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THE UNIVERSITY OF NEW SOUTH WALES

WATER RESEARCH LABORATORY

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Cooling Water Screen Chamber

Wangi Power Station

by

C. R. Dudgeon

MAY, 1960

The University of New South Wales

WATER RESEARCH LABORATORY

HYDRAULIC MODEL INVESTIGATION

of

COOLING WATER SCREEN CHAMBER AND T-JUNCTION IN NO.2 CONDUIT

WANGI POWER STATION, N.S.W.

by

C.R. Dudgeon

Project No. E.C. 1.1

Final Report to the Electricity Commission of New South Wales

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PREFACE

This study forms part of a series of hydraulic investigations undertaken by the Water Research Laboratory of the University of New South Wales at the request of the Electricity Commission of New South Wales. The study was commenced on 10th April 1959. On 4th June 1959, revised drawings were received from the Commission and reconstruction of portions of the model was undertaken. The study was completed on 8th September 1959.

Throughout the course of the study, close liaison was maintained with the Electricity Commission through an engineer on the staff of the Commission's Project Development Section, Mr. B.H. Keogh, whose co-operation in the supply of all necessary data is gratefully acknowledged. Internal progress reports of test results were forwarded to the Commission as experimental data became available.

The study was carried out at the Water Research Laboratory, Manly Vale, N.S.W. by Mr. C.R. Dudgeon. The Electricity Commission programme is under the direct supervision of Mr. D.N. Foster of the Laboratory Research staff.

H.R. Vallentine
Assoc. Professor of Civil Engineering
Officer in Charge of the Water Research Laboratory.

9th May 1960.

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SUMMARY

Additional cooling water for Wangi Power Station is to be drawn from Lake Macquarie through a new tunnel leading into a screen chamber, thence to be distributed to existing and future generating units of the station.

Tests were carried out on a model of the screen chamber and the junction between the proposed new and existing intake systems to check flow conditions through these structures.

The tests showed that, for the design flows, water was not distributed evenly to the screens and that the dividing walls in the screen chamber produced undesirable effects.

On the basis of modifications tested in the model, recommendations were made to alter the side walls of the entrance bay, the dividing walls within the screen chamber and the entrances to the screens.

Head losses through the screen structure were measured for various blockage conditions and found to be reduced by the modifications made to the screen entrances.

The behaviour of flow through the T-junction between the existing and proposed new intake systems was found to be satisfactory for all flow combinations proposed by the Commission.

1. INTRODUCTION

1.1 The Prototype

In order to supply additional cooling water to the generating units already constructed and to new units proposed for Wangi Power Station on Lake Macquarie, New South Wales, a tunnel 13 ft wide x 12 ft 6 in high is being driven through the hill separating the power station from Lake Macquarie. Water will be led from the lake through this tunnel into a screen chamber containing four self-cleaning rotating drum-type screens, 27 ft in diameter, and thence into two channels, one connecting with the existing intake system at a T-junction, and the other leading to a proposed new unit.

Part of the T-junction was built during the construction of the existing intake system and the shape of the connection of the proposed new intake to the junction has been controlled by this existing construction.

Fig. 1 shows the layout of the screen chamber and inlet conduits, and the main dimensional details which were used in construction of the model.

1.2 Purpose of Model Studies

Model studies were undertaken so that the conditions of flow in the tunnel transition, the screen chamber and outlet, and the T-junction between the existing and proposed new intake systems could be checked.

The main problems envisaged were:-

(i) Separation of the flow from the walls of the transition and the resultant vorticity of the flow.

(ii) The formation of disturbances in the screen chamber or T-junction that might be carried downstream to, and affect the operation of the axial flow cooling water pumps.

(iii) Unsatisfactory distribution of flow to the four screens in the chamber.

In addition, it was hoped to be able to make head loss measurements in the model so that these losses might be reduced by suitable modifications to the screen structure.

2. THE MODEL

2.1 Scale Ratios and Model Validity

2.11. Four model screens, of the same type as those to be installed at Wangi Power Station, were available from a model of the Tallawarra cooling water pump intakes previously constructed in the laboratory. With respect to the 27 ft diameter prototype screens to be used at Wangi, the scale ratio of these screens was 1: 19.5. Calculations showed that if both vertical and horizontal scales were fixed at this value flow depths and velocities would be sufficiently large to ensure the validity of comparisons to be made between model and prototype flow conditions.

A linear scale of 1: 19.5 was therefore adopted.

2.12. Since the dominant force controlling the free surface flow in both model and prototype would be that of gravity, the remaining model ratios were fixed by making Froude numbers in the prototype and model equal.

Ratios thus obtained are:-

Length Ratio $\frac{L_m}{L_p} = \frac{1}{19.5}$

Discharge Ratio $\frac{Q_m}{Q_p} = \frac{1}{1,680}$

Velocity Ratio $\frac{V_m}{V_p} = \frac{1}{4.42}$

Time Ratio $\frac{T_m}{T_p} = \frac{1}{4.42}$

Design inflows of 880, 730 and 400 cfs were thus represented by model inflows of 0.52, 0.44 and 0.24 cfs respectively.

2.13. The minimum value of the Reynolds Number in the model was calculated to be approximately 6,000. This value corresponded to an effective flow depth of 6 inches and inflow of 0.44 cfs. Turbulent flow in the model was thus assured.

2.14. Inflow to the model was measured, with a 3.40 inch diameter orifice in a 4-inch diameter pipe, to an accuracy of ± 2 per cent. Discharges over the outflow control weirs were also set by use of this meter.

2.2 Construction

2.21 General. Because of the proximity of the T-junction to the screen chamber, it was decided to construct and operate the models of both sections together as one unit. This simplified the provision of inlets and outlets to the models and thus saved construction costs.

2.22 Tunnel, Inflow Baffle and Transition Section. The tunnel and transition section were built as one unit of timber and plywood, provision being made for screwing this unit to the screen chamber.

In the initial design of the prototype tunnel, a horse-shoe cross-section was used. When the model was almost completed, the design was altered by the Electricity Commission in favour of a rectangular section and the model was modified accordingly. All tests were conducted using this latter section.

A flow straightening baffle made from perforated plywood and plastic tubes was incorporated into the tunnel at the inlet end. During preliminary testing, it was found that this baffle was not fully effective. An increase in length of the tunnel and the addition of a layer of gravel to the baffle yielded a satisfactory arrangement.

2.23 Screen Chamber. The screen chamber was built of plywood on timber framing with a perspex section in the wall of the channel opposite the downstream faces of the screens to allow flow out of the screens to be observed visually. Provision was made to vary the positions of the internal dividing walls as might be found necessary. Details of the screen chamber are shown in Fig. 1.

The screens were made of galvanised sheet steel, brass rod and wire with 20 mesh, 32 gauge brass wire gauze representing approximately to scale the prototype screen mesh. Provision was made to drive the screens at speeds corresponding to the range of 6-12 fps peripheral speed specified for the prototype screens. An electric motor with a cord and pulley system was used for the screen drive.

2.24 Outlet Channels. All channels leading from the model were built of plywood on timber framing. Some of these will be roofed over in the prototype and provision was made for perspex roofs to be installed over the model channels at points where full-bore flow might occur. In the prototype, the soffit of the section of No.2 conduit already constructed is lower than that proposed for the new section to be joined to it at the T-junction. A sloping section of the roof is to join the two soffit levels.

2.25 T-Junction between Existing and Proposed New Intake Systems. The T-junction was built of plywood on timber framing in such a manner that it could be bolted directly onto the appropriate outlet channel leading from the screen chamber.

Details of the T-junction are shown in Fig. 1.

2.26 Assembly of the Model. The complete model was assembled on steel and timber trestles 3 ft. above floor level to allow free overfall from outflow control weirs installed at the end of each outlet conduit.

2.27 Water Supply; Inflow and Outflow Measurement and Level Control. Water was drawn from the Manly Vale reservoir and metered by a 3.4 in. diameter standard orifice plate in a 4 in. diameter pipe. A water manometer was used to measure head differentials produced by this meter.

Adjustable-height, sharp-crested weirs were placed at each outlet from the model to control the proportion of flow each received, in accordance with four inflow and outflow combinations proposed by the Commission for the prototype. These weirs were also used to control the water levels in the channel just downstream from the screens to values calculated by the Commission for each flow combination.

Water levels in the model were measured in perspex stilling boxes connected by 1/4" O.D. tubing to 1/4" O.D. copper tube tappings set flush with the model floor. The stilling boxes were fixed to the outside of the model and point gauges with a limit of reading of 0.01 in. were mounted above them.

3. TEST PROCEDURE

3.1 Inflow - Outflow Combinations

Fig. 2 shows the four combinations of inflow and outflow which are likely to occur in the operation of the prototype cooling water intakes. These combinations were simulated in the model during testing. The results listed in this report all refer to one or other of these cases and they are specified by the reference numbers given in Fig. 2. Flow conditions for inflows and outflows lower than those shown in Fig. 2 were observed at various times during the testing of the model.

Most of the testing of the screen chamber was carried out for cases 1 and 2 shown in Fig. 2 as these represented the maximum respective inflows for a complete installation of four screens and a partial installation consisting of only the right hand three screens. The Commission considered it probable that only these three screens would be installed during the first stage of construction, the remaining screen being installed later when No.7 unit was constructed.

Case 3 was checked only visually to confirm that flow conditions were smoother than for the corresponding maximum inflow of case 2.

Case 4 was not proposed by the Commission until most of the testing had been completed and an inflow from the branch of the T-junction leading to the No.1 intake system had to be provided to allow this condition to be tested. A separate pump and orifice meter were used to provide this supply.

3.2 Establishing Flow Combinations and Levels in the Model

Setting up a particular flow combination entailed:-

(a) setting inflow to the correct value by adjusting a regulating valve installed downstream from the orifice meter, until the head difference produced by the orifice was equal to a pre-determined value.

(b) Adjusting the outflow weirs until flow was correctly proportioned between the three outlets, and the water level in the channel immediately downstream from the screens was equal to a calculated value supplied by the Commission. The levels for each flow combination are shown in Fig. 2.

4. TESTING AND RESULTS

4.1 Screen Chamber

4.11 Velocity Distribution in Model Inlet Tunnel. During preliminary testing it was visually observed that each screen did not pass the same amount of water. Two main factors seemed to be involved, namely:-

(a) The jet of water emerging from the tunnel separated from the walls of the transition and concentrated the flow mainly on the bulkhead openings to the centre pair of screens.

(b) The resistance to flow through each screen differed from that of the others because of the different lengths and configurations of the flow paths to the various screens. These factors also varied with different inflow-outflow combinations.

