SEQUENTIAL FLASH FOR PHOTOGRAPHING TRAJECTORIES OF SALTATING PARTICLES

by
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Abstract

To obtain statistically useful samples of the maximum heights attained by saltating snow during drifting, several thousand particle trajectories must be measured. This paper describes a light source for photographs of sufficient quality that computer analysis can determine these heights automatically. The method uses eight small electronic flash units fired in sequence through color filters. The flashes, combined with continuous white light, are projected through a narrow slit by a single lens, producing trajectory images that are white traces with colored dots noting particle position at sequential time intervals.

INTRODUCTION

Saltation of drifting snow, where each particle impacts the surface between flights only a few centimeters high and less than 1 m along the wind direction, accounts for much of the mass transported by moderate winds. Knowing how factors such as surface roughness and particle size influence the saltation rate is essential to improving equations for transport and deposition. Tests of several equations that relate the height and speed of the saltating particles to the windspeed profile await a method of sampling saltation trajectories. This paper reports initial steps toward such a method.

Previous attempts to photograph saltating snow particles demonstrate the difficulties. Kobayashi (1972) published the first photographs. By projecting a thin beam of light perpendicular to the ground, and parallel to the wind, he produced images of particle streaks. To obtain good contrast, he photographed at night. This lighting technique provided an image of the particle path, but not particle velocities. Kobayashi also tried a strobolight, flashing a number of times during each exposure, to give the particle's average velocity between light pulses. But, depending upon the time or distance between the dots on the photograph, and the number of particles in the photograph, it was very difficult to determine which dots correspond to which particle's path.

THE DESIGN

The concept of our design combines Kobayashi's methods to produce images in which low intensity traces of white light connect colored images of particle position at sequential time intervals. A continuous white light produces the trace, and firing small flash tubes behind colored filters produces the colored points. This combination will make possible a computer search along each trace in the digitized image for colored dots in a known order, from which particle position and speed will be determined. Field conditions dictate a design that is also blizzard-proof, battery-powered, and portable.

To facilitate description, this prototype system is divided into (a) the containment tube (b) the sequential flash unit and (c) the continuous light source and slit projector (Fig. 1).

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SEQUENTIAL FLASH

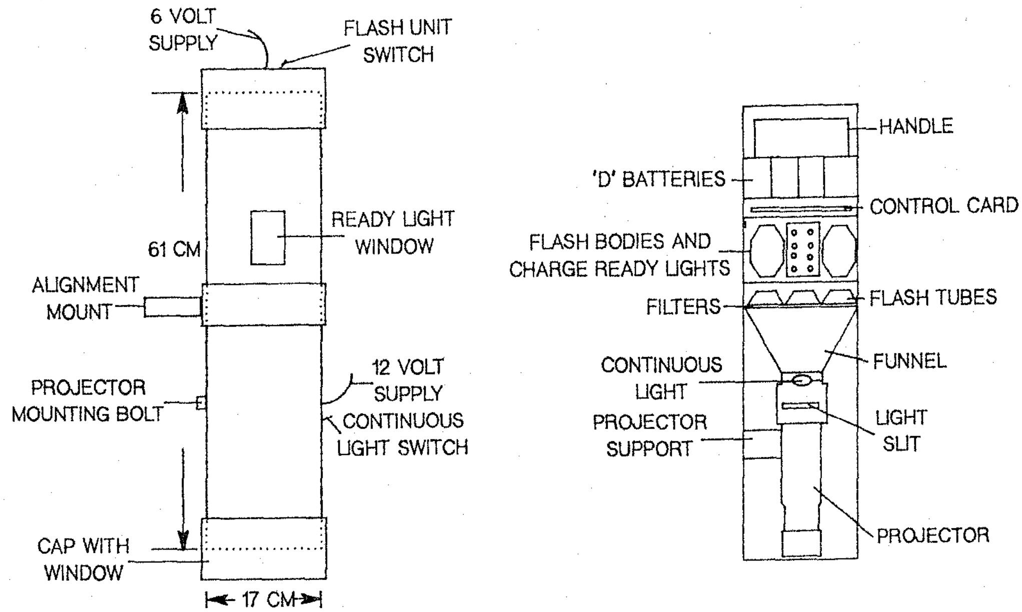

Figure 1. The containment tube (left) provides a weatherproof housing for the flash unit (top right) and projector (lower right).

The housing is plastic (PVC) pipe 17 cm in diameter and 61 cm long with two end caps. A 9-by-9-cm glass window in the bottom end cap passes the projected light, and for viewing the flash charge lights, a cut-out on the side is covered with clear acetate. The alignment mount allows turning the tube so the light is perpendicular to the surface and parallel to the saltating flow. For this, a ring (cut from an end cap) fitted with a piece of steel pipe slips over the tube and is held in place with a ring stop (Fig 2). A switch and leads for the 12-V power supply to the continuous light is on the side. The top cap is also fitted with a switch, for a 6-V power supply to the flash timing card.

