Wind Tunnel Division

Test Planning Guide for High Speed Wind Tunnels

NASA Ames Research Center

Wind Tunnel Division

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Record of Changes

Change	Date	Change Description	Initiator
Change A	4/98	CR 1408	A Crozier
Revision 2	4/99	CR 1562	A Crozier
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Revision 6	4/7/15	CR 3287, Removed all references to 12-ft tunnel. Removed Section 6.3 Separation Support System. Removed Section 7.3 12-ft Pressure Wind Tunnel. Removed Appendix D 12-ft PWT, Instrumentation, Data Acquisition, and Data Reduction.	John Holmberg
Revision 7	3/18	CR 3392, Major revision to reflect current operating environment, schedules, and procedures.	Jennifer Everett
Revision 8	7/19	CR 3462, Revised Risk Matrix (Section 5.1 2) to conform with NASA guidance. Updated Test Request Form to current revision (Section C.2). Updated Safety Quick Reference Guides (Section D). Also added numbering to sub-chapters.	Herb Finger

Revision 8.1	7/21	CR #3591 – Removed reference to Sandberg-Serrell (3.3.7). Restated that customer will not be authorized to operate NASA Cranes (4.2.4 & 4.5)	H. Finger

Table of Contents

List of Acronyms and Abbreviations

Term	Definition
ANSI	American National Standards Institute
APR	Ames Procedural Requirement
ASME	American Society of Mechanical Engineers
BEAP	Building Emergency Action Plan
CDR	Critical Design Review
CM	Configuration Management
CMTR	Certified Material Test Report
LARC	Langley Research Center
LOTO	Lock Out / Tag Out
LSO	Laser Safety Officer
NASA-STD	NASA Standard
ORR	Operational Readiness Review
OSHA	Occupational Safety and Health Administration
PSP	Pressure Sensitive Paint
SAA	Space Act Agreement
SOP	Standard Operating Procedures
SWT	Supersonic Wind Tunnel
TRR	Test Readiness Review
TSP	Temperature Sensitive Paint
TRD	Test Requirements Document
TWT	Transonic Wind Tunnel
UV	Ultra Violet
VAL	Visitor Authorization Letter
WTPR	Wind Tunnel Procedural Requirement

1 Introduction

1.1 Purpose of This Test Planning Guide

The purpose of this guide is to acquaint customers with the requirements for conducting tests in any of the Wind Tunnel Division's high-speed test facilities at Ames Research Center. It includes available services and capabilities of these facilities and standard practices/procedures to enable customers to achieve their test objectives.

1.2 Wind Tunnel Availability

The Wind Tunnel Division high speed wind tunnels are available for Government sponsored and commercial customers. Approval to conduct test programs must be justified on the basis of technical merit, national priority, and the capability of the Ames facilities to meet the test requirements.

Results from all tests are in the public domain and available for general distribution unless the data is proprietary by fee basis or classified by a Government sponsor.

1.3 List of Facilities

The Wind Tunnel Division is responsible for the operation of the following high-speed facilities located at the Ames Research Center.

- 9x7ft Supersonic Wind Tunnel
- 11ft Transonic Wind Tunnel

1.4 Inquiries

Inquiries regarding the use of these facilities should be directed to:

Chief, Wind Tunnel Division
NASA Ames Research Center
Mail Stop 227-3
Moffett Field, CA 94035-0001

Phone: (650) 604-1463

Timeline

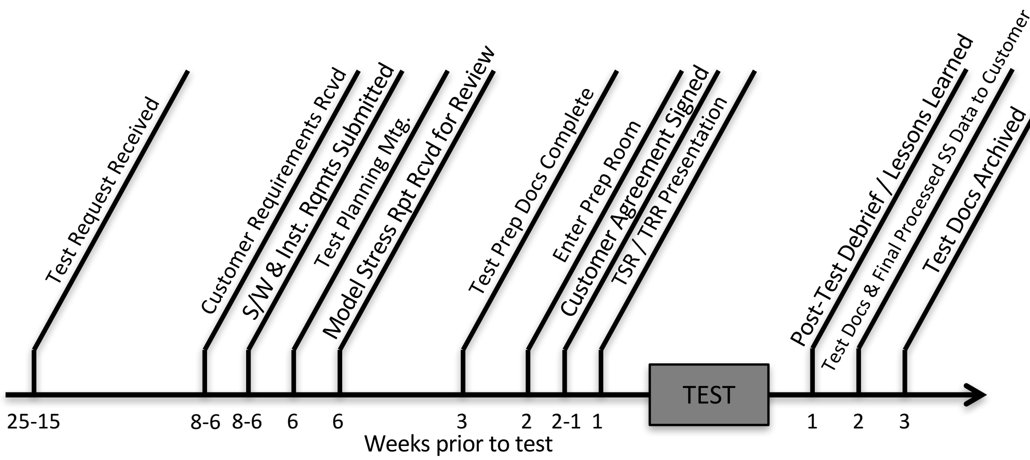


Figure 1-1: Nominal Test Process Timeline

2 Pretest Requirements

2.1 Initial Requests

The initial contact to request a wind tunnel test is Chief, Wind Tunnel Division. The contact should be made during the early stages of test program development (12 to 18 months before tunnel entry date) to discuss projected schedules and general requirements and concerns for tests in Ames Research Center tunnels.

Early notification will allow personnel to review the proposed test and to ensure that test requirements are compatible with the requested test facility and that schedule constraints can be addressed.

2.2 Requesting Tunnel Time

The following sequence of events should begin well before the desired test dates (7 months in requested) to be included in the wind tunnel test schedule:

- The test sponsor/customer contacts the Wind Tunnel Division Chief.
- The customer completes and submits a Test Request form. (Available at https://windtunnels.arc.nasa.gov). Upon receipt of the Test Request at Ames, a process to accommodate the test begins.
- A Test Objectives Meeting is scheduled to discuss the overall test requirements and the Ames facilities capabilities to meet these requirements.

2.3 Test Objectives Meeting

2.3.1 Purpose

The purpose of the Test Objectives Meeting is for the customer (or test sponsor) to discuss the subject test requirements with Ames/Wind Tunnel Division personnel to determine if the Ames facilities can meet the test objectives. When the required facility is heavily booked, the customer will be required to provide information supporting the urgency of the test.

2.3.2 Scheduling the Meeting

The Test Objectives Meeting will be held as soon as possible after the initial request and preferably 6 months prior to the proposed test start date.

2.3.3 Typical Meeting Agenda

The Test Objectives Meeting covers:

- purpose, scope, and criticality of test.
- test objectives.

- initial instrumentation requirements.
  - Balance
  - Static pressures
  - Dynamic pressures
  - Strain gauges
- initial controls requirements.
  - Remote drives
- initial data reduction software requirements.
- estimated test run matrix.
- any special or unusual test requirements.
- hardware fabrication requirements.
  - Model, support system hardware
- security requirements.

2.3.4 Test Acceptance

When the test program is accepted:

- the customer is notified
- a test date is scheduled
- a Test Manager is assigned, who functions as the principal point of contact between the customer and NASA
- an Initial Test Planning Meeting is scheduled
- resources are committed to support the test
- a Space Act Agreement may be required

2.4 Initial Test Planning Meeting and Test Requirements Document (TRD)

2.4.1 Purpose

The purpose of the Initial Test Planning Meeting is to discuss details regarding test requirements. The Test Manager and customer develop detailed plans together, and then management is briefed. **The meeting is held nominally 12 weeks prior to the test.** See Appendix C for recommended guidelines for the Initial Test Planning Meeting.

2.4.2 Test Requirements Document

The Test Manager must receive a complete TRD from the customer at least one week prior to the Initial Test Planning Meeting. See Appendix C for an outline of the TRD as well as at http://windtunnels.arc.nasa.gov. The document covers the following areas:

- Description of Test Objectives
- Model Hardware Requirements
- Instrumentation Requirements
- Data Processing Requirements
- Customer Computing Requirements
- Security Requirements (if applicable)

2.4.2.1 Description of Test Objectives

As part of the TRD, NASA requires a clear statement of the test objectives and techniques to achieve those objectives. Any special techniques or procedures should be explained. The customer must provide a prioritized run schedule compatible with the objectives and allotted test time.

2.4.2.2 Model Hardware

The TRD must provide drawings of the model, installation, and appropriate hardware to adapt the customer-supplied model to the tunnel or existing Ames equipment. This also includes any model remote devices or control systems. Gauges or jigs can be made available to the customer, and they will be sent on request. The customer is to return them within three weeks of receipt. All models tested require a supporting stress analysis. See Section 5.2 for details.

2.4.2.3 Instrumentation Requirements

The TRD must provide instrumentation requirements and demonstrate how the customer will adapt customer-supplied instrumentation to the wind tunnel data system. Ames will specify the required type of plugs, connectors, etc. These requirements include the use of balances, static pressure instrumentation, dynamic pressure instrumentation, and strain gages for hinge moments.

Requirements for Flow Visualization methods (e.g.: IR Thermography, Pressure Sensitive Paint, etc.) and Dynamic Data must also be submitted to the Test Manager.

2.4.2.4 Data Processing Requirements

Data reduction information (data inputs, equations in engineering language, data output format complete with units and scaling for accuracy and resolution) must be submitted to the Test Manager.

Customers must request subsequent changes to these data requirements in writing to the Test Manager for review and approval.

2.4.2.5 Customer Computing Requirements

The customer should indicate what, if any, computer resources will be required for their on-site staff. This should include desktop PCs and any required software (e.g.: Matlab, Techpot, Python, etc.) that might be needed for on-site processing. Printers are available in the Control Room, the Prep Rooms, and the Customer Office areas.

2.4.2.6 Security Requirements (if applicable)

The TRD must address in specific detail security requirements for model prep room, test section, control room, model access, photography/video, data acquisition, and data processing.

2.5 Space Act Agreement / Interagency Agreement

A Space Act Agreement is required for all commercial and non-Government entities wishing to conduct a test in the NASA Wind Tunnels. Space Act Agreements (SAAs) are a type of legal agreement that outlines the responsibilities (including financial) of all parties. A signed SAA, along with payment for the test services, must be in place prior to test start. The process typically takes about four months.

Wind Tunnel Division Management will prepare a draft of the SAA after initial contact and forward it to the customer for review and concurrence. Companies can develop a blanket SAA defining the general terms of the agreement and then submit Annexes to the SAA for particular wind tunnel test entries. These Annexes can be executed in one-to-two months, typically.

Similarly, U.S. Government Agencies are required to have an Interagency Agreement (IAA) that outlines the responsibilities (including financial) of both agencies. Wind Tunnel Division Management will prepare a draft of the IAA after initial contact and forward it to the customer for review and concurrence.

2.6 Customer Agreement

At the conclusion of the Initial Test Planning Meeting or as soon as possible thereafter, the NASA Test Manager will develop a detailed Customer Agreement. This technical document describes the Division's and Customer's deliverables with appropriate milestones and dates identified. The document will address the following items as appropriate:

- Introduction and background of test
- Test milestone dates
- Estimate of time required to accomplish test matrix and objectives
- Goals and objectives of test

- Customer and division points of contact (Initial Test Planning Meeting attendees)
- Overall requirements (model, model support, facility, instrumentation, computing)
- Test conditions and type(s) of data required
- Design reviews /additional requirements meetings
- Deliverables/due dates prior to test dates
- What the customer will provide in support of the test and when
  - equipment, hardware, fabrication
  - labor resources
  - analyses
  - model
  - any unique requirements for verification, storage, or maintenance of customer supplied products
- What the Division wisll provide in support of the test and when
  - equipment, hardware, fabrication
  - labor resources
  - analyses
  - facility dependent model hardware
  - computer servers, analysis PCs

The Customer Agreement will be signed by the Division and Customer representatives, distributed to all affected parties, and the original will be archived within the Division.

If during further test preparations significant changes in the Division's or Customer's responsibilities, deliverables, or milestones are deemed necessary, these changes will be managed according to the Test Change Control Process as defined in the Wind Tunnel Division Test Process Manual. The Test Manager and Customer representative will agree on the changes, the Test Manager will determine the appropriate level of Division Management involvement, and an addendum to the Customer Agreement will be created and signed by both the test Manager and the Customer representative.

2.7 Model and Equipment Delivery

2.7.1 Timely Arrival

Models and support hardware should arrive at the tunnel at least one week prior to the scheduled model preparation room entry. The Test Manager will provide appropriate shipping addresses.

Arrangements can be made to ship the model several weeks prior to the test if necessary.

2.7.2 Preassembly Requirements

All model parts, internal instrumentation, and customer-provided support hardware must be assembled and checked out by the customer prior to delivery to Ames to ensure proper fit, and form and to reduce installation delays.

2.7.3 Shipping Information

Immediately following shipment from the customer's plant or model vendor, the Test Manager must be notified of identifying shipping numbers and scheduled arrival time. Shipments must be prepaid and arrive on the specific day agreeable to the Test Manager.

- Models shipped via common carrier should be addressed to:
  (Name of Ames Test Manager)
  NASA Ames Research Center
  c/o Jacobs Technology
  Building N227 Room 120, Boyd Road
  Moffett Field, California, 94035
- The Test Manager's name, telephone number, delivery point, and the test number must be marked on the boxes.
- Large boxes are required to have skids at least 4 inches thick so they can be handled using a forklift.
- Deliver models brought via customer's private trucks directly to the testing facility.

2.7.4 Identification or Unsuitability of Customer Equipment

Model and test equipment delivered shall have appropriate identification that designates the contractor’s ownership of the equipment. The identification of the equipment shall be maintained while the equipment is at Ames. This is especially important for equipment that stays at Ames long after a test is completed.

If a customer supplied model or test equipment is damaged or found unsuitable for its intended use, the Test Manager will document the condition and archive the findings. The customer will be notified, and corrective actions will jointly be determined by the Test Manager and customer.

3 General Information

Primary Point of Contact

The Test Manager functions as the primary point of contact to facilitate requests, requirements, services, and standard procedures for the customer while at Ames Research Center.

Communications

Telephones, FAX machines, and Internet access are available.

Cafeteria Hours

The Ames cafeteria is open from 6:00 a.m. until 2:00 p.m. Monday through Friday.

Office Space

Private office space is not available in the control room but desk and filing space are provided. However, a Customer Office in the main building (connected to the wind tunnels) is provided with 4 desks, a conference table and speaker phone, internet connectivity, and a printer as well as a TV monitor connected to the internal TV network.

During preparation and testing, desk space may be available in the model buildup area.

Visitor Control

Visitor Control is located in Building 26, which is located on the right side of the Moffett Boulevard Main Gate. Business hours are from 6:00 a.m. to 6:00 p.m., Monday through Friday. All Ames visitors are required to obtain temporary badges at Visitor Control. Visitor must bring a current picture government ID (e.g., driver's license, passport, etc.). Permanent Residents (aka Green Card Holders) must also bring their Green Card to Visitor Badging. Arrivals other than normal business hours must make special arrangements through the Test Manager.

3.1 Security

3.1.1 Advance Notification Requirements

The customer must provide the Test Manager with a list of names and citizenship of all customer personnel who will require entry into Ames for the duration of the test. The times below are the advance notification requirements.

Table 3-1: Advance Notice Requirements

Category of Visitor	Advance Notice Required
U. S. Citizen	None
Permanent Resident Foreign Nationals (aka Green Card	None (Must have Green Card while on-site)
Other Foreign Nationals	3 Weeks (Will have to be escorted while on-site)
Classified visit	10 Days

- *If these lead times are not adhered to, delays, inconveniences and test stoppage can result.*

3.1.2 Secret or Confidential Clearances

If the visit is Secret or Confidential, visitors are required to have their security clearances sent in advance via a VAL – Visitor Authorization Letter to:

Security Clearances
NASA Ames Research Center
Mail Stop 15-1
Moffett Field, CA 94035-0001

(650) 604- 5546

3.1.3 Badges

While at Ames, all customer personnel are required to wear badges as issued by Visitor Control. The Test Manager is responsible for coordinating with the customer how and when to obtain badges and their applicable requirements (i.e., for second and third shifts, etc.).

In addition, a special Wind Tunnel Access Badge will be provided by the Test Manager to enable access to the test section, control room area and model preparation area.

3.2 Planning

3.2.1 Normal Operating Hours

Test facilities are operated on a normal five-day week beginning 2230 Sunday until 2300 Friday. One, two, or three-shift operation is available depending on test requirements. Typical shift hours are as follows:

Grave Shift	2230-0700
Day Shift	0630-1500
Swing Shift	1430-2300

Consult the Test Manager regarding the specific shift hours because they can vary between test facilities.

3.2.2 Off-Shift Coverage

Access to the test facility on shifts other than operating shifts must be coordinated through the Test Manager. Customer personnel are not permitted to work in the facility without facility personnel present.

3.2.3 Test Safety Review

A test safety review is held just prior to beginning test operations to review operations and safety aspects of the test and facility. This includes test objectives, run schedule, instrumentation, hardware, and stress limitations.

3.2.4 Test Debriefing (aka Exit Interview)

Just prior to the completion of the test, the customer's senior Test Manager will meet with NASA management for the purpose of evaluating the quality of the test support received by the customer. Wind Tunnel Division Management will make the arrangements for this meeting.

3.2.5 Charges for Test Time

The occupancy time charged to the customer starts at the beginning of the installation of the test hardware in the test section and concludes with the restoration of the facility to its pretest configuration. The customer's equipment must be crated and ready for shipment at the completion of the test period.

Schedule extensions can only be made by the Division Chief, Wind Tunnel Division at the request of the Test Manager.

3.2.6 Computation of Test Time

The time required for installation and test run, or test-run series, is dependent on several factors:

- the quality of test preparation

- the specific model
- the time to complete model changes
- test facility
- test conditions
- number of runs required
- number of data points
- and conditions changed between data points

Customers should consult the Test Manager about the time required to complete a test program. See also Table 3-2: Task Completion Times.

3.3 Support

3.3.1 Requests for Assistance

All requests for assistance or services must be made to the Test Manager or shift engineer.