So far as the first factor was concerned, it was important to ensure that the distribution of velocities in the inlet tunnel just upstream of the transition represented the distribution which would occur in the relatively long prototype tunnel. It was decided to check this by making a special cranked current meter rod that would enable a miniature Ott screw-type current meter with a $\frac{1}{2}$-inch (approx.) diameter screw to be inserted into the tunnel to allow velocity traverses to be made. Velocities were measured in a cross-section 5 feet (prototype) upstream of the junction of the tunnel and sloping roof of the transition.

A plot of the velocity distribution showed that the jet from the pipe supplying water to the tunnel pierced the inlet baffle and affected the distribution. Only after doubling the length of the model tunnel and incorporating a gravel blanket into the baffle was a satisfactory velocity distribution obtained. Fig. 3 shows this distribution which existed during all subsequent tests on the model.

4.12 Effect of Screen Rotation. It was found during the early tests on the model that the very slow rotation of the screens had no measurable effect on the distribution of flow to the screens. Dyes injected into the flow were used to compare conditions with the screens moving and stationary.

Because the front faces of the screens had to be kept clear of the entrance walls to prevent fouling during rotation, a gap existed between the face of the screen and the entrance wall through which water could pass without having to travel through the screen. The gap found necessary to ensure unobstructed rotation was equivalent to a prototype gap of approximately 4 inches. As the prototype edge is sealed by a rubber ring, it was decided to leave the screens stationary during tests so that they could be pressed hard up against the entrance wall. It was considered desirable to do this to prevent the possibility of variations in gap width from screen to screen or from test to test affecting relative resistances to flow through the screens.

4.13 Measurement of Flow Through Screens

4.131 Use of Current Meter. The miniature Ott current meter available was used to measure all velocities quoted in this report. In general, a $\frac{1}{2}$" diameter screw was used to enable measurements to be made as close as possible to walls, but at times a more sensitive 2-inch diameter screw was used to measure lower velocities where space allowed. All velocities were measured as the means over 30 second periods.

4.132 Measurements Downstream from Screens. An attempt was made to measure flow through each screen by taking velocity traverses across the rectangular openings between dividing walls downstream from the screens. It was found that at some points the velocities were too low to be measured with the current meter and at other points backflow existed. Backflow measurements would not be accurate because the meter is rated only for forward velocities and there was not sufficient room to allow the direction of the meter to be reversed.

The measurements were not reliable enough to allow the calculation of accurate discharges through each screen.

Fig. 4 shows the trial velocity measurements made in the downstream openings for a flow of 880 cfs. Using the velocities shown, the following calculations were made:-

Screen Bay No.		Discharge (cfs)
1		180
2		276
3		331
4		289
	Total Discharge	1,076

Error in Total = 23 per cent

4.133 Measurements Upstream of Screens. Velocity measurements upstream of the screens were made in sections across the flow in the positions of the bulkheads. The velocities at other cross sections were too low to be measured at all but a few points.

Figs. 5a, b, c; 6a, b, c show the velocities measured upstream of the screens for inflows of 880 and 730 cfs and three configurations of dividing walls. Because velocity measurements could not be made sufficiently close to the walls and because at many points velocities were too low to be measured by the meter, no calculations of flow through each screen were made. However, the velocities indicate the parts of the cross-section where flow is concentrated and show which screens pass more flow than others.

4.134 Flow Patterns. To supplement the velocity measurements, use was made of dyes and sawdust injected into the water to show flow paths in the screen chamber. In addition, the rate at which dye cleared from the various screen bays showed which screens were passing more flow than others. These observations agreed with the velocity measurements. The degree of circulation in each bay was shown up particularly well by the use of dyes and sawdust.

4.14 Effect of Dividing Walls on Flow through Screens

4.141 Tests with Various Configurations of Dividing Walls. It became obvious during early tests on the model that the system of screen bay dividing walls envisaged in the original design adversely affected flow to the screens. It was found that the jet of water emerging from the tunnel tended to concentrate on the openings to the centre pair of screens, allowing little flow to pass to the outer screens.

Tests were carried out with this wall layout and two modifications involving alterations to the wall lengths to determine whether the problem described above could be overcome by alterations to the dividing walls. It was thought that it might be possible to divert part of the jet from the tunnel towards the outer screens. Wall configurations tested were:-

(i) Original design - all walls commencing at junction of transition and screen chamber.

(ii) Design as modified by the Commission, the centre wall being extended to support the roof of the transition. (See Fig.1).

(iii) Modification proposed by the Laboratory with centre wall as in the original design and two outer walls extended into the transition as far as the centre wall was extended in case (ii).

For these three cases, velocities were measured in cross sections at the positions of the proposed bulkheads at the junction of the transition and screen chamber for inflows of 880 and 730 cfs. These velocities are shown on Figs. 5a,b,c and 6a,b,c. As mentioned previously difficulties of measurement prevented accurate calculations of discharge being made from these velocities.

A study of the velocity plots shows that the dividing wall configurations tested did not produce uniform distribution of the flow. The tests described, and other observations made with the walls held in intermediate positions, led to the conclusion that adjustment of dividing wall positions would generally bring about an improvement of flow distribution for one inflow-outflow combination and make conditions worse for another combination. This applied particularly to the 880 cfs and 730 cfs inflows because in one case 4 screens were operating and in the other, only 3. For example, Figs. 5a,b,c show that extension of the outer walls improved flow distribution for the 880 cfs inflow with 4 screens operating while Figs. 6a,b,c show that for the flow of 730 cfs with 3 screens operating and the same wall configuration, flow distribution was adversely affected. In the latter case, flow from the left hand side of the tunnel across the upstream end of the left hand dividing wall towards the right hand side of the screen chamber interferes with flow entering Bay No.2. Along both walls of this bay, velocities were reduced to very low values. The use of dye injected simultaneously into the flow at the entrance to each bay also indicated the relative flows in each bay. The photograph in Fig 7a shows dye lying in the relatively still water of Bay 2 after the flow through Bays 3 and 4 had removed all the dye from them.

4.142 Tests with Dividing Walls Removed. As a result of the abovementioned tests, attempts to adjust flow distribution by altering the dividing walls in the transition were abandoned.

To allow flow patterns in the absence of dividing walls to be determined, all dividing walls from the transition to the upstream face of the screen structure were removed. Sawdust and dyes injected into the flow for the 880 and 730 cfs inflow conditions then enabled flow patterns to be observed.

These patterns, shown in Fig. 8, illustrate the effect of separation of the flow from the divergent walls of the transition and screen chamber. The circulations set up were very pronounced. Fig 8 also shows how cross flow in front of the screens helps distribute more water to the screens which are remote from the main flow path from the tunnel. This cross flow is prevented when dividing walls are in position.

4.143 Possible Solutions of Flow Distribution Problem. The following methods of making discharges through the screens more nearly equal were considered:-

(i) Modifications to the lengths and positions of dividing walls, particularly near the transition section. This method was abandoned, as mentioned previously, because of the inability to obtain a solution for more than one flow combination at a time.

(ii) Increase in the length of the screen chamber and transition. This was ruled out on the grounds of cost as it would entail extensive excavations into the hill towards Lake Macquarie as well as an increase in the cost of the structure itself.

(iii) Removal of all dividing walls upstream of the screens to form a large entrance bay from which water would be drawn into the screens through modified screen entrances into which bulkheads could be fitted to isolate the screens when necessary. This would make the screen chamber much more flexible from a hydraulic viewpoint.

4.144 Tests with Modified Screen Chamber. On the basis of the observations made without the dividing walls, the following modifications were made to the screen chamber.

(i) All dividing walls upstream of the screens were removed.

(ii) Modified screen entrances were designed.

(iii) The outer walls of the entrance bay were moved inwards to decrease the angle of divergence and reduce the area occupied by the large eddies and, at the same time, fit in with the modified screen entrance design.

These modifications are shown on Fig 9.

In modifying the entrance bay and screen entrances the following points were borne in mind.

(i) Cross flow should be allowed to give more flow to the outer screens and assist re-distribution of the flow in the event of screen blockage.

(ii) Rectangular openings, sufficiently narrow to allow the installation of bulkheads, should be maintained in front of each screen.

(iii) Screen entrance walls should be designed to provide maximum streamlining to reduce head losses.

(iv) The angle of divergence of the outer walls of the entrance should be made as small as possible to reduce separation and eddying.

(v) Provision should be made to support the roof of the entrance bay on columns in the absence of the long dividing walls.

(vi) The modifications should suit all the inflow - outflow conditions as far as possible. Particular importance was placed on the 880 and 730 cfs inflows.

Tests on the model indicated that the distribution of flow was considerably improved for both the 730 and 880 cfs inflows after the modifications had been made.

Because the rectangular openings to the screens were wider than the original openings between dividing walls at the transition, and because the flow was now more evenly distributed it was found that velocities were too low to be measured by current meter. Observation of the passage of dyes and sawdust through the screen chamber had to be relied on for an assessment of the degree of improvement obtained.

Initially, the pier between the centre pair of screen entrances was made in the shape of a triangle with the apex pointing upstream. However, for the 730 cfs inflow with No 2 screen blocked, it was found that water passing from left to right past the pointed pier set up disturbances in the flow at the entrance to No.3 screen.

A semi-circular pier was substituted for the triangular pier and an improvement in flow past the pier was observed. This pier also had the effect of breaking up the jet issuing from the tunnel and forcing water towards the outer screens. For maximum inflow (880 cfs) the water level at the nose of the pier built up approximately 6 in. above the general level in the entrance bay because of the action of the jet from the tunnel.

The 400 cfs inflow-outflow combination shown in Fig 2 was tested in the model and flow conditions were found to be satisfactory.

4.15 Head Losses Through Screens

To allow measurements of head loss through the screen chamber to be made, 1/4 in. O.D. copper tube tappings were inserted flush with the model floor on the centre line of the chamber at the downstream end of the tunnel transition and at the intersection of the chamber centre line and the centre line of the lateral channel downstream of the screens. All head loss figures quoted in this report refer to head losses between these two points.

The aims of measuring head losses were:-

(i) To assess the effects of altering the screen entrances.

(ii) To allow the effect of various screen blockage combinations to be studied.

Tests were carried out for the inflows of 880 and 730 cfs with the original design of screen chamber with all dividing walls removed and then with the modified screen chamber and screen entrances.

The former case was chosen as a reference as it would give the head losses with the original design of screen entrances without the effect of the dividing walls being introduced.

Screens were blocked, when required, by completely sealing the entrances with plywood. Partial blockage of screens was not attempted because of the difficulty and time involved in assessing the per cent blockage of the screens.

Results of the tests are shown in Fig 10. They indicate that a substantial reduction of head loss was achieved when the modified screen entrances were used. Inspection of the effect of blocking different screens confirms that each screen does not pass the same flow, even with the modified screen chamber. However, it is clear that, with the modified chamber, flow is re-distributed more efficiently in the event of one or more screens becoming blocked as the increase in head loss is less than for the corresponding case with the original screen entrances.