The flash unit (Fig. 3) consists of four aluminum plates supporting (1) 8 D-size batteries, (2) the control card, (3) flash bodies with charging circuits and ready lights, and (4) flash tubes with filters. Holes (2.5 cm) drilled in the center of the top three plates allow wiring to pass between plates. Each battery in the holders mounted on the top plate charges a flash through a relay controlled by the 6-V supply switch, because the power to each flash must be independent (floating).

The flash control card (Fig. 4) fires each flash sequentially at fifteen millisecond intervals. This interval is adjustable by varying the frequency of an R-C oscillator. The chosen interval exposes a particle to all 8 flashes as it moves 20 cm at a speed of 2 $m\ s^{-1}$. Powered by a 6-V lantern battery, the free-running oscillator sends a pulse train to the counter, which is only enabled when the camera flash synchronization switch is closed. Then eight separate counter outputs produce a pulse in sequence, fifteen milliseconds apart. Buffers (CMOS-to-TTL) transfer each pulse to open-collector drivers whose output current is sufficient to trigger the optically-coupled silicon controlled rectifier. These SCR's provide an interface between the 5-V timing logic and the 200-V flash tube voltages.

Rewiring each electronic flash with longer leads allowed relocation of the flash tubes and charge ready lights. The flash housings, which still contained the charge pumps and capacitors that build 200-V charges from the 1.5-V batteries, were mounted on a plate that supports the ready-light board. These neon lamps are held in rubber grommets on a viewing board, and numbered with their respective flash tubes.

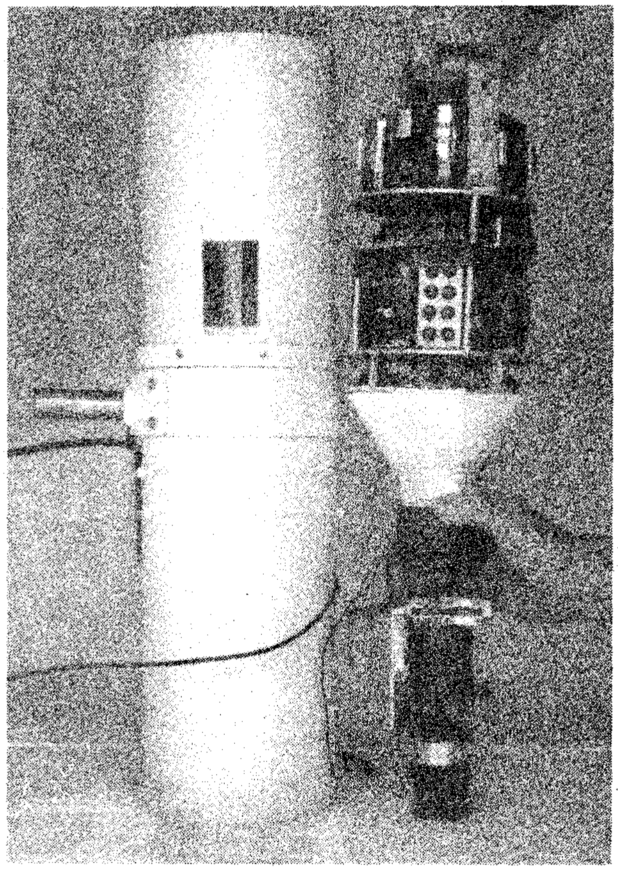

Figure 2. The flash unit mounts above the projector, and both subsystems slide into the housing (left). A slip-ring near the center of the housing supports the device.

