impossible to get a ladder to-day higher than the one they had seen in the yard—87ft.

He knew they were interested in building construction, and hoped they would do their utmost to get the building regulations as near perfection as possible.

He thanked them on behalf of the officers and men for the hearty manner in which they had responded to the resolution.

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**PAPER.**

**THE CONSTRUCTION OF IRRIGATION CHANNELS.**

By J. S. Dethridge.

In this article the writer has endeavoured to keep as closely as possible to the considerations which govern the design of irrigation channels, and the structures in connection with them, as practised in this State; but for purposes of comparison and illustration a few brief references to this branch of engineering work in other countries could hardly be avoided.

All discussion and criticism will be welcomed in the hope that it will lead to an advance of knowledge on the subject.

Having the task of designing an irrigation channel for the supply of a defined area, the first step is to determine the capacity required. This will depend upon:

(a) The mean depth of water to be applied to the area at each watering.

(b) The interval of time between waterings.

(c) The proportion of supply to be allowed for losses by seepage, evaporation and imperfections of regulation.

The depth of water to be applied over the irrigable area at each watering varies according to the kind of crop, the amount of natural rainfall, and the nature of the soil. The variation is so wide that only experience in the actual locality, or under approximately like conditions elsewhere, can be accepted as a safe guide.

In the case of some of the channels being constructed in this State for the supply of lands having a mean rainfall of about 16 inches, provision at the rate of one cubic foot per second (1 cusec) for each hundred acres to be supplied, is being made for waterings and losses, tentatively. But wherever it can be done without material increase of cost, allowance is made for enlargement in case of extra water being required for the defined area, or an extension thereof. In dealing with evaporation and seepage losses it is much safer to be guided by measurements of actual losses per unit area of channel bed on some existing work in
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like conditions, and to compute therefrom the whole loss to be anticipated, than to assume without observation or computation any percentage as being applicable to the proposed system of channels.

For instance, take a channel with length of 20 miles, a mean wetted perimeter of 30 feet, and capacity at commencement of 100 cusecs, in a district where the loss by seepage and evaporation in hot weather is one-tenth of a foot over the whole earth surface with which the water comes in contact per day of 24 hours. The total daily loss would be 316,800 cubic feet, which is equal to 3.8 per cent. of the supply at the head sluice. If now a volume of 20 cusecs be considered, with velocity about the same as in the first case, the mean perimeter would be about 10 feet, and a loss of one-tenth of a foot per day over a length of 20 miles would amount to 105,600 cubic feet, or about 6.1 per cent. of the supply at the head sluice. As the channel became smaller, the proportion of loss to supply would increase until a loss would be found which in the given length would absorb the whole supply. The loss of one-tenth of a foot is assumed for purposes of illustration only; but losses as high as this have actually been measured during hot weather in the northern parts of Victoria.

The formula in general use in Victoria for determining the cross section of a channel of a given capacity and slope is the well-known \( V = C \sqrt{RS} \) equation, with values of “\( C \)” as deduced by Kutter’s formula. Sir Hanbury Brown in “Principles and Practice of Irrigation” states that for the coefficient “\( C \)” Bazin’s values have perhaps been more generally accepted than others by hydraulic engineers. Bazin himself, in a letter to Clemens Herschel, recently published in the “Engineering News,” says of formula for channels: “Many people imagine there must exist a perfect one, which is impossible, the asperities of the perimeter not being susceptible of any exact definition. These formulae cannot be more than guides, and they will never enable the engineer to dispense with his personal experience.” The discharges of unlined channels that are fairly regular, and free from vegetation, agree fairly closely with the results of computations by Kutter’s formula with “\( N \),” the coefficient of roughness, = .025; but a small growth of aquatic vegetation will have a noticeable effect in retarding the flow, hence the importance of having some margin to provide against such contingencies as rapid weed growths and silting, in computing the capacity of a channel, and the need for maintaining it in good order when it is in operation.

In most irrigating countries the securing of sufficient velocity to prevent deposits of silt seems to be an important factor in design. In this State trouble through silting is not altogether unknown; but the waters of the principal rivers carry so little sediment that there is no necessity to fix any minimum velocity to prevent its deposit. A maximum velocity has, however, to be fixed with a view to the prevention of erosion. Knowledge of the behaviour of the earth in the locality is the best guide in this
respect. In the earth on some of our mountain ranges, streams may be found flowing with velocities of over 3 feet per second, and even falling in small cascades, without eroding their beds sufficiently to discolour the water to any perceptible degree. In much of the Mallee country runnels of the same volume and velocity would in a few hours erode deep gullies. Of course the earths are of different origin; the mountain coating being rock decomposed in situ, while the Mallee soil is deposited water borne material. But the point is that designs that would do in one place would prove quite unsuitable in the other, hence the need of local observation when any question of permissible velocities arises.

In the choice of cross section, many factors require consideration. The sections in general use are mostly trapezoidal when constructed, but after being in use for some time they assume a form approximating to a half ellipse, with the water surface line as the major axis. For reasons stated further on, the writer is of the opinion that in many cases there would be advantage in curving the bed in the first place. Keeping for the present to the trapezoidal section; it is well known that three sides of a half hexagon give the highest value of hydraulic radius. For small channels, or for large channels in rock, or in ground with much transverse slope, as close an approximation to the half hexagon as the angle of repose of the material will permit, should be considered in determining the cross section. But when the channel is to be through flat country, a form with much less depth in proportion to width is advantageous. To give an illustration of the economy of adopting the shallow and wide type of section in the case of a channel of large size on a level plain, a case can be imagined of the largest conceivable irrigation supply being conveyed between embankments of quite moderate size, spaced sufficiently far apart. It might rather hastily be assumed from this statement that the cost of a large irrigation channel through a plain should not be much greater than that of the two embankments confining the water. It is, however, to be remembered that in few places is the country so level as to permit the theoretical possibilities of such construction to be realised, and with great width costs would increase through the need for protection against wave action. In actual practice the aim is to secure the best section that the embankments in combination with the cutting (which provides the material for them) will permit. The first thing to be determined is proportion of depth to width.

An article in “Engineering News” of the 10th September, 1908, by C. E. Grunsky, M. American Society of C.E., is suggestive of some difference of opinion between American engineers as to whether wide and shallow channels are preferable to relatively narrow and deep ones. Mr. Grunsky is an advocate of the wide and shallow channel, and suggests, on the understanding that a
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A wide range of departure is allowable, proportions in the following scale—

<table>
<thead>
<tr>
<th>Width at water surface</th>
<th>Proportion of width to depth</th>
<th>Depth.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>10</td>
<td>6</td>
<td>1.6</td>
</tr>
<tr>
<td>20</td>
<td>8</td>
<td>2.5</td>
</tr>
<tr>
<td>40</td>
<td>12</td>
<td>3.3</td>
</tr>
<tr>
<td>100</td>
<td>16</td>
<td>6.7</td>
</tr>
<tr>
<td>200</td>
<td>22</td>
<td>9</td>
</tr>
</tbody>
</table>

The following figures show how some of the principal channels in Victoria compare with Mr. Grunsky’s scale:—

<table>
<thead>
<tr>
<th>Channel</th>
<th>Width at water surface</th>
<th>Depth</th>
<th>Depth by Grunsky’s Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goulburn Waranga</td>
<td>131</td>
<td>7</td>
<td>7.5</td>
</tr>
<tr>
<td>Waranga to Cornella</td>
<td>94</td>
<td>7</td>
<td>6.3</td>
</tr>
<tr>
<td>East Goulburn</td>
<td>56</td>
<td>6</td>
<td>4.2</td>
</tr>
<tr>
<td>Macorna</td>
<td>48</td>
<td>4</td>
<td>3.8</td>
</tr>
</tbody>
</table>

For smaller sizes with widths of water surface ranging from 6 to say 20 feet, the usual depth would be from 2 to 3 feet 6 inches, figures somewhat higher than given by the scale, and, in the writer’s opinion, preferable, because of less exposure to evaporation, and smaller risk of choking by the semi-aquatic growths that flourish in very shallow channels. Due regard must be paid to the nature of the formation in fixing the proportion of width to depth. On the footslopes of ranges, rock in many cases occurs nearly uniformly at a depth of a few feet below the surface. Obviously it is desirable to keep the bed of the channel above it, if possible, to save cost. In plain country, sand drifts may be found below a certain depth. This is the case on some parts of the line of the eastern Goulburn channel. Though loss of water through these drifts can generally be prevented by excavating below grade and covering them with clayey material, this involves expense, and if cutting into them can be avoided, it is well to do so.

It is of importance that the form of the cross section is such as to present no difficulties to the machines or implements likely to be used in construction. The methods of channel excavation in this State are as yet far from being uniform. Some contractors employ steam scoops having capacities up to five cubic yards. The material is first ploughed, then the scoop is drawn backwards and forwards across the channel by portable engines with winding attachments. Where material is to be conveyed for more than 20 feet, the cranked axle wheel scoop is a favourite implement; but the bulk of the work is still done by sliding scoops drawn by teams of four or five horses. The steam scoops can be made to draw stuff up slopes one and a half horizontal to one vertical, but horses can only do this advantageously when the height from bed to crest is not more than four or five feet. The question thus arises whether modification of the theoretical lines of a cross section is warrantable with a view of securing cheapness in construction.
It is to be kept in mind that channel work is tendered for by the cubic yard at prices of which 6d. is near the mean. Experience shows that contractors will readily make a difference of as much as 1d. per yard in favour of a cross section which suits their method of working. This would amount to about 16 per cent. on the whole cost of the earthwork. Having determined the dimensions of cross section that would deliver the required supply with the slope known to be available as the result of trial survey, a computation can be made to determine the depth of cutting that will yield the proper quantity of material for the two embankments. Fig. 1 Plate I. is a cross section diagram of an irrigation channel.

