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A Digital Pressure Transducer

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A digital pressure gauge that can measure pressures from 1 atm down to 0·5 mm Hg was developed using indigenously available materials and components. The performance of these gauges was tested by flying them on Russian M-100 rockets and comparing their performance with the performance of conventional meteorological pressure gauges used in standard meteorological payloads. Details of instrumentation and results of test flights have been presented.

1. Introduction

THE DIGITAL pressure gauge consists of an ionization chamber containing a radioactive source. The output of the chamber is connected to an electrometer which, in turn, is coupled to a blocking oscillator. The output of the oscillator is a series of pulses. At low pressures the number of molecules of air ionized in the chamber by the α emissions from the source is small resulting in a small electrometer current and a small pulse rate. At higher pressures, the pulse rate increases as larger current is detected by the electometer tube. Low pressure gauges devised on this principle for laboratory purposes have been described by Downing and Mellen[1], Sibley and Roehrig[2]; etc. The gauge described here is of the type devised by Vanderschmidt[3] and Cambou *et al.*[4].

2. Instrumentation

Gauges with different configurations were designed to measure atmospheric pressure up to 50 km altitude, by balloons as well as small and medium sized rockets. Fig. 1 shows some of these instruments. Gauges 1 (a) and 1 (b) use ionization chambers of conical shape cut out of rectangular blocks of brass. The conical chambers are similar in configuration to the chamber described by Cambou *et al*[4]. Four elliptical windows cut in the cone ensures quick equalization of pressure inside the chamber and the environment whose pressure is to be measured. The collector electrode is a tungsten wire of 0·5 mm in diameter. It runs centrally inside the chamber and is held in position at the broad end of the cone by a brass disc sandwitched between a pair of teflon rings. These teflon rings insulate the central electrode from the body of the chamber. The radioactive source used is polonium 210 of strength 50 μ curie or americium 241 of strength of 30 μ curie. The radioactive material is electrochemically deposited on a silver coin of 15·5 mm diameter and 3 mm thickness. The coin bearing the radioactive material is enclosed in a brass cap and screwed on to the narrow end of the chamber. All brass parts are polished and silver plated. The dimensions of the chamber and the windows and the angle of the cone are optimized to obtain the desired linearity between the collector current and the ambient pressure.

The gauge shown at 1 (c) is made out of a rectangular aluminium block. A circular hole of 1 cm diameter cut at the centre of the block along its length forms the chamber. The silver coin bearing the radioactive source is fitted at one end of the chamber and the tungsten wire electrode is introduced axially from the opposite end. The tungsten wire electrode is held in position with teflon discs as in the conical chamber. A 1 cm diameter window is cut on one side of the block to ventilate the chamber to outside air. This chamber is easy to mount and is more compact compared to the conical chamber.

The electonic circuits used are shown in Fig. 2. The circuit 2 (a) uses an electrometer tube amplifier coupled to a blocking oscillator. It is similar to the one used by Vanderschmidt, except for a few changes to make the output compatible with the telemetry requirements.

A more versatile circuit was developed which is shown in Fig. 2 (b). The potential at the grid of the electrometer tube at any instant is a function of the chamber capacitance and the charge on the central electrode. If the chamber capacitance and stray capacitance at the input of the electrometer tube remains constant, the potential at the grid of the electrometer tube rises as the charge accumulates on the chamber collector electrode. This potential is amplified by the electrometer tube and is fed to a comparator P which is connected in feedback loop with the transistor Q_1 to form a mono. When the probe potential at the input of the EM tube increases above a certain limiting value due to charge

