Report on Contract NAGW 248

of the National Aeronautics and Space Administration

for a

DESIGN STUDY OF AN ENTRY PROBE SPECTRO-REFLECTOMETER

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by

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Final Report on the "Design Study of an Entry-Probe Spectro-Reflectometer"

A renewal of proposal for this project was submitted in September 1983 to NASA for continued funding and this was approved. In the Renewal Request, we included a progress report on the work completed the previous year, which dealt mainly with the design on fabrication of the "Jupiter Wind Tunnel." This is reproduced below, and should serve as a final report for the first proposal. The actual renewal obtained for 1984 was given a new funding number, PR #10-31491.

I. Introduction

The Entry Probe Spectro-Reflectometer is an instrument which is suitable for measuring the condensable minor species of a planetary atmosphere, as well as the aerosols in a planetary cloud deck. The condensable minor gaseous species are frozen out on a cold finger and identified by their infra-red reflection spectrum. The aerosols are simply collected by an ambient surface, such as a filter, and may be identified by infrared reflection spectroscopy.

The probe is particularly useful in reducing atmospheres since the major components of these atmospheres (H_2 and He in the case of giant planets; or N_2 in the case of Titan) are not condensable at the temperatures of typical cold fingers (70-80K). This allows the minor components to be concentrated on the surface of the cold finger. One immediately achieves a thousand to one concentration effect. The minor gases, if condensable, are easily diagnosed by their characteristic IR reflection spectrum. Few condensed species interact with each other, with the exception of NH_3-H_2O and NH_3-H_2S; these two form the hydrate $NH_3 \cdot H_2O$ or the sulfide NH_4HS. Other components are condensed as simple mixtures. The components which are detectable by cryogenic freezing are: H_2O, NH_3, H_2S, PH_3, SO_2, and CO_2. CH_4 and CO are frozen only at lower temperatures.

Aerosol particles in a planetary atmosphere can be collected by impingement on a flat surface or by being trapped on a filter network. Since aerosols are likely to be complex polymers of carbon and/or other elements, the composition of the aerosol is not so uniquely identified, but rather the types of chemical bonds that exist in the aerosols may be evident in the IR reflection spectrum, and a qualitative analysis of the particles should be possible.

A more detailed description of the principles of operation of the entry probe spectro-reflectometer was presented in the first proposal. We add the section entitled: Principles of spectro-reflectometer operation as Appendix I, and the section: Comparison and advantages of the frost spectro-reflectometer as Appendix II. The reader interested in further details of the method can find them in these two sections.

It was realized when the original proposal was submitted, that the proposed studies could not be carried out within one year but would necessarily extend over a longer period. We therefore first give a review of the progress to data in section II, and then discuss the proposed investigation for the coming year in section III.

II. Progress To Date

Since we have had considerable experience in preparing frosts of volatile substances and recorded many spectra of typical frozen gases, such as listed in the introduction, we felt that the primary function of the first year of the grant was to construct a facility which would serve as a simulator for an entry probe spectrometer. Not only must the cryogenic cold finger sample the ambient gases of a planet's atmosphere, it must do so in a high velocity air flow. Therefore we concentrated on constructing a "Jupiter wind tunnel." The wind tunnel has been built and tested and satisfies our demands to a very high degree.

The "Jupiter wind tunnel" is a rough torus or oval 8 feet long, 4 feet high, and about one foot wide, with a one horsepower fan, turning vanes and carefully designed air path. A diagram of the wind tunnel is given in Fig. 1. Several polaroid pictures are shown in Fig. 2. The design was by Mike Williams, engineering designer at LPL and the construction by Mr. Williams and Ron James. Much of the heavy construction was performed by a metal fabricator in Tucson. The specifications for the wind tunnel were such that it should operate at pressures from 0.1 atmosphere to 4-5 atmospheres, comparable to those that a probe experiences in traveling through a Jovian type atmosphere. The wind tunnel has been tested with water and gas pressures to 45-50 lbs/in^2. There are a few small leaks, which are being sealed. At 45 lbs/in^2 the tunnel loses about 5 lbs of pressure in 12 hours. After the leaks near one flange are corrected, the leak rate should be minimal. The thick walls of the tunnel readily tolerate the high pressure as well as sub-atmospheric pressure. The air is circulated in the tunnel by a blower which is driven by a shaft through the wall of the tunnel. The shaft is sealed by a pressure-vacuum bearing. The bearing in our tests is gas tight, even at full power on the blower.

