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WAKE PROPERTIES BEHIND A FLARED CYLINDRICAL FOREBODY AND AERODYNAMIC CHARACTERISTICS OF SEVERAL FLEXIBLE AERODYNAMIC DECELERATORS AT MACH NUMBERS FROM 1.75 TO 4.75

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ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE STATION, TENN. 37389

M. L. Homan

ARO, Inc.

June 1970

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WAKE PROPERTIES BEHIND A FLARED CYLINDRICAL FOREBODY AND AERODYNAMIC CHARACTERISTICS OF SEVERAL FLEXIBLE AERODYNAMIC DECELERATORS AT MACH NUMBERS FROM 1.75 TO 4.75

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PER TAB 72-21, dated 1 November, 1972.

FOREWORD

The work reported herein was done at the request of the Air Force Flight Dynamics Laboratory (AFFDL), Air Force Systems Command (AFSC), under Program Element 62201F, Project 6065.

The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-69-C-0001. The test was conducted from January 26 to March 16, 1970, under ARO Project No. PS0061, and the manuscript was submitted for publication on May 12, 1970.

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This technical report has been reviewed and is approved.

George F. Garey
Lt Colonel, USAF
AF Representative, PWT
Directorate of Test

Roy R. Croy, Jr.
Colonel, USAF
Director of Test

ABSTRACT

A test was conducted in the Propulsion Wind Tunnel (16S) to determine the flow field properties in the wake of a strut-mounted cylindrical forebody with and without base bleed and to determine aerodynamic performance of two types of parachutes. The wake was surveyed from two to eight forebody diameters aft of the base. Parachute separation distance was remotely varied from four to nine forebody diameters aft of the base. Data were obtained at Mach numbers from 1.75 to 4.75 at a nominal free-stream dynamic pressure of 80 psf. Base bleed reduced the local wake Mach number and dynamic pressure behind the forebody at all X/D locations for Z/D = 0. The addition of webs to the Supersonic X parachute, in general, decreased the parachute dynamics at Mach numbers greater than three.

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I. ILLUSTRATIONS

NOMENCLATURE

C_{D_p}	Drag coefficient of parachute based on design projected canopy area, drag force/$q_\infty S_p$
$C_{D_{p_i}}$	Mean parachute drag coefficient value of each cell in the statistical analysis program, drag force/$q_\infty S_p$
D	Forebody diameter 1.4683 ft Forebody with simulated ejection seat 1.7500 ft
M_w	Wake local Mach number
M_∞	Free-stream Mach number
N	Total number of drag coefficient data samples used in the statistical analysis program
N_i	Number of drag coefficient data samples in each cell of the statistical analysis program
$(N_i)_{max}$	Maximum number of drag coefficient data samples in any cell of the statistical analysis program
p_c	Plenum pressure, psfa
p_∞	Free-stream static pressure, psfa
q_w	Wake local dynamic pressure, psf
q_∞	Free-stream dynamic pressure, psf
S_p	Projected area of the inflated parachute canopy design Supersonic X 9.6162 ft^2 Guide Surface, 3 ft 7.0680 ft^2 Guide Surface, 4 ft 12.5660 ft^2
X	Axial location of rake probe or parachute downstream of the forebody base, positive downstream, ft
Y	Horizontal location of rake probe from forebody centerline, positive to the right looking upstream, ft
Z	Vertical location of rake probe from forebody centerline, positive up looking upstream, ft
σ	Standard deviation of a distribution of drag coefficient data determined from the statistical analysis program

Relative Dynamic
Parameter

Ratio of the 95-percent confidence level interval, expressed as drag coefficient interval, of a distribution of drag coefficient data to the average drag coefficient value as determined from the statistical analysis program

SECTION I
INTRODUCTION

The purpose of this test program was to determine the flow field properties in the wake of a strut-mounted cylindrical forebody having a flared aft section with and without base bleed and to determine the drag and stability characteristics of two types of parachutes attached to the forebody with and without a simulated ejection seat. The wake was surveyed with a rake (extending horizontally 1.3 body diameters) at positions from two to eight forebody diameters aft of the base and vertically from 0.6 forebody diameters above to 1.0 forebody diameters below the forebody centerline. The parachute was suspended such that the parachute separation distance could be remotely varied by a winch pulley system. Nine parachutes were tested. Data were obtained at Mach numbers from 1.8 to 4.75 for the wake survey and from 1.75 to 4.5 for the parachutes. Dynamic pressure was maintained at 80 psf throughout the test.

SECTION II
APPARATUS

2.1 TEST FACILITY

Propulsion Wind Tunnel (16S) is a closed-circuit, continuous-flow wind tunnel currently capable of being operated at Mach numbers from 1.70 to 4.75. The tunnel can be operated over a stagnation pressure range from about 200 to 2300 psfa, depending upon Mach number. The test section stagnation temperature can be controlled through an approximate range from 100 to 620°F. The wind tunnel specific humidity is controlled by removing tunnel air and supplying makeup air from an atmospheric dryer. A more complete description of the facility and its operating characteristics is contained in Ref. 1.

A sketch showing the forebody location with both the survey rake support system and the decelerator support system and the decelerator support system in Tunnel 16S is presented in Fig. 1, Appendix I.

2.2 TEST ARTICLES

2.2.1 Model Forebody and Rake Survey System

The strut-mounted cylindrical forebody had a flared aft section. Base bleed was provided through an opening to the plenum of approximately 3 sq in. The variation of the plenum pressure to free-stream static pressure ratio with Mach number is shown in Fig. 2. The wake was surveyed both without and with base bleed with a rake containing eleven cone probes with each cone instrumented with a pitot and four static orifices. The static orifices were tied together to give one average pressure. The rake extended horizontally 1.3 forebody diameters from the model centerline. The sting-mounted rake was remotely translated from two to eight body diameters aft of the model base and translated vertically from 0.6 body diameters above to 1.0 body diameters below the model centerline. Dimensions of the forebody and rake details are presented in Figs. 3 and 4, respectively. Wind tunnel installation photographs of the forebody and rake are shown in Fig. 5. Photographs of the forebody configuration (no base bleed) and the survey rake are presented in Fig. 6.

2.2.2 Model Forebody and Deployment System

The parachutes tested during this investigation were deployed from the forebody with base bleed (approximate open area to plenum was 1 sq in.) both with and without the simulated ejection seat attached. Dimensions of the simulated ejection seat are presented in Fig. 7, and wind tunnel installation photographs of both configurations are shown in Fig. 8.

The parachute pack was placed in the forebody storage compartment against a spring-loaded plate. Four restraining straps, connected together by a release pin, were used to hold the parachute pack against the spring-loaded plate. The retaining straps were released by a pyrotechnic-actuated pin release mechanism.

The position of the parachute was remotely varied from four to nine forebody diameters downstream of the forebody base by means of a suspension line and cable attached to an electric winch. A sketch of the model and attachment system is shown in Fig. 9.

2.2.3 Parachute Details

A dimensioned sketch of the Supersonic X parachute is presented in Fig. 10. The cloth gore and the cloth web dimensions of the no-web, 6-web, and 12-web Supersonic X parachutes tested are presented in Figs. 11 and 12 in tabular form. The parachutes were constructed of a relatively nonporous cloth with a single exit opening that controlled the airflow through the canopy. The parachutes had a maximum projected diameter of 3.5 ft.

A dimensioned sketch of the Guide Surface parachute is presented in Fig. 13, and the dimensions of the Guide Surface panel and roof panel are presented in Fig. 14 in tabular form. The guide surfaces tested had a maximum projected diameter of three and four feet.

2.3 INSTRUMENTATION

The rake had 11 conical probes. Each cone was instrumented with a pitot and four static orifices. The static orifices were interconnected to give one average pressure. The vertical and axial location of the rake was determined by linear potentiometers.

The parachute drag was measured by a 5000-lb capacity, double-element load cell. The readings were corrected for the mechanical advantage of the pulley system (see Fig. 9) such that the load was measured to within ±10 lb. A direct-writing oscillograph was used to monitor the parachute drag load during testing. Four motion picture cameras and two television cameras, installed in the test section walls, provided visual coverage during testing. The position of the parachute, downstream of the forebody base, was determined by a linear potentiometer.

The outputs from the load cell, pressure transducers, and linear potentiometers were digitized and code punched on paper tape for on-line data reduction. The load cell output was also recorded on magnetic tape by a high-speed digital recording system at a sampling rate of 1000 per second for off-line data reduction.

SECTION III
PROCEDURE

When test conditions were established during the wake survey phase, steady-state data were obtained at free-stream Mach numbers from 1.8 to 4.75 at a nominal free-stream dynamic pressure of 80 psf. At each test Mach number, the wake was surveyed from two to eight body diameters aft of the model base and vertically from six tenths of a body diameter above the model centerline to one body diameter below the model centerline.

The parachute pack, which consists of a parachute enclosed in a deployment bag, was packed in the forebody storage compartment before wind tunnel test operation was initiated. Once the prescribed test conditions were established, a countdown procedure was used to sequence data acquisition during parachute deployment. The deployment procedure consisted of activating the test section cameras and the high-speed digital recording system, followed by firing a pyrotechnic squib in the release pin mechanism. Upon completion of the parachute deployment sequence, steady-state drag loads were calculated by averaging the analog output from the load cell over 1-sec intervals. Motion pictures and steady-state drag and dynamic drag data were obtained at each axial location downstream of the forebody. Drag distribution parameters, such as average drag coefficient, standard deviation, skewness, and kurtosis, were calculated from the data recorded on the high-speed digital data recording system by a statistical analysis program (Ref. 2). Data were obtained for various axial locations until the decelerator became unstable as determined from monitoring the television or until the desired X/D range was covered.

Upon completion of data acquisition at the deployment Mach number, the Mach number was increased, and the data cycle was repeated until the desired Mach number range was covered or until the parachute failed as determined by monitoring a television screen. If the parachute failed, a backup parachute was deployed at the Mach number at which the failure occurred, and additional data were obtained until the desired Mach number range was covered for that type of parachute.

Guide Surface parachutes of three- and four-foot diameter and Supersonic X parachutes with no webs, 6 webs, and 12 webs were tested. The Supersonic X parachutes were deployed at Mach number 2.0 from the forebody. The Guide Surface parachutes and a Supersonic X parachute with no webs were deployed at Mach number 1.75 from the forebody with the simulated ejection seat.

SECTION IV
RESULTS AND DISCUSSION

4.1 FOREBODY WAKE PROPERTIES

The wake properties are presented in the form of the ratio of the local wake Mach number to free-stream Mach number and local wake dynamic pressure to free-stream dynamic pressure in Figs. 15 through 17. The local wake Mach number ratios (M_W/M_∞) and the local wake dynamic pressure ratios (q_W/q_∞) with and without base bleed are presented in Figs. 14 and 15 for various X/D locations at Z/D = 0. In general, the effect of base bleed was to reduce the wake Mach number and dynamic pressure directly behind the forebody ($-0.5 < Y/D < 0/5$) at all X/D locations and for all test Mach numbers.

As shown in Fig. 17 at Mach number 2 and Y/D = 0, base bleed produced the largest reduction in the local wake properties on the model centerline for all X/D locations.

4.2 PARACHUTE STEADY-STATE PERFORMANCE

Base bleed (approximately open area to plenum was 1 sq in.) occurred on the forebodies when deploying parachutes as a result of the cable arrangement used to vary X/D.

The variation in drag coefficient with Mach number for a series of Supersonic X parachutes is shown in Figs. 18 and 19. As shown in Fig. 18, increasing the free-stream Mach number decreased the drag coefficient. Increasing X/D increased the drag coefficient at each test Mach number. Increasing X/D beyond six produced only small increases in the drag coefficient of the Supersonic X with no webs. As shown in Fig. 19, in general, the addition of webs to the Supersonic X parachutes resulted in small changes in drag coefficient except at Mach numbers greater than 3.5 for X/D = 5.1.

Two configurations of Guide Surface parachutes and one Supersonic X parachute with no webs were tested in the wake of a simulated ejection seat. The Guide Surface parachutes each had eight "gores" and were 3 and 4 ft in diameter. The data presented in Fig. 20 show that at a given M_∞, drag coefficient increased as X/D was increased from 3.9 to 7.5.

4.3 PARACHUTE DYNAMIC CHARACTERISTICS

The characteristics of the drag dynamics of each decelerator were determined from a statistical analysis program (Ref. 2). The statistical program reduces the data recorded by a high-speed digital data recording system at a sample rate of 1000 samples per second and calculates drag distribution parameters, average drag coefficient, standard deviation, skewness, and kurtosis. The drag distribution parameters are tabulated on the dynamic drag coefficient distribution sample plot present in Fig. 21 and are summarized in Table I (Appendix II) for each declerator. Also shown is the 95-percent confidence level interval which can be interpreted as representing a quantitative measurement of declerator drag dynamics at a 95-percent confidence level. To compare drag dynamics of one decelerator with those of another decelerator, it is first necessary to divide the 95-percent confidence level interval, expressed as drag coefficient interval, by the average drag coefficient to obtain a relative drag dynamic level for each decelerator. This term will be referred to as the relative dynamic parameter, and its value is tabulated in Table I for each decelerator. The significance of the relative dynamic parameter can be discerned by explaining the drag dynamic characteristics of a declerator, having a Gaussian-type drag distribution, when values of zero, unity, and two are assigned to the relative dynamic parameter. A value of zero implies no dynamics, a value of unity implies that the magnitude of dynamics about the average drag coefficient value is equal to 50 percent of the average drag coefficient, and a value of two implies that the magnitude of dynamics about the average drag coefficient value is equal to 100 percent of the average drag coefficient. If the skewness parameter deviates from a value of zero, the drag dynamics are not symmetrical about the average drag coefficient value. For skewness greater than zero, higher drag dynamics are encountered above the average drag coefficient value, and for skewness less than zero, lower drag dynamics are encountered above the average drag coefficient value. The variation of the relative dynamic parameter with decelerator separation distance is shown in Figs. 22 and 23. As shown in Fig. 22, the dynamics of the Supersonic X (12-web) decelerator increased, in general, as Mach number increased. The data indicate that there were large changes in the dynamics of this decelerator as the separation distance varied at Mach numbers greater than three. The dynamics of the Guide Surface (3-ft) decelerator were, in general, unchanged by Mach number and separation distance over the range of Mach numbers and separation distances of this test. As shown in Fig. 23, the additions of webs to the Supersonic X parachute, in general, decreased the parachute dynamics at Mach numbers of three and greater.

SECTION V
SUMMARY OF RESULTS

Tests were conducted to obtain local wake properties behind a forebody with a cylindrical flared afterbody both with and without base bleed and to obtain parachute drag and stability characteristics of two types of parachutes deployed from the forebody with base bleed. The results of these tests may be summarized as follows:

1. Base bleed reduced the local wake Mach number and dynamic pressure directly behind the forebody at all X/D locations for Z/D = 0.
2. Increasing X/D increased the parachute drag coefficient at each test Mach number.
3. The addition of webs to the Supersonic X parachute resulted in small changes in the drag coefficient except at Mach numbers greater than 3.5 for X/D = 5.1.
4. The addition of webs to the Supersonic X parachute, in general, decreased the parachute dynamics at Mach numbers greater than 3.

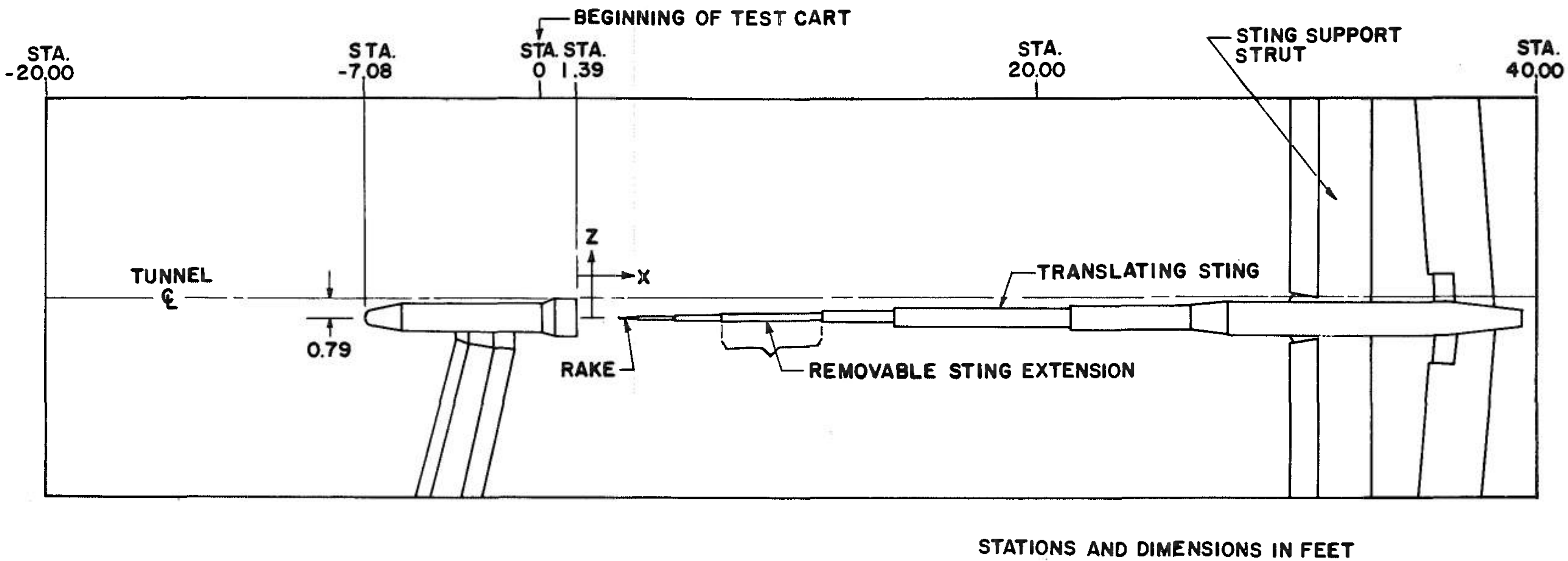
REFERENCES

1. Test Facilities Handbook (Eighth Edition). "Propulsion Wind Tunnel Facility, Vol. 5." Arnold Engineering Development Center, December 1969 (AD863646).

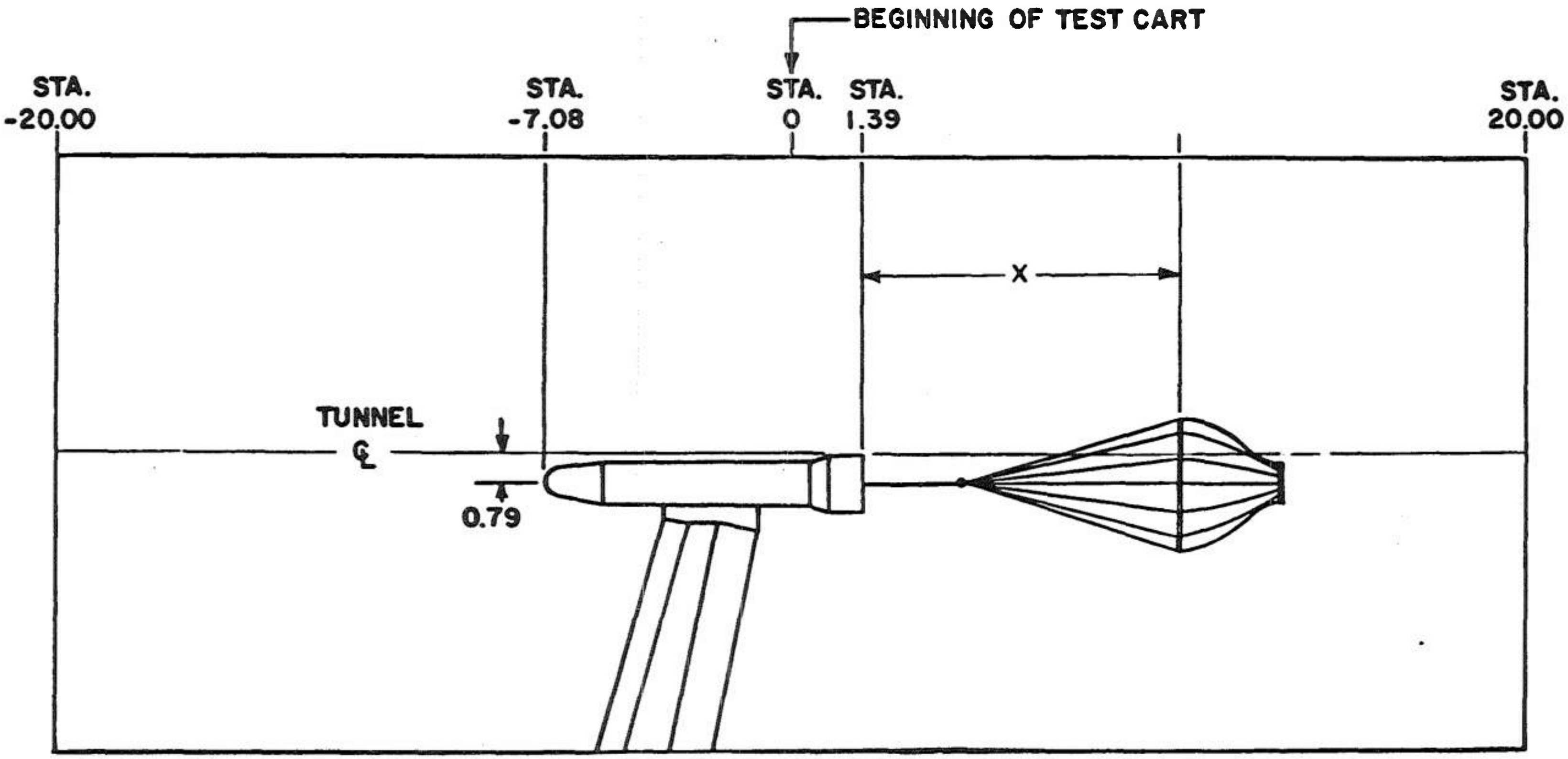
2. Galigher, Lawrence L. "Aerodynamic Characteristics of Ballutes and Disk-Gap-Band Parachutes at Mach Numbers from 1.8 to 3.7." AEDC-TR-69-245 (AD861437), November 1969.

