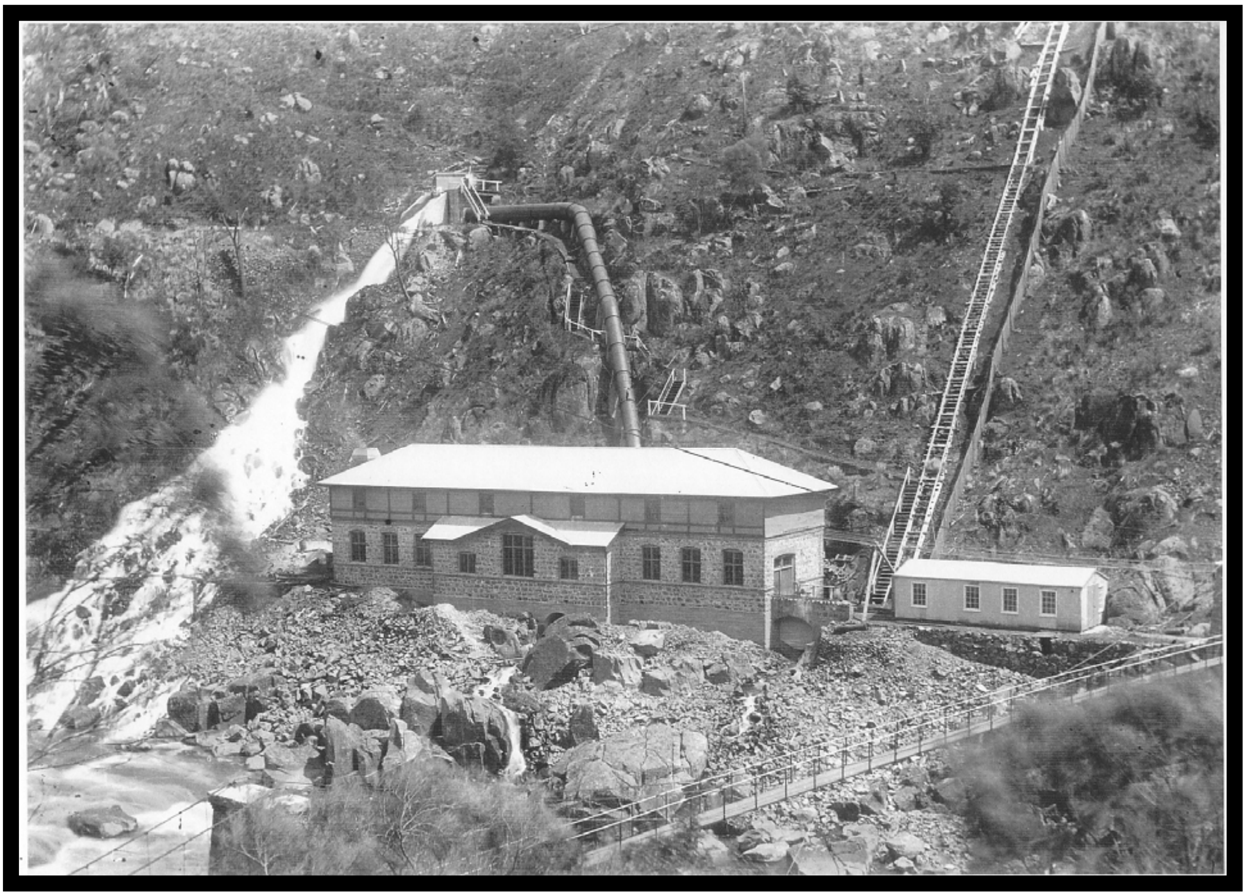
NOMINATION

OF

DUCK REACH POWER STATION

AS A

HISTORIC ENGINEERING MARKER



VOLUME 2 - APPENDICES

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Engineering Heritage Tasmania
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WILLIAM CORIN

Biography published in the Journal of the Institution of Engineers, Australia, No.1, 1929 page 208:

William Corin M.I.E.Aust. (1867-1929)

On the 13th October, 1867, William Corin was born at Forrest Hill, a suburb of London. He was educated at a private school and at King's College, London, and subsequently spent three years at the University College, London, in the Engineering Department studying under Sir Alexander Kennedy, Dr. J.A Fleming, Professor Victor Harcourt and Professor Carey Foster. After leaving University College, Mr. Corin went for a time to the works of Dubs & Co., Glasgow, and on leaving there was engaged by the firm of James Cleminson & Sons, Civil Engineers, chiefly inspecting railway material for South America and China. He then joined the staff of the Metropolitan Electric Supply Co., London, where he remained for four and a half years. He was appointed Electrical Engineer to the Municipality of Launceston, Tasmania, in November 1895, and was in charge of the Council's Electricity Department until 1907. [*When Duck Reach was being constructed*]

After leaving Launceston, Mr. Corin was for twelve months in private practice in Melbourne, during which time he also acted as Consulting Electrical Engineer to the Launceston Municipal Council. He joined the Department of Public Works, N.S.W., in 1908 and was appointed Chief Electrical Engineer in July, 1913. He also concurrently held the position of Consulting Electrical Engineer to the Department of Mines, N.S.W. Mr. Corin resigned from the Department of Public Works in order to take up private practice as a Consulting Engineer in Sydney.

Mr. Corin carried out many important electrical engineering works in Australia. From 1904 to 1907 he changed the electricity supply of Launceston to the three-phase, four-wire system. [*190/110 volts alternating current, the direct current system was removed. It was later changed again to 380/220 volts]*. This was among the first installation of the kind in the British Empire. Some years after leaving Launceston he prepared a report for the Council on the enlargement of the Launceston [*Duck Reach*] Power Station.

In 1913 Mr. Corin visited Europe and America on behalf of the New South Wales Government to study the progress which had been made in electrical engineering. Following that visit he prepared an important paper on the Power Requirements and Resources of New South Wales.

This paper marked the beginning of many important works which he subsequently carried out in New South Wales. On his recommendation, the Government authorised an investigation into the hydro-electric generation of the State, and this work has since gone on steadily. Mr. Corin initiated the bulk supply of electricity by the Department of Public Works. Beginning with the Port Kembla Power Station in 1915, he saw this plant increase its power rating ten fold. He also initiated, but did not complete, the Burrinjuck hydro-electric undertaking. While with the Department of Public Works, and subsequently, as consulting engineer, Mr. Corin designed and carried out the electricity undertakings of many country towns of N.S.W. Among these were the towns of Albury, Wagga Wagga, Wollongong, Orange, Dorrigo, Cowra and Jullaumbimby.

At the request of the Queensland Government, Mr. Corin prepared two reports, one in 1906 and the other in 1923, on the hydro-electric development of the Barron Falls. He also visited New Caledonia in 1920, and reported to private interests on a proposed hydro-electric scheme.

Mr. Corin was a Foundation Associate Member of the Institution of Engineers, Australia, transferring to full Member in 1920. He was President of the Electrical Association of Australia (New South Wales Section) in 1917.He was also a Member of the Institution of Civil engineers, London, being awarded the Telford Premium by that body for a paper on “ The Water Power of Tasmania” in 1911, and a Member of the Institution of Electrical Engineers, London.

Mr. Corin died at his residence, Chatswood, NSW on the 2nd March 1929.

CHARLES DAVID

Biography published in the Australian Dictionary of Biography Vol 5 1851-1890 pp 217-218.

Charles St John David (1855-1924)

David, Charles St John (1855-1924), civil engineer, was born at Chepstow, Monmouthshire, England. He arrived at Moreton Bay, Queensland, aboard the *Ramsay* on 13 January 1880. For three years he worked on railway construction in Queensland, and in 1884-92 was a partner in the Brisbane firm of Brown & David, civil engineers, architects and quantity surveyors. He was also consulting engineer to the Booroodabin suburban municipality and participated in the development of the Brisbane electric tramway.

David was appointed city surveyor in Launceston, Tasmania, on 1 March 1892. His predecessor had presented three proposals for the establishment of a municipal electricity generator to be driven by the South Esk River; David recommended and implemented a scheme which involved driving a tunnel large enough to transfer 62,500 gallons (284,000 litres) of water per minute half a mile (800 metres) through basalt rock. By late 1895 Launceston's main streets were illuminated by carbon arc lamps energised by Australia's first hydro-electric system. A public electric tramway was advocated and after investigations in 1894 and 1902, and an unsuccessful private venture, a further report in 1909 was adopted. David supervised the design and construction of permanent way, tram sheds and offices for the first tramcar service in 1911. Other achievements included the East Launceston sewerage system and, during the later part of his career, major improvements to the city's waterworks.

Three notable examples of David's ability as engineer, architect and surveyor are prominent in Launceston. In the city centre, the southern wing of the town hall, built to a design submitted privately in competition by David in 1904 offers in its plain, neatly proportioned façade a harmonious echo to the classical elegance of the earlier building. Westward of the city, in the savage ravine of the South Esk, David's engineering skill is attested by the sturdy pylons and graceful catenary span of the 1904 Alexandra Suspension Bridge. On the northern verge of Launceston stands Carr Villa cemetery, surveyed, designed and developed from 1902 according to David's directions.

He served in various community organisations. He was a committee member of the Launceston Mechanics' Institute and Public Library, and in 1907-22 of the Technical School. David advised the Tasmanian Agricultural & Pastoral Society on the construction of the Elphin Showground, the Tasmanian Turf Club on alterations to Mowbray Racecourse and acted as honorary consulting engineer to the Northern Tasmanian Fisheries Association. He was a Fellow of the Queensland Institute of Architects. Described as "generous and kindly" and highly valued as a "general all-round engineer", David died, aged 69, of pneumonia on 17 July 1924 at Wahroonga, New South Wales, while on holiday. His body was returned to Launceston for a civic funeral and burial in a special plot in Carr Villa cemetery. He was survived by an only son in England.

Examiner (Launc.), 1 Mar.1892, 11 Dec.1895, 18 & 29 July 1924; *Weekly Courier* (Launc.), 19 may 1921, 24 & 31 July 1924; Immigration records, 1880 (QA)

Alan Jones.

However, not reported in the ADB is the fact that Charles St.John David was a man of mystery, actually being Richard Thomas Sargent, who on leaving his wife and son, left England in September 1879, and landed in Queensland in 1880 as Charles St.John David.

WILLIAM KERNOT

Abridged version of the entry in ADB Volume 5 1851-1890 pp 20-22

Professor William Charles Kernot (1845-1909)

William Charles Kernot was born 16th June 1845 at Essex in the UK. He arrived with his family at Geelong in 1851 and, aged 15, he was admitted to the University of Melbourne. He gained a BA in 1864, a MA in 1866 and, by obtaining the Certificate of Civil Engineering in 1866, he became the first qualified engineer to be produced by the University. He also gained a Master of Civil Engineering in 1898.

From 1865 to 1875 he was employed within the Victorian Department of Mines and the Department of Railways. Also from 1868 he lectured part-time at the University in surveying and civil engineering,

In 1883 he became Professor of Engineering, the first in the University, and the first graduate of the University to gain a chair. Following his appointment, in 1884, the first graduates in engineering, as distinct from holders of the 'certificate' appeared.

As well as his University work, Kernot visited Europe and America to study engineering developments at schools and industrial establishments and in Australia/Tasmania he undertook many consulting positions, including Royal Commissions.

In 1888 he was in Tasmania reporting for the Tasmanian Government Railways, when he was sought to advise the Launceston Council, with Messrs G.Gordon MInstCE and Mr.C.W.James CE on the development of a suitable scheme to utilise the electric power potential of the South Esk River. Mr. K.L.Murray MIEE was engaged to define and supervise their findings.

K L MURRAY

Based on notes in Gibney & Smith: *A Biographical Register 1788-1939* and the *Tasmanian Register of Births, Deaths & Marriages.*

Kynaston Noel Lapthrop Murray V.I.E.

K N L Murray was born in Tasmania in 1836. He was appointed as a telegraph operator with the Tasmanian Government Service in 1858. In 1859 he was listed as the resident operator at Circular Head Station, which covered the first submarine cable linking Victoria and Tasmania. This cable failed after a short period.

In 1860 he married Mary Sophia Lee Archer (daughter of John Lee Archer) in New South Wales and was then appointed to the Victorian Postal Service as a telegraph operator at Ararat.

A son was born at Oatlands (Tasmania) in 1862 and died at Port Sorell (Tasmania) in 1863.

Murray joined the Victorian Railway Service in the early 1870s, in charge of their telegraph branch and directed the expansion of their telegraph system. He introduced safe working systems to track signalling including the Winter Block Instrument System, which was first introduced to Australia by the West Australian Railways.

He was responsible for the installation of the electric lighting system for the exhibition building of the Melbourne International Exhibition in 1888, and was highly praised for this by the State Government. He also implemented the installation of the electrical power station for the Spencer Street Railway Station, utilising Siemens machines.

As Lieutenant K.L.Murray, by March1881, he was the Chief Electrician for the Victorian Government Volunteer Submarine Mining and Torpedo Corps (also called Naval Torpedo Corps). In association with Professor Charles Kernot, he assisted Louis Brennan with the development of the Brennan torpedo which was eventually sold to the Royal Navy for £110,000. For this Brennan also received a knighthood in 1892. Whitehead, whose torpedo was the ultimate winner, received only £15,000.

Murray was President of the Victorian Institute of Electrical Engineers in 1888. He became a Commissioner for the Victorian Government Railways 1893-94, after which he retired aged 62.

He subsequently undertook the responsibility for the electrical design, procurement and commissioning of Duck Reach Power Scheme. On relinquishing this position in July/August 1897, he presented a paper on the experiences of Duck Reach.

He was a Lay Canon of St. Paul's Cathedral in Melbourne, and had been a chairman of the Jumbunna Coal Company.

Kynaston Murray died in 1916 at Bellerive in Tasmania.

ELECTRIC LIGHTING OF LAUNCESTON, TASMANIA

Paper by Mr K. L. Murray, Past President

Victorian Institute of Engineers, 1897

The utilisation of the River South Esk for electric light and motor work is the first case in Australia where water-power has been successfully made use of in so large a way, and the great success which is attended it, should be an inducement to look at other of our rivers and see if they cannot be similarly utilised.

A good many years before I became connected with it, the electric lighting of Launceston was discussed, and schemes formulated for the use of water-power to drive the machinery. The South Esk River was not the only source of power thought of, for Mr. Alderman Peter Barrett suggested St. Patrick's River as one from which power could be obtained. This, however, our Past President Gordon showed to be open to very serious objections, in a report he furnished to the City Council upon available water power in the locality. Our present President, Professor Kernot was asked some questions by the Council as to the water power at their disposal, and in his replies showed from data given him, that considerable over-estimating had been done. His and Mr. Gordon's reports, however made clear the fact that there was plenty of power to be obtained from the South Esk for all the lighting and motor work likely to be wanted in Launceston for many years, and when I went over in 1891, the Council told me that they would bring 800 H.P. to First Basin, a convenient spot for the power station, and wished me to advise them how to utilise that power for lighting and motor work in the city.

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Though they did not desire me to go into the question of providing the water power at the spot indicated, the various schemes suggested previously were explained to me. One of these contemplated fixing the Power Station on Picnic Rock, a place so exposed to floods that I could not imagine any engineer proposing it as a fit place for such a purpose. Another suggestion was to tap the river at Duck Reach, and tunnel through a bend to a spot far enough down the river to give the needful fall. This seemed to me to be the best of the plans suggested, but I was told that its practicability had been exhaustively tested, and that it had been proved commercially impossible. The plan which the Council had decided to adopt was to carry the water in a 40in. iron pipe from Duck Reach to First Basin, which it was estimated would provide 800 H.P. at an expenditure of about £20,000: When estimating the quantity of energy likely to be wanted, I found that 400 H.P. would be enough to arrange for at first, and that led me to go into the water power question generally, and I found that its cost had been very much under-estimated, and that, at least, £11,000 more than the sum named would be required to bring 800 H.P. from Duck Reach to First Basin.

From the plans of the river supplied me, I ascertained that 470 H P, could be brought to First Basin at a cost of £10,750 by tapping the river at a point not more than one-fourth the distance between Duck Reach and First Basin and that by fixing another and smaller pipe on top of the first one, an additional 390 H.P. could be secured at an added cost of £8263. I was able to show the Council; therefore, that for £19,015 they could secure 860 H P, at First Basin, whereas if they adhered to their arranged plan £31,680 would be required to obtain 800 H.P. I should add that it was afterwards ascertained that the river levels as given me were incorrect, and that it would have been necessary to fix the intake at a spot 15 chains further up the river than that I mentioned. This would have added about £5000 to my estimate of cost of the work, but there would still have been a saving of about £7000 in the cost of the water scheme.

One of the points taught by the history of this water power scheme is that it is useless for one to depend upon the accuracy of data given in connection with the power of water and its transmission. It is really remarkable how many inaccuracies there were in the different schemes formulated at Launceston. Even the supposed prohibitive cost of tunnelling from Duck Reach was proved to be a myth and, as will be shown later, its actual cost was proved to be considerably less than it was estimated the cheapest pipe line could be constructed for.

Basing my scheme, then, upon the generating station being fixed at the First Basin, I submitted a report to the Council, in November, 1891. The plans I suggested were adopted by the Council, and, as required by law, a poll of the ratepayers was taken upon them. The needful majority of two-thirds was obtained, and the Council decided to go on with the work, and requested me to prepare plans, specifications, etc., under which tenders for the supply and fixing of the machinery, etc., might be invited. A matter which afterwards caused a good deal of unpleasant discussion cropped up in connection with the conditions under which the contract was to be carried out.

When sending my specifications to the Council, I submitted with them two sets of Conditions of Contract; one placed the whole control of the work in the hands of the Superintending Engineer; the other allowed an appeal from his decision upon any disputed point to arbitrators. I would submit this question to the Institute as one of sufficient importance to engineers to be considered. Personally, I am entirely with the Council when they decided to leave all to the uncontrolled decision of the engineer, and I am sure if I had not had entire control of this work that, through the ignorant interference of several members of the Council, I would have been obliged to allow work to be done in ways I did not approve of, or, what would most likely have been the case, things would have been too unpleasant for me to bear, and I would have resigned my position.

My specification contemplated a schedule of prices contract, and I gave every possible information to enable firms to offer machinery of all existing types, being desirous that when considering tenders I should have as many possible to select from. Before drawing up my specification I spent some time in Northern Tasmania enquiring into the timber question. I was desirous of ascertaining whether the local timber was good enough for poles to carry the leads and lamps, or whether it would be necessary to import timber poles or to use iron ones. I found that while I could expect the life of local timber poles to be less than two-thirds that of the best wooden poles I could get elsewhere, the latter would cost quite three times as much as those of local timber which I accordingly decided to use. Those which were to carry the leads from the generating to the distributing station were to be left rough, and to have arms checked and bolted to them. The rest of the poles were to be dressed and painted and to have the arms morticed into them

I should say that before I had drawn up the specification, Mr. C. St.John David, who had become City Engineer, had proved the practicability of tunnelling from Duck Reach through the bend, and his recommendation (with which I most cordially agreed) that a tunnel should he substituted for the pipe scheme, and the generating station fixed at a spot about 90 chains above First Basin was adopted. This greatly improved the stability of the water part of the scheme and considerably reduced its cost. It increased, however the cost of the electrical work by removing the generating station about a mile further from the city, so that long and heavier leads were required to transmit the energy to the distributing station.

In due course tenders were called for and received, and after being opened and reported on by the city officials, were sent to me for consideration and recommendation. I found only two which I could consider; others received were from firms who dissented from the conditions under which the Council had decided the contract was to be carried out, and wished to formulate conditions for themselves. The two formal tenders were those of Messrs. W. T

Henley Telegraph Works Company and Messrs. Siemens Brothers and Company, both of England.

Upon examining them I found that Siemens Brothers' tender was lowest for supply of the machinery, but that for labour, fitting, etc., their tender was so much higher than Henley's, as to make the latter's total for supply, fitting up and maintenance for six months, the least.