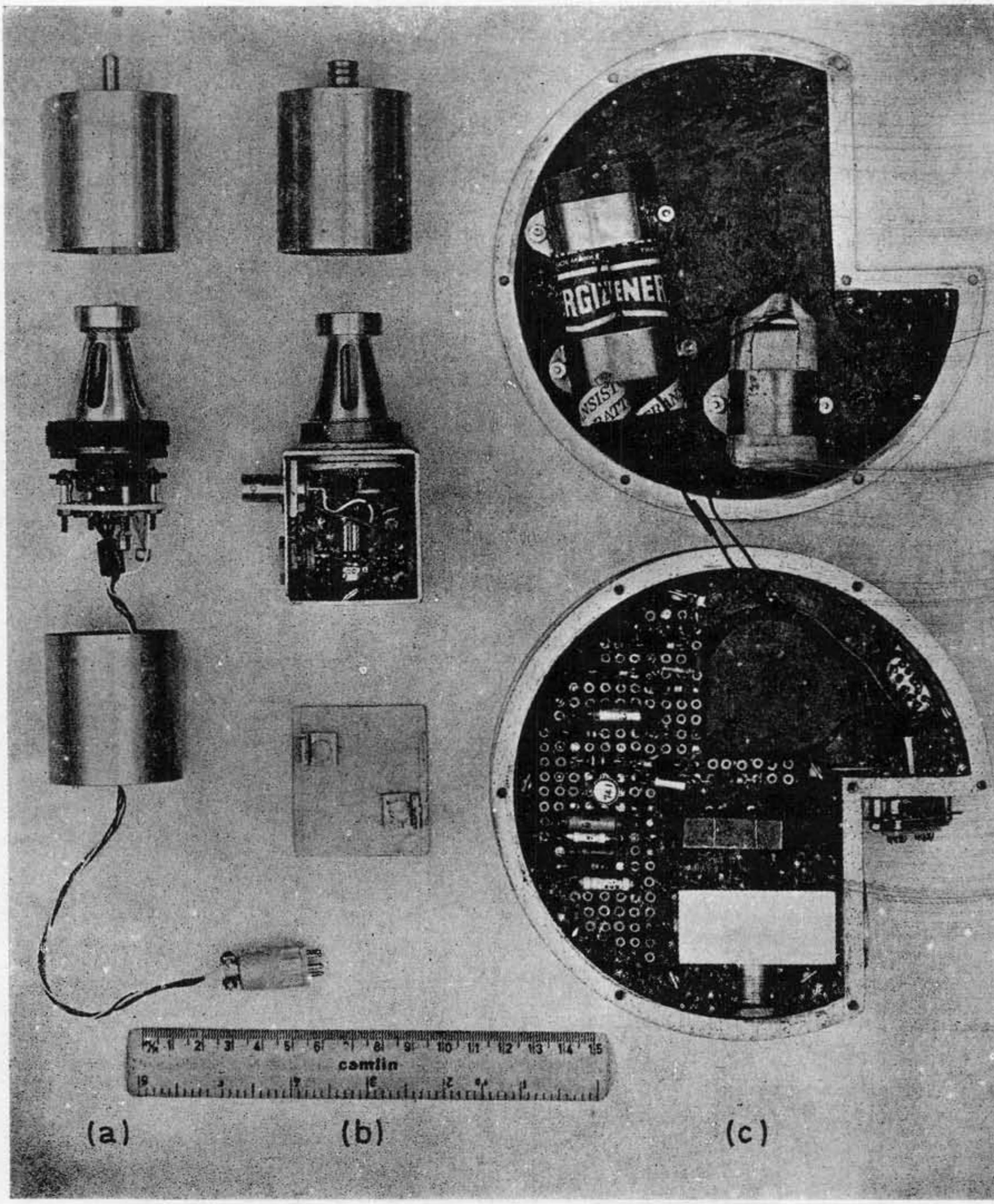

Fig. 1—The digital pressure gauges

accumulation at the grid, the mono generates a positive going pulse which is fed to the chamber through capacitor C. This pulse reaches the grid of the EM tube via the chamber capacitance and drives it to conduction, thus discharging the charge accumulated on the collector electrode of the chamber. At the end of the pulse from the mono, the central electrode is ready to collect the charges due to ionization in the chamber again and the process repeats. The charging rate of the chamber is proportional to the ambient density of air and if the temperature of air in the chamber does not change appreciably, the mono gives a pulse output whose frequency is proportional to ambient pressure. These pulses are fed to telemetry through the driver transistor Q_2. In this circuit it is possible to adjust the pulse rate appropriate to the ground pressure by adjusting the feedback. The sensitivity of the chamber depends on the capacitance of the chamber and stray capacitance of the input circuit. These must be stable and made as small as possible.

3. Preflight Calibration

The pressure gauges made for rocket flights will have to be calibrated after potting the section in which the electronic circuits are enclosed The potted unit is kept in vacuum chamber fitted with a standard pressure gauge. The voltage for the chamber and the circuit is fed through vacuum feed-throughs. The output of the chamber is connected to a digital counter. The counting rate at normal ground pressure is adjusted between 600 and 700 pulses per second. The counting rates for different pressures are noted as the evacuation of the chamber proceeds. The calibration curve of pressure against counting rate for the unit flown on flight 08·106 is shown in Fig. 3. It is found that the curve is linear even up to fraction of a mm of pressure.

