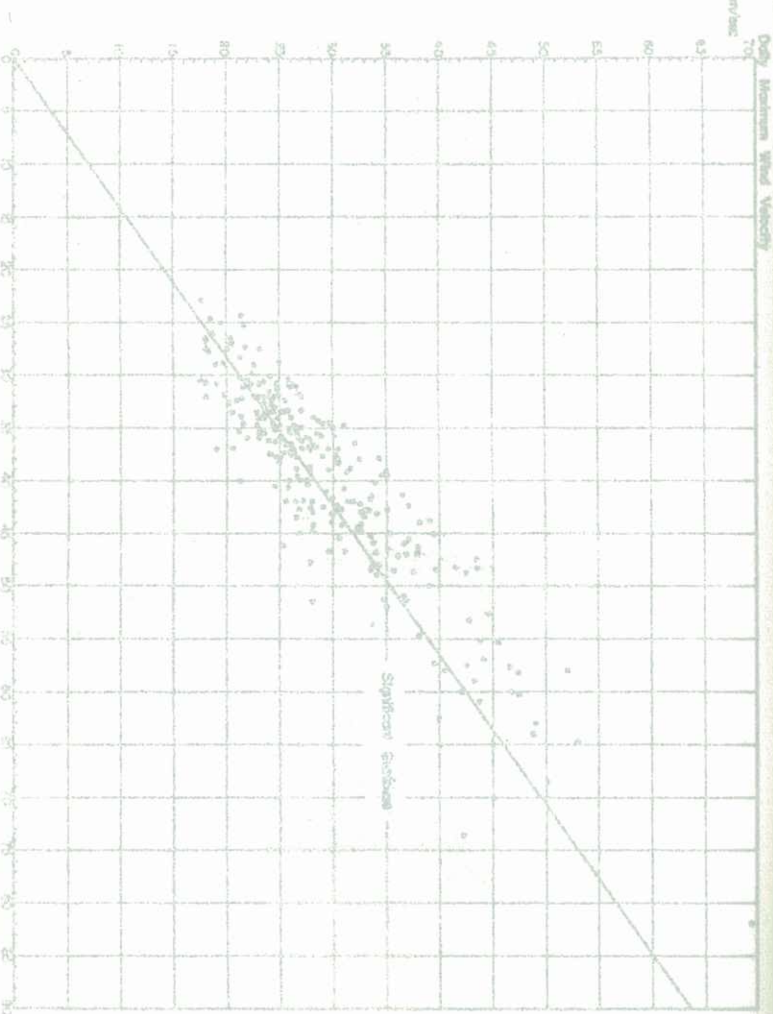

STUDIES ON STILLING BASINS
(With a special reference to the jet diffusion type stilling basins)

by

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Abstract: When a high velocity submerged jet issues into a standing pool of water its energy gets dissipated along its course. This phenomenon of energy dissipation is useful for the design of stilling basins under hydraulic structures. This paper deals with certain investigations conducted under different conditions of flow in our laboratories here.

In all the studies it has been noted that there exists a critical section within which the rate of energy dissipation is predominant and after this the energy left in the stream is quite small and the stilling basin need not be elaborate after this section. A chart giving the relationship between the length of the stilling basin required and the relative depth of the stilling basin with relative position of the jet as another parameter has been proposed. This chart can be used to fix up the stilling basin length.

Introduction:

Stilling basins and the appurtenances to destroy the energy of flowing water are being designed from a longtime using different methods, the main necessity being that the eddying that is prevalent in the high energy in coming flow results in high impact pressures on the bed of the stilling basin resulting in the scouring of bed and retrogression of levels which undermines the structure and result in the failure of the same if proper protective measures are not provided. In particular the case of the jet diffusion in a stilling basin occurs when the flood water discharges in the form of jets through high head sluices, syphons etc. under high tail water conditions. Such a jet ejected out with a high efflux energy travels for many diameters in nearly the same direction and the original energy gets gradually dissipated along its course in the stilling basin.

