WATER POWER PLANT OF THE STATE UNIVERSITY OF IOWA.

By B. J. Lambert.

When the Terrill dam, with its water-rights, was presented to the University, the question of its maintenance at the old site, or the building of a new dam some distance below, had to have serious consideration. Recognizing the fact that the old dam, built in 1840, was in need of rather extensive repairs, and also that the cut-off dam directly above it had lately been a source of trouble, it was finally decided, after a careful survey of several sites, to locate a new dam a short distance below the Burlington street bridge, across the Iowa River. This dam could make available the head of water at the old dam, and also take advantage of the small rapids immediately below it, and at several places between the old and the new—the fall of the river in this distance being something over two feet. Using the Iowa City datum for reference, it was found that the elevation of the crest of Terrill's dam was slightly more than 49′. The top being uneven, it was difficult to ascertain the true elevation, but several readings were taken at different points and an average of these was assumed practically correct. This gave an elevation of about 49′.2 In order to ascertain what fall might be expected in the pond between the old and the new dam when the new was in position, levels were run on the mill pond below Coralville. On several occasions it was found almost impossible to find any variation in elevation in the pond in a distance of 600 feet by means of an engineer's level. This was especially the case during low water. With a depth of about 6″ on the crest of the dam, there was found to be a fall of about 1½″ to 2″ per mile. It was decided to give the crest of the new dam an elevation of 49′, the difference of .2′ being assumed as the difference in elevation of the water between the two dams at an ordinary stage, and the intention being that upon the completion of the new dam, the condition of the river below Coralville will be practically the same as it was during the operation of the Terrill mill privilege.

In addition to obtaining an increased head of over 2 feet at the new dam, and thereby increasing the power 30 to 40 per cent, there are several other advantages in the new site. The location makes it quite accessible, as it is but 4 blocks from the present University Heat and Power Plant and new Engineering building. This nearness is quite a factor, since provision is being made whereby hydraulic and electrical investigations will be carried on to a considerable extent. In addition to this the pond will make it possible to beautify the campus river front, and also give an added zest to such pleasures as boating, swimming and skating. From varying standpoints then, financial, physical, aesthetic, and pleasurable, the change in location was highly desirable and practical.

Before it was definitely decided to relocate the dam, a careful topographic survey was made along both banks of the Iowa river, between the Rock Island bridge and Terrill's dam. One foot contours were plotted, and from these it could be plainly seen just what land would be affected by the back water at a normal stage of the river, say between elevations 49.′0 and 50.′0. To provide for damages should this question arise, the Commercial Club of Iowa City assumed this responsibility by signing bonds relieving the University from any future responsibility from back-water damages. In all, there will be about 30 acres of the adjacent lowland covered, most of which was at one time in the bed of the river, and which has never been of any practical value for agricultural purposes.

In designing the dam and power plant, several important questions arose, the most important of which was the determination of the flow of water. The United States Government had been gaging the flow of the river for about two years only, and this was practically the only data available on which estimates could be based. After a careful study and tabulation of this data, Professor Woodward of the Mechanical Engineering Department calculated the following curves:—

Fig. 1. Concerning the Diagram Professor Woodward says: "For the purpose of calculating the power of the stream, we assume a dam with a crest eight feet above the minimum stage of the river, which is at —1.5 feet on the gage. This puts the crest of the dam at the point 6.5 feet on the gage. The relative rates