Upon analysing the tenders further, I found that while the machinery offered by Siemens was all unexceptional, and of the highest class, every part being fully described, that proposed to be delivered by the Henley Co. was not described at all in a way to enable me to judge whether, in my opinion, it was suitable for the work required. I was not told either the maker or the design of the turbines; the couplings between them and the dynamos were simply described as “flexible" without any other particulars. Indeed, nothing was described; it seemed as if the firm thought it only necessary to say that all should be satisfactory, but, as I found that nothing proposed to be supplied but the leads was to be of the firm's manufacture, one article to be made by one firm and one by another, I did not feel that I could, dispense with description, particularly as the specification had in all cases instructed tenderers to fully describe item of the plant offered. I considered that the difference in the money amount of the tenders was not sufficient to allow me to accept responsibility of recommending Henley's heterogeneous plant, when the offer of a so much more satisfactory one, all made by a firm of the highest character, all parts being made to work together. I found that the sum named by Messrs. Henley for labour, fitting, etc. of plant was less than one third of that for which any other tenderers offered to do the work for, as well as of my estimate of what it should fairly cost, I felt, therefore, that it must have been named in error, or in ignorance of what was required to be done.

Finally I decided to recommend the acceptance of Messrs. Siemens Brothers (the lowest) tender for the machinery, and to point out to Council several ways of getting it fitted and worked.

After a deal of discussion the Council submitted the tenders to our present President, Prof. Kernot, for his views, and I was gratified find that he entirely agreed with me as to the undesirability of accepting the Henley tender.

My recommendation being thus backed up, the Council decided to accept it and to give Messrs. Siemens Brothers the supply of the machinery, and also its erection, and the carrying out of all parts of the scheme.

So far, Mr. President and gentlemen, preliminary, I have only troubled you with it because of the (as they seem to me) points of considerable importance and interest to engineers, which cropped up
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Now as to the details of the scheme itself. First the water supply part of it, which has been written and sent me by my friend, Mr. David, the City Engineer of Launceston, who designed and supervised the carrying of it out.

THE WATER WORKS.

It being unnecessary, Mr. David writes, to again go over the scheme proposed in the past for providing the necessary water power for this work the writer deals at once with the work actually carried out.

The writer's reasons for advocating the construction of a tunnel, in lieu of carrying the water in a flume or in pipes, were the almost perfect immunity from injury by falling rocks, etc., the additional working head gained by adopting a shorter route, and the avoidance of a sure and certain heavy annual expenditure on maintenance of the flume, race, or pipe line.

Having then to provide water at a sufficient working head to supply all the power reasonably expected to be required, the best scheme presenting itself was that of driving a tunnel through the hill from a point about 3 miles above the mouth of the river South Esk to a point about 2 ¼ miles above the same point. The normal difference in water level between the two points was 156.4 feet reduced owing to increased rise at the outlet during flood time to 131 feet.

Examination of the country through which it was proposed to drain the tunnel pointed to the probability of solid rock for the entire distance, the formation being an extremely hard and tough greenstone, locally known as basalt though quite unlike the basalt found in Victoria.

This rock is met with over the greater part of Northern Tasmania, and the precipitous declivities of the banks of the South Esk in the vicinity of Launceston are entirely composed of it.

As the writer had no previous experience of the cost of driving in this material, and as the data furnished him by mining authorities others were so utterly at variance one with another, all appearing to savour strongly of “day work" prices, he deemed it advisable before attempting to estimate the cost, to make a species of trial on which to base prices.

The Launceston City Council is the possessor of a quarry of similar material to that through which it was proposed to drive, the drills used in it being worked by compressed air, and setting a couple of men to work a face, with a pressure of 60 lbs of air, a number of shots were put in starting a drive of the size proposed for the tunnel. In three shifts of eight hours each the men had excavated to a depth of 2.8 feet, with rough diameter of 5ft. 6ins, and taking this as a basis, the cost of driving in the tunnel was estimated at £3/5s per lin. foot. This was a considerable reduction on the rates furnished by mining men which ranged from £7 to £13 per lineal foot for drives of 6ft x 6ft to 8ft x 6ft and it was freely stated that the work could not be done for the money or anything near it.

But before the construction of the tunnel was proceeded with, other preliminary works were necessary, it being deemed advisable to take advantage of the extremely low state of the river.

The main current of the South Esk at the intake formerly passed down the deeper channel on the southern side of the island, the tunnel entrance being on the north bank and it was therefore necessary to secure an adequate supply of water during the summer months, that means be taken to divert the stream to the eastern arm and this was done by constructing weirs of cement concrete. The principal difficulty experienced in this work was the ensuring of still water in which to place such of the concrete as was submerged, it not being considered necessary to go to the expense of the plant necessary to keep the water back altogether.

The ordinary velocity of the water at the site of the weirs was from 10ft to 14ft per second.

Foundations were simple, the bed-rock being quite clean and of good shape

First, a sand-bag dam was constructed about 10 feet up stream from the site of the weirs, each bag being a new corn sack containing about 3 cwt of good loam not easily affected by water. These bags, heavy and solid as they were, were often torn from the men's hands and carried away down stream. Once completed the sand bags kept back most of the water and the dam was considerably cheaper than a coffer dam, even had there been a suitable site for the latter.

The framing and sheeting for the permanent work were then put in, a couple of sluices being left for the escape of superabundant water. The water in the space enclosed by the sheeting was then fairly still and it was rendered perfectly so by the placing of sand bags along the outside, the water percolating through the sandbag dam escaping through the sluice!

The concrete for the weirs was composed 6 parts of clean 2 inch metal 3 parts of sand (local disintegrated quartz) and 1 part of Gillingham Portland cement, the latter being increased by one half for all sub merged works. The underwater concrete was put in place by means of bags. About a cubic foot was placed in each bag which was handed to two men, each taking hold of the bag by one upper and one lower corner, a little deft shaking then got the concrete right into the mouth of the bag which was placed right down on to the surface of the concrete already in position when the gentle withdrawal of the bag left the material in it place. By these means very little disturbance occurred and examination since has proved that the stone is well distributed in the matrix, making a good and solid piece of work. No ramming was attempted in the “drowned" work, but where above water level, the concrete was put in as it was possible to work it.

The weirs were of height varying from 5ft to13ft, the width on top 2ft 6in., the down stream face battered 1 in 6 (as there will always be a water cushion no curve was given to the face), the upstream face was sloped off, forming an apron at a slope of 1 in 3 (horizontally), the apron in the case of one weir being solid, and in the other being constructed of concrete in bags laid in alternate courses of headers and stretchers up to the water level, from which it was solid, the sluices being stopped when the aprons were put in.

Other smaller weirs were also constructed which call for no particular remark, the effect of the whole being that the dry weather flow was forced over to the tunnel inlet on the eastern bank. There is no attempt at conservation; the weirs are only of sufficient height to ensure an entry head of 1 foot to the tunnel during dry weather.

This work was all done by day labour under most careful superintendence, and as the quantity of dead work, such as framing, lagging, etc., varied considerably in the different weirs, irrespective of the cost of temporary dams, the rate per cubic yard of concrete ranged from £2 10s to £7.

To return to the tunnel; this work was set out and a contract let to Messrs. O'Neill Bros. and Rodgers, of Sydney, in July 1893, but, owing to the continuous wet weather, their contract time was allowed to date from November 1st in the same year, by which time it was expected that their plant would be in place. Owing, however, to an accident, the contractors did not get a fair start until December 1st, the small amount of driving executed before that date being all done by hand.

The total cost of the scheme, including weirs, race, surveys, etc., was estimated at £13,169, and the extraneous work having cost £1312, the sum of £11,857 remained on the estimates for the construction of the tunnel.

Messrs. O'Neill laid down a plant consisting of a 12 h.p. (nom.) horizontal boiler with enlarged firebox for burning wood and a direct acting engine and air -compressor, both steam cylinder and air chamber being 11 inches in diameter with 12 inch stroke, which, together with a receiver, were placed on the crown of the hill immediately over the tunnel and 260 feet above the inlet. 2½ inch wrought iron pipes led to both headings (the tunnel being worked from each end simultaneously), from whence 1½ inch pipes conveyed the air to the faces where the usual 1 inch hose was used.

Air driven drills of the "Little Giant" type were selected and installed in each face, giving every satisfaction, and it was found, contrary to the prognostications of the over-wise, that no difficulty was experienced in keeping up the required air pressure.

A 6 h.p. vertical boiler and engine performed the necessary haulage at the inlet end, pumping up water to the compressing plant in addition. This engine was also prepared for pumping out the drive if necessary but was not needed for this purpose, the headings being very dry.

At the inlet end, instead of constructing a coffer-dam, the contractors with the writer's concurrence, ran a drive from above flood level at a vertical angle of about 45deg. down to the tunnel floor, starting the drive proper thence, as indicated on the accompanying section, cutting out the dead on completion of the work. Curiously enough, the only serious accident occurring throughout the whole work was in cutting out this dead end, whereby a workman was unfortunately killed through a fall of earth.

The total length of the drive was, as finished, 2763 feet, about 30 feet of driving being replaced by open cutting. The transverse section was roughly circular, 5 ft. 6 in. in diameter and the grade 1 in 110.

Being in solid country for almost its entire length, it was quite unnecessary to timber more than a few loose places.

The work was carried out continuously by both night and day with the exception of Sundays and a few days at Christmas and Easter, and after 16 months labor, the last shot breaking down the rock separating the headings was fired on March 28th 1895. On clearing out the rubbish the writer had the satisfaction of ascertaining that the alignment of the two headings was almost exact, the distance of 7/8 of an inch only separating the marks. Levels were even nearer, the difference being 3/8 of an inch only.

In trimming up, no difficulty was experienced in working the air drills at the outfall, the supply being then taken down to the inlet in the 2½ inch pipes and through the entire length of the tunnel in the 1 ½ " pipes, a total distance of 4,300 feet from the receiver.

The contract price for driving was £3 9s per lin. foot, as against £3 5s estimated.

The extreme hardness and toughness of the rock was noticeable, the average length driven each 6 days or 18 shifts being about 20 feet in each face but in one particular instance, notwithstanding every effort, no less than 5 shifts were occupied in advancing rather less than 2 feet. The quantity of dynamite used, viz., 12,750 lbs is indication of the nature of the ground, being nearly 4½ lbs of explosive to the ton of material shifted.

On the accompanying section is shown the distance advanced at each measurement.

The invert of the drive was lined throughout its entire length to a semi- circular section of 2 feet 6in. radius, in fine cement concrete averaging 6 inches thick, certain portions, about 200 feet in all being lined throughout to an average thickness of 9 inches. The cost of lining was for the invert only, 7/- per lin. foot, and for the complete lining, 9 in thick, 20/- per lin. foot, this latter price was too low and did not pay the contractors.

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At the inlet of the tunnel is fixed a wrought iron sluice gate, with lifting screw and balance weights. A screen of 1½” by 1/4" bar iron with ½” spaces is also fixed here, together with a coarse screen of 1" bars, spaced 1½” apart for warding off floating logs and other debris.

At the outlet end, the water runs into a screening chamber, provided with screens of ¼” spaces. This chamber rises to a height of 5' 6 ins. above the crown of the tunnel, a bywash 9ft. wide being placed 3ft. above the tunnel.

The actual cost of the tunnel, as completed, was £11,913, or, if the screening chamber at the outlet be omitted, it not being contemplated when the original estimates were made out, £11,833, against £11,857 estimated.

As before stated, the grade of the tunnel is 1 in 110, which, giving as it does, a velocity of about 10ft per second, may appear open to question, but it was not decided upon without mature consideration. As will seen by the section, the declivity of the river bank is such that the few feet in length of tunnel which may have been dispensed with, by adopting a flatter grade would have been inappreciable, while the extra cost entailed by increased dimensions of the tunnel would have been very considerable. The nature of the rock, and of the proposed invert, made it possible to give even a greater velocity without injury, so the size of the drive was fixed at the smallest dimensions which would allow fair room to work at the face. This 5ft. 6ins. in dia., and the grade of 1 in 110 were therefore necessary to carry the required quantity of water, viz. 10,000 c. ft. per minute.

This amount, being two-thirds of the summer flow of the river, in dry weather, is all that can be legally made use of, and with the working head of 110ft. which is obtainable, will give, with turbines of 75 percent proficiency 1562 H.P.

The water supply therefore runs out thus -1562 H.P. for £13,225, rather less than £8 10s per H.P.-a rate which compares very favourably with similar work in any part of the world.
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The effect of placing the cill of the by-wash 3ft. above the crown of the tunnel is, of course, to fill the latter completely for a distance of 330ft. from the mouth, thus forming a water cushion which checks the velocity of the flow, and assists very largely in depositing sand, etc., held in suspension, and this unwelcome material is further intercepted by a catchpit, immediately in front of the fine screen, whence it is scoured through a 12in. pipe.

From the screening chamber the water, after straining, flows through a wrought-iron sluice gate opening, and by a pipe line is conveyed to the power station. The pipe is of wrought iron with flanged joints, is 1/4 inch thick and for the first 82 feet, is 5 feet in diameter, the remaining 121 feet being 4 feet in diameter. The lower (end) is expanded into a bell mouth, 5 feet by 2 feet 6 inches.

Getting the great pipes into position was a work of no little difficulty. The illustrations give some idea of what the hillside down which they had to be lowered is like, but no one who has not visited the place can appreciate the danger and difficulty which were met by those who lowered these 75 tons of pipes of the sizes named down a hill, rough with rocks and tree stumps at grades ranging from 1 in 10 to 1 in 11. As fixed, they lie on grades of 1 in 90, 1 in 2, and 1 in 1.2. They rest on cast-iron saddles, which are firmly supported by and fixed to concrete piers. Half-inch wrought-iron saddle plates are riveted to the under side of the pipes, and are provided with a lip on the upper end, which catches on the saddles and so prevents slip As additional precaution, and so that there will be no danger of them slipping when their weight is added to by the passage of water passing through them, 1 ½-inch anchor bars with coupling screws are strapped to the pipe, and held back to the solid rock by means of 1 ¾-inch dowels. The bell mouth before mentioned conveys the water to a wrought iron receiver 88 feet long, which extends along the back of the power house, and is supported in similar manner to the pipes. The central portion, 41 feet in length, is 6 feet in diameter, and is of wrought iron 3/8 inch thick ; the two end portions being 3 feet in diameter and ¼- inch thick, all being held back by 1½-inch anchor bars as before described. The receiver is fitted with four 4-inch dead weight safety valves.

From the 6-feet section, the water is led into the building by means of four 2 feet 4 inch pipes, and from the 3-feet sections by six 12-inch pipes, though only three of the former and five of the latter are at present in use, one of each being left for future extensions. The water from these pipes is taken directly to the turbines, draft tubes being made use of to ensure at least 110 feet of working head. Mr. W. H. Knight was the contractor for this part of the work. He did his work well, and received for supply and fixing of pipes, receiver, &c., £1,730.

The pipes will carry sufficient water to generate 900 h.p. (net at the turbines). The present cost per h.p. at the pipes is therefore

$$(£13,225 + £1730)/900 = £16\ 10s.$$

(End of Mr. David's Paper on Water Works)

THE POWER STATION.

The site for the generating station was selected at a spot a few yards lower down the river than the outlet opening of the tunnel. To the inexperienced and unprofessional eye it would have appeared the least suitable position, in that very uninviting locality on which to place the foundations of a building, consisting as it did of an immense mass of basalt boulders, rising higher than any other in that immediate vicinity, and presenting the most irregular surface imaginable. But to the engineer it presented special facilities for the erection of a water power house. Mr C.St.John David, M.S.E. City Engineer, who designed and carried out this part of the work, found from his survey that the solid floor beneath this mass of boulders was sufficiently high above flood level to form a safe position for the building, that through its centre and parallel with the river there ran, for a portion of the way, a deep recess which could be utilised as a tailrace for the turbines, and the outlet from which was in a suitable position and direction, and was protected against damage or obstruction by debris brought down the river in flood time. Having fixed on this position then as the site of the power house, Mr. David at once set to work and soon had the large boulders broken up and tumbled into the river.

The basalt bed was then levelled off and nature's tail race completed. On the floor thus roughly prepared the building was erected. The foundation is of concrete and the walls of basalt rubble, the roofing being galvanised iron. The internal dimensions of the building are Length, 105 feet ; width, 24 feet, excepting the central bay, which is, 30 feet (made that width to accommodate the large alternator sets) ; height to wall plate of centre bay, 22 feet, and of two end parts, 15 feet. The tail race is 9 feet deep, and extends nearly the whole length of the building. It is arched over with concrete, on which are bedded the wrought iron girders to which the turbines and other machinery are bolted. The cost of the buildings and foundations complete was £1838.

The building is large enough to contain four 100 kW alternators and six 35 light arc dynamos, although only three alternators and five arc lighters of these sizes were put in under the original contract. The turbines are directly coupled to the electrical machinery which they drive, and are arranged in a single row directly above the tail race. The machinery is placed with its axis of rotation at right angles to the direction of the building. The three alternators and turbines which drive them are in the central bay of the building, and the arc lighters are placed three in one wing and two in the other. The water is brought from the receiver outside the building to the turbines in wrought iron branch pipes. In each branch pipe there is a suitable sluice valve which controls the supply of water to its attached turbine. After passing through the turbine the water is discharged by means of the double draft pipes, which pass through the concrete arch over the tail race and reach nearly to the bottom of it. The tail race is so constructed that the ends of the draft tubes are always submerged.

The turbines belong to that class generally known as reaction turbines and are Professor James Thomson's inward flow or vortex type. The general appearance of this machine is shown in the illustration. The largest part consists of an annular chamber, which receives the water from the supply pipe and distributes it round the circumference of the wheel proper. But before the water can reach the wheel it has to pass through the spaces formed between the four guide blades which are a distinctive feature of Prof. Thomson's turbine. These guide blades are so arranged that the water in passing between them is directed almost tangentially against the circumference of the rotating wheel, which is really a double wheel, the two portions being symmetrical in all respects and separated by a central disc. Each section of this double wheel is furnished with a large number of blades, curved in such a way that the water leaving the guide blades by striking these blades almost normally and before leaving the wheel near the axis, has its direction of motion almost completely reversed.

The central or dividing disc causes the wheel to discharge the water on both sides, and for this reason the double draft tubes are provided, and the wheel is almost perfectly balanced, as far as lateral forces are concerned. As I have previously said, a distinctive feature of this turbine is the arrangement of guide blades which direct the motion of the water before it strikes the rotating wheel. These guide blades also serve the purpose of regulating the power of the turbine; each is provided with a pivot near its inner end, and the outer ends are connected to small cranks, the axis if which pass through the case, and are then connected together by means, of a system of link work, by which the outer ends of the guide blades can be made to close, down towards, or recede from, the periphery of the rotating wheel. In this way the guide blades can be so far closed down as to practically shut off the water and stop the turbine; or they may be; completely opened, giving a full supply of water to the wheel and causing it to develop its maximum power. It can be readily seen that this ingenious arrangement permits the turbine to develop various powers with maximum efficiency. In all cases the turbine runs completely full and the water passes smoothly through it without shock or noise. Indeed, so noiseless are these machines that it is difficult to tell by listening whether they are in motion or not. The running wheel is only about one quarter of the diameter of the outer case, and is not more than from two to three inches in thickness.

The three turbines which drive the alternators run at 460 revs. per minute, at which speed they give out, with full water supply, 158 effective horse power each. The five smaller turbines which drive the arc light dynamos run at 800 revs per minute and develop 21 effective horse power each. All the turbines are designed to work with an effective water head of 110 feet, 10 feet of which are obtained by means of the draft pipes. The speed regulation under varying loads is obtained in the case of all these turbines by means of the Murray hydraulic governor, the valve of which is actuated by suitable gearing from a Pickering centrifugal governor, driven from the turbine shaft. Each turbine and the generator it drives are mounted on a pair of wrought iron girders, which support the turbine over the tail race and at the same time bind the two rigidly together. In the case of the arc lighters the turbine and armature shafts are rigidly coupled by a pair of face plates and bolts, but the alternator armature shafts are connected to their turbines by flexible couplings. These couplings resemble the ordinary claw pattern, but the claws do not fit closely into each other, a parallel space being left between each pair of claws for the reception of a strong spring. The springs are prevented from falling out by means of a light iron hoop fastened to one of the halves of the coupling covering the spring gaps.