Investigations were conducted at the Hydraulic Laboratory of the Indian Institute of Science concerning the jet diffusion stilling basins by varying systematically the size of the jet efflux section, location of the jet above the bed of the stilling basin, velocity of efflux (i.e., head acting) and the tail water depth etc.

Such studies are useful in fixing up the length of the stilling basin from the given conditions such as the jet diameter, velocity of the jet, submergence of the jet and other boundary conditions.

Experimental Investigations: (Set up and procedure — Ref. Fig. 1)

The experiments were conducted in a flume 19' x 3' x 3'. At the upstream section the jets (efflux diameter - $1\frac{1}{2}$", 1", 0.8839") were fixed and were fed by high head pumps. A V-notch fixed at the downstream end was used for discharge measurements. The jet position was varied systematically (from $\frac{1}{2}$" to 21" from the bed of the stilling basin). For each jet position the tail water depth was also varied (from 21" to 33" from the bed of the basin). These studies were conducted under the range of efflux velocities from 10 f.p.s to 45 f.p.s. Suitable arrangements were made to vary the stilling basin length and the tail water levels. The energy of the jet stream across its various cross sections was determined from the elementary principles as

$$E_s = \int^{A} \tfrac{1}{2}\,\rho\, u^3 dA \quad \text{where } \rho \text{ is the density}$$

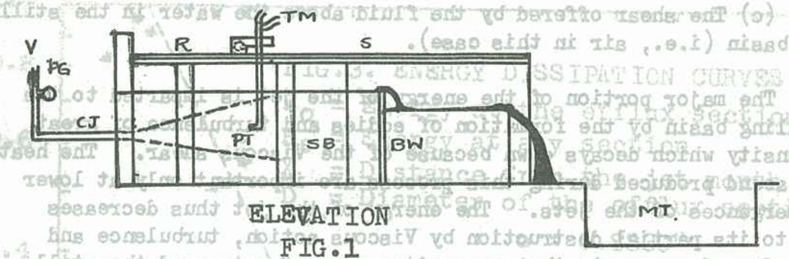
of water, u is the velocity over the area dA, A is the area of cross section of flow over which the integration is carried out. The velocity traverses (Fig. 2) were made through a Prandtl pitot tube.

Results and discussions:

The problem under investigation is one of the energy dissipation of high velocity jet flow. The Kinetic energy of the jet which is maximum at the instance when it delivers to the stilling basin goes on loosing its energy as it travels further. The energy dissipation takes place since the jet does work against the following forces.

(a) The Viscous shear force between the fluid of the stilling basin and the jet,

(b) The shear offered by the solid boundary at the bottom of the stilling basin,



ELEVATION

FIG.1

CJ	Circular jet	R	Angle iron rail
SB	Stilling basin	S	Horizontal scale
BW	Baffle wall	V	Regulating valve
TM	Traversing mechanism	MT	Measuring tank
PT	Prandtl pitot tube	PG	Pressure gauge

