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THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
HIGH ALTITUDE ENGINEERING LABORATORY
DEPARTMENTS OF
AEROSPACE ENGINEERING
METEOROLOGY AND OCEANOGRAPHY

Quarterly Report

High Altitude Radiation Measurements

1 July 1969 - 30 September 1969

FRED L. BARTMAN

Under contract with:

National Aeronautics and Space Administration
Contract No. NASr-54(03)
Washington, D. C.

Administered through:

December 1969

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Abstract

This report summarizes project activity during the period 1 July 1969 to 30 September 1969. Problems in the analysis of data from the 20 November 1968 balloon flight were solved and will be reported on in a technical report. High resolution measurements of the 15 μm CO_2 band were obtained and are shown. A survey of the literature regarding the distribution of CO_2 in the earth's atmosphere has been begun.

I. Introduction

This is the 27th Quarterly Progress Report on Contract No. NASr-54(03) covering the period 1 July to 30 September, 1969. The project effort during this period of time was divided among the following tasks.

1. Analysis and processing of Data for 20 November 1968 balloon flight.
2. High resolution measurements of the 15μ m absorption band of CO_2 (by L. W. Chaney).
3. Survey of the literature regarding distribution of CO_2 in the earth's atmosphere.
4. Report Writing.

II. Analysis and Processing of Data for 20 November 1968 Balloon Flight.

The analysis of the U. of M. Interferometer data from this balloon flight was continued. Problems associated with one-sided mode operation and with equipment failures during the flight were worked on and mainly solved. A technical report, describing these problems and solutions, was started.

III. High Resolution Measurements of the 15μm Aborption Band of CO_2

(by L. W. Chaney)

In September 1968, arrangements were made to obtain high resolution spectra of the 15μ m CO_2 band with the 1.8 meter Jarrell Ash spectrometer at the Willos Run Research Laboratories. Reorganizations and personnel terminations have inhibited progress on this work, so that in September 1969, arrangements were made to have High Altitude Engineering Laboratory personnel learn to operate this instrument and make the measurements. The following description describes the status of the instrument as of the end of September.

History of the Instrument

The spectrometer to be used for the proposed measurements is a double passed 1.8 meter Jarrel Ash spectrometer. The spectrometer is a Fastie-Ebert design and belongs to the Infrared Laboratory of IST and is located at Willow Run. The Willow Run group purchased the main frame including the Ebert mirror and grating drive from the manufacturer. The input optics, slit assemblies, passing mirrors, exit optics and detector mounts were designed and built by the Willow Run laboratory.

The completed instrument was originally used to measure the transmission of possible laser materials. The original application did not require that the instrument be evacuated, although the basic design allowed for this possibility. The original project for which the instrument was assembled was completed more than a year ago.

The instrument was made available to the High Altitude Engineering Laboratory and the decision to use the equipment for CO_2 measurements was made during the early part of the present year. The modifications required for our use were as follows:

1) Installation of a grating blazed for 16μ.

2) Modification of the exit optics to accept a Cu:Ge detector.

3) Construction of vacuum feed-thrus for the slit adjustments.

4) Alignment and preparation of the instrument for vacuum operation.

The steps 1-3 were carried out during the spring of the year. The fourth step has been started three separate times due to personnel termination and contract rearrangements. The present effort was started September 28, 1969.

Instrument checkout: - main frame

The following instrument checks have been made:

1) A ray trace of the basic spectrometer was made using both a helium-neon laser and a low pressure Hg lamp and filter.

2) The slit image position for single pass and double pass was determined.

3) The angular displacement between the exit slit and the image of the entrance slit was measured.

4) A visual stray light check indicated that the directly reflected light from the Ebert mirror was not baffled. The best location for this baffle is directly across the Ebert mirror. However, this was phsically impossible and a baffle was installed near the grating.

5) A check of the 1st pass light indicated that some of the light could reach the exit slit. A mask was placed across the entrance slit to prevent this occurrence.