It is to be noted that the above tests were made to check the effect of the new screen entrances and that the effect of the dividing walls in the original screen chamber design was not studied.

Results would have shown even greater differences between original and modified screen chamber losses had the dividing walls been retained during the tests on the original screen chamber.

No quantitative predictions can be made from the model head loss results without considering scale effects introduced by the Reynolds Numbers not being equal in the model and prototype. The head loss may be divided into two parts, namely, that due primarily to form losses in the free surface flow through the screen structure and that due to losses across the actual screen mesh. The former would be reproduced accurately in the model, but the latter would not necessarily be reproduced accurately as the Reynolds Numbers for flow through the model and prototype screen mesh were not equal. However, it was deduced that, for the velocities concerned, the loss through the screen mesh was not the major part of the total loss since modifications to the shape of the screen entrances were found to halve the original head losses in some instances. It was concluded that head losses to be expected in the prototype would not be greatly different from the prototype equivalents listed in Fig 10.

With these reservations, the following head losses might be expected using the modified screen chamber design.

TABLE I

Prototype Equivalents of Model Head Losses

Blockage Conditions	Head Loss (inches)
Inflow 730 cfs, 3 screens installed	
All screens clear	Less than 1
Screens Nos. 2 or 4 blocked	" " 3
Screen No.3 "	" " 5
Inflow 880 cfs, 4 screens installed	
All screens clear	" " 1
Screens Nos. 1, 2, 3 or 4 blocked	" " 2

4.16 Provision of Bulkheads Downstream from Screens

After the tests on the modified screen entrances had been completed, the Commission decided to provide bulkheads on the downstream side of the screens to allow any screen to be completely isolated if necessary. Because the downstream openings from the screens were wide (approx. 27 ft.), intermediate piers were necessary to support the bulkheads. In addition, to allow a clearance between the bulkheads and the downstream faces of the screens, the walls dividing the screen bays had to be extended further downstream until the clear distance between the ends of these walls and the face of the wall of the lateral channel was 16 ft.

The model was modified in accordance with these requirements and the design flows were run through it. It was found that flow conditions in the screen chamber and outlet channels remained satisfactory.

4.17 <u>Flow in Channel towards No.7 Unit</u>

Flow occurs in this channel only for the 880 cfs inflow condition. It was found that for this flow, with both the modified and unmodified screen chamber designs, conditions in the channel were completely satisfactory.

The effect of the provision of piers and extensions of the dividing walls downstream of the screens, referred to in paragraph 4.16, on the flow to No 7 unit was studied. It was found that for the design flow of 480 cfs to No.7 unit (880 cfs total inflow), flow was still satisfactory, but if the flow was increased beyond this figure, eddies were formed at the left hand side of the outlet from Screen Bay No 1. These eddies were caused by the sharp change in direction of water flowing from No 2 screen as it approached the left hand wall of the channel to No 7 unit.

If it were required to increase the capacity of this channel to more than 480 cfs, it would be desirable to move the channel further to the left and provide a curved entrance. Such modifications would need to be tested in the model.

4.18 <u>Flow in Channel towards T-Junction</u>

Under all test conditions, flow in the channel leading to the T-junction was found to be satisfactory. The effect of reducing the radius of the curved wall at the entrance to this channel to fit in with the modifications required for the provision of downstream bulkheads, referred to in paragraph 4.16, was tested and found to remain satisfactory.

<u>4.2 T-Junction</u>

4.21 <u>General</u>

The flow combinations tested are those shown in Fig 2. The behaviour of flow at the junction is described in the following sections and was satisfactory under all conditions.

4.22 Eddy Formation

It was found that some minor circulations were set up in the flow in the vicinity of the T-junction but that these decayed rapidly in the section of No 2 conduit leading to the pumps. No eddies were apparent downstream of a point approximately 75 ft from the junction. The majority of the eddies were started by separation of the flow at the downstream end of the existing bulkhead pier. Eddies were most obvious for the maximum flow condition of 730 cfs.

Tests in the model showed that the eddies could be almost completely eliminated by removing the bulkhead pier. A circular pier substituted for the diamond-shaped pier caused the eddies to become more pronounced.

4.23 Wave Formation

Waves formed at the T-junction under maximum flow conditions had an amplitude of approximately 6 in. and were damped quickly in the channel downstream of the junction.

4.24 Water Levels at Junction

From information available as to probable inflows, head losses and lake levels, it appears that, for conditions of high flow with a high level in Lake Macquarie, or of low flow (e.g. of the order of 400 cfs) with normal or high lake levels, No 2 conduit will run full, while for high inflows and normal lake levels the conduit will run as an open channel. There will be intermediate cases when the flow will be in some transition stage.

Observations of flow when the water surface was brought up to and lowered from a perspex roof fitted to part of the conduit gave no indication that difficulties would arise in these transition stages. Air trapped under the roof was released at the downstream end of the roofed section. The 6 in. high waves present in the T-junction had no adverse effect on the flow.

5. CONCLUSIONS

5.1 Screen Chamber

Tests in the model have shown that the original design of screen chamber would not yield a satisfactory distribution of flow to the screens. Adjustment of the lengths and positions of the screen bay dividing walls was found to improve the flow distribution but would not give a solution covering all inflow-outflow combinations.

A modified design featuring a large open entrance bay with short dividing walls, less divergent side walls and more streamlined screen entrances was tested and found to give satisfactory flow conditions.

These modifications did not produce equal flow through each screen but the proportions were more nearly equal than those found to occur for the original design.

Head losses through the modified screen structure were also lower.

The large entrance bay improved the re-distribution of flow in the event of one or more screens becoming blocked and the increase in head loss under these circumstances was less than for the original design.

It is to be noted that most of the floating and suspended foreign matter carried by the prototype flow from Lake Macquarie will tend to follow the paths of higher velocity. This means that any screen passing more than an equal share of the flow will tend to block first with a consequent drop in flow, increase in head loss through it and subsequent increase of flow to the other screens. The lack of uniform distribution is thus self-remedying to some extent in the event of a heavy influx of foreign matter such as weeds and jelly fish. With the modified screen chamber, the re-distribution of flow occurs without excessive increase in head loss.

The modifications tested, if adopted for the prototype, should result in a saving in the cost of floor and walls and an increase in the cost of screen entrances.

Should it be decided to provide a roof over the entrance bay, as in the original design, some system of supporting columns might be required in place of the original dividing walls. Piers of circular section, placed in the entrance bay had no significant effect on flow conditions in the model.

5.2 Outlet Conduits

Flow conditions in all conduits leading from the screen chamber were found to be satisfactory for all inflow-outflow combinations.

5.3 T-Junction

The T-junction operated satisfactorily for the specified flows. Only slight eddy formation occurred and tests have shown that this could be prevented by removing the existing bulkhead pier in the junction if desired. This is not essential from a hydraulic viewpoint because the eddies formed were found to decay before travelling far from the junction, and should not affect the pumps. Wave action in the junction is not serious.

It should be noted, however, that for flows higher than those tested both wave and eddy formation became serious. Any increase in the design flows could lead to air entrainment troubles.

6. RECOMMENDATIONS

1. It is recommended that the modifications shown in Fig 9 be incorporated into the final design of the screen chamber.

These modifications entail:-

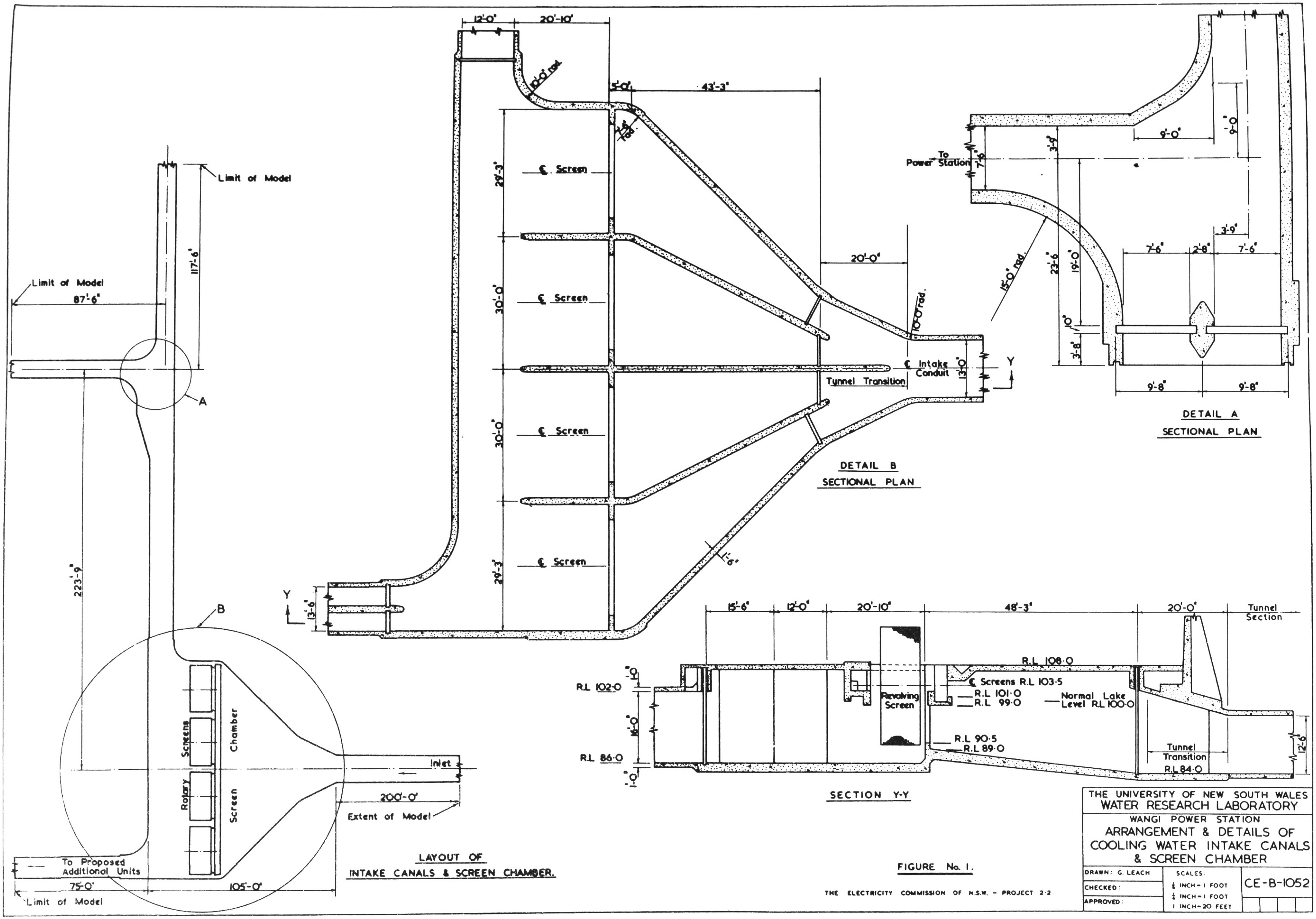
(i) Removal of dividing walls in the entrance bay.