Making \( X \) = Economical depth of cutting.

\[ A = \text{Width of bed.} \]

\[ C = \text{Width of each crest.} \]

\[ H = \text{Height from bed to crest.} \]

We have for a channel with side slopes of cutting \( 1\frac{1}{2} : 1 \), and side slopes of embankments \( 2 : 1 \):

\[
(A + 1\frac{1}{2} x) x = 2 \left( C ( H - x ) + 2 ( H - x )^2 \right)
\]

If a number of computations of the kind have to be made, tables of sectional areas of cuttings and embankments can be used with saving of time. As stated, the formula assumes that the embankments will be of the same volume as that of the cutting from which the material came. Some writers on earthwork state that though at first earth built into embankments by means of horses and scoops increases in bulk as compared with its natural state, eventually, as the result of settlement, it becomes considerably less. Earths of different kinds, though subjected to the same treatment to ensure consolidation, behave very differently. The writer knows of cases in which earth of a clayey nature in embankments was found to be of considerably greater volume than the cutting from which it had been taken, several months after the work had been completed and used for the conveyance of water.

When the depth of cutting has been determined, the channel may be set out on the ground on the most suitable line. If the country be fairly regular with a decided transverse slope, and the longitudinal slope be slight, the line will approximate to a contour. If the channel be large, economy requires that the line involving least cost in construction be adopted, regardless of such considerations as the severance of private property; but in the case of distributory channels in flat country, some concession may be made to the desire of the cultivator to have allotments in convenient form for working. In making trials of short cuts through ridges to determine their merits, as compared with longer routes on the contour, it is advantageous to take for the short cut a section having greater depth and less width than the normal section, for example:—the portion of the Waranga-Mallee Channel, which
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normally has bed width of 73 feet and carrying depth of 7 feet, is changed to a bed width of 40 feet and depth of 10 feet where it passes through ridges, with the result of considerable saving in excavation. The joinings of the different sections are made without abrupt change of form, and surface level and slope are both without break. Generally short cuts through ridges are not so advantageous as they appear at first sight: the material may be expected to be harder, and in any case the greater depth makes its excavation more costly. Then regarding the work as completed, the tendency to silting by erosion of the slopes of the cutting has to be kept in mind. When due allowance is made for all of these factors there should not be much difficulty in deciding which of two routes is the more economical.

The question whether dredging could not be advantageously employed in the construction of main channels is sometimes asked. Contracts large enough to warrant considerable outlay in plant have from time to time been let, but though some of the contractors have given consideration to dredging methods, so far their employment has not been ventured on. One difficulty anticipated is that the placing of dredged material in the comparatively narrow and steep embankments of an irrigation channel would involve an undue proportion of hand labour in such work as brush or shovel built dams for the confining of the stuff before it set.

Fig. 2 Plate I. is a typical section of the Waranga-Mallee channel as constructed between Waranga reservoir and Colbinabbin. Fig. 3 is a section of the same channel as being constructed between Piccaninny and Serpentine creeks. A segmental bed is here adopted for the following reasons. The nature of the formation does not change in the extra depth involved by the segment; there will be an advantage as compared with a flat bed in the event of small supplies being required for stock and domestic purposes; the segmental is preferred to the trapezoidal section by contractors using either steam or horse machinery, because it is easier to take material out of it as the work approaches completion.

Figs. 4 and 5 are typical sections of distributory channels. In 4 the cutting is sufficient to provide the material for embankments. In 5 it is not, therefore side-cuttings have been resorted to. The question to what extent these side-cuttings should be avoided by enlargement of the cutting between the embankments is one worthy of discussion. In the location of distributaries it is impossible to avoid all places where more material than the normal cutting furnishes is required for the embankments. In practice considerations of cost limit the distance from which material may be brought to within two or three chains.

If the enlargement between the embankments is considerable this part of the channel becomes a comparatively still pool favouring the deposit of silt. This is to some extent an advantage, but not entirely so, because the deposited silt and low velocity of the
water are conducive to aquatic growths, and by their agency the place which at first had greater sectional area than the rest of the channel might become one of constriction. As against these drawbacks, there is the fact that a channel with side cuts takes more land than one with centre cut only; that in many cases leakage, probably due to the burrowing of yabbies from the channel to the side cut, develops, with the result that the evaporating surface becomes much greater than that of the enlarged channel. While of the opinion that the uniform cross section should be adhered to as closely as considerations of cost will permit, the writer inclines to the view that if the choice lies between an enlarged cross section and side cuttings the former is preferable, provided there is no intention to line them with concrete.

As yet not much lining of channels has been done in this State elsewhere than at Mildura and Bacchus Marsh; but as the value of water increases it is to be expected that the lining of channels will be gone in for more extensively.

So far only matters related to the earthworks of channels have been dealt with. The various structures required in connection therewith are, however, equally deserving of attention. First in order of these are the head sluices placed where a main channel takes off from a storage reservoir. In nearly all cases the conditions are such that the full supply level of the storage is higher than the full supply level of the channel. As, however, it may be desirable to send a full supply along the channel when the reservoir is nearly depleted, it is necessary to provide sufficient sluice area to give the full discharge with comparatively small loss of head; thus in the case of Waranga reservoir, though top water level of the storage is 11 feet above full supply level of the outlet channel, the sluiceways are of sufficient area to deliver the full supply with heading of only three inches.

The control of such sluiceways is generally by gates moving in a vertical plane. The parts of the gates in contact with the gate seats may be plane faces of wood or metal, or arrangements of rollers may be introduced with a view to reduction of friction. The Stoney gate which is in use at the Assouan dam is the best known of the roller path gates. Descriptions of it may be found in most text books, but no gate of the type is yet in use in this State. Of plain sliding gates there are, however, numerous examples, the operation in nearly all cases being by means of screws and tooth wheel gear. The writer has known so many cases in which the power necessary to operate a sluice has been under-estimated, and has found the rules given for its computation in some text books so misleading, that some simple arithmetical computation giving results in fairly close agreement with those found by tests of actual works are here stated. As in all cases where the work to be done is mainly the overcoming of frictional resistances, much depends on the accuracy, smoothness, and state of lubrication of the parts in moving contact.
Plate II. shows one of the eight sluice gates at the main outlet of the Waranga reservoir, together with the screw and winch by which it is operated. The velocity ratio of the gate to the winch handle is 1:5238.

The weight of the gate and its attachment is... 4,618 lbs.

Taking the coefficient of friction of gunmetal on gunmetal in water as .3, the friction load on the gate with reservoir full and channel empty = area of gate ( = 45 sq. feet), x head of water above centre of pressure on gate ( = 17.5 feet), x 62.5 x .3 = 13,782 lbs.

Were the screw and tooth wheel frictionless, the power required at the winch handles would be about 3½ lbs., but taking into account the frictional work, as follows, it is found to be about 24 lbs. Assuming the gate to be raised a height equal to the pitch of the main screw, in this case 8½ in. and taking the coefficient of friction of parts such as the screw and nut, which are capable of being lubricated, though not perfectly, as .1, the total work in inch pounds is:

\[
\begin{align*}
(a) & \quad \text{Load of } 18,400 \text{ as already found } \times 3 \text{ ins.} = 11,500 \\
(b) & \quad \text{Friction between nut and screw} \quad \times 1 = 19,540 \\
(c) & \quad \text{Friction between nut and bearing} \quad \times 1 = 23,129 \\
(d) & \quad \text{Work absorbed by one pair of bevel wheels with efficiency of } 88 \text{ and two pairs of spur wheels with efficiencies of } 90 \text{ each} = (54,162 \times .88 \times .9 \times .9) - 54,169 = 21,825 \\
(e) & \quad \text{For journal friction allow} \quad (54,169 \times .88) - 54,169 = 2,851 \\
\end{align*}
\]

In doing this work the winch handle travels through 3,280 inches, the power required is thus 24 lbs.

Tests made of the actual power required at the winch handles of the flood gates of the Goulburn weir and of the Waranga gates gave results approximating to those obtained by computation. It must not, however, be understood that the power required is capable of being computed with preciseness, because results were found to vary considerably with gates of the same design to all appearance working under like conditions. In some recent examples of this type of lifting gear frictional work has been reduced by the use of steel rollers and balls for the nut bearings. If it were of importance that the expenditure of energy in the manipulation of a head sluice be minimised, as it is in the case of industrial machinery, higher efficiency would no doubt be aimed at. But generally head sluices have to be raised and lowered only once or twice a year, therefore the aim
is mainly to keep the power required down to that which one man is able to exert, and little regard is paid to the total expenditure of work.

Each of the Waranga sluice gates was built of two castings of about equal size. In arriving at the stresses to be allowed for, the gate was assumed to be a beam with span equal to the width of the opening. The pressure of water at each foot of height was taken as a uniform load, and the ribs on the back were proportioned accordingly. As far as possible the metal is protected from corrosion by casing with cement concrete. In some of the earlier reservoir works of this State the rods of sluices were not given sufficient stiffness to prevent their buckling when thrust down against the friction load on the gate. In the gate under notice a rigid cast iron column extends from the gate castings to the lower end of the lifting screw. This serves both to resist any buckling tendency and as a side guide. As a precaution against fracture of the columns a mild steel rod of sufficient size to provide for the greatest tensile stress is enclosed in each of them and protected from corrosion by the filling of the annular space with cement grout.

Sluice gates of the vertical pivot type are in use at the head of the main channel from the Goulburn weir to Waranga reservoir. These have the merit of being workable with small total expenditure of labour, but as compared with sliding gates they have the drawback that the gauging of supply is more difficult, and they cannot easily be made to close so tightly as to prevent considerable leakage.

Regulators, or checks, are structures in a channel for the purpose of maintaining the water upstream of their situations at such levels as may be desired. In some Victorian channels ordinary vertical sluiceways have been employed as regulators. The defects of this type are that a comparatively small variation in the volume of flow causes a considerable alteration in the upstream surface level. Moreover, adjustment of the gates to secure a desired level when, as is very often the case, the volume of flow is not known precisely by the operator, involves difficulty. These drawbacks are largely obviated by the use of regulators of the weir instead of the orifice type. Fig. 1 of plate III. shows the kind of regulator in use on the Western irrigation channel from the Goulburn weir. These consist of wrought iron shutters worked by means of screws from a bridge. When closed the shutters are at an angle of 45 deg. In closing the top of the shutter is lowered and the bottom is run upstream until a horizontal position is assumed. Although friction is minimised by rollers the manipulation of this type of regulator involves considerable labour, because the whole shutter, while under its water load, has to be moved, however slight the alteration of its position required. Judging by recent articles in their engineering journals the sector gate with horizontal axis is finding favour with the Americans. A good illustration of a gate of this type
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appears on p. 514 of "Engineering News" of 12th November, 1908. Although the reduction of gate friction to the comparatively small quantity required at the axle is a good feature, there remains the drawback that the whole sector has to be moved at every alteration.

