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Investigative Report

Supersonic Particle Impact Test Capabilities

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Abstract

NASA Johnson Space Center White Sands Test Facility (WSTF) performed particle impact flow tests to determine the maximum capabilities of the particle impact test systems in different configurations. Additional flow tests were performed to determine the target pressures at given upstream conditions to supplement the WSTF data located in ASTM Manual 36 (2000).

This report summarizes the investigation and results of the flow tests completed at WSTF.

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Abbreviations

ABO	Aviator's Breathing Oxygen
ASTM	American Society for Testing and Materials
ECN	Engineering Control Number
JSC	NASA Johnson Space Center
PT	Pressure Transducer
STP	Special Technical Publication
TT	Temperature Thermocouple
WSTF	White Sands Test Facility

1.0 Introduction

NASA Johnson Space Center (JSC) requested NASA JSC White Sands Test Facility (WSTF) to perform particle impact system flow tests to determine the maximum capabilities of the supersonic particle impact test system in different configurations. The WSTF supersonic particle impact test system is normally used with an injector capable of injecting single large particles. Testing was performed December 7 and 11, 2006 to determine the capabilities of the supersonic test system in this normal configuration, as well as with the subsonic injector, which is capable of injecting particle mixtures. In addition, flow testing was performed to determine the target pressures at given upstream conditions to supplement the data located in American Society for Testing and Materials (ASTM) Manual 36, pp. 58-59 (2000). ASTM Manual 36 (2000) was developed and written at WSTF.

This report summarizes the flow tests completed at WSTF.

2.0 Objective

The objective of this investigation was to determine the maximum capabilities of the WSTF supersonic particle impact test system in different configurations, as well as to determine the target pressures at given upstream conditions in order to supplement ASTM Manual 36 (2000).

3.0 Test Methods

The following paragraphs describe the materials and procedures used in this investigation.

3.1 Materials

There were no particles or target samples for these tests. A pitot tube was used to measure the pressure where the target would normally be in actual tests.

3.2 Test Setup and Procedures

For the first series of flow tests, the supersonic nozzle was installed on the outlet of the flow straightener and subsonic injector assembly (Figure 1). In actual testing, the use of the subsonic injector would allow particle mixtures to be used, instead of the normal supersonic configuration that allows only single particles. The pitot tube was positioned on the end of the supersonic nozzle (Figure 2). In this first series of tests, the maximum capabilities for performing supersonic tests with particle mixtures were determined.

For the second series of flow tests, the standard supersonic test configuration was used, which is comprised of the supersonic injector, flow straightener, and the supersonic nozzle (Figure 3). Flow tests were performed in this second test series to determine the maximum capabilities of the normal supersonic test system, which allows for testing with single particles. In addition, tests were performed to determine the target pressure and temperature, with given upstream conditions, to supplement WSTF test data located in ASTM Manual 36, pp. 58-59 (2000).

For both series of tests, all six tube banks of oxygen were used. The tube banks provide pressure to the test system.