6) A check of 1st pass plus a direct reflection showed that the light could enter the exit optics above the exit slit. A mask was placed over the top of the exit slit. Unwanted light via this route could be a source of trouble in the future and may require a mask across the center of the Ebert mirror as well as masking the passing mirrors.

7) A measurement was made of the back lash in the grating drive and a wavelength check made, based on the position of the Hg green line.

In carrying out the above checks the only real problem was in placing the baffle noted in step 4. About two days were spent in trying to cut and properly place the baffle.

Entrance Optics

Following the basic spectrometer checks the input optics was bolted into position and a Hg source was placed at the exit slit. An image of the exit slit was formed at the source position. The illuminated grating can be observed from this point and any observation of the grating by a succeeding mirror can be observed.

Exit Optics

Next the exit optics was bolted in position and a high pressure Hg lamp with a green filter was used as a source. The advantage of this arrangement is that there is ample light to trace the beam. A trace of the beam revealed that the first spherical mirror was not evenly filled with light. However, a remedy would require the unsoldering and resoldering of a connecting flange. Hence, it was decided to go ahead with the instrument checkout before making the correction. The correction has now been made, but the flange has not yet been re-installed.

The previous instrument checkout revealed that the alignment was affected by reducing the pressure in the instrument. The first elliptical mirror in the detector optics was suspected. The design of both the entrance and exit optics is such that the spherical and elliptical mirrors are held in position by telescope mounts. The suspected mirror tube was slightly egg shaped and almost too small for the mount. Hence, positioning the three mounting screws was difficult and someone removed one of the screws and pushed that side of the mount against the tube wall. The third screw was replaced and by careful positioning the mirror was secured by the three screws. The alignment is now unchanged by the pressure change.

Vacuum check

The previous use of the instrument had been at atmospheric pressure. Hence, it was a matter of concern to determine the presence of any leaks. The first leaks were quite large and were located by using acetone. Many smaller ones were located with the helium leak detector and patched with high vacuum sealant. The system was pumped with a mechanical pump only and the best vacuum obtained was 4 microns. There are probably other leaks in the system, but this will suffice for the present. For the future when it becomes desirable to seal the instrument a gate valve will be installed between the pump and the main frame and another leak check will be made.

Source

The source to be used was put in operation and it burned out after one day. The repair required one full day due to unfamiliarity with the device. The basic unit is a carbon rod about 5" long and 1/2" diameter with a slit 1/16" wide by 1/2" long milled in the side. The slit forms a cavity which is the source. The transformer used to heat the source can supply 500 amp at the 15 volts. A copper pipe of 1/2" diameter is the transformer secondary. Cooling water from the tap flows through the pipe and source mounting. Insulation is provided by the clever use of high temperature "O" rings and an elaborate assembly.

Detector

It was necessary to learn some of the techniques required for handling and transferring liquid nitrogen and liquid helium. There was a problem in that the liquid helium started boiling whenever the dewar was screwed securely into the instrument and would stop when untightened slightly. The problem seems to be in the dewar window which is sealed between two "O" rings. The instrument pumped down satisfactorily in the slightly loose position. Further investigation will be made into this problem.

An attempt was made to run a spectra of the air path outside the instrument. The results indicated that the available energy was low by about an order of magnitude. Because of the low energy the detector became suspect. Hence, a measurement was made of the detector sensitivity and found to have a D^* of about 7×10^{10}. This is equal to or above specification. At this point it was decided to go ahead with the flange modification mentioned earlier.

Conclusion: It is obvious that the utmost care will be required in adjusting all mirrors in order to obtain the required through put. The spectra of figures 1 and 2 show portions of the 15μm CO_2 absorption band. Line wave-numbers and identifications are indicated. It appears quite certain that the resolution desired can be realized with this instrument.

IV. Survey of the Literature Regarding the Distribution of CO_2 in the Earth's Atmosphere.

It has been apparent for many years that carbon dioxide plays an important role in the transfer of infrared radiation through the earth's atmosphere. The important part played by CO_2 in the thermal budget of the atmosphere and the recent development of satellite experiments using atmospheric radiation measurements in the 4.3μm and 15μm bands of CO_2 for remote sensing of atmospheric temperature structure make it necessary to know accurately what the distribution of CO_2 is in the atmosphere up to at least 35 km. Accordingly a literature survey is being made to locate all information available regarding the distribution of CO_2 in the lower and upper atmosphere.