The continuous current arc lighters, five in number, are exactly alike, all parts of them being interchangeable. They are designed and constructed to give an output of 12¼ kilowatts, when running at 800 revolutions per minute. The potential difference at the terminals is 1750 volts and the normal current 7 amperes. These machines are bi-polar, the pole pieces, being formed on the yokes, which, together with the magnet cores, are made from the best wrought iron or mild steel. The general form of the field magnet resembles that of the Manchester dynamo and is of a very neat and solid construction. The armature is of the ring or gramme type. The core is composed of thin washers of the best charcoal iron, which are carried, and positively driven, by means of the two gun metal spiders keyed to the armature shaft, which is of mild steel. The core is carefully insulated by a special material which, the makers say is unaffected by the highest temperature attained by the machines when run continuously at full load. The armature conductors are carefully insulated, being first wrapped with silk tape and afterwards covered in the usual manner with cotton and finally varnished. The conductors are positively driven by wooden pegs fixed in the core, and are prevented from displacement due to centrifugal force by means of strong bands, which are well insulated from the windings. The armature winding is divided into 252 sections, and the commutator contains a similar number of segments of hard drawn copper carefully insulated with mica.

The machines are fitted with automatic regulators, which maintain the current constant, irrespective of the number of lamps in series from full load to short circuit. The regulation is effected by rocking the brushes round the commutator, the disposition of iron in the pole pieces and the armature reaction being so proportioned that the field in which those sections undergoing commutation are moving is sensibly constant for any position of the brushes. The motive power for rocking the brushes is obtained in this as in some other machines, from the armature shaft, through the intervention of suitable gearing. A small pawl is kept constantly rocking in proximity to a double ratchet wheel, and is caused to engage with one or other portion of it by means of a core suspended in a solenoid, through which the current generated by the machine passes. If, owing to the number of lamps in the circuit being altered, or to any other cause, the current departs from its normal value, the consequent alteration in the attractive force of the solenoid, causes the pawl to engage with that part of the ratchet which produces the motion of the brushes in the desired direction, and this motion will continue until the current has assumed its normal value, and the pawl again rocks free of the ratchets.

These machines are in several ways eminently suitable for arc lighting purposes. The current is almost absolutely constant, and so far as those rapid changes are concerned, which produce the well known telephone disturbances, unfortunately familiar to us all here in Melbourne, they are non-existent. The dynamos are more efficient than the open coil types of machines, and are not liable to flash over and therefore do not require the various arrangements introduced to correct this vice in other dynamos. Indeed, with such fine machines as this in the market it is difficult to understand why the open coil machines with their fluctuating current and consequent outside troubles should be adopted, seeing that they possess no compensating advantages.

The alternators are of Messrs Siemens Brothers well known type. I say “well known“ advisedly, for except in detail, these machines are essentially the same as those originally constructed by this firm at the time which must now be regarded as ancient in the history of electric lighting. The field magnets consist now, as then of a double crown of cylindrical cores, carrying coils, and pole pieces, between which a disc form of armature rotates. Although this machine illustrates to some extent the persistency of type, it also illustrates the very marked changes which have been introduced in dynamo construction during the last ten years. The earlier machines, when looked at besides those now constructed, or in light of present day knowledge, are more suggestive of the instrument maker than the engineer. They are flimsy and lack solidity in all parts, and were but ill calculated to withstand the stresses to which they would be subjected in continuous working. Whereas in the modern machines the hand of the engineer is everywhere apparent, solidity of construction, accessibility of all parts for examination and repair, large bearing surfaces for the running parts, and attention to those smaller details which affect commercial efficiency, and indicate a knowledge and appreciation of the ends to be attained.

The Launceston alternators, 3 in number, are of 100 KW capacity and when running at the normal speed of 400 revs, per min., give a potential difference at the terminals of 2,000 volts with a frequency of 92 complete periods per second. The two field magnet crowns are mounted on the bed plate, in such a manner that they can be quickly moved parallel to the axis, thus exposing the armature for cleaning, examination, or repair. The field-magnet pole pieces are carefully covered with ebonite caps, which are vulcanised in position, their object being to prevent the possibility of a discharge taking place between the armature conductors and framework of the machine. The armatures of these machines are of the disc form, and contain 24 coils of sector shape, which are firmly attached to a central steel disc, and are clamped between plates of platinoid. The winding consists of a compound strip conductor, formed of a number of small wires pressed together and insulated in the usual manner with a covering of specially prepared tape. The armature coils are carefully insulated from each other, and from their supports, and are connected together in such a way that the maximum P.D. does not exist between adjacent coils.

As the armatures of these machines constitute the running part, it is evident that collectors must be provided. These are constructed of gun metal, and are insulated from the steel shaft by means of heavy ebonite collars. The brush gear terminals and minor details are too well known to require special comment, and it is sufficient for me to add that the whole of the workmanship and materials employed are of the best description, and reflect credit on the designer and contractor.

Each machine is provided with an exciter carried on a bracket at such a height that the exciter armature can be attached to a prolongation of the alternator armature spindle, and the exciter therefore runs at the same speed as the alternator. The exciters are high-polar single magnet drum armature machines, but beyond stating that my concluding remarks as to workmanship, etc., of the alternators apply also to them, they call for no special comment.

The generating station is provided with two independent switch-boards - one for the arc lighters and circuits and the other for the alternating machinery. The arc light switch board is constructed on the plug and flexible cord system, and enables any machine to be run on any circuit, and any required changes to be effected with the greatest rapidity. This board is constructed for five machines and four circuits, and contains the usual apparatus, such as an ampere meter for each circuit, a single electrostatic static voltmeter (Swinburn's patent), and multiple way switch for connecting it to any one of the machines, circuit switches and lightning arresters.

The alternator switch board is designed for parallel running, a system which is usually adopted by Messrs. Siemens Brothers, and for which their alternators are well adapted. The board contains the apparatus generally supplied in such cases, viz.- double pole switches, fuses, synchroniser, ampere meters, electrostatic voltmeters, exciter regulating switch gear and lightning arresters, all of which (as is also the case of the arc switch board) are mounted and enamelled slate panels set in a strong polished oak frame
.

THE DISTRIBUTING SYSTEM.

Before forming an opinion from the plans of the city and suburbs as to which system of distribution would be most economical and at the same time giving a thoroughly satisfactory service I personally made a very careful examination of the whole of the area to be supplied with current. The various directions in which the suburbs were expanding, together with their probable future extension were noted and all information from the local authorities then in power, relating to the probable consumption in the various districts was obtained. On the last point, viz., probable consumption in various districts only very scanty information was given me, but the authorities promised to ascertain approximately the desired data before the time arrived for ordering cables.

With complete information on all but the last point, and a promise that what I required on that also should be furnished me in time, I soon came to the conclusion that by far the greatest part of the area to be supplied could be most economically served by means of the transformer sub-station system, and that a few of the outlying districts should be wired on the distributed transformer system.

Besides the actual economy in first cost, efficiency in distribution, and lower annual up-keep charges, I considered that as a matter of policy, it would be well to restrict the mileage of high tension cables to the lowest possible limit, consistent with an efficient and reliable service.

With such a system the number of weak points where a break-down may take place in the insulation, and cause trouble and danger, is minimised.

The parts of the system requiring critical inspection is reduced so that more time is available to make the periodical examinations thoroughly, and the larger transformers, together with their location enable safety devices to be employed with advantage.

These, and others I regarded as valuable points in favour of the transformer sub-station system for such a city as Launceston; where there was little probability of any considerable extensions in the near future; for economical reasons too, it was very desirable to reduce the inspection work to the lowest.

As however, the requisite data were not obtained tenders had to be called giving only roughly approximate quantities and dimensions of cables required. Even after the tenders had been received and the contract signed, no satisfactory data were forthcoming and as electric light had become a bone of contention in the Council and to some extent, also outside, and as the contractors were urging me to give them plans of the wiring and sizes of cables, I was obliged either to order the distributing system to be laid down on my original plans with transformer substations on the assumption that gas would be entirely displaced, or to cast aside this system altogether and get out fresh plans and details on the more flexible distributed transformer system.

Had I carried out my original proposals with the very imperfect data at my command, I felt that a considerable expenditure might be incurred, which would not pay interest for years to come. I therefore, at the last minute, decided to throw over my original plans and adopt the distributed transformer system.

The fact that the whole of the municipal lighting had to he done by means of electricity, compelled me to wire, practically, the whole of the city and suburbs; many poles and great lengths of leads being used where only two or three street lamps would ever be fixed. Again, it was specially desired that the wiring should be so arranged that all municipal lamps could be controlled from two or three points, and thus reduce the cost of lighting and extinguishing, together with the wear and tear of incandescent lamps, and consumption of arc lamp carbons to a minimum.

It must be remembered that with a water power scheme such as we are considering, where the power available is largely in excess of requirements for many years, economies can only be effected by close attention to the material actually consumed, i.e., carbons, incandescent lamps, lubricating oils, and, above all, labour. In the power station fuel economies, feed heaters, super-heaters, efficient lagging of hot surfaces, scientific firing, condensing, and the many other points requiring attention at a place where the heat of combustion is the source of power, find no place, and the light load losses, and all day efficiency of transformers, which are all important items in a steam power plant, are comparatively of little moment.

The full load efficiency of the plant must not however be disregarded, as it ultimately determines the maximum output from the station, and therefore the amount of business which can be undertaken for a given capital expenditure at the generating station. It is therefore evident that with a water power plant such as that under consideration, where the cost of the water tunnel and necessary works in connection with it practically fix the limit of the cost per effective horse power available at the generating station for driving the machinery; that close attention to such matters as lighting and extinguishing street lamps as quickly as possible, so as to save both incandescent lamps and arc lamp carbons and the labour of attending to them is important. With this end in view, I arranged that all incandescent lamp circuits should be run with a single lead and a split return. The transformers for the street lighting bridge the common lead and one of the returns, and the house lamp transformers bridge the common lead and other return. In this way a continuous supply is given to private consumers and at the same time the street lamps can be controlled by opening one terminal of the transformer primaries only. This arrangement permits a small condenser current to traverse the transformer primaries all day; but, as I have said, the day loss is comparatively unimportant, and due to this cause it is negligible. On the other hand, a considerable saving is effected by reducing the number of wires from four to three. As less insulators and pole fittings are needed, the cost of labour for erecting is reduced, and the total cost for cable is a little less. At the same time the maintenance cost will be diminished, and the smaller number of wires is less obtrusive.

The distributing system which I finally adopted is as follows. The current produced at the generating station is brought to a building called the Distributing Station, on the outskirts of the city, by means of overhead conductors, all of which are carried on steel suspending wires in the usual manner, supported by a line of strong wooden poles with wooden cross arms. The distance from the generating to the distributing station is nearly 11 miles, and the poles are on an average 50 yards apart. The span crossing the river is 150 yards, and the wires are supported at the ends on each side of the river by a substantial wooden tower. The steel suspending wires along this main pole line are shackled off into lengths of 220 yards in the usual way, and the insulated cables are suspended by means of hoop-iron clips placed 6 feet apart. The hoop-iron clips are designed and made for this work, and completely embrace both conductor and steel suspending wire. Tarred felt is put round the cable under each clip, which firmly clasps and keeps it in position, so that there is no risk either of the clips shifting their position or injuring the insulation of the cable. The insulators are of Siemens Indo-European pattern and support the steel suspending wire at points between the shackle terminations. Near the pole arms longer clips are used, so as to allow the cable to pass underneath the insulators, thus avoiding the sharper bend which would be caused if the cables ran parallel to the suspending wire at all points. Another advantage of this method of suspension is the elimination of the local bending of the cable which would take place if it were fastened to insulators at the pole arms at times when heavy winds cause the cables to swing.

The poles along this line carry 13 cables. There are four independent arc circuits, two independent incandescent circuits, and one twisted twin telephone cable. The arc circuit cables are of £7 16s stranded copper, insulated to 1000 megohms per mile. The incandescent circuits are of £19 14s stranded cable. The wires are arranged on the poles, so that the vertical distance between them is about 1 foot, and the horizontal distance about 3 feet.

During the progress of the work some curiosity was expressed as to what (if any) effect would be produced on the impedance of the cables for carrying the current from the alternators, due to the presence of the iron clips. As, however, the hoop-iron composing them was galvanised, the magnetic circuit formed would not be very good, and though I had not made any calculations on this matter, I felt sure that no material effect would be produced. At the completion of the work some rough tests were made with the ordinary station instruments, but, as was anticipated, no appreciable detrimental effect was found; the ordinary station instruments were not sufficiently sensitive to enable any certain difference to be measured between the drop due to the ohmic resistance of the cables, and that actually due to the resultant impedance.

Outside, and at short distance from the Distributing Station, a strong and well stayed pole is fixed, which takes the strain due to the tension on the suspending wires which are terminated there. From this pole the cables pass to a wood frame work, built as a sort of open tower in the centre of the distributing station building. From this tower, they are all led down into the main room in which are located the various switches, fuses, and lightning arresters. Thence the various branch circuits are led up through the tower to the respective parts of the city and suburbs they are to supply. In this building the switches are fixed which control the whole incandescent street and private lighting circuits; and from it the lighting and extinguishing of the street lamps is effected.

The Distributing Station contains four rooms. The switch room is intended to serve the purpose of a testing room as well, and affords a convenient place at which to carry out tests for localising faults should they occur in the high tension circuits. Besides the switching and testing room, there is a workshop fitted for repairing arc lamps, and doing other small work incidental to the distributing system. Another room contains lamp racks in which arc lamps can be adjusted when brought in for cleaning or repair.

The high tension alternating circuits are so arranged that in no case does more than one pair of these conductors run along any one street, and, as far as practicable, the less important streets were selected as the routes for these wires. The object of distributing the wires as far as possible was to localise any inconvenience which might be caused by fire, or otherwise, and prevent the unsightly appearance presented by large poles carrying a number of cables.

From the Distributing Station the arc circuits are run as dictated, by the positions of the lamps, and the fact that it was desired as far as practicable to arrange so that every alternate lamp should be on a different circuit, the obvious reason being to prevent a total extinction of the lamps along a line due to the failure in any one dynamo or circuit. Another reason was to permit of half the lamps being put out after midnight should it be desired or found expedient to do so. The general disposition of the circuits can be seen in the diagram of the city, which also shows approximately the distribution of transformers for street lighting purposes, together with all municipal street lighting lamps, both arc and incandescent. The arc lamps are marked ÷ and **0**, the distinction indicating those in different circuits. The Incandescent lamps are marked **x**, and transformers with a point within a circle.

A glance at this diagram will show that the arc lights have been placed according to the business requirements of each part of the city, being close in the most busy streets, and more widely spaced where the traffic is less. In the suburbs the incandescent lamps have replaced the gas lamps, but the lighting is much improved, inasmuch as each 10 or 12 candle power gas light has had substituted for it a 50 candle power electric lamp.

The arc lamps are placed in lanterns similar in design and dimensions to those used in our Melbourne railway stations, and which have proved to be both economical to maintain and satisfactory from a lighting point of view. The only difference is that the Launceston lanterns are glazed with dioptre glass instead of ground glass used in the railways. The dioptre glass keeps cleaner, permits more light to pass, and at the same time effectively breaks up the light, and prevents the abominable glare which I noticed as being common in America when I was there a few years ago, and which, I regret to say, offends my eyes in our own city where clear, or partly clear, globes are used.

The arc lanterns are on 35ft. poles, and are placed in the centres of the streets. An arc lamp is placed at each street intersection, and in the busy parts of the city one or two between, depending upon the distance. A small number of series incandescent lamps are used on the arc circuits to light small lanes and such like places in the area where the arc lamps are used for street lighting.

The incandescent street lamps are supported on long brackets attached to poles at the sides of the streets. Above these lamps enamelled iron reflectors are placed. These serve the purposes of throwing the light down and protecting the lamps and holders from the weather.

Each arc lamp is provided with an isolating switch, fixed to the lamp post which enables the lamp to be totally disconnected from the circuit. There is also a switch at each of the incandescent street lamps by which it can be extinguished if desired.

The transformers have isolating switches similar to those used with the arc lamps.

The arc lamps have the usual form of automatic cut-out, the action of which is dependent on the potential difference at the terminals of the lamp. The incandescent lamps are connected to the circuits through safety fuses which are mounted on the top of a special form of insulator, and, of course, are protected from the weather by a close-fitting cap.

The primary and secondary transformer fuses are mounted on the transformer frame in the usual manner.

The transformers for street lighting are almost all of one kW capacity and are mounted on the poles which carry the conductors. The transformer boxes are of circular form, and made of strong galvanised iron.

I think, before finishing my remarks about the distributing, it may not be uninteresting to touch on two questions which arose during the progress of this part of the work.

I had strongly recommended the Council to appoint as early as possible the engineer who should permanently have charge of the works, so that he might have the best opportunity of acquainting himself with the details of the machinery, etc., during erection and while in the contractor's hands. Shortly after the appointment was made I was honoured by a communication from the gentleman appointed, informing me that I had made an error in my calculations re the stresses to which some of the conductors would be subjected due to wind pressures, requesting me to look over my calculations, and after (as he said would be the case) assuring myself that they were wrong, have the requisite steps taken to rectify the work which had been improperly executed. As my young friend was kind enough to supply me with the data on which his computations were based, I checked the latter, and found that his conclusions were in agreement with his premises, that he had clearly assumed wind pressure to be at right angles to the direction of gravity, and had successfully determined the resultant of these two forces. But in mathematics the conclusions are no more accurate than the premises from which they are drawn, and an assumed horizontal component of wind pressure of 50 lbs per square foot lead to very absurd conclusions as to the stresses on the cables. That such wind pressures are given in some text books is well known, but engineers of experience know also that few structures around could stand against the force of such a pressure; and as Professor Kernot here and others elsewhere have pointed out, chimneys, omnibuses, railway carriages which could be overturned with less than half of this pressure, but are not, may be taken as conclusive evidence that the wind does not exercise anything like such a pressure as that assumed. Again, the shielding effect of buildings, trees, etc., and the disturbing effects of eddies was wholly ignored by the city electrician. I think several experts in Melbourne were appealed to by the Mayor, to whom his expert related his fears, and owing to my obstinate adherence to my own practice, and after considerable correspondence, the matter dropped.

Another point to which my attention was directed was the possibility of a condenser current partly lighting the street incandescent lamps. The gentleman who suggested the possibility of this was Mr. Stotherd, one of Messrs. Siemens Bros. engineers, a gentleman of skill and experience, so that any suggestion from him was entitled to careful consideration. His question, which was put in the modest way usual with men who have a solid grasp of their subject, was: would an appreciable effect be produced by the condenser action of the conductor used to control the street incandescent lamps?

The possibility had escaped my notice, but after consideration and consultation with Mr. Stone and others whom I had the opportunity of consulting, and with whom I endeavoured to determine a first degree of approximation the probable magnitude of the current through the lamps due to this cause, I did not anticipate that any appreciable effect would be produced.

It must not be forgotten that the inductance and capacity of such a system of conductors and transformers as that I am referring to, can only be roughly determined by calculation. I therefore endeavoured to err on the side that would give a larger current than the true one, and found that even then, in the worst case, the condenser current would not be sufficient to cause a single lamp filament to approach a red heat.

I may add, that at the completion of the work the practical test proved that the condenser current is in this case of no importance, and indeed the losses due to it are much less than those which would have taken place if the street lamps had been run from the same transformers that supplied the private lamps; for in that case the time required to turn on and extinguish the street lamps would have been considerable, and the all day "excitation losses of the transformers would have been increased. Although, as I have pointed out, a small loss of power in the day time with a plant such as we are considering is of no moment, it is evident that the system adopted effects an appreciable economy in the life of the incandescent lamps.