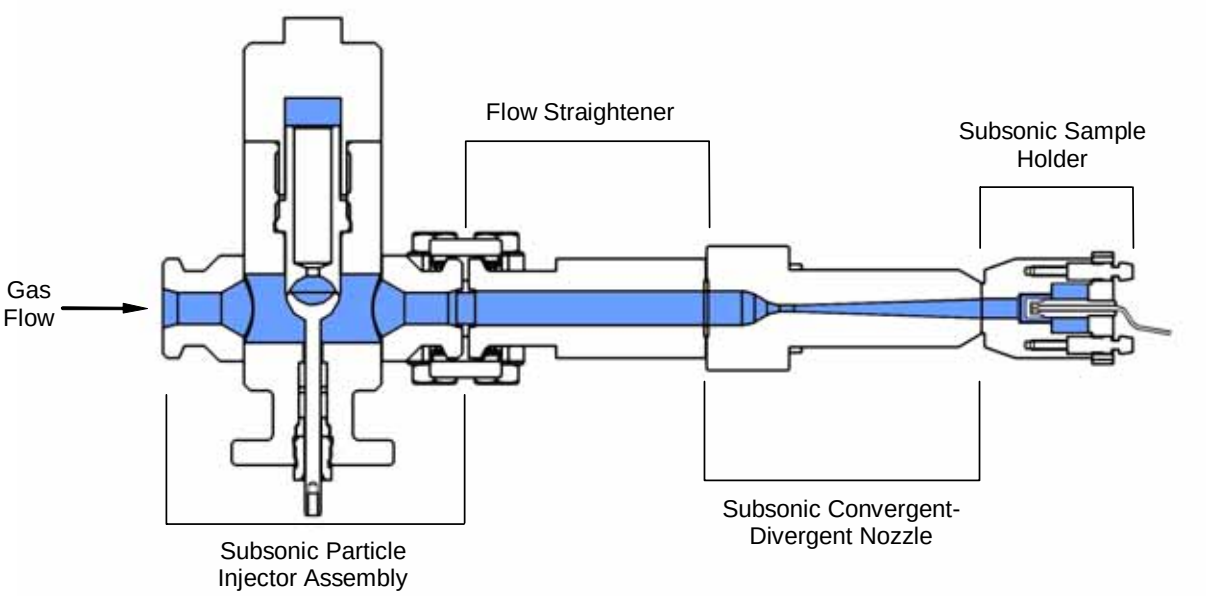

Figure 1
Subsonic Injector with Supersonic Nozzle Configuration

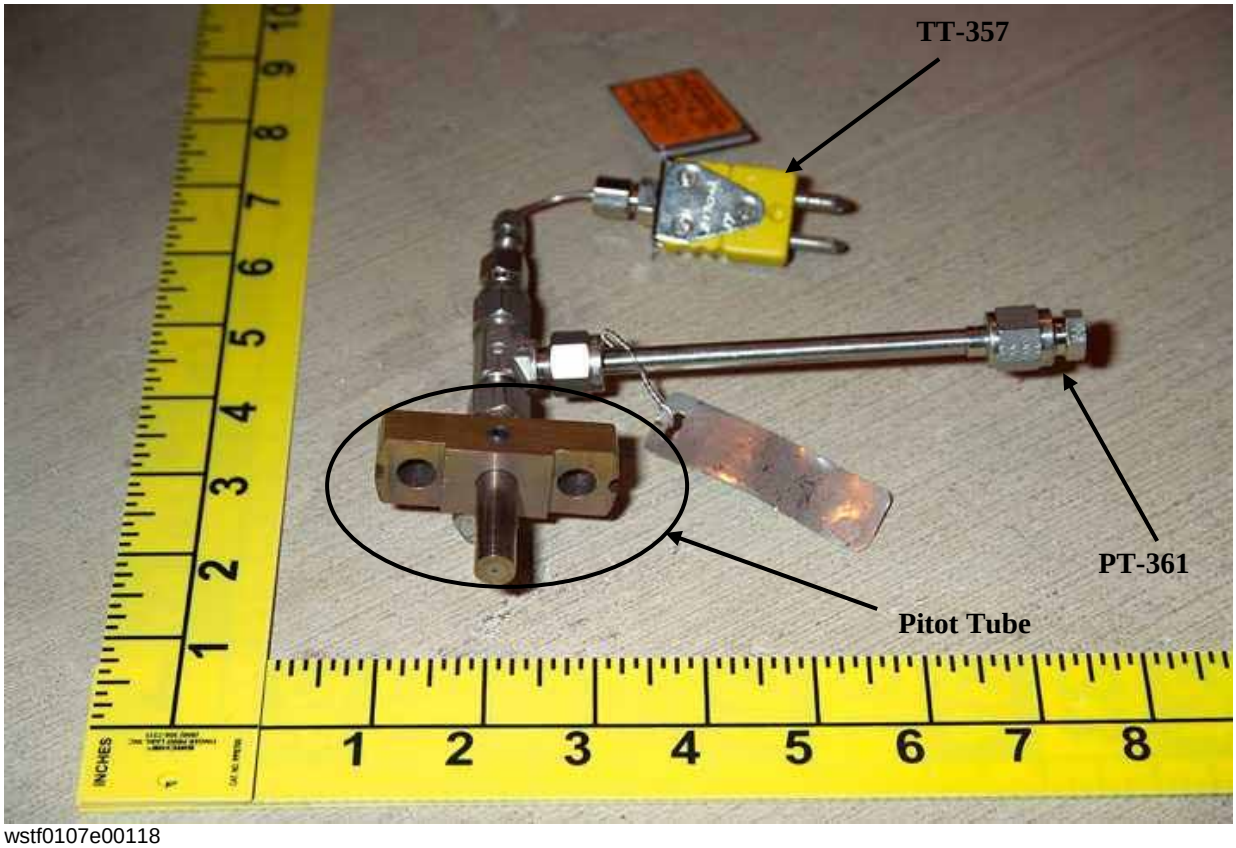

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Figure 2
Supersonic Pitot Tube

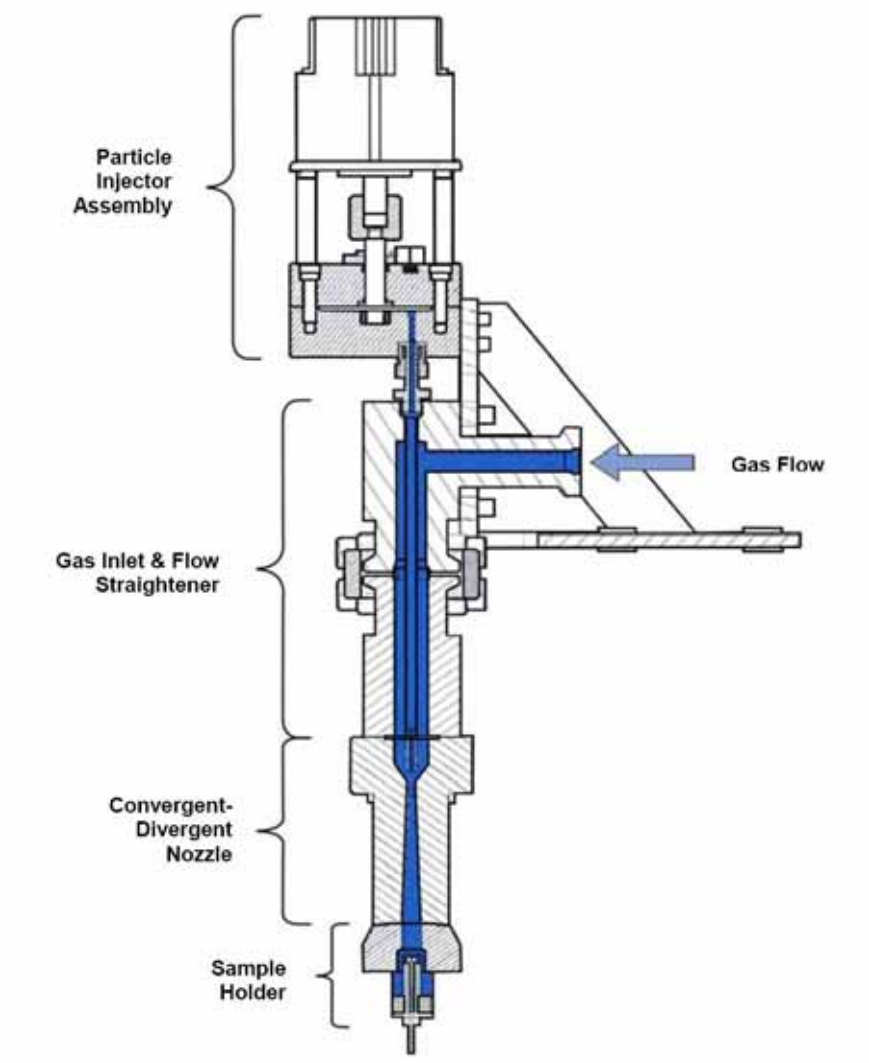

Figure 3
WSTF Standard Supersonic Particle Impact Test System

After system preparation was completed, the test area was cleared of personnel and placed in a red status. A video camera was positioned to record any reaction visible at the end of the test fixture. The SUBPITX data acquisition program was started, and then test conditions were entered into the test computer. The SUBPITX program is used only to collect flow data. The computer established the conditions in the test facility. Heated gaseous aviator's breathing oxygen (ABO-) grade oxygen at test pressure was allowed to flow until the desired temperature of the target sample was achieved and the gas flow stabilized. Upon command, the test computer activated the data collection system. After an acceptable amount of data was collected, data collection was stopped, the oxygen flow was terminated, and the test system was allowed to vent down to ambient pressure. The test computer saved the test data and system data. The test pressures, test temperatures, and average flow meter data were recorded in the 250-Area test log book. At the completion of test data storage, the procedure was repeated.

