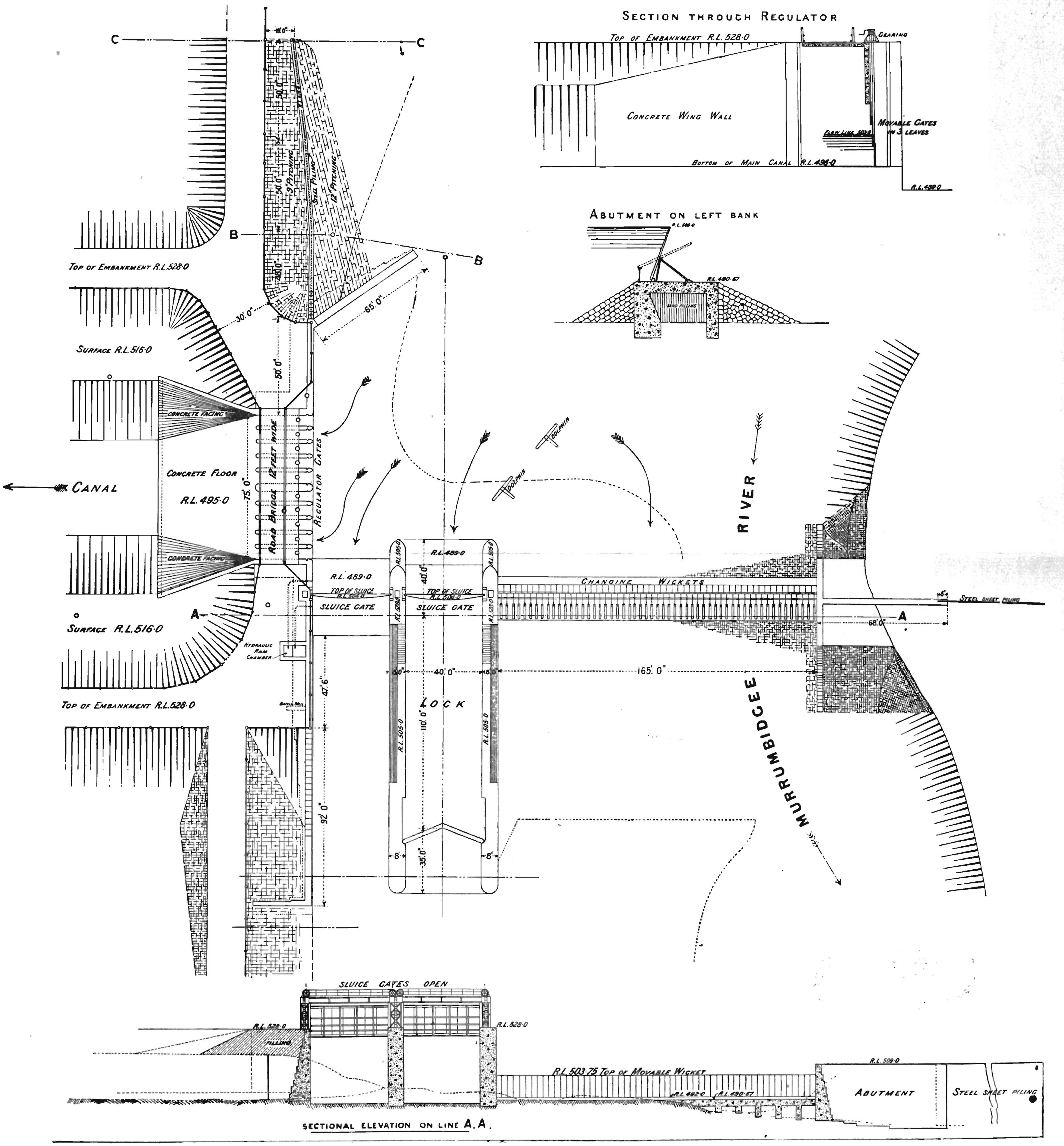

Section through Regulator
Top of Embankment R.L. 528·0
Gearing
Concrete Wing Wall
Movable Gates in 3 leaves
Bottom of Main Canal R.L. 495·0
Abutment on left bank
Sand Filling
R.L. 480·67
Top of Embankment R.L. 528·0
Surface R.L. 516·0
Concrete Facing
Concrete Floor R.L. 495·0
Canal
Road Bridge 12 feet wide
Regulator Gates
Steel Piling
9" Pitching
12" Pitching
Dolphin
River
Murrumbidgee
Chanoine Wickets
Sluice Gate
Top of Sluice
R.L. 489·0
Lock
Hydraulic Ram Chamber
Steel sheet piling
165' 0"
68' 0"
110' 0"
40' 0"
92' 0"
47' 6"
35' 0"
65' 0"
30' 0"
50' 0"
75' 0"
Sluice Gates Open
R.L. 528·0
Filling
R.L. 503·75 Top of Movable Wicket
R.L. 509·0
Abutment
Steel Sheet Piling
Sectional Elevation on line A.A.

Plate 8.

second. This will be more than ample to cover all possible losses in the Bundidgerry Creek channel, which has a cross section in excess of the excavated channel, and deliver 1,000 cubic feet per second at the end of the creek channel into the excavated channel where it commences at Narrandera. The real canal excavation to a fixed cross section may be said to commence at this last-named point, and continue onwards from there, and this will be the point for the measurement of the volumes that will be afforded to meet irrigation requirements and upon which the duties of water passed down the canal will be calculated. This excavated main canal will then have a bed width of 50 feet, sides slopes $1\frac{1}{2}$ to 1, and with an inclination of 9 inches per mile will be capable of discharging 1,000 cubic feet per second, with a flow of 7 feet in depth and a velocity of 2.32 feet per second. The main channel will bifurcate after it crosses the Hay railway line in the vicinity of Yanco Siding. The actual dimensions of these branch channels will be determined at a later date, in view of the volumes that will be afforded to the different areas and qualities of land commanded by them.

