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FORCE TESTING MANUAL FOR THE LANGLEY 20-INCH MACH 6 TUNNEL

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CONTENTS

Introduction

This manual describes the data reduction and procedures for conducting force tests in the Langley 20-inch Mach 6 tunnel. The pre-test and testing phases are discussed in Section I and the data reduction is discussed in Section II. An appendix by James C. Emery, formerly of the Langley Research Center, which presents a description, operating characteristics, and Mach number calibration of the tunnel is also included (reporduced from NASA TN D-6280, 1971). The tunnel characteristics described in this appendix have been updated.

Section I outlines items that should be checked during model design and construction. Safety requirements and starting loads tests as well as instructions for data acquisition and model installation are discussed and outlined. Measurement of balance and model misalignment angles and instructions for calibrating the angle-of-attack screen are covered. Procedures for making reference pressure, attitude-tare, and data runs are included.

Section II discusses the 20-inch tunnel force program along with a description of the Beckman data recording system input and load constant sheets. Programs for calculating balance accuracy, beta derivatives, and data plotting are described. Input sheets for these programs are also presented. The definitions of terms used in this manual are found on pages 25 thru 30.

SECTION I - PRE-TEST AND TEST

I. PRE-TEST

A. MODEL DESIGN AND CONSTRUCTION

Steps to be taken in the design of force models.

1. Method of model construction

   (a) Machined.
   (b) Cast.
   (c) Fabricated.
   (d) Consult with shop concerning construction of model; easiest or fastest method of construction.

2. Availability of balance (see current listing of active force balances)

   (a) Primary balance and cooling shield or cooling adapter (Table 1).
   (b) Current balance calibration.
   (c) Alternate or backup balances.
   (d) Availability of dummy balance (Table 2).

3. Sketch of model in tunnel (Figs. A1 and A2 of Appendix)

   (a) Show model position relative to center of window and center of rotation of support system.
   (b) Determine position of the angle-of-attack prism on model (locate 1/2" to 1" downstream of cenber-of-window). Prism always faces right side of tunnel looking upstream. Note: Prism can be rotated $\pm$ 42° about longitudinal axis and still reflect light in plane of light source.
   (c) Determine strut to be used and length and size of sting holder and sting needed (Tables 3 and 4). Sting sized for stress and base pressure interference criteria. Note: In order to avoid sting effects on the base pressure the ratio of sting diameter to model base diameter must not exceed .5 and any increase in the sting diameter must not occur within 5-8 sting diameters downstream of the model base.
   (d) Check for fouling of sting holder, sting, or cooling coil with base of model.
   (e) Check for interference of Mach number probe and its shock ($\approx$ 11°) with model (Fig. A4 of Appendix).

4. Model drawings

   (a) Check for correct dimensions.
   (b) State on drawing that balance and dowel holes to fit and match actual balance with cooling shield in place.

(c) State on drawing that balance sleeves to be fitted on balance then fitted to model.
(d) Provision for prism and location on correct side.
(e) Specify that all dimensions and angles be checked and correct values noted on drawing, also misalignment of balance hole and dowel holes with respect to horizontal and vertical plane of model are to be noted.
(f) Provision for flat reference surface for setting angles of attack either on model or as an attachment.

5. Stress check

(a) Calculate stress in model parts if necessary.
(b) Calculate stress in sting, sting holder, and cooling adapters. All stings made specifically for a test must meet safety standard for heat treatment.
(c) Supply necessary calculations as stated below in "Safety Requirements for Force Testing".
Note: The yield strengths of the materials must be based on the actual fabrication conditions and heat treatment.

B. SAFETY REQUIREMENTS FOR FORCE TESTING

All models, with their associated support systems and bolts, to be tested in this facility must be capable of withstanding stresses calculated for the following condition; tunnel unstarted (assuming normal shock) on one side of model and started on opposite side. If this condition cannot be satisfied, it may be possible to test provided stress calculation will allow for 3-1/2 times the normal force at 30° angle of attack.

Before model is tested in the tunnel, a copy of the stress calculations (signed by one who assumes responsibility for their reliability) must be given to the tunnel coordinator.

Any deviation from this procedure must be approved by the Branch Head or tunnel coordinator.

C. STARTING LOADS TEST

Prior to running any force test in the tunnel, the following procedure must be followed. Any deviation from this procedure can be made only with the prior consent of the Branch Head or tunnel coordinator.

1. All force tests will be run by injecting the model if possible. Also, tests should be run to the vacuum sphere instead of using the air ejector.

2. Model must first be mounted on dummy balance in same location and with same sting size as will be used for tests to determine optimum second minimum setting and lowest ejector pressure (if used) in that order, for each stagnation pressure to be run in test program. Tunnel will be unstarted with model in α and β attitude. For safety reasons, a dummy model is desirable but not necessary.

3. Starting loads must be determined with a balance having at least a 50 percent higher allowable load on each component than the balance to be used for tests. Model will be injected in the same attitudes at which tests will be made. Approximately three visicorder traces showing safe starting and unstarting loads should be obtained before installing proper balance to conduct test.

PRIOR TO MODEL INSTALLATION

1. Instructions for data reduction (see SECTION II - DATA REDUCTION, pages 25-30 and 45-51).

    (a) Notify data reduction personnel at least one week before start of test and supply proper Beckman recording channel set-up sheets (pp 46-48).
    (b) Balance sensitivity constants, pressure transducer sensitivity constants, model dimensions and angles, etc. must be supplied before test begins. Input sheets on pp 49-51.

2. Instructions for model installation

    (a) Fill in Job Sheet (Figure 1) - one copy to tunnel coordinator and one copy to tunnel technician.
    (b) Supply tunnel technician with drawings, sketches and a copy of Beckman set-up sheets. Sketches will show base pressure tube location and number of each tube, balance cooling water tubes, balance component and thermocouple lead hook-up, angle-of-attack and angle-of-sideslip ranges, etc.

3. Model

    (a) Check all model parts for fit and correct dimensions.
    (b) Check prism and prism location.
    (c) Check flat reference surface for setting angle of attack.

4. Sting

    (a) Check fit of sting holder in support, sting in holder, and balance in sting (also check fit of balance cooling adapter between sting and balance if used).

5. Balance

   (a) Check length of both balance and thermocouple leads.
   (b) Check balance components and record zeros.
   (c) Check balance thermocouples.
   (d) Check cooling shield and tubes for leaks and proper water flow.

6. Cooling water system

   (a) Check water filters
   (b) Check water flow

7. Schlieren system

   (a) Check schlieren components (mirrors, power supply, camera, controls, knife edge, and light source).
   (b) Install "eyepiece" system for more detail photographs if needed.

8. TV system

   (a) Check operation of camera, monitor, and controls.
   (b) Check for proper camera lens.

9. Mach number probe

   (a) Check operation.

AFTER MODEL INSTALLATION

1. Balance

   (a) Check all components.
   (b) Check thermocouples.
   (c) Check water flow through cooling shield.
   (d) Check base pressure tubes for correct location and clearance to avoid fouling with model base. Make sure tubes are secured to sting and support to prevent fore and aft movement when sweeping thru angle of attack.
   (e) Span check balance leads.
   (f) Calibrate visicorder and Sanborn recorder for maximum loads (Figures 2 and 3).

2. Instrumentation hookup

   (a) Check hook-up of Beckman system to test instrumentation (balance, pressure transducers, Baratrons, thermocouples, and thermocouple reference junction) thru patch board using the digital voltmenter.

3. Balance and model misalignment (see "Note" below, fig. 4, and pages 25-30 in Section II - DATA REDUCTION for definition and sign convention of angles).

(a) With fixture on balance and ALPHA BAL = 0° measure roll angle of balance relative to vertical plane of tunnel (DELTA PHI BAL) using standard sign convention (positive clockwise looking upstream with top center = 0°). Normally DELTA PHI BAL can be set = 0° by adjusting the sting holder. DELTA PHI BAL is a data reduction input.
(b) Leave balance at ALPHA BAL = 0°, remove fixture, put on model and measure angle of attack of model (ALPHA MOD) and roll of model (DELTA PHI MOD) relative to vertical plane of the tunnel using the same sign convention as above. DELTA PHI MOD is a data reduction input.
(c) Then determine the angle (ALPHA ZERO) between the balance centerline and the model centerline relative to the balance. ALPHA ZERO = ALPHA MOD - ALPHA BAL. ALPHA ZERO is a data reduction input.
(d) Alternate method of determining ALPHA ZERO for heavy models relative to balance stiffness is as follows:

1) Set balance and fixture at ALPHA BAL = 0°.
2) Hang weight equal to weight of model on fixture at a distance X from the balance pitch center (X - distance form balance pitch center to model cg).
3) Measure angle of fixture (α_2).
4) Remove fixture and place model on balance, measure angle of attack (α_3).
5) Then ALPHA ZERO = $\alpha_3 - \alpha_2$.

(e) Determine the angle DELTA BASE between model vertical axis and base. DELTA BASE is a data reduction input.

4. Calibration of the angle-of-attack screen (see 'Note' below)

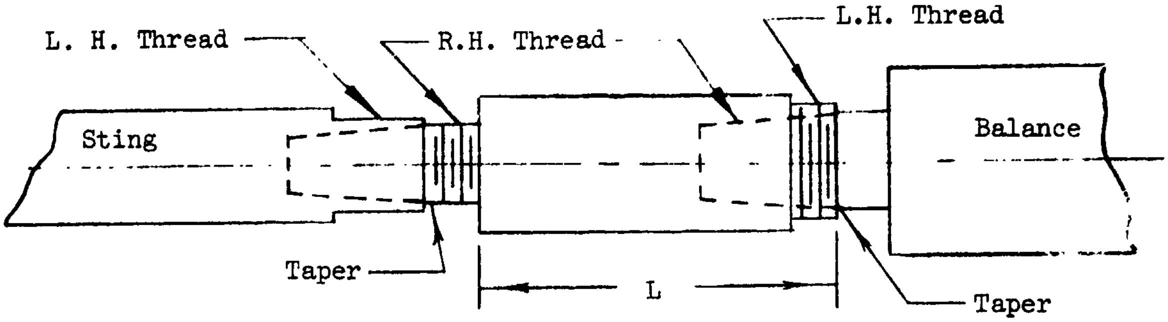
(a) Set model at ALPHA MOD = ALPHA ZERO, mark screen, and label the mark ALPHA BAL = 0°.
(b) Set the model at the prescribed angles of attack for the test, mark the screen, and determine the value of ALPHA BAL to label each mark. Include a mark for ALPHA MOD = 0°. For example, if the model is set at ALPHA MOD = 4° and ALPHA ZERO is calculated to be - 1°, then the screen would be marked for ALPHA MOD = 4° and labeled ALPHA BAL = 5°.
(c) The same procedure for marking and labeling the screen would be used if the model is set at an angle-of-sideslip BETA.

5. Align schlieren system

6. Align TV camera for viewing angle-of-attack screen

NOTE: ALPHA BAL is always positive when balance centerline is rotated upward relative to tunnel centerline regardless of model roll angle, balance roll angle, or sideslip angle.
ALPHA ZERO is always positive when model centerline is rotated upward relative to balance centerline regardless of model roll angle, balance roll angle, or sideslip angle.
BETA is always positive when balance is rotated to left looking upstream regardless of balance roll angle or model roll angle.

Table 1. - Balance-To-Sting Adaptors and Nuts
(all dimensions in inches)



Balance-To-Sting Adaptors

Taper max. dia.		Thread		L	Water cooled	No. of each
Bal.	Sting	Bal. (LH)	Sting (RH)			
.392	.500	None	9/16 - 24	1.594	Yes	1
.392	.500	None	9/16 - 24	1.594	No	1
.392	.687	3/4 - 20	3/4 - 20	2.00	No	1
.500	.500	None	9/16 - 24	2.094	Yes	3
.500	.500	None	9/16 - 24	2.094	No	1
.500	.687	1 - 20	3/4 - 20	2.50	No	1
.500	.750	None	None	0.	No	2
.750	.937	None	None	0.	No	1

Nuts

O.D., Max	Thread		No. of each
	(RH)	(LH)	
.750	9/16 - 24	5/8 - 24	4
.875	9/16 - 24	3/4 - 24	3
.937	9/16 - 24	11/16 - 24	1
1.187	3/4 - 20	1 - 20	1
1.250	9/16 - 24	1 - 20	1
1.250	9/16 - 32	1 - 20	1
1.250	3/4 - 20	1 - 20	1
1.250	13/16 - 20	1 1/8 - 20	1

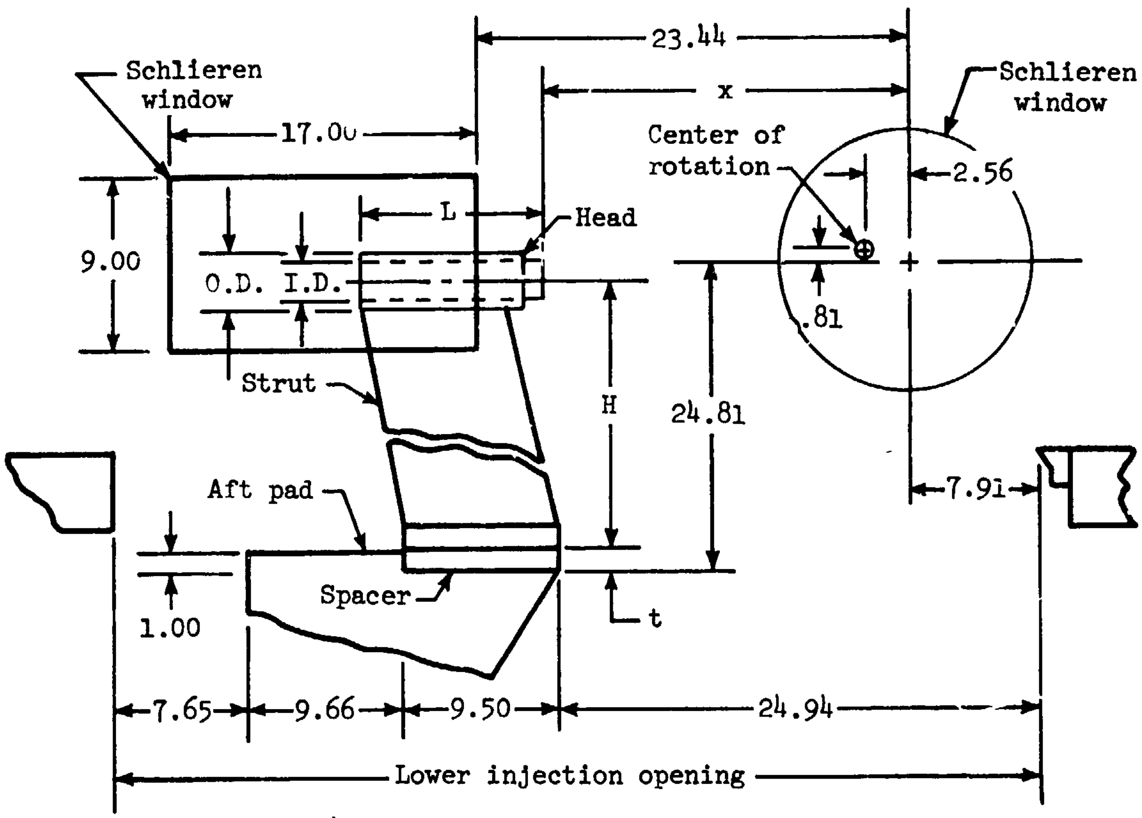
Table 2 - Dummy Balances
(All dimensions in inches)

Balance number	Outside diameter	Distance from balance L.E. to dowel	Taper max. diameter
2001	1.250	(1.975 & 3.905) bottom	.6875
2007	1.250	.600 top	.6875
2008	1.250	.951 bottom	.6875
2009	.875	.645 bottom	.5000
2010	1.300	plug & bolt	.6875
2011	1.250	.750 top	.6875
2012	1.250	.700 bottom	.6875
2014	.875	.250 bottom	.5000
2018, 19, 20, 21	.750	.530 bottom	.3920
2022	.8125	.575 bottom	.3920
2023	.750	.530 top	.3920
2024	.8125	.575 top	.3920
2025	.750	.565 bottom	.3920
2026	.8125	.680 top	.3920
2027	.8125	.680 top	.3920
2028	1.500	.920 top	.7500
2029, 32	1.250	.800 top	.6875
2030, 31	1.000	.800 top	.5000
2033	1.000	.800 top	.5000
2034	.875	.870 bottom	.5000
2035	.750	.530 top	.3920
2036, 37	.750	.525 top	.3920
2039	.500	.350 top	.3125

Table 2 (Continued)

Balance number	Outside diameter	Distance from balance L.E. to dowell	Taper max. diameter
733	.750	.680 top	.3920
826	1.000	1.050 bottom	.5000
827	1.000	(.700 & 1.450) top	.5000

Table 3.- Location and dimensions of sting support struts.
(All dimensions are in inches)



Solid strut and head assemblies

Head No.	x	H	L	O.D.	I.D.	Thread	Remarks
1	22.56	23.5	9.75	3.00	2.20		
2	20.19	23.5	11.00	3.00	1.25	2.75 - 12	Adj
3	21.13	23.44	9.50	2.50	1.50		
4	13.44	23.5	17.50	2.50	1.50		{ 1.5 I.D. 3 deep
5	22.75	22.63	9.69	1.75	.93		
6			9.75	2.50	1.00		+
	One piece water-cooled strut and head						
WC	21.56	24.87	12.31	3.00	1.25	2.75 - 12	Adj

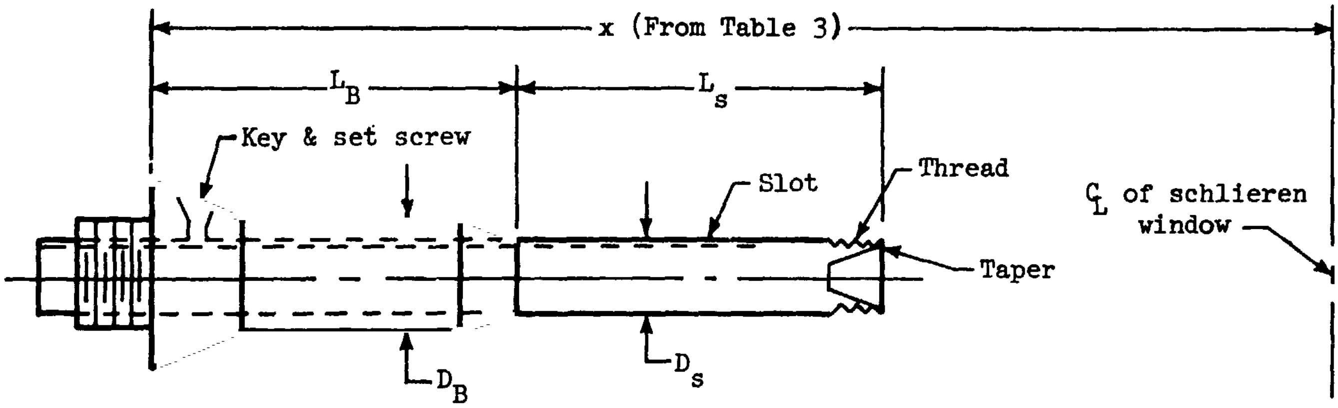
Spacers

t
0.375
1.000
2.313
3.313
See Note 2

WC -- Water cooled
Adj -- For adjustable sting holder
\+ -- 15° negative angle of attack for limited use only

Notes: 1. Support struts may also be mounted on aft pad (x + 9.5)
2. Support struts may also be mounted on inclined spacers (-5° or -10°)

Table 4.- Stings and Sting holders (all dimensions in inches).



Sting					Sting holder (barrel)			Sting support strut head No.	Remarks
O.D., D_s	Length, L_s Max.	Length, L_s Min.	Taper max. dia.	Thread (L.H.)	No.	Length, L_B	O.D., D_B		
0.625	10.937	2.187	0.500	0.625-24	1	5.625	0.750	2, WC	Vee slot
.625	12.625	3.750	.393	.500-20	1	5.625	.750	2, WC	Vee slot
.625	16.375	4.875	.500	.625-24	1	5.625	.750	2, WC	Vee slot
.750	9.375	0.500	.500	.750-24	3	9.250	1.000	2, WC	Sq. slot
.750	12.188	1.000	.500	.750-24	3	9.250	1.000	2, WC	Vee slot
.750	12.188	2.125	.500	.750-24	3	9.250	1.000	2, WC	Sq. slot
.750	21.188	9.875	.500	.750-24	3	9.250	1.000	2, WC	Vee slot
.938	14.313	3.000	.500	.625-24	2	6.750	1.500	2, WC	Vee slot
.938	14.313	3.375	.688	1.062-20	2	6.750	1.500	2, WC	Vee slot
.938	23.313	11.812	.500	.750-24	2	6.750	1.500	2, WC	Vee slot
.938	23.313	11.812	.688	1.062-20	2	6.750	1.500	2, WC	Vee slot
1.062					4	8.212	1.500	2, WC	No keyway
1.000	22.000	3.000	.500	.750-24	5	8.000	1.250	2, WC	Vee slot
1.000	22.000	3.000	.688	1.000-20	5	8.000	1.250	2. WC	Vee slot
1.125	22.000	3.000	.750	1.000-20	6	8.000	1.500	2, WC	Vee slot
0.625	7.375	2.875	.500	0.625-24	1	5.625	0.750	6	10° bend
.750	5.500	5.500	.500	.500-20	3	9.250	1.000	6	30° dbl bend
.750	11.000	6.250	.393	none	3	9.250	1.000	6	25° dbl bend
.750	11.625	5.250	.393	none	3	9.250	1.000	6	30° dbl bend

Figure 1. - Job Sheet

Test Project or Program ______________________________ Date ______________

Project Engineer ______________________________ Job Order ______________

Estimated date of installation ____________________ Are drawings available? ____

Type of test: (1) Force? _____ (2) Heat transfer? _____ (3) Pressure distribution? _____ (4) Boundary layer survey? _____ (5) Other? ______________________________

____

____

Type of mount: Sting? _____ Injection? _____ Stationary? _____ Sidewall? ________

Other? ____

____

1 - Force test: Balance No.? ____________ Sting cooling coil? ______________

Alpha calibration - (Degrees)? _______ Beta calibration - (Degrees)? ________

Number base pressure tubes? ____________ Other information? ______________

____

____

2 - Heat transfer: Type of thermo. wire I.C.? _____ C.A.? _____ Other? ________

No. thermocouples? ___________ Plugs to be installed? ____ Removable instrumented sections (number)? ___________ Patch board hook-up furnished? ____________

Phase change paint? ________ Number of models? ______ Grid models available? ____

Paint and thinner available for all temperatures? ______________________

Other? ____

____

3 - Pressure dist.: No. of orifices? __________ Tubes to be numbered? _________

Sequence of hook-up and range of gages furnished? ______________________

Patch board hook-up furnished? __________ Extension required for tubes? ________

Other? ____

____

Schlieren pictures required? ______________ Shadowgraph? ______________

Instrumentation equipment required not normal to this facility. List: ________

____

____

____

Use back of sheet for additional information.

To: 1 - Technical Support Supervisor

2 - Technical Support Unit Facility Coordinator/Operator

MORE INFORMATION MEANS BETTER SERVICE

Figure 2.- Calibration of Visicorder

Balance No. ______ Date _______

Balance component	NF	AF	PM	RM	YM	SF	
Design load, lb or in-lb							1
Bal. sens., lb/mV or in-lb/mV							2
Visicorder input, mV/V							3
Gage voltage, V							4
Visicorder input, mV							5
Visicorder deflection, in							6
Visicorder sens., lb/in or in-lb/in							7

Notes:

1. Visicorder must be calibrated for each balance by balance technicians.
2. Balance gage voltage should be checked before calibrating visicorder - 8000counts on Beckman, or approximately 10 mV on the digital voltmeter.
3. Visicorder calibration, ⑦ = $\frac{②⑤}{⑥}$ where ⑤ = ③④.

Figure 3.- Calibration of Sanborn Recorder.

