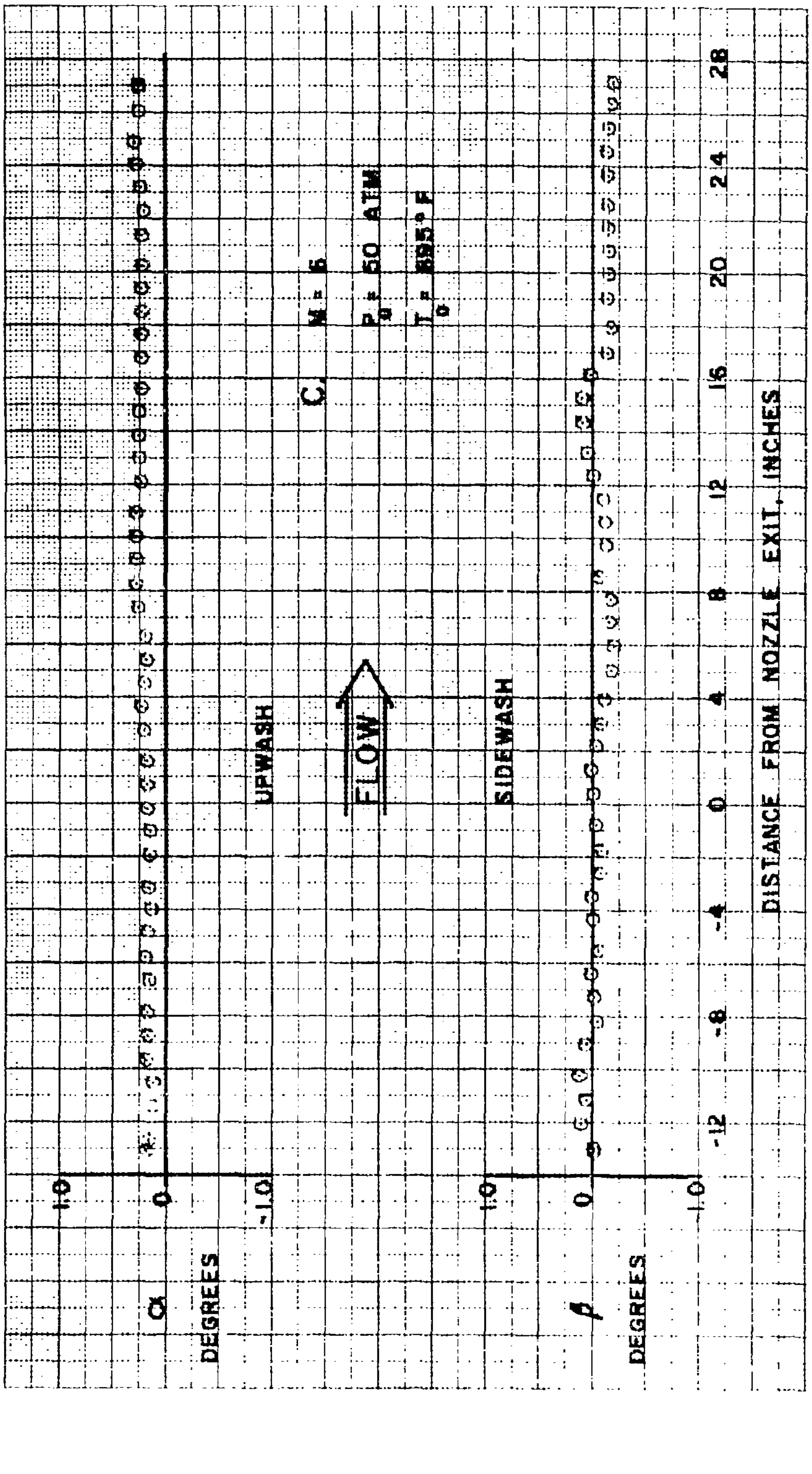

FIG. 7-C MACH 6 NOZZLE FLOW ANGULARITY

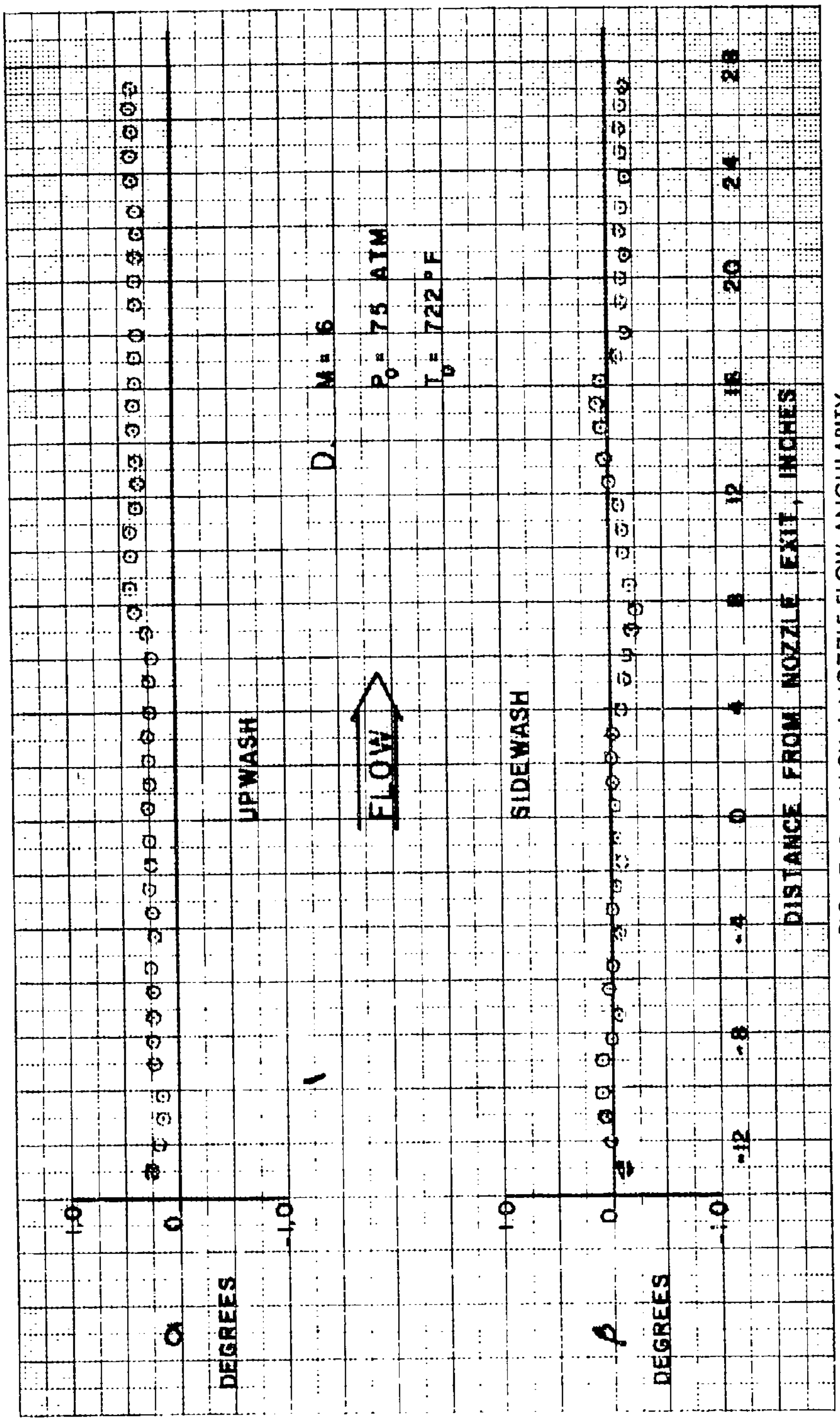

FIG. 7-D MACH 6 NOZZLE FLOW ANGULARITY

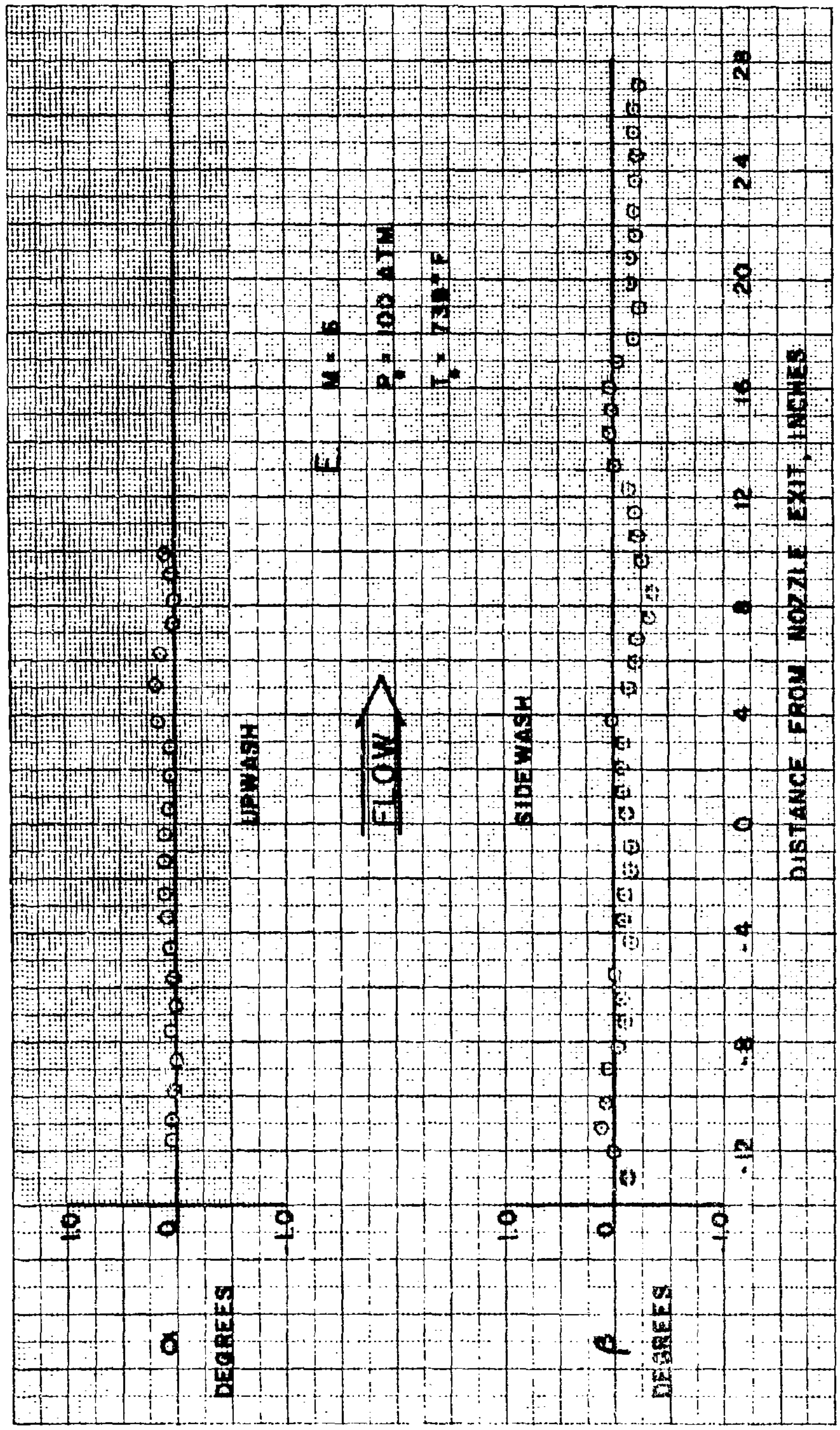

FIG. 7-E MACH 6 NOZZLE FLOW ANGULARITY

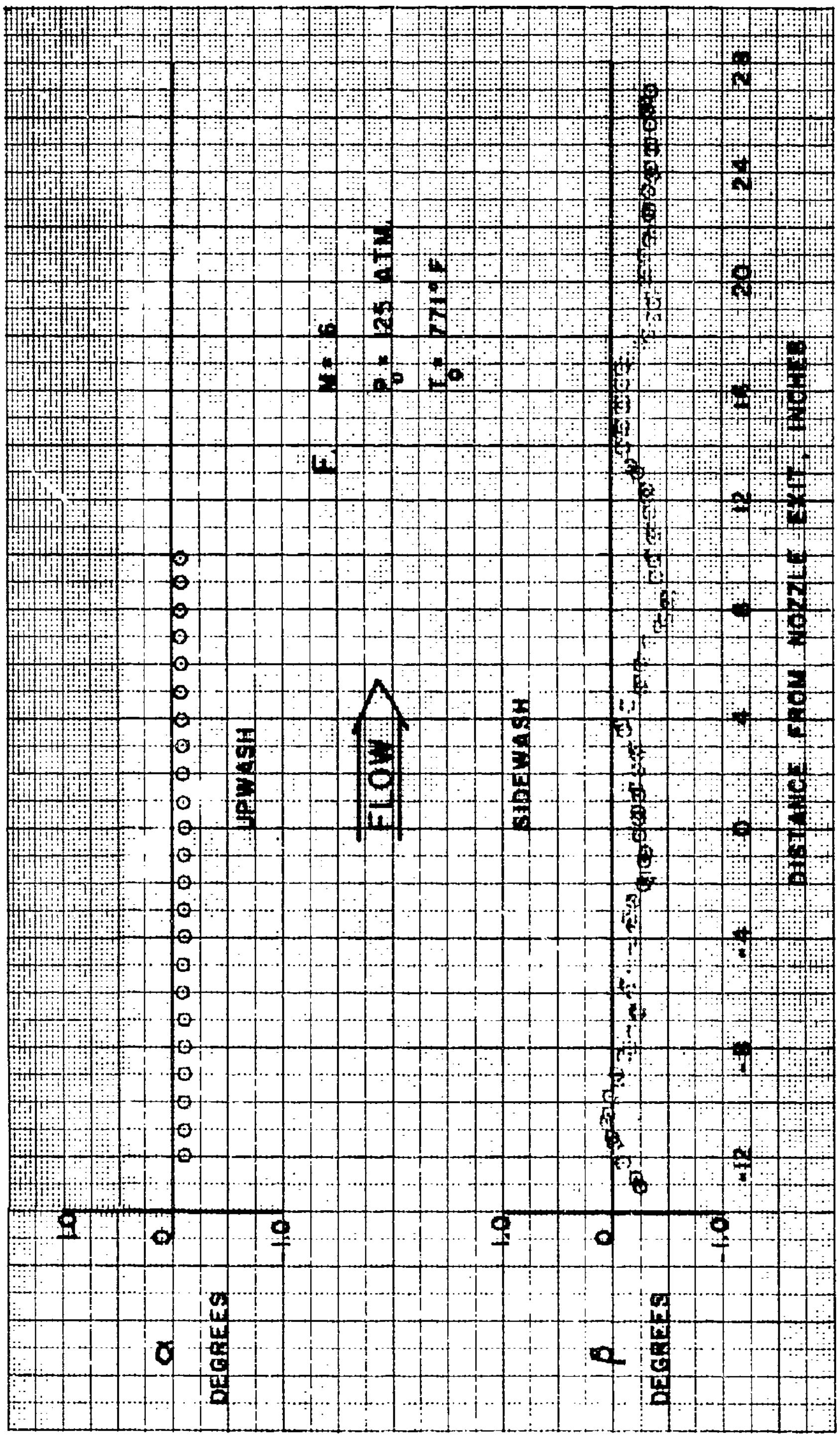

FIG. 7-F MACH 6 NOZZLE FLOW ANGULARITY

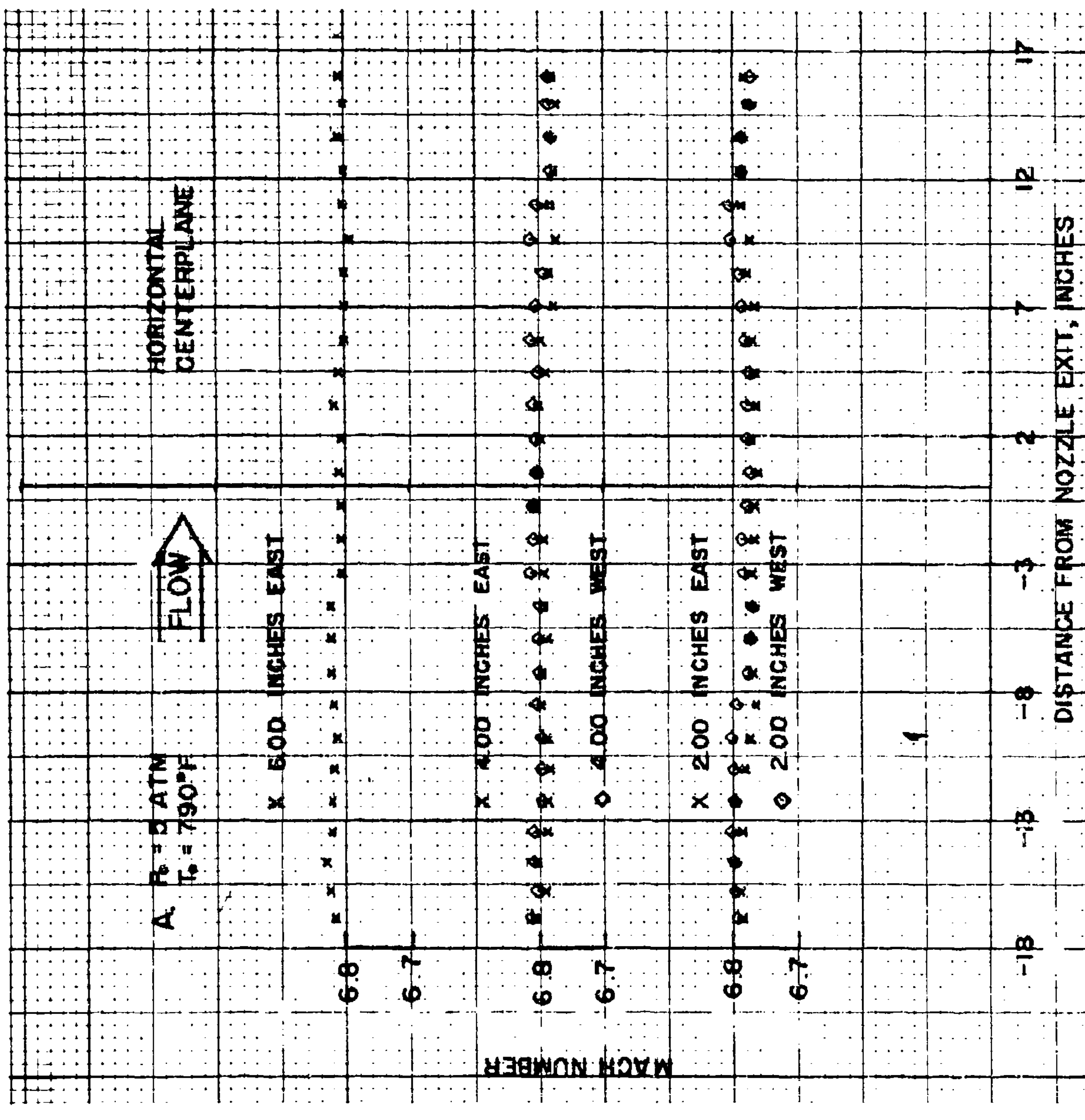

FIG. 8-A MACH 7 NOZZLE FLOW MACH NUMBER

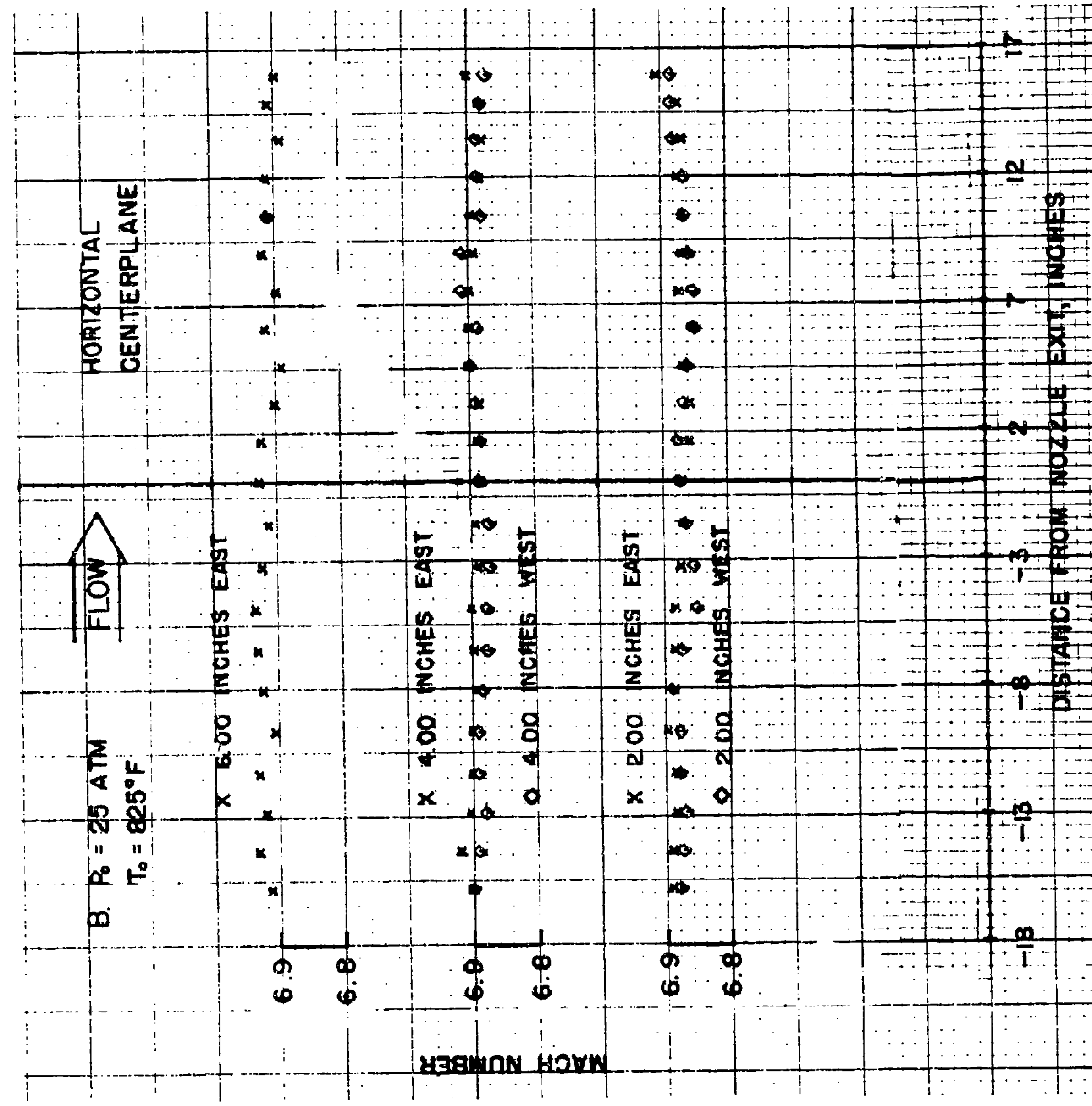

FIG. 8-B MACH 7 NOZZLE FLOW MACH NUMBER

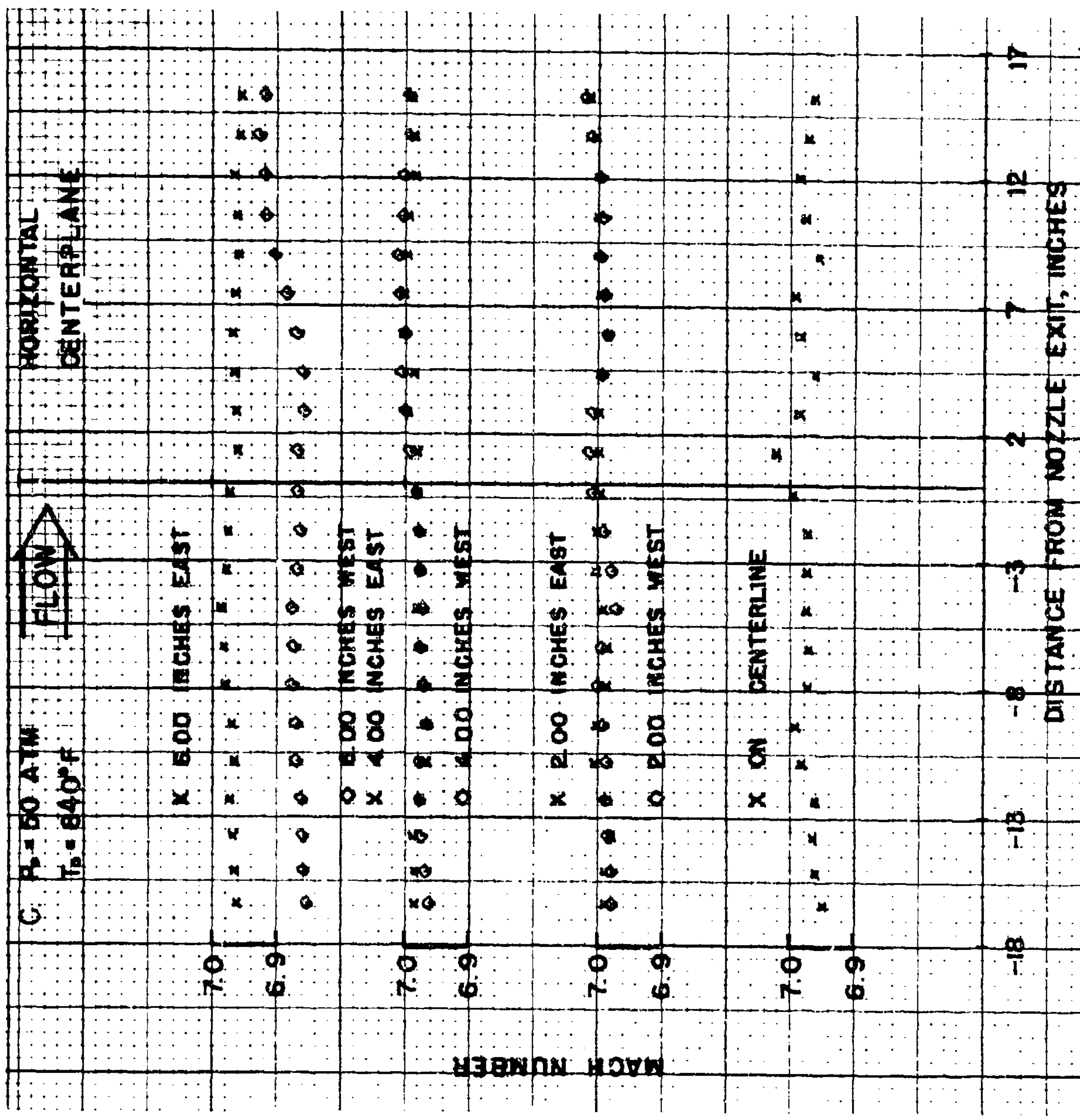

FIG. 8-C MACH 7 NOZZLE FLOW MACH NUMBER

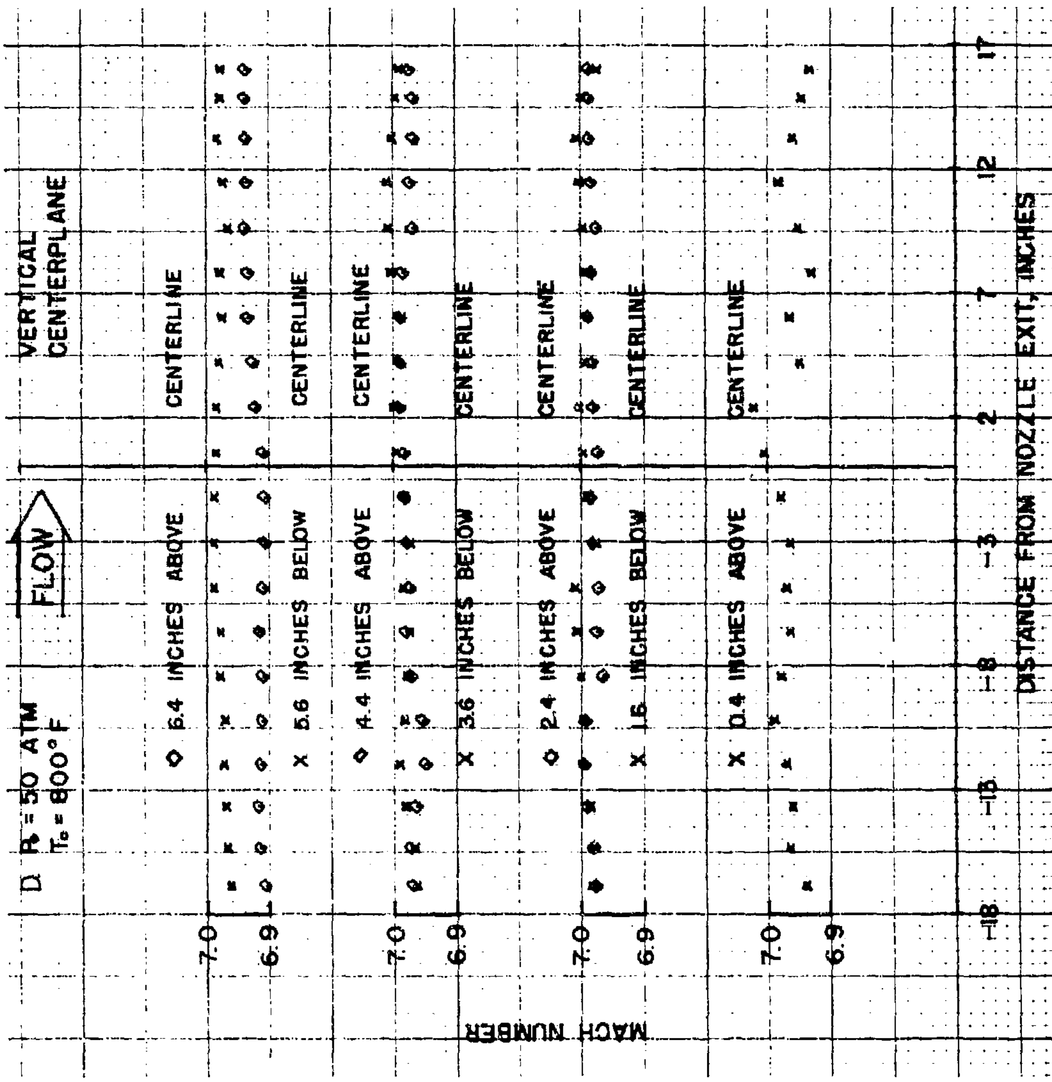

FIG. 8-D MACH 7 NOZZLE FLOW MACH NUMBER

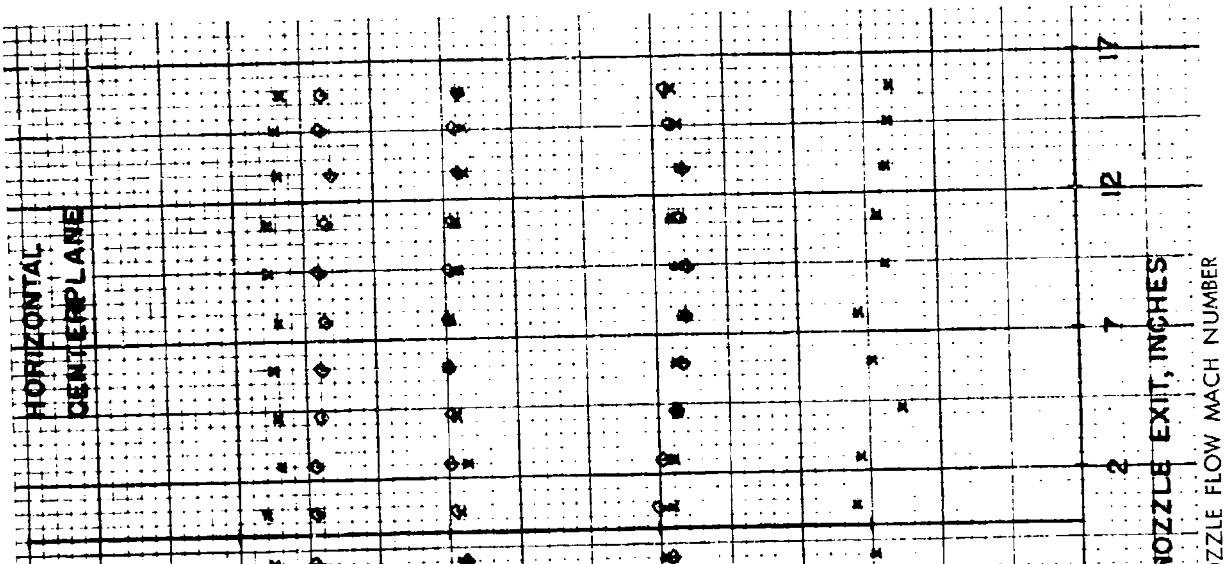

FIG. 8-E MACH 7 NOZZLE FLOW MACH NUMBER

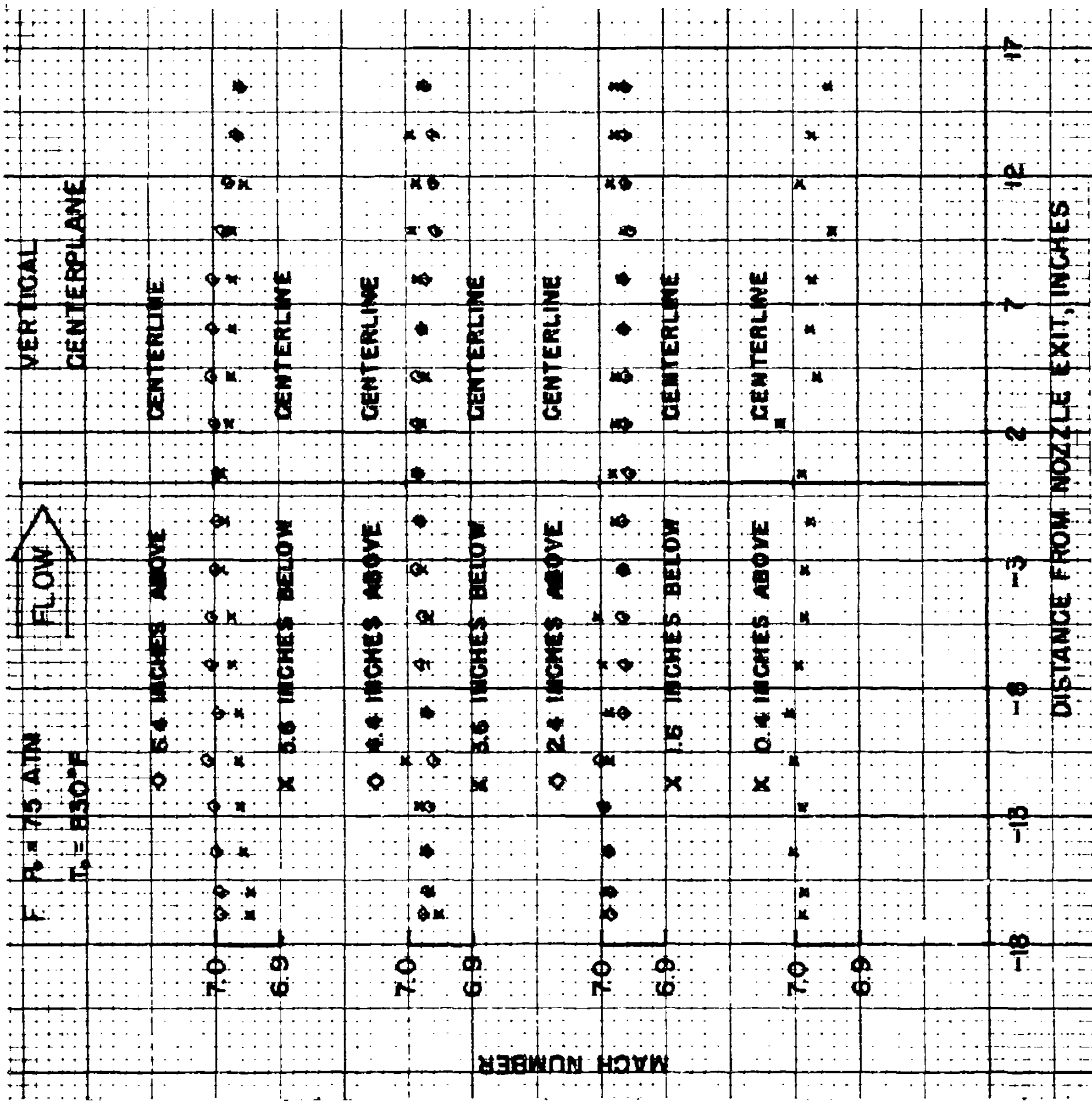

FIG. 8-F MACH 7 NOZZLE FLOW MACH NUMBER

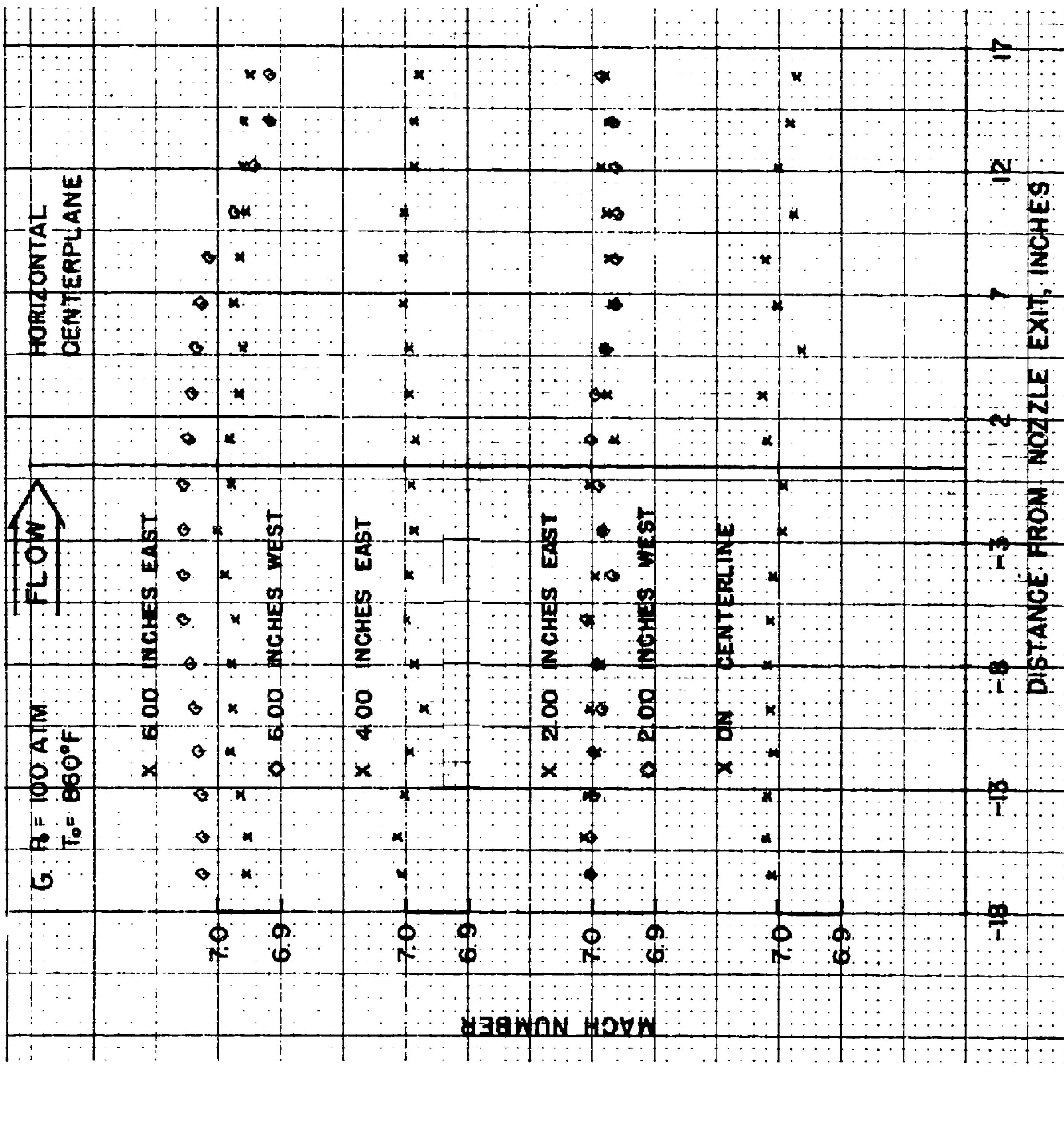

FIG. 8-G MACH 7 NOZZLE FLOW MACH NUMBER

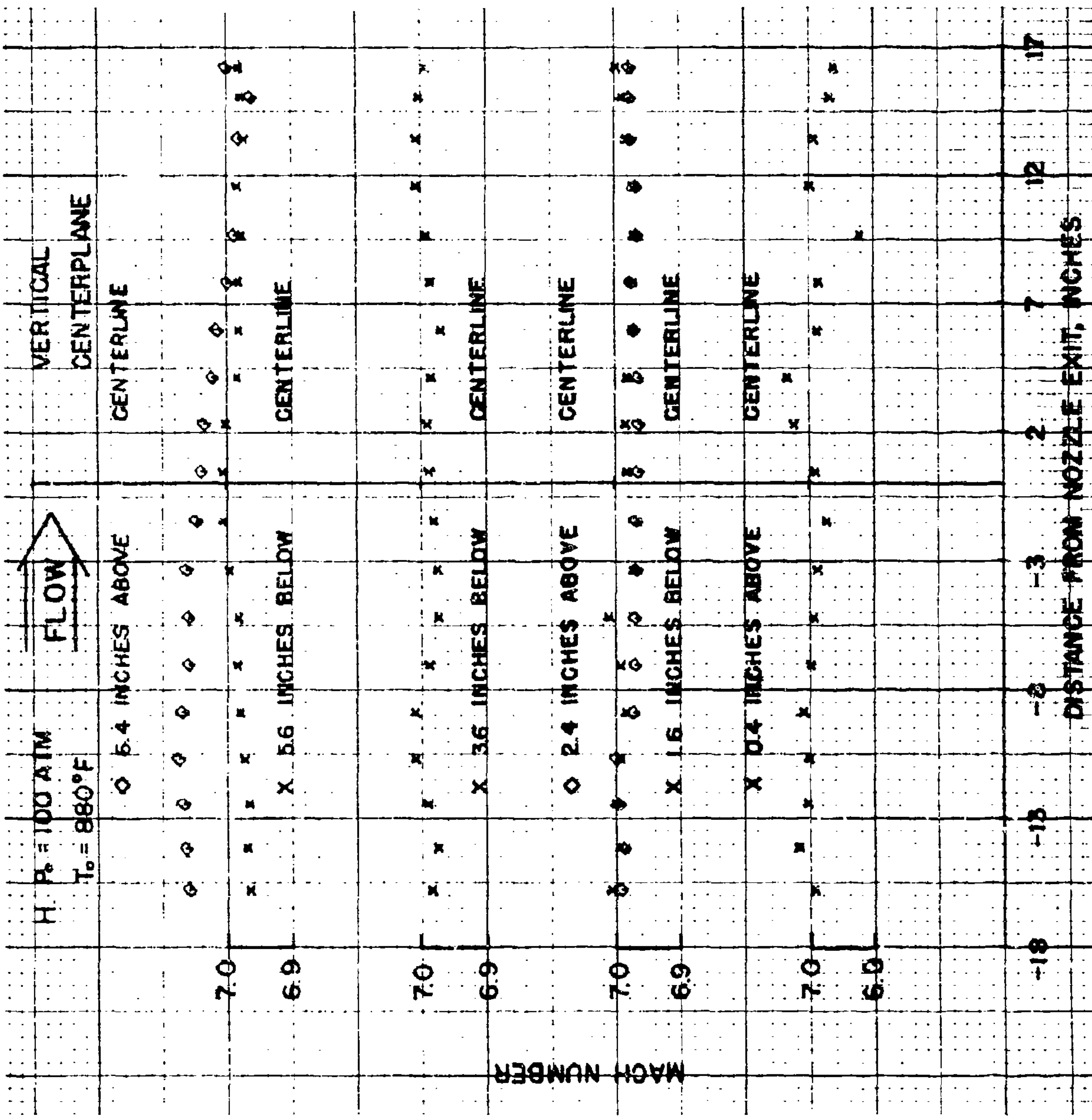