In this State there has been a reversion to the simple stop plank weir for the regulation of water in channels. Fig. 2 Plate III. shows one of this type recently constructed in the Waranga-Mallee channel. Reinforced concrete is used for those parts of the structure that could not readily be renewed, for other parts timber is employed; lockers are provided for the storing of the stop planks when not in use. Besides low first cost the advantages of a stop plank as compared with a gate regulator are that no gear has to be kept lubricated, and that to make any ordinary alteration of the level of the water upstream of a structure, provided the volume of flow is constant, and that there is a clear overfall, it is only necessary to remove or add a portion of the barrage corresponding approximately in height to the alteration of height required. An operator working a regulator with stop planks each six inches high, knows that by removing one row of planks he will make an alteration of six inches in the level of the channel. With the knowledge gained by experience, and aided by tables of weir discharges, he is able to readily make any alterations that may be called for. In the past a good deal of trouble was at times experienced in getting planks out when the difference between head and tail water exceeded two or three feet; often this task required a man with a hook at each end of the plank, and unless the ends were kept in the slots, which meant overcoming frictional resistance throughout the whole lift, there was risk of the plank getting adrift. The lifting hook shown on the drawing, to a considerable extent overcomes this difficulty. In using it the wooden handle is fitted loosely into the socket of the forked hook and kept therein by tension on the rope attached to the fork. The latter is then run down the slot until the fork straddles the plank. It is then moved along the plank until it engages with the pin through the plank, the handle is drawn from the socket and laid aside, one end of the plank is pulled out of the slot by the rope and hook and the freed plank easily hauled on to the gangway. The saving in labour is due to only one end of the plank having to be drawn against frictional resistance, and that end for only a comparatively short distance.

Fig. 1 Plate IV. shows the kind of regulator, or check, and drop combined used in some of the comparatively small distributory channels recently constructed; these being generally in localities where material for concrete is costly, are made of timber. The conditions of irrigation development necessarily cause much work of this kind to be regarded as tentative, therefore it is warrantable to pay regard to low first cost as well as to assured durability.
Closely associated with regulators and checks are the outlet sluices by which water is delivered from main to distributary channels. These may be either stop plank or sluice gate structures. But whereas the overfall is preferable for regulating the surface level in the channel upstream from it, the orifice has advantages where the purpose is to maintain constancy of volume below its site. The reason for this is that though the head may vary, the sectional area of the issuing jet remains constant; whereas with an overfall, fluctuations in the main channel cause alterations of both head and sectional area of the jet.

Fig. 2 Plate IV. shows a typical outlet from a main to a distributary channel. Figure 1 Plate V. shows an outlet for the supply of water from a distributary to an irrigated field, of a kind used where precise measurement of the water is not of prime importance.

Fig. 2 Plate V. shows a type of outlet which was found to give satisfactory results where supplies of from 4 to 16 cubic feet per minute, delivered uniformly throughout a week, were in demand. It consists of a trough at the channel end of which a metal plate, pierced with an orifice of the size for the delivery of the required volume, can be fixed and locked. The portion of the plate to be submersed is painted a different colour than the upper part. The custodian can therefore see at a glance if there is the proper head above the orifice, and if there is not the plate can be rapidly adjusted. Provided there is no wide range of water level in the channel, fairly accurate measurement of small supplies can be made with this outlet; its defect is the loss of about six inches of head. The Grant-Mitchell registering meter is the approved apparatus where precise measurement of delivery from channel is desired. This meter has already been fully described in the papers of this Institute, therefore only passing reference is necessary.

In many cases irrigation areas are plain lands bounded on one side at least by mountain ranges. To command the plains the main channel line is approximately a contour located on the foot slopes. This location involves the crossing of the watercourses that drain the upland. To provide for these cross flows, so as not to risk having his work destroyed, and yet avoid undue outlay in their construction, is one of the most difficult tasks the designer of channels has to face. It is to be remembered that the channel is embanked and thus forms a barrier to the natural drainage. The Waranga-Mallee channel near Rochester is an exception as regards embanking. The flood of September, 1906, in the Campaspe Valley attained a volume of about 60,000 cubic feet per second, and spread to a width of about three miles. As no structures could be provided at practicable cost to keep such a volume out of the channel the cutting is made in ground slightly higher than full supply level, the excavated material being gathered into mounds. When such a flood recurs it will simply flow between the mounds and across the channel, and the worst to
be feared is that some silt may have to be removed from the cutting when it is over. If the floods that occur at rare intervals from abnormal rainfalls were to be provided for in all cases, the cost would be much greater than if security be obtained against ordinary heavy floods with some margin of safety. There is no question of risk of life involved, therefore a policy of allowing the abnormal flood to make a breach rather than incur heavy interest charges in the construction of works which will rarely come into operation may in certain cases be warrantable.

The crossings of water-courses of considerable size are usually effected by flumes, weirs and regulators, or inverted siphons, by which the channel flow is conveyed beneath the water-course. If the natural cross flow may exceed the volume of the channel it is usually preferable to convey the known volume of the channel beneath the water-course in one or more tubes. If head is available it may be advantageously disposed of in giving extra velocity, as compared with that of the normal channel, through the subway tubes and thus minimising their size.

Fig. 3 Plate V. shows one of several subways of this type on the Eastern Goulburn channel. These were constructed of reinforced concrete by the Reinforced Concrete and Monier Pipe Company of this State. As it was of importance that the loss of head at these structures should be minimised, all tube ends are tapered in the manner of the Venturi meter.

In some of the earlier main channels timber flumes were employed for the crossings of water-courses. At first it was considered that while local timber, particularly red gum, was suitable for framing, imported pine was necessary for the lining of the trough. Experience, however, showed that oregon pine had a life of about ten years only as flume lining. On the Goulburn to Waranga channel there is one large flume, carrying water to a depth of seven feet, in which the decayed oregon lining has been replaced with red gum, which, after ten years' service, appears to be perfectly satisfactory. The clear span of the deck planks is eight feet, the thickness thereof five inches. The joints are V shaped for a depth of about one inch from the upper side, caulked with oakum and coated with a mixture of coal tar and ground lime. Although flumes such as this may be expected to have length of life commensurate with their cost, the desire for permanence has led to a preference for concrete wherever possible.

Fig. 1 Plate VI. shows a concrete flume at the crossing of the Waranga-Mallee channel and the Cornella Creek. At this crossing it was desired to keep the channel without constriction, therefore a flume was preferred to a subway. Ordinary floods pass beneath the flume, but exceptional floods may pass both beneath and over it. Stop planks are provided in one side for the release of water into the creek, should this be desired, and to guard against the arches of the floor being subjected to undue lifting stress in the event of a flood occurring when the channel
is empty, automatic flaps are also provided, which in such a case, would allow water to flow from the creek into the channel. The novel feature of this design is that the creek bed—a firm sandy clay—after being protected from erosion beneath the structure and for some distance up and down-stream of it by a sheet of reinforced concrete six inches thick, is trusted to carry the structure and its load without excavations for footings. The compressive stress at the seats of the vertical walls is about 7,200 lbs. per square foot. Allowing that the sheet concrete distributes this over an area twice as great as that of the wall seat, the load on the clay would not exceed 3,600 per square foot.

Fig. 2 Plate VI. shows a weir crossing at the eastern branch of the Wanalta Creek. The creek flow is here allowed to enter the channel; floods are controlled by a regulator down-stream of the point of entry, and by regulation of the stop planks of the weir. Near Rochester there is a depression which, at rare intervals, carries large volumes of flood water. Where the channel crosses it hinged timber gates are provided on each side of the channel, connected across by wire ropes—see Fig. 1 Plate VII. The gates that are upstream in regard to the floods rest in a sloping position on buttresses; the opposite gates are vertical. As flood water rises against the outside of the slanting gate the internal pressure is counter-balanced and the pressure against the vertical gate causes the pair of gates to fall and leave clear way to the floods.

Apart from the structures at stream crossings, subways ranging in sectional area of waterway from seven to 24 square feet are provided to discharge the run off from the numerous small catchments intercepted by the channel embankments. Most of these subways are concrete tubes built in situ, as shown by Fig. 2 Plate VII. The method of construction is to trim the bottom of the subway excavation as neatly as possible to the shape of the exterior of the lower half of the tube, place the concrete in the bottom of the required thickness, set the curved iron plates of the centering truly to line, set and clamp the upper portion of the centering, and complete the placing of concrete.

If a number of these works have to be built it is advantageous to have sufficient centering to enable a subway to be completed before any removal thereof is necessary. The older types of subway had vertical end wells and horizontal tubes sometimes of sheet iron. The advantages of sloping the tubes up to ground level at ends are saving of the cost of wells, and facility for cleaning with wire rope and drag hooks, or scoops, if necessary. In most cases, however, the subways may be trusted to be cleaned out by the flow. An outlet valve on a subway often proves convenient for the delivery of stock supplies to adjoining lands.

Bridges across irrigation channels differ from those across natural streams in not having to withstand floods or the piling of drift wood against their piers. The piles may therefore rest on sills instead of being driven. Fig. 3 Plate VII. shows a typical bridge over a main channel. It will be observed that the deck-
IRRIGATION CHANNELS.

...ing overhangs the outer beams. This arrangement permits of better circulation of air about the ends of the decking than that by which the outer beams have the gravel beams above them, and enables the deck beams to be placed where the load has to be borne. The channel section is enlarged at bridges sufficiently to compensate for obstruction by piers.