For force tests the Beckman recording range is 12.5 mV for Sanborn channels 1 thru 6 with each channel divided into 50 small divisions. The sensitivity for each Sanborn range is as follows:

Sanborn range			Sensitivity, $\frac{\text{divs.}}{\text{mV}}$
1.0	$\frac{50\ \text{divs.}}{12.5\ \text{mV}}$	or	4
.5	$\frac{\text{Range 1}}{.5}$	or	8
.2	$\frac{\text{Range 1}}{.2}$	or	20
.1	$\frac{\text{Range 1}}{.1}$	or	40
2.0	$\frac{\text{Range 1}}{2.0}$	or	2

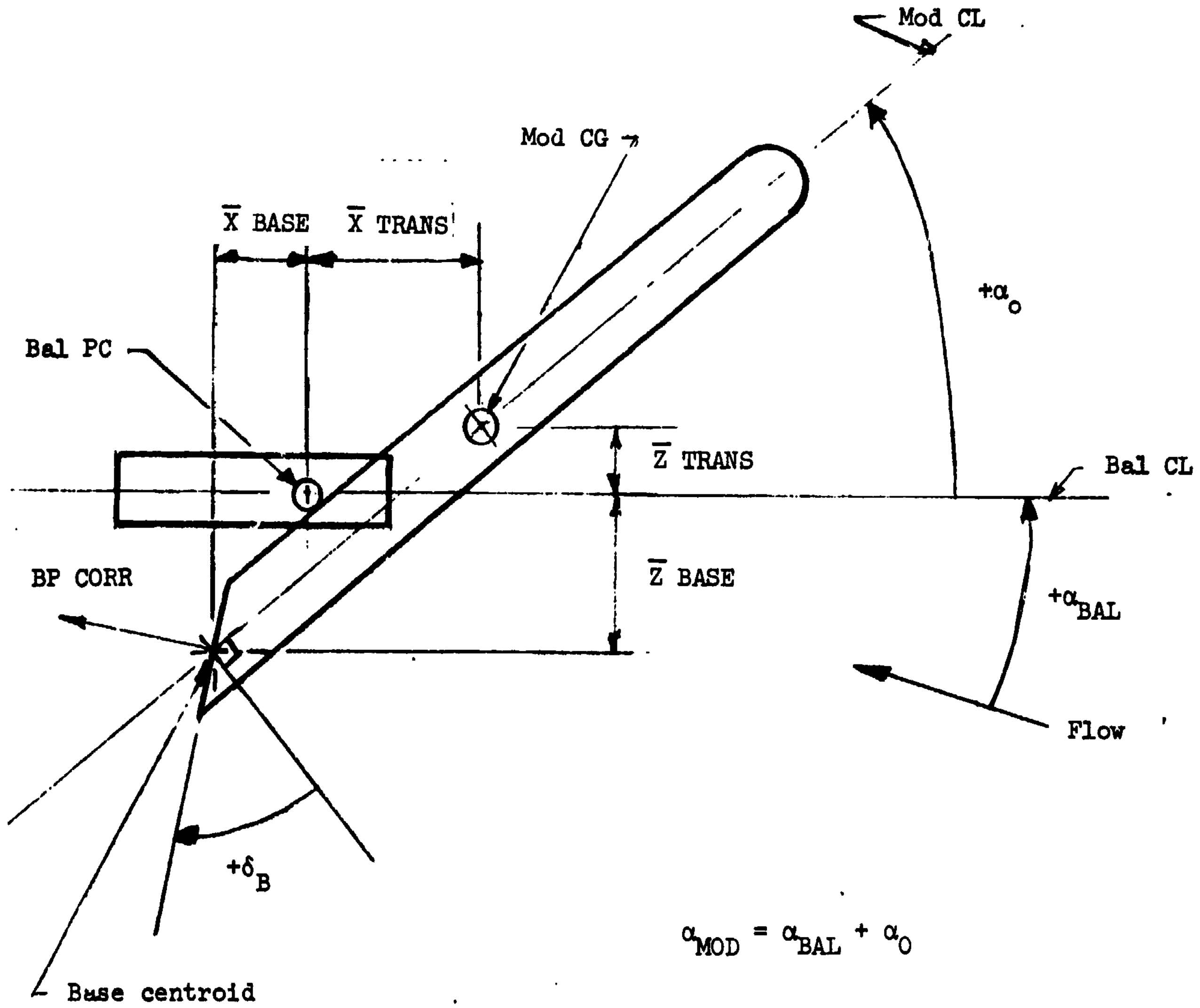
The number, N, of divisions for each balance component design load for Sanborn range 1 is calculated using the following equation:

$$N = \left(\frac{\text{Balance component design load}}{\text{Component sensitivity}}, \frac{\text{lb}}{\text{lb/mV}} \text{ or } \frac{\text{in-lb}}{\text{in-lb/mV}}\right)\left(4\ \frac{\text{divs.}}{\text{mV}}\right)$$

For example: Axial component design load = 100 lbs.
Axial component sensitivity = 40 lb/mV.

Sanborn range			N
1.0	$\left(\frac{100\ \text{lb}}{40\ \text{lb/mV}}\right)\left(4\ \frac{\text{divs}}{\text{mV}}\right)$	or	10 divs. for 100 lb.
.5	$\frac{\text{range 1}}{.5}$	or	20 divs. for 100 lb.
.2	$\frac{\text{range 1}}{.2}$	or	50 divs. for 100 lb.
.1	$\frac{\text{range 1}}{.1}$	or	100 divs. for 100 lb.
2.0	$\frac{\text{range 1}}{2.0}$	or	5 divs. for 100 lb.

Figure 4. - Angles and transfer distances

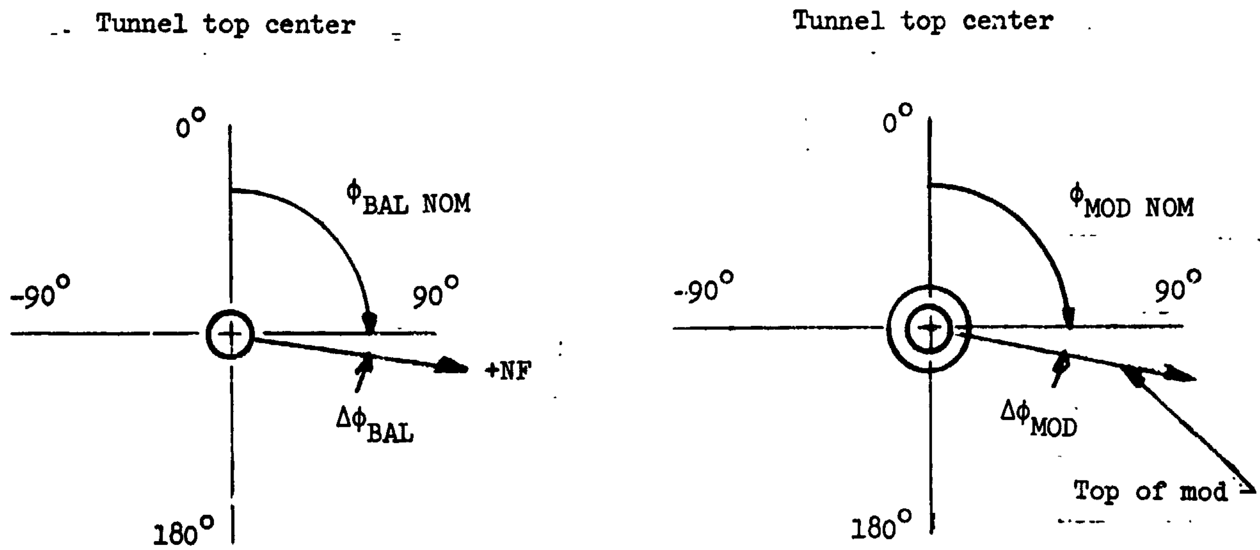


$$\alpha_{MOD} = \alpha_{BAL} + \alpha_O$$

NOTE: $\overline{Y}$ TRANS & $\overline{Y}$ BASE not shown in this view

(a) Angles of attack, base angle, and transfer distances

Figure 4. - Concluded



$$\phi_{BAL} = \phi_{BAL\ NOM} + \Delta\phi_{BAL}$$

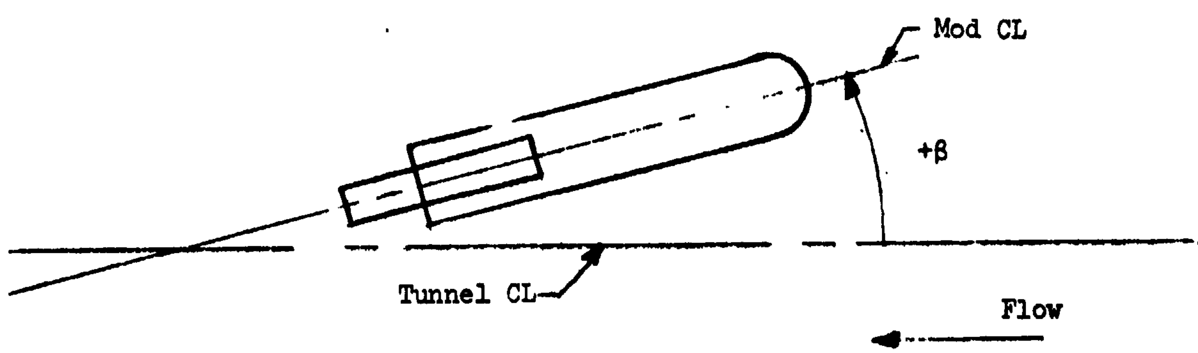
$$\phi_{MOD} = \phi_{MOD\ NOM} + \Delta\phi_{MOD}$$

Balance

Model

Rear view (looking upstream)

(b) Balance and model roll angles



Top view

(c) Angle of sideslip

I. TEST PROCEDURE

No change can be made in the following data recording method without prior approval of Branch Head.

A. BECKMAN SYSTEM

1. Call for system 20 minutes prior to need.

2. Give facility number (20 inch Mach 6 tunnel is facility 6), test number and upcoming run number.

3. Dial in 24 ACH's at 40/sec. sample rate. ACH is analog channel.

4. Check balance (ACH23) and transducer (ACH24) power supplies and adjust to 8000 counts. Check all other channels.

B. REFERENCE PRESSURE RUN (2XXX RUN)

Notes:
You may take reference pressures for base pressure, Mach number probe, and stagnation pressure transducers in any order but for each of them you must take reference pressures in ascending order.

If error is made in reference run, void run and start over with a new run number.

See Input Description (pages 25-30) in Section II for definition of terms.

Digital Channel (DCH) Input

Digital Channel	Designation	Digital channel input for each type		
		Base Pressure	Mach Probe	Stagnation Pressure
DCH 1	TEST	XXXX	XXXX	XXXX.
DCH 2	RUN	2XXX	2XXX	2XXX.
DCH 6	PREF BP	X.XXX	0000	0000
DCH 7	PREF PR	0000	XX.XX	0000
DCH 8	PREF PT	0000	0000	XXXX.
DCH 9	Not used	0000	0000	0000
DCH 10	Not used	0000	0000	0000

1. Enter 2 in first digit of run number (DCH2 = 2XXX) and zeros in DCH9 and DCH10 (0000).

2. Get Beckman control.

3. Set manifold pressure is psia to approximate reference base pressure (PREF BP). Dial set pressure value in DCH6 (X.XXX) and zeros in DCH7 and DCH8 (0000). For a series of runs where the stagnation pressure is to be

varied, up to four reference base pressures can be taken but they must be taken in ascending order. If multi-range Baratrons are substituted for the transducers, then only one range can be used. Make sure reference values fall within that range since there is no automatic range selection for BP. Use, $(BP - p_\infty) / q_\infty = -1 / M_\infty^2$, to estimate BP, where p_∞, q_∞, and M_∞ are the free-stream static and dynamic pressures and Mach number, respectively.

4. Take a data zero and single frame for each reference pressure.

5. Several check pressures can be taken for each reference pressure by dialing in DCH6 and using the single frame mode.

6. Set manifold pressure in psia near expected reference Mach number probe (PREF PR) value, dial value in DCH7 (XX.XX), and zeros in DCH6 and DCH8 (0000). If the stagnation pressure is varied, up to nine reference values can be taken in ascending order (three per Baratron range). Make sure reference values fall in range to be used (between 20 percent and 80 percent of full scale for each range used in automatic range selection mode). No limits on one range operation.

7. Take a data zero and single frame for each reference pressure.

8. Several check pressures can be taken for each reference pressure by dialing in DCH7 and using the single frame mode.

9. Set required reference pressures in psia on dial gage outside of control room for stagnation pressure transducers (PREF PT). Dial value in DCH8 (XXXX.), and zeros in DCH6 and DCH7 (0000), up to six reference pressures can be taken in ascending order. Make sure reference pressure fall in range of the transducers.

10. Take data zero and single frame for each reference pressure.

11. Several check pressures can be taken for each reference pressure by dialing in DCH8 and using the single frame mode.

12. Push finish switch.

C. ATTITUDE - TARE RUN (1XXX RUN)

Notes:
If error is made in attitude-tare run, void run, advance run number, and start over.

Turn balance water off when not needed to prevent water from condensing on balance.

See Input Description (pages 25-30) in section II for definition of terms.

Digital Channel (DCH) Input

Digital Channel	Designation	Input
DCH 1	TEST	XXXX.
DCH 2	RUN	1XXX.
DCH 6	CONF	XXXX.
DCH 7	DELTA PHI MOD	XX.XX
DCH 8	DELTA PHI BAL	XX.XX
DCH 9	ALPHA ZERO	XX.XX
DCH 10	ALPHA BAL	XX.XX

1. Enter 1 in first digit of run number (DCH2 = 1XXX) and advance run number.

2. Set in the following:

   (a) Put configuration number in DCH6 (XXXX) if used.
   (b) Put model roll angle, DELTA PHI MOD, in DCH7 (XX.XX)
   (c) Put balance roll angle, DELTA PHI BAL, in DCH8 (XX.XX).
   (d) Put angle of attack between balance and model centerlines, ALPHA ZERO, in DCH9 (XX.XX).

3. Get Beckman control.

4. Turn balance water on and maintain a balance temperature differential of less than 5° if possible and an overall temperature ≈ 125°F.

5. Take data zero at ALPHA BAL = 0° with model and balance fixture off.

6. Turn balance water off.

7. Put model on.

8. Turn balance water on.

9. Starting at lowest ALPHA BAL, set model at each ALPHA BAL marked on screen in ascending order, stopping to dial in value in DCH10 (XX.XX) and take single frame. You must take a single frame at ALPHA BAL = 0°.

10. Return model to ALPHA BAL = 0°.

11. Turn balance water off.

12. Push finish switch.

D. DATA RUN (XXXX RUN)

Notes:

If error is made during data run, note error on run sheet, and inform data reduction personnel.

Turn balance cooling water off when not needed to prevent water from condensing on balance.

See Input Description (pages 25-30) in Section II for definition of terms.

Digital Channel (DCH) Input

Digital Channel	Designation	Input	Remarks
DCH 1	TEST	XXXX.	
DCH 2	RUN	XXXX.	
DCH 6	ALPHA BAL ID AND PREF BP	1.XXXX or 2.XXXX	1 = α', 2 = θ
DCH 7	CONF	XXXX.	
DCH 8	CONF	XXXX.	
DCH 9	BETA	XX.XX	
DCH 10	ALPHA BAL	XX.XX	α' or θ

1. Remove 1 or 2 in first digit that was there for attitude or reference run number (XXXX), advance run number, and enter 1 or 2 in first digit of DCH6. Normally 2 is used (2XXX) for the support and sting system currently in use. That is, model longitudinal axis and support axis are in same plane and BETA is set by rotating the support system. (1XXX) is used when BETA is set by bending the sting (model longitudinal axis is at sideslip angle to support pitch plane). Set in configuration (CONF) in DCH7 and 8 and BETA angle in DCH9.

2. Get Beckman control.

3. Turn on balance water at same setting as attitude-tare run.

4. Set base pressure transducers at expected reference value and dial value in last three digits of DCH6 (1.XXX) or (2.XXX). If zeros are dialed in DCH 6 (X.000) then the last reference value taken in previous run will be used.

5. Take data zero at ALPHA BAL = 0° (wind off). For sensitive balance take data zero with tunnel pumped down to tunnel static pressure value.

6. Turn balance water off.

7. Record balance zeros from digital voltmeter.

8. Set model at ALPHA MOD = 0°. ALPHA MOD = ALPHA BAL + ALPHA ZERO. If ALPHA ZERO is large set model at ALPHA BAL = 0°.

9. Start tunnel (operate visicorder if model not to be injected).

10. Turn balance water on (approximately 20 percent open).

11. Inject model (operate visicorder) and inject Mach probe.

12. Open pinchbar to BP and PR transducers and close pinchbar to manifold.

13. Observe stagnation pressure and temperature.

14. When using the Mach number probe, first and last data points of each run with wind-on must be with Mach probe in tunnel. Probe may be left in tunnel or reinjected into the tunnel any number of times during a run. Mach number will be computed for the points when the probe is in the tunnel and interpolated for frames when the probe is not in tunnel.

15. Normally start a ALPHA MOD = 0°, if not possible then start at ALPHA BAL = 0°, go to the lowest ALPHA BAL dial in ALPHA BAL in DCH10 (XX.XX) and take single frame at each ALPHA BAL in ascending order. Final data point will be at ALPHA MOD = 0°. For runs to vacuum sphere it may be better to start at highest ALPHA BAL and come down. (Use vacuum sphere when possible even if test program is lengthened).

16. Monitor digital voltmeter at each ALPHA BAL to assure that the base pressure settles out (BP normally settled by the time ALPHA BAL set).

17. Inject probe if not already in tunnel and take single frame data.

18. If the model is to be run through an angle-of-attack range at another sideslip angle, push finish switch, advance run number and dial in new BETA angle. Get Beckman control, inject probe if not already in tunnel, take single frame data, run through angle-of-attack range, take final probe single frame and continue run procedure. (You will need to make separate run if using vacuum sphere since run time is limited to approximately one minute).

19. Close pinchbar to model.

20. Withdraw model (operate visicoder).

21. Unstart tunnel (operate visicoder if model not retracted).

22. Push finish switch.

23. Turn balance water off.

24. Record balance zeroes from digital voltmeter with ALPHA BAL = 0°.

25. Turn balance water on if balance heats up between runs.

26. Change run number, configuration, and BETA.

27. Notify Beckman of next run number and approximate time of next run.

F. BASE PRESSURE DATA RUN (3XXX RUN).

The purpose of this type of run is to obtain base pressures on models where component changes will have a negligible effect on base flow. These base pressures will be applied to subsequent force data runs. The procedure is the same as the force data runs with the exception that a 3 is dialed in DCH2 (3XXX).

SECTION II - DATA REDUCTION

G0590 20 - INCH TUNNEL FORCE PROGRAM

In brief, the program converts Beckman counts to millivolts, corrects for gage voltage fluctuations, and computes the temperature and various pressures, forces, and moments. The stagnation pressure and temperature are used to calculate Mach number, free stream static and dynamic pressures, and Reynolds number per foot. Next the correct angles (angle of attack, side-slip, and roll) are calculated. The forces and moments are corrected for interactions, initial and attitude tares, and base pressures if desired. They are in turn transferred and rotated through the various angles. Final coefficients are computed for the body and stability axis systems. Center of pressure, trim and stability data are then computed. A more detailed discussion including equations and input and output definitions are in the following sections. Input and output are in U.S. customary units.

I. INPUT DESCRIPTION

A. DIGITAL INPUT (Page 47)

Item	Digital Channel	Description
TEST	1 (all runs)	Test number (XXXX)
RUN	2 (all runs)	Run number (XXXX, 1XXX, 2XXX, or 3XXX)
PREF BP	6 (reference and data run)	Reference pressure for base pressure transducers (X.XXX), psia
PREF PR	7 (reference run)	Reference pressure for Mach number probe (XX.XX), psia
PREF PT	8 (reference run)	Reference pressure for stagnation pressure transducers (XXXX.), psia
DELTA PHI MOD ($\Delta\phi_{MOD}$)	7 (attitude run)	Small misalignment roll angle of model added to PHI MOD NOM, (XX.XX), deg. Positive clockwise (cw) looking upstream and measured from vertical (top center = 0°). See fig 4(b), pp. 17.
DELTA PHI BAL ($\Delta\phi_{BAL}$)	8 (attitude run)	Small misalignment roll angle of balance added to PHI BAL NOM, (XX.XX), deg. Positive cw looking upstream and measured from vertical (top center = 0°). See fig 4(b), pp 17.

ALPHA ZERO (α_0)	9 (attitude run)	Angle from balance centerline to model centerline XX.XX, deg. Positive when model centerline rotated up relative to balance centerline. See fig. 4(a), pp 16 and "Note", pp 7.
ALPHA BAL (α_{BAL})	10 (attitude and data run)	Uncorrected angle of attack of balance (XX.XX), deg. Positive when balance centerline rotated up relative to tunnel centerline. See fig 4(a), pp 16 and "Note", pp 7.
ALPHA BAL ID	6 (data run)	Type of angle of attack dialed in DCH10 (1.XXX or 2.XXX). See pp 33.
BETA (β)	9 (data run)	Angle of sideslip (XX.XX), deg. Positive when balance rotated to left looking upstream. See fig 4(c), pp 16 and "Note" pp 7.

B. CARD INPUT (Pages 49-51)

Item	Location	Description
NORMAL SENS	1	Normal force sensitivity, lbs/mv
AXIAL SENS	2	Axial force sensitivity, lbs/mv
PITCH SENS	3	Pitching moment sensitivity, in-lbs/mv
ROLL SENS	4	Rolling moment sensitivity, in-lbs/mv
YAW SENS	5	Yawing moment sensitivity, in-lbs/mv
SIDE SENS	6	Side force sensitivity, lbs/mv
BP1 SLOPE	7	Base pressure 1 transducer slope, psia/mv
BP2 SLOPE	8	Base pressure 2 transducer slope, psia/mv
BP3 SLOPE	9	Base pressure 3 transducer slope, psia/mv
BP4 SLOPE	10	Base pressure 4 transducer slope, psia/mv
BP5 SLOPE	11	Base pressure 5 transducer slope, psia/mv

Item	Location	Description
BP6 SLOPE	12	Base pressure 6 transducer slope, psia/mv
PROBE 1 SLOPE 5	13	Mach probe Baratron 19 slope for range 5, psia/mv
PROBE 1 SLOPE 6	14	Mach probe Baratron 19 slope for range 6, psia/mv
PROBE 1 SLOPE 7	15	Mach probe Baratron 19 slope for range 7, psia/mv
PROBE 2 SLOPE 5	16	Mach probe Baratron 20 slope for range 5, psia/mv
PROBE 2 SLOPE 6	17	Mach probe Baratron 20 slope for range 6, psia/mv
PROBE 2 SLOPE 7	18	Mach probe Baratron 20 slope for range 7, psia/mv
PT1-1 SLOPE	19	Stagnation pressure tranducer slope, $0 < PT1 < 90$, psia/mv
PT1-2 SLOPE	20	Stagnation pressure transducer slope, $0 < PT1 < 190$, psia/mv
PT1-3 SLOPE	21	Stagnation pressure transducer slope, $0 < PT1 < 290$, psia/mv
PT1-4 SLOPE	22	Stagnation pressure transducer slope, $0 < PT1 < 550$, psia/mv
PT1-1 RANGE	23	Overrides PT1-1 upper limit (if $\neq$ 90), psia
PT1-2 RANGE	24	Overrides PT1-2 upper limit (if $\neq$ 190), psia
PT1-3 RANGE	25	Overrides PT1-3 upper limit (if $\neq$ 290), psia
PT1-4 RANGE	26	Overrides PT1-4 upper limit (if $\neq$ 550), psia
BASE AREA-SB	35	Base pressure reference area, in^2
REF AREA-S	36	Reference area for coefficients, in^2
CHORD-CBAR	37	Reference length for longitudinal moment coefficient, in.
SPAN-B	38	Reference length for lateral and directional moment coefficients, in.