FIG. 8-H MACH 7 NOZZLE FLOW MACH NUMBER

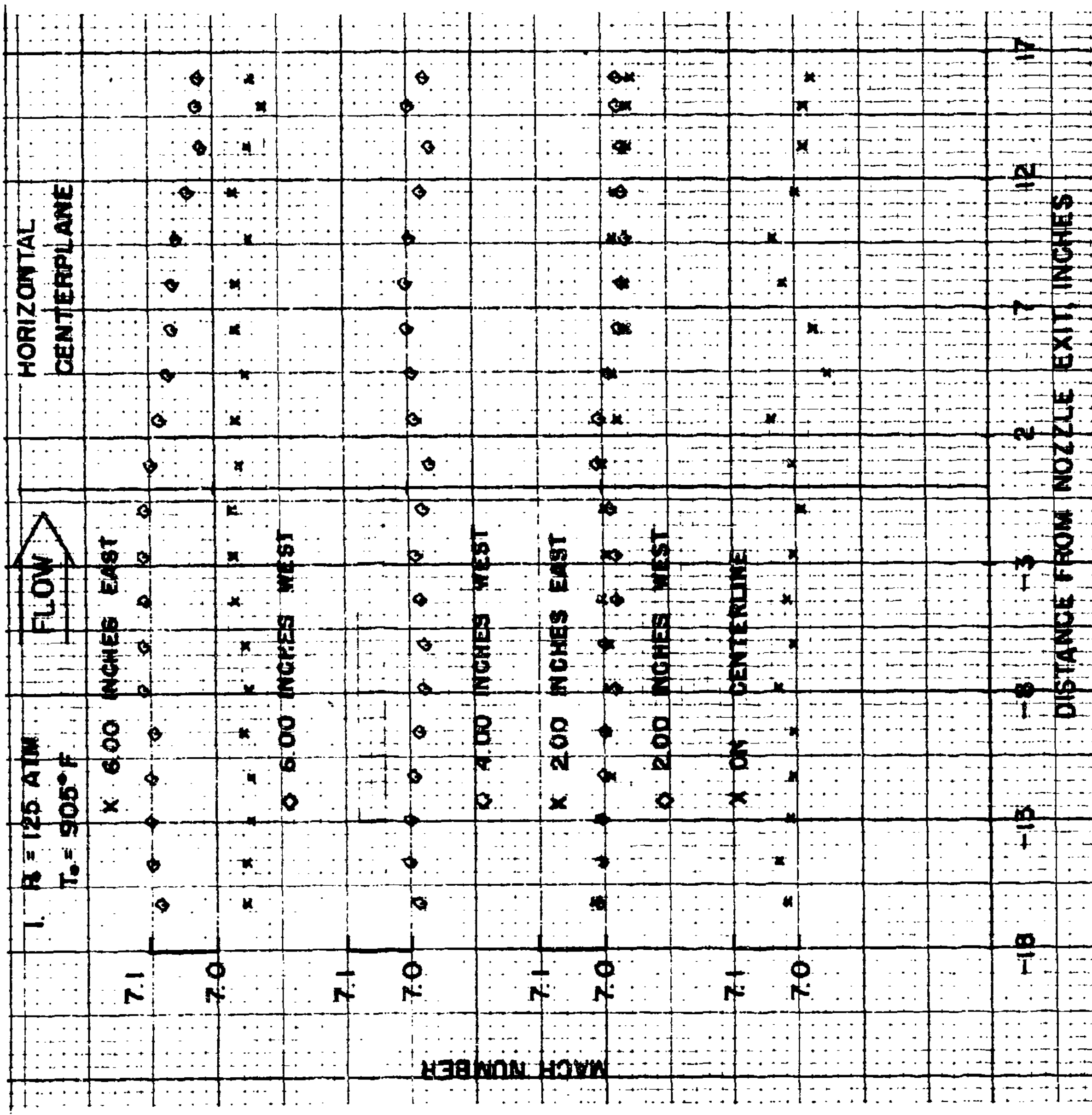

FIG. 8-1 MACH 7 NOZZLE FLOW MACH NUMBER

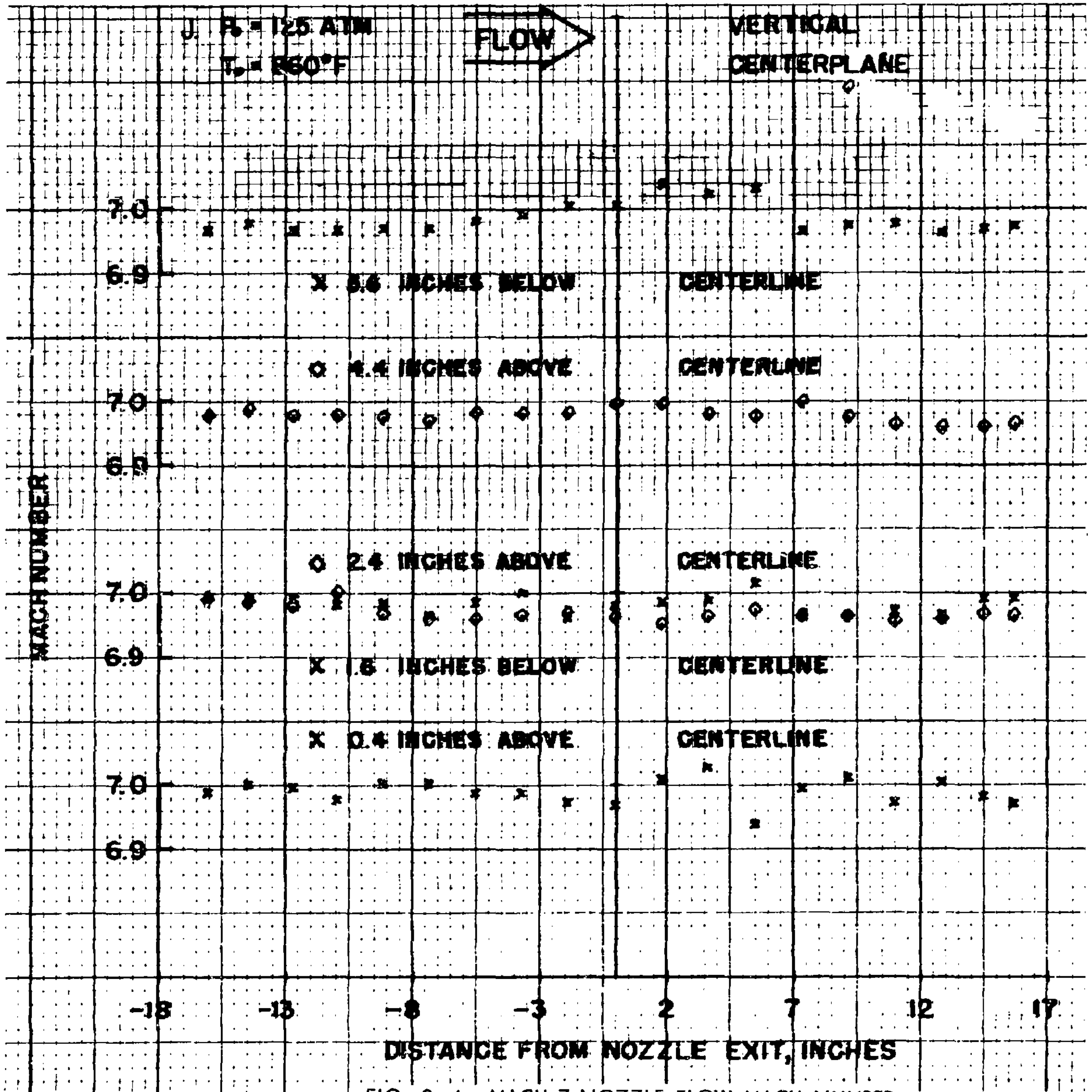

FIG. 8-J MACH 7 NOZZLE FLOW MACH NUMBER

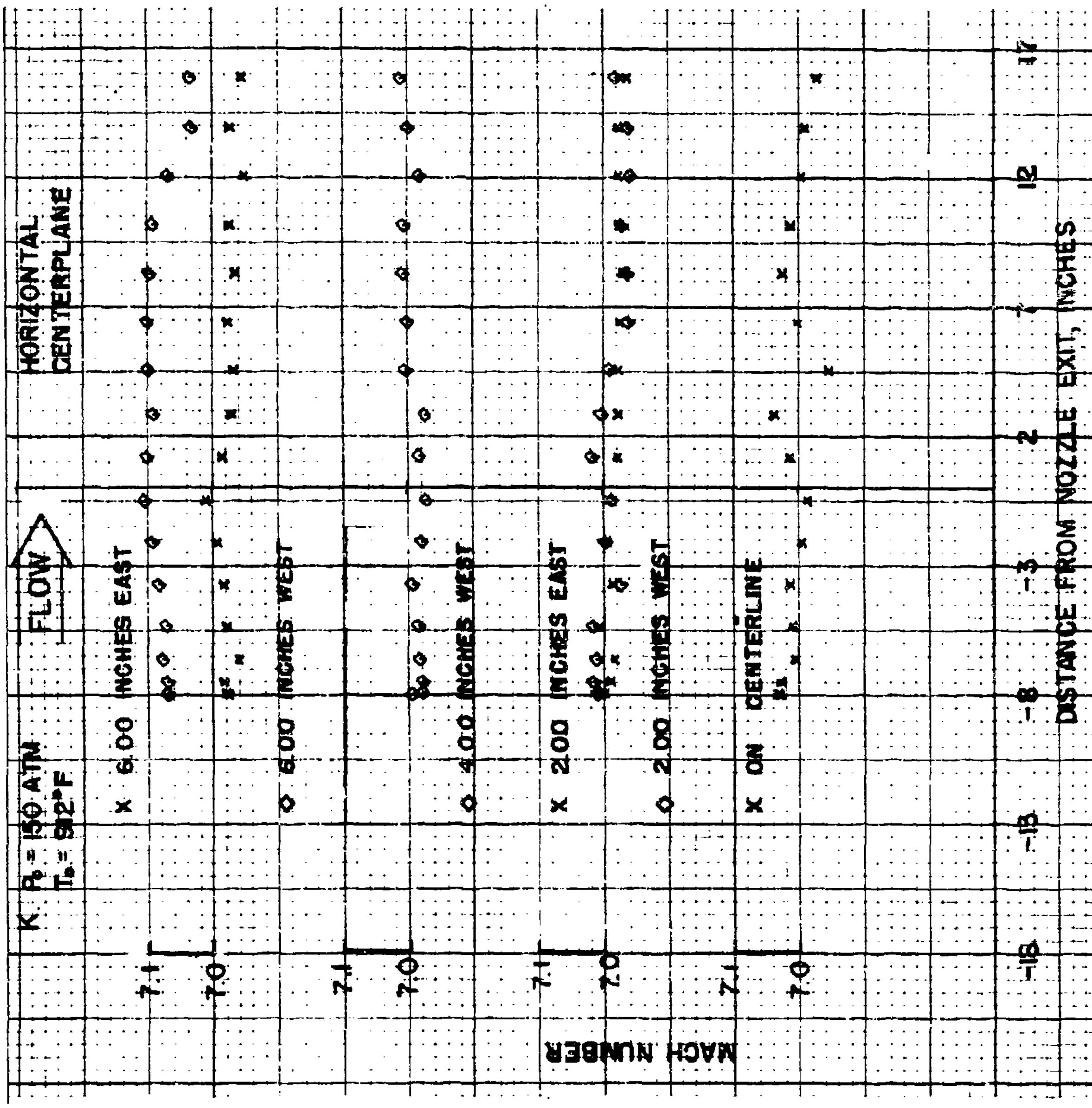

FIG. 8-K MACH 7 NOZZLE FLOW MACH NUMBER

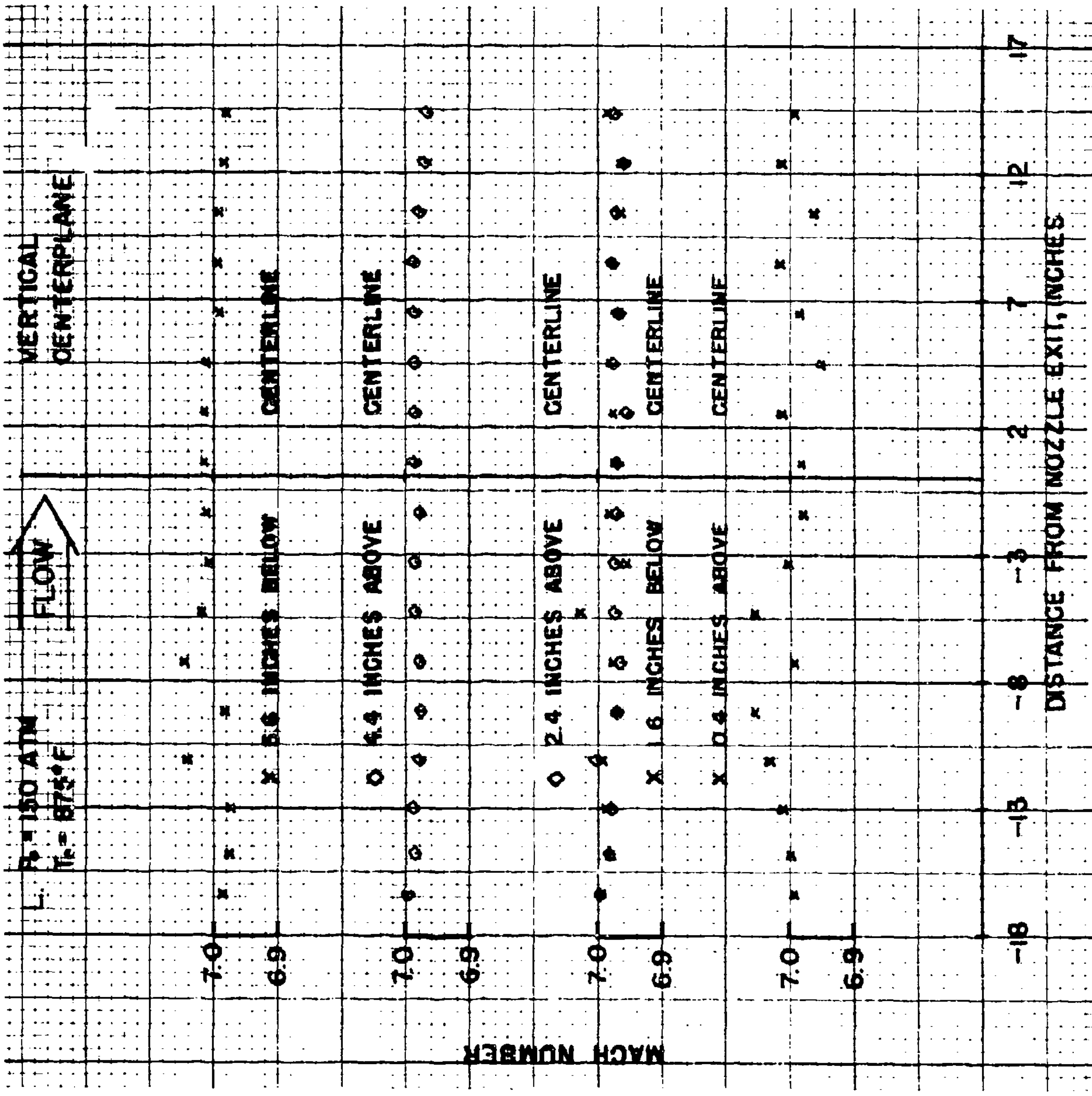

FIG. 8-L MACH 7 NOZZLE FLOW MACH NUMBER

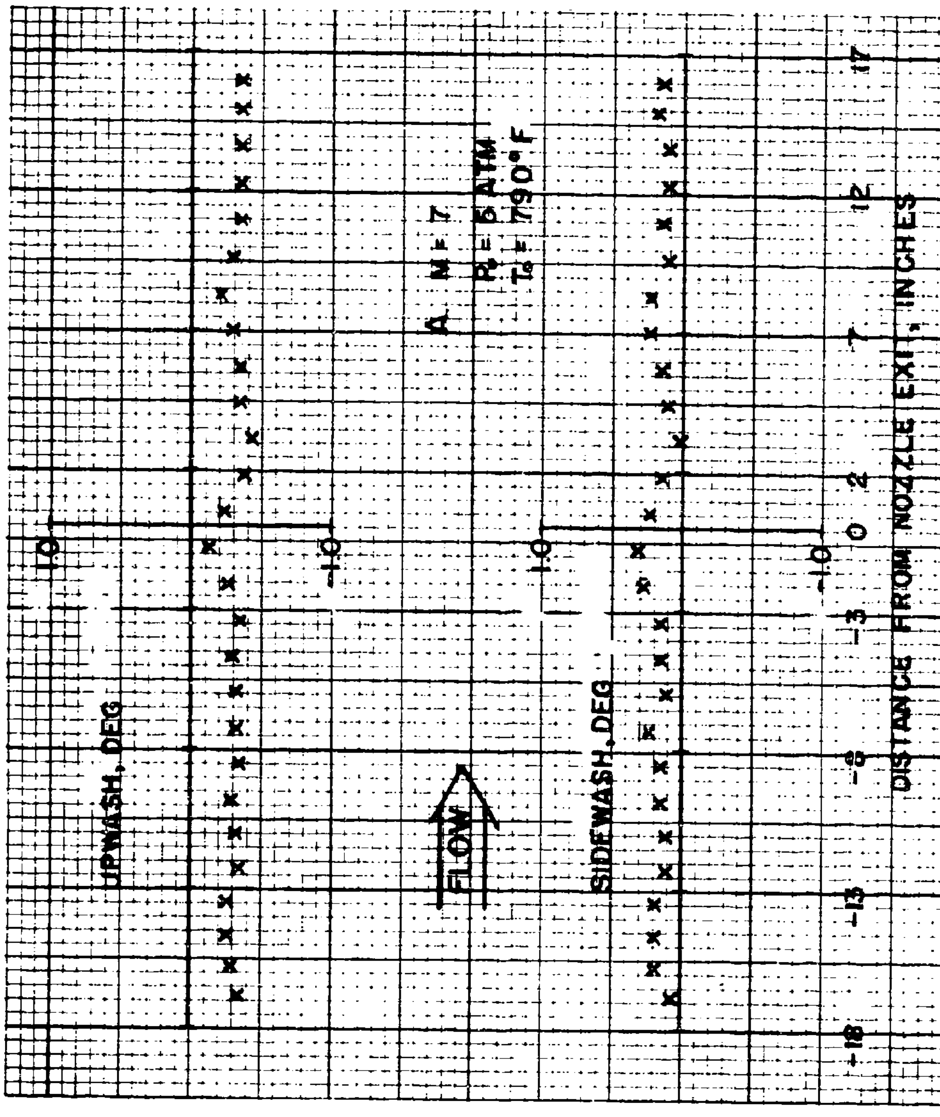

FIG. 9-A MACH 7 NOZZLE FLOW ANGULARITY

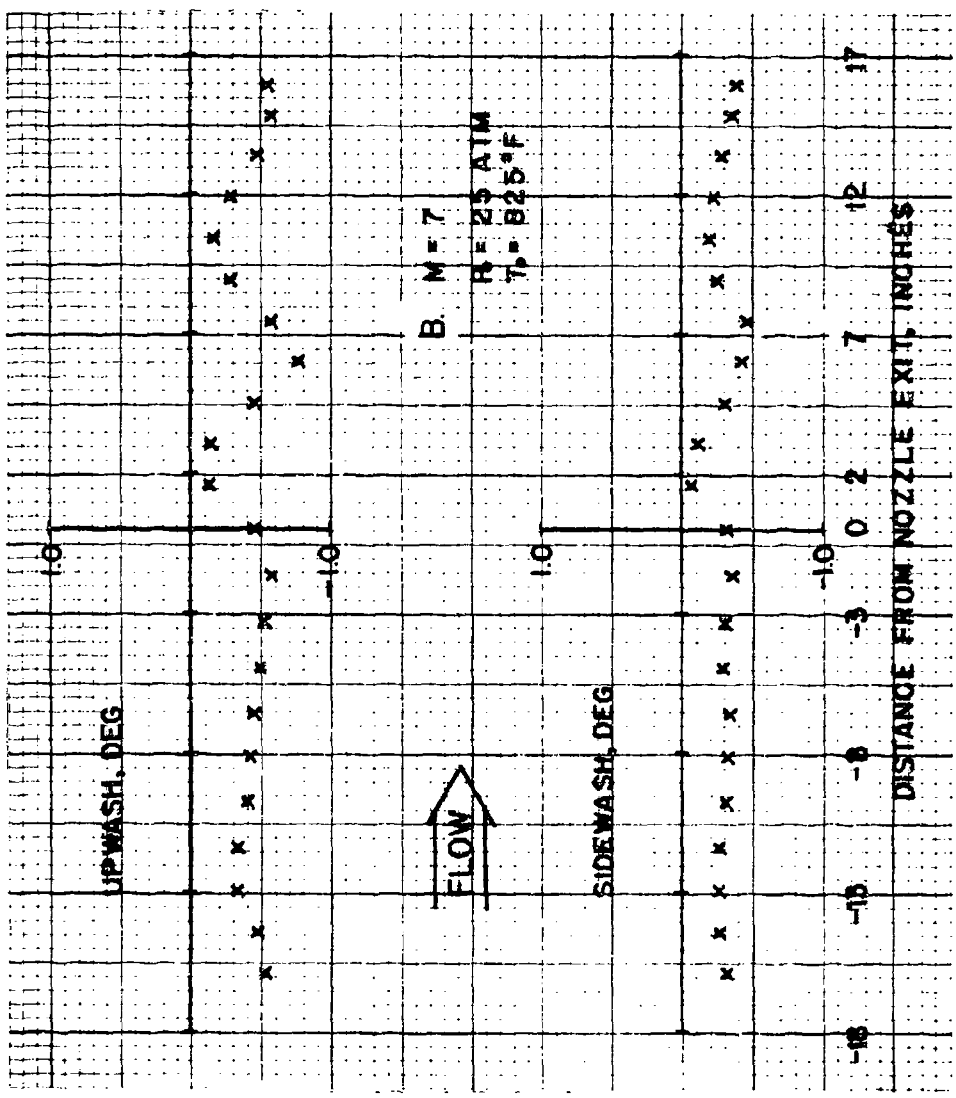

FIG. 9-B MACH 7 NOZZLE FLOW ANGULARITY

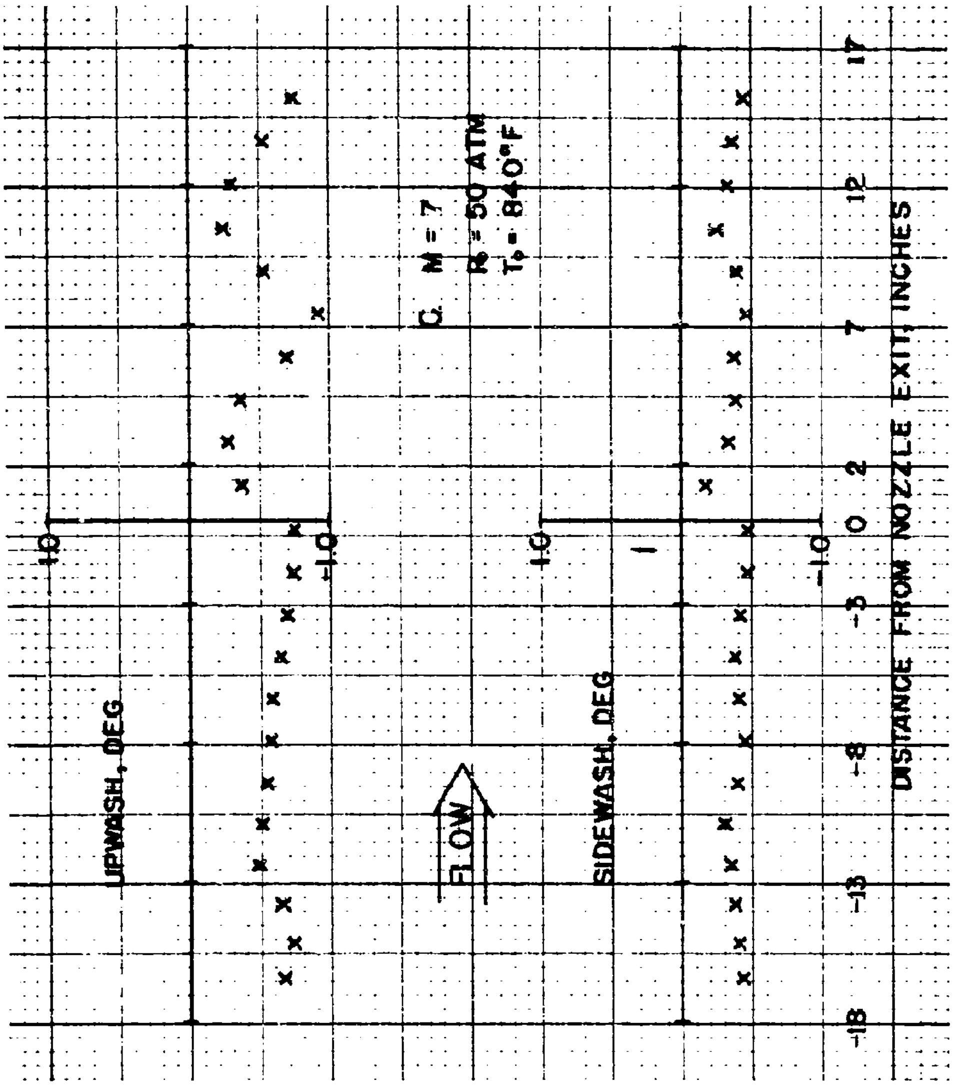

FIG. 9-C MACH 7 NOZZLE FLOW ANGULARITY

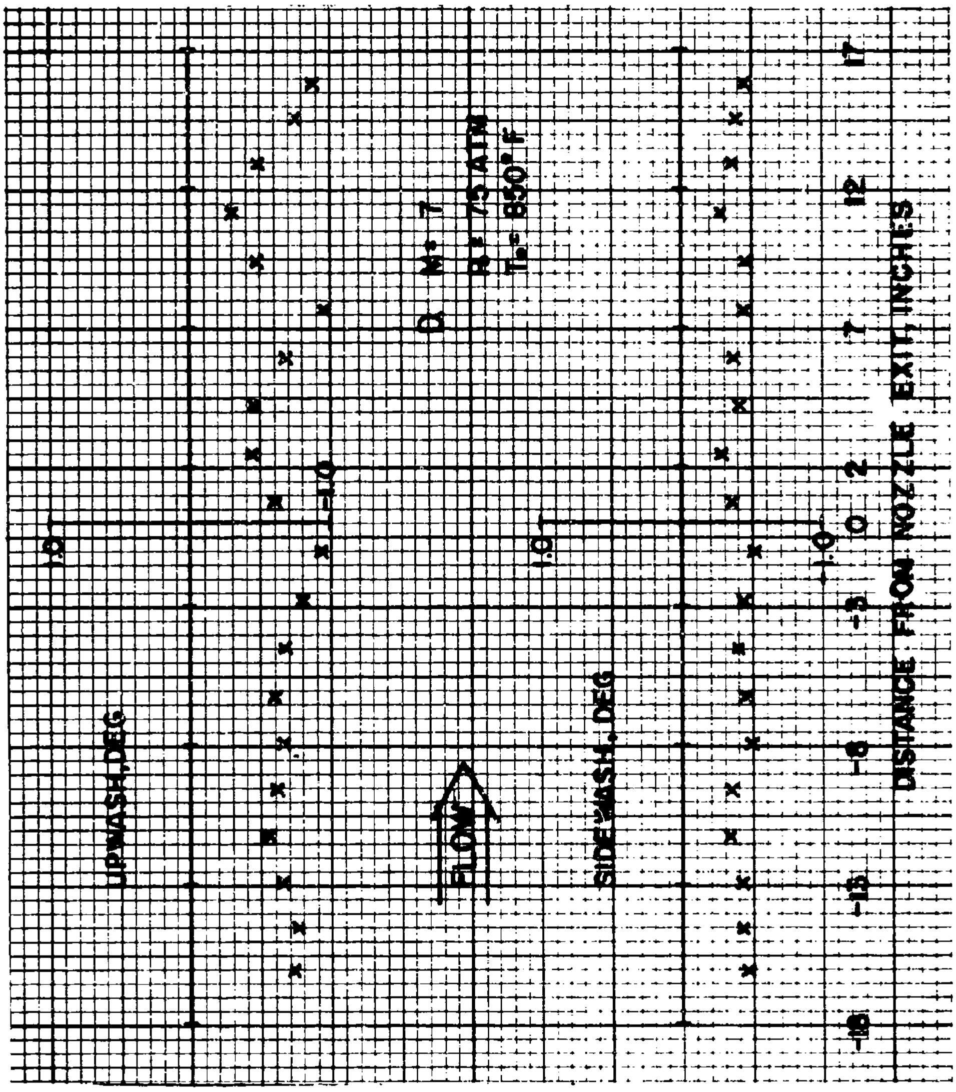

FIG. 9-D MACH 7 NOZZLE FLOW ANGULARITY

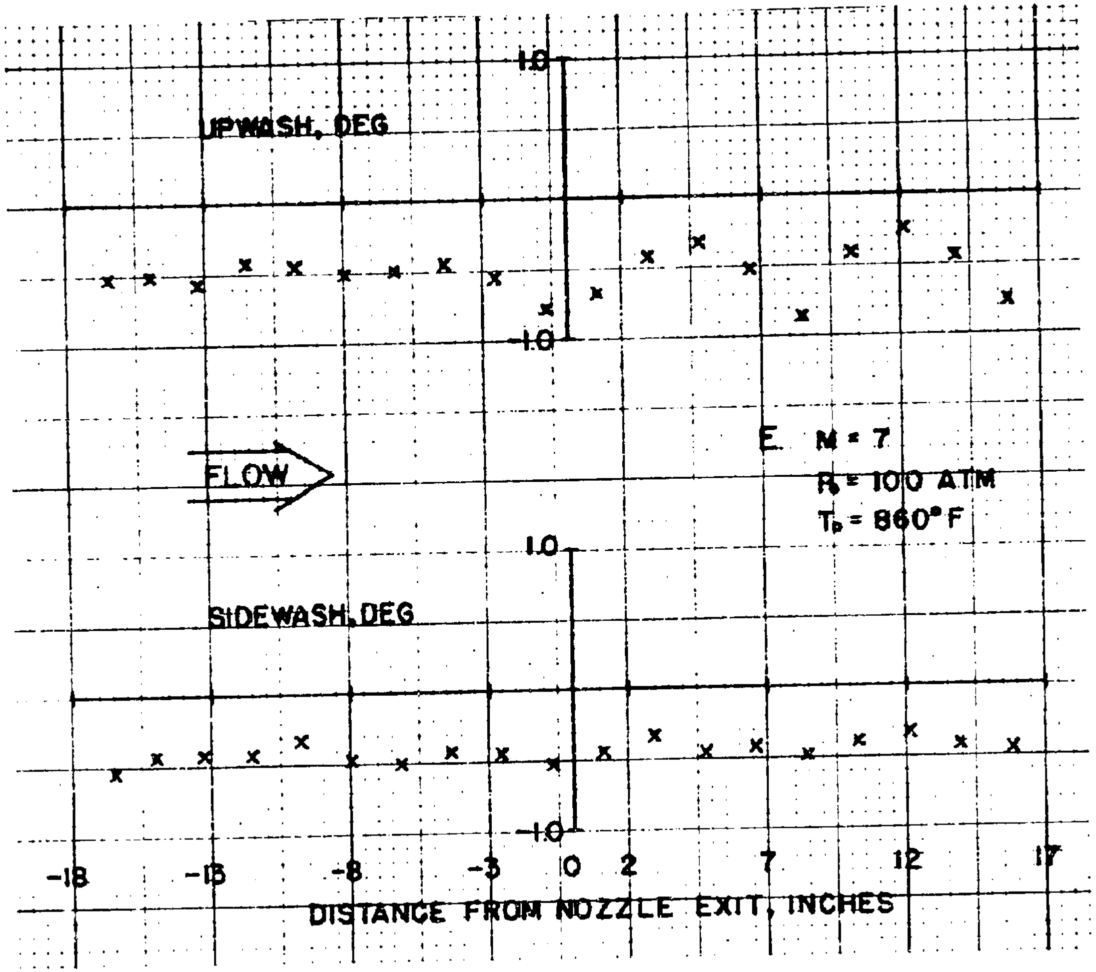

FIG. 9-E MACH 7 NOZZLE FLOW ANGULARITY

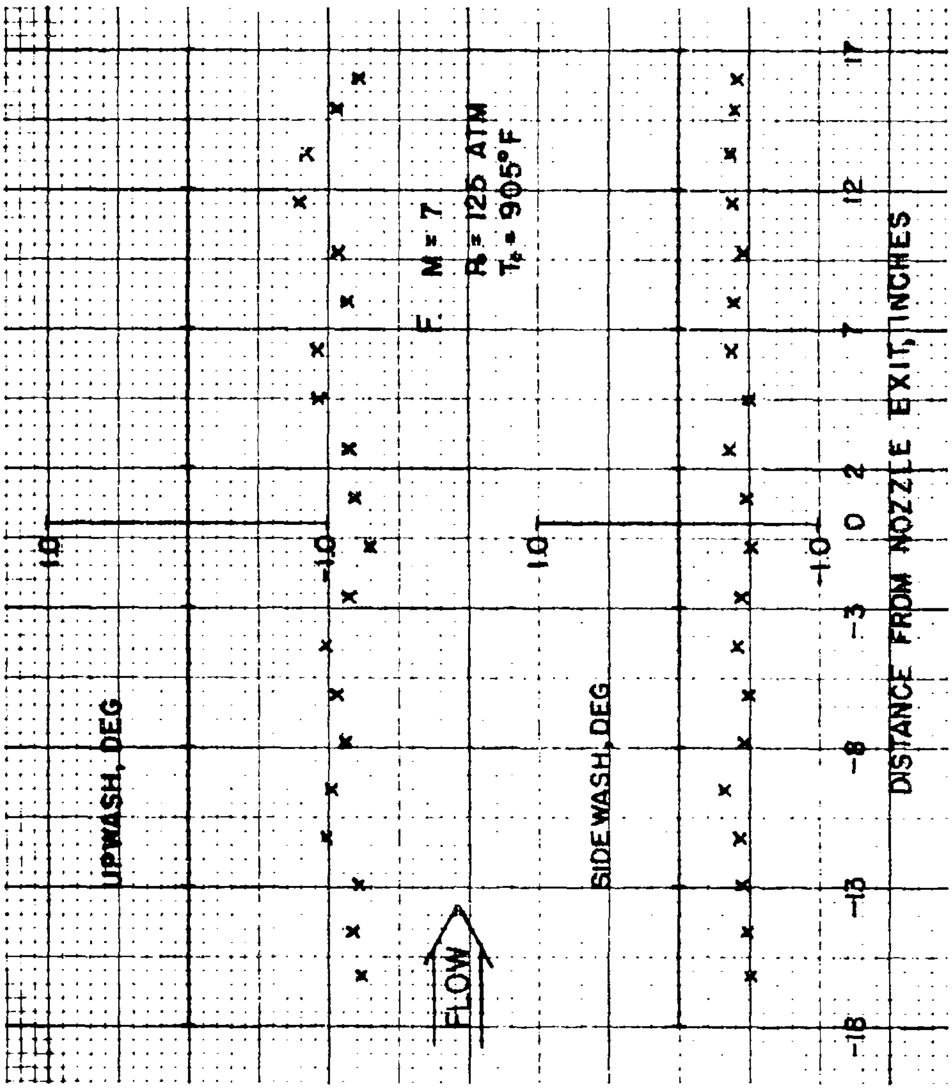

FIG. 9-F MACH 7 NOZZLE FLOW ANGULARITY

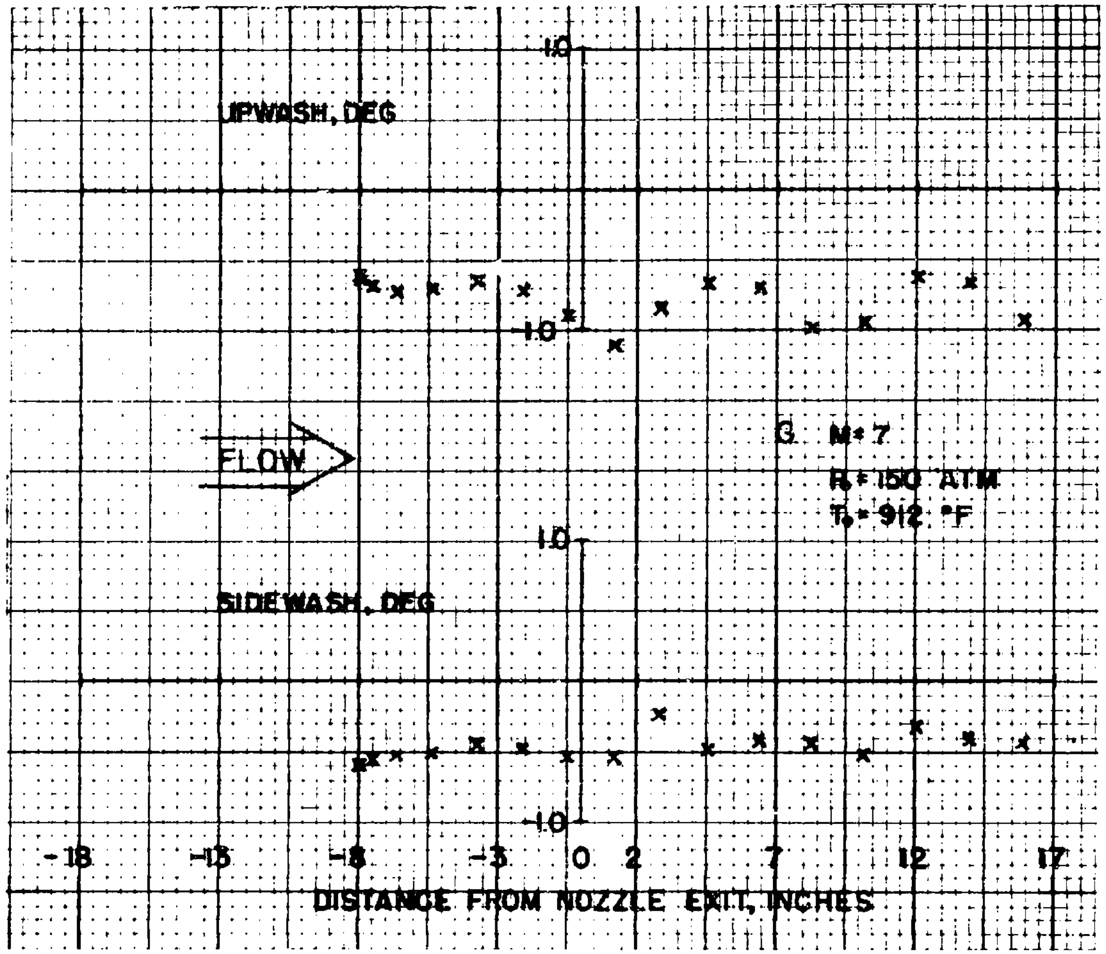

FIG. 9-G MACH 7 NOZZLE FLOW ANGULARITY

