Positive displacement vacuum-sweep dispenser for small particles

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A dispenser was developed for feeding small particles into a laboratory burner at a very constant flow rate. A positive displacement of a continuously replaced volume of particles is employed combined with a sonic ejector. The combination meets the requirements for good chemical measurements. The system also satisfies the requirements for laser-Doppler anemometry.

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INTRODUCTION

There have been many particle dispensers developed in the past, but each type has had disadvantages and leaves much to be desired. Methods used to date do not easily produce a constant flow rate and, hence, are not convenient for accurate measurements. The problems encountered involve the formation of particles into clumps before delivery and intermittent slowing down and speeding up of the mass flow with general unevenness of flow rate. In addition, for mixtures of particles of different sizes there is the problem of size separation with removal and segregation of large particles from the mainstream of the flow. The mixture of sizes and shapes must remain constant for constant characteristics and steady-state flow conditions.

Perhaps the most common device is the standard screw feeding[1] or moving belt[2] mechanism. They unfortunately tend to deliver clumps of particles and have uneven feed rates. The often-used gravity-feed vibrating-hopper[3] arrangement, associated with many feeders, also tends to deliver dust at an unsteady feed rate. The fluidized bed feeder[4,5] that many researchers often depend on is sensitive to slight pressure changes and tends to segregate particles by size and weight, thus departing from a steady and uniform flow. Blower types likewise have produced irregular delivery rates. A new (now commercial) bead-belt feed[6] type is good only for extremely small flow rates for very small particles and cannot be scaled up. The approach described here makes use of a positive displacement of an accurate volume of particles and a sonic ejector. The dispenser described here was developed in order to supply coal particles at various fixed (constant) rates to a ceramic tube burner.

I. EXPERIMENTAL APPARATUS AND APPROACH

In order to eliminate the problems of erratic flow the present idea was to pick up *all* of the dust in a given small volume which is continuously replaced. To remove all the

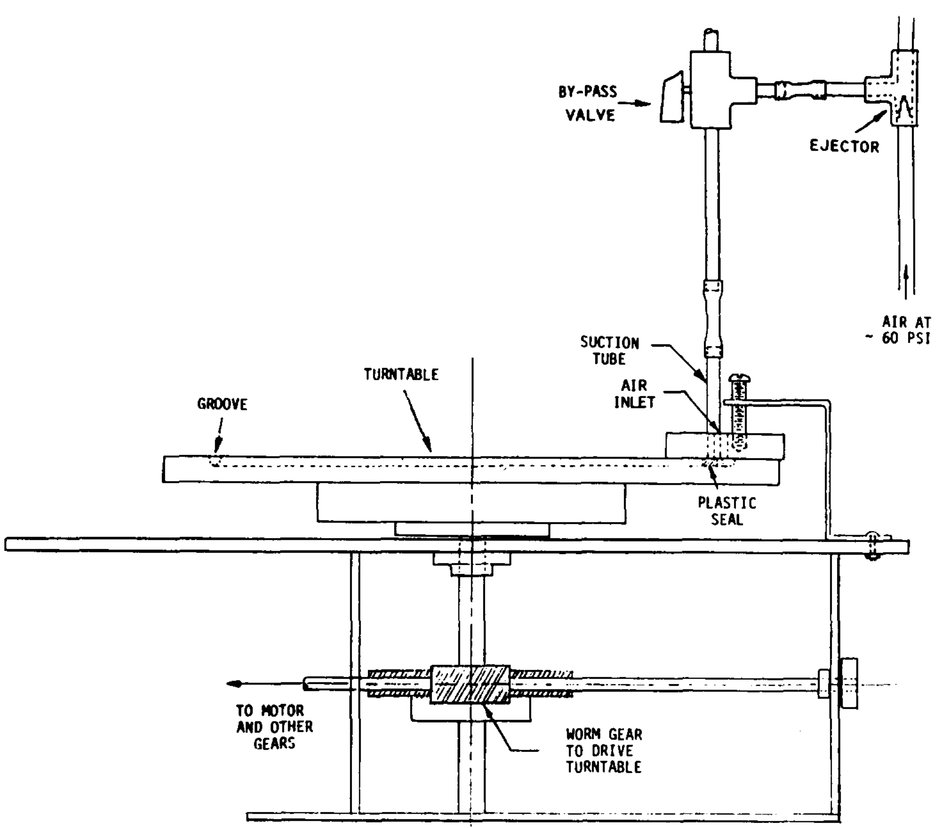

FIG. 1. Sketch of dispenser.

dust a vacuum pickup driven by a small sonic ejector was chosen. The small volume of dust is continuously replaced by using a groove in a rotating disk to hold the dust. A seal extending into the groove is attached to the plate that is a mounting for the ejector intake. The plate has an intake hole for air and an exhaust hole through which the mixture of dust and air is sucked by the ejector. The groove filled with dust rotates under the vacuum pickup and is emptied as it turns. The rate of rotation determines the rate at which the dust is removed from the groove and exhausted into the receiving system by the vacuum pickup ejector. To make sure that the groove is swept clean of dust as it rotates, a shallow groove without corners, of semicircular cross section was used. See Fig. 1 and Fig. 2.