The regulators to be provided in the vicinity of the Bundidgerry woolshed and Narrandera, which will be known as the "Bundidgerry" and "Narrandera" Regulators will be of similar design, the floor and abutment arrangements being varied to meet the conditions of a stiff clay foundation at Bundidgerry and sand-stone rock foundation at Narrandera. Both regulators are divided into five 12 feet openings by concrete piers, two feet in thickness, each opening being controlled by a quadrant sluice. These sluices are of interest as being the first of the type proposed to be utilized in the Commonwealth.

They consist of two end frames of mild steel joists, and angle bars built to resemble the segment of a wheel. These segments are connected by channels and angle bars, and the periphery planked with carefully fitted dressed timber. The hub of each segment will be bored to fit on to a gudgeon built into the concrete pier on either side, and on which the sluice revolves, and through which water pressures are transmitted to the other portions of the regulator. A reinforced concrete curtain wall, commencing at 9 feet above the sill of regulator, closes the bay between the piers above the sluices. The sluices are operated by a steel rope attached tangentially to the periphery of the sluice, and raised and lowered by a travelling winch. Each sluice is fitted on its end frame with guide rollers which travel on a cast iron path embedded in the concrete pier. Water-tightness is obtained by staunching flaps of insertion. This type of sluice is rapid in its operation and, as designed, can be operated by means of a winch by one man.

Both regulators are designed with warped wing walls upstream and down-stream for the purpose of guiding the flow in