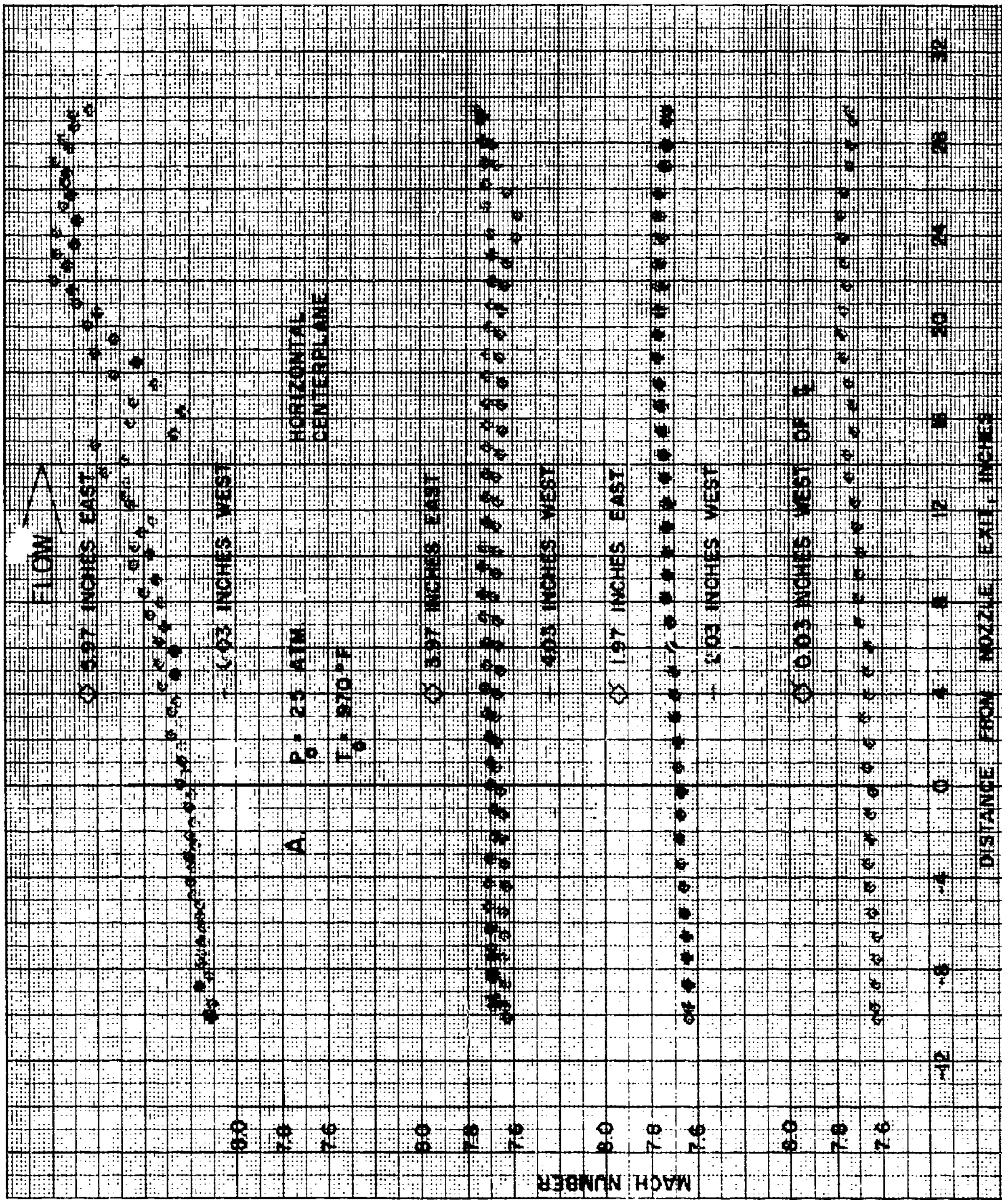

FIG. 10-A MACH 8 NOZZLE FLOW MACH NUMBER

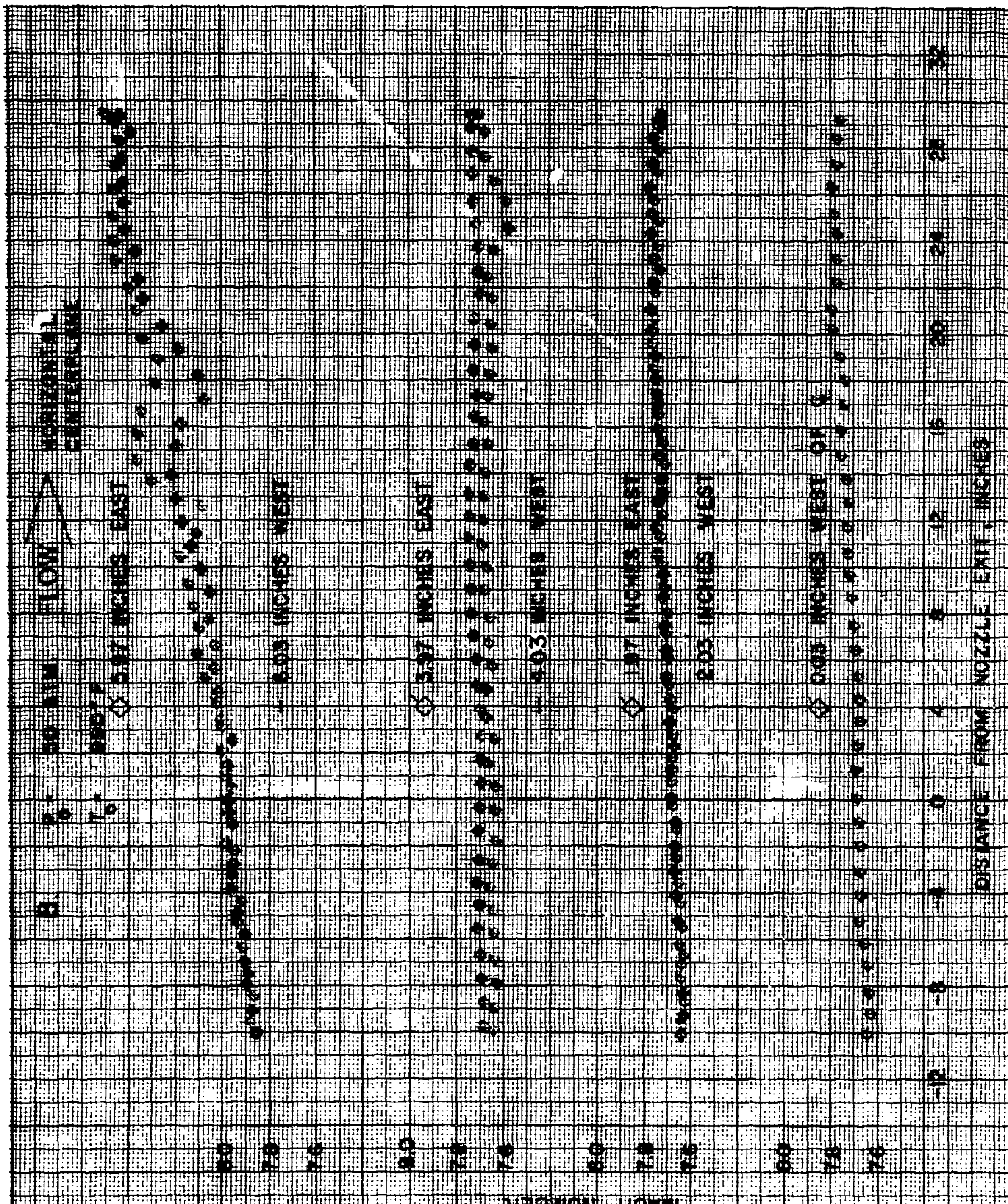

FIG. 10-B MACH 8 NOZZLE FLOW MACH NUMBER

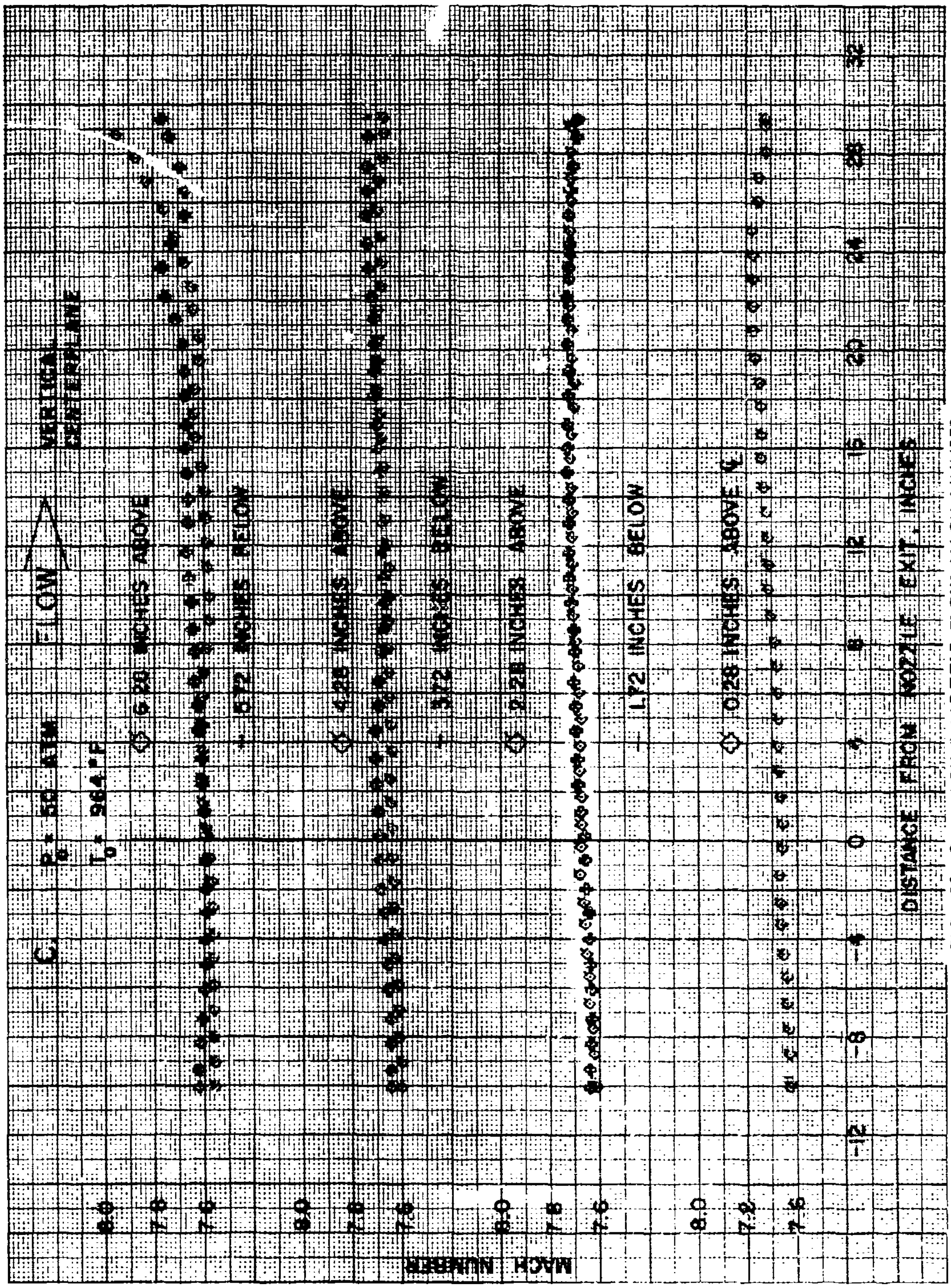

FIG. 10-C MACH 8 NOZZLE FLOW MACH NUMBER

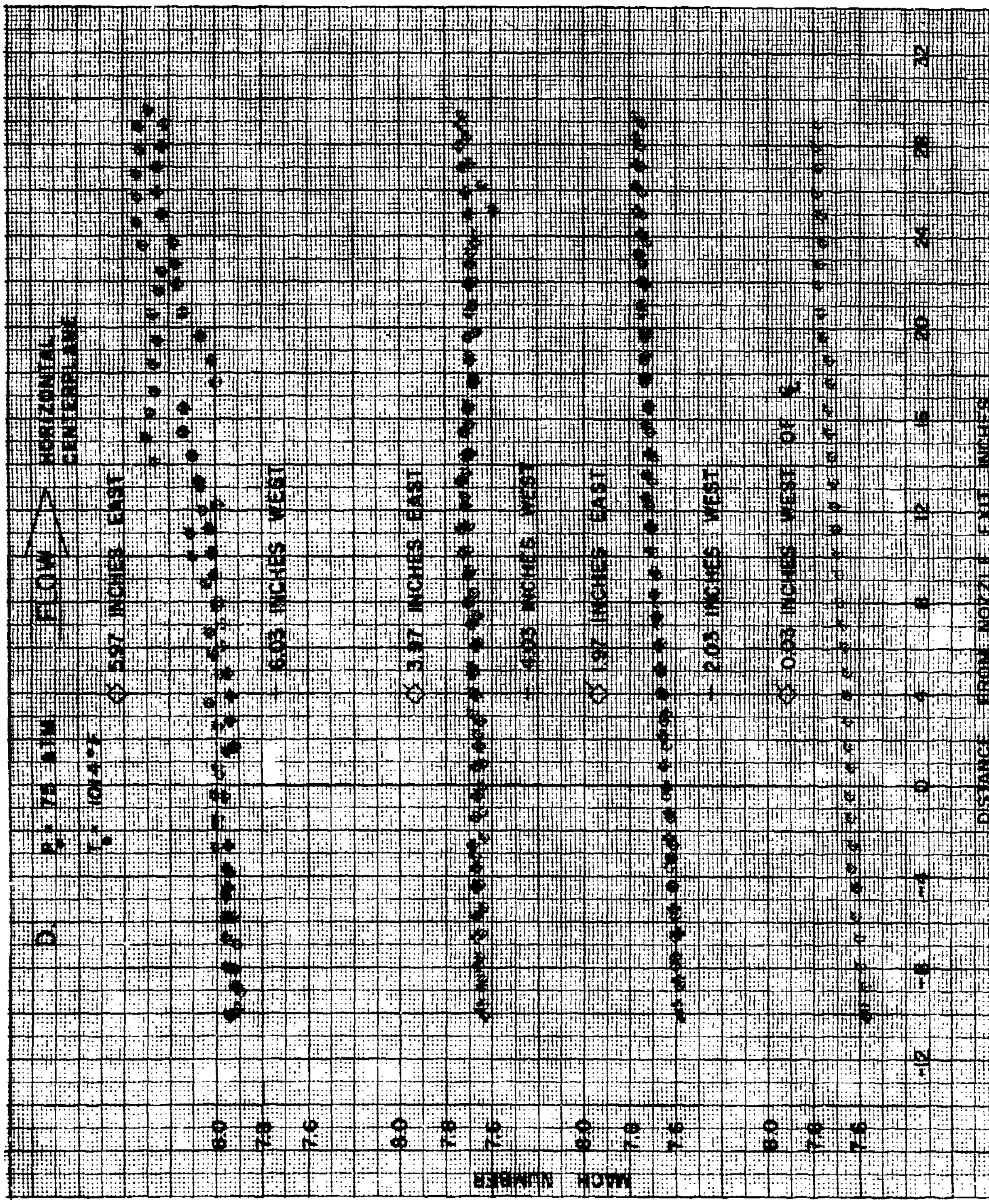

FIG. 10-D MACH 8 NOZZLE FLOW MACH NUMBER

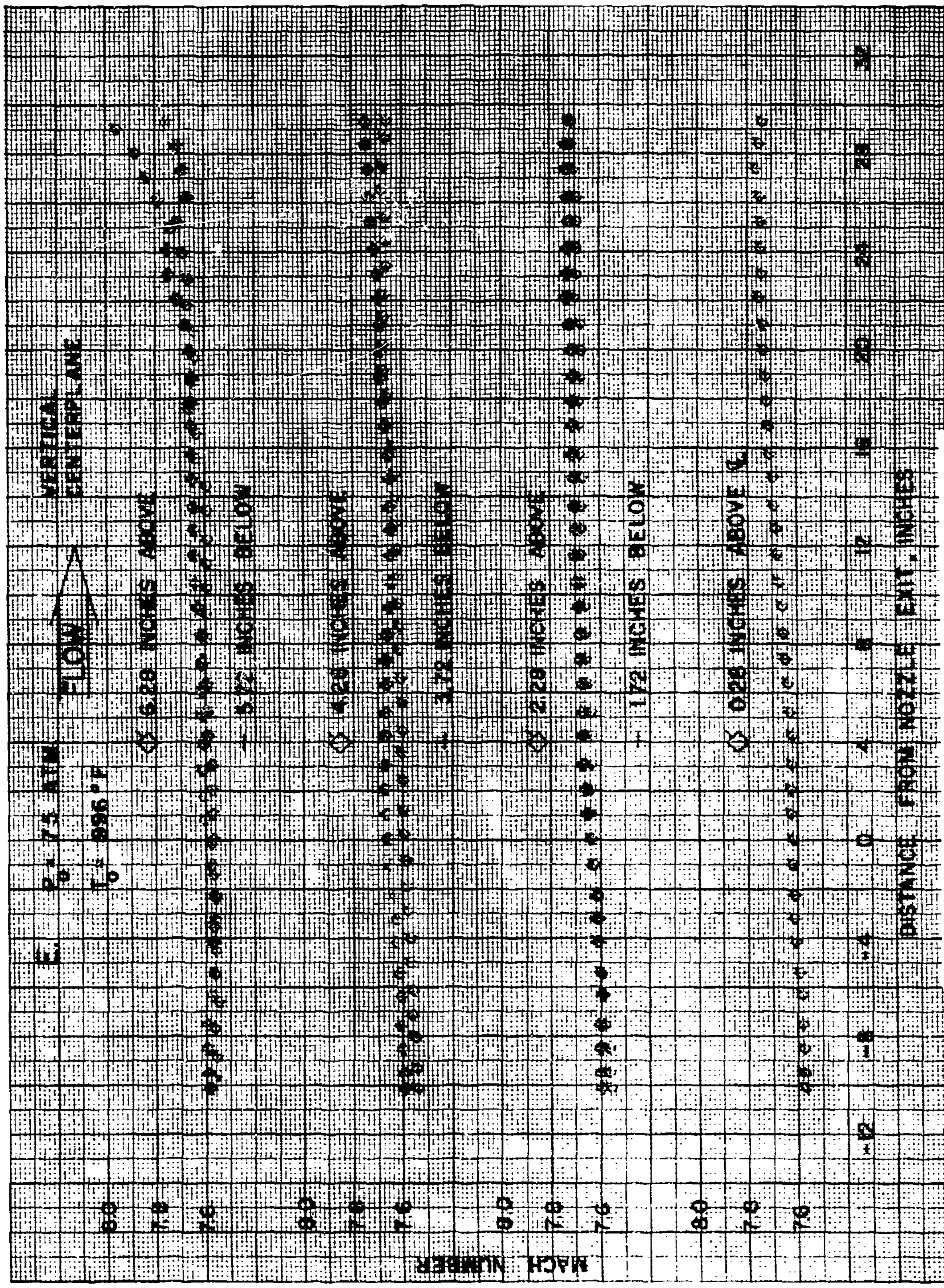

FIG. 10-E MACH 8 NOZZLE FLOW MACH NUMBER

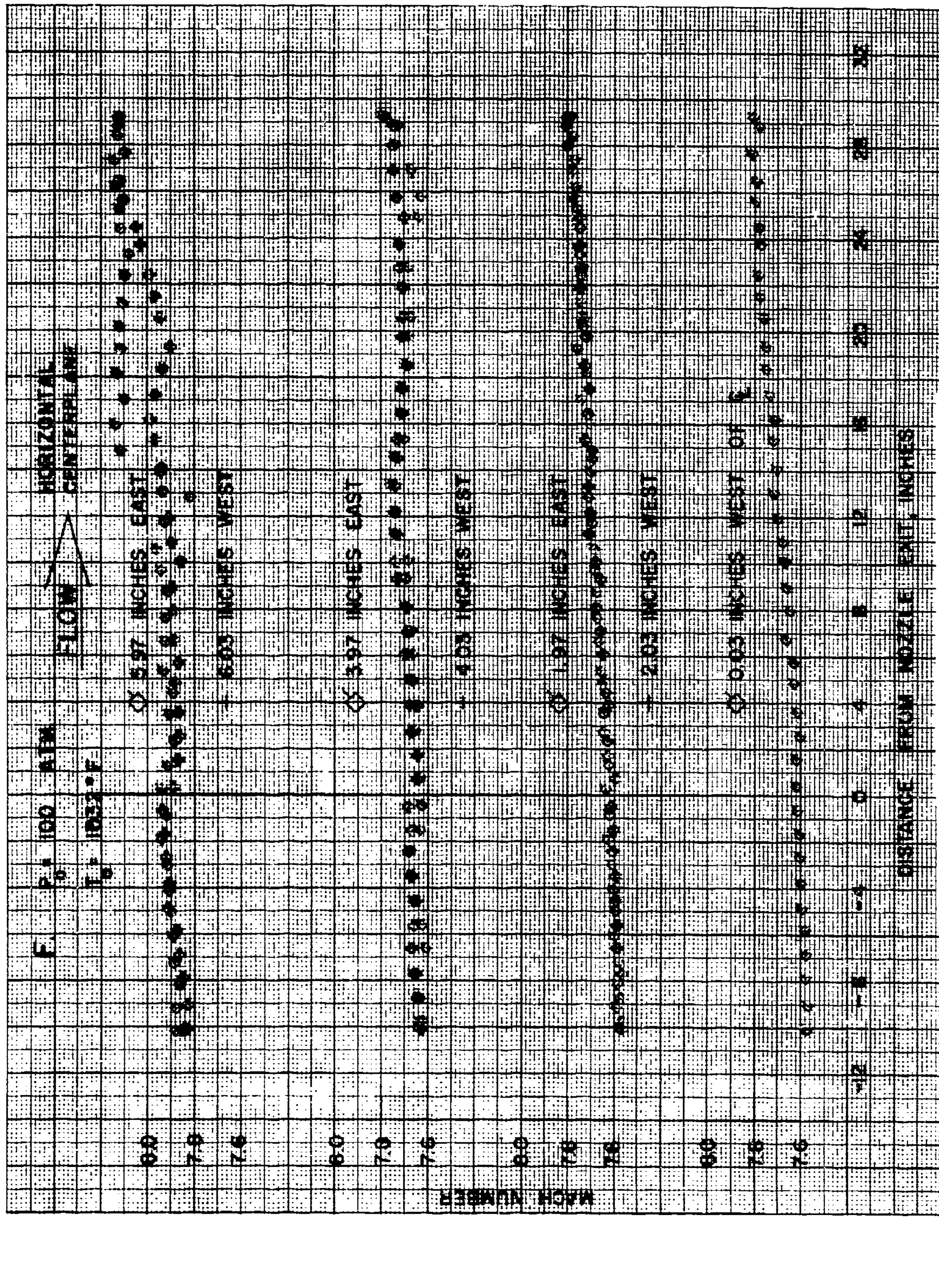

FIG. 10-F MACH 8 NOZZLE FLOW MACH NUMBER

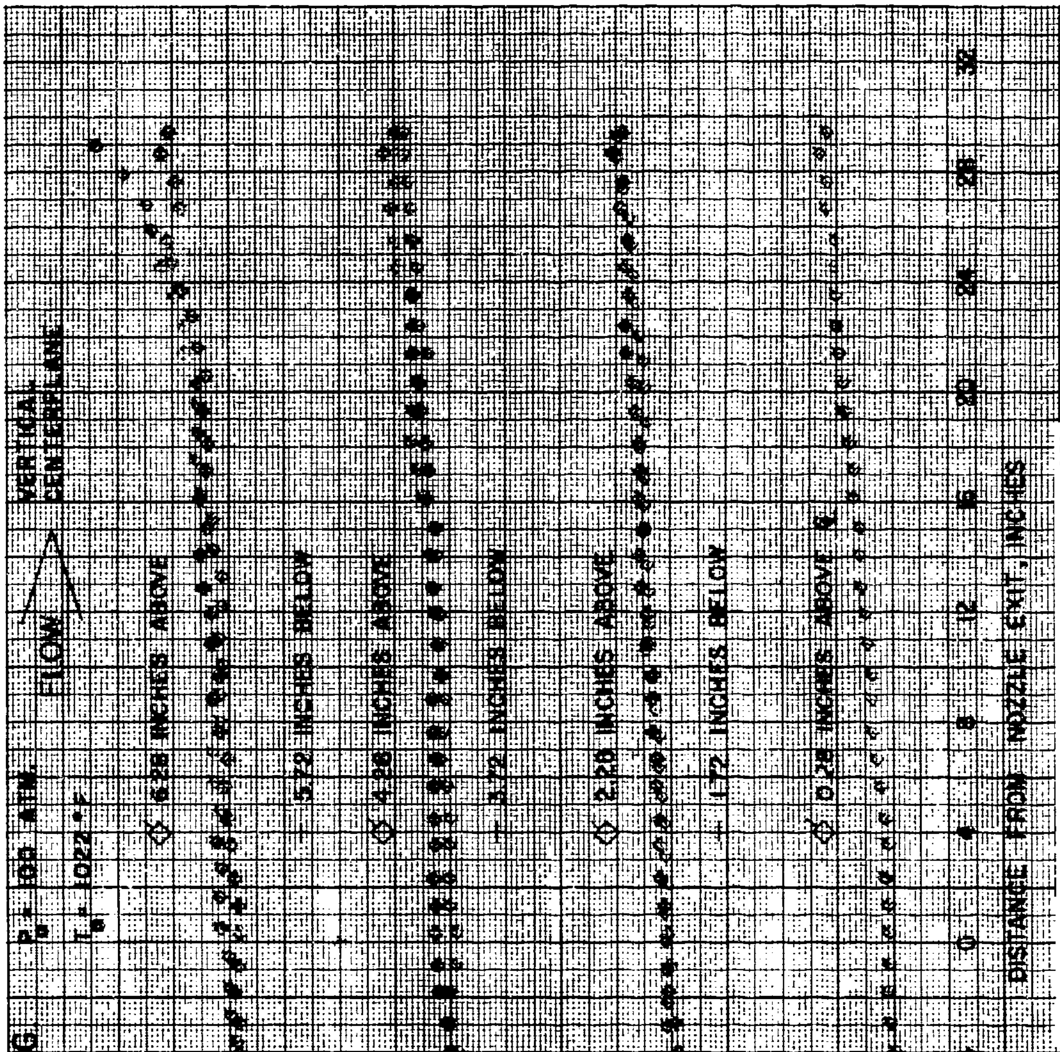

FIG. 10-G MACH 8 NOZZLE FLOW MACH NUMBER

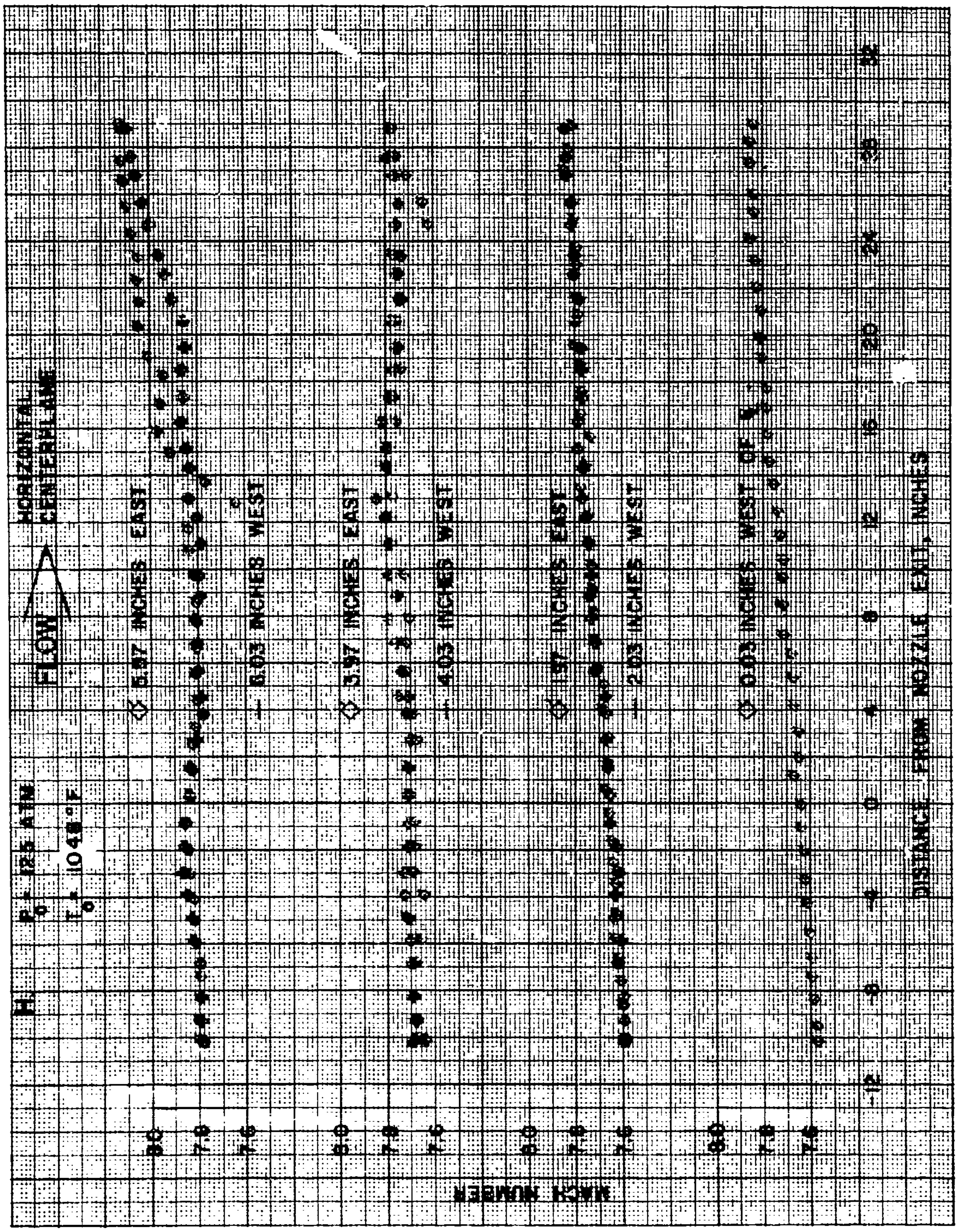

FIG. 10-H MACH 8 NOZZLE FLOW MACH NUMBER

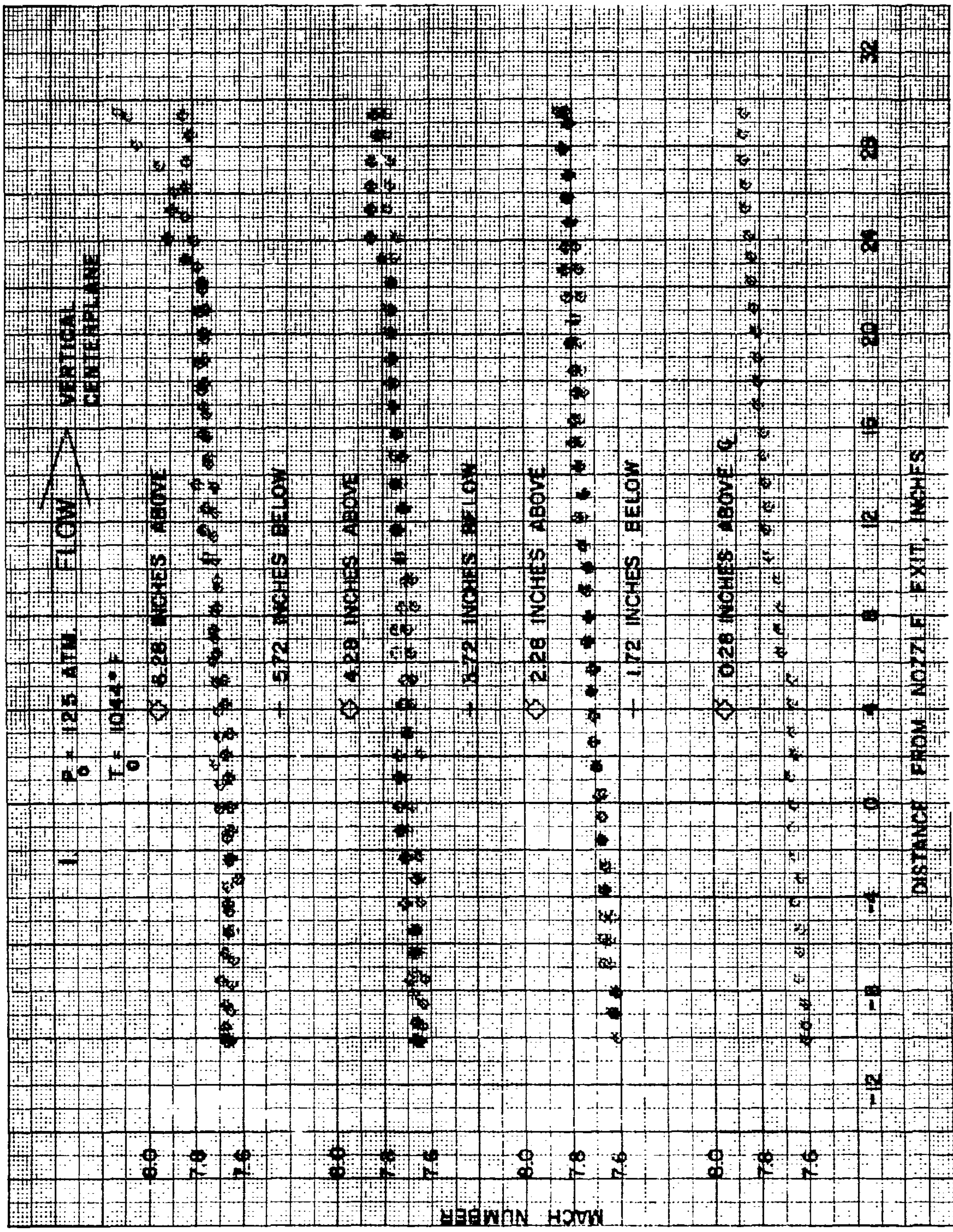

FIG. 10-1 MACH 8 NOZZLE FLOW MACH NUMBER

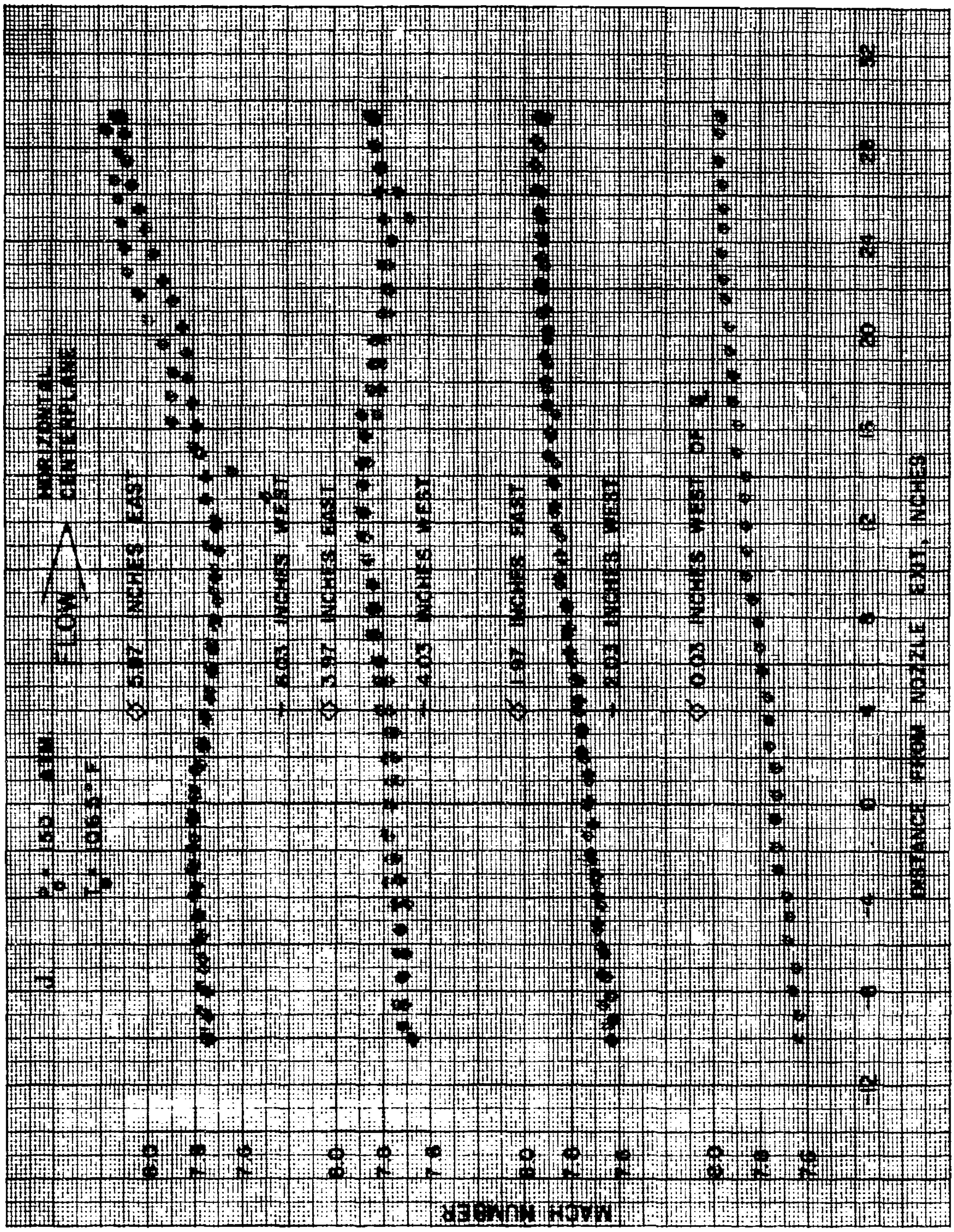

FIG. 10-J MACH 8 NOZZLE FLOW MACH NUMBER

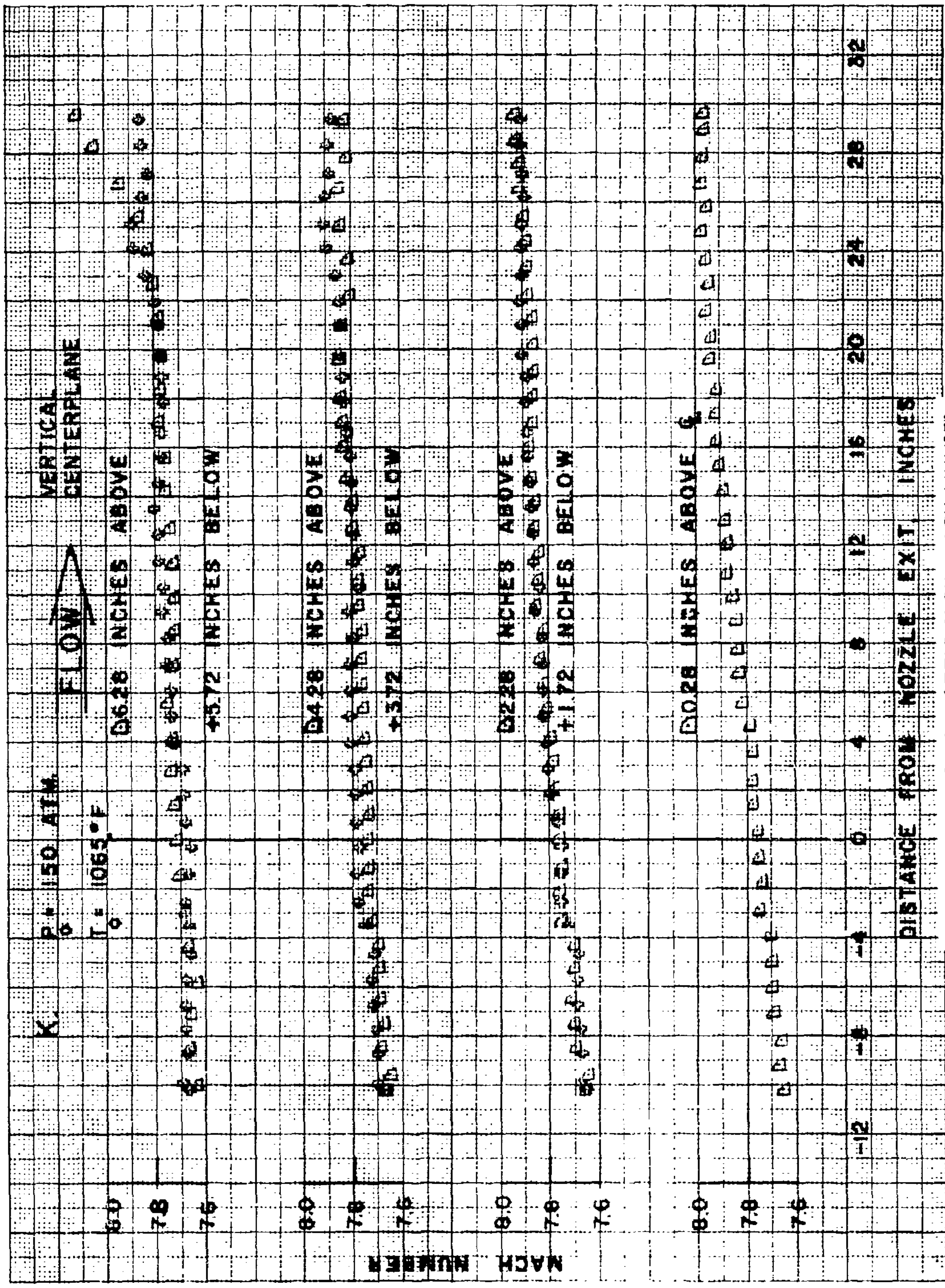

FIG. 10-K MACH 8 NOZZLE FLOW MACH NUMBER

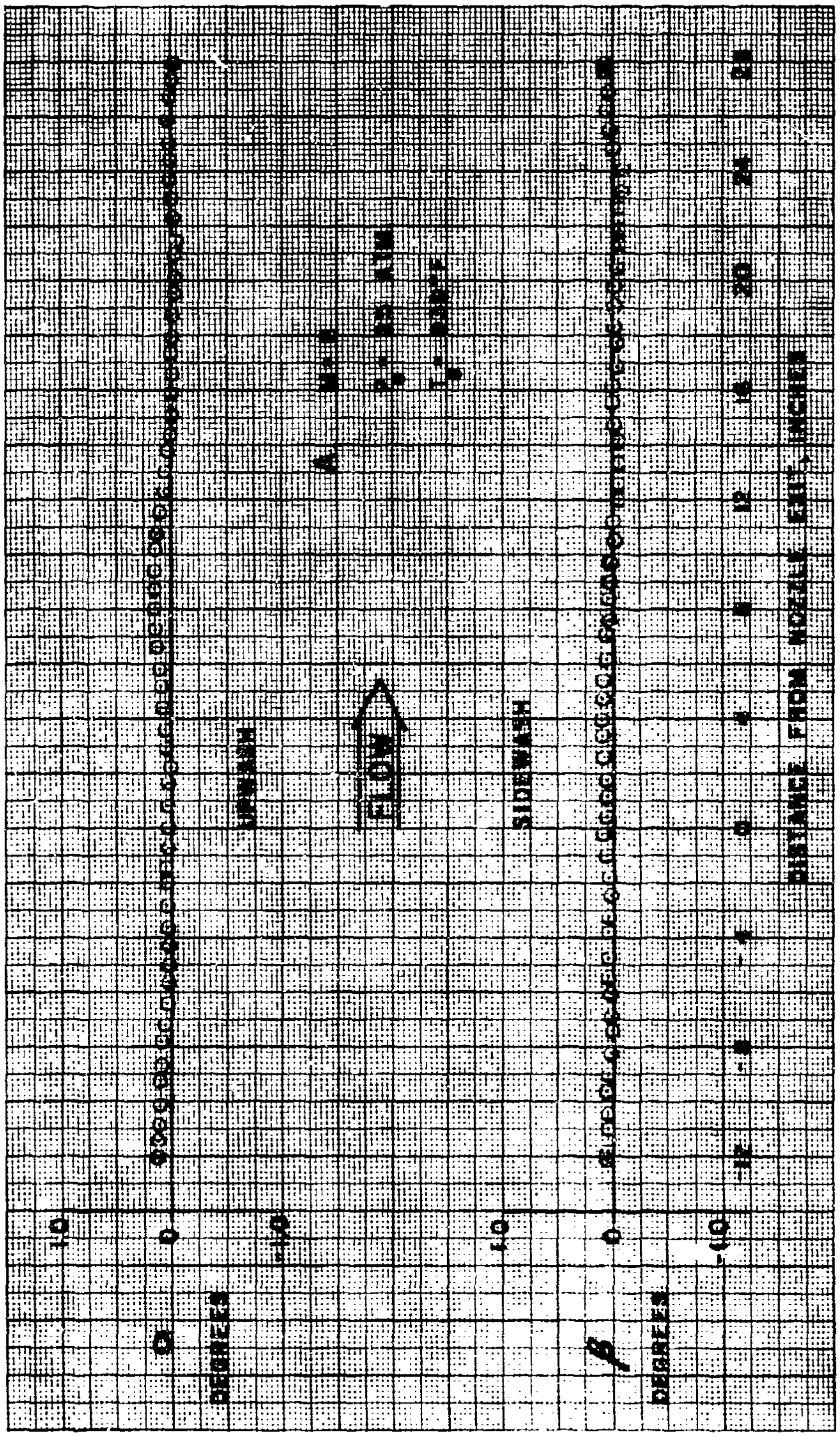