(ii) Modification of the screen entrances and the provision of short walls to support bulkheads.

(iii) Re-alignment of the outer walls of the entrance bay to reduce the angle of divergence.

2. In all other respects, the screen chamber, conduits and T-junction may be constructed as originally designed.

Proposals by the Commission to modify the screen bay dividing walls downstream from the screens and provide intermediate piers to support bulkheads may be included in the design without ill effect.


LAYOUT OF INTAKE CANALS & SCREEN CHAMBER.
Limit of Model
87'-6"
117'-6"
A
B
223'-9"
Rotary Screens
Screen Chamber
Inlet
200'-0"
Extent of Model
To Proposed Additional Units
75'-0"
105'-0"
DETAIL B
SECTIONAL PLAN
12'-0"
20'-10"
10'-0" rad.
5'-0"
43'-3"
20'-0"
10'-0" rad.
℄ Screen
29'-3"
30'-0"
℄ Intake Conduit
13'-0"
13'-6"
Tunnel Transition
1'-6"
Y
DETAIL A
SECTIONAL PLAN
To Power Station
7'-6"
3'-9"
9'-0"
15'-0" rad.
23'-6"
19'-0"
7'-6"
2'-8"
3'-9"
10"
3'-8"
9'-8"
SECTION Y-Y
15'-6"
12'-0"
20'-10"
48'-3"
20'-0"
Tunnel Section
R.L 108·0
℄ Screens R.L 103·5
R.L 101·0
R.L 99·0
Normal Lake Level R.L 100·0
R.L 102·0
R.L 86·0
R.L 90·5
R.L 89·0
R.L 84·0
Revolving Screen
Tunnel Transition
16'-0"
12'-6"
1'-0"
FIGURE No. 1.
THE ELECTRICITY COMMISSION OF N.S.W. – PROJECT 2·2
THE UNIVERSITY OF NEW SOUTH WALES
WATER RESEARCH LABORATORY
WANGI POWER STATION
ARRANGEMENT & DETAILS OF COOLING WATER INTAKE CANALS & SCREEN CHAMBER
DRAWN: G. LEACH
CHECKED:
APPROVED:
SCALES:
¼ INCH = 1 FOOT
⅛ INCH = 1 FOOT
1 INCH = 20 FEET
CE-B-1052

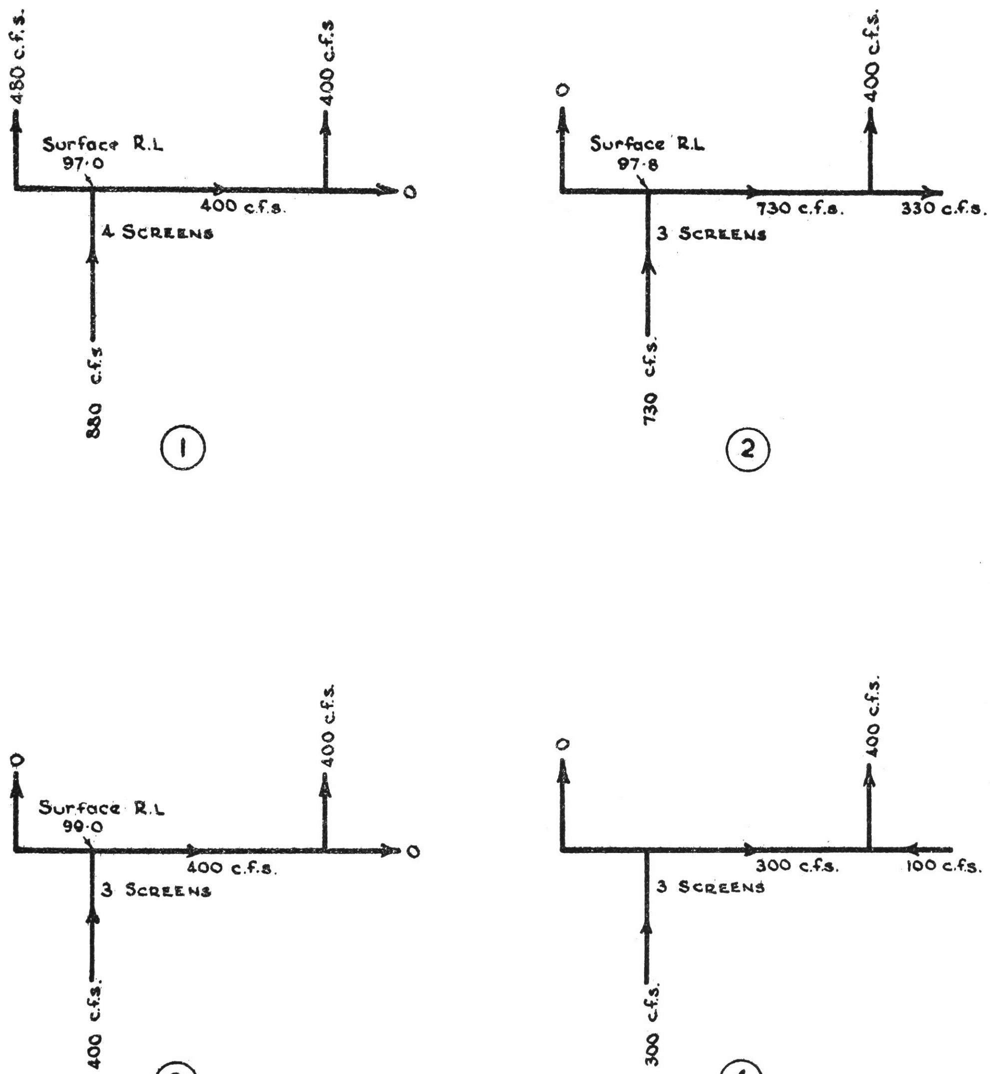


FIGURE No. 2.

THE UNIVERSITY OF NEW SOUTH WALES
WATER RESEARCH LABORATORY

The Electricity Commission of N.S.W. Project 1·1 Wangi Power Station INFLOW-OUTFLOW COMBINATIONS FOR No.2. COOLING WATER INTAKE SYSTEM	Scale: Drawn: C. Dudgeon Traced: P.A. Checked:	Date: 11·4·60 CE-Q-1065

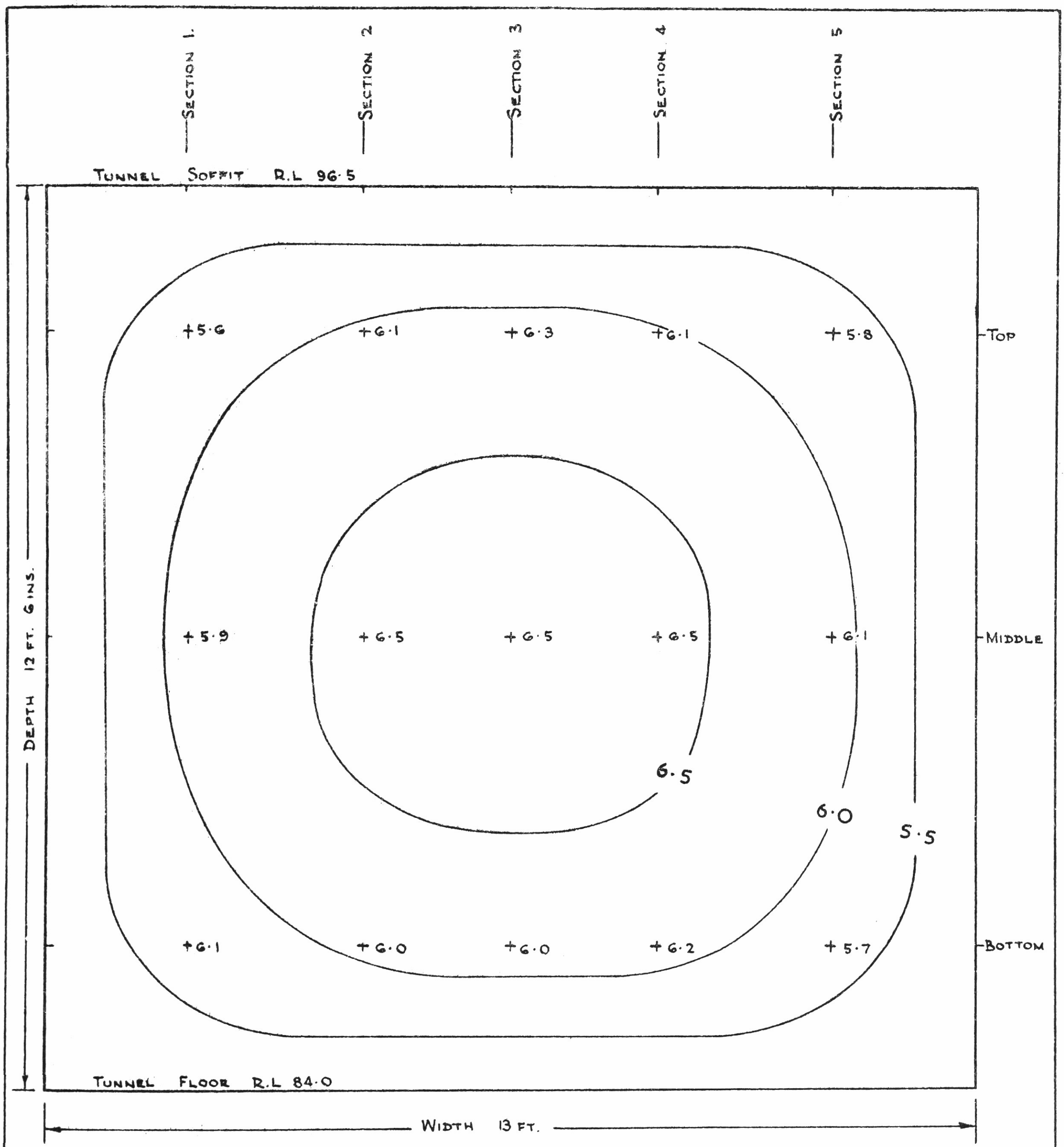


FIGURE No. 3.

