A "CLOSED-CIRCUIT" FLUME FOR SUSPENDED-LOAD STUDIES

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Scope of suspended-load study--One phase of the study of fundamental problems of dynamics of stream-flow which confronts the Cooperative Laboratory of the Soil Conservation Service is the determination of the influence of suspended load upon flow-characteristics of a stream. Some of the aspects to be considered are: (a) The effect of suspended load on mean velocity, velocity-distribution, entrainment-force, competence, and capacity; and (b) variations of vertical distribution of suspended load with variations of change, variations of grain, and variations of material.

Flume for suspended-load studies--After a thorough investigation of various types of flumes, it was decided to use a "closed-circuit" flume. The basic principle of this flume is the use of a pre-made mixture (water plus solid material) of known concentration which may then be used as a homogeneous mixture.

By means of a "closed-circuit" flume employing this principle, the material-handling problem is simplified, a uniform concentration of solid material is obtained, velocity and depth can be varied independently of concentration and the problem of adsorbed air is eliminated.

Design objectives--Preparatory to the design of a flume of this type, consideration must be given to the individual factors that will produce the desired results. In brief, the following requirements must be fulfilled: (1) Uniform concentration of material in a horizontal plane upon entrance to the flume; (2) adjustable slope; (3) variable depth; (4) uniform flow; (5) uniform entrance-conditions; (6) circulation of water together with suspended load; (7) walls of flume must have negligible coefficient of friction; and (8) rigidity of flume must be such that deflections are small.

Flume-design

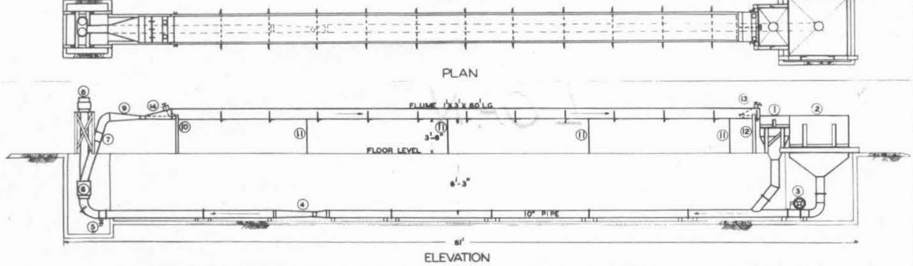
General--Essentially the flume and appurtenant works will consist of a storage-tank, Venturi meter, circulating pump, diffuser, flume, tail-gate, and collection-tank. A schematic drawing of the layout is shown on Figure 1.

Water and solid material will be first mixed in the storage-tank to a desired concentration. The resultant homogeneous mixture will then be pumped to the flume through a depth-control device and discharged through a tail-gate into the collection-tank.

Storage-tank--As previously mentioned, the "closed-circuit" system is dependent on the circulation of a homogeneous mixture in order to gain concentration-control. To this end a tank of 1200-gallon capacity is proposed. A sufficient quantity of water and solid material, necessary to satisfy test-conditions, are to be thoroughly mixed to any desired concentration in this tank before being admitted to the "closed-circuit" system. It can reasonably be expected that a homogeneous mixture will be obtained at this point, but as an additional precautionary measure, the fluid is to be circulated through the system a few times.

Application of this method should insure uniform concentration of material in a horizontal plane upon entrance to flume due to an accurately pre-made mixture and the elimination of ad-

FIG. 1

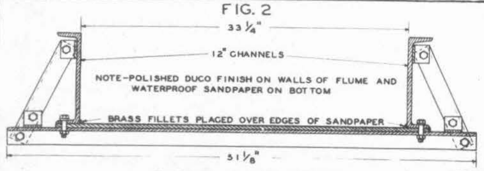


SUSPENDED LOAD FLUME

LEGEND

(1) COLLECTION TANK 220 GAL. CAP. (2) STORAGE TANK 1200 GAL. CAP. (3) VALVE (4) VENTURI METER (5) DRAIN (6) CIRCULATING PUMP (7) FLEXIBLE JOINT (8) VARI-DRIVE UNIT (9) TRANSITION SECTION (10) FIXED PIVOT SUPPORT (11) SCREW JACKS (12) ADJUSTABLE END SUPPORT (13) TAIL GATE (14) DIFFUSER

FIG. 2



TYPICAL FLUME SECTION

sorbed air. In addition, variable depth and velocity may be obtained independent of concentration, and a large material-handling problem will be eliminated. The advantages of this method over the customary practice of charging a stream with material by dumping from wheelbarrows or bunkers can readily be seen.

Circulating-system--The circulating-pump and control must handle solid material suspended in water. Consequently, it must be designed so that there is a minimum amount of wear on the apparatus, a minimum amount of grinding of solid material in the water, and satisfactory control of quantity of flow.

In order to realize the above requirements, it is necessary to have (1) high pump-

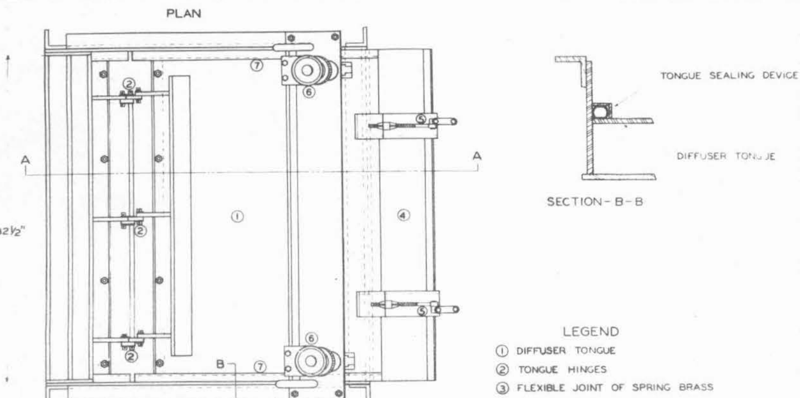


FIG. 3
DIFFUSER

efficiency, (2) low speeds, and (3) variable speed. High pump-efficiency is necessary in order to keep wear on the pump a minimum because loss of efficiency is a measure of the energy dissipated in the pump and resultant wear on parts. Also to keep wear of suspended particles a minimum, the relative velocities in the pump-chamber must be low and this requires low pump-speeds. The use of a throttle-valve to vary the quantity of flow would cause increased turbulence and particle-wear due to excess energy imparted to the fluid during the process. As this is undesirable, variable quantity of flow is to be accomplished by varying the speed of the pump through the use of a variable-drive unit.