NARRANDERA REGULATOR

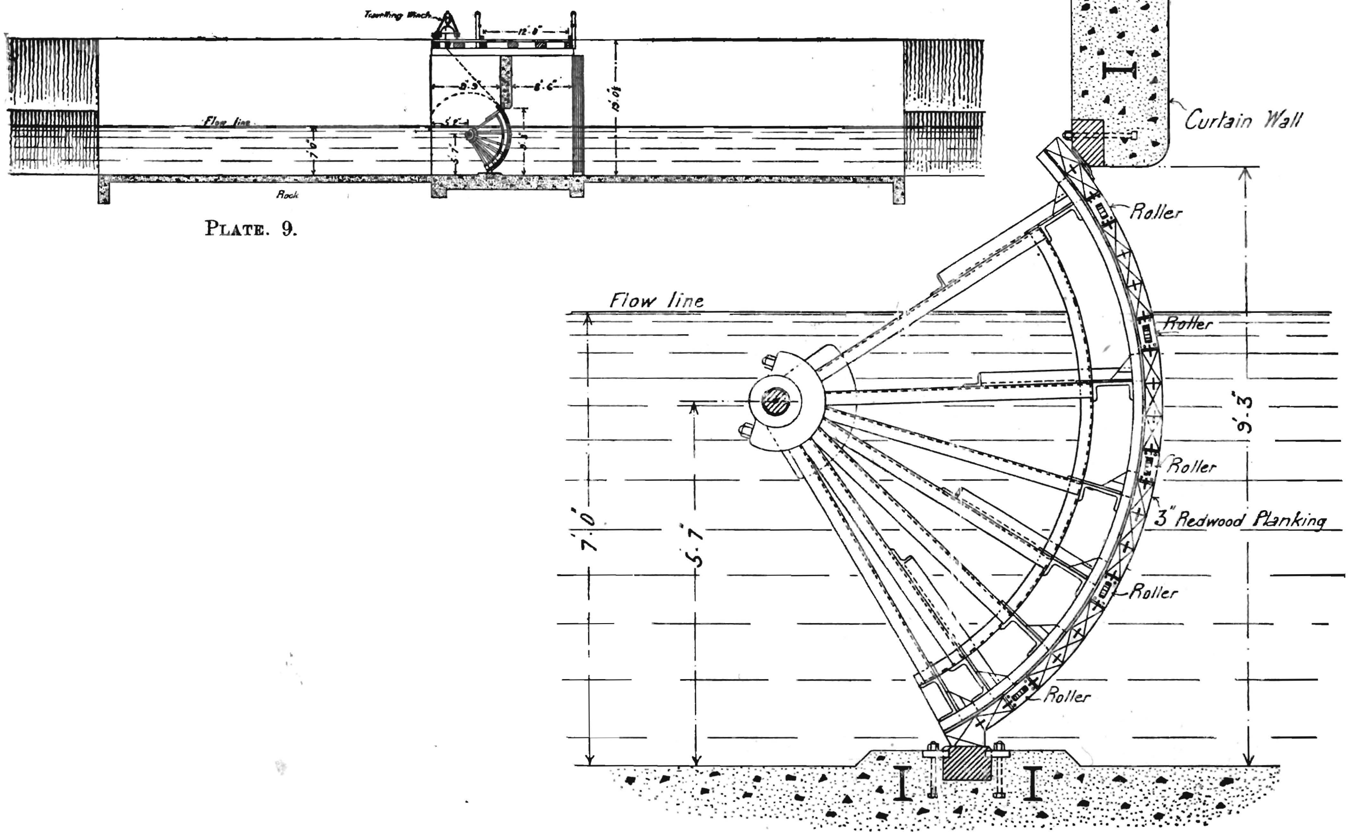


PLATE. 9.

and out from and to the normal canal cross section. This type of wall has been found to form the best combination of guide and retaining wing wall.

Three escapes will be provided on the main canal. The conditions at the Bundidgerry regulator afford a natural escape for the uncontrolled flood-waters naturally entering the Bundidgerry Creek; these will return to the river over a low stone weir which it will be necessary to place across the creek at this point for the diversion of supplies into the canal. The next escape will be in the form of a culvert through the flood embankment immediately before the main canal crosses the Hay Road, the surplus waters being discharged into the head of the Cudgel Creek, through which they will eventually pass to the river. The third escape will be at about 43¼ miles on the main channel; the surplus waters will be passed through a regulator into a short cutting into a drainage depression and thence back into the river.

The whole of the works in connection with the construction of the canal will be carried out by contract.

Cost of Works Included in the Scheme.

The total estimated cost of the whole proposal is as follows:

Storage Works	£810,000
Main Canal	375,904
Hay Branch Canal	138,104
Distributaries	250,000
	£1,574,008
Less Half Cost of Storage	405,000
Total Chargeable against Present Scheme ..	£1,169,008

Administration of Scheme.