As a customer, please provide Test Managers with clear, complete, and timely requirements to ensure adequate and effective test support can be provided.

3.3.2 Model Buildup

Final details of model preparation and Ames support required during buildup must be established with the Test Manager at least one week prior to the customer's scheduled arrival.

3.3.3 Customer Responsibility

Customers shall provide their own mechanics to perform model changes. All tools, spare parts (including certified fasteners), and supplies necessary for personnel to work on the model and any special equipment not available at the particular tunnel are supplied by the customer. A competent aerodynamicist familiar with the model and test objectives must be accessible during the test. The customers may request the use of NASA personnel to assist in model changes.

3.3.4 Government Equipment

Customer personnel are not to operate government-furnished equipment or to make connections to this equipment. Such equipment includes, but is not limited to,

- instrumentation
- data processing and recording equipment
- facility control equipment

- pressure regulating and measuring equipment
- electrical and pressure disconnect panels
- overhead cranes

3.3.5 Shop Services

Ames shop services are available to the customers and must be requested through the Test Manager.

A local machine shop is available day shift only. If services are required by the main machine shop, an additional cost will be charged to the customer

3.3.6 Photographic Services

Photographs of the model installation are taken to the extent necessary for one configuration. Additional photographic requirements should be discussed with the Test Manager prior to the test.

3.3.7 Balance Availability and Calibration

Balance calibrations are contracted to an outside vendor with direct cost passed onto the customer.

To assist with scheduling and to ensure availability, customers must consult the Test Manager during the initial test planning meeting if planning to use an Ames balance or if requesting calibration for a customer balance.

3.3.8 Time Estimates

The following table lists some typical times (in minutes) for how long it takes to complete various tasks.

Table 3-2: Task Completion Times (minutes)

Activity	Wind Tunnel	
	11ft	**9x7ft**
Close Tunnel (Prior to Drive Start)	5	5
Pump Tunnel to Limit Pressure from 1 Atmosphere	10	10
Pump to Tunnel Limit Vacuum from 1 Atmosphere	15	10
Start Tunnel Drive	5	20
Set Initial Tunnel Conditions	10	10
Time for Typical Data Point	.08	.08
Avg. change Test Conditions (M, Pt, rpm, IGV angle, etc.)	3	7-10

Stop Tunnel Drive	5	20
Blow Down to Atmosphere from Tunnel Limit Pressure	5	5
Model Changes	**	**
Start-of-Operating Period Inspections and Activities	30	30
Post Operating Period Inspections and Activities	30	30
Drive Compressor Blade Insp. (every 50 hrs. of running time)	90	—
Slip Ring Cleaning (50 hrs. – 11-ft.; 40 hrs. – 9x7)	240	240 Max
Uncouple/Couple Drive Motors	45	45
Plant Equipment Warm-Up	120	120
Plant Equipment Cool-Down	60	240

*** Function of the model and change required.*

4 Environment, Health and Safety

Description

This section acquaints the Customer with the Wind Tunnel expectations concerning emergencies, safety, and hazards. Procedures, controls, and guidelines are described to ensure the Customer understands what is required to protect personal safety, the facility and environment, and to reduce associated risks to acceptable levels. The Test Manager, or in their absence the Shift Engineer, has the responsibility for and authority to take all steps that are necessary during test planning, preparation, execution, and closeout to ensure the safety of personnel, equipment, and the facility.

4.1 Emergency Information

4.1.1 Emergencies

For any emergency, **dial 911** from a site phone or 650-604-5555 from a cellular or off-site phone, to reach the Ames Dispatch. Report the nature and location of the incident and stay on the line. Appropriate response personnel will be dispatched immediately. The Ames Test Manager will discuss specific emergency and evacuation procedures with Customer personnel at the beginning of the test.

4.1.2 Evacuation

When the evacuation alarm sounds (a very loud buzzer), all persons shall leave the building immediately through the nearest safe exit in an orderly manner. After evacuating the building, report to your Ames Test Manager or Shift Engineer at the designated assembly area and do not leave unless authorized to do so. Evacuation maps are posted on each floor of every building.

Customers must advise the Test Manager of special needs for any planned visitor who is disabled before they arrive on site. This will ensure that appropriate actions are taken in advance to ensure their safety during their visit to Ames.

4.1.3 Fire

Evacuate immediately. Fire alarm pull stations are strategically located for emergency use. Call **911** from a safe location. Do not use elevators. If possible, close doors to slow spread of fire and limit smoke damage. If heavy smoke is present, stay low. Fire extinguishers are available for small fires in all work areas, but do not use one unless you have first called **911** and have been trained to use it.

4.1.4 Earthquake

Should an earthquake occur, choose a safe place (under a sturdy desk or table, and away from glass, machinery, and chemicals), drop, cover, and hold on. Do not run out of the building. Once the shaking has stopped, proceed with caution to your assembly area and be prepared for aftershocks.

4.1.5 Injuries and Treatment

Dial **911** (or 650-604-5555 from cellular) for emergency treatment of injuries occurring at Ames Research Center. The closest emergency facility is the El Camino Hospital emergency room at 2500 Grant Road in Mountain View. During the day shift, first aid treatment is available at the Ames Health Unit located across the street from the north entrance to the cafeteria. First-aid kits can be found at many strategic locations in the work areas.

4.1.6 Personal Illness

Treatment for personal illness must be obtained at medical facilities in one of the local communities. El Camino Hospital (650-940-7000) in Mountain View offers a referral service.

4.1.7 Safety Quick Reference Guides

Safety Quick Reference Guides for 11 Foot and 9x7 Foot Wind Tunnels as well as the Model Prep Rooms can be found in Appendix D of this document.

4.2 Wind Tunnel Hazards

4.2.1 General

The Test manager will discuss the hazards peculiar to the facility and the particular test with all personnel, at the beginning of the test.

4.2.2 Aerial Lifts

Only authorized and trained persons shall operate any aerial lift on site. Proper fall protection equipment shall be used during operation.

4.2.3 Confined Spaces

Many of the work locations within the wind tunnel meet the OSHA definition of non-permit or permit-required confined spaces (permit-required will be labeled as such). All entries into a confine space will follow the Wind Tunnel Confined Space Program and the Wind Tunnel Entry Procedures contained in the SOP. The Test Manager will brief test personnel on any special entry requirements at the beginning of the test.

4.2.4 Cranes/ Lifting Devices

Due to Ames training and certification requirements, Customer personnel may not operate facility overhead cranes and hoists. Personnel shall keep a safe distance away from lifting operations.

4.2.5 Electrical

At the Wind Tunnels, there is medium voltage at ground floor and power service panels (480, 220, 120, 120/208 volts). The wind tunnel test section, plenums, and air stream circuit are completely grounded with many metal surfaces which increase the potential for electric shock. To minimize this risk only electric cords and equipment that are in good physical working condition will be allowed in the facility. In addition, equipment shall be powered through Ground-Fault Circuit Interrupter (GFCI) protected electrical outlets, or through the use of in-line GFCI devices.

4.2.6 Ergonomics

Avoid repetitive motions and heavy lifting. Get help or mechanical aid for heavy lifts. Adjust the workstation to your physical needs to reduce strains and injuries.

4.2.7 Fall Protection

Anyone on site working from an unprotected elevation of six feet or more above the ground or next lower level, or who may fall into hazardous equipment, shall use appropriate personal fall protection equipment. This includes while traveling, stationary, or at any time exposed to a fall from a surface not protected by a standard guardrail or other approved fall prevention device. Personal fall protection equipment shall only be used by personnel who have completed the appropriate training.

4.2.8 High Pressure

High pressure air up to 3000 psi and hydraulic systems are present in the Wind Tunnel. Personnel entering the wind tunnel during tests that utilize these utilities will be required to follow Division lock and tag requirements as directed by the Test Manager.

4.2.9 Lead

The wind tunnels have many aged surfaces containing lead paint. Assume paint contains lead unless otherwise proven. Do not disturb painted surfaces unless previously authorized to do so. Dusty areas may contain lead dust from deteriorated paint. Limited on-site work activities using lead include soldering, welding, cutting and grinding. Always wash hands before eating, drinking or smoking. Eating and drinking in shop areas is prohibited.

4.2.10 Lock-out/Tag-out

Our policy is to prevent an undesirable release of hazardous energy during any servicing, maintenance or modification activity. The Wind Tunnel Division LO/TO procedures shall be strictly followed whenever it is necessary to work on any equipment that may release any form of hazardous energy including, but not limited to, electrical, rotational, mechanical, chemical, hydraulic or pneumatic energy. Visitor locks and tags are readily available from the Test Manager or Shift Engineer and must be used during LO/TO operations.

4.2.11 Mechanical

Rotating equipment and moving parts in the Wind Tunnel, such as the model support system, roll mechanisms, and the kick sting can cause compression, collision, pinching, impact or crushing hazards.

4.2.12 Noise

All personnel must wear hearing protection when entering a designated noise-hazard area. Visitor earplugs are placed in strategic locations. Noise levels adjacent to equipment areas can be elevated and, in some cases, may reach greater than 100 dB(A).

4.2.13 Sharp Edges

Models installed in wind tunnels may have sharp cutting edges that should be covered each time personnel enter the wind tunnel for model work.

4.2.14 Trips, Bumps, and Falls

The Wind Tunnels have high numbers of cords, cables, conduit, piping and other obstructive structures. Take special care when maneuvering through close quarters and areas with equipment.

4.2.15 Wind Tunnel Entry

Most portions of the wind tunnels including the test section, wind tunnel circuit, and test section plenums, etc. meet the OSHA definition of confined spaces, therefore, all entries into the wind tunnel are controlled by facility personnel. Access to the test section is usually allowed without special controls; however, access to other areas generally requires the application of locks or tags to secure the facility, equipment, or systems in a safe configuration. Work activities within the wind tunnel beyond the test section must be coordinated with and approved by the Test Manager before work commences.

4.2.16 Working Alone

The term "working alone" means that an individual is in a work location, environment, or situation that will prevent others from observing and communicating verbally with them unless steps are taken to establish a means of remote communication. The primary risk of concern for those working alone is that they will become injured or ill and will not be able to perform a self-rescue or be able to summon required assistance. It is not practical or desirable to eliminate all instances of working alone. For example, single individuals on flexible schedules may work alone in offices or control rooms before or after regular business hours, and craftsmen may conduct rounds while alone on swing or grave shifts. However, steps must be taken in all instances to ensure that Customer and facility personnel identify the risks posed by working alone and manage them to an acceptable level. Personnel may not work alone when the activities they will be performing or the environment they will be performing them in pose higher than normal risks. Examples of such activities include:

- Entering permit-required confined spaces.
- Entering the wind tunnel plenums.
- Entering the wind tunnel circuits.
- Working in any wind tunnel test section.
- Breaking connections on, or pressure testing hydraulic or pneumatic systems with operational pressures exceeding 15-psig, excluding shop air and instrument air up to 140 psig in lines and not exceeding 1-inch in diameter.
- Conducting work where an individual may come in contact with un-insulated, energized electrical equipment or components having a potential greater that 50-volts.
- Operating or conducting maintenance on unguarded equipment that poses mechanical, point of operation, or mechanical power transmission hazards, such as adjusting or performing functional tests.
- Conducting work requiring the use of life-saving safety equipment, such as personal fall-arrest or restraint equipment and supplied air respirators.]
- Using or working around unenclosed Class IV lasers.
- Working with dangerous quantities of hazardous materials.

All instances requiring working alone shall be discussed with and approved by the Test Manager.

4.3 Hazardous Materials

4.3.1 Definition

Hazardous materials are defined as any materials having properties that may result in risk or injury to health, destruction of life or facilities, or harm to the environment. Hazardous materials, as defined, include, but are not limited to, toxic, flammable, combustible, corrosive, asphyxiating, reactive, and explosive materials. Other hazardous material examples are compressed gases, oxidizers, reproductive toxins, carcinogens, irritants, and sensitizers.

4.3.2 Beryllium Alloys

The machining, filing, sanding, and polishing of metal alloys containing Beryllium is strictly prohibited in all NASA Ames facilities.

4.3.3 Safety Data Sheets (formerly Material Safety Data Sheets)

The Customer must provide the Safety Data Sheets for all Customer-supplied hazardous material, regardless of quantity, at least 4 weeks prior to test date.

4.3.4 Hazardous Material Approval Process

The Test Manager shall provide the Division Safety Office with the Customer's proposed Safety Data Sheets 4 weeks prior to test date. The Wind Tunnel Division Safety Office shall approve proposed hazardous materials operations and procedures before work begins. The Ames Safety Office will be notified when a material that may present a hazard to persons or has the potential to harm the environment will be introduced into the workplace. After approval, the Safety Data Sheets shall be maintained at the worksite during the duration of tests.

4.3.5 Labels

As a minimum, all hazardous material containers must be legibly labeled with the name of the chemical or product that it contains and the hazards the material poses to personnel (such as toxic, corrosive, flammable, etc.).

4.3.6 Operations Involving Hazardous Materials

The basic premise for ensuring safety during any operation involving hazardous materials is that the individuals involved have an adequate understanding of the specific:

- Hazards, warning signs, and symptoms
- Precautions to be taken
- Procedures for handling emergencies

Gaining this understanding must be accomplished before starting operations and should be an important consideration in planning the work. This means that every operation must be thoroughly screened for safety, and all personnel must be made aware of the hazards, precautions, and procedures for handling hazardous materials and responding to accidents and other emergencies before the proposed activities begin.

4.3.7 Customer-Generated Hazardous Waste

Any waste generated by the Customer must be stored and labeled appropriately. The Customer shall remove their generated hazardous waste from Ames unless prior arrangements are made with Ames waste operations.

4.3.8 Spills

Notify the Test Manager of any hazardous material spills immediately. If appropriate, 911 will be alerted for any reportable spill (potential risk to health or environment).

Assist in evacuation and deny entry to affected area. Small spills that are not reportable (no potential risk to health or environment) can be controlled without external assistance if spill response materials and PPE are available and persons are trained. Do not go beyond your level of competence.

4.4 Protective Equipment

General

Customer personnel must be equipped with hearing protection, safety glasses, safety shoes, appropriate gloves, and any other protective equipment justified by the nature of the work. Emergency eyewash fountains are located at each facility. The Customer shall provide training necessary to perform their work with the protective equipment in a safe manner.

4.5 Personnel Training

General

Customer personnel are responsible for having the necessary training and knowledge to understand the job hazards and their controls.

4.6 Laser Safety

4.6.1 Safety Standards

The use of lasers at Ames is governed by the "Standard American National Standards Institute (ANSI) Z136.1 for the Safe Use of Lasers" and the Ames Health and Safety Manual, Chapter 8 (https://cdms.nasa.gov/assets/docs/centers/ARC/Dirs/APR/APR8715.1C8.pdf). The Test Manager coordinate with Center personnel as required to assist Customer personnel in meeting the requirements contained in these documents.

4.6.2 Approval Authority

The Ames Laser Safety Officer (LSO) must evaluate and approve all laser installations and operations. Approval must be coordinated through the Test Manager. Class 3B and 4 laser installations require a Permit to Operate to be issued by the LSO with concurrence from the Non-ionizing Radiation Safety Committee. Be advised to budget at least two weeks of time and for this process.

4.6.3 Authorized Laser Customers

Authorized Laser Customers are responsible for compliance with safety regulations in the operation of their equipment, and:

- Must provide a Standard Operational Procedures document for Class 3B and 4 laser installation which includes a system description, identification of all hazards associated with the installation (i.e., high-voltage power and water cooling, chemical dyes, flow seeding materials, high-pressure gas canisters), calculation of optical density requirements for each laser wavelength, a diagram of the installation and a checklist for starting the laser, shutting down the laser and aligning the laser. A template for the SOP is available

- Are responsible for ensuring that personnel using lasers under their supervision are properly instructed and trained (within the last 2 years).
- Must establish and maintain a current list of all personnel authorized to operate specific types of Class III and IV lasers under their direction.

4.6.4 Safety Eye Wear

Safety eye wear shall be provided by the laser user(s) that protect the users from specular and diffuse reflections of the Class 3B and 4 lasers. Calculations of the required Optical Density for each laser wavelength and power are required. Eyewear will be inspected and approved by the LSO and NIRSC during the permitting process for Class 3B and 4 laser installations.

4.6.5 Required Ophthalmological Exam

Ames Unitary Wind Tunnel personnel are required to have a baseline eye exam to be cleared as a laser user. It is suggested to on-site contractors and external customers to have this exam prior to laser usage, but it is left to employers to establish this as a requirement.

4.6.6 UV Illumination

Experiments using UV illumination, such as PSP, TSP, or oil flow will have to comply with Ames Health and Safety Manual, Chapter 8 regulations that cover UV sources. Contact the LSO for further information. Wind Tunnel Division policy requires that Lockout/Tagout (LOTO) procedures be used in the test section when PSP or TSP is in use for a test.

4.7 Other Safety Guidelines

4.7.1 Blood-borne Pathogens

Be aware that if any injury or accident occurs, do not clean up blood since there may be a potential exposure to blood-borne pathogens. Notify your Test Manager or Shift Engineer immediately for assistance.

4.7.2 Equipment

All equipment will be inspected prior to operation and tagged out if damaged.

4.7.3 Housekeeping

There shall be no hazardous accumulations of combustible trash and debris. Access must be maintained for all exits, electrical panels, and fire protection panels. Corridors and stairways shall be kept clear of obstacles. Equipment and material will be stored in a stable configuration. Working and walking surfaces must be dry, smooth, and free of clutter.

4.7.4 Permits

Any activities involving hot work (e.g., welding, cutting, burning, brazing), generating solvent vapors into the air, entering a confined space, or disposing of industrial wastewater, must be permitted prior to activities. Contact the Test Manager for more information.

4.7.5 Postings

All visitors shall abide by area signs and postings.

4.7.6 Storm Drains

Nothing is allowed to pass through the storm drains but rainwater.

4.7.7 Vehicles

The speed limit on the Ames Facility is 25 mph unless otherwise posted. Ames Security is responsible for enforcing federal and state driving laws. Vehicles shall be parked only in authorized parking spaces.