Item	Location	Description
REF LENGTH-LREF	39	Length of model, chord, or diameter of model, in.
CP REF-XREF	40	Distance from model center of gravity (cg) to reference point of center of pressure, in
$\bar{X}$	41	Transfer distance along balance x-axis from balance pitch center (pc) to model cg, in. Positive when cg is aft of pc relative to balance. See fig 4(a), pp 16.
$\bar{Y}$	42	Transfer distance along balance y-axis from balance (pc) to model cg, in. Positive when cg is to right of pc relative to balance when looking upstream. Specify 4(a), pp 16.
$\bar{Z}$	43	Transfer distance along balance z-axis from pc to model cg, in. Positive when cg is below pc relative to balance. See fig 4(a), pp 16.
CG	44	Model center of gravity location relative to model nose, percent body length.
PHI MOD NOM ($\phi_{MOD\ NOM}$)	45	Nominal model roll angle deg. Positive clockwise (cw) looking upstream and measured from vertical (top center = 0°). 0° = model upright, 180° = model inverted, 90° = model rolled 90° cw, -90° = model rolled 90° ccw. See fig 4(b), pp 17.
PHI BAL NOM ($\phi_{BAL\ NOM}$)	46	Nominal balance roll angle deg. Positive cw looking upstream and measured from vertical (top center = 0°) to balance positive normal force. 0° = balance upright, 180° = balance inverted, 90° = balance rotated 90° cw, -90° = balance rotated 90° ccw. See fig 4(b), pp 17.
PHI MOD (ϕ_{MOD})	47	Overrides DELTA PHI MOD (DCH7) + PHI MOD NOM (location 45), deg. Same sign convention as other roll angles.
PHI BAL (ϕ_{BAL})	48	Overrides DELTA PHI BAL (DCH8) + PHI BAL NOM (location 46), deg. Same sign convention as other roll angles.

Item	Location	Description
DELTA ALPHA ZERO ($\Delta\alpha_0$)	49	Added to ALPHA ZERO dialed in DCH9 of attitude run, deg. ALPHA ZERO correct = ALPHA ZERO (DCH9) + DELTA ALPHA ZERO. Positive when model centerline rotated up relative to balance centerline.
DELTA ALPHA ($\Delta\alpha$)	50	Added to ALPH BAL dialed in DCH10 of data run, deg. Same sign convention as ALPHA BAL. ALPHA BAL correct = ALPHA BAL (DCH10) + DELTA ALPHA. Only one value of DELTA ALPHA can be applied per run.
DELTA BETA ($\Delta\beta$)	51	Added to BETA dialed in DCH9 of data run, deg. BETA correct = BETA (DCH9) + DELTA BETA. Positive when balance rotated to left looking upstream. Only one value of BETA can be applied per run.
DELTA BASE (δ_B)	52	Angle between model base and model vertical axis, deg. Positive when base slopes forward. See fig 4(a), pp 16.
COLD JUNCTION	55	Overrides cold junction reference (ACH21) for stagnation temperature, mv.
$\bar{X}$ BASE	56	Transfer distance along balance x-axis from balance pc to centroid of base, in. Positive when centroid is aft of pc relative to balance. See fig 4(a), pp 16.
$\bar{Y}$ BASE	57	Transfer distance along balance y-axis from balance pc to centroid of base, in. Positive when centroid is to right of pc relative to balance when looking upstream. See fig. 4(a), pp 16.
$\bar{Z}$ BASE	58	Transfer distance along balance z-axis from balance pc to centroid of base, in. Positive when centroid is below pc relative to balance. See fig 4(a), pp 16.
XT	60	Distance along tunnel centerline from forward window vertical centerline to model, in. Used to compute difference between Mach number at probe and at model. XT positive when model is upstream of forward window vertical centerline. (x' in Appendix)

Item	Location	Description
CORRECT MACH	61	Corrects computed probe Mach number to obtain Mach number at model using XT. MACH MODEL = MACH PROBE - .0013 XT - .01. YES = 0, NO = 1. Does not correct location 62.
MACH NUMBER	62	Mach number used instead of computed value.
AVG SAMPLES	63	Averages two samples of data for each ACH frame. YES = 0, NO = 1. NO uses first sample only.
CORRECT FOR BP	64	Corrects data for base pressure. YES = 0, NO = 1.
USE BP RUN 3XXX	65	Use base pressure from 3XXX run for subsequent runs. YES = 0, NO = 1.
GV1 CORR-BAL	66	Corrects balance (ACH1-6) for varying gage voltage. YES = 0, NO = 1.
GV2 CORR-BP	67	Corrects BP (ACH7-12) transducers for varying gage voltage. YES = 0, NO = 1. If Baratrons used for BP set = 1.
GV2 CORR-PT1	68	Corrects PT1 (ACH17-20) transducers for varying gage voltage. YES = 0, NO = 1.

II. COMPUTATIONS

A. CONVERSION TO ENGINEERING UNITS (EU)

Conversion from counts (CTS) to millivolts (mV) for all analog channels (ACH) using a gage voltage (GV).

$$mV = \frac{(CTS)(8000)}{(ATTENUATOR)(GV\ in\ CTS)}$$

Above equation corrects for gage voltage fluctuation if locations 66, 67, and/or 68 = 0 on load constant sheet (page 51). Gage voltage for balance (ACH1-6) is in ACH23 and for transducers (ACH7-12, 17-20) is in ACH24. Also the 2 samples of data taken for each ACH at 40/sec are averaged if location 63 = 0 on load constant sheet (page 51).

1. Forces and moments, NF, AF, PM, RM, YM, SF (ACH1 - 6).

$COMP_{EU} = (COMP_{mV} - ZERO_{mV})(SENS)$ $ZERO_{mV}$ - zero value, SENS - component sensitivity constant.

2. Base pressure, BP1-6 (ACH7-12)

(a) Reference pressure (PREF BP), mode 4

Run number = 2XXX, DCH7 and 8 = 0000, DCH6 = PREF = X.XXX. A maximum of 4 different PREFs can be taken. A mV value for each of the 6 BP transducers is stored for each of the PREFs taken and is designated $BPZEROS_{ij}$. The PREF values are also stored as $BPINTC_{ij}$.

Where i = 1-6 is the number of the BP and j = 1-4 is the number of the PREF taken.

(b) Wind-on data (BP), mode 2

A ΔmV_{ij} is computed for each PREF that was taken for each BP transducer. The PREF that gives the smallest ΔmV_{ij} is used as ΔmV_i in the following equation to calculate BP_i.

$$\Delta mV_{ij} = BP_{mV_i} - BPZEROS_{ij}$$

Where BP_{mV_i} is BP data in mVs.

$$BP_i = (\Delta mV_i)(BP\ SLOPE_i) + BPINTC_j$$

3. MACH number probe pressure, PT2 (ACH13-16)

Baratron 20 with range identification (ID) in mVs in ACH15 and reading in ACH 16: Backup Baratron 19, ID in ACH13 and reading in ACH14.

(a) Reference pressure (PREF PR), mode 4

Run number = 2XXX, DCH6 and 8 = 0000, DCH7 = PREF = XX.XX. The ID's (ACH13 and 15) or ACH14 and 16 respectively, are checked to determine the proper range for the reference pressure. The allowable ranges are 5(65 - 75mV), 6(75-85mV), 7(85-95mV). Three PREF may be taken in each range. The PREFs and mV values are designated as:

PROBEZ (1,j,k) = PREF
PROBEZ (2,j,k) = PREF mV value for ACH14
PROBEZ (3,j,k) = PREF mV value for ACH16

where j = 1-3 for ranges 5,6,7, respectively, and k = 1-3 for three separate PREFs for each range.

(b) Wind-on data (PT2), mode 2

For each channel (ACH14 and 16) the program determines the range from its ID (ACH13 or 15). For each PREF of that range a ΔmV_{ijk} is computed as follows,

$$\Delta mV_{ijk} = PT2_{mV_i} - PROBEZ_{ijk}$$

where i = 2, 3 for Baratron 19 or 20, respectively, j = 1-3 for range 5, 6, or 7, and k = 1-3 for the three different PREFs of each range.

The PREF that gives the smallest ΔmV_{ijk} is used as ΔmV_i in the following equation to calculate $PT2_i$.

$$PT2_i = (\Delta mV_i)(PROBE\ SLOPE_{ij}) + PROBEZ_{jk}$$

$PROBEZ_{jk}$ is the PREF corresponding to the mV value used to compute ΔmV_i.

If Baratron 20 (ACH16) is recording, it will be used to compute PT2.

4. Stagnation pressure, PT1 (ACH17-20)

There is a possibility of 1-4 transducers recording PT1. Each transducer has a different range; they are in order 0-90, 0-190, 0-290, and 0-550 psia. The upper limits on the transducers may be changed by using locations 23-26 on constant sheet pages 49 and 50.

(a) Reference pressure (PREF PT1), mode 4

Run number = 2XXX, DCH6 and 7 = 0000, DCH8 = PREF = XXXX. The value of DCH8 is checked against the upper limits of each transducer to determine which transducers the PREF should be applied;

e.g. if DCH8 is less than or equal to 90, the PREF is stored for all transducers; if DCH8 is greater than 290 and less than or equal 550, the PREF is stored for transducer 4 (ACH20) only. A maximum of 6 PREFs can be taken for PT1.

PTIZR (1-6,1) contain the PREF mV values.
PTIZR (1-6,2) contain the PREF values.
ICHANPT (1-4) contains the lowest channel number to which the mV values and the PREFs can be applied.

(b) Wind-on data (PT1), mode 2

For each transducer the array of channel numbers is searched to find which PREFs apply to that transducer. For each PREF applying to a transducer a ΔmV_{ij} is computed.

$$\Delta mV_{ij} = PT1_{mV_i} - PTIZR_{ij}$$

where i = 1-4 for the number of the transducer and j = 1-6 for the number for the PREF.

The PREF that gives the smallest value of ΔmV_{ij} is used as ΔmV_i in the following equation to calculate $PT1_i$

$$PT1_i = (\Delta mV_i)(PT1\ SLOPE_i) + PT1ZR_j$$

After the pressure for each PT1 transducer that is in range has been computed, the program takes the difference between the pressure for each transducer and the pressure for the transducer with the next highest range. The first transducer for which the difference is less than or equal to 20 will be used as the value of PT1. Or if no difference is less than 20, the transducer with the highest range is used.

5. Stagnation temperature, TT1 (ACH22)

The stagnation temperature mV value is calculated as follows:

$$TT1_{mV} = ACH22_{mV} + COLD\ JUNCTION_{mV}.$$

Where cold junction mV value is either recorded in ACH21 or input in location 55 on constant sheet page 50.

Using the IRON CONSTANTAN THEMOCOUPLE table, a slope and intercept are found corresponding to $TT1_{mV}$ and inserted in the following equation to calculate TT1.

$$TT1\ (deg.\ R) = (TT1_{mV})(SLOPE) + INTERCEPT + 459.6$$

B. COMPUTATION OF TUNNEL PARAMETERS

1. Probe Mach number (MACH PROBE)

There are three possible ways of computing MACH PROBE.

(a) If the probe remains in the tunnel during the run the ratio PT2/PT1 is interpolated in the Ames Tables to find the corresponding value of MACH PROBE if location 62 = 0 on the load constant sheet page 51.

(b) If the probe is being inserted and removed during the run the program will read data tape; find the record of the probe-in data corresponding to the current run and using the current time and the values from the tape, interpolate to find PT2 for each frame. Then the ratio PT2/PT1 is interpolated in the Ames Table to find MACH PROBE if location 62 = 0.

(c) If location 62 ≠ 0 and Mach number is given on page 51, then MACH PROBE = location 62 and is called MACH.

2. Model Mach number (MACH MODEL)

The probe Mach number (MACH PROBE) can be corrected to any axial position in the tunnel by setting location 61 = 0 and applying XT (location 60) as follows;

MACH MODEL = MACH PROBE - (XT)(0.0013) - 0.01

This correction is not applied if the Mach number value is given in location 62 or location 61 = 1 on constant sheet page 51.

3. Pitot pressure (PT2)

After the Mach number has been given, computed, interpolated, and/or corrected, PT2 is recomputed for all frames using the following equation.

$$PT2 = \left(\frac{6M^2}{M^2 + 5}\right)^{7/2} \left(\frac{6}{7M^2 - 1}\right)^{5/2} (PT1)$$

where M = MACH, MACH PROBE, or MACH MODEL

4. Free-stream static pressure (PTS) and dynamic pressure (Q)

PTS and Q are computed using M = MACH, MACH PROBE, or MACH MODEL in the following equation.

$$PTS = (1 + 0.2M^2)^{-7/2}(PT1)$$

$$Q = (0.7M^2)(PTS)$$

5. Reynolds number per foot (R/FT)

$$(R/FT) \times 10^{-6} = \frac{(4943.61388)(M)(PT1)}{(TT1)^{3/2}(1+0.2M^2)^2}$$

An average Reynolds number for a complete run is also computed.

6. Base pressure force correction (BPCORR)

An average base pressure (BPAVG) is computed from the total number of base pressures taken. From this average, a base pressure coefficient (BPCOEF) and the base pressure force correction (BPCORR) are computed using the following equations.

BPCOEF = (BPAVG - PTS)/Q
BPCORR = (BPAVG - PTS)SB

The pressure coefficient BPCOEF is used only for printing. BPCORR is used to compute the effect of base pressure on the 6 balance components. The base pressure force coefficient along the model x-axis CAB is also printed.

$$CAB = - [(BPAVG - PTS)(SB)(\cos\delta_B)]/[(Q)(S)] = - [(BPCORR)(\cos\delta_B)]/[(Q)(S)]$$

The base pressure correction will always be computed if there are base pressures but it will only be applied if location 64 = 0 on the load constant sheet on page 51.

C. INITIAL TARES AND ATTITUDE LOADS

Initial tare and attitude loads are recorded with a run number of 1XXX. On encountering a mode 4 of run 1XXX the program will set a switch that void any former tares or attitude loads. Following the mode 4 should be a number of frames (maximum 25) of mode 2 at different ALPHA BAL values. Note: One of the mode 2's must have the same value of ALPHA BAL as the mode 4. For a tare run, DCH7, 8, 9, and 10 must be set appropriately.

1. Initial tares. To compute initial tares the program uses the mode 4 which is a balance alone frame and the mode 2 at the same ALPHA BAL value with the model on the balance.

$$\text{INITIAL TARE (uncorrected)}_i = (\text{Mode2}_i - \text{Mode4}_i)(\text{SENS}_i)$$

where i = 1-6 for the six balance components.

The program uses subroutine INTR to remove interactions from the initial tares. The resulting values are used in INTR to correct attitudes and wind-on data.

2. Attitude loads. Each point (ATT_{my}) in the attitude load table has a corresponding ALPHA BAL. The mode 4 with balance alone is used as the zero for computing attitudes loads as follows:

ALPHA BAL = DCH10

$\text{ATTITUDE LOAD (uncorrected)}_i = (\text{ATT}_{mV} - \text{ATTZERO}_{mV})(\text{SENS}_i)$

where i = 1-6 are the six balance components and SENS is the component sensitivity constant.

Each point of the attitude loads table is passed through INTR and corrected for interactions and initial tares. To facilitate the interpolation of attitude loads between given values of ALPHA BAL, the ALPHA BALs are arranged in ascending order, indexed by k and stored in the following arrays (ATTK1 and ATTK2) for each component (COMP).

$$\text{ATTK1}_{k,j} = (\text{COMP}_{k+1,j} - \text{COMP}_{k,j})/(\text{ALPHA BAL}_{k+1} - \text{ALPHA BAL}_k)$$

$$\text{ATTK2}_{k,j} = \text{COMP}_k - (\text{ATTK1}_{k,j})(\text{ALPHA BAL})_k$$

The attitude load for any ALPHA BAL for a wind-on point is obtained from the following equation;

$$\text{ATTITUDE LOAD}_{k,j} = (\text{ALPHA BAL}_{\text{wind-on}})(\text{ATTK1}_{k,j}) + \text{ATTK2}_{k,j}$$

where k = 1-25 is the frame number and j = 1-6 is the balance component.

D. ANGLES

All angle load constants, (location 45 thru 51) are listed on constant sheet page 51.

1. Angle of attack (ALPHA CORR = α_c)

The corrected angle of attack ALPHA CORR is as follows;

$\alpha_c = \tan^{-1}(Z/X)$ where

$$Z = [(\cos\phi_{MOD})(\sin(\theta + \alpha_o))(\cos\beta') - (\sin\phi_{MOD})(\sin\beta')]\cos\alpha' + [(\cos\phi_{MOD})(\cos(\theta + \alpha_o))]\sin\alpha'$$

$$X = [(\cos(\theta + \alpha_o))(\cos\beta')(\cos\alpha')] - [(\sin(\theta + \alpha_o))(\sin\alpha')]$$

and α_o, α', θ, β', and ϕ_{MOD} are defined below.

ALPHA ZERO = α_o = DCH9 + location 49. Angle of attack between balance and model axis recorded in DCH9 of attitude run.

α' = DCH10. Pitch angle of support when it pitches in the plane of symmetry of the tunnel.

θ = DCH10. Pitch angle of balance when support pitches in plan of symmetry of model.

If the left-most digit in DCH6 is 1; $\theta = 0°$ and α' = DCH10 + location 50.

If the left-most digit in DCH6 is 2; $\alpha' = 0°$ and θ = DCH10 + location 50.

2. Angle of sideslip (BETA CORR = β_c)

The corrected angle of sideslip BETA CORR is,

$$\beta_c = \sin^{-1} \{[(\sin \phi_{MOD})(\sin(\theta + \alpha_o))(\cos \beta') + (\cos \phi_{MOD})(\sin \beta')] \cos \alpha' + [(\sin \phi_{MOD})(\cos (\theta + \alpha_o))] \sin \alpha'\}$$

β' = DCH9 + location 51. Angle between balance X-axis and plane of symmetry of tunnel.

3. Angle of roll (PHI MOD, PHI BAL, PHI PRIME).

PHI MOD = ϕ_{MOD} = DCH7 from attitude run + location 45. PHI MOD may be over-ridden by location 47.

PHI BAL = ϕ_{BAL} = DCH8 from attitude run + location 46. PHI BAL may be over-ridden by location 48.

PHI PRIME = $\phi' = \phi_{MOD} - \phi_{BAL}$. Angle of roll of model about balance X-axis relative to NF of balance.

E. FORCE AND MOMENT COEFFICIENTS

The program expects one six-component balance with NF = normal force, AF = axial force, PM = pitching moment, RM = rolling moment, YM = yawing moment, and SF = side force in ACH1-6.

1. Conversion to engineering units

$$COMP_{EU_i} = (COMP_{mV_i} - ZERO_{mV_i})(SENS_i)$$

where $ZERO_{mV_i}$ is from the most recent mode 4 and i = 1-6 balance components.

2. Removal of interactions

Subroutine INTR is called. By using the previously calculated initial tares and the interaction array supplied by input cards the interactions are removed from each component as follows:

$$COMP_{CI_i} = [COMP_{EU_i} + \text{Corrected initial tare}_i] - [\text{Final epsilon of combined value}_i - \text{Final epsilon initial tare}_i] - [\text{Corrected initial tare}_i].$$

where i = 1-6 balance components.

3. Correction for attitude loads

Using DCH10 of the current record as ALPHA BAL, a table lookup is done to find an ALPHA BAL in the array of tare points that is greater than or equal to the ALPHA BAL of the current record. The program then interpolates to find the attitudes for the current value and subtracts them from the forces and moments.

$$ATT_i = (ATTK1_{k,i})(ALPHA\ BAL) + ATTK2_{k,i}$$

where i = 1-6 balance components and k = index of first attitude angle greater than or equal to ALPHA BAL. Then the component corrected for attitude loads is;

$$COMP_{CA_i} = COMP_{CI_i} - ATT_i$$

4. Correction for base pressure

The balance components are corrected for base pressure effects $\Delta COMP_{BP_i}$ in the following manner.

$$\Delta NF_{BP} = -(\cos\phi')(\sin(\alpha_o - \delta_B))(BPCORR)$$

$$\Delta AF_{BP} = (\cos(\alpha_o - \delta_B))(BPCORR)$$

$$\Delta PM_{BP} = -(\Delta NF_{BP})(\bar{X}\ BASE) - (\Delta AF_{BP})(\bar{Z}\ BASE)$$

$$\Delta RM_{BP} = -(\Delta NF_{BP})(\bar{Y}\ BASE) + (\Delta SF_{BP})(\bar{Z}\ BASE)$$

$$\Delta YM_{BP} = -(\Delta SF_{BP})(\bar{X}\ BASE) + (\Delta AF_{BP})(\bar{Y}\ BASE)$$

$$\Delta SF_{BP} = -(\sin\phi')(\sin(\alpha_o - \delta_B))(BPCORR)$$

where BPCORR = (BPAVG - PTS)(SB) and the load constants from page 50 are SB = location 35, δ_B = location 52, $\bar{X}$ BASE = location 56, $\bar{Y}$ BASE = location 57, and $\bar{Z}$ BASE = location 58. The corrected components are:

$$COMP_{BP_i} = COMP_{CA_i} + COMP_{\Delta BP_i}$$

where i = 1-6 balance components

$$NF_{BP} = NF_{CA} + \Delta NF_{BP}$$

$$AF_{BP} = AF_{CA} + \Delta AF_{BP}$$

$$PM_{BP} = PM_{CA} + \Delta PM_{BP}$$

$$RM_{BP} = RM_{CA} + \Delta RM_{BP}$$

$$YM_{BP} = YM_{CA} + \Delta YM_{BP}$$

$$SF_{BP} = SF_{CA} + \Delta SF_{BP}$$

5. Rotate forces and moments through PHI PRIME from balance to model axis.

$$NF_P = (NF_{BP})(\cos \phi') + (SF_{BP})(\sin \phi')$$

$$AF_P = AF_{BP}$$

$$PM_P = (PM_{BP})(\cos \phi') + (YM_{BP})(\sin \phi')$$

$$RM_P = RM_{BP}$$

$$YM_P = (YM_{BP})(\cos \phi') - (PM_{BP})(\sin \phi')$$

$$SF_P = (SF_{BP})(\cos \phi') - (NF_{BP})(\sin \phi')$$

6. Transfer moments to reference point (CG).

$$PM_T = PM_P + (\bar{X})(NF_P) + (\bar{Z})(AF_P)$$

$$RM_T = RM_P + (\bar{Z})(SF_P) + (\bar{Y})(NF_P)$$

$$YM_T = YM_P + (\bar{X})(SF_P) - (\bar{Y})(AF_P)$$

7. Rotate forces and moments through initial angle of attack (ALPHA ZERO) to body axis.

$$NF_B = (NF_P)(\cos \alpha_o) + (AF_P)(\sin \alpha_o)$$

$$AF_B = (AF_P)(\cos \alpha_o) - (NF_P)(\sin \alpha_o)$$

$$PM_B = PM_T$$

$$RM_B = (RM_T)(\cos \alpha_o) - (YM_T)(\sin \alpha_o)$$

$$YM_B = (YM_T)(\cos \alpha_o) + (RM_T)(\sin \alpha_o)$$

$$SF_B = SF_P$$

8. Compute body axis coefficients

$$CN_B = NF_B/[(Q)(S)]$$

$$CA_B = AF_B/[(Q)(S)]$$

$$CM_B = PM_B/[(Q)(S)(\bar{C})]$$

$$CR_B = RM_B/[(Q)(S)(B)]$$

$CY_B = YM_B/[(Q)(S)(B)]$

$CS_B = SF_B/[(Q)(S)]$

where Q = dynamic pressure, S = location 36, $\bar{C}$ = location 37, and B = location 38, from load constant sheet page 50.

9. Rotate to stability axis.

$CL = (CN_B)(\cos \alpha_c) - (CA_B)(\sin \alpha_c)$

$CD = (CA_B)(\cos \alpha_c) + (CN_B)(\sin \alpha_c)$

$CM_S = CM_B$

$CR_S = (CR_B)(\cos \alpha_c) + (CY_B)(\sin \alpha_c)$

$CY_S = (CY_B)(\cos \alpha_c) - (CR_B)(\sin \alpha_c)$

$CS_S = CS_B$

10. Center of pressure (XCP LONG AND XCP DIR)

The longitudinal center-of-pressure location is;

$XCP\ LONG = SRED/LREF - [(CM_B)(\bar{C})]/[(CN_B)(LREF)]$

and the directional center-of-pressure location is;

$XCP\ DIR = XREF/LREF - [(CY_B)(B)]/[(CS_B)(LREF)]$(computed only if $\beta_c \neq 0$)

where XREF = location 40 and LREF = location 39 from load constant sheet page 50.

11. Maximum values (CL MAX, L/D MAX, CL AT L/D MAX, and ALP AT L/D MAX)

A least squares fit of order 5 is made to obtain a curve of CL/CD vs $\alpha = \alpha_c$. L/D MAX and ALP AT L/D MAX are obtained at a critical point on this curve. A second curve of CL vs α is generated to find CL MAX. CL AT L/D MAX is also obtained from this curve at α = ALP AT L/D MAX.

