Progress Report

A STUDY OF THE SEDIMENT CARRYING CAPACITY

OF

CLOSED CONDUITS

Sponsored
by

Armco Drainage & Metal Products, Inc.
Middletown, Ohio

Department of Civil Engineering
Colorado A & M College

July 15, 1953

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A Study of the Sediment Carrying Capacity of Closed Conduits

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Abstract

The design and construction of all basic equipment has been completed; and the test section and facilities for obtaining data on sediment load and head loss have been installed. A single size distribution of sediment is being used. Calibration of the data-taking instruments is now under way.

Basic Equipment

The basic equipment (see Fig. 1) consists of a 60-hp high head vertical turbine pump which delivers clean water to a nozzle to create the jet. The jet discharges into a mixing tube, the lower end of which is submerged in a hopper containing water and sediment. The high velocity jet picks up part of the sediment mixture as it enters the mixing tube. On the downstream end of the tube, which is physically above the nozzle, there is both an orifice for determining discharge, and equipment for sampling the total sediment load. From this point the mixture of water and sediment is carried to a diffuser located at the upstream end of the test pipe line. A plastic sampling section is located at the downstream end of the test pipe line. Immediately subsequent to this section the line empties into a pipe that carries the mixture back to the hopper. All of the sediment and a part of the water are retained in the hopper for recirculation. The remainder of the water is returned to the 60 hp pump to operate the jet.

The jet pump was the apparent solution as a method to deliver large discharges at low heads, and at the same time use the high head vertical turbine pump which was available. Furthermore, it was the only way available for recirculating the sediment and yet not pass it thru the runners of a turbine or centrifugal pump. The design of the jet pump was based on qualitative computation, as a review of the literature indicated little quantitative data exists for the jet type of pump especially when a sediment mixture is involved. To date two designs of jets have been tried, neither giving entirely satisfactory results.

A simple method is still needed for separating the water and sediment at a rapid rate. The size of the stilling basin (hopper) around the jet is limited to the dimensions of the sump. At present it appears to be inadequate for large discharges because turbulence keeps the sediment from settling in the vicinity of the jet as desired. A screen was installed as one means of forcing the sediment to concentrate over the jet, but this procedure proved to be unsuccessful.

Instrumentation

1. Determination of Head Loss:

The head loss along the pipe line is determined by piezometers located at 10 ft intervals. Each piezometer tap is located at the low point of a corrugation (nearest center-line of the pipe) on the HEL-COR. Additional taps will be installed at the high points of the corrugations and about the periphery of a cross section, to make sure the data obtained from the low points are correct.

2. Total Sediment Load and Fluid Discharge:

As shown in Fig. 2, the instruments for determining total sediment load and discharge of the water-sediment mixture are located at the upper end of the vertical mixing tube, a short distance downstream from the region required for the jet to diffuse to the full dimensions of the tube. This location insures that all the sediment will be in suspension when the total load is measured regardless of concentration.

The orifice plate for measuring discharge is an annular plate designed with the sharper edge on the downstream side. It is believed that with this shape the dimensions of the orifice opening will be less subject to change due to the abrasive action of the sediment. Another factor that may affect the calibration is the sediment concentration. It requires calibration at several concentrations to determine the magnitude of this affect.

The total sediment load is measured with a set of four samplers, each located $\pi/2$ radians apart along 1/2 of a diameter of a normal cross section. The sampler entrance is located at the downstream edge of the orifice; a region of quite uniform velocity distribution. It is hoped that after calibration a single point in the region may be used to determine total load.