Cross Section 5ft. U/S from Transition
showing Distribution of Velocities (Prototype Equivalent - ft/sec)
in Final Modified Model Tunnel

Discharge 880 cusecs

THE UNIVERSITY OF NEW SOUTH WALES

WATER RESEARCH LABORATORY

The Electricity Commission of N.S.W. Project 1·1	Scale:	Date: 25·2·60
Wangi Power Station	Drawn: C. Dudgeon	CE-E-743
VELOCITY DISTRIBUTION INLET TUNNEL	Traced: P.A.	
	Checked:	

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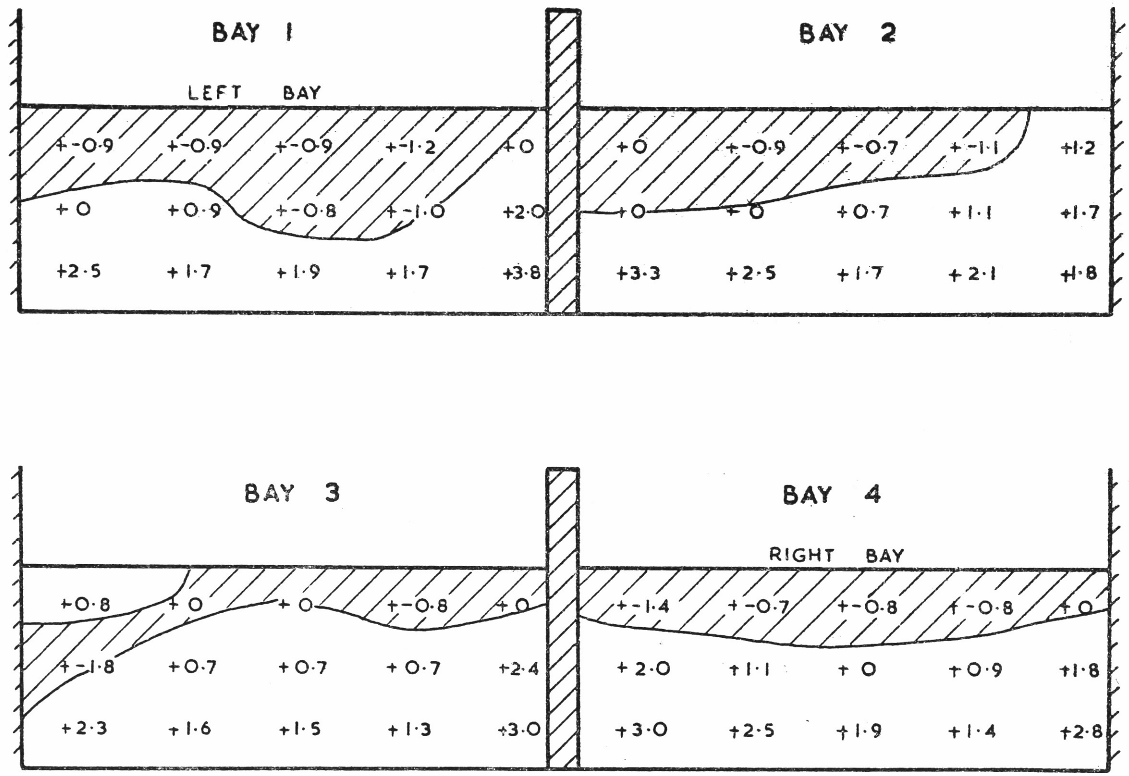
WATER RESEARCH LABORATORY

The Electricity Commission of N.S.W Project 1.1
WANGI POWER STATION

VELOCITY PATTERNS IN
C.W SCREEN CHAMBERS

Scale:	Date: 31.5.60
Drawn: C. Dudgeon	CE-Q-2000
Traced: P.A.	
Checked:	

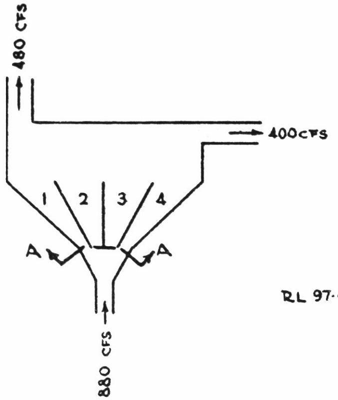
FIGURE No. 4.



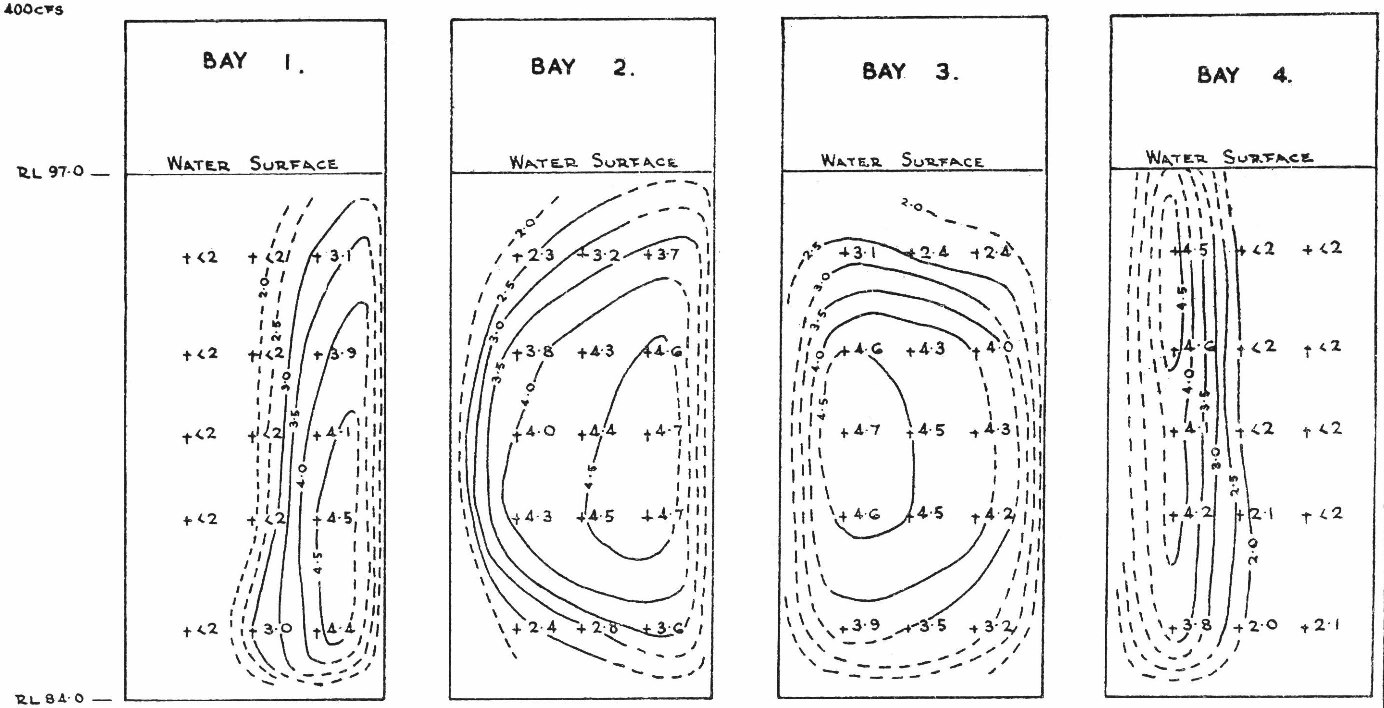
VELOCITIES APPROX. 2 FEET D/S FROM SCREENS

Discharge 880 cusecs

FIGURES REPRESENT PROTOTYPE VELOCITIES IN FT/SEC
NEGATIVE VALUES INDICATE REVERSE FLOW (SHADED AREA)



INFLOW - OUTFLOW DATA



FIGURES REPRESENT PROTOTYPE VELOCITIES IN FT/SEC.

FIG. 5a.

VELOCITIES IN CROSS SECTIONS A-A AT POSITIONS OF BULKHEADS

AT U/S ENDS OF SCREEN BAYS

INFLOW 880 CUSECS

ALL DIVIDING WALLS COMMENCING AT BULKHEADS

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Water Research Laboratory

Wangi Power Station

VELOCITY PATTERNS IN

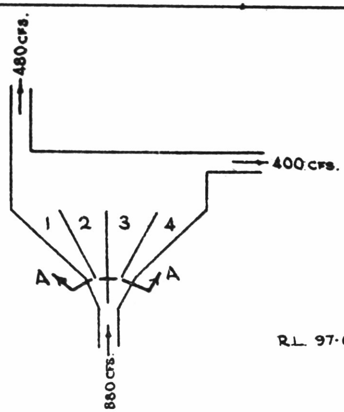
C.W SCREEN CHAMBERS

Electricity Commission of N.S.W Project 1·1

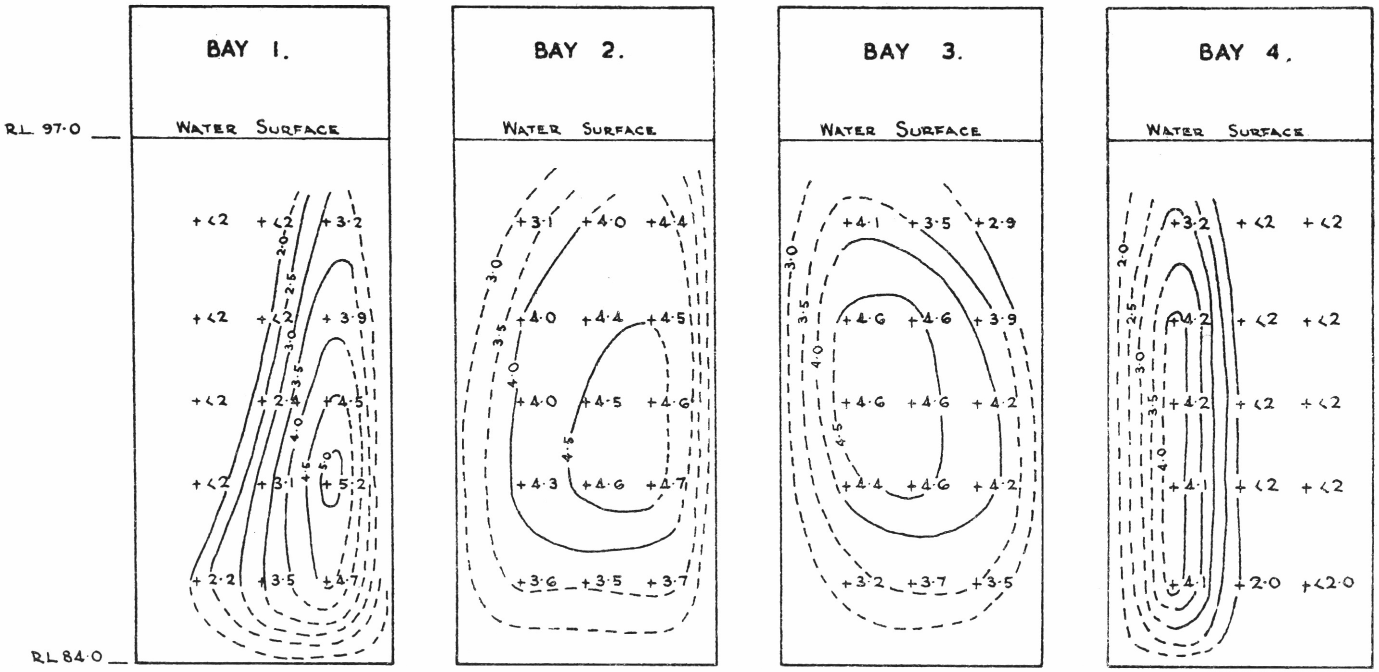
Drawn:

Checked:

CE - E - 616



INFLOW - OUTFLOW DATA



FIGURES REPRESENT PROTOTYPE VELOCITIES IN FT/SEC.