After the completion of the works, it will be necessary to make legal provision for their administration, with a view to obtaining the most beneficial results from the use of the water and also an adequate monetary return on the outlay. This State is favourably situated in dealing with these questions in advantage can be taken of the experience of the neighbouring State of Victoria to steer clear of the difficulties that have cropped up in the administration of works of a similar nature, and also on account of the fact that the areas to be irrigated consist of pastoral holdings which must necessarily be subdivided and occupied by new men and that there are no settlements of dry farmers whose lifelong prejudices have to be uprooted.

An essential principle to be incorporated in any legal enactments for the administration of an irrigation proposal is that of the attachment to the irrigable lands of certain volumes of water which will form a permanent charge on that land for all time, whether the water be taken by the owner or occupier or whether it be not. Water so attached to the land, and any additional water supplied under agreement, should be charged for at such rates as would necessitate its careful use and the intense cultivation of the land to which it is applied. With the embodiment of these two principles, it is anticipated that the Northern Murrumbidgee Irrigation Scheme will be successful, both from an agricultural and financial point of view.

The financial position of the scheme has been based upon a delivery of 269,348 acre feet of water on the irrigable lands during the irrigating season; this, for a canal to deliver 1,000 cubic feet per second, will mean a duty of 135 acres per cubic foot per second, assuming an average watering of 2 feet in depth. This duty may seem high, but it must be borne in mind that it is calculated upon the delivery being measured at the Narrandera regulator or immediately above the irrigable lands.

The statements of finance placed before the Parliamentary Standing Committee on Public Works were based on the assumption of a period of 15 years being required before all water that could be supplied would be availed of, or attached to the lands; and that half rates for water would be charged in the first year, increasing in amount uniformly until full rates were charged in the fifth year, the charge being at the rate of 5/- per acre foot of water delivered on the land.

These assumptions, which may seem conservative, must necessarily be applied to the conditions of the introduction of a new form of intense agriculture to a sparsely populated country where in the past agriculturalists have been accustomed to deal with large areas assisted by Nature only.

Readers are referred to the Report of the Standing Parliamentary Committee on Public Works for many interesting details of the proposal that cannot be included in such a paper as this.

APPENDIX A.

Public Works Department.

Irrigation and Drainage Branch.

Instructions Regarding Methods to be Adopted in Measuring and Recording River Discharges.

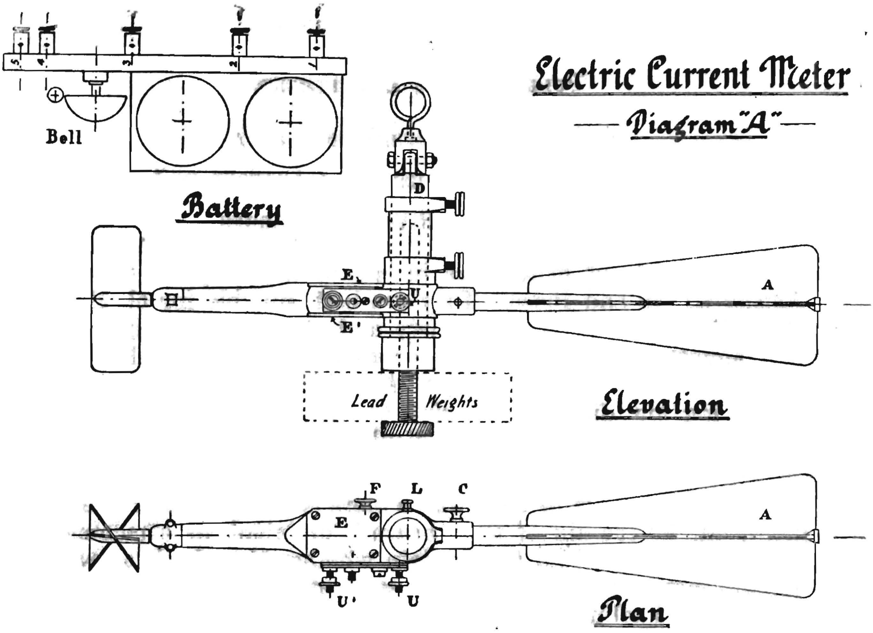
Two kinds of meters are in use in this Department, viz., Amsler-Laffon and Price. They are both suitable for all classes of work, even when used in dirty and muddy water they alter very slightly in rating, and give very satisfactory results. The Price (which is largely used in America) is specially adapted for taking low discharges, owing to the propeller moving in a horizontal instead of a perpendicular plane as in the Amsler-Laffon.