3. Distribution of Sediment at a Section Normal to the Direction of Flow:

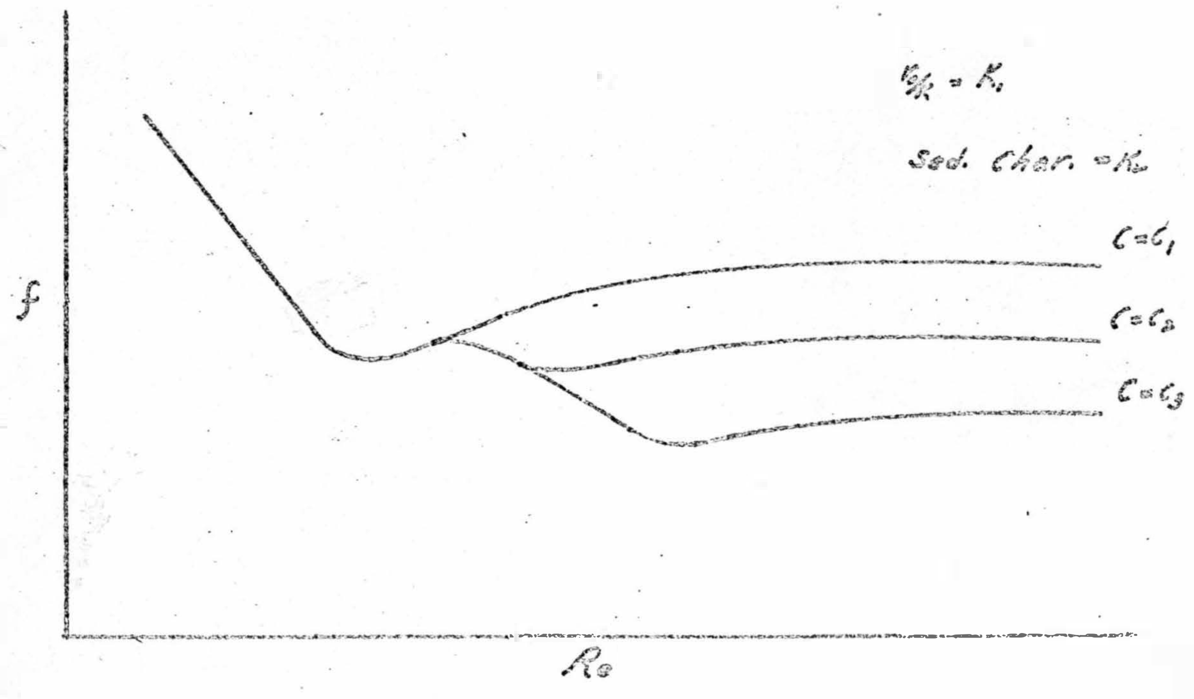
The sediment concentration at a point in a section normal to the flow is found by means of a combination pitot tube and sampler, see Fig. 3. The ambient velocity is measured with the pitot. The velocity of flow into the sampler is determined with a Venturi meter, and regulated by a variable speed centrifugal pump. When the two velocities are identical a sample is taken.

The sample is put in an inverted cone and the sediment permitted to settle to the apex of the cone. The concentration of sediment is found from volumetric calibration of the cones. When properly calibrated, the concentration may be computed directly from the volume the submerged sediment occupies in the apex.

Proposed Presentation of Data

The data may be presented as shown below; where f is the Darcy-Weisbach resistance coefficient, R is Reynolds number, r_o/k is the pipe line relative roughness and C is the sediment concentration. The plot is f vs. Re with C as the third variable; for given characteristics of the sediment and for a constant relative roughness. This plot will enable the designer to determine in advance the hydraulic gradient to be expected for given sediment concentrations, sediment characteristics, pipe characteristics, Reynolds number, and flow velocities.

Another plot which will be studied is a re-arrangement of the foregoing wherein concentration C will be the dependent variable plotted against Reynolds number Re with the resistance coefficient f as the third variable. These plots, and others of a similar nature, are expected to disclose optimum operating conditions with respect to both concentration and economy of sediment transport.



Variation of the resistance coefficient f with Reynolds number Re for different sediment concentrations.

Literature Review

Most of the literature on the transportation of sediment in pipe lines has been reviewed. The two principle fields studied are fluid mechanics and chemical engineering.

Reports have been found of laboratory studies on 1, 2, 3, 4-inch lines carrying sediments ranging from sand to gravel. In addition, considerable data, of questionable value, are available from the records of dredge operators. These data include pipe as large as 42-in. diameter.

The chemical engineers have done considerable work on sediment but they are primarily concerned with muds and sludges, rather than sand. The fundamentals of sediment transport which they have established are indirectly applicable to sands.