FIG. 5 b.

VELOCITIES IN CROSS SECTIONS AA AT POSITIONS OF BULKHEADS AT U/S ENDS OF SCREEN BAYS

INFLOW 880 CUSECS

CENTRE DIVIDING WALL EXTENDED

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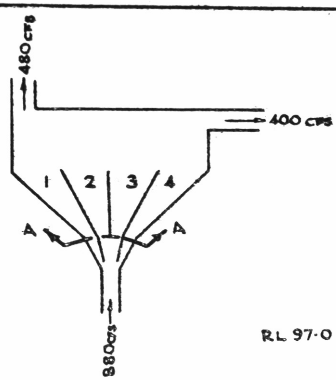
VELOCITY PATTERNS IN C.W SCREEN CHAMBERS

Electricity Commission of N.S.W Project 1.1

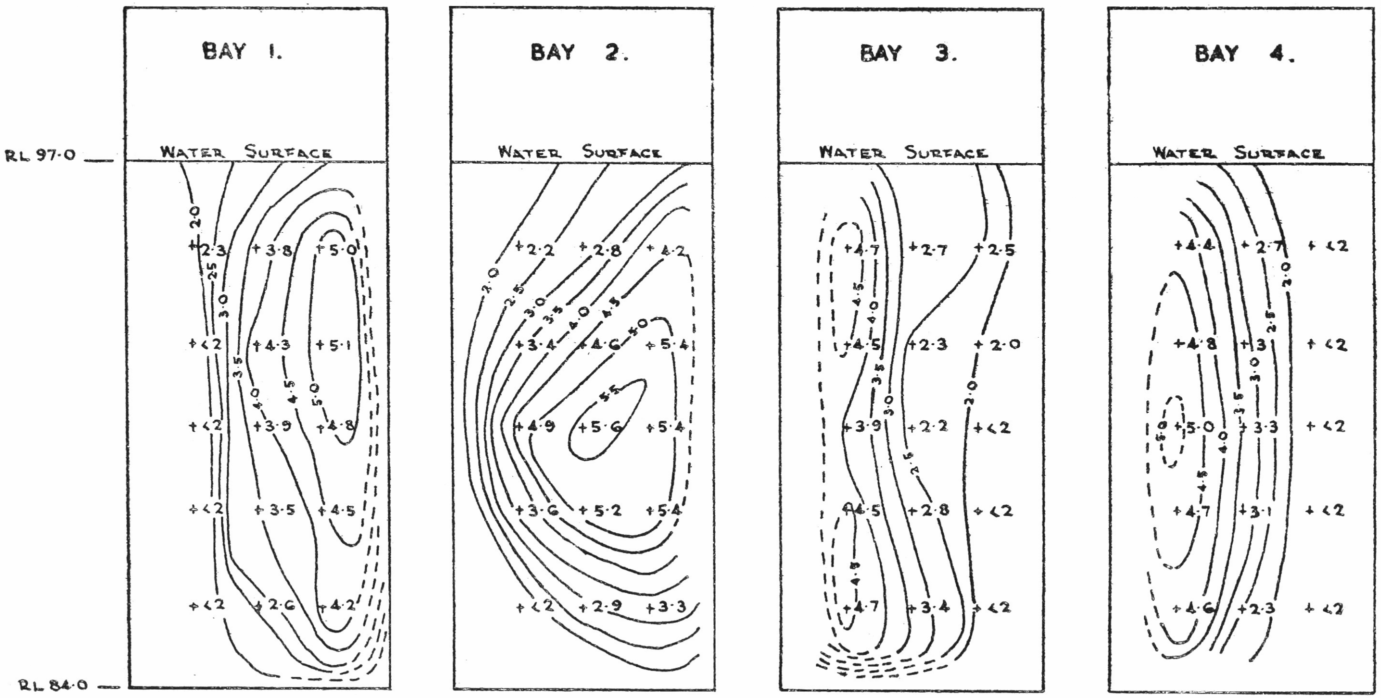
Drawn:

Checked:

CE - E - 617



INFLOW-OUTFLOW DATA



FIGURES REPRESENT PROTOTYPE VELOCITIES IN FT/SEC.

FIG. 5c.

VELOCITIES IN CROSS SECTIONS A-A AT POSITIONS OF BULKHEADS

AT U/S ENDS OF SCREEN BAYS

INFLOW 880 CUSECS

ALL DIVIDING WALLS COMMENCING AT BULKHEADS

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Water Research Laboratory

Wangi Power Station

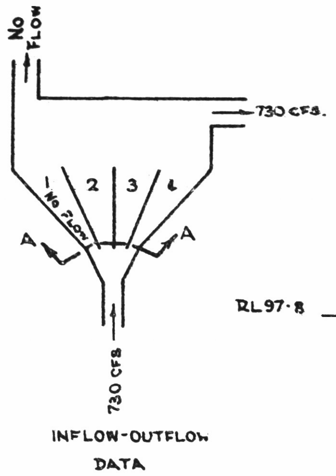
VELOCITY PATTERNS IN C.W SCREEN CHAMBERS

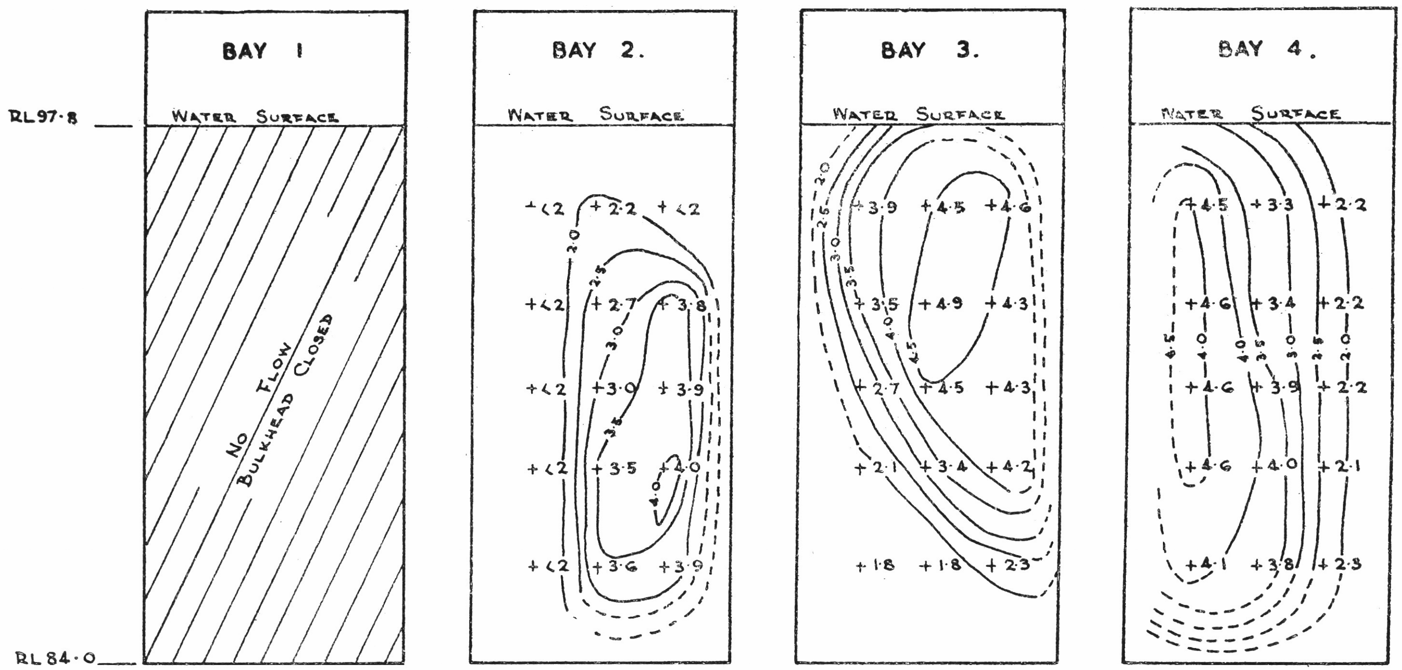
Electricity Commission of NSW Project 1·1

Drawn:

Checked:

CE-E-618





FIGURES REPRESENT PROTOTYPE VELOCITIES IN FT/SEC.

FIG. 6a.

VELOCITIES IN CROSS SECTIONS A-A AT POSITIONS OF BULKHEADS AT U/S ENDS OF SCREEN BAYS

INFLOW 730 CUSECS

ALL DIVIDING WALLS COMMENCING AT BULKHEADS

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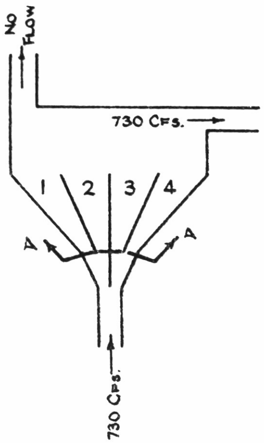
Wangi Power Station
VELOCITY PATTERNS IN
C.W SCREEN CHAMBERS

