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THE UNIVERSITY OF MICHIGAN
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COLLECTION AND ANALYSIS OF UPPER-AIR SAMPLES

Quarterly Report

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by

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TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS	ii
ABSTRACT	iii
OBJECTIVE	iii
1. INTRODUCTION	1
2. PROGRESS ON THE NEW ANALYZER	1
2.1 ION-GAGE TESTS	1
2.2 MICRO PIRANI GAGES	2
2.3 ANALYSIS OF GROUND AIR	2
3. DIFFUSIVE SEPARATION	5
4. FUTURE PLANS	6
5. ACKNOWLEDGMENT	6

LIST OF ILLUSTRATIONS

Figure		Page
1	Four helium analyses.	3
2	Step-by-step helium analysis	4

ABSTRACT

Progress in the testing of a selective adsorption analyzer for upper-air samples is described. Results of calibrating analyses of ground air are noted. Progress in investigating the possibility that separation occurs during sampling is described.

OBJECTIVE

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."

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1. INTRODUCTION

This is the fourth 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 Contract W-36-039 SC-32307, DA-36-039 SC-125, and DA-36-039 SC-15443. The last report summarizes the current status of the sampling program, the principal objective of which has been the investigation of diffusive separation.

2. PROGRESS ON THE NEW ANALYZER

Prior to this report the selective adsorption analyzer was completed. Later a damaged bottle-opening system, 800 cc Töpler pump, and storage Töpler pump were removed to facilitate the early testing of the analyzer. The final unit needed to make the system operative was a suitable arrangement for measuring the output of the fractionating column.

2.1 ION-GAGE TESTS

Work on ion gages, as noted in the previous report, continued. The WL5966, Alpert type ionization-gage tubes previously used were discarded. A modified Alpert type gage, as used by M.I.T., was attached to the analyzer. This gage was free of the difficult outgassing problem and did not blacken. However, the best vacuum obtained was of the order of 5×10^{-8} mm of Hg with ion pumping.

The M.I.T. gage was removed from the analyzer and attached to a system evacuated by an oil-diffusion pump and outgassed in the usual manner. It was then sealed off from the system and allowed to outgas by ion pumping. Equilibrium was reached at about 5×10^{-9} mm of Hg.

Two new Alpert type WL5966 gage tubes were purchased. One was pumped and outgassed on the oil-pump system and sealed off. It readily pumped by ion pumping to vacuums of the order of 5×10^{-10} mm of Hg. By special cooling of the gage, vacuums of the order of 3×10^{-11} mm of Hg were obtained. This gage was attached to the analyzer system and prepared in the usual manner. Vacuums of the order of 5×10^{-10} mm of Hg were easily obtained. Thus it appeared that the new Alpert gages would be satisfactory for the analyzer.

2.2 MICRO PIRANI GAGES

Before the ion gage was successfully operated, work proceeded on the development of micro Pirani gages to insure that an output gage would be available. A few micro gages were constructed and tested. Each gage consisted of a length of thin, flat ribbon of pure nickel about $2.5 \times 0.0001 \times 0.0025$ in., sealed in an approximately 0.8-cc soft-glass envelope with platinum lead-in wires. One of the gages was tested and calibrated on a vacuum system. Its sensitivity and short-term stability were found to be adequate for measuring the amount of helium in an air sample as small as 0.03 cc NTP.

The gage showed the highest sensitivity at low pressure with a bridge voltage of 0.25 volt. The following table shows a typical calibration at low pressure with the gage immersed in liquid nitrogen:

<u>Pressure in μ</u>	<u>Pirani Resistance in Ω</u>
0.00	8.38
0.20	7.97

The short-term stability of the gage was believed to be less than 0.003 Ω in 8.38 Ω .

It is believed that if another Pirani gage were used as the compensating arm of the bridge circuit, the overall reliability and useful sensitivity would be enhanced.

Work on these gages was discontinued after successful tests with ionization gages.

2.3 ANALYSIS OF GROUND AIR

Preparation for analysis was made by attaching a 50-cc vial, containing a small ground-air sample, to the analyzer. To identify this series of determinations, this sample vial was called II and the analyses were

numbered from 1 to 4 in sequence. To date four analyses have been made on sample II, using portions varying from 0.06 cc NTP to 0.14 cc NTP. Before the first analysis the system was baked at 350°C overnight. Between analyses only the charcoal traps on the fractionating column were baked.