Future Work

When the calibration of instruments is completed, the data for plotting f vs. Re with $C = 0$, will be obtained for the 12-inch HEL-COR, in order to provide information which may be used immediately.

The next step is to obtain data for the type of plot shown, for say three sediments, with 12-inch HEL-COR, then the entire procedure will be repeated for smooth pipe, and some intermediate value of r_0/k. According to the literature, the effect of slope is apparently a secondary factor. Therefore, initial studies will be made with the pipe at a single slope.

The data mentioned above are very important but more time must be spent reviewing the literature and plotting all available data for various pipe sizes and sediments.

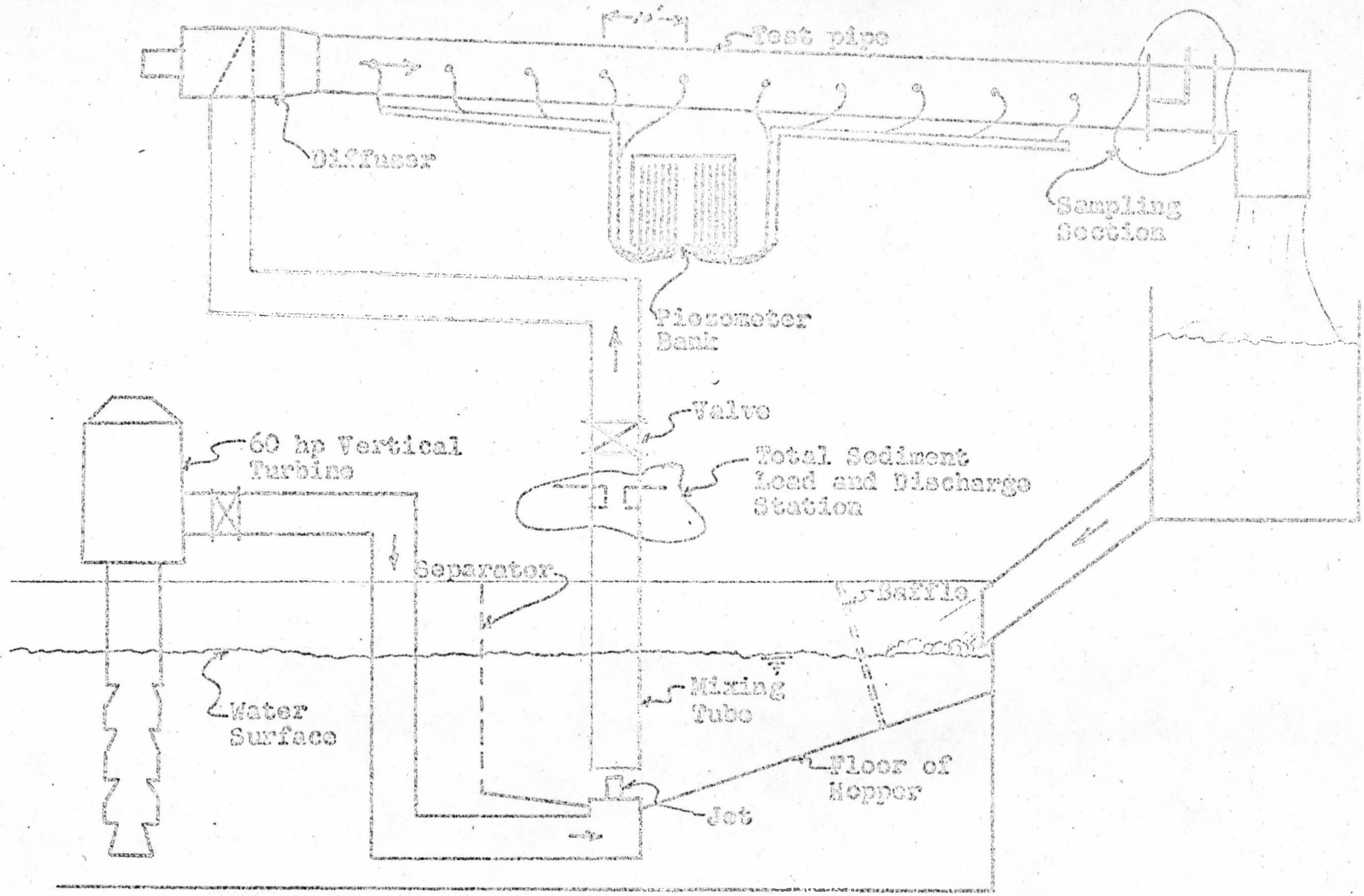
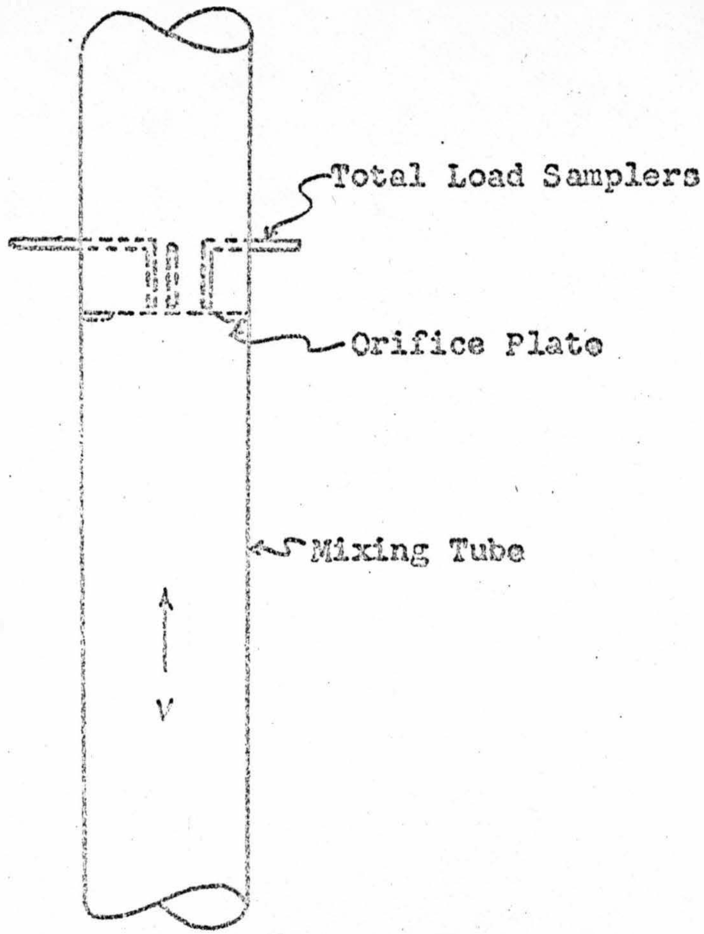
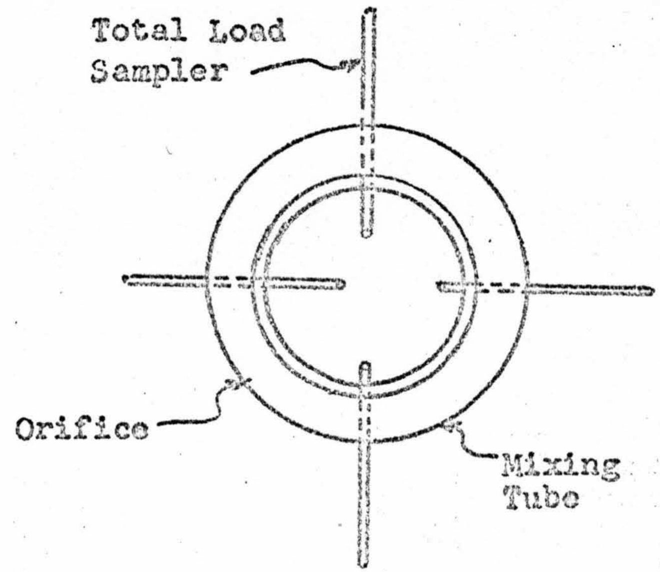


Fig. 1 - Schematic Drawing of the Basic Circulation System



(a) Elevation



(b) Cross section

Fig. 2 - Measuring Instruments for Total Sediment Load and Water-Sediment Discharge