Electricity Commission of N.S.W Project 1.1

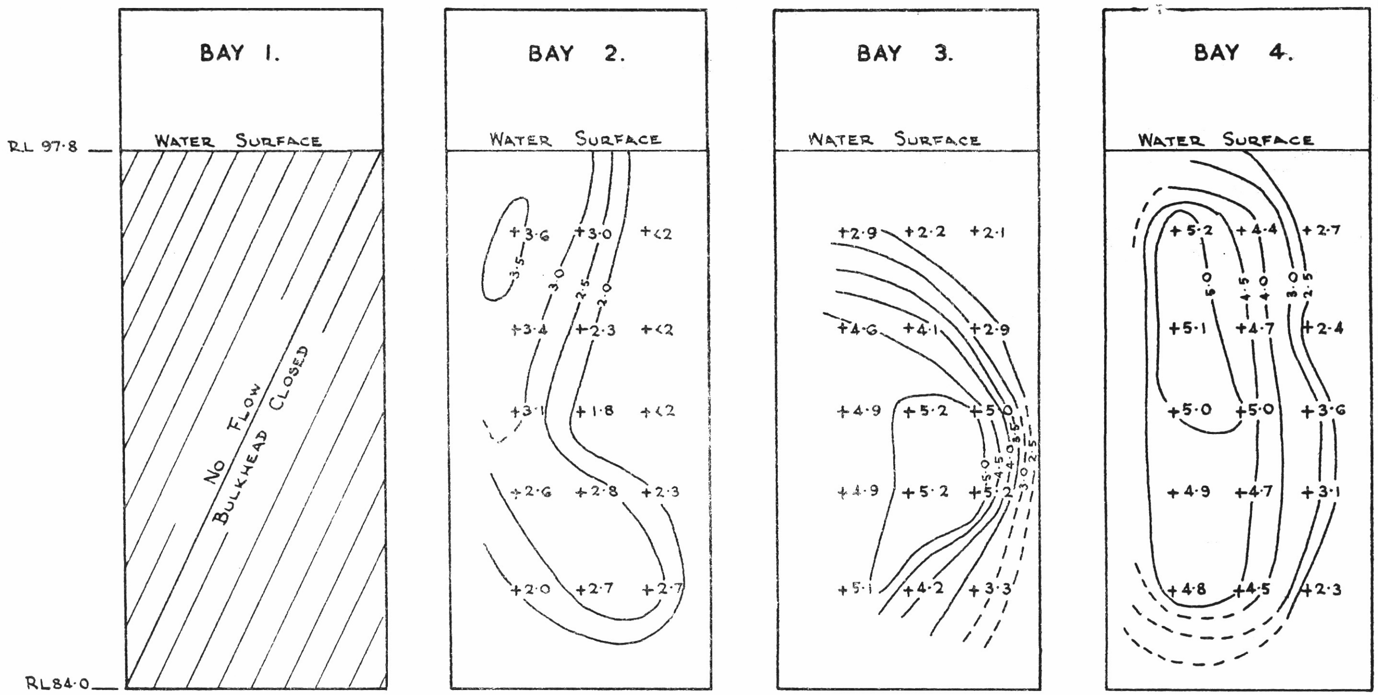
Drawn:

Checked:

CE-E-619



INFLOW - OUTFLOW DATA



Figures Represent Prototype Velocities in ft/sec.

FIG. 6 b.

Velocities in Cross Sections A-A at Positions of Bulkheads
at U/S ends of Screen Bays
Inflow 730 cusecs
Centre Dividing Wall Extended

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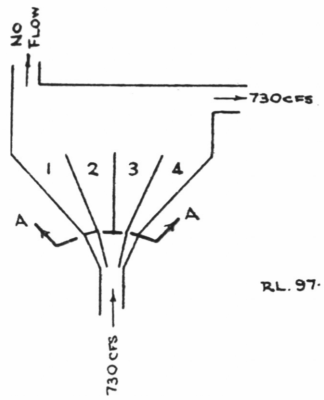
Wangi Power Station
VELOCITY PATTERNS IN C.W SCREEN CHAMBERS

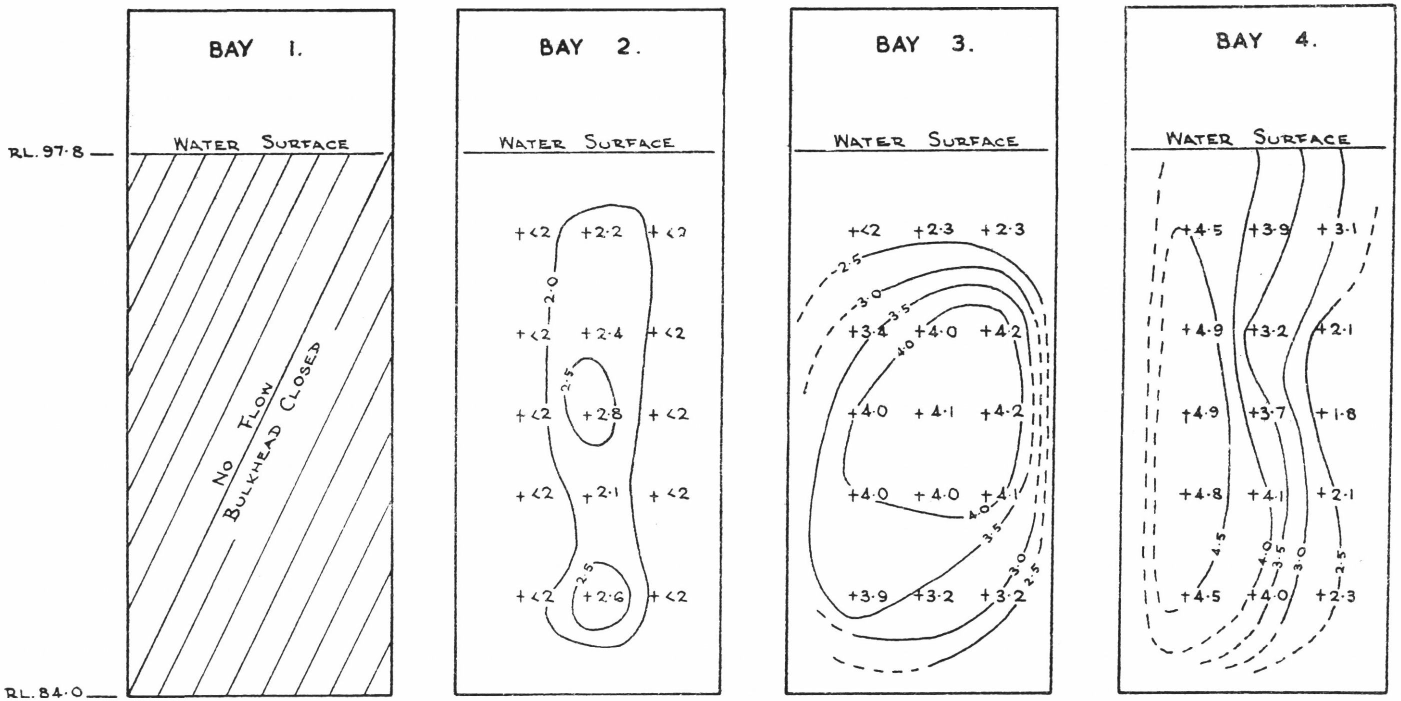
Electricity Commission of N.S.W Project 1.1

Drawn:
Checked:

CE-E-620



INFLOW - OUTFLOW DATA



Figures Represent Prototype Velocities in ft/sec.

FIG. 6c.

Velocities in Cross Sections A-A at Positions of Bulkheads
at U/S ends of Screen Bays
Inflow 730 cusecs
Two Outer Dividing Walls Extended

THE UNIVERSITY OF NEW SOUTH WALES
Water Research Laboratory

Wangi Power Station
VELOCITY PATTERNS IN
C.W SCREEN CHAMBERS

Electricity Commission of N.S.W Project 1·1

Drawn:
Checked:

CE - E - 621

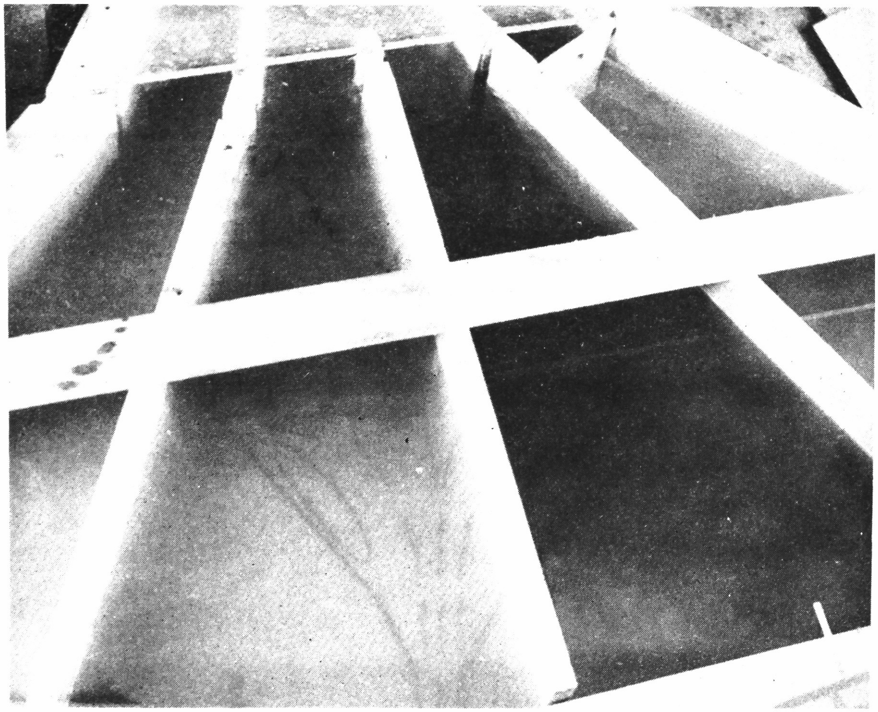


FIG. 7a

Injection of dyes simultaneously into screen bays reveals low flow through No. 2 screen as indicated by dye lying in screen bay No. 2.
Inflow 730 c.f.s., two outer dividing walls extended.

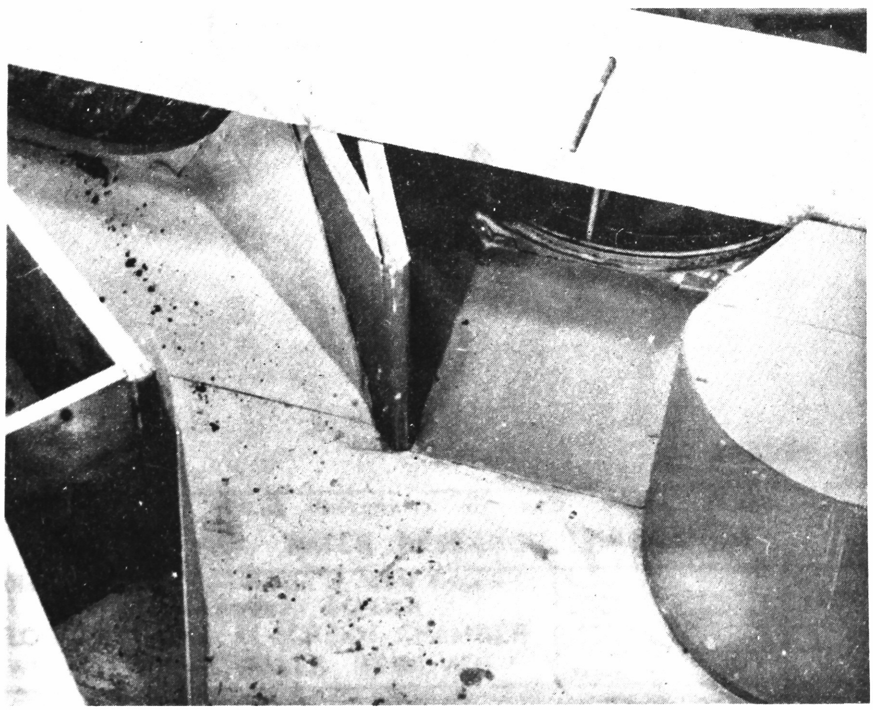


FIG. 7b

View of modifications to screen chamber walls and screen inlets which improved flow through screens.