The output of the column was indicated by the Alpert ionization gage. The ion current was calculated from the voltage reading of a sensitive electrometer across a known resistor in series with the gage collector. A single-channel recorder recorded electrometer output. The gage-tube ionizing current was hand regulated at 1 ma in each of the four analyses.

To preserve the copper filament in the oxygen cell, all four analyses were performed without removing the oxygen from the sample.

Figure 1 shows the results of the four analyses and the tentative calibration curve for helium.

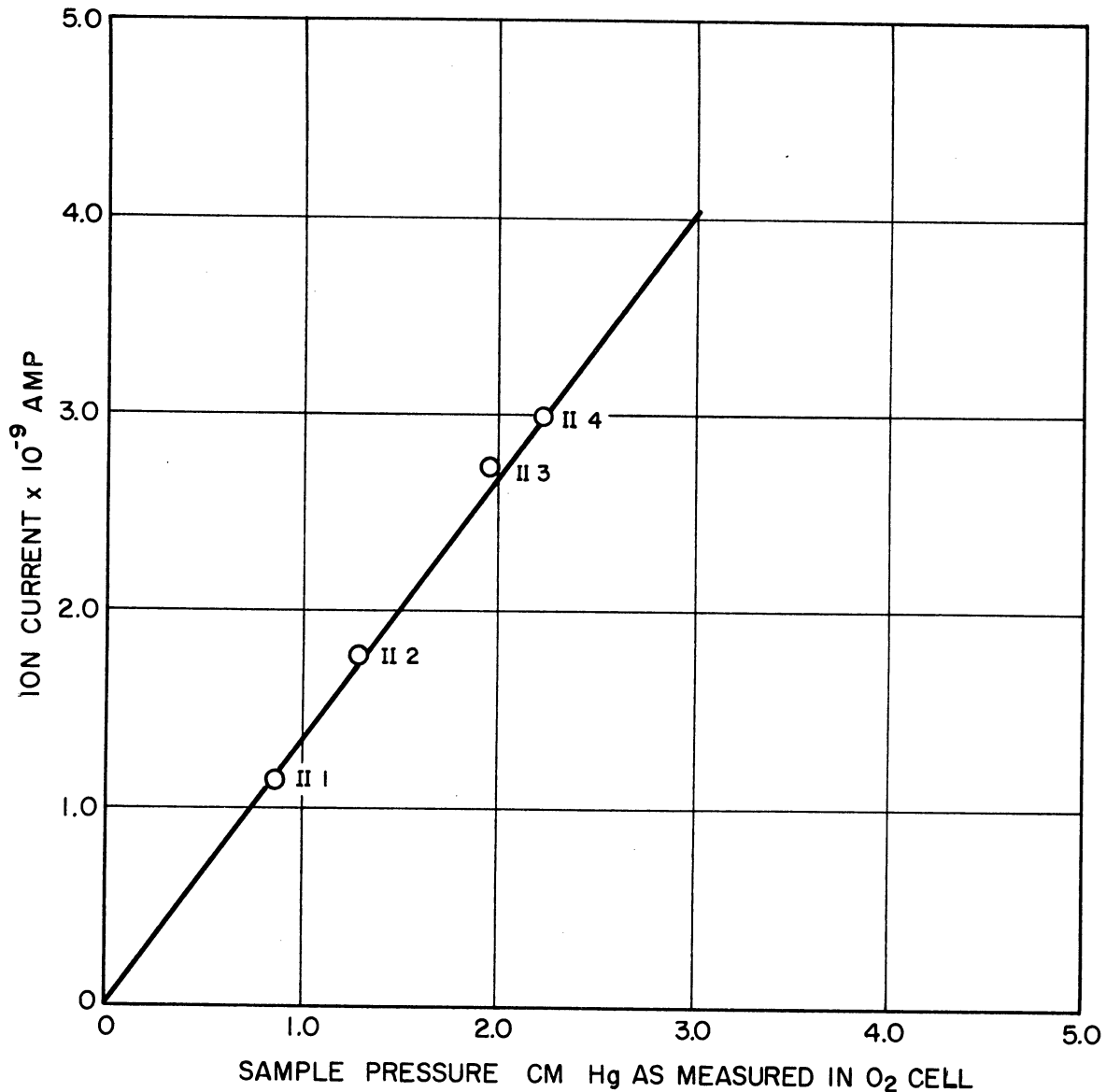


Fig. 1. Four helium analyses.

