On an Instrument for Measuring Low-Level Vertical Temperature Profiles

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1. Introduction

Many instances of high concentrations of atmospheric pollution are due to temperature inversions. These inversions occur in stable air masses throughout the year as the result of nocturnal radiation and are generally transitory in nature. They reach maximum intensity in the early morning hours and last until they are dissipated by either heat from the sun or wind conditions. As part of an air pollution study at Purdue University, an instrument was developed which is capable of measuring the low-level vertical temperature profile of the atmosphere.

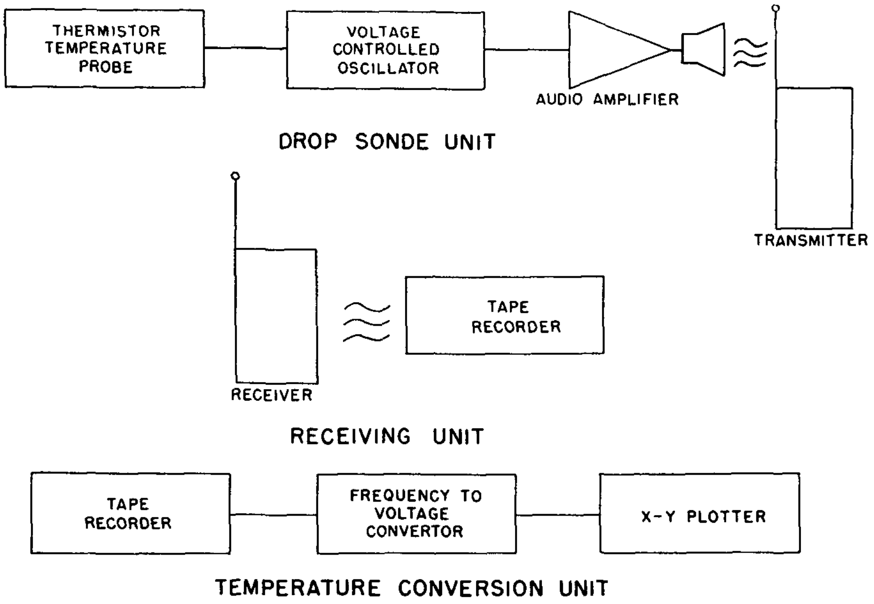

FIG. 1. Schematic of dropsonde system.

2. Other measurement methods

Prior to the development of the instrument two existing methods were considered for possible use: the radiosonde and the rocketsonde. The first of these is that used by the U. S. National Weather Service for its twice-daily measurements of the temperature, pressure and humidity profiles at various locations around the country. The radiosonde is released attached to a large meteorological balloon and transmits the information back to a receiving station on the ground. Unfortunately, no such measurements are made in the near vicinity of our experimental site, the closest facility being Peoria, Ill., 100 km away. In addition, the information from the radiosonde is very limited in the lower atmosphere. Because the lapse rate as it applies to air pollution dispersion is a very localized low-level phenomenon, remote measurements have little or no value.

Colspan Environmental Systems, Inc., of Boulder, Colo., has developed the rocketsonde. This instrument is composed of a small rocket which launches an instrument package to a known altitude, dependent upon the propulsion unit used. The rocket then descends on a parachute and the temperature information is monitored and transmitted to a ground station. Though yielding the desired information, the cost of the system was beyond the economic limitations of our project.

3. The Purdue University dropsonde

The development of a temperature measurement instrument was undertaken by Purdue University with criteria being low cost and accurate analog data. The necessity of measuring temperature continuously during either an ascent or descent through the lower layer of the atmosphere and the economic desirability of recovering the instrument package in a reusable state suggested a parachute drop from an aircraft.

A block diagram of the final measurement concept is presented in Fig. 1. As indicated, the instrument is composed of three basic units: the dropsonde which is released from the airplane, the receiving unit which monitors the temperature information, and the data conversion unit which decodes the data resulting in a graphical analog display of the vertical temperature profile.