APPENDIXES

I. ILLUSTRATIONS
II. TABLE



a. Wake Survey Rake
Fig. 1 Model Location in Test Section



STATIONS AND DIMENSIONS IN FEET

b. Decelerator
Fig. 1 Concluded

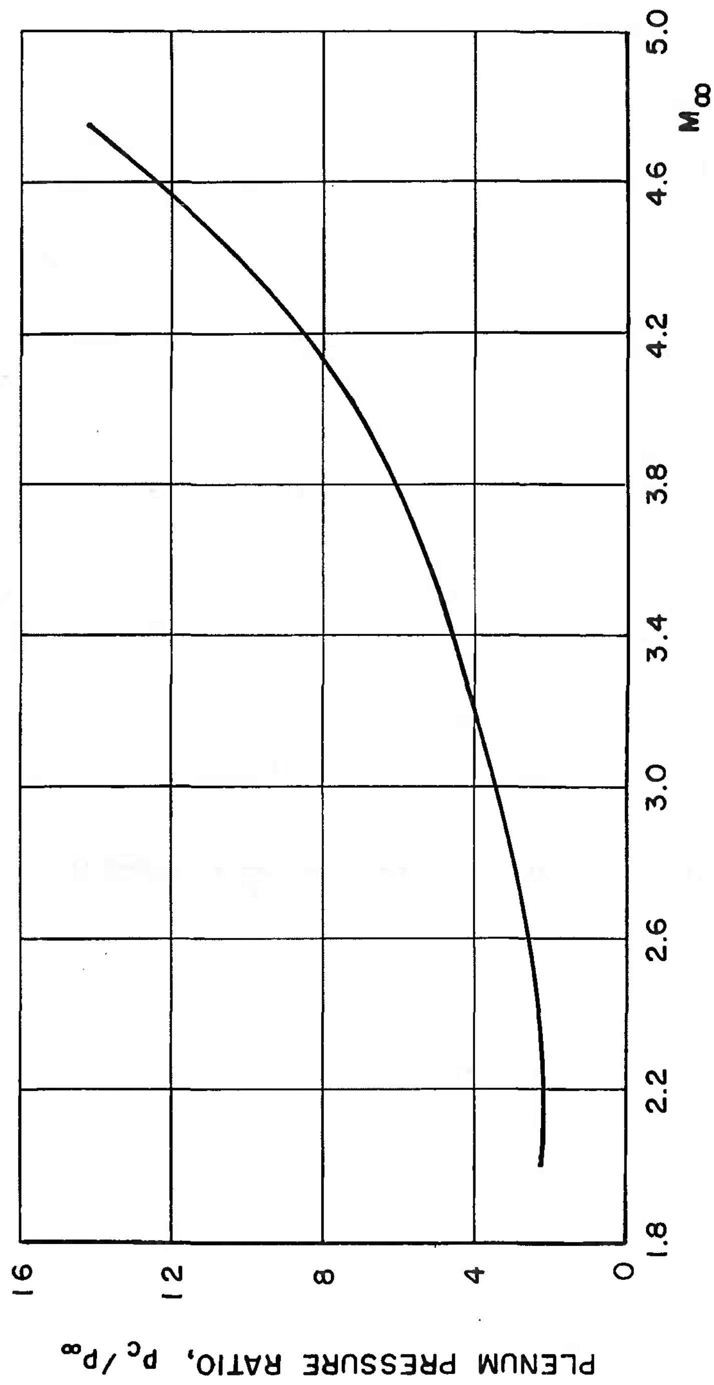


Fig. 2 Variation of Plenum Pressure with Mach Number

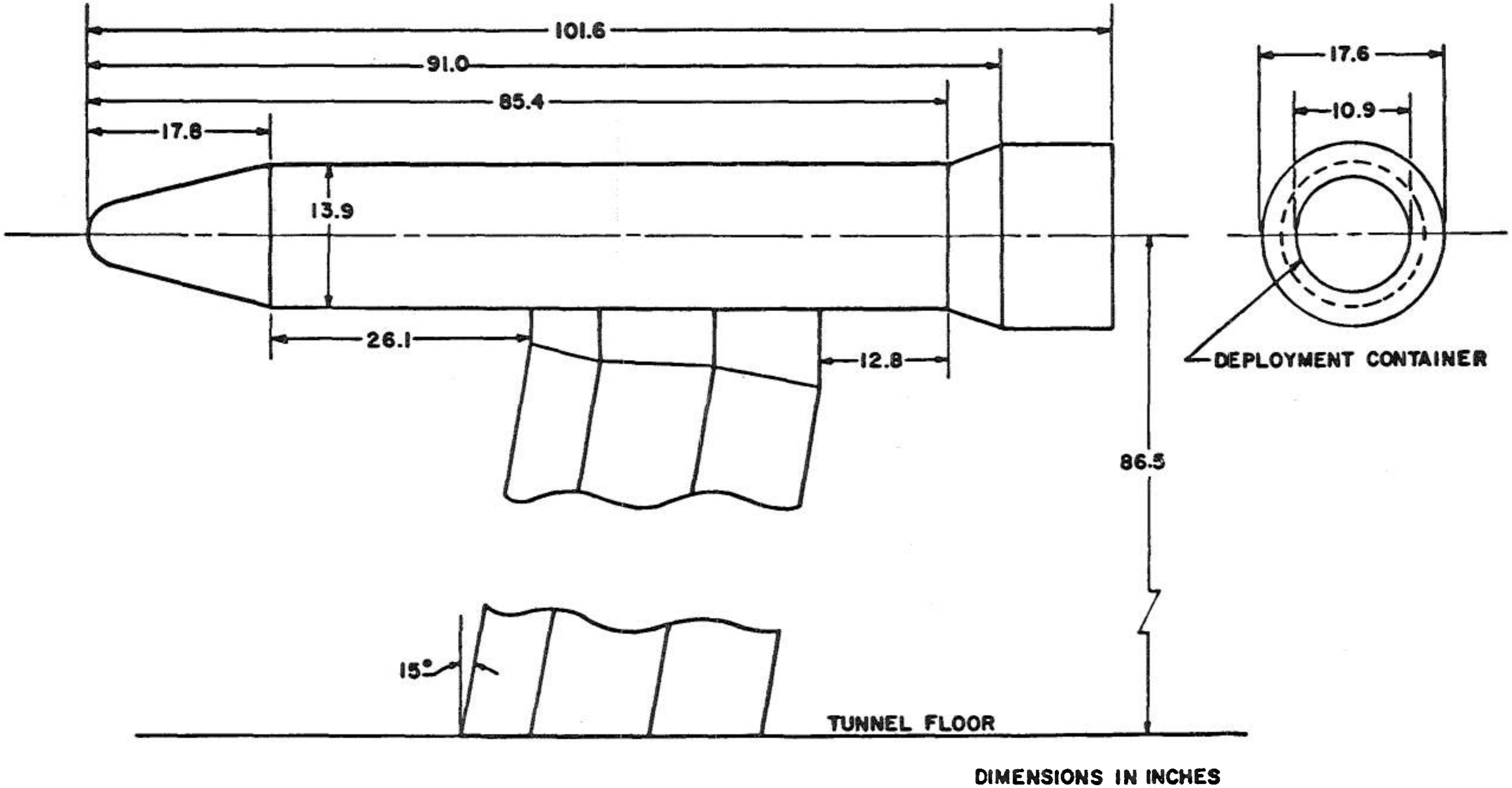


Fig. 3 Dimensioned Sketch of Model Forebody

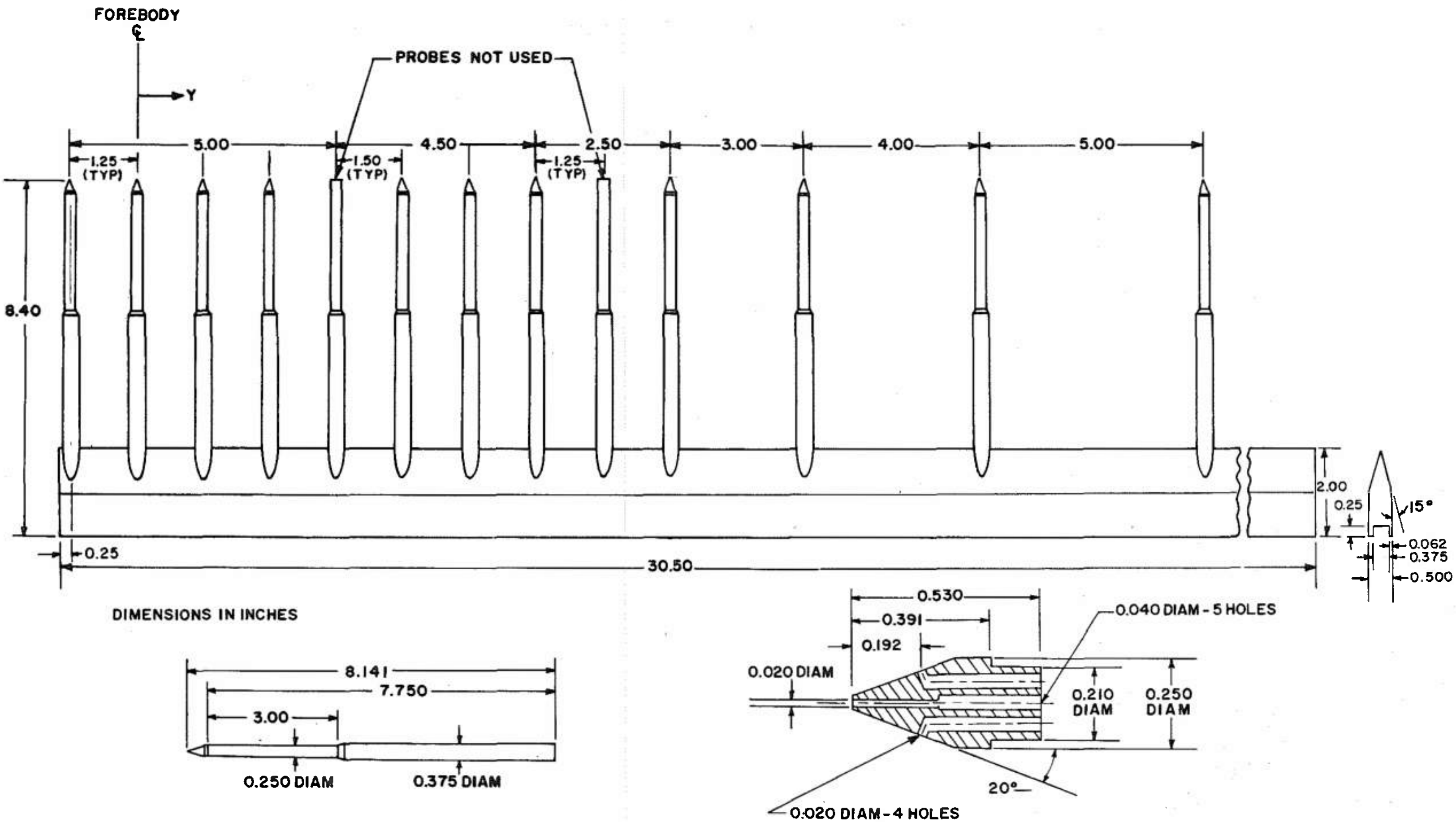


Fig. 4 Rake Details

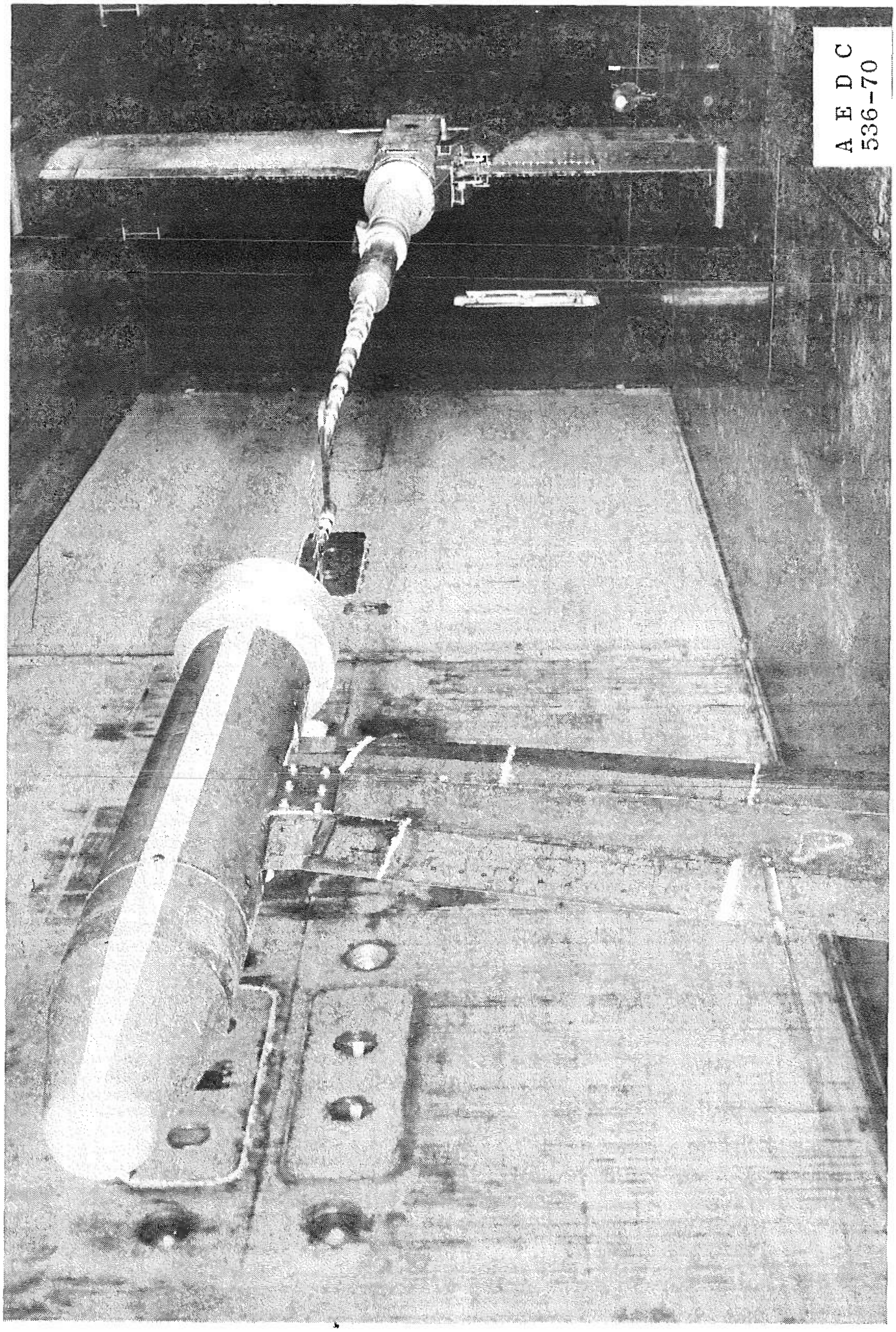
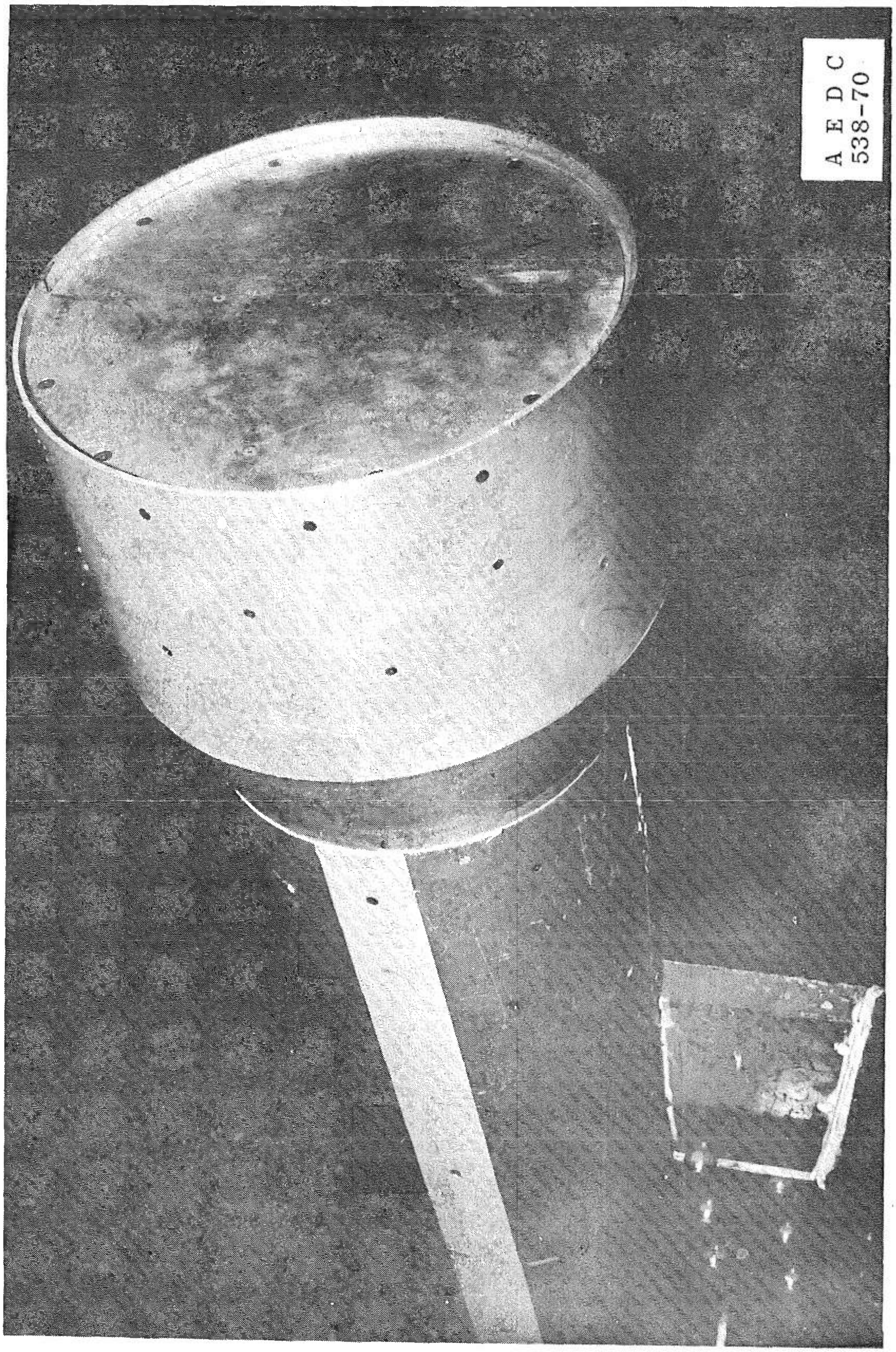
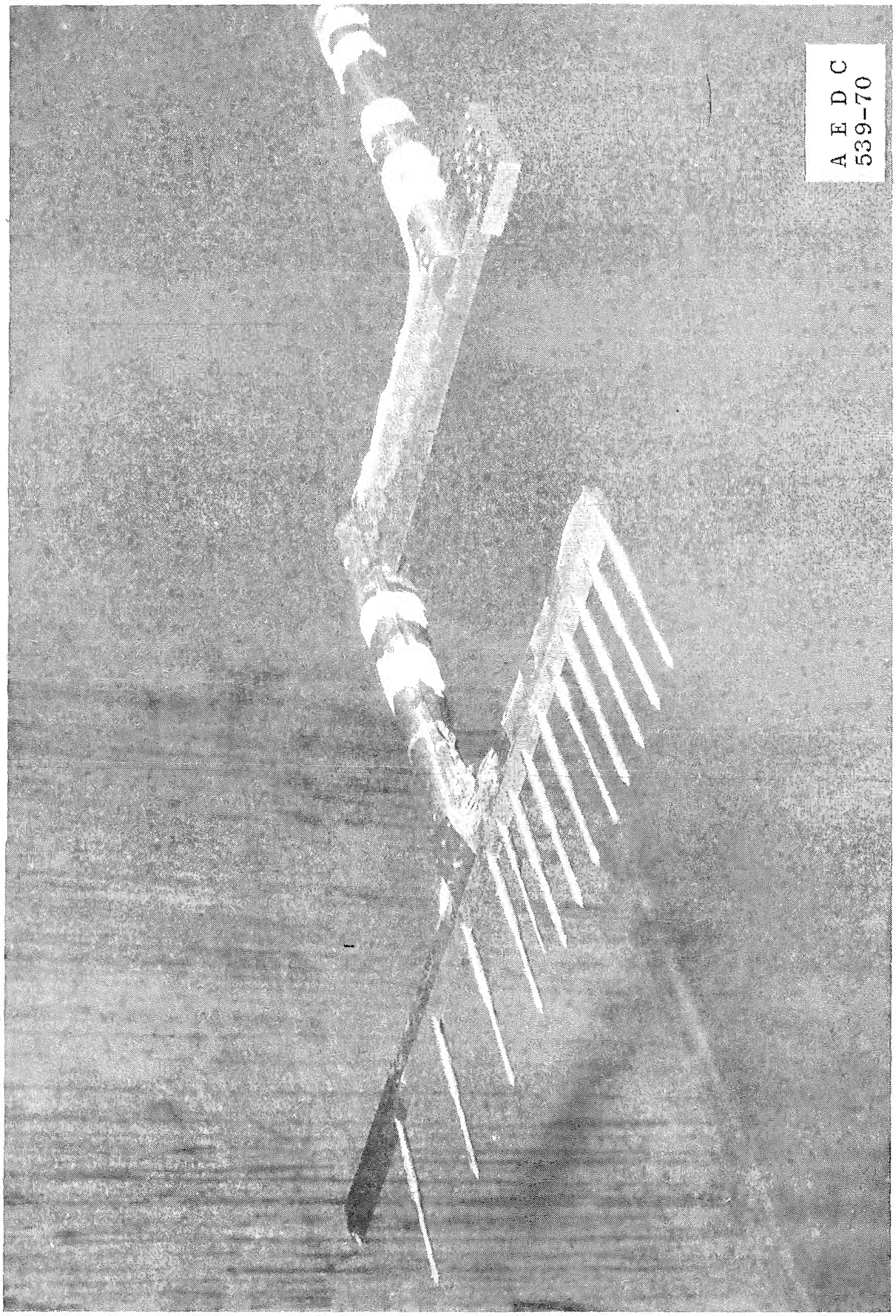


