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Langley 14- by 22-Foot Subsonic Tunnel Test Engineer's Data Acquisition and Reduction Manual

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1. Introduction

This manual is a guide for the test engineer in the use of the Langley 14- by 22-Foot Subsonic Tunnel static data acquisition system. The information is applicable to the installation and tests of models in this facility. Detailed facility specifications, data acquisition system operating procedures, and data acquisition hardware and software applications may be found in reference 1 and other manuals.[1]

2. Facility Description

The Langley 14- by 22-Foot Subsonic Tunnel complex consists of a model preparation area (MPA) and a closed-return, atmospheric wind tunnel, as shown in figure 1. (See ref. 2.) The principle applications are the tests of low-speed powered models and large-scale aircraft components at low speed ranges. The MPA is used for model setup, checkout, and static tests when required. The wind tunnel is used for low-speed tests with a maximum dynamic pressure of 144 psf (Mach 0.3).

2.1. Model Preparation Area

The model preparation area (MPA) is a large enclosed high bay. A high-pressure air station and a motor generator distribution box are available for powered models. A view of the MPA and control of the air station and motor generators are provided for from a second-floor control console. The MPA has five model interface stations hereafter called test sites (test sites 2–6) which may be shared by several models depending upon test instrumentation similarity. A model support system was designed to permit models to be installed on a mobile cart in the MPA and moved into the wind tunnel test section fully assembled and calibrated.

2.2. Test Section

The wind tunnel test cross section is 14.5 ft high by 21.75 ft wide and may be configured closed with walls and ceiling in place, open with the walls and ceiling displaced, or slotted with slots in the floor, ceiling, and walls. The test section floor is composed of two removable floor sections (front and back) which may be replaced with carts in various combinations of model supports, a moving ground belt, or a slotted floor. Also, floor boundary layer control is provided by a suction device ahead of the front cart. A high-pressure air station and motor generators are available for model power. Visual access into the test section is provided by television cameras located at various positions in the test chamber. The test section is serviced by test site 1 which is located in an area just beneath the test section.

3. Data Acquisition System

The static data acquisition system (SDAS) consists of model interface (MIF) cabinets, two static data acquisition units (DAU's), two computers, input/output (I/O) peripherals, and a dynamic data acquisition system (DDAS). These subsystems are connected by a data cable plugboard cabinet which routes data from the various test sites to the appropriate data acquisition subsystems. (See fig. 2.) *Either computer is capable of processing only one test on-line at a time.* Usually one computer is dedicated to the wind tunnel and the other to the MPA.

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[1] Wyle Laboratory document numbers SD 63160-129 R1-D4.1, *4- × 7-m Applications Software Maintenance Manual (Program Theory)*, SD 63156-129 R0-D4.2, *4- × 7-m Applications Program Software and Subroutine Descriptions (Software Maintenance Manual)*, and HD 63203-067 R1-D8, *Wyle 4- × 7-m Tunnel Site Notebook*.

3.1. Model Interface (MIF)

The model interface (MIF) is designed to act as a portable interface system between the model and the data acquisition subsystems. Each MIF contains a Neff 300[2] analog signal conditioner, a digital interface (DIF), and a tachometer interface (TIF). Once connected to a particular model, each MIF moves with the model from one test site to another. Model interface data cable pin-out assignments are given in appendix A.

3.1.1. Neff 300 Analog Signal Conditioner

The Neff 300 series signal conditioner provides instrument calibration and excitation voltages compatible with many analog measuring devices. The output signals from the NEFF 300 are amplified, converted to digital codes, recorded, and directly processed; each of the 96 channels can be tailored for a particular measurement device. Also, the Neff 300 provides constant excitation voltage, strain gage bridge completion circuitry, and programmable calibration.

The Neff 300 has strain gage mode cards which configure individual channels for strain gage bridges with one, two, or four active arms. Also, the mode cards provide manual potentiometers to adjust the excitation voltage for each channel from 2 to 10 V within 10 mV resolution. Balance control of the signal is provided by another potentiometer with manual adjustment.

3.1.2. Digital Interface (DIF)

Each DIF has a capacity of 8 digital channels (6-digit binary coded decimal (BCD) with polarity, 24-bit natural binary with polarity, or 5-digit grey code) at transitor-transitor logic (TTL) input signal levels through 32-pin electrical connectors (KPT type). For the static data acquisition system, the 8 channels are converted to the 24-bit binary code and multiplexed onto 1 cable. However, isolated signal outputs are available for specialized cases. For instance, one DIF, which is located in the data plugboard cabinet in the control room, has four channels dedicated to wind tunnel pressure sensors.

3.1.3. Tachometer Interface (TIF)

Each TIF has a capacity for eight-pulsed signals. Input is through a 3-pin XLR connector with signal conditioning provided by the TIF. Individual outputs are BCD values of counts which are input to the data system through a DIF. The conditioned pulse signals are also accessible through an eight-channel analog cable at the data plugboard cabinet in the control room.

3.2. Data Plugboard Cabinets

Analog and digital data signals are transmitted from the six test sites to a plugboard cabinet in the control room. From this plugboard cabinet, data signals are then sent to the two static or the dynamic data acquisition system located in the computer room. Analog data are patched, 16 channels at a time, by 55-pin KPT panel connectors. Digital data are patched, 8-multiplexed channels at a time, by 55-pin KPT panel connectors. Access channels are also provided for nonmultiplexed digital data and conditioned pulse signals from each test site (32-pin KPT connectors). Selected analog channels may be monitored independently of the data systems by using available 55-pin KPT to 3-pin XLR break-out panels.

3.3. Static Data Acquisition Unit

Each computer has a Neff 620/500 controller and a Neff 620/600 DAU to acquire the static or the time-averaged digital and analog data.

[2] Neff Instrument Corp., Monrovia, CA 91016.

3.3.1. Analog Input Specifications

Each DAU acquires data from up to a maximum of 128 analog channels at a maximum rate of 100 000 samples per second per single channel with 16-bit resolution. Currently, the software is capable of handling only 96 analog channels. The Neff 600 has programmable gains of 1 to 512 to provide ±0.625 mV to ±10.24 V, respectively, and filters of 1 to 1000 Hz. It also has the capability of autoranging on four preset ranges.

3.3.2. Digital Input Specifications

Each DAU may acquire 16 channels of digital data (BCD, binary, or grey code) that are converted to binary coding and multiplexed by up to two DIF's. This digital data may include any tachometer data that are passed from a TIF to one of the DIF's. The input signals are at the TTL level through a 32-pin KPT connector. Digital input buffers can be serially connected to provide up to 32 channels of digital data on either DAU.

3.4. Pressure Scanning Subsystems

Time-averaged pressure data are obtained with electronically scanned pressure (ESP) transducers on up to a maximum of 2048 channels. Currently the facility uses the 780B ESP system with one data acquisition and control unit and two pressure calibration units for each computer system. This system can accommodate ESP modules with 16, 32, and 48 ports. The facility has modules with pressure ranges from 10 in. of water to 45 psi. The 5-psi-range modules are most frequently used and 20 are available.

3.5. Computer Systems

Two MODCOMP 9250[3] computers for the SDAS are located on-site for data acquisition, reduction, and storage.

3.5.1. CPU and Operating System

These computers have 32-bit CPU's, 8 MB of memory, I/O processors, and a digital interface subsystem. The operating system runs in real time and is capable of multitasking. Program languages which are available include an assembler and an enhanced FORTRAN 77 compiler. The computers share switchable peripherals but generally run independently.

3.5.2. Peripherals

Each computer system includes the following peripherals:

1. One 9-track tape drive with autotape mount (switchable)
2. Two 663 MB disks
3. One 96-character, 600-lpm line printer (switchable)
4. Six interactive terminals (movable)
5. One high-speed graphics display
6. Three touch-screen, interactive graphic terminals

[3] Modular Computer Systems, Inc., Fort Lauderdale, FL.

7. Two IEEE-488 interfaces
8. Thirty-two RS-232-C ports

3.6. Dynamic Data Acquisition

The dynamic data acquisition system (DDAS) is comprised of a single host computer, which controls a variety of hardware and software subsystems. These subsystems are broadly configured as acquisition, processing, and tape backup. The recording system is capable of collecting up to 72 channels of data at a time. All channels are capable of a 0- to 20-kHz bandwidth, are digitized in real time (16 bits for a 90-dB dynamic range), and are stored on removable disk drives. Each channel is single-ended, can be either AC- or DC-coupled, and can range from 20 V to 10 mV full-scale. At the maximum bandwidth, approximately 14 min of data can be stored on each disk. The Zonic 7000[4] recording system is connected through the local network to provide parametric data from the SDAS and to control calibration sequences; the recording system has order-tracking capability. The Zonic hardware is hosted by a Hewlett-Packard 9000/750 computer, which runs a UNIX operating system. The Zonic software Zeta is X compatible so the system can be run remotely from an X terminal. The host computer also controls the three FM tape recorders with three time-code readers, and one time-code generator. Automatic acquisition and playback control is available. Application software for processing data is also available and includes SDRC[5] tdas and PV-Wave. These commercial software packages provide off-line data processing and graphics display capability not otherwise available. Some custom processing routines are also available. The host computer is networked to an optical storage server, which provides 20 GB of storage in an optical jukebox; because a fully configured test generates approximately 9 GB of data, the capacity is considered adequate. Color and monochrome hard copies of plots are available through network resources.

3.7. Laser Velocimeter System

The laser velocimeter (LV) in use in the Langley 14- by 22-Foot Subsonic Tunnel is operated in the backscatter mode and is capable of collecting two or three components of velocity from most locations within the 14.5-ft-high by 21.75-ft-wide by 50-ft-long test section. The Rosebening scanning system has five degrees of freedom which provide the capability of continuously scanning a volume 14 ft high by 21 ft wide by 6 ft long. The data system currently associated with the LV system operates independently of the tunnel SDAS except to receive data from the SDAS to indicate tunnel operating conditions. The LV data system currently

1. Collects raw data for two or three independent velocity components
2. Collects raw data from one auxiliary input which is normally associated with rotor or propeller location
3. Converts raw data to engineering units
4. Statistically analyzes data and provides on-line graphic display of the results
5. Interfaces with a microcomputer to control the measurement location with the five-degrees-of-freedom scanning system
6. Provides access to the laser system through a menu-controlled operating system which includes a comprehensive diagnostics package

A complete description of the system is available in reference 3.

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[4] Zonic Corp., Milford, OH 45150.

[5] Structural Dynamics Research Corp., Milford, OH 45150.

3.8. Thermocouple Data Logging

Thermocouple cables connect each of the data acquisition stations to the control room. A chart recorder is used to monitor and record up to a maximum of 32 temperatures and provides both alarm and data communication capabilities. The alarm feature is mainly used for safety monitoring of propulsion simulation or rotorcraft tests.

4. Data Reduction Theory and Equations

On-line, on-site static data reduction includes the capability to accommodate wind tunnel models with up to 96 analog and 32 digital data channels, four 6-component internal balances, and 2048 pressure readings from electronically scanned pressure (ESP) modules. The wind tunnel data reduction parameters are summarized in appendix B; the output data array is listed in appendix C.

4.1. Engineering Units

Before analog data are converted to engineering units, corrections are made to the data for analog cable losses and excitation voltage drift. The analog cable loss correction is

```
RDG (N) = RDG(N) * SPAN(N), N = 1:96
```

and the excitation voltage correction is then applied as

```
RDG(N) = RDG(N) * VOLT(N) / RDG(IVOLT(N))
```

where

`RDG(1:128)` are the data obtained from the DAU

`SPAN(1:96)` are the analog cable loss factors

`VOLT(1:96)` are the excitation voltages recorded when the channels were calibrated (sec. 6.1.4)

`IVOLT(1:96)` are the analog channel numbers for the excitation voltages

Engineering unit values are then calculated for the analog and digital data channels using one of the following equations:

For `ITYPE(N) = 0` then

```
EUNITS(N) = RDG(N)
```

For `ITYPE(N) = 1` then

```
EUNITS(N) = (RDG(N) - ZERO(N)) * CON(N) + OFFSET(N)
```

For `ITYPE(N) = 2` then

```
EUNITS(N) = (RDG(N) - ZEROI(N)) * CON(N) + OFFSET(N)
```

For `ITYPE(N) = 3` then

```
EUNITS(N) = ASIN((RDG(N) - ZERO(N)) * CON(N)) + OFFSET(N)
```

For ITYPE(N) = 4 then

```
EUNITS(N) = ASIN ((RDG(N) - ZEROI(N)) * CON(N)) + OFFSET(N)
```

For ITYPE(N) = 5 then

```
EUNITS(N) = ASIN(RDG(N) * CON(N) + (RDG(N)**2) * USERP(100)) + OFFSET(N)
```

where

ITYPE(1:128) are the conversion type codes

EUNITS(1:128) are the calculated engineering unit values

ZERO(1:128) are the data obtained from the DAU at a zero reference

ZEROI(1:128) are the zeros as input at setup

CON(1:128) are the sensitivity constants determined from instrumentation calibration

OFFSET(1:128) are the engineering unit offsets from the zero reference

USERP(100) is the second-order coefficient determined from instrumentation calibration

A type-1 data channel is usually a strain gage balance or other transducer signal that drifts from its zero reference. A type-2 data channel is a digital, thermocouple, or other instrumentation signal that does not drift from a zero reference. Type-3, -4, and -5 data channels are arcsine functions used for certain attitude transducers which produce a sinusoidal output. Channel types 3 and 4 are similar to types 1 and 2; a type-5 channel processes data in terms of a second-order equation to more closely match higher order sinusoidal output devices.

4.2. Wind Tunnel Parameters

Wind tunnel parameters which are either directly measured or calculated include the following:

PA is the ambient pressure (measured), psfa

PTOT is the settling chamber total pressure (measured), psfa

TA is the entrance cone ambient temperature (measured), °F

QI is the differential pressure of sidewall static pressure in the entrance cone referenced to PTOT (measured), psfd

PITOT is the test section dynamic pressure as measured by a pitot tube, psfd

TDEW is the dew point (measured), °F

Q is the test section dynamic pressure (measured or calculated), psfd

VEL is the test section free-stream velocity (calculated), fps

PI is the PSTAT, test section static pressure (calculated), psfa

RN is the Reynolds number per foot (calculated)

RHO is the air density (calculated), slugs/ft^3

Normally, Q and PI are calculated from the settling chamber total pressure and the entrance cone sidewall static pressure by using the relations

```
PI = PTOT - C * QI
Q = PTOT - PI = C * QI
```

where

C = 1.1496, QCODE = 2 for a closed test section (CTS)

C = 1.1266, QCODE = 3 for a CTS with boundary layer suction

C = 1.1425, QCODE = 4 for an open test section (OTS)

C = 1.1334, QCODE = 5 for an OTS with boundary layer suction

C = 1.1952, QCODE = 6 for an OTS with acoustic panels

These constants are based on a calibration of the test section dynamic pressure. If a pitot-static probe is used to measure dynamic pressure directly in the test section (sec. 6.5), then

```
PI = PTOT − PITOT (QCODE = 1) else PI = PTOT
```

QCODE = 0—No Q calculated (usually applies for static tests)

The air density RHO is calculated as a function of total pressure, test section static pressure, ambient temperature, and dew point, and corrected for compressibility using the following equations:

```
TR = 459.69 + TA

PV = 2.80288 + 0.0954685 * TDEW + 0.0070509 * TDEW * TDEW

RHO = (PTOT - PV * 0.3789) * ((PTOT / PI)**(-1.0 / AGAM)) / (GR * TR)
```

where

TR is the ambient temperature, °R

PV is vapor pressure as calculated from dew point, psf

AGAM is ratio of specific heats for air (1.4)

GR is the product of the gravitational constant and the gas constant for air, $(\text{ft/sec})^2$ / °R (1718.0)

VEL is calculated by

```
VEL = SQRT(2.0 * Q / RHO)
```

The Mach number is defined as

```
MACH = SQRT(5.0 * ((PTOT/PI)**(2.0 / 7.0) - 1.0))
```

and the Reynolds number per foot is calculated from the equations

```
XMU = 0.0002672 / (TR + 198.72) * (TR / 518.69)**1.5

RN = RHO * VEL / XMU
```

where

XMU is the absolute viscosity of air corrected for temperature, lb-sec/ft^2

4.3. Model Attitude Calculations

Model attitude parameters (fig. 3) which are either directly measured or calculated include the following:

ALPHA is the model angle of attack (calculated), deg

BETA is the model angle of sideslip (calculated), deg

THETA is the model angle of pitch (measured), deg

PSI is the model angle of yaw (measured or calculated), deg

PHI is the model angle of roll (measured), deg

HGT is the height of model reference point above test section floor (calculated), in.