4. Flight Results

A Russian M-100 rocket (FL 08·106) carrying the digital pressure gauge was launched from Thumba on January 3, 1973 at 2120 hrs IST. Earlier the same day at 2000 hrs IST a standard meteorological payload (FL 08·105) was launched to measure atmospheric pressure, temperature and wind velocity. Both the rockets carried radar transponders to enable trajectory determination. The rocket FL 08·105 payload contained two Pirani (hot wire) manometers for measuring pressure from 50 to 5×10^{-3} mm Hg and two membrane manometers operating in the range 5 to 250 mm Hg. Pressure measurements from 760 to 350 mm Hg were obtained by balloon borne meteorological payload which usually preceeds a standard Met. M-100 flight. The procedure adopted to derive the pressure values from data sent by a standard Met. M-100 payload has been described by Narayanan[5]. In Fig. 4 the pressure measurements from the digital pressure gauge of FL 08·106 have

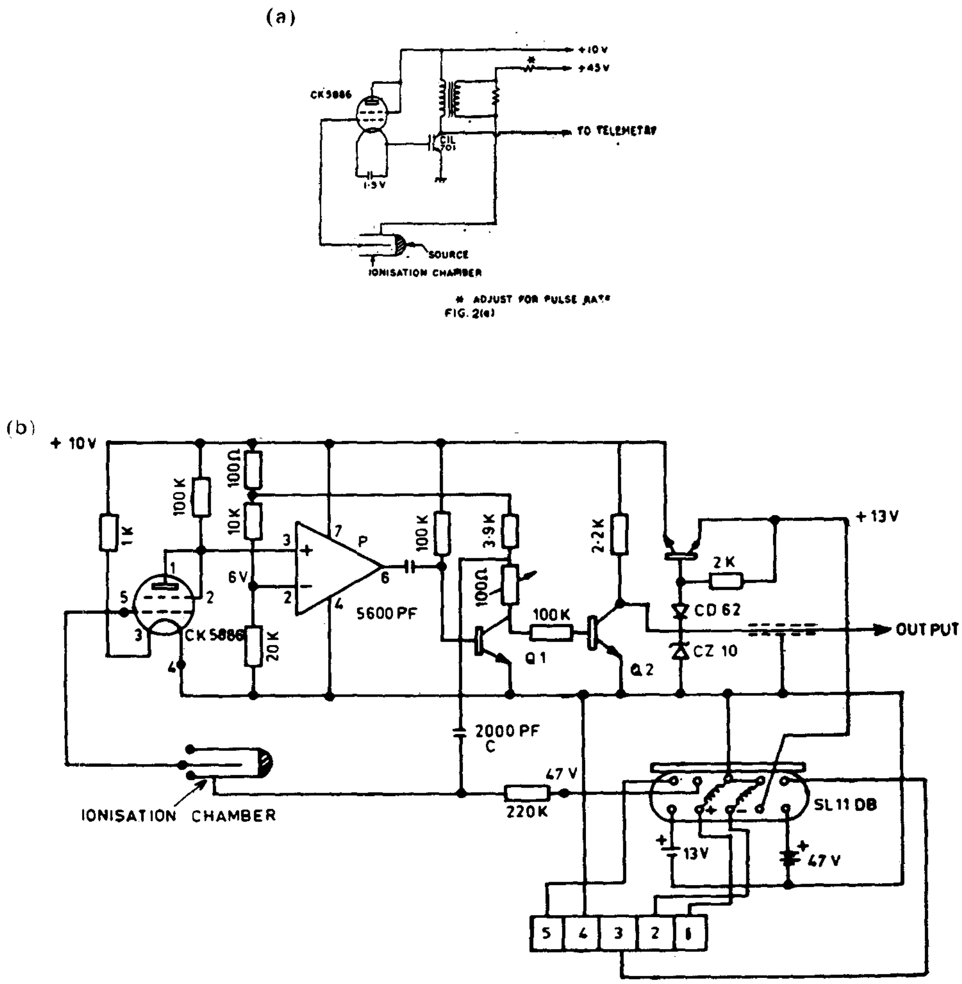

Fig. 2—The electronic circuits used for the rocket-borne digital pressure gauges

been compared with the pressure values derived from the meteorological rocket (FL 08·105) and the balloon data. It is seen that the agreement between the atmospheric pressure measured by the two independent methods is good especially above 20 km altitude.