4.0 Experimental

For both series of tests, pressure transducer PT-361 measured the pressure at the pitot tube and PT-132A measured the upstream pressure at the inlet to the subsonic injector. PT-361 (Engineering Control Number (ECN) # M891536) was a 3K pressure transducer. PT-132A (ECN # M895582) was a 7.5K pressure transducer. PT-132B controls the flow control valve and should remain with a 7.5K pressure transducer. PT-132A and PT-132B should read the same upstream pressure. Temperature thermocouple TT-357 measured the temperature at the pitot tube, and TT-133B measured the upstream temperature at the inlet to the subsonic injector.

5.0 Results and Discussion

The following paragraphs present the results and discussion for the two series of flow tests performed with the WSTF particle impact test systems.

5.1 Test Series 1 Flow Test Results

For the first series of flow tests, the supersonic nozzle was installed on the outlet of the subsonic injector assembly (Figure 4). Figure 4 shows the locations of the PTs and TTs that were used for data collection in Test Series 1. In this configuration, the approximate maximum capabilities were determined for supersonic particle impact testing with particle mixtures (Table 1). The pressure readings at PT-361 are approximations of what can be obtained at the target in the actual particle impact tests. This maximum pressure will vary depending on temperature and the tube bank pressure. The maximum tube bank pressure could be as high as 5900 psi after recharging; however, if testing is not completed the same day as the recharge, pressure decays overnight. So, the initial tube bank pressures shown in Table 1 are more representative of what would actually be available on a day of particle impact testing. It is important to note that although the target pressure of approximately 1954 psia can be obtained, not many tests can be performed at this condition in one day.

5.2 Test Series 2 Flow Test Results

For the second series of flow tests, the standard supersonic configuration was used (Figure 5). In this configuration, the approximate maximum capabilities were determined for supersonic particle impact testing with single particles (Table 2). In addition, given specific upstream pressures and temperatures, the target pressures and temperatures were determined (Table 3) so that the WSTF test data located in ASTM Manual 36, pp.58-59 (2000), can be used appropriately. The testing reported in ASTM Manual 36 (2000) was performed at an upstream pressure of 3900 psig with upstream temperatures ranging from 115 to 800 °F. However, the pressures at the target for this set of data were not known. In the flow tests, the upstream pressure achieved was between 3905 and 3908 psig. For an upstream pressure of exactly 3900 psig, the target pressure (PT-361) would be slightly below 1273 psia.