Note: If the data do not have sufficient definition near the critical points, their values may be of questionable value.

12. Trim data (ALPHA T, CL T, CD T, L/D T, and DCM/DCL T and DCM/DCH T AT CM = 0

Piecewise linear curves of CM vs α, CM vs CL, and CM vs CD are used to obtain ALPHA T, CL T, and CD T for each CM = 0. At each CM = 0, CL/CD T or L/D T is computed providing CM = 0 is not an end point.

The slope of DCM/DCN T is also computed at CM = 0 on the CM vs CN curve. If the CM = 0 is at an end point then DCM/DCL T and DCM/DCN T are set equal to 0.

13. Stability data (CL ALPHA, CN ALPHA, CM ALPHA and DCM/DCN AT ALPHA = 0°)

Using only selected points with $|\alpha| < 3.5°$ a linear least square fit is made to describe each of CL vs α, CN vs α, CM vs α, and CM vs CN by a line. CL ALPHA, CN ALPHA, CM ALPHA, and DCM/DCN are the slopes of each of the respective lines.

F. PROGRAM OPTIONS

These options are handled by the data reduction personnel only at the request of the engineer.

1. Omit whole runs or certain frames of a run.
2. Process several series of runs. A reference pressure and attitude run must precede first data run of each series.
3. Raw mV listing or card input listing may be omitted.
4. Raw Beckman counts may be listed instead of mV.
5. Test title may be changed for any run.
6. Extra copies of output listing can be made.
7. Extra computations (trim data, CL_{MAX}, etc.).
8. Check point (run and frame).
9. Any DCH or ACH mV reading may be changed (added to, subtracted from, multiplied by, or divided by a constant). Only one frame at a time.
10. Type of run can be changed (1XXX to 2XXX, 1XXX or 2XXX to XXX, etc.).
11. If data obtained before 5-14-76 is reprocessed inform data reduction personnel so angle of attack will be handled correctly.

III. OUTPUT DESCRIPTION

TEST	test number
RUN	run number
AVG R/FT	average free-stream Reynolds number per foot
CG	center-of-gravity location, percent body length
FRAME, FRM	frame number (data has been averaged for both samples per frame) - 4XX frame is with Mach probe in tunnel when probe is operated in the inject and retract mode
Q	free-stream dynamic pressure, psia
MACH PROBE	uncorrected probe Mach number

MACH MODEL	corrected Mach number
PT1	stagnation pressure, psia
PT2	Mach number probe (pitot) pressure, psia
TT1	stagnation temperature, °R
R/FT	free-stream Reynolds number per foot
CAB	base pressure force coefficient along model X-axis
TIME	time, sec
DCH6-DCH8	Beckman digital channels (DCH6-ALPHA BAL IDENTIFICATION and PREF BP, DCH7 and 8 - CONFIGURATION)
BETA	angle of sideslip, deg.
ALPHA	corrected angle of attack, deg.
CN	normal force coefficient
CA	axial force coefficient
CM	pitching moment coefficient
CL	lift coefficient
CD	drag coefficient
L/D	lift-to-drag ratio
CROLL B	rolling moment coefficient (body axis)
CYAW B	yawing moment coefficient (body axis)
CSIDE B	side force coefficient (body axis)
CROLL S	rolling moment coefficient (stability axis)
CYAW S	yawing moment coefficient (stability axis)
CSIDE S	side force coefficient (stability axis)
XCP/LONG	longitudinal center of pressure
SCP/DIR	directional center of pressure
BPCOEFF	average base pressure coefficient

BP1 - BP6	base pressure, psia
BP AVG	average base pressure, psia
CL MAX	maximum lift coefficient
L/D MAX	maximum lift-to-drag ratio
CL AT L/D MAX	lift coefficient at maximum lift-to-drag ratio
ALP AT L/D MAX	angle of attack at maximum lift-to-drag ratio, deg.
CL ALPHA	slope of lift coefficient versus angle of attack at zero angle of attack, per degree
CN ALPHA	slope of normal force coefficient versus angle of attack at zero angle of attack, per degree
DCM/DCN	slope of pitching moment coefficient versus normal force coefficient at zero angle of attack or zero pitching moment
CM/ALPHA	slope of pitching moment coefficient versus angle of attack at zero pitching moment, per degree
DCM/DCL	slope of pitching moment coefficient versus lift coefficient at zero pitching moment
ALPHA T	value of angle of attack at trim, deg.
CL T	value of lift coefficient at trim
CD T	value of drag coefficient at trim
L/D T	value of lift-to-drag ratio at trim

NF	normal force, lb	corrected for interactions, attitudes, and tares
AF	axial force, lb	
PM	pitching moment, in-lb	
RM	rolling moment, in-lb	
YM	yawing moment, in-lb	
SF	side force, lb	

Data Reduction Turn-Around Time

In order to decrease data reduction turn-around time the following steps must be taken:

1. Engineers should supply Request for Data Reduction Support form and Beckman set-up sheets to ACD data reduction personnel at least one week (earlier if possible) before start of test program.

2. Notify data reduction personnel as soon as possible if quick turn-around (3-4 hours) is necessary and for what runs and channels.

3. Check with data reduction personnel if data is late in delivery. Do not notify contract personnel.

4. Keep up with data reduction programs. Do not wait more than two days before contacting data reduction personnel.

5. Inform Branch Head if data reduction falls behind on your test and keep <u>brief</u> records of how much time.

DATA REDUCTION INPUT SHEETS

Copies of all data reduction and plotting input sheets are located in the 20-inch tunnel control room.

REQUEST FOR ACD DATA REDUCTION SUPPORT (Page 46)

1 - Standard form used for ACD support for all types of testing.

BECKMAN SETUP SHEET - DIGITAL CHANNEL INPUTS - SHEET 1 (Page 47)

1 - Shows digital channel inputs for reference pressure run, attitude-tare run, and force data run.

2 - Specifies facility data, test number, balance number, balance calibration date, number of runs, number of Beckman channels (N), and test title. Also specifies configuration code for data runs (DCH7 and 8).

BECKMAN SETUP SHEET - ANALOG CHANNELS - SHEET 2 (Page 48)

1 - Shows analog channel locations for balance components, base pressure transducers, Mach probe Baratrons, stagnation pressure and temperature, reference temperature, and gage voltage for the balance and transducers.

2 - Specifies mV. range for balance components (12.5 mV.), Baratrons (100 mV.), stagnation temperature (25 mV.) and reference temperature (12.5 mV.). The gage voltages GV 1 (12.5 mV.) and GV 2 (25 mV.) are set to read 10 mV. and 20 mV., respectively, on the digital voltmeter. MV ranges for the base pressure and stagnation pressure transducers must be specified for each test. (Note: The stagnation pressure transducers are protected by gage savers and cannot sense full scale pressure.)

20-INCH TUNNEL FORCE PROGRAM CARD INPUTS. SHEET 3, 4, and 5 (Pages 49-51)

1 - Specifies balance number and calibration date, test number, and run number for card input. Cards not used should be left blank.

2 - A description of the card inputs is in "G0590-20INCH TUNNEL FORCE PROGRAM - INPUT DESCRIPTION" (Pages 25-30).

REQUEST FOR ACD
DATA REDUCTION SUPPORT

FACILITY NAME ______________ ORGANIZATION CODE __________ DATE __________

PROJECT ENGINEER ______________________ PHONE __________

PROJECT OR TEST NUMBER __________ TENTATIVE TEST DATE ______ TO __________

JOB ORDER __________ ESTIMATED RUNS OR POINTS __________

ACCOUNT NO. __________

PROJECT OR TEST TITLE ____

CLASSIFICATION: UNCLASSIFIED ☐ CONFIDENTIAL ☐ SECRET ☐

TYPE OF TEST	CHARACTERISTICS	
FORCE ☐	QUANTITIES ONLY ☐ COEFFICIENTS ☐ OTHER ________ ☐	BASE PRESSURE ☐ INTERNAL DRAG ☐ BALANCE NUMBER ________
PRESSURE ☐	QUANTITIES ONLY ☐ INTEGRATIONS ☐ COEFFICIENTS ☐	TRANSDUCER TYPE — NUMBER INDIVIDUAL GAGES ☐ ________ SCANIVALVES ☐ ________ OTHER ________ ☐ ________
TEMPERATURE ☐	QUANTITIES ONLY ☐ HEAT TRANSFER COEF. ☐	THERMOCOUPLE ☐ ________ THERMISTOR ☐ ________ OTHER ________ ☐ ________
DYNAMIC ☐	QUANTITIES ONLY ☐ TIME SERIES ANALYSIS ☐ OTHER ________ ☐	TYPE OF MODULATION DIRECT ☐ FM/FM ☐ PAM/PDM ☐ PCM ☐

RECORDING SYSTEM ______________ NUMBER OF CHANNELS ______ ON-LINE ☐

INPUT: CARDS ☐ COMPUTER COMPATIBLE TAPE ☐ OTHER ________

OUTPUT: TABULATED ☐ NO. OF COPIES ______ PLOTS ☐ CALCOMP ☐

TAPE ☐ TRANSMITTAL TAPE ☐ DDI HARDCOPY ☐

DDI FILM ☐

PROCESSING INSTRUCTIONS ATTACHED ☐
DATA REDUCTION REQUIREMENTS DOCUMENT:
ATTACHED ☐ TO FOLLOW ☐ DATE ________

SUPERVISOR APPROVAL ______________

DATE ______________

G0590 - 20 INCH TUNNEL FORCE PROGRAM

BECKMAN SETUP SHEET - DIGITAL CHANNEL INPUTS SHEET 1 OF____

PROJ. ENGR.____________________ REVISION YES____NO__________

FAC.__________PHONE____________ DATE____________________

BLDG.__________ROOM____________ JOB ORDER________________

TEST__________BALANCE__________ BALANCE CALIB. DATE__________

DATA RUN________TO____________ N(40/SEC)________________

TEST TITLE	$		$

DIGITAL CHANNEL INPUT FOR EACH TYPE OF RUN

REFERENCE PRESSURE RUN (2XXX)

DIGITAL CHANNEL	VARIABLE NAME	UNITS NAME	INPUT		
			BASE PRESS.	MACH PROBE	STAG. PRESS.
D 6	PREF BP	PSIA	X.XXX	0000	0000
D 7	PREF PR	PSIA	0000	XX.XX	0000
D 8	PREF PT	PSIA	0000	0000	XXXX.
D 9	------	----	0000	0000	0000
D 10	------	----	0000	0000	0000

ATTITUDE TARE RUN (1XXX)
(DCH 6 MAY BE USED FOR CONFIGURATION CODE)

DIGITAL CHANNEL	VARIABLE NAME	UNITS NAME	INPUT	REMARKS
D 6			XXXX.	
D 7	DELTA PHI MOD	DEG.	XX.XX	
D 8	DELTA PHI BAL	DEG.	XX.XX	
D 9	ALPHA ZERO	DEG.	XX.XX	
D 10	ALPHA BAL	DEG.	XX.XX	α´ or θ

FORCE DATA RUN (XXXX)
(USE DCH 7 & 8 FOR CONFIGURATION CODE AND DCH 6
FOR ALPHA BAL IDENTIFICATION AND PREF BP IN LAST 3 DIGITS)

DIGITAL CHANNEL	VARIABLE NAME	UNITS NAME	INPUT	REMARKS
D 6	ALPHA BAL ID & PREF BP		1.XXX or 2.XXX	1=α´, 2=θ
D 7			XXXX.	
D 8			XXXX.	
D 9	BETA	DEG.	XX.XX	β
D 10	ALPHA BAL	DEG.	XX.XX	α´ or θ

ACD USE

DATA PROCESSING REVIEW____________________DATE__________
CENTRAL DATA RECORDING____________________DATE__________
CENTRAL DATA PROCESSING___________________DATE__________

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G0590 - 20-INCH TUNNEL FORCE PROGRAM
BECKMAN SETUP SHEET - ANALOG CHANNELS

FACILITY NO. ______ TEST NO. ______ RUN ____ TO ____ J.O. ______ DATE ________

ANALOG		OUTPUT		INSTRUMENTATION	REMARKS
CHAN-NEL	RAN-GE	VARIABLE	UNITS		
A 1	12.5	NORMAL FORCE	LBS.	Balance	
A 2	12.5	AXIAL FORCE	LBS.	Balance	
A 3	12.5	PITCHING MOMENT	IN LBS	Balance	Balance No. ______
A 4	12.5	ROLLING MOMENT	IN LBS	Balance	
A 5	12.5	YAWING MOMENT	IN LBS	Balance	Calib. Date ______
A 6	12.5	SIDE FORCE	LBS.	Balance	
A 7		BASE PRESS BP1	PSIA	Transducer or Baratron	Circle instrument used
A 8		BASE PRESS BP2	PSIA	Transducer or Baratron	Circle instrument used
A 9		BASE PRESS BP3	PSIA	Transducer or Baratron	Circle instrument used
A 10		BASE PRESS BP4	PSIA	Transducer or Baratron	Circle instrument used
A 11		BASE PRESS BP5	PSIA	Transducer or Baratron	Circle instrument used
A 12		BASE PRESS BP6	PSIA	Transducer or Baratron	Circle instrument used
A 13	100	MACH PROBE ID -1	MV	Baratron	Baratron, No. 19
A 14	100	MACH PROBE PT2-1	PSIA	Baratron	Baratron, No. 19
A 15	100	MACH PROBE ID -2	MV	Baratron	Baratron, No. 20
A 16	100	MACH PROBE PT2-2	PSIA	Baratron	Baratron, No. 20
A 17		STAG PRESS PT1 - 1	PSIA	Transducer	Range, 0<PT1<90 PSIA
A 18		STAG PRESS PT1 - 2	PSIA	Transducer	Range, 0<PT1<190 PSIA
A 19		STAG PRESS PT1 - 3	PSIA	Transducer	Range, 0<PT1<290 PSIA
A 20		STAG PRESS PT1 - 4	PSIA	Transducer	Range, 0<PT1<550 PSIA
A 21	12.5	STAG TEMP REF	MV	32^{o}F cold junction	Iron Constantan
A 22	25	STAG TEMP TT1	DEGR	Thermocouple	Iron Constantan
A 23	12.5	GAGE VOLT GV1	MV	Balance power supply	Used for ACH 1-6
A 24	25	GAGE VOLT GV2	MV	Transducer power supply	Used for ACH 7-12, 17-20

Note: Baratrons do not have gage voltage through Beckman

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G0590 - 20-INCH TUNNEL FORCE PROGRAM

BAL. NO. ________ TEST ________ ENG. ____________

BAL. CALIB. DATE ________ RUN _____ TO _____ J.O. ______

Key punch instructions: Punch cards with numbers in VALUE only. Punch everything but REMARKS.

Location	VALUE		CONSTANT NAME	UNITS	REMARKS
1		:	NORMAL SENS	lBS/MV	
2		:	AXIAL SENS	lBS/MV	
3		:	PITCH SENS	IN-lBS/MV	
4		:	ROLL SENS	IN-lBS/MV	
5		:	YAW SENS	IN-lBS/MV	
6		:	SIDE SENS	lBS/MV	
7		:	BP1 SLOPE	PSIA/MV	Transducer or Baratron (one range only)
8		:	BP2 SLOPE	PSIA/MV	Transducer or Baratron (one range only)
9		:	BP3 SLOPE	PSIA/MV	Transducer or Baratron (one range only)
10		:	BP4 SLOPE	PSIA/MV	Transducer or Baratron (one range only)
11		:	BP5 SLOPE	PSIA/MV	Transducer or Baratron (one range only)
12		:	BP6 SLOPE	PSIA/MV	Transducer or Baratron (one range only)
13		:	PROBE 1 SLOPE 5	PSIA/MV	Baratron 19
14		:	PROBE 1 SLOPE 6	PSIA/MV	Baratron 19
15		:	PROBE 1 SLOPE 7	PSIA/MV	Baratron 19
16		:	PROBE 2 SLOPE 5	PSIA/MV	Baratron 20
17		:	PROBE 2 SLOPE 6	PSIA/MV	Baratron 20
18		:	PROBE 2 SLOPE 7	PSIA/MV	Baratron 20
19		:	PT1-1 SLOPE	PSIA/MV	Transducer 0-90 psia
20		:	PT1-2 SLOPE	PSIA/MV	Transducer 0-190 psia
21		:	PT1-3 SLOPE	PSIA/MV	Transducer 0-290 psia
22		:	PT1-4 SLOPE	PSIA/MV	Transducer 0-550 psia
23		:	PT1-1 RANGE	PSIA/MV	Overrides Range 1 if ≠ 90 psia
24		:	PT1-2 RANGE	PSIA/MV	Overrides Range 2 if ≠ 190 psia
25		:	PT1-3 RANGE	PSIA/MV	Overrides Range 3 if ≠ 290 psia

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G0590 - 20-INCH TUNNEL FORCE PROGRAM

SHEET 4 OF ____

BAL. NO. ________ TEST ________ ENG. ________

BAL. CALIB. DATE ________ RUN ____ TO ____ J.O. ________

Key punch instructions: Punch cards with numbers in VALUE only. Punch everything but REMARKS.

Location	VALUE		CONSTANT NAME	UNITS	REMARKS
26		:	PT1-4 RANGE	PSIA	Overrides Range 4 if ≠ 550 psia
35		:	BASE AREA - SB	IN^2	For base pressure correction
36		:	REF AREA - S	IN^2	For force and moment coefficients
37		:	CHORD - CBAR	IN	For longitudial moment coefficients
38		:	SPAN - B	IN	For lateral and directional moment coefficients
39		:	REF LENGTH - LREF	IN	Model length, chord, or diameter
40		:	CP REF - XREF	IN	Distance from model cg to cp ref. point
41		:	$\overline{X}$ TRANS	IN	Distance from bal. pc to mod. cg[1]
42		:	$\overline{Y}$ TRANS	IN	Distance from bal. pc to mod. cg[2]
43		:	$\overline{Z}$ TRANS	IN	Distance from bal. pc to mod. cg[3]
44		:	CG	%	cg location in percent model length
45		:	PHI MOD NOM	DEG	Nominal mod. roll angle added to DCH7[5]
46		:	PHI BAL NOM	DEG	Nominal bal. roll angle added to DCH8[6]
47		:	PHI MOD	DEG	Overrides PHI MOD NOM + DCH7
48		:	PHI BAL	DEG	Overrides PHI BAL NOM + DCH8
49		:	DELTA ALPHA ZERO	DEG	Added to DCH9 in attitude run
50		:	DELTA ALPHA	DEG	Added to DCH10[7]
51		:	DELTA BETA	DEG	Added to DCH9 in data run[7]
52		:	DELTA BASE	DEG	Mod. base angle relative to mod. vert. axis[4]
55		:	COLD JUNCTION	MV	Overrides ACH21
56		:	X BASE	IN	Dist. from bal. PC to mod. base centroid[1]
57		:	$\overline{Y}$ BASE	IN	Dist. from bal. PC to mod. base centroid[2]
58		:	$\overline{Z}$ BASE	IN	Dist. from bal. PC to mod. base centroid[3]
60		:	XT	IN	Dist. from window vert. CL to mod.
					Pos. when mod. upstream of window CL

1. + when cg/centroid aft of pc
2. + when cg/centroid to right of pc looking upstream
3. + when cg/centroid below pc
4. + when base slopes forward

(Notes 1–3: Relative to balance axis)

5. Mod. upright (=0°), mod. invert (=180°), mod, rolled 90 cw (=90°) mod. rolled 90° ccw (=-90°) - looking upstream and 0° at top cente of tunnel
6. Bal. angles same as mod. (0°, 180°, 90°, -30°)
7. One value per run

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G0590 - 20-INCH TUNNEL FORCE PROGRAM

BAL. NO. ________ TEST ________ ENG. ____________

BAL. CALIB. DATE __________ RUN ____ TO ____ J.O. ________

Key punch instructions: Punch cards with numbers in VALUE only. Punch everything but REMARKS.

Location	VALUE		CONSTANT NAME	UNITS	REMARKS
61		:	CORRECT MACH	YES = 0, NO = 1	If = 0 uses XT to correct Mach number
62		:	MACH NUMBER		Set = 0 if Mach is to be computed+
63		:	AVG SAMPLES	YES = 0, NO = 1	If = 0 both samples of a frame are averaged. If = 1 only first sample is used.
64		:	CORRECT FOR BP	YES = 0, NO = 1	
65		:	USE BP RUN 3XXX	YES = 0, NO = 1	Uses BP from run 3XXX for following runs
66		:	GV 1 CORR - BAL	YES = 0, NO = 1	Corrects bal. (ACH1-6) for gage voltage
67		:	GV 2 CORR - BP	YES = 0, NO = 1	Corrects BP (ACH7-12) for gage voltage *
68		:	GV 2 CORR - PT1	YES = 0, NO = 1	Corrects PT1 (ACH17-20) for gage voltage

* Set = 1 if Baratrons used for base pressures
\+ If Mach number is not computed list Mach number in VALUE column

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FORCE DATA ACCURACY CALCULATIONS PROGRAM

Accuracies for each of the six balance components, CL, CD, L/D (MAX) and the three beta derivatives are calculated using the Theorem of Superposition of Errors. The angles of attack at which the maximum errors in CL and CD occur are calculated. Effect of base pressure error on the axial force is also included. The following inaccuracies are considered in the calculations.

1. Balance component calibration
2. Balance zero shift
3. Beckman
4. Angle of attack and angle of sideslip
5. Pressure transducer calibration
6. Dynamic pressure measurement

The inputs include the balance design loads, balance sensitivities, transfer distances, reference area and lengths, average beta derivatives and coefficients, angles of attack and sideslip, maximum L/D, Beckman mV. range, and base pressure error. The computations input and output descriptions, and input sheet computations follow. Input and output are in U.S. customary units.

I. COMPUTATIONS (Using the Theorem of Superposition of Errors)

A. BALANCE COMPONENT ERRORS

Four sources of error are considered for each balance component (balance calibration error, balance zero shift error, Beckman error, and error due to error in measuring Q). Error in measuring base pressure is also included in the axial force error calculation.

1. Conversion of errors to percentage of balance design load for each component

(a) Balance calibration error, BCPCE = 0.5 percent
(b) Balance zero shift error, BZPCE = 0.5 percent
(c) Beckman error, ARPC =0.1 percent

$$BE(\ ) = \frac{(AR)(BCS(\ ))(ARPC)}{FDL(\ )}$$

Where,
BE( ) - Beckman percent error for each component
BCS( ) - balance sensitivity for each component, lb/mV or in-lb/mV
FDL( ) - design load for each component, lb or in-lb
AR - Beckman millivolt range, mV

(d) Error in force or moment due to error in dynamic pressure, ΔQ = 0.5 percent (average based on tunnel conditions from PT = 75 psia to 440 psia)

$$FOMQ = \frac{(F(\ ))(\Delta Q)}{FDL(\ )}$$

Where,
FOMQ - percent error in force or moment due to ΔQ
F( ) - average force or moment

In general assume F( ) = 0.5 (FDL())

Then
FOMQ $\approx$ 0.5 (ΔQ)
= 0.25 percent

(e) Base pressure error effect on axial force, BPE, psia

$$AFBPE = \frac{(SB)(BFE)(100)}{FDLAF}$$

AFBPE - percent error of component design load.

SB - base area, in^2

$$AFBPAVE = \frac{(AFBPE)(FDLAF)}{(CAAV)(Q)(S)}$$

AFBPAVE - percent error of average axial force coefficient

CAAV - average axial force coefficient
Q - dynamic pressure, psia
S - reference area, in^2

2. Combined probable error in forces and moments in percent design load

(a) Normal force

$$CENF = \pm [(BCPCE)^2 + (BZPCE)^2 + (BENF)^2 + (FOMQ)^2]^{.5}$$

(b) Axial force

$$CEAF = \pm [(BCPCE)^2 + (BZPCE)^2 + (BEAF)^2 + (FOMQ)^2 + (AFBPE^*)^2]^{.5}$$

*AFBPE can be deleted.