The stresses to be provided for in channel works are, as a rule, moderate in comparison with those in other engineering structures. Water falling through a height of ten feet will not exert a pressure greater than a column of water of twice that height—say 1,250 lbs. to the square foot—on the surface it strikes. It may then be asked, how it is that extensive damage often results from water falling through moderate height? The answer is that such damage is nearly always piecemeal. In the case of a failure of a weir or regulator it may be that a leak develops round a wing, or beneath a curtain wall; or it may be that the apron protection is not carried downstream to where the water has lost its power of erosion. The result is the scouring of a hole where the apron ends, the displacement stone by stone of the masonry, and if not checked the sapping of the foundations of the structure. Such effects show the need of an effective diaphragm to cut off percolation beneath a structure, and of sufficient protection of all erodible material in its vicinity. For both of these purposes reinforced concrete, because of its durability, its adaptability to any form, and the resistance to piecemeal destruction afforded by its tenacity, is of the highest value, and there is little doubt that with the material at command some of the difficulties that have often puzzled and sometimes defeated the channel constructor in the past will be overcome.

In conclusion a few words on the possible extent of construction of irrigation works in the Murray River Basin, which is the part of Australia with which Victorian water supply engineers are most concerned. In the report of the Interstate Royal Commission of 1902 on the Murray River it is shown that in a typical mean year the discharge of the Murray at Mildura is about 8½ millions of acre feet. It is also shown that the area of land in the basin that might be profitably irrigated if water were available is about fifty millions of acres. It is not to be hastily assumed that storages could be constructed which would make available annually for irrigation any volume even approximately equal to the discharge of the river in a mean year. But having regard to the fact that the total diversion from the river and its tributaries at present is only some half million of acre feet, it would not be rash to predict that all that has yet been done towards storing and distributing the water of the Murray Basin is but a small portion of the work, which many of the members present may expect to see accomplished in their life time.
Plate 11.

HEAD SLUICES, WARANGA BASIN.
REGULATORS IN MAIN CHANNELS.
IRRIGATION CHANNELS.

Plate IV.

FIG. 1.

CHECK AND DROP IN DISTRIBUTARY.

FIG. 2.

OUTLET SLUICE, MAIN CHANNEL TO DISTRIBUTARY.
Plate V.

**Fig. 2.**

Irrigation Outlet

Sliding Orifice Outlet

Octlets.

**Fig. 3.**

Reinforced Concrete Subway

Under Water Course.
IRRIGATION CHANNELS.

Plate VI.

WARANGA-MALLEE CHANNEL.

Fig. 1.

CONCRETE FLUME OVER CORNELLA CREEK.

Fig. 2.

WEIR CROSSING EACH BRANCH WANALTA CREEK.
WARANGA-MALLEE CHANNEL.

Fig. 1.

FLOOD GATES AT 38M. 63C.

Fig. 2.

TYPICAL SUBWAY.

Fig. 3.

TYPICAL BRIDGE. PICANNINY CREEK TO SERPENTINE CREEK SECTION.
DISCUSSION—IRRIGATION CHANNELS.

DISCUSSION.

The President asked whether any statistical record had been departmentally compiled as to the temperature of the water in relation to depth of channel, the time of the year, and the surrounding temperature at the time? There was another point: there were a great many interesting matters concerning the construction of reinforced concrete tubes, could Mr. Dethridge give them the data employed by his department?

The mechanical methods of raising the larger gates had been dwelt upon in some detail. He noticed that the screw was still in use. If there was one piece of mechanism more than another which devoured power under the conditions given, it was the screw. The threads might be considered as thrust rings; there was also the friction of the nut against its abutment. The ratio of the travel of the moving surfaces to the rising of the gate would be some 34 : 1, and, with a coefficient of friction of .3 (water contact) about 10 foot lbs. of energy would be consumed for each 1ft. pound of useful work done. Had Mr. Dethridge considered the use of well-designed rack gears for his larger gates? With well-designed cut gears the loss would be reduced to one-fifth or one-sixth.

Mr. M. E. Kernot said he had been very much interested in the paper. They owed Mr. Dethridge much credit for the way in which he had placed the matter before them. They had been given a very plain and useful account of what had been done of late years. He had had in his mind the same point mentioned by the President—the screw. He recollected having taken part in the designing of large screw and worm-wheel gearing for lifting gates of the sort described, but they were very soon left on the scrap heap. He thought it possible that the rack means might be developed as the rack-jack had been developed. One advantage of the rack was that it was less liable to get out of repair through rust; when using the screw method the repair of a damaged part might mean long delay.

He had lately been connected with the converse of irrigation—the drainage of the country—and it had been very interesting. Some amateur water supply engineers in the country, owing to the experience of dry years, got the idea that they should save all the water that fell, and thought that by utilising the natural water-course they would get a very good reservoir, and very cheaply. When they found such courses they built dams and weirs across them and blocked the water, and in rainy seasons, such as the present, flooded the country.

One point that struck him was the mention of the grading of the channels. Would it not be worth while to vary the grading when going through a spur, taking advantage of that to save the cost? It was a point he thought worthy of consideration.

Mr. T. W. Fowler said he had listened with very great interest to the paper, which he thought would form a very valuable
acquisition to their Proceedings. Mr. Dethridge had placed before them a very interesting account of the work which had been done in the Victorian Water Supply Department—a work which had undoubtedly been of very great benefit to the State, and must largely increase its productiveness. He thought the details which had been presented would be of very great use to the members of the Institute generally. He for one would have much pleasure, when the paper had appeared in their Proceedings, in referring to it from time to time as he found it necessary. There were some points in connection with it in which perhaps there might be room for discussion—he would not say difference of opinion. He had always felt in connection with water channels and irrigation channels, more inclined to adopt the narrower and deeper section than what had at times been adopted by the Department. For instance, if he mistook not, the main western channel from the Goulburn was something like 110 ft. wide and 6 ft. or 7 ft. carrying depth. It seemed to him that he should like to have carefully investigated the possibility of economy and increased efficiency derivable from a somewhat narrower and deeper channel.

They had to remember that the deeper and narrower channel had the advantage of a less wetted perimeter, consequently the seepage loss would probably be less. It had also the advantage of a greater hydraulic radius, so that with the same fall the velocity would be greater. That would mean that a smaller channel, so far as actual cross section was concerned, would carry the same volume of water. It might be, however, that that might involve an excess in velocity. The alternative to that would be to lay a narrow and deep channel with a smaller grade, which naturally would mean commanding a larger area. On the other hand narrow deep channels necessarily had certain disadvantages. It necessarily meant greater depth of excavation. If they were taking material out from a greater depth, if they had to lift it to a greater height, they naturally expected to pay somewhat more, assuming the texture of the materials to be the same. And then, as Mr. Dethridge had very properly pointed out, there was the possibility that with the deeper channel they might get into a very difficult excavation. That was a point which, of course, tended to justify comparatively wide and shallow channels.

Then, again, Mr. Dethridge had pointed out the liability in certain cases with deep channels to cut through sand drifts. That, of course, was a tendency that one had to guard against; but after all it usually was not a very serious matter. He had had certain channels cut through sand drifts, and he had found that with very slight precautions they gave no trouble. In fact, the amount of sediment that might be carried down during a flood would very frequently be sufficient to silt up the spongy strata and make the channel sufficiently water tight for all practical purposes.

Another point in favour of a narrow channel was where they were going through any deep cutting: if, for instance, they had to cut through any considerable amount of excavation above the full
DISCUSSION—IRRIGATION CHANNELS.

supply level. Then naturally by having the narrow and deep channel they reduced the amount of excavation. Mr. Dethridge had indicated that in passing through spurs narrow and deep sections had been adopted. Thus the surface level remaining constant throughout, it necessarily meant that the bottom of the channel in the narrower parts was at a lower level than at other parts where the channel widened out. He would be glad to know whether any silting up had taken place in the deeper places referred to.

One other point was in connection with the gates or stops for controlling the water passing in various directions. In his own experience he had had to construct gates at the heads of channels where the ground was of a very light alluvial character, which melted very readily when subjected to the action of water. In that connection he had had a good deal of trouble at times to prevent the water getting round or under the gates.

In some of the designs Mr. Dethridge exhibited, where stops had been constructed in connection with the gates, apparently the ditch had first been excavated, the timber sheeting put in, and earth or other material rammed in round them to make a watertight joint. His own experience had been that it was preferable to disturb the soil as little as possible, and drive the sheet piling so as to have it buried to a very considerable extent. He did not know whether Mr. Dethridge had tried that.

Mr. Dethridge had referred to concrete and reinforced concrete in connection with those stops. Where concrete was available for the purpose nothing could be better. They could make the excavation and ram the concrete in tight so that it gripped firmly against the undisturbed soil; and he should think gates or stops constructed in that way would be most effective. He had listened with great pleasure to the paper, and thought it was a most valuable acquisition to their Proceedings.

The President said he had asked Mr. Dethridge a question as to temperature. He thought Mr. Fowler had that in mind also in relation to the width and depth of channels. It was a marked fact, the greater the depth the lower the temperature and the less the evaporation. It was an important factor in designing, and in certain cases would govern decision between a deep and narrow, or wide and shallow channel.

Mr. Fowler said some years ago he took a number of observations of temperatures of water—mainly salt—where the water was shallow, and where it was deep, and it was most striking to notice how high the temperature of shallow water went as compared with the deep. It must promote a very great deal of vegetation and large evaporation.

Mr. W. R. Bell said the paper was bristling with information and subjects for discussion, when members had had an opportunity to read it at leisure.
Mr. J. S. DETHRIDGE said in respect to the temperature of water, so far as practice in this State went, and so far as his reading of the design of irrigation structures went, little attention was paid to it in the design of channels. They must remember that the power to control the depth was confined almost entirely to the main channels. When they got to the tributary channels they could hardly avoid shallowness of depth. Considerations of cost confined them to three or four feet. And he did not think the two or three feet of additional depth they would get in the main channel would be a large matter in checking the evaporation loss. But to answer the question as it was put—little attention was paid to it.