4.8 References

The following Ames documents contain further information on environmental, health and safety issues.

- SOPs - Each wind tunnel has documented Standard Operating Procedures that contain safety and emergency shutdown procedures
- Division and Branch Safety Plans - General safety procedures and guidelines
- Building Emergency Actions Plan (BEAP) for the building being occupied located in each lobby
- Division Health & Safety Manual (A027-9991-XS1) is available upon request
- Ames Health and Safety Manual (APR 8715.1)- Center parent document on all safety issues at https://cdms.nasa.gov/assets/docs/centers/ARC/Dirs/APR/APR8715.1.html
- "Standard American National Standards Institute (ANSI) Z136.1 for the Safe Use of Lasers

5 Risk Assessment and Safety Review Requirements

Introduction

Wind tunnel testing inherently involves potential hazards that could affect personnel, equipment, or test progress.

Controlling these hazards is essential to ensuring personnel, equipment, and test operations are protected from harm and that the facilities operate to their fullest capacity. Therefore, model and associated equipment design and operation must incorporate safety principles presented in this document.

The Ames Health and Safety Manual describes procedures used to ensure equipment and systems are designed and operated safely.

5.1 Risk Assessment

5.1.1 Overview

The risk associated with conducting a test is a function of the hazard's severity and the likelihood or probability that the hazard will actually be encountered.

The Ames Health and Safety Manual describes in general terms how the risk of hazards should be identified and mitigated. The Wind Tunnel Division has further refined that process and adapted it to wind tunnel testing and operations as described in the following paragraphs.

The Customer is responsible for preparing the Risk Assessment, following guidelines presented in this document, and presenting the results of the assessment at the Initial Test Planning Meeting.

The Division may request, based on the Risk Assessment, that a Hazards Analysis be performed. This may be done by the customer or by the Division's System Safety Analyst or a combination.

First, hazard severity is assessed, then probability, then these factors are considered together to determine the final risk. Finally, hazard controls are implemented to decrease or control the risk.

5.1.2 Risk Assessment Matrix

The following matrix shows the relationship between risk levels and their corresponding attribute ranges (adapted from NPR 8000.4).

Table 5-1: Wind Tunnel Division Risk Matrix

Likelihood		A	B	C	D	E
	5 Likely to occur (90%)	L	M	H	H	H
	4 Probably will occur (70%)	L	M	M	H	H
	3 May occur (50%)	L	L	M	M	H
	2 Unlikely to occur (30%)	L	L	L	M	M
	1 Improbable (10%)	L	L	L	L	M

Consequences	A	B	C	D	E
General	Minimal	Minor	Moderate	Significant	Severe
Personal Injury/Illness	Negligible injury or illness no lost worktime (Close Call)	Minor injury or illness <1 week lost worktime (Type D)	Moderate injury or illness 1 week lost worktime (Type C)	Partial Disability Multiple Hospitalizations (Type B)	Fatality or Permanent Disability (Type A)
Facility Damage or Increased Project Cost	<$50,000	$50,000 to $150,000	$150,000 to $500,000	$500,000 to $2,000,000	>$2,000,000
Project Schedule Slippage or Test Downtime	<1 day	1-day	1-2 weeks	2-10 weeks	>10 weeks
Data Compromise	Re-calculations	Rerun of last run	Repeat of multiple data runs	Repeat of test	Data not recoverable or primary objectives lost
Safety and Environmental	Non-reportable OSHA/EPA violation	Reportable OSHA/EPA violation that does not require immediate remediation	Reportable OSHA/EPA violation which requires immediate remediation	Reportable OSHA/EPA violation causing temporary stoppage	OSHA/EPA violations resulting in termination of Activity

Approval Level:

H = Center Level/Code A M = Division Level/Code AO L = Branch Level/Code AOO

5.1.3 Risk Assessment Approval

Sign -off authority requirements apply to Test Readiness Reviews (TRRs), Operational Readiness Reviews (ORRs), and Hazard Reports that result from system safety analyses of test installations and facility modifications.

Referring to Table 5-1.

H – Center Director

M – Wind Tunnel Division Chief

L – Wind Tunnel Operations Branch Chief

5.1.4 Hazard Controls

The Ames Health and Safety Manual describes the order of preference for controlling hazards. The Wind Tunnel Division also implements controls for facility and test hazards following this order of preference, summarized as follows.

1. Design for Minimum Hazards—Provide inherent system safety by selecting appropriate design features and qualified components.
2. Incorporate Safety Devices—Includes mechanical barriers or inhibiting mechanisms. Conduct periodic functional checks of such safety devices.
3. Incorporate Protective Systems—Includes fire suppression systems, radiation shielding, flash shields, containment, etc.
4. Incorporate Warning Devices—Includes signals, lights, signs, horns, etc., and include requirements for training to ensure a proper and timely response to warning devices.
5. Institute Special Procedures—Include emergency procedures that effectively limit initiating a hazardous sequence. Includes caution and warning statements in normal operating procedures. A formal Operational Hazards Analysis will be required for all deviations from the Standard Operating Procedure (SOP) Manual for each facility.

5.2 Model Safety Requirements

5.2.1 Stress Report

A stress report is normally required for all models to be tested in the Wind Tunnel Division facilities. See Section 5.3, Design Criteria-Reduced Requirements, and Section 5.5, Model Acceptance Criteria-Waivers, for limited exceptions to this requirement. The stress report establishes that the model has met all structural requirements. It should be complete and sufficiently comprehensive to preclude further explanation.

The Test Manager and customer personnel negotiate the delivery schedule for the stress report and other documentation at the Initial Test Planning Meeting. The report is due no later than 6 weeks prior to the tunnel entry date.

5.2.1.1 Stress Report Changes

Design evolution could dictate changing stress report content after decisions made at the Initial Test Planning Meeting. Negotiate changes with the Test Manager.

5.2.1.2 Stress Report Contents Overview

In the following order, the report must contain (as a minimum):

1. A table of contents.
2. Documentation of load envelopes. Steady-state aerodynamic loads and thermal loads for extremes of test conditions. Include starting loads for the 9x7ft wind tunnel.
3. A summary of the expected stresses and safety factors.
4. A discussion of the sources of design loads and the methods used to determine them.
5. The stress analysis (see next section).
6. Drawings of the model configuration, support components, and the model as installed in the tunnel.
7. Quality-inspection reports to validate the integrity of the completed model.
8. Documentation of stability requirements (see, 5.3 Design Criteria, for details on the stress analysis).
9. Frequencies and estimated dynamic loads on model for dynamic and transient testing.

5.2.2 Other Requirements

Ames might also require other items such as:

- material certification
- calibration data
- dimensional certification
- operator certification
- detailed design drawings to validate the integrity of the completed model
- quality check documentation and angle verification of model leveling surface relative to main balance
- weld certification

These items are normally requested at the Initial Test Planning Meeting, if required.

5.2.3 Formal Design Review

Formal design reviews are not normally required of models to be tested in the Ames facilities. The Test Manager can, however, require design reviews for those designs that are especially complicated and potentially hazardous. Ames personnel can participate in the design process through teleconferences with the Customer and model vendor.

5.3 Design Criteria

Overview

This section describes design criteria, specifically:

- Stress Analysis
- Material Selection
- Allowable Strength
- Structural Joints
- Pressure Systems
- Electrical Equipment
- Model Support Systems

5.3.1 Stress Analysis

5.3.1.1 Stress Analysis Overview

The stress analysis must include, but is not limited to, the following elements:

- An analysis showing that all models, including mountings and emergency restraint systems, are statically and dynamically stable and free from divergence throughout the model test envelope (refer to Model Support Systems near the end of 5.3 Design Criteria).
- Aerodynamic derivatives used in the analysis, their source, and a discussion of the consideration given to effects of Reynolds number, Mach number, surface condition, etc.
- Source and range of mass and inertia parameters, including cross-coupling terms such as I_{xz} and support-system stiffness coefficients.
- Parametric variations of significant design variables, i.e., tension-to-weight ratio, center-of-gravity location, pulley locations, etc., to establish sensitivity.

5.3.1.2 Stresses or Loads

Allowable stresses are the lessor of the material ultimate stress divided by a safety factor of 4, or the material yield stress divided by a safety factor of 3.

The stress analysis is to show that allowable stresses or loads are not exceeded for the worst load case, including but not limited to:

- Dynamic factors that could result from separated flows in wakes, on model surfaces or components, etc.
- Thermal stresses due to factors such as cold or preheated air used in some propulsion tests
- Stress concentration factors
- Wind tunnel starting loads
- Maximum operating loads

5.3.1.3 Forces and Moments

Each detailed analysis section should contain a sketch showing forces and moments acting on the part and a statement of:

- Assumptions
- Approximations
- Section properties
- Type and heat treat condition of the material
- Pertinent drawing number

5.3.1.4 General Equations

In all calculations, the general equations and their source must be given before substituting numerical values.

5.3.1.5 Air-Loaded Surfaces

Give shear and moment distribution diagrams resulting from worst-case pressure distribution.

5.3.1.6 Section Properties

Define section properties of the structural member for shear, axial load, bending, and torsion at an adequate number of stations to facilitate a check on the location of the designated critical sections.

5.3.1.7 Air Loads

All parts with lifting surfaces (such as vertical stabilizers, pylons, and struts) that are designed for operating only at zero angle of attack must be checked for air loads of ±2 degrees.

5.3.1.8 Static Test Instead of Stress Analysis

Static tests may be accepted in lieu of a stress analysis under the following conditions:

- If the load on the component in question can be directly and continuously monitored, the stress tests will be carried to twice the predicted operating load, and measured deflections must not indicate a permanent deformation. These tests must be witnessed by facility personnel.
- If the load on the component in question cannot be directly and continuously monitored (for example slats, ailerons, elevators, rudders, flaps), the static test must be carried to three times the predicted load without permanent set.
- Following static testing, nondestructive inspection techniques are required to validate the structural integrity of the component.

5.3.1.9 Gauged Components with Stress Analysis

If the load on the component in question can be directly and continuously monitored, a safety factor of three (3) or greater, calculated using the allowable tensile stress (Ftu), is required in the stress analysis.

5.3.1.10 Reduced Requirements

If the model safety factors cannot be met (4.0 for ultimate and 3.0 for yield), contact the Test Manager to discuss the possibility of reducing (waiving) these requirements. Examples include tests of actual flight components, dynamically similar models, or aeroelastic models. Compensation for the safety factor reduction could include additional instrumentation, closely monitoring critical areas, provision of safety catches, or special proof loadings.

The provisions of this paragraph can only be implemented by waiver approval. See also Model Acceptance Criteria, Model Acceptance Criteria.

5.3.1.11 Previously Tested Components

Stress analysis must be submitted for all components to be tested in Ames facilities, even if they have been tested at Ames before. The customer must revise previous stress reports of previously tested models to incorporate any new worst-case loads for each component.

5.3.2 Material Selection

5.3.2.1 Materials Standards

Where applicable, materials are to be selected using mechanical properties and other specifications in the latest issue of one of the following standards:

- ASTM Specifications
- MIL-HDBK-5, Metallic Materials and Elements for Aerospace Vehicle Structures.

- MIL-HDBK-17, Plastics for Flight Vehicles

5.3.2.2 Mechanical Properties Corrections

All mechanical properties used must be suitably corrected for

- Temperature
- Pressure
- Other environmental effects that might be present when the material is under stress

5.3.3 Allowable Strength

5.3.3.1 Safety Factors

Except for gauged elements (previously discussed), safety factors of 4.0 on ultimate and 3.0 on yield must be maintained on parts and hardware. Plastic bending analysis is not accepted.

Refer to the Ames fastener guidelines later in this section.

5.3.3.2 Shear Stresses

If the shear ultimate strength of the material is unknown, calculate it as 60 percent of the tensile ultimate strength.

5.3.3.3 Thermal Stresses

Any thermal stresses that could occur must be algebraically subtracted from ultimate tensile and tensile yield strength of materials before the factors for allowable stresses are applied.

5.3.3.4 Material Properties

Material stress properties should reflect the expected minimums that will occur within the expected temperature range.

5.3.3.5 Buckling Stress

The allowable compressive stress in columns and skins must be equal to or less than one-third of the critical buckling stress.

5.3.3.6 Oscillating Stresses

Allowable oscillating stresses caused by oscillating loads with or without accompanying steady-state loads must be computed as follows:

- The mean stress, if any, must be applied to the proper Modified Goodman Diagram.
- The gross allowable oscillating stress must then be obtained from this diagram.
- The allowable oscillating stress must be obtained by dividing the gross oscillating stress by the appropriate stress concentration factor, if any.

5.3.4 Structural Joints

5.3.4.1 Fastener Quality Standards

The models, tested in the Wind Tunnel Division wind tunnels, must be assembled using high-quality fasteners of SAE grade 5 or more.

Ames requires using certified fasteners; if used exclusively and proof of certification is supplied to the Ames Test Manager in the form of a Certified Material Test Report (CMTR), no further checking will be required. If a CMTR cannot be provided, then all noncertified critical bolts will be removed from the model for examination and Rockwell hardness verification during test installation.

5.3.4.2 Fastener Assembly

Critical fasteners must be assembled using a calibrated torque wrench. The fastener manufacturer's torque specification will be used if the full-rated strength of the fastener is required to maintain Ames required safety factors.

5.3.4.3 Structural Joint Drawings

Drawings for all structural connections must list the following:

- Strength and quality of fasteners
- Torque values for tightening screws and nuts
- All welded, soldered, brazed, bonded, or other non-bolted, structural-connection techniques must be listed, showing locations on drawings and exact fabrication specifications, as well as analyzed in the stress report

5.3.4.4 Mil Spec Standards for Joints

Joining components (including tubing) by methods other than welding, soldering, or bonding is to be accomplished as appropriate in compliance with military specification standards.

All joints must be inspected using the appropriate nondestructive inspection technique decided upon by the customer and Ames personnel.

At NASA's discretion, certain joint designs located at critical load-carrying sections might not be permitted. Soft-soldered joints are not acceptable. Silver-soldered joints might be acceptable, depending on application.

5.3.4.5 Welded Joints

All welded joints must be designed and fabricated in compliance with the code of the American Welding Society. All welds must be verified by appropriate inspection techniques such as, but not limited to, magnetic particle inspection, X-ray, or dye penetrant methods.

Critical welds (those whose failure would result in model or facility damage) must be analyzed in the stress report. Include inspection certification as an addendum to the stress report.

5.3.4.6 Shear Loads (bolted joints)

Shear loads must be transmitted by keys, pins, pilots, or shoulders.

5.3.4.7 Bolt Preload

For bolt preload in bolted structural joints:

- Use manufacturer's recommended value.
- Avoid oscillating stresses in threads.

5.3.4.8 Thread Engagements

Critical fastener thread engagement with nuts and/or tapped holes must be sufficient to develop strength equal to the fastener or to the application design load with the appropriate safety factors applied.

5.3.4.9 Countersinks, Counterbores and Spot Faces

Model countersinks will be inspected during the test installation period to ensure that they are cut concentric to the threaded hole, have the proper countersink angle, and the fastener heads seat properly in the countersinks.

Counterbores and spot faces will likewise be inspected to verify that the contact surface does not bend or pry on the fastener body when it is tightened.

5.3.4.10 Small Screws

Fasteners of size #4 or less that are removed during a model change must be replaced with a new fastener.

5.3.4.11 Screw Joints

To assure tight joints between parts joined by screws, screws and threaded connectors must be sufficiently torqued to provide loads greater than the expected maximum separating forces.

5.3.4.12 Bolted Joints

Bolted joints with the primary function of transmitting moments must be designed in such a manner that the bolt preload divided by the joint contact area is at least 1.25 times the applied moment divided by the section modulus of the contact area.

Any bolt torque values that are different from the published vendor data must be derived in the stress analysis.

5.3.4.13 Fastener Locking

All structural bolted or screwed connections must be provided with positive mechanical locks such as**:**

- Locking inserts
- Self-locking-type nuts
- Safety wiring (drilled heads must be provided)
- Fastener adhesive such as Loctite (within rated temperature)

All bolted and screwed connections must meet these requirements, even if the connection is to be repeatedly disassembled during testing (e.g., changes in flap deflections).

5.3.5 Pressure Systems

5.3.5.1 High-pressure Air Availability

Most Wind Tunnel Division facilities can supply up to 3,000 psi heated air with various burst disk capacities.

5.3.5.2 Pressure-Relief Devices

Relief devices are required in the system (but not necessarily in the model) and must be capable of discharging the full flow of the pressure source under all conditions including those resulting from malfunctions.

Users are to inform the Test Manager on the requirements of the maximum and minimum pressures the model can withstand to determine system burst disk pressures. Users must provide pressure relief devices appropriate to the model as required. If rapid air discharge constitutes a noise hazard, mufflers are required on discharge lines.

Users should check with the Test Manager to verify the appropriate burst disks are available; otherwise, customers must supply their own.

5.3.5.3 Pressure System Codes

Models, support equipment, and test equipment using hydraulic, pneumatic, propulsion, or other systems with operating pressures above 15 psig are to be designed, fabricated, inspected, tested, and installed to comply with the following codes and definitions:

- ASME Boiler and Pressure Vessel Code
- ASME B31.1 Power Piping Code
- ASA Codes as sponsored by ASME
- Department of Transportation Regulations

5.3.5.4 Pressure System Components

Definition

The components of a pressure system include

- vessel
- relief devices
- piping

Testing/Storage

Pressure components that have been proof-tested must be stored in a clean, dry, sealed condition with controlled accessibility.

Identification

All pressure system components (including piping) are to be indelibly marked in a conspicuous place with sufficient information to determine:

- Part number
- Proof test pressure
- Working pressure
- Date of proof test
- Volumes and temperature range

Certification

All pressure system components must have current certification (valid throughout the test). Certifications are required annually. **A certification report must be submitted for all tested systems.**

5.3.5.5 Pressure Vessel

Definition

All shells, test chambers, tanks, and model parts designed for internal pressures greater than 15 psig are considered pressure vessels.