Fig. 5 Installation of Model Forebody and Survey Rake in Test Section



a. Model Forebody (No Base Bleed)
Fig. 6 Photographs of Model Forebody and Survey Rake



b. Survey Rake
Fig. 6 Concluded

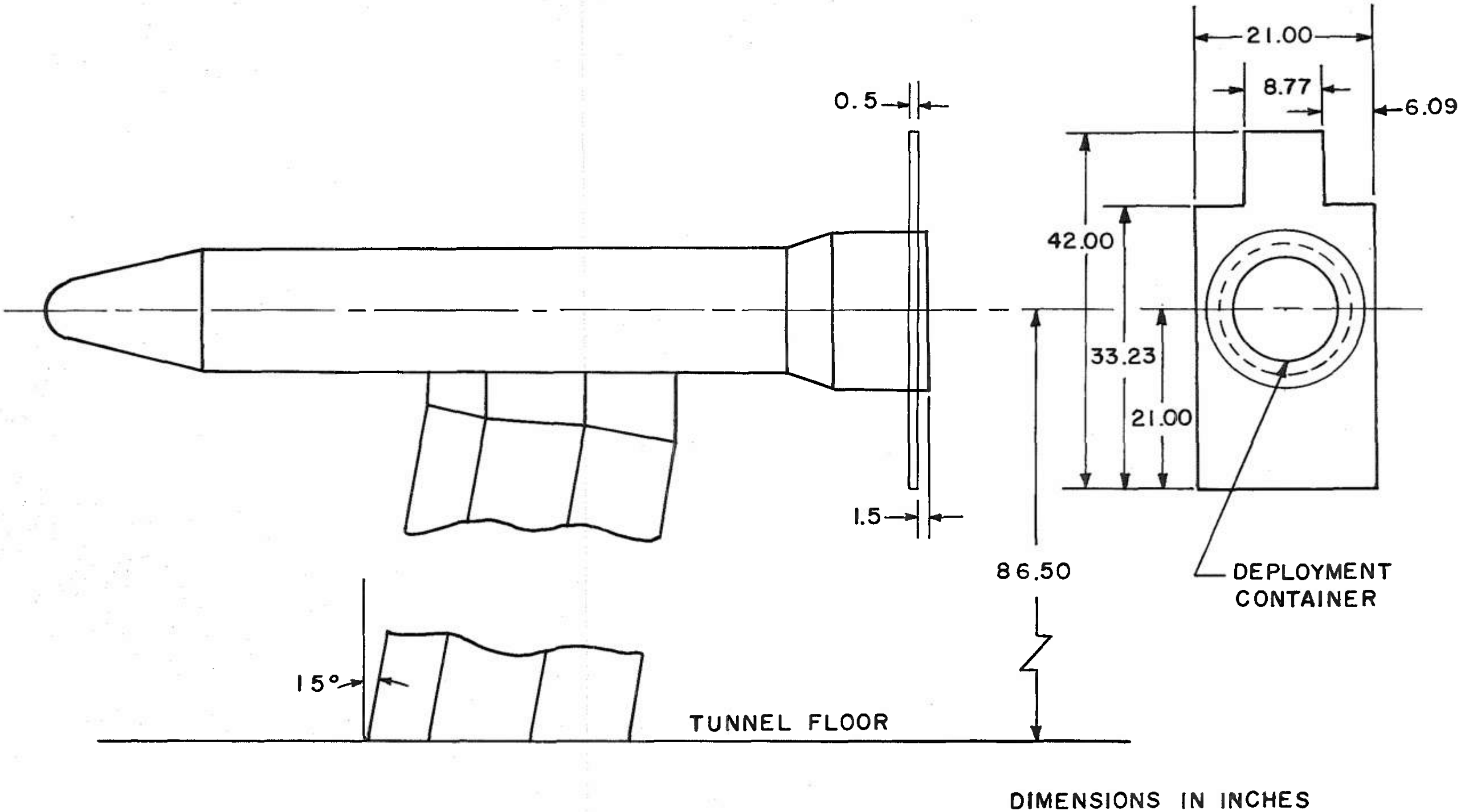
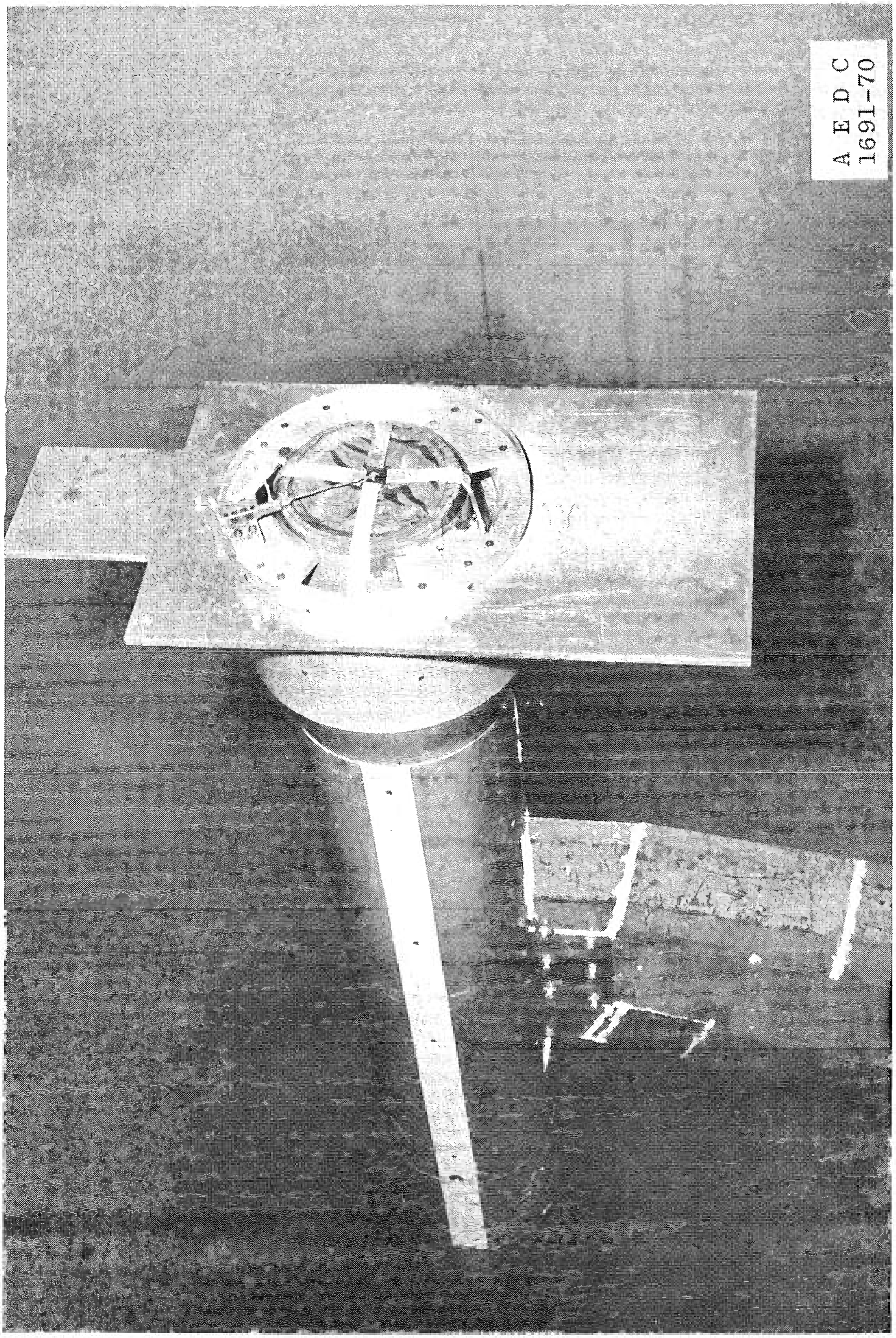
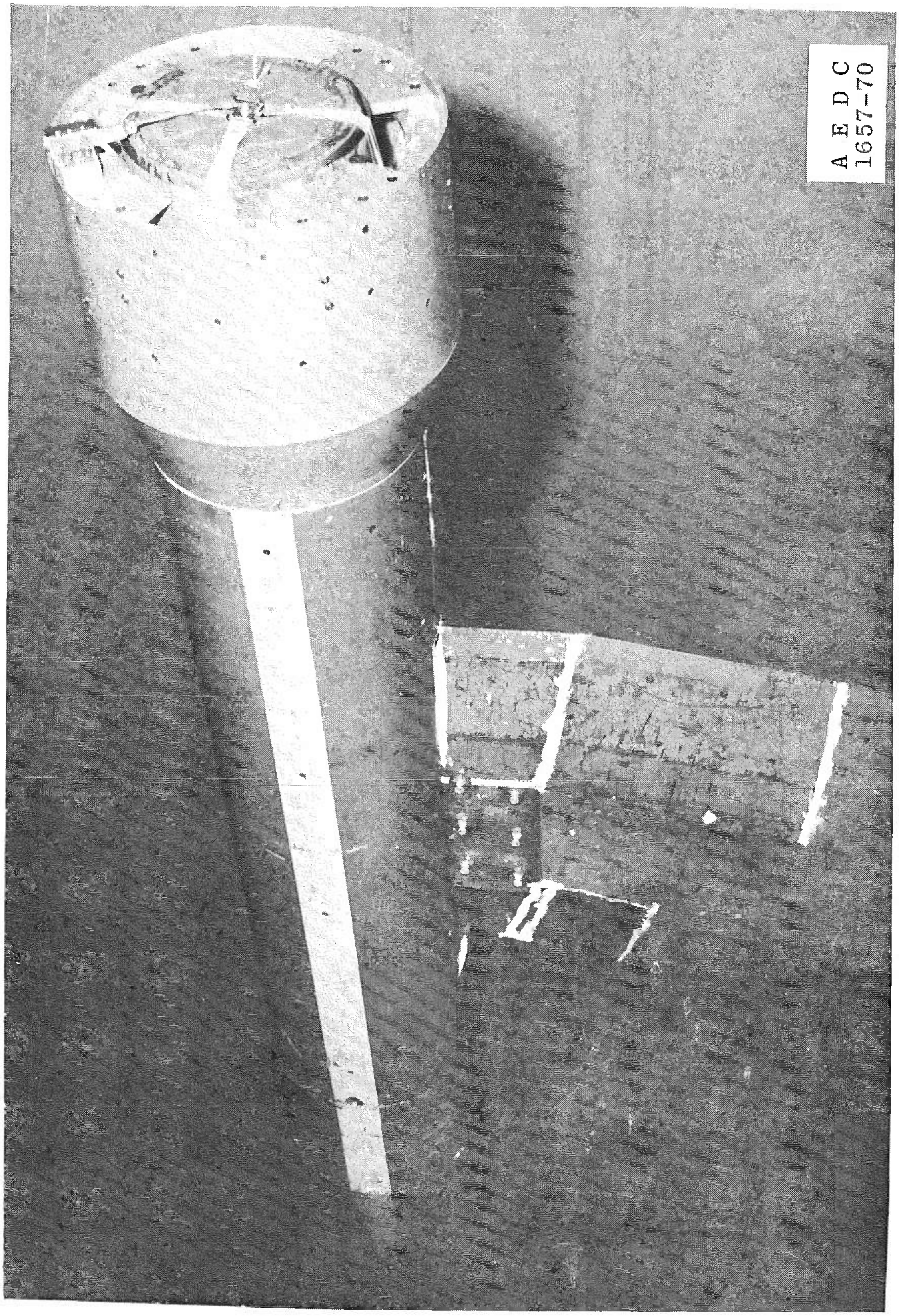


Fig. 7 Simulated Ejection Seat Details



a. Simulated Ejection Seat
Fig. 8 Parachute Installation in Model Forebody



b. Model Forebody
Fig. 8 Concluded

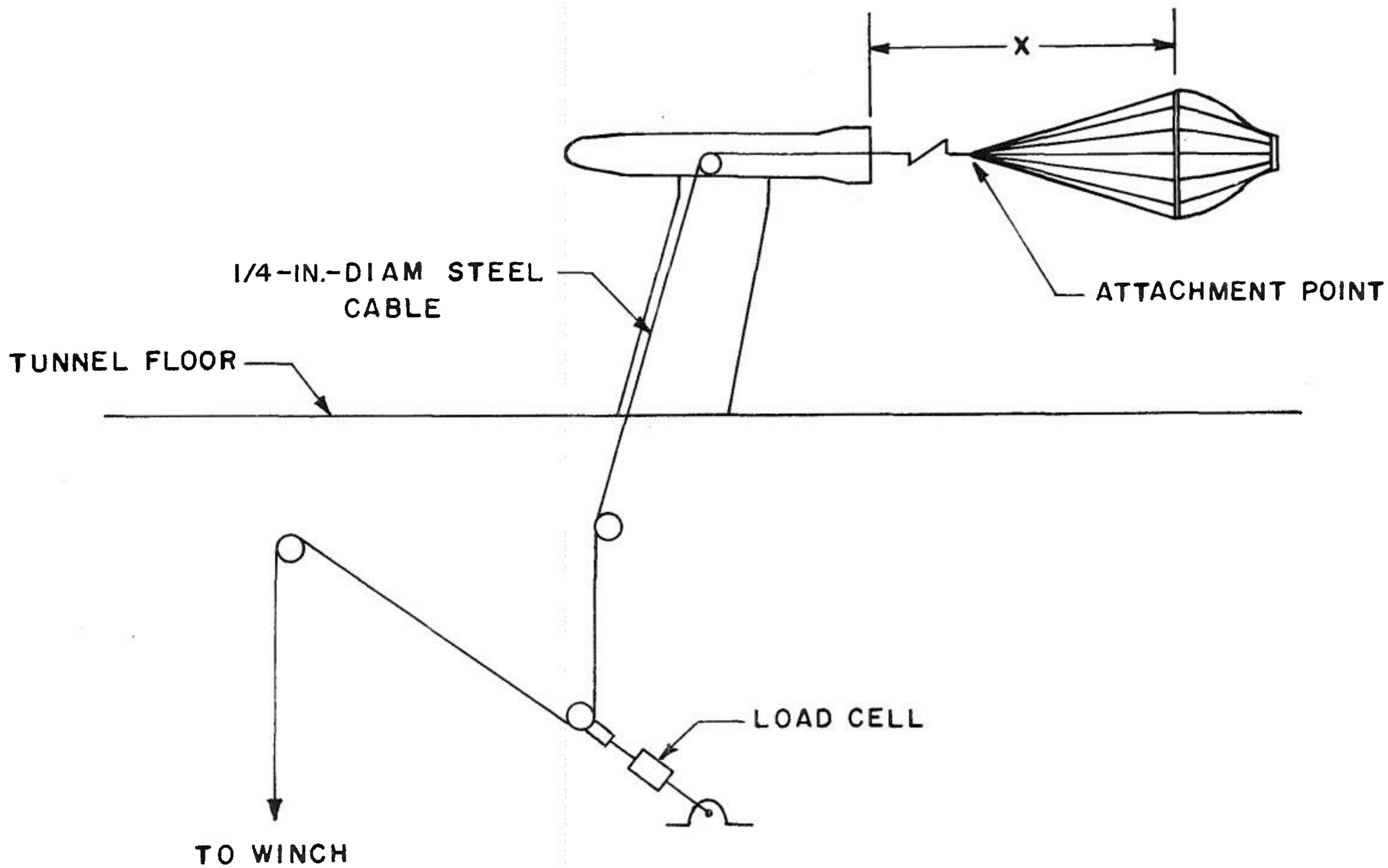


Fig. 9 Sketch of Model Forebody Showing Decelerator Load Cell Installation

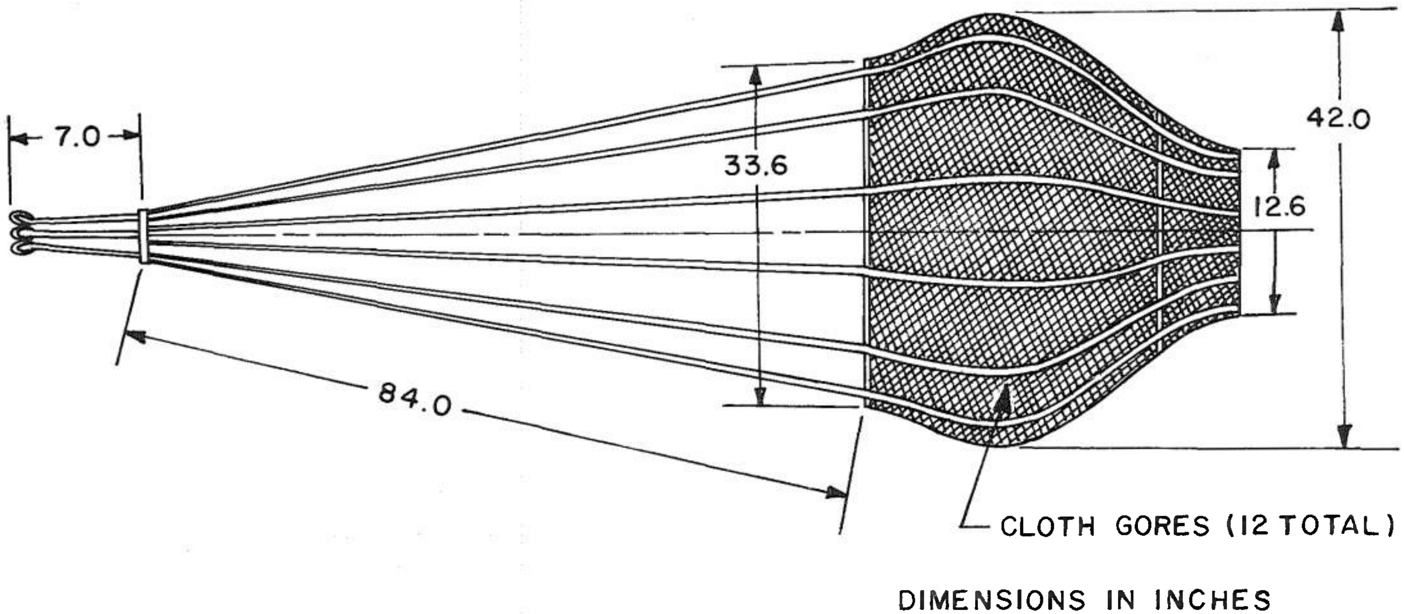
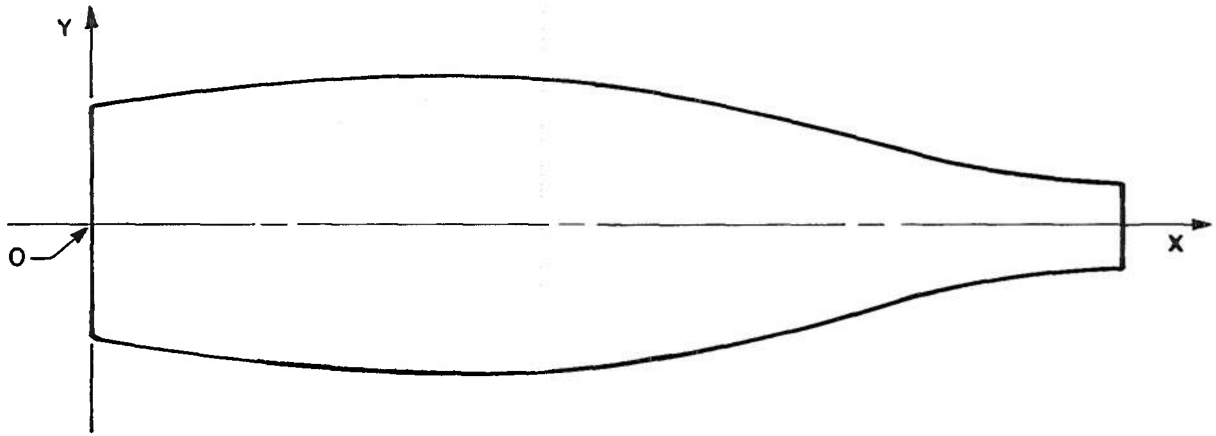


Fig. 10 Dimensioned Sketch of the Supersonic X Parachute

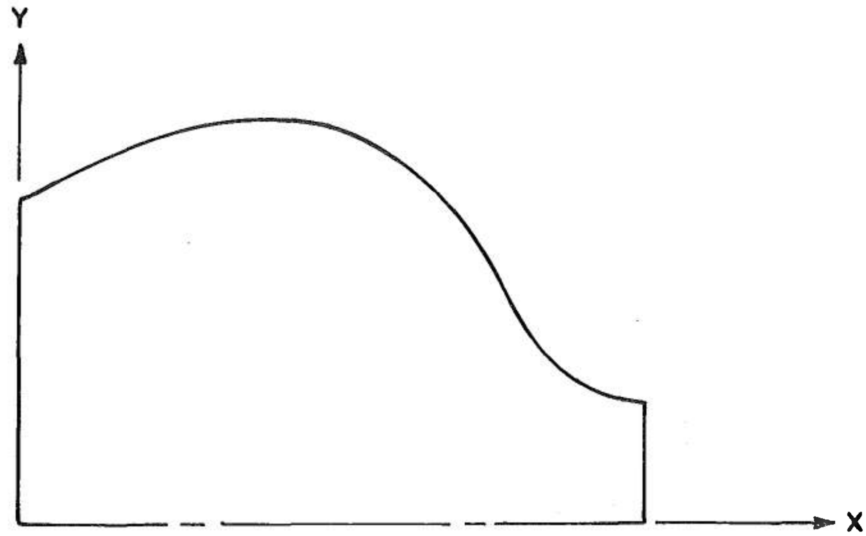


GORE COORDINATES

X	SUPERSONIC X-2 Y	X	SUPERSONIC X-2 Y
0.0	4.389	23.10	4.704
2.10	4.599	25.20	4.347
4.20	4.809	27.30	3.864
6.30	5.019	29.40	3.360
8.40	5.208	30.02	———
10.50	5.355	31.50	2.898
12.60	5.481	33.60	2.457
14.35	5.498	35.70	2.016
14.70	5.481	37.06	———
16.80	5.418	37.80	1.743
18.90	5.250	39.90	1.659
21.00	5.019	40.06	1.649

DIMENSIONS IN INCHES

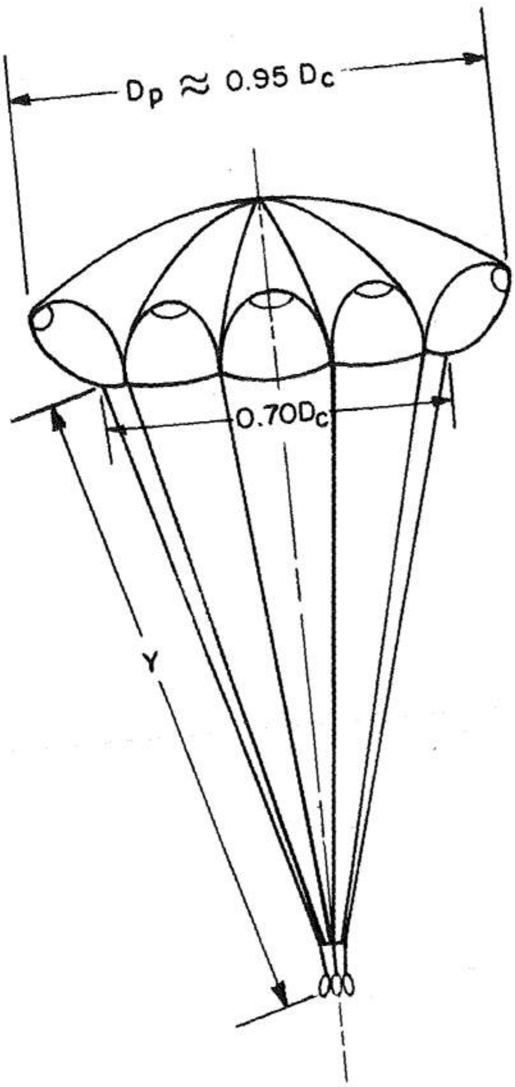
Fig. 11 Gore Dimensions of the Supersonic X Parachute