I do not think there is anything more connected with the machinery and the distribution of its output which I need trouble you with, unless it be to speak of the difficulties the contractors encountered in fixing the poles. A large number of holes for them had to be excavated in solid rock, and the poles then fixed in cement concrete. A large number more stand in a quagmire, where the question was not only how are we to fix the poles upright, but also how are we to prevent them sinking out of sight The very satisfactory appearance of the lines of poles shows that these difficulties were successfully overcome, but I know that the cost of over coming them, and placing the poles in position was more than the total amount of money named by Messrs. Henley and Co. for labour and fitting of the whole of the machinery, poles, leads, etc.

All that now remains for me to do there is to furnish a few figures, showing the cost of supplying the electrical energy to the distributing station.

I should say that, not withstanding the strenuous efforts made by those interested in discrediting electric light, it jumped into popularity at once, after the brilliant street illumination had proved its superiority to gas light, though Welshbach burners were used and every means taken to make the latter as efficient as it could be made.

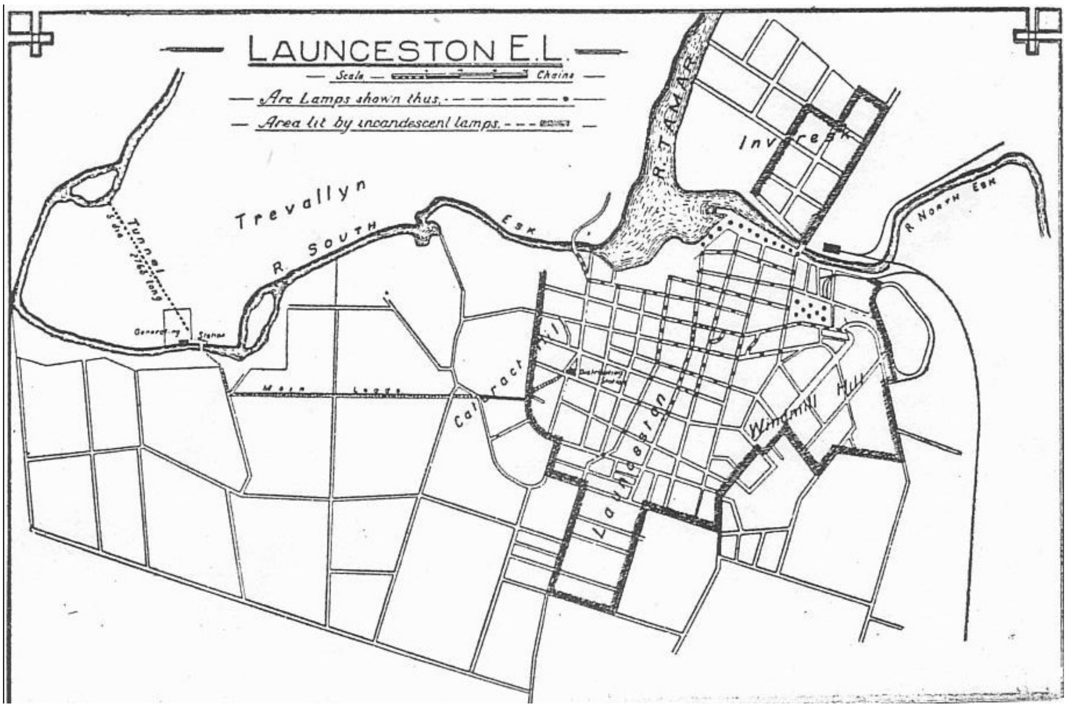
The City Council were embarrassed by the rapidity with which applications for private lighting came in. House fitting could not be done by those in the business quickly enough, and within a twelve-month of the turning on of current to the mains the Council found it needful to add to their alternating plant, and, as I mentioned before, Messrs. Siemens Bros. have been instructed to supply and fix two more Alternator sets similar to those placed, under their original contract. Being favoured with the cost of this addition to the plant, I am able to give not only the cost per horse-power at the distributing station for the energy now transmitted over the mains, but also of that which will be so transmitted after the addition of the two new units. I have also carefully, and upon the basis of past cost, gone into the question of what will be the cost per horse power at the Distributing Station when the full power of the water brought through the tunnel is carried to that station.

1. The cost of the whole water at generating station is £8 10s per horse power.
2. The cost of 490 h.p. (at present carried) at the distributing station is £60 per horse power.
3. The cost of 760 h.p., which includes out-put of old machines and that of the two new alternators, at the distributing station is £43 per horse power.
4. The cost at distributing station of 1560 h.p. (total of water passing through tunnel) is £32 per horse power.

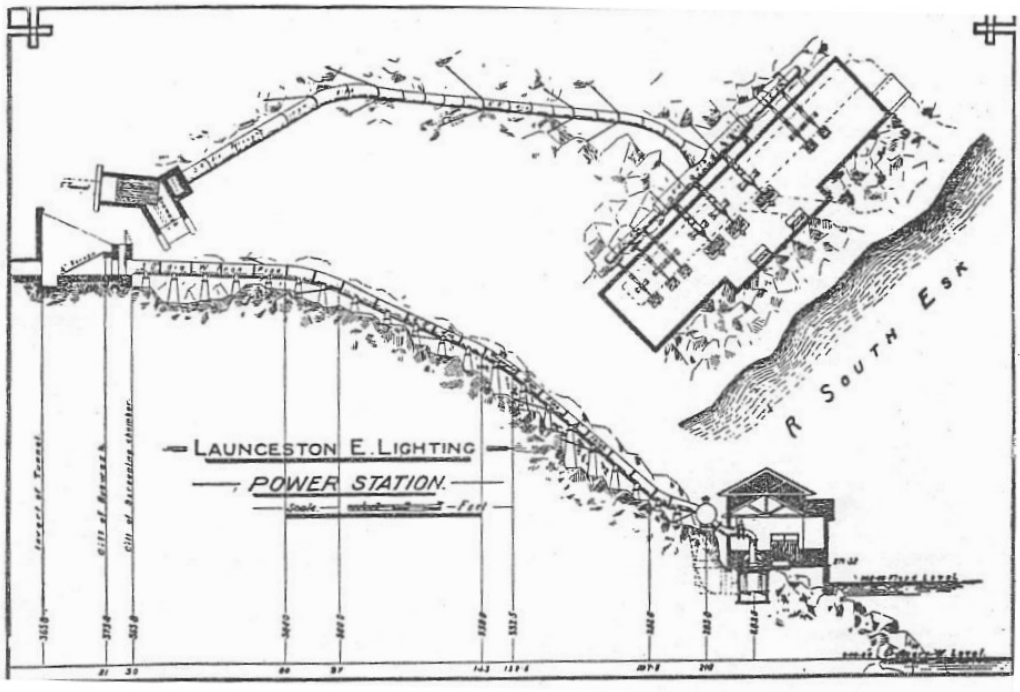
You will see Mr. President that I have not said a word as to the cost at which the electric energy can be profitably supplied at Launceston. That of course depends upon the skill and economy with which the works are managed.

I have thought it sufficient in this paper to give you the cost of the energy brought to the point from which it is distributed and to explain that the distribution has been effected with the greatest regard for economy of working.

The Council now supply at 6d per unit, and I am informed do so at a profit. If that is the case, then when the two new alternators are at work the profit will be considerable and will be still greater when the whole of the power brought to the outlet of the tunnel is being used. I may add that at present there is very little motor work done, but judging from the numerous enquiries about electric motors, that will soon increase, and with its increase there will be a corresponding addition to the profits of the works.



Duck Reach – layout of power scheme and street lighting.



Duck Reach Power Station, plan & section, 1895.

Discussion 1, 4 August 1897, on

ELECTRIC LIGHTING OF LAUNCESTON, TASMANIA

by K L Murray

Mr. H. V. Champion said with regard to the conditions of contract, no appeal was allowed from the decision of the Superintending Engineer on any point that might arise. In Melbourne there were varying conditions of contract under the different departments. The principal question was whether the engineer who designed and supervised the construction of works should be the sole arbitrator in claims made by the contractor. He thought it would be fairer if the contractor had the right of appeal to some other body. If the contractor were not satisfied, the claims should be settled by arbitration, one arbitrator appointed by the engineer and one by the contractor; and these two gentlemen to select an umpire. Expert gentlemen should constitute the Board. The engineer should decide matters during the progress of contract, and if the contractor was not satisfied he could appeal to the Board after its completion.

He was glad to see that local timber had been used. Regarding the tunnelling, he would like a little information as to how the difficulty of taking the last piece of the dead end out had been overcome. No information had been given as to the total cost of all the works. He understood it was £50,000. If so, was the undertaking likely to be a financial success. According to a report from the Gas Engineers' Institute of England, extensive progress had been made in Gas Lighting. Would the introduction of Electric Lighting in Launceston be financially a greater success than the construction of a gas system? Great improvements had been made in connection with the incandescent burner.

Mr. Gordon thought Mr. Murray meant that (and he thought properly so) the general design of the work was not to be interfered with. He agreed with Mr. Champion's remarks re the Superintending Engineer. If he was left as sole judge of any dispute that might arise, he was put in a difficult position sometimes; but at the same time there were some points in the reading of the specification which no one knew better than the Engineer himself, as he had drawn it up. For his own part he had had less trouble with the contractors themselves in general management of work than from outside interference. In municipal work one set of councillors generally supported the Engineer as a reasonable man whilst the other set went dead against him; that was where the trouble came in. It was a good plan where the work was not of too great a magnitude for the engineers of departments to take charge of and carry it out without contracting at all. Regarding the first scheme, at the time it was intended to bring the water down to the mouth of the river at a point not at all suitable for erecting the works (Picnic Rock). He had estimated for the Launceston Council that the power available was 1000 H.P., reckoning the turbine to give 75 per cent of the theoretical power. It had been proposed to take the whole quantity at the mouth of the river, except what was required for a mill lower down.

Mr. Thompson thought Mr. Champion's remarks with reference to the arbitration clause were very much to the point. It was desirable to have some clause whereby the contractor might be protected. If they had not such a clause the matters in dispute should be submitted to the Supreme Court. The expenses would be heavy, and contractors would not carry disputes there unless they had a just cause for arbitration. It seemed to him a very loose way to call for tenders for the distributing system without proper data being given such as giving the sizes of cables, etc.

Mr. Murray should be congratulated on the excellence of the paper which he had submitted, and Mr. David had given a very good account of the water works - clear, plain, and straightforward as became an engineer. The work at that part did not seem at all expensive. Mr. David mentioned the accuracy of the levels, and the alignments being demonstrated when they broke through. They were now so accustomed to tunnelling in Melbourne that little surprise need be felt at that. One good point was that the parts of the machinery were all interchangeable and easy of access for repair. He was rather surprised that everything in connection with the machinery was set out with such minuteness and so little trouble taken with the specifications for the distributing system. The distributing system was very important, and the engineer risked a great deal by setting out a scheme and ordering machinery without some data before him. The expenses attached to this scheme were very heavy indeed, taken in comparison with Melbourne.

He was of opinion that it would prove a “White Elephant" - not, perhaps, a large one, but still a “White Elephant." In Melbourne they used to pay £23,000 a year for gas lighting, and spent £90,000 to £100.000 in substituting electric light for gas, whereas in Launceston, with small population, they simply paid £1800 a year for gas lighting purposes, yet they spent £50,500 to £60,000 upon the scheme under consideration. Those figures spoke for themselves. If they had the motors, even with a water scheme, the consumption in the day would be light. The interest on the borrowed money would be £3000 per annum. Gas and electricity could go in a large city very well together, but could a city like Launceston support them both? This lighting would have been better had the water scheme been left out. The light itself was very good indeed and well up to the mark. It was hard on Messrs. Henley to he disqualified when sufficient particulars had not been given.

Mr. Champion asked with regard, to Mr. Gordon's remarks was it a fair way to look at it that the engineer should be the best man to interpret his own specification? If a dispute arose during the contract, the engineer could put the best construction on the meaning of the words to suit himself.

Mr. Turner regretted that fuller information had not been given as to the cost of the system. Assuming that it was deemed advisable to adopt electric lighting for Launceston, would it not have been better to have erected the generating station near the wharves and nearer the centre of the town and have used steam instead of water power. This would have saved the cost of the mains running from the generating station to the distributing station.

Roughly if a loan of £20,000 had been obtained and interest charged at 8 per cent; coal landed at Launceston at 10s per ton, about 600 h.p. could have been supplied almost in the centre of the town.

The President stated that this was a scheme for private as well as public lighting. The great power of the Launceston station was remarkable, 300 h.p. for the alternators, 5 smaller turbines, one for standby, 84 h.p. That gave about 400 h.p. turned into electricity; which was more than half that of the Melbourne City Council station. This station under review must be producing a great deal more lights than could be obtained for the £5,800 spoken of. In the company of which he was Chairman, they could work up to 1000 h.p.; that was their greatest output of electricity, or about 21 times that of Launceston; their revenue from that source was nearly £20,000 per annum. The consumption of electricity per inhabitant in Launceston seemed to be very high. The machinery was capable of turning out a good deal more than they were using at present. The application of electricity to motive power would not be very extensive, owing to the general adoption of alternating coils.

In New York the lifts were worked with electricity; that was not seen in Melbourne.

Discussion 2 on

ELECTRIC LIGHTING OF LAUNCESTON, TASMANIA

by K L Murray

Mr. W. Stone said: - After very briefly referring to the history of the Launceston Water Power Scheme, Mr. Murray directs our attention to the "Conditions of Contract" under which the work was carried out or rather to those clauses of the conditions which define the powers of the Superintending Engineer. The question which Mr. Murray has raised undoubtedly a difficult one and I think, in this as in many other cases, the surrounding circumstances very materially affect the answer which should be given. In Mr. Gordon's comments on this question he has touched on the vital point where he says “For his own part he had less trouble with the contractors themselves in general management of work than from outside interference. In municipal work one set of councillors generally supported the engineer as a reasonable man, whilst the other set were dead against him; that was where the trouble came in." It may at first appear strange that such a state of things is possible; however, when we remember Carlyle's remark about the inhabitants of the earth and recognise that the majority must be represented, our difficulty vanishes. Those of us who have followed the progress of the Launceston Lighting Scheme as detailed in the local daily papers, will experience no difficulty in understanding Mr. Murray's remarks, and will see at once that Mr. Gordon's statements *re* Municipal work held in this case.

The difficulty is not between the Superintending Engineer and Contractor, or even City Engineer, but between the Superintending Engineer and his employer viz the Council; a body possessing those peculiar characteristics to which Mr Dawbarn drew our attention a few months back here in Melbourne, when he said it possessed "neither a head to be punched nor a soul to be damned”. A body lacking these restraining members is not the most desirable of employers and the engineer who takes up work for such a body without amply protecting himself against what Mr. Murray calls the ignorant interference and I would add, too often interested interference, lays himself open to all sorts of trouble.

In cases such as that brought before us by Mr. Murray, where the employer is a corporation, the individual members constituting which may change from time to time during the progress of the work, thus probably introducing elements whose opinions or personal interests are at variance with those existing at the initiation of the work, it is clearly evident that the Superintending Engineer must occupy a position enabling him to act independently from his employer, so that there may be some guarantee of constancy of purpose until the work is completed. In cases such as this, conditions similar to those adopted by the Launceston Council are a great safeguard, as they enable the Engineer, if he be an honest man, to carry out his work in a manner which will be ultimately satisfactory to those who pay for it. The subject of "Conditions of Contract" is too large a one to receive more than a passing comment during the discussion on a paper such as that brought before us by Mr. Murray, bristling as it does with so many interesting and debatable points.

Turning now to the engineering aspect of the paper brought before us, the water power scheme first claims our attention. Whilst listening to Mr. Murray's paper I determined to make some comparisons between the actual cost of the present water power scheme, and the probable cost of an efficient steam power plant of equal output, and since hearing and read the very unfavourable comments on the adoption of the water power scheme by some of those who have so far taken part in the discussion I have been a little more careful to obtain correct data on which to base my estimate. Quite apart from its economic aspect, the Launceston water power scheme is an engineering work of no mean order and the very successful manner in which the whole was carried out reflects the greatest credit upon the Launceston City Engineer, Mr. St. John David.

From the first I have watched this scheme with considerable interest, due mainly to the fact that water power was to be utilised for driving the electrical machinery. In the colonies we have but few opportunities of examining different types of generating station and when a unique system such as that adopted for Launceston is started it should be regarded as an object lesson well worthy of our attention. I, therefore, made it my business to visit Launceston several times during the progress of the contract, and the very interesting nature of the works which I had the opportunity of examining well repaid me for the trouble. When an engineer is called upon to report on the practicability of a proposal such as on which Mr. Murray was asked report, he will - if he does his duty - look fully into the financial aspect the question, and not simply regard it from an engineering standpoint. He will remember that the most important factors in the problem before him must be expressed in terms of £.s.d.

If the very disparaging remarks so freely expressed at our previous meeting, when we were told that the scheme was a “white elephant", and further “that it would have been better if the water scheme had been left out" are justifiable, it is evident that one of two things has occurred - Mr Murray must either have failed to place sufficient importance on the £.s.d. factors, or he must have erred in his calculations concerning them. I have, therefore looked into the water-power scheme, keeping in remembrance the purpose for which it is required, and have compared it with a steam-power plant of equal output, working approximately under the conditions that obtain at Launceston. In the first place I have compared the actual present cost of the water at the turbine stop-valves with the calculated cost of steam at steam engine stop-valves. I have assumed that the maximum power that can be utilised by the present plant is 400 H.P., thus leaving only one alternator and one arc lamp as spares.

I have considered that the cost of the water-power is made up of the following items, viz., interest on the total cost of the whole water-power scheme up to the turbine stop-valves, and upkeep on plant at suitable rates on the different classes of works up to the same point. I have considered that the cost of steam power is made up is follows :-Cost of fuel, wages of firemen, interest on capital, and upkeep on plant, the different classes being charged at different rates. In neither case have I allowed anything for supervision, as I consider that this would be done by the engineer in charge of either plant, and would be sensibly equal for both, the charge under this heading being small as the engineer's time would be mainly occupied with the running machinery and distributing plant. I have then considered the fact that the water-power plant necessarily removed the generating station to a considerable distance from the city, thus increasing the cost, of transmission of current; and, finally, the relative cost of water and steam motors. As I am desirous of putting the steam plant in the most favourable light, I shall for the present purpose assume that it can be located close to the river, so that the water for condensing purposes may be had for the cost of pumping, which includes of course, the interest and upkeep of pumping plant. This location, also favourable for coal delivery, which I shall assume is direct into the coal bunkers of the boiler-house without handling. Again, as the steam plant is to be compared to first-class permanent water-power scheme, the whole work must be carried out in a manner which will enable steam to be produced at the lowest annual rate for all time. This means that the steam-producing plant must be thoroughly substantial, and every attention must be paid to the economical working. As the plant is required for a 24 -hour service, although the day load will be small, every precaution must be taken to prevent the loss of heat by radiation. I shall, therefore, assume that the boiler-house, stacks, flues, and boiler fittings are of brick; that a fuel economiser, such as Green's, is employed; that surface condensers are used, and the feed water is obtained from the hot well. I shall not assume that mechanical stokers are employed as with such a small plant little if any labour would be saved and mechanical stokers are not yet regarded as an integral part of boiler house equipment in the colonies. The worst case that we have to consider is a comparison of the annual cost per h.p. of the water power actually used for the present plant assuming, for the time being, that no extensions are to be made, and that the whole cost of the water scheme has to be charged against the 400 brake H.P. now utilised.