Design

Pressure vessels must be designed in compliance with the latest edition of the ASME Boiler and Pressure Code, Section VIII or Section III.

Welding

Pressure-vessel welding must be in compliance with the ASME Boiler and Pressure Code as follows:

- Section IX for welding qualifications
- Section V for welding inspection

5.3.5.6 Pressure Piping

All piping must be designed, fabricated, inspected, tested, and installed in compliance with the latest edition of the ANSI Standard Code for Pressure Piping.

Tubing to Powered Models

For powered models, the internal supply tubing is considered pressure piping.

Piping in Pressure Vessels

Pressure vessels fabricated from standard pipe, standard pipe fittings, and standard flanges are also considered pressure piping. They are defined as those covered by these ANSI dimensional standards**:**

- Pipe: B.36.10 and B.36.19
- Fittings: B.16.9
- Flanges: B.16.5

Welding

Welders, welding operations, and welding procedures are to be qualified in compliance with Section IX, ASME Boiler and Pressure Vessel Code, except as modified by the applicable section of the Piping Code.

Threading

Allowances must be made as required or recommended by the Piping Code for pipe threading, corrosion, and wall thinning due to pipe bending.

Threaded Pipe Joints

Threaded joints, flange joints, and seal welding of threaded joints must be in compliance with the requirements and recommendations of the Piping Code.

Tube Fittings

Tube fittings must be in compliance with the latest issue of applicable Military Standards.

Service Line Identification

All service lines must be properly identified for working pressures, flow direction (in or out), and fluid or gas carried.

5.3.6 Electrical Equipment

5.3.6.1 General

All electrical devices and wires used in the test section must be capable of withstanding the test section environment.

5.3.6.2 Material Criteria

Use only qualified hardware or equipment and material conforming to the National Electrical Code. Wires and cable require good abrasive resistance. All wiring is to be identified in accordance with schematic and wiring diagrams by using color coding, bands, tags, etc.

5.3.6.3 Fuses and Shielded Wires

Protect electric circuits with proper fuses. Pressure transducers, strain gauges, vibration pickups, and other low-voltage devices should have each set of wires shielded. Also use shielded wiring with high-voltage and AC devices. Determine the required size, type, and length of wiring at the pretest conference.

5.3.6.4 User-Furnished Electrical Materials

The customer should provide the following electrical devices as discussed at the Initial Test Planning Meeting and required by the test.

- Control panels and/or control boxes required to operate model components.
- Control panel leads of sufficient length to make proper connections in the respective control rooms.
- Mating electrical connectors for any customer-furnished equipment requiring connectors at interfaces located at control boxes in and/or at the model.
- Electrical schematics, wiring diagrams, and hookup sheets for model and control panels with the model design drawings in compliance with documentation requirements.

Documentation should be provided to the Test Manager 4 weeks before the start of the test.

5.3.7 Model Support Systems

5.3.7.1 Specification

An adequate margin of bending and torsional stability must be shown for models and model support systems and must meet the following divergence criteria:

$$\frac{dN/d\alpha}{dF_{SS}/d\Theta} < \frac{1}{2}$$

For all test conditions and configurations, the ratio of model air load increase due to a change in angle of attack ($dN/d\alpha$) to the support system restoring force generated by such an angle change ($dF_{SS}/d\Theta$) must not exceed one-half.

Customers must supply a divergence check

5.3.7.2 Aerodynamic Interference

The customer, after consulting the Test Manager, is responsible for providing a design that reduces aerodynamic interference to minimum acceptable limits, including models to be tested on Ames-furnished stings.

5.3.7.3 Model Support Hardware

Any customer-supplied hardware must be fit-checked and forwarded to Ames for verification at least 6 weeks before the test date. Taper fits must have at least 80 percent evenly distributed contact on each land. A report of fit-check results must accompany the hardware (see Appendices A, B and C). Taper fits will be verified at Ames using the fluorescent oil technique described in Appendix A.

If customer hardware is to match with Ames gauges, the gauge(s) will be provided at the customer's request by the Ames Test Manager.

An inventory of model support hardware available at Ames is listed in Appendix B.

5.4 Model Fabrication Requirements

5.4.1 General

The customer is responsible for having models fabricated and assembled in compliance with:

- Design drawings and specifications
- Model safety requirements (see 5.2 Model Safety Requirements)
- Design Criteria (see Section 5.3)
- Inspection and tests established by the Test Manager (see Section 5.5)

5.4.2 Model Assembly

Models are to be completely assembled for all test configurations at the manufacturer's plant and discrepancies corrected before shipment to ensure that:

- All model parts fit properly.
  - Assembled with stings / balances
  - Pins & roll keys installed
  - Fasteners tightened or torqued
- Model loading fixtures have proper fit and have been certified for the required loads.
- All remote-controlled model components function properly.
- All position indicators can be calibrated.
- All strain gaged parts can be calibrated.
- Sufficient clearances are provided for differential deflections due to air loads.
- All leads are identified.
- All instrumentation pressure lines are clean, free of oil and debris, and are leak-checked at operating pressures.
- All required inspections and certifications have been performed and documented (welds, concentricity, etc.).

- Model quality reports have reviewed by vendor and customer.
- Model level plate/surface has been verified as a quality reference for data quality, fits well to the model, and is installed repeatedly onto the model in same location. (ARC can provide an Angle Measurement System (AMS) drawing or CAD file for the model vendor.

If desired, ARC can send a representative to model buyoff.

5.5 Model Acceptance Criteria

5.5.1 Model Acceptance

Model acceptance for testing in the Wind Tunnel Division facilities is contingent upon satisfaction of the requirements presented in Section 5.2, Model Safety Requirements through Section 5.4, Model Fabrication Requirements, in addition to the requirements listed below.

5.5.2 Alternate Model Acceptance

Models may be designed to criteria presented in NASA-STD-7011, Wind Tunnel Model Systems Criteria [https://standards.nasa.gov/] or LARC Design Guide, LPR 1710.5 [https://lmse.larc.nasa.gov/admin/public_docs/LPR_1710-5_140317_J.pdf]

5.5.3 Inspections

The customer must be prepared to provide inspection reports (records, inspection reports, and test results) for defining and verifying the quality of the model throughout all operations, including:

- Procurement
- Fabrication
- Test
- Delivery

The inspection report requirements are set by the Test Manager and will be provided for the customer at the Initial Test Planning Meeting. Typical reports required include the results of non-destructive weld examinations and fastener/material certifications.

Inspection Reports on Model Reference Level Surface (Level plate) are required. This includes the location of level surface in relation to the balance and possibly the body axis.

5.5.4 Structural Reports

The customer must provide:

- Any reports of inspections and tests of all materials by chemical or physical means to verify compliance with applicable drawings and specifications.
- Any written procedures, or other controls, over processes used to assure uniform quality of articles or materials.
- Documentation of all articles and materials that do not conform to applicable drawings, specifications, or other requirements.

5.5.5 Waivers

Requests for deviations from the requirements outlined in this document must be submitted in writing at the earliest possible time. The preferred time for waiver submission is at the Initial Test Planning Meeting. However, events in the model fabrication process may move the submittal of a waiver closer to the actual test time.

The Deviation Waiver request should include:

- Full justification for the waiver with supporting data and analysis.
- Previous test data of the same model in other facilities if applicable.

The following process is used for waiver approval:

- The Test Manager is responsible for the disposition of all submitted waiver requests.
- Waivers will be processed within four weeks of submittal to the Test Manager.
- The waiver will be analyzed and reviewed at a specially called Test Safety Review. (A detailed explanation of Test Safety Reviews can be found in the Wind Tunnel Division Test Process Manual.
- The customer will be apprised of the results of the Test Safety Review which will include acceptance, rejection, or required modifications to the waiver.

6 General Test Support Systems

Description

This section discusses these available test support systems:

- High-Pressure Air
- Hydraulic System
- Roll Adapter

6.1 High-Pressure Air

6.1.1 Description

High-pressure air (3,000 psi) is available at most of the Wind Tunnel Division facilities.

In the 9x7ft and 11ft wind tunnels, a digital-valve system is installed for high-pressure air. Flow rates can be set in increments of 0.01 pounds per second and is repeatable to 0.02 pounds per second. An outlet pressure control mode is also available with a tolerance of ±2% of set point.

6.1.2 Air Pumping and Storage Capacities

The pumping plant consists of two compressor systems having capacities of 6 and 8 pounds per second, for a combined capacity of 14 pounds per second at 3,000 psi. The current storage capacity consists of 5 million standard cubic feet at 3,000 psi.

6.1.3 Air Heaters

Electric heaters (rated at 1.0 megawatt each) are available for heating high-pressure air. The heaters are made of four, equal-capacity resistive elements and are rated for 3,000 psi. The maximum heater outlet temperature is 400° F.

6.1.4 Low Air Heater Flows

The air heater controls may prohibit heater operation at very low air flows (below 0.5 lb/sec). For tests requiring low air flows or when preheated air lines are desired, it might be necessary to consult with a Test Manager for a particular facility.

6.1.5 Facilities Available for Heater Setup

Each of the following Wind Tunnel Division facilities are set up for installation of heaters.

- 9x7ft Supersonic Wind Tunnel
- 11ft Transonic Wind Tunnel

6.2 Hydraulic Systems

Portable Systems

Two portable hydraulic systems are available for use in any of the Ames High Speed Wind Tunnel facilities. The supply capabilities of each system are as follows.

- 5.8 gallons per minute at 3,000 psi
- 1.0 gallons per minute at 1,500 psi

6.3 Roll Adapters

6.3.1 Available Facilities

Two electrically driven, remotely controlled roll adapters are available for tests in the **9x7ft Supersonic Wind Tunnel** and the **11ft Transonic Wind Tunnel**

Availability and use of either of these adapters must be coordinated with the Test Manager.

6.3.2 Capacities

The roll adapters mount to the primary strut support system in the above wind tunnels. The adapters are capable of +185/ -175 degrees of roll.

The Large Model Roll Mechanism (LMRM) used in the 11ft TWT is 44" long with load capacities shown in the Table below.

The Small Model Roll Mechanism (SMRM) used in either the 11ft TWT or 9x7ft SWT is 23" long with load capacities shown in the Table below.

	NF (lbs.)	SF (lbs.)	AF (lbs.)	PM (in-lbs.)	YM (in-lbs.)	RM (in-lbs.)	Comments
LMRM	10,000	5,000	5,000	70,000	30,000	30,000	Dwg. # A306-9024-ZM207
SMRM (old 6x6)	Resolved NF + SF 2,000		700	Resolved RM + YM 100,000		5,000	1. Built in 7.5° pre-bend 2. Dwg. # 326-3701M 3. Tapers marginal, not recommended for winged model
SMRM (new)	Resolved NF + SF 2,000		700	Resolved RM + YM 100,000		5,000	1. Dwg. # M100 thru M108 2. Acceptance testing not complete as of 10/2017l

7 Description of Test Facilities

Facilities

The facilities discussed herein are under the jurisdiction of the Wind Tunnel Division of Ames Research Center. These facilities consist of two, closed-circuit, continuous-flow, wind tunnels.

Unitary Plan Wind Tunnels

The Unitary Plan wind tunnels are a set of two interconnected tunnels that share a central main drive system that can be used to drive either a transonic leg or a supersonic leg. The Unitary Plan Wind Tunnels are as follows.

- 11-by 11-Foot Transonic Wind Tunnel
- 9-by 7-Foot Supersonic Wind Tunnel

7.1 11ft Transonic Wind Tunnel

7.1.1 Description

The 11-by 11-Foot Transonic Wind Tunnel is a closed-return, variable-density tunnel with a fixed-geometry, ventilated test section, and a dual-jack flexible nozzle.

The test section has 5.6 percent porosity consisting of evenly distributed slots on all four walls.

Air flow is produced by a three-stage, axial-flow compressor powered by four, wound-rotor, variable-speed, induction motors.

7.1.2 Operating Characteristics

The operating characteristics of the 11-by 11-Foot Transonic Wind Tunnel are presented in the following graph. The ranges of the pertinent performance characteristics are:

Mach number (continuously variable)	0.20 to 1.40
Stagnation pressure	3.0 to 32.0 psia
Reynolds number	$0.3x10^6$ to $9.6x10^6$ /ft
Maximum stagnation temperature	600°R
Strut angle of attack range	nominally ± 15°

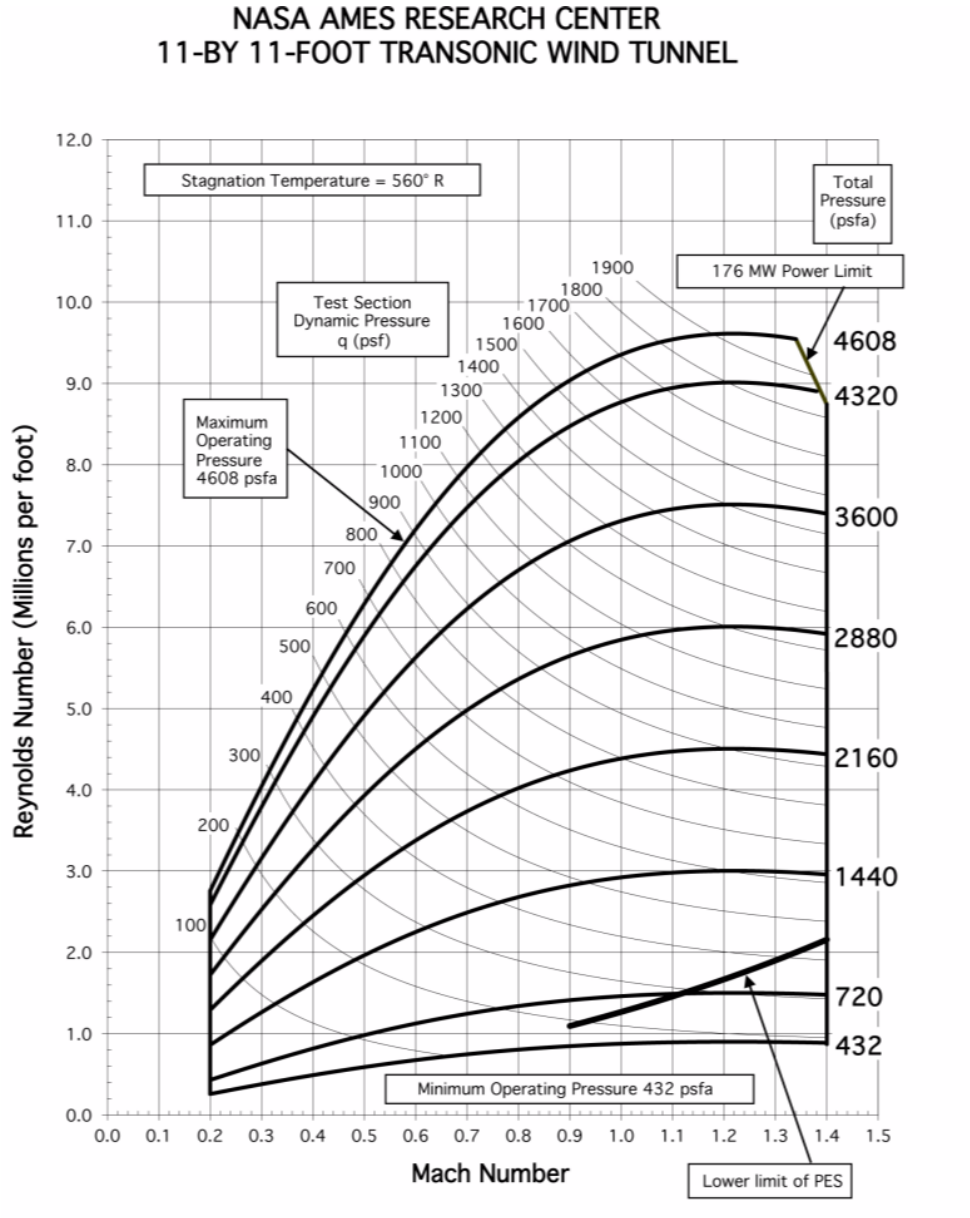


Figure 7-1: 11ft Transonic Wind Tunnel Operating Characteristics

7.1.3 Test Section Dimensions

7.1.3.1 Pertinent test section dimensions are:

Height	11.0 ft
Width	11.0 ft
Length	22.0 ft
Access hatch, top:	11.0 x 22.0 ft
Side doors:	3.0 x 4.9 ft

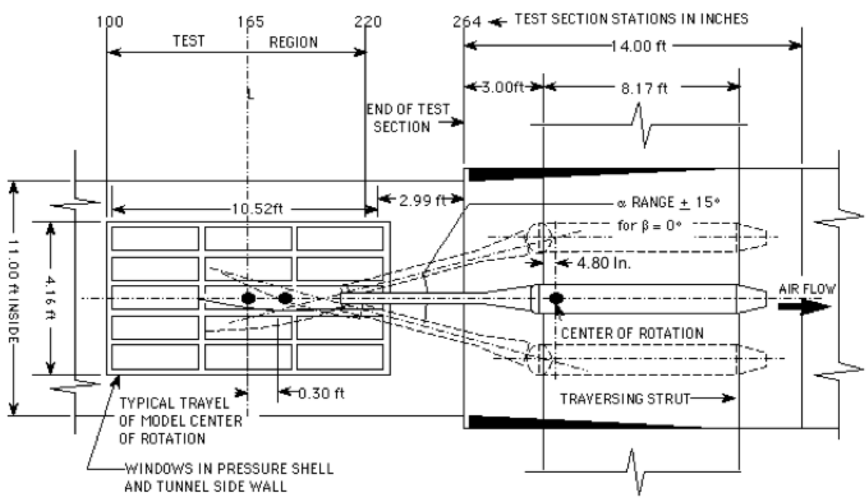


Figure 7-2: 11ft Transonic Wind Tunnel Test Section Dimensions

Model Installation Diagram

This diagram shows a sting installed with a 40-inch extension.