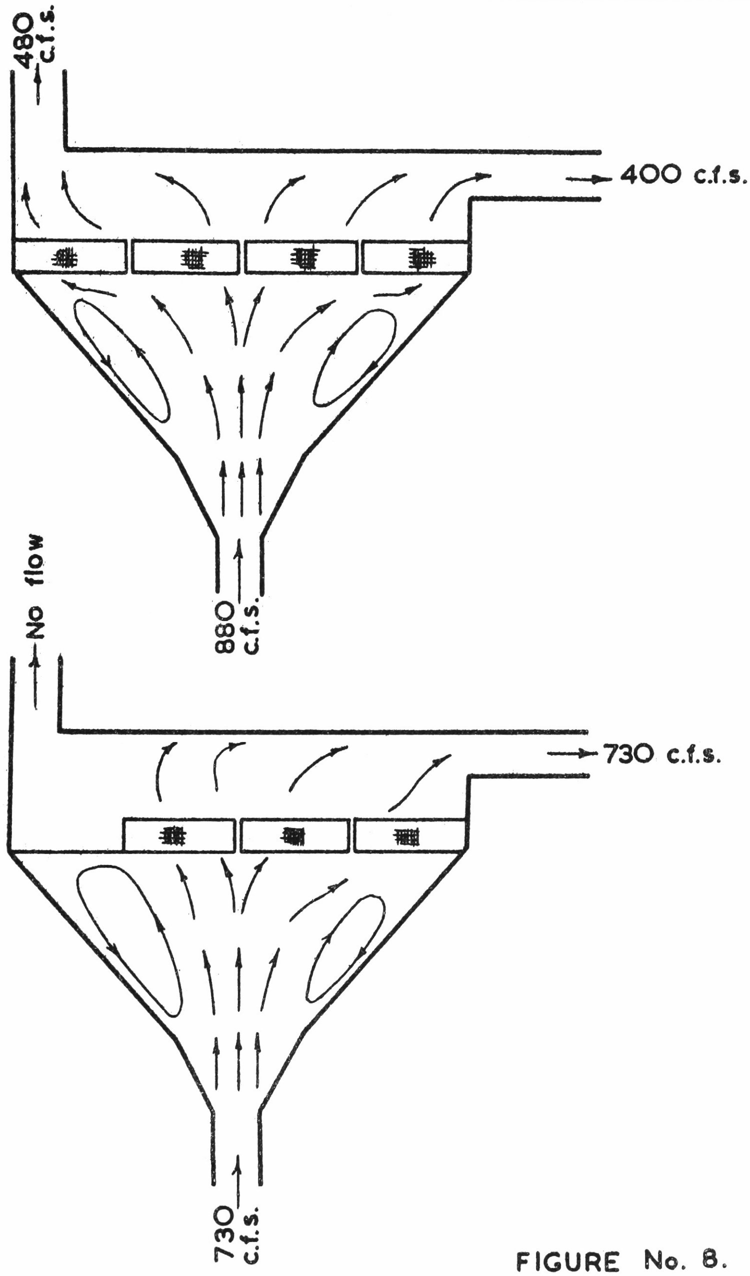
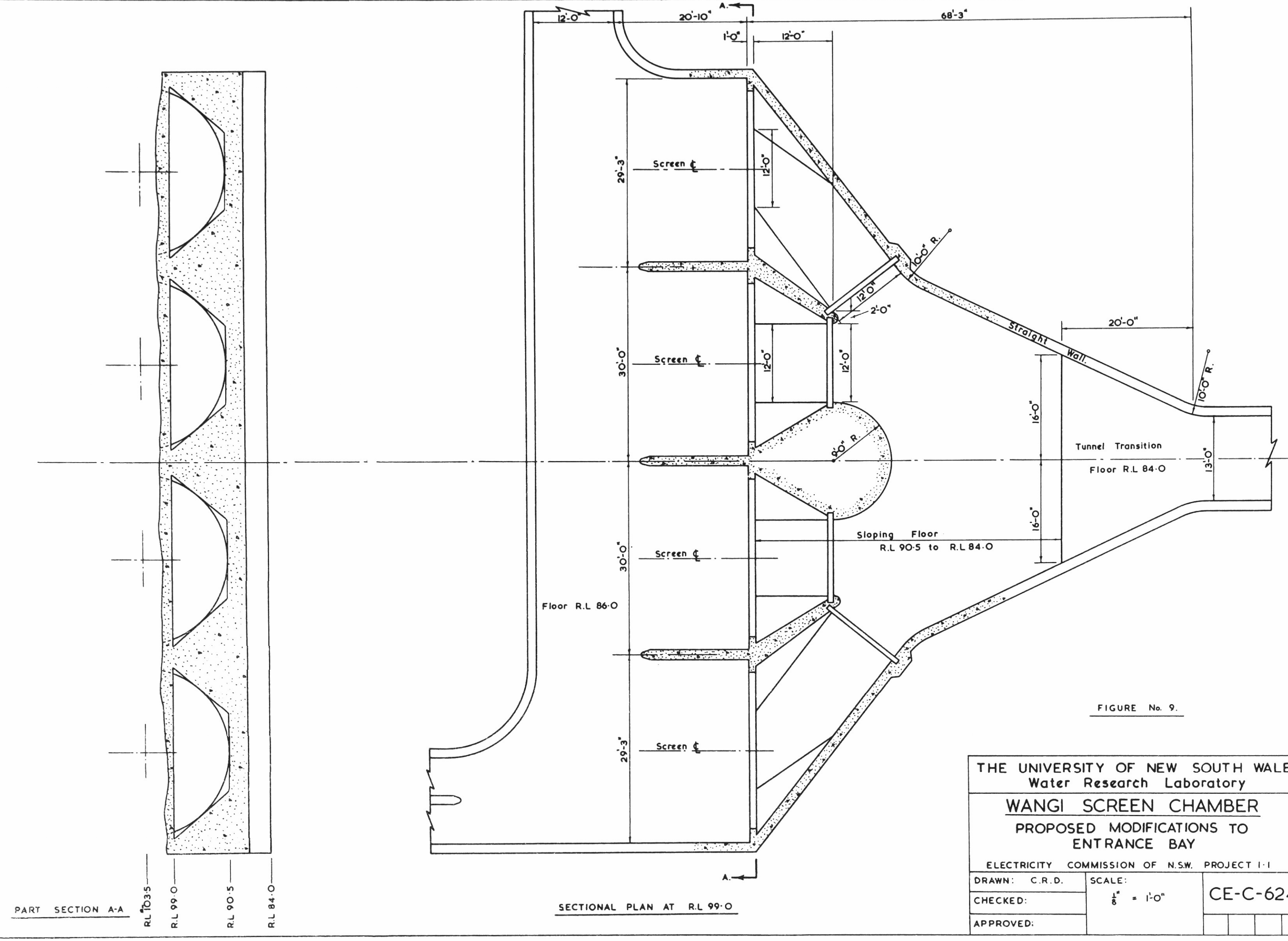


FIGURE No. 8.

THE UNIVERSITY OF NEW SOUTH WALES

WATER RESEARCH LABORATORY

The Electricity Commission of N.S.W. Project 1·1 Wangi Power Station FLOW PATTERNS IN SCREEN CHAMBER WITH DIVIDING WALLS REMOVED	Scale :		Date : 7·4·60
	Drawn: C. Dudazon		CE-Q-1064
	Traced: P.A.		
	Checked :		



PART SECTION A-A

SECTIONAL PLAN AT R.L 99·0

FIGURE No. 9.

THE UNIVERSITY OF NEW SOUTH WALES
Water Research Laboratory

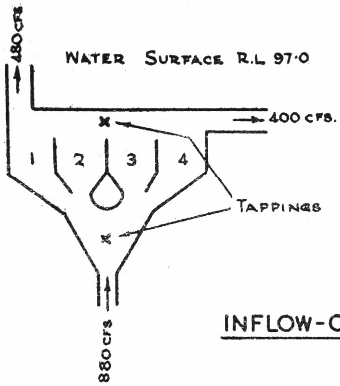
WANGI SCREEN CHAMBER

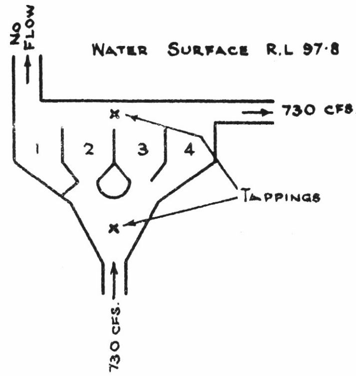
PROPOSED MODIFICATIONS TO ENTRANCE BAY

ELECTRICITY COMMISSION OF N.S.W. PROJECT 1·1

DRAWN: C.R.D.	SCALE:	CE-C-624
CHECKED:	$\frac{1}{8}$" = 1'-0"	
APPROVED:		

HEAD LOSSES THROUGH SCREEN STRUCTURE





INFLOW-OUTFLOW DATA

Head Losses - Prototype Equivalent * (inches)

Inflow 880 cusecs	Original Screen Entrances No Dividing Walls	Modified Screen Entrances and Walls
All Screens Clear	1·4 (inches)	Less than 0·5 (inches)
No. 1 Screen Blocked	4·5	2·1
No. 2 " "	4·9	2·9
No. 3 " "	3·7	2·0
No. 4 " "	3·5	1·8
Nos. 1 & 2 Screens Blocked	10·3	9·6
Nos. 2 & 3 " "	10·5	8·2
Nos. 3 & 4 " "	10·0	8·0
Nos. 1 & 4 " "	6·6	4·5
Inflow 730 cusecs with No. 1 Screen not Operating		
All Screens Clear (i.e. 2,3,4)	1·4	0·5
No. 2 Screen Blocked	2·5	2·3
No. 3 " "	5·8	4·7
No. 4 " "	4·7	2·7
Inflow 730 cusecs with Four Screens Operating		
All Screens Clear (i.e. 1,2,3,4)	0·8	0·4

*NOTES:- Model Screens have not been constructed exactly equivalent to prototype screens. However, ratios of blocked to open area of model and prototype screen mesh are of the same order, and, as form effects make up most of the head loss through the screen structure, model head losses should approximate losses to be expected in the prototype.

The results are intended mainly for comparison of various blockage conditions, and to show the improved performance of the modified screen entrances.

FIGURE No. 10.

CE-E-662