N75 20403

IMPACT OF THE RETAINED HEAT SHIELD CONCEPT ON SCIENCE INSTRUMENTS

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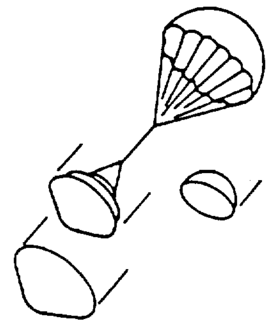
MR. KESSLER: The preceeding speakers in the science session have discussed the design and the operation of a specific science instrument. This presentation will consider the associated interface problems between the mass spectrometer and the actual probe design and consider the problem of providing a clean sample to the gas detection instrument.

McDonnell-Douglas has adopted the retained heat shield concept (Figure 8-33) where the heat shield is retained throughout the entire descent trajectory, in the design of an outer planet probe. This was done because of potential high reliability and savings in development costs as well as an associated lower weight. Once the peak deceleration and peak heating environment have been traversed and the probe reaches subsonic velocity, it becomes necessary to expose the scientific instruments to the ambient atmosphere. This is accomplished in the probe design by penetrating the heat shield with sampling tubes.

Of particular interest is the penetration of the heat shield by the mass spectrometer sampling tube, because not only do we have to demonstrate that the sampling tube can penetrate the heat shield but also that the mass spectrometer can be supplied with a contaminant-free gas sample, free of contaminants from out-gassing of the heat shield.

These two shadow-graph photographs (Figure 8-34) were obtained in the pressurized ballistic range facility at NASA Ames. The ballistic range models incorporate an extended tube at the stagnation point to simulate the sampling tube for the mass spectrometer. The tests were conducted at a Mach nine-tenths condition to match the actual flight deployment conditions for the sampling tube. These flow field visualization pictures illustrate basic flow field features that cannot be duplicated by computational techniques. Note that right around the base of the sampling tube there is a small



	RETAINED HEATSHIELD (BASELINE)	JETTISONED HEATSHIELD
PRIMARY ADVANTAGES	• SIMPLE PASSIVE SYSTEM	• M/C_DA IS MORE ACCURATE
PRIMARY DISADVANTAGES	• CANNOT TAILOR DESCENT RATES, IF REQUIRED	• ΔWt = 33 LB (13% INCREASE OVER BASELINE) • COMPLEX ACTIVE CHUTE STAGING
QUESTIONS REQUIRING PROOF OF CONCEPT	• DEMONSTRATE INHERENT DYNAMIC STABILITY • DEMONSTRATE HEATSHIELD PENETRATION TECHNIQUE • ENSURE CONTAMINATION FREE ATMOSPHERIC SAMPLES	• DEMONSTRATE HEATSHIELD RELEASE AND CHUTE DEPLOYMENT SEQUENCE • DEMONSTRATE SPACE STORAGE LIFE OF CHUTES • ENSURE CONTAMINATION FREE ATMOSPHERIC SAMPLES