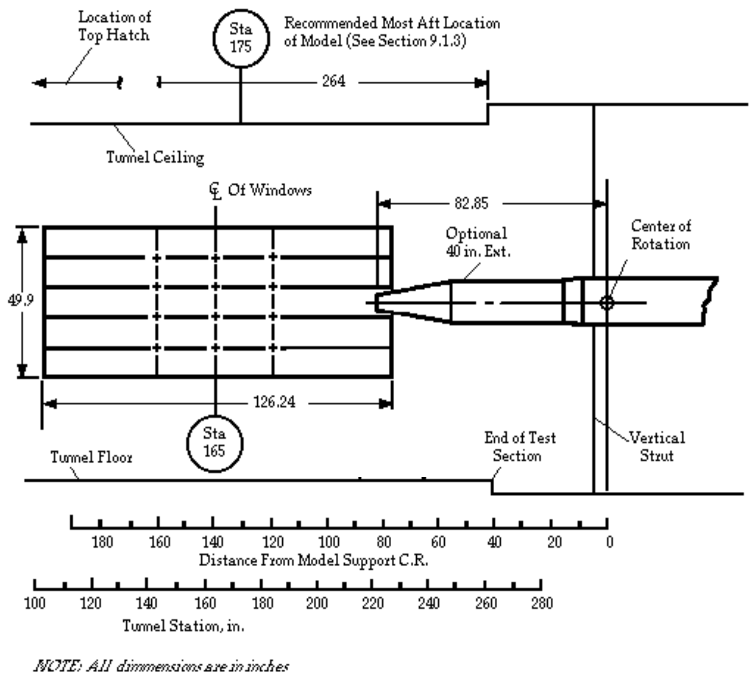


Figure 7-3: 11ft Transonic Wind Tunnel Sting Installation

7.1.3.2 Forward and Aft Limits

The forward and aft limits of the model location in the test section are dependent on the Mach number and the type of data required. As identified by tunnel station:

Table 7-1: 11ft Transonic Wind Tunnel Model Location Limits

Station	Limit
175	Aft limit for subsonic drag performance testing
193	Aft limit for subsonic static stability and control testing
220	Aft limit for supersonic static stability and control testing
60	Forward limit for subsonic testing
100	Forward limit for supersonic testing

Consult the Test Manager for any deviations from these limits.

7.1.4 Forces and Moments

A traversing strut downstream of the test section can be programmed to translate vertically to maintain a desired point of model-pitch rotation throughout the vertical plane angle-range. The model support center-of-rotation in the horizontal plane is 4.8 inches aft of the strut leading edge. These angles are continuously variable and are determined by the relative positions of a knuckle and sleeve inside the support body.

The model support system can position the model at attitudes circumscribed by a 15-degree half-angle cone. Bent primary adapters of 5, 10, 12.5, and 20 degrees are available to alter the range of model angles. Forces and moments about the model support center of rotation are limited to:

Vertical	±8,000 lbs.
Lateral	±4,000 lbs.
Axial	±3,000 lbs.
Rolling moment	±104,000 in-lbs.
Combined vertical and lateral bending moment	±800,000 in-lbs.

7.1.5 Turntable Model Support

A subfloor-mounted turntable model support, used primarily for semi-span model testing, is located at tunnel station 106. This support system can be rotated ±180 degrees and forces and moments are limited to:

Lateral force (at a height of up to 24 inches above the floor):	±50,000 lbs.
Torque (about axis of turntable):	±500,000 in-lbs.

7.1.6 Semi-span Testing

Provisions are available for sealing the slots in the test section floor to provide a solid image plane for semi-span testing.

7.1.7 Installation and Personnel Access

Models can be installed through a hatch in the top of the test section. Personnel gain access to the test section through doors in the diffuser sidewalls downstream of the model support strut.

7.1.8 Flow Visualization

Flow visualization techniques are available through multiple, optical-quality windows in the tunnel sidewalls. Optical-quality windows are also available in the test section ceiling and floor.

7.1.9 High-Pressure Air

High-pressure air (3,000 psi) is available at weight flows to 80 pounds per second through dual, independently regulated lines ending within the support strut. A one-megawatt, moveable heater can preheat air from one of these lines. Preheated air at 60 pounds per second is available at the turntable.

7.2 9-by 7-Foot Supersonic Wind Tunnel

7.2.1 Description

The 9-by 7-Foot Supersonic Wind Tunnel is a closed-return, variable-density tunnel equipped with an asymmetric, sliding block nozzle.

The test section Mach number can be varied by translating, in the streamwise direction, the fixed contour block that forms the floor of the nozzle.

Airflow is produced by an 11-stage, axial-flow compressor powered by four variable-speed, wound-rotor, induction motors.

7.2.2 Operating Characteristics

Pertinent performance characteristics are:

Mach number (continuously variable)	1.54 to 2.56
Stagnation pressure	4.4 to 29.5 psia
Reynolds number	0.9×10^6 to 6.5×10^6 /ft
Maximum stagnation temperature	600°R

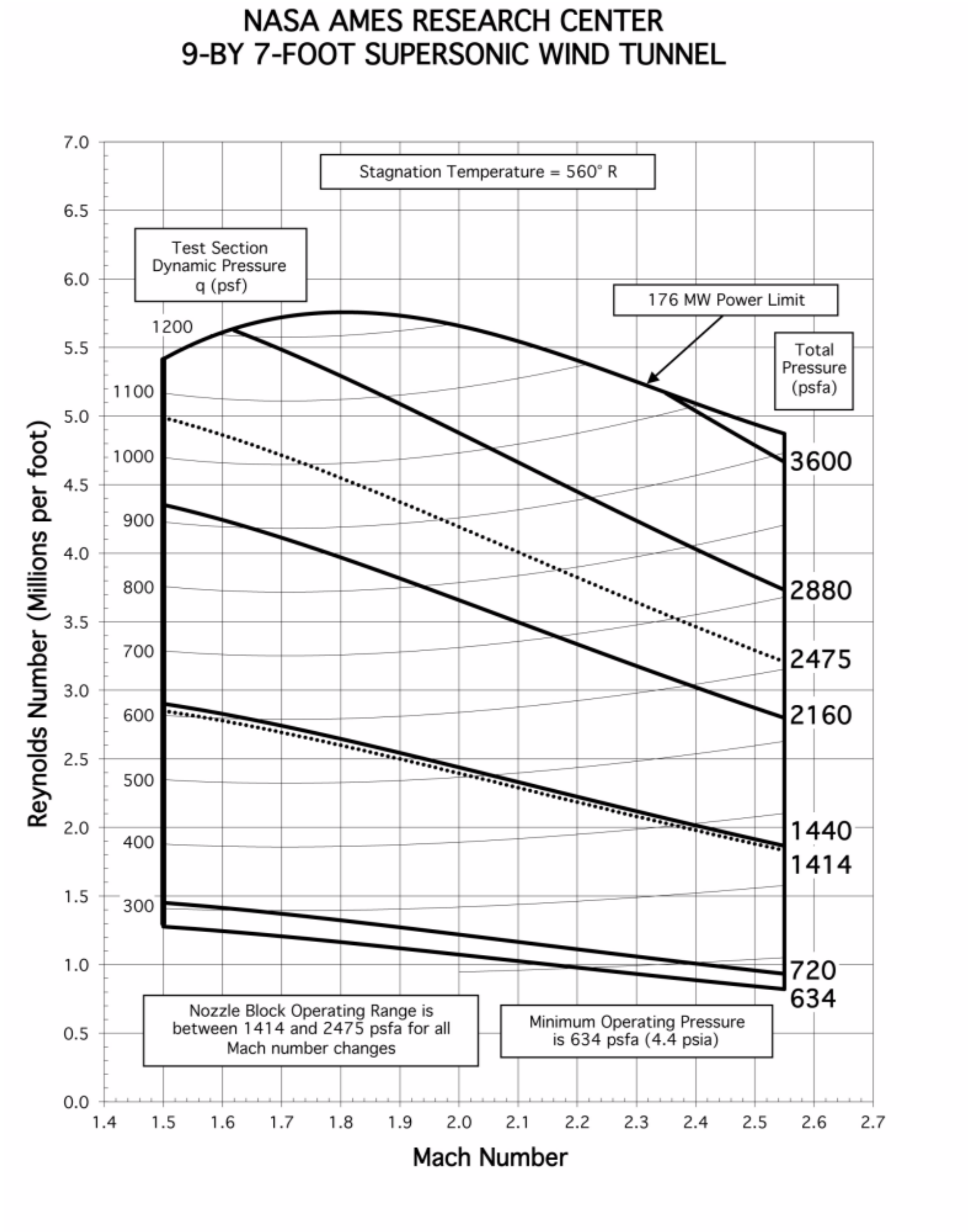


Figure 7-4: 9x7ft Supersonic Wind Tunnel Performance Characteristics

7.2.3 Test Section Dimensions

Pertinent test section dimensions are:

Height	7.0 ft
Width	9.0 ft
Length	18.0 ft
Access Hatches	
Removable Ceiling Panel:	6.0x9.0 ft
Side door:	3.0x6.5 ft

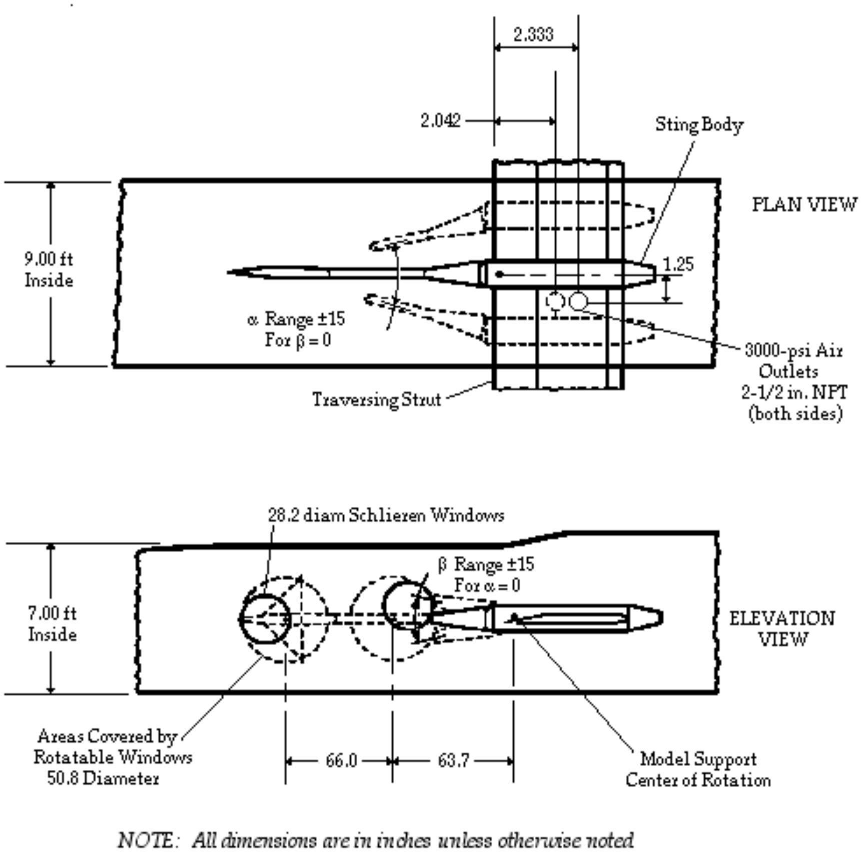


Figure 7-5: 9x7ft Supersonic Wind Tunnel Test Section Dimensions

7.2.4 Model Installation Diagram

Model installation is normally accomplished through a 3x6.5-foot door in the north wall of the diffuser. Under special circumstances the model may be installed through the 6x9ft ceiling panel.

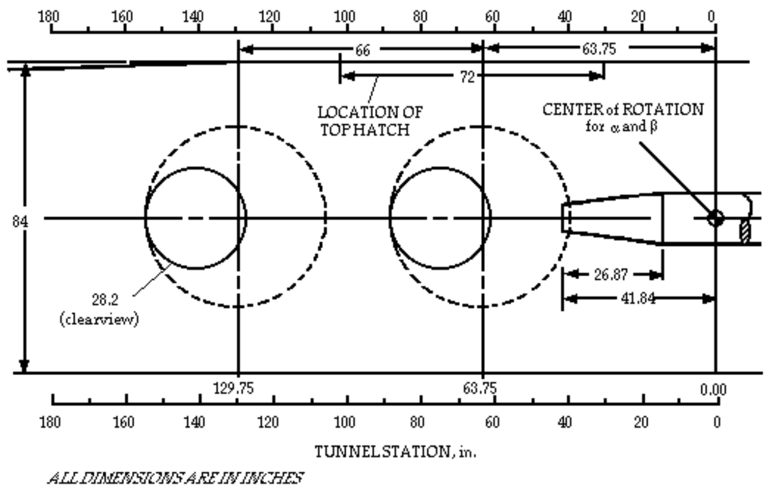


Figure 7-6: 9x7ft Supersonic Wind Tunnel Model Installation

7.2.5 Model Support System

A traversing strut downstream of the test section can be programmed to translate horizontally to maintain a desired point of rotation throughout the horizontal-plane angle-range, generally angle-of-attack.

The center of rotation in the vertical plane is 5.3 inches aft of the strut leading edge. The horizontal and vertical plane angles are continuously variable and are determined by the relative positions of a knuckle and sleeve inside the support body. The model support system can position the model at attitudes circumscribed by a 15-degree half-angle cone.

Bent primary adapters of 5, 10, 12.5, and 20 degrees are available to alter the range of model angles.

7.2.6 Forces and Moments

Forces and moments about the model support center of rotation are limited to:

Lateral	±8,000 lbs.
Vertical	±4,000 lbs.
Axial	±3,000 lbs.

Rolling moment	±104,000 in-lbs.
Combined vertical and lateral bending moment	±800,000 in-lbs.

7.2.7 Flow Visualization

Schlieren and other flow visualization techniques can be obtained by appropriately positioning 2.35-foot diameter optical-quality windows in the test section sidewalls.

7.2.8 High-Pressure Air

High-pressure air (3,000 psi) is available at weight flows up to a total of 80 pounds per second through dual, independently regulated lines. Air from one of these lines can be preheated using a one megawatt moveable heater.

7.2.9 Reflected Shock Waves

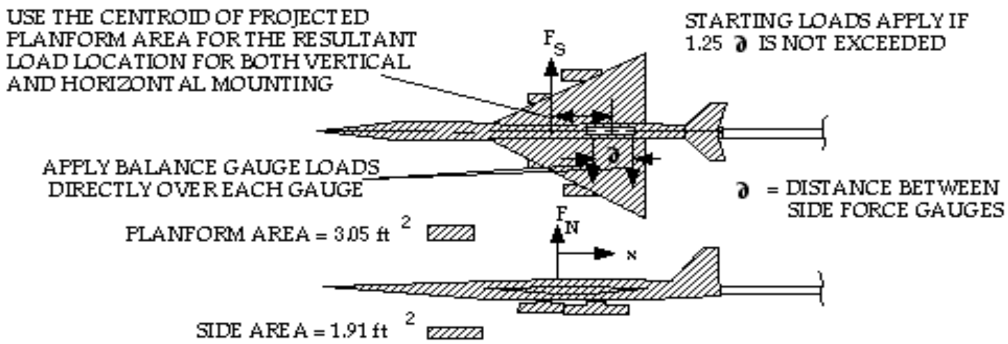
Shock waves reflecting on the model from the solid test section walls can have a significant effect on the model forces and pressures. To calculate the location of this reflected wave, assume it is reflected at the Mach angle from a 4-inch thick wall boundary layer.

7.2.10 Starting Loads

The design of models to be tested in the 9-by 7-Foot Supersonic Wind Tunnel must allow for additional critical conditions associated with blockage (the ratio of model-projected frontal area to test section cross-sectional area) and transient starting loads. Large model blockages provide a potential to "unstart" the airflow, allowing a strong shock wave to pass through the test section resulting in possible damage to the model, sting and balance.

Normal procedure is to reduce the tunnel pressure and position the model for minimum loads before beginning the acceleration to, or deceleration from, supersonic conditions.

However, significant transient loads are still generated by the swirling, subsonic, separated flows preceding the establishment of sonic velocity in the upstream throat. To ensure that a model, sting and balance will withstand these transients, they must be designed to withstand the empirically derived starting loads indicated in the following charts.



EXAMPLE 1. MODEL MOUNTED VERTICALLY	EXAMPLE 1. MODEL MOUNTED HORIZONTALLY
MODEL AND STING LOAD	MODEL AND STING LOAD
SIDE FORCE LOAD	SIDE FORCE LOAD
$F_S = (300)(1.91) = 573$ lb	$F_S = (75)(11.91) = 143$ lb
NORMAL FORCE LOAD,	NORMAL FORCE LOAD,
$F_N = (175)(3.05) = 534$ lb	$F_N = (200)(3.05) = 610$ lb
MOMENT, $M_x = \sqrt{F_S^2 + F_N^2}\ x = 783\ x$	MOMENT, $M_x = \sqrt{F_S^2 + F_N^2}\ x = 626\ x$
INDIVIDUAL BALANCE GAUGE LOAD	INDIVIDUAL BALANCE GAUGE LOAD
SIDE FORCE LOAD, EACH GAUGE,	SIDE FORCE LOAD, EACH GAUGE,
$F_S = (375)(1.91) = 716$ lb	$F_S = (90)(1.91) = 172$ lb
NORMAL FORCE LOAD, EACH GAUGE	NORMAL FORCE LOAD, EACH GAUGE,
$F_N = (210)(3.05) = 641$ lb	$F_N = (280)(3.05) = 854$ lb

Figure 7-7: 9x7ft Supersonic Wind Tunnel Load Locations

STARTING LOADS				
MODEL ORIENTATION	MODEL AND STING LOADS, lb/ft^2		INDIVIDUAL BALANCE GAUGE LOADS, lb/ft^2	
	WINGED MODELS	BODY ALONE	WINGED MODELS	BODY ALONE
VERTICAL PRIMARY LIFTING SURFACES:				
SIDE FORCE (VERTICAL DIRECTION)	300	200	375	200
NORMAL FORCE (HORIZONTAL DIRECTION)	175	150	210	150
HORIZONTAL PRIMARY LIFTING SURFACES:				
SIDE FORCE (HORIZONTAL DIRECTION)	75	150	90	150
NORMAL FORCE (VERTICAL DIRECTION)	200	200	280	200

Figure 7-8: 9x7ft Supersonic Wind Tunnel Starting Loads

Appendix A Checking Taper Fits

Taper Fits

Wind tunnel models at Ames are supported by stings or wall-mounted assemblies that have mated, tapered joints. The contact between the male and female tapers must be accurate to assume full and even transfer of loads.