The fourth determination is a summation of the outputs of the individual fractions, starting with the 12th fraction. The results are in relatively good agreement with the theoretical results published by Glückauf.* The comparison is shown in Fig. 2 which gives the yield of each fraction from the 12th to the 27th as the electrometer reading of the Alpert gage in millivolts vs fraction number. The line shows our experimental result. The dots show Glückauf's theoretical calculation, with the proper conversion to fit our experimental set-up.

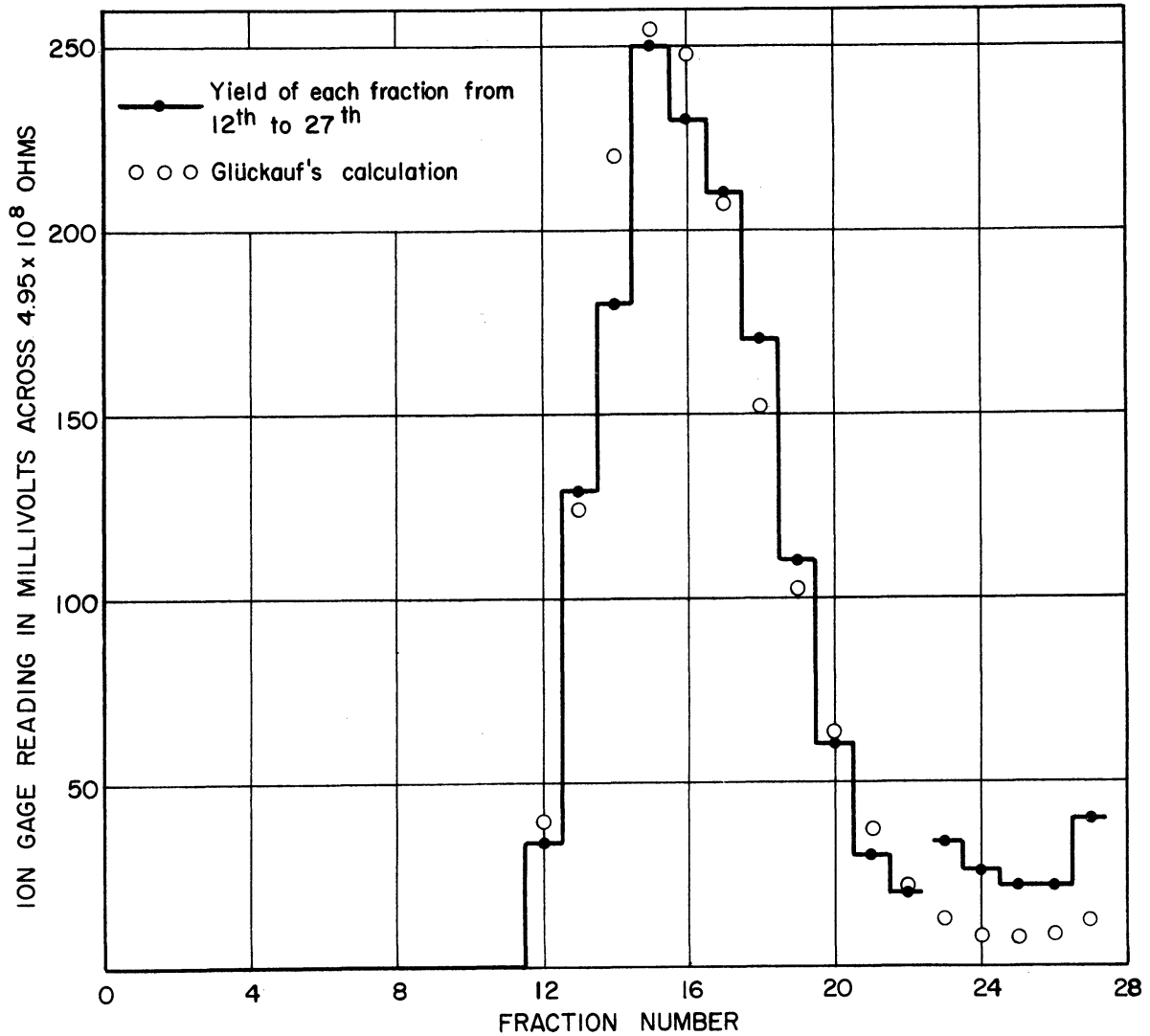


Fig. 2. Step-by-step helium analysis.