FIG. 11-A MACH 8 NOZZLE FLOW ANGULARITY

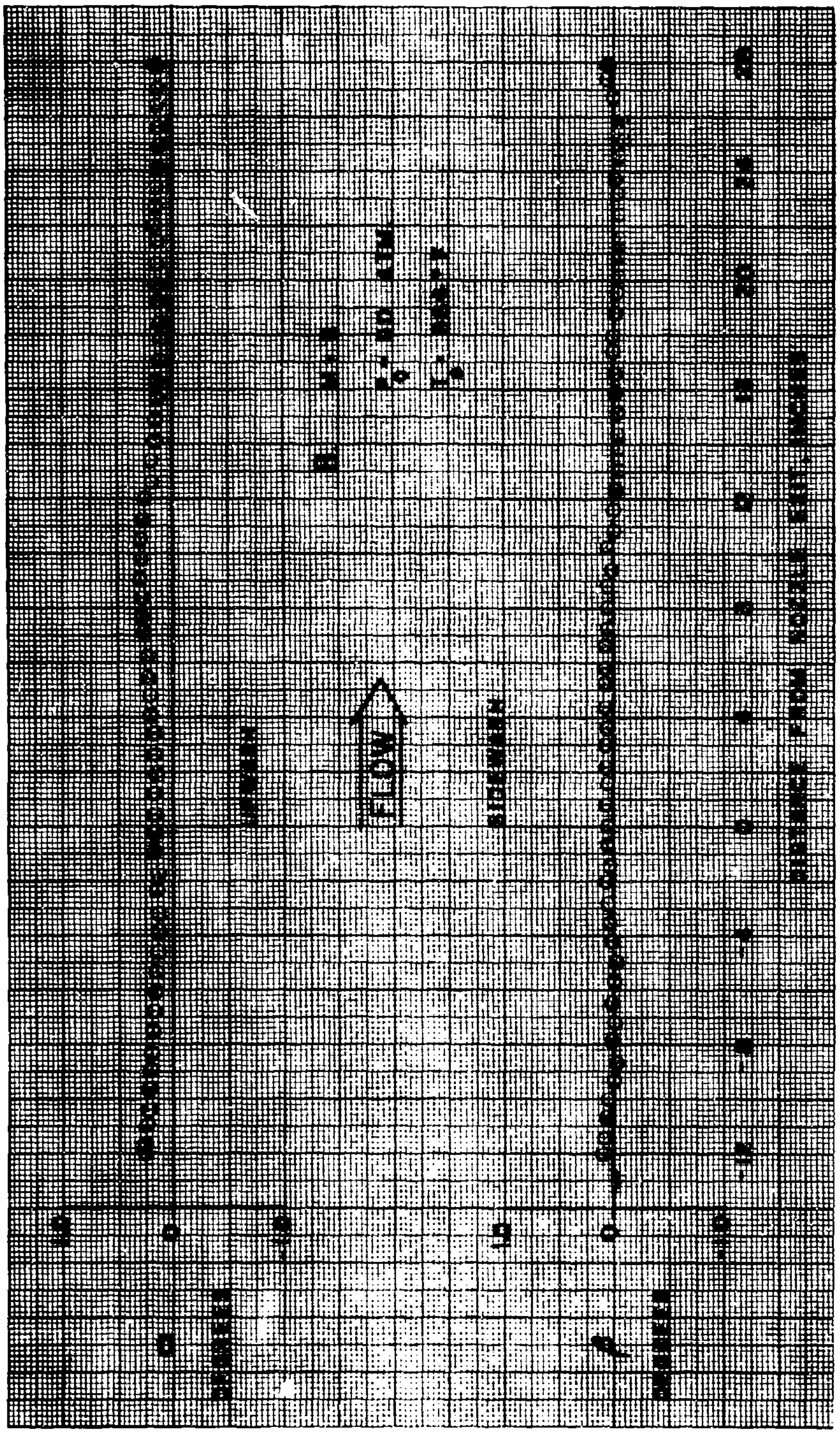

FIG. 11-B MACH 8 NOZZLE FLOW ANGULARITY

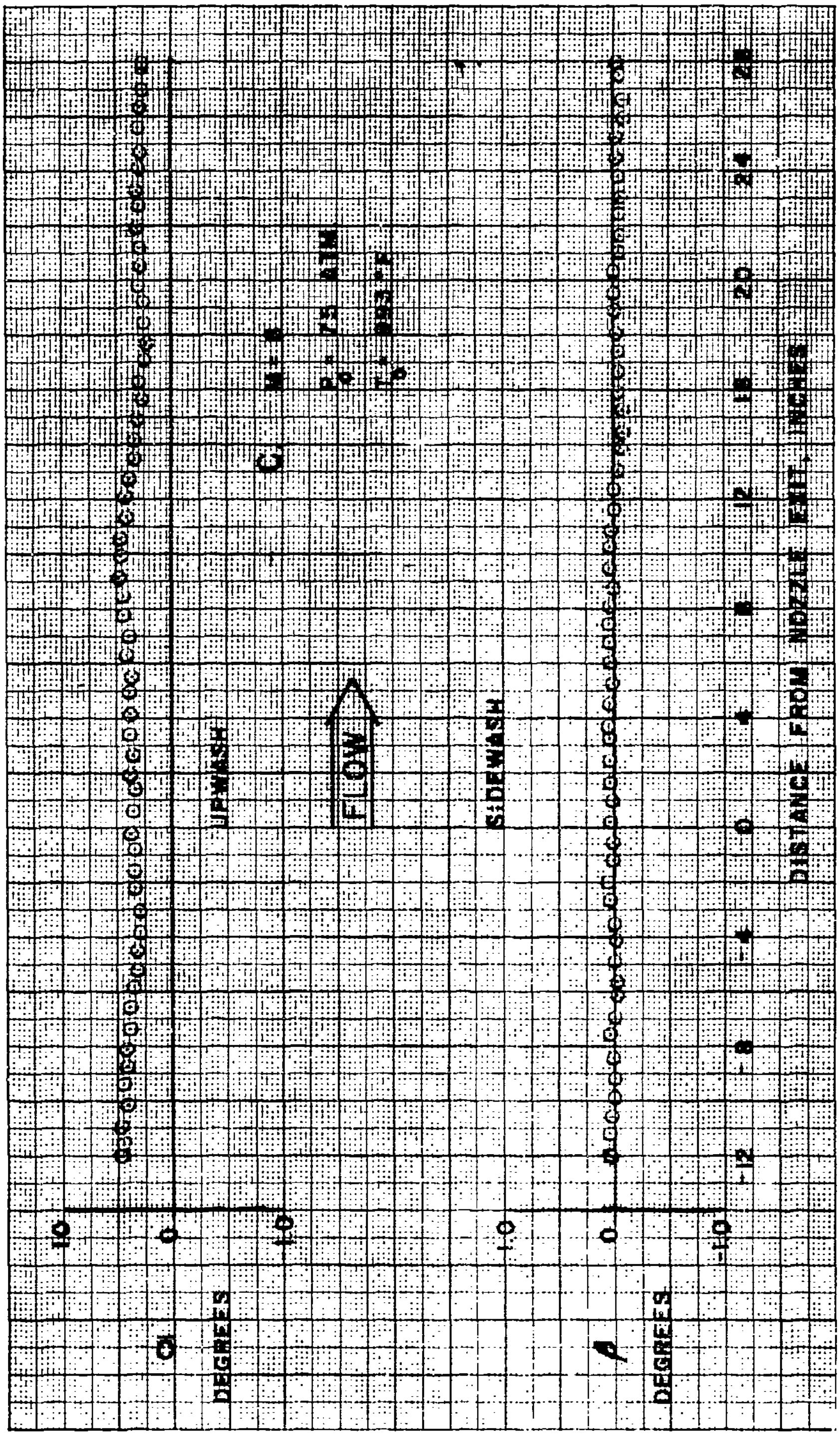

FIG. 11-C MACH 8 NOZZLE FLOW ANGULARITY

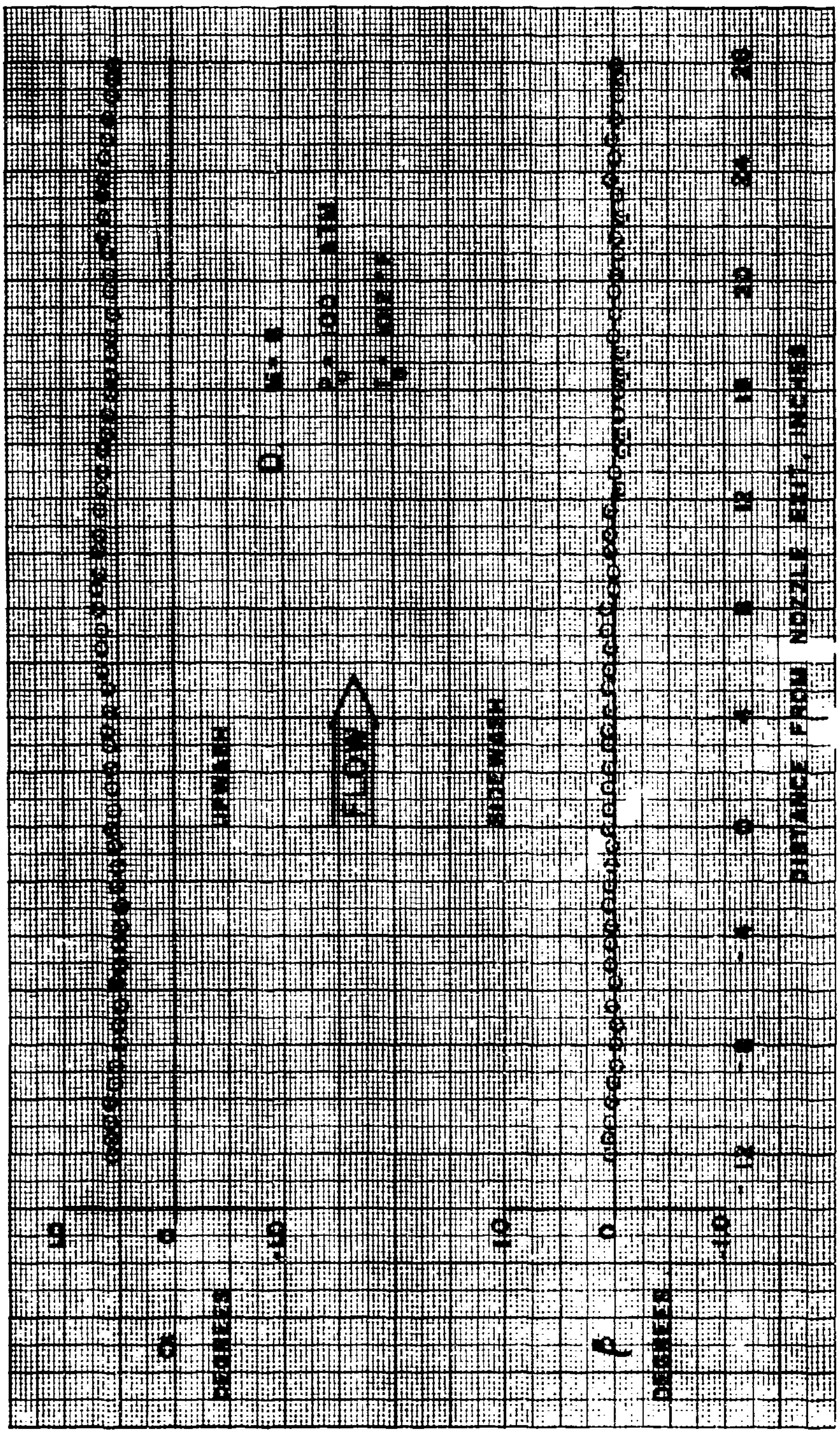

FIG. 11-D MACH 8 NOZZLE FLOW ANGULARITY

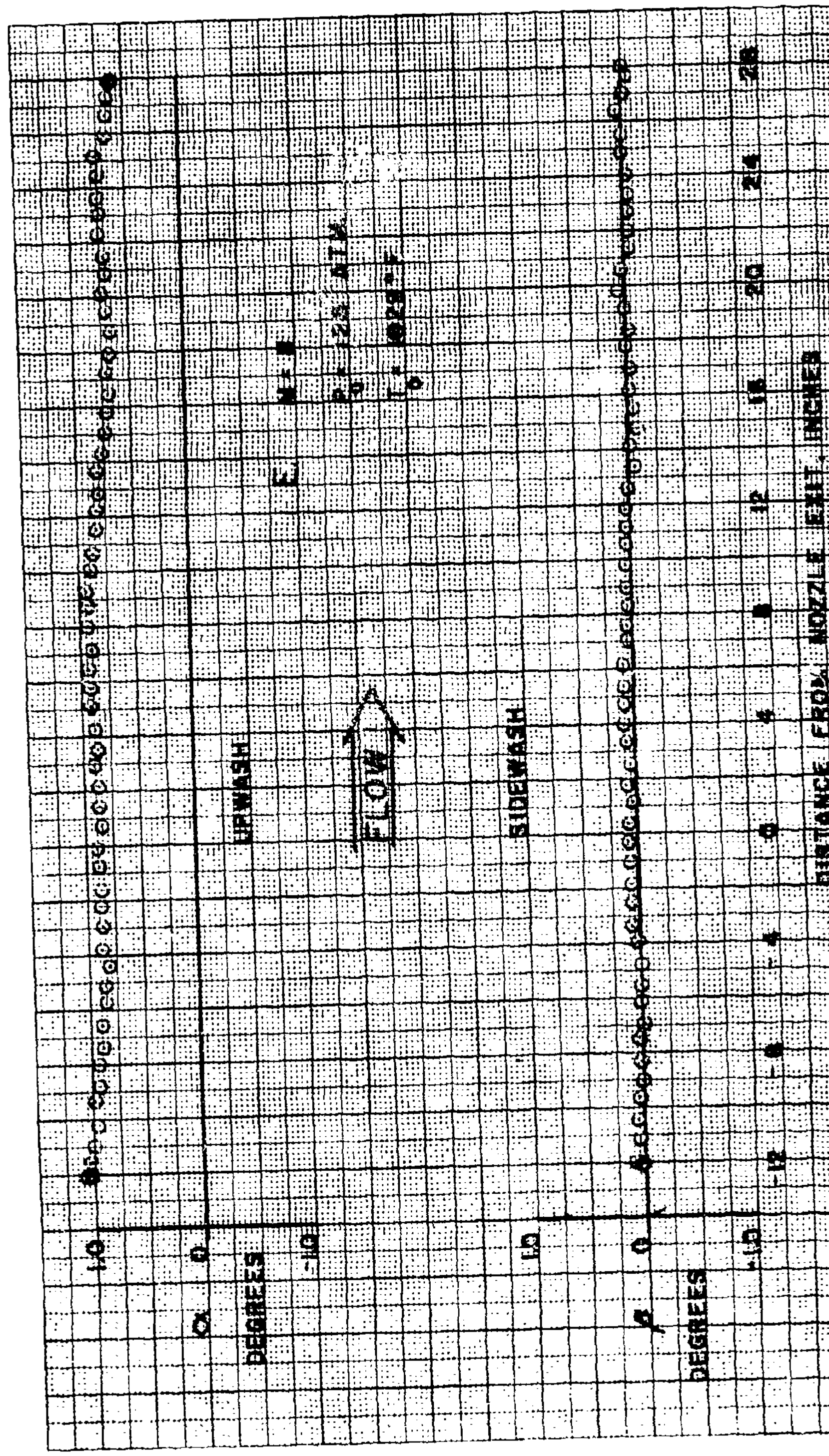

FIG. 11-E MACH 8 NOZZLE FLOW ANGULARITY

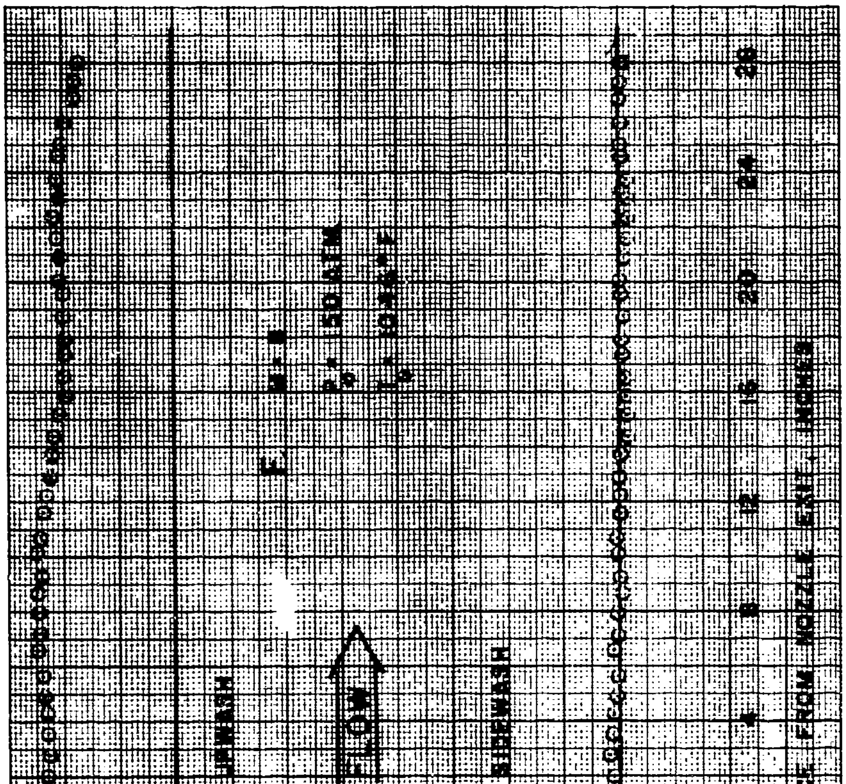

FIG. 11-F MACH 8 NOZZLE FLOW ANGULARITY

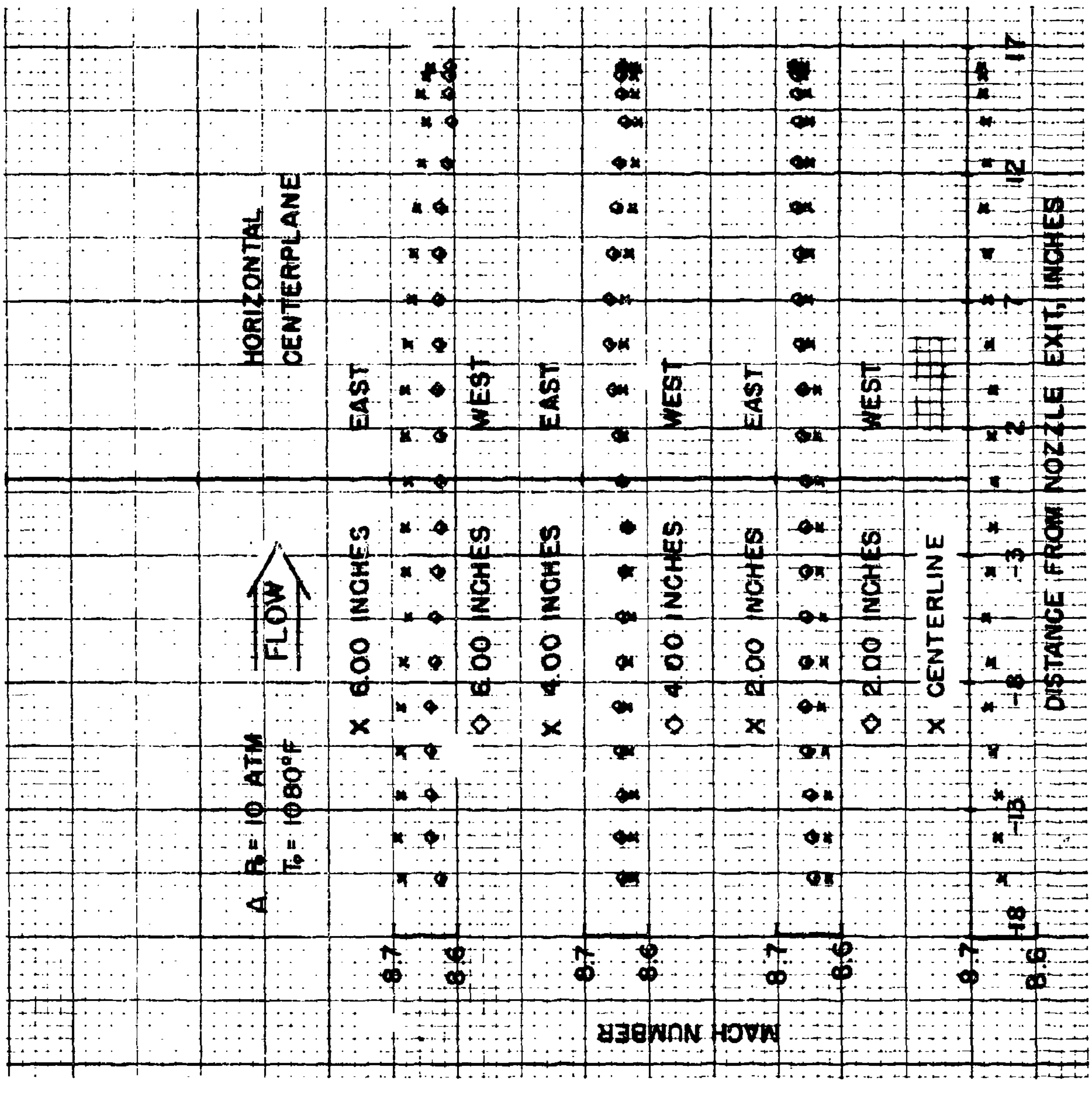

FIG. 12-A MACH 9 NOZZLE FLOW MACH NUMBER

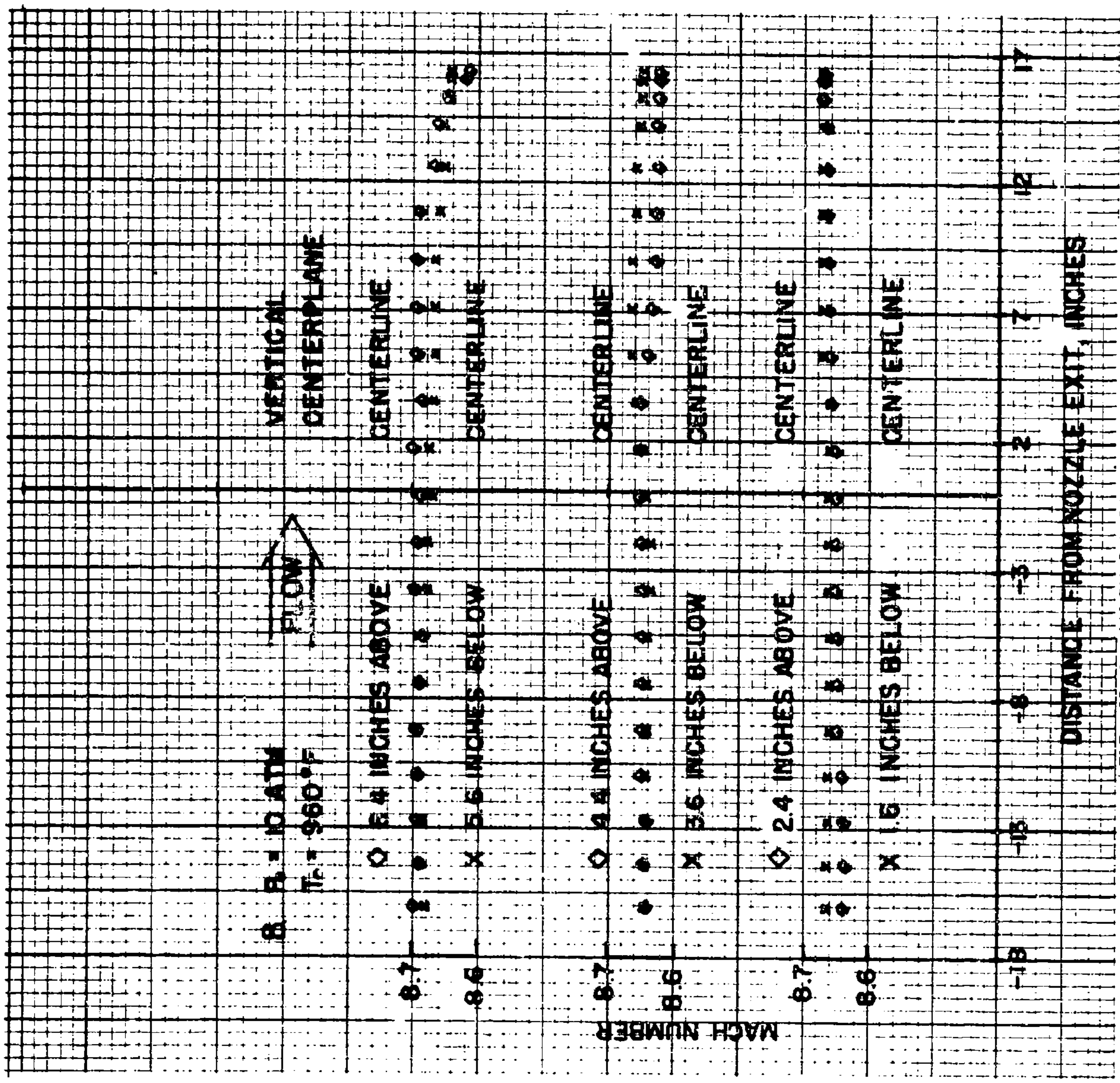

FIG. 12-B MACH 9 NOZZLE FLOW MACH NUMBER

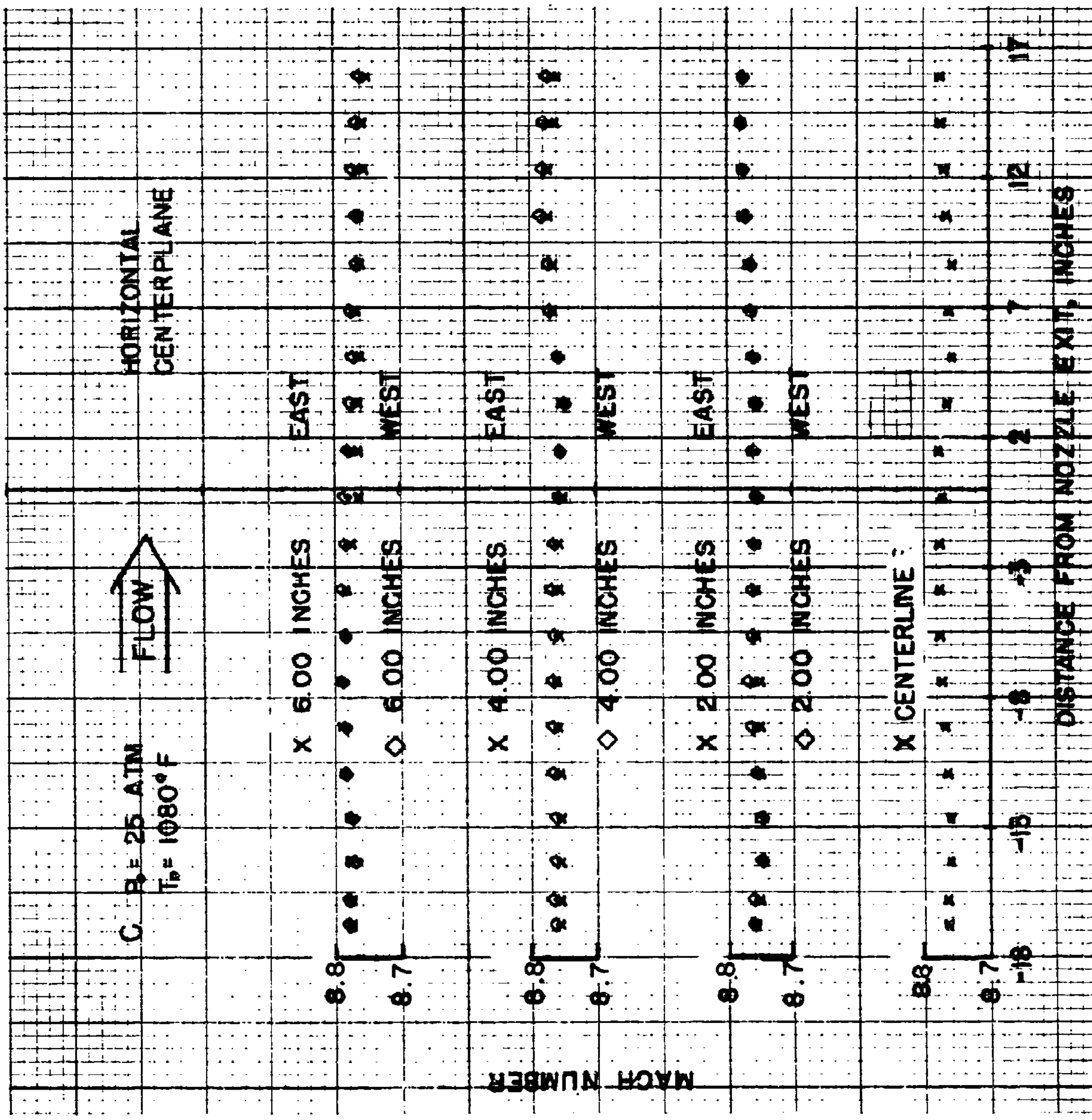

FIG. 12-C MACH 9 NOZZLE FLOW MACH NUMBER

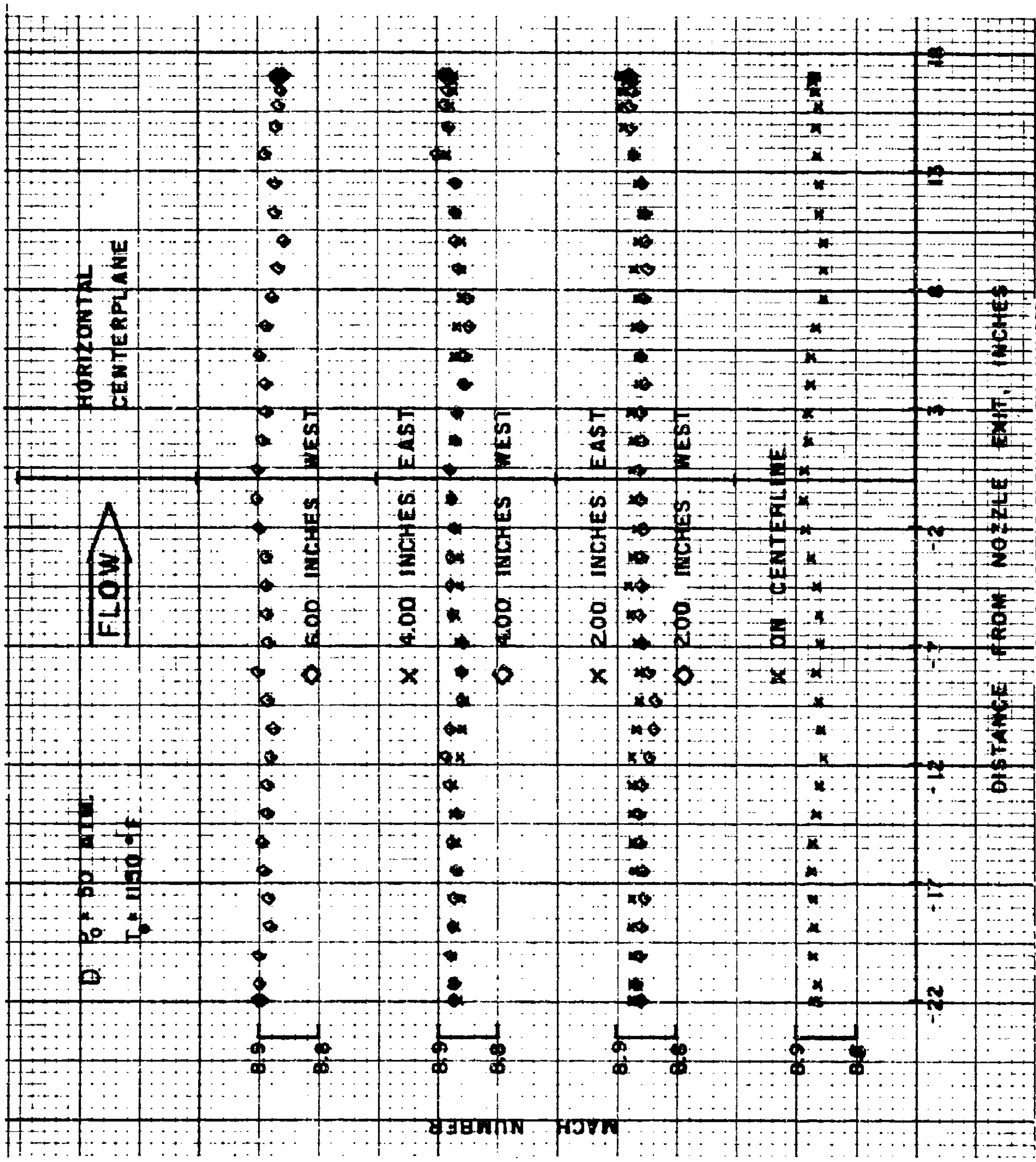

FIG. 12-D MACH 9 NOZZLE FLOW MACH NUMBER

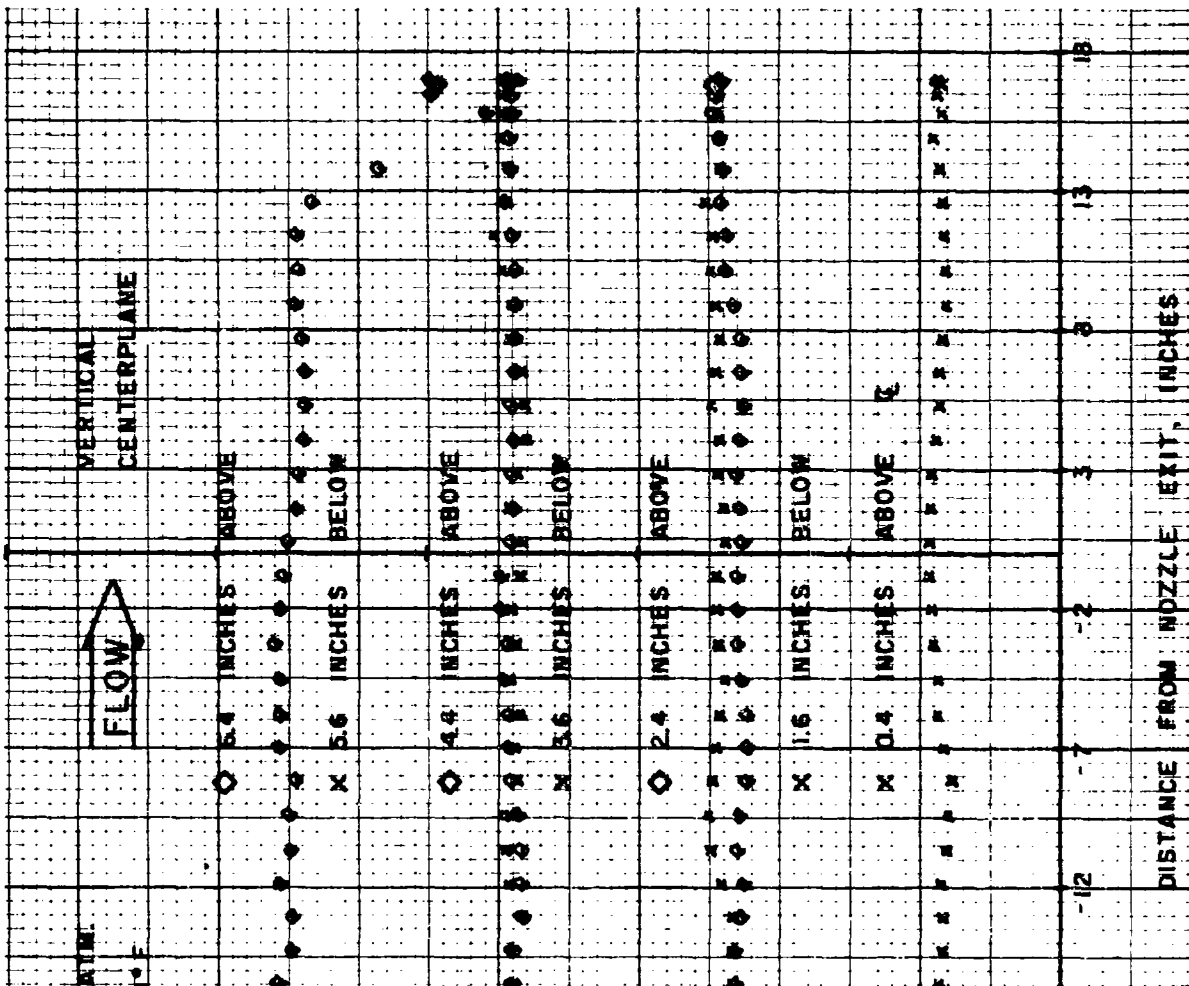

FIG. 12-E MACH 9 NOZZLE FLOW MACH NUMBER

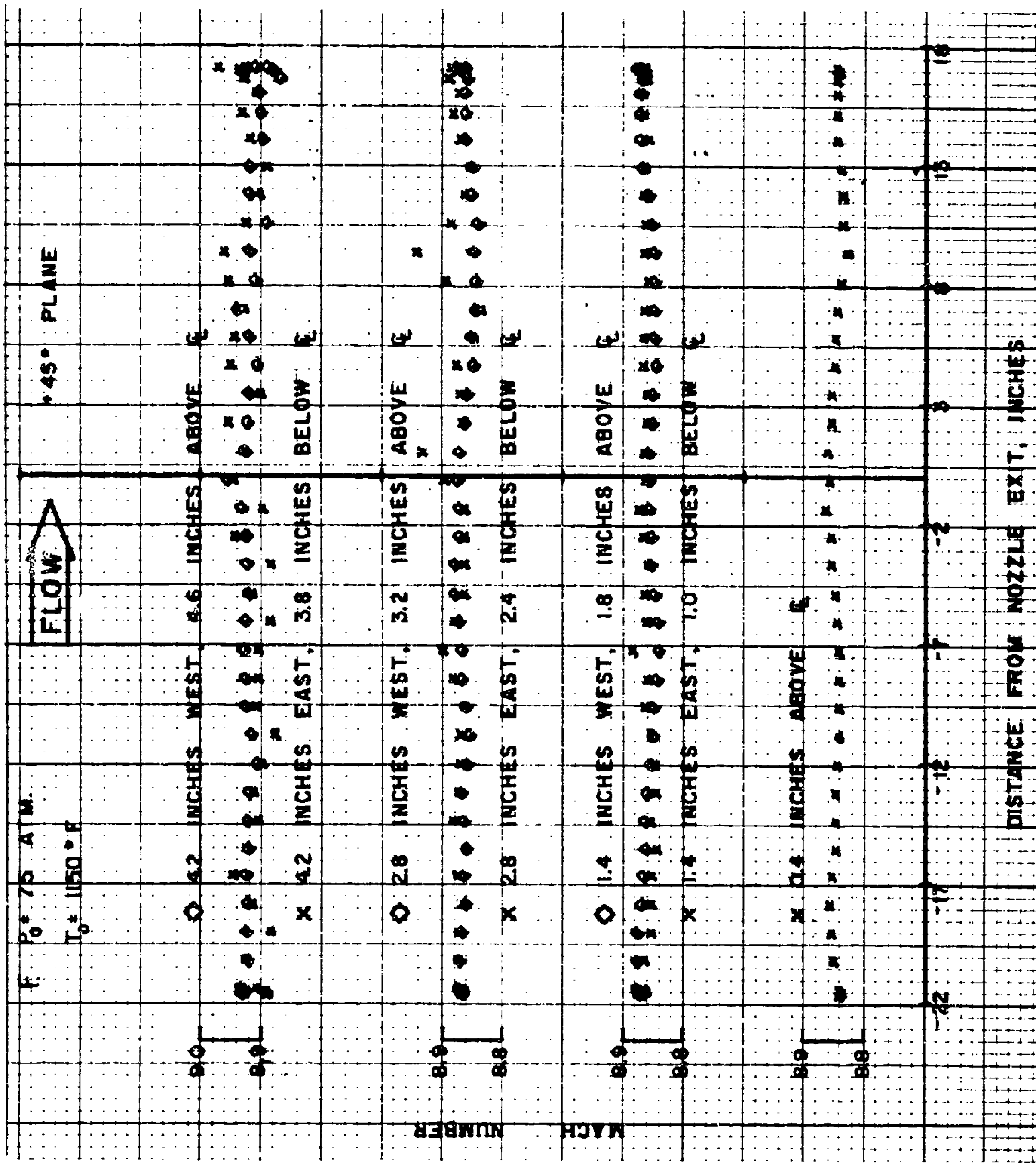