The dropsonde consists of the thermistor probe, a voltage-controlled oscillator, an audio amplifier, and a transmitter. In operation a change in temperature produces a change in the resistance of the thermistor which in turn produces a voltage change. This voltage change, when applied to the oscillator, produces a linear frequency change. The frequency of the output is directly related to the instantaneous temperature. An equation for the conversion of temperature to voltage is furnished with each thermistor by the manufacturer. Using this equation in conjunction with measured characteristics of the voltage-controlled oscillator yields the following table of correspondence.

Temperature (°F)	Frequency (Hz)
120	1400
110	1433
100	1467
90	1500
80	1533
70	1567
60	1600
50	1633
40	1667
30	1700
20	1733
10	1767
0	1800
−10	1833
−20	1867

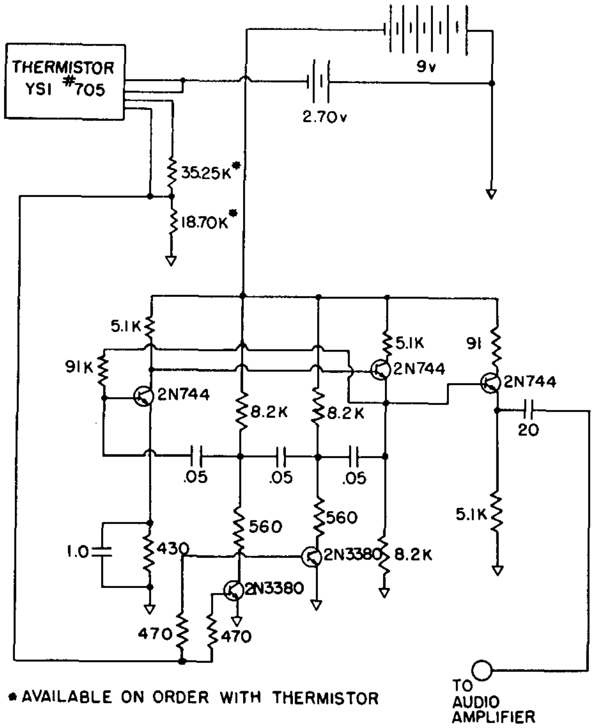

FIG. 2. Circuit diagram of voltage-controlled oscillator.

Experimental results, in a controlled temperature environment, indicate a system error of less than 1% deviation from the frequencies in the table. This frequency range has been found to be especially well-suited to the transmission characteristics of the transceiver unit. The frequency-to-voltage convertor has a rather broad range of adjustment and can easily be calibrated for a one-to-one correspondence between the input frequency and the output voltage. This has proven to be most practical for our measurements in that a frequency of 1000 Hz is 1.000 V dc; 1500 Hz is 1.500 V dc, etc.

Selection criteria for the thermistor probe involved 1) an optimum response time, 2) a maximized linear response, 3) and shielding which would minimize direct solar heating, allow maximum air circulation, and also provide protection against accidental damage. The Yellow Springs Instruments # 705 thermistor probe was selected for the sensor and has met or exceeded the design specifications. Prior to a drop the probe is taped loosely to a side of the instrument package. No additional shielding is provided as during the fall the package gyrates randomly from the single point parachute suspension thus ensuring that no one attitude is maintained continuously. Analysis of the drop recordings obtained thus far shows no discernible solar heating effects. Optimum response to a step or continuous change in temperature is obtained by using a thermistor with a time constant of about 0.6 sec.