COORDINATES

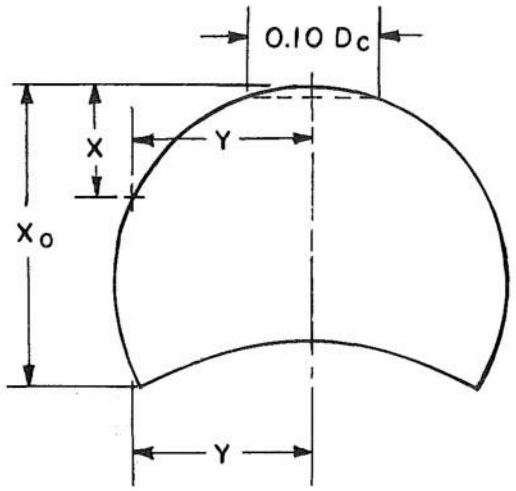
X (INCHES)	Y (INCHES)	X (INCHES)	Y (INCHES)
0	16.80	16.80	20.52
2.10	17.68	18.90	19.59
4.20	18.56	21.00	18.08
6.30	19.36	23.10	16.02
8.40	20.03	25.20	12.81
10.50	20.58	27.30	8.95
12.60	20.94	29.40	7.08
13.65	21.00	31.50	6.34
14.70	20.96	32.55	6.30

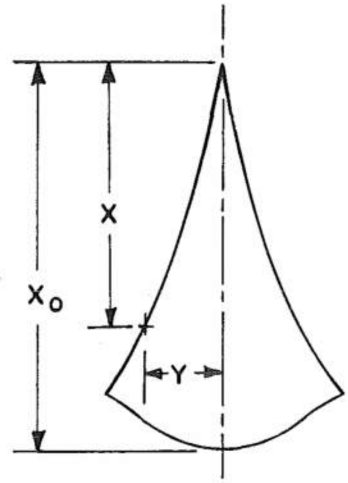
Fig. 12 Web Dimensions of the Supersonic X Parachute



Dc, ft	Y, in
3	115
4	82

Fig. 13 Dimensioned Sketch of the Guide Surface Parachute





GUIDE SURFACE COORDINATES

X/X_o	Y/X
0.050	5.520
0.100	3.810
0.150	2.960
0.200	2.430
0.300	1.800
0.400	1.420
0.500	1.170
0.600	0.977
0.700	0.823
0.800	0.705
0.900	0.603
0.919	0.586
0.919	0.000
0.950	0.559
0.950	0.305
1.000	0.517

$X_o = 0.230\ D_c$

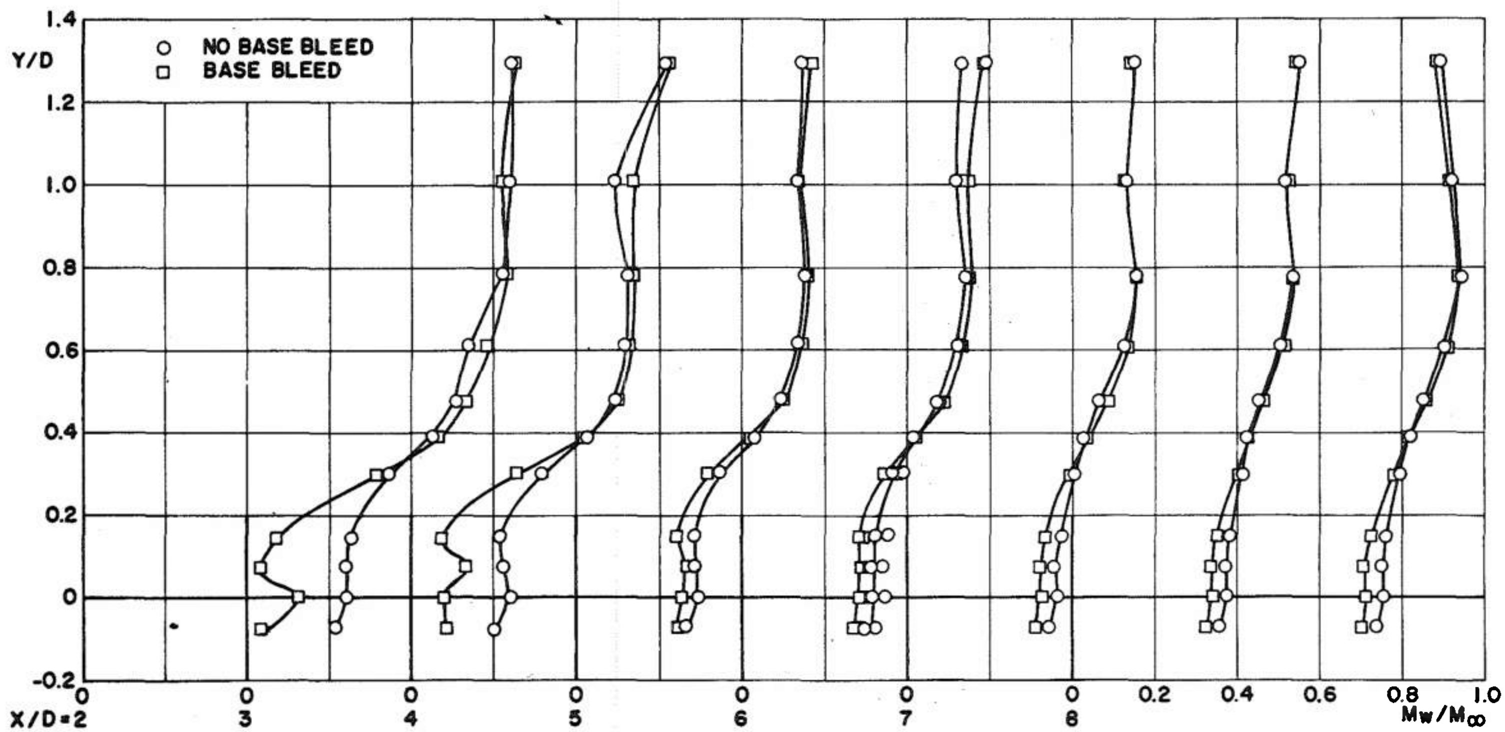
ROOF COORDINATES

X/X_o	Y/X
0.100	0.532
0.150	0.520
0.200	0.516
0.300	0.514
0.400	0.511
0.500	0.511
0.600	0.509
0.700	0.525
0.800	0.588
0.866	0.713
0.900	0.496
0.950	0.261
0.975	0.1625
1.000	0.000

$X_o = 0.500\ D_c$

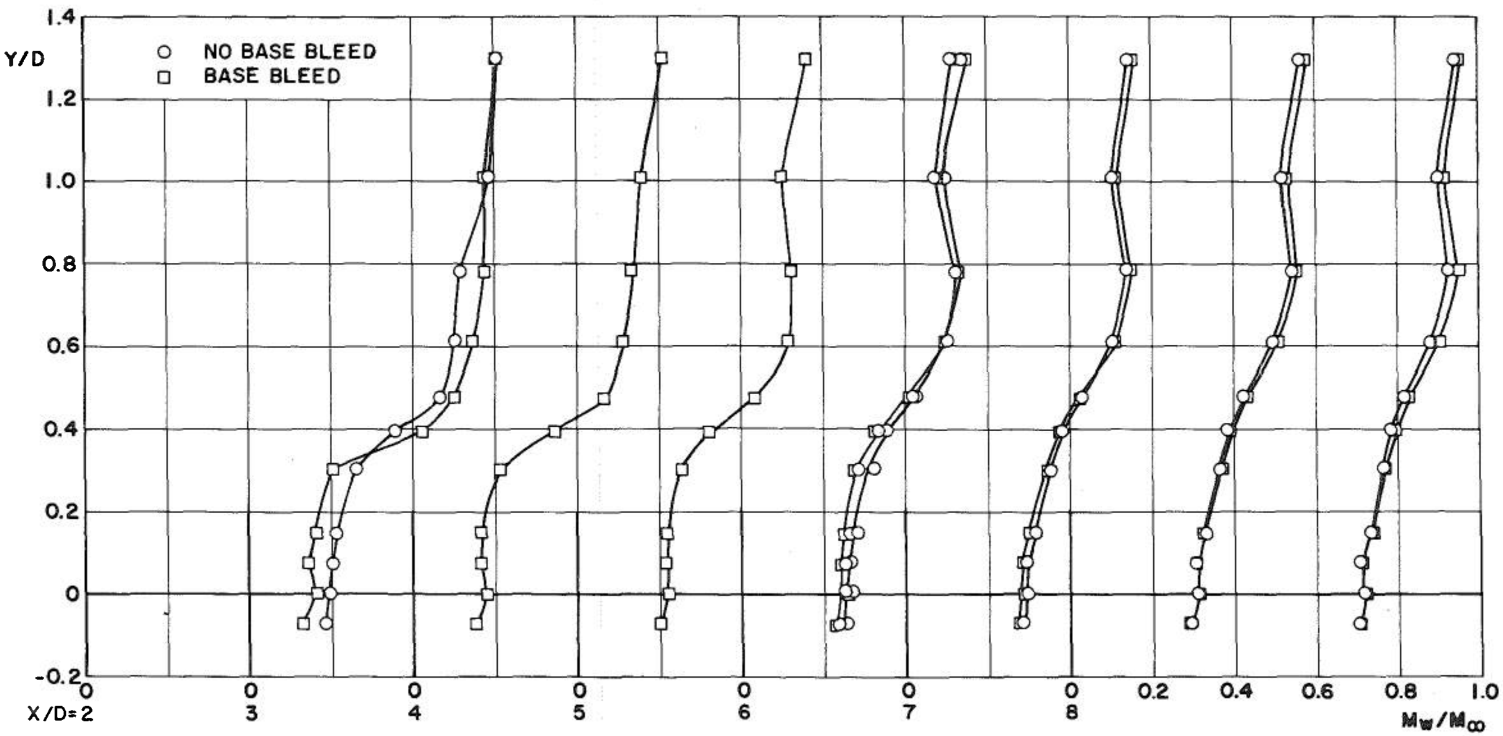
DIMENSIONS IN INCHES

Fig. 14 Guide Surface Panel and Roof Panel Dimensions

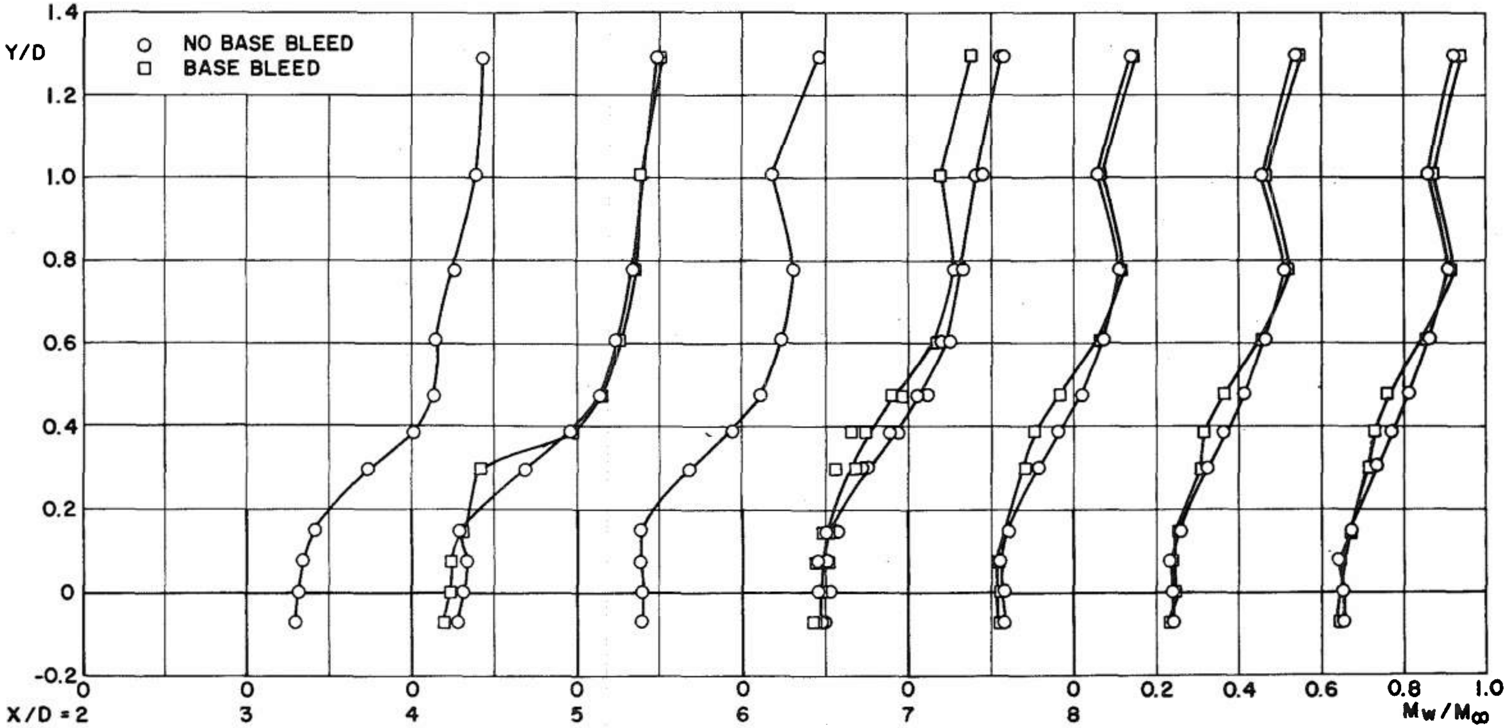


a. $M_\infty = 2.0$

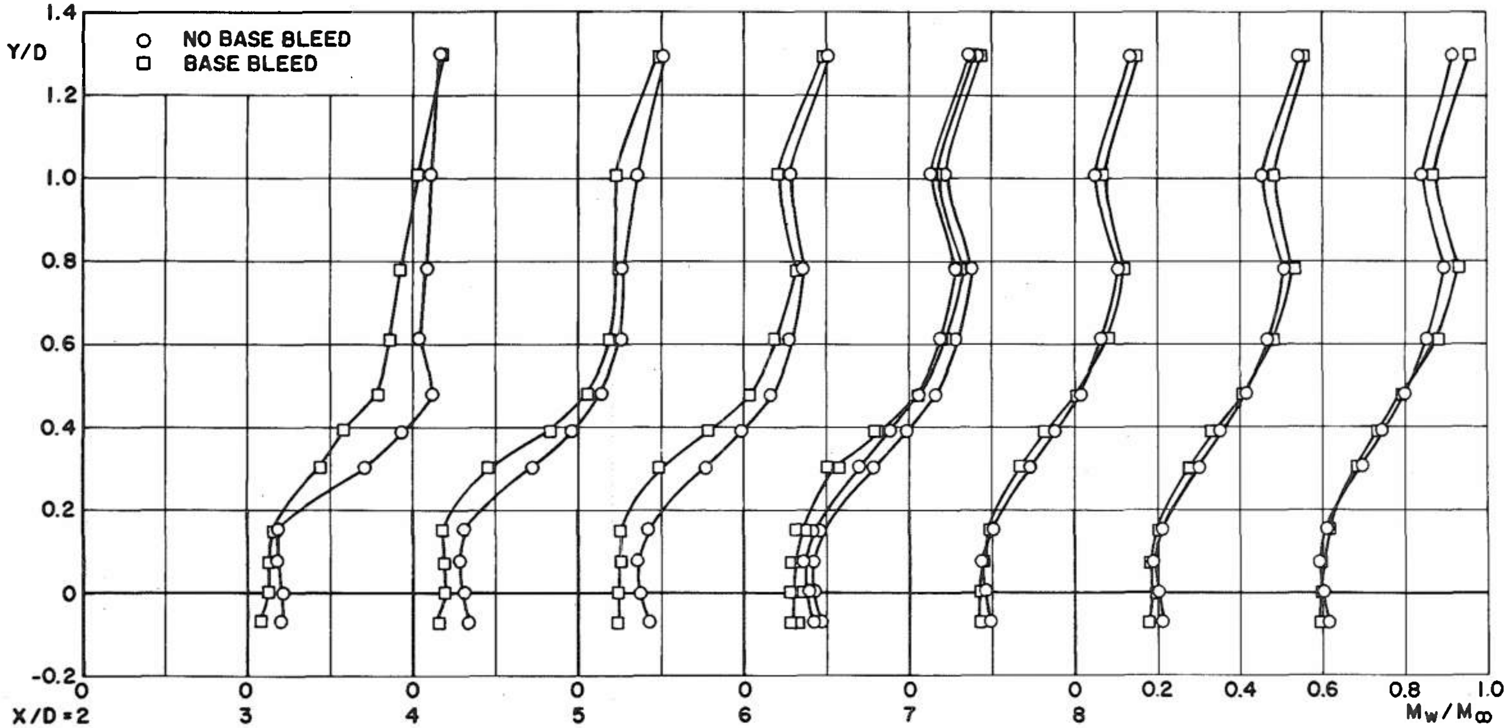
Fig. 15 Local Mach Number Distributions, Z/D = 0, D = 1.4683 ft