For the purpose of this comparison we shall assume that high class compound condensing engines taking steam at 160 pounds per square inch are employed, such engines of the dimensions required would do well if they developed 1 brake H.P. per 20 lbs of steam for the all day load. If the steam plant is not worked too hard during the period of maximum output we may expect 10lbs of steam per pound of coal from the above plant as the all day evaporation or 2 lbs of coal will be required per brake H. P. hour. If we assume three (3) boilers to be installed, two (2) working and one spare,
the total maximum evaporation required per hour is 400 x 20=-8000 lbs. The economical evaporation from each boiler must therefore be 4000lbs per hour. If Lancashire boilers are employed we should require three (3) say 28' x 6'6" with 2'6" flues. The capital cost of such a plant would be approximately:-

3 boilers at £450	£1350 0 0
160 pipe, economiser	350 0 0
2 feed pumps at £25	50 0 0
Boiler house, bunkers, brick stack, flues, &c	2500 0 0
Steam and Water Pipes, &c.	220 0 0
	£4470 0 0

The cost of maintenance of such a steam plant would be approximately

Interest on Capital £4470 at 4 per cent	£178 16 0
Upkeep on boilers £1350 at 6 per cent	81 0 0
Upkeep on Economiser, £350 at 7 percent.	24 10 0
Upkeep on Buildings. Flues, &c., £2500 at 2 per cent	50 0 0
Three (3) fireman at 8/- per day	438 0 0
Fuel consumption taken equal to 6 hours at full load 782 tons at 14/-	547 0 0
Water	Nil
Oil, waste, firing tools, firebricks, fire bars &c is	13 0 0
	£1348 6 0

The. cost of the water power plant as given by Mr. David up to the turbine connections is:

Tunnel and extraneous works	£13225 0 0
Pipe work	1730 0 0
	£14955 0 0

The maintenance of the water power scheme will therefore be :

Interest on Capital £14955 at 4 per cent.	£598 4 0
Upkeep on cost of lining tunnel, £700 at 3 per cent	21 0 0
Intake and Outlet £1392 at 4 percent	55 14 0
Pipe work £1730 at 6 per cent	103 16 0
	£778 14 0

Thus it will be seen that even if the whole cost of the water power scheme (which is as far as the tunnel works are concerned capable of supplying about four times the power at present utilised) is charged against the present output from the generating station that we have the cost of steam at the engine stop valves £1343 6s and water at the turbine stop valves £778 14s per annum. These are the costs at the points where the power is generated and the cost of water is seen to be but 58 per cent of the cost of steam and the annual difference in the cost is £564 12s. As, however, the water power plant is situated at a considerable distance from the city, the cost of transmitting this power to a point as favourably situated for distribution as the position of the steam plant must he added to the cost of the water power just obtained. The cost of transmission consists of the following items: -Interest and upkeep on poles and cables and all fittings required to carry the cables from the generating station to she distributing point, and the cost of the power which is lost between the generating station and the point of distribution. To this must be added, the increased cost of carriage of stores to the generating station. The capital involved in transmitting the power from the generating station to the city I estimate at £3000 and the annual cost as follows:

Interest on £3000 at 4 per cent.	£120
Upkeep on £2200 at 5 per cent.	110
Upkeep on £800 at 10 per cent.	80
Cost of power lost 3 per cent of annual cost of machines	20
Carriage of stores, say	25
Interest and upkeep on bridge over river	40
	£395

Thus we see that to the cost of water power at the turbine stop valves we must add a further sum of £395, which represents the annual cost of transmitting this power into the city, and the total cost of the water power is therefore £778 14s. + £395 = £1173 14s as against £1343 6s for steam generated at an equally convenient point for distribution, and having the water facilities previously mentioned.

That is, the cost of steam, though produced by a plant which is designed to be economical, and has no unnecessary spares, is greater by over 14 per cent than the cost of water, even though the whole cost of the present scheme be charged against the 400 H.P. which we have considered. It will be noticed I have not charged the cost of the condensing plant against the capital cost of steam production, although, strictly speaking it should be so charged, and the cost of upkeep and running should be added to the annual cost of the steam power at the engine stop valve. We may, if we choose, regard these items as charges against the prime movers or machines which convert the energy of the steam into a useful form. In the same way the tail race and draft pipes may be regarded as belonging to the water motors. In the above comparison I have endeavoured to give the steam plant every possible advantage. The fuel consumption taken as equal to 6 hours per day at full load is very low when it is remembered that this covers everything, including lighting up, driving feed pumps, etc. It may be argued, and correctly so, that as the day load on the steam plant increases the cost of producing does not go up in proportion, that practically the only item affected to a material extent is the fuel, and even this does not increase directly as the output, for the all day losses are necessarily included in the previous estimate and are not affected by the increased output. The same line of argument, however, holds in the case of the water power plant, for there is practically no difference in the cost per annum so far as the water is concerned, whether the power be used for one or twenty-four hours per day. The wear on the tunnel invert is the same, for the water which is not utilised simply runs over the bye-wash and the upkeep of the iron pipes and pole line can be taken as constant. Thus it will be seen that the greater the number of hours per diem that the power is required the more favourably does the water scheme stand out when compared with steam. Again, as soon as the maximum demand increases, the difference in favour of the water power scheme increases in a greater ratio.

The present water power scheme provides for 900 brake H.P. at the turbine shafts, and therefore the cost of the water will not be increased until this limit is exceeded at the time of maximum demand. But, of course, we must add to the cost of the water, the cost of transmitting the power to the city, and as this will necessitate additional cables being erected, it is evident that the cost of transmission will be increased, though, as additional poles would not be required, the cost of transmission will not increase as rapidly as the power transmitted. Before passing on from the consideration of the relative cost of steam and water power, there are one or two other items which should not be overlooked. The cost of the prime movers is an important item in every power station, and in the case before us we must compare the annual cost of the turbines, draft tubes, and tail race, with the annual cost of engines and condensers.

The cost of the 8 turbines (including spares) was	£2600
Draft tubes, etc	150
Tail race	220
	£2970

The cost of 8 Willans Engines of output same as turbine	£3540
Surface condensers for same, including circulating and air pumps and pipe work	320
	£3860

Thus we, see that the vortex turbines when compared with Willans engines cost 23 per cent less.

But it is evident that, attendance and upkeep charges are even more important. Of course, different types of turbines and engines might be compared, and each individual engineer will have, his own opinions concerning their relative merits. For this reason I have thought it better to make the comparison between the cost of steam and water, and have not included the motors and necessary adjuncts in either case, as the types of either selected depends on the taste of the engineer. The above comparisons of the cost of Willans engines and Thomson turbines simply indicates the bearing of the principal items on the final cost.

Turning to the electrical part of the paper Mr. Murray first directs our attention to the arc lighters. These machines are of interest, as they are the first of this type in use out here, so far as I know. I had a good opportunity of examining these machines, and was very pleased with their general design. They are compact, and a thoroughly good and solid job, and appear to be well made throughout. The only point about these machines which seems open to objection is the very large commutator, which must be costly to renew. Of course, whether this is an objectionable point or not depends entirely on its life and this again in all probability depends mainly on the skill and attention bestowed on it by the dynamo attendant. Whenever I saw these machines running they appeared to be working well, with very little sparking at the commutator, and the current was maintained fairly constant by the automatic regulator, though as the load was not varied during my presence I cannot say whether its action is satisfactory under such conditions.

Mr. Murray calls our attention to the suitability of these machines for series arc lighting in cities where overhead wiring is adopted and telephones are employed. The almost perfect constancy of the current produced by machines of this type makes it difficult to understand why machines which produce fluctuating currents, such as the Brush and Thomson-Houston, are permitted for city lighting, unless with the restriction that concentric conductors be employed in all streets containing telephone wires. The old idea that the Gramme form of commutator could not be used for machines producing considerable potential differences has long since been shown to be without foundation, and the excellent machines turned by Woods, Crompton, Siemens and others have proved that the Gramme type of commutator is well suited for such work when carefully made and good materials are employed. Again, the constant current machines are more efficient, and run with much less noise than some of those of the open coil type, two features which are appreciated by central station engineers. It would be interesting to hear later on from Mr. Murray - or, possibly, Mr. St. John David, who is now a member of this Institute - how these machines fulfil the requirements of central station work.

The alternators and exciters are very nice machines, and are well constructed and finished throughout. They are mounted on high bed-plates, which bring the exciters and other parts requiring manipulation to a convenient height. As Mr. Murray says, these machines are so well known (although, I think, the Launceston alternators are the only representatives of this make in Australia) that they seem to call for no comment; the chief feature of interest to Melbourne engineers consists of the disc armature. The types of alternators usually employed in Melbourne central stations have either running fields or drum armature.

The switchboards are neat, and in the main are well arranged, though, I think, the alternator board should have been arranged for separate as well as parallel running. Possibly it is so, but Mr. Murray has not spoken definitely on this point, and I do not remember the details of its construction. The exciter and field regulating gear is exceedingly neat, and conveniently arranged for operating the resistances either singly or together.

The distributing system adopted for Launceston, a description of which occupies a considerable portion of Mr. Murray's paper, has suffered some rather adverse criticism at the hands of Mr. R. 0. Thompson. When I had the opportunity of looking over this part of the Launceston scheme, I was struck by the exceedingly workmanlike manner in which it was carried out. I do not think there is anywhere in Victoria a sample of city wiring to be compared with that which I saw in Launceston. I was therefore much surprised at Mr. Thompson's unfavourable comments, for he tells us that “everything in connection with the machinery was set out with such minuteness and so little trouble was taken with the specifications for the distributing system, &c." There is nothing in the finished work to indicate such neglect, and I have carefully looked over a copy of the specifications for the Launceston Electric Lighting and must say that my opinion regarding it is diametrically opposed to Mr. Thompson's. I find that the clauses dealing with the distributing system occupy fully 2½ times as much space as those dealing with the generating plant, and that whereas the clauses dealing with the generating plant are left as open as possible, those dealing with the distributing system are much more complete, and where necessary detailed dimensions are given and the tenderer is instructed to supply samples of such minor fittings as it was practicable to submit for examination.

Again, though not referred to in the printed statement of Mr. R. 0. Thompson's contribution to the discussion, I have no doubt but that it is still fresh in the memory of many, that he severely criticised Mr. Murray's action in altering the system of distribution to be employed at the last minute. Here again I cannot agree with Mr. Thompson. When one has made up his mind to adopt a certain system after carefully considering the conditions of supply, nothing is easier than to carry out that system regardless of any altered circumstances which may arise. I fully agree with Mr. Murray that the transformer substation system of distribution would be the most suitable and economical for an old established city like Launceston with possibly the addition of the distributed transformer system in the outskirts or more recently formed and growing suburbs.

But it is evident that some reasonable idea of the probable requirements of the different districts to be served must be obtained before finally determining the dimensions of the conductors to be put down, unless the Corporation is prepared to expend a considerable sum on copper for which it will get no immediate return. Mr. Murray tells us that the City authorities promised to supply him with the approximate data as to the probable demand by the different districts. But as the City authorities chose to spend their energies in quarrelling amongst themselves, and neglected to fulfil their promise, nothing would have been easier for Mr. Murray than to carry out the work to the plans which he had already prepared effecting the distribution in accordance with his own judgment. He tells us that rather than run the risk of incurring useless expenditure on copper, he discarded his original plans and went to the trouble and expense of preparing fresh plans on a system which he knew could be carried out and extended as the demand arose. For my own part I think Mr. Murray should be complimented for the zeal he has shown in considering a Corporation from whom in return he has received such scant courtesy. When we consider the circumstances under which Mr.

Murray had to prepare his new scheme and plans, and remember that the contractors were worrying him for plans and details, we should not be surprised if the scheme as adopted gave some evidences of hurry. I have carefully looked over the interesting description of the distributing system as given in Mr. Murray's paper and fail to find evidence of any such hurry. In all points, economy, efficiency and suitability to the required ends seem to have received careful consideration. The arrangement of the incandescence circuits permitting of the control of municipal lamps from the distributing station, whilst at the same time giving a twenty-four hour service to private consumers, is simple and apparently effective. The arrangement of the wiring is, as pointed out, economical, both as regards first cost and subsequent maintenance. The distribution of the high tension wires with a view to minimising fire risks and preventing: the unsightly appearance of heavily wired poles is good, and as I have previously remarked, the distributing system as I last saw it during the six months run by the contractor will compare favourably with any in Victoria.

So far as I can see there is nothing, either in the specification, or in the execution of the work, to suggest that it has not received the careful attention of the Superintending Engineer. With regard to the actual lighting of the city I think there can be but one opinion, and on this point I am, pleased to say I can endorse Mr. Thompson's remarks. The distribution of the light is good, the position and distances of, the lamps do not appear to have been settled by a draughtsman in his office, but it is evident to anyone who has walked through the city and suburbs at night that the disposition of the lamps has been effected with a due regard to local requirements. The arc lighting is especially good. I do not mean that there is a great blaze of light, but rather the reverse; the subdued light as broken up by the dioptric glass in the large lanterns is a pleasant change to those of us who are used to the glare of the practically bare arcs used so largely in Melbourne.

Mr. Murray seems to have given, some consideration to the physiological, and perhaps too pathological, aspect of the question, and Launceston has decidedly gained thereby, the only points in connection with the distributing system which I did not like was the form and arrangement of the pole transformers. They, to say the least of it, are not artistic. The concluding paragraphs of Mr. Murray's description of the distributing system tell us that the monotony even of a prosaic engineering job like that is sometimes relieved by amusing incidents. To those of us in Melbourne who have repeatedly had the subject of wind pressure in its relation to engineering brought before us by our President, Professor Kernot, and others, it is bard to believe that Mr. Murray's correspondent was writing in earnest, especially when we remember that he, could so easily have determined whether his premises were sound by applying the same process of calculation to other structures which have withstood the severest storms in Launceston for many years.

Mr. Murray concludes by giving some figures relating to the capital cost per H.P. delivered at the distributing station. These figures must, of course be largely, hypothetical, as it is evident that the cost per H. P. at the distributing , station is very materially affected by the dimensions of the generators at the water power station, and the pressure at which the energy is transmitted to the point of transformation or distribution. Again, current required be continuous or alternating and the purpose for which it is required must be considered in determining the cost per H.P at the distributing station. Mr. Murray's figures appeared to have been attained on the assumption that the present unit of plant and voltage will be retained for the extensions, both of which assumptions are, I think highly improbable.

The next large increase in power required to be delivered in the city will probably be for an electric tram service. If this be so the question of dimensions of new generators and pressure of transmission will have to be carefully reconsidered and in all probability the cost will be reduced considerably below that given by Mr. Murray. The capital cost of the water power plant up to the turbine stop valves per effective H.P at the turbine spindles is as follows:

		Per H P
Present 400 H.P	£14,955 / 400	£37 8 0
When the authorised increase of 2 alternators is completed	£ 14, 9155 / 806	£18 15 0
When 900 H.P for which pipes are designed are utilised	£14.955 / 900	£16 12 0
When 1560 H.P. or total from tunnel is required	£16,255 / 1560	£10 10. 0

That the City of Launceston is fortunate in being the possessor of a water power scheme of such magnitude and so favourably situated must, I think, be admitted by all who are familiar with this subject. It does not, of course, necessarily follow that the whole - even the larger par - will be utilised in the immediate future, or that if utilised any material benefit will accrue to the ratepayers.

The ultimate financial success or failure of the scheme will largely depend on those who hold the reins at the time when new works are initiated, and on the ability and integrity of the engineer under whose supervision they may be designed and carried out. The present financial success, or otherwise, of the lighting scheme in like manner depends on those in charge. That Mr. Murray recognised this is evident from his concluding remarks. In either case I think the engineers who designed and carried out this scheme can give a good account of themselves, and point to schemes less favourably arranged which are a financial success.

Mr. J.T. V. Anderson said with regard to the waterworks portion, he was present in 1893 when the work was being carried out, and he had an opportunity of judging of the hardness of the rock, and what the tunnelling ought to have cost. It was not harder than the millstone grits in Lancashire. The cost of the tunnelling under review was in excess of that of the Manchester Waterworks Tunnel. This could not be entirely attributed to the higher rate of wages prevailing here - as compared with England - 10d. and 1s. 2d. per hour being paid at home for men in the face, which was as high as was paid here.

The millstone grits were generally as tough to drive through as any in the world. The basaltic rock at Launceston should not be more difficult, but the prices were almost double. The price for concrete was double that paid in Manchester. The tunnels there were 7' 6" internal dimensions, and of course in Launceston the men would be more cramped. From 24s to 44s per cubic yard was the rate in Lancashire with tunnels ¼ mile to 1 mile and, in shorter tunnels, averaging 300 yards between shifts the price ranged from 25s to 30s per. cubic yard. Making due allowance for the difference in the price of labour, that would equal about 50s here. The prices quoted for concrete in the paper under review were from 50s to £7 per cubic yard. He thought the average should have been 50s.

It had been shown that the cost, per horse-power was less than obtained in most water supplies. The fact should be remembered that this place was very favourably situated for obtaining good results. It would be interesting to know what the cost was on the basis of electrical horse-power. It seemed to him that the cost of steam and the present system would about balance. Assuming steam and water to be equally good the preference should be given to the latter; in the case of coal strikes, etc., there would be no danger of the water scheme failing.

Mr. Fyvie asked if the turbines had been tested as to their efficiency and did the results give an all round efficiency of 75 degrees. Some turbines gave a high result up to a certain power, and, when they went beyond it, fell off very much. Any turbine that would give out 75 per cent, distributed over a large variation in the power from 25 per cent to its maximum would be most remarkable.

The President was by no means clear as to why the station was put so far from Launceston The longitudinal section showed that the present generating station was at a height of 262' above sea level. As the first basin at Launceston could not be more than 20' above sea level, it would seem that there was something like 240' of level between the outlet race of the present station, and what was known as the first basin. Could not that 240' have been utilised? He was of opinion that the generating station should have been brought down to the first basin where there was much more level ground and a more accessible place than the present site. That would have brought it a mile nearer Launceston. As it was, there was a possibility of putting a water scheme between the present one and Launceston. With regard to the question of driving the tunnel, it seemed somewhat risky to judge the cost of a tunnel half a mile long by the cost of one a yard long! It worked out all right, but different classes of rock were not infrequently met with in tunnelling; some portions were exceptionally difficult, while others might be comparatively easy. He (Prof. Kernot) would have tried a deeper drive. The actual tunnel was made on a grade of 1 in 110, and reference was made in the paper to the high velocity which might appear to be open to question. Was there not a “velocity bogey"? Was there not a good deal of unnecessary alarm about the fact of water running at a high velocity in contact with many materials. Water seemed in some cases to have much less effect than was anticipated. In the Coliban scheme there were concrete channels of 1 in 5. These had been in use for many years and had stood well.

Regarding the alternators: They were nice looking machines, but when examining them he thought they looked rather delicate, but he was told that they worked well. The alternators used in Melbourne looked more massive. Re the arc dynamos: He agreed with Mr Stone's remarks. The dynamos referred to gave an almost perfectly uniform current, and should he preferred to the coil dynamos where telephones were in use. He had been told that the arc switch board on the plug and flexible cord system worked very well, but it had the appearance of a "make shift". He liked the solid metallic switch board. He agreed with Mr. Stone that the lighting of the streets was a remarkable improvement on Melbourne.

The dioptric glass in the lamps toned down the glare of the lights and spread the illumination over a greater area. In Sydney Road (Melbourne) the lamps threw huge circles of shadow on the ground, and when it was windy the effect was much worse. In fact he was surprised that no accidents were reported from horses becoming terrified. The "wind bogey" was a worse one than the “water velocity bogey". 50lbs. per sq. foot had somehow got into the text books, and some authorities would design for nothing less. Broad gauge railway trains would blow over with half that pressure and narrow gauge trains with considerably less; and, on the other hand, some time ago, before the Railways Standing Committee, he had been roughly referred to as an alarmist, because he expressed some misgiving as to safety railway carriages which would blow over at 10 lbs per sq. in. On the subject of wind pressure some people were extremely mad. If a wire were to blow down, it could be put up again without much trouble. It would not kill anyone unless they interfered with it. He congratulated members on the excellent discussion which had taken place on Mr. Murray's paper, and regretted that Mr. Murray was unable to be present.

Abstract published in Trans ICE Vol CLXVIII pp 434-5

Launceston Hydraulic Power-Station.