Customers who make tapers to mate with Ames' equipment can obtain the appropriate male or female taper gauge by contacting the Test Manager. Customers are responsible for fitting their taper to the gauge, and all customer-supplied taper joints, with not less than 80% contact area that is evenly distributed on the contacting surfaces.

The approved technique is to use fluorescent penetrant. Other techniques may be used, but please first submit procedures to and receive approval from the Test Manager.

Taper Fit Procedures

The procedures for performing taper fits are found in the Standard Operating Procedures for Sting Assembly and Storage Facility.

Customers may request a copy of these procedures from the Test Manager.

Appendix B List of Sting Hardware in Ames Inventory

Description

This appendix contains a list of model support (sting) hardware that Ames has available as of October 2017.

Table Legend

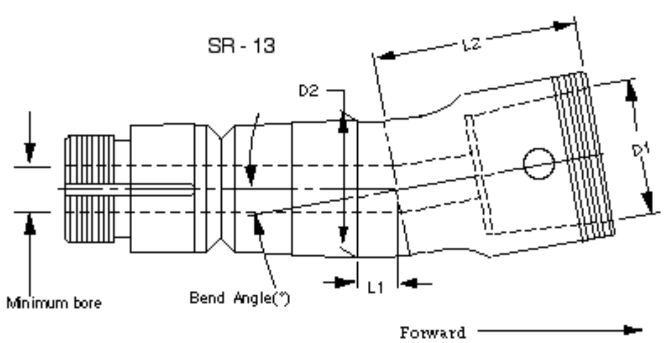
The sting hardware table legend is shown below.

SR #	Sting Assembly and Storage Facility Inventory Number
FTS	Front (upstream) Taper Gage diameter (inches)
FG	Front Taper Gender (M=male, F=female)
RTS	Rear (downstream) Taper Gage diameter (inches)
RG	Rear Taper Gender (M=male, F=female)
B	Bend Angle (degrees)
MB	Minimum Bore Diameter Through Sting (inches)
L1	Axis 1 Length (inches) Rear Taper Not Included
L2	Axis 2 Length (inches)
VO	Vertical Offset (inches)
W	Weight (pounds)
RC	Rockwell C Hardness

Examples

Hardware items in the following examples are identified by “sting room” number (SR #). The following examples illustrate properties for two types of hardware.

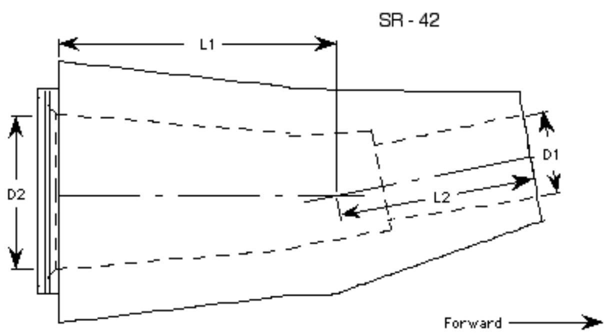
Example One: Adapter SR-13



Primary Adapter – SR-13

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc
13	4.5	F	Cornell 4.5"	4.5	M	Ames 4.5" Threaded Push- on/off	10	1.5	1.364	6.78	0	50	45

Example Two: Primary Adapter SR-42



Primary Adapter – SR-42

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc
42	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	10	4	14.69	10.613	0	405	26

Sting Hardware Table

The table is divided into the following categories:

- B-1: Adapters
- B-2: Extensions
- B-3: Extension/Adapters
- B-4: Primary Adapters
- B-5: Primary Adapter/Stings
- B-6: Roll Mechanism/Extensions
- B-7: Stings
- B-8: Sting/Adapters

Table B-1: Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
1	2.75	F	?	4.5	M	Ames 4.5" Threaded Push-on/off	0	1.25	7.38	0	1.25	63	45	
2	4.0	M		4.0	M		5	1.5	0	0	0	40	44	
3	4.5	M	Ames 4.5" Push-on/off	4.5	M	Ames 4.5" Push-on/off	15	1.75	0	0	0	55	43	
5	3.25	F	Task 4.0 Mk-II, gauge #300400	3.25	M	Task 4.0 Mk-II, gauge #300400	5	1.25	30.3	-20.2	0	52	45	
6	3.0	F	Sleeve	4.5	M	Ames 4.5" Threaded	0	1.5	0	0	0	20	46	
8	1.44	F	Task 2.0 gauge# 300300 (300231)	3.25	M	Task 4.0 Mk-II, gauge# 300400	0	1	10.75	6	0	25	33	Needs repair
11	4.5	F	Cornell 4.5"	4.5	M	Ames 4.5" Threaded Push-on/off	0	1.5	5.59	0	0	50	45	Female socket to match 12-ZS-123-7 sting.
12	4.5	F	Cornell 4.5"	4.5	M	Ames 4.5" Threaded Push-on/off	0	1.25	6.38	5.25	0	65	44	This sting adapter is very similar to adapter Number RDK-30506.
13	4.5	F	Cornell 4.5"	4.5	M	Ames 4.5" Threaded Push-on/off	10	1.5	1.364	6.78	0	50	45	

Table B-1: Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
14	4.5	M	Ames 4.5” Push-on/off	4.5	M	Ames 4.5” Push-on/off	21	1.75	0	0	0	65	40	
18	4.5	M	Ames 4.5” Push-on/off	4.5	M	Ames 4.5” Push-on/off	5	1.75	0	0	0	55	40	
19	2.9	M	Cylindrical	4.5	M	Ames 4.5” Push-on/off	0	1.5	14.25	0	0	38	35	
20	3.25L	F	Task 4.0 Mk IV, gauge# 4626	4.5	F	Ames 4.5" Push-on/off	0	1.75	17.75	0	0	50	44	
35		F	Press Fit Bolt On	4.5	M	Ames 4.5" Push-on/off	0	0	12.38	47.25	33.5	510	38	
94	2.0L	F	Task 2.5 MkXX, gauge#3340, 2.5L	3.25	M	Task 4.0 Mk II, gauge# 300400	25	1.38	0.25	21	0	40	43	
96	1.44	F	Task 2.0 gauge# 300300(300231)	2.0	M	Task 2.5 Mk III, gauge# 300373	49	0	7.32	13.81	0	25	41	
106	3.25	F	Task 4.0 Mk II, gauge# 300400	3.25	M	Task 4.0 Mk II, gauge# 300400	13	0.68	7	0	0	30	43	
126	2.875	F	Ames 2.875" Standard(6X6)			Bolt On	0	0	9	0	0	30	-11	
127	4.5	F	Ames 4.5" Push-on/off	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	9	0	0	35	43	

Table B-1: Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
141	1.05	F	Task 1.5 Mk II, gauge# 300366			Bolt On	0	0.9	2.19	0	0	3	34	
143	2.0	F	Task 2.5 Mk III, gauge# 300373	1.44	M	Task 2.0 gauge# 300300(300231)	0	0.44	3.25	0	0	3	37	
145	2.0	F	Task 2.5 Mk III, gauge# 300373	2.0L	M	Task 2.5 MkXX, gauge#3340, 2.5L	0	0.63	4.25	0	0	5	39	Needs repair
146	2.0	F	Task 2.5 Mk III, gauge# 300373	2.0L	M	Task 2.5 MkXX, gauge#3340, 2.5L	5	0.75	4	0	0	7	50	Needs repair
149	1.44	F	Task 2.0 gauge# 300300(300231)	2.0	M	Task 2.5 Mk III, gauge# 300373	55	0.5	0	0	0	12	36	
150	1.44	F	Task 2.0 gauge# 300300(300231)	1.125	F	Fork	0	0.75	3.75	8.25	0	5	37	
165.1	3.25L	F	Task 4.0 Mk IV, gauge# 4626			Bolt On	0	0	15.25	0	0	40	47	Only useable with SR165
165.2	2.0	F	Task 2.5 Mk III, gauge# 300373			Bolt On	0	0	11.25	0	0	10	43	Only useable with SR165
165.3			Bolt On			Bolt On	0	0	7.63	2.75	1	5	31	Only useable with SR165
165.4	4.5	F	Ames 4.5' Push-on/off	4.88	M	Sleeve	0	0	13.75	0	0	20	29	Only useable with SR165

Table B-1: Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
165.5	3.25	F	Task 4.0 Mk II, gage# 300400			Bolt On	0	0	0	0	0	0	0	Only useable with SR165
169.1	5.50	F	?	4.875	F	?	0	0	6	0	7	80	36	
169.2	4.875	M	?	4.5	M	Ames 4.5 Threaded, Push-on/off	0	0	0	0	0	55	41	
170	4.5	F	Ames 4.5" Push-on/off				0	4.1	9.75	0	0	50	47	Sting socket used with Kicksting
171	5.0	F	?				0	0	24	0	0	125	31	
174.9	1.00	F	Pinned			Bolt On	0	0	23.3	0	0	325	-12	
183	2.875	F	Ames 2.875" Standard(6X6)			Bolt On	0	1.75	8.25	0	0	30	37	
184	1.44	F	Task 2.0 gauge# 300300(300231)	2.0	M	Task 2.5 Mk III, gauge# 300373	0	.75	3.88	0	0	10	42	
185	3.2	M	Boeing threaded/pinned adapter	4.5	M Taper	Ames 4.5" Threaded	0	1.5	3.25	0	0	60	52	Adapts to SR# 186
205	.75	F	1" MK-14C balance	1.05	M	1.05" Gage 300366	0	.38	15.9	5.5		6	31	

Table B-1: Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
223	4	M	LaRC Gage LC-517080	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.25	3.636	0	0		40	
224	1.5	F	Cylindrical Bore	2.875	M	Ames 2.875" Standard(6X6)	0	1.5	15	0			35-36	

Table B-2: Extensions

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
27	4.5	F	Ames 4.5" Push-on/off	4.5	M	Ames 4.5 Threaded, Push-on/off	0	2	30	10	0	275	39	
28	4.5	F	Ames 4.5" Push-on/off	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.5	27.3	10	0	270	36	
29	4.5	F	Ames 4.5" Push-on/off	4.5	M	Ames 4.5 Threaded, Push-on/off	0	2	30	10	0	280	36	
30	4.5	F	Ames 4.5" Push-on/off	4.5	M	Ames 4.5 Threaded, Push-on/off	0	2	30	10	0	280	44	
34	4.5	F	Ames 4.5" Push-on/off	4.5	M	Ames 4.5" Threaded	0	1.5	22.5	10	0	160	46	
64	4.5	F	Ames 4.5" Push-on/off	4.5	M	Ames 4.5 Threaded, Push-on/off	0	2	50	9.75	0	470	46	
75	2.875	F	Ames 2.875" Standard(6X6)	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	30	0	0	100	30	
159	8.3	M	Ames 8.3" Standard	8.3	F	Ames 8.3" Ringless	0	2	40.69	0	0	1640	34	
163	8.3	M	Ames 8.3" Standard	8.3	F	Ames 8.3" Standard	0	2	20	0	0	730	41	
167	2.875	F	Ames 2.875" Standard(6X6)	2.875	M	Ames 2.875" Standard(6X6)	0	1	64.7	0	0	210	-5	

Table B-2: Extensions

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
168	2.875	F	Ames 2.875" Standard(6X6)	2.875	M	Ames 2.875" Standard(6X6)	0	1	13.7	0	0	45	26	
182	2.875	F	Ames 2.875" Standard(6X6)	2.875	M	Ames 2.875" Standard(6X6)	0	1	15.6	0	0	50	26	

Table B-3: Extension/Adapter

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
4	2.875	F	Ames 2.875" Standard(6X6)	4.5	M	Ames 4.5" Threaded	0	2	14.57	0	0	70	35	
7	2.0	F	Task 2.5 Mk III, gauge# 300373	4.5	M	Ames 4.5" Threaded	0	1.5	15.38	0	0	75	42	
9	4.0	F	Co-op gage H580	3.25L	F		0	1.53	22.18	0	0	85	41	
15	2.875	F	Ames 2.875" Standard(6X6)	4.5	M	Ames 4.5 Threaded, Push-on/off	0	2	15.57	0	0	75	33	
22	2.5	M	Langley	4.5	M	Ames 4.5" Threaded	0	0	23.5	0	0	170	39	
23	2.875	F	Ames 2.875" Standard(6X6)	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.5	30.37	0	0	130	37	
24	3.25	M	Langley	4.5	F	Ames 4.5" Threaded	0	1.12	16.81	0	0	190	40	
33	2.875	F	Ames 2.875" Standard(6X6)	4.5	M	Ames 4.5 Threaded, Push-on/off	0	2	30	0	0	130	33	
44	4.5	F	Ames 4.5" Push-on/off	8.3	F	Ames 8.3" Standard	0	1.75	46.38	0	0	570	31	
57	4.75	F	Cylindrical	8.3	F	Ames 8.3" Standard	0	.875	32.8	0	0	400	44	6x6 SMRM Adapter
63	2.875	F	Ames 2.875" Standard(6X6)	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.75	47.08	0	0	310	38	

Table B-3: Extension/Adapter

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
74	4.0	M Taper	Co-op gage H580	4.5	M	Ames 4.5 Threaded, Push-on/off	12	1.5	16.87	0	0	130	43	
80	2.875	F	Ames 2.875" Standard(6X6)	4.5	M	Ames 4.5" Threaded	0	1	28.38	0	0	110	35	
153	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0.38	55.5	79	0	125	32	
154	1.875	F	Sleeve	2.875	M	Ames 2.875" Standard(6X6)	45	0	0	0	0	80	31	
155	4.0	F	Specific to the W1148 Parts Series	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.5	27.39	0	0	145	42	
158	2.875	F	Ames 2.875" Standard(6X6)	4.5	M	Ames 4.5" Threaded	0	2	14.38	0	0	70	34	

Table B-4: Primary Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
36	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	0	4.5	25.38	0	0	370	26	
37	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	10	4	14.69	10.61	0	405	23	
38	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	0	4.38	25.38	0	0	360	35	
40	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	20	4.1	15.81	10.61	0	400	32	
41	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	12.5	4	14.69	9.90	0	405	32	
42	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	10	4	14.69	10.613	0	405	26	
43	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	0	4.38	25.38	0	0	370	27	
45	6.9	F	Grumman 6.9"	8.3	F	Ames 8.3" Standard	5	6	26	0	0	360	11	
46	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	5	4	14.69	10	0	375	38	
47	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	0	4	25.38	0	0	375	35	

Table B-4: Primary Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
48	4.5	F	Ames 4.5" Threaded	8.3	F	Ames 8.3" Standard	0	4.1	25.38	0	0	380	28	
49			Bolt-On	8.3	F	Ames 8.3" Standard	0	2	47.73	26.22	0	755	47	
59	2.875	F	Ames 2.875" Standard(6X6)	8.3	F	Ames 8.3" Standard	0	1.5	59	0	0	900	29	
161			Northrop Model 403	8.3	F	Ames 8.3" Standard	0	4	55.21	0	0	1880	33	
162	6.0	M	Langley NTF	8.3	F	Ames 8.3" Standard	0	0	38.5	0	0	870	44	Ames to NTF adapter
164		F	Fork	8.3	F	Ames 8.3" Standard	0	2	38	0	0	410	24	
164.1			Pinned			Bolt On	0	0	8.25	0	0	70	12	Pylon Fittings Only use with SR164
164.2			Pinned			Bolt On	0	0	11.38	0	0	70	34	Pylon Fittings Only use with SR164
164.3	4.5	F	Ames 4.5 Threaded, Push-on/off	1.5	F	Pinned	0	4.1	8.25	9	0	60	36	Pivot Arm Only use with SR164

Table B-4: Primary Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
164.4	1.00	F	Pinned	1	F	Pinned	0	0	52	0	0	60	19	Turnbuckle Arm Only use with SR164
175	9.2	M	Clamp	8.3	F	Ames 8.3" Standard	0	7.2	17.88	0	0	295	34	

Table B-5: Primary Adapter/Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
50	3.25L	F	Task 4.0 Mk IV, gauge# 4626	8.3	F	Ames 8.3" Standard	0	2	111.6	0	0	885	27	
51	3.25	F	Task 4.0 Mk II, gauge# 300400	8.3	F	Ames 8.3" Standard	0	2	115.6	0	0	890	33	
52	3.25L	F	Task Mk IVA 4.0 Bal	8.3	F		0	2	89.5	0	10	905	33	
53	4.0	F	Task 4.0 Mk IV, gauge# 4626	8.3	F	Ames 8.3" Standard	12	2	48.8	67.519	0	0	0	