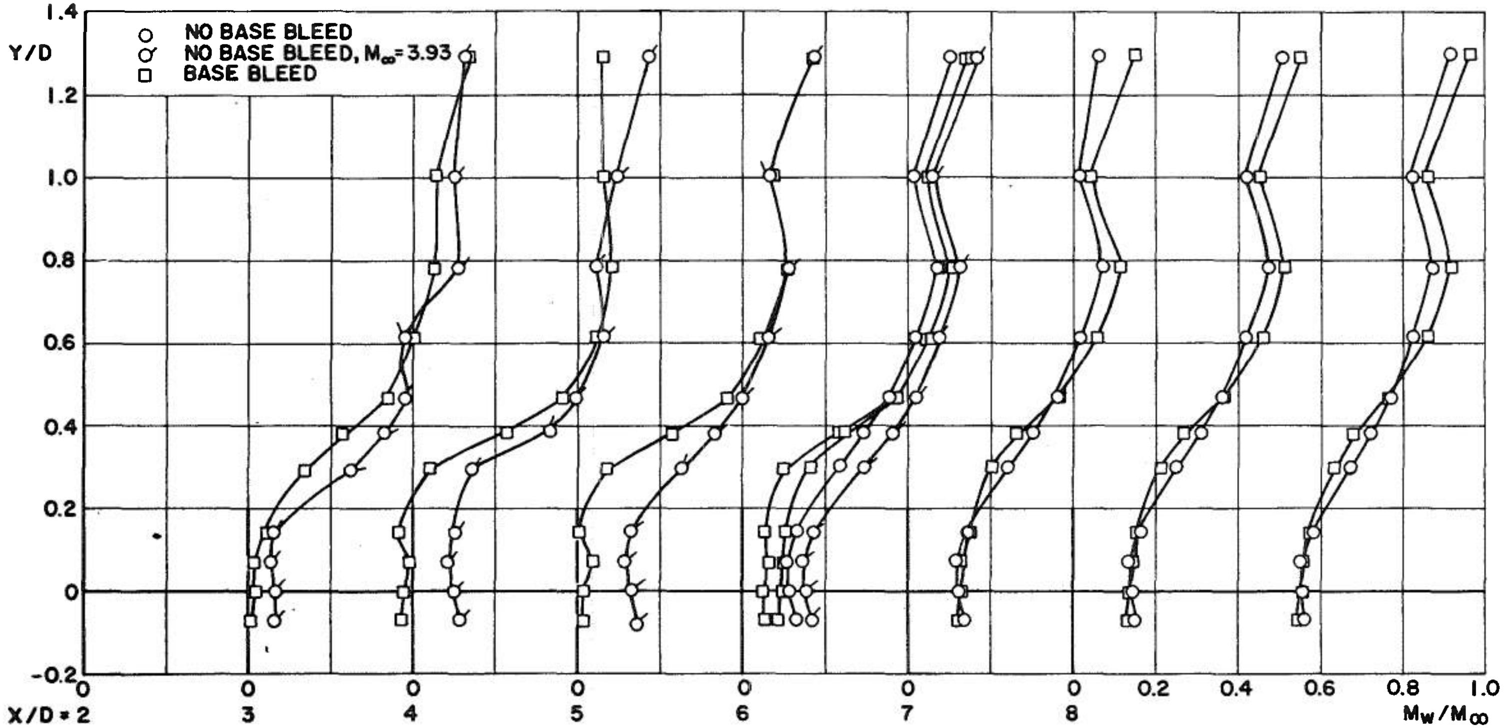
b. $M_\infty = 2.5$
Fig. 15 Continued



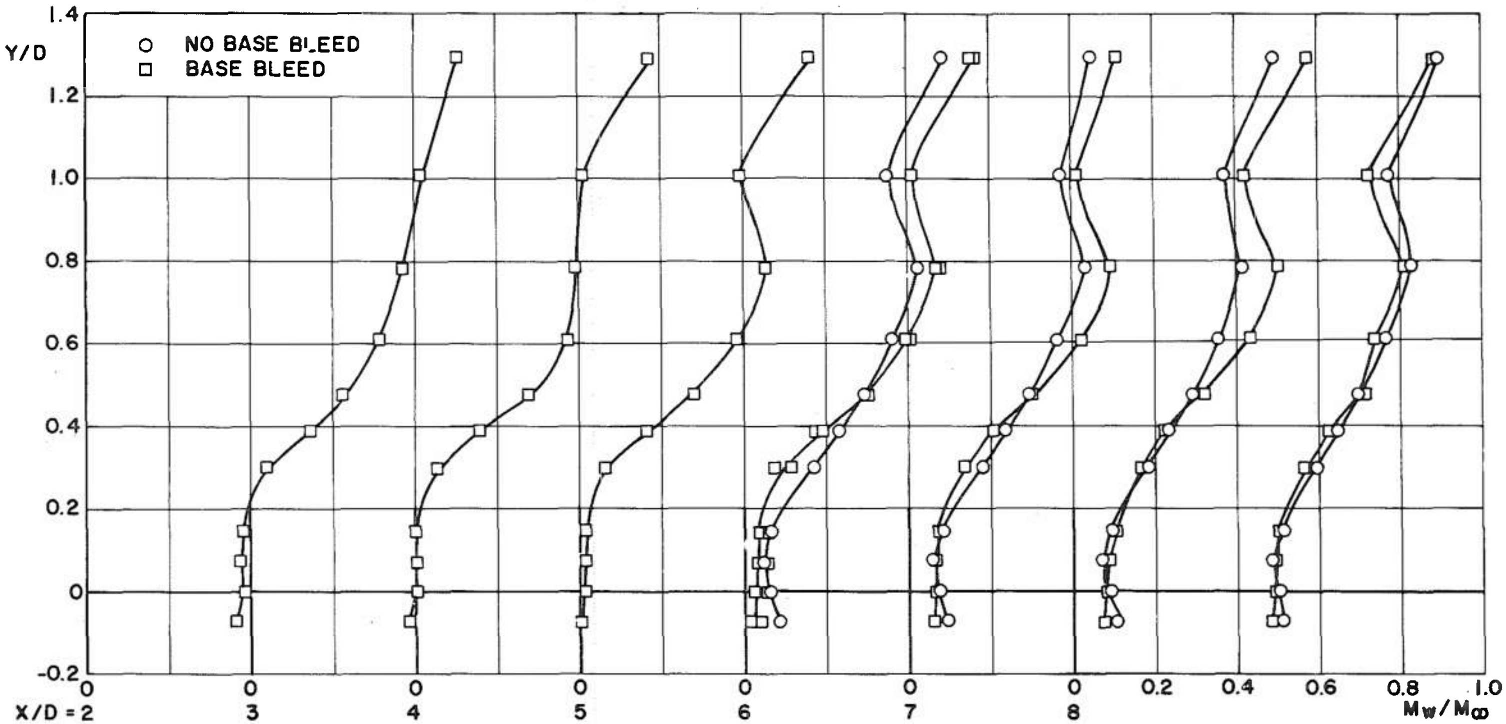
c. $M_\infty = 3.0$
Fig. 15 Continued



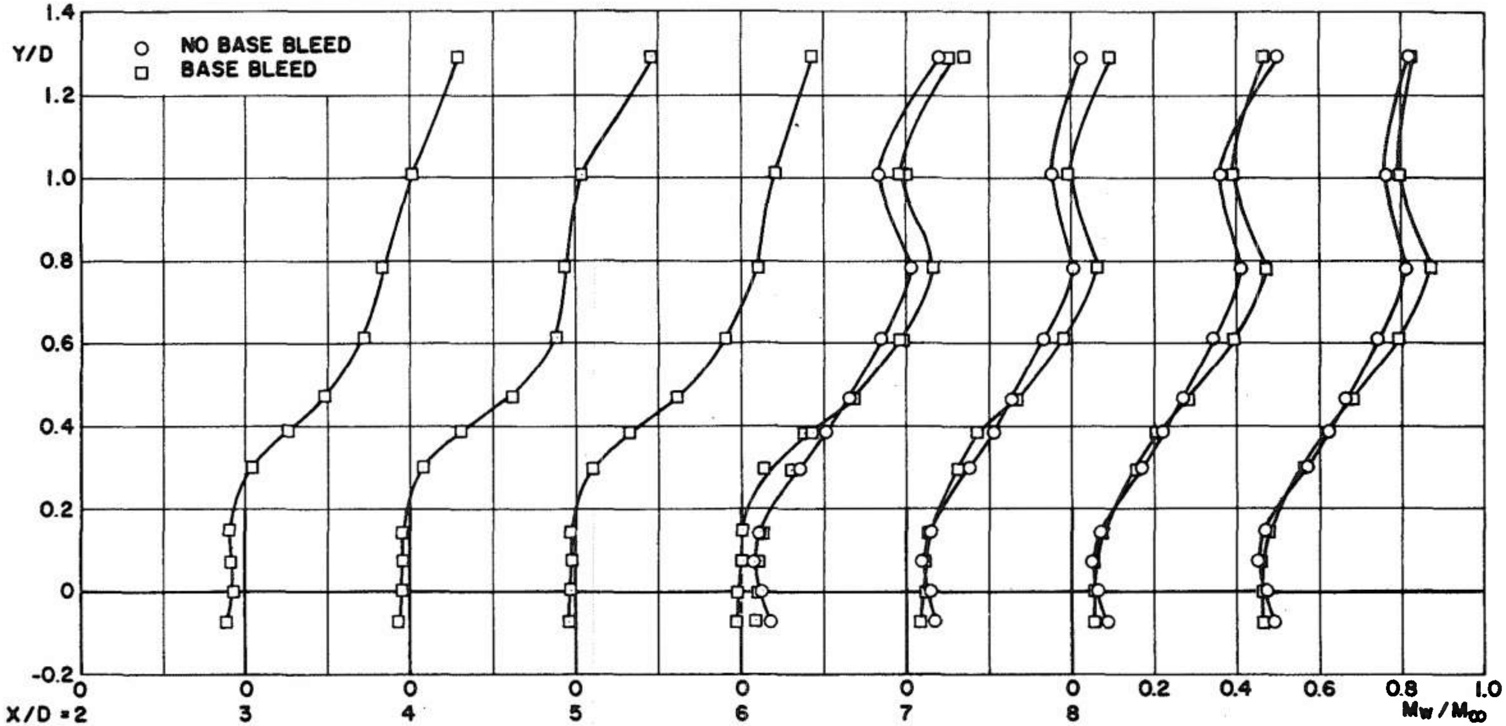
d. $M_\infty = 3.5$
Fig. 15 Continued



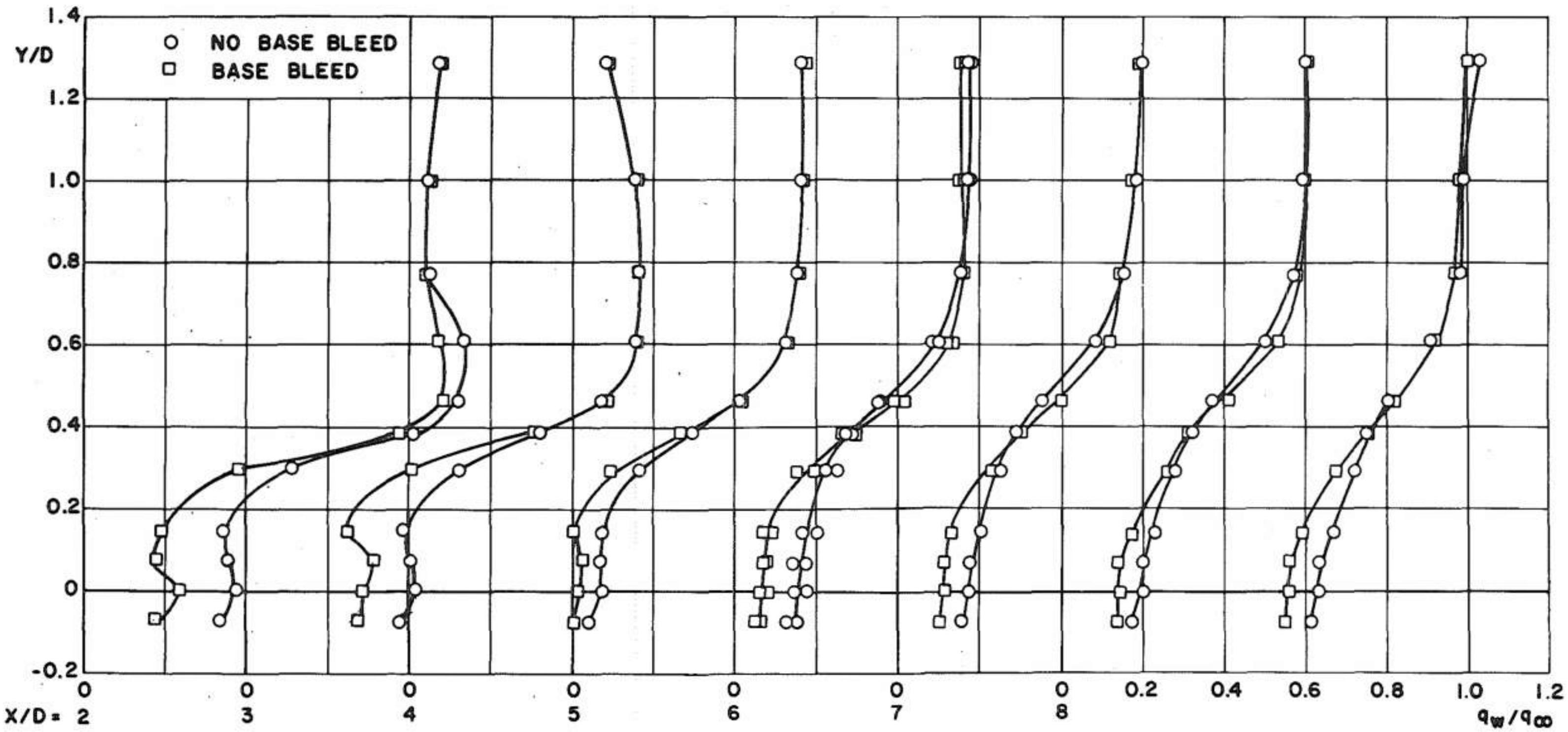
e. M_∞ = 4.0
Fig. 15 Continued



f. $M_\infty = 4.5$
Fig. 15 Continued

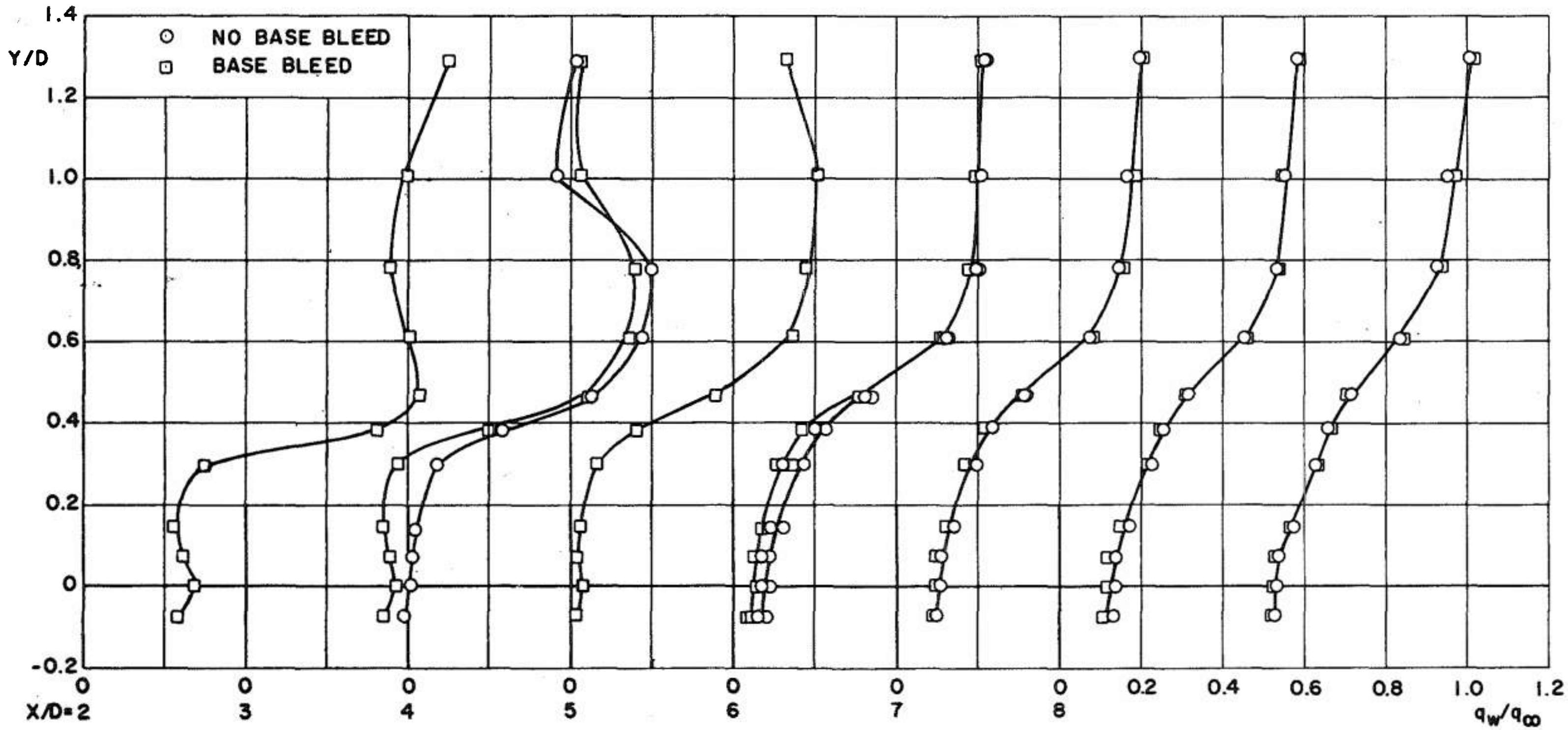


g. $M_\infty = 4.75$
Fig. 15 Concluded

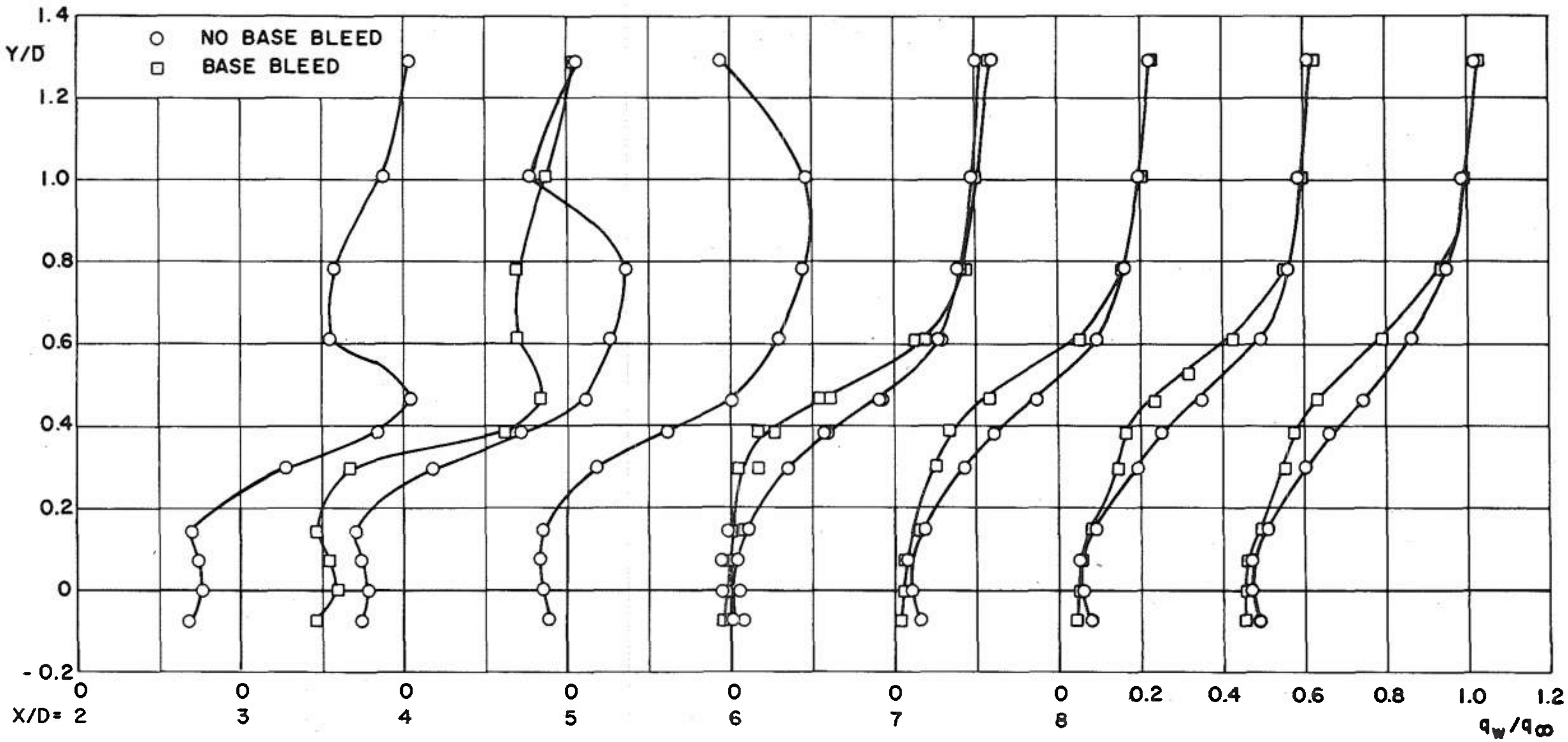


a. $M_\infty = 2.0$

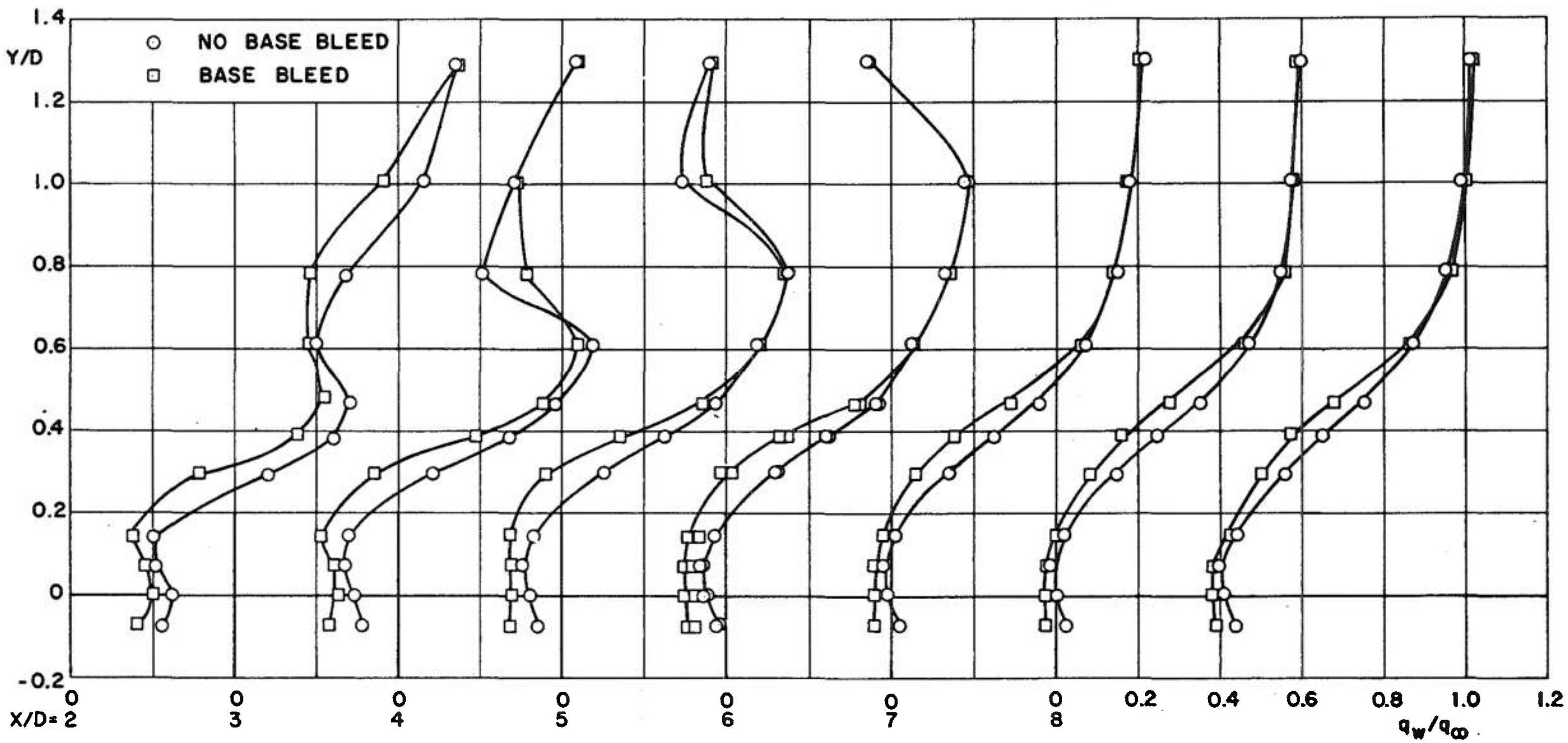
Fig. 16 Local Dynamic Pressure Variation, Z/D = 0, D = 1.4683 ft