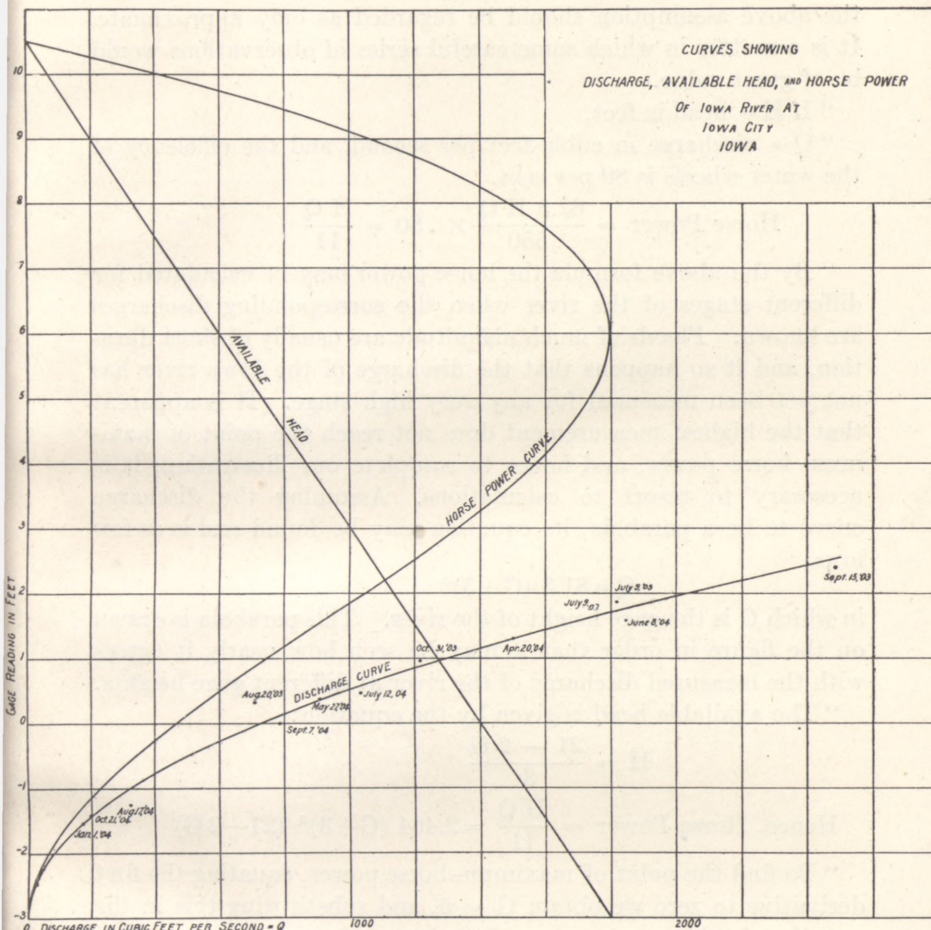

FIG. 1

at which the water will rise during a flood on the crest of the dam and in the tail race can only be estimated, but from the best information that can be obtained from a similar plant two miles above, it seems fair to assume that the water will rise three times as fast in the tail race as on the crest of the dam.

"On this assumption the head may be computed for all stages of the river. The relation between the rates of rise of head water and tail water would be different at every different location, and the ratio would probably not be constant at the same location, so the above assumption should be regarded as only approximate. It is a matter in which some careful series of observations would be of great value.

"If H = head in feet,

"Q = discharge in cubic feet per second, and the efficiency of the water wheels is 80 per cent.

$$\text{Horse Power} = \frac{62.5\ H\ Q}{550} \times .80 = \frac{H\ Q}{11}$$

"By the above formula the horse power may be calculated for different stages of the river when the corresponding discharges are known. Floods of much magnitude are usually of short duration, and it so happens that the discharge of the Iowa river has not yet been measured for any very high stage. It is apparent that the highest measurement does not reach the point of maximum horse power, and hence to complete our illustration, it is necessary to resort to calculations. Assuming the discharge curve to be a parabola, its equation may be found and is as follows:

$$Q = 81.3\ (G+3)^2$$

in which G is the gage height of the river. This parabola is drawn on the figure in order that it may be seen how nearly it agrees with the measured discharge of the river at different gage heights.

"The available head is given by the equation:

$$H = \frac{21 - 2\ G}{3}$$

$$\text{Hence, Horse Power} = \frac{H\ Q}{11} = 2.464\ (G+3)^2\ (21-2\ G)$$

"To find the point of maximum horse power, equating the first derivative to zero we obtain G = 6, and substituting this in the equation for horse power, we find the maximum horse power to be 1796. The available head and the horse power according to the above equation are plotted on the diagram above, showing graphically the point of maximum horse power and the rate at which the horse power varies."

In Professor Woodward's diagram he has assumed a maximum head of 9 feet, whereas if he had continued his original assumption of 8 feet, the equation for available head would be:

$$H = \frac{18 - 2\ G}{3}$$

which inserted in H. P. equation, the value of G. obtained for maximum H. P. would be 5 feet, and the resultant H. P. 1230.

The writer has chosen a somewhat different method of approaching the question of max. flow and H. P. Assuming the the dam to be a round-topped wier over which the flow can be roughly approximated by the formula Q = (3.01) (length of crest) (depth of crest)$^{1.53}$ the accompanying table was computed showing the amount of flow with varying depths on the crest from 0.1 feet to 5.0 feet, and the resultant H. P. assuming the head variable and dependent on the ratio of rise of headwater to rise of water below the dam.