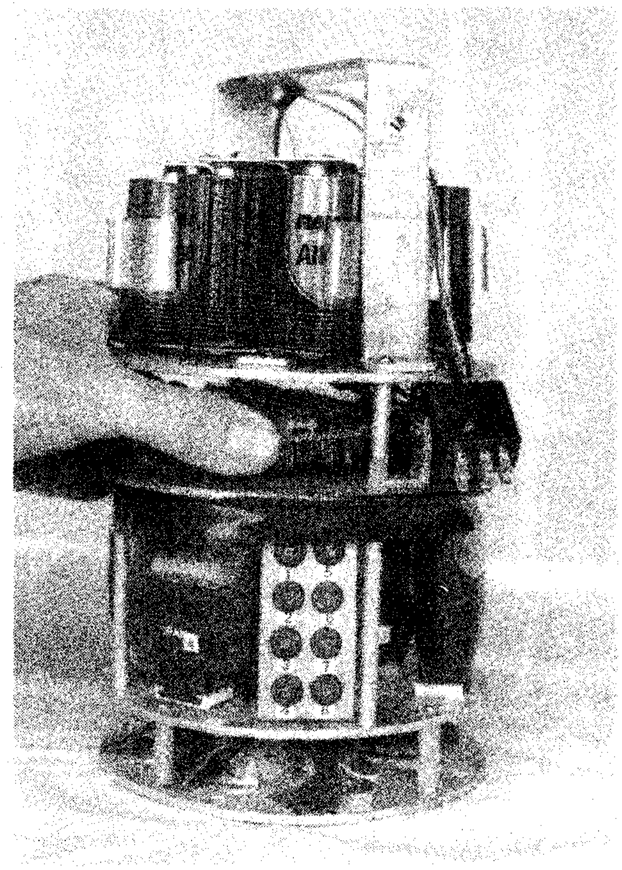

Figure 3. The flash unit consists of four plates supporting (from top to bottom), batteries, control card, flash circuits, and flash tubes.

The flash tubes are mounted over rectangular windows cut at equal angles in the bottom plate. Each flash window is fitted with a different colored filter. A handle attached to the top plate aids in the removal of the flash unit from the containment tube.

Continuous light from a 12-V, 50-W, halogan bulb attached to a modified slide projector is directed through a narrow slit (1 mm x 2.5 cm) in an opaque slide placed in the slide holder. A funnel acts as a spacer and light guide between the projector and the flash unit. Focusing the projector lens produces a sharp image of the slit on the saltation surface.

TESTS

The device operates reliably in cold temperatures during storms, and requires about 30 s to fully recharge all flash units under such conditions. When mounted 1 m above a flat surface the projected slit measures 3 mm by 20 cm. Because we will measure oscillator frequency during photographic sampling, stability of the oscillator is not a major concern, and has not been tested yet.

Two objectives of initial testing were determination of a balance between the intensity of continuous and flashed sources, and determination of proper exposure. Results of balance tests led to increasing the continuous lamp to 50 W, and color slide film rated at 3200 ASA produced useful images.

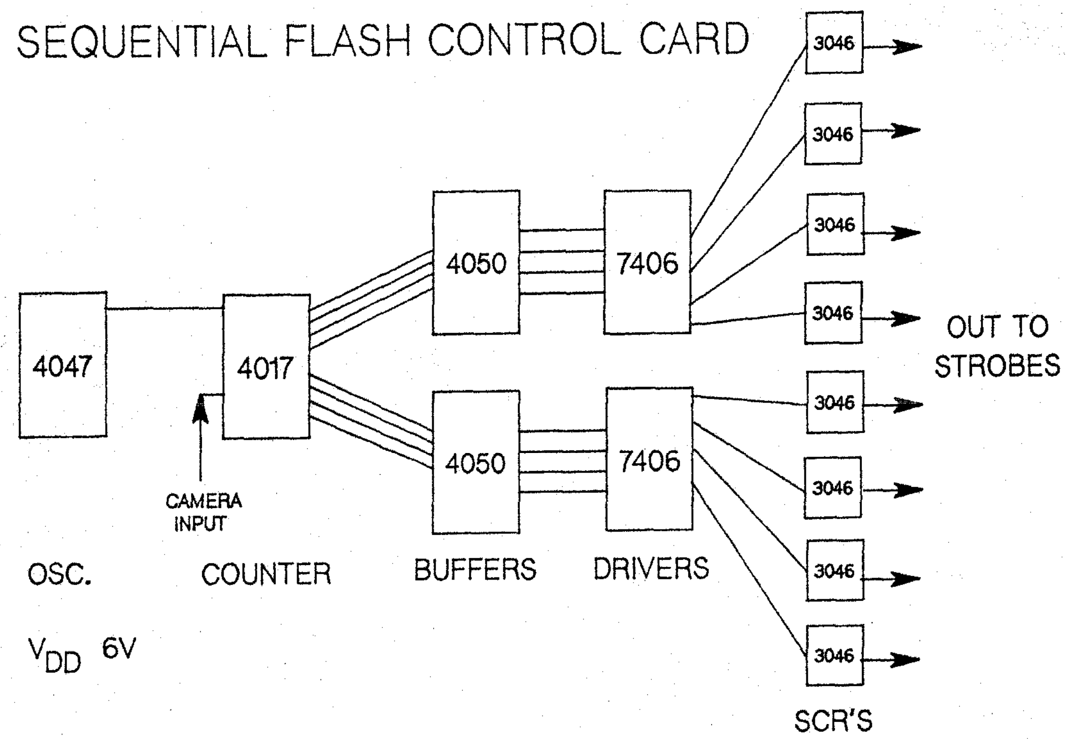

Figure 4. Diagram of the control card. Camera input is the closure of the flash synchronization switch. (Numbers are chip designators.)

REFERENCES

Kobayashi, D. 1972. Studies of snow transport in low-level drifting snow. Contributions from the Institute of Low Temperature Science, Series A, No. 24, pp. 1-58.