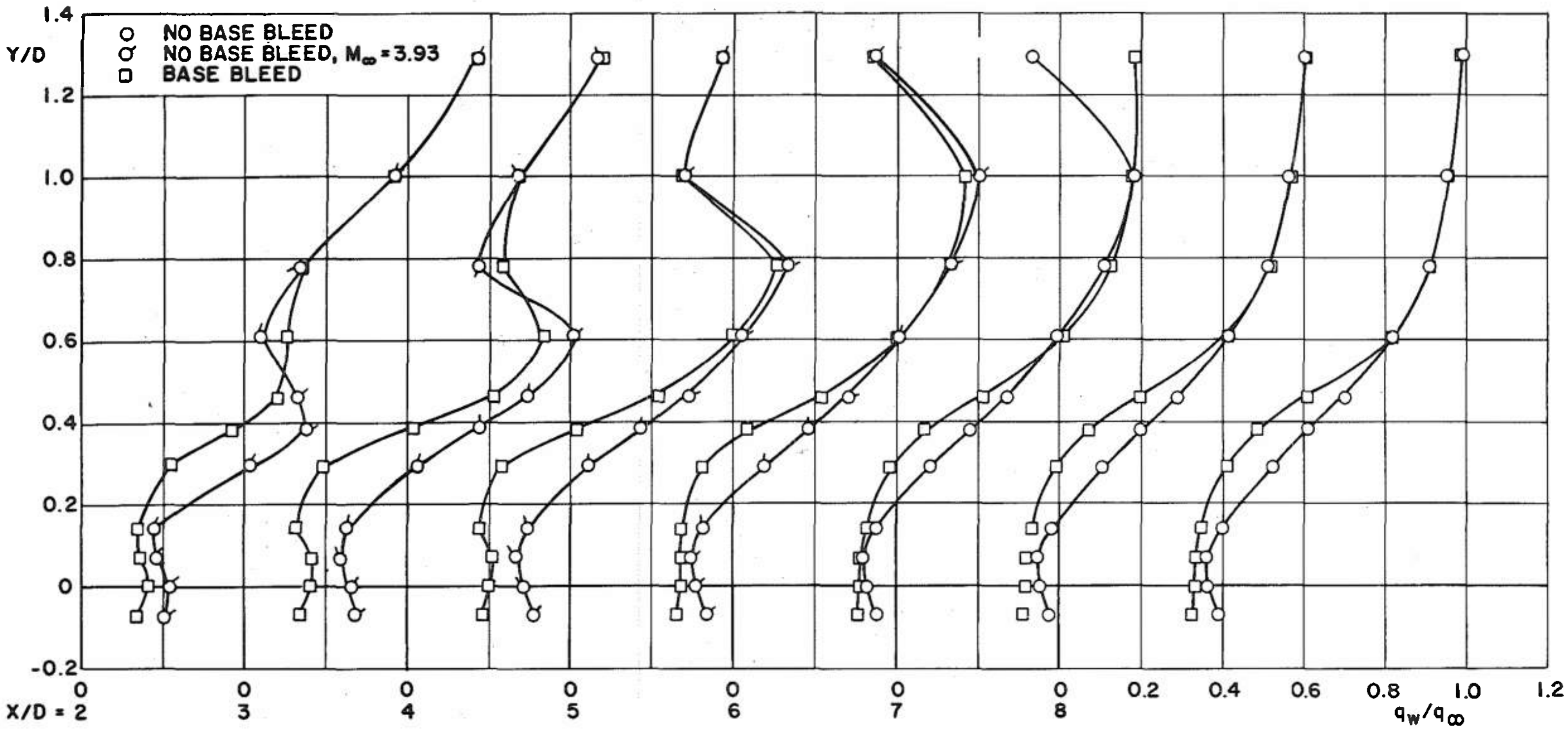
b. $M_\infty = 2.5$
Fig. 16 Continued



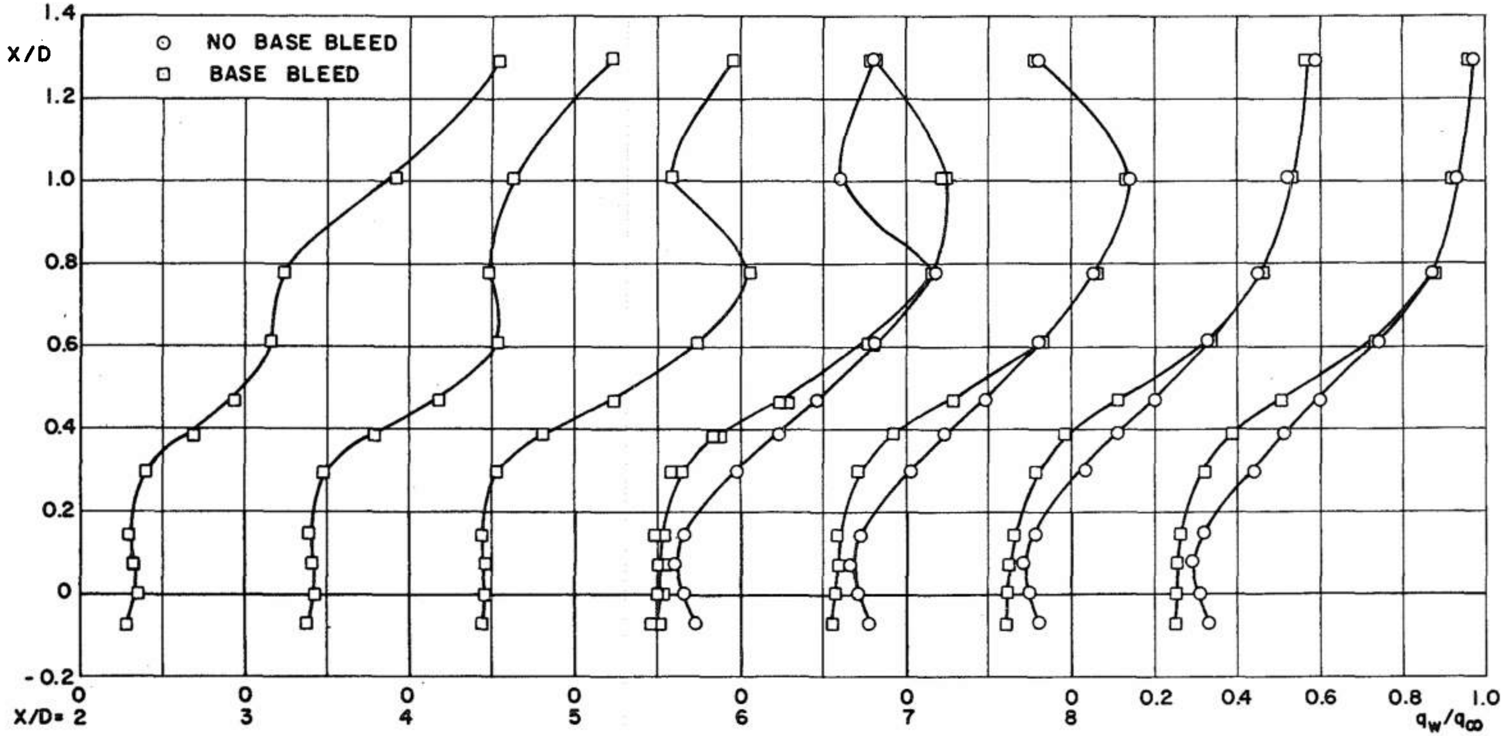
c. $M_\infty = 3.0$
Fig. 16 Continued



d. $M_\infty = 3.5$
Fig. 16 Continued

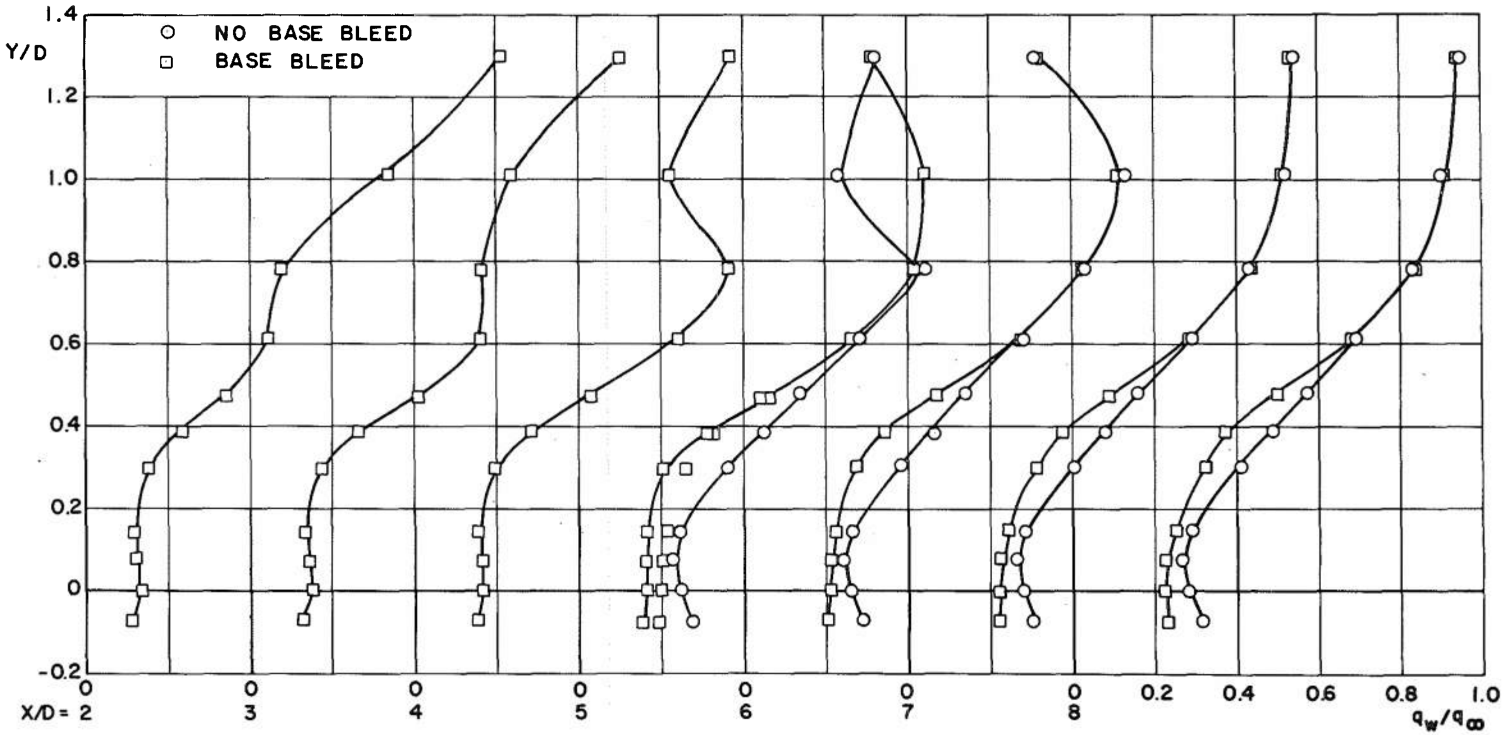


e. M_∞ = 4.0
Fig. 16 Continued

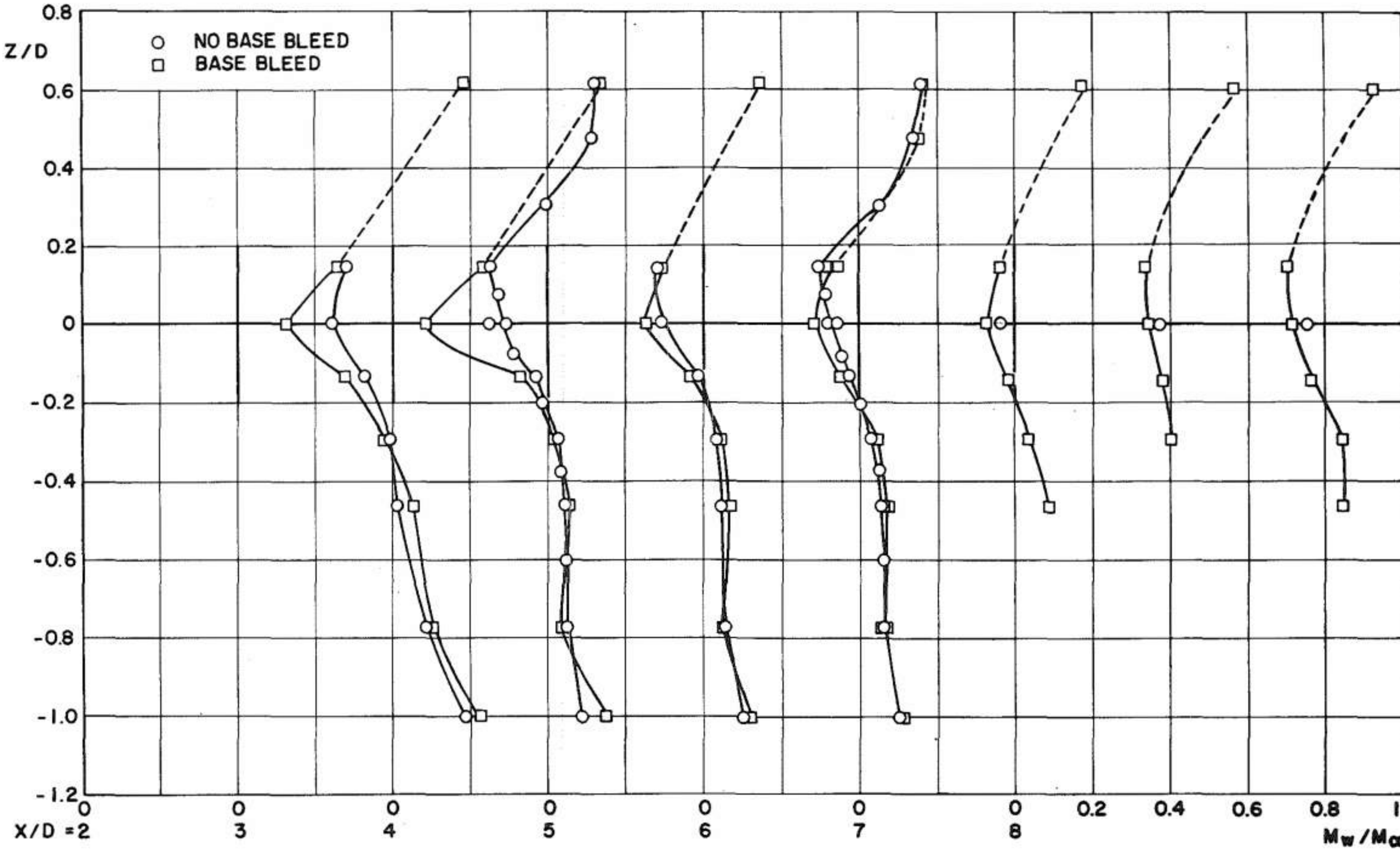


f. $M_\infty = 4.5$

Fig. 16 Continued

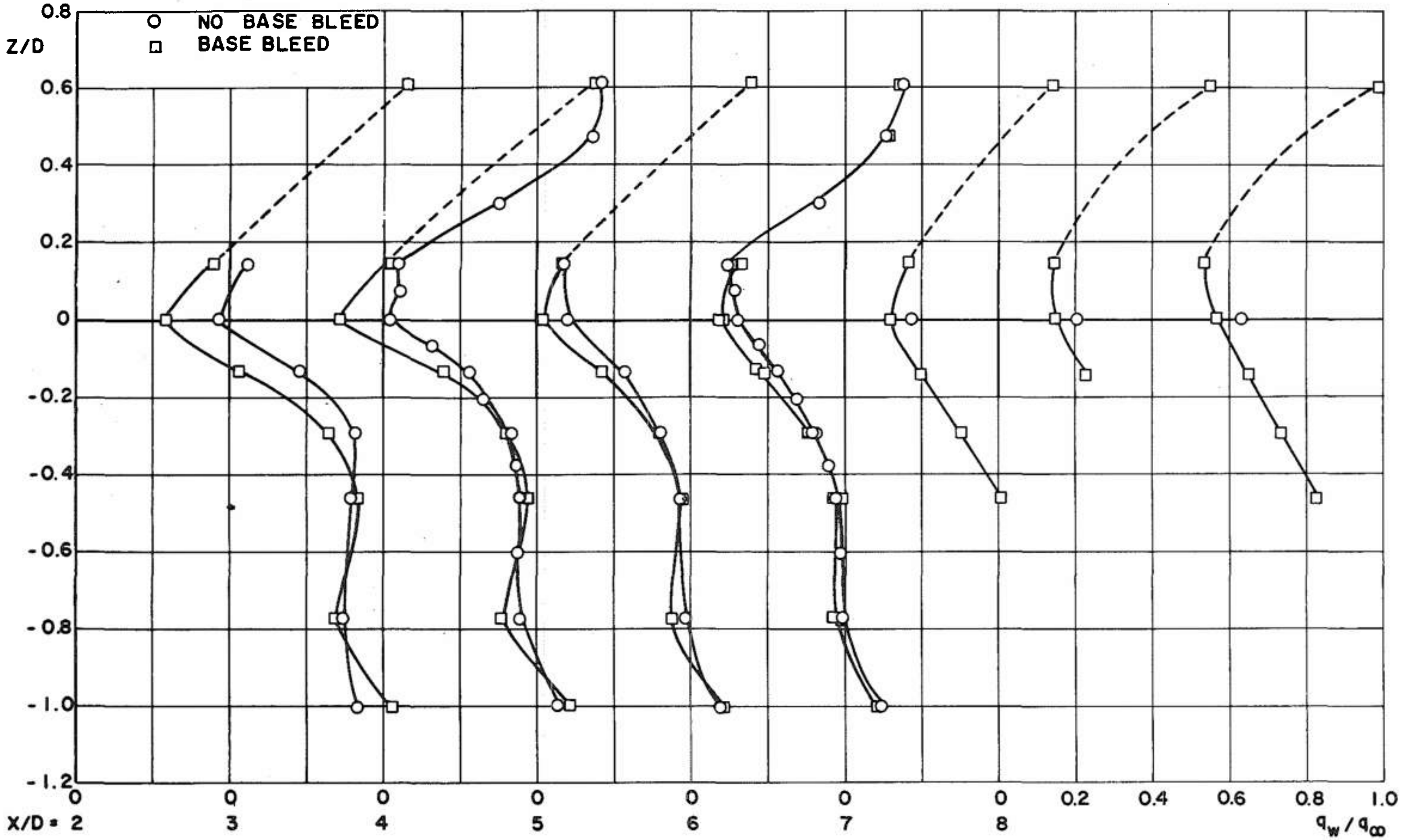


g. $M_\infty = 4.75$
Fig. 16 Concluded

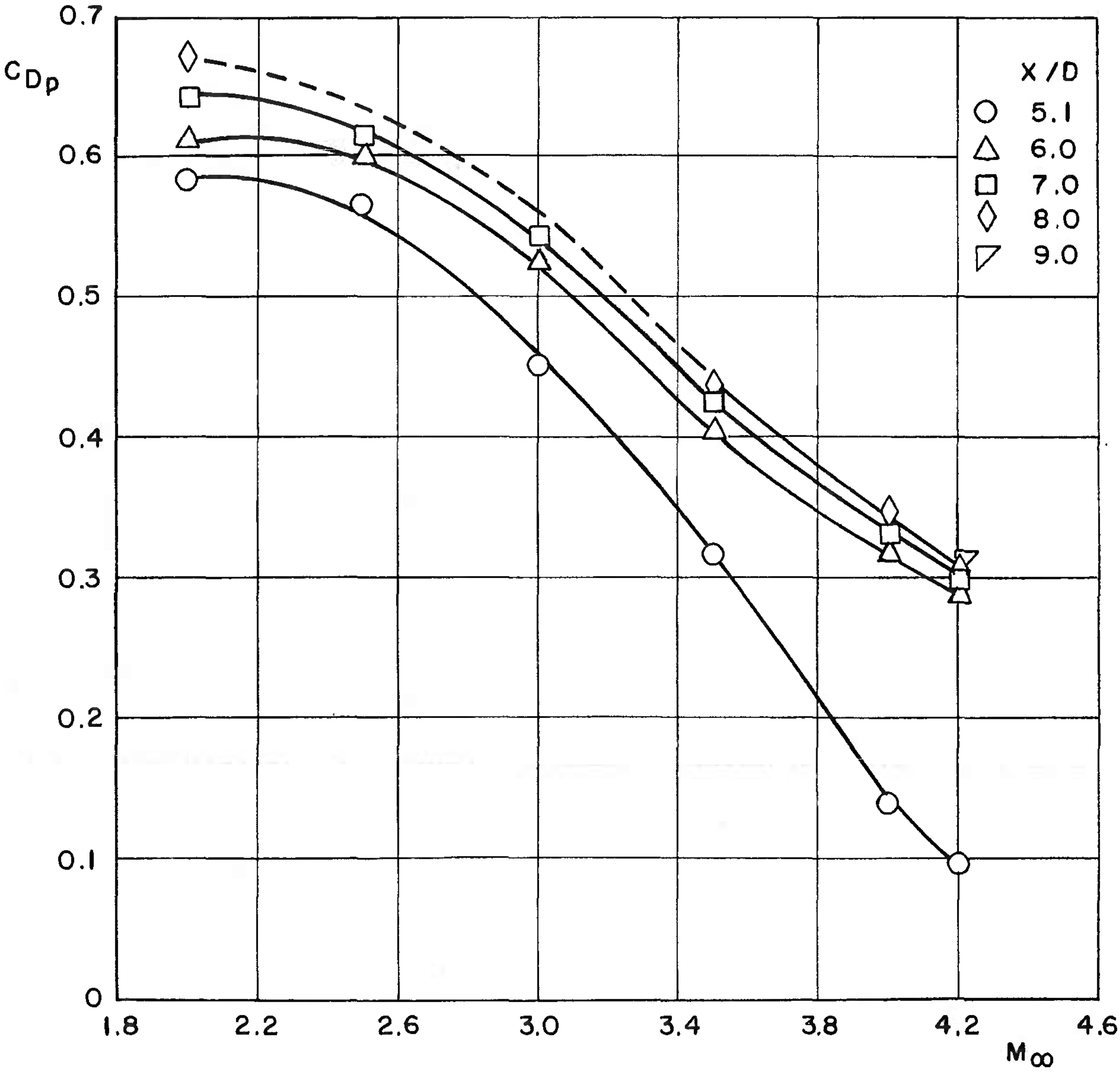


a. Local Wake Mach Number

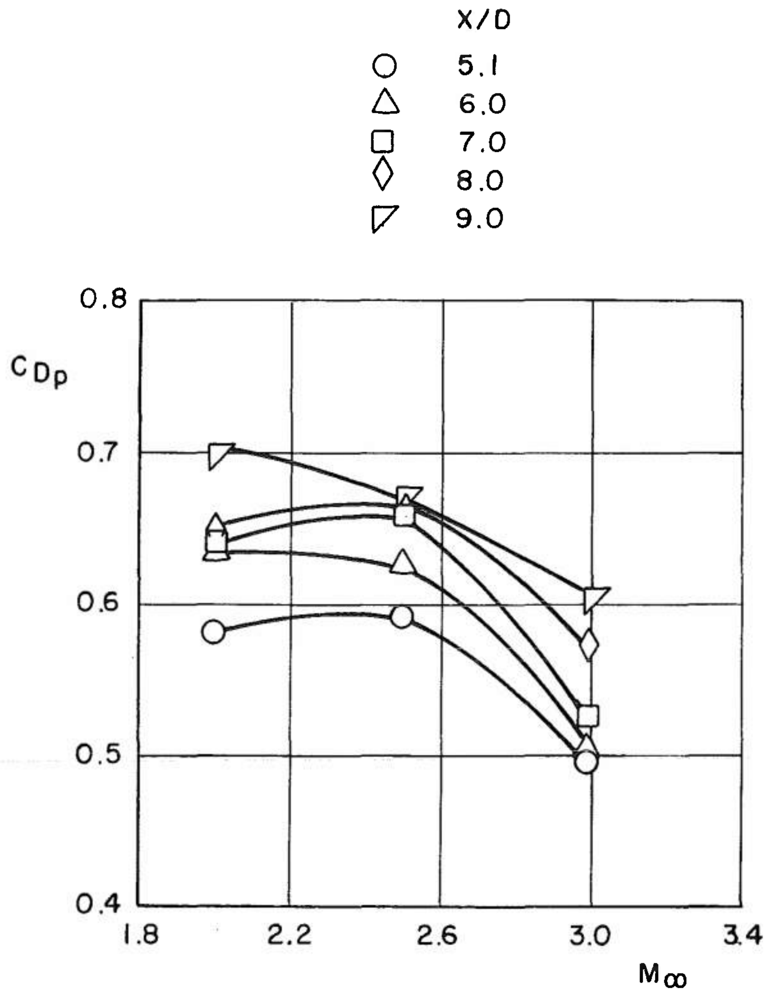
Fig. 17 Local Wake Properties, M_∞ = 2.0, Y/D = 0, D = 1.4683 ft