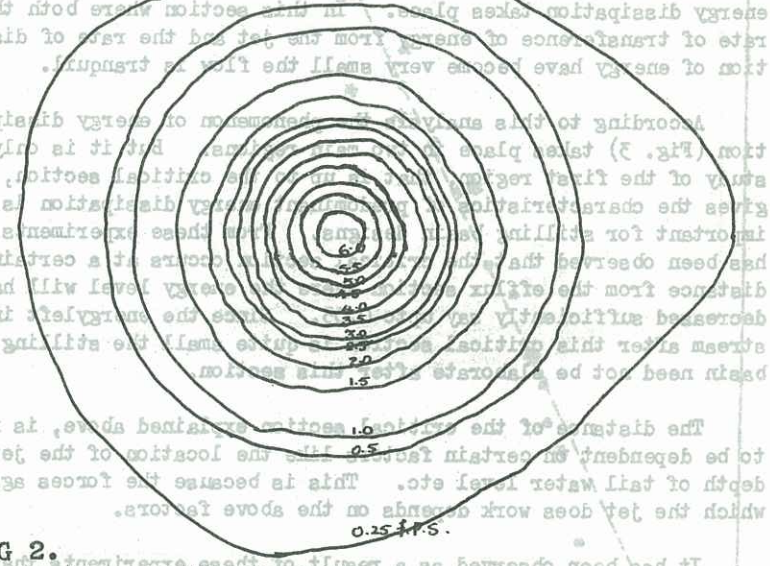


FIG 2.

ISOVELS OF THE EXPANDING JET

Velocity of efflux = 20 f.p.s.

Distance from the efflux section = $1\frac{1}{2}$'

(c) The shear offered by the fluid above the water in the stilling basin (i.e., air in this case).

The major portion of the energy of the jet is imparted to the stilling basin by the formation of eddies and turbulence of great intensity which decays down because of the Viscous shear. The heat and sound produced during this process are important only at lower submergences of the jets. The energy of the jet thus decreases due to its partial destruction by Viscous action, turbulence and transfer of energy to the surrounding mass of water and the stilling basin. Thus there is evidently a critical section where the energy of the jet equals the total of that destroyed due to turbulence. In this critical distance, between the efflux section and the critical section the energy of the jet predominates although the dissipation of energy takes place because of turbulence. After this critical section the energy left in the jet is quite small and the dissipation of energy is due to turbulent shear, boundary resistance and the energy of the surrounding mass of water predominates. Thus as the energy of the jet grows smaller and smaller, the rate at which the surrounding mass of water can absorb the energy of the jet becomes smaller as also the rate at which the energy dissipation takes place. In this section where both the rate of transference of energy from the jet and the rate of dissipation of energy have become very small the flow is tranquil.

According to this analysis the phenomenon of energy dissipation (Fig. 3) takes place in two main regions. But it is only the study of the first region, that is up to the critical section, which gives the characteristics of predominant energy dissipation is important for stilling basin designs. From these experiments it has been observed that the critical section occurs at a certain distance from the efflux section where the energy level will have decreased sufficiently say upto 0.05. Since the energyleft in the stream after this critical section is quite small the stilling basin need not be elaborate after this section.

The distance of the critical section explained above, is found to be dependent on certain factors like the location of the jet, depth of tail water level etc. This is because the forces against which the jet does work depends on the above factors.

It has been observed as a result of these experiments that the above characteristics do not depend appreciably on the velocity of efflux or the size of the efflux section. These results are explained through the figures 4 and 5. These curves have been plotted on dimensionless coordinates, for different velocities, diameters etc. The universal nature of the graphs is concluded since the same characteristics were observed under different velocities, diameters etc.