The angle parameters follow the NASA standards for definition and sign conventions. (See ref. 4.) The HGT is normally positive with 0.0 being the floor; the test section centerline is at 87.0 in. above the tunnel floor (i.e., HGT = 87.0).

THETA and PHI are normally measured by attitude transducers mounted internally to the model. PHI is adjusted for the model attitude by adding PHIM which is the roll offset in degrees from the normal attitude of the model (i.e., PHIM = 180.0 if the model is tested upside down). PSI is measured directly from the model cart turntable except when the alpha-beta sting is used. This sting is designed to produce pitch and yaw angles of up to ±45° and roll angles of ±180° without affecting the position of the model in the test section. (See ref. 2.) The yaw angle and, optionally, the pitch and roll attitudes are calculated from the positions of the three joints of the alpha-beta sting and the turntable by using the following equations:

```
S22 = SIN(22.5)

C22 = COS(22.5)

SINT2 = SIN(T2)

COST2 = COS(T2)

SINT3 = SIN(T3)

COST3 = COS(T3)

PAR1 = C22 * C22 + S22 * S22 * COST2

PAR2 = -S22 * (SINT2 * COST3 + C22 * SINT3 * (COST2 - 1.0))

PAR3 = S22 * (SINT2 * SINT3 - C22 * COST3 * (COST2 - 1.0))

PAR4 = SINT3 * COST2 + COST3 * SINT2 * C22

PAR5 = S22 * S22 * COST3 + C22 * (COST3 * COST2 * C22 - SINT3 * SINT2)

PHI = T1 + ATAN(PAR4 / PAR5) + PHIM

PSI = ATAN(PAR2 / PAR1)

THETA = ATAN(PAR3 * COS(PSI) / PAR1)
```

where

T1 is the rotation angle of the front joint, deg

T2 is the rotation angle of the middle joint, deg

T3 is the rotation angle of the rear joint, deg

NOTE: Zero rotation of the three joints is with zero roll on the front joint and with the middle and rear arms perpendicular to the floor.

Angle of attack and angle of sideslip are calculated by using the equations below:

```
ALPHA = ATAN((COS(PSI) * SIN(THETA) * COS(PHI) + SIN(PHI)
  * SIN(PSI)) / (COS(THETA) * COS(PSI))
```

and

```
BETA = ASIN(COS(PSI) * SIN(THETA) * SIN(PHI) - SIN(PSI) * COS(PHI)
```

where the order of rotation is assumed to be PSI, THETA, and PHI. If a value for PSI, THETA, or PHI is not measured, 0.0 is assumed for the value. Corrections to ALPHA for wall effects are described in section 4.4.6; upflow and sideflow corrections are not made.

HGT is calculated from the elevation and pitch angle of the model support cart mast using the equation

```
HGT = 87.0 + (ELEV - 87.0) * COS(PITCHM) + RLENGTH * SIN(PITCHM)
```

for SCODE = 3 (for vertical air STRUT)

```
HGT = ELEV - VLENGTH * (1 - COS(PITCH)) - RLENGTH * SIN(PITCH)
```

where

ELEV is the mast displacement distance, in.

PITCHM is the mast pitch angle (0.0 vertical, positive pitched back), deg

RLENGTH is the horizontal distance from the center of the masthead to the model reference point with the mast vertical, in.

VLENGTH is the vertical distance from the pivot center on the vertical strut-to-model reference, in.

4.4. Force and Moment Data

The data acquisition system hardware and software are designed to accommodate up to a maximum of four six-component, internal balances per test. The balances have individual excitation power supplies and are treated as voltage devices by the Neff 300. Force and moment data reduction for the balances include interaction corrections, attitude tare corrections, and balance-to-model reference center transformations. By convention, balance data are assumed to be in the following order: normal force (NF), axial force (AF), pitching moment (PM), rolling moment (RM), yawing moment (YM), and side force (SF) for a NASA balance; and normal force 1 (N1), AF, normal force 2 (N2), RM, side force 1 (S1), and side force 2 (S2) for a Task[6] balance. (Refer to sec. 6.2.5.) The axis systems which are used include the following:

1. The balance axis is aligned with the balance.
2. The gravity-oriented model axis is aligned with the yaw and pitch of the model; roll is aligned with the gravity axis.
3. The model or body axis is aligned with the model.
4. The stability axis is the model axis rotated by the angle of attack.

4.4.1. Balance Interactions

Actual forces and moments are obtained by correcting all balance component test data for the applicable component interaction data that were recorded during the balance calibration. These correction coefficients are contained in a 6 × 27 matrix that consists of 6 × 6 first-order corrections and 6 × 21 second-order corrections referenced to the zero load output of the balance. Because the zero load output cannot be obtained, during the actual operation of the balance, the

[6] Able Corp., Yorba Linda, CA 92686.

balance interaction routine relies on the zero reference forces and moments as its input. These initial tare loads are calculated at each zero reference (wind-off zero) point by using the relations

```
FZ(1) = -WTN * COS(THETAZ + THETAO) * COS(PHIZ + PHIO)
FZ(2) = WT * SIN(THETAZ + THETAO)
FZ(6) = WTN * COS(THETAZ + THETAO) * SIN(PHIZ + PHIO)
FZ(3) = -FZ(1) * XBAR + FZ(2) * ZBAR
FZ(4) = FZ(1) * YBAR + FZ(6) * ZBAR
FZ(5) = -FZ(6) * XBAR - FZ(2) * YBAR
```

where

FZ(1:6) is the array of initial tare loads (NF, AF, PM, RM, YM, and SF), lb and in-lb

WTN, WT, XBAR, YBAR, ZBAR, THETAO, and PHIO are attitude tare (weight) parameters (sec. 4.4.4)

THETAZ is the pitch angle of the model at the zero reference, deg

PHIZ is the roll angle of the model at the zero reference (PHI - PHIM), deg

The balance component interaction corrections may then be made by adding the initial tare loads to the uncorrected balance loads relative to the last wind-off zero reference, applying the balance calibration coefficients to these uncorrected absolute loads to obtain corrected absolute loads, and then subtracting the initial tare loads to obtain corrected balance loads relative to the last wind-off reference point. In equation form,

```
XNFUA(N) = EUNITS(ICHB(IBAL) + N - 1) for N = 1 to 6
XNFUB(N) = XNFUA(N) + FZ(N)
XNFC(N) = f(AM, BCON)
CORR(N) = XNFC(N) - FZ(N) for N = 1 to 6
```

where

XNFUA(1:6) are the uncorrected loads

EUNITS is the array of uncorrected data engineering units

ICHB(IBAL) is the channel number for the normal force component of balance IBAL

XNFUB(1:6) are the uncorrected absolute loads

XNFC(1:6) is the array of corrected absolute loads

AM(1:27) is the array of XNFU and the products of its elements

BCON (1:174) is the array for the balance interaction file

CORR(1:6) are the relative corrected balance loads

4.4.2. Installation Interaction Corrections

The installation of a model on a model support system often requires that various instrumentation cables, hoses, and electrical wires be routed across the balance(s). This is especially true for powered models. To correct for this interference, first-order interaction equations are included in the data reduction program and require the input of a 6 × 6 matrix of interaction coefficients. This correction is of the form

```
CORR(N) = UNCORR(1) * B1(1,N) + UNCORR(2) * B1(2,N) + UNCORR(3) * B1(3,N)
  + UNCORR(4) * B1(4,N) + UNCORR(5) * B1(5,N) + UNCORR(6) * B1(6,N) for
  N = 1 to 6
```

where

`CORR(1:6)` is the array of six corrected forces and moments (balance-axis system)

`B1(1:6,1:6)` is the 6 × 6 interaction matrix

`UNCORR(1:6)` is the array of six uncorrected forces and moments

4.4.3. Pressure Tares

When an air line interferes with a balance, corrections are made to the data as a function of the pressure in the air line. These corrections are of the form

```
CORR(N) = UNCORR(N) - PC(1,N) * PST - PC(2,N) * PST**2 - PC(3,N) * PST**3
  - PC(4,N) * PST**4 - PC(5,N) * PST**5 - PC(6,N) * PST**6 for N = 1 to 6
```

where

`CORR(1:6)` is the array of corrected forces and moments

`PC(1:6,1:6)` is the matrix of sting pressure coefficients

`UNCORR(1:6)` is the array of uncorrected forces and moments

`PST` is the air line pressure, psi

Sting pressure coefficients are obtained from the calibration of the air pressure effect on the six balance components. The calibration is performed by capping or sealing the plenum or similar air chamber and pressurizing the air system.

4.4.4. Attitude Tares

Attitude tares are the model weight corrections to the force and moment data to obtain aerodynamic forces and moments. The contribution of model weight to the total loads (gravity-oriented model axis) on the balance is given by

```
CTHE = COS(THETA + THETAO)

STHE = SIN(THETA + THETAO)

CPHIT = COS(PHI + PHIO - PHIM)

SPHIT = SIN(PHI + PHIO - PHIM)

DELTA(1) = -WTN * CTHE * CPHIT - FZ(1)

DELTA(2) = WT * STHE - FZ(2)

DELTA(6) = WTN * CTHE * SPHIT - FZ(6)

DELTA(3) = -DELTA(1) * XBAR + DELTA(2) * ZBAR

DELTA(4) = DELTA(1) * YBAR + DELTA(6) * ZBAR

DELTA(5) = -DELTA(6) * XBAR - DELTA(2) * YBAR

CORR(N) = UNCORR(N) - DELTA(N) for N = 1 to 6
```

where

THETA is the model pitch attitude, deg

THETAO is the calculated balance pitch misalignment, deg

PHI is the absolute model roll angle from horizontal, deg

PHIO is the calculated balance roll misalignment, deg

PHIM is the model roll offset in the test section, deg

WTN and WT are calculated weights on the balance, lb

XBAR, YBAR, and ZBAR are the distances from the center of gravity of the model weight to the balance moment reference center, in. (figs. 3 and 4 show positive directions)

DELTA(1:6) are the differential attitude tares

UNCORR(1:6) is the array of uncorrected forces and moments

CORR(1:6) is the array of corrected forces and moments

WTN, WT, XBAR, YBAR, ZBAR, THETAO, and PHIO are calculated from data obtained by an attitude sweep at zero free-stream velocity by an iterative, least-squares, curve-fitting method. The differential data are first rotated from the balance-axis system to the gravity-oriented, model-axis system. The two weights (WT and WTN) are calculated using the axial and normal force variations of the data so that

```
WT = TARE(2) / (SIN(THETA + THETAO) + SIN(THETAZ + THETAO))

WTN = -TARE(1) / (COS(THETA + THETAO) * COS(PHI + PHIO - PHIM)
  + COS(THETAZ + THETAO) * COS(PHIZ + PHIO))
```

where

TARE(1) is the differential NF load in the gravity-oriented model axis, lb

TARE(2) is the differential AF load in the gravity-oriented model axis, lb

Normally, WT is the best estimate of the actual weight on the balance since the sine variation (axial force) creates larger differential loads. Differences of more than 10 percent between the two weights indicate possible interferences on the balance by the model installation. If the interference cannot be corrected physically, installation interaction coefficients should be input. (See sec. 4.4.2.) THETAO and PHIO are balance misalignment angles which are used as iterative parameters in the attitude tare routine to minimize the difference in WT and WTN. Large values of THETAO or PHIO (greater than 1.0 degree) usually indicate that the balance-to-model reference center angles (sec. 4.4.5) have not been accurately determined.

4.4.5. Transformations

Each balance requires Euler rotational angles (GAM(1:3)) and translational dimensions (TRAN(1:3)) to perform rotations and translations from the balance moment center to the model moment reference center (MRC). Axis conventions (fig. 4) include

the X-axis is positive forward

the Y-axis is positive to the right looking forward

the Z-axis is positive down

The order of Euler rotations is Z-axis (yaw), Y-axis (pitch), and X-axis (roll). The translations are from the balance to the model MRC so that a balance behind, to the left of, and above the MRC has positive X-, Y-, and Z-axis translations, respectively. The rotations are performed before the translations with these equations:

```
CORR(1) = CORR(1) * COS(G2) * COS(G3) + CORR(2) * (COS(G1) * SIN(G2)
  * COS(G3) - SIN(G1) * SIN(G3)) + CORR(6) * (COS(G1) * SIN(G3) - SIN(G1)
  * SIN(G2) * COS(G3))

CORR(2) = -CORR(1)* SIN(G2) + CORR(2) * COS(G1)* COS(G2) - CORR(6) * SIN(G1)
  * COS(G2)

CORR(3) = CORR(3) * (SIN(G1) * SIN(G2) * SIN(G3) + COS(G1) * COS(G3))
  + CORR(4) * (COS(G1) * SIN(G2) * SIN(G3) - SIN(G1) * COS(G3)) + CORR(5)
  * COS(G2) * SIN(G3)

CORR(4) = CORR(3) * SIN(G1) * COS(G2) + CORR(4) * COS(G1) * COS(G2) - CORR(5)
  * SIN(G2)

CORR(5) = -CORR(3) * (COS(G1) * SIN(G3) - SIN(G1) * SIN(G2) * COS(G3))
  + CORR(4) * (COS(G1) * SIN(G2) * COS(G3) - SIN(G1) * SIN(G3)) + CORR(5)
  * COS (G2) * COS(G3)

CORR(6) = -CORR(1) * COS(G2) * SIN(G3) - CORR(2) * (COS(G1) * SIN(G2)
  * SIN(G3) - SIN(G1) * COS(G3)) + CORR(6) * (SIN(G1) * SIN(G2) * SIN(G3)
  + COS(G1) * COS(G3))
```

The translational equations for the three moments are

```
CORR(3) = CORR(3) - TRAN(1) CORR(1) + TRAN(3) * CORR(2)

CORR(4) = CORR(4) + TRAN(3) * CORR(6) * TRAN(2) * CORR(1)

CORR(5) = CORR(5) - TRAN(1) * CORR(6) - TRAN(2) * CORR(2)
```

where

CORR(1:6) is the array of forces and moments

TRAN(1:3) is the array of three translational distances (with x, y, and z order), in.

GAM(1:3) is the array of Euler rotational angles (i.e., G1, G2, AND G3), deg

LIFT and DRAG are defined as

```
LIFT = CORR(1) * COSA - CORR(2) * SINA

DRAG = CORR(2) * COSA + CORR(1) * SINA
```

where CORR(1) is NF1, CORR(2) is AF1, SINA is sin(ALPHA), and COSA is cos(ALPHA).

4.4.6. Wall Corrections

The data reduction program includes a standard wall correction, into which parameters can be easily entered. A more elaborate wall correction developed by Harry Heyson can be used as a program subroutine. Parameters for the Heyson wall corrections cannot be changed on-line as easily as those for the standard wall corrections. The input parameters for either wall correction program must be supplied to the Data Reductions Group personnel prior to the test.

4.4.6.1. Standard wall corrections. Powered models, especially rotorcraft, are affected by the presence of the test section floor, walls, and ceiling. A routine is available in the data reduction program that corrects dynamic pressure and angle of attack for the test section configuration. These corrections are of the form

```
ALFCOR = ALPHA + DELALF(1) + DELALF(2) * CL+DELALF(3) * CL * CL

QCORR = Q * (DELQ(1) + DELQ(2) * CL+DELQ(3) * CL * CL)
```

where

CL is the effective lift coefficient

DELALF(1:3) is the array of angle of attack correction coefficients

DELQ(1:3) is the array of three dynamic pressure correction coefficients

ALFCOR is the corrected angle of attack, deg

QCORR is the corrected dynamic pressure, psf

The DELALF and DELQ coefficients are input (sec. 6.2.3) for five values of drag-to-lift ratios and are usually a function of parameters such as model size, test section configuration, and position of the model in the test section.

4.4.6.2. Heyson wall corrections. Wall corrections developed by Harry Heyson (refs. 5–7) can be incorporated as a software subroutine. Heyson's correction offers 16 different program options that range from a point interference of a small model to the tail interference of side-by-side rotors. In addition, corrections are made for the various types of test section configurations (e.g., fully open, closed, closed on bottom only). The corrections are obtained through an iterative process and consume large amounts of computing space. The corrections can be done for each data point but cannot be displayed in real time. A sample subroutine for the average interference over a swept wing is presented in appendix D.