Figure 8-33. Basic Concept

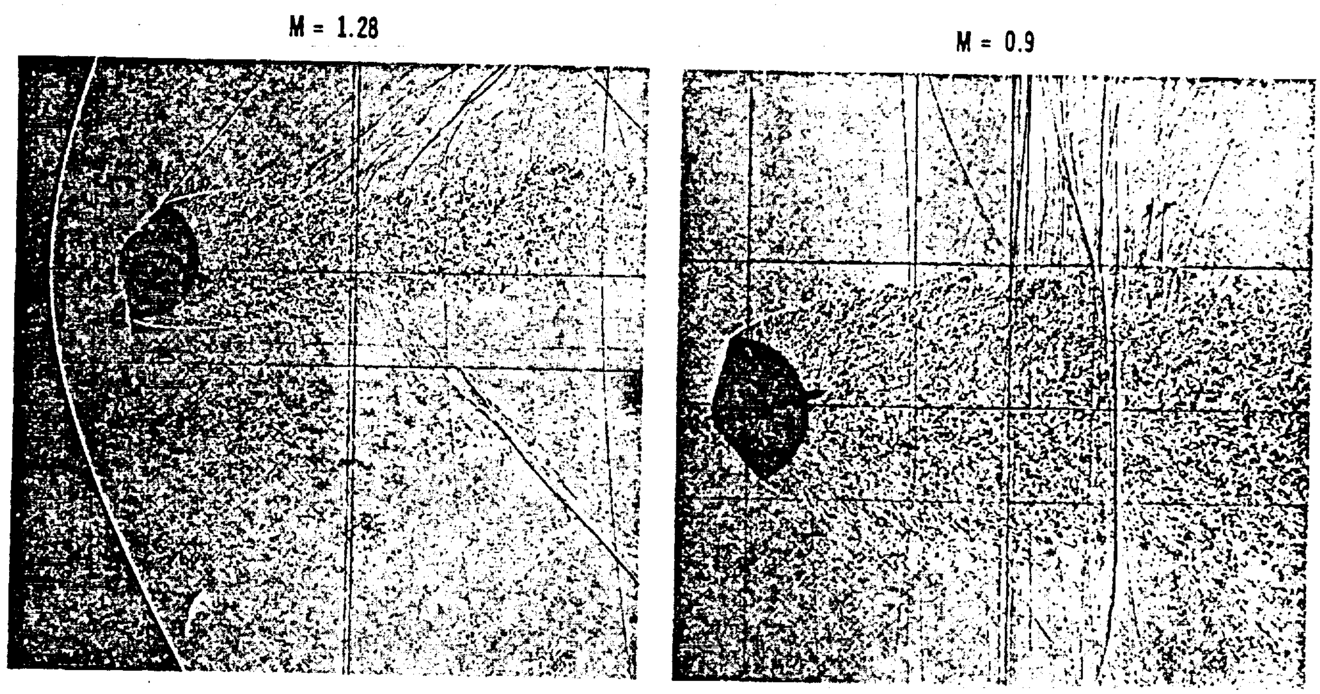


Figure 8-34. Ballistic Range Tests

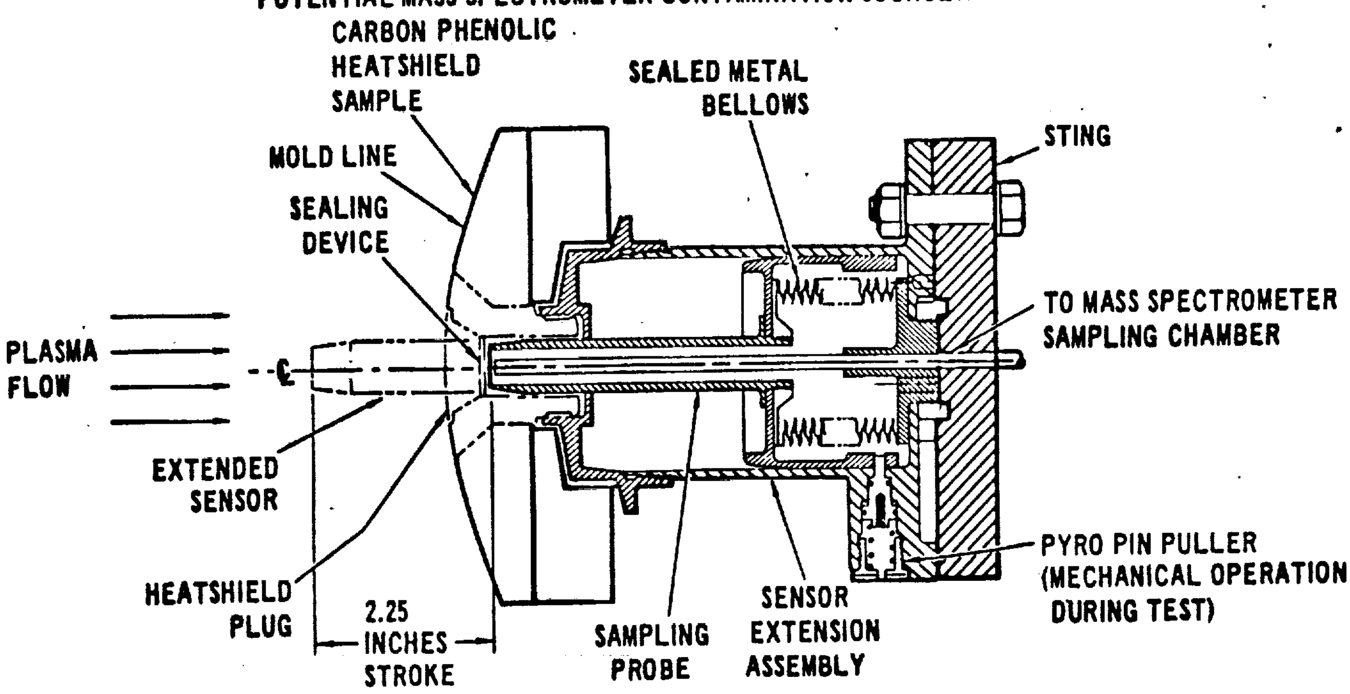
region of separated flow. It is also noted that locally the sampling tube appears to trip the laminar boundary layer.

