A Radio-Command-Control Puffer for Studying Airflow *

D. L. RANDALL ** and A. B. J. CLARK ***
Naval Research Laboratory, Washington 25, D. C.

ABSTRACT

A system is described with which airflow in the lower one or two thousand feet of the atmosphere can be studied by the use of a radio-command-control smoke puffer. Several applications of this system are proposed in connection with balloon sounding techniques.

INTRODUCTION

O  

ne of the obstacles to the advancement of knowledge in tropospheric radio propagation and atmospheric turbulence is the lack of instrumentation for measuring the behavior of air currents in free space. Early investigators observed smoke [1] for this purpose, some of whom photographed either smoke plumes [2] or smoke puffs [3]. Measurements of turbulence have also been made by recording the displacements of spherical balloons [4] attached with rubber bands to a tethered balloon cable. Finally, others have photographed soap bubbles [5] generated below a tethered balloon.

It was in an attempt to use the method of photographing controlled smoke puffs to find the airflow at a tethered-balloon level that the authors conceived the idea of using a model airplane command-control system. This article will describe the principal components of this system. Applications of this instrumentation will be proposed for:

1. Determining the instantaneous wind speed and turbulence, at several heights simultaneously, in a given layer of air,
2. Measuring the airflow around a freely rising tethered balloon,
3. Making low-level soundings without an electric cable to tether the balloon or to switch the sensing elements, and
4. Controlling the altitude of a free radiosonde balloon, and switching the pressure-, temperature-, and humidity-sensing elements of the transmitter by radio-command control.

A schematic diagram of the principal components of the radio-command-control smoke-puffer system is shown in Figure 1.

The ground component is a 27.2-megacycle crystal-controlled model-airplane transmitter [6] that uses a 3A5 tube. Power is provided by two 67.5-volt "B" batteries and one 1.5-volt "A" battery. The power of this transmitter is sufficient to control the receiver and fire the puffer unit, under normal conditions, over a radius of 1800 feet from the ground. Radio energy is supplied by a 5-foot telescoping antenna tube which is bolted to the case of the transmitter. The entire ground unit weighs about 3 pounds.

The airborne components include: (1) a radio receiver powered by two 22.5-volt hearing-aid "B" batteries and a 1.5-volt "A" battery, (2) escapement control relay, (3) escapement-switching mechanism, and (4) a smoke-puffer unit of six pill boxes filled with black gunpowder.

The receiving unit uses one XFG-1 gas-filled tube which is normally in the conducting state until a radio signal is received from the transmitter. A very sensitive relay in the receiver unit's plate circuit keys the escapement circuit consisting of the relay-contact points, a 6-volt "C" battery, and a low-resistance escapement solenoid. When keyed by the relay, the solenoid

---

* The Material in this article is Unclassified.
** Atmosphere and Astrophysics Division, Aerology Branch.
*** Mechanics Division, Ballistics' Branch.
FIG. 2. The Radio-command-control-puffer, showing the transmitter, the receiver, with its modified escapement and switching mechanism, and the puffer.

operates an armature against a spring which permits a 180 degree rotation of a rubber-band-powered escapement shaft. This shaft, in turn, operates a 12-point wafer switch through a 6-to-1 reduction gear train, thus advancing the contact arm 30 degrees at each step. By this means the contact arm of the wafer switch is set in sequence on a single contact point of the wafer. (In developmental tests, every other contact point was connected to a pill box in the puffer unit through a 7-conductor cable; up to 11 pill boxes could have been connected.) A second 6-volt "C" battery is connected to the common return of the wafer switch for igniting the filaments in the pill-box puffers.

The six pill boxes in the puffer unit are mounted on a narrow strip of balsa wood. A 1-ohm piece of nichrome wire is soldered between the conductors inside each pill box. (The electrical continuity of the conductors is checked with an ohmmeter.) When the puffer unit is connected in series with the 6-volt "C" battery through the wafer switch, the nichrome wire fuses and ignites about 110 grains of FFF black gunpowder in each pill box. Operation of the puffer unit is checked on the ground before flight by testing the circuitry with light bulbs that are connected in the same manner as the pill boxes. To avoid accidental firing of the pill boxes, the puffer unit is connected to the receiver unit with the wafer switch in open-circuit position.