4.4.7. Blockage and Jet Boundary Corrections

Blockage corrections (ref. 8) are as follows:

```
CSAF = REF(1) / (4.0 * TSA)

ACD = CDW - (CL * CL * REF(1)) / (PI * (REF(3) / 12.0)**2)

XMACH2 = 2.0 * Q / (AGAM * PI)

BCF = JBCORR(4) / (1.0 - XMACH2)**1.5 + (1.0 + 0.4 * XMACH2) * ACD
  * CSAF / (1.0 - XMACH2)

Q = QUNCOR * (1.0 + (2.0 - XMACH2) * BCF)

VEL = VEL * (1.0 + BCF)

PI = PI * (1.0 - 1.4 * XMACH2 * BCF)

RN = RN * (1.0 + (1.0 - 0.7 * XMACH2) * BCF)

RHO = RHO * (1.0 - XMACH2 * BCF)
```

where

CSAF is the test section cross-sectional area factor

TSA is the test section cross-sectional area (315.375 ft^2)

ACD is the apparent drag coefficient

CDW is the uncorrected wind-axis drag coefficient

CL is the lift coefficient

REF(1:3) is an array containing reference area (ft^2), chord (in.), and span (in.)

XMACH2 is the Mach number squared

AGAM is the ratio of specific heats for air (1.4)

BCF is the blockage correction factor

JBCORR(4) is the sum of the blockage factors KWI and KBI (sec. 6.2.4)

KBI is the solid-blockage velocity effect for a body of revolution

KWI is the solid-blockage velocity effect for a wing

QUNCOR is the uncorrected dynamic pressure, psf

The jet boundary corrections (ref. 9) are

```
CD = CD + JBCORR(1) * CL**2

ALPHA = ALPHA + JBCORR(2) * CL

PM = PM + CL * JBCORR(3) * Q * REF(1) * REF(2)
```

where

CD is the stability-axis drag coefficient

ALPHA is the model angle of attack, deg

PM is the body-axis pitching moment, in-lb

JBCORR(1) is the jet boundary factor J1 (sec. 6.2.4)

JBCORR(2) is the jet boundary factor J2 (sec. 6.2.4)

JBCORR(3) is the jet boundary factor J3 (sec. 6.2.4)

4.4.8. Coefficients

After all corrections are made to the forces and moments, aerodynamic coefficients are calculated. The body-axis and stability-axis coefficients (ref. 4) are given by

```
DENCOF(1) = 1.0 / (REF(1) * Q)

DENCOF(2) = 1.0 / (REF(1) * Q)

DENCOF(3) = 1.0 / (REF(1) * REF(2) * Q)

DENCOF(4) = 1.0 / (REF(1) * REF(3) * Q)

DENCOF(5) = 1.0 / (REF(1) * REF(3) * Q)

DENCOF(6) = 1.0 / (REF(1) * Q)

COSA = COS(ALPHA)

SINA = SIN(ALPHA)

BDATA(N,1) = CORR(N), N = 1:6

BDATA(N,2) = BDATA(N,1) * DENCOF(N), N = 1:6

BDATA(1,3) = BDATA(1,2) * COSA - BDATA(2,2) * SINA

BDATA(2,3) = BDATA(2,2) * COSA + BDATA(1,2) * SINA

BDATA(3,3) = BDATA(3,2)
```

```
BDATA(4,3) = BDATA(4,2) * COSA + BDATA(5,2) * SINA
BDATA(5,3) = BDATA(5,2) * COSA - BDATA(4,2) * SINA
BDATA(6,3) = BDATA(6,2)
```

where

DENCOF(1:6) is the array of nondimensioning factors

REF(1:3) is an array containing reference area (ft^2), chord (in.), and span (in.)

Q is the dynamic pressure, psf

BDATA(1:6,1) is the array of corrected forces and moments

BDATA(1:6,2) is the array of body-axis coefficients

BDATA(1:6,3) is the array of stability-axis coefficients

4.5. Flowmeter Calculations

A Hershel-type venturi flowmeter is placed in the high-pressure air supply line to measure the mass flow (FMWP), and Reynolds number (FMRN) of air being used by the air-powered models. Detailed flowmeter equations are presented by Hoad (1973).[7] These equations require 5 real-time measurements and 13 constants. Three measurements are made at the flowmeter.

FMP1 is the inlet static pressure, psi

FMDELP is the inlet static pressure minus the throat static pressure, psi

FMTDE is the flowmeter air temperature, °F

The two additional parameters are ambient temperature (TA) and ambient pressure (PA). The flowmeter-dependent constants are input into the program at test setup.

4.6. Pressure Data

Surface pressure orifice data (sec. 6.3) can optionally have engineering units in the form of absolute pressures, differential pressures referenced to total pressures, or coefficients given by

```
CP = (DP + PA - PI) / Q
```

or

```
CP = (DP / Q) + 1
```

where

CP is the pressure coefficient

DP is the differential pressure referenced to atmospheric pressure

P is the absolute orifice pressure, DP + PA, psf

PA is the ambient pressure, psf

PI is the free-stream static pressure, psf

Q is the free-stream dynamic pressure, psf

[7] Hoad, Danny R.: *Weight-Flow Measurements and Calculation Procedures for Flow-Dyne Venturi Meters* Memorandum for record Subsonic Aerodynamics Branch, LSAD, Langley Research Center, December 17, 1973.

The data reduction program is capable of processing up to a maximum of 2048 pressure ports per model. Data are stored in the array PVAL(1:2098). (See appendixes C and E for details.)

4.7. Base and Chamber Pressure Corrections

If a sting support system extends through an opening at the aft end of the model, a base pressure may act on the surface of the opening. The equations for base and chamber (cavity) pressure corrections are as follows (two base pressure corrections are available):

```
AB1 = (PB1 + PA) * SB1

AB2 = (PB2 + PA) * SB2

AC = (PC + PA) * SC

DELTAA = AB1 + AB2 + AC
```

Correction of base and chamber pressure on axial force and pitching moment are as follows:

```
CORR(2) = CORR(2) + DELTAA

CORR(3) = CORR(3) + DELTAA * Z2
```

where

AB1 and AB2 are base pressure forces, lb

PB1 and PB2 are the base pressures, psf

SB1 and SB2 are the base areas, ft^2

AC is the chamber pressure force, lb

PC is the chamber pressure, psf

SC is the chamber area, ft^2

DELTAA is the combined base and chamber pressure forces, lb

CORR(2) is the axial force, lb

CORR(3) is the pitching moment, in-lb

Z2 is the transfer distance from the model base to model reference center, in.

5. Software Description

The data reduction and applications programs are coded in FORTRAN 77 whenever possible. Only certain file manager coding is nonstandard. The following definitions are used to describe the purposes of the various tasks which make up the application software (see ref. 1 and footnote 1):

1. A real-time task is a program that executes cyclically with no operator interaction and has the highest relative execution priority.
2. An interactive task is a program that depends upon operator interaction and has a high execution priority. Normally, this task requires operator input to complete.
3. A batch task is a program with the lowest execution priority and runs until the completion of a specific task. This task may require operator interaction.
4. In this documentation, XXX denotes a test number.

5.1. Data Reduction Components

Each test (maximum of one per system) requires several tasks for data reduction purposes. These tasks are unique to that test and have the three-digit test number as part of their task names.

5.1.1. TXXX

Time-averaged data acquisition is controlled by the interactive task TXXX. This task may be activated from any of the facility remote terminals designated for use with the operating acquisition program (OAP). Through this task, the data acquisition operator makes data channel assignments, alters data acquisition and reduction parameters, and initiates data acquisition. Data are normally acquired as a series of data points (e.g., an angle-of-attack sweep) which constitute a run. As shown in table I, various options are available to the operator by menu selection from an interactive terminal. Table II, which lists a description of each option, follows table I. (See ref. 1 for details.)

Table I. Menu of ID Codes

ID code	Option	ID code	Option
0	WIND-OFF ZERO	1	TAKE TARES
2	WIND-ON DATA	3	DYNAMIC ZERO
4	PT CHECK PARAMETERS	5	BAL. SPAN
6	CALIBRATION	7	RECALL ZEROS
8	CHANGE LIMITS	9	RUN SUMMARY
10	MODIFY OPTIONS	11	CALC. TARES
12	MODIFY CHANNELS	13	MODIFY BALANCE
14	MODIFY PRESS.	15	PRINT SPOOL
16	DISMOUNT TAPE	17	MODIFY FMETER
18	Currently not used	19	Currently not used
20	LAIRD TELEMEDIA	21	ESP CALIBRATION
22	TACH. RANGE CONTROL	23	Currently not used
24	REAL-TIME PLOT	25	TUNNEL DISPLAYS
26	DTALK		
99	PLAYBACK TAPE	EX	EXIT

Table II. Description of Each Option

ID code	Description
0	The WIND-OFF ZERO option acquires data to be used as the zero reference. This option should be used as often as practical to minimize zero shifts.
1	The TAKE TARES option acquires data as an attitude tare point. A minimum of 10 tare points is required for an attitude tare run with a maximum of 15 tare points possible. The weight and center of gravity are automatically calculated when the option code is changed to 0, 2, or 3.
2	The WIND-ON DATA option is the normal data acquisition code for test data. Full data reduction is performed and the reduced data are stored in the database. A common set of test data (e.g., an angle-of-attack sweep) is given a unique run number as defined in the test schedule.

Table II. Continued

ID code	Description
3	The DYNAMIC ZERO option is similar to the WIND-ON DATA code in performing full data reduction; however, the data are not stored in the database as a test data point. This option is normally used for powered models at a wind-off condition with rotors, propellers, or engine simulators in operation to provide a powered baseline reference point.
4	The PT CHECK PARAMETERS option permits additional printout of selected data parameters at end of regular data point printout.
5	The BAL. SPAN option acquires data from a resistance calibration of the balances.
6	The CALIBRATION option acquires and stores raw data in the database for sensitivity constant calculation by the least-squares (LSQ), curve-fit plotting program. (Refer to sec. 5.3.1.)
7	The RECALL ZEROS option allows the previous wind-off zeros to be exchanged for present values.
8	The CHANGE LIMITS option is used to interactively change the upper and lower limit values for any of the data parameters.
9	The RUN SUMMARY option provides a line printer copy of the data for any run contained in the database.
10	The MODIFY OPTIONS option is used to interactively change any of the data reduction or output options. (Refer to sec. 6.5.)
11	The CALC. TARES option allows the attitude tare parameters to be calculated before a wind-off zero is taken.
12	The MODIFY CHANNELS option is used to add or delete data channels from the test. Also, data channel parameters (e.g., sensitivity constants or names) may be modified interactively.
13	The MODIFY BALANCE option is used to set up balance data reduction parameters (e.g., interaction parameters, reference area, chord, span, Euler rotation angles, and moment reference center translations).
14	The MODIFY PRESS. parameter option is used to input pressure orifice location and strip information.
15	The PRINT SPOOL option allows the operator to dump the line printer buffer. When the data list option is selected, the data reduction listing, which is actually stored on the disk, is sent to the line printer.
16	The DISMOUNT TAPE option writes end-of-file marks on the data tape and rewinds it.
17	The MODIFY FMETER option is used to interactively modify parameters of the high-pressure air flowmeter.
18	No current assignment.
19	No current assignment.

Table II. Concluded

ID code	Description
20	The LAIRD TELEMEDIA option allows the operator to activate and edit the character generator for the video system.
21	The ESP CALIBRATION option is used to perform a three-point calibration of the ESP modules. Initial calibration should be performed through the Operating Acquisition Program (OAP) menu.
22	The TACH. RANGE CONTROL option lets the operator modify the desired range for a particular tachometer connected to a particular TIF.
23	No current assignment.
24	The REAL-TIME PLOT option allows the operator to activate the real-time plots of either force or pressure data.
25	The TUNNEL DISPLAYS option is used to activate and change the parameters in the 14-in.-display terminals located in the computer and control areas.
26	The DTALK option allows the operator to remotely enable data point initiation from a terminal or other computer.
99	The PLAYBACK TAPE option is used to run the data reduction program in a batch mode with data read from the 9-track tape.
EX	EXIT the program.

5.1.2. PRXXX

The PRXXX program is a real-time task that calculates engineering units as well as force and moment data for real-time display. This task interacts with the TXXX program through global commons (shared memory locations) and the test database to obtain data reduction parameters and options.

5.1.3. SUBXXX

Both TXXX and PRXXX call the FORTRAN subroutine UDATA after the force, moment, and pressure data are calculated but before the final data are stored in the database or on the magnetic tape. This subroutine performs additional calculations to suit the particular test requirements. Each test has a version of this subroutine in source form stored on a disk file that is labeled SUBXXX. Data passed to the subroutine include the following:

RCON(1:30) is the array of test parameters

where

RCON(1) is the test number (TEST)

RCON(2) is the run number (RUN)

RCON(3) is the point number (POINT)

RCON(4) is the option identifier (ID)

RCON(5) is the dynamic pressure option (QCODE)

RCON(6) is the model roll attitude (MCODE)

RCON(7) is the number of balances (NBAL)

RCON(8) is the number of cycles to average (SAMPLES)

RCON(9) is the test section code (WCODE)

RCON(10) is the user configuration code (CONF)

RCON(11) is the tape save flag (TAPE)

RCON(12) is the database save flag (DBASE)

RCON(13) is the pressure coefficient code (PCODE)

RCON(14) is the listing flag (LIST)

RCON(15) is the maximum stepper port, no longer used (MPORT)

RCON(16) is the present stepper port, no longer used (IPORT)

RCON(17) is the ESP system code (IESP)

RCON(18) is the model support flag (SCODE)

RCON(19) is the debug list flag (DEBUG)

RCON(20) is the flowmeter code (FMCODE)

RCON(21) is the distance from the mast to point on the model where the height is calculated (RLENGTH)

RCON(22) is the distance from the vertical strut pivot point to model reference (VLENGTH)

EUNITS(1:128) is the array of channel data engineering units

TUNP(1:6) is the array of free-stream conditions

where

TUNP(1) is dynamic pressure (Q), psf

TUNP(2) is free-stream velocity (VEL), fps

TUNP(3) is ambient pressure (PA), psf

TUNP(4) is test section static pressure (PI), psf

TUNP(5) is Reynolds number per foot (RN)

TUNP(6) is free-stream density (RHO), slugs/ft^3

SUPP(1:8,1:2) is the array of model attitude values

where

SUPP(1,1) is the angle of attack (ALPHA), deg

SUPP(2,1) is the angle of sideslip (BETA), deg

SUPP(3,1) is the angle of pitch (THETA), deg

SUPP(4,1) is the angle of yaw (PSI), deg

SUPP(5,1) is the angle of roll (PHI), deg

SUPP(6,1) is the height above the floor (HGT), in.

SUPP(7,1) is the uncorrected angle of attack (ALPHAU), deg

SUPP(8,1) is the uncorrected dynamic pressure (QUNCOR), psf

SUPP(1,2) is the Mach number (MACH)

SUPP(2,2) is the corrected model list (LIFT), lb

SUPP(3,2) is the corrected model drag (DRAG), lb

BDATA(1:6,1:3,1:4) is the array of force data

where

1:6 are the six components

1:3 are forces and moments, body-axis coefficients, and stability-axis coefficient indexes

1:4 are balance number indexes

PVAL(1:2098) is the array for the pressure database

where

PVAL(1:30) is equivalent to RCON(1:30)

PVAL(31:36) is equivalent to TUNP(1:6)

PVAL(37:44) is equivalent to SUPP(1:8)

PVAL(45) is equivalent to SUPP(9)

PVAL(51:2098) are the pressure data, psi or psf

AVG(1:128) are the averaged force raw data

FMDATA(1:4) is the array of flowmeter parameters

where

FMDATA(1) is the flowmeter weight flow rate (FMWP), lb/sec

FMDATA(2) is the Reynolds number per foot (FMRN)

USERP(1:100) is the array of user parameters which can be changed interactively through TXXX

Parameters, which are calculated in this subroutine, may be stored in the database and placed in the array PLIST(1:24) for printing.

5.2. Database

The data reduction programs use two databases: one for the force data and one for the pressure data. The force data disk file is labeled DBXXX and has 4100 logical records of 1200 bytes (300 real variables). The pressure data disk file is labeled DBXXXP and has 4100 logical records of 3200 bytes (800 real variables). Each database can store up to a maximum of 4000 data points in records 101 to 4100. Test parameters and directory information are stored in the first 100 records.

5.2.1. Force and Moment Database (DBASE)

Data are stored in the force database (DBXXX) from the TXXX task. Access to the data stored in the database is through the interactive task DBASE, which is executed from an interactive terminal. This task permits the recall of individual data parameters by name and run number, the print out of run summaries on the line printer, the storage of archive file data on the magnetic tape, the deletion of data points or test runs, and the restoration of an archived database to the system.