A meter cannot be used where there is much floating weed or grass, but by the aid of the "buzza," or telephone attachment, the observer is enabled to ascertain whether the wheel is revolving and meter recording. It requires great care in its use, careful cleaning and oiling after each gauging. When cleaning meter, clean hot water should be run through till all mud and grit is washed out of the toothed wheels and the ball bearings. This is a tedious proceeding, but one absolutely necessary to ensure the correct working of the parts, and should be carried out by the officer himself. Plenty of oil should be run through the bearings before putting away until the next observation. It is found that the best oil to use is that known as "phonogram," which seems to be a pure mineral oil. The meter can be used in streams of all sizes. It gives the mean velocity of the impulses. Only one section of the river need be taken. Instead of using the meters attached to a metal rod so that it can be held rigid, it is suspended by the insulated copper wires, which allows the meter to turn in any direction, the screw being kept facing upstream by a four-blade tail. Leaden weights up to 60 lb., varying according to the velocity, are attached to keep the instrument at right angles to the vertical; this also allows of the meter being raised or lowered very quickly to any desired position.

The method of procedure is as follows:—

First of all, select a gauging site. This should be on a straight reach, far enough from a bend to be out of its influence; the bed should be permanent and not stony. The banks should be sufficiently high to contain all the water at the highest stages.

The section should be free from all disturbing influences, such as bridge piers, snags, and eddies; sounding to be taken at each 10 feet, or closer if required.



Pegs should be put in at the ends of the section, and bench marks left for future reference.

Next, fix the rudder A (Diagram A) by means of the screw C; place the instrument on a metal bar D so that it is entirely free to turn in any direction with the current. Connect the terminals 2 and 3 of the electric battery with L and U respectively on the meter.

At every fifty revolutions of the axle of the wheel, a small arm or wiper inside the meter revolves, completes the circuit, and causes the bell to ring. To inspect and oil the electric contact, the cover E must be removed. The bottom E^1 should never be taken off. In order to empty the case, the outlet F should be opened, and water drained off each day. When using the "telephone, or buzza," connect two ends of the telephone wires to No. 4 and No. 5 clamps of the electric battery and one wire from clamp No. 5 to U^1 on the meter; if the axis of the meter is going forward, one sharp tick is given; if reversed, two ticks.

To measure the velocity of water, proceed as follows:—When the bell rings, observe on a stop watch the instant when the ringing ceases, and then observe the interval of time (expressed in seconds) till the next signal ceases. The beginning of the signal is only for advising the observer. The interval of time from signal to signal is denoted by the letter t; V denotes the speed of the water. If, for example, that interval has been twenty seconds, then $t = 20$.

Next, a tagged wire is stretched across the cross-section, and when a boat is available, two others above it for holding the boat in any required position; the insulated wires, with the meter and weights attached, pass over a pulley at the end of of a pole projecting from the boat, so that the meter is well clear. The boat is then held in position by the two upper wires, the meter is suspended just under one of the tags on what might be called the cross-section wire. The insulated wire is marked at each foot, the measurement starting from the centre of the fan.

In cases where a boat has not been procurable, the meter is run across the section by means of a small traveller on the cross-section wire. Both the soundings and meter observations are thus obtained, and, unless the streams are very wide, it has proved itself to be an excellent method.

If the rivers are wide, there is too much vibration in the thin wire used for the purpose; and if the meter be near the bottom, it has every chance of being knocked and put out of action.

Two methods of measuring velocity may be used with such a current meter as is described above:—

(*a*) Multiple measurements.

(*b*) Unit measurements.

Method (*a*) is the more exact, and, when the water surface is not fluctuating rapidly, is the method which should be adopted. In this method the velocity at several points on each vertical is measured at the surface, and each one or two feet down to within 0.4 feet of the bottom (as a rule, the meter should have a run of 100 or 150 revolutions at each point). The verticals are 10 or 20 feet apart across the cross-section, closer together, as a rule, near the banks. A vertical velocity curve for each vertical is drawn, and the area of the curve divided by the depth gives the mean velocity of that vertical.