Coming to the matter of the screw. In the paper he drew attention to the fact that from the point of view of conservation of energy the design was a very wasteful one indeed. The objections he gave showed the great amount of dead work which was done. But it was very safe, and the whole thing only had to be operated two or three times a year. It might be that each gate was only travelled up and down once. Therefore the actual cost was a minor matter compared with safety and getting the work done. The latest thing in gate mechanism was the hydraulic cylinder, but with oil instead of water. Cylinders of that type were being used to directly lift the valve stem on the Roosevelt dam in America. There they would, he thought, reduce the quantity of work expended to a minimum, and were a very nice piece of mechanism. But for the construction he had described it was not important to keep down the quantity of work.

Respecting the design of reinforced concrete subways, the quantity of steel employed was arrived at much on the principle that the thickness of a boiler shell was arrived at—simply the ordinary formula for arriving at the bursting pressure inside a cylinder. They did not consider the tensile strength of the concrete, they depended entirely on the steel, and had a pretty liberal factor of safety at that. The various retaining walls and bridges were abutted in the various ways that would be applicable to particular cases.

With reference to Mr. Kernot's remarks as to taking into consideration the gradients of the channels, that was one thing to which a great deal of consideration was given, when the trial survey of the country to be dealt with was made. At present they were thoroughly contouring the country before channels were laid out, so that they had a good opportunity of fixing the grades. In the large channels a slope of only six inches to the mile, with an average width of 110 ft. and depth of 7ft., with a velocity of slightly over 2ft. per second, was about the maximum they could allow in most cases. So that in the big channels the range was not very great. They kept the slope as flat as possible with the idea of commanding as much country as possible. So that most of the big channels were laid with a slope of only three to six inches per mile.
DISCUSSION—IRRIGATION CHANNELS.

The subject Mr. Fowler had touched upon, as to the relative values of shallow and wide as against narrow and deep channels, was an interesting one. He thought he had touched upon nearly all the considerations that governed the choice in that way. But when they got into a big spur and were able to construct a channel by simply throwing up a bank on one side, they could understand how very easily the channels could be constructed on the wide and shallow principle as compared with the deep and narrow.

So far they had not found the deposit of silt in the deepened parts in spurs to give trouble. If the silt were deposited it would not cause much difficulty. The velocity was if anything rather better in those parts; and if they were liable to have silt they were not likely to have more silt owing to slackness of velocity. But there was no difficulty anticipated in that direction.

In many soils the sheet pile diaphragm was used; the wooden diaphragm was put in so that the concrete filled in the trench. But they had been remarkably successful by filling the concrete in against the natural soil, and they had also been recently successful with the wooden diaphragm with the earth put in back and rammed against it. But there were parts of the State in which Mr. Fowler's method would have advantages.

If there were any points in the discussion upon which he had not touched, if it were mentioned he would be glad to reply.

The President asked, in connection with the lost work of the screw, had Mr. Dethridge in his further remarks considered that the substitution of a rack for a screw movement would, by reducing the lost work at the screw, also reduce in a still greater degree the ratio between the handle and gate velocities, say from 4,000 : 1 to 700 : 1. That would greatly simplify the gear train, otherwise necessary.

Mr. Dethridge said that was so. But if he decided to reduce the lost work ratio it would be first, by the adoption of roller paths and, secondly, by the introduction of the hydraulic cylinder. Together they would give a high efficiency.

Further discussion postponed.
On the motion of the President a hearty vote of thanks was accorded by acclamation to Mr. Hunt for the opportunity he had given members of inspecting the instrument.

At 10.30 p.m. the meeting closed.

DISCUSSION.

NOTES ON THE CONSTRUCTION OF IRRIGATION CHANNELS.

The President said the first business was the discussion of Mr. Dethridge's paper, and he thought the proper way to open that discussion would be to ask Mr. Elwood Mead, Chairman of the Victorian Rivers and Waters Commission, who was an expert of experts in the matter, and who had been given authority no other irrigation engineer in Victoria had had before, to be the first speaker.

Mr. Elwood Mead said he thought Mr. Dethridge had placed the engineering profession under an obligation by giving them the benefit of his ripe experience and judgment in the matter. With most of his conclusions he was in accord, and so had no debatable matters to bring forward. But there were one or two matters he thought he might amplify.

One of these was with reference to the measurement of water from channels. Heretofore the greater part of the water had been sold by the acres irrigated. That was objectionable, because it gave no incentive to economy and no idea as to the amount of water used. The man who paid by the acre, or by the irrigation, naturally felt that the more water he used, the better the bargain he was driving. The consequence was that he injured his land, and the irrigation system as well, by the lavishness with which he used water. When they came to measurement they found in other countries that the orifice or the weir was the usual means of measurement used. Taking the irrigation works of Italy, they would find most elaborate orifices constructed in a stone plate. But the principle was the same. In all cases the difference between the pressure on two sides of the orifice determined the discharge. In the western parts there had been in recent years a considerable use made of the weir. There the fall varied from 8ft. to 9ft., to the mile, and they had ample velocities for getting a clear discharge. The Cipoletti weir had come largely into use because its originator was one of the leading practitioners, and he introduced it on the canals he planned.

In America the same thing held true. In most parts of America there was sufficient inclination of the canal to enable
either the weir or the orifice to be used. But the weir had one disadvantage, in that the great amount of sediment in most of the streams tended to fill up the weir. The streams of the south west would fill up the space in front of the weir in 24 hours. There, too, the orifice had been largely adopted because irrigation followed mining. Almost universally the miner measured water by the inch—that was, the quantity of water that would pass through a one inch orifice under a four inch pressure above the orifice.

In Victoria they were required under the law of 1905 to sell water by measure. But they had this difficulty, that in the northern plains there was so little fall—in some cases less than 1 ft. to the mile—that it was impossible to use the weir. And it was also impossible to use the orifice without a free discharge. It became, therefore, a problem of devising a method of measuring where they could only have a difference of a few inches in the heads. They must have a device that would measure without a submerged orifice. Mr. Dethridge had, in his paper, submitted a design that was largely used in America.

They had in their work here put in a good many boxes in the past 12 months that were so built that they could utilise the Grant-Mitchell meter. He did not feel that they had reached a point yet where they could express an opinion with regard to the practical working of the meter. At present it seemed to give excellent results, and had the advantage that they could read directly from a dial the quantity of water that had passed through. It was convenient, and appeared to be quite accurate under a wide range of velocity. But it had this defect, that if an ingenious irrigator could arrange to insert a wire into it it did not work. There was no diminution in the supply of water, but there was no registration. He knew of a case in which a board had dived down a foot or two and come up the other side and got into the meter and stopped there. It was impossible to say it was not an accident, but there was no registration. Unless that could be overcome it of course presented a very serious problem with regard to the use of the meter, and that caused them to be very careful in its general adoption. They had tried it in a limited area last year, and were going to try it again on a larger scale this year. They wanted to see what the human element was going to do—as well as the gravitation element—with the water. Another difficulty was its cost. So far the expense both of the meter and of the box in which it was enveloped caused them to be particular about adopting it. They were putting in a large number of boxes for the meter, with a diaphragm in the lower part, which could be used as an orifice measurement. That, however, was one of the things about which they felt that further investigation and study was necessary, and he was bringing it before them in order to invite them to give it consideration and trial wherever they had an opportunity. The Commission intended to establish a sort of ex-
experimental plant in one of the canals this year, to test the different measuring devices to determine under local conditions those adapted to the work here.

He noticed Mr. Dethridge’s reference to the use of dredges in the excavation of channels, and while he agreed with the conclusion expressed that the making of properly shaped banks with dredges was a difficult matter, still he believed they would find it necessary to adopt dredges in the enlargement of channels. They had built in some of the older districts a large number of channels which were designed to only water a part of the ground. In time they were going to irrigate every acre of good ground. That would necessitate considerable enlargement of those channels. It would be in districts where they were already irrigating, and would have to continue irrigating, that they would have to use floating dredges. It had been done in a great many instances with considerable economy. So in that respect he thought they would see considerable dredge work done in the older districts in time.

He agreed with Mr. Dethridge’s conclusion regarding the impossibility of determining without actual trial and observation the extent of either seepage or evaporation losses. But so far as the losses by percolation were concerned they were less in all the channels east of the Loddon than in any other irrigation districts he had seen. That was because of the large preponderance of clayey soils. There was a great difference, as many of them knew, in channels built of local materials. It was necessitating the lining of some of the Mildura canals, and might lead to the lining of some of the canals at Nyah and White Cliffs. But in the channels that were supplied from the Goulburn and the greater part of those supplied by gravitation from the Murray the percolation losses were very low. The losses generally in the United States were about one-third, but that was where irrigation was compact, and not where the water had to travel three or four or five miles to irrigate one mile of land. He had not seen any measurements to determine definitely what the losses were in the Goulburn system. But in the channels supplied by pumping at Swan Hill and Cohuna last year, where there was a relatively small quantity of water, they lost two-thirds of all the water turned into the channels. They required at Swan Hill to pump 60 feet of water to cover 18 inches, and the land certainly did not receive more than 6 inches. At Cohuna they required enough water to cover the land 22 inches deep to give it one watering. That served to show the tremendous waste that was occasioned where only a small fraction of the land was irrigated. In both cases the land was only irrigated about one or two acres at a time.

He thought he had no further remarks to offer at present.

The President said he had calculated the capacities of the whole of Australia’s reservoirs—those constructed, under construction, and those probably to be constructed. He had found that they were capable of containing water sufficient to submerge
to a depth of six inches an area capable of sustaining the whole Commonwealth population, if it were as densely settled as that of England and Wales. In other words, their reservoir area was capable of giving them, over an area sufficient to support them, an annual irrigation to the extent of six inches over and above meteoric fall and river flow. The diagram exhibited pointed the lesson, which was obvious. The relation of the sufficing space for the present population in relation to the area of the continent was negligible. There was the same paucity of present population; what it might increase to in the future it was hard to say.

Although Mr. Mead was assisting to lay a sure and stable foundation, yet it was a foundation only. They were dealing more effectively at present than ever they had in the past for the population for the time being; and also were doing a little for those to come. But what should be the general engineering policy to adopt now as regarded the greater future? How far could, or should, their present population carry the weight of such a policy? What was the limitation of the total supply? In short, to what extent could they ultimately develop the continent by means of that supply? He thought they would all like to hear Mr. Mead's views.