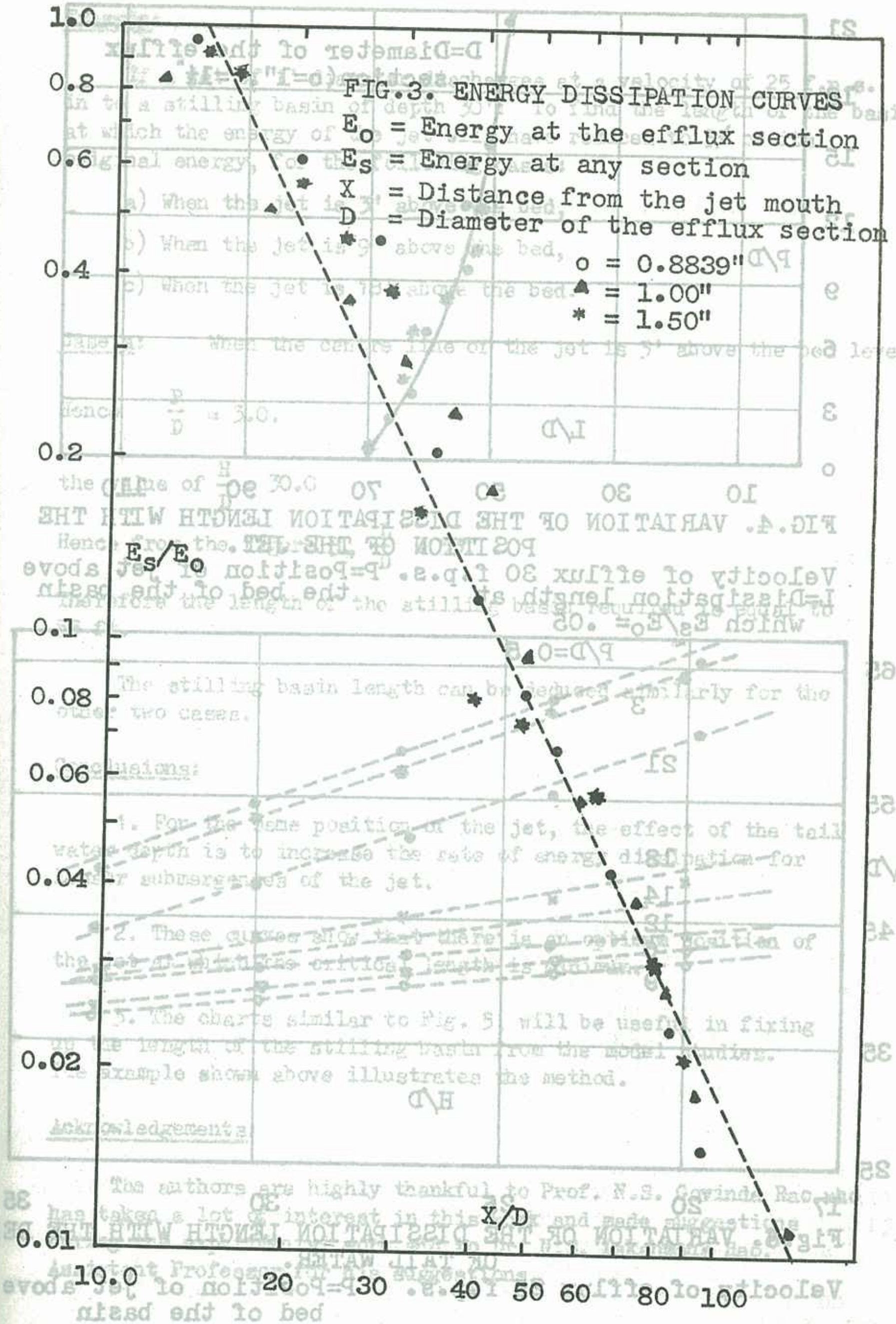


FIG.3. ENERGY DISSIPATION CURVES

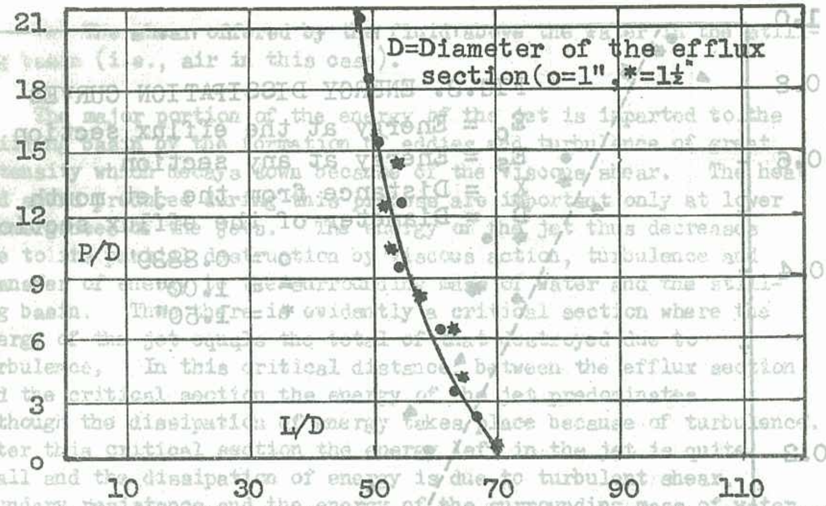


FIG.4. VARIATION OF THE DISSIPATION LENGTH WITH THE POSITION OF THE JET.

