

A Portable Wind Tunnel and Dust Collector Developed to Evaluate the Erodibility of Field Surfaces¹

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EVALUATION of the phenomena of soil movement by wind presents a difficult problem. Evaluating natural occurrences in the field is almost impossible due to the factors of time and place, and a lack of control over the variables involved. If progress is to be made, it appears that an artificial device is a prerequisite. Where the latter is used, the results are a step removed from the natural phenomena and must be interpreted accordingly if they are to be other than qualitative. The dynamic characteristics of air flow over surfaces in an artificial device and in the open must be known to surmount this difficulty.

The research reported here deals with the wind tunnel approach. The task of tying natural occurrences to artificial device is in progress.

Portable Wind Tunnel

Portable wind tunnels have been constructed previously to study wind erosion in the field. Citations of reports dealing with their description have been given previously by Zingg and Chepil.³ The requirements of a portable wind tunnel, based on the author's interpretation of these prior experiences, may be summarized briefly as follows:

1. The wind tunnel must be capable of producing an air stream free of general rotation and of known and steady characteristics.
2. It must provide easy and positive control of a range of wind velocities and forces common to the natural wind.
3. It must be durable.
4. It must be safe to use.
5. It should have sufficient size to afford free movement and representative sampling of eroding materials over field surfaces.
6. It must have ready portability.
7. It should be light in weight and amenable to quick and positive assemblage and dismantling.

In assembling the present tunnel, commercial equipment was used in so far as possible. The air-moving unit consists of a heavy duty axial-type ventilating fan with adjustable vane-inlet control. The fan has 6 blades and is 3 feet in diameter. It is driven with a 30 h.p. governor-controlled commercial gasoline power

unit. These items are mounted on a rigid welded 4-inch channel iron framework. The addition of a hitch, axle, and wheels converts it to a portable unit. It is trailed for short distances and for immediate use in the field with a pickup. It is transported long distances on a truck for safety considerations. A controlled air flow up to approximately 32,000 c.f.m. is possible without exceeding the ratings of either fan or engine. The unit is capable of creating sufficient air flow in a 9 square foot duct to satisfy requirement 2.

The air stream is conveyed from the 4-foot diameter round delivery section of the fan to the 3-foot square section of the tunnel duct by a lightweight aluminum transition section 6 feet in length. In passing through the transition section the flow is diffused and made uniform by a system of screening, and it is kept free from general rotation by passage through a honeycomb straightening device. It then enters the duct with proper alignment, and a turbulent or eddy boundary layer of determinable characteristics develops with length over the test surface.⁴

The 3-foot square duct sections are 6 feet in length. They are made of heat treated 24-ST aluminum sheets of 0.072-inch thickness. Three sheets form the top and sidewalls of the duct section. Each is reinforced by a 1-inch welded and rivet-attached aluminum angle framework. The three sheets of each section are hinged to fold flat for ease in handling and transportation in the body of a pickup. Five aluminum sections constitute a duct length of 30 feet which is considered sufficient to satisfy requirement 5. The use of this length is arbitrary.

To assemble the complete tunnel for field use requires:

1. Raising the front end of the trailing power unit with a hoist until the wheels clear the ground, removal of the wheels, and lowering of the framework of the unit to the ground.
2. Attachment of the aluminum transition and air straightening sections to the delivery section of the fan.
3. Assembly of the collapsible aluminum duct sections by joining together with vise-grip clamps.

The operations described above require from 10 to 15 minutes for a three-man crew. The 6-foot tunnel sections have rigidity sufficient to provide positive alignment and to require no side support. Dismantling is accomplished in reverse order and requires slightly less time.

A photograph of the assembled portable tunnel is shown in Fig. 1.

Portable Dust Collector

A dust collector for sampling the air stream above eroding test surfaces is a necessary complement to a portable wind tunnel. Several requirements must be

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³A. W. Zingg, and W. S. Chepil. Aerodynamics of wind erosion. *Agric. Eng.*, 31 (6):279-284. 1950.

⁴A. W. Zingg. Some characteristics of the expanding turbulent boundary layer in a wind tunnel designed for the study of soil erosion. Progress Report on Investigations of the Mechanics of Wind Erosion 1949. Manhattan, Kans. (Mimeographed).

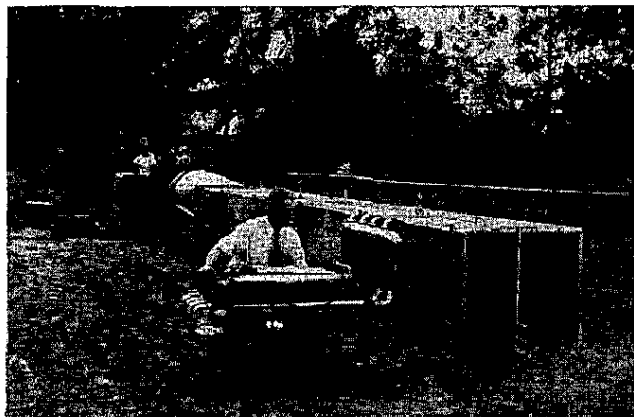


FIG. 1.—View of portable wind tunnel and dust sampler oriented for field use.

met to collect a quantitative sample from the end of the tunnel:

1. The apparatus must be lightweight, reliable in operation, and portable for use in the field.
2. The sampling device must have a velocity of intake equal to that of the air stream.
3. The air stream should be sampled simultaneously at several elevations since the velocity of air flow and the concentration of eroding material vary with height above a test surface.
4. The installation of the sampling device in the tunnel must be such as to create minimum disturbance of the air stream.

