with which, is a horizontal apron of some description, for protection again erosion of the river bed by falling water. In this particular case an impervious masonry floor is provided. The base of this floor C D, rests on a stratum of pure sand. The vertical wall holds water up to the summit level H, the tail level, i.e., the original low water level of the river is supposed to be at B, i.e., coincident with the floor surface. The head H is the difference of level between the summit and tail levels, which is a **maximum** when the reservoir level is flush with the weir crest. The reason for this is as follows: When the water overtops the crest the velocity of the film passing over exceeds that of the tail water in the normal channel below, consequently the rise of the tail water will be more rapid than that of the head water—the ratio being from 2 or 3 to 1, varying mainly with the slope of the river bed. The action of the impounded water in its endeavour to reach its own level, a property inherent in liquids, is to force a passage through the sand stratum underneath the impervious floor, the particles of liquid taking a curved course, first downwards then horizontally, and once the obstructing plane is passed, upwards.

The proposition here presented is exactly similar to that in Fig. 1, the only difference being that instead of the water being confined in a pipe of a limited size, it is confined within the sand substratum, being prevented from rising above it. The initial velocity due to the head of water, is reduced in the pipe by friction against its sides to a constant velocity right through, in exactly the same way, reduction, or neutralization of head is effected by friction in the passage of water between the particles of the sand. The greater the length of the confined passage, the less will be the velocity of the slowly percolating stream.

It is evident that under similar conditions of head and base length, the velocity of the current in different weir beds must vary with the nature of the sand stratum in accordance with its qualities of fineness or coarseness. Fine sand will be closer in texture, passing less water at a given head than a coarser variety, at the same time fine sand will be disintegrated and washed out under a less pressure. The problem now to be solved is evidently what proportion the base CD, or l, should hold to the head H in order, to insure safety from washing out or from what is technically termed piping. This value can only be obtained experimentally, that is, by deduction from sections of existing successful river weirs. Fortunately there are also some most instructive examples of failures due to insufficient length of base, so that the safe value of the relation of l to H or of the sine of the hydraulic gradient can be deduced with absolute certainty.

In Fig. 2, supposing the length of the base CD or l, of the floor (which clearly must be some multiple of H). provides a length of creep or percolation sufficient to reduce the head, or, strictly speaking, the velocity of the current, to such proportions, as will just prevent piping. Then the hypothenuse HB will represent the hydraulic gradient. This slope starts from the summit level itself, for this reason, that the velocity head is insignificant and the loss at entry is nil. This gradient is found to be about 1 in 10 for fine sands and 1 in 8 for coarse sands, and might be termed the equilibrium gradient. Now the water having free egress at the point D, the conditions are identical with those in Fig. 1, and the upward head of water, acting on the base of the floor CD will be correctly represented by the vertical ordinates of the triangle HAB, and the total pressure by the area HAB.

In these expressions the unit weight of water generally represented by the letter W, which is 62.5 pounds, i.e., 1/36 ton per cubic foot, or 1 ton per cubic metre, is invariably omitted. Where weight comes under consideration it is represented by Area × S.G. or by A ρ, while unit weight (as per ft. run) is represented by t ρ, i.e., thickness × SG, the Greek letter ρ being the sign for specific gravity, which is much better than the G, sometimes employed, and which can be confounded with the recognized symbol denoting gravity. In the same way the pressure of water is represented by the head H, omitting W, it being virtually HW.

With regard to the value to be assigned to l, in actual construction a considerable factor of safety is necessary so that the safe proportional value of l must be half as much again as its bare value. If the floor be thus increased in length to the point E, so that CE = 1½ CD, the safe hydraulic gradient will be HE, and the value of c in the expression l = cH will become 15. This lengthening of the floor will, however, have the effect of increasing the upward pressure on it in proportion as the area HAE is greater than HAB, consequently there is a positive disadvantage in lengthening the impervious floor beyond what is necessary to insure an absolutely safe base length, i.e., one sufficient to prevent disintegration of the sand substratum by piping.

Supposing the length of floor reduced below the minimum CD, to CG, the hydraulic gradient then will be HG. This triangle of hydrostatic pressure HAG is less than either of the preceding, but failure will take place by piping, the floor becoming gradually undermined, by the sand being slowly washed out, the reduction of the velocity effected by friction in this shorter length being insufficient to overcome the disintegrating horizontal influences of the current of water. Two such cases have actually occurred in the case of the Chenab and the Jhelum weirs.

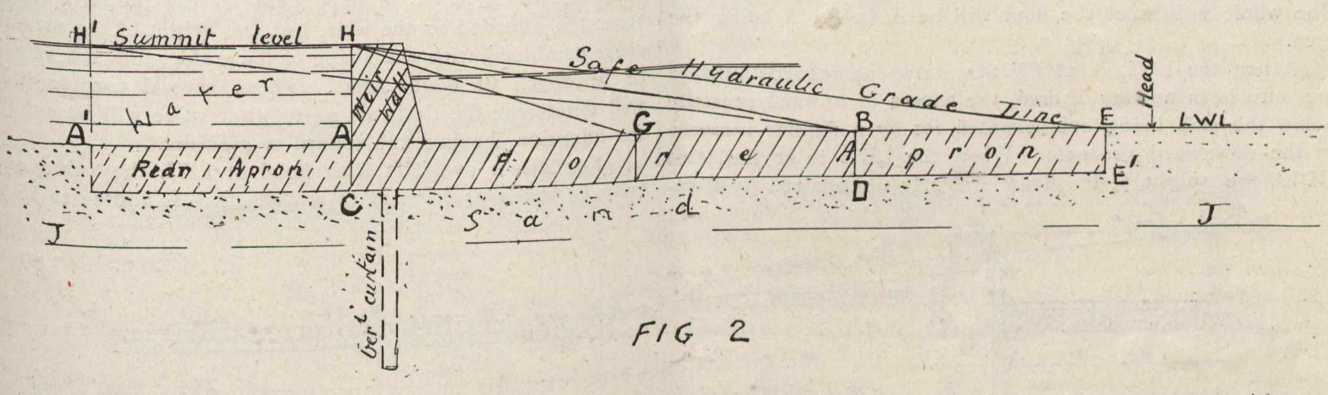

FIG 2

It is self-evident that the effective weight of the floor must equal or exceed that of the upward hydrostatic pressure unless its construction is such as to render it capable of resistance to bending stress. In this latter case the downward pressure on the sand will be simply the reaction of the hydrostatic pressure, as is the case in a pipe. This reacting pressure is hardly enough, although in the case of Narora weir a floor of insufficient weight has been known to stand for several years, but eventually, owing to a comparatively small increase in the upward pressure, it blew up. Weight in the floor and superstructure generally, well in excess of the hydrostatic pressure, is always a desideratum. and is only limited by considerations of economy.

We have already seen that the proportion of l: H or the value of c, the expression l = cH varies in different rivers. River sands will be classified according to the following known qualities:

Class 1a.—The Nile. Coefficient adopted 18.

Class 1.—Rivers taking their source in the Himalayas, which include the Ganges, Jumna, Indus, and the four main Punjab Rivers of fine light micaceous sand, to this category belongs the Colorado River. Coefficient adopted 15.

Class 2.—The coarse grained sands of the rivers of Central India and Madras and Bengal, most rivers belong to this class. Coefficient adopted 12.