In such a survey it is appropriate to start with the summary of Junge[1] in the book "Air Chemistry and Radioactivity". Section 1.3 of this book contains discussions of the exchange of CO_2 between the atmosphere and the land and ocean surface, the distributions of CO_2 in the atmosphere, the secular increase

of CO_2, and the detailed analysis of the CO_2 cycle. For our immediate objective knowledge of the distribution of CO_2 in the atmosphere, Junge's discussion can be summarized as follows.

IGY measurements by Keeling[2] at two antarctic stations, 2 arctic stations, at Mauna Loa Observatory in Hawaii and during flights and cruises in the Pacific show concentrations of CO_2 between 307 and 318 ppm. by volume. Regional differences appear to be small in the southern hemisphere and almost no seasonal variation is obtained. An increase of 1.3 ppm annually during the years 1957-1960 was measured. In the north Pacific and Arctic marked seasonal variations of 5 ppm were measured, with a maximum in spring at the onset of the growing season and a minimum in fall, when plant growth has ceased.

Junge also concludes that the CO_2 mixing ratio is constant up to at least 80 km., since the atmospheric mixing is intense enough to inhibit gravitational separation. The measurement of Hagemann[3] is cited (311 ± 2 ppm up to 30 km.).

The secular increase of CO_2, because of the burning of fossil fuel by man is estimated to be 13% from 1870 to 1958 as given by Callendar[4].

Other results of interest include:

a) A report by N. A. Lieurance[5] of measurements of CO_2 on the Rockwell Polar Flight: Nov. 14-17, 1965. Measurements from an aircraft show CO_2 concentrations at 500 mb. in the range of 315.9 to 319.0 ppm in the latitude range of $66^{\circ}N$ to $75^{\circ}S$.

b) Measurements at Barrow, Alaska between 1961 and 1967,[6] which show high winter and low summer concentrations with 12 month running means described by the regression equations:

(1961-1963) $C_{CO_2} = 315.27+0.0259M$

(1965-1967) $C_{CO_2} = 318.50+0.045M$

where M is the number of months from the beginning of the period. The weighted average of both rates of increase was found to be 0.46 ppm per year.

c) Rocket measurements by Martell at White[7] Sands Proving Grounds, New Mexico showed average concentrations of 322.8± 2.5 ppm in the altitude range of 43.4 to 62.8 km., as compared to 319± 5 ppm in ground samples.

d) A paper[8] "Carbon Dioxide and Monoxide Above the Troposphere" by P. B. Hays and J. J. Olivero has recently been submitted for publication to Planetary and Space Science. The Abstract indicates:

The dependence of the atmospheric distributions of CO_2 and CO upon the combined effects of photochemical production and loss, and diffusion is examined. It is found that, for CO_2, major deviations from complete mixing are possible in both the stratosphere and mesosphere. Further, sufficient quantities of CO may be maintained, as a product of CO_2 photodissociation, to be aeronomically significant."

e) Measurements[9] of atmospheric transmission of infrared radiation from balloon borne spectrometers using the sun as a source indicate that "the use of uniform mixing ratios of CO_2 for altitudes such as these" (30.5 km and higher) enable one to calculate infrared spectra in agreement with the experimental spectra obtained. A previous report by the same authors[10] indicated the possibility of lower mixing ratios above the tropopause however the authors now believe that these earlier results are in error.[11]

V. Report Writing

Quarterly progress report 05863-26-P, covering the period 1 April 1969 to 30 June 1969 was published and distributed in August 1969.

The technical report 05863 - 18 - T, "An Experimental Fourier Transform Asymmetrical Interferometer for Atmospheric Radiation Measurements," by L. W. Chaney was written.