Table B-6: Roll Mechanism/Extensions

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
21	1.625	Square	Unknown	2.875	M	Ames 2.875" Standard(6X6)	0	0	34	0	0	210	21	
LMRM	8.3	M	Ames 8.3" Standard	8.3	F	Ames 8.3" Standard	0	0	43.808	0	0	1640	0	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
25	2.5	F	Sliding fit w/D111-2	4.5	M Taper	Ames 4.5" Threaded	13	2	9.88	19.25	0	85	26	
26	3.25L	F	Task 4.0 Mk IV, gauge# 4626	4.5	M	Ames 4.5 Threaded, Push-on/off	15	1.38	0	30.38	0	130	43	
31	1.25	F	Fork	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1	35.75	0	0	270	45	
54	2.5	M	Langley	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.5	69.75	0	0	365	43	
55	2.0	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Ames 4.5" Threaded	0	1.25	73.38	0	0	240	53	
56	1.44	F	Task 2.0 gauge# 300300(300231)	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.25	76.75	0	0	185	51	
61	2.25	M	Balance outer sleeve dimensions	4.5	M	Ames 4.5" Threaded	0	1	59.5	10	0	170	37	
62	3.25	F	Task 4.0 Mk II, gauge# 300400	4.5	M	Ames 4.5" Threaded	0	2	61.25	0	0	235	33	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
68	2.0	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1	54.41	0	0	155	46	
70	2.0	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1	51	0	0	150	51	
72	2.0	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Ames 4.5" Threaded	0	0.83	58	0	0	210	49	
76	2.5L	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Ames 4.5" Push-on/off	15	1	13	24	0	90	45	
79	2.0	F	Task 2.5 Mk III, gauge# 300373	4.5	M	Ames 4.5" Threaded	0	0.75	66.37	0	0	230	35	
83	.9375	F	?	2.875	M	Ames 2.875" Standard(6X6)	0	0.38	38.84	0	0	35	43	
84	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	34	0	0	40	51	
85	.75	F	Task 1.0 MkVI & XIV, gauge#6674	2.875	M	Ames 2.875" Standard(6X6)	0	1	40.75	0	0	30	53	
86	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	0.781	32.59	0	0	40	35	
87	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	1	38.9	0	0	40	26	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
88	1.44	F	?	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	35.5	0	0	50	36	
89	1.05	F		2.875	M	Ames 2.875" Standard(6X6)	0	0.75	39.38	0	0	40	44	
90	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	0	0.79	17.88	0	0	30	35	
91	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	0	0.781	17.75	0	0	30	33	
92	1.5	M	Balance outer sleeve dimensions	2.875	M	Ames 2.875" Standard(6X6)	0	1.25	23.25	0	0	20	40	
93	.75	F	Task 1.0 MkVI & XIV, gauge#6674	2.875	M	Ames 2.875" Standard(6X6)	0	1	23.13	0	0	20	44	
97.2	1.75	F	Fork	2.0	M	Pivot Arm Sting	0	0.75	24	1	0	80	36	
97.3	1.05	F	Task 1.5 Mk II, gauge# 300366	1.75	M	Pivot Arm Sting	0	0.75	15.5	1	0	10	34	
101	1.30	F	Task 1.75 Mk I, gauge# 10191	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	12.5	0	0	20	32	
107	2.0	F		2.875	M	Ames 2.875" Standard(6X6)	0	1	37.63	0	0	45	44	
108	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	5	0.78	37.69	0	0	70	28	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
109	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	0	0.78	37.69	0	0	55	19	
110	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	33	0	0	45	54	
111	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	5	0.78	33.25	0	0	0	20	
112	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	0	1	37.69	0	0	60	29	
113	2.0	F	Task 2.5 Mk III, gauge# 300373	3.25	M	Task 4.0 Mk II, gauge# 300400	0	0.75	21	0	0	60	44	
114	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	15	1	14.75	13	0	55	32	
115	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0	22.5	0	8	40	43	
116			?	2.875	M	Ames 2.875" Standard(6X6)	0	0	23.5	0	0	55	11	
117	2.0	F	Task 2.5 Mk III, gauge# 300373	3.25	M	Task 4.0 Mk II, gauge# 300400	36	1.38	0.65	17.5	0	35	44	
118	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	0.78	32.59	0	0	40	33	
119	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	4	0.75	13.1	3.2	0	20	38	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
123	.613	F		1.44	M	Task 2.0 gauge# 300300(300231)	0	0.38	0	0	0	5	40	
124	1.05	F	Task 1.5 Mk II, gauge# 300366	2.0	M	Task 2.5 Mk III, gauge# 300373	0	0.38	16.63	0	0	15	40	
125	2.0	F	Task 2.0 gauge# 300300(300231)			2 LAND SLEEVE	0	0	0	0	0	15	32	
128	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	32.63	0	0	60	35	
129	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0.78	37.69	0	0	40	26	
130	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	0.78	36.88	0	0	45	35	
131	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	37.75	0	0	40	37	
132	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	0.78	32.59	0	0	30	37	
133	.938	F	?	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	0	0	0	35	41	
134	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	32	0	10	65	38	
135	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	37.75	0	0	30	41	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
136	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	30	0.75	0	0	0	30	36	
137	1.0	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	37.75	0	0	35	40	
138	1.44	F	Task 2.0 gauge# 300300(300231)	2.875	M	Ames 2.875" Standard(6X6)	0	0.78	32.63	0	0	40	30	
139	1.05	F	Task 1.5 Mk II, gauge# 300366	2.875	M	Ames 2.875" Standard(6X6)	0	0.38	34.63	0	0	30	43	
144	1.44	F	Task 2.0 gauge# 300300(300231)	1.44	M	Task 2.0 gauge# 300300(300231)	6	0.5	0	0	0	3	38	
151	2.0	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Cornell 4.5"	0	0.75	42.78	0	0	100	46	
152	1.44	F	Task 2.0 gauge# 300300(300231)	4.5	M	Cornell 4.5"	0	0.75	43	2.56	0	120	40	
157	2.0L	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Ames 4.5" Push-on/off	0	1	39.75	0	3	140	0	
160	3.25	F	Task 4.0 Mk II, gauge# 300400	4.5	M	Ames 4.5 Threaded, Push-on/off	0	2	29	0	0	105	38	
165			Bolt On	4.5	M	Ames 4.5 Threaded, Push-on/off	0	0	98	0	0	545	43	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
166	3.25	F	Task 4.0 Mk II, gauge# 300400	6.9	M	Grumman 303	0	0	93	0	0	640	41	
169			Bolt On	5.50	M	?	0	0	75	0	0	275	41	
172	2.0	F	Task 2.5 MkXX, gauge#3340, 2.5L	4.5	M	Ames 4.5 Threaded, Push-on/off	0	1.25	66.38	0	0	255	41	
173			Balance outer sleeve dimensions			Pivot Arm Sting	0	0	0	0	0	510	46	
176	1.44	F	Task 2.0 gauge# 300300(300231)	4.5	M	Cornell 4.5"	0	0.75	44.5	2.56	0	120	46	
178	3.25	F	Task 4.0 Mk II, gauge# 300400	4.5	M	Cornell 4.5"	0	1	40.75	0	0	165	47	
181	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	0	0.785	36	0	0	55	39	
186		F Socket	0		F Socket		0	1	50.21	0	0	0	0	
187	2.0	F	Task 2.5 Mk III, gauge# 300373	2.875	M	Ames 2.875" Standard(6X6)	0	0.78	40.41	0	0	0	0	
220		AEDC Clutch Face	1-20 RH Thread and 24 tooth Clutch Face	2.875	M	Ames 2.875" Standard(6X6	0	.375	35	0	0		40	

Table B-7: Stings

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
221	1.05	F	Task 1.5 Mk II, gage# 300366	2.875	M	Ames 2.875" Standard(6X6	0	0.75	34	0	0	32	40	
222	1.12	F	Task 1.5 XXXVI, Gage # 003688	4.5	M	Ames 4.5 Threaded, Push-on/off	0	0.75	48	0	0		52-54	
225	2.0	F	Gage 300373	4.5	M	Ames 4.5 Threaded, Push-on/off		16.0				TBD		
227	4.75	Bolted	HPA Flange	4.5	M	Ames 4.5 Threaded, Push-on/off	0		67.5	0	0	212	29-30	
228	2.5	F	Task Taper Gage 3340	4.5	M	4.5" Push On/Push OffGage A9758-D108-2	0	1.25	42.933			122	47	
230	1.05	F	Task 1.5"Gage: 300366	2.875	M	Ames 2.875" std (6x6)Gage 9758-D66	0	0	68.0		0	100	N/A	Linear Adapter Built by AOX for Sonic Boom Testing.
231	4.5	Bolted Flange	Eight 1/2" Bolts	4.5	M	Push-On/Off, Threaded Gage A9758-D108	0	2.0	40.725		0	110	50	

Table B-8: Sting/Adapters

SR#	FTS	FG	Front Taper Type	RTS	RG	Rear Taper Type	Bα	MB	L1	L2	VO	W	Rc	Comments
69	1.44	F	Task 2.0 gauge# 300300(300231)	3.25	F	Langley?	0	0.75	62.25	0	0	105	41	
71	3.0	F	?	4.5	M	Ames 4.5" Threaded	0	2	47.13	0	0	215	40	
97.1	2.0	F	Fork	2.875	M	Ames 2.875" Standard(6X6)	0	0.75	6	1	0	30	36	
174	1.375	F	Pivot Arm Sting	4.5	M	Ames 4.5 Threaded, Push-on/off	0	0	33	0	0	230	38	
174.1			Pinned			Bolt On	0	0	9.25	7.75	0	40	44	Pivot Arm Only use with SR174
174.2			Bolt On			Pivot Arm Sting	0	0	22.75	0	0	45	44	Pivot Arm Only use with SR174
174.3			Bolt On			Pivot Arm Sting	0	0	22.75	0	0	55	41	Pivot Arm Only use with SR174
174.4	2.0	F	Task 2.5 Mk III, gauge# 300373			Pivot Arm Sting	0	0	44.5	0	0	75	35	Pivot Arm Only use with SR174

174.5	1.313	F	?			Bolt On	0	0	15.63	0	0	10	33	
174.6	1.375	F	?			Bolt On	0	0	15	0	0	20	44	
174.7	2.0	F	Task 2.5 Mk III, gauge# 300373			Pivot Arm Sting	0	0	44.5	0	0	75	35	Pivot Arm Only use with SR174
174.8	2.875	F	Ames 2.875" Standard(6X6)			Pivot Arm Sting	0	0	0	0	0	45	39	Pivot Arm Only use with SR174
177			?	4.5	M	Cornell 4.5"	0	0	45.75	0	0	165	41	

Appendix C Summary of Customer Actions and Deliverables

C.1 General Checklist

Description

The following table is a checklist of items expected from customers in the time frames shown.

Table C-1: Customer Supplied Items Checklist

Item	Recommended no. of weeks prior to test
Test Justification Meeting	26
Initial Test Planning Meeting	12
Test Objective Document	13
Request for use of general support systems contained in Section 6.0	8
Request for use of instrumentation items contained in Appendix D.	8
Data-plotting requests	8
Drawings of model support systems and installations	6
Customer data-reduction equations	6
Customer balance if calibration required	6
Customer-supplied model support hardware (stings)	6
Stress report	6
Model assembly, installation, and change procedures	6
Model cross-sectional area distribution	4
Finalized run schedule	4
Details of Customer-furnished equipment	4
Customer-supplied constants for the data-reduction program	4
Customer-supplied calibrations	4
MSDS sheets for all Customer-supplied chemicals	4
Personnel arrival information	See sec. 3
Model and support equipment	1

C.2 Test Request Form

Description

This form is filled out by the customer to inform the Wind Tunnel and Aerodynamics group of the services needed. A blank form is shown in Figure C-1. This form may be copied for use by a Customer. It is also available electronically on Microsoft® Word at https://www.nasa.gov/sites/default/files/643639main_Test_Request.doc.

NASA Ames Research Center

Wind Tunnel Division

TEST REQUEST FORM

Test Title: _____

Requestor Information:
Organization: _____
Contact *(include name and title)*: _____
Address: _____
_____
_____

Telephone: Desk: _____ Cell: _____
E-mail: _____

Sponsor Information:
Organization *(Principle sponsor such as NASA, DoD, Air Force, Navy, Company, etc.)*:
_____

Contact *(include name and title)*: _____
Address: _____
_____
_____

Telephone: Desk: _____ Cell: _____
E-mail: _____

Other Organizations Supporting the Test:
(Secondary organizations that will be supporting the test and what that support is: staffing, money, equipment, etc. For example provide company name, number of researchers, number of test engineers, and number of model technicians)

NASA Program Affiliation:
☐ Aeronautics Research
☐ Human Exploration & Operations ☐ SLS ☐ Orion
☐ Science
☐ Space Technology
☐ Other: _____

AO42 Test Request Form (06/19)

Schedule:
Requested Test Section Occupancy Entry Date (mm/dd/yy)
Estimated (Test section occupancy hours)
Earliest date model can be delivered to facility (mm/dd/yy)
Latest date for test completion (M/D/Y)

Facility Preference (if known):
☐ **11-by 11-foot TWT** (Mach 0.2-1.4) ☐ **9-by 7-foot SWT** (Mach 1.55-2.5)

General Description of the Test:
_____

Specific Test Objectives:
_____

Model/Test Hardware:
Designation: _____ Scale: _____
Description: _____

Size (key dimensions such as, wing area, span, length, blockage area, weight, etc.
Minimum possible scale should also be included): _____

Current Status: ☐ Concept definition ☐ Design ☐ Fabrication ☐ Ready for test
☐ Previously Tested
Where tested _____
When tested _____

Type of Test (all that apply):
- ☐ Aircraft/spacecraft/missile performance
- ☐ Aircraft/spacecraft/missile stability and control
- ☐ Inlet
- ☐ 2-D Airfoil
- ☐ Acoustic
- ☐ Other test type - describe: _____

Model/Configuration Changes:
Total number of changes:
Percent - Remove and re-install model:
Percent - Major model component change:
Percent - Control surface change:
Estimate of average time required to make changes (if known):
Remove and re-install model:
Major model component change:
Control surface change:
Indicate time required for any changes that are significantly longer than the average.
_____

AO42 Test Request Form (06/19)

Type of Data Required:

- ☐ Force and moment — No. of data points _____
- ☐ Strain gauge — Approx. # of gauges _____ — No. of data points _____
- ☐ Pressures (ESP) — Approx. # of orifices _____ — No. of data points _____
- ☐ Model Deformation — No. of data points _____
- ☐ Dynamic (Unsteady pressures) — No. of data points _____
- ☐ Pressure sensitive paint — No. of data points _____
- ☐ Temperature sensitive paint — No. of data points _____
- ☐ Acoustic (Microphones) — No. of data points _____
- ☐ Skin Friction — No. of data points _____
- ☐ Off-body velocity (PIV) — No. of data points _____

☐ Flow visualization
Type: ☐Surface flow ☐Off-body
Describe requirements: _____

☐ Other data requirements: _____

Classification requirements:

Test Conditions:

Mach number range: _____
Reynolds number range: _____
Dynamic Pressure(s): _____
Angle of attack range: _____
Angle of side slip range: _____
Nozzle pressure ratio range: _____
Weight flow range (inlet): _____

Other: Include detailed test matrix as enclosure if known: _____

Instrumentation Requirements

Facility supplied:

User supplied:

Special Requirements:

High pressure air (pressure level and mass flow rate), exhaust (vacuum level and mass flow rate), cooling (temperature, water or air with mass flow rates), heating requirements, unique systems, additional space, hydraulics, (pressure level and flows), special data reduction requirements (plotting, format, etc.), know facility modifications required to accommodate test apparatus, etc.

_____

Request Submitted (Date M/D/Y):

AO42 Test Request Form (06/19)

C.3 Initial Test Planning Meeting Guide

This guide is used by both the Customer and the Test Manager to set the agenda for the Initial Test Planning meeting. An example is shown in Figure C-2.

Test Planning Meeting Agenda

TEST NO.: XX-XXXX

TITLE :

I. OPENING **Approx. 10-15 min.**

(Test Manager or AOO Branch Chief)

1. Introduction of user representatives.
2. Introduce key Ames personnel.
3. Explain Ames' role regarding this test. (Including staffing)
4. State test date, prep room availability, 8 occupancy hours/shifts per day.
5. Restate required/updated dates for stress, program, stings, model.

II. TEST OVERVIEW AND OBJECTIVES **Approx. 20-30 min.**

(Customer Representatives)

Customer will distribute electronic version of requirement document prior to the meeting.

1. Test program overview and objectives.
2. Ames specific objectives & requirements. (Drag, S&C, pressure/loads...)
3. Sponsoring agency/Co-op & security classifications, if any.
4. Review present run schedule. (stream, high Rn, bridging, expected loads) - What are the real alpha schedule requirements-angles or increments?

III. MODEL AND HARDWARE DESCRIPTION **Approx. 30-45 min.**

(Customer Representatives)

1. Support system:
   - Whose stings & adapters. (what is total length & tunnel stations)
   - Status/locations of pieces and tapers. (are gauges needed?, timeframes)
   - Has aerodynamic interference been investigated?
2. Model description:
   - Scale, blockage, & pertinent dimensions. (Include drawing if appropriate)
   - Boundary trip kind, sizing & application pattern. How long to apply?
   - Top & side planform for starting loads
3. Test Specific Requirements:
   - High pressure air & hydraulics requirements.
   - Control surface inputs/requirements. (Manual or remote)
     (Address remote surface power/signal specs & control system in section IV)
   - Level plate specifics. (Size, weight, good at phi = 0, 90, 180 deg. as app.)
     (Beta reference surface required)
   - Special fixtures for check loading etc.
   - Other test dependent equipment or facility modifications required
4. Optical / Flow Visualization Requirements
   (Schlieren/Shadowgraph, IR Thermography, PSP, PIV, Flourescents, Skin Friction Interferometry)
   - List of options
   - Data deliverable format requirements

IV. STRESS REQUIREMENTS **Approx. 15-20 min.**

(ARC Stress Engineer)

- What conditions are loads based on; theoretical or previous data?
- Model & sting assembly: (what parts have S.F. < 4 & 3 on ult. & yield?)
- Any exposed welds that are not otherwise bolted in. (inspect. req'd)

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Figure C-2: Initial Test Planning Meeting Guide (Sheet 1 of 3)

- Screw/bolt/pin certification, Hardness checks/requirements, lot inspection of fasteners
- Support system: Will any stings/adapters need special inspections?
- Balance inner rod safety factor. (catastrophic > 3.0)
- Proof loading requirements.
- We need estimated sting assembly deflection & lift curve slopes, & ref area.