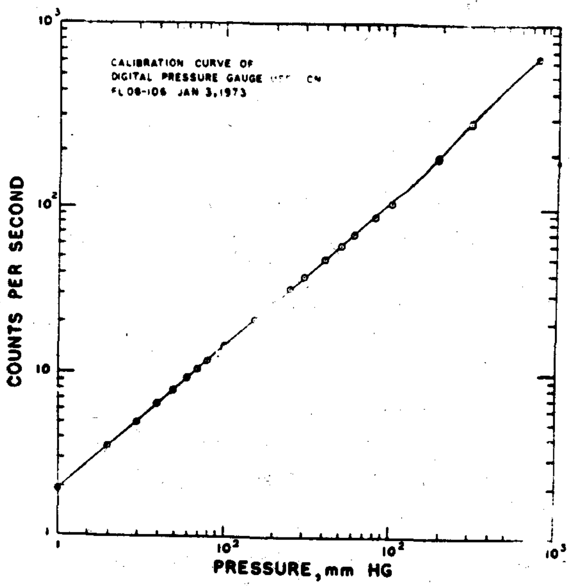

Fig. 3—Preflight laboratory calibration curve of pressure against counting rate for a typical digital pressure gauge instrumented for a rocket payload

A second digital pressure gauge was flown on 11 January 1973 at 2142 hrs IST on M-100 FL 08·108. This rocket did not reach the full expected altitude of 88 km but data could be obtained both on ascent and descent. The data from this flight along with CIRA model pressure has been shown in Fig. 5. In the flight 08·106 launched on January 3, the pressure gauge was mounted in the cylindrical part of the nose cone where the effects of the wake on the measured pressure are least. In the flight FL 08·108 the gauge was located in the conical part of the nose cone where the effects of the wake are more. This appears to have affected the measured ambient pressure at the sensor.

5. Conclusions

The performance of the digital pressure gauge described here compares well with the performance of conventional meteorological pressure gauges. It has the added advantage that its output is digital and hence easy to transmit and count. It also has a wide dynamic range for pressure measurements. Its response to pressure changes, stability of calibration and accuracy of measurement compares well with similar gauges imported and flown in the first few rocket flights from Thumba.[6] As a laboratory vacuum