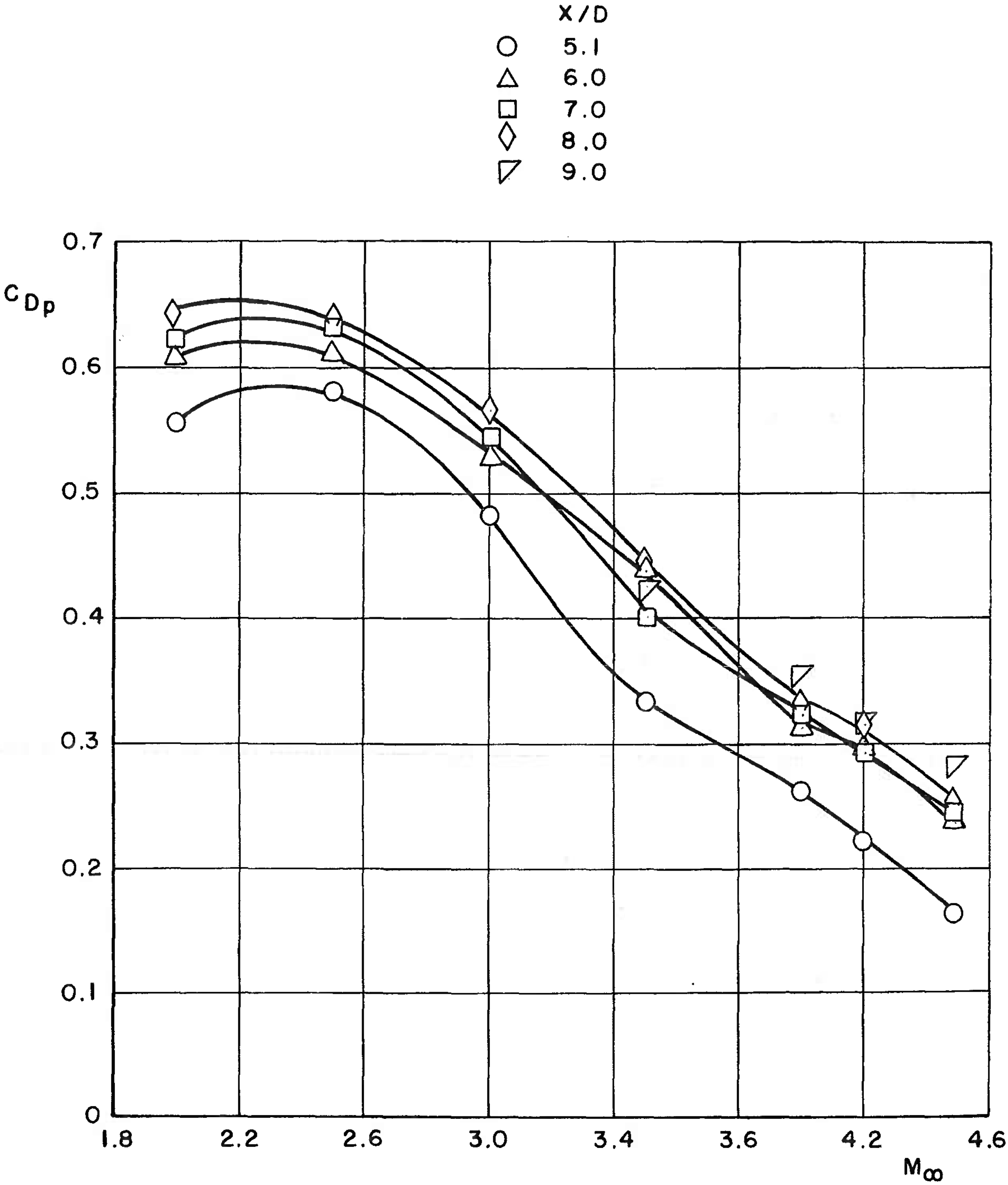
b. Local Wake Dynamic Pressure
Fig. 17 Concluded



a. Supersonic X, No Webs
Fig. 18. Variation of Supersonic X Drag Coefficient with Mach Number, D = 1.4683 ft



b. Supersonic X, 6 Webs
Fig. 18 Continued



c. Supersonic X, 12 Webs
Fig. 18 Concluded

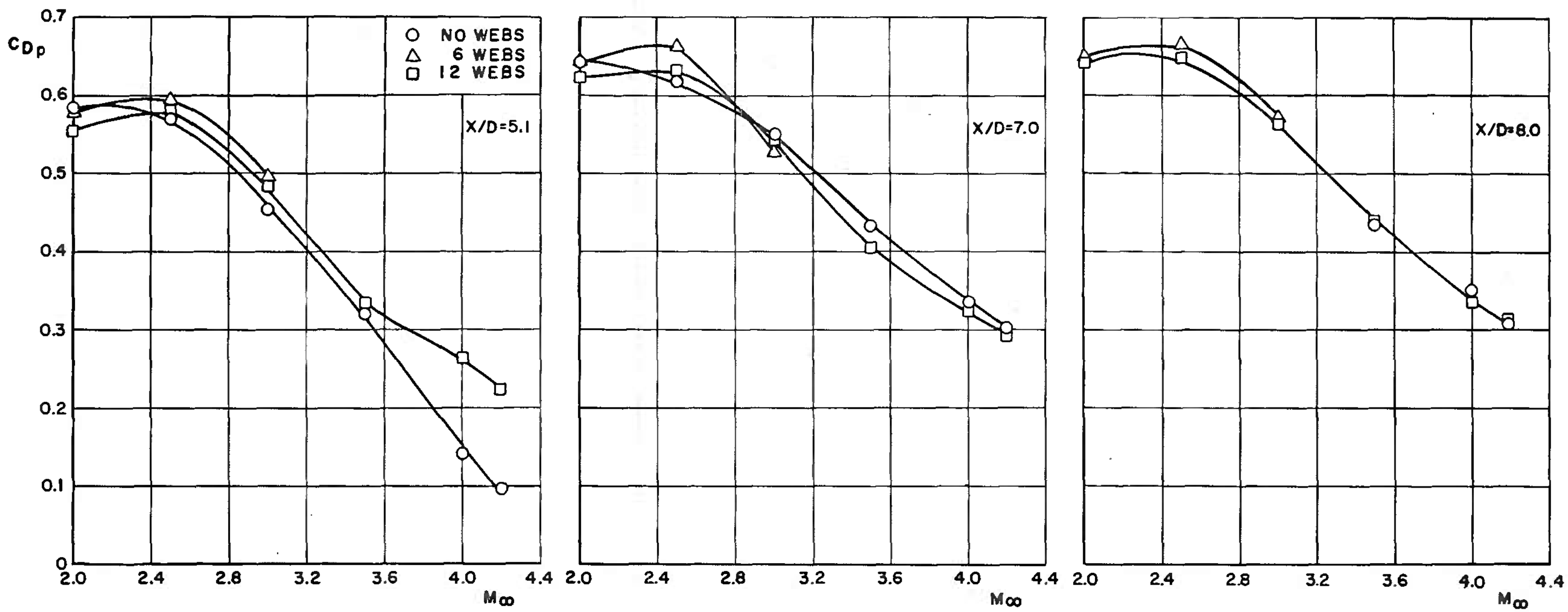
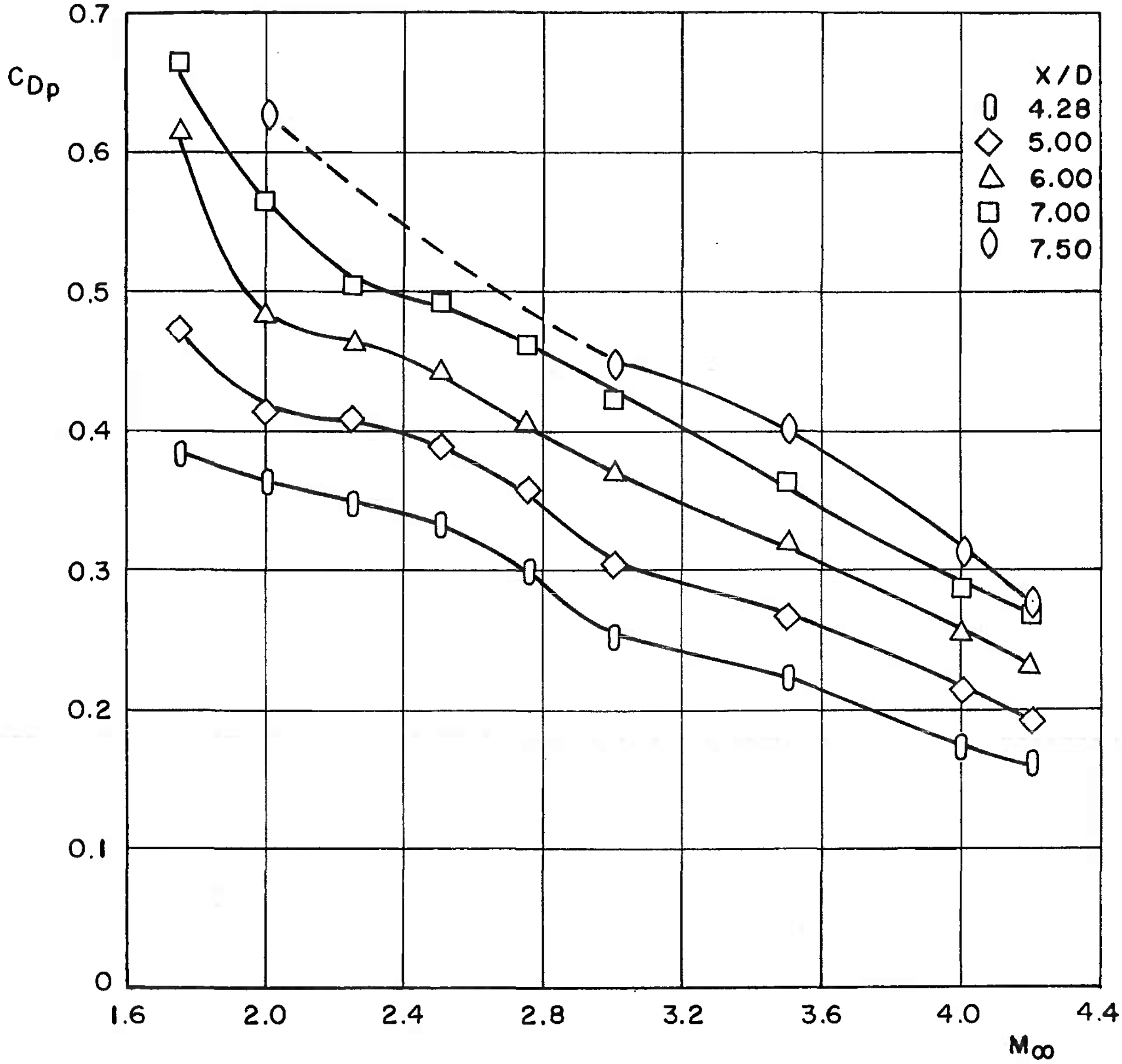
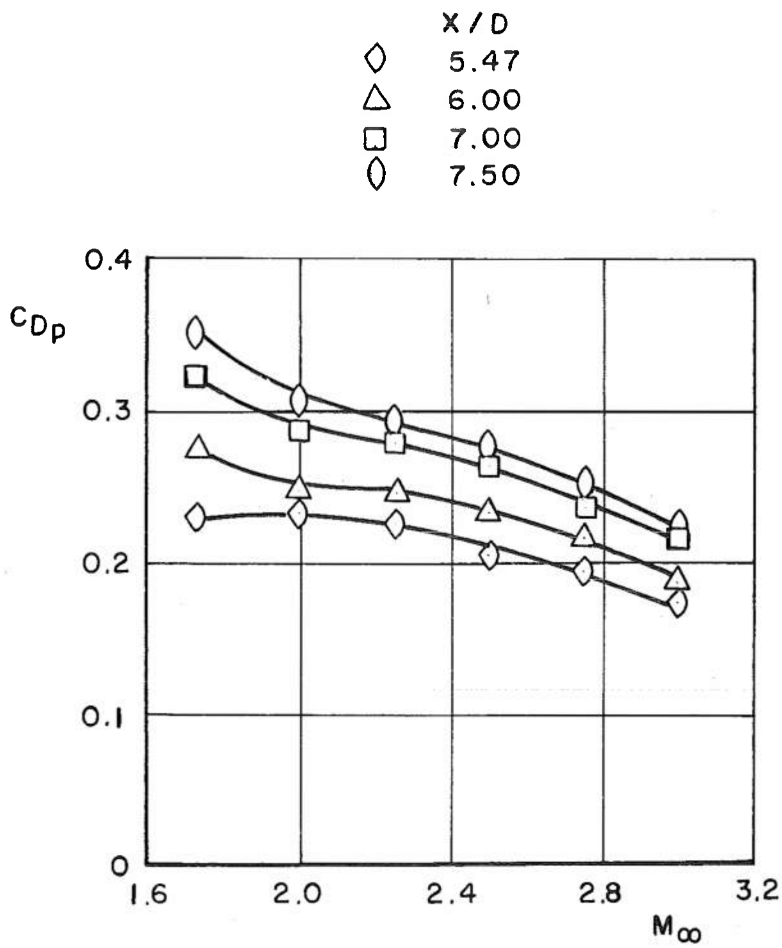


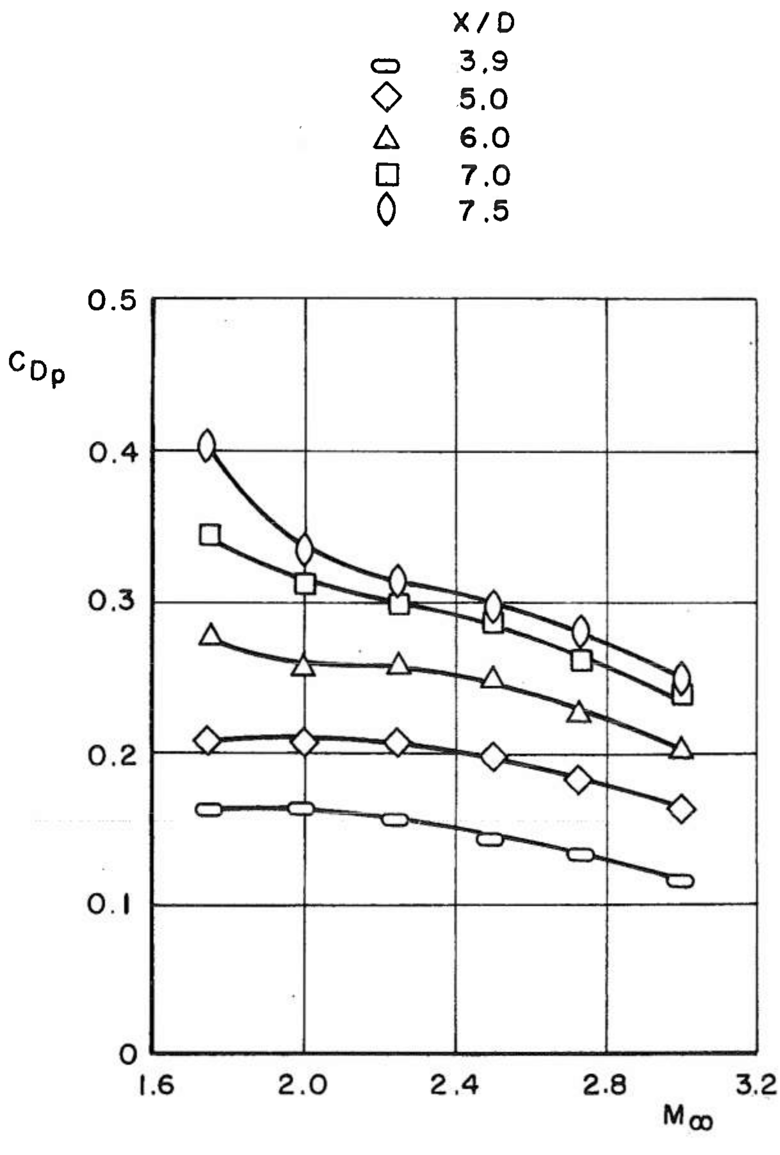
Fig. 19 Effect of the Addition of Webs to the Supersonic X Parachute Drag Coefficient, D = 1.4683 ft



a. Supersonic X, No Webs
Fig. 20 Variation of Parachute Drag Coefficient with Mach Number (Simulated Ejection Seat) D = 1.7500 ft



b. Guide Surface, 3 ft
Fig. 20 Continued



c. Guide Surface, 4 ft
Fig. 20 Concluded

C_{Dp}	σ	SKEWNESS	KURTOSIS	$(N_i)_{MAX}$	N
0.335	0.098	0.347	4.507	298	4095

$$C_{Dp} = 0.335 \begin{matrix} +0.200 \\ -0.179 \end{matrix} \quad \text{(95\% CONFIDENCE LEVEL)}$$

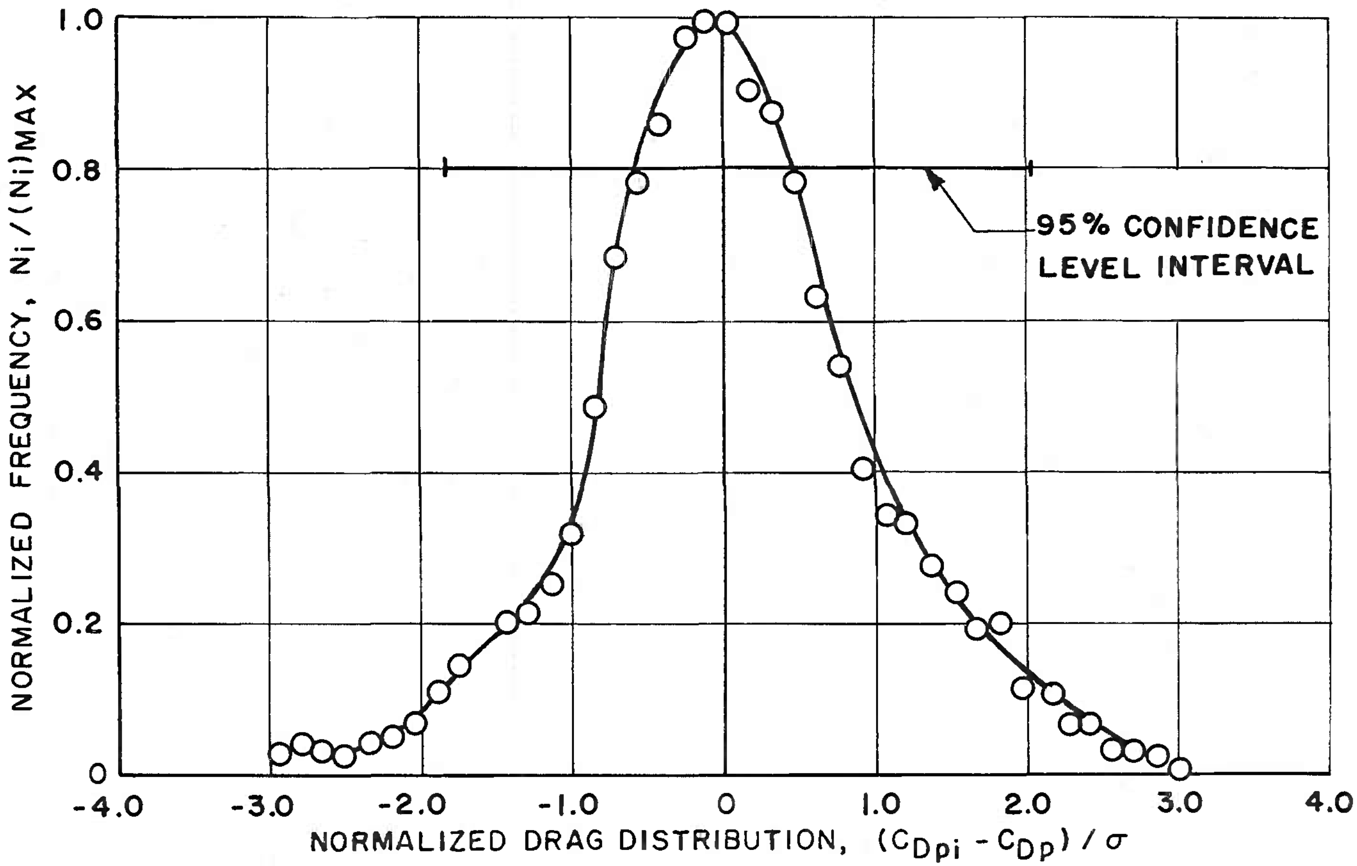
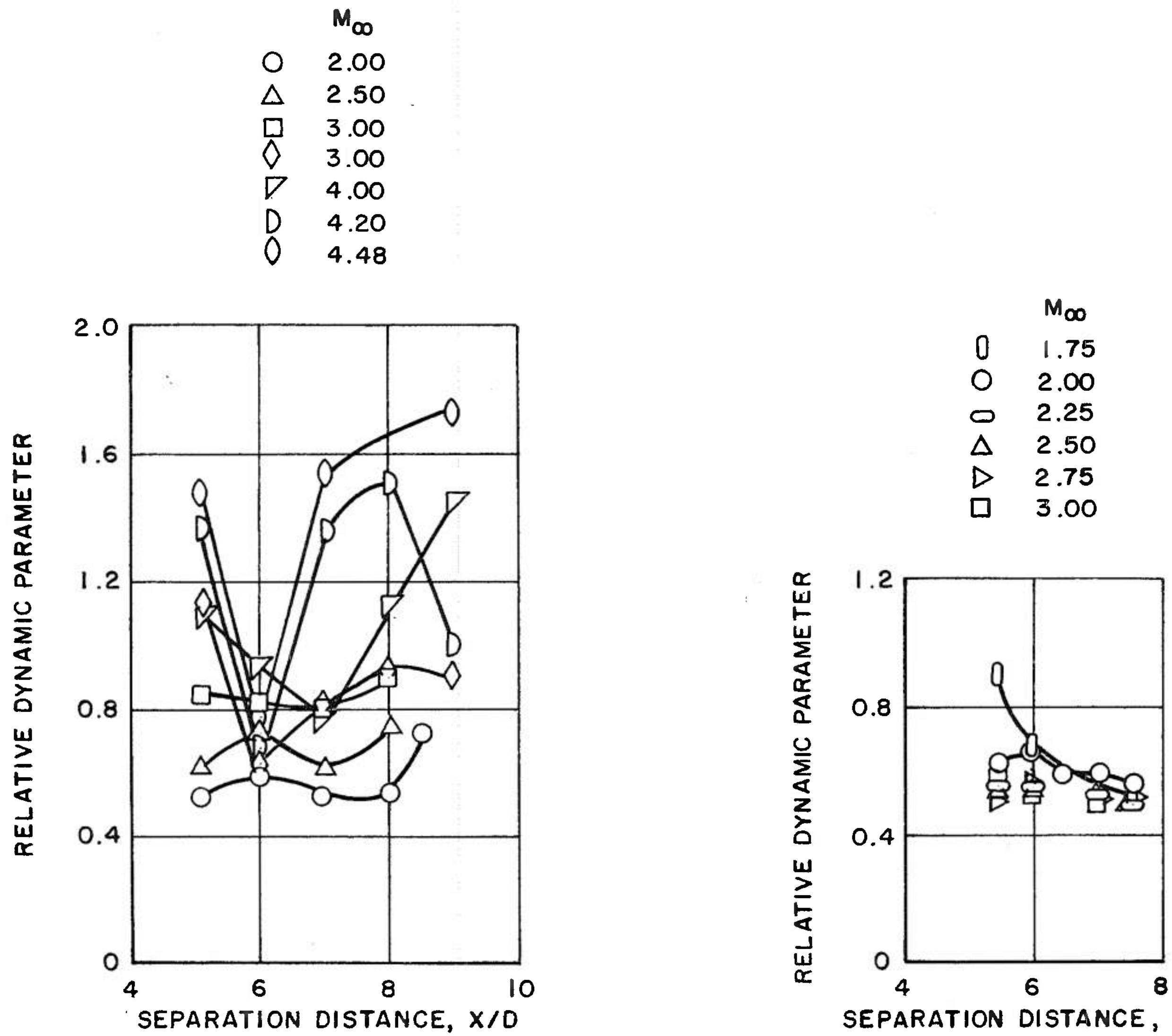