5.2.2. Pressure Database (DBASEP)

The DBASEP task has the same capabilities as force data task DBASE but is used to provide access to the pressure data on file.

5.3. Utilities

Several programs are available for interactively fitting and plotting curves of force data.

5.3.1. Least-Squares Curve-Fit Plotting (LSQ)

The LSQ interactive task applies a linear to eighth-order polynomial, least-squares curve fit to the force data, which are stored in the database. This program calculates the sensitivity constants of data channels following a calibration test. The data points and the curve fit are plotted on the interactive graphics terminal and printed on the line printer. This task may be executed from any of the interactive terminals available to the computer system on which the force database is located.

5.3.2. Off-Line Data Plotting (PLTFDA)

The PLTFDA interactive task provides quick-look plots of the force data on the graphics terminal. Five runs of data may be plotted on up to six graphs per page; data are recalled by name and run number.

5.3.3. Pressure Plot Routine (PLTPD)

The PLTPD is an interactive task similar to PLTFDA, which plots the pressure data for ESP's or Scanivalves on the graphics terminal. Rectilinear and polar coordinate plots are available; data are recalled by name, run number, and point number.

5.4. Tape Format

Data and test parameters are stored on the magnetic tape in formatted line images. Each logical record consists of one or more lines of ASCII characters with the first line containing the record parameters and the following lines containing the record data. Record types, which could be on the data or archive file tapes, are given in appendix E.

6. Test Requirements

The wind tunnel application programs require varying amounts of information depending upon the complexity of the model and test to be conducted. As always, the results are dependent upon the input.

6.1. Data Channel Parameters

The purpose of the data reduction program is to convert each channel of raw data to its appropriate engineering units. To accomplish the conversion, the program requires several parameters for each analog or digital data channel.

6.1.1. Channel Numbers

Analog data channel numbers range from 1 to 96 with the signals divided into groups of 16. (Refer to sec. 3.1.1.)

Each model balance normally requires seven analog channels, which include the six forces and moments and the balance excitation voltage. *Note: Do not use the excitation voltage from the Neff 300 signal conditioner.*

Digital data channel numbers range from 97 to 128 and include any tachometer data. Facility personnel should be consulted to determine which digital channels are dedicated to the acquisition of the wind tunnel parameters. The default channel number is 0.

6.1.2. Channel Names

Each data channel must be assigned a unique one- to eight-character name. These names are used to access the data from the database and are used by the data reduction program to locate certain required parameters. Names that are dedicated for tunnel parameters include the following:

`PITCH` for the model pitch transducer

`ROLL` for the model roll angle transducer

`YAW` for the model support turntable

`PA` for the ambient pressure transducer

`QI` for the entrance cone differential pressure

`PTOT` for settling chamber total pressure

`PITOT` for the test section pitot-static probe

`JT1` for the front joint of the alpha-beta sting

`JT2` for the middle joint of the alpha-beta sting

`JT3` for the back joint of the alpha-beta sting

`PST` for the air line inlet (air sting) pressure transducer

`TA` for the ambient temperature

`TDEW` for the dew point temperature

`ELEV` for the model support mast elevation

`PITCHM` for the model support mast pitch

`FMTDE` for the flowmeter temperature

`FMDELP` for the flowmeter differential pressure (ΔP)

`FMP1` for the flowmeter pressure (P1)

Parameters `PITCH`, `ROLL`, `YAW`, `ELEV`, and `PITCHM` are required to determine the model attitude. Parameters `PA`, `QI`, `PTOT`, or `PITOT`, `TA`, and `TDEW` are required to calculate free-stream conditions. Parameters `JT1`, `JT2`, and `JT3` are required when the alpha-beta sting is used. Parameters `FMTDE`, `FMDELP`, and `FMP1` are required when flowmeter calculations are to be made.

Names that are reserved for system parameters include the following:

TEST	RUN	POINT	ID
QCODE	MCODE	NBAL	SAMPLES
WCODE	CONF	TAPE	DBASE
PCODE	LIST	MPORT	IPORT
IESP	SCODE	DEBUG	FMCODE
RLENGTH	VLENGTH	YRMODA	HRMNSC
XNPUT1	XNPUT2	XNPUT3	Q
VEL	PTOT	PSTAT	RN
RHO	ALPHA	BETA	THETA
PSI	PHI	HGT	NF1
AF1	PM1	RM1	YM1
SF1	NF2	AF2	PM2
RM2	YM2	SF2	NF3
AF3	PM3	RM3	YM3
SF3	NF4	AF4	PM4
RM4	YM4	SF4	CNF1.B
CAF1.B	CPM1.B	CRM1.B	CYM1.B
CSF1.B	CNF2.B	CAF2.B	CPM2.B
CRM2.B	CYM2.B	CSF2.B	CNF3.B
CAF3.B	CPM3.B	CRM3.B	CYM3.B
CSF3.B	CNF4.B	CAF4.B	CPM4.B
CRM4.B	CYM4.B	CSF4.B	CL1.S
CD1.S	CPM1.S	CRM1.S	CYM1.S
CSF1.S	CL2.S	CD2.S	CPM2.S
CRM2.S	CYM2.S	CSF2.S	CL3.S
CD3.S	CPM3.S	CRM3.S	CYM3.S
CSF3.S	CL4.S	CD4.S	CPM4.S
CRM4.S	CYM4.S	CSF4.S	EUNIT1...EUNIT128
FMWP	FMRN		

The variable names for the SDAS database or the data reduction programs have no character restrictions. The default channel name is EUNITnnn where nnn is the data channel number. The variable names for data display in the operating acquisition program (OAP) are restricted to the following characters: A–Z, 0–9, colon (:), dollar symbol ($), period (.), and character space.

6.1.3. Calibration Constants

Each channel requires the input of calibration constants. These constants consist of type, slope, intercept, and offset. (Refer to sec. 4.1.) The default values are 0 for TYPE (no engineering unit conversion required), 1.0 for CON, 0.0 for ZERO, and 0.0 for OFFSET.

6.1.4. Reference Voltage Channel

Corrections may be made to the analog raw data for excitation voltage drift by supplying the excitation monitor channel number for each analog channel. Self-powered transducers (e.g., thermocouples and most model attitude transducers) do not need this correction. Normally, the excitation voltage for a balance is monitored on the seventh channel of the balance output sequence. The reference voltage value should be obtained when the particular transducer is calibrated and be entered with the engineering unit conversion constants. The default reference channel (IVOLT) is 0 (no correction made for voltage drift), and the default reference voltage (VOLT) is 0.0

6.2. Balance Parameters

The data reduction program calculates force and moment data for up to four six-component internal balances per test. The balance parameters are input into the program and stored in the database by the interactive program TXXX option 13.

6.2.1. Balance Name

Each balance is given a one- to six-character name which is used as an identifier. This name is stored in both the database and the archive tape file to aid in the identification of the balance parameters that are associated with it. There is no default balance name.

6.2.2. Calibration Parameters

Each balance requires a set of calibration constants. (Refer to sec. 4.4.1.) These interaction parameters are determined from off-site load tests of the balance. The parameter file is then transferred from the central computer complex over a communications link to the facility. After input, these constants are stored in the database. There are no default calibration parameters (BCON(1:174)).

6.2.3. Wall Corrections

The wall corrections consist of 5 drag-to-lift ratios, 15 angle-of-attack correction factors (3 for each drag-to-lift ratio), and 15 dynamic pressure correction factors for open and closed test sections. (Refer to sec. 4.4.6.) The default wall correction coefficients (DOL(1:5), DELALF(1:3,1:5), and DELQ(1:3,1:5)) are all 0.0.

6.2.4. Blockage and Jet Boundary Corrections

The blockage correction consists of one parameter; the jet boundary corrections consist of three parameters: drag, angle of attack, and pitching moment. (Refer to sec. 4.4.7.) The default blockage and jet boundary parameters (JBCORR(1:4)) are all 0.0.

6.2.5. Balance Type

Normally, two types of six-component balances are used in the 14- by 22-Foot Subsonic Tunnel. The most common is the NASA balance, which has the six components NF, AF, PM, RM, YM, and SF; this balance has the default 0. The other is the Task balance (type 1), which has the six components N1, AF, N2, RM, S1, and S2 where NF = N1 + N2, PM = N1 - N2, SF = S1 + S2, and YM = S1 - S2. (Refer to sec. 4.4.)

6.2.6. Nondimensioning Factors

The three nondimensioning factors of reference area S, longitudinal reference length C, and lateral reference length B are required to compute the body- and stability-axis coefficients. (Refer to sec. 4.4.8.) The defaults are $S = 1.0$ ft^2, $C = 1.0$ in., and $B = 1.0$ in.

6.2.7. Transformation Parameters

Three Euler rotational angles and three translational distances are required to determine the model-axis force data. (Refer to sec. 4.4.5.) The defaults are GAM(1:3) = 0.0,0.0,0.0 and TRAN(1:3) = 0.0,0.0,0.0.

6.2.8. Attitude Tare Parameters

If attitude tares are not to be calculated by the data reduction program, the attitude tare parameters, WT, WTN, XBAR, YBAR, ZBAR, THETAO, and PHIO must be input. (Refer to sec. 4.4.4.) The defaults are all 0.0.

6.2.9. Installation Interaction Parameters

To compensate for the effects of hoses and cables crossing the balance, correction parameters can be input for each balance. (Refer to sec. 4.4.2.) The defaults are

```
B1(1:6,1) = 1.0, 0.0, 0.0, 0.0, 0.0, 0.0
B1(1:6,2) = 0.0, 1.0, 0.0, 0.0, 0.0, 0.0
B1(1:6,3) = 0.0, 0.0, 1.0, 0.0, 0.0, 0.0
B1(1:6,4) = 0.0, 0.0, 0.0, 1.0, 0.0, 0.0
B1(1:6,5) = 0.0, 0.0, 0.0, 0.0, 1.0, 0.0
B1(1:6,6) = 0.0, 0.0, 0.0, 0.0, 0.0, 1.0
```

6.2.10. Air Line Pressure Tares

Balance readings are affected by high-pressure air in hoses and tubing that cross the balance. Pressure tare parameters (PC(1:6,1:6)) are used to make corrections for this effect. (Refer to sec. 4.4.3.) The defaults are all 0.0.

6.3. Pressure Data Parameters

Normally, pressure data are obtained from orifices drilled into the surface of a model. These orifices are generally grouped into strips and networks; a strip is a set of orifices with a common location parameter such as span location and a network is two or more strips which may be logically grouped. (See fig. 5.) The data reduction program requires certain network, strip, and orifice information to facilitate the handling of the data. These parameters are placed in a disk source file using a text editor and then are inputted into the program from this file.

The format of the strip information is as follows:

```
K = 0
For I = 1 to NSTRIP do
  Read NET(I),NORF(I),REFLC(I),ZCOORD(1,I),ZCOORD(2,I),
  ZCOORD(3,I)
  for J = 1 to NORF(I) do
    K = K + 1
    Read IDORF(K),JPORT(K),JDRIVE(K),XLOC(K),
    YLOC(K),ZLOC(K)
  End do
End do
```

where

NSTRIP is the number of orifice strips (maximum of 120)

NET(1:120) is the array of network numbers

NORF(1:120) is the number of orifices in each strip

REFLC(1:120) are the reference lengths for nondimensioning purposes

ZCOORD(1:3,1:120) are the x, y, and z coordinates of a reference point for nondimensioning purposes

IDORF(1:2048) are the orifice identification numbers

JPORT(1:2048) is the port number of the pressure sensing device

JDRIVE(1:2048) are the pressure transducer channel numbers for the mechanical scanning devices; or -1 or -2 for the electronic scanning devices 1 or 2, respectively

XLOC(1:2048) are the X-axis coordinates of the orifices

YLOC(1:2048) are the Y-axis coordinates of the orifices

ZLOC(1:2048) are the Z-axis coordinates of the orifices

6.4. User Parameters

An array of 100 parameters (USERP(1:100)) is available to input variables into the user subroutine (sec. 5.1.3) of the data reduction program. These parameters are entered and modified interactively via TXXX. (See ref. 1.) The defaults are all 0.0. Some examples of user parameters are frequently changed channel numbers, curve-fit constants, model configuration codes, and reference areas.

6.5. Data Reduction Parameters

The data reduction parameters (RCON(1:30)) are used to set options and parameters in the data reduction program. (Refer to sec. 5.1.3.) The defaults are all 0.0. (See appendix C for complete details.)

TEST (RCON(1)) is the test number. It should be the same as XXX.

RUN (RCON(2)) is the run number. This may be any integer from 1 to 9999.

POINT (RCON(3)) is the point number. It resets automatically when the run number is changed and increases incrementally when a data point is taken.

QCODE (RCON(5)) is the dynamic pressure calculation option. The options are

0 for no calculations

1 for test section pitot

2 for closed test section

3 for closed test section with boundary layer (BL) suction

4 for open test section

5 for open test section with BL suction

6 for open test section with acoustic panels

MCODE (RCON(6)) is the roll angle, in degrees, at which the model is installed. Right side up would be 0.0 and upside down would be 180.0.

NBAL (RCON(7)) is the number of balances (0 to 4).

SAMPLES (RCON(8)) is the number of data sampling cycles to average for the time-averaged data. SAMPLES will be 5 per second.

WCODE (RCON(9)) is the test section configuration code, which is used to enable and disable the wall corrections. The options are

0 to inhibit wall corrections

1 to make walls-down corrections

2 to make walls-up corrections

3 to make blockage and jet boundary corrections

CONF (RCON(10)) is a user-supplied model reference configuration code.

TAPE (RCON(11)) is the data tape save flag. The options are

0 to inhibit write data to tape

1 to write data to tape

DBASE (RCON(12)) is the database save flag. The options are

0 to inhibit write data in the database

1 to write data in the database

PCODE (RCON(13)) is the pressure data calculation flag. The options are

0 to calculate differential pressures (DP's)

1 to calculate absolute pressures

2 to calculate pressure coefficients

LIST (RCON(14)) is the line printer list option. The options are

0 to inhibit the listing of on-line data

1 to spool the data listing to disk for subsequent printing after each data point

2 to spool the data listing when commanded by option 15 or the program exit

`MPORT (RCON(15))` is the maximum port to scan with the mechanical steppers, no longer used (scanivalves 0–47).

`IESP (RCON(17))` is the electronically scanned pressure subsystem flag. The options are

0 to inhibit ESP data

1 to activate ESP 1

2 to activate ESP 2

3 to activate both

`SCODE (RCON(18))` is the model support or sting flag. The options are

0 to inhibit model attitude calculations

1 for normal internal attitude transducer calculations

2 for alpha-beta sting calculations

3 for the strut

`DEBUG (RCON(19))` is the debug option. The options are

0 to inhibit debug listing of balance data

1 to list intermediate balance data parameters

`FMCODE (RCON(20))` is the flowmeter number 0–9.

`RLENGTH` is the distance from the center of the vertical mast forward to the model height reference point in inches.

`VLENGTH` is the vertical distance from the pivot center on the vertical strut to the model reference point in inches.

`ID` and `IPORT` cannot be changed by the user. `ID` shows the option status and `IPORT` indicates the present scanner port number 1, 2, 3, 4, or 5.

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Appendix A

Data Cable Pin-Out Assignments

Connector pin assignments[8] for analog, digital, and tachometer data follow:

Analog input cable connector (Cannon XLR-5-11C)

Pin	
1	+ Power
2	High data
3	Shield
4	Low data
5	− Power

Analog output cable connector (Cannon XLR-3-11C)

Pin	
1	High data
2	Low data
3	Shield

Tachometer input or output cable connector (Cannon XLR-3-11C)

Pin	
1	Signal
2	Common
3	Shield

Tachometer input or output cable connector (Cannon XLR-3-11C)

Pin	
1	Signal
2	Common
3	Shield

[8] Additional cable details in *System Documentation for the Static Data Acquisition System at the 4- × 7-m Tunnel*, Wyle Laboratory document number HD 63303-056R2-D8.