A. Martinek and A. Lauri.

(Elektrotechnische Zeitschrift, Berlin, 19 July, 1906, pp. 672-7.)

This installation in Tasmania consists of five 500 HP. turbines direct-coupled to 400 kilowatt three-phase generators running at 500 revolutions per minute, and giving 5,200 volts with a frequency of 50 cycles.

The power-station is about 3 miles from the town itself, and is situated near the River Esk, from which the water is taken, first through a tunnel cut in the rock 850 metres (2,788 feet) long, and then through two riveted iron pipe-lines, each 62 metres (203 feet) long, 1.5 metre (4 feet 11 inches) in diameter at the top, and 1.2 metre (3 feet 11 1/4 inches) in diameter at the bottom, to the main turbine supply-pipe, which is 1.85 metre (6 feet 1 inch) in diameter, and runs along the back of the power-house.

Each turbine takes about 1,400 litres (49.4 cubic feet) of water per second under a total available head of 34.5 metres (113 feet). The speed is controlled by a sensitive governor acting on the turbine guide-blades through a hydraulic servomotor-cylinder, and a system of levers.

By means of a small electric motor acting on the governor-spindle through worm-gear, the speed of the turbines can be regulated from the switchboard.

The high-tension overhead power-line to the distributing transformer-station in the town is about 5 kilometres (3.1 miles) long, and is supported on porcelain insulators fixed to iron standards. The Esk Valley or Canyon being 90 metres (295 feet) wide at the point where the transmission-line crosses it, and it being impracticable to build a tower in the middle of the river, a wire cable made of silicon bronze, having a specially high tensile strength of 61.1 kilograms per square millimetre (87,000 lbs. per square inch) and of 45.36 square millimetres (0.07 square inch) section was stretched between two strong iron towers on extra heavy insulators. The power station being in a very inaccessible place for vehicular traffic, a special wire ropeway was built over the river for the transport of machinery and goods, while a light suspension-bridge served for foot passengers.

The overall efficiency of the plant at the official trials was found to be 75.2 per cent at full load, the turbine and generator efficiencies being 80 and 94 per cent respectively.

The article is accompanied by a number of illustrations and diagrams.

C. J. G.

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ELECTRIC LIGHTING

Henry Button

Launceston has become famous for its municipal electric lighting works, for the artificial public illumination of the whole city and its suburbs are exclusively electrical. For many years the idea has been mooted, the proximity of great water power naturally suggesting its employment for this purpose. As the South Esk leaped and swirled through miles of its rocky channel, in winter and spring swollen to a torrent that was often appalling, the thought instinctively arose, why should this immense force run to waste; why not apply it to generate electricity? I say, it was quite natural that this idea should have occurred to casual beholders, and because it was not so employed they were apt to impute to men in official positions remissness or timidity. They noted only one factor in the undertaking: they saw the potentiality in the stream, but they did not take account of the cost of harnessing it to work. In our case this aspect of the question, including tunnel, dams, pipes, fixing, &c., but not including turbines, amounted roundly to nearly £15,000. The Municipal Council of the time was simply cautious. It was assumed that the project must necessarily involve an immense outlay, and it prudently proposed to wait until population should so increase that the inevitable burden would fall more lightly upon each burgess. Moreover, electric lighting was then, and indeed still is, in the experimental stage, and the council felt that the improvements that were of almost daily occurrence, both in the cost of generating and in applying electricity, would amply compensate the city for waiting.

The first practical step taken by the Launceston Municipal Council with the object of ultimately supplying the city with electric light was to obtain an act of Parliament for the purpose. This was passed in December 1887. Although the act provided for the generating and distribution of the current, its main feature was to secure to the Council the right to use the water of the South Esk for this object, which right was to continue for three years. At that time I was a member of the Council, and we felt compelled to take this action to prevent speculators seeking, and possibly obtaining, from Parliament the rights in question, which would then become a marketable commodity for which the burgesses would have to pay. I should have been better pleased had the limit been ten years instead of three; but it was plausibly said by eager company-mongers, if the Council will not undertake the work, why should the burgesses be deprived of the boon? This argument had some weight in Parliament, where a sounder view might have been expected, for the interests of the people should always receive first consideration. In November, 1890 (in the interval I had retired from the Council), a short act was passed extending the option for two years from 1st January, 1891, within which time the Council was bound to commence operations in a *bona fide* manner, or both acts “shall cease and determine”. Under such coercive legislation the work had to be started much earlier than otherwise would have been the case. The result has shown that it might have been for ten years with advantage.

Without attempting to describe the various steps that led up to the scheme finally adopted, it is sufficient to say that towards the close of 1890 the City Surveyor, Mr. Fitzherbert, was instructed to survey and report on the South Esk. As the result of this enquiry he submitted three alternative plans, one of which, with considerable alterations, was adopted. In June of the following year Mr. K.L. Murray, M.Inst.E.E., of Melbourne, was invited to prepare a scheme upon which definite action could be taken. He came to Launceston to procure full information, and in November submitted a report, estimating the cost of the water scheme at £11,000, buildings £2000, and the electrical plant £29,000. Mr. Murray’s report also included, although as a separate feature, a scheme for electric trams, amounting to £35,200, but this was not deemed necessary at that time.

In March 1892, Mr. C. St. John David was appointed City Surveyor in succession to Mr. Fitzherbert, who had died some months previously. The electric lighting scheme was submitted to Mr. David, and he set to work on the permanent surveys. Whilst thus engaged it occurred to him that a tunnel through the hill (so cutting off a bend in the river) would be in every way better than taking a line of pipes down the gorge, where they would always be exposed to damage from falling rocks and timber. On examination the idea was found to be quite practicable, and it was adopted. The cost of this altered scheme, including dams (as the river bifurcates here and forms an island) and other attendant works was estimated at £13,169. The dams and a race to the mouth of the tunnel were constructed under Mr. David's personal supervision at a cost of £1312. A poll of the citizens had been taken in compliance with the act, resulting in a larger majority than that required in favour of the project. Mr. Murray had also been appointed consulting engineer. Messrs. O'Neill Bros. & Rodgers, of Sydney, had the contract for driving the tunnel at £11,921. From intake to outlet above the Power-house it is 921 yards long by five feet diameter, and is pierced through almost solid diorite. It was started simultaneously from both ends, and when at the expiration of sixteen months' actual working time the drives connected, the discrepancy in the levels was found to be less than one inch. The head of water thus obtained is 110 feet, giving 1560 horse-power, only one-fourth of which was needed at first. Why that spot was chosen for the Power Station, instead of a site lower down the river, where an additional fall of more than a hundred feet could have been obtained, I never understood, unless it was to avoid possible interference with Mr. Ritchie's right to water for his mill. When the increased power is needed, as is inevitable, the error will have to be remedied. The total cost of this part of the scheme was £13,233, being only £64 in advance of the estimate.

The Power-house, or Generating Station, is built on the river bank, rather more than a mile above the First Basin, and was erected by Mr. J.T.Farmilo, of Launceston, for £1838. Seventy-five tons of wrought iron pipes, ranging in size from five feet to twelve inches diameter, were supplied and fixed, besides other work, by Mr. W.H.Knight, of Launceston, at £1730. The Distributing Station, at the extreme southern end of Bourke Street, was erected by Messrs. J & T Gunn, also of Launceston for £364. This station has since been removed to a more central and convenient building fronting on Cameron Street, adjoining the Mechanics' Institute. In December, 1892, Mr. Murray was requested to prepare plans, specifications, &c. for the supply, erection, and working for six months of all the necessary machinery for carrying out the electric lighting scheme. This was done, and tenders were invited in the Australasian Colonies, England, and America. In due time four tenders were received, viz., from Siemens Bros. & Co., W.T.Henley's Company, Brush E.E. Co., and Electric Construction Co. These were referred to Mr. Murray, and on his recommendation the tender of the first named firm was accepted at £32,021 15s. No time was lost in getting to work, but unexpected causes of delay occurred which prevented the contract period from being observed, and it was not until 10th December, 1895, that the energy from the dynamos was turned into the arc lamp circuits, and Launceston rejoiced in first class electric illumination.

The difficulty of getting to the Generating Station from the city, which is much greater on the northern side of the river than on the southern side, induced the Council to construct a suspension bridge across the Gorge just below the station. The bridge was designed and erected by the City Surveyor. It has a span of 184 feet, it is three feet wide, is a light and graceful structure, and cost £310. The Salisbury Foundry Company were the contractors.

The six months during which Siemens & Co. had to maintain the works, expired in August, 1896, when the plant was taken over by the Corporation. Up to that date the expenditure on the electric light scheme totalled nearly £70,000. Since then the single-phase scheme has been changed to the three-phase system, which is said to be greatly superior, especially where the same current has to be utilised for light and power. The transformation cost a large amount, bringing up the total expenditure to the end of 1906 to £161,364. In the latter sum are included the materials of all classes on hand, and also the discarded electric plant, which represents about £22,000, though perhaps it would not sell for one-fourth of that amount. Mr. Murray's original estimate for the project had been £42,000 and the act of Parliament (51 Vict. No.43) authorised the Council to borrow £50,000. Since then Parliament has passed four additional loans acts- two for £25,000 each, and two for £30,000 each, making a total of £160,000,- so insidiously yet so inexorably does expenditure on works of this character creep-or jump-upwards. The revenue is improving, but it will probably be years before the undertaking will be entirely self-supporting.

And now in simple justice I must add that amongst all the advocates of the electric light for Launceston, the one whose energy, perseverance, and unbounded faith contributed most to its accomplishment, was unquestionably the late Mr.S.J.Sutton, at one time member of the House of Assembly for this city, and its Mayor for three years in succession.

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EFFICIENCY TESTS OF A HYDRO-ELECTRIC PLANT, WITH OBSERVATIONS UPON THE WATER-POWER OF TASMANIA (Abridged)

William Corin, M. Inst. C.E

The tests described in the present Paper were made to determine the efficiency of four 300-kilowatt hydraulic turbo-generators, supplying three-phase current for light and power to the City of Launceston, Tasmania. A certain amount of historical and descriptive matter prefaces the main subject, and the Paper closes with a general reference to the water-power of Tasmania.

RIVER SYSTEM FORMING THE SOURCE OF POWER

The hydro-electric works from which the power for the electric supply of Launceston is derived are situated some 2 miles from the city on the South Esk River, which drains the central portions of the northern end of the island. The catchment area, outlined by hatching in Fig.1, Plate 8, is about 3,500 square miles in extent. Of the contributing streams the most easterly is the South Esk, which takes its rise in Ben Lomond, a mountain range 8 miles long, on the top of which there are several small lakes. The northern summit of this range has been established as probably the highest point in the island, the altitude, according to Colonel Legge, being about 5,100 feet above sea-level. On the left bank of the South Esk the first important tributary is the Macquarie, which rises some 50 miles farther south, about 1,500 feet above sea-level. It first joins the Lake River, whose source is on the central plateau in the two Arthur's Lakes and Woods' Lake (about 2,500 feet and 2,150 feet respectively above sea-level, by the Author's uncorrected aneroid observations), and the combined waters flow into the South Esk at Longford, some 12 miles from Launceston.

Four miles lower down, the river is joined by the Meander, the last important affluent, which rises in the central plateau or Western Tiers, and issuing from Lake Meander at a height of 3,750 feet above sea-level, descends from the plateau in a single fall 500 feet in height. The Meander River thence falls rapidly to the comparatively level country at the base of the Tiers, averaging from 1,500 to 1,000 feet above sea-level, and thereafter flows gently through pastoral and agricultural country for about 40 miles, with an average fall of roughly 15 feet per mile, to its junction with the South Esk at a point approximately 400 feet above sea-level. For the next 4 or 5 miles the main river gradually descends to about 300 feet above sea-level, and then for the last 3 miles or so falls rapidly to sea-level.

It is at the lower end of a convenient bend in this last 3 miles, where the river-bed falls about 150 feet in less than 2 miles, that the electric power-station is situated. A tunnel, about 44 chains in length and 5 feet in diameter, has been driven across the bend and leads the water to the intake chamber where the pipe-line commences.

The normal minimum flow of the South Esk River at Launceston is probably about 120 cubic feet per second, though in very dry seasons it is believed to have been as low as 42 cubic feet per second; for some years, however, the flow has been artificially regulated, first by dams at Tooms Lake on the Upper Macquarie River 1,500 feet above sea-level, and also at Lake Leake on the Elizabeth River, an affluent of the Macquarie, constructed in connection with the water-supply of the towns of Ross and Campbelltown respectively ; and secondly, by dams constructed by the municipal council of Launceston across the exits from the lower Arthur's Lake and Woods' Lake with the object of ensuring a greater constancy of flow for the electrical works.

The existing machinery requires approximately 150 cubic feet of water per second at full load, but fortunately, to a mid-winter maximum load requiring this flow of water there corresponds a dry season maximum some 25 per cent less.

Up to the present, although several times in past years in February and March the water has been low, with the help of the Storage provided and by further conserving the water daily behind a low dam at the entrance of the tunnel at hours of light load, there has been just sufficient to tide over each dry season.

HISTORY AND DESCRIPTION OF WORKS.

Historical. The original works were started in 1893 and completed in 1896, the City Engineer, Mr. C. St. John David, being responsible for the tunnel and other hydraulic works, with Mr. K. L. Murray acting as consulting electrical engineer. The machinery then consisted of three 100-kilowatt sets, each comprising a Thomson vortex turbine, developing 160 B.H.P. with the normal head of 111 feet, and a direct-coupled Siemens alternator supplying single-phase current at 1,900 volts and 92 cycles per second. For street lighting five smaller (21 B.HP.) turbines furnished power for driving continuous-current dynamos, of which four were in use at one time, each supplying thirty-five 7-ampere arc-lamps The transmission-mains, some 2 miles long, were led to a small distributing station on the outskirts of the city.

In November, 1895, shortly before the completion of the contract, the Author was appointed City Electrical Engineer. As soon as the supply was available the demand for light was so great that it was found necessary to increase the plant by adding two more 100-kilowatt sets. This plant worked well for some years, being very satisfactory as regards lighting, and earning for Launceston the reputation of being the best-lighted city in Australasia, and in many of the modern applications in connection with electric supply Launceston led the way. Thus it was the first city in Australasia to make use of the maximum-demand method of charging, and while supply-authorities in England were considering the question of free wiring, Launceston introduced a rental and a hire-purchase system, which added immensely to the popularity of the light; the price for this was fixed at a figure that led to its use in an unusually large number of small houses, so that at the present day over two-thirds of the houses in the city are electrically lighted. The free renewal of glow lamps, which were carefully and systematically tested, formed a feature of the supply from an early date.

The rather remarkable position of the Launceston electrical undertaking can be gauged by comparing with published English records the following figures, taken mostly from the annual report of the present City Electrical Engineer (Mr. J. R. Strike) for the year ending the 31st December, 1908:

Population (estimated)	24,000
Completed year of working	12th
Capital Expenditure	£164,586
Sinking and Reserve Funds	£28,035
Total Revenue	£17,683
Total Costs	£8,078
Plant Capacity (including spares)	1,200 kilowatts
Maximum Load	760 kilowatts
Total units for year, generated	1,965,780
Total units for year, sold	1,533,286

Distribution.-The sub-station was built in the very heart of the City about 2½ miles from the power-station, and it took the place of the small distributing station on the outskirts, previously referred to. The transmission line was simplified to two three-phase circuits, one of 19/14, and the other, for the time being only, of 7/16 S.W.G. At the sub-station the transmission mains are led via circuit-breakers fitted with reverse current relays to bus-bars feeding six circuits, the largest consisting of three 120-kilowatt transformers in the sub-station, supplying through a low-tension switchboard eight underground four-core feeders connected with different parts of a four-wire low-tension reticulation, erected overhead in the central area of the City.

Four of the remaining five circuits lead from the sub-station to the north, south, east and west of the City respectively, supplying principally the residential areas, the necessary transformation being effected at some twenty transformer positions. At each of these, three Burnand single-phase transformers, air-cooled, are mounted, being supported about 15 feet from the ground on brackets fixed to a tubular steel pole carrying the high-tension lines. Each residential area is so divided that the longest low-tension distributor is in general not farther than 500 yards from the transformer position.

The four-wire, star-connected system of low-tension distribution is employed with earthed neutral. The neutral is earthed at more than one point, but careful balancing has prevented any interference with telephones. The pressure adopted is 190 volts between phases and 110 volts between each phase and neutral, but the transformers were specially ordered with the windings so arranged that by altering the terminal connections the pressure may be raised to 380 and 220 respectively. The Author contemplated having to do this within a comparatively few years, but the advent of the metallic filament lamp will probably render it unnecessary for a considerable time.

The sixth circuit at the sub-station feeds a four-panel switchboard controlling the arc lighting of the City, the old lamps being displaced by enclosed alternating arc-lamps, fed from four 50-lamp constant-current transformers.

Power-Station.-The arrangement of the plant and switchboard is shown in Figs. 3, Plate 8. The water is discharged from the turbines into a tail-race measuring about 100 feet by 9 feet, excavated in the solid rock for the whole length of the power-station and having two outlets, one at the down-stream end of the station and the other right in the middle. The latter measures about 8 feet broad, and was chosen for the tests described later.

At the tunnel-intake, certain alterations were designed with a view to render the screens fixed there self-cleansing, and to prevent blocking-up such as had previously caused trouble in times of flood. The wing-walls at the entrance to the tunnel were raised to the usual flood-level, the up-stream one being extended into the river; and a screen, constructed of 1-inch horizontal iron rods with 3-inch spaces, was built in, together with an inner 1-inch screen in duplicate, the latter being arranged for hoisting and lowering.

At the other end of the tunnel, to provide the additional water, required consequent upon the power-plant being trebled, a new 5-foot pipe was added (Figs. 3, Plate 8). This was led in a straight line down the hill and was joined on to the up-stream end of a 6-foot pipe or receiver which had from the first been fixed behind the station. The old pipe, which is 5 feet in diameter at the top, reducing to 4 feet, was originally led into the middle of the receiver. This was altered so as to join on to the extreme down-stream end of the receiver, the receiver itself being cut in two and a 4-foot valve being fixed between the two portions.

The turbines are of the radial inward-flow type, and the arrangements for governing comprise certain novel features. Regulation is effected by means of sixteen balanced guide-blades, each provided with a pin attached to a block moving in a slot in a movable ring, ***1***, Figs. 2, Plate 8, which is moved backwards and forwards by crank-pins acting at small radius, fixed in the ends of the rocking-shafts ***2*** and ***3***. These are operated by a powerful hydraulic mechanism consisting of cylinder and piston, the movement of the latter being controlled by the governor-valve.

This valve is shown in Fig. 2a, and consists of a differential piston-valve, of which the upper area is greater than the lower and the middle portion is open to exhaust. The upper part of this piston terminates in a hollow stem pierced with holes so that the interior of the stem is in communication with the space above the piston. The full pressure from the turbine case acts on the lower or smaller area, and on the upper or larger area the same pressure acts, but reduced by an amount determined by the degree of opening to exhaust of a small port through the side of the hollow end of a valve-rod ***4,*** which works up and down in the hollow stem referred to, the upper end of which is opposite the port. At the position of equilibrium this port is opened so much that the total forces above and below the piston-valve are balanced. The valve-rod is hung from the lever, ***5***, one end of which follows the up and down motion of the governor collar, the other end being supported by the rod ***6***; the length of the latter can be adjusted by means of the hand-wheel ***7***, and its lower end carries a wheel rolling on the inclined plane ***8*** attached to the crosshead.