(c) Pitching moment

$$CEPM = \pm [(BCPCE)^2 + (BZPCE)^2 + (BEPM)^2 + (FOMQ)^2]^{.5}$$

(d) Rolling moment

$$CERM = \pm [(BCPCE)^2 + (BZPCE)^2 + (BERM)^2 + (FOMQ)^2]^{.5}$$

(e) Yawing moment

$$CEYM = \pm [(BCPCE)^2 + (BZPCE)^2 + (BEYM)^2 + (FOMQ)^2]^{.5}$$

(f) Side force

$$CESF = \pm [(BCPCE)^2 + (BZPCE)^2 + (BESF)^2 + (FOMQ)^2]^{.5}$$

3. Maximum combined probable error in forces and moments in lb or in-lb

(a) Normal force

$$DELNF = \pm [((CENF)(FDLNF))/100]$$

(b) Axial force

$$DELAF = \pm [((CEAF)(FDLAF))/100]$$

(c) Pitching moment

$$DELPM = \pm [((CEPM)(FDLPM))/100]$$

(d) Rolling moment

$$DELRM = \pm [((CERM)(FDLRM))/100]$$

(e) Yawing moment

$$DELYM = \pm [((CEYM)(FDLYM))/100]$$

(f) Side force

$$DELSF = \pm [((CESF)(FDLSF))/100]$$

4. Maximum combined probable error in force and moment coefficients

(a) Normal force coefficient

$$DELCN = \pm [DELNF/((Q)(S))]$$

(b) Axial force coefficient

$$DELCA = \pm [DELAF/((Q)(S))]$$

(c) Pitching moment coefficient

$$DELCM = \pm [(DELPM + (XTRANS)(DELNF) + (ZTRANS)(DELAF))/((Q)(S)(CBAR))]$$

(d) Rolling moment coefficient

$$DELCR = \pm [(DELRM + (ZTRANS)(DELSF) + (YTRANS)(DELNF))/((Q)(S)(B))]$$

(e) Yawing moment coefficient

$$DELCY = \pm [(DELYM + (XTRANS)(DELSF) - (YTRANS)(DELAF))/((Q)(S)(B))]$$

(f) Side force coefficient

$$DELCS = \pm [DELSF/((Q)(S))]$$

B. PROBABLE ERROR IN LIFT AND DRAG COEFFICIENTS AND MAXIMUM LIFT TO DRAG RATIO

1. Errors in lift and drag coefficients were calculated using the average positive angle of attack (AL2MA), average lift coefficient (CL2MA), average drag coefficient (CD2MA), and error in angle of attack (DELALP) in radians.

(a) Lift coefficient

$$DELCL = \pm [((DELCN)(Cos(AL2MA)))^2 + ((DELCA)(Sin(AL2MA)))^2]^{.5}$$

(b) Drag coefficient

$$DELCD = \pm [((DELCN)(Sin(AL2MA)))^2 + ((DELCA)(Cos(AL2MA)))^2]^{.5}$$

2. Angle of attack at which maximum errors in lift and drag coefficient occur.

(a) Angle at maximum lift coefficient error

$$ALPCL = TAN^{-1} [(DELCA/DELCN)]$$

(b) Angle at maximum drag coefficient error

$$ALPCD = TAN^{-1} [(DELCN/DELCA)]$$

3. Error in maximum lift to drag ratio

$$DELOD = \pm [\frac{[(DELCL)^2 + ((ALOD)(DELCD))^2]^{.5}}{CDLOD}]$$

Where ALOD = maximum lift-to-drag ratio
CDLOD = drag coefficient at ALOD

C. PROBABLE ERROR IN BETA SLOPES

1. Errors in C_{R_β}, C_{Y_β}, C_{S_β} based on average slope values (CRBAV, CYBAC, CSBAV) and measured β difference

(a) Error in CRBETA

$$DCRR = \pm [\frac{[(DELCR)^2 + ((|CRBAV|)(DELBER))^2]^{.5}}{DELBT}]$$

Where DELBER and DELBT are in degrees

(b) Error in CYBETA

$$DCYR = \pm [\frac{[(DELCY)^2 + ((|CYBAV|)(DELBER))^2]^{.5}}{DELBT}]$$

(c) Error in CSBETA

$$DCSR = \pm \left[\frac{[(DELCS)^2 + ((|CSBAV|)(DELBER))^2]^{.5}}{DELBT}\right]$$

2. Error in C_{R_β}, C_{Y_β}, C_{S_β} in percent average slope

(a) CRBETA

$$ROLL = \pm \left[\frac{(DCRR)100}{CRBAV}\right]$$

(b) CYBETA

$$YAW = \pm \left[\frac{(DCYR)100}{CYBAV}\right]$$

(c) CSBETA

$$SIDE = \pm \left[\frac{(DCSR)100}{CSBAV}\right]$$

II. INPUT DESCRIPTION

TEST	test number
RUNF	first run number for balance
RUNL	last run number for balance
AMACH	free-stream Mach number
PT	stagnation pressure, psia
BAL	balance number
MONTH, DAY, YEAR	balance calibration date
FDLNF	full design load, normal force, lb
FDLAF	full design load, axial force, lb
FDLPM	full design load, pitching moment, in-lb
FDLRM	full design load, rolling moment, in-lb
FDLYM	full design load, yawing moment, in-lb
FDLSF	full design load, side force, lb

BCSNF	balance component sensitivity, normal force, lb/mV
BCSAF	balance component sensitivity, axial force, lb/mV
BCSPM	balance component sensitivity, pitching moment, in-lb/mV
BCSRM	balance component sensitivity, rolling moment, in-lb/mV
BCSYM	balance component sensitivity, yawing moment, in-lb/mV
BCSSF	balance component sensitivity, side force, lb/mV
AL2MA	average positive angle of attack ($\alpha_{MAX}/2$), deg
DELBT	measured change in angle of sideslip ($\beta_{\beta=X^\circ} - \beta_{\beta=0^\circ}$), deg
Q	free-stream dynamic pressure, psia
AR	Beckman analog millivolt range, mV
SB	base area, in^2
BPE	base pressure error (normally .005), psia
CAAV	average axial force coefficient
CBPE	compute base pressure error, YES = 0, NO = 1
S	reference area, in^2
B	reference span, in
CBAR	reference chord, in
XTRANS	x transfer distance, in
YTRANS	y transfer distance, in
ZTRANS	z transfer distance, in
ALOD	maximum lift-to-drag ratio
CDLOD	drag coefficient at maximum lift-to-drag ratio
CRBAV	average value of C_{R_β}

CYBAV	average value of C_{Y_β}
CSBAV	average value of C_{S_β}
BCPCE	balance component percent calibration error (normally 0.5 percent of design load), percent
BZPCE	balance component zero shift error (normally 0.5 percent of design load), percent
ARPC	Beckman recording system error (normally 0.1 percent of mV range AR), percent
FOMQ	error due to error in Q (normally 0.25% design load), percent
DELALP	angle-of-attack error (normally 0.1 percent), deg
DELBER	angle-of-sideslip error (normally 0.1 percent), deg

III OUTPUT DESCRIPTION

TEST	test number
FIRST RUN	first run number
LAST RUN	last run number
BALANCE	balance number
CALIB. DATE	balance calibration date
MACH NO.	Mach number
PT	stagnation pressure, psia
NF	balance normal force
AF	balance axial force
PM	balance pitching moment
RM	balance rolling moment
YM	balance yawing moment
SF	balance side force
CNORMAL	normal force coefficient

CAXIAL	axial force coefficient
CPITCH	pitching moment coefficient
CROLL	rolling moment coefficient
CYAW	yawing moment coefficient
CSIDE	side force coefficient
CL	lift coefficient
CD	drag coefficient
L/D(MAX)	lift-to-drag ratio
CRBETA	C_{R_β}
CYBETA	C_{Y_β}
CSBETA	C_{S_β}
ALPHA (CL)	angle of attack at maximum CL error
ALPHA (CD)	angle of attack at maximum CD error
AFBPE	error in axial force due to error in base pressure, percent design load
AFBPAVE	error in axial force due to error in base pressure, percent CAAV

FORCE DATA ACCURACY CALCULATIONS PROGRAM

INPUT SHEET

TEST__________ RUN_____ TO_________ BAL.__________ CAL. DATE__________________

MACH_____ PT_______ psia Q_________ psia

BALANCE DESIGN LOADS

FDLNF______________ lb
FDLAF______________ lb
FDLPM______________ in-lb
FDLRM______________ in-lb
FDLYM______________ in-lb
FDLSF______________ lb

BALANCE SENSITIVITIES

BCSNF______________ lb/mV
BCSAF______________ lb/mV
BCSPM______________ in-lb/mV
BCSRM______________ in-lb/mV
BCSYM______________ in-lb/mV
BCSSF______________ lb/mV

ANGLE

AL2MA______________ deg
DELBT______________ deg

BECKMAN MV. RANGE

AR______________ mV

COEFFICIENTS

ALOD______________
CDLOD______________
CRBAV______________
CYBAV______________
CSBAV______________
CAAV______________

REFERENCE AREA AND DISTANCES

S______________ in^2
SB______________ in^2
B______________ in
CBAR______________ in
XTRANS______________ in
YTRANS______________ in
ZTRANS______________ in

BASE PRESSURE ERROR

BPE______________ psia

CBPE YES____ NO____

FIXED ERRORS

BCPCE______________ % design load
BZPCE______________ % design load
ARPC______________ % of mV range
FOMQ______________ % design load
DELALP______________ deg
DELBER______________ deg

ADDITIONAL INSTRUCTIONS

G0310 - BETA DERIVATIVES PROGRAM

The program is capable of computing the 3 beta derivatives, printing an output listing, and generating a plotting tape. There is a limit of 50 points per run and a limit of 250 runs on a tape. Beta derivatives or slopes can be computed for either the body axis coefficients or the stability axis coefficients or both in the same submission. A "CONFIDENTIAL" header can be printed on the data listing and plots if necessary. Slopes can be plotted using program, G0613 - BETA DERIVATIVE PLOTTING PROGRAM.

The program uses data from the G0590 - 20 INCH TUNNEL FORCE PROGRAM answer tape for 2 specified runs (primary ($\beta_p = X^\circ$) and secondary ($\beta_s = Y^\circ$) to compute the 3 slopes at each angle of attack (α_p and α_s).

$$\text{SLOPE}_{(p - s)} = \frac{\text{Data}_p \text{ (at } \alpha_p) - \text{Data}_s \text{ (at } \alpha_s)}{\beta_p - \beta_s}$$

where p and s are two different run numbers and $|\alpha_p - \alpha_s|$ is less than a specified tolerance (normally = 0.5°).
Description of input, output, and input sheets are as follows:

INPUT DESCRIPTION

PRIMARY RUN	$\beta = X^\circ$ run
SECONDARY RUN	$\beta = Y^\circ$ run (Normally $Y^\circ = 0^\circ$)
TOLERANCE	angle-of-attack tolerance between primary and secondary runs

OUTPUT DESCRIPTION

MACH	Mach number
TEST	test number
RUN	primary or secondary run
BODY AXIS SLOPES	slopes based on body axis coefficients
STABILITY AXIS SLOPES	slopes based on stability axis coefficients
POINT	frame number
ALPHA	angle of attack of primary or secondary run
BETA	sideslip angle of primary (X°) run
AVE ALPHA	average angle of attack of primary and secondary runs

ROLL	slope of rolling moment vs. sideslip curve, C_{R_β}
YAW	slope of yawing moment vs. sideslip curve, C_{Y_β}
SIDE	slope of side force vs. sideslip curve, C_{S_β}

G0310 - BETA DERIVATIVES PROGRAM

SET-UP SHEET

SHEET_1__ OF_

FAC.__________TEST____________ENG.___________DATE________________

AXIS SYSTEM (check one)

________ Compute body axis slopes

________ Compute stability axis slopes

________ Compute body and stability axis slopes

PLOTTING TAPE FOR G0613 PLOTTING PROGRAM

________ Yes

________ No

SPECIAL HEADINGS (Check one)

________ None

________ "CONFIDENTIAL" and date at top and bottom

________ "CONFIDENTIAL" and date at top - "GROUP 3...." at bottom

________ "CONFIDENTIAL" and date at top - "GROUP 4...." at bottom

ANGLE OF ATTACK TOLERANCE

________ Give value if $\neq .5^{\circ}$

ADDITIONAL INSTRUCTIONS

G0310 - BETA DERIVATIVES PROGRAM

CARD INPUT

SHEET____OF____

FAC.__________TEST__________ENG.______________DATE________________

RUN		PRIMARY	SECONDARY
COLUMN	1	21 30	31 40
	B		
	B		
	B		
	B		
	B		
	B		
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	B		
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	B		

Keypunch instructions: Punch B in Column 1, right justify numbers within specified fields.

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G0613 - BETA DERIVATIVE PLOTTING PROGRAM

Program plots slopes from the plotting tape of GS310. Input includes type of plot, paper size, grid size, grid color, and ink color. Additional input are run number, labels, scale size, symbol size, centered or open symbols, zero lines, and plot location. Input sheets are presented.

G0613 - BETA DERIVATIVE PLOTS

SET-UP SHEET

SHEET 1 OF ____

FAC.____________ TEST____________ ENG.____________ DATE____________

DATA TAPE NOS.____________

TYPE OF PLOTTER

CALCOMP 12 IN.____________
CALCOMP 30 IN.____________
VARIAN____________

GRID COLOR

RED____________
GREEN____________
BLUE____________

PAPER NO. (GRID SIZE)

CALCOMP 12 IN.
00 (NO GRID) ____________
01 (10/IN.) ____________
02 (20/IN.) ____________
CALCOMP 30 IN.
300 (NO GRID) ____________
301 (10/IN.) ____________
302 (20/IN.) ____________

INK COLOR

RED____________
GREEN____________
BLACK____________
BLUE____________

ADDITIONAL INSTRUCTIONS

G0613 - BETA DERIVATIVE PLOTS

CARD INPUT (RUNS TO BE PLOTTED)

SHEET 2 OF ____

TEST ____ ENG. ____ DATE ____ DATA TAPE NOS. ____

Keypunch instructions: Puncn everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE *
1	4 8	9 Column number 34	35 38	39 52
J	00001	BETA DERIVATIVE RUN (PRIMARY)	0001	
J	00002		0002	
J	00003		0003	
J	00004		0004	
J	00005		0005	
J	00006		0006	
J	00007		0007	
J	00008		0008	
J	00009		0009	
J	00010		0010	
J	00011		0011	
J	00012		0012	
J	00013		0013	
J	00014		0014	
J	00015		0015	
J	00016		0016	
J	00017		0017	
J	00018		0018	
J	00019		0019	
J	00020		0020	
J	00021		0021	
J	00022		0022	
J	00023		0023	
J	00024		0024	
J	00025		0025	

* List runs in same order as data tape G0310. End run list with 999999.

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G0613 - BETA DERIVATIVE PLOTS

CARD INPUT (OPTIONS)

SHEET 3 OF ____

TEST ________ ENG. ________ DATE ________ DATA TAPE NOS. ________

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE *
1	4 8	9 Column number 34	35 38	39 52
J	00001	TEST & RUN = 1, RUN ONLY = 2	0201	
J	00002	CENTERED SYMBOL = 10, OPEN = 0	0232	
J	00003	PRINT LABELS, YES = 1, NO = 0	0214	
J	00004	PRINT RUNS, YES = 1, NO = 0	0228	
J	00005	WIDTH OF SHEET (X), INCH	0212	
J	00006	LENGTH OF SHEET (Y), INCH	0213	
J	00007	SPACE BETWEEN PLOTS, INCH	0230	
J	00008	NO OF END POINTS TO OMIT	0229	
J	00009	SYMBOL SIZE, S = 1, M = 2, L = 3	0245	

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G0613 - BETA DERIVATIVE PLOTS

CARD INPUT (PLOT LAYOUT NO____)

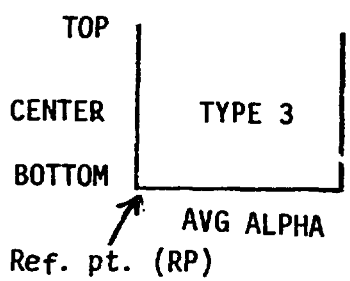
SHEET 4 OF ____

TEST__________ ENG.__________ DATE__________ DATA TAPE NOS.______________

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE
1	4 8	9 Column number 34	35 38	39 52
J	00010	TOP WORD LOCATION	0202	
J	00011	TOP OFFSET, INCHES FROM RP	0235	
J	00012	TOP SCALE, PER INCH	0234	
J	00013	CENTER WORD LOCATION	0203	
J	00014	CENTER OFFSET, INCHES FROM RP	0237	
J	00015	CENTER SCALE, PER INCH	0236	
J	00016	BOTTOM WORD LOCATION	0204	
J	00017	BOTTOM OFFSET, INCHES FROM RP	0239	
J	00018	BOTTOM SCALE, PER INCH	0238	
J	00019	ALPHA OFFSET, INCHES FROM RP	0241	
J	00020	ALPHA SCALE, PER INCH	0240	

LAYOUT



WORD LOCATION

01 AVG ALPHA
02 CLBB
03 CNBB
04 CYBB
05 CLBS
06 CNBS
07 CYBS

Any WORD LOCATION = 0 will suppress an X, Y combination

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G0613 - BETA DERIVATIVE PLOTS

CARD INPUT (SYMBOLS) SHEET 5 OF ____

TEST ____ ENG. ____ DATE ____ DATA TAPE NOS. ____

Keypunch instructions: Punch 1 in cc1 and 3 in cc21. Right justify number in specified fields.

	LAYOUT *	SHEET	TYPE	○	□	◇	△	◺	◗	⌓	⬠	◊	⌂
1	2 11	12 16	17 21	22 26	27 31	32 36	37 41	42 46	47 51	52 56	57 61	62 66	67 71
1			3										
1			3										
1			3										
1			3										
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1			3										
1			3										
1			3										

* Match LAYOUT no. with SHEET no. when more than one LAYOUT used.

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G0610 and G0614 - GENERAL FORCE DATA PLOTTING PROGRAMS

Programs plot data from answer tape of GS590. G0610 plots symbols only, whereas G0614 plots symbols and fits a spline fairing to the symbols. Input includes type of plot, paper size, grid size, grid color, and ink color. Additional input are run number, labels, scale size, symbol size, centered or open symbols, zero lines, and plot location. Input sheets are presented.

G0610 or G0614 - GENERAL FORCE DATA PLOTS

SET-UP SHEET SHEET__1__OF_____

FAC.____________ TEST____________ ENG.____________ DATE____________

DATA TAPE NOS.____________

TYPE OF PLOTTER

CALCOMP 12 IN.____________
CALCOMP 30 IN.____________
VARIAN____________

GRID COLOR

RED____________
GREEN____________
BLUE____________

PAPER NO. (GRID SIZE)

CALCOMP 12 IN.
00 (NO GRID) ____________
01 (10/IN.) ____________
02 (20/IN.) ____________
CALCOMP 30 IN.
300 (NO GRID) ____________
301 (10/IN.) ____________
302 (20/IN.) ____________

INK COLOR

RED____________
GREEN____________
BLACK____________
BLUE____________

ADDITIONAL INSTRUCTIONS

G0610 or G0614 - GENERAL FORCE DATA PLOTS

CARD INPUT (RUNS TO BE PLOTTED)

SHEET 2 OF ____

TEST ________ ENG. ________ DATE ________ DATA TAPE NOS. ____________

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE *
1	4 8	9 Column number 34	35 38	39 52
J	00001	RUN TO BE PLOTTED	0001	
J	00002		0002	
J	00003		0003	
J	00004		0004	
J	00005		0005	
J	00006		0006	
J	00007		0007	
J	00008		0008	
J	00009		0009	
J	00010		0010	
J	00011		0011	
J	00012		0012	
J	00013		0013	
J	00014		0014	
J	00015		0015	
J	00016		0016	
J	00017		0017	
J	00018		0018	
J	00019		0019	
J	00020		0020	
J	00021		0021	
J	00022		0022	
J	00023		0023	
J	00024		0024	
J	00025		0025	

* List runs in same order as data tape. End run list with 999999.

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G0610 or G0614 - GENERAL FORCE DATA PLOTS

CARD INPUT (RUNS TO BE PLOTTED)

SHEET 3 OF ______

TEST ______ ENG. ______ DATE ______ DATA TAPE NOS. ______

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE *
1	4 8	9 Column number 34	35 38	39 52
J	00026	RUN TO BE PLOTTED	0026	
J	00027		0027	
J	00028		0028	
J	00029		0029	
J	00030		0030	
J	00031		0031	
J	00032		0032	
J	00033		0033	
J	00034		0034	
J	00035		0035	
J	00036		0036	
J	00037		0037	
J	00038		0038	
J	00039		0039	
J	00040		0040	
J	00041		0041	
J	00042		0042	
J	00043		0043	
J	00044		0044	
J	00045		0045	
J	00046		0046	
J	00047		0047	
J	00048		0048	
J	00049		0049	
J	00050		0050	

* List runs in same order as data tape. End run list with 999999.

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G0610 or G0614 - GENERAL FORCE DATA PLOTS

CARD INPUT (RUNS TO BE PLOTTED)

SHEET 4 OF ____

TEST ________ ENG. ________ DATE ________ DATA TAPE NOS. ____________

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE *
1	4 8	9 Column number 34	35 38	39 52
J	00051	RUN TO BE PLOTTED	0051	
J	00052		0052	
J	00053		0053	
J	00054		0054	
J	00055		0055	
J	00056		0056	
J	00057		0057	
J	00058		0058	
J	00059		0059	
J	00060		0060	
J	00061		0061	
J	00062		0062	
J	00063		0063	
J	00064		0064	
J	00065		0065	
J	00066		0066	
J	00067		0067	
J	00068		0068	
J	00069		0069	
J	00070		0070	
J	00071		0071	
J	00072		0072	
J	00073		0073	
J	00074		0074	
J	00075		0075	

* List runs in same order as data tape. End run list with 999999.

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G0610 or G0614 - GENERAL FORCE DATA PLOTS

CARD INPUT (RUNS TO BE PLOTTED)

SHEET 5 OF ___

TEST__________ ENG.__________ DATE__________ DATA TAPE NOS.________________

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE *
1	4 8	9 Column number 34	35 38	39 52
J	00076	RUN TO BE PLOTTED	0076	
J	00077		0077	
J	00078		0078	
J	00079		0079	
J	00080		0080	
J	00081		0081	
J	00082		0082	
J	00083		0083	
J	00084		0084	
J	00085		0085	
J	00086		0086	
J	00087		0087	
J	00088		0088	
J	00089		0089	
J	00090		0090	
J	00091		0091	
J	00092		0092	
J	00093		0093	
J	00094		0094	
J	00095		0095	
J	00096		0096	
J	00097		0097	
J	00098		0098	
J	00099		0099	
J	00100		0100	

* List runs in same order as data tape. End run list with 999999.

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G0610 or G0614 - GENERAL FORCE DATA PLOTS

CARD INPUT (OPTIONS)

SHEET 6 OF ____

TEST ____ ENG. ____ DATE ____ DATA TAPE NOS. ____

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE
1	4 8	9 Column number 34	35 38	39 52
J	00001	TEST & RUN = 1, RUN ONLY = 2	0201	
J	00002	CENTERED SYMBOLS = 10, OPEN = 0	0232	
J	00003	PRINT LABELS, YES = 1, NO = 0	0214	
J	00004	PRINT RUN NO., YES = 1, NO = 0	0228	
J	00005	WIDTH OF SHEET (X), INCH	0212	
J	00006	LENGTH OF SHEET (Y), INCH	0213	
J	00007	SPACE BETWEEN PLOTS, INCH	0230	
J	00008	NO. OF END POINTS TO OMIT	0229	
J	00009	SYMBOL SIZE, S = 1, M = 2, L = 3	0245	
J	00010	A ZERO LINE YES = 1, NO = 0	0175	
J	00011	B ZERO LINE YES = 1, NO = 0	0176	
J	00012	C ZERO LINE YES = 1, NO = 0	0177	
J	00013	D ZERO LINE YES = 1, NO = 0	0178	
J	00014	E ZERO LINE YES = 1, NO = 0	0179	
J	00015	F ZERO LINE YES = 1, NO = 0	0180	

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G0610 or G0614 - GENERAL FORCE DATA PLOTS

CARD INPUT (PLOT LAYOUT NO.____)

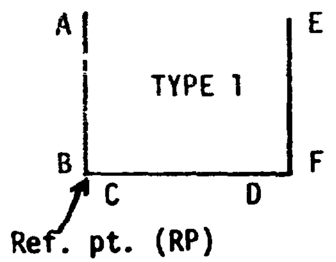
SHEET 7 OF ____

TEST________ ENG.________ DATE________ DATA TAPE NOS.____________

Keypunch instructions: Punch everything except DESCRIPTION. Right justify numbers within specified fields.