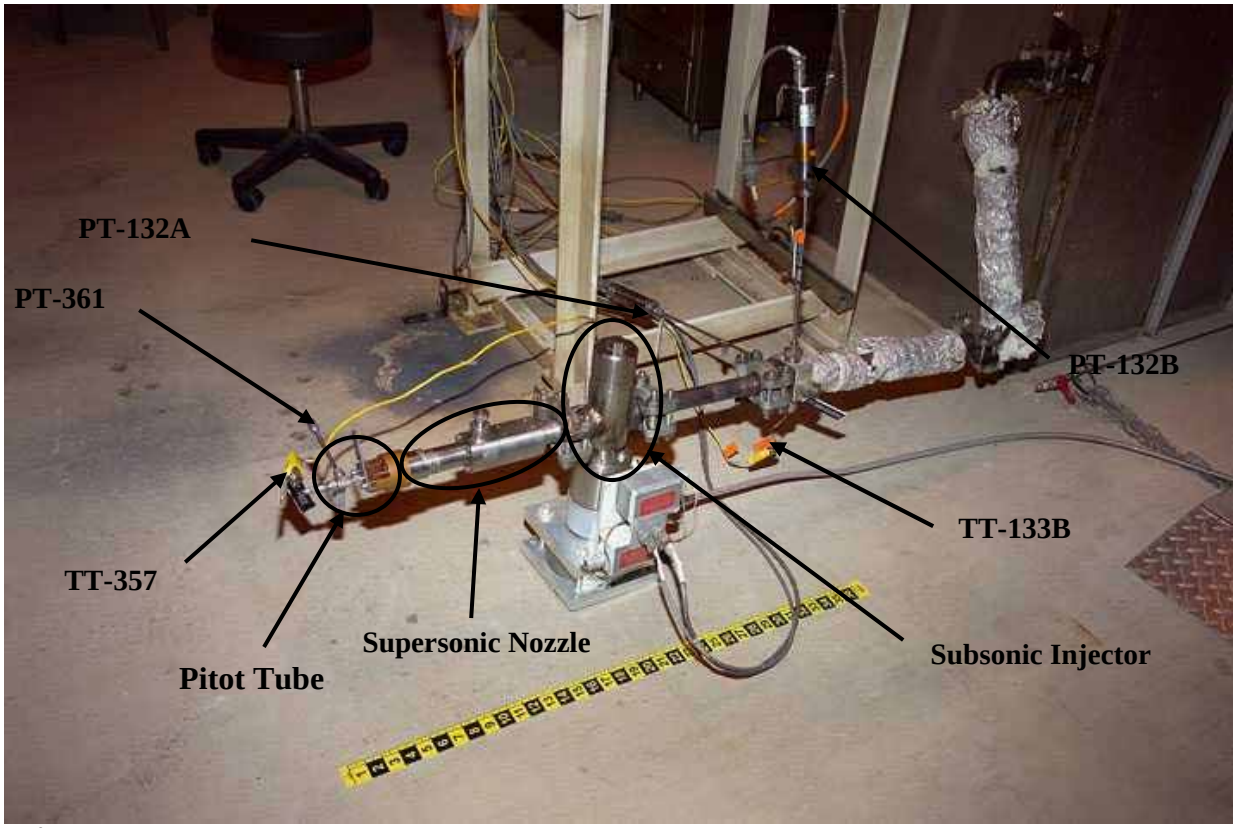

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Figure 4
Subsonic Injector with Supersonic Nozzle Configuration

Table 1
Test Series 1 Flow Test Data
(Maximum Capabilities for Supersonic Particle Impact Testing with Particulate Mixtures)

Tube Bank Pressure	Pitot (Target) Pressure PT-361	Upstream Pressure PT-132A	Pitot (Target) Temperature TT-357	Upstream Temperature TT-133B
(psi)	(psia)	(psig)	(°F)	(°F)
5336	1954	5093	250	248
5283	1944	5042	220	213
5205	1904	4939	155	155
5156	1832	4895	126	134
5122	1789	4848	112	124