The first effect of any inward or outward movement of the governor-balls is a corresponding movement of the valve-rod causing the waste though the port via the valve-stem to be increased or reduced, thus upsetting the balance of forces above and below the piston-valve and causing the valve to rise or fall. This movement admits water to the corresponding side of the hydraulic cylinder, thereby moving the main piston and its cross-head with its attached inclined plane and simultaneously operating the guide-blades so as to raise or lower the speed of the machine. The piston continues to move until the inclined plane by moving the left-hand end of the lever ***5*** in the opposite direction to the movement given to the right-hand end by the governor-balls has brought the valve-rod ***4***,and with it the piston-valve, into its former position of equilibrium,

The difference of speed between no-load and full load, if the governor is not readjusted, amounts to about 5 per cent. The only part of the link-motion returning to its original position after change of load is the valve-rod ***4.*** If it is desired to bring the turbine to its original speed a new position for equilibrium may be arrived at by altering the length of the rod ***6*** by means of the hand-wheel, or by altering the forces acting on the other end of the lever ***5***. The latter method was originally used, a spring contained in the cylinder ***9*** being actuated by rotating the electric motor ***10***. This motor could be started, stopped or reversed from the switchboard, and was supplied in order to comply with a clause of the specification providing for complete switchboard control.

It was found, however, in practice that the use of this arrangement resulted in the regular action of the governor being interfered with by the introduction of an additional force, which had apparently not been allowed for in the original design. Consequently the hand-wheel ***7*** was used not only for minor speed adjustments but also for starting up and synchronizing. As this was inconvenient and necessitated the attention of a man who would otherwise have been free for other duty, the Author had the electric motor moved from its original position and geared on to a nut connected with the hand-wheel ***7***. The result of this alteration was quite satisfactory, and the operations of starting, synchronizing, regulating the speed and dividing the load between two or more machines in any desired proportions are now readily carried out from the switchboard.

The erection of the plant was satisfactorily completed in November 1905, and the year of maintenance provided for by the specification in 1906.

HYDRO-ELECTRIC EFFICENCY TESTS.

These tests were undertaken primarily to determine the ratio of the electrical energy delivered from the generator, measured at the switchboard terminals, to the kinetic energy developed by the water falling through a height equal to the actual head; the method of measuring the water and of determining the "actual head " being specified as indicated later.

This ratio on full non-inductive load, with the turbines using 2,700 cubic feet of water per minute (45 cubic feet per second), and with the excitation separately provided for, was to be not less than 73.8 per cent, a combined efficiency arrived at by allowing 80 per cent efficiency for the turbine and 92 1/4 per cent for the generator.

The specification provided for a bonus or penalty according as the efficiency shown by the tests were higher or lower than 73.8 per cent. It was thus necessary, in order to be just to both parties to the contract, that these measurements should be made with the utmost care.

Measurement of Kinetic Energy of the Water.-Taking the latitude of Launceston as 41° 26', and the height of the power-station above sea-level as 200 feet, and using the Board of Trade Standards Department's formula,[1] the value of ***"g"*** is found to be 980.28 centimetres or 32.160 feet per second per second. The effect of the increased height of the head-race above sea-level is negligible.

It was specified that the discharge of water should be measured by observing the height over a weir about 6 feet wide; but this was ultimately increased to 8 feet. As a result of experiments to determine the coefficient **C** in the expression

$$Qo = 2/3\ C\ell \sqrt{2g}\ H^{3/2}$$

where Q, is the discharge in cubic feet per second, ℓ the breadth of weir in feet, and H the head in feet, the Author eventually adopted the figure 0.6444, this being the mean of the five most reliable experiments made to determine the factor. The results of the weir experiments are given in the Appendix, together with a discussion of some results obtained by Mr. H. Bazin.

For convenience, substituting h in inches for H in feet and giving ℓ its exact value 8.005, the equation becomes

$$Qo = 0.6635\ h^{3/2}$$

The weir and the apparatus for measuring h were arranged thus: The down-stream end of the tail-race, Figs. 3, Plate 8, was temporarily blocked. The central exit already referred to, which measured about 26 feet 6 inches long by 8 feet broad, was extended by constructing a concrete channel of the same breadth and with level floor to a distance of 12 feet 6 inches from the wall of the station. This channel terminated in an angle-bar frame let into the concrete flush with the face, securely anchored and provided with holes drilled and tapped for studs to hold 3-inch hardwood planks, which blocked the end of the channel. The uppermost plank, forming the crest of the weir, was bevelled to an angle of about 48° with the vertical, the thickness of the top edge being 1/10 of an inch. The side walls ended at the crest.

Eight feet back from the notch thus formed, a channel-bar spanning the race was set in the concrete and provided at its ends with two iron supports about 18 inches high, across which was stretched a wire. The wire was accurately adjusted to be perfectly level at a height of 40 ¾ inches above the weir-crest.

[1] *Everett's Units and Physical Constants, 1886, p. 26.*

At the middle points of five equal divisions across the flume, holes were formed in the channel-bar flanges to receive five removable hook-gauges, which could be raised or lowered by means of thumb-screws. A piece of stout brass wire filed to a chisel-end, was attached to the lower end of a square stem, this being formed into a hook with sufficient breadth to prevent the ripple caused by the wire on the surface of the water from reaching the point. The point was 23¾ inches from a mark engraved on the square stem of the gauge, and a scale also was engraved on the stem, a range of from 16 to 18 inches over the crest being sufficient for most purposes.

The hook-gauges were measured before and after each set of measurements, from mark to point, to ensure that they were not bent, and the heights of the weir-crest and of the reference wire were determined (and the latter readjusted if found necessary) by accurate levelling relatively to a bench-mark.

During the 15-minute tests readings were taken of each hook-gauge at intervals of 1½, 4½, 7½, 10½ and 13½ minutes from the start of the test. The average of the five simultaneous readings was taken as the height over the crest at the time of each observation, and as tests were only taken with a very steady load, the variation of "*h* " in general not exceeding ¼ inch, the mean of the five averages was taken as the height for the whole 15 minutes. A calculation was made in one case to find the extent of error introduced by this method of averaging, and it proved to be quite inappreciable.

It was also necessary to determine the necessary allowance for leakage and for water used by the exciter set. The tail-race was known to be not absolutely water-tight, and moreover, as the exciter turbines were not supplied by the contractor, and the efficiency of the three-phase generating sets was alone in question, it was necessary to allow for the water used in the former. In the earlier experiments it was sought to determine the two quantities involved separately, but, owing to the small amount of exciter water and the consequently small head over the weir, it was found impossible to make an accurate determination in this way.

The Author consequently decided to measure the two amounts together by observing the rise or fall in the tail-race with only those quantities flowing and with all outlets blocked up as tightly as was possible. To effect this, immediately after each test the end of the measuring channel was blocked and the main turbine gate was closed, leaving all else *in statu quo* The water level invariably rose, showing that the quantity measured must be deducted. An examination was made after each test, to ensure that the main turbine gate was tightly shut off.

The area of the tail-race was found by measurement to be 1194½ square feet, so that a 1 inch rise was equivalent to a gain of 99.55 cubic feet.

The actual head referred to was defined as the measured height between the levels of the water in the head-race and the tail-race, less a deduction on account of the loss of head in the pipe calculated according to the following form of Weisbach's formula:-

$$\text{Loss of head in feet} = (0.0144 + 0.01746/\sqrt{V})\,\ell V^2/\,5.4d$$

where V denotes the linear velocity of water in the pipe in feet per second,
ℓ denotes the length of pipe in feet, and
d denotes the diameter of pipe in inches.

The deduction for friction-head was once for all calculated by this formula, and amounted to 0.393 foot.

The heights of water in both head-race and tail-race were measured from bench-marks for each experiment, and the difference between the two levels, less the friction head, gave the actual head; in the full-load tests this varied from 111.3 to 111.45 feet.

A hydraulic power constant was calculated, the following expression being arrived at:-

Hydraulic H.P. = 0.11335 Q H.

Measurement of Electrical Energy-For the artificial load a circular wooden tank, 8 feet in diameter and 4 feet 6 inches deep, was provided. The current was led from the generator under test to three vertical lead pipes, hung from insulators suspended by a rope over a pulley and leading thence to the power-station. By this means the current could be adjusted to a nicety. A stream of water was kept continually passing through the tank.

In order to minimize the number of observations necessary at one time, the Author decided to calibrate the integrating watt-hour meters carefully at leisure, and to confine the electrical observations of precision at the time of the experiment to observation of the total number of turns of the rotating element or disk of the meter belonging to the generator under test. As each turn of the disk represents the transference of a definite amount of electrical energy, an amount determined by the independent calibration test, the integrated output during the period of the experiment and consequently the average electrical power was thus known.

Method of Carrying out Test-The number of physical quantities necessary to be observed during each test was thus reduced to four, as follows:
(a) The height of water over weir-crest, observed at regular intervals during the test;
(b) The height of water in screening chamber, observed at regular intervals during test;
(c) The elapsed time from start to finish of each test; and
(d) The number of revolutions during this period of the disk of the watt-hour meter.

In addition, readings were naturally taken of the switchboard voltmeters and ammeters both on generator and exciter panels, but with the exception of the high-tension voltmeter, no steps were taken to calibrate these.

The time-standard used was a Parkinson and Frodsham half chronometer in the possession of the Author, the variation of which at the time of the experiments was within 3 seconds a day. This error was neglected.

Two chronographs of less expensive construction were also used, and at each test were compared with the half chronometer by an observation usually extending over 17 minutes (1,020 seconds) the probable error of this comparison being not greater than 1/5th second or 1 in 5,000.

Before starting a test the generating set was allowed to run for 20 minutes or half-an-hour on the water-load in order to obtain steady conditions, the height of the pipes in the water and excitation being meanwhile carefully adjusted to give the desired load at the correct voltage. By this time the water in the tank had arrived at a steady temperature, and under the most favourable conditions the load remained so steady that during the 15 minutes over which the test extended the variation of head at the weir did not exceed 0.2 inch.

Having told off observers to their stations, the Author started the test by giving the word to the observer at the watthour-meter who commenced counting 0 at the next appearance of a mark on the disk. The Author simultaneously started the stop-watch, noting for confirmation the nearest 1/5th second on another chronometer. A minute later he gave a signal to the observers at the by-wash and at the weir who took their first readings 1/2 minute later, and thereafter at intervals of 3 minutes until 13½ minutes from the start, the Author personally examining the hook-gauges, and checking the observer's reading several times, usually every 3 minutes, during the test. Towards the end of the 15 minutes he either gave the word to the watt-meter observer to stop at a given number, and as the word was called stopped the stop-watch and noted the half chronometer reading, or in some of the earlier tests called out as the nine-hundredth second was completed, leaving it to the meter observer to estimate the part of a turn of the disk to be added.

After carrying out thus three or more consecutive tests the generator was stopped, and its main sluice-valve being closed, the leakage test was taken as before described.

Results of Tests- Considerable difficulties had to be overcome before consistent results could be obtained, one of the chief being the limited time available for experiments. No matter how steady the town load might be on certain occasions, such as Saturday afternoons when motors were not working and the demand was otherwise light, the Author found it impossible to obtain a steady flow except by shutting off the town and working solely on a water-load. The City Council has always reserved the right to shut down on Sundays whenever necessary, but one of the largest churches in the City is warmed by electric radiators, and on this account the tests were necessarily carried out in the summer. Again, still days which frequently occur in winter are unusual in summer, a strong breeze usually rising at 9 or 10 in the morning and lasting until sunset. As is well known by any who have attempted measurements of this character, such a wind renders extreme accuracy impossible. In the case in point on such occasions the surging of the water in the tail-race made delicate hook-gauges a useless refinement. Consequently the most reliable experiments were carried out on Sunday mornings in summer time, when the wind happened to be light or absent, and when other work, of which much was in progress, permitted of this being continued.

Eight tests, each of 15 minutes' duration, were taken on the 29th October, 1905, including at least one full-load test of each generating set, and as regards one set, tests at approximately half and three-quarter load and 30 per cent overload.

On this occasion all the machines were tested cold, and the method of allowing for leakage and exciter water described not having reached its final exact form, the efficiencies appear to be in general too high throughout. Nevertheless, for the sake of showing the general character of the efficiency curve, the results of the four tests of this set are plotted in Fig. 4, Plate 8.

On the 5th November four more tests were taken with the same generating set, the leakage and exciter water being accurately allowed for. The efficiencies measured were 77.06, 77.06, 76.78 and 76. 99, averaging 76.97, with a variation from the average ranging from +0.09 to -0.19. The generator in this case was tested cold.

On the 19th February another generating set was taken, and in this case it was kept working all night, and early in the morning was put on the water load for some hours prior to the trials, to bring it to its normal working temperature. On this occasion the conditions generally were so favourable that, the engineer for the contractor concurring, the Author decided to accept the results as crucial and as applying to all four generating sets. The efficiencies attained were 76.02, 75.16 and 75.50, with an average of 75.56 and a variation from the average ranging from +0.46 (0.61 per cent) to -0.4 (0.53 per cent).

As regards the closeness of the results in each case, assuming fairly good weather conditions and the correctness of the constants for the weir discharge-coefficient and watt-hour meter, the probable extent of error must be sought for by examining the possible errors in determining the four quantities enumerated, the first two of which would affect the hydraulic and the other two the electric power. The following absolute and relative values may be assigned to these errors:-

(a) *Height of Water over Weir-crest*.-This error is the most variable, and depends very largely upon the weather conditions. Under fairly good conditions such as obtained in the last two tests, allow +0.05 inch, which in 17 inches is 1 in 340. As the final result depends upon the square root of *h* cube this variation in *h* will cause a variation in the hydraulic horse-power of 1 in 226, or say 0.44 per cent.

(b) Height of Water in Screening chamber.-Allow ± 1 inch in 111 feet, say 0.075 per cent.

If both causes (a) and (b) operate at the same time in the same direction the maximum error is then 0.515 per cent.

(c) and (d) Time of Revolution.-Allow 2/5th second in 900, or say 0.05 per cent.

The observed variations in the efficiency figures are of the same order of magnitude as the possible errors thus assigned.

In addition to the main efficiency trials, the usual subsidiary tests were made of the governing properties of the turbine; of the temperature of the generators under full load and overload; and of the inherent regulation.

The results of the governing tests were generally that with half load thrown on or off the momentary speed variation was 6½ per cent as against 5 per cent guaranteed; the permanent variation, however, was only 2 per cent. With full load thrown on or off, the momentary variation was 14 per cent and the permanent variation 4½ to 6 per cent. These figures were capable of adjustment, but too close setting of the governor was liable to lead to hunting.

The results of the tests as a whole were quite satisfactory, and with the exception of one or two minor details, capable of adjustment in some cases, the contractors fulfilled their guarantees, and they received a bonus on account of the high efficiency shown by the tests. The plant has now been working between 4 and 5 years without hitch.

OBSERVATIONS UPON THE WATER-POWER of TASMANIA.

During an extended residence in Tasmania, the Author many times visited the central highlands, noting particularly their physical configuration, with a view to form some conclusion as to the value of the upland waters for power purposes.

The central plateau inclines generally with a moderate slope southwards, the country to the west and south-west being very broken and the boundaries of the plateau being lost in the rugged mountains with which this district abounds. A well-defined edge exists to the north and east, shown on the map, Fig. 1, Plate 8, by the hatching marked Western Tiers. Here is an abrupt rise of from 1,500 to 2,000 feet above the level of the adjacent lower-lying country. The main watershed of the plateau runs east and west, parallel and close to the northern escarpment, so that the greater parts of the waters flow south. A glance at the map will show that the river system of the Derwent, in addition to the headwaters flowing from Lake St. Clair, includes the Nive, the Dee from Lake Echo, the Ouse which like the Nive is fed from quite a number of small lakes near the northern edge of the plateau, the Shannon which is fed from the Great Lake and afterwards joins the Ouse, and the Clyde from Lakes Crescent and Sorell. There are other tributaries which, however, do not rise on the plateau. This succession of fine streams is sufficiently impressive to a traveller visiting the uplands, and all rise at a considerable altitude to join and swell the Derwent, which river eventually debouches into the estuary that has furnished Hobart with such an excellent deepwater harbour.

In 1897 the late Mr. Alfred Mault, Engineering Inspector to the Central Board of Health, drew attention to the possibility of using the water from the Great Lake for power purposes. He proposed, and quite recently the matter was resuscitated by Professor Alex. McAuley, of the University of Hobart, to lead the water from the Shannon, 6 miles below the Great Lake, in an open cut across to the Ouse Valley, where with a drop of 600 feet it was estimated that 40,000 H.P. would be available.

The first Lewis Ministry, 1899 to 1903, obtained a series of valuable reports on the Water Power of the Island from Mr. K. L. Rahbek. In one of these[1], after commenting upon the absence of rainfall and river gauging records, Mr. Rahbek estimates, on certain assumptions which he sets forth, that 82,000 BHP would be available from the waters of these three lakes. The barometrical heights for the waters of the Derwent system, shown on the map (Fig. 1, Plate 8), are taken from this report. It will be seen that the power is necessarily not available all in one place, and Mr. Rahbek recommended dividing the head on each river into steps of 600 to 700 feet each, with a system of canals and a chain of three or more power-stations for each stream, interconnected, so that from eight to ten stations would be necessary. The power he proposed to transmit electrically to Hobart, the distance of transmission probably averaging 50 miles.

Another report by Mr. Rahbek dealt specially with Lakes Crescent and Sorell on the eastern edge of the plateau, and others again with water-power in the north-east of the island, essentially a tin mining district; the Briseis, Anchor and Pioneer mines being all in this locality.

[1] K. L. Rahbek, "Lake St. Clair, Lake Echo and the Great Lake Water-Power." Hobart 1901.

No notice appears hitherto to have been taken by any observer of the possibilities connected with the northern edge of the tableland, between which and the watershed is a narrow strip of upland country with heavy rainfall, whose waters flow northward. This strip is intersected by numerous gullies, which at times of heavy rain form watercourses that quickly drain the adjacent area. During the winter months this area is covered with snow which usually melts towards the end of September or later, a few hours' warm rain at this season causing serious floods in the rivers. Generally speaking, for 5 months in the year these rivers are high with frequent freshets and occasional floods, and for the remaining 7 months they are low excepting after rainfall.

Rain in general comes from the north and north-west, and this northern edge of the Western Tiers reaps the full benefit of the approaching moisture laden clouds. Such few records as have been obtained, together with what is common knowledge amongst the shepherds and other residents in the locality, show conclusively that the rainfall here is greatly in excess of that farther south on the plateau, where 20 miles away, at the southern end of the Great Lake, is situated the only station on the plateau where rain-gauging has been regularly taken for a number of years. It is unfortunate that no observations of the rainfall on the edge of the Tiers have been taken.

For 16 months only, including the year 1903, when a constable was stationed at the north end of the Great Lake, were gaugings regularly taken near this area, and for that year the record for the north end was 84 inches as against 31 only for the south end.

Added to the particularly advantageous rainfall thus evidenced, the opportunities for storage on this area are considerable; for with comparatively low dams across the northern end of a number of the gullies referred to, it would be possible to form a chain of lakes - in continuation of the shallow lakelets which already exist - and thus to conserve the greater part of the winter snows. Floods would then be prevented; enabling a much larger body of water to be used for power purposes in the lower reaches of the rivers; and at the same time water would be stored at a point convenient for the development of power, with a fall of about 2,000 feet to the low lying country below.

This lower district is within easy reach (12 or 15 miles) of the Western Railway, which has two shipping ports, 82 miles apart, at Launceston and Devonport; and a possible transmission line might meet the railway, say, 30 miles from Devonport. Limestone abounds, and apart from coal which is proved to exist, wood is available in practically unlimited quantities, so that carbide might readily be manufactured there; nor is there any reason why the power should not be used generally for town lighting, railways, and agricultural operations, and for manufactures such as wool, for copper refining, and for other industries calculated to develop the economic resources of the State.

In the opinion of the Author, for the purposes of the Launceston Municipal Council, the vicinity of Lake Meander and of other small adjacent lakes, offers very considerable advantages for the construction of storage dams. The fact, however, that not only the City of Launceston but the riparian owners and other users of the waterpower of the Meander, who are now inconvenienced both by floods and droughts, would be benefited, points to such work being undertaken either by the Government or by some company, who would also make use of the very considerable power developed by the fall of the water down the first 2,000 feet.