Digital input cable connector (MS3116F-20-41P) and digital single-ended output cable connector (MS3116F-20-41S)

Pin	BCD data			Binary data
A	LSD		1	1
B			2	2
C			4	4
D			8	8
E	Digit	2	1	10
F			2	20
G			4	40
H			8	80
J	Digit	3	1	100
K			2	200
L			4	400
M			8	800
N	Digit	4	1	1000
P			2	2000
R			4	4000
S			8	8000
T	Digit	5	1	10 000
U			2	20 000
V			4	40 000
W			8	80 000
X	MSD		1	Not used
Y			2	Not used
Z			4	Not used
a			8	Not used
				Description
b				SIGN (high neg.)
c				DATEX (high not DATEX)
d				BINARY (high not binary)
e				TRUE (high or low true data)
f				DATA VALID (low good data)
g				THIS CHAN ADDR (high to inhibit update)
h				DATEX CR (digital input only)
i				DATEX CA (digital input only)
j				Not used
k				Not used
m				Not used
n				Not used
p				Not used
q				COMMON
r				Not used
s				Not used
t				Not used

Appendix B

Data Reduction Parameters

The following list describes the various parameters used in the data reduction program:

ACD	apparent drag coefficient
AF	axial force, lb
AGAM	ratio of specific heats for air
ALFCOR	corrected angle of attack, deg
ALPHA	angle of attack, deg
B	span, in.
BCON(1:174)	balance interaction factors
BDATA(1:6,1:3,1:4)	balance data
BETA	angle of sideslip, deg
B1(1:6,1:6)	installation interaction matrix
C	chord, in.
CDW	wind-axis drag coefficient
CL	lift coefficient
CON(1:128)	force data sensitivity constants
CONF	user configuration code
CORR(1:6)	corrected forces and moments
CP	pressure coefficient
CSAF	test section area factor
DBASE	database save flag
DEBUG	force data debug list flag
DELALF(1:3)	angle-of-attack correction factors
DELQ(1:3)	dynamic pressure correction factors
DELTA(1:6)	attitude tare corrections
DENCOF(1:6)	nondimensioning factors for force and moment data
DOL	drag divided by lift
ELEV	mast elevation, in.
EUNITS(1:128)	array of force data in engineering units
FMCODE	flowmeter code
FMDATA(1:4)	flowmeter data
FMDELP	flowmeter inlet static pressure minus throat static pressure, psi
FMP1	flowmeter inlet static pressure, psi

FMRN	flowmeter Reynolds number
FMTDE	flowmeter air temperature, °F
FMWP	flowmeter mass flow, lb/sec
FZ(1:6)	initial balance loads
GAM(1:3)	Euler rotation angles from balance axis to model axis, deg
GR	product of gravitational constant and gas constant for air, $(\text{ft/sec})^2/^\circ\text{R}$ (1718.0)
HGT	height of model reference point above test section floor, in.
IBAL	balance number
ICHB(1:4)	balance channel number of first component
ID	data reduction option flag
IDORF(1:2048)	orifice identification numbers
IESP	electronically scanned pressure flag
IPORT	present stepper port
IVOLT(1:96)	array of excitation voltage channel numbers of analog channels
JBCORR(1:4)	jet boundary and blockage correction factors
JDRIVE(1:2048)	mechanical pressure transducer channel number or electronically scanned device number
JPORT(1:2048)	pressure-sensing port number
LIST	line printer list flag
MACH	test section Mach number
MCODE	model roll attitude at installation
MPORT	maximum stepper port
NBAL	number of balances
NET(1:120)	pressure orifice network numbers
NF	normal force, lb
NORF(1:120)	number of orifices in each pressure strip
OFFSET(1:128)	force data engineering unit offsets
P	pressure, psf
PA	ambient pressure, psf
PC(1:6,1:6)	pressure tare coefficients
PCODE	pressure coefficient code
PHI	Euler roll angle, deg
PHIO	balance roll misalignment angle, deg
PHIZ	model roll angle at zero reference, deg
PI	test section static pressure, psf

PITCHM	mast pitch angle, deg
PITOT	test section dynamic pressure measured by pitot tube, psf
POINT	point number in run
PM	pitching moment, in-lb
PSI	Euler yaw angle, deg
PST	air line pressure, psi
PSTAT	same as PI
PTOT	settling chamber total pressure, psf
PV	vapor pressure, psf
PVAL(1:2098)	pressure data
Q	dynamic pressure, psf
QCODE	dynamic pressure calculation code
QCORR	corrected dynamic pressure, psf
QCOVRQ	dynamic correction factor for wall interference
QI	differential pressure of sidewall static pressure in entrance cone referenced to PTOT, psf
RCON(1:30)	array of test parameters
RDG(1:128)	time-averaged raw force data
REFLC(1:120)	pressure strip reference length, in.
RHO	test section air density, slugs/ft^3
RLENGTH	horizontal distance from center of masthead to model height reference point, in.
RM	rolling moment, in-lb
RN	test section Reynolds number per foot
RUN	run number
S	reference area, ft^2
SAMPLES	number of data cycles to average
SCODE	model support code
SF	side force, lb
SPAN(1:96)	analog cable correction factors
SPANI(1:96)	initial analog cable reference values
SUPP(1:8)	model attitude values
TA	ambient temperature, °F
TAPE	tape save flag
TD	dew point, °F
TEST	test number

THETA	Euler pitch angle, deg
THETAO	balance pitch misalignment angle, deg
THETAZ	model pitch angle at zero reference, deg
TR	ambient temperature, °R
TRAN(1:3)	translation distances from balance moment reference center to model reference center (in x, y, and z order), in.
TSA	test section cross-sectional area, ft^2
TUNP(1:6)	array of tunnel parameters
T1,T2,T3	alpha-beta sting joint angles, deg
UNCORR(1:6)	uncorrected forces and moments
USERP(1:100)	user parameters
VEL	test section free-stream velocity, fps
VOLT(1:96)	analog reference excitation voltages
WCODE	test section configuration code
WT	weight based upon sine variation, lb
WTN	weight based upon cosine variation, lb
XBAR	distance on X-axis from center of gravity to balance moment center, in.
XLOC(1:2048)	X-axis coordinates of pressure orifices, in.
XMACH2	Mach number squared
XMU	absolute viscosity of air, lb-sec/ft^2
YBAR	distance on Y-axis from center of gravity to balance moment center, in.
YLOC(1:2048)	Y-axis coordinates of pressure orifices, in.
YM	yawing moment, in-lb
ZBAR	distance on Z-axis from center of gravity to balance moment center, in.
ZCOORD(1:3,1:120)	coordinates of pressure strip reference point, in.
ZERO(1:128)	force data wind-off zeros
ZLOC(1:2048)	Z-axis coordinates of pressure orifices, in.

Appendix C

Output Data Arrays

Data which are stored in the force database and on the data tape are located in a 300-word array of real numbers. The data and their indexes are

Index	Variable		Description
1	TEST	RCON(1)	test number
2	RUN	RCON(2)	run number
3	POINT	RCON(3)	point number
4	ID	RCON(4)	option identifier
5	QCODE	RCON(5)	dynamic pressure calculation code
6	MCODE	RCON(6)	model initial roll angle, deg
7	NBAL	RCON(7)	number of balances to be processed
8	SAMPLES	RCON(8)	number of cycles to average data
9	WCODE	RCON(9)	test section wall configuration code
10	CONF	RCON(10)	optional configuration code
11	TAPE	RCON(11)	tape save option
12	DBASE	RCON(12)	database save option
13	PCODE	RCON(13)	pressure coefficient code
14	LIST	RCON(14)	line printer list option
15	MPORT	RCON(15)	maximum scanner port number (no longer used)
16	IPORT	RCON(16)	present scanner port number (no longer used)
17	IESP	RCON(17)	electronic-scanning option
18	SCODE	RCON(18)	model support code
19	DEBUG	RCON(19)	force data intermediate list option
20	FMCODE	RCON(20)	flowmeter code
21	RLENGTH	RCON(21)	height calculation reference length, in.
22	VLENGTH	RCON(22)	vertical strut reference length, in.
23		RCON(23)	not used
24		RCON(24)	not used
25		RCON(25)	not used
26	YRMODA	RCON(26)	coded date
27	HRMNSC	RCON(27)	coded time
28	XNPUT1	RCON(28)	operator input variable
29	XNPUT2	RCON(29)	operator input variable
30	XNPUT3	RCON(30)	operator input variable

Index		Variable	Description
31		EUNITS(1)	engineering unit of channel 1
to		to	to
158		EUNITS(128)	engineering unit of channel 128
159	Q	TUNP(1)	dynamic pressure (corrected), psf
160	VEL	TUNP(2)	free-stream velocity, fps
161	PBAR	TUNP(3)	barometric pressure, psf
162	PSTAT	TUNP(4)	test section static pressure, psf
163	RN	TUNP(5)	Reynolds number per foot
164	RHO	TUNP(6)	air density, slugs/ft^3
165	ALPHA	SUPP(1)	corrected angle of attack, deg
166	BETA	SUPP(2)	angle of sideslip, deg
167	THETA	SUPP(3)	Euler pitch angle, deg
168	PSI	SUPP(4)	Euler yaw angle, deg
169	PHI	SUPP(5)	Euler roll angle, deg
170	HGT	SUPP(6)	model height, in.
171	ALPHAU	SUPP(7)	uncorrected angle of attack, deg
172	QUNCOR	SUPP(8)	uncorrected dynamic pressure, psf
173	MACH	SUPP(9)	Mach number
174	LIFT	SUPP(10)	corrected model lift, lb
175	DRAG	SUPP(11)	corrected model drag, lb
176		SUPP(13)	not used
to		to	to
180		SUPP(16)	not used

Balance 1, index 181–198

181	NF1	BDATA(1,1,1)	normal force, lb
182	AF1	BDATA(2,1,1)	axial force, lb
183	PM1	BDATA(3,1,1)	pitching moment, in-lb
184	RM1	BDATA(4,1,1)	rolling moment, in-lb
185	YM1	BDATA(5,1,1)	yawing moment, in-lb
186	SF1	BDATA(6,1,1)	side force, lb
187	CNF1.B	BDATA(1,2,1)	body-axis normal force coefficient
188	CAF1.B	BDATA(2,2,1)	body-axis axial force coefficient
189	CPM1.B	BDATA(3,2,1)	body-axis pitching moment coefficient

Index	Variable		Description
190	CRM1.B	BDATA(4,2,1)	body-axis rolling moment coefficient
191	CYM1.B	BDATA(5,2,1)	body-axis yawing moment coefficient
192	CSF1.B	BDATA(6,2,1)	body-axis side force coefficient
193	CL1.S	BDATA(1,3,1)	stability-axis lift coefficient
194	CD1.S	BDATA(2,3,1)	stability-axis drag coefficient
195	CPM1.S	BDATA(3,3,1)	stability-axis pitching moment coefficient
196	CRM1.S	BDATA(4,3,1)	stability-axis rolling moment coefficient
197	CYM1.S	BDATA(5,3,1)	stability-axis yawing moment coefficient
198	CSF1.S	BDATA(6,3,1)	stability-axis side force coefficient
		Balance 2, index 199–216	
199	NF2	BDATA(1,1,2)	normal force, lb
200	AF2	BDATA(2,1,2)	axial force, lb
201	PM2	BDATA(3,1,2)	pitching moment, in-lb
202	RM2	BDATA(4,1,2)	rolling moment, in-lb
203	YM2	BDATA(5,1,2)	yawing moment, in-lb
204	SF2	BDATA(6,1,2)	side force, lb
205	CNF2.B	BDATA(1,2,2)	body-axis normal force coefficient
206	CAF2.B	BDATA(2,2,2)	body-axis axial force coefficient
207	CPM2.B	BDATA(3,2,2)	body-axis pitching moment coefficient
208	CRM2.B	BDATA(4,2,2)	body-axis rolling moment coefficient
209	CYM2.B	BDATA(5,2,2)	body-axis yawing moment coefficient
210	CSF2.B	BDATA(6,2,2)	body-axis side force coefficient
211	CL2.S	BDATA(1,3,2)	stability-axis lift coefficient
212	CD2.S	BDATA(2,3,2)	stability-axis drag coefficient
213	CPM2.S	BDATA(3,3,2)	stability-axis pitching moment coefficient
214	CRM2.S	BDATA(4,3,2)	stability-axis rolling moment coefficient
215	CYM2.S	BDATA(5,3,2)	stability-axis yawing moment coefficient
216	CSF2.S	BDATA(6,3,2)	stability-axis side force coefficient
		Balance 3, index 217–234	
217	NF3	BDATA(1,1,3)	normal force, lb
218	AF3	BDATA(2,1,3)	axial force, lb
219	PM3	BDATA(3,1,3)	pitching moment, in-lb
220	RM3	BDATA(4,1,3)	rolling moment, in-lb

Index	Variable		Description
221	YM3	BDATA(5,1,3)	yawing moment, in-lb
222	SF3	BDATA(6,1,3)	side force, lb
223	CNF3.B	BDATA(1,2,3)	body-axis normal force coefficient
224	CAF3.B	BDATA(2,2,3)	body-axis axial force coefficient
225	CPM3.B	BDATA(3,2,3)	body-axis pitching moment coefficient
226	CRM3.B	BDATA(4,2,3)	body-axis rolling moment coefficient
227	CYM3.B	BDATA(5,2,3)	body-axis yawing moment coefficient
228	CSF3.B	BDATA(6,2,3)	body-axis side force coefficient
229	CL3.S	BDATA(1,3,3)	stability-axis lift coefficient
230	CD3.S	BDATA(2,3,3)	stability-axis drag coefficient
231	CPM3.S	BDATA(3,3,3)	stability-axis pitching moment coefficient
232	CRM3.S	BDATA(4,3,3)	stability-axis rolling moment coefficient
233	CYM3.S	BDATA(5,3,3)	stability-axis yawing moment coefficient
234	CSF3.S	BDATA(6,3,3)	stability-axis side force coefficient
		Balance 4, index 235–252	
235	NF4	BDATA(1,1,4)	normal force, lb
236	AF4	BDATA(2,1,4)	axial force, lb
237	PM4	BDATA(3,1,4)	pitching moment, in-lb
238	RM4	BDATA(4,1,4)	rolling moment, in-lb
239	YM4	BDATA(5,1,4)	yawing moment, in-lb
240	SF4	BDATA(6,1,4)	side force, lb
241	CNF4.B	BDATA(1,2,4)	body-axis normal force coefficient
242	CAF4.B	BDATA(2,2,4)	body-axis axial force coefficient
243	CPM4.B	BDATA(3,2,4)	body-axis pitching moment coefficient
244	CRM4.B	BDATA(4,2,4)	body-axis rolling moment coefficient
245	CYM4.B	BDATA(5,2,4)	body-axis yawing moment coefficient
246	CSF4.B	BDATA(6,2,4)	body-axis side force coefficient
247	CL4.S	BDATA(1,3,4)	stability-axis lift coefficient
248	CD4.S	BDATA(2,3,4)	stability-axis drag coefficient
249	CPM4.S	BDATA(3,3,4)	stability-axis pitching moment coefficient
250	CRM4.S	BDATA(4,3,4)	stability-axis rolling moment coefficient
251	CYM4.S	BDATA(5,3,4)	stability-axis yawing moment coefficient
252	CSF4.S	BDATA(6,3,4)	stability-axis force coefficient

Index	Variable		Description
253	FMWP	FMDATA(1)	flowmeter mass flow, lb/sec
254	FMRN	FMDATA(2)	flowmeter Reynolds number
255	FMTA	FMDATA(3)	flowmeter ambient temperature, °F
256		FMDATA(4)	not used
257 to 276		XMISC(1) to XMISC(20)	these locations are reserved for extra test-dependent calculations
277		PLIST(1)	user output
to		to	to
300		PLIST(24)	user output

Data which are stored in the pressure database and on the data tape are located in an 800-word array of real numbers. The data and their indexes are

Index	Variable		Description
1	TEST	PVAL(1)	test number
2	RUN	PVAL(2)	run number
3	POINT	PVAL(3)	point number
4	ID	PVAL(4)	option identifier
5	QCODE	PVAL(5)	dynamic pressure calculation code
6	MCODE	PVAL(6)	model initial roll angle
7	NBAL	PVAL(7)	number of balances to process
8	SAMPLES	PVAL(8)	number of data cycles to average
9	WCODE	PVAL(9)	test section wall configuration code
10	CONF	PVAL(10)	optional configuration code
11	TAPE	PVAL(11)	tape save option
12	DBASE	PVAL(12)	database save option
13	PCODE	PVAL(13)	pressure coefficient code
14	LIST	PVAL(14)	line printer list option
15	MPORT	PVAL(15)	maximum scanner port number
16	IPORT	PVAL(16)	present scanner port number
17	IESP	PVAL(17)	electronic-scanning option
18	SCODE	PVAL(18)	model support code