The ejector was constructed very simply from several short lengths of stainless-steel tubing of decreasing diameters making a converging sonic nozzle which exhausts into a small mixing chamber of larger tubing. The sonic ejector has the added advantage of breaking up clumps of particles which may have formed. Figure 2 is a schematic of the dispenser arrangement.

The drive system used to rotate the disk holding the dust was taken from a chart recorder which had several different speed settings. The calibrations at the two speeds used is shown in Fig. 3. A change in the diameter of disk (length of groove) or in the depth of the groove would of course change the slope of the curve and the rate of delivery. Thus changes can easily be made. The delivery was found to be quite uniform for fine lime dust and coarse sand as well as for the coal dust for which it was developed.

For batch operation the groove is filled before starting.

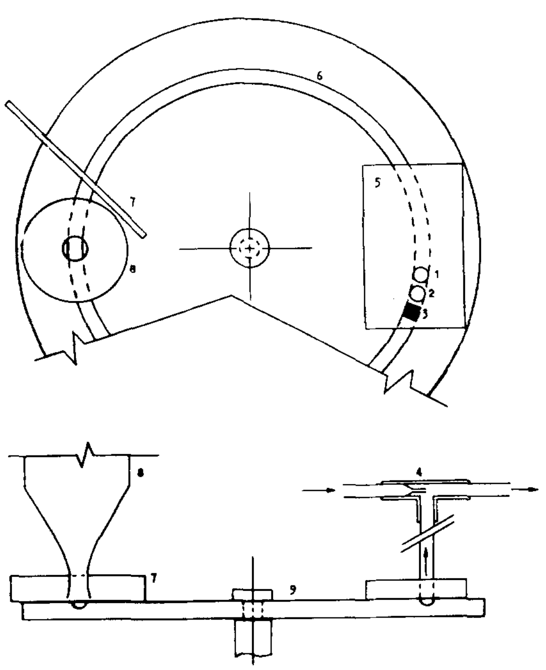

FIG. 2. Schematic of dispenser components. (1) air inlet—$\frac{1}{8}$-in. diameter; (2) suction outlet—$\frac{1}{8}$-in. diameter; (3) wiper seal; (4) ejector—0.5-mm throat; (5) pick-up assembly; (6) storage groove—10-in. diameter, $\frac{1}{4}$ in. deep; (7) wiper blade; (8) storage hopper/with vibrator; (9) rotating disk.

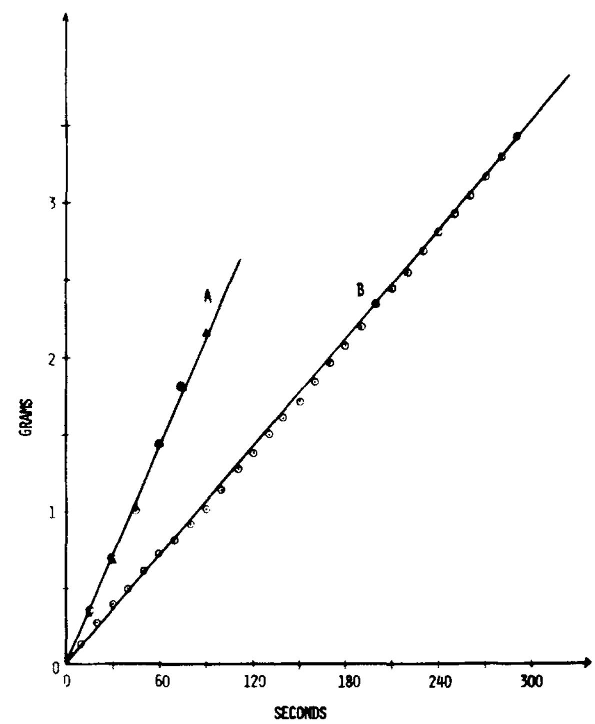

FIG. 3. Calibration of dust dispenser. (A) medium feed rate; (B) low feed rate.

For continuous operation a hopper is necessary. However, with the groove arrangement uniform delivery can be maintained by overfilling the groove and using a wiper to remove the excess. In this way, the flow of dust falling from a hopper need not be steady since the variation will occur only in the excess quantity which is wiped away. The flow from the hopper can be maintained in the usual fashion by means of gravity and a vibrator. As long as the flow from the hopper is appreciably greater than that needed to fill the groove, and the excess is wiped off, the delivery from the filled groove will be uniform and constant.

II. DISCUSSION

The dispenser described is capable of delivering a steady uniform flow of particles ranging in size from submicron to several hundred microns. The strong shearing action of the supersonic primary stream in the ejector tends to break up any large "clumps" which may have survived the mixing action of the suction pickup. This was confirmed by observations of the flow from the dispenser. The positive and steady removal of all of the dust from a relatively small well-defined section of the channel (groove) in a disk rotating at a constant speed provides an extremely well-controlled dust feed rate. (The usual problem with gravity feeds, even with good vibrators, is the uncontrolled manner in which the dust falls with more or less dust falling from time to time.) This dispenser can be easily scaled up or down and can be used for laser-doppler anemometry as well as for accurate combustion measurements. It can also be adapted for operation at other than atmospheric pressure by putting the whole dispenser into a large sealed box maintained at the desired pressure.

ACKNOWLEDGMENT

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