average of the deep masses of gravel, sand, cobbles, and boulders as they lie in place under the dam. Homogeneity cannot exist to any degree in material of greatly varying sizes deposited by successive floods of varying intensity.

Assuming, however, that the samples used in the author's tests are representative of the general foundation, the tests made in a rectangular box with a model of a dam with varying depths of tight cut-off show the quantity of seepage under full head. For the first model tested, this averaged approximately 0.0040 sec.-ft., and, for the second model, 0.0025 sec.-ft. per lin. ft. of model. The writer understands that these quantities refer to the flow measured in the experiments, on a scale of 1/120 of full size. If this understanding is correct, then, so far as the experiment goes, the deduction may be made that, for similar material in the foundation, the seepage for a dam built on the basis of the second model would be 120 × 0.0025, or 0.3 sec.-ft. per lin. ft. of dam.

The longitudinal section shows the dam to be 400 ft. in length across the general river bed and 1,600 ft. in length on the adjoining bench. No data are at hand as to rise of rock under this bench. It may be interesting, nevertheless, to inquire as to what the total seepage under the dam would be if the rock were to rise but slightly away from the river. In that case the average gradient and seepage per linear foot for the bench portion of the dam would approximate one-half that for the full height of the dam. On such assumptions, a seepage would result of $\left(400 + \frac{1,600}{2}\right) \times 0.3 = 360$ sec.-ft. This quantity of seepage is clearly inadmissible, and the writer deems it likely that some of the foregoing assumptions may be known by the author to be erroneous.

Independent of the doubt regarding test samples being representative of material in place, there must be serious uncertainty as to the possibility of driving sheet-piling to a depth 80 ft. below the bottom of the cut-off trench, and as to the tightness of such sheet-piling when driven.

It will be noted that the final design of the dam as presented by the author shows an approximate gradient of 1 to 10 for full reservoir. This may be about twice the gradient which prevailed when there was 25 ft. of head against the present dam, at which time heavy seepage losses occurred.

A detailed study of the pressures as registered in the experimental box with the model of the dam reveals some marked inconsistencies, which, if the experimental results are to be made the basis for design, may require explanation. In considering this subject, the writer has confined himself to the use of experiments made under a full head of 10 in. representing 100 ft. on the scale of the experiment, and has selected for this purpose only those numbers, four in the first and three in the second series, for which pressures are recorded at all points.

Individual differences of flow and pressure are rather large, the maximum variations from the average being as follows:

	First series: Experiments 9, 14, 19 and 24.	Second series: Experiments 4, 8 and 12.
Flow	7%	20%
Pressure	20%	13%

In order to eliminate individual variations, whatever may be their cause, pressures and pressure drops are figured on the basis of average values and are listed for comparison in Table 5.

Table 5 shows the following rather surprising results as to pressure head destroyed by percolation: The pressure drop is greater from open water to A, from B to C, and from D to E, with smaller than with larger flow; the pressure drop is greater from A to B without sheet-piling, and with small flow than with sheet-piling and with large flow; the pressure drop is greater from C to D, in proportion to the flow, with shallow than with deep sheet-piling.

Table 5.—Pressures and Pressure Drops.

	Average of Experiments.			
	1st Series: Nos 9, 14, 19 and 24.		2nd Series: Nos. 4, 8 and 12.	
Measured flow...	0.0040 sec-ft.		0.025 sec-ft.	
	Pressure.	Pressure drop.	Pressure.	Pressure drop.
Water toe.......	100 ft.	....	100 ft.	
		58 4 ft.	....	60.5 ft.
A........	41.6	....	39.5	
Cut-off......	50 ft. in 240 ft.	4.0	25 ft. in 240 ft.	11.8
B........	37.6	....	27.7	
		2.8	....	5.7
C........	34.8	....	22.0	
Cut-off......	85 ft. in 240 ft.	21.9	125 ft. in 240 ft.	17.7
D........	12.9	....	4.3	
		2 8	....	3.7
E..............	10 1	....	0.6	
		2.2	....	0.6
F	7.9	....	0	
	....	92.1	....	100.0

The drop from open water to the point, A, up stream from the points of cut-off, is 60% of the total head, in spite of the short distance of travel; so that the upper portion of the water gradient is steepest. The great loss of head at entrance appears to be inherent in experiments of this kind. It may well be doubted, however, whether such losses occur in the case of actual dams, where the area of entrance is very extensive, unless it is induced by silt deposits. Should no such loss with the actual dam be experienced, and should the pressure at A be 80 or 90% of the total head instead of 40%, the actual seepage losses may be double those deduced from the experiments.

In regard to the feature of the design consisting of a tight blanket up stream intended to lengthen the path of the water the reasoning of the author is believed to be sound. The same method was advocated by the writer and was adopted in the case of the Grand River Diversion Dam built by the Reclamation Service near Grand Junction, Colo. The object in this case was the reduction both of uplift and of seepage. Fig. 18 shows a cross-section of this dam.

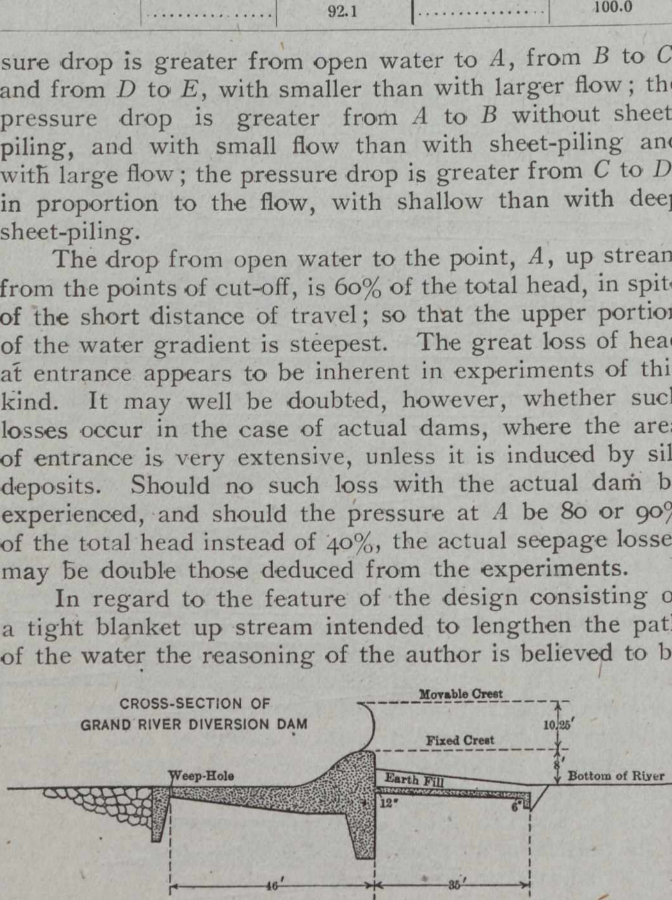

FIG. 18.

It may be stated that in this case measurements of uplift pressures were made through pipes placed in piers in the dam and ending in pockets of screened gravel under the foundation. The results indicate complete absence of entrance losses. They also show drop of pressure to be closely proportionate to distance along line of creep. It should be stated, however, that owing to delay in placing movable gates, the heads at the time of the two measurements were in each case only between 4 and 5 ft., and that measurements under a full head of 18 ft. may give different results.

Experiments of the character made by the author must always be of intense interest to hydraulic engineers and deserve full recognition.