The total instrumentation in this system (Fig. 2) weighs about 5 pounds. The airborne equipment (about 2 pounds in weight), when ready for use (Fig. 3), is attached* to the tethering cable just below the balloon and the pill boxes fired, one at a time as desired, by the operator. The camera is used to photograph smoke puffs as they drift by the balloon. The known dimensions of the balloon and the framing rate of the camera are used to compute the speed of the smoke puffs, and consequently the speed of the air current.

FIGURE 4 shows the system as it was used to measure the wind speed of smoke puffs beneath two JX-5 kite balloons at a height of 400 feet. Four seconds intervened between the two photographs shown. Using the 18-foot balloons as a scale, it was estimated that the center of the puff traveled 10 feet within the time interval between exposures, or a rate of 1.7 miles per hour.

PROPOSED APPLICATIONS

Whereas the reason for developing this system was to obtain the wind speed at the balloon level, there are many other purposes for which a radio-command-control system could be used:

1. Study of instantaneous wind speed and atmospheric turbulence through a layer of air. Figure 5 depicts a proposed system for such a study.

* The unit may be attached to the balloon cable at any desired position for favorable photography and exposure.
 Motion-picture photographs showing the distance between centers of the puffs for a known interval of time could be used to find wind speed at several heights simultaneously, and the time of dissipation and broadening of the puffs [3]. In addition, wind-shear zones and vertical diffusion rates may be determined, and the strata located where smoke particles and water vapor will collect. The present technique for studying this type of problem for radio-propagation and air-pollution investigations is to measure temperature and humidity as a function of height by a slowly moving point sensor. This proposed system may obtain a direct, observable, and instantaneous picture of wind speed and atmospheric turbulence for an entire layer.

2. Study of airflow patterns around a freely rising balloon. Radio-controlled puffers attached in the proper locations on a freely rising balloon could give valuable information about the airflow around the balloon, and give valuable design information for the construction of special-purpose balloons.

3. Switching of elements in a tethered balloon-borne radiosonde transmitter without an electric cable. The switching mechanism of the radio-command-control system, when altered so as to have a range of two or three thousand contacts, could be satisfactorily employed to switch the temperature and humidity elements in a standard tethered radiosonde transmitter in place of the conventional baroswitch. The information sensed at the balloon level could be recorded on the radiosonde ground recorder, and the height of the balloon obtained from the length of the tethering string, and the angular position of the balloon [7]. Thus the same type of detailed information could be obtained about the temperature and humidity structure of a layer of air as with the present electric-cable type of low-level sounding systems. For locations where radio silence is not imperative, this system would eliminate many of the problems of cable breakage, temperature compensation, and dirty-slide contacts. For radiosonde stations, detailed low-level soundings could be made with very little additional equipment.

4. Controlling the height of a free radiosonde balloon and switching of the radiosonde elements in the transmitting circuit. A radio-command-
control unit could be devised for switching pressure, temperature, and humidity elements in a standard radiosonde unit, and for controlling the rate of ascent or descent of a balloon by valving out ballast or gas. Such a low-level sounding system would be practical around airports where a tethered balloon is a hazard to aviation. This system would necessitate the construction of a different type of pressure-sensing transducer, and a more powerful command-control transmitter. The present radiosonde ground equipment could be used. This system would make it possible to measure pressure, temperature, and humidity at any desired level instead of in a fixed increment of nearly 500 feet as is done in the present radiosonde system.

**Conclusions**

The radio-command-control smoke-puffer system described here was more practical than any other method considered for measuring the speed of airflow at the balloon level on this particular test. It is believed that this system, as proposed, would be a useful tool for obtaining simultaneous wind velocities in a layer of air 1000- or 2000-feet thick above ground, and that it would have other useful applications in balloon-sounding techniques.

**Acknowledgments**

The authors wish to thank the many persons who have assisted them with this problem. Particular thanks are due Messrs. S. O. Bailey, C. H. Kingsbury, C. C. Hauver, W. E. Anderson, H. T. Heyward, P. T. Boltz, and C. H. Bury, Sr. This work was supported by the Aerology Branch of the Bureau of Aeronautics.

**References**


