

EXPERIMENTS ON THE ACOUSTIC PROPERTIES OF TITAN-LIKE ATMOSPHERES. J. R. C. Garry¹ and T. Shettle², ¹Astrobiology group, Soft/Condensed Matter dept., Leiden University (j.garry@chem.leidenuniv.nl), ²Independent.

Abstract: The arrival of the *Huygens* spacecraft at Titan offers a novel opportunity for the study of an atmosphere via its acoustic properties. Preliminary measurements of the speed of sound in cryogenic nitrogen, methane, and ethane have been made, with absorptivity factors in gas mixes being the goal. With such data, it is expected that it would be possible to discriminate between two-component particulate-laden mixtures, or clean three-component gas mixtures.

Introduction: Measurement of the speed of sound in a gas mixture yields an effective molecular mass from which a mixing ratio can be inferred in a two-component mix. Sensors to determine the speed of sound in the atmosphere of Titan were built into the *Huygens* probe's payload [1] and similar payloads have been examined both theoretically [2] and experimentally [3]. The last reference employs a further degree of sophistication and can also measure the adsorption experienced by a sound waves in an unknown gas mixture.

Classically, the non-zero thermal conductivity and shear viscosity of gases provide routes by which acoustic energy is dissipated; in nitrogen-dominated methane mixtures at ~1bar, for example, such absorption becomes significant above 10^7 Hz. For real gases mixes, mechanisms, such as vibrational relaxation, can be important and generally cause absorption at 10^5 Hz or so in N_2/CH_4 mixtures [4].

An experimental apparatus has been built to measure the speed and attenuation of sound in cryogenic nitrogen-dominated atmospheres. While many studies have examined the use of velocimetry in characterizing an atmosphere, absorption processes are less well understood for real non-terrestrial atmospheres. Partly, this arises from a lack of both data about the absorption processes in real cryogenic gas mixtures, and the additional complications found in non-terrestrial atmospheres such as condensation of liquids or solids. The equipment outlined here, and further work, will not consider dust or droplet-laden atmospheres.

Equipment: Commercial ultrasonic transducers are used in this equipment, with one transducer being driven by a continuous 280 kHz signal. The second sensor is held on an Invar frame such that the relative position of the two transducers can be read with an external micrometer. The chamber itself is made from copper, and is insulated by a close-fitting polyurethane foam shell. A Teflon gasket between

the circular brass lid and the brass mating ring makes the chamber gas-tight for modest pressure differentials. Coarse thermal control is achieved with a pumped liquid-nitrogen system, fine temperature control is performed with a 20W resistor bolted to the underside of the chamber, and driven from a DC power supply by a digital PID temperature controller. Internal temperatures are sensed by three miniature Pt100 elements supported on the two Invar posts that run through the chamber, which is shown in fig. 1.

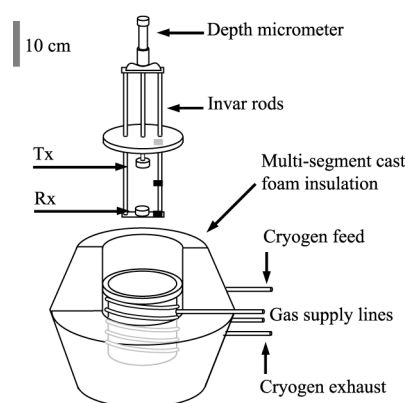


Figure 1 — The wiring harness for the thermometers (2 black and 1 grey rectangles), and the lines for the transmitter (Tx) and receiver (Rx) are not shown.

Unlike time-of-flight velocimeters, such as that used on the *Huygens* probe [1], this experimental rig measures the phase differences between the transmitted and received signals. The difficulty of repeatable pulse-edge detection led to the adoption of a phase-based method; the triggering ambiguity of a time-of-flight method is illustrated in fig. 2 which shows the waveforms sent and received by the acoustic velocimeter on the *Huygens* probe.