FIG. 12-F MACH 9 NOZZLE FLOW MACH NUMBER

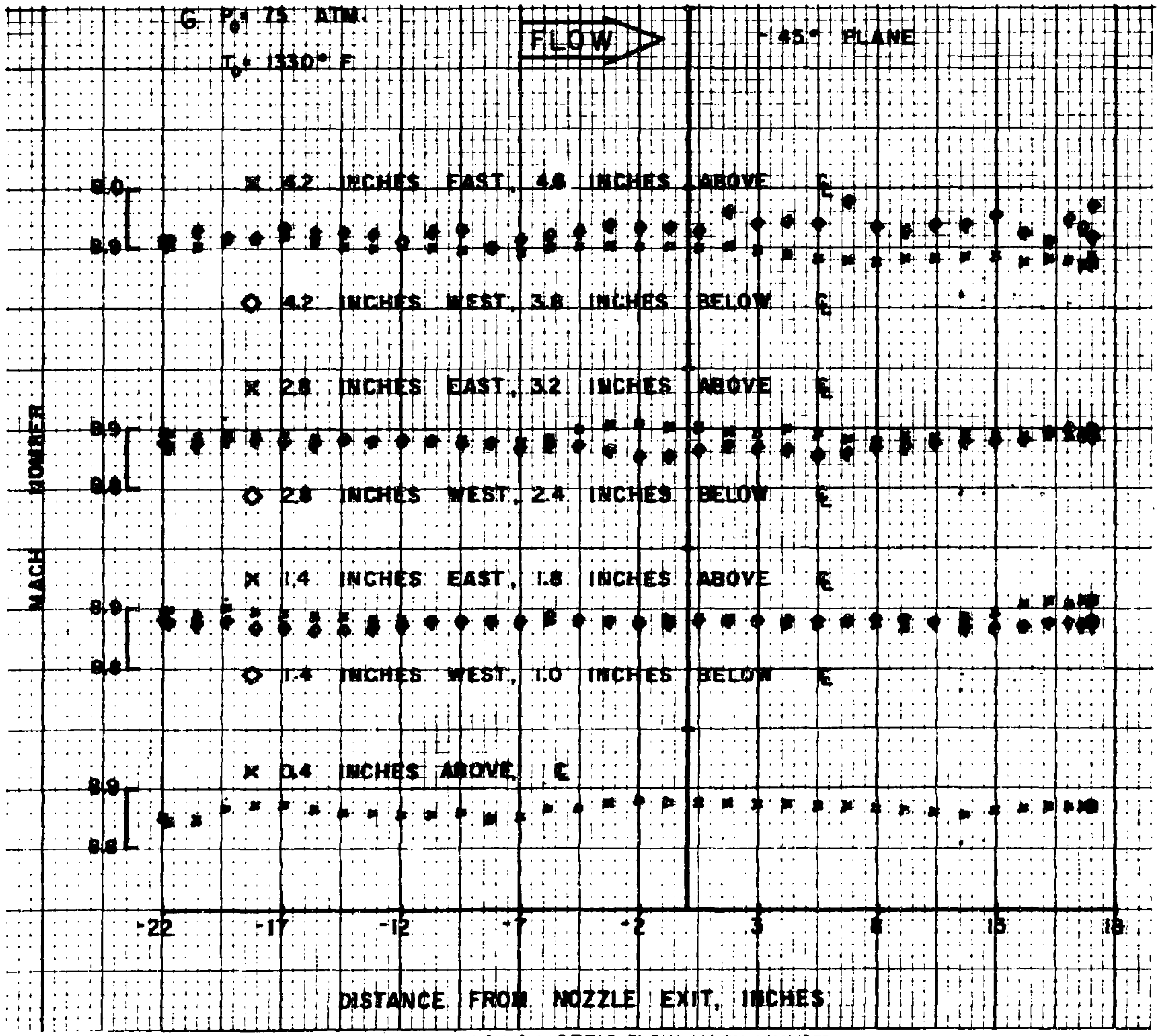

FIG. 12-G MACH 9 NOZZLE FLOW MACH NUMBER

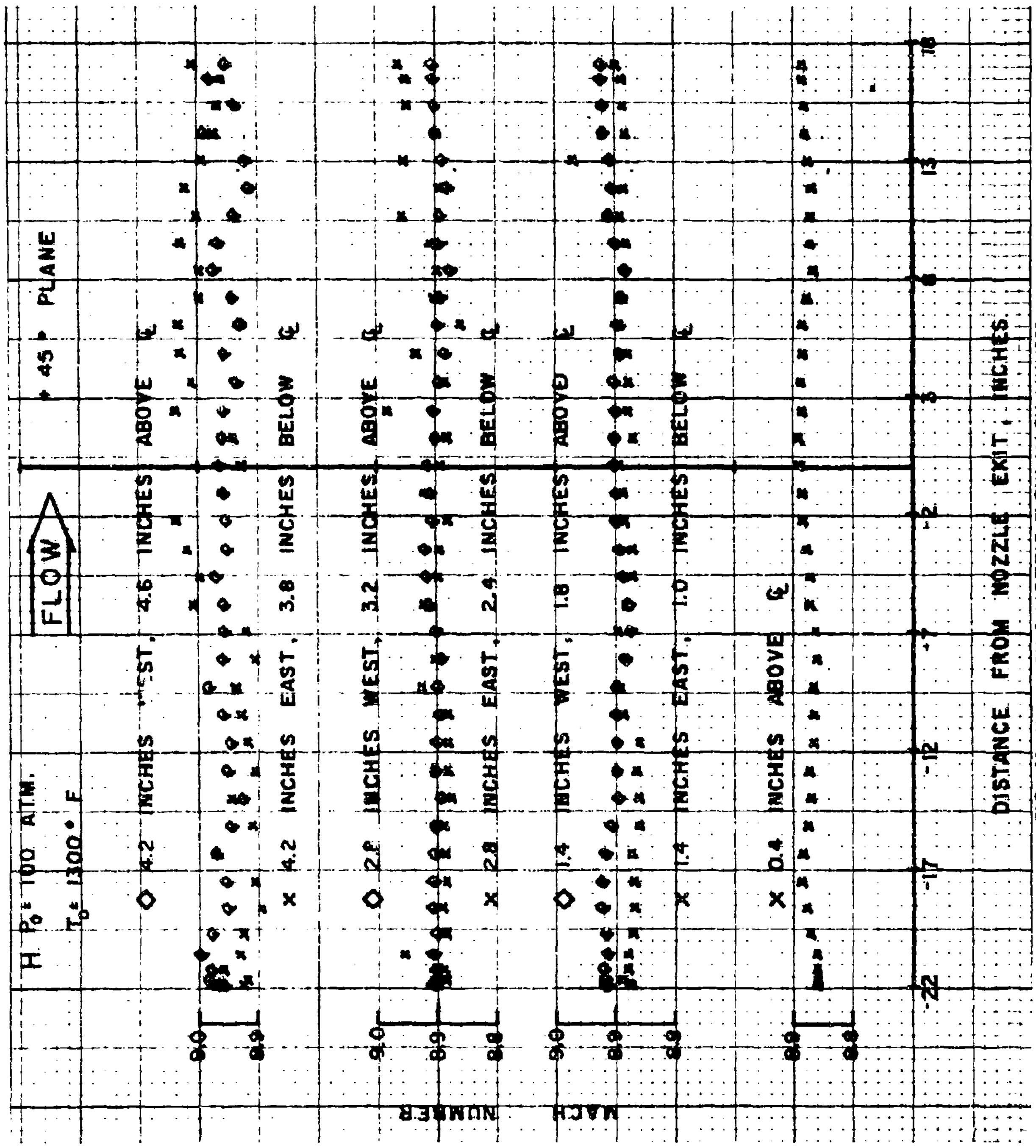

FIG. 12-H MACH 9 NOZZLE FLOW MACH NUMBER

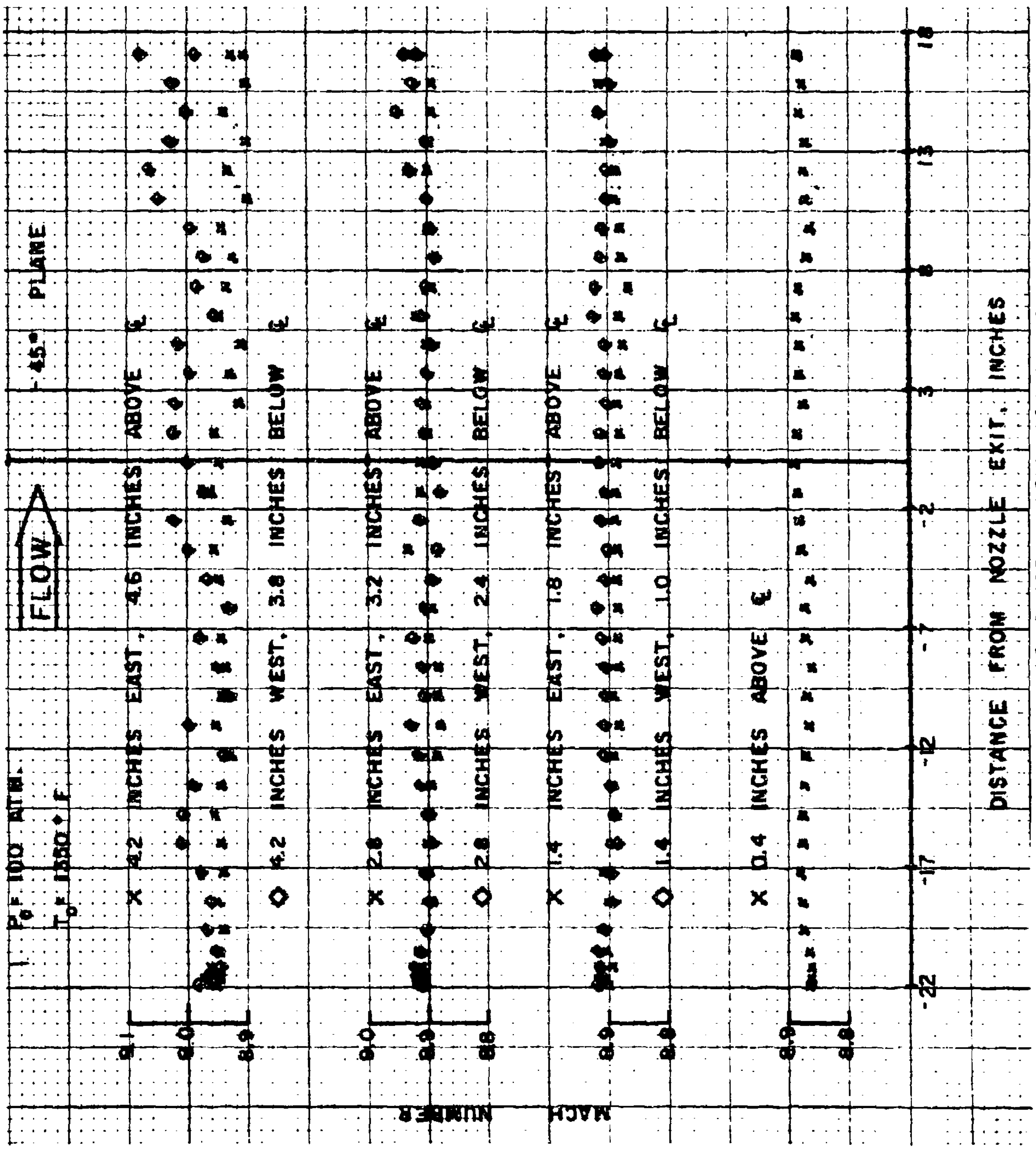

FIG. 12-1 MACH 9 NOZZLE FLOW MACH NUMBER

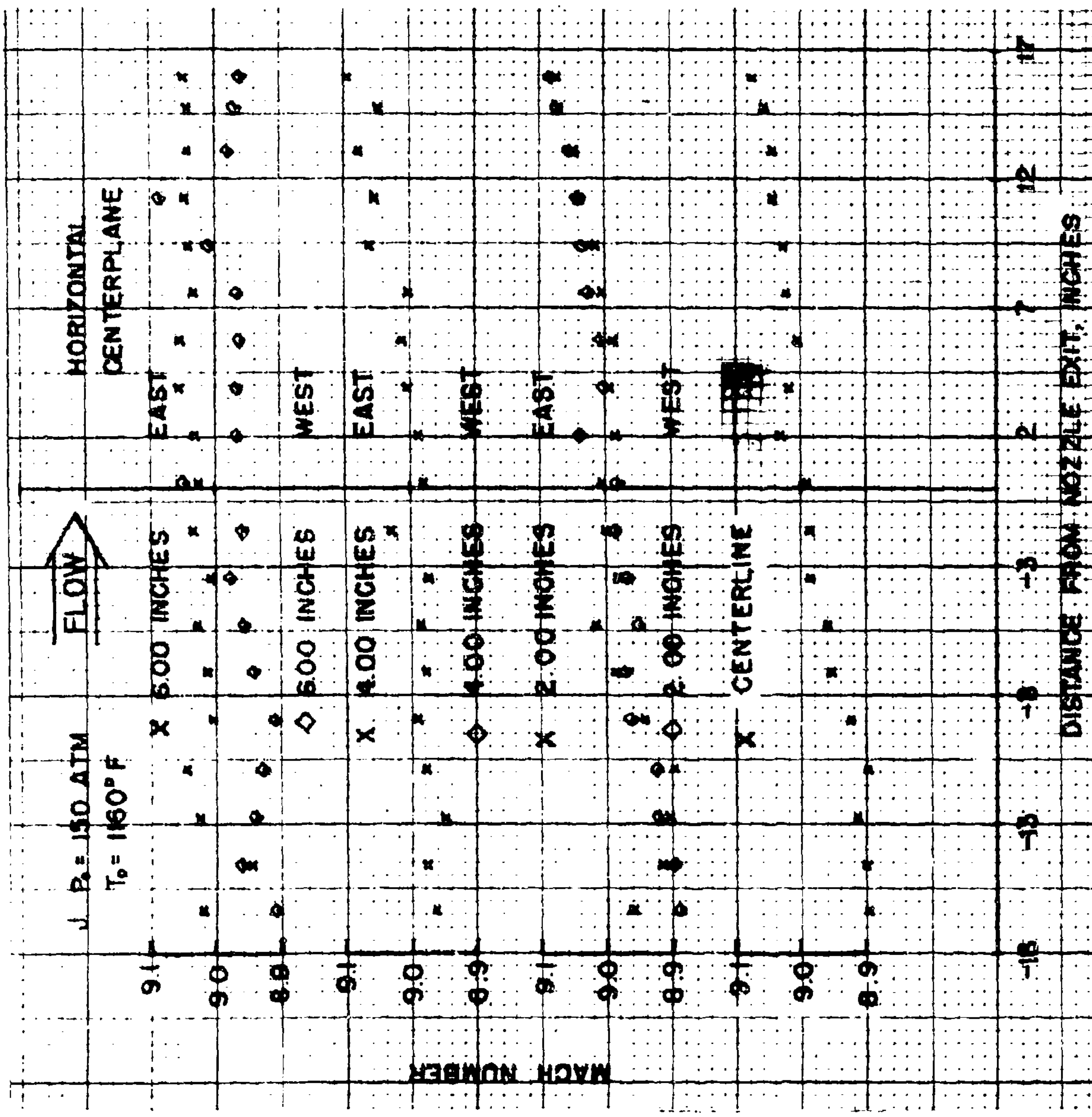

FIG. 12-J MACH 9 NOZZLE FLOW MACH NUMBER

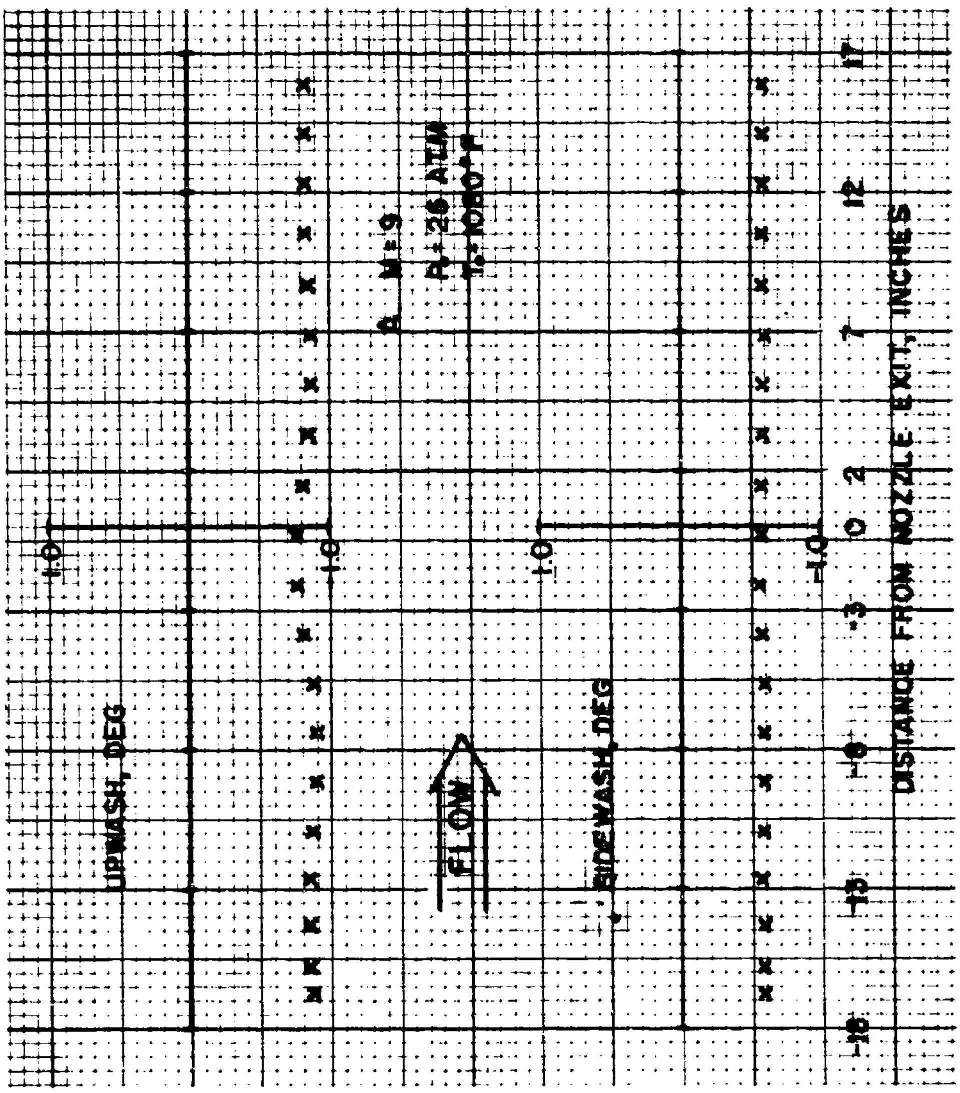

FIG. 13-A MACH 9 NOZZLE FLOW ANGULARITY

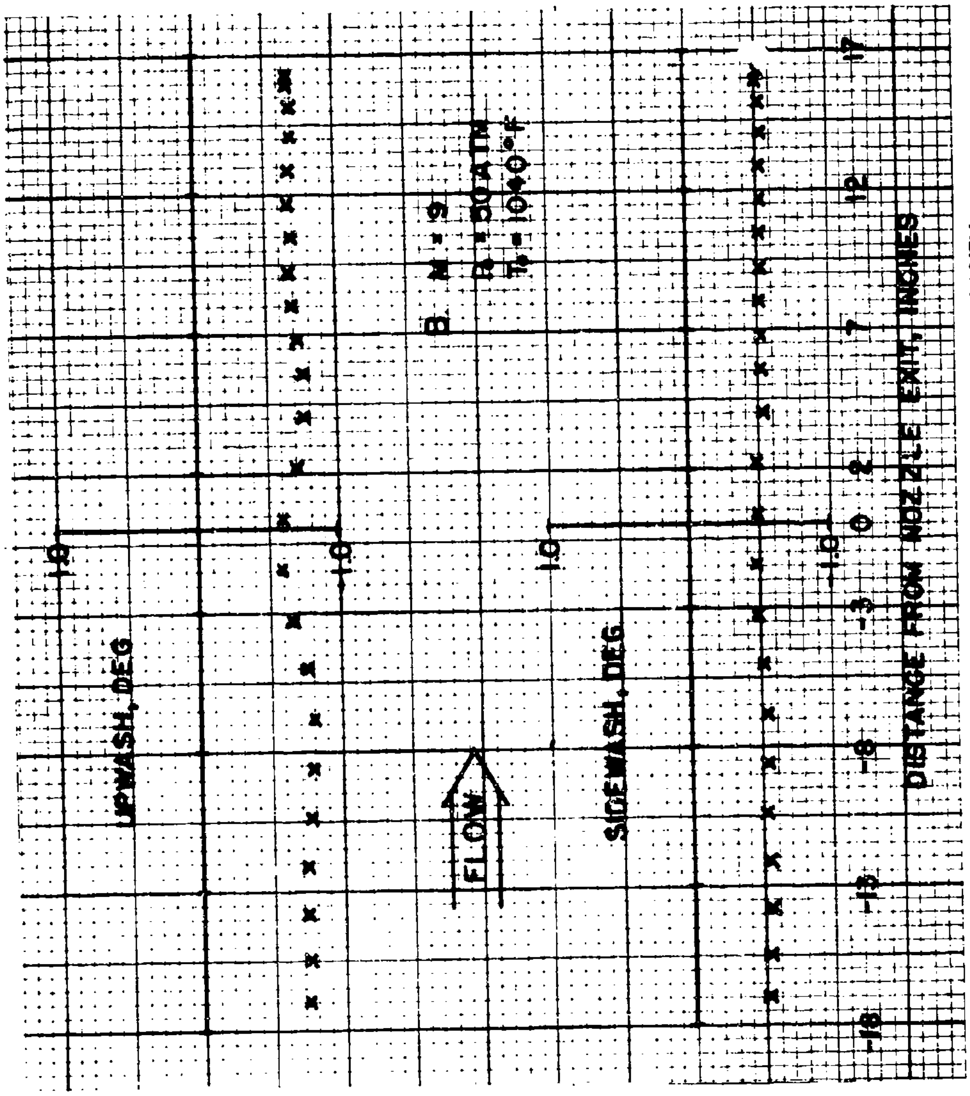

FIG. 13-B MACH 9 NOZZLE FLOW ANGULARITY

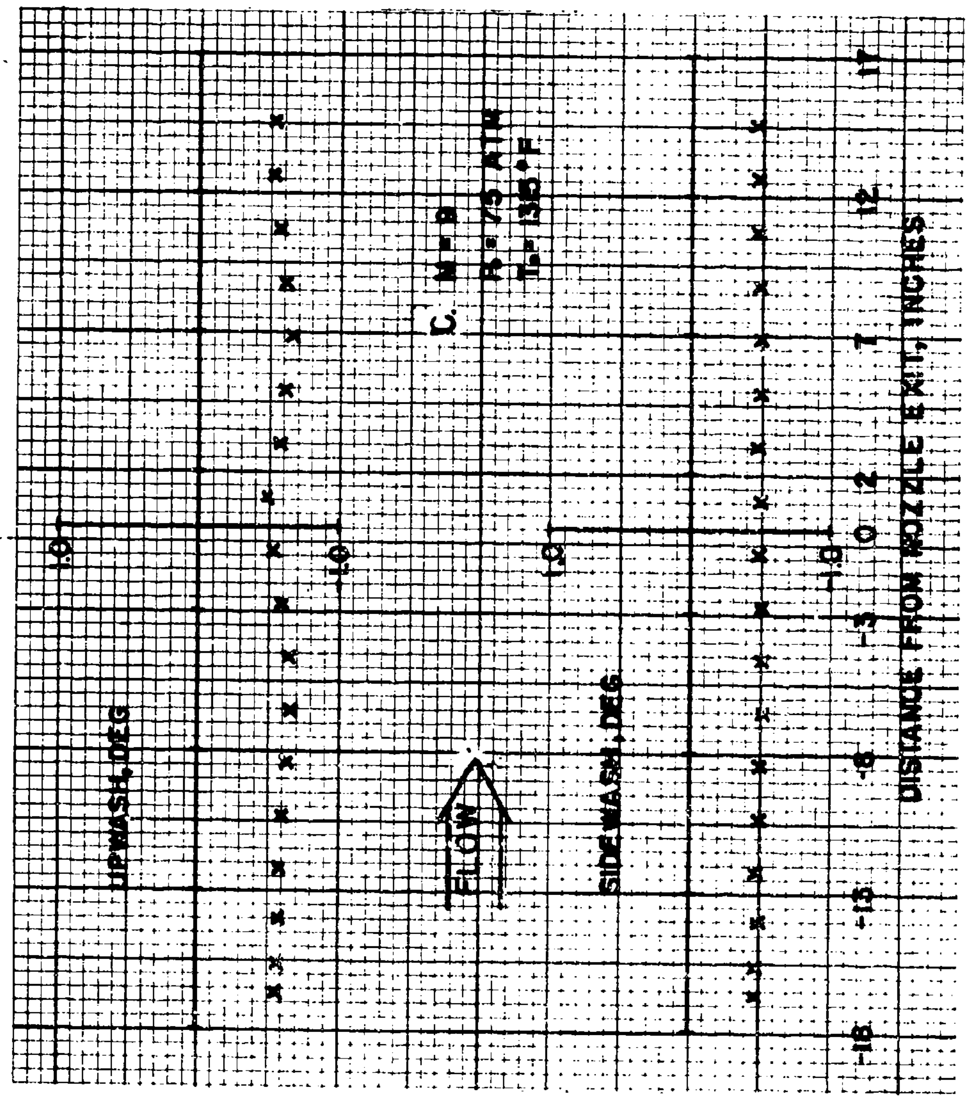

FIG. 13-C MACH 9 NOZZLE FLOW ANGULARITY

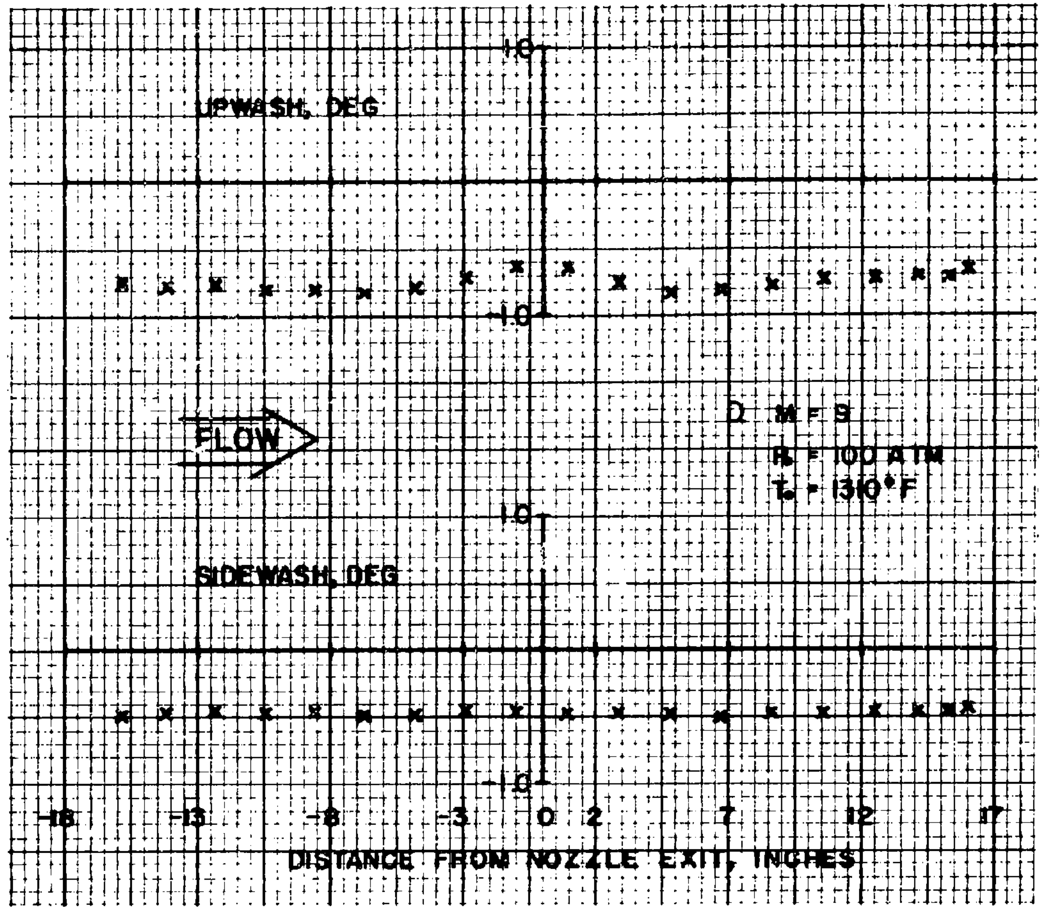

FIG. 13-D MACH 9 NOZZLE FLOW ANGULARITY

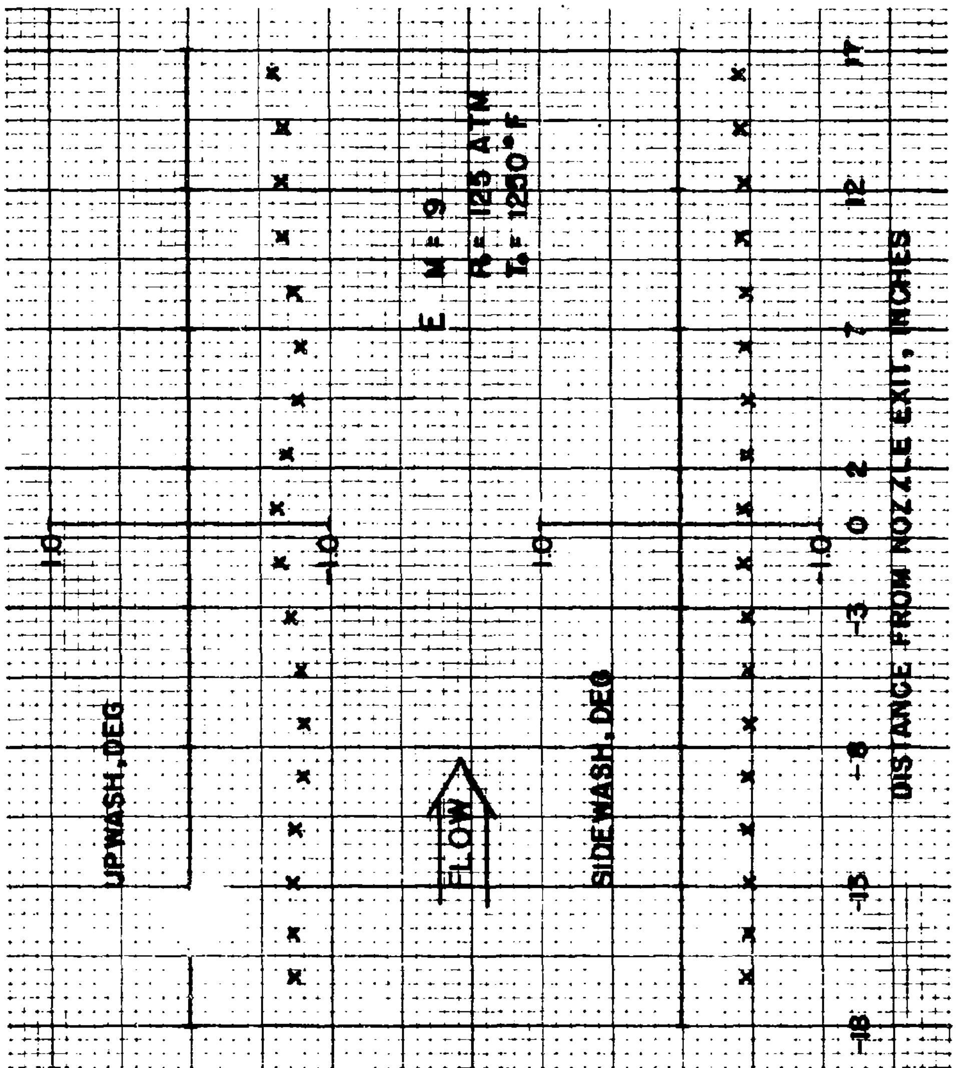

FIG. 13-E MACH 9 NOZZLE FLOW ANGULARITY

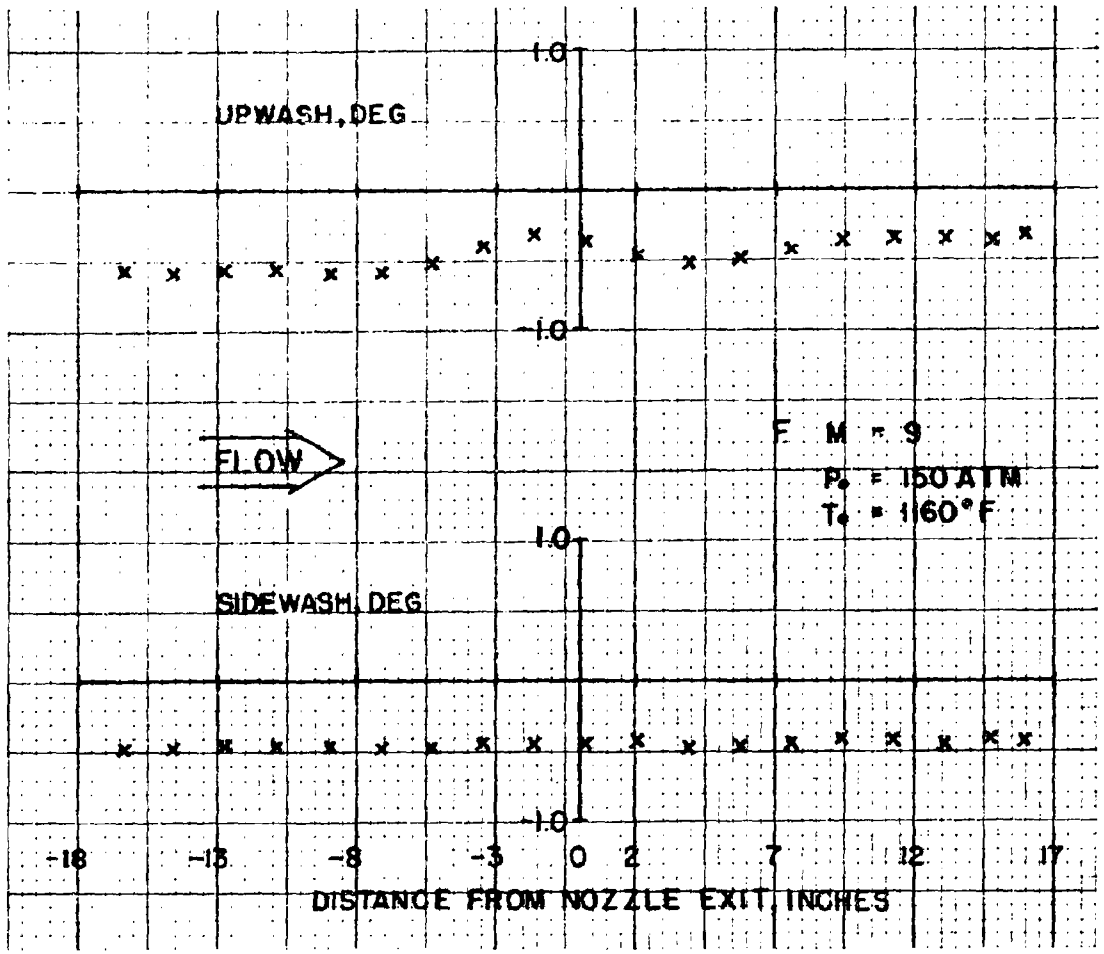

FIG. 13-F MACH 9 NOZZLE FLOW ANGULARITY

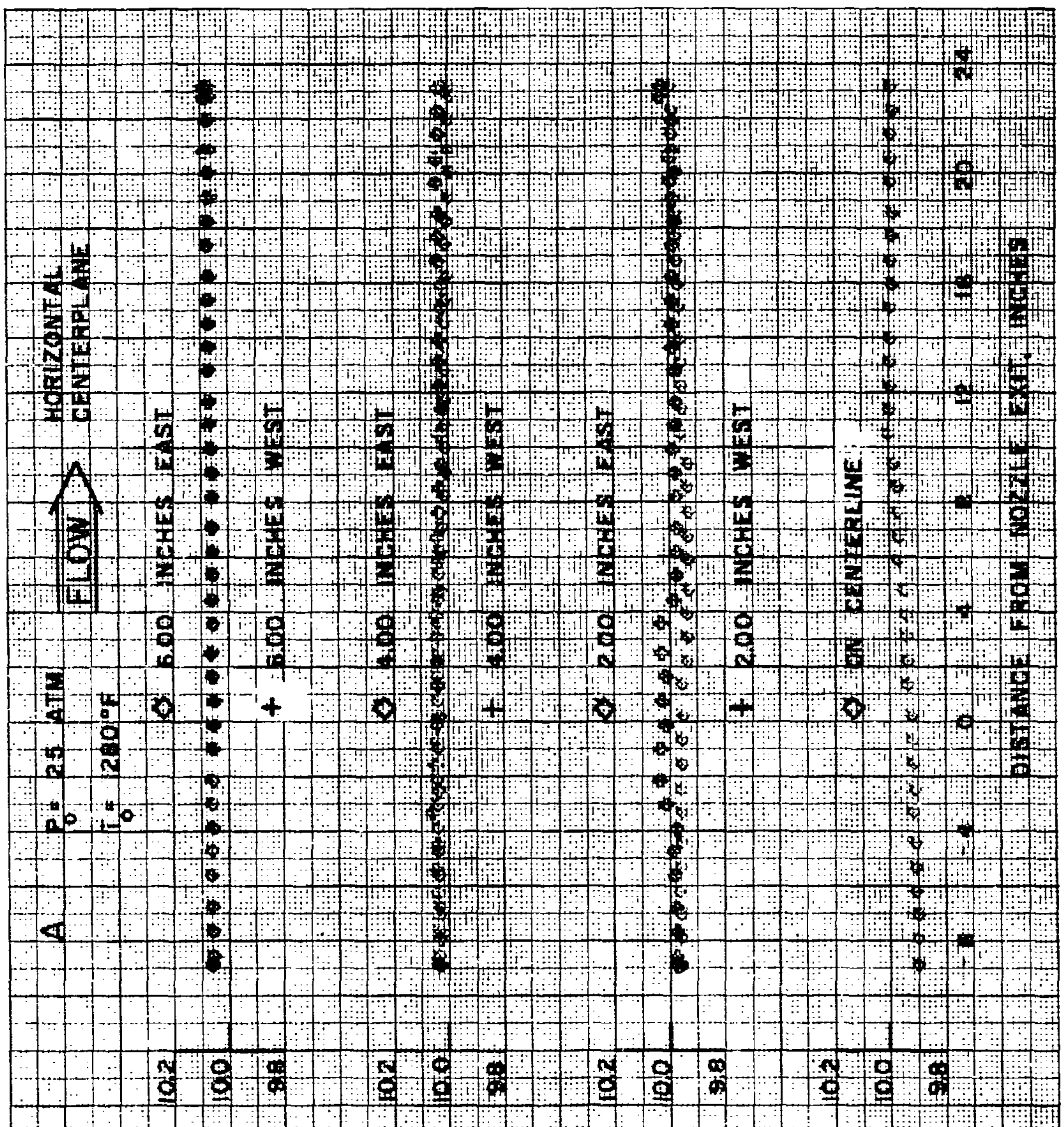

FIG. 14-A MACH 10 NOZZLE FLOW MACH NUMBER