Mr. Mead said he did not feel qualified to speak as to the Continent; but he could speak with certainty as to Victoria. The statement recently prepared by Mr. Dethridge dealing with storages that had been surveyed and about which they had accurate knowledge as to capacity and approximate knowledge as to cost made it certain that there was an ample water supply in northern Victoria to irrigate one and a half to two million acres of land. Before a start was made on construction the question of population must be considered. That was the obstacle to irrigation work to-day. He knew of no successful irrigation work anywhere where there was a population of less than fifty to the square mile. They had here nowhere more than ten to the square mile, excluding Melbourne, Bacchus Marsh and Bendigo. Most of our areas would support 350 people to the square mile.

They could make no progressive utilisation of their climatic possibilities with the present population. They had to-day on an area of 150,000 acres a population that would do for about 3000 acres. Cohuna had 25,000 acres, with an ample water supply and very fine soil. In that the Closer Settlement Board had purchased 5000 acres and settled about forty families on it. That was about one family to 100 acres, or one person to ten acres, or 60 people to the square mile. In the remainder of the district the population had increased by the private subdivision of holdings. But it required a much greater population to utilise the still water as it should be utilised. Under the Goulburn scheme, which they extended to the existing Rodney district, they had

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water enough to irrigate 150,000 acres of new land. In that district there was one estate of 26,000 acres that had not twenty people on it. Another estate of 30,000 acres had not more than two or three families at the outside.

It was hopeless to expect any development under those conditions. They needed to-day in the northern country, to utilise the water already available, fully 30,000 more people than they had. Until they got these it was of no use talking of larger reservoirs on the Goulburn or Murray. The State would be taxed with large expenditure without having any way of putting it to a practical use. The finding of population was the next step in their development. They could take any good land in the Goulburn Valley and get precisely as good a return as at Mildura. They were now getting £10 per acre there at dairying, and were doing better than that at fruit farming.

They had here simply an undeveloped and unappreciated field for the creation of an export trade in fruit. Take apples and pears, and he thought he could safely add table grapes. They not only grew them in great abundance and perfection, but they reached the purchasing countries of the northern zones at the off season—at the time when fruit commanded its highest price. And they were about the only country that was developing that trade. Africa and South America were doing nothing. So that they had the field to themselves. The ship on which he came to Victoria was largely laden with apples. It seemed to him they could load half a dozen cargoes to Canada's one, because in that frozen north there was only a very small portion that could grow fruit at all. But there was a large consuming country there. The same applied to Europe. This was a country free from the pear blight, which was the curse of the pear grower of every other country. So what they wanted was to get the population here and an appreciation of the possibilities of cultivation.

The question now was, where were they to get the 30,000 people? If they could pick them up from one part of Victoria and plant them in the irrigated area they would simply unsettle conditions in one part to improve conditions in another part. He did not believe they could do that. The people who lived outside the irrigated areas were wedded to agriculture that depended on rain. In the recent attempts at settlement nearly all the people who had gone to White Cliffs and Cohuna were men who knew something about irrigation and its possibilities. They could not develop their irrigators as rapidly as they needed to. They had already built their system beyond the supply of water users; and they had already built their cities, like Melbourne, Geelong, Ballarat, and Bendigo, beyond the supporting country. They must therefore look to other intensely populated countries for a large part of the population to fill the irrigated areas. It was not necessary that they should know much about irrigation; but it was necessary that they should know how to make the most out of the land. And it was absolutely necessary that the
man who wished to succeed at irrigation should get it out of his head that he could cultivate 1000 acres, because he could not do it. He was speaking with Mr. Cameron, the veterinary, who was thoroughly informed regarding everything that pertained to dairying, and he said that when a man undertook to intensely cultivate more than 100 acres of land he usually broke down. And that was just what he had done in the irrigated areas. They could on the two million acres of irrigable land put a great many more people than Victoria had to-day.

The President said that he had, within the past few days, seen photographs of some large Egyptian irrigation channels which were constructed of sheet steel and were wholly above the surface of the soil. He desired to ascertain the author's views as to the applicability of the system here when percolation was excessive, or when it was desired to carry the channel at hydraulic grade across depressed country.

In regard to Mr. Mead's remarks as to percolation, he would like to know what views were available in regard to the commercial limit of length in channels through permeable land. Thus, at the beginning of such a channel, unit section of land would receive the whole of unit volume of initial flow; at the end of a long channel, to receive unit volume per unit area might require many unit volumes of initial flow. Obviously the nearer sections were then carrying the expenditure incurred by the more distant. Generally, when did such apportionment become inequitable, or the irrigation of such distant sections become uncommercial?

Mr. Mead said he did not think steel construction was practicable with the price of water as it was at present. In California most of the channels that lost water were lined with a light coating of cement. In some cases it was only half an inch thick. The earth was rammed and then wet, and the cement was plastered right on. Channels 30 miles long had been in use 15 or 20 years with a thin coating of cement like that. The most economical lining would be to utilise lime mortar. That seemed to do very well at Mildura. They could not afford to use much sheet iron at the present price of water.

Mr. W. R. Bell thought Mr. Mead had touched upon the root of the whole matter—a point which could not be too often insisted on. He had taken it up almost alone at present. Irrigation could only be conducted in highly organised countries, and the root of irrigation, and strength of irrigation, was founded on a law-abiding population. Until the question of population was settled very little could be done. He had to face the same question in South Africa. It had not yet been settled, and until it was settled they could not carry out irrigation works to any great extent. In Africa they had a better climate than Victoria, but they had not the immense volume of water running in the rivers that we had, neither had they the great plains.
Mr. Dethridge's paper dealt with a great many most interesting points. The illustration given of the supply of water to the land and seepage and evaporation losses, showed that too much water was given by the farmer to his crops. This supported Mr. Mead in his insistence that water should be paid for by measurement. The effect of too much water was seen in much of the summer fruit sold in Melbourne, which was sometimes soft, watery, and tasteless, and the stones were found to be split. The only thing the engineer could do in this matter was by methods of administration to assist—and insist upon—economy on the part of the farmer. The difficulty of the farmer in getting water on the land was that he could not get it when he wanted it. The first principle to be observed in the economy of water distribution was that the water must be distributed in large units; and this was conditioned by the fact that the farmer could only water a limited area per day. Working out an example given by Mr. Dethridge, a twenty mile channel of 100 cusecs capacity would supply 10,000 acres of land. Applying this to an ideal square block of land, it would mean 87 inches of water on the land delivered at the head. The losses under these ideal conditions might mean 4\frac{1}{2} per cent. on the full supply at the intake. But he thought most irrigation engineers would agree with him that the actual losses in irrigation works were nearer 43 per cent. than 4.3 per cent. If that were the case it would mean about 40 inches actually put on the land.

In South Africa they had some difficulty in ascertaining the losses due to percolation, and as a tentative measure he aimed at getting an annual watering of 42 inches on the land, and then they calculated the losses for the conveyance of the water. The summer was the rainy season in the Transvaal, and the winter was the time when irrigation was chiefly needed. Generally speaking better results would be obtained in Victoria by cutting down the actual water put on the land to one cusec to 200 acres of land. Perhaps Mr. Dethridge could say what the result was in actual practice. It was impossible to generalise, but it might be said that the stricter the economy in the application and the less water used—provided it was skilfully applied—the better would be the results both in the aggregate harvest and in the maintenance of fertility.

The extraordinary results where irrigation existed were apt to blind them to the fact that water was no substitute for tillage. Pure water without silt impoverished the soil by leaching out the valuable salts. The best results would be obtained by the use of the least amount of water and the greatest amount of tillage and consistent manuring. But they could not irrigate successfully without a large population. The constant tillage and working of the soil took labour, and without the cheap labour of the farmer and his children they could not irrigate over a large amount of country. Only wealthy individuals here and there could do it, but that did not mean prosperity to the country.
The statement that the principal rivers carried a great deal of silt had a most important bearing on the question of design. With basin irrigation, using silty water, the land could not easily be injured by overdoses. But in a country with a decided surface slope every inch of water above what was absolutely necessary was an injury both to the growing crop and to the land. He found that generally in channels running constantly full a depth of 3 feet of clear water was hardly sufficient to keep down the growth of weeds at certain times of the year. Shallow channels were very liable to gather banks of silt, in which the weeds germinated.

He agreed with Mr. Dethridge's opinion that the proper section was a semi-ellipse. But he did not agree with Mr. Grunsky's view as to the benefit of shallow channels. He considered it was only practical considerations of cost and construction that prevented them from making the semi-ellipse a semi-circle. The first channel constructed in the Transvaal after the war was designed by him in 1902, and he adopted the semi-elliptical section with success. It was a small channel about 9 feet wide and 3 feet deep. That channel was in use to-day, and answered its purpose very well. It carried about 19 cusecs at the head and 15 at the tail. However, when all was said and done with regard to the theoretical design of channels, it was the nature of the soil, together with the means and cost of construction, that determined the section. Mr. Dethridge had pointed that out in the paper.

With regard to cutting through spurs, it had to be noted that one consideration was the loss of height occasioned by contouring round a hill. It was important to get all the height they could. As to the sections of main channels, those shown were all in flat country, where the full supply level was above the surface level of the country, and the land could be watered right up to the toe of the slope. The section between Piccaninny Creek and Serpentine Creek was an excellent example of a good hydraulic radius combined with economy of construction by scoops; but he would like to ask if it were necessary to leave such wide berms at each side. Unless there was any reason to fear disintegration or seepage at the surface, the benefits of the section would be much enhanced by suppressing as much as possible of the berm. The evil of the berm was shown in Fig. 4. It presented a great water surface for evaporation and seepage, the mean velocity was retarded by the reduction of the hydraulic radius, and the weeds that were likely to flourish would consume an enormous quantity of water.

He would like Mr. Dethridge to give them some information as to the ravages of crabs, especially as regarded the maintenance of the artificial banks above the natural surface level. In South Africa the trouble from crabs was so great that he would hesitate there to lay out a channel on side-long ground with the full supply level above the natural surface of the ground.