Velocity of efflux 30 f.p.s. P=Position of jet above the bed of the basin
L=Dissipation length at which E_s/E_o= .05

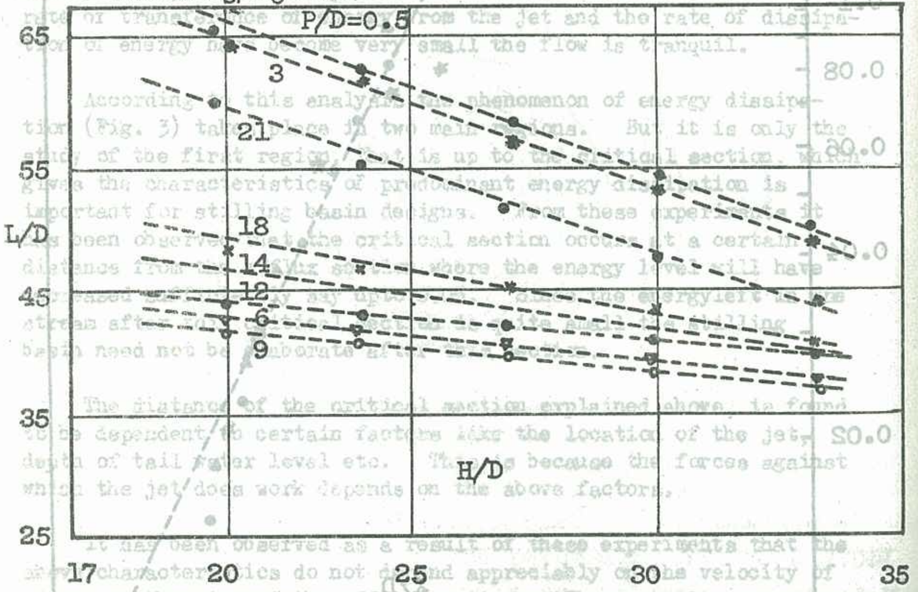


Fig.5. VARIATION OF THE DISSIPATION LENGTH WITH THE DEPTH OF TAIL WATER.

Velocity of efflux 25 f.p.s. P=Position of jet above th bed of the basin
L=Dissipation length at which E_s/E_o = 0.05 D=Diameter of the efflux section.

Example:

If a jet of 1' diameter discharges at a velocity of 25 f.p.s. in to a stilling basin of depth 30': To find the length of the basin at which the energy of the jet will have reduced to 5% of its original energy, for the following cases:

a) When the jet is 3' above the bed,
b) When the jet is 9' above the bed,
c) When the jet is 18' above the bed.

Case a: When the centre line of the jet is 3' above the bed level:

Hence $\frac{P}{D} = 3.0$.

the value of $\frac{H}{D} = 30.0$

Hence from the figure 5, $\frac{L}{D} = 53$.

Therefore the length of the stilling basin required is equal to 53 ft.

The stilling basin length can be deduced similarly for the other two cases.

Conclusions:

1. For the same position of the jet, the effect of the tail water depth is to increase the rate of energy dissipation for lesser submergences of the jet.

2. These curves show that there is an optimum position of the jet at which the critical length is minimum.

3. The charts similar to Fig. 5, will be useful in fixing up the length of the stilling basin from the model studies. The example shown above illustrates the method.

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