Index	Variable		Description
19	DEBUG	PVAL(19)	force data intermediate list option
20	FMCODE	PVAL(20)	flowmeter code
21	RLENGTH	PVAL(21)	height calculation reference length, in.
22	VLENGTH	PVAL(22)	vertical strut reference length, in.
23		PVAL(23)	not used
24		PVAL(24)	not used
25		PVAL(25)	not used
26	YRMODA	PVAL(26)	coded date
27	HRMNSC	PVAL(27)	coded time
28	XNPUT1	PVAL(28)	operator input variable
29	XNPUT2	PVAL(29)	operator input variable
30	XNPUT3	PVAL(30)	operator input variable
31	Q	PVAL(31)	dynamic pressure, psf
32	VEL	PVAL(32)	free-stream velocity, fps
33	PBAR	PVAL(33)	barometric pressure, psf
34	PSTAT	PVAL(34)	test section static pressure, psf
35	RN	PVAL(35)	Reynolds number per foot
36	RHO	PVAL(36)	air density, slugs/ft^3
37	ALPHA	PVAL(37)	corrected angle of attack, deg
38	BETA	PVAL(38)	angle of sideslip, deg
39	THETA	PVAL(39)	Euler pitch angle, deg
40	PSI	PVAL(40)	Euler yaw angle, deg
41	PHI	PVAL(41)	Euler roll angle, deg
42	HGT	PVAL(42)	model height, in.
43	ALPHAU	PVAL(43)	uncorrected angle of attack, deg
44	QUNCOR	PVAL(44)	uncorrected dynamic pressure, psf
45	MACH	PVAL(45)	Mach number
46		PVAL(46)	not used
to		to	to
50		PVAL(50)	not used
51		PVAL(51)	differential pressure for orifice 1
to		to	to
800		PVAL(2098)	differential pressure for orifice 2048

Appendix D

Sample of Heyson Wall Corrections

The following FORTRAN subroutines were used for the fixed wing model in both open and closed test sections:

```
      SUBROUTINE WALCOR(ITS,LI,ZETA1,ETA1,GAMMA,SIGMA,LAMBDA,NF1,AF1
     1                 QUNCOR,RHO,ALPHAU,WNGAREA,AR,TSAREA,SPAN,
     2                 LIFTC,DRAGC,CLC,CDC,QC)
      REAL LAMBDA,LIFT,NF1,LIFTC,MWBYMT,MUBYMT
      DATA RAD/0.0174533/,PI/3.1415926/,EFF/0.90/
C     WRITE(6,*)'***********PROGRAM WALCOR******************'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'THIS PROGRAM CALCULATES WALL CORRECTION FACTORS'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'*********VARIABLE DEFINITIONS***************'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'ITS:     test section configuration- 1 for closed'
C     WRITE(6,*)'                                     2 for closed on bottom'
C     WRITE(6,*)'                                     3 for open (semispan)'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'LI:      wing loading- 1 for uniform'
C     WRITE(6,*)'                       2 for elliptic'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'ZETA:    ratio of wind tunnel semiheight to height'
C     WRITE(6,*)'         of model above tunnel floor (H/h)'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'ETA:     ratio of lateral distance between model center'
C     WRITE(6,*)'         and right-hand wall to tunnel semiwidth (y/B)'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'GAMMA:   ratio of wind tunnel width to height (B/H)'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'SIGMA:   ratio of wingspan to tunnel width'
C     WRITE(6,*)'                                             '
C     WRITE(6,*)'LAMBDA:  angle of wing sweep (deg)
C     WRITE(6,*)'                                             '
      ALPHAR=ALPHAU*RAD
      LIFT=NF1*COS(ALPHAR)-AF1*SIN(ALPHAR)
      CL=LIFT/(QUNCOR*WNGAREA)
      DRAG=AF1*COS(ALPHAR)+NF1*SIN(ALPHAR)
      CD=DRAG/(QUNCOR*WNGAREA)
      DRAGI=(CL*CL/(PI*AR*EFF))*QUNCOR*WNGAREA
      CDI=DRAGI/(QUNCOR*WNGAREA)
      DGOL=DRAGI/LIFT
      C=ABS(LIFT)
      D=DRAGI
C     WRITE(6,200) NF1,AF1,ALPHAU,QUNCOR,LIFT,DRAG,DRAGI
```

```
C  200     FORMAT(1X,'NF1, AF1, ALPHAU, QUNCOR = ',4F10.4,
C       1          /,' LIFTUNCOR, DRAGUNCOR, DRAGIUNCOR = ',3F10.4)
C          WRITE(6,200) ALPHAU,QUNCOR,LIFT,DRAG,DRAGI
C  200     FORMAT(1X,'ALPHAU, QUNCOR = ',2F10.4,
C       1          /,' LIFTUNCOR, DRAGUNCOR, DRAGIUNCOR = ',3F10.4)
           VBYWH=-SQRT((QUNCOR*PI*SPAN*SPAN)/C)
           G=VBYWH
           A=1.0+(D/C)*(D/C)
           B=2.0*G*D/C
           F=G*G
           H=0.0
           E=-1.0
           W=0.5
10         FX1=A*W**4+B*W**3+F*W**2+H*W+E
           FX2=4.0*A*W**3+3.0*B*W**2+2.0*F*W+H
           W2=W-FX1/FX2
           IF(ABS(FX1/FX2) .GT. 0.001) THEN
              W=W2
              GO TO 10
           ELSE
              WX=W2
           END IF
           WX=W2
           VBYWO=G/WX
           S=VBYWO
C          WRITE(6,300) VBYWH,WX,VBYWO
C  300     FORMAT(1X,' VBYWH, WX, VBYWO = ',3F10.4)
C          WRITE(6,400) CL,S,D,DGOL
C  400     FORMAT(1X,' CL, S, D, DGOL = ',4F10.4)
C          IF(CL .LE. 0.0) THEN
C             XI=90.
C          ELSE
              X1=ABS(ATAN(SQRT(1.0-(WX**4))/(WX*WX)))
              XI1=X1/RAD
              X=ABS(ACOS(WX*WX))
              XI=X/RAD
C              WRITE(6,'(" CHI = ",F10.4)') XI
C              WRITE(6,'(" CHI1 = ",F10.4)') XI1
              IF(-S .LE. DRAGI/LIFT) XI=-XI
C          END IF
C          XI = 90.
C          WRITE(6,'(" CHI = ",F10.4)') XI
C          WRITE(6,'(" CHI1 = ",F10.4)') XI1
           T=(SPAN*SPAN*PI/4.)/TSAREA
           MWBYMT=T/S
           Y=MWBYMT
           MUBYMT=Y*(DRAGI/LIFT)
           T1=MUBYMT
           XEFF=(ATAN((PI**2/4.)*TAN(XI*RAD)))/RAD
C          XEFF=90.
```

```
      CALL WNG302(XEFF,ALPHAU,DWLCTS,DULCTS,DWDCTS,DUDCTS,
     1            DWLOTS,DULOTS,DWDOTS,DUDOTS,LI,ZETA1,ETA1,
     2            GAMMA,SIGMA,LAMBDA)
C     WRITE(6,'(" DWLCTS, DULCTS, DWDCTS, DUDCTS = ",4F10.4)')
C    1       DWLCTS,DULCTS,DWDCTS,DUDCTS
C     WRITE(6,'(" DWLOTS, DULOTS, DWDOTS, DUDOTS = ",4F10.4)')
C    1       DWLOTS,DULOTS,DWDOTS,DUDOTS
      IF(ITS .EQ. 1) THEN
      WL=DWLCTS*MWBYMT
      UL=DULCTS*MWBYMT
      WD=DWDCTS*MUBYMT
      UD=DUDCTS*MUBYMT
      ELSEIF (ITS .EQ. 2) THEN
      WL=DWLCOB*MWBYMT
      UL=DULCOB*MWBYMT
      WD=DWDCOB*MUBYMT
      UD=DUSCOB*MUBYMT
      ELSE
      WL=DWLOTS*MWBYMT
      UL=DULOTS*MWBYMT
      WD=DWDOTS*MUBYMT
      UD=DUDOTS*MUBYMT
      END IF
C     WRITE(6,'(" WL, UL, WD, UD = ",4F10.4)') WL,UL,WD,UD
      DW=WL+WD
      DU=UL+UD
C     WRITE(6,'(" DELTAW, DELTAU = ",2F10.4)') DW,DU
      DALPHA=ATAN(DW/(1.0+DU))/RAD
      DALPHAR=DALPHA*RAD
      QCBYQ=(1.0+DU)**2+DW**2
      ALPHA=ALPHAU+DALPHA
      Q=QCBYQ*QUNCOR
      QC=Q
      VEL=SQRT(2.0*Q/RHO)
      LIFTC=LIFT*COS(DALPHAR)-DRAG*SIN(DALPHAR)
      DRAGC=DRAG*COS(DLAPHAR)+LIFT*SIN(DALPHAR)
      CLC=LIFTC/(Q*WNGAREA)
      CDC=DRAGC/(Q*WNGAREA)
C     WRITE(6,100) DALPHA,QCBYQ,Q,VEL,LIFTC,DRAGC,ALPHA,CLC,CDC
C 100 FORMAT(1X,'DELTA ALPHA = ',F10.4,10X,'QC/Q = ',F10.4,/,
             'QCORR = ',F10.4,5X,'VELOCITY = ',F10.4,/,
             'LIFTCOR = ',F10.4,5X,'DRAGCORR = ',F10.4,/,
             'ALPHA = ',F10.4,5X,'CL = ',F10.4,5X,'CD = ',F10.4)
      RETURN
      END


      SUBROUTINE WNG302(CHI,ALPHA,DWLCTS,DULCTS,DWDCTS,DUDCTS,
     1                  DWLOTS,DULOTS,DWDOTS,DUDOTS,LI,ZETA1,ETA1,
     2                  GAMMA1,SIGMA,LAMBDA)
```

```
      PROGRAM WNG302 (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,PUNCH)
C
C
C     APPENDIX B OF NASA TM X-1740
C
C     THIS PROGRAM COMPUTES THE AVERAGE INTERFERENCE OVER A SWEPT WING
C
C
C     THIS PROGRAM REQUIRES THE USE OF SUBROUTINE DLTAS
C
C
      CHARACTER*8  IALPHA
      COMMON ZETA,ETA,GAMMA,XOVERH,YOVERH,ZOVERH,DELTA(28)
      DIMENSION XDELTA(28),XLOAD(10),XLE(10),C(8)
      DIMENSION SAVIT(4,8),NAMIT(4)
      REAL LAMBDA
      DATA (C(I),I=1,8)/86.5,30.,40.,50.,60.,70.,86.5,90./
      DATA (NAMIT(I),I=1,4)/2HWL,2HUL,2HWD,2HUD/
      XLE(1)=0.43579
      XLE(10)=0.43579
      XLE(2)=0.71422
      XLE(9)=0.71422
      XLE(3)=0.86603
      XLE(8)=0.86603
      XLE(4)=0.95394
      XLE(7)=0.95394
      XLE(5)=0.99499
      XLE(6)=0.99499
      LI=1
      ZETA1=1.0
      ETA1=1.0
      GAMMA=GAMMA1
      SIGMA=0.537
      LAMBDA=0.0
      ALPHA=15.503
      DO 803 L1=1,28
  803 XDELTA(L1)=0.
      PI=3.14159265358979
      RAD=.0174532925199
C     WRITE (6,902)
C   1 READ (5,900) LI,ZETA1,ETA1,GAMMA,SIGMA,LAMBDA,ALPHA,PH,PL
C     PH AND PL ARE THE PIVOT HEIGHT AND LENGTH AT ZERO ALPHA.
C     POSITIVE FOR PIVOT BEHIND AND ABOVE ORIGIN.
C     IF (EOF(5)) THEN
C     GO TO 999
C     ELSE
C     GO TO 47
C     END IF
C  47 ZETA1=ZETA1/(1.+(PH*(1.-COS(ALPHA*RAD))+PL*SIN(ALPHA*RAD))*ZETA1)
C     GAMMA=1.9472
C     SIGMA=SIGMA*60./54.5215
```

```
C              USE H = 14 FEET
C         ITUNNEL=0
C         DO 501 I=1,4
C         DO 501 J=1,8
C   501   SAVIT(I,J)=0.
C         AALP=ALPHA
          IF (LI.EQ.1) GO TO 804
          IALPHA='ELLIPTIC'
          SUML=0.0126104
          DO 808 M2=1,10
    808   XLOAD(M2)=XLE(M2)
          GO TO 160
    804   SUML=0.01
          IALPHA='UNIFORM'
          DO 809 M2=1,10
    809   XLOAD(M2)=1.0
    160   CONTINUE
C   160   WRITE (6,901) IALPHA,GAMMA,ETA1,SIGMA,ZETA1,ALPHA,LAMBDA
C         WRITE (6,210)
C         WRITE (6,211)
C         WRITE (6,212)
C         WRITE (6,213)
C         WRITE (6,214)
C         WRITE (6,215)
C         WRITE (6,216)
C         WRITE (6,217)
C         WRITE (6,218)
          CONST1=1.
          LAMBDA=LAMBDA*RAD
          ALPHA=ALPHA*RAD
C         DO 41 K=1,1
          IF (SIGMA.NE.0.)  GO TO 811
          M6=1
          M7=1
          N6=1
          N7=1
          XLOAD(1)=1.0
          SUML=1.0
          GO TO 8120
    811   IF (ETA1.NE.1.)  GO TO 813
          N6=1
          M6=6
          N7=10
          M7=10
          CONST1=2.
          GO TO 812
    813   M6=1
          N6=1
          M7=10
          N7=10
    812   DO 801 M1=M6,M7
```

```
          DO 802 N1=N6,N7
          XSTAR=(11.-2.*FLOAT(M1))/10.
          YSTAR=(2.*FLOAT(N1)-11.)/10.
          ZSTAR=(11.-2.*FLOAT(N1))/10.
          ETA=ETA1+YSTAR*SIGMA
          ZETA=ZETA1/(1.-ABS(YSTAR)*SIGMA*GAMMA*ZETA1*TAN(LAMBDA)*SIN(ALPHA))
          XOVERH=SIGMA*GAMMA*TAN(LAMBDA)*COS(ALPHA)*(ABS(XSTAR)-ABS(ZSTAR))
          YOVERH=(FLOAT(M1)-FLOAT(N1))*SIGMA*GAMMA*(-.2)
          ZOVERH=SIGMA*GAMMA*TAN(LAMBDA)*SIN(ALPHA)*(ABS(ZSTAR)-ABS(XSTAR))
C
C
          CALL DLTAS  (CHI)
C
C
          DO 805 L1=1,28
  805     XDELTA(L1)=XDELTA(L1)+DELTA(L1)*XLOAD(N1)
  802     CONTINUE
  801     CONTINUE
          DO 807 L3=1,28
  807     DELTA(L3)=XDELTA(L3)*SUML*CONST1
C         WRITE (6,149) CHI
          DWLCTS=DELTA(1)
          DULCTS=DELTA(2)
          DWDCTS=DELTA(3)
          DUDCTS=DELTA(4)
          DWLCOB=DELTA(5)
          DULCOB=DELTA(6)
          DWDCOB=DELTA(7)
          DUDCOB=DELTA(8)
          DWLOTS=DELTA(9)
          DULOTS=DELTA(10)
          DWDOTS=DELTA(11)
          DUDOTS=DELTA(12)
          ALPHA=ALPHA/RAD
C         WRITE(6,'(" DWLOTS, DULOTS, DWDOTS, DUDOTS = ",4F10.4)')
C      1        DWLOTS,DULOTS,DWDOTS,DUDOTS
C         WRITE (6,150) (DELTA(I),I=1,25,4)
C         WRITE (6,151) (DELTA(I),I=2,26,4)
C         WRITE (6,152) (DELTA(I),I=3,27,4)
C         WRITE (6,153) (DELTA(I),I=4,28,4)
          DO 814 L4=1,28
  814     XDELTA(L4)=0.
C         DO 502 I=1,4
C 502     SAVIT(I,K)=DELTA(I+4)
C  41     CONTINUE
C         DO 503 I=1,4
C         PUNCH 504,  (SAVIT(I,K),K=1,8),AALP,ITUNNEL,NAMIT(I)
C 503     CONTINUE
C         WRITE (6,903)
C         GO TO 1
  149     FORMAT (' CHI =',F7.3/)
```

```
  150     FORMAT (3X'(W,L)'7(F17.4))
  151     FORMAT (3X'(U,L)'7(F17.4))
  152     FORMAT (3X'(W,D)'7(F17.4))
  153     FORMAT (3X'(U,D)'7(F17.4)//)
  210     FORMAT (1X131('-'))
  211     FORMAT (1X'I'11X'I'31X'CORRECTION FACTORS FOR CORRECTING FROM A '
        1 WIND TUNNEL WHICH IS'25X'I')
  212     FORMAT (1X'I'11X'I'117('-')'I')
  213     FORMAT (1X'I'11X'I'16X'I'5X'CLOSED'5X'I'16X'I'2X'CLOSED FLOOR'2X
        1 I'6X'OPEN'6X'I'16X'I'5X'CLOSED'4X'I')
  214     FORMAT (1X'I'3X'DELTA'3X'I'5X'CLOSED'5X'I'4X'ON BOTTOM'3X'I'6X'OP-
        1 'EN'6X'I'6X'ONLY'6X'I'5X'FLOOR'6X'I'5X'CLOSED'5X'I'3X'ON BOTTOM'
        2 3X'I')
  215     FORMAT (1X'I'11X'I'16X'I'6X'ONLY'6X'I'16X'I(GROUND EFFECT) I'6X
        1 'ONLY'6X'I'16X'I'6X'ONLY'5X'I')
  216     FORMAT (1X'I'11X'I'84('-')'I'32('-')'I')
  217     FORMAT (1X'I'11X'I'36X'TO FREE AIR'37X'I'8X'TO GROUND EFFECT'8X'I')
  218     FORMAT (1X131('-')/)
C 504     FORMAT (8F7.4,16X,F3.0,I1,A2,2HWW)
C 900     FORMAT (I1,F9.3,7F10.3)
  901     FORMAT ('1'///42X,'AVERAGE INTERFERENCE OF SWEPT WING OF FINITE '
        1 'SPAN'//58X,A8,' LOADING'//36X,'GAMMA =',F6.3,10X,'ETA =',F7.3,
        2 10X,'SIGMA =',F7.3//36X,'ZETA ='F6.3,10X,'ALPHA =',F7.3,10X,
        3 'LAMBDA =',F7.3//)
C 902     FORMAT ('I'//////42X,'AVERAGE INTERFERENCE OF SWEPT WING OF FINI
C       1 TE SPAN')
  903     FORMAT (40X,'COMPUTED USING EQUATIONS OF NASA TR R-302' )
  999     RETURN
          END

          SUBROUTINE DLTAS (ANGL)
C
C
C         APPENDIX Q OF NASA TM X-1740
C
C
C         THIS SUBROUTINE IS REQUIRED BY ALL THE ABOVE PROGRAMS.
C
C
          COMMON ZETA,ETA,GAMMA,XOVERH,YOVERH,ZOVERH,DELTA(28)
          DIMENSION V(3,9),ADEL(28)
          SC=SIN(ANGL*0.0174532925199)
          CC=COS(ANGL*0.0174532925199)
          Z6=ZETA*ZOVERH+1.
          Z8=-Z6
          Z7=Z8-1.
          DO 8 J1=1,28
    8     DELTA(J1)=0.
          DO 10 M=1,7
          DO 10 N=1,7
          IF (N.EQ.4.AND.M.EQ.4) GO TO 10
```

```
      DO 11 J1=1,3
      DO 11 J2=1,9
11    V(J1,J2)=0.
      DO 12 J1=1,28
12    ADEL(J1)=0.
      AM=M-4
      AN=N-4
      X=ZETA*XOVERH
      Y=ZETA*(YOVERH-2.*AM*GAMMA+GAMMA*(1.-ETA)*(1.-(-1.)**M))
      Z=ZETA*(ZOVERH-4.*AN)
      A=SQRT(X*X+Y*Y+Z*Z)
      B=A+Z*CC-X*SC
      V(1,1)=((X*X+Y*Y)/(B*A*A*A))-((Z+A*CC)/(B*A))**2
      V(2,1)=-(X*Z)/(B*A*A*A)-(Z+A*CC)*(X-A*SC)/(B*B*A*A)
      V(3,1)=((Y*Y+Z*Z)/(B*A*A*A))-((X-A*SC)/(B*A))**2
      Z=-Z-2.
      A=SQRT(X*X+Y*Y+Z*Z)
      B=A+Z*CC-X*SC
      V(1,3)=((X*X+Y*Y)/(B*A*A*A))-((Z+A*CC)/(B*A))**2
      V(2,3)=-(X*Z)/(B*A*A*A)-(Z+A*CC)*(X-A*SC)/(B*B*A*A)
      V(3,3)=((Y*Y+Z*Z)/(B*A*A*A))-((X-A*SC)/(B*A))**2
      IF (ANGL.EQ.90.0) GO TO 13
      X=X-(SC/CC)
      Z=-Z-1.
      A=SQRT(X*X+Y*Y+Z*Z)
      B=A+Z*CC-X*SC
      V(1,2)=((X*X+Y*Y)/(B*A*A*A))-((Z+A*CC)/(B*A))**2
      V(2,2)=-(X*Z)/(B*A*A*A)-(Z+A*CC)*(X-A*SC)/(B*B*A*A)
      V(3,2)=((Y*Y+Z*Z)/(B*A*A*A))-((X-A*SC)/(B*A))**2
      B=A-X
      V(1,5)=((X*X+Y*Y)/(B*A*A*A))-(Z/(B*A))**2
      V(2,5)=Z/(A*A*A)
      V(3,5)=X/(A*A*A)
      Z=-Z
      B=A+Z*CC-X*SC
      V(1,4)=((X*X+Y*Y)/(B*A*A*A))-((Z+A*CC)/(B*A))**2
      V(2,4)=-(X*Z)/(B*A*A*A)-(Z+A*CC)*(X-A*SC)/(B*B*A*A)
      V(3,4)=((Y*Y+Z*Z)/(B*A*A*A))-((X-A*SC)/(B*A))**2
13    ADEL(1)=V(1,1)-V(1,2)-V(1,3)+V(1,4)
      ADEL(2)=V(2,1)-V(2,2)+V(2,3)-V(2,4)
      ADEL(3)=V(2,1)-V(2,2)-V(2,3)+V(2,4)+2.*V(2,5)
      ADEL(4)=V(3,1)-V(3,2)+V(3,3)-V(3,4)+2.*V(3,5)
      ADEL(5)=((-1.)**(M+N))*ADEL(1)
      ADEL(6)=((-1.)**(M+N))*ADEL(2)
      ADEL(7)=((-1.)**(M+N))*ADEL(3)
      ADEL(8)=((-1.)**(M+N))*ADEL(4)
      ADEL(9)= ((-1.)**M)*(V(1,1)-V(1,2)+V(1,3)-V(1,4)+2.*V(1,5))
      ADEL(10)=((-1.)**M)*(V(2,1)-V(2,2)-V(2,3)+V(2,4)+2.*V(2,5))
      ADEL(11)=((-1.)**M)*(V(2,1)-V(2,2)+V(2,3)-V(2,4))
      ADEL(12)=((-1.)**M)*(V(3,1)-V(3,2)-V(3,3)+V(3,4))
      DO 14 J1=1,12
```

```
14    DELTA(J1)=DELTA(J1)+ADEL(J1)
10    CONTINUE DO 15 J1=1,8
15    DELTA(J1+20)=DELTA(J1)
      X=ZETA*XOVERH
      Y=ZETA*YOVERH
      Z=Z7
      A=SQRT(X*X+Y*Y+Z*Z)
      B=A+Z*CC-X*SC
      V(1,7)=((X*X+Y*Y)/(B*A*A*A))-((Z+A*CC)/(B*A))**2
      V(2,7)=-(X*Z)/(B*A*A*A)-(Z+A*CC)*(X-A*SC)/(B*B*A*A)
      V(3,7)=((Y*Y+Z*Z)/(B*A*A*A))-((X-A*SC)/(B*A))**2
      IF (ANGL.EQ.90.0) GO TO 16
      X=X-(SC/CC)
      Z=Z6 A=SQRT(X*X+Y*Y+Z*Z)
      B=A+Z*CC-X*SC
      V(1,6)=((X*X+Y*Y)/(B*A*A*A))-((Z+A*CC)/(B*A))**2
      V(2,6)=-(X*Z)/(B*A*A*A)-(Z+A*CC)*(X-A*SC)/(B*B*A*A)
      V(3,6)=((Y*Y+Z*Z)/(B*A*A*A))-((X-A*SC)/(B*A))**2
      B=A-X
      V(1,9)=((X*X+Y*Y)/(B*A*A*A))-(Z/(B*A))**2
      V(2,9)=Z/(A*A*A)
      V(3,9)=X/(A*A*A)
      Z=Z8
      B=A+Z*CC-X*SC
      V(1,8)=((X*X+Y*Y)/(B*A*A*A))-((Z+A*CC)/(B*A))**2
      V(2,8)=-(X*Z)/(B*A*A*A)-(Z+A*CC)*(X-A*SC)/(B*B*A*A)
      V(3,8)=((Y*Y+Z*Z)/(B*A*A*A))-((X-A*SC)/(B*A))**2
16    DELTA(13)=-V(1,6)-V(1,7)+V(1,8)
      DELTA(14)=-V(2,6)+V(2,7)-V(2,8)
      DELTA(15)=-V(2,6)-V(2,7)+V(2,8)+2.*V(2,9)
      DELTA(16)=-V(3,6)+V(3,7)-V(3,8)+2.*V(3,9)
      DELTA(17)=-V(1,6)+V(1,7)-V(1,8)+2.*V(1,9)
      DELTA(18)=DELTA(15)
      DELTA(19)=DELTA(14)
      DELTA(20)=-V(3,6)-V(3,7)+V(3,8)
      DO 17 J1=1,4
17    DELTA(J1)=DELTA(J1)+DELTA(J1+12)
      DO 18 J1=5,12
18    DELTA(J1)=DELTA(J1)+DELTA(J1+8)
      AMT=-2.*GAMMA*ZETA*ZETA/3.14159265358979
      DO 19 J1=1,28
19    DELTA(J1)=AMT*DELTA(J1)
      RETURN
      END
```