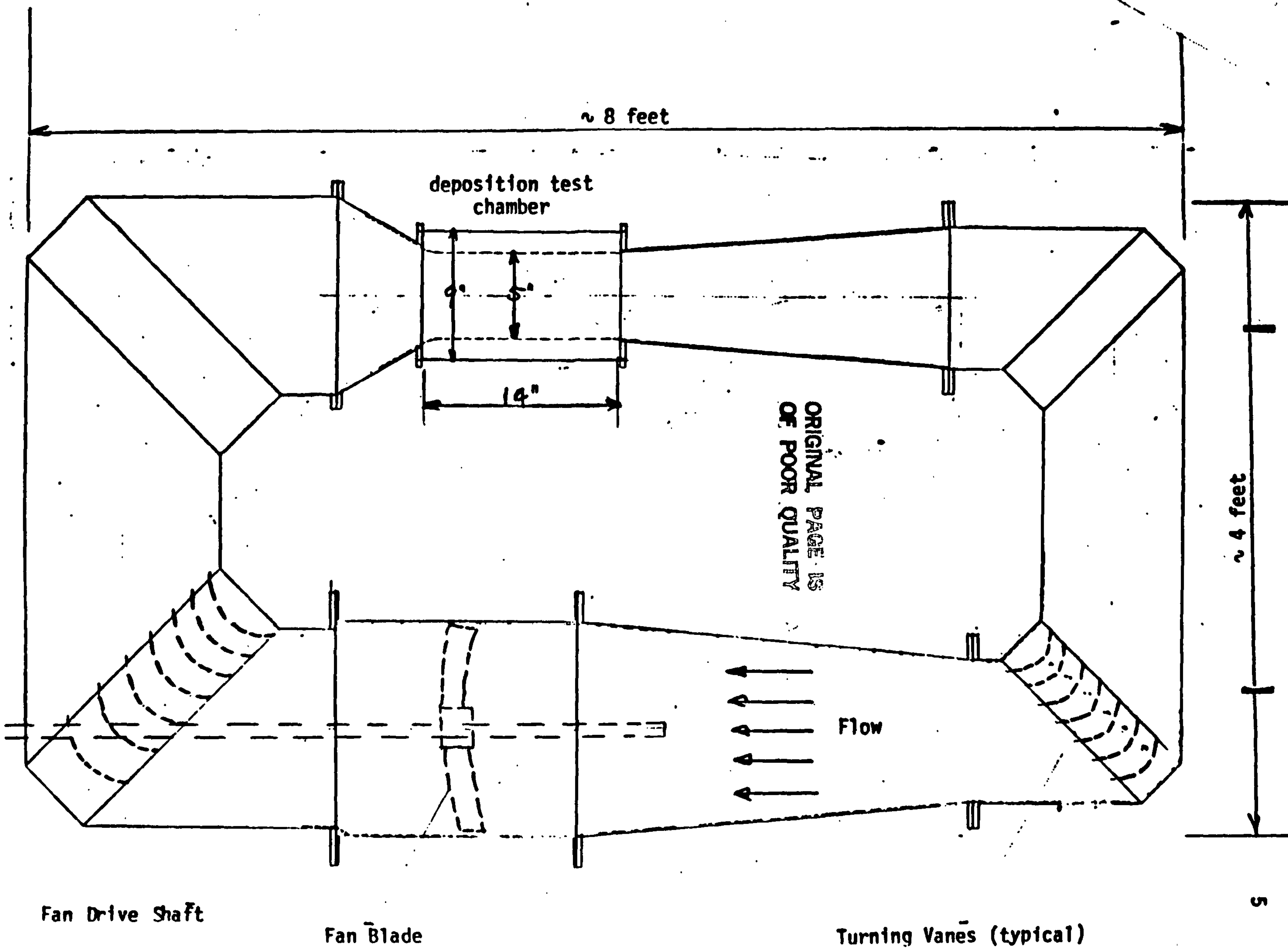
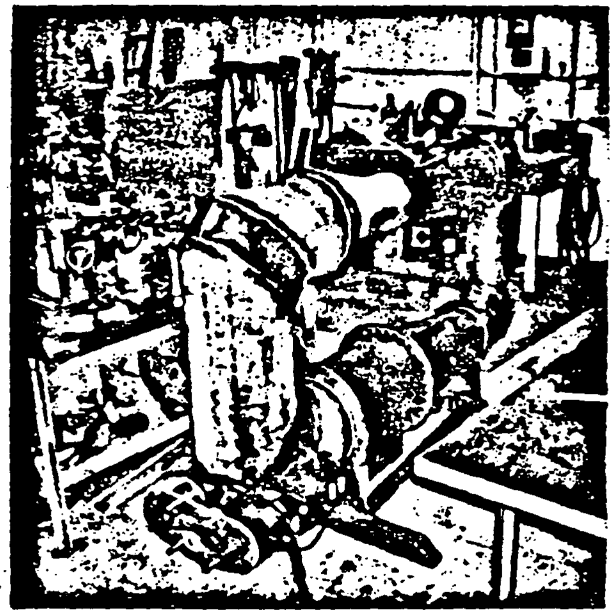
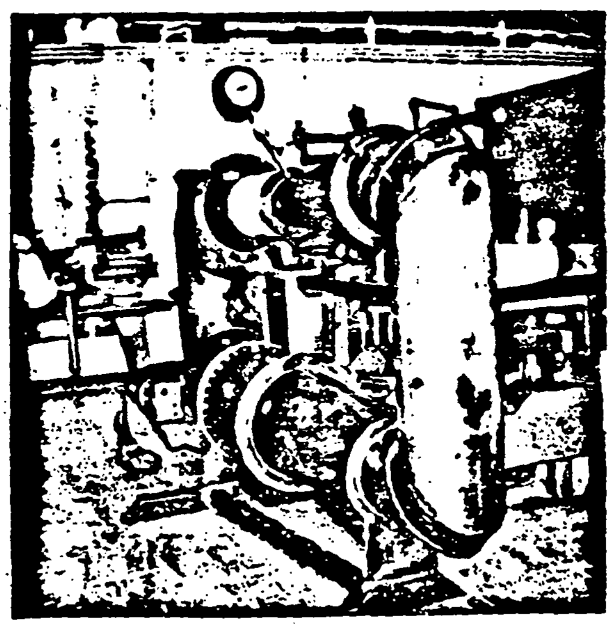