The well known form of the Prismoidal Formula, with areas substituted for ordinates, is generally used for calculating these areas. When the mean velocity of each vertical is obtained, the cross-section of the river is plotted, and above each vertical its mean velocity.

Then the discharge is computed. Thus, let b in feet be the distance between each vertical, where d_1, d_2, etc., are the mean depth between each two verticals; V_1, V_2, etc., the measured mean velocity of the area between each two verticals; and A the area in square feet of the cross-section, then total discharge

$$Q = b\,(V_1 d_1 + V_2 d_2 + \text{etc.,})$$

$$\text{Then, } V = \frac{Q}{A}$$

By this means it takes about three hours to gauge a stream like the Murray or Murrumbidgee.

The method by unit measurements is the best method to use when the water level is fluctuating rapidly, and should be adopted when a river has been rising or falling 8 or 9 feet per day.

This method consists in giving the meter a longer run at one point in each vertical (generally 500 revolutions), as, no matter where the surface velocity is the greatest, or whether the maximum velocity be below the surface, a point at which the velocity is equal to the mean remains remarkably constant at a certain distance below the surface at each vertical.

Humphrey and Abbott give this distance as .63 depth; T. G. Ellis, .64 depth; and Wheeler and Lynch, .67 depth.

The experiments made at Cornell by E. C. Murphy agree with the latter; but they, as well as those by Wheeler and Lynch, were made in flumes and channels having a greater ratio of depth to width than on most rivers.

Departmental experiments at Gundagai and Hay show that a single observation at .64 depth of vertical gives a very close approximation to the mean velocity of that vertical. This agrees with the result obtained by T. G. Ellis.

A common American practice is to take .6 depth, but it has been proved by observations that this invariably gives too high results for New South Wales rivers.

In order to obtain accurate results, the meter must be rated frequently between observations. This is done by dragging the meter through still water at known velocities. and the number of revolutions noted.

For this particular meter a runner has been devised to travel over a stretched wire. On this runner is a piece of gas-piping, projecting about 3 feet into the water; on the end of this pipe the meter is attached.

The meter is then drawn through the water at different velocities, and the exact time (with a stop-watch) and distance travelled while the fan has made fifty revolutions is noted in each case.

Then, plotting the revolutions per second as ordinates, and velocity or distance travelled, divided by time as abscissæ, it will be noticed that the points lie on a curve that can be exceedingly closely approximated to, by two or three straight lines.

Theoretically, if there were no friction, the points would lie on one straight line, passing through the origin of coordinates.

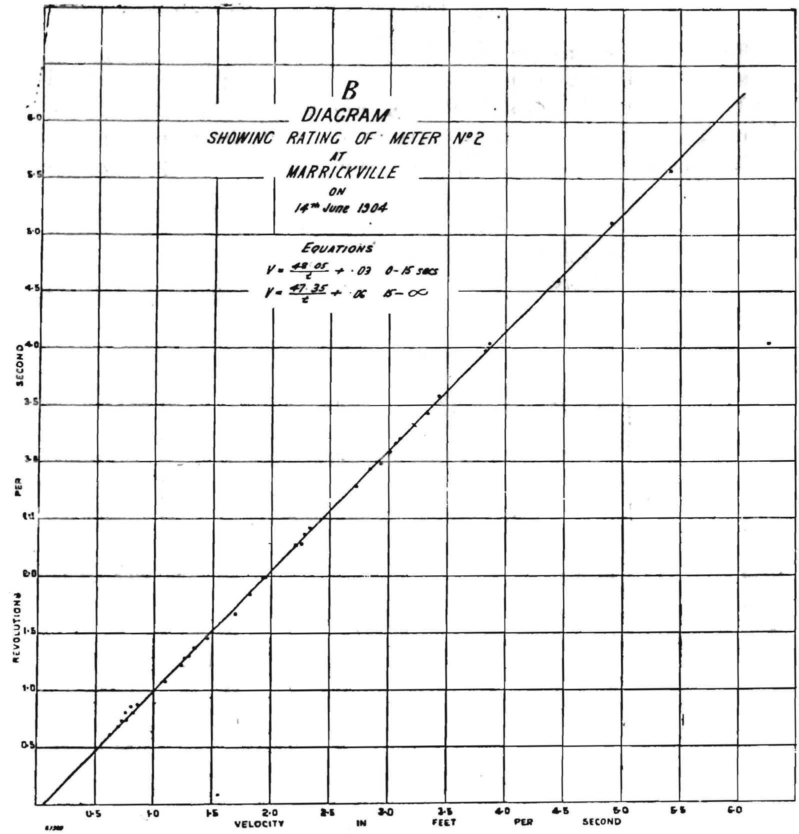
Thus, the equation of the meter is in the form of $y = mx + c$, in which y and x are found by experiment, and m and c are co-efficients that can easily be obtained by the method of least square. It will be found that the co-efficient m does not alter much, but the co-efficient c generally has the greater change.