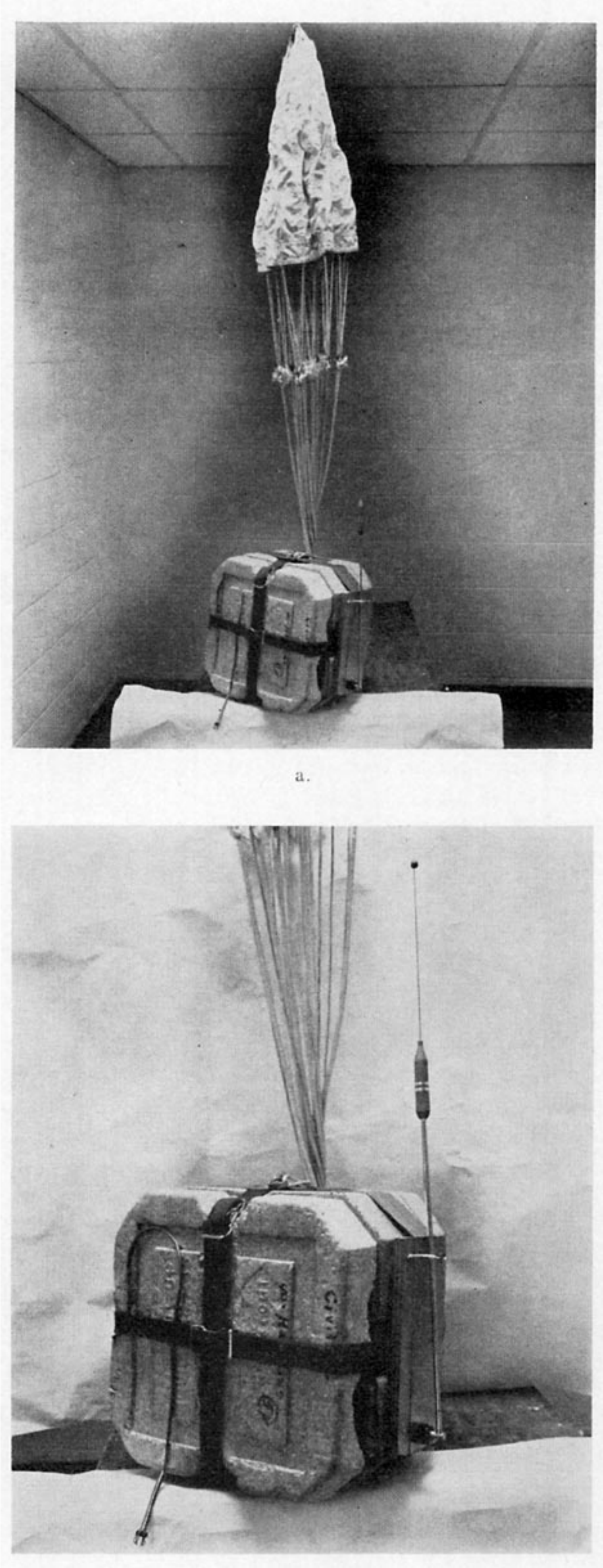
a.

FIG. 3. View of dropsonde with attached parachute, a., and closeup, b.

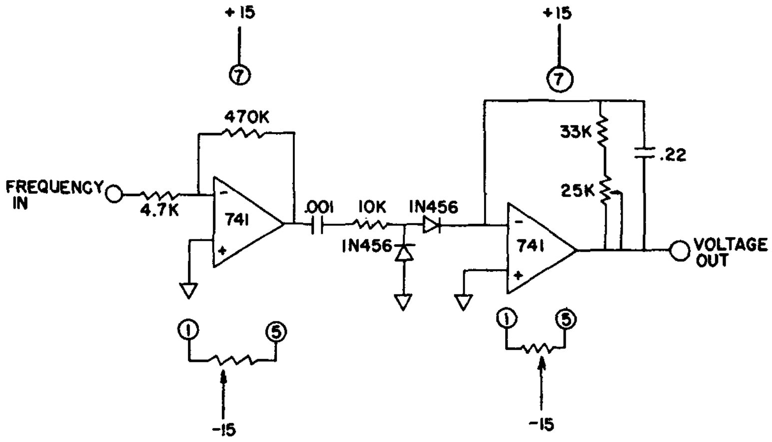

Fig. 4. Circuit diagram of frequency-to-voltage convertor.