There is a discontinuity at the 23rd fraction shown in the above chart. At this point the quantity of gas given off by each fraction was small compared to the quantity of gas in the ion gage. Therefore, the gage

*Glückauf, E., "A Micro-Analysis of the Helium and Neon Contents of Air," Proc. Roy. Soc., A185 (1946), p. 98.

was pumped to a good vacuum before continuing. This reconditioning of the gage is believed to be responsible for the discontinuity. Whatever the cause, it should be noted that the minimum reading occurs around the 24th fraction and that the total quantity of gas is little affected by the discontinuity.

3. DIFFUSIVE SEPARATION

A theoretical analysis of the phenomenon of diffusive separation of a gas mixture due to combined causes of convective flow, pressure, and temperature gradients was initiated. This constitutes a continuation of a previous effort to determine whether or not diffusive separation of air can happen through the intake action of the sampling air bottle.

To simplify the analysis, the fluid medium is assumed to be a binary gas mixture. The object of the analysis is to determine the distribution of the concentration of one of the gas components as a function of space and time variables.

In spite of the fact that the phenomenon of diffusive separation in a flow field is involved in many physical problems, to our knowledge the theory in question has not been developed.

In comparison with the previous analysis, the compressibility effect and temperature gradient of the fluid medium are also considered.

The following analysis is restricted to one-dimensional problems.

Starting with the system of equations:

$$\frac{\partial n_1}{\partial t} + \frac{\partial}{\partial x} (n_1 w_1 + n_1 V) = 0, \text{ equation of continuity of gas "1,"} \quad (1)$$

where

n_1 = number density,
 w_1 = diffusion velocity, and
 V = mixture flow velocity.

$$\frac{n_1 w_1}{n} = -D \left[\frac{d}{dx} \left(\frac{n_1}{n} \right) + \frac{n_1 n_2 (m_2 - m_1)}{n p_0} \frac{dp}{dx} + \frac{n_1 n_2}{n^2 T} \frac{\alpha dT}{dx} \right], \text{ diffusion flux equation,*} \quad (2)$$

*S. Chapman and T. G. Cowling, Mathematical Theory of Non-uniform Gases, Cambridge, 1952.

where

$$\begin{aligned}
 n &= n_1 + n_2, \\
 \rho &= n_1 m_1 + n_2 m_2, \\
 m_1 &= \text{molecular masses of gas "1,"} \\
 m_2 &= \text{molecular masses of gas "2,"} \\
 D &= \text{diffusion coefficient,} \\
 \alpha &= \text{thermal diffusion factor,} \\
 p &= \text{pressure, and} \\
 T &= \text{temperature.}
 \end{aligned}$$

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x} (\rho v) = 0, \text{ equation of continuity of the mixture,} \quad (3)$$

we obtain a diffusion equation which governs the concentration distribution of gas "1," namely $f = n_1/n$.

$$\frac{\partial f}{\partial t} + v \frac{\partial f}{\partial x} = \frac{\partial}{\partial x} \left[D \frac{\partial f}{\partial x} + \frac{D}{p} \frac{\partial p}{\partial x} f + \frac{\alpha D}{T} \frac{\partial T}{\partial x} f \right] + \left[D \frac{\partial f}{\partial x} + \frac{D}{p} \frac{\partial p}{\partial x} f + \frac{\alpha D}{T} \frac{\partial T}{\partial x} f \right] \frac{1}{n} \frac{\partial n}{\partial x} \quad (4)$$

assuming $m_2 \gg m_1$.

Equation 4, in conjunction with the given pressure, temperature, and convective flow velocity and appropriate boundary values of f , can be used to calculate the concentration distribution $f(x,t)$. These calculations will be made for several specific examples.

The physical significance of this analysis can be evaluated only after practical cases have been tried.

4. FUTURE PLANS

A circuit for stabilizing the ionizing current on the output gage of the analyzer will be built. Further calibration runs with helium will be made. Neon calibrations will be attempted. A new He leak detector will be purchased for use in the preparation of sample bottles. The design of peak-sampling Aerobee SC-34 will be reviewed.

5. ACKNOWLEDGMENT

Thanks are due to the Meteorological Branch of Evans Signal Laboratory for continued cooperation and financial support.