J	CARD NO.	DESCRIPTION	LOCATION	VALUE
1	4 — 8	9 Column number 34	35 — 38	39 — 52
J	00010	A WORD LOACATION	0202	
J	00011	A OFFSET, INCHES FROM RP	0216	
J	00012	A SCALE, PER INCH	0217	
J	00013	B WORD LOCATION	0203	
J	00014	B OFFSET, INCHES FROM RP	0218	
J	00015	B SCALE, PER INCH	0219	
J	00016	C WORD LOCATION	0204	
J	00017	C OFFSET, INCHES FROM RP	0220	
J	00018	C SCALE, PER INCH	0221	
J	00019	D WORD LOCATION	0205	
J	00020	D OFFSET, INCHES FROM RP	0222	
J	00021	D SCALE, PER INCH	0223	
J	00022	E WORD LOCATION	0206	
J	00023	E OFFSET, INCHES FROM RP	0224	
J	00024	E SCALE, PER INCH	0225	
J	00025	F WORD LOCATION	0207	
J	00026	F OFFSET, INCHES FROM RP	0226	
J	00027	F SCALE, PER INCH	0227	

LAYOUT



WORD LOCATION

01- MACH	07- CM	13- CM
02- Q	08- CLB	14- CLS
03- BETA	09- CNB	15- CNS
04- ALPHA	10- CY	16- CY
05- CN	11- CL	17- L/D
06- CA	12- CD	

Any WORD LOCATION = 0 will suppress an X,Y combination

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G0610 or G0614 - GENERAL FORCE DATA PLOTS

CARD INPUT (SYMBOLS)

SHEET 8 OF ____

TEST ______ ENG. ______ DATE ______ DATA TAPE NOS. ______

Keypunch instruction: Punch 1 in cc1 and cc21. Right justify number within specified fields.

	LAYOUT	SHEET	TYPE	○	□	◇	△	◺	D	⌓	⬭	◊	⌂
1	2 — 11	12 — 16	17 — 21	22 — 26	27 — 31	32 — 36	37 — 41	42 — 46	47 — 51	52 — 56	57 — 61	62 — 66	67 — 71
1			1										
1			1										
1			1										
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1			1										

* Match LAYOUT no. with SHEET no. when more than one LAYOUT used.

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APPENDIX

DESCRIPTION AND CALIBRATION OF THE LANGLEY 20-INCH MACH 6 TUNNEL*

By James C. Emery
Langley Research Center

SYMBOLS

M	Mach number
ΔM	difference between Mach number of rake and fixed probe, $M_r - M_p$
p	pressure, MN/m^2 (psia)
s'	inside measurement of tunnel in vertical and horizontal planes (see fig. A4), cm(in)
T	temperature, K (°R)
x'	distance measured along longitudinal axis of tunnel from centerline of upstream window (positive in upstream direction, see fig. A4), cm (in)
μ	viscosity, N sec/m^2 (lb sec/ft^2)
φ	rake angle: horizontal, 0°; vertical, 90°

Subscripts:

a	average (always calculated within the core given in table AII)
p	fixed probe (see fig. A4)
r	rake probe
t	total or stagnation
1	condition in settling chamber
2	condition behind normal shock

*Appendix from NASA TN D-6280, 1971. Revised 5/77 by J. Wayne Keyes.

APPENDIX

Facility Description

The Langley 20-Inch Mach 6 tunnel is a blowdown type with air as the test medium. Figure A1 schematically shows the general arrangement of this facility in which heat transfer, pressure, and force tests are conducted. The test Mach number is achieved with a fixed-geometry two-dimensional contoured nozzle (side walls are parallel) forming a throat section of 0.86 by 50.80 cm (0.339 by 20.0 in) and a test section of 52.00 by 50.80 cm (20.5 by 20.0 in). The nozzle length from the throat to the tunnel window centerline measures 2.27 m (89.37 in).

Models can be mounted either in a fixed position on the tunnel floor or on injection systems at top and bottom of the tunnel test section. The opening in the bottom of the test section measures approximately 132 by 40 cm (52.4 by 15.7 in) for the lower injection system which includes a remote controlled sting-support system capable of moving the model (up to 122 cm (48 in) long) during wind-on operation, through an angle-of-attack range from -5° to 55° and a sideslip-angle range from 0° to -10°. For heat-transfer tests, the lower injection system traverses the last 25 cm (9.8 in) in approximately 0.3 sec with a maximum acceleration of 6g ($1g = 9.807\ m/sec^2$ or $32.2\ ft/sec^2$). For force tests, the model can also be injected to reduce starting and unstarting loads. For this type of test the injection time for the last 25 cm (9.8 in) is adjusted to about 0.9 sec with a maximum 2g acceleration. Details of the lower model injection system including sting support and mounting pad are shown in figure . The top injection system, with a usable opening of 50 by 36 cm (19.7 by 14.2 in) and a similar injection rate, is used primarily for heat-transfer tests since the model attitude cannot be changed during wind-on operation. The top injection-system opening and mounting plate are shown in figure A3. A reference Mach number is obtained from a fixed pitot probe mounted in the upper wall of the test section as shown in figure A4.

The tunnel has a movable second minimum and exhausts either into the atmosphere with the aid of an annular air ejector or into a 18.3 m (60 ft) dia vacuum sphere or this sphere plus a 12.5 m (41 ft) dia sphere. The tunnel can exhaust to the vacuum spheres and through the ejector simultaneously. This mode of operation is frequently used with force tests to reduce starting and unstarting loads. Tunnel operating conditions are as follows:

Stagnation pressure .... $0.21\ MN/m^2$ to $3.62\ MN/m^2$ (30 to 525 psia)

Stagnation temperature .... 450 K to 560 K (810 to 1018°R)

Reynolds number....................... $2.3 \times 10^6/m$ to $29.5 \times 10^6/m$

.... $(0.7 \times 10^6/ft$ to $9.0 \times 10^6/ft)$

Dynamic pressure...................... $3.35\ kN/m^2$ to $57.8\ kN/m^2$ (0.8 to 8.7 psia)

Running time (maximum):

With 1 sphere.................... 1 min (18.3 m (60 ft) dia)

With 2 spheres .... 1.5 min (18.3 m and 12.5 m (60 ft and 41 ft) dia)

With ejector..................... 20 min

Tunnel mass flow (maximum)........... 27 kg/sec (60 lbm/sec)

Ejector mass flow..................... 60 to 80 kg/sec (133 to 177 lbm/sec)

Tunnel air, heated by an electrical resistance heater, is supplied from a 4.1 MN/m^2 (600 psia) reservoir with a storage capacity of 1195 m^3 (58,500 kg) (42,200 ft^3 (129,000 lbm)). Air for this reservoir is transferred from a 21.0 MN/m^2 (3000 psia) tank field and/or a 34.9 MN/m^2 (5000 psia) tank field with a combined storage capacity of 8920 m^3 (297,000 kg)(31,500 ft^3 (655,000 lbm)). This combination can supply air to the tunnel and ejector at a maximum combined rate of 127 kg/sec (280 lbm/sec). An activated alumina dryer provides a dewpoint temperature at 233 K (419°R) at a pressure of 4.1 MN/m^2 (600 psia). One hundred analog channels and seven digital channels of data can be recorded on a central data recording complex.

Mach Number Calibration

This facility was calibrated by using a 19-tube rake with tubes spaced 2.54 cm (1.0 in) apart, placed at four stations along the test-section axis. Calibrations were made for both vertical and horizontal positions at each station for four stagnation pressures ranging from 0.5 MN/m^2 to 3.0 MN/m^2 (72.5 to 435.0 psia).

Previous tunnel calibrations had shown that the Mach number varied with time (time during each run, the time between runs, and total elapsed time) probably as a result of temperature effects on the boundary layer and nozzle. This phenomenon makes it extremely difficult to obtain an exact calibration curve of Mach number, since all rake positions could not be taken simultaneously; therefore, the variation in test-section Mach number ΔM is presented as the difference between the Mach numbers calculated from the rake pitot pressures and the fixed-probe pitot pressures. In addition, to further minimize temperature differences between runs, the interior walls of the test section were preheated to 325 K (585°R) prior to each survey. Desired test conditions were then established and data were taken at various pressures within a time interval of 3 to 5 min.

The Mach number distributions determined from the measured pressures on the rake and fixed position probe are presented for each axial station and test condition in table AI. The variation in test-section Mach number ΔM obtained from these data is presented in figure A5 along with the Mach number for the fixed probe.

For convenience in determining the practical size of models to be tested in this facility, the variation in the test core size with pressure and axial station is shown in figure A6. These cores were obtained from the data of table AI or figure A5 and represent the region where the maximum Mach number variation was approximately ± 0.02 in the horizontal and vertical planes. The average values of ΔM within each core are given in figure A7 and table AII. Figure A7 suggests a possible fairing of these averages. The average Mach number at any station may be determined by adding ΔM_e to the measured probe Mach number. This method assumes the same effect of temperature on Mach number at each point in the test section. Figure A8 illustrates how the Mach number differential for two repeat runs decreases when the rake Mach numbers are referred to the fixed probe.

The Reynolds number for various temperatures and pressures is presented in figure A9. Also shown are the values of the pressures and temperatures for liquefaction obtained from reference 1 and the viscosity relationship from reference 2.

REFERENCES

1. Buhler, R. D.; and Nagamatsu, H. T.: Condensation of Air Components in Hypersonic Wind Tunnels - Theoretical Calculations and Comparison With Experiment. GALCIT Men. No. 13 (Contract No. DA-04-495-Ord-19), Dec. 1, 1952.

2. Bertram, Mitchel H.: Comment on "Viscosity of Air." J. Spacecraft Rockets, vol. 4, no. 2, Feb. 1967, p. 287.

TABLE AI. - MACH NUMBER CALCULATED FROM $p_{t,2}\backslash p_{t,1}$

(a) $p_{t,1}$ = 0.52 MN/m^2 (75.4 psia); $T_{t,1}$ = 478 K (860° R)

s', cm (in.)	M for -							
	x' = 21.59 cm (8.5 in.)		x' = 1.59 cm (0.6 in.)		x' = -25.40 cm (-10.0 in.)		x' = -55.88 cm (-22.0 in.)	
	$\phi = 0^\circ$	$\phi = 90^\circ$	$\phi = 0^\circ$	$\phi = 90^\circ$	$\phi = 0^\circ$	$\phi = 90^\circ$	$\phi = 0^\circ$	$\phi = 90^\circ$
22.86 (9.0)	8.24	7.57	8.72	7.54	----	7.48	----	7.44
20.32 (8.0)	6.15	6.26	6.57	6.29	6.98	6.07	7.73	6.28
17.78 (7.0)	5.96	6.00	5.78	5.98	5.89	5.86	6.06	5.97
15.24 (6.0)	5.94	5.98	5.92	5.97	5.87	5.86	5.92	6.00
12.70 (5.0)	5.92	5.97	5.93	5.93	5.91	5.88	5.94	5.75
10.16 (4.0)	5.91	5.95	5.94	5.91	5.90	5.89	5.92	5.96
7.62 (3.0)	5.91	5.93	5.94	5.91	5.89	5.89	5.96	5.97
5.08 (2.0)	5.91	5.90	5.93	5.92	5.91	5.90	5.98	5.89
2.54 (1.0)	5.88	5.90	5.92	5.91	5.91	5.90	5.97	5.98
0	5.88	5.91	5.91	5.92	5.91	5.90	5.97	5.99
-2.54 (-1.0)	5.88	5.90	5.92	5.91	5.91	5.89	5.98	5.98
-5.08 (-2.0)	5.91	5.91	5.93	5.91	5.90	5.90	5.97	5.98
-7.62 (-3.0)	5.91	5.93	5.95	5.91	5.90	5.89	5.94	5.97
-10.16 (-4.0)	5.92	5.96	5.94	5.91	5.90	5.89	5.94	5.93
-12.72 (-5.0)	5.92	5.98	5.93	5.91	5.92	5.87	5.95	5.94
-15.24 (-6.0)	5.97	5.99	5.91	5.93	5.89	5.83	5.94	5.97
-17.78 (-7.0)	5.97	6.01	5.95	5.97	5.99	5.86	6.37	5.95
-20.32 (-8.0)	6.83	----	7.26	6.31	7.78	6.17	8.30	6.25
-22.86 (-9.0)	8.36	7.58	----	7.54	----	7.28	----	7.29
M_p	5.912	5.944	5.941	5.944	5.905	5.890	5.953	5.960

(b) $p_{t,1}$ = 1.14 MN/m^2 (165.3 psia); $T_{t,1}$ = 478 K (860° R)

s', cm (in.)	M for -							
	x' = 21.59 cm (8.5 in.)		x' = 1.59 cm (0.6 in.)		x' = -25.40 cm (-10.0 in.)		x' = -55.88 cm (-22.0 in.)	
	$\phi = 0^\circ$	$\phi = 90^\circ$	$\phi = 0^\circ$	$\phi = 90^\circ$	$\phi = 0^\circ$	$\phi = 90^\circ$	$\phi = 0^\circ$	$\phi = 90^\circ$
22.86 (9.0)	8.09	7.27	8.46	7.26	8.94	7.26	----	7.00
20.32 (8.0)	6.05	6.06	6.20	6.10	6.65	6.01	7.33	5.97
17.78 (7.0)	6.02	6.02	5.95	5.99	5.96	5.94	5.98	6.06
15.24 (6.0)	6.00	6.01	5.95	5.98	5.97	5.94	5.98	5.93
12.70 (5.0)	5.99	5.93	5.95	5.94	5.98	5.95	5.99	5.96
10.16 (4.0)	5.98	5.98	5.95	5.92	5.97	5.96	5.99	6.00
7.62 (3.0)	5.98	5.96	5.96	5.92	5.97	5.97	6.02	6.00
5.08 (2.0)	5.97	5.93	5.94	5.92	5.97	5.96	6.03	5.97
2.54 (1.0)	5.95	5.93	5.93	5.92	5.99	5.97	6.04	6.01
0	5.95	5.95	5.93	5.92	5.98	5.97	6.04	6.01
-2.54 (-1.0)	5.96	5.93	5.93	5.92	5.98	5.96	6.04	6.01
-5.08 (-2.0)	5.98	5.95	5.93	5.93	5.98	5.97	6.03	6.01
-7.62 (-3.0)	5.98	5.97	5.96	5.92	5.98	5.97	6.02	6.00
-10.16 (-4.0)	5.98	5.99	5.96	5.93	5.97	5.96	6.00	5.97
-12.72 (-5.0)	5.98	6.00	5.95	5.95	5.99	5.95	6.00	5.97
-15.24 (-6.0)	6.03	6.01	5.93	5.99	5.96	5.93	6.01	5.99
-17.78 (-7.0)	6.03	6.02	5.99	6.00	5.98	5.84	6.09	6.00
-20.32 (-8.0)	6.47	----	6.88	6.06	7.50	6.09	8.02	6.04
-22.86 (-9.0)	8.86	7.36	---	7.26	----	7.19	----	7.01
M_p	5.986	5.974	5.947	5.962	5.973	5.965	5.994	5.982

TABLE AI.- MACH NUMBER CALCUATED FROM $p_{t,2}/p_{t,1}$ – Concluded

(c) $p_{t,1}$ = 2.17 MN/m^2 (314.7 psia); $T_{t,1}$ = 478 K (860° R)

s', cm (in.)	M for –							
	x' = 21.59 cm (8.5 in.)		x' = 1.59 cm (0.6 in.)		x' = -25.40 cm (-10.0 in.)		x' = -55.88 cm (-22.0 in.)	
	φ = 0°	φ = 90°	φ = 0°	φ = 90°	φ = 0°	φ = 90°	φ = 0°	φ = 90°
22.86 (9.0)	7.71	7.03	8.11	6.94	8.69	7.00	----	6.81
20.32 (8.0)	6.04	6.02	6.06	6.05	6.39	6.02	6.99	5.99
17.78 (7.0)	6.04	6.04	5.98	6.01	5.98	5.97	5.98	6.12
15.24 (6.0)	6.03	6.03	5.98	6.01	6.00	5.97	6.00	5.91
12.70 (5.0)	6.02	6.02	5.98	5.97	6.00	5.98	6.00	5.99
10.16 (4.0)	6.01	6.01	5.99	5.95	6.00	5.99	6.0[illegible]	6.03
7.62 (3.0)	6.00	5.99	5.98	5.95	5.99	5.99	6.[illegible]	6.03
5.08 (2.0)	5.99	5.96	5.96	5.96	6.00	5.99	6.03	6.02
2.54 (1.0)	5.98	5.95	5.96	5.96	6.02	5.99	6.04	6.04
0	5.98	5.98	5.95	5.96	6.01	6.00	6.04	6.04
-2.54 (-1.0)	5.99	5.97	5.96	5.96	6.01	5.99	6.05	6.03
-5.08 (-2.0)	6.00	5.97	5.96	5.96	6.00	6.00	6.03	6.04
-7.62 (-3.0)	6.00	5.99	5.99	5.95	6.00	6.00	6.03	6.03
-10.16 (-4.0)	6.02	6.01	5.98	5.96	6.00	5.99	6.01	6.02
-12.72 (-5.0)	6.01	6.02	5.98	5.98	6.02	5.98	6.01	6.01
-15.24 (-6.0)	6.05	6.03	5.97	6.01	5.99	5.98	6.03	6.03
-17.78 (-7.0)	6.04	6.04	5.99	6.03	6.00	5.96	6.02	6.04
-20.32 (-8.0)	6.01	6.04	6.54	6.02	7.16	6.04	7.68	6.03
-22.86 (-9.0)	8.52	7.12	8.82	7.04	----	6.99	----	6.86
M_p	5.997	5.993	5.965	5.980	5.990	5.981	6.011	6.002

(d) $p_{t,1}$ = 3.03 MN/m^2 (439.5 psia); $T_{t,1}$ = 478 K (860° R)

s', cm (in.)	M for –							
	x' = 21.59 cm (8.5 in.)		x' = 1.59 cm (0.6 in.)		x' = -25.40 cm (-10.0 in.)		x' = -55.88 cm (-22.0 in.)	
	φ = 0°	φ = 90°	φ = 0°	φ = 90°	φ = 0°	φ = 90°	φ = 0°	φ = 90°
22.86 (9.0)	7.48	6.95	7.90	6.89	8.49	6.94	8.92	6.77
20.32 (8.0)	6.04	6.02	6.03	6.05	6.26	6.03	6.79	6.02
17.78 (7.0)	6.05	6.05	5.99	6.02	5.98	5.97	5.99	6.11
15.24 (6.0)	6.03	6.03	5.98	6.01	6.01	5.97	6.01	5.91
12.70 (5.0)	6.02	6.02	5.97	5.99	6.00	5.98	6.00	5.99
10.16 (4.0)	6.00	6.02	5.98	5.96	6.00	5.99	6.01	6.02
7.62 (3.0)	6.00	5.99	5.98	5.96	5.99	5.99	6.03	6.03
5.08 (2.0)	5.99	5.97	5.96	5.97	6.00	5.99	6.03	6.03
2.54 (1.0)	5.98	5.96	5.96	5.96	6.01	5.99	6.04	6.04
0	5.99	5.98	5.95	5.96	6.01	5.99	6.04	6.04
-2.54 (-1.0)	5.99	5.97	5.96	5.97	6.01	5.98	6.04	6.03
-5.08 (-2.0)	5.99	5.98	5.95	5.96	6.00	5.99	6.03	6.04
-7.62 (-3.0)	6.00	6.00	5.98	5.96	6.00	6.00	6.03	6.02
-10.16 (-4.0)	6.02	6.02	5.98	5.97	5.99	5.99	6.01	6.02
-12.72 (-5.0)	6.01	6.03	5.98	5.99	6.02	5.98	6.02	6.00
-15.24 (-6.0)	6.05	6.04	5.96	6.02	5.99	5.99	6.03	6.03
-17.78 (-7.0)	6.05	6.04	5.99	6.03	6.00	5.97	6.01	6.04
-20.32 (-8.0)	6.15	6.03	6.39	6.02	6.99	6.05	7.48	6.05
-22.86 (-9.0)	8.34	7.06	8.65	6.98	----	6.95	----	6.79
M_p	5.997	5.995	5.964	5.982	5.995	5.981	6.012	6.006

TABLE AII. - TUNNEL FLOW PARAMETERS

x', cm (in.)	$p_{t,2}$, MN/m^2 (psia)	ϕ, deg	M_p	ΔM	ΔM_a	Core size cm (in.)
21.59 (8.5)	0.52 (75.4)	0	5.912	-0.007	-0.018	25 (9.8)
21.59 (8.5)	.52 (75.4)	90	5.944	-.032		16 (6.3)
1.59 (0.6)	0.52 (75.4)	0	5.941	-0.011	-0.020	33 (13.0)
1.59 (.6)	.52 (75.4)	90	5.944	-.029		28 (11.0)
-25.40 (-10.0)	0.52 (75.4)	0	5.905	-0.004	-0.004	33 (13.0)
-25.40 (-10.0)	.52 (75.4)	90	5.890	-.004		31 (12.2)
-55.88 (-22.0)	0.52 (75.4)	0	5.953	-0.001	+0.002	31 (12.2)
-55.88 (-22.0)	.52 (75.4)	90	5.960	+.004		28 (11.0)
21.59 (8.5)	1.14 (165.3)	0	5.986	-0.013	-0.018	26 (10.2)
21.59 (8.5)	1.14 (165.3)	90	5.974	-.024		18 (7.1)
1.59 (0.6)	1.14 (165.3)	0	5.947	-0.002	-0.016	33 (13.0)
1.59 (.6)	1.14 (165.3)	90	5.962	-.030		28 (11.0)
-25.40 (-10.0)	1.14 (165.3)	0	5.973	+0.005	-0.002	36 (14.2)
-25.40 (-10.0)	1.14 (165.3)	90	5.965	-.010		36 (14.2)
-55.88 (-22.0)	1.14 (165.3)	0	5.994	+0.023	+0.017	31 (12.2)
-55.88 (-22.0)	1.14 (165.3)	90	5.982	+.012		28 (11.0)
21.59 (8.5)	2.17 (314.7)	0	5.997	+0.001	-0.009	23 (9.1)
21.59 (8.5)	2.17 (314.7)	90	5.993	-.020		16 (6.3)
1.59 (0.6)	2.17 (314.7)	0	5.965	+0.009	-0.006	36 (14.2)
1.59 (.6)	2.17 (314.7)	90	5.980	-.022		26 (10.2)
-25.40 (-10.0)	2.17 (314.7)	0	5.990	+0.014	+0.009	36 (14.2)
-25.40 (-10.0)	2.17 (314.7)	90	5.981	+.005		36 (14.2)
-55.88 (-22.0)	2.17 (314.7)	0	6.011	+0.016	+0.020	33 (13.0)
-55.88 (-22.0)	2.17 (314.7)	90	6.002	+.025		28 (11.0)
21.59 (8.5)	3.03 (439.5)	0	5.997	+0.002	-0.007	26 (10.2)
21.59 (8.5)	3.03 (439.5)	90	5.995	-.016		18 (7.1)
1.59 (0.6)	3.03 (439.5)	0	5.964	+0.006	-0.003	33 (13.0)
1.59 (.6)	3.03 (439.5)	90	5.982	-.013		26 (10.2)
-25.40 (-10.0)	3.03 (439.5)	0	5.995	+0.008	+0.005	36 (14.2)
-25.40 (-10.0)	3.03 (439.5)	90	5.981	+.003		36 (14.2)
-55.88 (-22.0)	3.03 (439.5)	0	6.012	+0.009	+0.013	36 (14.2)
-55.88 (-22.0)	3.03 (439.5)	90	6.006	+.018		28 (11.0)