Following is an example copied from the current meter field-book, showing the observations taken to determine the rating of meter No. 2 at Marrickville, on 14th June, 1905 :—

Length of base.	Time in seconds.	Velocity in feet per second.	Revolutions per second.	Length of base.	Time in seconds.	Velocity in feet per second.	Revolutions per second.	Length of base.	Time in seconds.	Velocity in feet per second.	Revolutions per second.
47·3	62·3	·76	·80	50·3	34·5	1·46	1·45	49·1	18·0	2·73	2·78
84·1	59·1	·81	·85	50·6	30·0	1·69	1·67	48·4	17·0	2·85	2·94
50·3	68·4	·74	·73	49·3	27·1	1·82	1·84	48·8	14·6	3·34	3·42
49·5	57·7	·86	·87	49·6	27·2	1·82	1·84	48·1	14·0	3·44	3·57
51·7	82·5	·64	·61	48·9	25·1	1·95	1·99	48·7	16·2	3·01	3·09
52·5	68·4	·77	·73	49·4	21·9	2·26	2·28	48·3	15·6	3·10	3·20
52·0	73·9	·70	·68	48·4	21·2	2·28	2·36	48·3	12·6	3·83	3·97
51·9	62·7	·83	·80	97·6	50·5	1·93	1·98	47·9	12·4	3·86	4·03
51·3	46·8	1·10	1·07		(100 rev.)			48·5	10·9	4·45	4·59
49·4	39·0	1·27	1·28	48·7	22·0	2·21	2·27	48·8	9·0	5·42	5·56
50·8	41·0	1·24	1·22	48·2	20·7	2·33	2·41	48·1	9·8	4·91	5·10
49·3	36·4	1·35	1·37	49·4	16·8	2·94	2·98				
50·2	38·5	1·30	1·30	48·3	15·8	3·06	3·16				

The accompanying diagram (marked B.) shows the foregoing observations plotted on co-ordinate paper. The abscissæ representing velocities in feet per second, and the ordinates, revolutions of the fan per second.

By drawing the most probable lines through the points of observation it will be seen that a bend takes place about $3\frac{1}{3}$ revolutions per second, and the following shows the calculations to determine the rating for each line.



* The observations put in the form of the equation $y = mx + c$ are as follows :— From 0 to 15 seconds.

No. of Observations.	Length of Base.	t = Time in Seconds for 50 revolutions.	Revolutions per Second.	Velocity in feet per Second.	x^2.	xy.
			x	y		
1	48·1	9·8	5·10	4·91	26·01	25·04
2	48·8	9·0	5·56	5·42	30·91	30·14
3	48·5	10·9	4·59	4·45	21·07	20·43
4	47·9	12·4	4·03	3·86	16·24	15·56
5	48·3	12·6	3·97	3·83	15·76	15·21
6	48·3	15·6	3·20	3·10	10·24	9·92
7	48·7	16·2	3·09	3·01	9·55	9·30
8	48·1	14·0	3·57	3·44	12·74	12·28
9	48 8	14·6	3·42	3·34	11·70	11·42
10	48·4	17·0	2·94	2·85	8·64	8·38
11	49·1	18·0	2·78	2·73	7·73	7·59
12	48·3	15·8	3·16	3·06	9·99	9·67
13	49·4	16·8	2·98	2·94	8·88	8·76
13 = n			48·39	46·94	189·46	183·70

* Irrigation Papers of United States Geological Survey No. 64—1902.