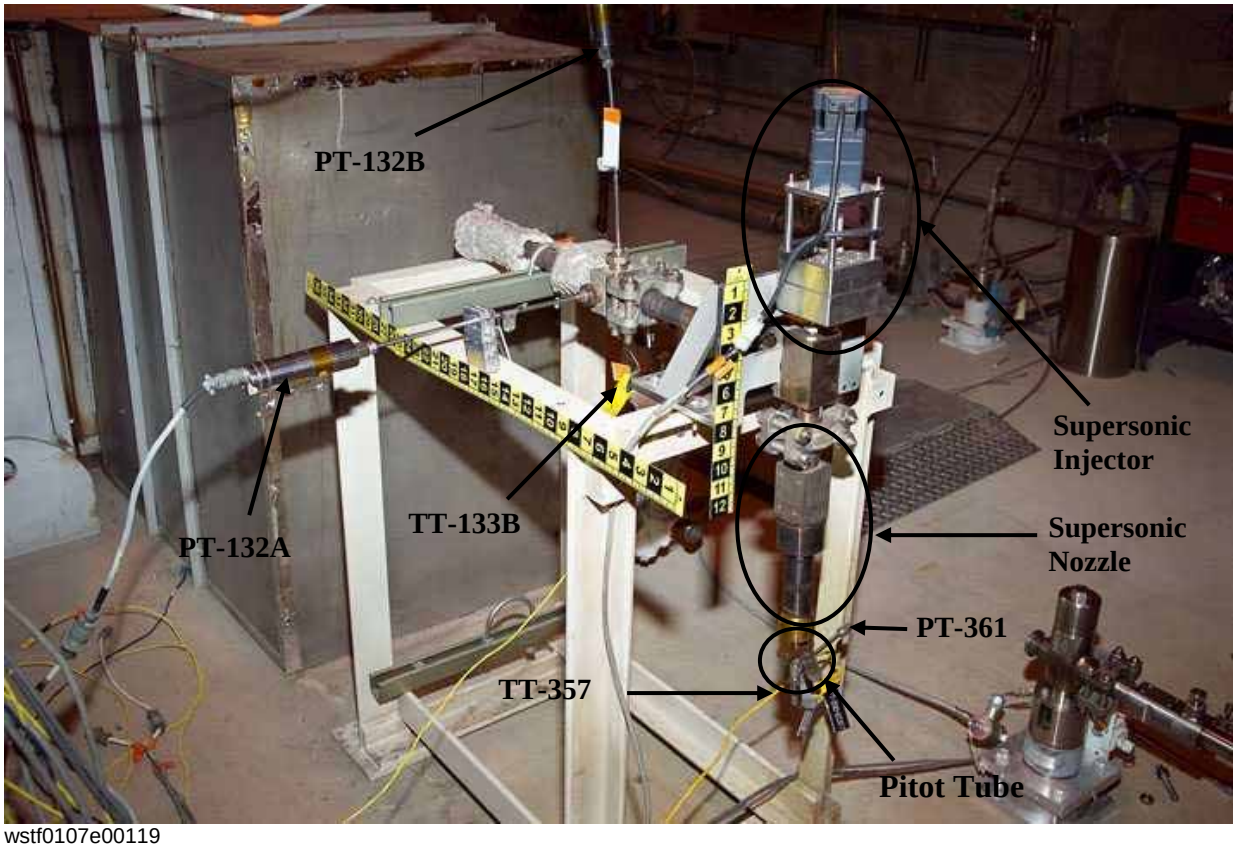

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Figure 5
Standard Supersonic Configuration

Table 2
Test Series 2 Flow Test Data
(Maximum Capabilities for Supersonic Particle Impact Testing with Single Particles)

Tube Bank Pressure	Target Pressure PT-361	Upstream Pressure PT-132A	Pitot (Target) Temperature TT-357	Upstream Temperature TT-133B
(psi)	(psia)	(psig)	(°F)	(°F)
4900	1532	4636	114	127
5736	1822	5338	169	169

Table 3
Test Series 2 Flow Test Data
(Manual 36)

Tube Bank Pressure	Target Pressure PT-361	Upstream Pressure PT-132A	Pitot (Target) Temperature TT-357	Upstream Temperature TT-133B
(psi)	(psia)	(psig)	(°F)	(°F)
5604	1273	3908	801	751
5551	1280	3908	591	538
5512	1292	3908	417	369
5434	1305	3905	208	196
5439	1305	3908	118	128

6.0 Conclusions

The maximum test capabilities for the WSTF supersonic particle impact test system were determined for both the standard configuration (which allows testing with single particles) as well as a modified configuration (which allows testing with particle mixtures). In the standard configuration, it was determined that the maximum target pressure is ~ 1800 psia. In the modified configuration, it was determined that the maximum target pressure is ~ 2000 psia.

In addition, tests were performed to determine the target pressures that correspond with the WSTF data reported in ASTM Manual 36, pp. 58-59 (2000). It was determined that the target pressures for this data were in the range of 1260 to 1310 psia. This information is useful in ensuring that the data in Manual 36 (2000) is applied appropriately.

Reference

ASTM Manual 36. *Safe Use of Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation,* H. D. Beeson, W. F. Stewart, S. S. Woods, Editors, American Society for Testing and Materials, West Conshohocken, Pennsylvania, pp. 58-59, 2000.

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