A survey of commercial dust collectors failed to disclose one adaptable to these special requirements.

A differential-type sampler with four controlled intake tubes was designed. It became apparent that the building of the complete unit in one package was impracticable. It was, therefore, broken down into three units: (1) the power supply, (2) the controlled air intake and dust separation apparatus, and (3) the sampling tubes located at the mouth of the tunnel.

A 2,000-watt capacity, 110 volt a.c. portable motor generator was obtained from war surplus sources to provide the power supply. Four commercial vacuum cleaners of the household tank type were procured for separating the dust from the portions of the air stream to be sampled. Lightweight electrical conduit pipe, size 0.84 inch I.D., was used for the sampling tubes. The intake end of the sampling tubes was drawn to a square shape, retaining the original area of the tubing. These tubes were mounted on a staff for attachment and placement at the mouth of the tunnel.

To adapt the vacuum cleaners to the desired system they were sawed in half to separate the cleaning bags from the motor sections. The sawed ends were re-capped and fitted with the electrical conduit pipe mentioned previously. In subsequent description of the collector it will be helpful to refer to the photographs of Figs. 1 and 2.

A control table was constructed and the four collector bag adapters mounted in an upright position at one end. Two of the electric motor units were mounted below the opposite end of the table. One

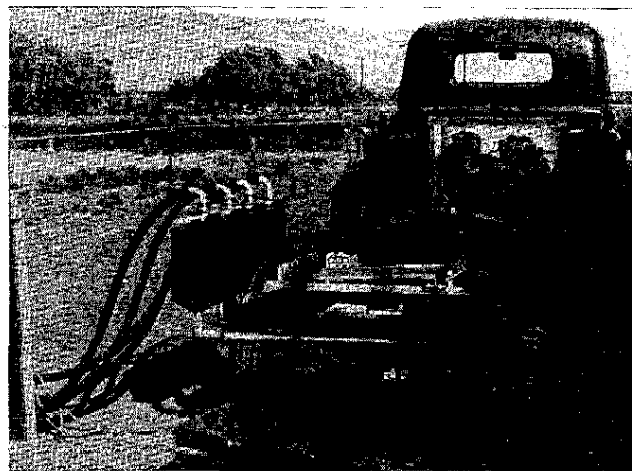


FIG. 2.—View of dust collector, showing the motor-generator power unit and the dust separation and air control devices with which samples are obtained at the end of the tunnel.

vacuum motor unit was capable of drawing air through two cleaner bags and the conduit pipe sampling tubes at a rate sufficient to sample any flow developed by the wind tunnel. Each motor was therefore connected to two conduit pipes, which in turn passed immediately beneath the table to two of the bag adapter units. Gate valves for manually regulating the air flow in each of the pipes were also installed.

The problem of gaging the air flow through the sampling tubes, when connected with rubber hose to the air cleaning apparatus, was solved by the use of impact and piezometer tubes located in the conduit pipes beneath the table. Turbulent air flow in a pipe of large length/diameter ratio has a maximum velocity in the center and lesser velocities as the wall is approached. It is, therefore, possible to locate an impact tube in its cross-section to record a pressure associated with the average rate of fluid flow. This location was determined by trial and error methods with the aid of a test-type gas meter.

The average rate of flow in each of the calibrated sampling pipes beneath the table represents the inflow of the intake tubes at the leeward end of the tunnel when they are connected with rubber hose to the separation bag adapters. The system is then free of leaks. It remains only to register the average velocity pressure through the pipes on manometers to control the intake with the gate valves installed in the system.

Impact tubes are mounted on the sides of the sampler intake tubes, and a single piezometer mounted on the top of the tunnel immediately above them. They yield the velocity pressures of the air stream in the tunnel at the elevations of sampling.

Eight manometer tubes are required to measure and control the velocity pressures germane to the system. The multiple manometer used was made with the tubes placed in pairs. They are recessed into a milled aluminum plate which is placed in an inclined position. Alcohol is used to register the velocity head. One manometer of each pair registers the level of air movement in the tunnel at the elevation of a sampling tube

at the leeward end of the tunnel. The other registers the intake of air through the sampling tube. Operation is quite simple. It requires only that the gate valves be adjusted until the reading on each pair of manometer tubes is the same.

The entire dust sampler, including the motor generator, the table containing the separation, manometer, and control units, and the staff of sampling tubes is hauled in the bed of a pickup truck. It requires about 5 minutes for two men to unload the table, level the battery of manometers, place and connect the staff of sampling tubes, and start the motor generator for sampling.

Summary

The requirements of a portable wind tunnel for the study of soil erosion by wind are outlined. The tunnel constructed to meet these needs is described. A differential-type dust collector developed for obtaining quantitative estimates of materials eroded from test surfaces with the tunnel is also described. These two units are portable with two pickup trucks and constitute the basic equipment with which the erodibility of field surfaces is evaluated. Subsequent papers will deal with the methods of calibrating and using the wind tunnel and dust collector, and also with results obtained in tests over field surfaces.