		Head = 8.0		Head = 8.0		Total Head = 9.0	
		$\frac{\text{Rise of headw.}}{\text{Rise of water below dam}} = \frac{1}{2}$		$\frac{\text{Rise of headw}}{\text{Rise of water below dam}} = \frac{1}{3}$		Ratio = ⅓	
Ft. Depth on Crest	Volume Cu. Ft. P. Sec.	Effective Head	H.P.	Effective Head	H.P.	Effective Head	H P.
.1	26	7.9	19	7.8	18	8.8	21
.2	77	7.8	55	7.6	53	8.6	60
.3	143	7.7	100	7.4	96	8.4	109
.4	223	7.6	152	7.2	143	8.2	166
.5	315	7.5	215	7.0	200	8.0	228
.6	414	7.4	280	6.8	255	7.8	293
.7	522	7.3	345	6.6	315	7.6	360
.8	642	7.2	420	6.4	375	7.4	432
.9	770	7.1	500	6.2	435	7.2	506
1.0	903	7.0	575	6.0	495	7.0	575
1.2	1200	6.8	740	5.6	610	6.6	720
1.4	1510	6.6	900	5.2	720	6.2	850
1.6	1860	6.4	1080	4.8	810	5.8	980
1.8	2220	6.2	1250	4.4	890	5.4	1040
2.0	2610	6.0	1420	4.0	950	5.0	1140
2.4	3440	5.6	1750	3.2	1000	4.2	1310
2.8	4360	5.2	2060	2.4	950	3.4	1320
3.0	4850	5.0	2200	2.0	880	3.0	1310
3.4	5860	4.6	2450	1.2	640	2.2	1170
3.8	6960	4.2	2660	.4	250	1.4	880
4.0	7500	4.0	2720	.0	0	1.0	680
4.4	9000	3.6	2950	....	....	.2	160
4.8	10200	3.2	2980	....	....	....	....
5.0	11000	3.0	3000	....	....	....	....

In connection with this table Fig. 2 was drawn, and is self-explanatory. While this table shows the approximate quantities of water that would flow over the dam with head gates closed at the depths on crest indicated and also the equivalent H. P., yet it must not be understood that this power could be developed, even

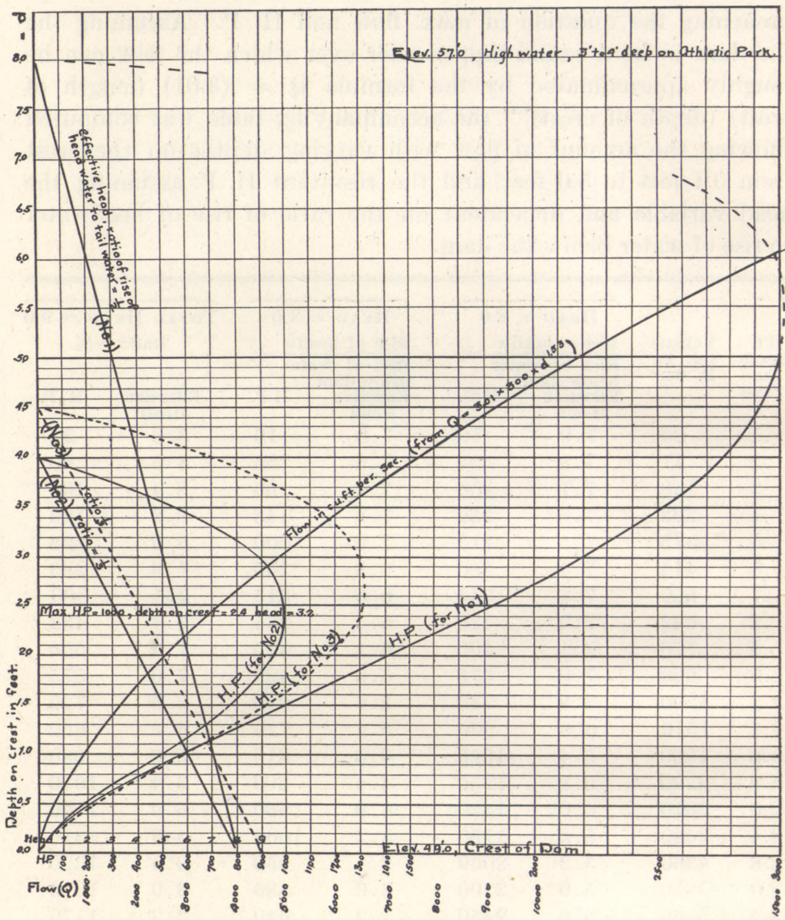

FIG. 2

had the wheels a sufficient capacity to take the total flow, for when the gates are opened the head decreases and flow through wheels consequently diminishes. Taking the case at max. H. P. of water over the crest at ratio of rise of water on crest to rise below dam as 1 to 3. The depth on crest =2′.4, the head 3.′2, flow 3440 cu. ft. per sec., the H. P. = 1000. On opening the gates, even though the wheels at a head of 3.′2 had a capacity of 3440 cu. ft. per sec., this amount diverted from crest to wheels, begins to diminish the head, and consequently the flow, until finally a balance is established, a certain amount going through the wheels, and the rest over the dam.