Fig. 1 Schematic diagram of the wind tunnel facility to be used in the frost deposition tests.



Frost Deposition Test
Facility 1983 Sept.06



Frost Deposition Test
Facility 1983 Sept.06

Fig. 2 Two views of the completed frost deposition test facility (wind tunnel) in the machine shop of the Lunar and Planetary Laboratory.

The blower speed is controlled through a SCR motor speed control. Full power at one atmosphere of pressure gives a velocity of 45 meters/sec (∿ 100 m.p.h.). This compares very well with the velocity of a probe in a Jovian-type atmosphere. The Galileo probe for its 56 minute proposed lifetime has an average velocity of 50 m/s, with pressures ranging from 0.1 bar to 19 bar. We can simulate velocities from zero to 45 m/s and pressures from 0.1 bar to 4 bar. While the atmospheric temperature of Jupiter over the range of the Galileo probe varies from 130 K to 400 K as the probe drops from 0.1 bar to 19 bar, our device is limited to room temperature (300 K). This should not be a disadvantage in our simulation tests; one should be able to correct for the heat excess or deficit in our simulation runs.

The wind tunnel has one section (the deposition chamber) where the condensation simulation experiments will be performed. The air flow velocity across the diameter of the deposition chamber is quite uniform as is shown by the measurements given in Table I. This device can be run with various mixtures of gases from H_2-He mixtures through N_2 and ordinary air. It is and will be available for any experimenters who wish to test devices in the airflow surrounding an entry probe. M. Tomasko, who has proposed an IR spectrometer for analyzing the ambient gas around the probe over a few meter pathway plans to test his device in the turbulent flow by utilizing the wind tunnel. Temperature and pressure probes, as well as other devices could well utilize the versatility of this simulation device.

We have made preliminary investigations of the feasibility of quantifying the amound of precipitated volatile. The depth of an absorption band can often be used to determine the optical path, and hence the thickness of a frost deposit. But since the depth of an absorption band is dependent on other parameters of the frost beside thickness, we decided to investigate whether the frost substrate itself could serve as a thickness monitor. We

Table I

Determination of Air Flow Velocity Across Deposition Chamber

Distance from Edge (inches)	Dynamic Pressure -Static Pressure (inches H_2O)	Velocity (miles/hour)	Velocity (m/sec)
0	4.30	94	42.0
0.5	5.07	102	45.6
1.0	5.30	105	46.9
1.5	5.40	106	47.4
2.0	5.40	106	47.4
2.5	5.50	107	47.8
3.0	5.60	108	48.3
3.5	5.60	108	48.3
4.0	5.75	109	48.7
4.5	5.90	110	49.2
5.0	6.10	112	50.1
5.5	6.30	114	51.0

purchased a Kronos QM-301 Thickness Monitor and designed a special cell to hold the quartz-crystal oscillator. These oscillators typically are used to monitor the thickness of thin film deposits for optical purposes, such as beam splitters and interference filters. They usually operate near room temperature. We have succeeded in operating them at 200 K, and successfully measured the deposition of ambient humidity as a thin ice coating on the crystal. However, the quartz oscillators can easily be overloaded by the ice or frost deposit. Masking the area of the crystal detector by an opaque shield seems to be one way to prolong the measurement process, i.e. to measure greater thicknesses.

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FINAL REPORT

NAGW-561

July 15, 1986

A wind tunnel was built to simulate the rapid movement of an entry probe through the Jupiter atmosphere. The wind tunnel could develop wind speeds from 1 to 50 meters per second in a closed system. The wind tunnel had a viewing section 6 inches in diameter in which one could place wind velocity and temperature probes as well as cryogenically cooled cold "finger".

The initial testing of the wind tunnel involved running sectional profiles through the observation port of air currents of 1/10 of an atmosphere to 3 atmospheres and the velocity profile was very uniform throughout the cross section of the experimental port, with the exception of wall effects. The deposition of cooled volatiles using the wind tunnel was not performed due to termination of the grant. However, under ambient conditions, namely room temperature and pressure, we did make measurements of the deposition of H_2O ice on a cryogenically cooled thickness modulator. This device was able to measure ice deposition at thicknesses of about a half a millimeter and produced frost whose reflectivity could easily be measured by reflectance FTS spectroscopy.