As the depth becomes less than the critical, the flow is taking place at the high velocity of the lower alternative stage, and if obstructed will jump and flow under the condition of the upper stage of low velocity. With the flow taking place at or near the critical depth, as shown by the flatness of the curve at this point, any slight change in energy will cause a decided change in the depth. It is thus to be expected that in such a case the water surface will be rough and the depth will shift back and forth along the curve. A jump may be expected if the flow is at all restrained.

The velocity at which the water will flow at the critical stage is termed the critical velocity and may be shown to be equal to $V = \sqrt{g\frac{A}{T}}$, the corresponding velocity being $h_v = \frac{A}{2T}$, in which

V = critical velocity,
g = acceleration due to gravity,
A = cross-sectional area of flume,
T = width of water surface.

From this formula the depth at which the critical velocity is developed may be obtained. For the case in hand this was found to occur at a depth $D = 3.54$ ft. with a velocity of 9.09 ft. per second. Thus we have the co-ordinates for the critical stage as follows: $D = 3.54$, $D + h_v = H = 4.82$. These were plotted and furnished the lowest point through which the energy curve must pass.

Having obtained the critical depth, $D = 3.54$ ft., the dotted line indicating this depth of flow throughout the flume was plotted on Fig. 2. This line shows the critical stage. It was observed that the actual water surface for the test was close to the critical stage throughout the flume. From the explanation given above it follows that an unstable condition of flow was to be expected.

As stated above and as is shown by the energy curve, there are two stages at which the flow will take place for any definite energy. In Fig. 1 the actual water surface is taken as one stage and for each observed elevation the opposite stage is taken from the energy curve and plotted. These points are then connected and this line represents the alternative stage at which the water could have flowed in this particular flume with the same energy with which the flow actually took place.

It is observed that up to station 1 + 83 the flow takes place at the upper alternative stage, but that the actual was so close to the critical stage that the flow was rough and unstable, and with a slight change of energy could easily have shifted to the high velocity or lower alternative stage. At station 1 + 83 the flow-line drops below the critical stage and assumes the lower alternative stage. At station 2 + 30 the flow jumps to a point near the critical stage and then drops again to the lower stage. This rise at station 2 + 30 was probably caused by the rise in the subgrade. Had this rise in subgrade been a little more pronounced the flow-line would have taken approximately the elevation 97.78 as shown for the alternative stage.

The above data show the unstable conditions of flow which may be expected to take place in a flume with the water flowing at or near the critical stage. The necessity for consideration of the above principles in connection with flume design is apparent. It is believed that for all flumes in which the water is flowing at a high velocity, similar investigation should be made before final designs are prepared. In case of flow at or near the critical stage, additional freeboard should be provided.

INTAKE AND OUTFLOW VELOCITIES

BULLETIN No. 96 of the Engineering Experiment Station of the University of Illinois contains a description of and conclusions from experiments on the effect of attaching mouth pieces to the intake and outflow ends of a short pipe, so far as these affect the head lost at entrance and exit and the velocity of flow through the pipe. The problem investigated might appear to be one of very little practical value, but in certain classes of work having to do with water (including sewage) the solutions of it are by no means unimportant. Concerning this, the investigator (Fred B. Seely, Associate in Theoretical and Applied Mechanics) cites a number of instances where it is of considerable importance to know how to reduce this lost head. For example, the passages through a large valve or through locomotive water columns, the draft tube to a turbine, the connection from a centrifugal pump to a main, sluice ways through dams, slat screens at head gates, culverts and short tunnels, suction and discharge pipes of dredges, and the guide vanes and runner of a turbine. The efficiency of a pump working under low head may be increased by an entrance mouthpiece on the suction pipe because it would allow the pump to receive the water in smoother condition of flow. It is well known that a turbine must receive the water from the guide vanes without shock if, in the subsequent flow through the runner, the energy of the water is to be absorbed efficiently by the turbine. The loss of head through a Venturi meter may be considerably increased if the meter is placed too short a distance downstream from a valve, elbow, or other obstruction or cause of disturbance in the pipe. It is worth mentioning in this connection that the recent advances in turbine design have been due largely to the attention given to the approach channels to the guide vanes and to the design of the draft tube.

The experiments described in this bulletin consisted in attaching conical mouthpieces to the entrance and discharge ends of a pipe 6 ins. in diameter and 22½ ins. long. No experiments were made with mouthpieces with curved elements rather than straight, although it would appear to us that the effect would have been increased by the use of such mouthpieces. The velocities through the pipe during these experiments were made to range from about 0.6 of a foot per second to 5 feet, or those which are most commonly found in flow in sewers, water mains and other forms of conduits.

Without going into any of the details of the experiments, the author's conclusions may be quoted as follow:

"The preceding discussion has shown that the losses accompanying the flow of water depend largely upon the state of its motion, which in turn is influenced by many factors, the effects of which in many cases can be but roughly estimated. While the results of these experiments tend to define the range of such effects for certain conditions of flow, additional experiments would be necessary to establish all the inferences which have been suggested. The following conclusions, however, seem justified:

"(a) As applying to conditions likely to be met in engineering practice, the value for the head lost at the entrance to an inward-projecting pipe (i.e., without entrance mouthpiece and not flush with the wall of the reservoir) is 0.62 of the velocity head in the pipe $(0.62\frac{v^2}{2g})$, instead of $0.93\frac{v^2}{2g}$, as usually assumed. To put it in another