Appendix E

Data and Archive File Tape Records

Data and test parameters are stored on the archive file magnetic tape in formatted line images. Each logical record consists of one or more lines of ASCII characters. The first line contains the record parameters

KEY, ITEST, NLINE, NVALS, and FMAT

in the format

(A8, I4, I4, I4, A40)

where

KEY is the 8-character record name;

ITEST is the integer test number;

NLINE is the integer number of lines in the record;

NVALS is the integer number of values formatted into the record; and

FMAT is the 40-character FORTRAN format of the values.

A sample routine to read the 14- by 22-Foot Subsonic Tunnel ASIFT tape format follows.

```
          CHARACTER KEY * 8, FMAT * 40, NAMES(300) * 8,
              NODATA * 1
          INTEGER ITEST,NLINE,NVALS,NDEX(300)
          REAL FDATA(300)
* __
* __    Generate default NDEX, NAMES, and FDATA arrays
* __      DO 10 I=1,300
          NDEX(I) = I
          NAMES(I) = '
          FDATA(I) = 0.0
     10   CONTINUE
* __
* --    Read first line of logical record
* --    Logical unit number 8 is assigned to input device
* __
     20   READ(8,'(A8,3I4,A40)',END=999) KEY,ITEST,NLINE,NVALS,FMAT
* __
* --    Begin testing for particular record types
* __
          IF(KEY.EQ. 'NDEX') THEN
          READ(8,FMAT,END=100) (NDEX(I),I=1,NVALS)
          ELSE IF(KEY.EQ.'NAME') THEN
          READ(8,FMAT,END=100)
          (NAMES(NDEX(I)),I=1,NVALS)
          ELSE IF(KEY.EQ. 'FDATA') THEN
          READ(8,FMAT,END=100)
          FDATA(NDEX(I)),*=1,NVALS)
* __
* __    Tests for other KEYs would go here if needed
* __
```

```
         ELSE
* __
* __     Read over remainder of record if not interested
* __
         DO 30 LINE=1,NLINE
         READ(8,'(A1)',END=100) NODATA
   30    CONTINUE
         ENDIF
* __
* __     Go read next record type
* __
         GO TO 20
  100    WRITE(1,*) 'UNEXPECTED END OF FILE ENCOUNTERED'
  900    RETURN
         END
```

The following list gives the logical records which are written to the magnetic tape by the data reduction and the database archive programs. *Note that * records are stored in the pressure database.*

Key	Variable	Description
AVG	RCON(1:30)	test parameters
	AVGBUF(1:128)	averaged analog and digital raw data
BALPAR	NBAL	number of balances being processed
	IBAL	index of this balance
	NAMB(IBAL)	6-character name of this balance
	ICHB(IBAL)	channel number for first component
	IBTYP(IBAL)	balance type
	REF(1:3,IBAL)	balance reference area and lengths
	TRAN(1:3,IBAL)	balance to MRC transfer distances
	GAM(1:3,IBAL)	balance to model axis Euler rotation angles
	B1(1:6,1:6,IBAL)	installation interaction parameters
	PC(1:3,1:6,IBAL)	pressure tare parameters
	BCON(1:174,IBAL)	balance interaction matrix
CHAN	ICHAN(1:NVALS)	DAU channel table
CON	CON(ICHAN(1:NVALS))	channel sensitivity constants
ESPAVG	ESPAVG(1:NVALS)	pressure data from electronically scanned devices
FDATA	RCON(NDEX(1:NVALS))	calculated force data output parameters
FIND	NPAR	number of parameters in output array
	NCHAN	number of analog and digital channels in DAU channel table

	NALOG	number of analog channels
	NDIG	number of digital channels
	IFIND(1:24)	array of data parameter pointers
	NBAL	number of balances being processed
FMETER	MC	flowmeter number
	AA	flowmeter parameters
	CDA	
	YAA	
	YAB	
	D2	
	COEF(1:4,1:2)	
JET	JBCORR(1:4)	jet boundary correction parameters
LIMITS	LWLIM(NDEX(1:NVALS)	lower limits
	UPLIM(NDEX(1:NVALS)	upper limits
NAME	NAMED(NDEX(1:NVALS))	array of 8-character names assigned to output variables
NDEX	NDEX(1:NVALS)	array of indexes of output variables being used
OFFSET	OFFSET(ICHAN(1:NVALS))	channel engineering unit offsets
*PDATA	PVAL(1:NVALS)	calculated pressure data
*PSTRIP	NSTRIP	number of strips
	I	strip number
	NET(I)	network number for strip I
	NORF(I)	number of orifices in strip I
	LIM1	first data array number in this strip
	LIM2	last data array number in this strip
	K	data array number
	IDORF(K)	orifice identification number
	JDRIVE(K)	pressure transducer channel
	JPORT(K)	port number
	XLOC(K)	orifice X-axis location
	YLOC(K)	orifice Y-axis location
	ZLOC(K)	orifice Z-axis location
	K=LIM1 to LIM2	
RVOLT	(IVOLT(N),VOLT(N), N=1:NVALS)	excitation voltage channel and reference value

	SPAN (SPANI(N),SPAN(N), N=1:NVALS)	initial analog channel span and span correction factors
SVAVG	SCNBUF(1:NVALS)	raw pressure data from mechanical steppers
SVCHAN	PFACT(1:2)	pressure data conversion factors
	ISV(1:10)	array of steppers
	ISV(11)	number of active steppers
	JSV(1:60)	array of active pressure transducer channels
	JSV(61)	number of active pressure transducer channels
TARES	TARES(1:7,1:4)	attitude tare parameters
TITLE	TITLE*80	80-character ASCII comment
TYPE	ITYPE(ICHAN(1:NVALS))	channel engineering unit calculation types
UNIT	NAMEU(NDEX(1:NVALS))	array of 8-character unit labels
USERP	USERP(1:100)	array of user input parameters
WALL	DOL(1:5,1:2)	array of drag-to-lift ratios
	DELALF(1:3,1:5,1:2)	array of delta-alpha coefficients
	DELQ(1:3,1:5,1:2)	array of delta-q coefficients
ZEROI	ZEROI(ICHAN(1:NVALS))	channel wind-off zeros

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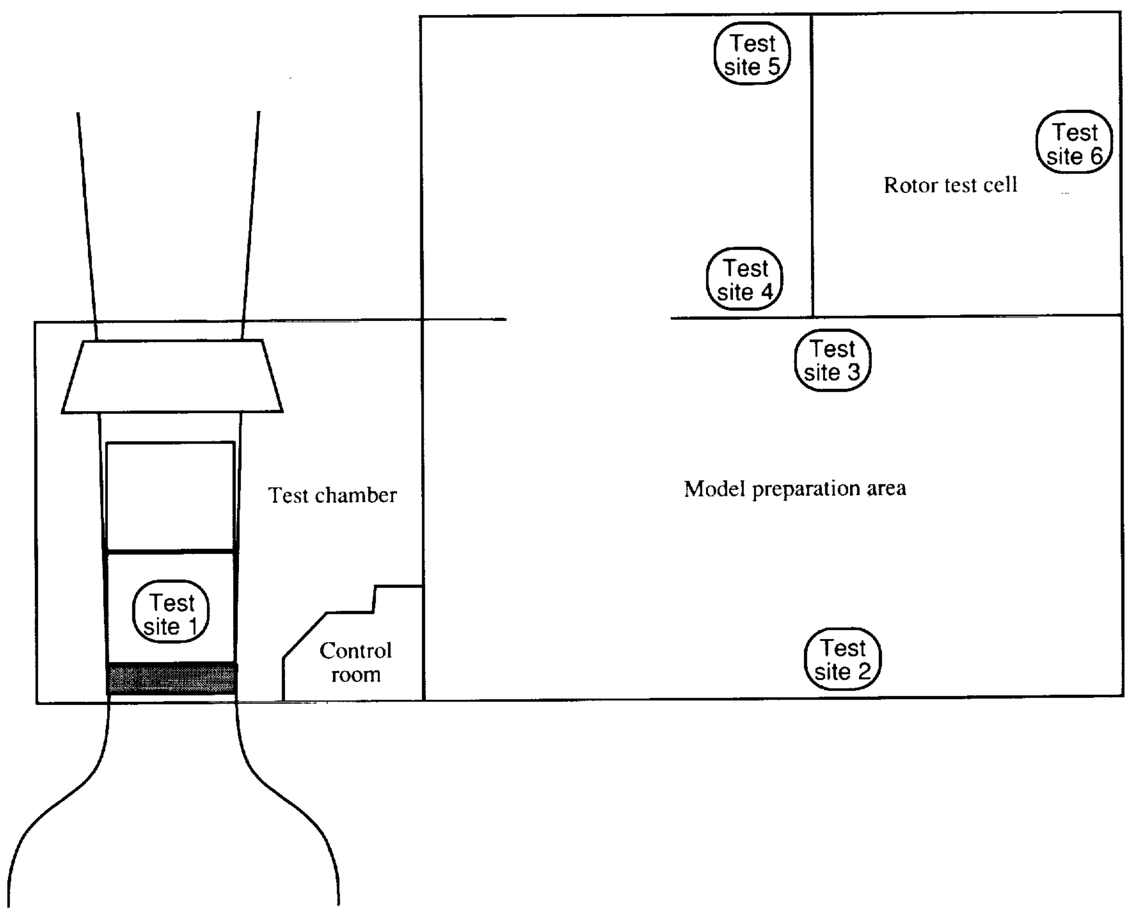


Figure 1. Location of 14- by 22-Foot Subsonic Tunnel test sites.