The remaining charts review two "proof-of-concept" test programs that will be conducted in the near future at the NASA Ames Research Center. The first test will determine the feasibility of penetrating the charred heat shield with a sampling tube and collecting a clean sample for the mass spectrometer analysis. The second test will determine whether or not any contaminants from the out-gassing of the charred heat shield are ingested by the sampling tube.

The first test is to verify the feasibility of penetrating the charred heat shield. The interface between the mass spectrometer sampling chamber and the ambient atmosphere is the sensor extension assembly (Figure 8-35). Within the sensor extension

PURPOSE

VERIFY CAPABILITY TO PENETRATE HEATSHIELD AND EVALUATE POTENTIAL MASS SPECTROMETER CONTAMINATION SOURCES.



TEST RESULTS

- HIGH SPEED MOTION PICTURES OF THE HEATSHIELD PENETRATION
- HEATSHIELD TEMPERATURE TIME HISTORIES
- CONTAMINATION MEASUREMENTS BEFORE, DURING AND AFTER SENSOR DEPLOYMENT

Figure 8-35. Test 1: Sensor Extension Test Program assembly there is a sealed metal bellows which is in a compressed condition. Once the peak deceleration and peak loading regime has been traversed and a subsonic environment encountered, the energy in the compressed bellows is released and the carbon phenolic plug and the sealing device are pushed out into the main stream of the flow. The sampling tube extends two inches in front of the charred heat shield ablator and is used to bring samples of the atmosphere into the mass spectrometer.

This test will be conducted in the plasma arc facility at NASA/ARC. High speed motion picture data will be used to determine the trajectory of the plug as it comes out of the heat shield.

The tests will be conducted at two extreme conditions: one, typical of a shallow entry into a warm atmosphere; and the other a steep entry into a cool atmosphere. The solid lines on Figure 8-36 indicate the actual conditions along the descent trajectory, the dashed lines indicate the simulating test condition. During