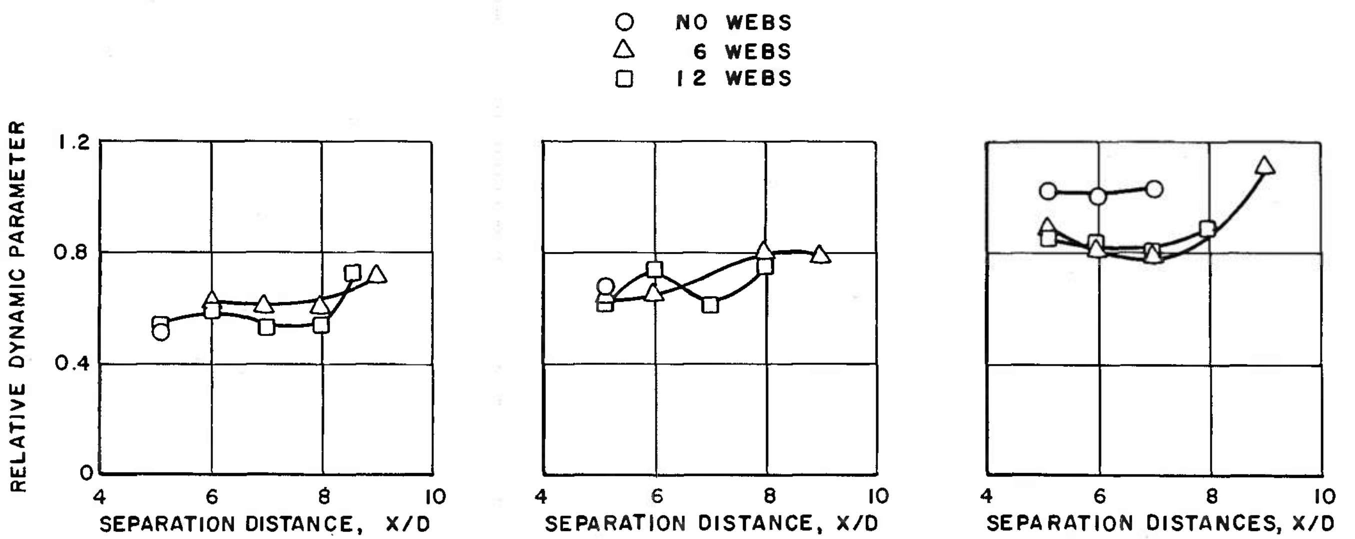
Fig. 21 Typical Distribution Plot of Supersonic X, 12 Webs, Dynamic Drag Characteristics, $M_\infty = 3.98$, X/D = 7.99, D = 1.4683 ft



a. Supersonic X, 12 Webs, Forebody

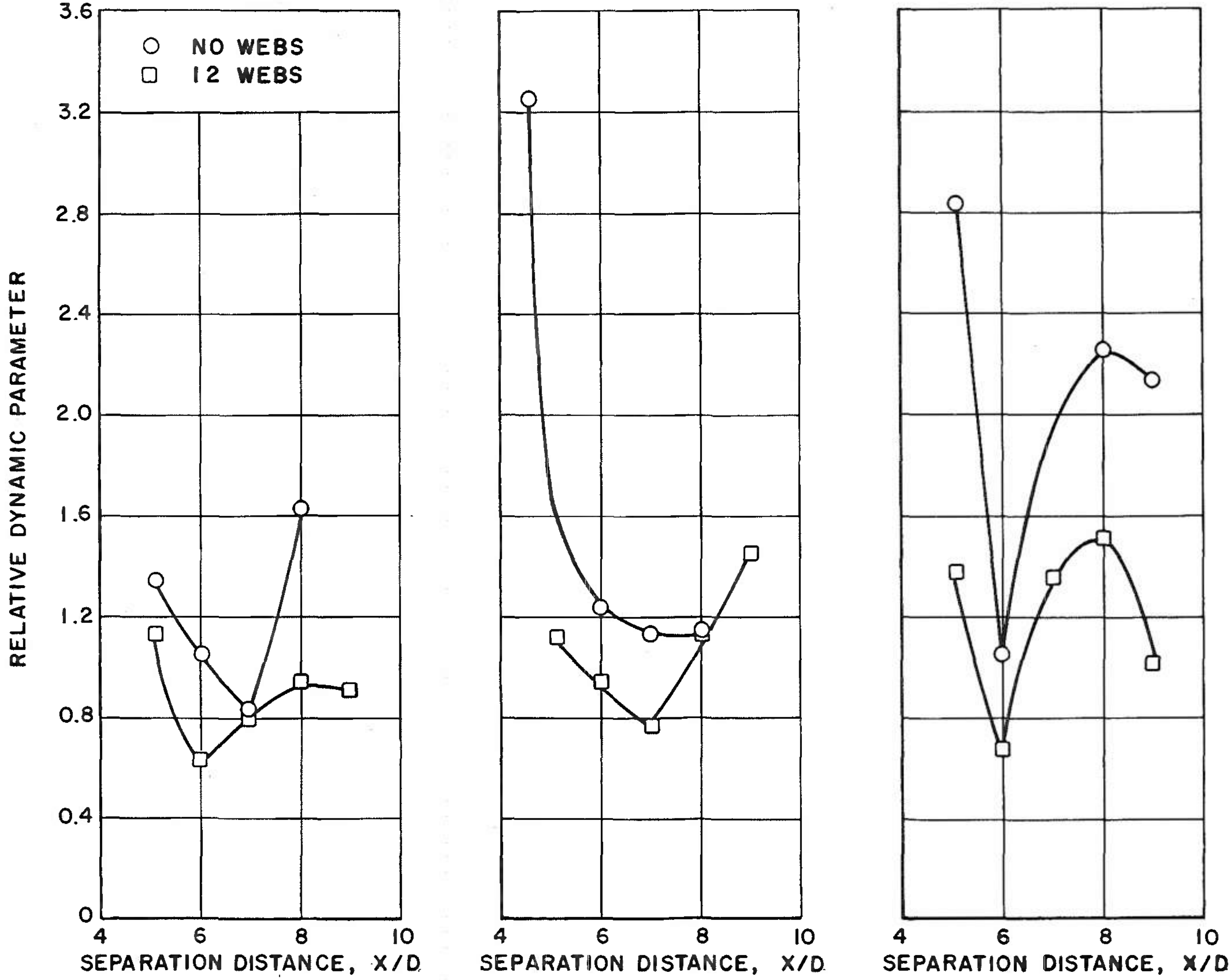
b. Guide Surface, 3 ft, Simulated Ejection Seat

Fig. 22 Variation of Relative Dynamic Parameter with Decelerator Separation Distance



a. $M_\infty = 2.0$ b. $M_\infty = 2.5$ c. $M_\infty = 3.0$

Fig. 23 Effect of the Addition of Webs to the Supersonic X Parachute of the Relative Dynamic Parameter



d. $M_{\infty} = 3.5$

e. $M_{\infty} = 4.0$

f. $M_{\infty} = 4.2$

Fig. 23 Concluded

TABLE I
SUMMARY OF PARACHUTE STATISTICAL ANALYSIS RESULTS

Decelerator	Mach Number, M_∞	Dynamic Pressure, q_∞, psf	Forebody Configuration	X/D	C_{D_p}	σ	Skewness	Kurtosis	N	Relative Dynamic Parameter
Supersonic X NO WEBS	2.003	83.5	Forebody	5.10	0.588	0.078	0.112	2.618	4067	0.512
		83.8		6.00	0.585	---	---	---	---	---
		83.6		6.98	0.629	---	---	---	---	---
		83.6		7.95	0.672	---	---	---	---	---
	2.504	83.0		5.11	0.569	0.102	0.188	2.591	4067	0.679
		82.8		6.01	0.603	---	---	---	---	---
		82.8		6.89	0.616	---	---	---	---	---
		82.9		7.35	0.833	---	---	---	---	---
	3.006	83.9		5.10	0.460	0.122	0.381	3.074	4076	1.022
		84.0		6.00	0.520	0.135	0.184	2.992	4065	1.007
		84.0		7.00	0.541	0.145	0.004	2.789	4078	1.036
		---		---	---	---	---	---	---	---
	3.501	82.8		5.10	0.317	0.110	0.248	2.881	4086	1.339
		81.7		6.01	0.420	0.115	0.278	3.002	4085	1.057
		82.2		6.99	0.426	0.092	0.288	2.879	4058	0.826
		83.0		7.43	0.428	---	---	---	---	---
		82.5		8.00	0.438	0.182	0.202	3.030	4076	1.622
	4.008	79.7		5.10	0.142	0.111	1.364	3.988	3883	3.25
		79.4		6.01	0.314	0.101	0.223	2.854	4070	1.239
		79.7		6.99	0.340	0.099	0.156	3.292	4083	1.137
		79.1		8.00	0.354	0.104	0.034	3.437	4068	1.149
	4.203	81.8		5.11	0.117	0.082	1.575	5.331	4027	2.839
		82.0		6.00	0.283	0.079	0.321	3.088	4081	1.041
		82.1		7.00	0.302	---	---	---	---	---
		82.0		8.00	0.340	0.205	0.847	3.675	4055	2.255
		81.8		9.00	0.311	0.175	0.763	3.568	4034	2.123
Supersonic X 6 Webs	2.007	79.8		5.10	0.681	---	---	---	---	---
		79.5		6.00	0.611	0.099	0.172	2.699	4083	0.621
		79.6		6.99	0.637	0.102	0.163	2.743	4074	0.612
		79.8		8.00	0.643	0.102	0.266	2.826	4066	0.606
		80.0		8.00	0.715	0.135	0.110	2.565	4070	0.715
	2.495	80.1		5.10	0.590	0.097	0.148	2.722	4082	0.631
		80.2		6.00	0.637	0.109	0.102	2.542	4072	0.651
				7.01	0.662	---	---	---	---	---
				8.00	0.680	0.137	-0.311	3.530	4064	0.812
				9.01	0.668	0.135	0.162	3.323	4064	0.791
Webs Failed	2.988	79.8		5.10	0.480	0.108	0.318	2.926	4057	0.871
		80.3		6.00	0.554	0.126	0.121	2.477	4064	0.857
		80.2		6.98	0.562	0.144	-0.033	3.269	4075	1.001
		80.0		7.98	0.603	0.206	0.031	3.183	4082	1.335
		80.1		9.01	0.805	0.139	-0.132	3.810	4082	0.902
Backup Supersonic X (6 Webs)	2.885	80.0		5.11	0.485	0.111	0.222	2.633	4071	0.908
		79.4		6.01	0.504	0.107	0.286	2.637	8116	0.805
		78.8		6.99	0.535	0.109	0.184	2.751	8040	0.782
		80.4		7.99	0.573	---	---	---	---	---
		80.2		9.00	0.594	0.169	-0.158	3.379	8175	1.115
Webs Failed	3.493	79.2		5.10	0.362	0.096	0.536	3.108	4076	1.009
		80.0		6.00	0.439	0.094	0.424	2.924	4068	0.813
		80.2		6.99	0.454	0.111	0.175	3.273	4081	0.956
		80.1		8.00	0.466	0.149	0.078	3.378	4088	1.253
		80.0		8.99	0.472	0.140	0.118	2.825	4075	1.146
	3.886	80.0		5.79	0.336	0.082	0.263	2.789	4077	0.938
		79.7		5.10	0.223	0.120	0.244	2.429	4058	2.001
		79.8		6.01	0.331	0.097	0.242	2.841	4084	1.130
		80.1		6.99	0.364	0.086	0.292	3.229	4088	0.915
		80.0		8.00	0.362	0.082	0.010	3.502	4082	0.889
		80.0		9.01	0.382	0.199	0.474	2.829	4060	1.958
	4.188	79.8		5.10	0.153	0.118	1.001	3.046	4035	2.632
		80.1		6.01	0.298	0.082	0.202	3.333	4088	1.072
		78.8		6.98	0.332	0.076	0.280	3.254	4086	0.886
		80.1		7.99	0.340	0.064	0.609	3.563	4080	0.719
		80.1		9.01	0.340	0.117	0.302	3.260	4069	1.336

NOTE: When the X/D range was not completed, the parachute was observed on television to be violently unstable.

TABLE I (Continued)

Decelerator	Mach Number, M_∞	Dynamic Pressure, q_∞, psf	Forebody Configuration	X/D	C_{D_p}	σ	Skewness	Kurtosis	N	Relative Dynamic Parameter
Supersonic X 12 Webs	2.007	79.8	Forebody	5.10	0.555	0.075	0.161	2.866	4076	0.525
		79.8		6.00	0.609	0.099	0.105	2.762	4087	0.592
		79.5		6.98	0.622	0.085	0.119	2.699	4076	0.526
		70.4		8.00	0.643	0.091	0.113	2.618	4070	0.539
		78.0		8.54	0.722	0.133	0.142	3.343	4095	0.722
	2.495	80.0		5.11	0.580	0.093	0.193	2.988	4095	0.618
		80.4		6.00	0.612	0.117	0.212	2.869	4095	0.738
		80.0		6.99	0.633	0.100	0.079	2.886	4095	0.812
		80.0		8.00	0.642	0.123	-0.031	4.128	4095	0.751
	2.998	80.1		5.11	0.482	0.105	0.297	3.286	4095	0.848
		80.3		6.01	0.527	0.111	0.200	2.842	4085	0.811
		80.4		6.99	0.542	0.111	0.082	3.206	4095	0.799
		80.4		9.00	0.565	0.129	-0.028	3.735	4085	0.891
Backup Supersonic X 12 Webs	3.500	80.2		5.10	0.334	0.098	0.329	2.929	4095	1.128
		80.2		6.00	0.441	0.072	0.151	3.018	4095	0.631
		80.3		6.98	0.404	0.082	0.283	3.118	4085	0.787
		80.3		7.99	0.435	0.105	0.218	3.563	4095	0.939
		80.3		9.01	0.424	0.098	0.365	3.726	4095	0.906
	3.988	80.1		5.10	0.261	0.075	0.435	3.856	4095	1.117
				6.00	0.311	0.075	0.268	3.527	4095	0.940
				6.88	0.321	0.064	0.363	3.067	4095	0.772
		80.2		7.99	0.335	0.098	0.347	4.507	4085	1.131
				9.01	0.357	0.133	0.308	3.645	4091	1.453
	4.190	00.1		5.10	0.222	0.078	0.274	3.489	4094	1.367
		00.3		6.00	0.300	0.051	0.008	3.103	4095	0.663
				7.00	0.291	0.101	0.428	3.806	4092	1.353
		79.9		8.00	0.313	0.122	0.640	3.866	4095	1.502
		79.4		9.00	0.312	0.073	0.169	6.522	4095	1.003
	4.496	80.3		5.11	0.163	0.064	0.082	2.417	4085	1.482
		80.4		6.00	0.239	0.047	-0.057	3.391	4095	0.775
		80.5		6.999	0.246	0.099	0.460	3.265	4095	1.546
		80.5		7.99	0.249	---	---	---	---	---
		80.2		9.01	0.283	0.126	0.488	3.384	4095	1.722
Guide Surface 3 ft	1.748	80.2	Forebody with simulated ejector seat	5.47	0.236	0.056	0.449	3.222	4095	0.905
				6.00	0.275	0.040	0.057	3.173	4095	0.680
				7.06	0.324	---	---	---	---	---
				7.53	0.364	0.052	0.222	3.010	4095	0.550
	1.999	79.6		5.47	0.233	0.037	0.266	3.414	4095	0.621
		79.2		6.01	0.248	0.043	0.186	2.966	4095	0.665
		78.4		6.43	0.258	0.040	0.169	2.769	4069	0.589
		00.0		7.04	0.288	0.045	0.294	2.827	4001	0.596
		80.2		7.55	0.307	0.044	0.189	2.975	4074	0.552
	2.242	79.8		5.47	0.224	0.032	0.090	2.813	4072	0.554
		79.5		6.01	0.246	0.036	0.257	2.825	4071	0.551
		80.5		7.06	0.279	0.038	0.203	2.782	4067	0.526
		80.8		7.55	0.293	0.038	-0.014	2.864	4081	0.497
	2.497	78.8		5.47	0.211	0.030	0.174	2.773	4072	0.550
		79.9		6.00	0.234	0.032	0.045	2.698	4070	0.521
		80.0		7.03	0.263	0.036	0.069	2.743	4077	0.534
		80.2		7.55	0.278	0.039	0.147	2.823	4078	0.537
	2.742	80.6		5.47	0.194	0.027	0.128	2.824	4055	0.530
		80.5		6.01	0.215	0.030	0.069	2.686	4069	0.529
		80.3		7.05	0.245	0.034	0.126	2.797	4072	0.534
		80.3		7.552	0.254	0.036	-0.016	2.937	4071	0.553
	2.997	78.9		5.47	0.174	0.025	0.208	2.933	4003	0.561
				6.01	0.187	0.025	0.138	2.052	4074	0.522
		80.2		7.06	0.216	0.028	0.049	2.687	4061	0.499
		80.3		7.53	0.227	0.032	0.074	2.895	4063	0.540
Guide Surface 4 ft	1.744	79.8		3.905	0.158	0.044	0.268	2.685	4088	1.050
		81.0		4.974	0.206	0.064	0.306	2.374	4083	1.138
		80.7		6.00	0.274	0.086	0.265	2.979	4087	0.926
		80.2		7.03	0.354	0.060	0.096	2.653	4075	0.650
		78.3		7.63	0.391	0.063	0.291	3.026	4076	0.620

TABLE I (Concluded)

Decelerator	Mach Number, M_∞	Dynamic Pressure, q_∞, psf	Forebody Configuration	X/D	C_{D_p}	σ	Skewness	Kurtosis	N	Relative Dynamic Parameter
Guide Surface 4 ft Backup	1.996	79.7	Forebody with simulated ejection seat	3.91	0.161	0.048	0.447	3.052	4007	1.147
		79.8		4.99	0.206	---	---	---	---	---
		80.2		6.00	0.260	0.049	0.445	3.259	4080	0.729
		80.2		6.99	0.303	0.058	0.062	2.750	4079	0.731
		80.0		7.50	0.328	0.056	0.373	2.866	4067	0.652
	2.247	80.0		3.90	0.164	0.030	0.391	2.999	4072	0.694
		79.7		4.99	0.218	0.040	0.172	2.535	4084	0.694
		79.4		5.99	0.264	0.041	0.204	2.699	4069	0.800
		79.5		7.00	0.298	0.043	0.173	2.731	4082	0.558
		79.9		7.50	0.314	0.045	0.073	2.835	4084	0.550
	2.502	80.3		3.90	0.147	0.027	-0.109	3.197	4083	0.725
		80.1		4.98	0.199	0.033	0.191	2.692	4064	0.834
		80.3		5.99	0.248	0.038	0.130	2.967	4082	0.588
		80.4		7.01	0.286	0.037	0.264	2.810	4069	0.493
		80.4		7.50	0.301	0.037	0.150	2.785	4075	0.472
	2.750	80.1		3.90	0.131	0.025	0.184	2.781	4071	0.744
		80.1		4.98	0.184	0.031	0.126	2.568	4068	0.847
		80.2		5.99	0.225	---	---	---	---	---
		80.2		6.99	0.261	---	---	---	---	---
		80.3		7.50	0.287	0.039	0.002	2.674	4071	0.520
	3.003	79.6		3.91	0.118	0.023	0.199	3.068	4091	0.771
		80.0		4.98	0.168	0.030	0.204	2.727	4087	0.673
		79.9		5.99	0.206	0.032	0.139	2.894	4077	0.594
		80.0		7.01	0.242	0.034	0.159	2.774	4080	0.541
		80.1		7.49	0.261	0.036	0.140	2.856	4080	0.526
Supersonic X NO WEBS	1.752	80.7		4.28	0.379	0.109	0.183	2.699	4062	1.096
		80.3		4.99	0.460	0.138	0.177	2.791	4062	1.155
		80.1		5.67	0.542	0.127	0.103	2.782	4076	0.906
		80.0		5.99	0.595	---	---	---	---	---
		79.9		7.00	0.593	0.136	0.080	3.080	4076	0.896
		79.9		7.500	0.717	0.189	0.383	3.080	4052	1.013
	2.001	81.4		4.28	0.363	0.082	0.223	2.695	4073	0.863
		81.0		5.00	0.415	0.093	0.254	2.933	4073	0.860
		80.8		5.99	0.484	0.108	0.189	2.936	4066	0.883
		80.7		6.99	0.585	0.132	0.157	3.204	4081	0.585
		80.6		7.50	0.624	0.184	0.197	2.490	4069	0.987
	2.254	81.0		4.28	0.360	0.072	0.107	3.257	4072	0.782
		81.0		4.99	0.411	0.078	0.228	3.101	4090	0.737
		81.0		5.99	0.465	0.089	0.138	3.013	4080	0.740
		80.9		7.00	0.512	0.106	0.078	2.828	4076	0.797
		81.0		7.50	0.636	0.159	0.237	2.953	4054	0.963
	2.500	81.6		4.28	0.339	0.057	0.197	2.876	4060	0.649
		81.1		4.99	0.393	0.070	0.171	2.695	4077	0.679
		80.8		5.99	0.447	0.094	0.246	3.087	4085	0.815
		80.5		7.00	0.517	0.125	0.224	2.806	4064	0.927
		80.2		7.50	0.573	0.141	0.539	3.295	4071	0.941
	2.746	80.0		4.286	0.303	0.065	0.365	3.263	4087	0.827
		79.7		4.99	0.359	0.073	0.187	2.869	4062	0.784
		80.3		5.98	0.413	0.081	0.109	2.628	4058	0.744
		79.7		7.00	0.475	0.116	0.397	3.136	4082	0.941
		79.9		7.50	0.499	0.123	0.487	3.455	4070	0.950
	3.003	80.2		4.29	0.258	0.052	0.307	3.003	4064	0.770
		79.6		4.99	0.303	0.055	0.279	2.924	4080	0.697
		79.6		5.99	0.362	0.085	0.329	3.062	4061	0.901
		78.9		7.00	0.418	0.100	0.119	2.571	4062	0.907
		80.2		7.49	0.438	0.113	0.251	2.845	4079	0.992
	3.502	80.6		4.28	0.224	0.044	0.126	2.746	4068	0.753
		80.5		4.99	0.260	0.087	0.412	2.823	4074	0.972
		80.4		5.99	0.309	0.078	0.122	2.715	4079	0.972
		80.4		7.00	0.354	0.085	0.305	3.090	4071	0.928
		80.4		7.50	0.434	0.168	0.823	4.182	4086	1.452
	4.001	79.6		4.29	0.174	0.041	0.309	2.775	4081	0.895
		80.0		4.99	0.213	0.051	0.414	3.098	4080	0.927
		79.9		5.99	0.249	0.064	0.381	2.868	4067	0.979
		80.1		7.01	0.288	0.071	0.196	3.058	4072	0.953
		79.9		7.50	0.304	0.087	0.110	3.121	4091	1.114
	4.198	80.1		4.286	0.154	0.037	0.291	2.891	4082	0.926
				5.00	0.192	0.047	0.330	3.266	4078	0.947
				5.99	0.227	0.050	0.277	2.754	4070	0.842
				7.00	0.264	0.065	0.453	3.023	4067	0.939
				7.50	0.278	0.073	0.239	2.741	4063	1.007

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13. ABSTRACT

A test was conducted in the Propulsion Wind Tunnel (16S) to determine the flow field properties in the wake of a strut-mounted cylindrical forebody with and without base bleed and to determine aerodynamic performance of two types of parachutes. The wake was surveyed from two to eight forebody diameters aft of the base. Parachute separation distance was remotely varied from four to nine forebody diameters aft of the base. Data were obtained at Mach numbers from 1.75 to 4.75 at a nominal free-stream dynamic pressure of 80 psf. Base bleed reduced the local wake Mach number and dynamic pressure behind the forebody at all X/D locations for Z/D = zero. The addition of webs to the Supersonic X parachute, in general, decreased the parachute dynamics at Mach numbers greater than three.

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