The single-stage vertical deep-well pump proposed for use is rated to deliver five cubic feet per second at 7-foot head at a speed of 638 revolutions per minute. Rubber bearings are called for, and the usual stuffing-box where the drive enters the pump-chamber has been eliminated. A stuffing-box is not necessary as the enclosing tube of the pump-shaft will project above the level corresponding to the bottom of the flume, that is, static overflow-level.

Adjustable flume-slope--Velocity-control independent of depth of water is to be made possible through the use of a tilting-flume that may be adjusted to a maximum slope of 1:60. The entrance end of the flume will be mounted on a fixed bearing support and supported in a downstream-direction by four pairs of screw-jacks. Another support is provided at the discharge-end for clamping in a fixed position to prevent lateral vibration. Movement in the section between the upstream-end of the flume and the pump will be taken by a flexible joint of rubber hose which can be loosened and clamped into place for each major adjustment of flume-slope.

Uniform flume-slope--As considerable work will be with small slopes, it is important that deflections of the flume proper be small. Deflections not appreciable on large slopes increase to make an appreciable percentage of error on small slopes. Therefore, the flume is designed so that variations of the slope from a straight line will be small and design-calculations give a deviation from true grade of slightly less than one one-thousandth of a foot.

Flume proper--To simulate a stream of infinite width and reduce secondary circulations, the flume-walls must have a negligible coefficient of friction. It is believed that the requirements will be satisfied by the use of a smooth-rubber lining.

The bottom of the flume must be roughened to known degrees for various experimentations. Water-proof sandpaper of a desired grain-size is to be cemented to the bottom and the edges are held down by brass fillets (see Fig. 2). It is particularly adaptable here because the sand-grains are of a fairly uniform size. If at any time in the future a graded base is found necessary, it can be quite simply made.

It is important to insure against any deposition of material in the system in order to maintain concentration-control as it is anticipated working with suspended loads close to the saturation-point. To accomplish this, the cross-sectional area of the flume is designed to be slightly greater than the remainder of the system which will result in lower flume-velocities and hence deposition will occur in the flume first. Since it is contemplated that all work in this flume will be carried on at velocities greater than those permitting deposition, there should be no difficulty with the rest of the system.

Variable depth--Variable depth of water independent of velocity will be obtained through the use of a diffuser (see Fig. 3). Also the use of a diffusing section will give a greater effective length of flume as it will reduce the distance necessary to obtain equilibrium-conditions.

Water is to enter the diffuser through a rectangular opening, 3 inches by 33-1/4 inches, and there be diffused or spread to depths between three inches and nine inches by means of an adjustable tongue which hinges near the entrance to the diffuser. Although this design is not conventional, a similar arrangement has been used with success in the California Institute of Technology Laboratory. A 3-inch minimum and a 9-inch maximum depth of water will cover the normal range of experimentations. The joint between the body of the diffuser and the tongue is to be made of spring brass in order to make it water-tight and yet flexible. Special hinges are specified in this conjunction to carry the shear-load. A screw-control mechanism is provided for tongue-adjustments. A spring-brass strip extends beyond the end of the tongue. By adjustment of this lip through the control-mechanism shown, fluid discharging from the diffuser can be deflected parallel to the slope of the flume. Due to the movement of the tongue along the walls of the diffuser, a seal must be provided to prevent leakage. An angle is to be welded along the edges of the tongue encasing a rubber tube which will be inflated to a pressure sufficient to prevent leakage.

Uniform-flow--In order to maintain uniform flow and uniform depth which govern the major portion of tests as now envisaged, a tail-gate in the form of an undershot-weir is to be installed at the discharge-end of the flume. Also the use of a tail-gate will eliminate the "drop-down" curve at discharge and thus make possible a longer working section of flume. The undershot-weir of parabolic profile has been used for some time in the Institute Laboratory with satisfactory results.

Circulating-system--The "closed-circuit" system is to be constructed in a vertical plane to eliminate pipe-bends and reduce wear to a minimum. Also wear may be kept a minimum by pumping against a low head, which condition will be established by keeping the collection-tank full. When water and suspended load is pumped from the storage-tank, the water-level in the collection-tank will follow that in the storage-tank. As the draw-down is several feet, an additional volume of mixture will be necessary to fill the collection-tank. In order to supply this additional volume, the tail-gate at the discharge-end of the flume is to be closed and thus an additional volume of water over and above that needed for the run may be stored in the flume. Upon closing the discharge-valve from the storage-tank, the tail-gate can be raised and circulation started. An adjustable overflow-weir is to be installed between the collection- and storage-tanks to take care of surplus volume in the circulating-system.

Conclusion

The fundamental aspects of suspended load as it affects the dynamics of stream-flow is of great importance not only to hydraulic research but also to the Soil Conservation Service in its study of the erosional problems confronting the country today. Research of this nature has been somewhat limited in the past and it is believed that results obtained from studies carried out in a flume of the above construction will add materially to the knowledge concerning the phenomena of suspended load.

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