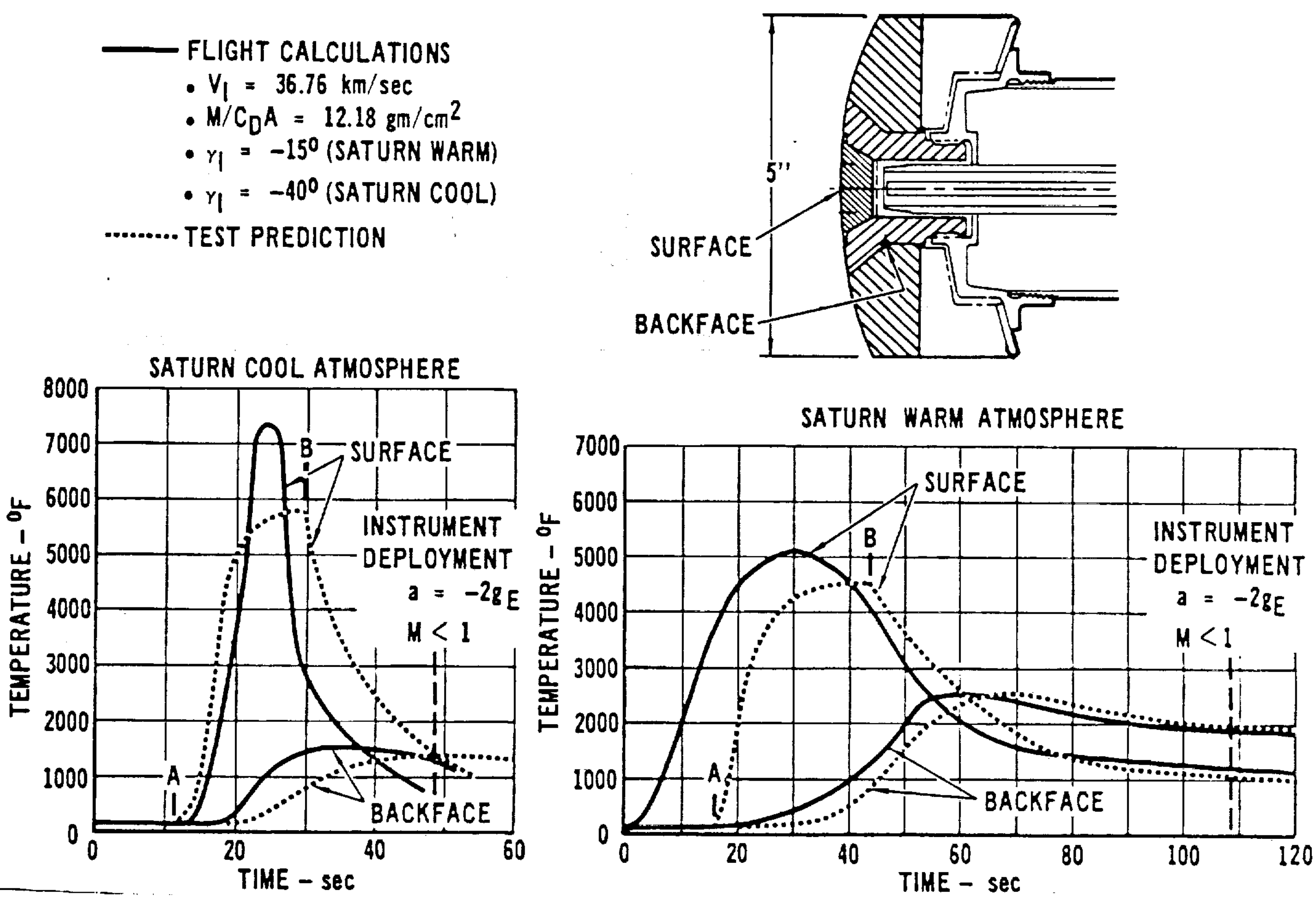


Figure 8-36. Test 1: Plasma Jet Simulation of Entry Environment

the test, the backface temperature at the deployment conditions and the total heat flux underneath the curves will be matched.

The second program to be conducted will determine if any contaminants from the heat shield outgassing are ingested by the sampling tube. The tests will be conducted for the worse case flight conditions for outgassing (Figure 8-37). These worst case conditions are the shallow entry into the warm model atmosphere. The trajectory point being the deployment conditions for the mass spectrometer sampling tube. This point is where the outgassing mass flow rate is still high. Setting the worst case conditions for outgassing determines the local free stream conditions - a Mach number of nine tenths, and a Reynolds number based on the probe diameter of one and one half million. Also, at this point the ablator characteristics and the wall conditions are known from heat shield analysis. The test program, to be defined here, considers methods of scaling these flight conditions to a wind tunnel test program to obtain parametric data on outgassing contamination.