The question of lining channels was a very difficult one indeed, but no doubt as the necessity became very pressing a solu-
ELLiptical Channels.

Pondtown weir: Information, Townsville, 1903.

\begin{tabular}{|c|c|}
\hline
Feature & Value \\
\hline
\hline
A & 2.56 \\
B & 1.56 \\
C & 12.56 \\
\hline
\end{tabular}
tion of the problem would be found. He had tried the design of iron channels, but when they came to face the construction of iron and steel channels of any length the advantage soon disappeared. It must be remembered that the application of water to the surface of land was an imperfect method of using it for agriculture, and was accompanied by several evils. He believed in the days to come irrigation would be much more perfect and the aim of the irrigationist would be to regulate the saturation levels from channels. Mr. Mead had pointed out the evils resulting from the reckless application of the water, and it was very usual indeed to ruin a crop by applying the water at the wrong time. But when they had deep tillage, provided they had the water supply within reach of the roots, nature was alert to act in her own time and in her own way much better than the farmer could.

With regard to sluices, those by the late Mr. F. G. M. Stoney had been mentioned. He had known Mr. Stoney many years ago. The first sluice he built was in 1872. It was made with 20 feet span and 12 feet rise. He suggested first putting the closing point on the water side of the sluice, instead of on the down side. He took the percentage of the water pressure by means of a run with rollers in it. Since then they saw the perfection of design, and the improvement of the methods of laying out in the great Assouan dam gate, which was the latest of Stoney’s works, in which the closure was simply by a single metallic rod close to the face to make the sluice watertight.

The speaker illustrated the question of sluice gate construction by a number of sketches on the blackboard, some of which are reproduced in the accompanying plate.

Mr. C. P. F. Wright said with regard to the screw lifting gates of the type used on the Western Goulburn irrigation channel and the Waranga weir, the motive power was applied to the female screw or the nut. The screw was attached to the gate, and when the nuts were rotated by the gear the gate rose. The objection was that the screw, being exposed to the weather, rain and dust, it was liable to become bent or damaged. His suggestion was that the motive power should be applied to the head of the screw. On rotating the screw the gate would be raised, and when at its full extent the screw would be entirely protected from injury.

Another matter was in regard to timber. Mr. Dethridge had mentioned the very satisfactory results obtained from red gum. The timber he recommended—the Huon pine of Tasmania—was not obtained in large quantities; but it was a splendid wood. It was very easily worked, and light, 33 lbs. to the cubic foot, and the most durable wood Tasmania produced. On the basin at the head of the Hobart water supply were small screens that had been exposed, wet and dry, for eleven years. They were still as good as new. Mr. Mann, of the Melbourne University, had assured him the timber was sound after 70 years. There was a water
wheel in Tasmania of the timber in question which was, he believed, of that age. It had been largely used for shipbuilding, whilst in water it was practically indestructible. It was also very durable when used in the ground as posts. The trouble was that the timber in the more exposed parts had been to a large extent cut out. Although there was yet a great growth it was in a somewhat inaccessible position, and consequently difficult to get in large quantities. He had used it himself at the entrance to the septic tanks at Hobart. It had been in use six years, and had proved very satisfactory.

In connection with the losses in the channels, they required to know accurately the flow in the channels. That brought them back to the formula. Recent experience seemed to show that the coefficient* hitherto in use was rather too high, and at the Simla Irrigation Conference it was shown to be considerably too high.

The President said with regard to the durability of Huon pine in water it had been fully proved to have had, in authenticated cases, an effective life of over 80 years; the water wheel referred to had a verified history extending that distance back. That corroborated Mr. Wright’s statement as to the long life of the timber.

Mr. H. J. I. Bilton said he was interested in Mr. Mead’s remarks about the Grant-Mitchell meter, and in the instance he had given of the board having got through the guards and blocked the mechanism. The same sort of thing had occurred in metropolitan practice with the turbine meters. Some Chinese gardeners had adopted the principle of boring a hole in the pipe some little distance up and inserting a wire sufficiently long to engage in the turbine, with the result that there was no registration. With regard to the measuring of water through circular orifices, he had had some experience of that. He had occasion to gauge the flow of a small channel, and thought he would try circular orifices. He had a brass plate made, in which there were three sizes of orifices. He found in that case that a very little head was available to measure the discharge. If he blocked the two larger orifices and allowed the small one to run he found it was too small; on trying the large one it was found to be too large; and finally he tried the middle one. He got a head of water about one diameter above the centre of the orifice. In those low heads, where the head was less than two or three diameters, it was recognised that the coefficient of discharge was much higher than it would otherwise be. He believed it had never been determined precisely what the coefficient of discharge was under those very low heads. It struck him that if he were going to measure that stream again, instead of having one large orifice, as Mr. Dethridge used, a better result might be obtained if the plate were put horizontally in the channel and a number of similar smaller orifices put in. This might easily be

* n, in Kutter’s formula.
done if they had only about three inches head to work on. Why not have a number of one-inch orifices with a head of three inches? Then they would have three diameters, which would give a much more accurate result.

It was satisfactory to see that the use of reinforced concrete was undertaken by the Water Supply Department. There was a very interesting article on that subject recently published in "Engineering News." It was worth inquiring into. It was the case of a weir at Pittsburg, in America. The weir was built of reinforced concrete. It was 400 feet long and 40 feet high. Unfortunately they had not carried the concrete down to a good bottom. The water got underneath it and scoured a large hole under it. The strange thing was that the weir remained standing. The paper gave a description and showed the great cavity scooped out by the water under the weir. It was a very good example of the usefulness of reinforced concrete.

Mr. T. W. Fowler forwarded the following written notes:—

He had but little to add to the remarks he had made at the previous meeting. On the question of general policy he submitted that, as far as possible, for irrigation purposes all diversions in Victorian territory, north of the Dividing Range, should be westerly. In northern Victoria the well-watered portions were to the east, the more arid parts to the west. The country east of the Goulburn should be supplied from the Upper Murray, the Ovens and the Broken River, rather than from the Goulburn, the surplus waters of which would be ultimately required further west. No doubt at present the Eastern Goulburn area could more economically be supplied from the Nagambie weir, which had already been constructed, than from works not yet built on the Murray or the Ovens, but for every acre of Eastern Goulburn land permanently supplied from the Goulburn, one acre of land to the west must go without unless Murray waters were ultimately taken across the Goulburn.

He had observed a good deal of interest in the occupation bridges. The carrying of the wing walls out in line with the abutments had the merit of simplicity in construction and, in cases where a sluggish flow had to be provided for, was perfectly satisfactory. He had adopted a similar construction with four bridges across the Broken Creek some twenty-five years ago. The author had not mentioned what timber was used in the bridges, but if red gum were adopted he would prefer heavier beams or else shorter spans. The ratio of depth to breadth (two to one) no doubt was satisfactory if the beams were sawn out of large logs, but was not the most suitable if each had to be squared from a single tree. In his own practice he generally used round logs, dressed on the upper surface for the central beams and on the upper, outer and lower surfaces for outer beams.

The arrangement of planking overhanging the beams did not appeal to him. The traffic would usually pass down the centre of the bridge, and if the beams were further apart they would
come more directly under the loads. When the outer beams were
directly under the gravel beams the attachment of the hand railing
was much simpler, and in his experience was satisfactory. He
had not found decay starting through want of air circulation
there; but if this were feared the expedient adopted in Tasmania
of placing packing pieces under the gravel beams so as to give a
free circulation of air over the ends of the planking might be
adopted.

The decking 10in. x 6in. section seems unnecessarily heavy
and, indeed, objectionable. He almost invariably used a width of
6in., giving a better foothold for horses, whilst with beams
12in. wide and 5 feet centres (his usual practice) he has found
4 inches thick ample. The only place where he has found such
planking to fail was on a bridge exposed to very heavy traffic
and having excessively light beams. These always deflected
under the loads, causing excessive bending of the planking, with
of course, subsequent straightening, the result being that the
deck rapidly wore out.

The President said there were several other communications
pending; therefore, they might give Mr. Dethridge the option
of making an interim reply at the present stage, and defer the
further discussion of the paper until next meeting.

Mr. Dethridge said two or three remarks had been made in
the nature of direct questions. Mr. Bell had wondered at the
wide berms in the section of channels on the Piccaninny and Ser-
pentine Creek works. One reason was that no beaching was
employed there. Clay was very expensive, and their experience
was that with channels of that width there was very considerable
wash. So the berm was there purely to encourage the vegetable
growth, of which Mr. Bell was afraid.

Mr. Wright had drawn attention to applying the force to the
screw instead of the nut. It was assumed the screws were
not under cover. The screws he had described were all under
cover, therefore there was no risk from dust or weather. The
mechanism at Kow Swamp head works were of the nature de-
scribed by Mr. Wright. They were working well, but were a
little more difficult.

He was interested to know of the Huon pine. In cases where
submerged beams were required it might be very useful infor-
mation.

He might mention with reference to Mr. Bilton’s criticism,
that in the orifices in the illustration only one head was shown.
As a matter of fact, in the particular case in question, the Col-
ban water works, a set of heads was kept. By having four differ-
ent sizes it had answered all requirements for about 14 years,
so that in that case there seemed to be no need for change.

It was very gratifying to him that the paper had evoked dis-
cussion of such wide interest, spreading out much wider than
the subject matter of the paper—as wide as an irrigation subject
could spread; and in that respect it was satisfactory.
The President said Mr. Dethridge had opened up not one phase of the question, but the whole question. Therefore the discussion was not nearly exhausted. They did not want to close a discussion of such immediate value too abruptly; it would be continued at the next gathering.

EXHIBIT.

The President introduced Mr. Hunt, one of their Associates, the Commonwealth Meteorologist. The instrument Mr. Hunt had designed and would exhibit and describe was one to record the impulse and pressure of wind upon structures. This was one of those matters upon which in Australia they had exceedingly little local data. They were working upon data which had been calculated in other countries; but they knew very little yet of the wind velocity even in the immediate vicinity of Melbourne. Mr. Hunt's apparatus performed functions that other apparatus had not performed. He would ask Mr. Hunt to show them the machine in operation.