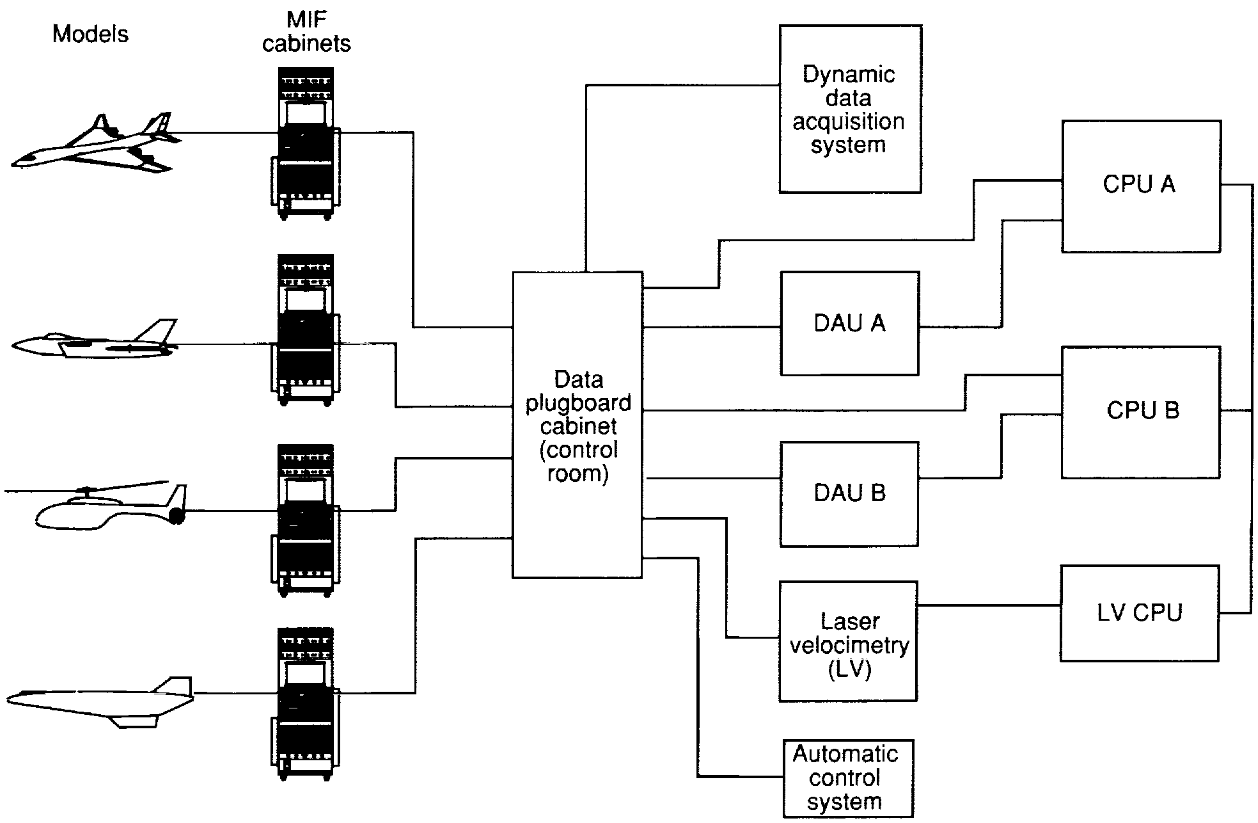


Figure 2. Diagram of 14- by 22-Foot Subsonic Tunnel data acquisition system.

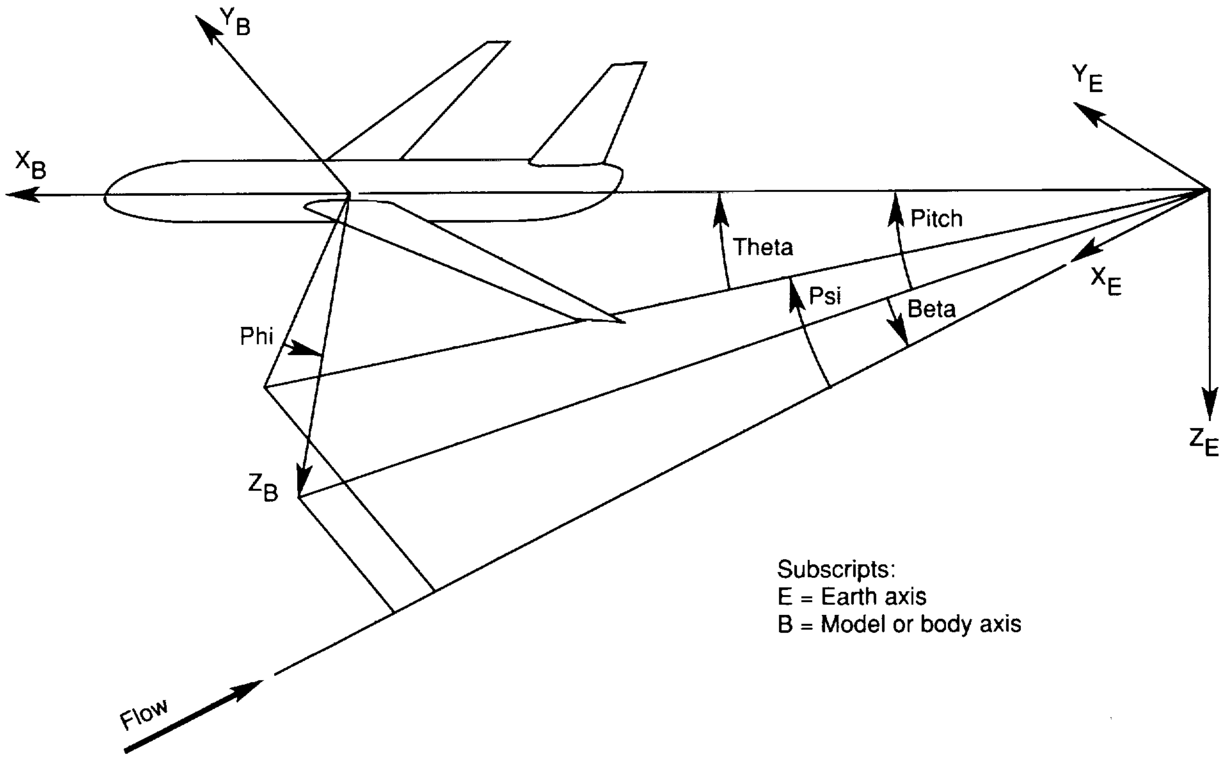
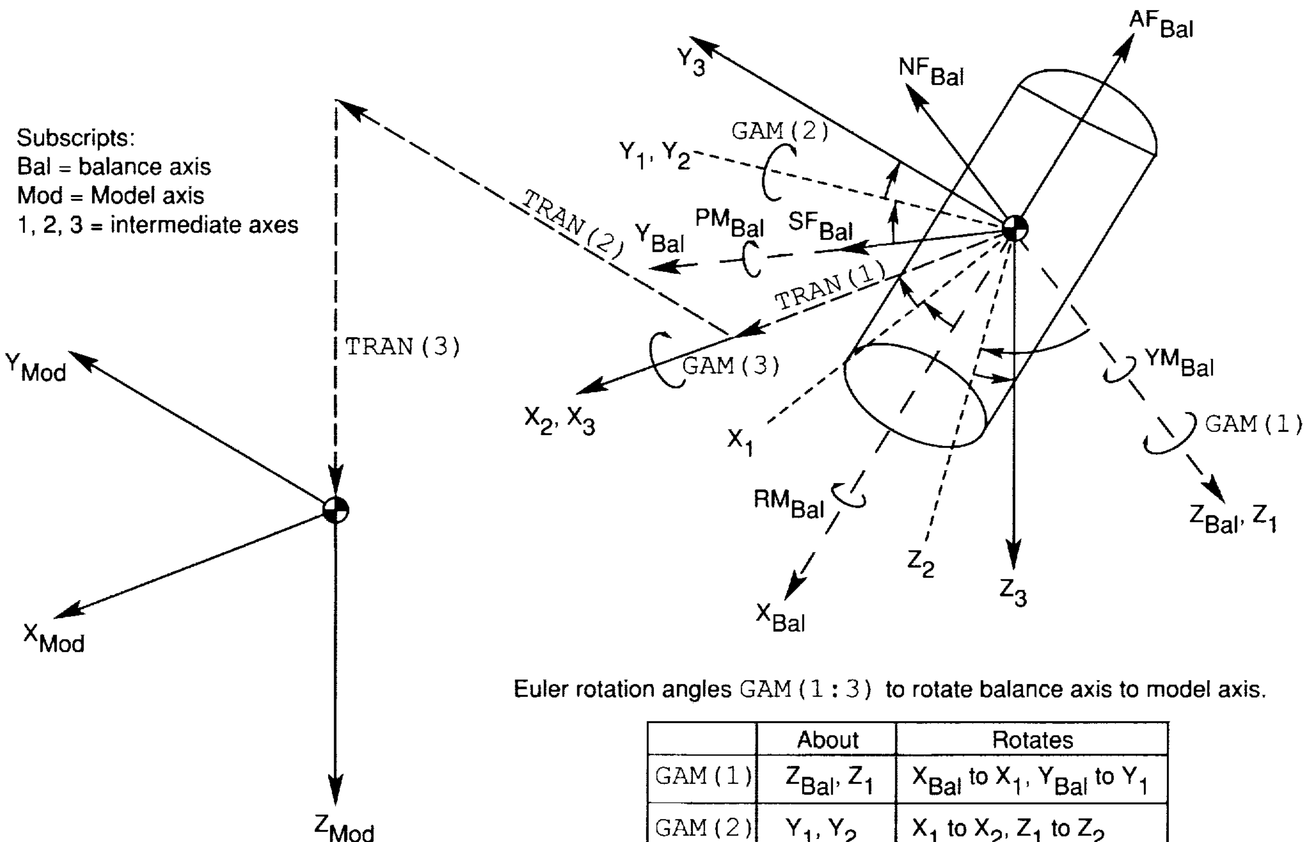


Figure 3. Model attitude parameters.



Euler rotation angles GAM (1 : 3) to rotate balance axis to model axis.

	About	Rotates
GAM (1)	Z_{Bal}, Z_1	X_{Bal} to X_1, Y_{Bal} to Y_1
GAM (2)	Y_1, Y_2	X_1 to X_2, Z_1 to Z_2
GAM (3)	X_2, X_3	Y_2 to Y_3, Z_2 to Z_3

X_3, Y_3, Z_3 ready to be translated to X_{Mod}, Y_{Mod}, Z_{Mod} thru TRAN (1 : 3)

Figure 4. Balance to model transformations and rotations.

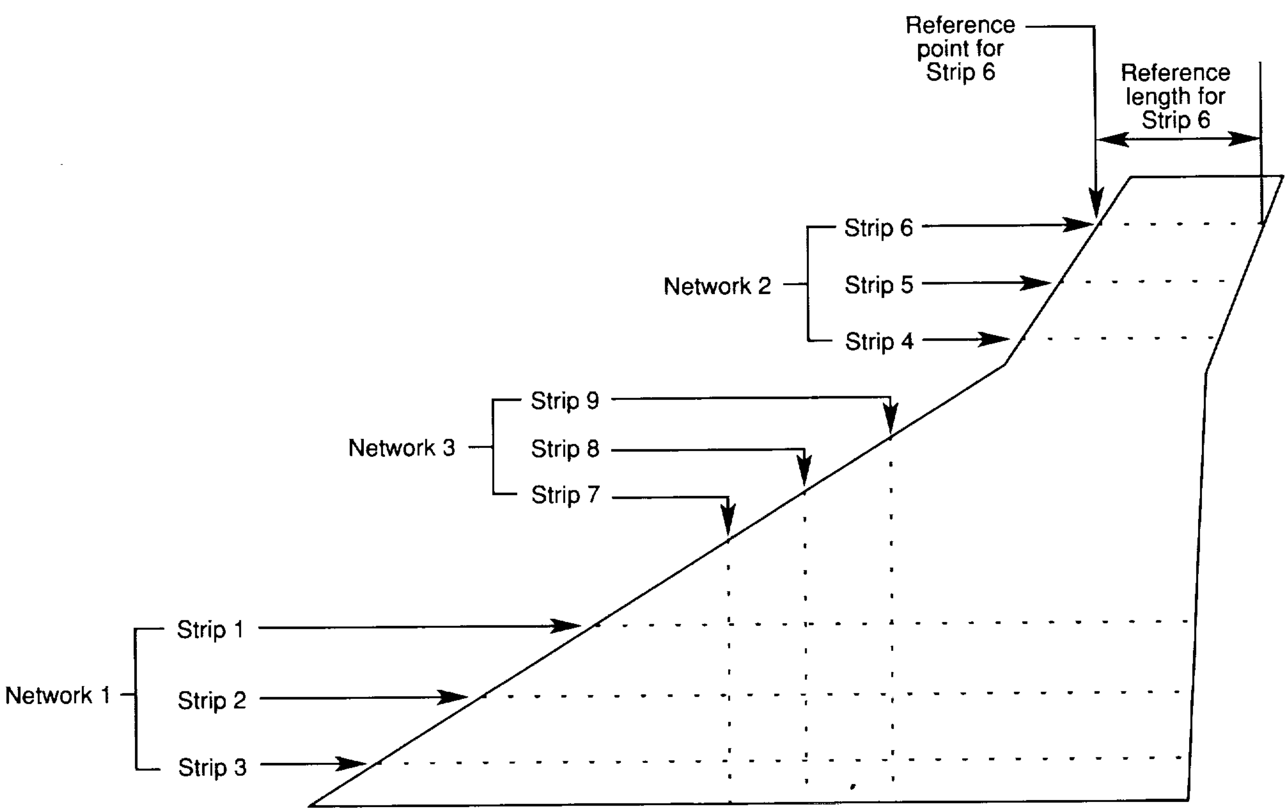


Figure 5. Wing pressure ports arranged in strips and networks.

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The Langley 14- by 22-Foot Subsonic Tunnel is used to test a large variety of aircraft and nonaircraft models. To support these investigations, a data acquisition system has been developed that has both static and dynamic capabilities. The static data acquisition and reduction system is described; the hardware and software of this system are explained. The theory and equations used to reduce the data obtained in the wind tunnel are presented; the computer code is not included.

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