Figure 2 — Signals from the flight model speed of sound sensors on the *Huygens* probe; transmitted pulse shown above received pulse in an ethane atmosphere at rtp.

The high carrier frequency (1MHz) of the Titan probe's sensors reduces, but does not eliminate, the error arising from triggering on the n^{th} rather than the 1st peak of the received signal. In nitrogen gas at 100K an error of 0.3 ms^{-1} per missed wavepeak can occur with the *Huygens* probe's method. Resonance techniques such as those used in [3] do not suffer from such difficulties, but instead move their need for accuracy and precision to the time-domain, requiring accurate signal generation and phase detection; both of which are readily achieved with standard laboratory equipment. By noting the relative phase between the transmitted and received signal as a function of the transducer separation, the wavelength of the signal can be measured unambiguously.

A high-pressure mixing rig has also been built so that arbitrary gas mixes can be piped to the chamber.

Results: Tests with methane have been conducted down to 120 K, and with pure ethane down to 200 K. Substantially colder temperatures would lead to the liquefaction of those pure compounds at 1bar and for lower temperatures nitrogen-dominated mixtures will be examined instead, following the safe arrival of the *Huygens* probe.

Rather than measure a single wavelength, the measurement accuracy can be improved by recording the distance needed to pass through an arbitrary number of points having zero phase shift between the transmitted and received signals. In the figure below, 16 wavelengths are traversed, with the red data points showing the spacing between points of zero phase difference between the Tx/Rx signals. The data were taken with the electrical heater operated to desiccate the air within the chamber prior to cooling. Near-field effects were considered in using the system, in that the separation of the two sensors is always larger than ~ 10 wavelengths, and no change is seen in the local value of the sound field's wavelength.

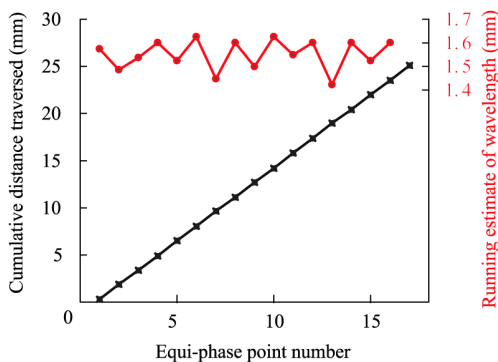


Figure 3a — Raw data collected for warmed (desiccated) air at 1 bar.

These data can then be converted into speeds, using the frequency of the signal.

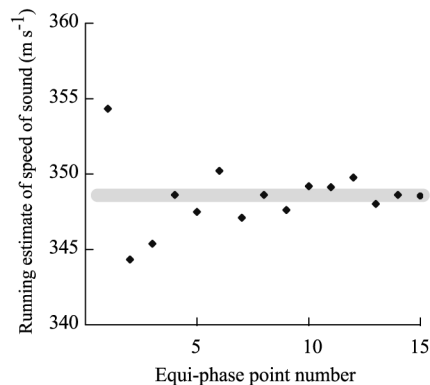


Figure 3b — Data from fig. 3a shown as speeds.

The grey bar in fig. 3b guides the eye to show how the accuracy of the calculated speed improves as progressively more wavelengths are considered. Practical limits to the motion of the transducers constrains the number of wavelengths to be less than 20, but precisions of $\sim 0.5\%$ are nevertheless achievable.

Conclusions: A desk-top laboratory simulator has been built to provide speed of sound measurements for nitrogen-dominated mixtures and to discriminate between absorption processes in dry gases and those that should be experienced by the *Huygens* probe.

References: [1] Svedhem, H. et al. (2004) *Proc. Int. Workshop on Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science*, ESA SP-544, 221-228. [2] Lorenz, R. (1999) *Planet. and Space Sci.* 47, 67-77. [3] Farrelly, F.A. et al. (2004). *Planet. and Space Sci.*, 52 (1-3), 125-131. [4] Dain, Y. and Lueptow, R.M., (2001) *J. Acoust. Soc. Am.* 109 (5), 1955-1964.

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