Mr. H. A. Hunt said the apparatus, to be understood, was an apparatus more to be looked at than described. The unit of measurement was a cubic foot. His object in asking their indulgence to show it that evening was that unless he took that opportunity it would be very difficult to show it again. It was to be placed on top of a building for exposure, and being awkward to get at, it would be almost impossible to describe it in such a situation. A cube of 1 foot measurement was adopted as a unit and receiver; it at once presented a flat surface and a body to the wind, and also provided for suction action on its lee side.

Mr. Hunt described the apparatus in detail as follows:

The Cube or Receiver is a box of light aluminium, so pivoted as to present one side constantly to the direction whence the wind is blowing.

Internal mechanism is provided to enable the wind pressure to induce linear movement of the cube. The cube is stiffened inside by two three-armed aluminium castings attached thereto by bolts. These frames are connected together by three rails made of brass tubing, which run in guide rollers, in order to keep the cube in a rigid horizontal plane. The weight of the cube and attachments, which amounts altogether to about five pounds, is supported by two of the rollers, pivoted on uprights at either end of a revolving table; and to prevent the cube swinging sideways two other pulleys, set horizontally, are so placed under the table as to barely touch the inside edge of the two bottom connecting rails of the cube.

To allow the cube to move freely with changes in the direction of the wind, the table carrying the cube is fixed upon a sleeve, which revolves around a stationary upright tube inside it; and works on ball bearings fixed at its inside extremities. A brass
procedure, in relation to the accuracy required, it is equally applicable to gas thermometry, which then becomes as simple in application as any other system, whilst special advantages, and the potentiality of accomplishing high-class work, are retained.

The paper was illustrated by demonstration of the construction, calibration, and use of a typical instrument. An annular gas vessel was used, and in this was placed about 5 lbs. of water at 65°. The immersion of the point of the finger in the liquid for a few seconds caused a variation of about ¼ inch in the gauge readings.

DISCUSSIONS.

NOTES ON THE CONSTRUCTION OF IRRIGATION CHANNELS.

Mr. J. T. N. Anderson communicated by letter the following contribution:

The expression of appreciation for the generosity of the author in so unreservedly laying open the methods he adopts in his great department is now fittingly shaped in a frank and candid criticism.

The author rightly foreshadows the greatness of the future of irrigation in this country. It is impossible to overrate the importance of the work in which he is engaged. To say that the prosperity of the half-million people living on Victorian agriculture depends on its success is to completely understatement the facts. Indirectly all Australia's future development will be moulded on what is now being done here. With such issues all minor points such as the best type of sluice become important, but at the outset such questions must be subordinated to questions of more vital import.

The first important question raised is the proper section of water channel. It is known to all engineers that for open channels the semi-circular invert is the most economical. Apart from working out its mathematical advantages (maximum area for minimum border) the other practical considerations of minimum exposed surface, least friction and consequently flattest gradient and consequently highest level at which the areas to be served can be reached, and maximum depth, all are in its favour. Of course where the channels must be of unlined earthwork this section cannot be obtained.

The author has pointed out that the segmental invert is simple in construction, and has the advantage of being easier to retain than the cruder form of section with level invert and plane sloping sides. Of this latter, as he says, the half-hexagon is the best. But the fact must not be lost sight of that this is due to its approximation to the half circle. So far as the hexagon is nearer to a circle than a square, or a pentagon, the hexagon section is more fitting. But compared with the octagon or regular figure of greater number of sides, obviously the hexagon is best suitable.
However, it were better to put aside all such plane figure sections and adopt without reserve the segmental section which the author, in common with modern practice, prefers.

In many things one is struck by the heavy loss which this country has sustained by the narrow and illiberal manner in which the various Governments have in the past treated their engineers. The late Professor Kernot used to say that every chief engineer ought to make a trip round the world every five years—and certainly the leading engineers in London and New York, though they are far less isolated than we are, lose no opportunity of informing themselves by travel of what is being done by their contemporaries. In regard to the formulae of Mr. Grunsky, a Californian hydraulic engineer, who has collected many valuable statistics, instead of looking on the similarity in the sections of the channels as they are carried out here with those formulae, as proof that the practice here is the best, it was merely a proof that our conditions are similar to the conditions which prevail in Western America.

There are conditions of extravagance—expensive water, and results that are only possible while the country is still partially populated—but conditions which must inevitably be displaced in time. Had the author taken for comparison the sections of channels being made in Egypt to-day, he would have a different result.

In this question of shallow channel the author seems to think that because the water when it reaches the minor distributories will be shallow and hot, and encounter many losses, that therefore the question of temperature in the main channels is of no importance. Here, evidently, there is some confusion. The two things are entirely separate. It may or may not be important to make distributories so that they will use the water with the least possible loss from evaporation and percolation, but that has little to do with the design of the main channel. So far as the main channel is concerned the chief economy in distributories is effected if it can enable the distributories to get the water as rapidly as possible, so that each distributory need not remain in use any longer than is absolutely necessary.

The losses the author quotes at $\frac{1}{10}$ foot per ft. area of wetted border (page 5 of the paper) certainly seem very high and do not justify complaisance in what has so far been achieved.

After the question of best channel section, perhaps the next important question is the design for syphons and water-crossings. Reinforced concrete construction is being, here as elsewhere, largely used in this. But here less skill is noticeable in taking advantage of the points of this method of construction.

For instance, take the subways, Plate V. Fig. 3. Here the reinforcement is placed in the centre of the ring, and therefore can add nothing to the strength, and consequently the ring contains as much concrete material as if it had no steel reinforcement.

The celebrated syphons under the river Pišia on the Cavour Canal could have been followed with advantage here, and the
elliptic section with the use of reinforced concrete would have been stronger, and far cheaper than the circular sections used. It is to be hoped that in relying so much on reinforced concrete aprons, and economising the multiplicity of checks or guards at weirs and such like places the reliance may be justified by results. Here and there a “cut out” is likely to occur, but perhaps it will be cheaper to repair than it would be to go to the full expense in the first instance. Personally from his own experience, the writer is inclined to treat our Victorian soils with very great respect, and give them as much protection against erosion as any of those in India. The immense proportion of soluble soda which many of them contain make them most dangerous, melting on the slightest provocation, as though they were sugar. There is little time now to deal with the constructional details. Sluices have already been criticised. The usual rack and pinion, with a double pawl arrangement, seems the most suitable for small wooden sluices. For larger sluices, ever since the writer can remember, the British practice has been to use the hydraulic cylinder, somewhat similar to that used by the Melbourne and Metropolitan Board here. Latterly, during the past twenty years, the roller type has come, both for open and closed sluices.

Another minor constructional matter. The type of stop plank advocated has the lifting studs projecting. This does not commend itself as a good innovation. All that is claimed for these stop planks can be got with the usual form where the lifting stud is reached by a recess in the thickness of the plank. The usual 4 x 3 in. plank is not too heavy, and gives ample thickness for this. Such planks are best made of beech wood, but of Australian woods, the writer has found jarrah to answer well. The advantage of the recessed form, without external projections, will be appreciated by those who have to manipulate the stop planks. The projections on the type used by the Department are a terrible nuisance, because they are always catching on weeds, and the matted stuff which accumulates on the top plank, and then, too, when they are stored aside, they do not lie well together.

In conclusion, one detail suggests itself as having, on more than one occasion, led to wash out behind timber wings, namely, the method adopted of using wooden fillets, with tarred felt to cover the joints. It would seem to be safer to follow the shipping practice, and have joints caulked, and examined and recaulked at regular intervals.

The President called upon Mr. Dethridge to reply.

Mr. J. S. DETHRIDGE said he did not desire to add to his interim reply made at the last meeting.

As to the subways shown in Fig. 3, plate V., and referred to in Mr. Anderson's communication. He did not think he could have correctly understood the remarks to the effect that the reinforcement could add nothing to the strength of the structure because placed in the middle of the concrete. Theoretically there
might be some minor advantage in placing it elsewhere; but in practice the method adopted had been found satisfactory.

The President exhibited lantern view illustrations of the steel irrigation channels referred to by him at the preceding meeting.

Slides prepared by Mr. A. S. Kenyon in illustration of Victorian irrigation practice were exhibited on the screen, and were explained (in the absence of Mr. Kenyon) by Mr. Dethridge.

**LIST OF LANTERN VIEWS ILLUSTRATING VICTORIAN IRRIGATION PRACTICE**

1. Casey’s Weir, Broken River.
2. Off-take from Casey’s Weir.
4. Goulburn Weir, Western Channel.
5. Goulburn Weir, Western Channel Regulator.
7. Coliban Scheme, Gauging Weir near Malmsbury.
8. Coliban Scheme, Inlet No.1, Tunnel under Railway between Malmsbury and Taradale.
9. Coliban Scheme, Outlet Tunnel, Branch Channel to Expedition Pass Reservoir, Castlemaine.
10. Coliban Channel, Ferguson’s Flume on Bendigo Branch.
12. Head-works, Cudgel Creek on Murrumbidgee River to supply Yanko, Narrandera, etc.
15. Mildura—Nicholl’s Point.
17. Mildura—70ft. Channel, lined.
18. Wyuna Farm—Irrigating.
19. Wyuna Farm—Irrigating Fruit Trees.
21. Scooping at Birchip-Sea Lake Channel.
22. Preparing Land for Irrigation, by Buck Scraper.
23. Using the Buck Scraper.

Discussion closed.

**PITOT TUBES, AND THEIR USE IN MEASURING THE VELOCITIES OF WATER, GAS AND AIR.**

The President said a discussion on Mr. Bilton’s paper would be no light undertaking. The communication would, however, have considerable value for reference purposes. In the title, Mr. Bilton had referred to “Gas and Air.” He could not find that that application had been specifically dealt with in the body of the paper. Naturally, as an hydraulic expert, Mr. Bilton had given prominence to the question of water flow. Of course the principle was the same for all classes of fluid flow, and there was no great difference in the application if the air velocities were relatively high, such as the discharge from a pressure fan.

He had, however, found that there were very considerable difficulties in dealing with air, or gas, velocities of from ten feet down to a few inches per second. He had been brought into contact with such problems and had found the Pitot tube