ENGINEERING RESEARCH INSTITUTE

COLLECTION AND ANALYSIS OF UPPER-AIR SAMPLES

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1. INTRODUCTION

This is the second in a series of Quarterly Reports on Contract No. DA-36-039 SC-56737 describing an experimental program of collecting and analyzing upper-air samples. The work is a continuation of one phase of a program of upper-air research which has been carried out since 1946 by the University for the Meteorological Branch of the Signal Corps. The other phase of the work, that of measuring pressure, density, temperature, and winds, will continue on a separate contract. For background material, the reader is referred to the Final Reports of Contracts W-36-039 SC-32307, DA-36-039 SC-125, and DA-36-039 SC-15443. The latter report summarizes the current status of the sampling program, the principal objective of which has been the investigation of diffusive separation.

2. PURPOSE

The purpose of the research as given in Signal Corps Technical Requirements SCL-2370 of 19 January 1954 is as follows:

"This specification covers the research into the necessary techniques for the collection and analysis of air samples in the region of 30 to 100 km altitude and a continuing review of the field of upper air research for the purpose of keeping in contact with work of interest to the Signal Corps.

"The techniques shall be confirmed by field experiments using Aerobee or other rockets as vehicles. Emphasis shall be placed on the following experiments.

"(a) The analysis of the upper air and control samples using the gas adsorption analysis and/or other techniques.

"(b) The collection of samples in the region 30 to 100 kilometers.•

"(c) The performance of subsidiary experiments, reduction of data, calculation of results and preparation of reports."

3. ABSTRACT

Progress in the construction and operation of a selective adsorption analyzer for upper-air samples is described. Progress in the use of a new bottle-closure device is noted. An analytical approach to the question of the effect of the sampling method on the composition of the sample is described.

4. NEW ANALYZER

A description of the construction of the nearly completed analyzer was given in the previous report. During the quarter the entire effort went into placing the analyzer in operation. In the course of the work two difficulties of some importance arose.

An 800-cc toepler pump for transferring the sample from the bottle to the analyzer was designed and built. A McLeod gauge for general system monitoring and a small oven for baking out the charcoal traps were also constructed. Upon attaching these three units to the system it was considered to be ready for receiving mercury prior to operation.

The mercury was processed as follows:

1. Washed with nitric acid.
2. Washed with distilled water to remove nitric acid.
3. Bubbled with air to dry and to oxidize residual base metals missed by acid.
4. Gold filtered to remove oxides.
5. Paper filtered for visual check of residual dirt.
6. Distilled.
7. Redistilled into analyzer.

Distillation into the analyzer proceeded at the rate of about 250 cc per day. At this rate it was possible to fill one control pot per day and the large toepler in three days. As each unit was filled, it was tested for operation. In operating the input toepler the float valve (which is iron enclosed in

glass) fractured upon application of a moderate pressure to the input side. As a result, mercury drained from the toepler into the input tubing. The toepler was removed and the input system cleaned. A modification of the input toepler will be made. While this is progressing, it will be possible to operate the analyzer by attaching vials of air directly to the input, the large toepler being required only for transferring samples from upper-air sample bottles.

Mercury was also distilled into the fractionating-column mercury pots, and an attempt was made to operate the column. This was found to be extremely difficult, however, as the mercury tended to stick in the side tube exits, making it impossible to drain the pumps. It had previously been determined by experiment that mercury could be satisfactorily manipulated in 0.8-mm capillaries. The tube used for the test, however, was straight and smooth. In the column, the tubes are curved and have slight constrictions which result from blowing. The result is that the mercury does not flow smoothly. Construction of a new column with capillary tubes of 1.5-mm I.D. in the more critical places and 2-mm I.D. where dead space is less important was started.

Work on subsidiary parts of the sampling program was continued. Further tests and calibrations of the vibrating-reed electrometer were made. A set of containers for resistors of 5×10^8, 10^9, and 10^{12} ohms was built. A vialing system for taking standard roof samples was constructed. Work on the cold-closure method for upper-air bottles was continued (see previous report). Two successful seals were made and a prototype flight bottle was constructed and is being tested.

5. DIFFUSIVE SEPARATION

The effort to make an analytical approach to the problem of whether or not diffusive separation is caused by the sampling process continued. It is likely that local diffusive separation occurs in the region of high pressure and temperature gradient which exists in the flow field, especially within the shock-wave transition region at the mouth of the sampling bottle. Such a phenomenon has been demonstrated analytically in a special

case by Cowling.[1] It is expected that during the transient sampling period before pressure equilibrium is established, the relative concentration of helium in the bottle will be increased; but in the steady-state condition with equilibrium pressures and temperatures, it is expected that the tendency will be for the helium concentration gradient to decrease towards ambient concentration.

Several models were considered in an attempt to find one susceptible to analysis during transient conditions. A complete model would include a normal shock wave across the flow field at the mouth of the bottle, the shock wave being the result of the forward supersonic velocity of the rocket. The analysis of this case is extremely difficult, and a first simplification is to neglect the velocity and resulting shock wave. The basic phenomenon, that of the effect on composition of a suction flow effect, is preserved. A mathematical "sink" was used to represent the bottle suction effect, and the equation describing the conservation of mass of helium was set up:

$$\nabla \cdot (c\vec{v}) + \frac{\partial c}{\partial t} = 0 \qquad (1)$$

where

c = concentration of helium gas, the "solute."

$\vec{v}$ = velocity of the "solute."

$\vec{U}$ = convective velocity of air, the "solvent."

$= -\frac{a^2}{r^n}$ (a^2 = strength of the sink; r = radial displacement; n = 1 for flow into a cylindrical sink, = 2 for flow into a spherical sink.)

$\vec{\mu}$ = "solute" velocity relative to the "solvent."

$= \frac{K}{c} \nabla c$ (Fick's law of diffusion).

In an incompressible flow field ($\nabla \cdot U = 0$) equation (1) becomes

$$K \nabla^2 c - U \cdot \nabla c - \frac{\partial c}{\partial t} = 0. \qquad (2)$$

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[1] T. G. Cowling, "The Influence of Diffusion on the Propagation of Shock Waves," Philosophical Magazine, London, 33 (1942), p. 61.

A solution for the case of the cylindrical sink (n = 1) will be sought. A complete solution with approximate boundary conditions may present some difficulty. It is thought that if diffusive separation is demonstrated for the cylindrical case (n = 1), it will indicate qualitatively diffusive separation for the spherical sink (n = 2) which more nearly approximates the bottle conditions. Further, it is thought that imposing the shock wave on the model would not lessen any diffusive separation effect. A solution for this rather difficult model may be tried.

6. ACKNOWLEDGMENT

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