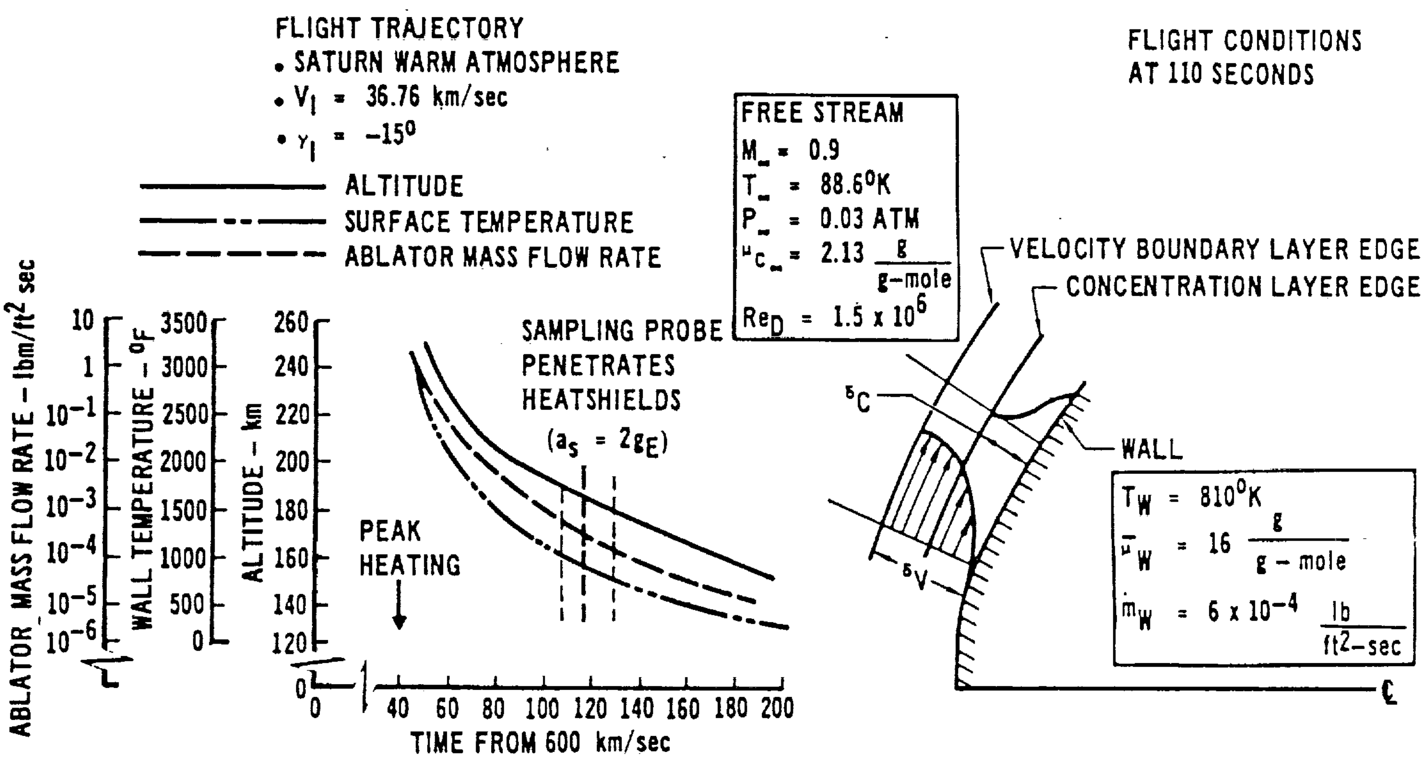


Figure 8-37. Test 2: Flight Conditions

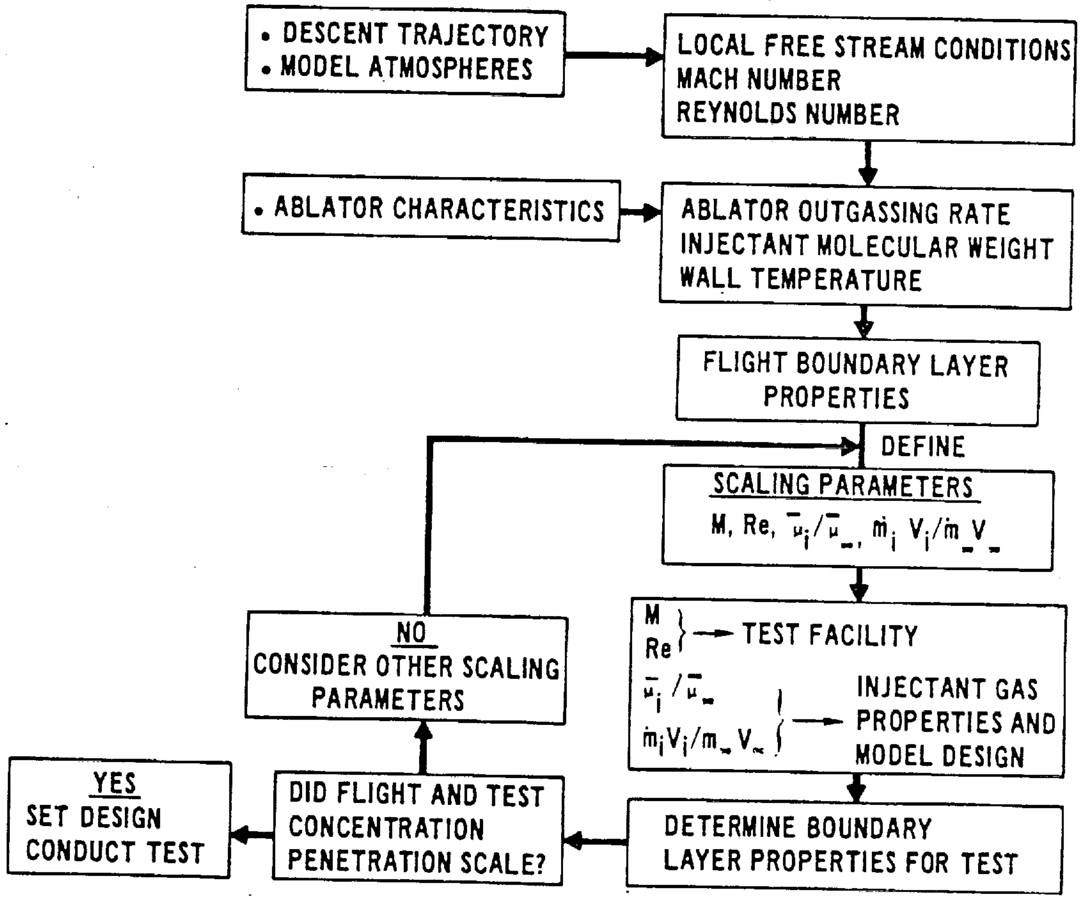


Figure 8-38. Test Definition Flow Diagram

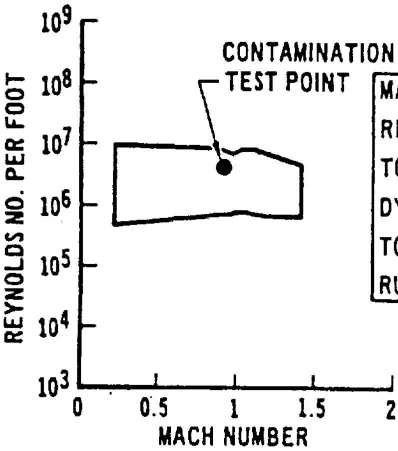
The technique used in the test definition is to define the descent trajectory and the heat shield characteristics (Figure 8-38) so that the flight boundary layer properties can be determined. The objective then becomes scaling these parameters to an inexpensive wind tunnel test program. The Mach number, the Reynolds number, the ratio of the injected gas to free stream molecular weight, and the momentum flux ratio of the injected gas and the free stream are the flight parameters matched in the test. The Mach number and the Reynolds number define the test facility which for these conditions will be a transonic test facility. The molecular weight ratio and the momentum flux ratio determine the injected gas and the mass flow properties of the injected gas. Boundary layer calculations are made for the probe without a sampling tube at the stagnation point and the flight and test boundary layer profiles compared to determine if a simulation was achieved.