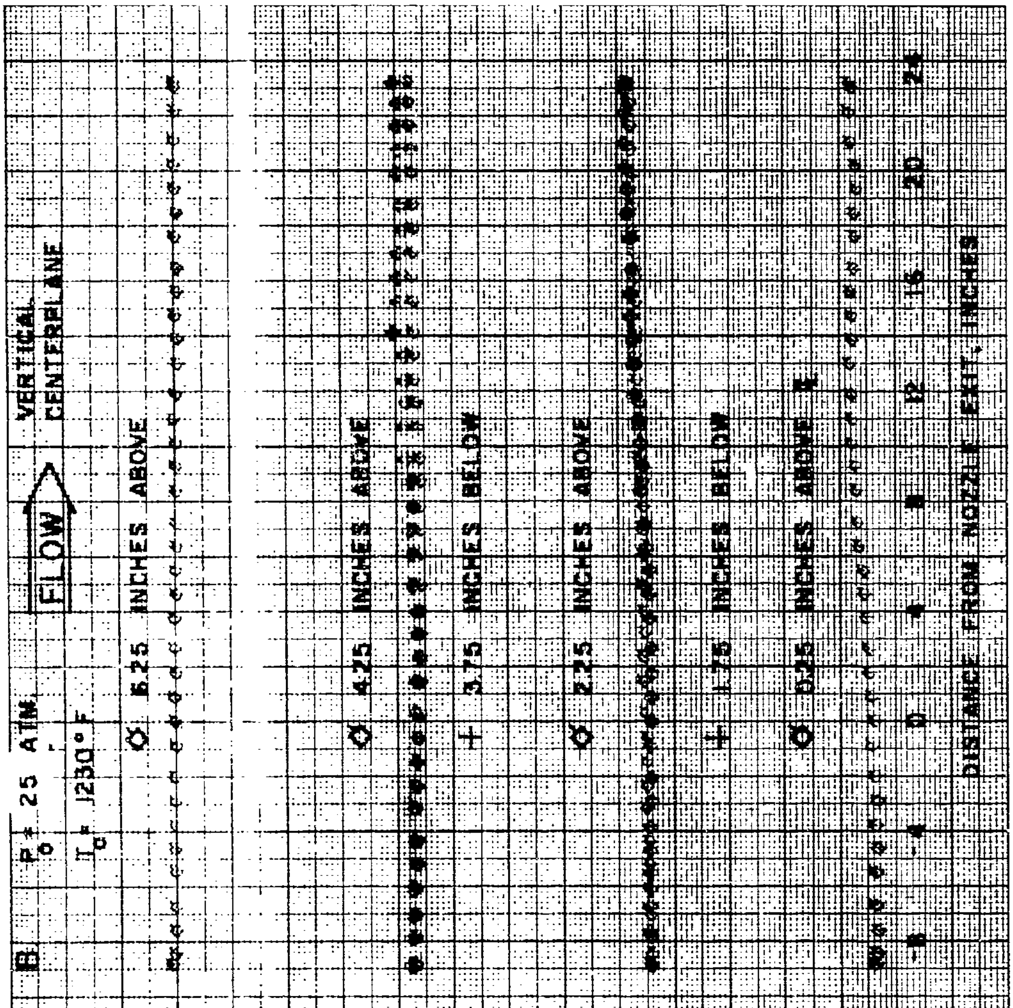

FIG. 14-B MACH 10 NOZZLE FLOW MACH NUMBER

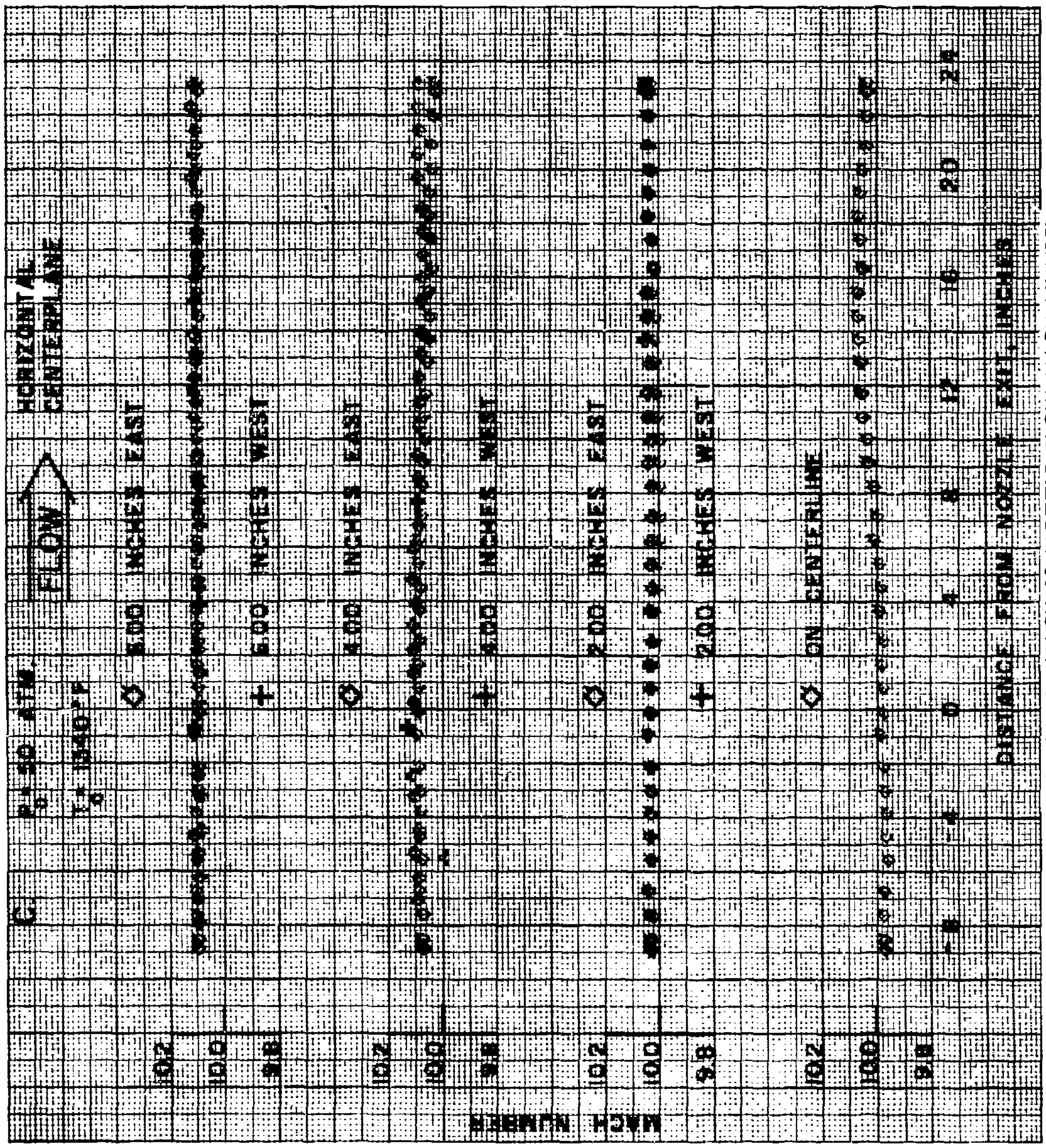

FIG. 14-C MACH 10 NOZZLE FLOW MACH NUMBER

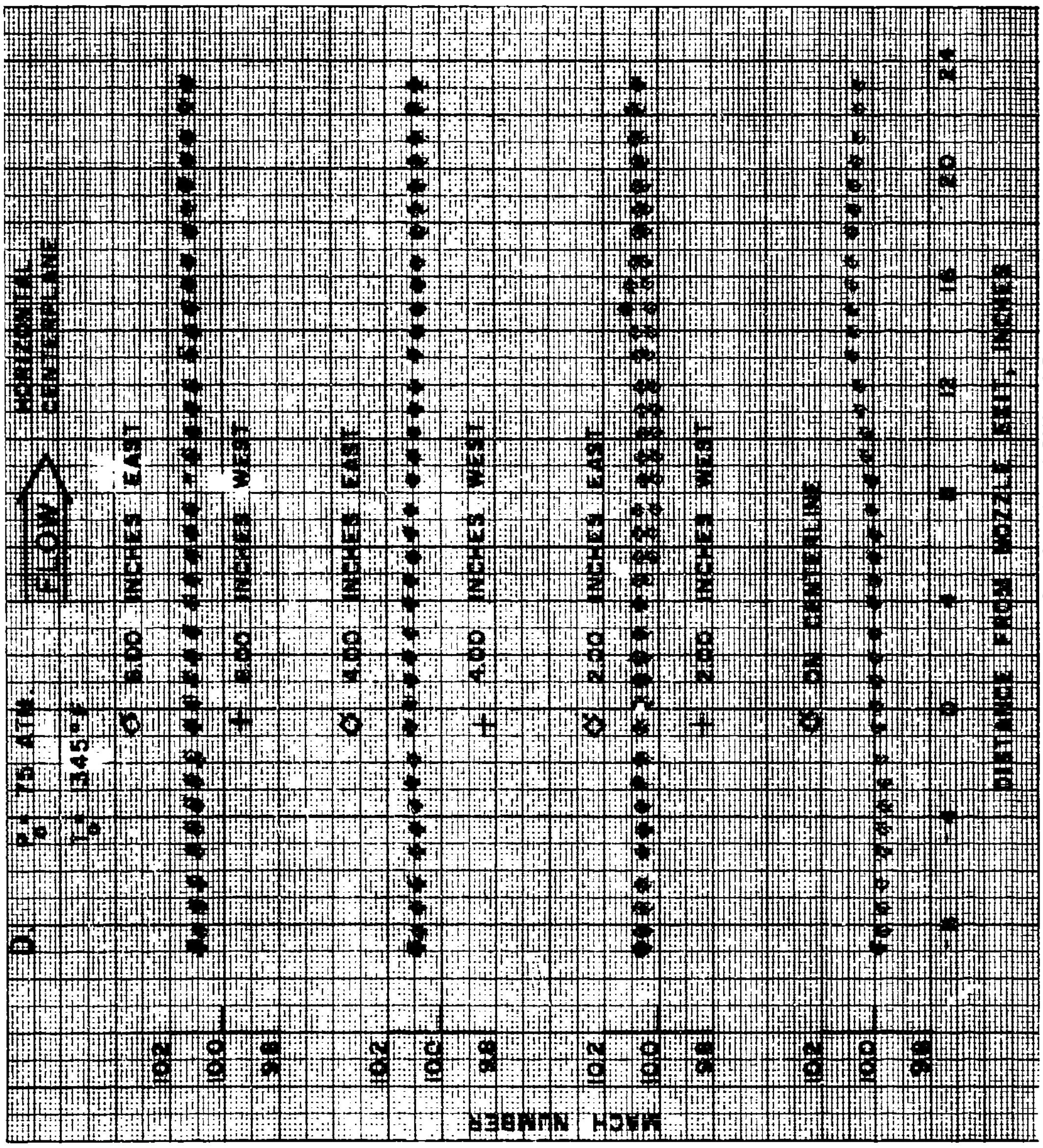

FIG. 14-D MACH 10 NOZZLE FLOW MACH NUMBER

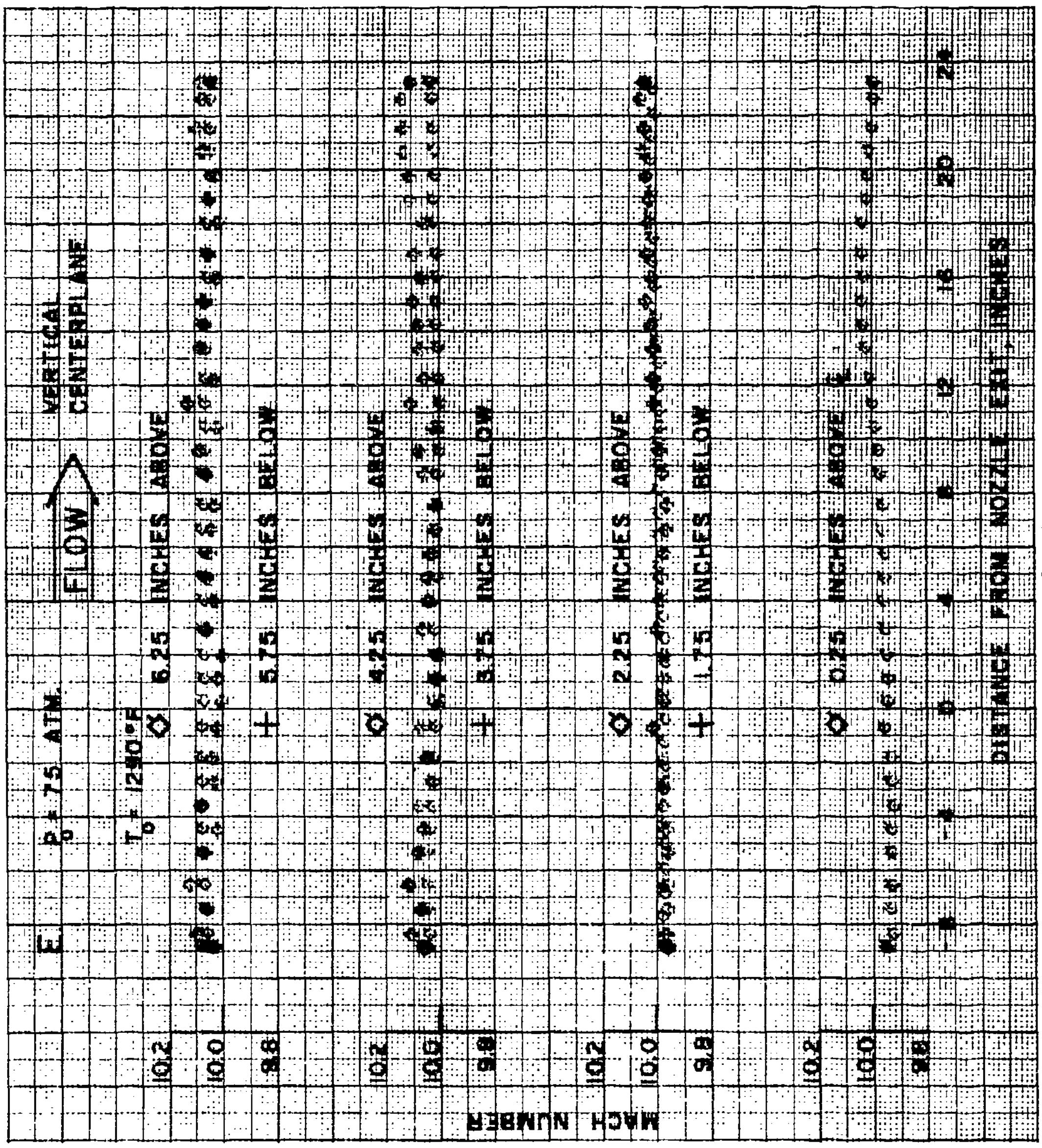

FIG. 14-E MACH 10 NOZZLE FLOW MACH NUMBER

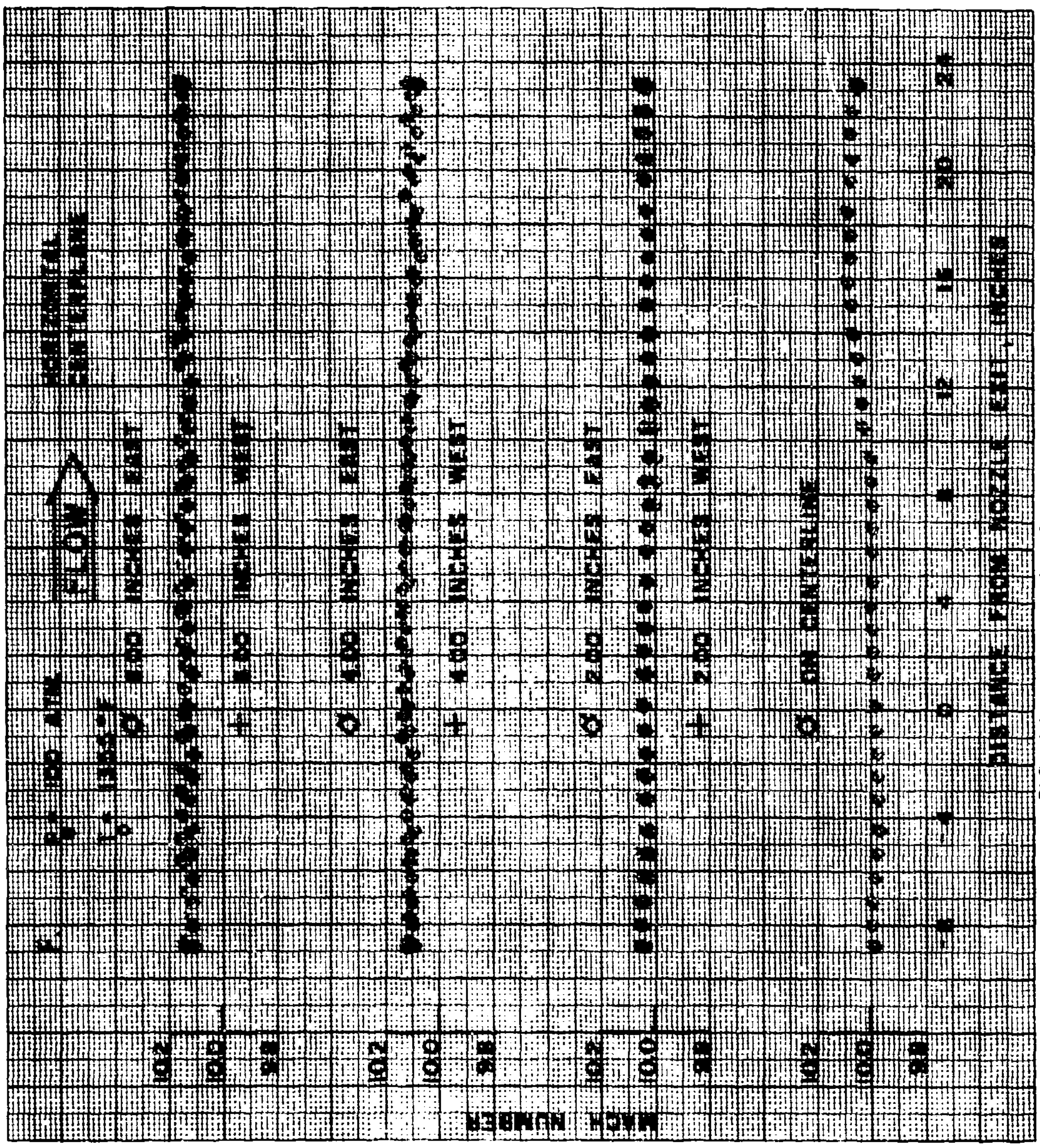

FIG. 14-F MACH 10 NOZZLE FLOW MACH NUMBER

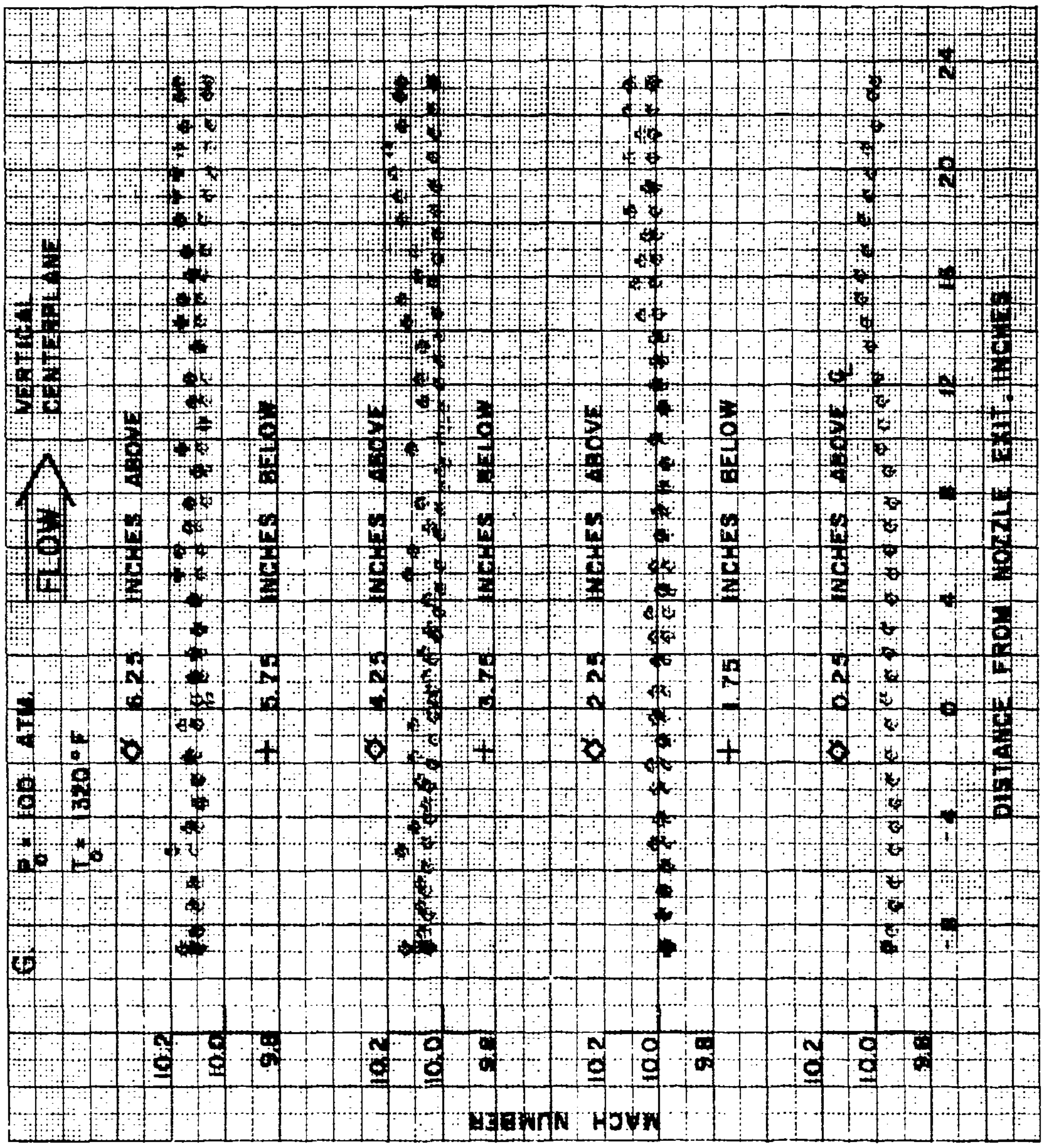

FIG. 14-G MACH 10 NOZZLE FLOW MACH NUMBER

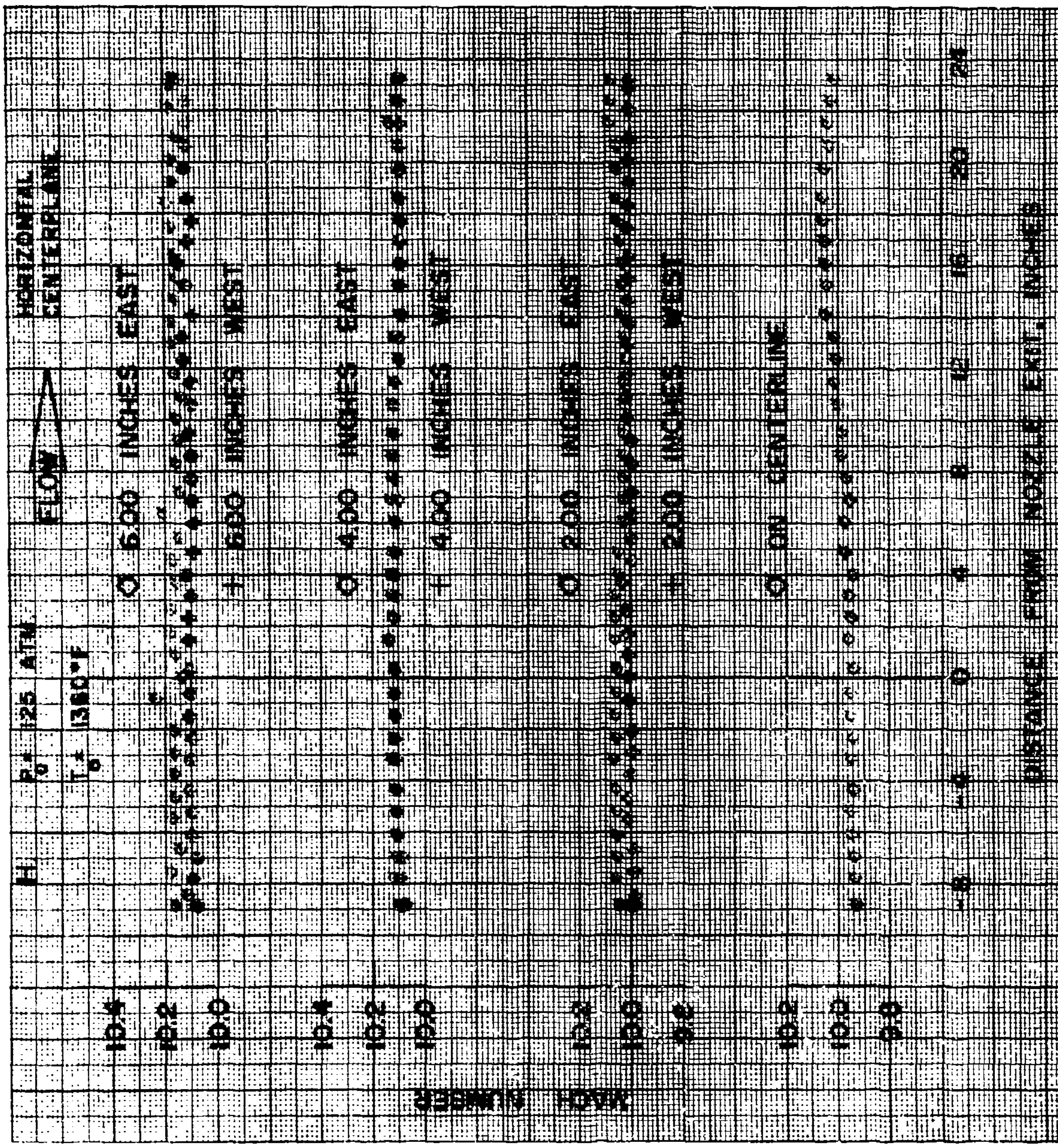

FIG. 14-H MACH 10 NOZZLE FLOW MACH NUMBER

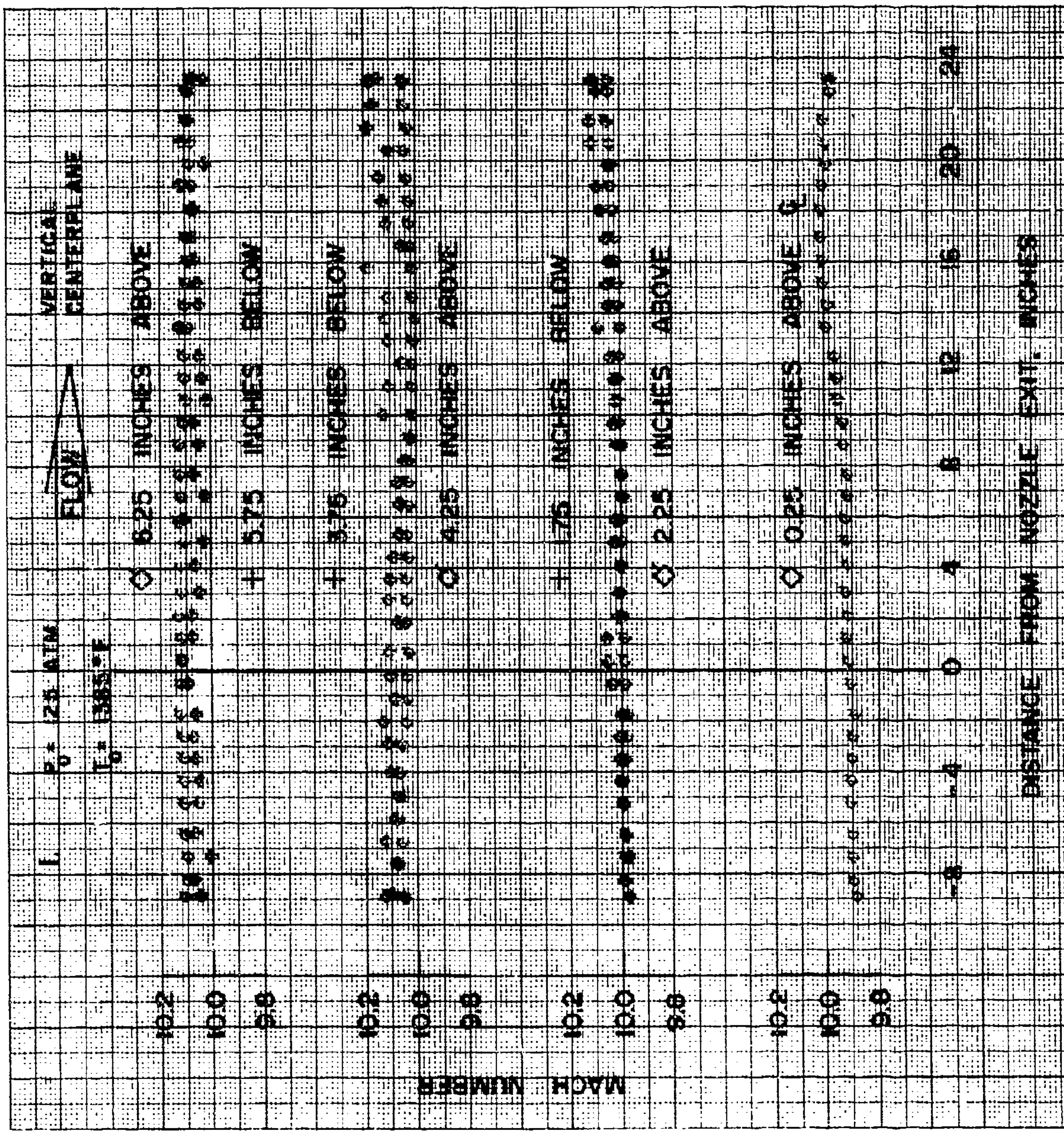

FIG. 14-1 MACH 10 NOZZLE FLOW MACH NUMBER

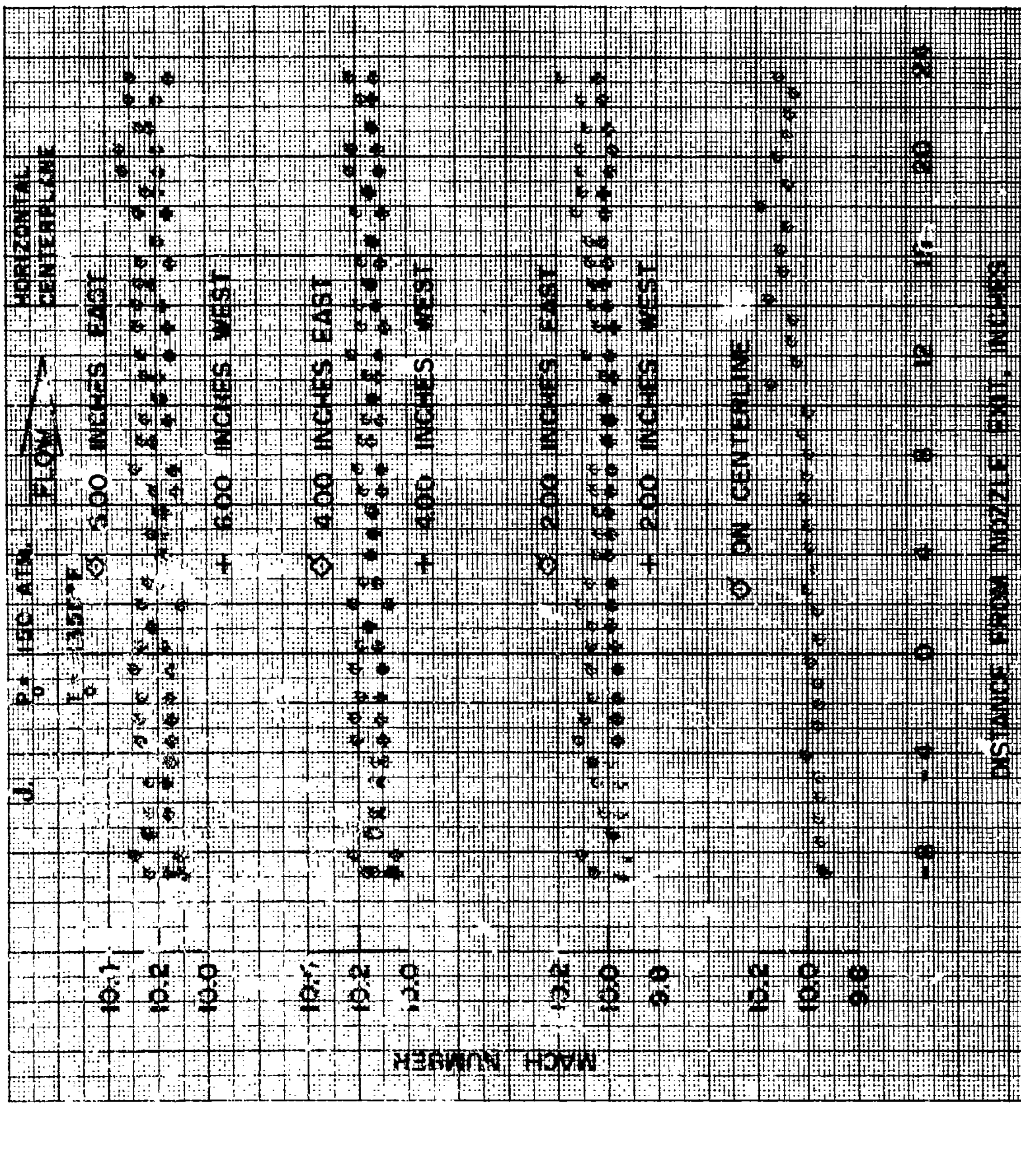

FIG. 14-J MACH 10 NOZZLE FLOW MACH NUMBER

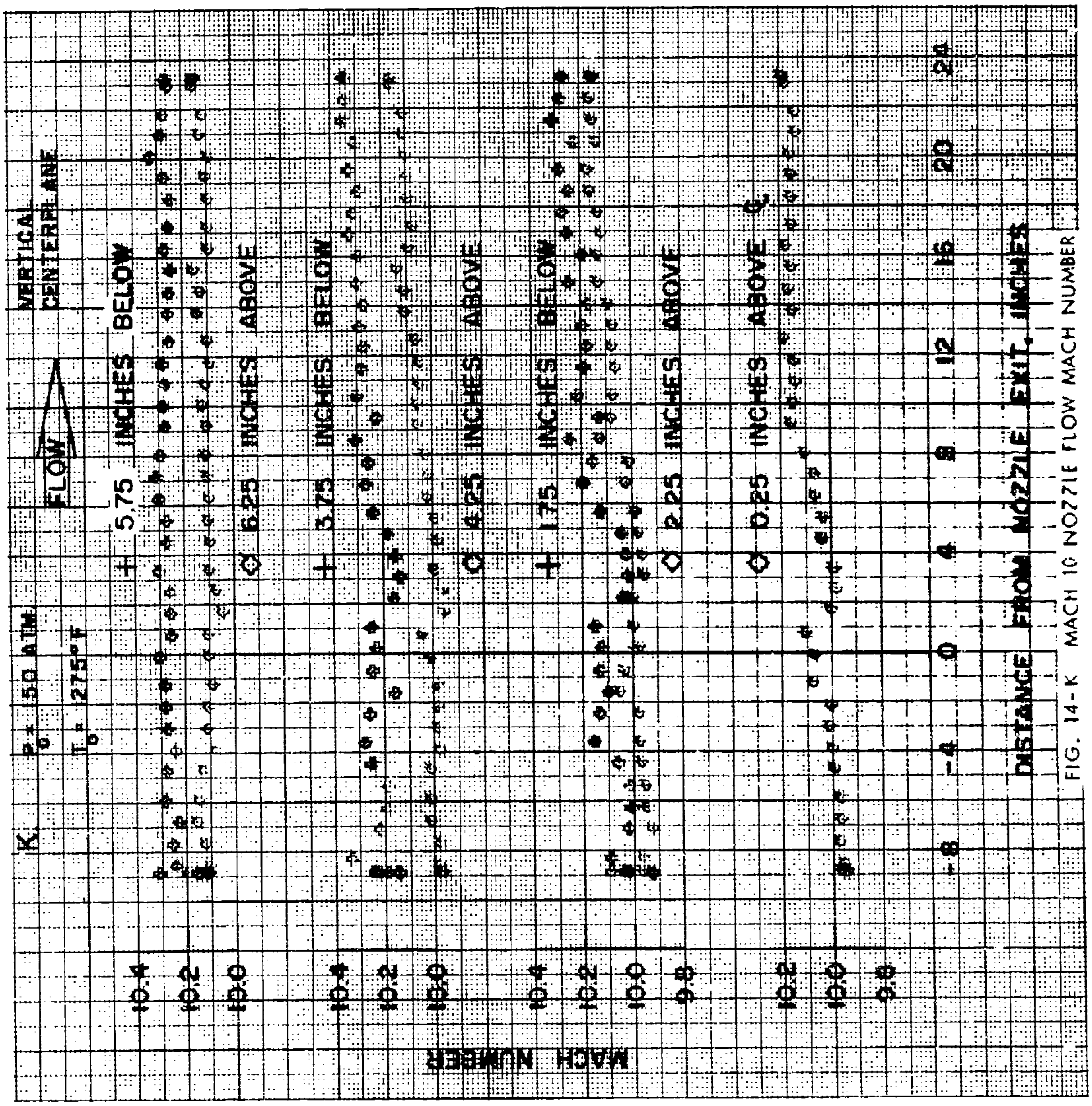

FIG. 14-K MACH 10 NOZZLE FLOW MACH NUMBER

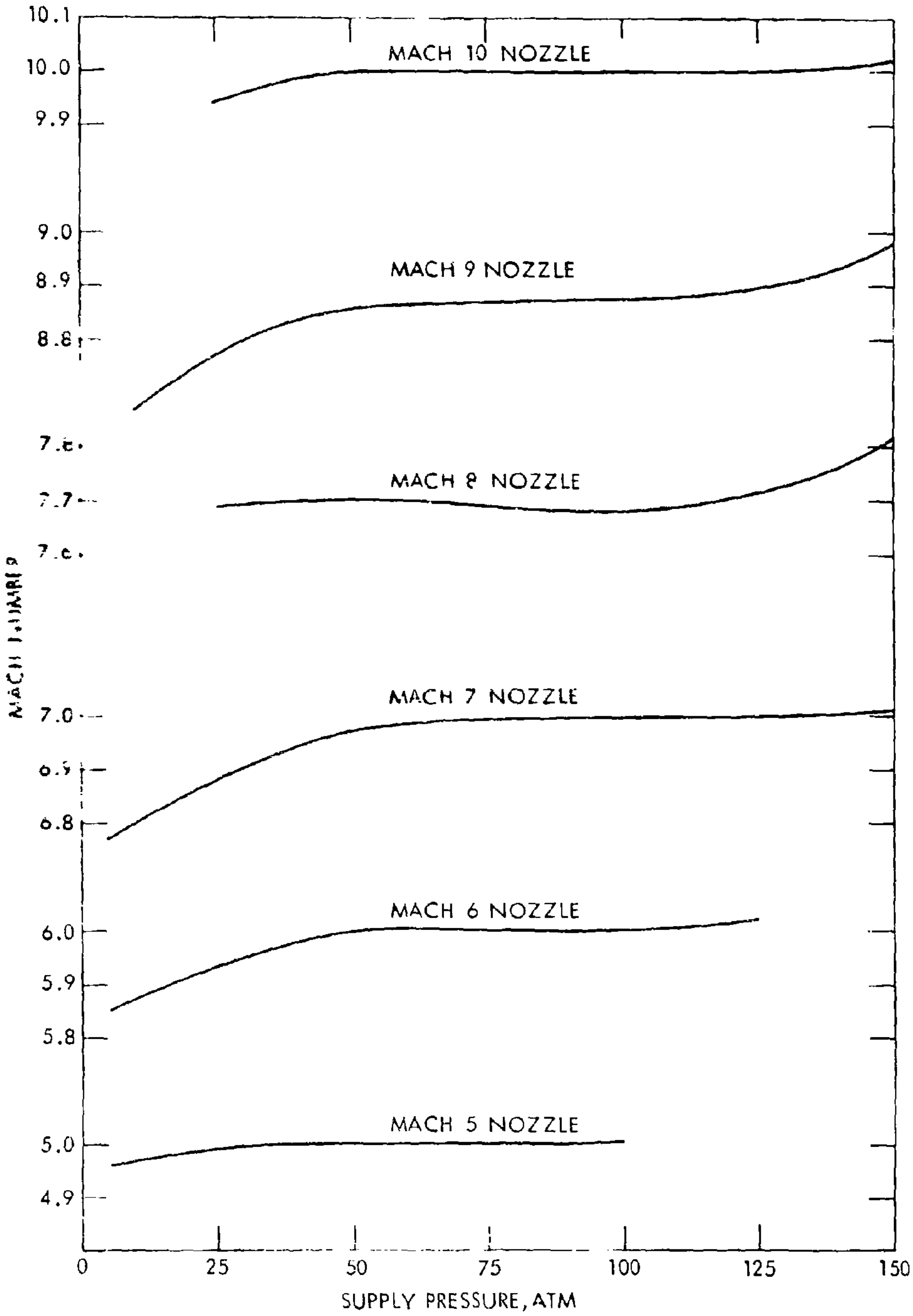

FIG. 15 TEST SECTION MACH NUMBER VERSUS SUPPLY PRESSURE.