Our results indicate that this time constant is the greatest source of apparent error in the entire system. However, as indicated, the error is a constant and mathematically results in a true downward displacement of all vertical measurements by 6 m. No temperature anomalies have been observed either in the controlled environment or in field usage. A circuit diagram of the thermistor and the voltage controlled oscillator is given in Fig. 2.

The audio output from the oscillator is fed through an amplifier to enhance the signal. An integrated circuit amplifier is used for this purpose. The amplifier signal drives a small speaker which is acoustically coupled to the transmitter. A Realistic® Model TRC-99C Transceiver is used as the transmitter.

The dropsonde unit is packaged in a styrofoam case. A webbed belt harness is strapped around the case which is attached to a 1.3 m diameter army-surplus target parachute. The descent velocity of the dropsonde is controlled by the number and size of parachutes used. A descent velocity of 10 m $\sec^{-1}$ is possible without causing any impact damage to the dropsonde. Two views are shown in Fig. 3.

The ground-based receiving station is composed of a second TRC-99C Transceiver and a Sony® Model 110 A casette tape recorder. The receiver and recorder are both portable, battery operated, and enable the operator to perform the dual function of recording and recovering the dropsonde instrument package.

Once on tape the temperature data can be played back and a permanent record made using the frequency-to-voltage convertor and the x-y plotter which form the data conversion unit. A detailed schematic of the frequency-to-voltage convertor is shown in Fig. 4. The plotter used must have a linear time base for the x axis which can be set to approximately 1 cm $\sec^{-1}$. The y axis is then representative of the temperature.

In taking a measurement the dropsonde is carried to the desired altitude. The altitude is measured by the altimeter in the aircraft. Upon reaching the drop site the dropsonde is released through the window of the plane. The time of fall can either be measured from the ground at the time of the drop or from the tape recording of the signal. A constant fall velocity is assumed. The signal is received and recorded at the drop site, and the recording is then taken to the laboratory for decoding.

4. Test results

A typical trace from an actual release of the dropsonde is shown in Fig. 5. The dropsonde was released from an altitude of 800 m and the unit descended at a rate of 6 m $\sec^{-1}$. The trend of the lapsed surface condition is clearly evident in the figure.

The use of citizens band radio channels for data transmission precludes interference-free signals. Instances of occasional interference have occurred, but

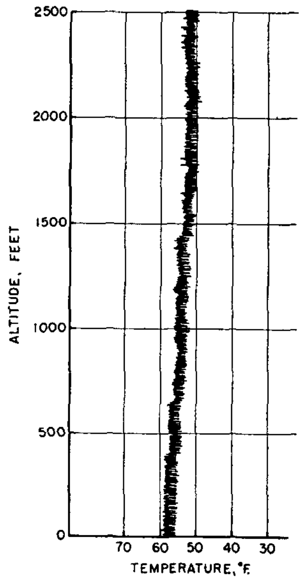

Fig. 5. Dropsonde measurement of temperature profile.

they are minimized by the nature of the data taking, i.e., early morning, and the relatively short recording period which is generally less than 3 min. When interference occurs it is manifested by erratic loss of data. Return of the clear signal restores the graphical representation with minimum loss of coherence.

The transceiver is rated by the manufacturer to have an effective radiated power output of 3 W. No effort has been made to drop the instrument package from altitudes >3000 ft above ground level. Allowances must be made for wind drift but even so, the slant range is never significantly greater than the vertical range. Loss of signal due to power limitations has never occurred for any given drop and with the exception of signal loss due to simultaneous voice transmissions on the same channel as mentioned previously, no range limitation has been observed.

5. Summary

An instrument has been developed at Purdue University which is capable of measuring the vertical temperature profile through the lower layer of the atmosphere. The total cost of the instrumentation is about $250 and each measurement costs about $7.00. Such an instrument can prove to be a valuable tool to meteorologists and environmentalists in measuring low-level lapse rates.