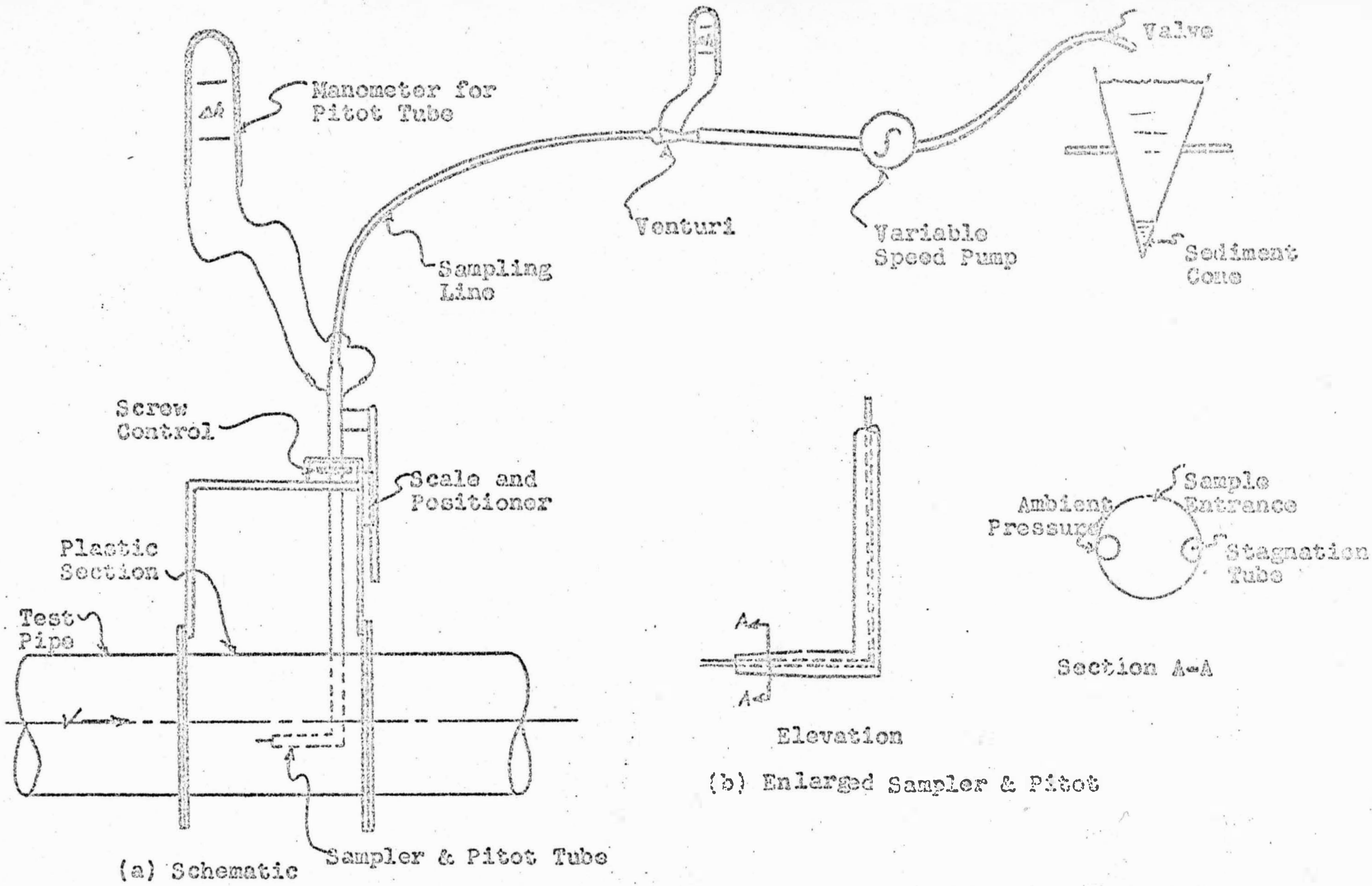


Fig. 3 - Schematic Drawing of the Equipment for Sampling Sediment Distribution