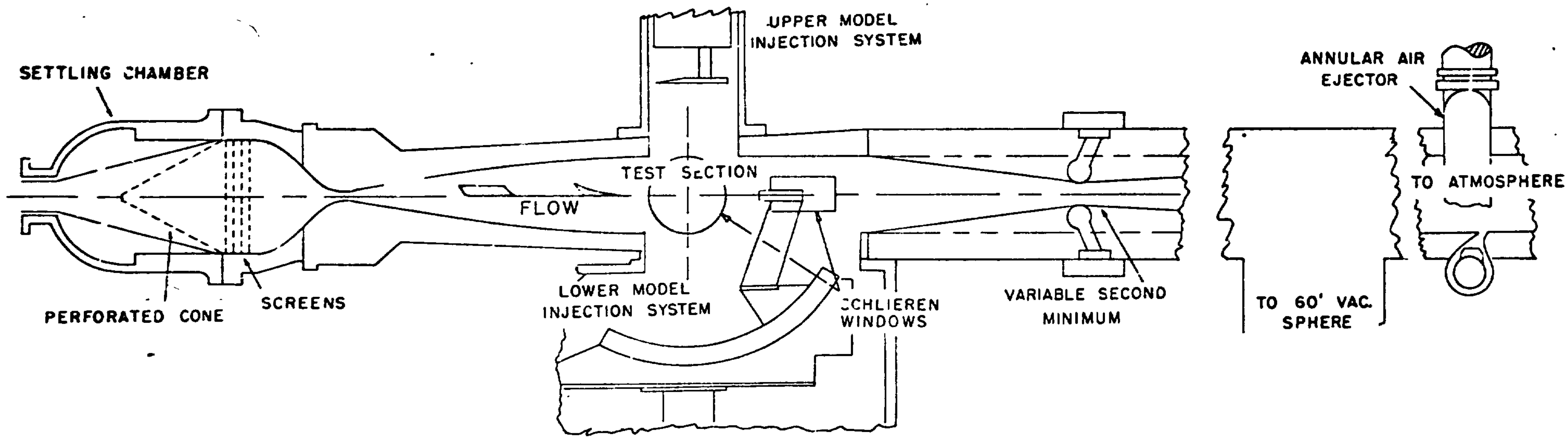
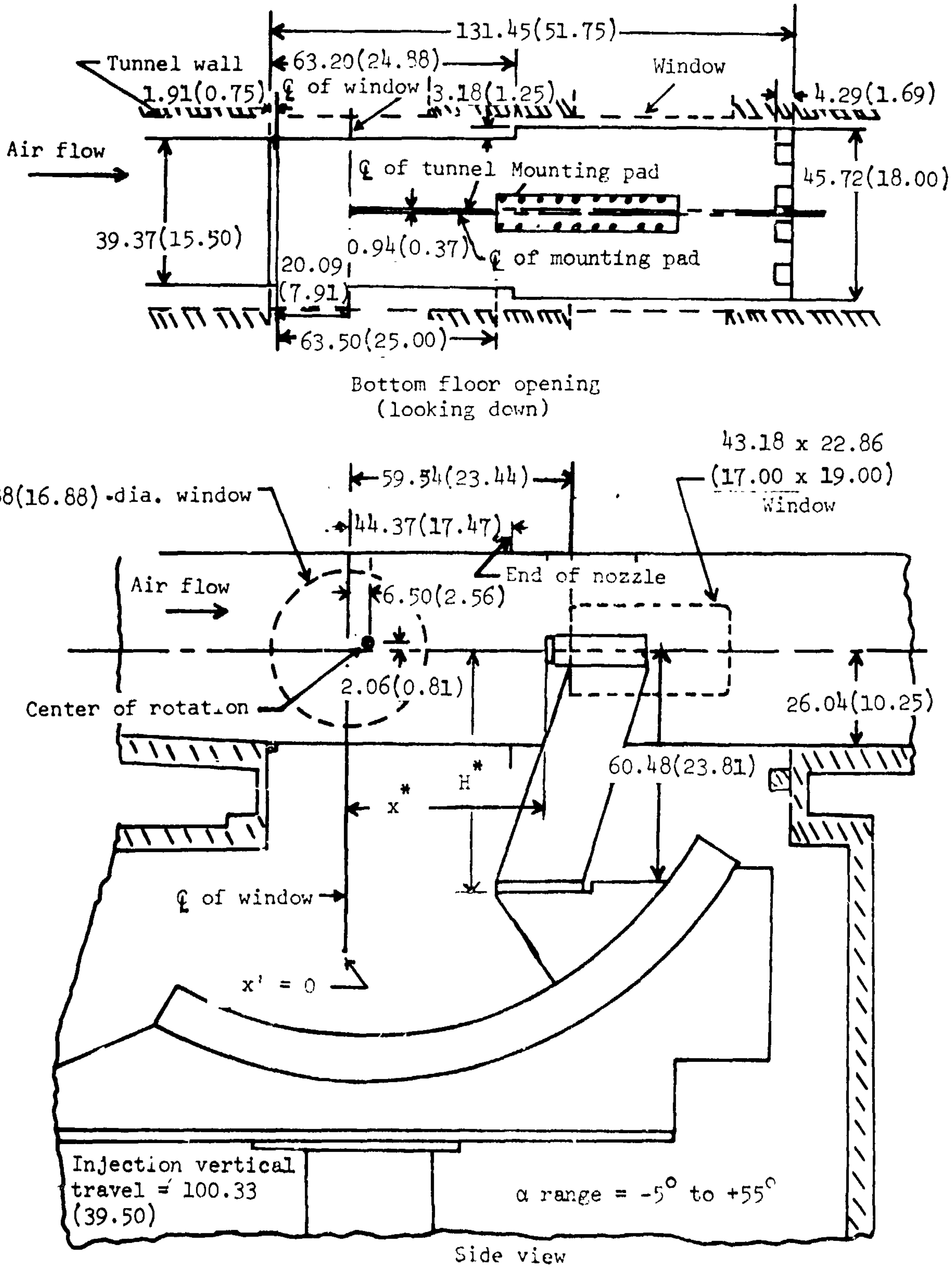


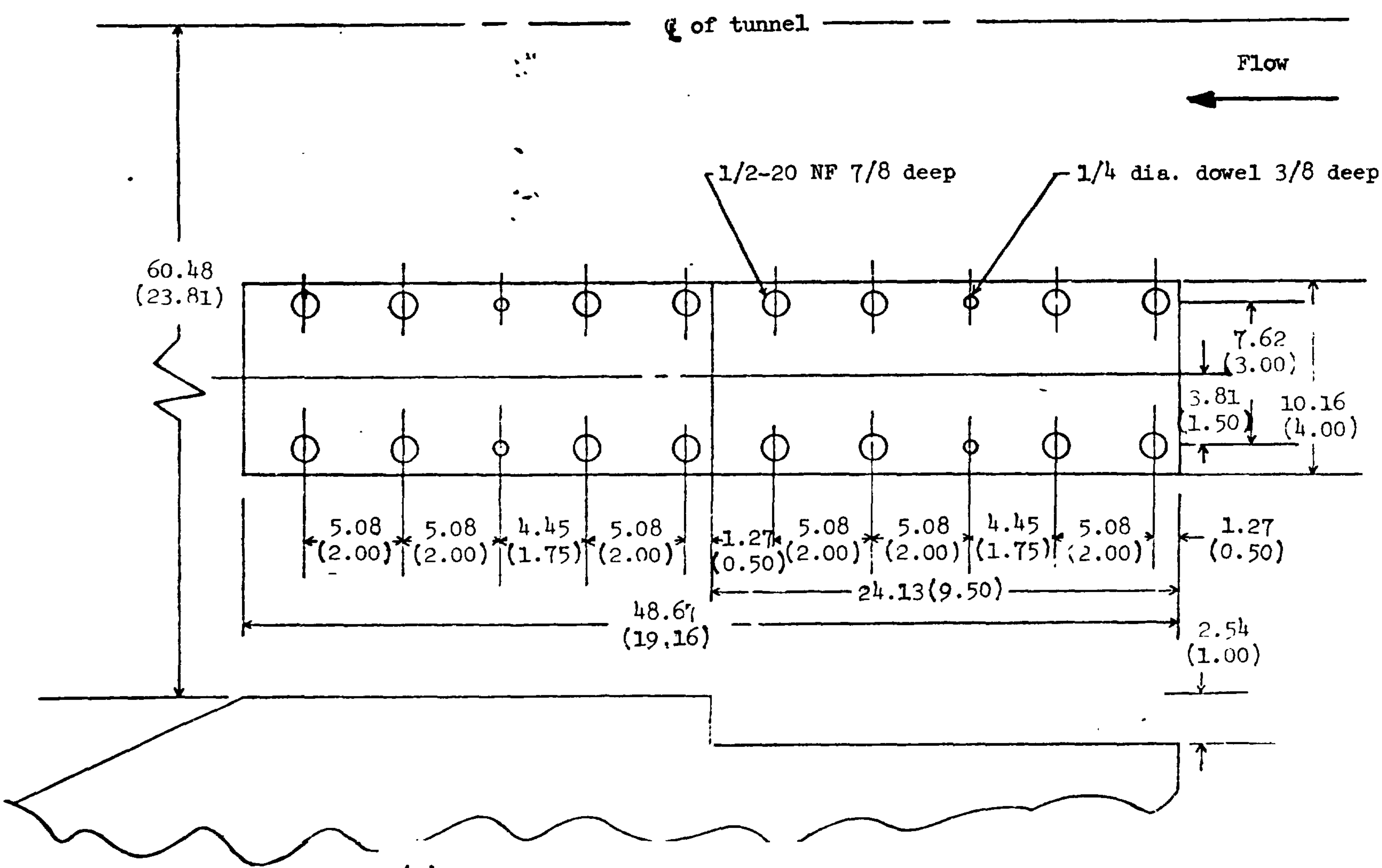
Figure A1. - Langley 20 - inch Mach 6 tunnel.



*See Table 3 of text for strut and head locations and dimensions.

(a) Overall view

Figure A2. - Lower model injection-system for the Langley 20-inch Mach 6 tunnel. All dimensions are in cm (in.)



(b) Mounting pad for sting support strut.

Figure A2. - Concluded.

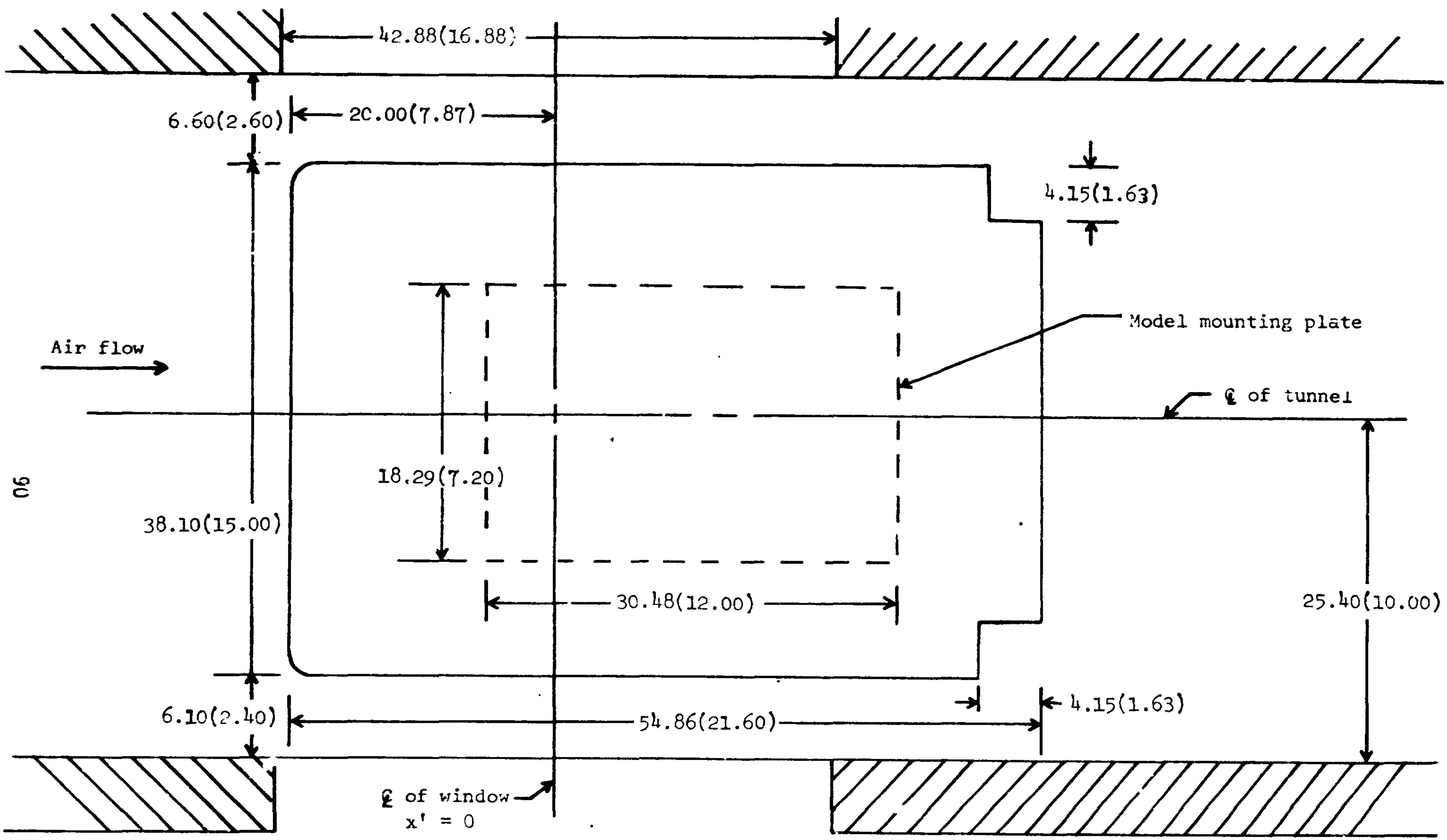


Figure A3. - Top injection - system opening for Langley 20-inch Mach 6 tunnel. All dimensions are in cm (in.)

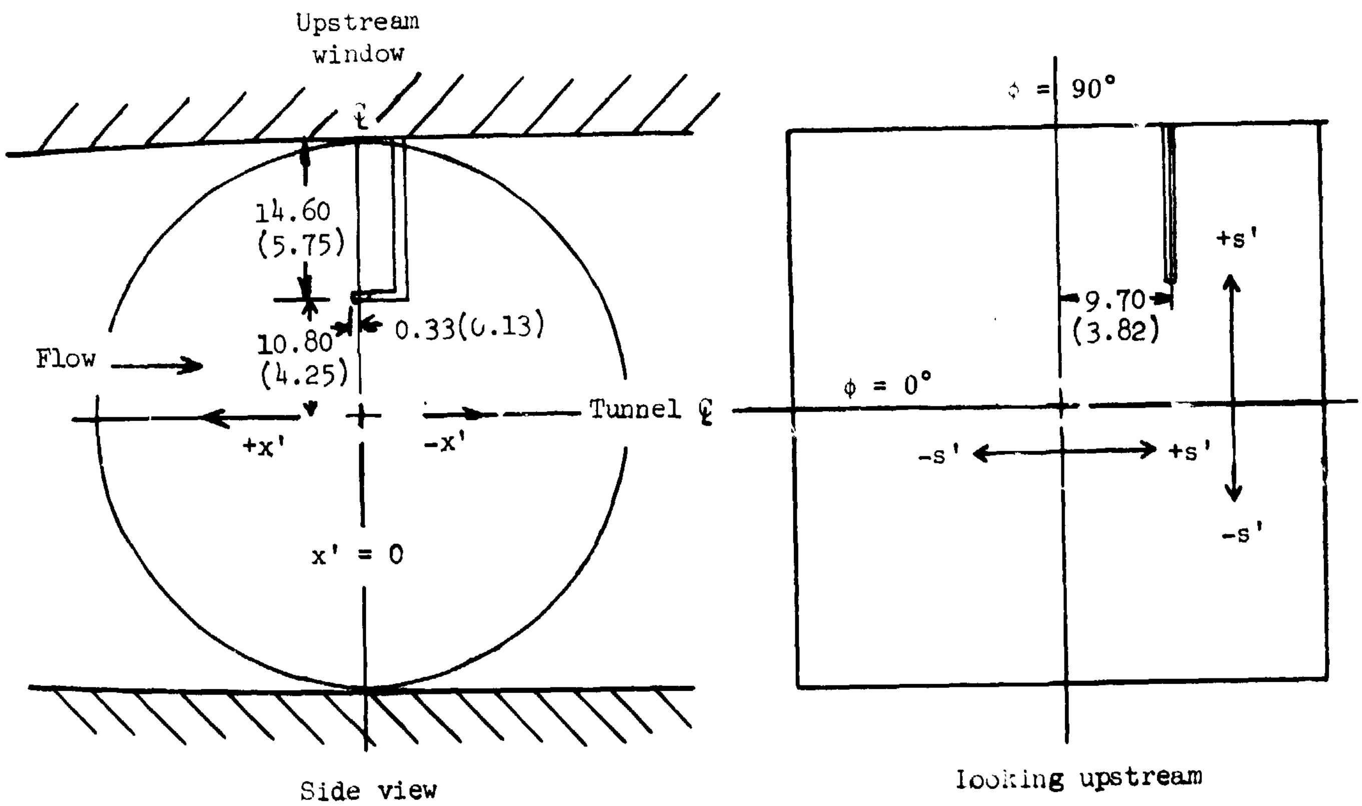
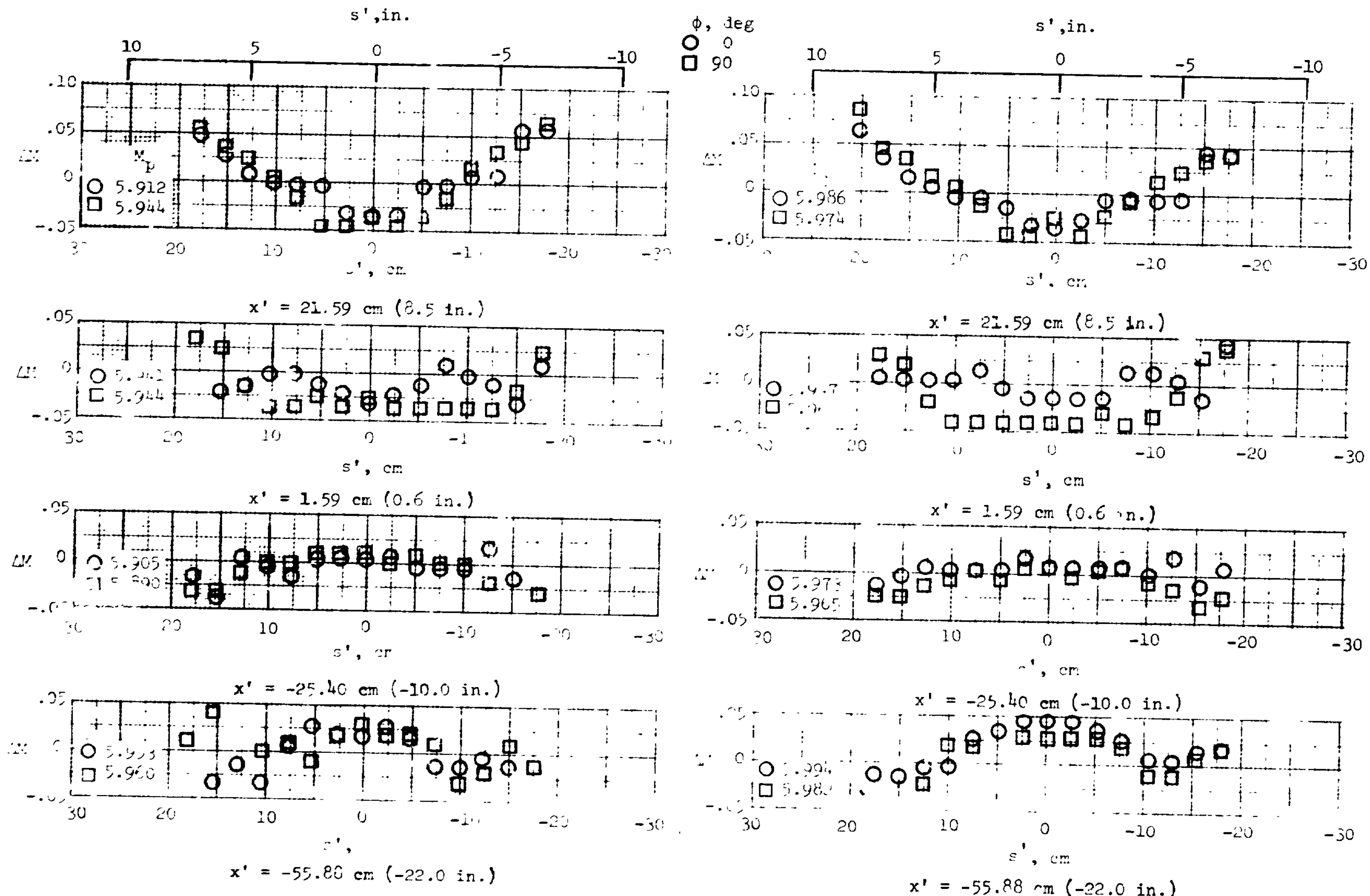


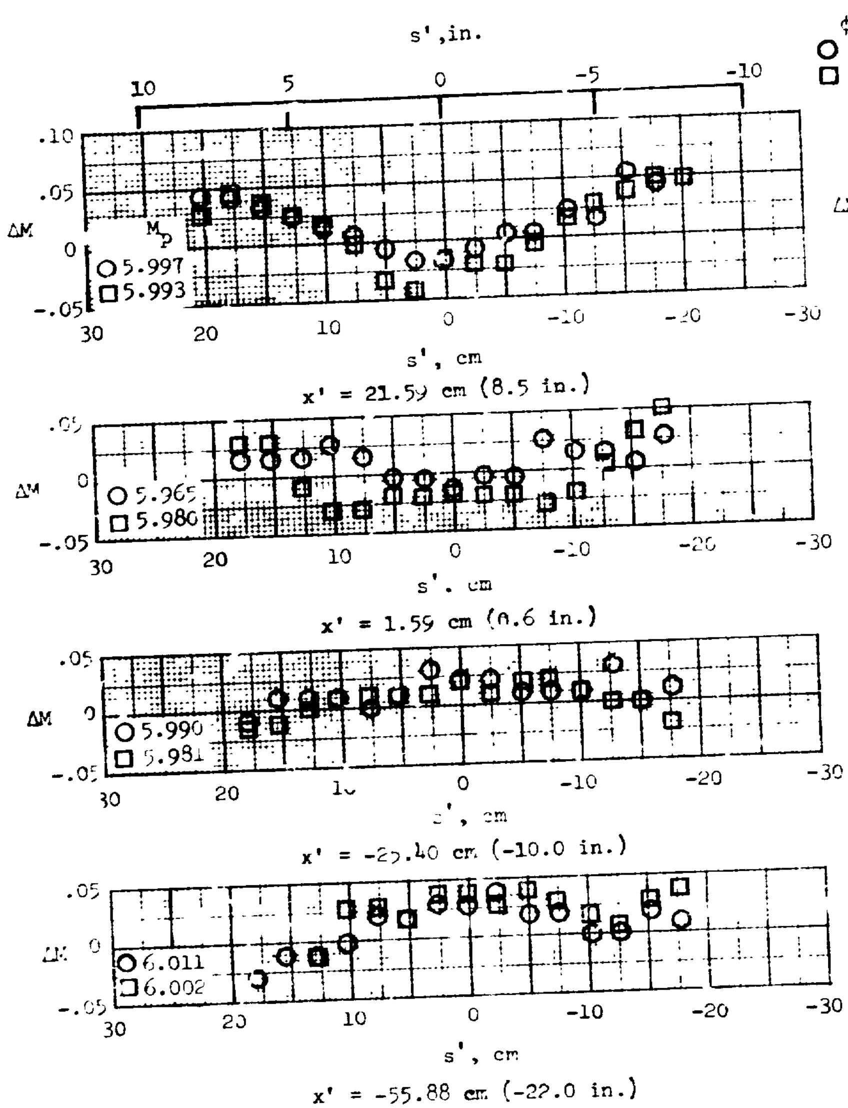
Figure A4. - Probe location. All dimensions are in cm (in.)