But in practice, with wheels of definite capacities, under known heads, but a very small proportion of the water can be used at the high stages, with low heads. So, again taking the case of max. H. P. over the dam, and assuming the wheels 36″, 48″, and 60″. At the head of 3.′2 they will discharge, say 50, 90, and 150 cu. ft. per sec., respectively, or a total of 290 cu. ft. per sec., leaving a flow over the dam of 3150 cu. ft. per sec. This gives a depth on crest approx. .2′ lower than the original, or 2.′2. The height of tail race water remaining constant, approximately, the head is reduced to 3.0′, the flow through wheels thereby being also reduced by about 20 cu. ft. per sec., leaving 270 cu. ft. through wheels, or an equivalent of about 75 H. P., at this head. In the same way it can be shown that at 1.′0 depth on crest (assuming ratio of rise of headwater to water below dam as 1 to 3), and a resultant head of about 5.′5 when gates are opened, that these wheels will develop about 200 H. P.

The maximum output of the above wheels is found to be at a point when the depth of water on the crest with gates closed is about .6 ft., with a flow of 415 cu. ft. per sec., and a resultant head, with open gates, of about 6.5 ft., thus giving approx. 240 H. P. With an assumed minimum flow of 200 cu. ft. per sec., the effective head would be about 7 ft., and the H. P. 130, which is approximately the capacity of the two smaller wheels at this head. With an assumed min. flow of 150 cu. ft. per sec., the effective head would be about 7.2 ft. and H. P. 100.

The above computations have taken no account of the storage capacity of pond, and while it may be best to place no reliance on this, yet at times, it may be used to considerable advantage.

Assuming that the gates are closed at 10 p. m. to all wheels except the 36″, which will use about 70 cu. ft. of water per sec., and furnish from 40 to 50 H. P.; if the water, during the evening, has been drawn down .4 to .5 of a ft., then from 10 p. m. to 6 a. m., on an assumed min. flow of 200 cu. ft. per sec. (leaving 130 cu. ft. per sec. for storage), there will be an inflow of 1,150,000 cu. ft., which amount would again approx. fill the pond to a level with top of dam. This water may be withdrawn as required. Its value is 17,000 H. P. for 1 min., or 280 H. P. for 1 hour, or 40 H. P. for 7 hrs., this, of course, in addition to the 130 H. P. due to flow of 200 cu. ft. per sec.

All the above computations are based on assumptions which may vary considerably from the exact quantities. On the completion of the plant, it is planned to carry on some interesting lines of experiments suggested as a result of these studies.

In regard to the power plant, details will be given next year. The interior will be 28′x45′, with a height from floor of dynamo room to ceiling of 14 ft., thus giving ample room for the transmission, generators, governors, switchboard, gate stems, office, storeroom, and an overhead crane of sufficient capacity to handle the heaviest turbine. Each wheel will be placed in a separate bay, the smaller wheel having one headgate opening, the next larger two openings, and the largest three openings. These openings being 5′x8′ in the clear, provide sufficient area so that practically under no conditions will the velocity of inflow exceed 2½ ft. per sec. The dead water under the wheels will be from 8 to 10 ft. in depth, and the tail race openings have an area of about 300 sq. ft., or 25 per cent. in excess of head gate openings. When but one wheel is running its discharge has two exits, one direct to the outside and one into the adjacent tail race. The electrical equipment, as now planned, will consist of 2 generators—a 50 K. W., and a 100 K. W., belt driven. The shafting, driving pulleys, and bevel gears will be so arranged with friction clutches and quills, that any wheel or combination of wheels and generators, may be used that is desired. A full description of the details and installation will be given in the next issue of THE TRANSIT.

In designing the dam, which is about 300 ft. long and 20 ft. in height at deepest section, the concrete was assumed to weigh 130 ℔ per cubic ft. In addition to the water pressure on the back of the dam, there was assumed an additional pressure due to the back filling of sand up to elevation 42.0′. Inasmuch as the elevation of low water is about 10 ft. above the foundation, the back pressure due to this was considered in the design. Varying ratios of rise of water on crest to rise below the dam were assumed, and then, with varying heads on crest the critical sections were investigated, until practically under the most extreme assumptions it was found that there was a sufficient width, so that the resultant line of pressure was everywhere within the middle third of the section. Previous to the design of the dam, in addition to soundings made by the water jet and steel pump rod, a test pit 8′x12′ was sunk on the east bank of the river a short distance above the

Burlington St. bridge, in order to investigate the character of the foundation stone. It was found to be practically level bedrock, without seams or crevasses, and its elevation agreeing exactly with that taken by the rod and jet, it was concluded that the profile obtained from the original soundings would be reasonably correct. Thus far in the construction of the dam it has been found that the profile agrees almost exactly with that laid out from the soundings.

Near the west end of the dam will be built a canal 10 ft. wide and 6 ft. deep, arranged with gates and wiers so that many useful hydraulic experiments may be carried out. Adjoining this canal will be built a fishway, as required by the laws of Iowa. Details of these will be given later.

The dam and power plant will be completed and all machinery installed by the opening of the school year, next September.