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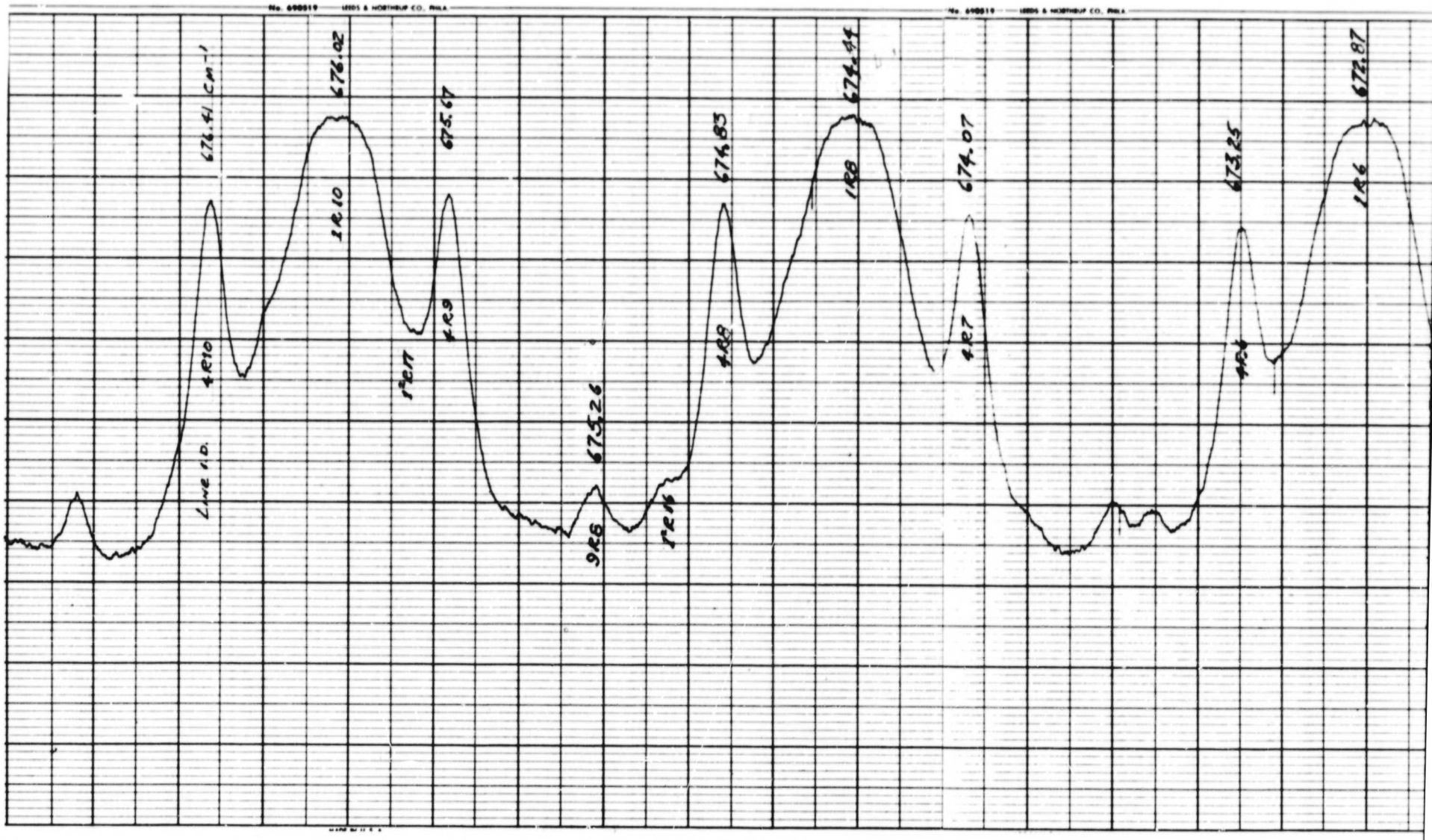
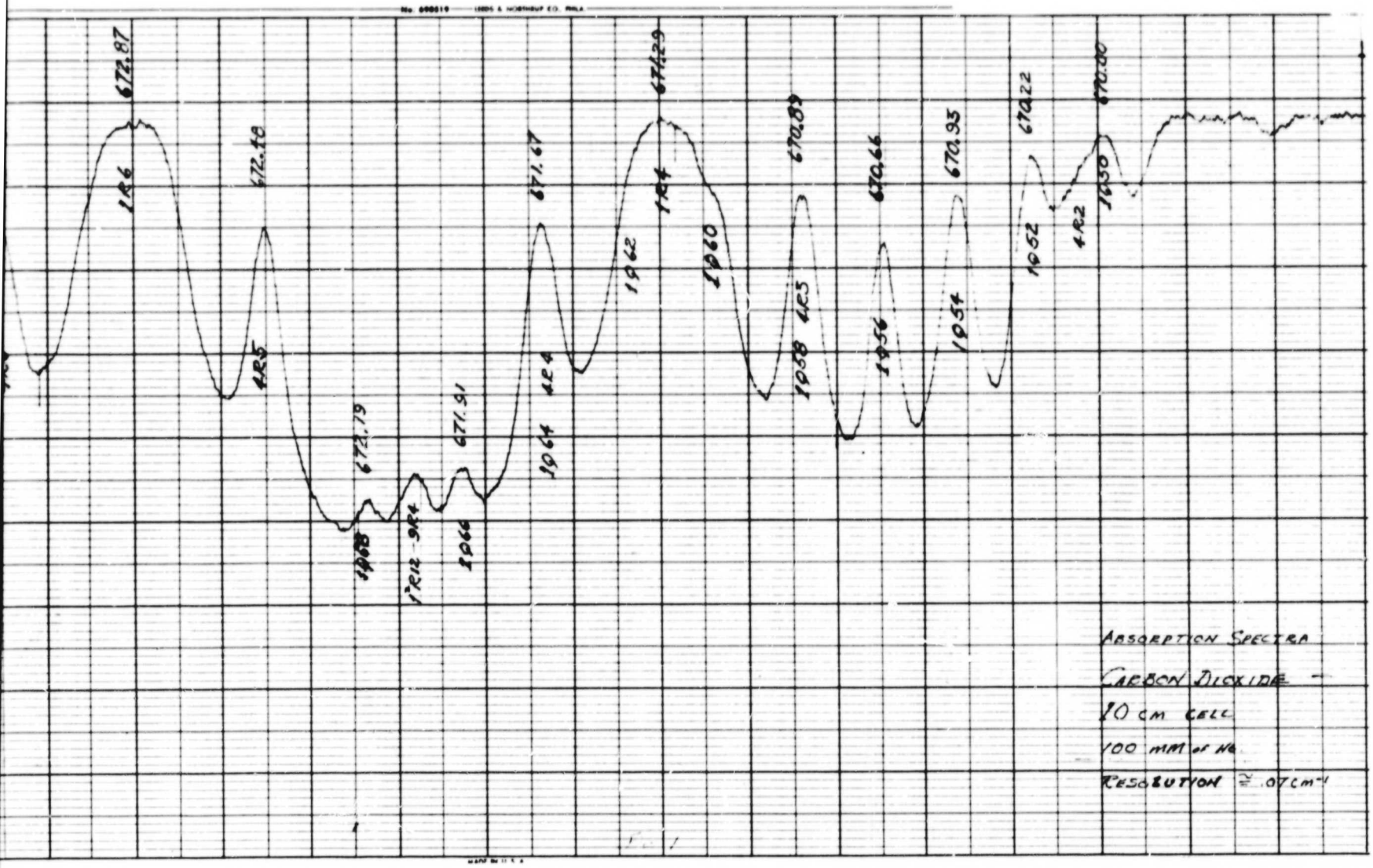