V. INSTRUMENTATION **Approx. 30-45 min.**
(Test Manager and Instrumentation Engineer)

1. Balance: How was it sized? (supplier & backup)
   - Calibration (by who, load range, delivery format for Ames....)
   - Status of internal thermocouples.
   - Real-time & BLAMS monitoring capabilities.
2. Angle of attack: Sources (how many, main, supplier, conditioning....)
3. Pressures: PSI's or individual transducers. (who will supply, size, kind....)
   - Location (model or strut) (how are base & cavity read?)
   - Reference, monitor requirements, port assignments etc.
   - Tubing: Number, size, kind, supplier...
4. Dynamic (Test Dependent) Sensors
   - Dynamic Pressures: Kulites or PCB? Absolute or Differential?
   - Other Dynamic sensors
     - Type and number of sensors
     - Sampling data rate and point duration
5. Thermocouples. (additionals & type if applicable)
6. Position indicators. (if applicable)
7. Strain gages, hinge moments, buffet gauges, accelerometers, RMS system, & other unique requirements.
8. Photo/video requirements.
9. Cable routing, (internal or external to sting assembly) & length.

VI. DATA PROCESSING: Static and Dynamic, Data Quality **Approx. 30-45 min.**
(Test Manager)

<u>Standard Data System</u>

1. Acquisition Parameters
   - Set-point tolerance (Mach, Rn, Alpha/Beta, Humidity, Diamond Lane Productivity)
   - Sample duration (pitch-pause, continuous sweep)
   - Conditional sampling for improved data quality
2. Equations & corrections: Test equations supplied by NASA or Customer?
   - Aero Coefficients (Base & Cavity, Stream Angle, Buoyance, Wall Interference, Ducts)
   - Sign Convention
   - Coefficient Set Definitions (Uncorrected, Base and Cavity Only, Buoyance Only, Fully Corrected)
   - Axis System (Standard: Balance, Body, & Stability; Other: Missile, Aero Ballistic, ???)
   - Display &/or monitoring requirements.
3. Data reporting, monitoring, & analysis
   - ARC Standard names (AIAA standard nomenclature)
   - SDS standard features (Real-time monitors, DPS near-time plotting, formatted DBreport file outputs)
   - Customer plotting requirements (Map, tap, region pressure file set up?)
4. User computer: Ames-supplied / Customer-supplied
   - Files sent to AERONET Server (format and frequency, number of workstations required, other special needs)
   - Data system coordinator, Guest network access (control room, customer room)
5. Final transmittal medium and format (End of test & at 2 weeks post)
   - Post test recomputes

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Figure C-2: Initial Test Planning Meeting Guide (Sheet 2 of 3)

– Data media (Hard drive/DVD/CD-R format)

Dynamic Data Processing

1. Number of Channels
2. Sampling Rate
3. Sample Duration
4. Other
   – Pressure range / Frequency range
   – Amplifier requirements including voltage specs
   – AC or DC coupled?

Data Quality Assurance Plan (DQAP) / SDS Verification

1. Balance (Checkload criteria, Repeat runs, Wind off, Weight tares)
2. Angles (Referenced to standard, Calibrated and zeroed, Wind-off verification)
3. Pressures (Optimus System daily calibration, Up to 4 monitor pressures per module)
4. Humidity (monitored to keep data acqusition Within tolerance)
5. Excel Test case (independent verification)

VII. TEST SECURITY **Approx. 10-15 min.**

(Test Manager OR Security Representative)

1. Classification: Computed & raw data, model, pictures, etc....
2. Facility lock up, padlocks, combinations, main entrance, guards.....
3. Access list, changes, escorting, data storage.

VIII. SUMMARY AND ACTION ITEMS **Approx. 10-15 min.**

(Test Manager)

1. Review & summarize all action items and dates due.
   – Schedule, hardware, instrumentation, data reduction.

IX. Additional Information (As needed/As Desired)

The following information should be made available for presentation during the conduct of the Test Planning Meeting. Items 1-5 are available in the Test Planning Guide. Items 6-8 should be made available as required.

1. Test Planning Guide or sections of (stings, stress requirements…)
2. Facility true (actual) operating envelope
   a. Mach, Reynolds number and dynamic pressure limits
   b. Facility Accuracy limitations (Mach, PT, Q, balance)
3. Model support systems
4. Available balances and load limits
5. Instrumentation inventory
6. Facility dependent correction parameter requirements
   a. Starting loads
   b. TWICS, wall and blockage, Buoyancy
7. Conferees attendance list

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Figure C-2: Initial Test Planning Meeting Guide (Sheet 3 of 3)

C.4 Test Requirements Document Outline

Description

This outline is used by both the Customer and the Test Manager to delineate the requirements and objectives of the Customer. An example is shown in Figure C-3 and is also available at http://windtunnels.arc.nasa.gov/.

TEST REQUIREMENTS DOCUMENT OUTLINE

I. TEST PROGRAM OVERVIEW
- a) Program Overview and Objectives
- b) Program Schedule: Test Date and Duration
  - i) The current planned test dates include
    - (1) Model Preparation Room – 2 weeks of single shift operation starting XX
    - (2) 11x11-Ft TWT – XX week of double shift operation starting XX
    - (3) 9x7-Ft SWT – XX week of double shift operation starting XX

II. TEST OBJECTIVES AT AMES
- a) Type of Test
  - i) Force and Moment
  - ii) Dynamic Data
  - iii) Etc.
- b) Pressure Data Requirements
  - i) Static, Dynamic
- c) Run Schedule (Run Matrix)
  - i) Mach and Reynolds number range and tolerances required
  - ii) Run or Configuration Priorities
  - iii) Model Configuration Codes
  - iv) Expected Loads
  - v) Flow Angularity Runs
  - vi) Angle Schedule Requirements
    - (1) Angle ranges and increments
      - (a) Are these angle ranges the same for every Mach number? If not, provide different schedules and increments. Example: Alpha Schedule A1: -5 to 5 degrees by 1 deg.
    - (2) Angle Schedule Type: Sweep or Move Pause
    - (3) Tolerance required
- d) Test Support, Contacts, Addresses & Phone Numbers

III. MODEL & HARDWARE DESCRIPTION
- a) Support System Hardware
  - i) Ames Supplied and Customer Supplied
- b) Model Description and Scale
  - i) Reference Area, Span, Chord
  - ii) Model cross sectional areas and sting cavity area
  - iii) Inlet capture and nozzle exit areas
  - iv) Body and wing volumes for blockage
  - v) Top and side planform areas for starting loads
- c) Control Surfaces
  - i) Hinge Moment requirements, Load fixtures available, etc. Manual and/or remote - Power and signal conditioning, control and feedback
- d) Parts/Drawings list
- e) Boundary Layer Transition
  - i) Location, size and spacing

M Delgado 4/2014
JBE Updated 12/2016

Figure C-3: Test Requirements Document Outline (Sheet 1 of 3)

TEST REQUIREMENTS DOCUMENT OUTLINE

- ii) Who will supply and apply the transition
- f) Loads Sources & Estimates
- g) Model Instrumentation
- h) Model Leveling surface
  - i) Size and dimensions
  - ii) Functional at phi = 0°, 90° 180°, and 270° (where applicable)
  - iii) Functional at all alpha ranges (where applicable)
  - iv) AMS attachment pattern to be added to the level plate (drawing is available)
  - v) Reference surface for beta
- i) Model Check loading
  - i) Single point checkload performed in MPR and repeated in test section
  - ii) Requirements to load the model beyond single point load
    - (1) Provide load points on model

IV. INSTRUMENTATION
- a) Balance
  - i) Description, Capacity, Calibration, Backup, Pinhole to be used (to attach balance to model).
  - ii) Required accuracies (force and coefficients)
  - iii) Balance to Body Angles
  - iv) Balance to sting relationship
- b) Angle of Attack Source(s) and Locations
  - i) We have QFlex™ Model QA2000 sensors that can be used in the model and also can be placed on the support for base mounted sources. Accuracy of approximately 0.005º.
  - ii) The Support System Knuckle Sleeve Encoder outputs are also used as base angle sources. The accuracy of the Knuckle Sleeve Encoders is 0.05º.
- c) Pressure Instrumentation, Type, and Port Assignments
- d) Thermocouples, Strain Gages, Accelerometers, Position Indicators, Fouling Strip & Other
- e) Flow Visualization requirements
- f) Model Photo & Video
  - i) Required still and video recording equipment
  - ii) Digital Cameras available for use by customer
  - iii) Professional Installation images will be provided for one model configuration

V. DATA PROCESSING
- a) Acquisition Parameters
  - i) Point duration. For example:
    - (1) 1 second for move-pause data
    - (2) 0.5 second for continuous sweep
- b) Equations and Corrections
  - i) Test Dependent Equations and Parameters (supplied by Customer)
    - (1) ARC data system standard equations will be used. Tunnel conditions, balance, angles, weight tares, pressures measurements
  - ii) Aerodynamic Coefficients

M Delgado 4/2014
JBE Updated 12/2016

Figure C-3: Test Requirements Document Outline (Sheet 2 of 3)

TEST REQUIREMENTS DOCUMENT OUTLINE

(1) Corrections
  (a) Base and Cavity – Body Axis
  (b) Stream Angle (where applicable)
  (c) Buoyancy (where applicable) – Body Axis
  (d) Wall interference (TWICS) – Stability Axis
  (e) Duct Corrections – Table look up or curve fits of duct calibrations provided by customer
(2) Coefficient set definitions (examples below)
  (a) Uncorrected
  (b) Corrected for base and cavity only
  (c) Corrected for buoyancy only
  (d) Fully Corrected – Base, cavity. Buoyancy, wall interference

c) Customer Nomenclature list
  i) These are for the Data Transfer files provided to the customer for each run during the test. Please also provide the file format (.csv, .dat, etc)
  ii) Include Name, description and units for each term
  iii) Comprehensive List of Parameters

d) Computer Requirements in the Control Room and any special programs required on these computers

VI. SECURITY

a) Classification
  i) Model and Data: Supply required markings for test information and data
  ii) Installation and Configuration Photos

M Delgado 4/2014
JBE Updated 12/2016

Figure C-3: Test Requirements Document Outline (Sheet 3 of 3)

Appendix D Safety Quick Reference Guides

D.1 11-Foot Wind Tunnel

11-Foot TWT Safety Quick Reference Guide

Upon arrival, please see Shift Engineer or Test Manager for Facility Orientation and Questions

EMERGENCY RESPONSE

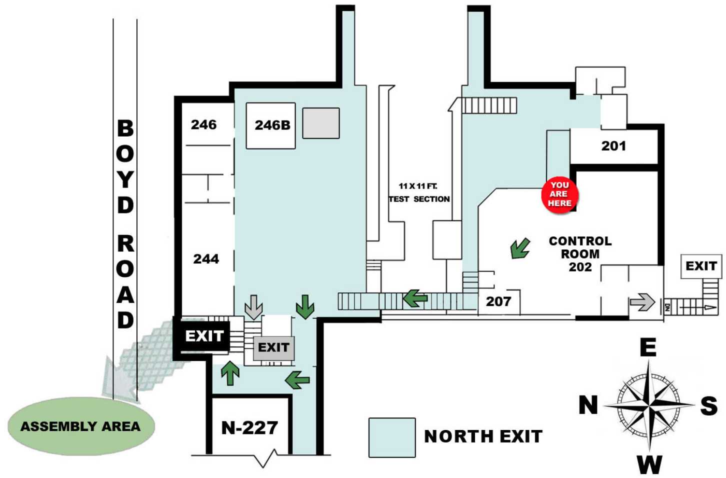
To report emergencies, call 911 from any Ames landline or 650-604-5555 by cell phone

Do not dial 911 from your cell phone, as it will not alert local emergency response personnel on Center.

Fire Emergencies - Audible and visible fire alarms will notify you of the need to evacuate the facility.

Earthquake Emergencies - Your assembly area following an earthquake will be the same as the fire emergency assembly area. Please remain at the assembly area until emergency personnel notify us that it is safe to reenter the building. The red dot on the map is near the customer area of the control room.

Evacuation Map



ACCIDENTS/INCIDENTS

All incidents and injuries that take place within our facilities must be reported immediately to the Shift Engineer (SE) or the Test Manager (TM). For non-emergency injuries, visitors are permitted to utilize the services of the Ames Health Unit between the hours of 7:30 am and 4:00 pm M-F. The Health Unit is located in building N-215 (across the street from the cafeteria). You may contact the Health Unit from any Ames phone Ext 4-5287. After hours and weekends, use El Camino Hospital Emergency Room 2800 Grant Ave, Mountain View CA 94040.

TEST SECTION SAFETY

The test section shall not be entered until the Wind Tunnel Mechanics have prepared the test section with adequate lighting, model edge protection and Lockout/Tagout as needed.

11-Foot TWT - When entering the test section diffuser hatches there is low overhead clearance that can deliver a dangerous head bump. Please use the handrails as you descend the stairs.

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D.2 9x7-Foot Wind Tunnel

9x7-Foot SWT Safety Quick Reference Guide

Upon arrival, please see Shift Engineer or Test Manager for Facility Orientation and Questions

EMERGENCY RESPONSE

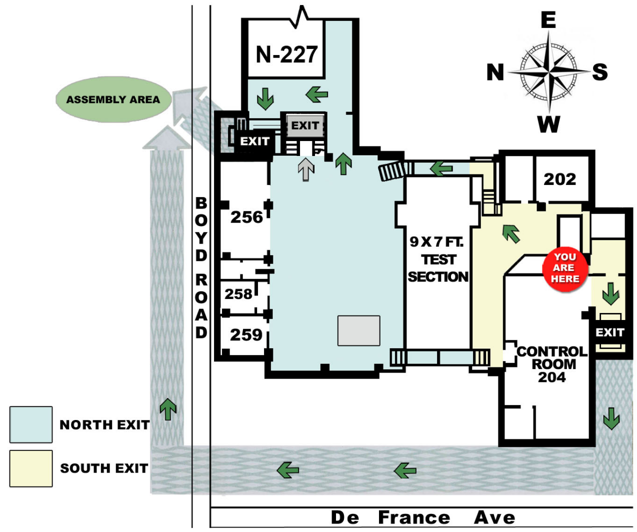
To report emergencies, call 911 from any Ames landline or 650-604-5555 by cell phone

Do not dial 911 from your cell phone, as it will not alert local emergency response personnel on Center.

Fire Emergencies - Audible and visible fire alarms will notify you of the need to evacuate the facility.

Earthquake Emergencies - Your assembly area following an earthquake will be the same as the fire emergency assembly area. Please remain at the assembly area until emergency personnel notify us that it's safe to reenter the building. The red dot on the map is near the customer area of the control room.

Evacuation Map



ACCIDENTS/INCIDENTS

All incidents and injuries that take place within our facilities must be reported immediately to the Shift Engineer (SE) or the Test Manager (TM). For non-emergency injuries, visitors are permitted to utilize the services of the Ames Health Unit between the hours of 7:30 am and 4:00 pm M-F. The Health Unit is located in building N-215 (across the street from the cafeteria). You may contact the Health Unit from any Ames phone Ext 4-5287. After hours and weekends, use El Camino Hospital Emergency Room 2800 Grant Ave, Mountain View CA 94040.

TEST SECTION SAFETY

The test section shall not be entered until the Wind Tunnel Mechanics have prepared the test section with adequate lighting, model edge protection and Lockout/Tagout as needed.

9x7-Foot SWT - There is low overhead clearance when crossing under the model support system.

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D.3 Model Prep Rooms

Model Prep Room Safety Quick Reference Guide

Upon arrival, please see Shift Engineer or Test Manager for Facility Orientation and Questions

EMERGENCY RESPONSE

To report emergencies, call 911 from any Ames landline or 650-604-5555 by cell phone

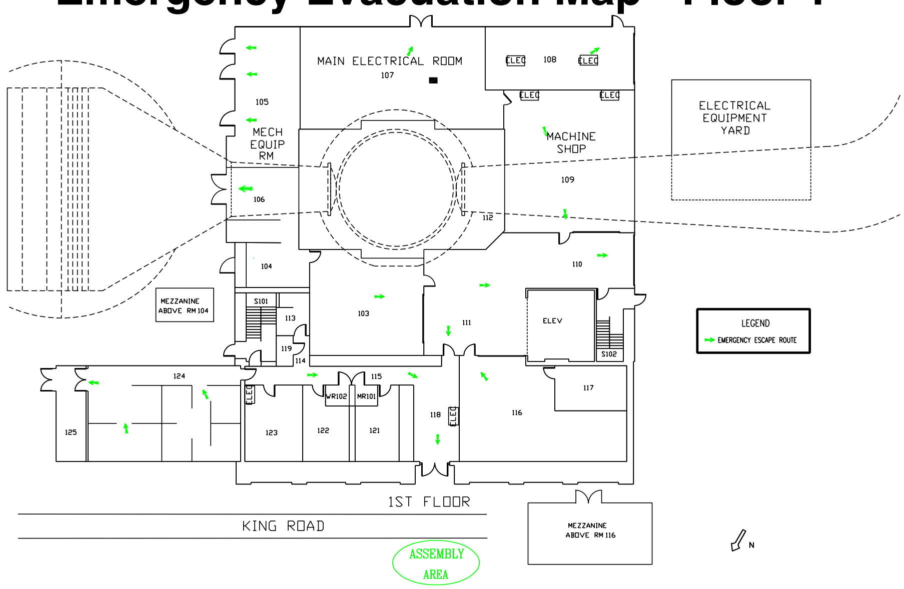
Do not dial 911 from your cell phone, as it will not alert local emergency response personnel on Center.

Fire Emergencies - Audible and visible fire alarms will notify you of the need to evacuate the facility.

Earthquake Emergencies - Your assembly area following an earthquake will be the same as the fire emergency assembly area. Please remain at the assembly area until emergency personnel notify us that it is safe to reenter the building.

Evacuation Map

N-206
Emergency Evacuation Map - Floor 1



ACCIDENTS/INCIDENTS
All incidents and injuries that take place within our facilities must be reported immediately to the Shift Engineer (SE) or the Test Manager (TM). For non-emergency injuries, visitors are permitted to utilize the services of the Ames Health Unit between the hours of 7:30 am and 4:00 pm M-F. The Health Unit is located

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