In comparing the results, the determination if the contaminant gas (the one that is injected) penetrates the same distance through the velocity boundary layer as it did in the flight case is considered to be the criterion for simulation. These boundary layer computations have been completed and the indicated scaling parameters were found to be the test for simulating the flight conditions.

The test program will be conducted in the NASA Ames two-foot by two foot transonic test facility. Figure 8-39 illustrates the envelope of the test conditions and where the contamination test point is located. The schematic on the right is the test model. The model has a permeable forebody, the center is the plenum chamber for the contaminate gas. The plenum will be supplied with a heavy molecular weight gas that diffuses through the permeable forebody and into the boundary layer to simulate the heat shield out-gassing under flight conditions. Parametric data will be obtained in the program by varying the angle of attack range from zero degrees to twenty degrees, the sampling tube length from zero to twice nominal, and the injected mass flow rate by a factor of five (greater and less) about the nominal.

An on-line mass spectrometer will measure the presence of the contaminant gas in the sampling tube.

In conclusion (Figure 8-40) the retained heat shield concept requires various proof of concept tests to demonstrate the feasibility of penetrating the heat shield and the cleanliness of the mass spectrometer sample. Test programs have been defined to demonstrate these points and we are currently in the process of conducting these tests.



MACH RANGE:	0.2 TO 1.4
REYNOLDS NUMBER ($\times 10^6$/ft):	0.5 TO 8.7
TOTAL PRESSURE (psia):	2.3 TO 44.1
DYNAMIC PRESSURE (psf):	60 TO 2175
TOTAL TEMPERATURE (^oR):	580
RUN TIME:	CONTINUOUS

FLIGHT CONDITIONS MATCHED IN WIND TUNNEL TEST:

- MACH NUMBER
- REYNOLDS NUMBER
- MOLECULAR WEIGHT RATIO
- MOMENTUM FLUX RATIO

TEST PARAMETERS

ANGLE OF ATTACK: $0^o - 20^o$

SAMPLING TUBE LENGTH: 0.0 – 0.2 INCHES

INJECTANT MASS FLOW RATE: $0.5 \times 10^{-2} - 3 \times 10^{-2}$ $\frac{lb_m}{ft^2 - sec}$

MEASUREMENTS

PRESENCE OF CONTAMINATE GAS

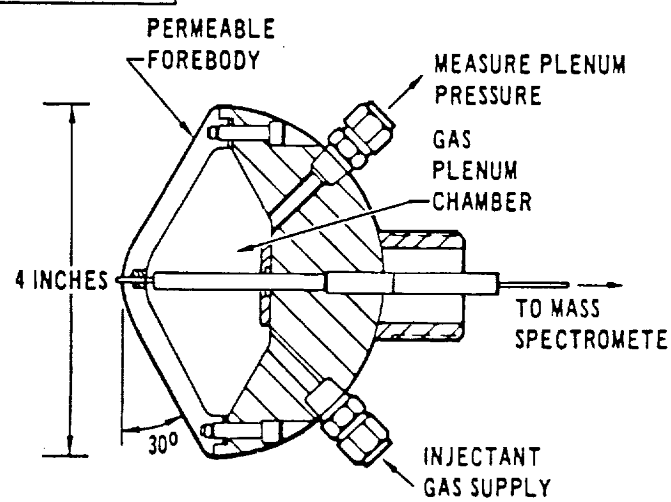


Figure 8-39. Test 2: Transonic Wind Tunnel Test Program

- THE RETAINED HEATSHIELD CONCEPT POTENTIALLY PROVIDES A HIGHLY RELIABLE MINIMUM WEIGHT ENTRY PROBE DESIGN.
- PROOF-OF-CONCEPT TESTING IS REQUIRED TO DEMONSTRATE HEATSHIELD PENETRATION AND TO ENSURE AGAINST SAMPLING CONTAMINATION.
- TEST PROGRAMS HAVE BEEN DEFINED AND WILL BE CONDUCTED TO PROVIDE THE NECESSARY DATA FOR EVALUATING THE RETAINED HEATSHIELD CONCEPT.

Figure 8-40. Summary