Figure 1. CO_2 absorption spectrum, showing spectrum with approximately .07

FOLDOUT FRAME 1



rum, showing 670-676 cm^{-1} region of
ximately . 07 cm^{-1} resolution.

FOLDOUT FRAME 2

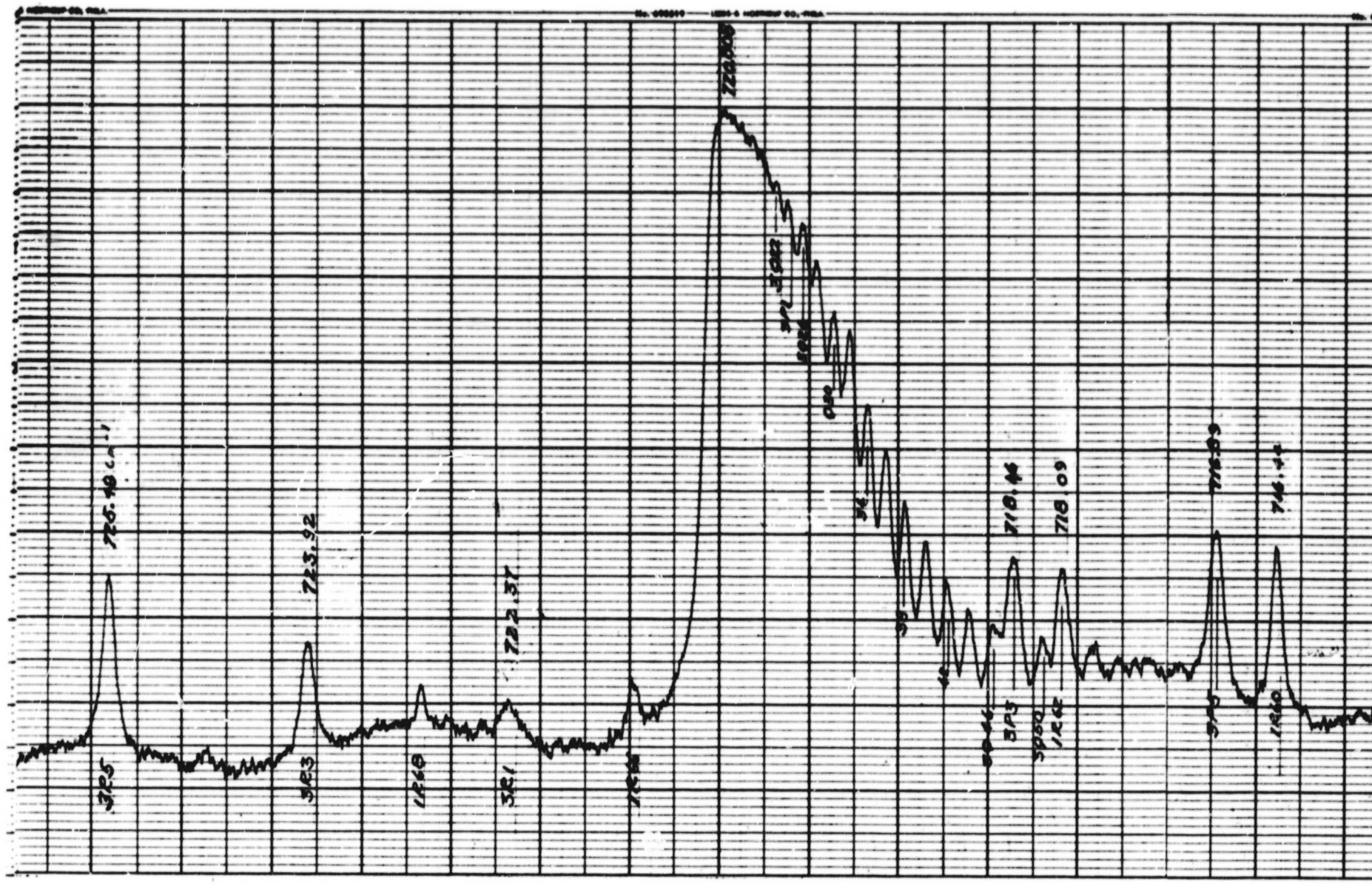