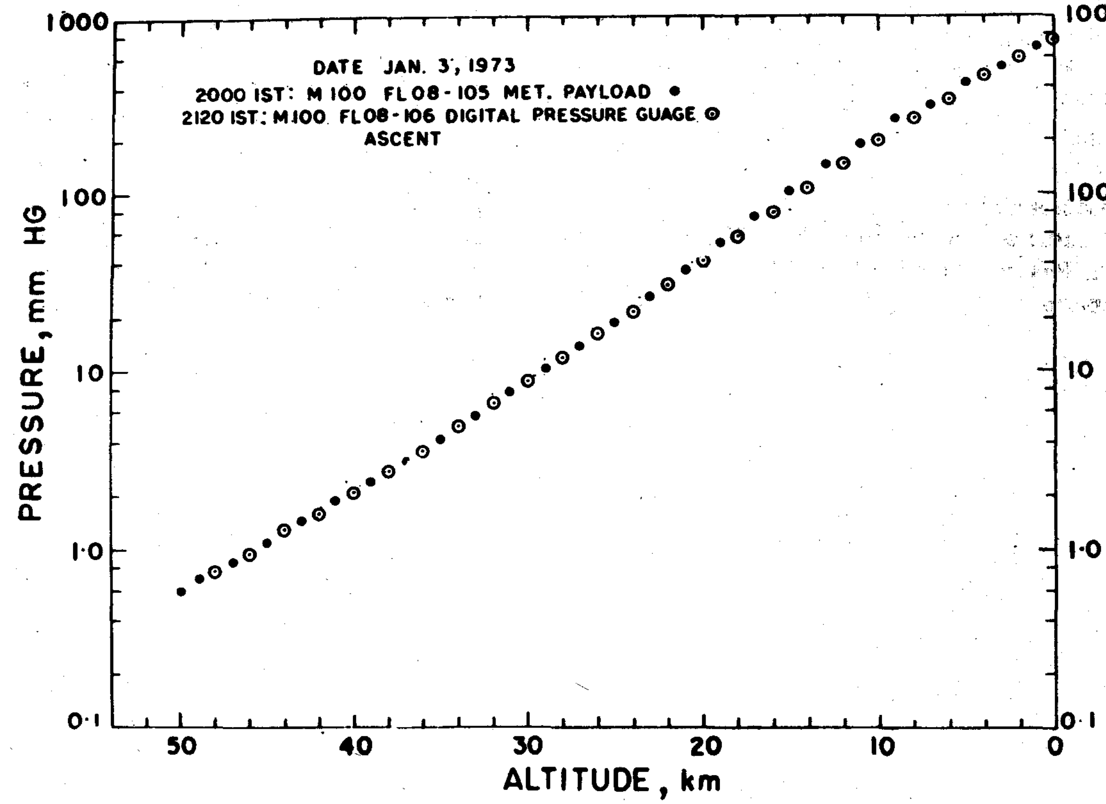

Fig. 4—Comparison of pressure measurements obtained by the digital pressure gauge on FL 08·106 and those obtained from a standard meteorological payload of FL 08·105

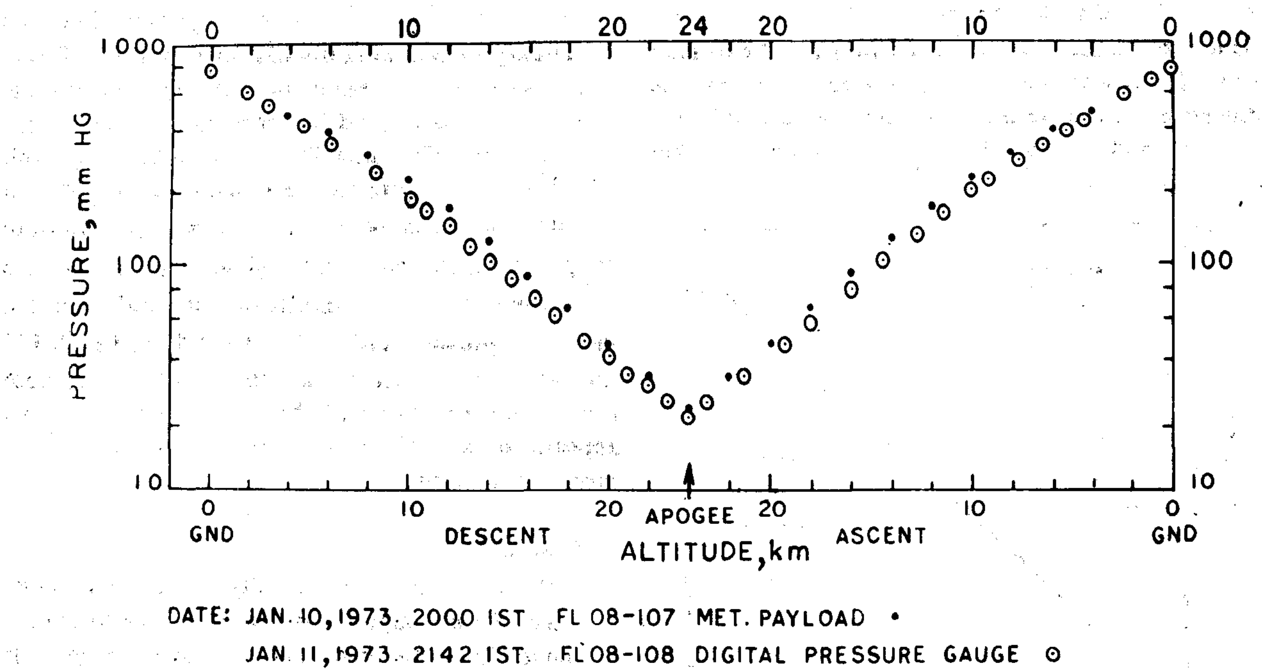

Fig. 5—Comparison of pressure measurements obtained from the digital pressure gauge flown on FL 08·108 and pressure from CIRA model

pressure gauge, its range and performance can be improved on the lines described by Sibley and Roehrig[2]. As a rocket-borne instrument, the range of the digital pressure gauge can be extended to 10^{-2} mm Hg by connecting two chambers in parallel. Using the principle described here, a differential chamber pressure gauge, sensitive to small changes of atmospheric pressure can be instrumented. Such an instrument will be useful as a laboratory barograph.

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