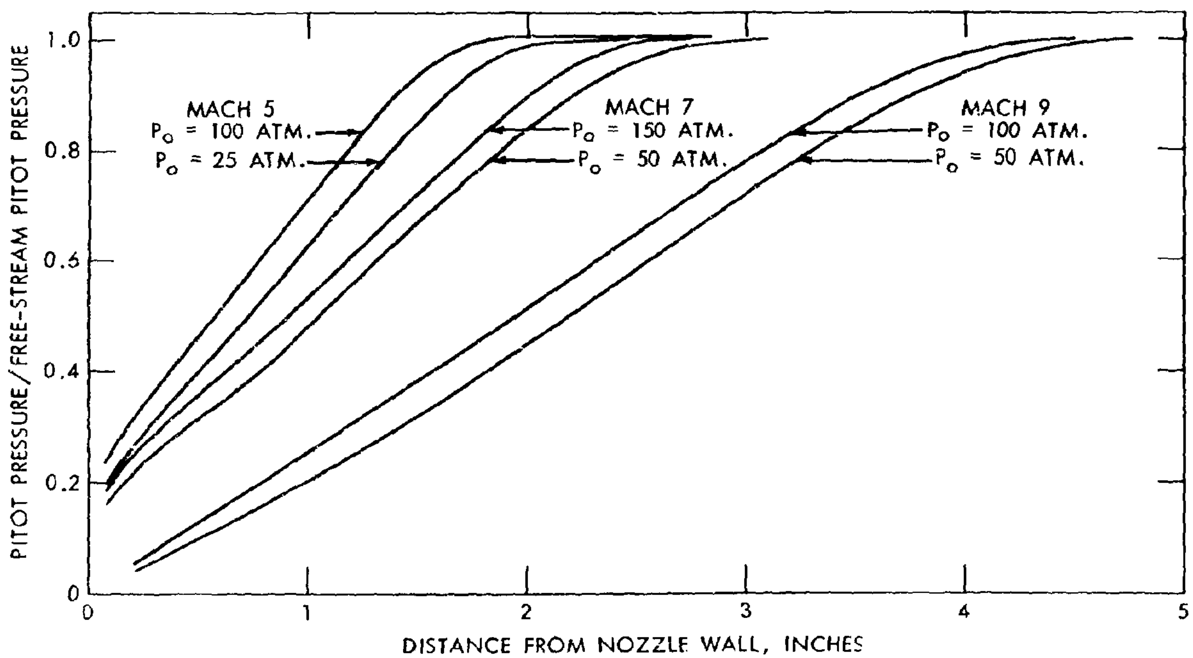

FIG. 16 BOUNDARY LAYER THICKNESS VARIATION WITH NOZZLE MACH NUMBER AND SUPPLY PRESSURE.

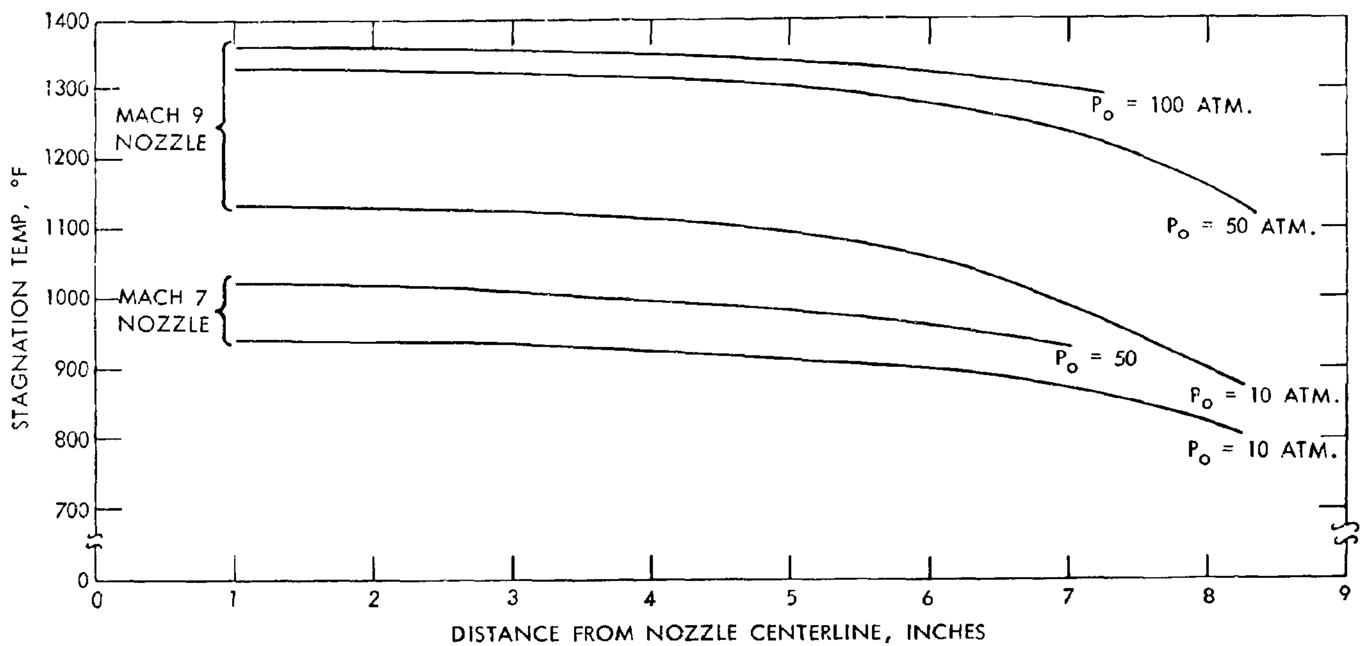

FIG. 17 VARIATION IN STAGNATION TEMPERATURE ACROSS THE TEST JET.

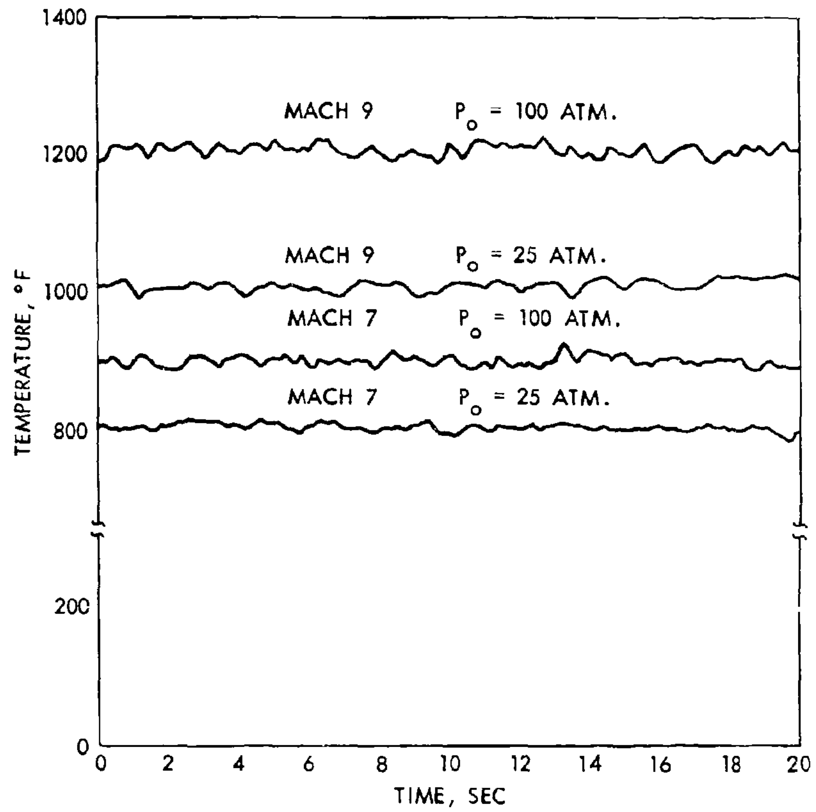

FIG. 18 VARIATION IN TEST SECTION STAGNATION TEMPERATURE WITH TIME.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

U. S. Naval Ordnance Laboratory
White Oak, Silver Spring, Maryland

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

Performance Capability of the NOL Hypersonic Tunnel

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Frank P. Baltakis

6. REPORT DATE	7a. TOTAL NO OF PAGES	7b. NO. OF REFS
24 October 1968	118	5

8a. CONTRACT OR GRANT NO

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

NOLTR 68-187

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document is subject to special export controls and each transmittal to foreign government or foreign nations may be made only with prior approval of NOL.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

U. S. Naval Ordnance Laboratory
White Oak, Silver Spring, Maryland

13. ABSTRACT

This report summarizes the performance capability data of the U. S. Naval Ordnance Laboratory's Hypersonic Tunnel. The report includes a brief description of the facility, overall performance capability data, nozzle calibration data, and some nozzle boundary-layer thickness and temperature variation data. The nozzle aerodynamic design method is indicated and its adequacy in the range of the supply and test flow conditions of the Hypersonic Tunnel is briefly discussed.

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Wind Tunnel						
Hypersonic Tunnel						
Tunnel Performance						
Flow Quality						
Nozzle Performance						
Mach Number Variation						
Flow Angularity						

UNCLASSIFIED
Security Classification