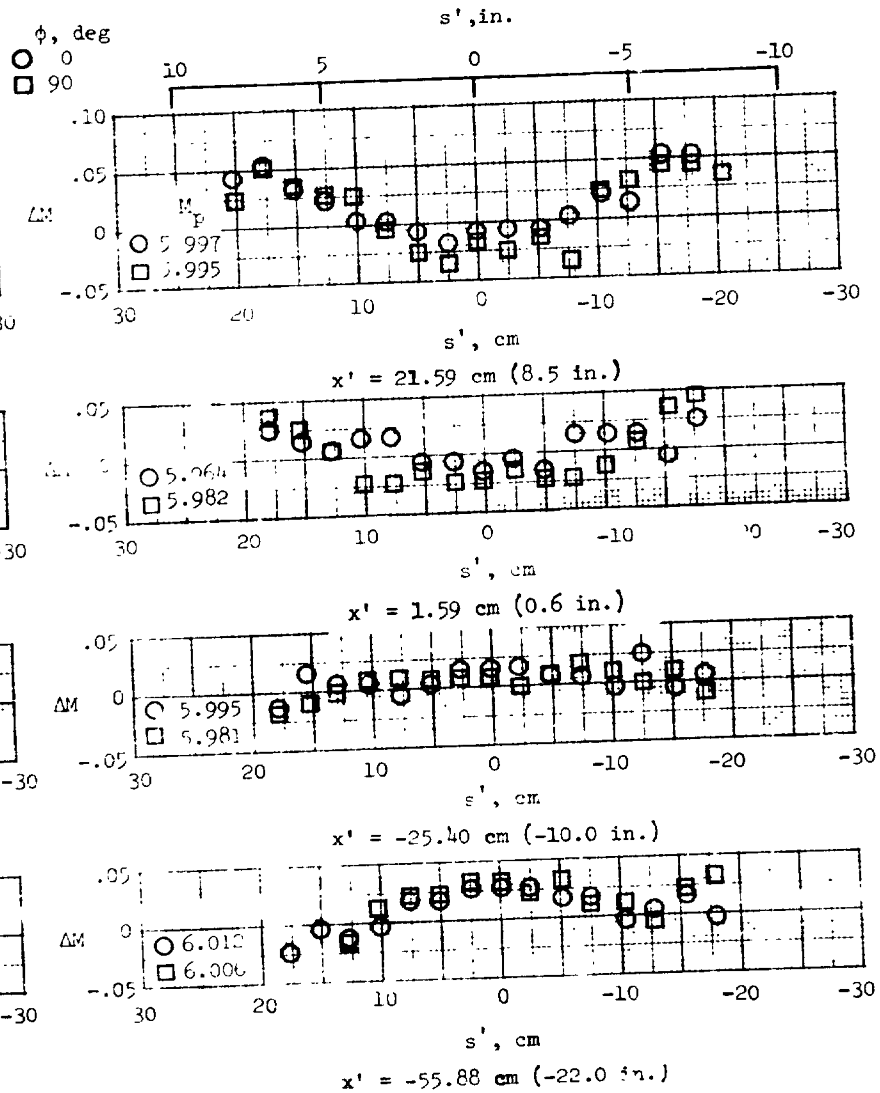
(a) $p_{t,1}$ = 0.52 MN/m^2 (75.4 psia)

(b) $p_{t,1}$ = 1.14 MN/m^2 (165.3 psia)

Figure A5. - Mach number deviation as a function of span.

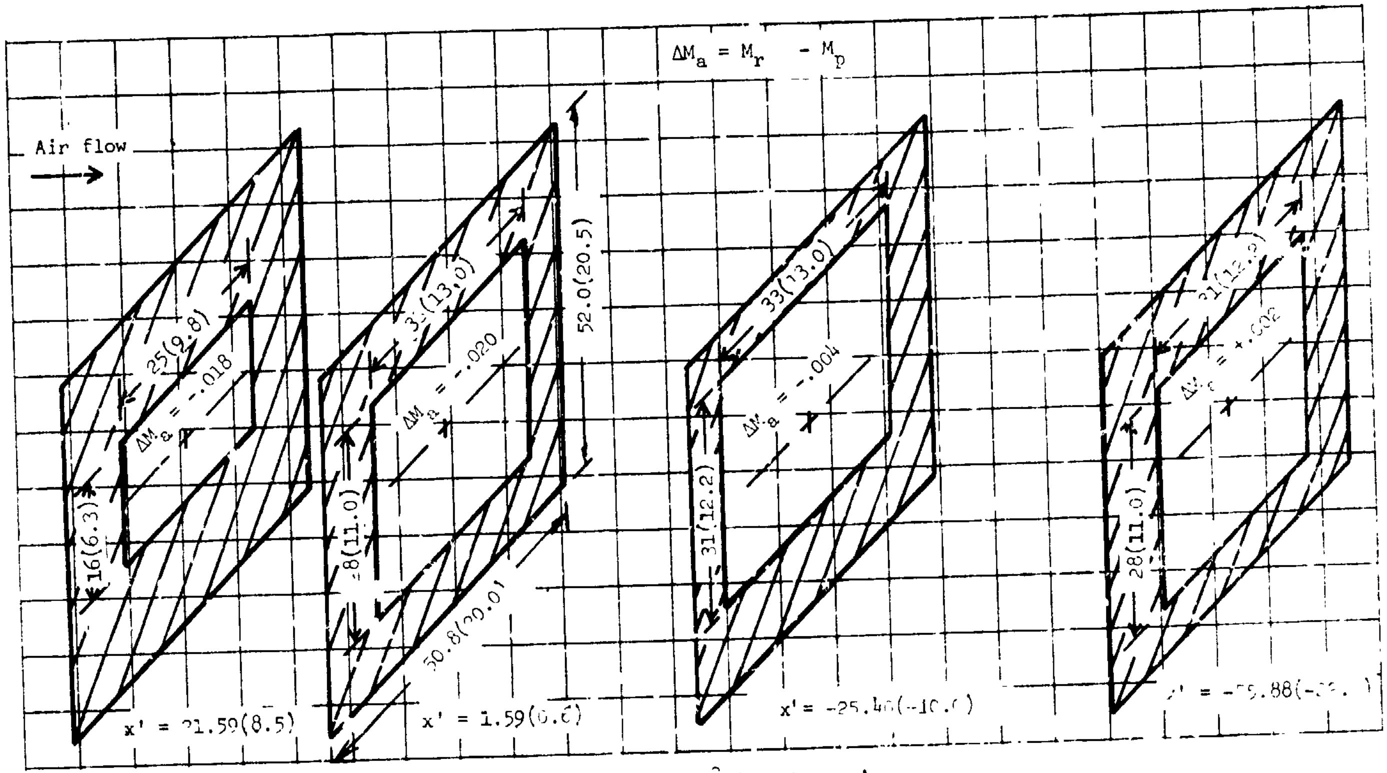


(c) $p_{t,1}$ = 2.17 MN/m^2 (314.7 psia)

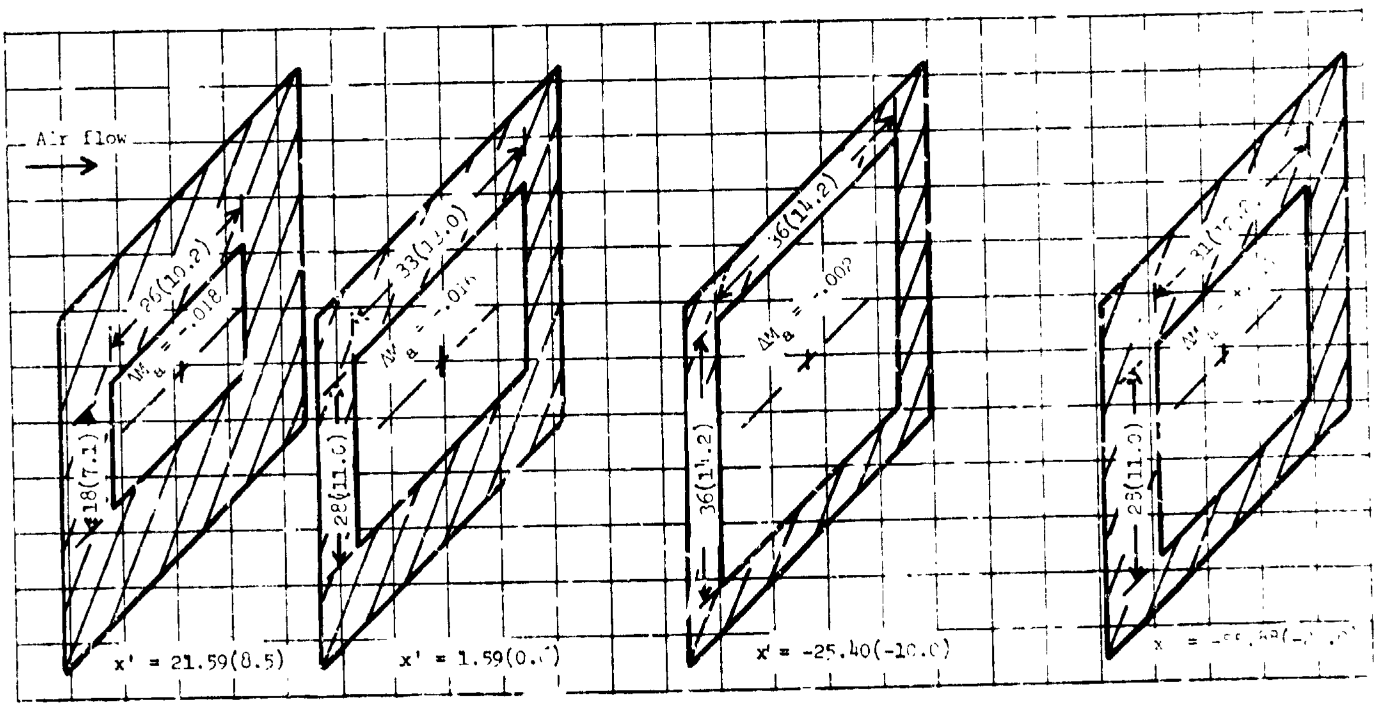


(d) $p_{t,1}$ = 3.03 MN/m^2 (439.5 psia)

Figure A5. - Concluded.

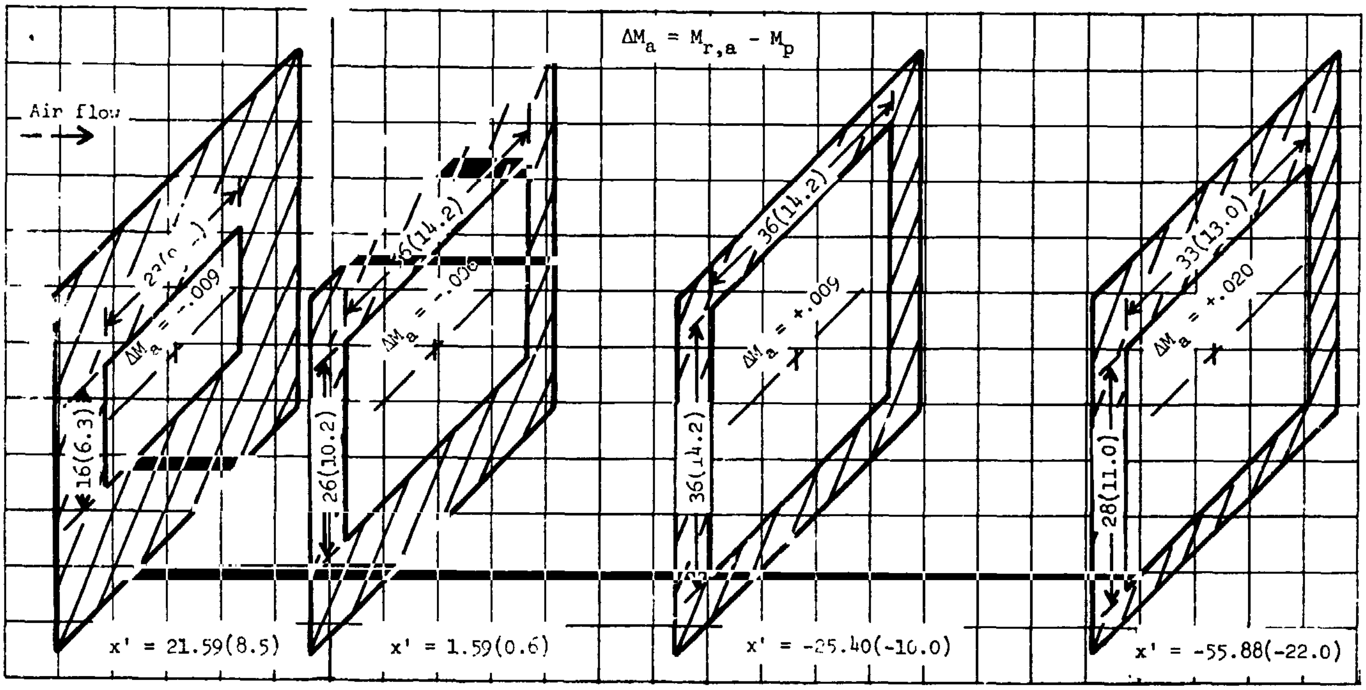


(a) $p_{t,1'}$ = 0.52 MN/m^2 (7 . 4 psia)

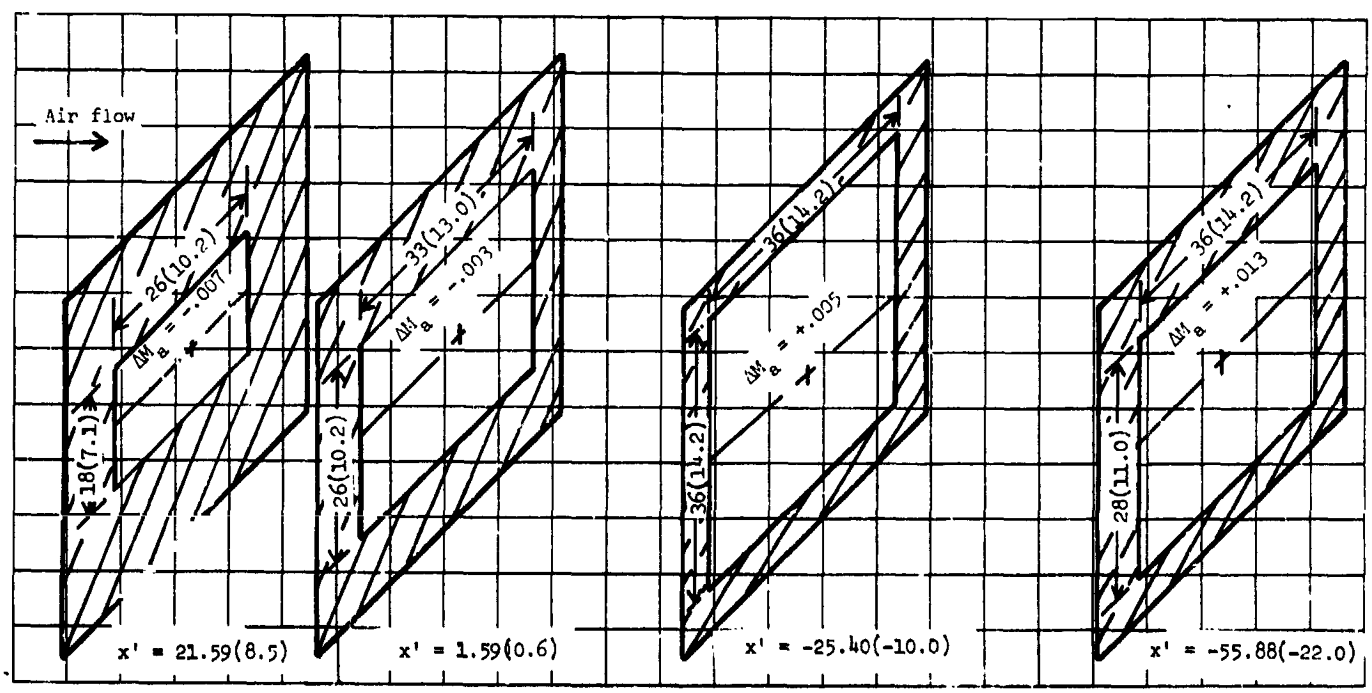


(b) $p_{t,1'}$ = 1.14 MN/m^2 (165.3 psia)

Figure A6. - Flow window at various axial stations. All dimensions are in cm (in.).



(c) $p_{t,1}$, = 2.17 MN/m^2 (314.7 psia)



(d) $p_{t,1}$, = 3.03 MN/m^2, (439.5 psia)

Figure A6. - Concluded.

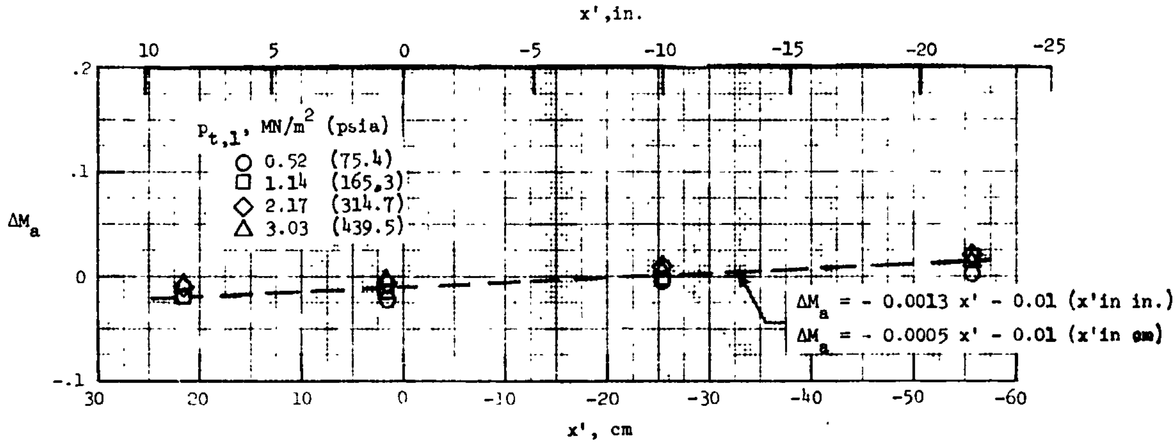
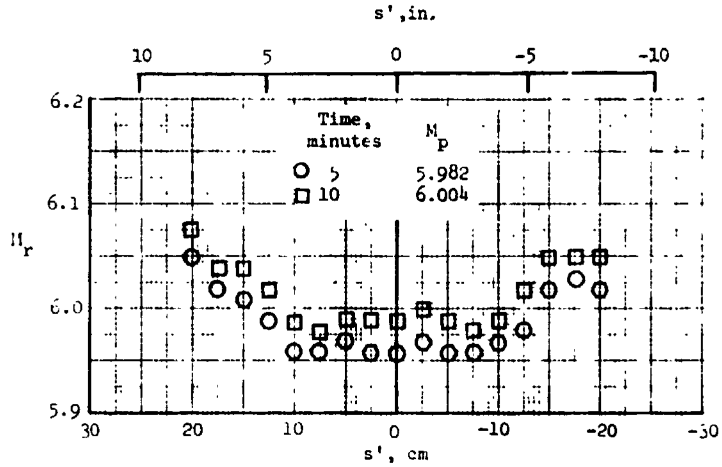
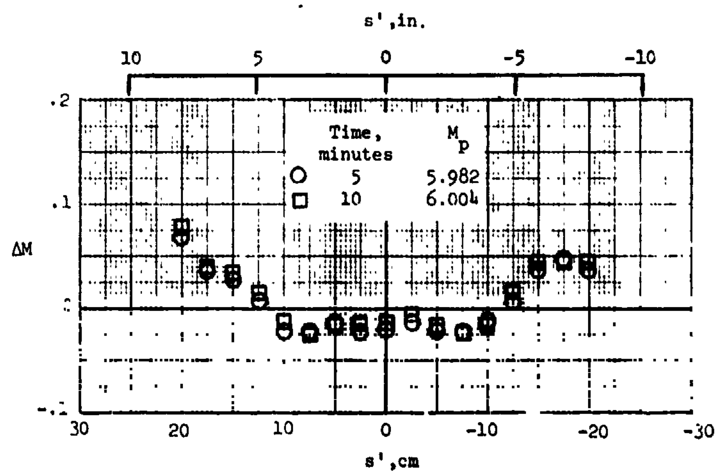


Figure A7.- Variation of ΔM_a with x'.



(a) Rake Mach number distribution with no adjustment.



(b) Differential Mach number distribution.

Figure A8. - Mach number variation with time. x' = 1.59 cm (0.6 in.); $\phi = 90^\circ$; $p_{t,1}$ = 3.03 MN/m² (439.5 psia).

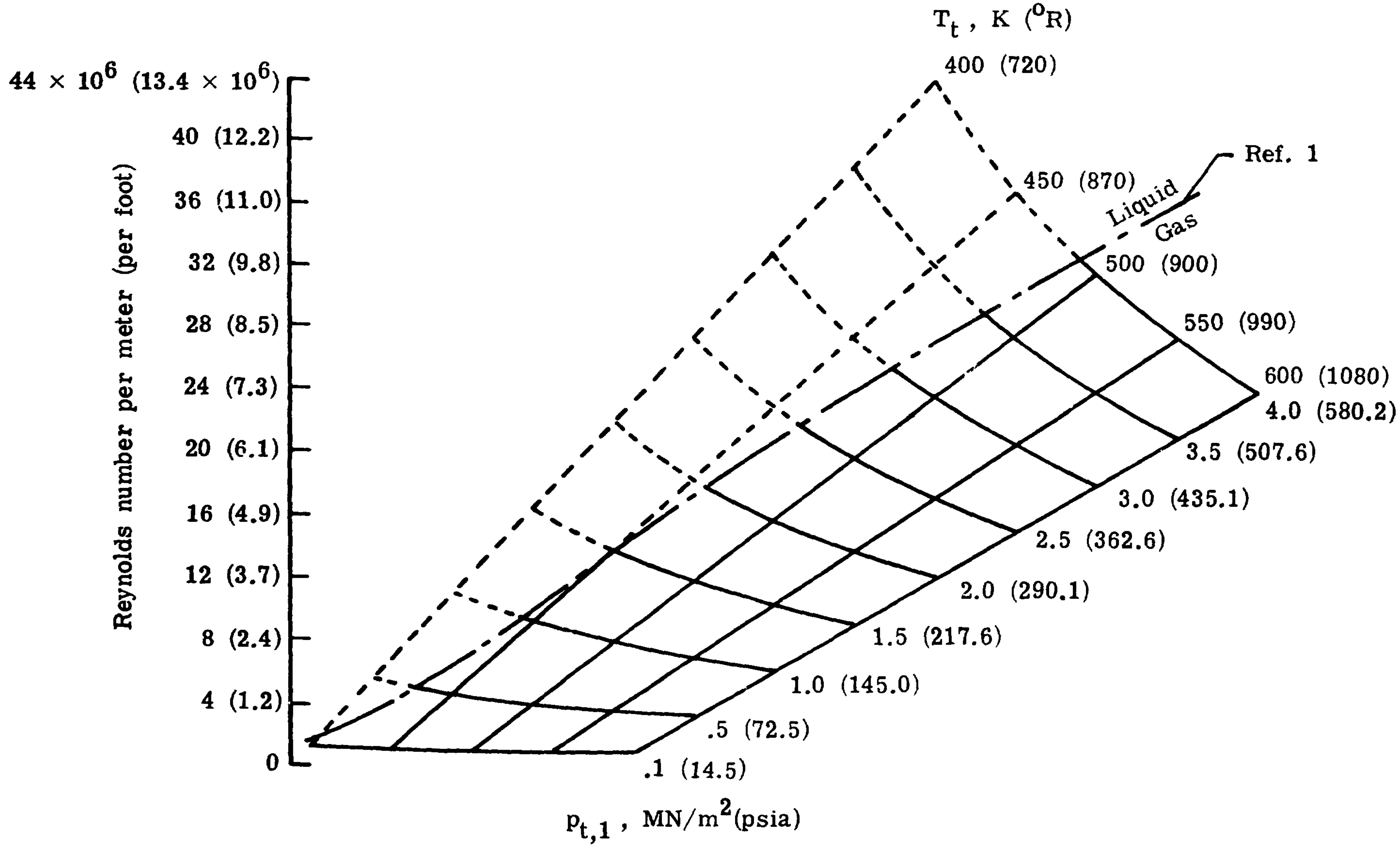


Figure A9.- Reynolds number as a function of stagnation pressure and temperature for M = 6. $\mu = 398.36 \times 10^{-10}T$, N sec/m^2 ($\mu = 8.32 \times 10^{-10}T$ (°R), lb-sec/ft^2) (ref. 2).