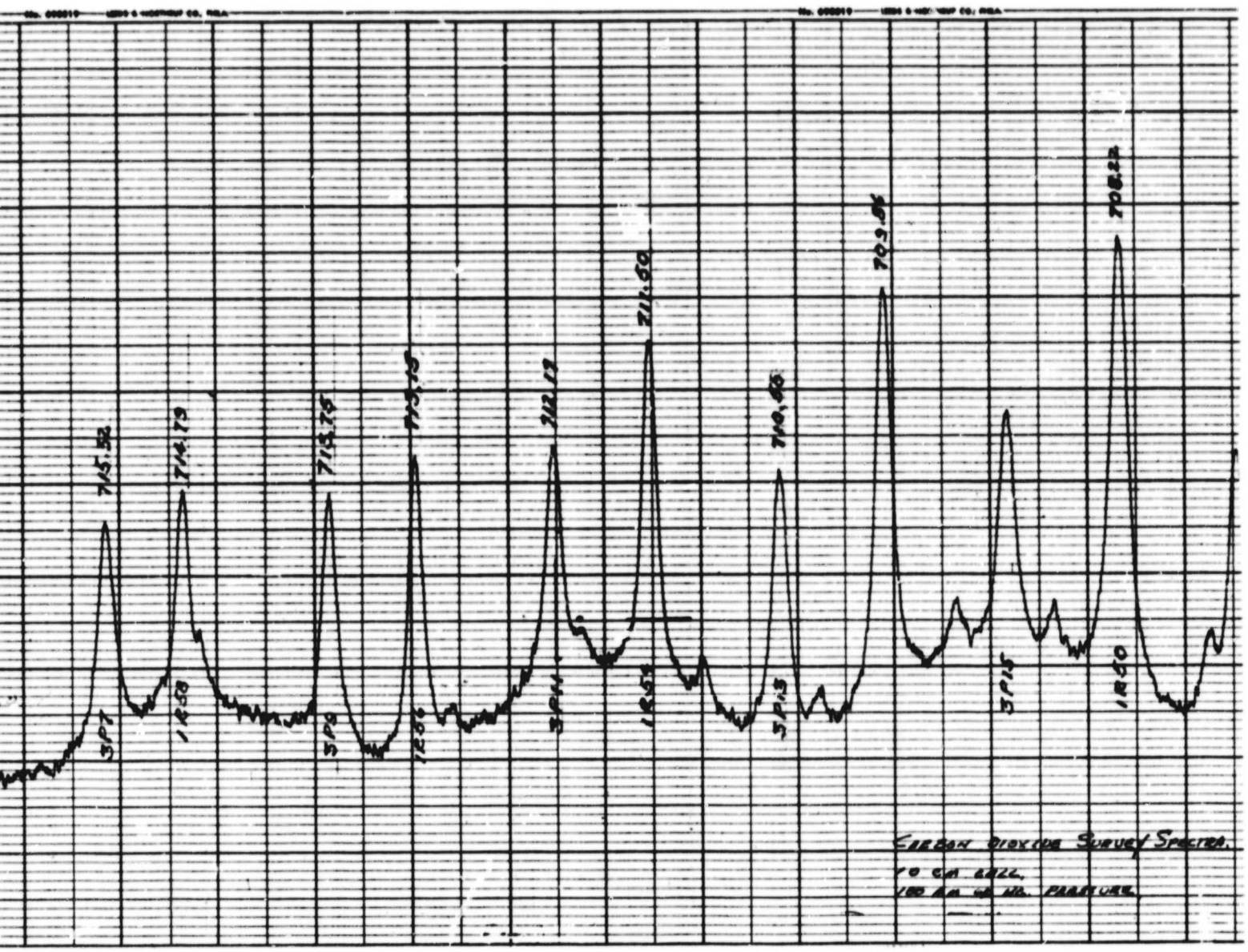


Figure 2. CO_2 absorption spectrum, whow
spectrum with approximately . 0

FOLDOUT FRAME 1



howing 708-725 cm^{-1} region of
y . 07 cm^{-1} resolution.

FOLDOUT FRAME 2