The headwaters of the Mersey, which flow into the sea at Devonport, form another possible source of power which the Author has visited, and he is of opinion that careful survey and comparison of the relative advantages of the more easily-developed water powers of Tasmania may demonstrate that, for commencing on systematic lines, it will be found advisable first to make use of the rivers flowing north from the tableland, and this, by reason of the foregoing advantages which they possess. These may be summarized as heavy rainfall, facilities for storage, steep escarpment with high fall, proximity to railway and to northern ports, and facilities for using the power.

In conclusion, the Author regrets that he must echo the oft repeated complaint as to the lack of reliable data. In a report to the Government, dated 10th December, 1900, Mr. Rahbek described modern methods of river-gauging, and urged the necessity of regularly carrying out this work, strongly recommending the Government systematically to gauge the streams of the island; he pointed out the unnecessarily expensive character of works designed for unknown conditions on the one hand, or on the other hand, the disastrous results which might be anticipated if works were constructed of insufficient strength to withstand floods more severe than allowed for.

In 1908 the Commonwealth Bureau of Meteorology was established, and took over from the several State Governments the compilation of statistics as regards rainfall, although those States that had made an earnest commencement in the measurement of their inland waters still continued this work. It is manifest, however, that a Federal institution cannot be expected to collect data on a large scale in the interests of individual States, and consequently at the present time no systematic addition to the knowledge of Tasmania's water resources is being made on a scale commensurate with the importance of the subject[1]. Confining attention for the moment to the central plateau, as containing large natural reservoirs at an elevation, through the courtesy of Mr. H. A. Hunt, the Commonwealth Meteorologist, the Author is able to supply the following information. The gauging station at the south end of the Great Lake has been in existence for 19 years, the average rainfall for this period being 32.54 inches; a station was also established at Interlaken, between Lakes Crescent and Sorell, in 1900, but was discontinued after 6 years, the mean rainfall for this time being 32.10 inches. This station Mr. Hunt has again this year succeeded in re-establishing, so that further records maybe anticipated in ensuing years. The only other recorded rainfall on the plateau appears to be the 84 inches referred to, as observed in 1903 at the north end of the Great Lake.

What is necessary to provide for future needs is for the State Government, first to increase the number of rain-gauges under the care of competent observers on the important catchment areas; secondly, to establish snow-gauges to be visited after each snowstorm and otherwise at regular intervals, say fortnightly, on those areas which, being covered with snow in winter, are uninhabited and unvisited at that season except by the casual kangaroo-hunter or excursionist in quest of a day's skating; and thirdly, and most important, to establish gauging-boards, arranging for observers on all the important rivers of the island, so that daily readings of the height may be taken and the flow-off may be computed year by year.

Tasmania has spent much money in opening up her mines. Her water-power is another natural asset, perhaps of equal value to her mineral wealth, at all events too great to be despised. It is to be hoped, therefore, that the Government will take steps to provide that in the future every assistance and all possible information may be available for the engineer[2] who comes forward to develop this hitherto unexplored source of wealth.

With regard to the tests described, the Author desires to acknowledge the ready co-operation and valuable assistance rendered by the engineer for the contractors, Mr. A. S. Herbert, in carrying out the trials of the generating plant. Also to thank Mr. W. E. Pennefather, the power-station engineer during the earlier trials; Mr, R. J. Strike, the Author's chief assistant and successor in the position of City Electrical Engineer; Mr. Spencer Jewkes, who succeeded Mr. Pennefather in 1906 and who helped largely with the determination of the weir-discharge coefficient; and Mr. Arthur Allison, sub-station and test-room electrician, whose assistance was especially of value in carrying out the electrical measurements.

The Paper is accompanied by eight tracings and by Tables giving details of the tests, from which Plate 8 (Figures 1 – 5) and the following Appendix have been prepared. There are also a number of photographs.

[2] *Since this was written the Government has appointed a hydraulic engineer, Mr. W. Reid Bell, M.Inst.C.E., to investigate and advise generally upon the resources of the State in this respect.*

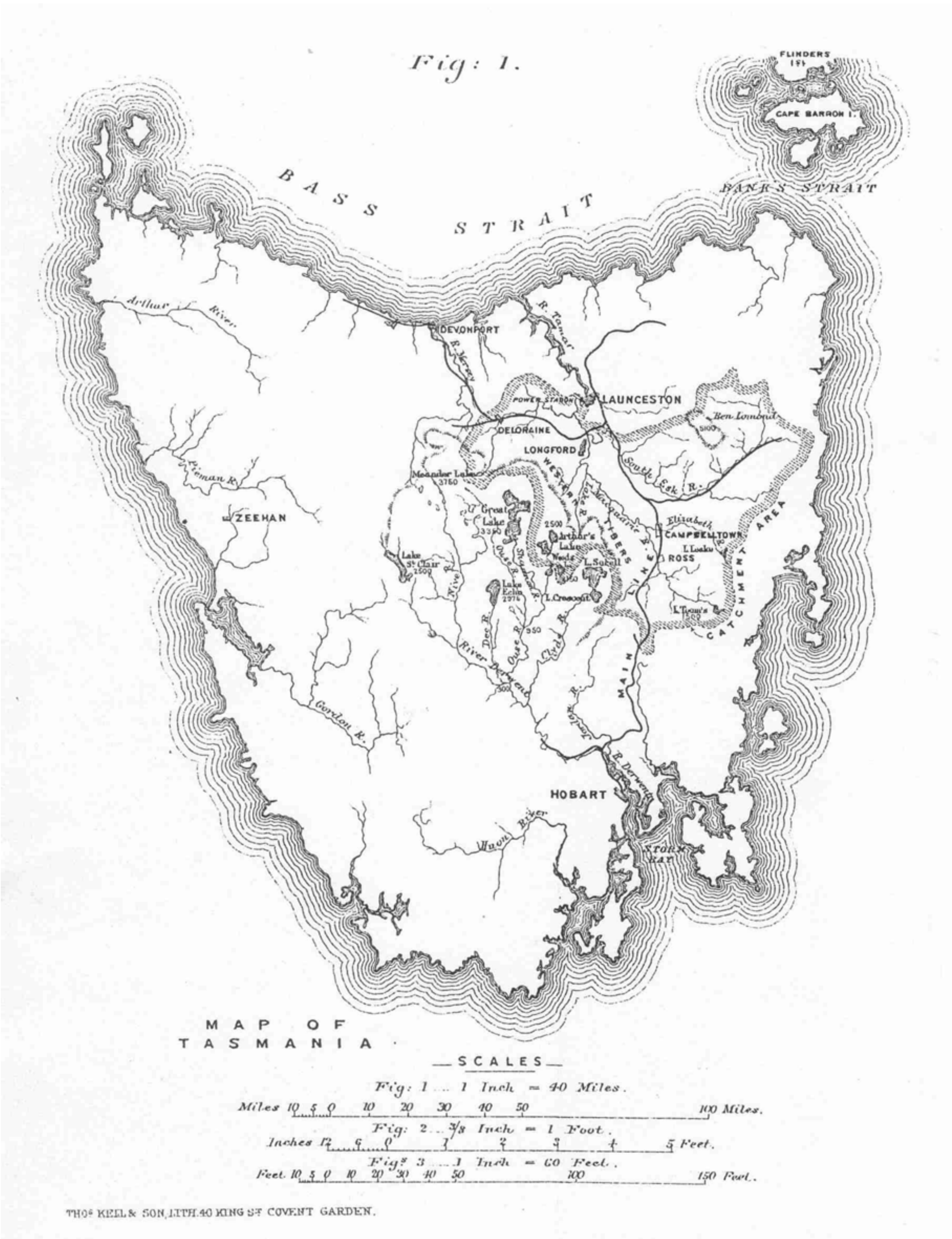

Figure 1 - Map of Tasmanian Rivers

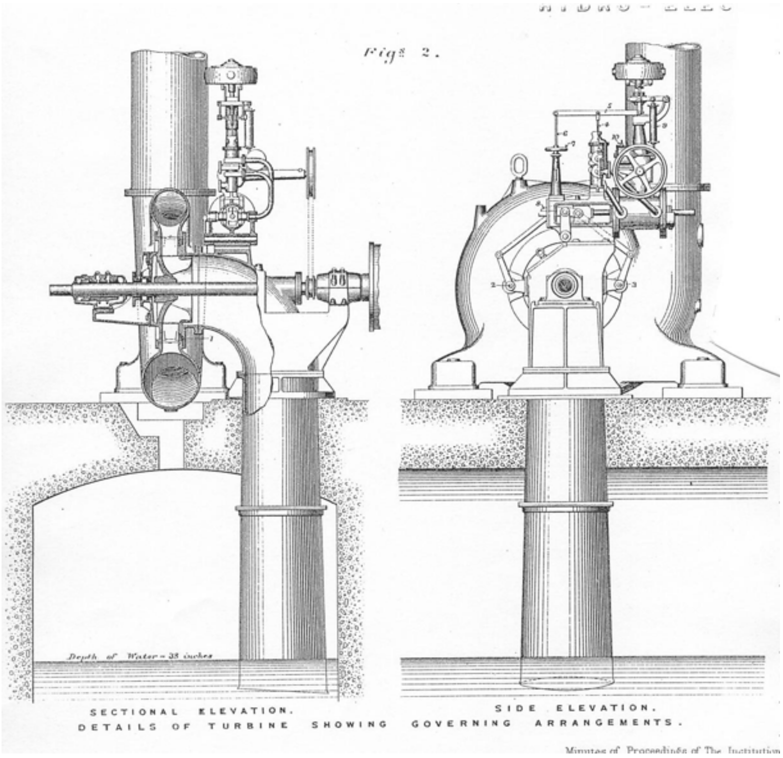

Figure 2 - Details of turbines showing governing arrangements

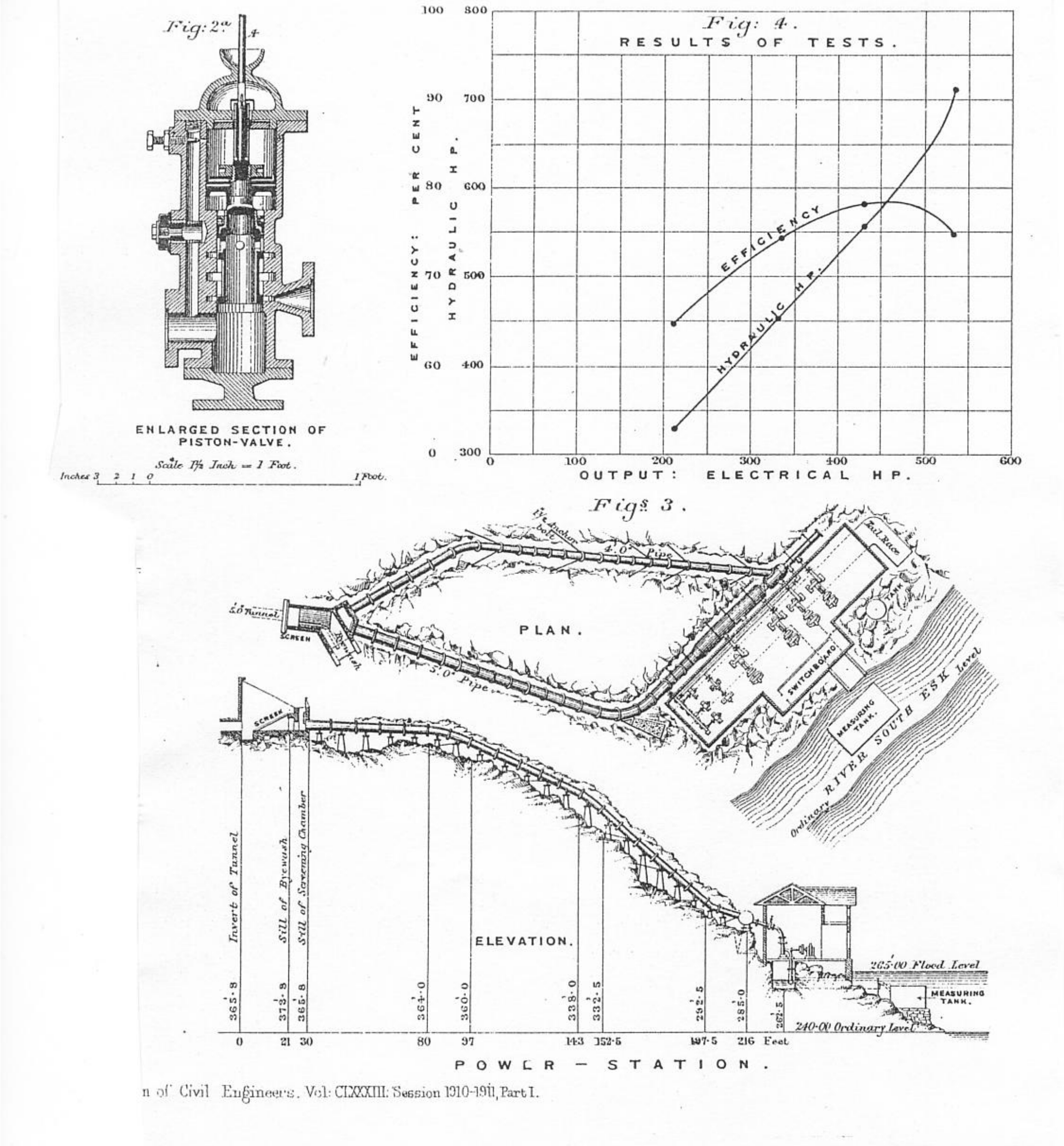

Figure 2a – Enlarged section of piston valve
Figure 3 – Plan and elevation of power scheme
Figure 4 – Results of tests

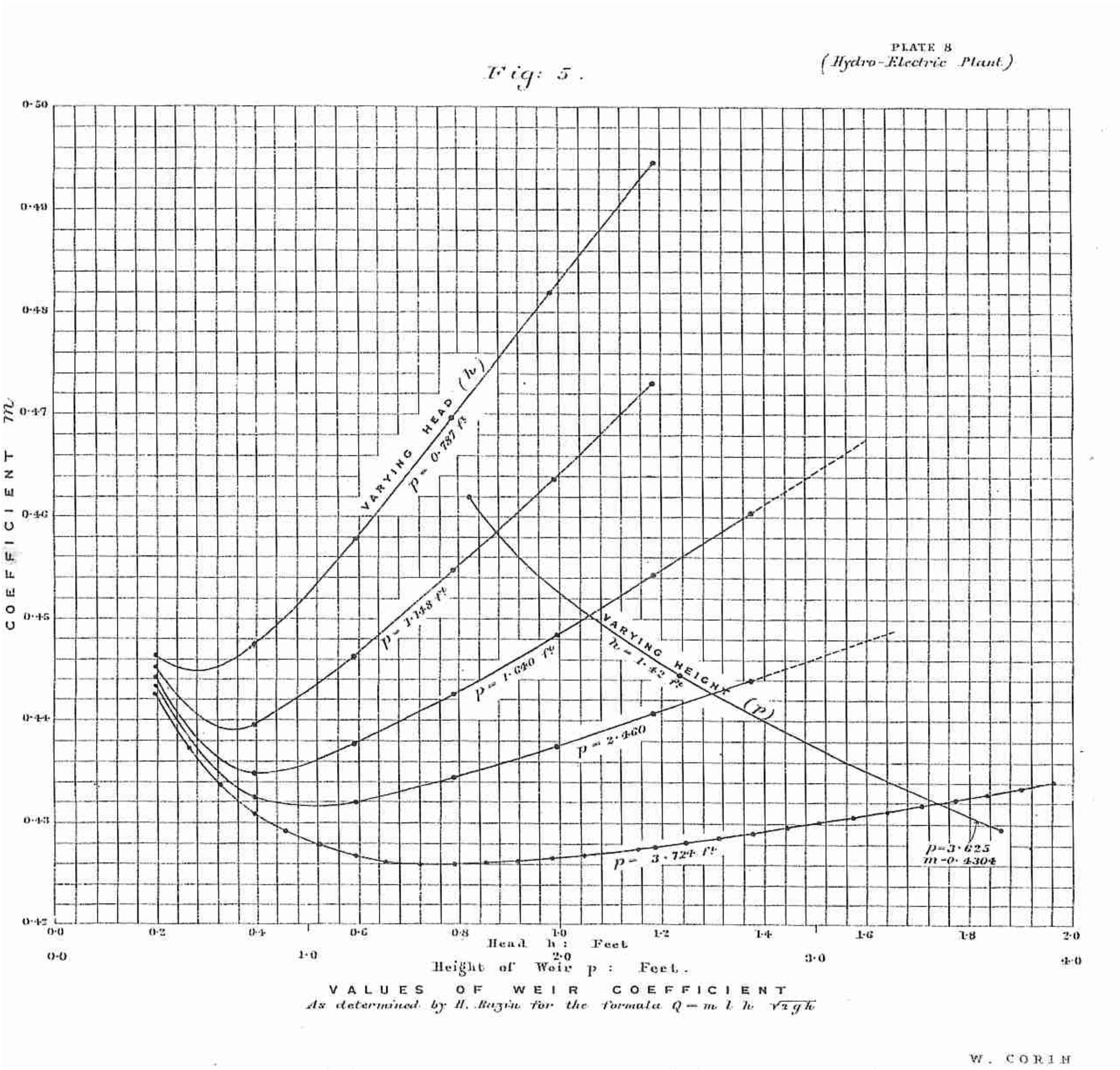

Figure 5 – Values of weir coefficient

Garvie, Robert, 1962: Extract from A Million Horses*. The Hydro Electric Commission, Tasmania, p.19.*

THE BEGINNINGS

On the night of 10th December, 1895, the people of Launceston congregated in the streets of their city in anticipation of a long awaited event. At eight o'clock, for the first time, arc lamps were switched on and the gas light of the older standards "was dwarfed into a sickly glimmer compared with its more useful, vigorous, and powerful competitor. Night was for once turned into day."

So spoke the "Daily Telegraph" the following morning, and with justifiable pride. With its newly commissioned Duck Reach hydro-electric power station, situated on the South Esk barely two miles upstream from its confluence with the River Tamar, the City of Launceston established itself among the world's pioneers in the generation of electricity from water power for the use and convenience of man. It was only three years earlier, in 1892, that the mighty Niagara Fall was first harnessed to generate electricity (for paper making), and in those days most of the hydro-electric power then being produced was derived from very low head machines, such as were installed below a weir across a river. At Duck Reach, the head was 110 feet, then regarded as a very high figure, and it was a bold decision on the part of the city fathers and the people to accept the recommendation of their consulting engineer, Mr.K.L.Murray, to make use of it to light the streets of Launceston. All honour is due to those men for their courage and vision in first embarking on the development for the common good of what is now recognised as one of Tasmania's most valuable assets, its water power resources.

The principal features of the scheme were a low diversion weir across the gorge of the South Esk, a tunnel half a mile in length and about five feet diameter through dolerite rock, and a five feet in diameter wrought iron penstock leading down the steep slope to the power station below.

The original installation in the Duck Reach Power Station is of interest, especially in contrast to the machines of today. The principal contract for the supply of the generating equipment was awarded to the famous German electrical firm of Siemens Bros., and the turbines were supplied under a sub-contract by Gilbert Gilkes & Co. of Kendal, England. The tendered price was £32,021/15/0, for the supply of eight complete generating sets. Of these, five had a rated output of 21 horse-power each, and three of 158 horse-power. Thus the total installed capacity of that first hydro-electric power station was 579 horse-power, which, although apparently adequate for its designed purpose of illuminating the city streets in the nineteenth century, would barely suffice to boil two hundred and fifty electric kettles in the middle of the twentieth.

At the present time, sixty-seven years later, the same firm of Siemens has been awarded the contract to supply the alternators for the Poatina underground power station in the Great Lake Power Development, where each of the turbines is rated at 69,000 horse-power.

The Duck Reach Power Station was enlarged in 1904 and again in 1920, to a maximum capacity of 2,600 horse-power. To increase the supply of water, a wooden flume was constructed round the mile long bend in the gorge and a second penstock joined the original wrought iron pipe. For many years, the power station was a place of pilgrimage to citizens and tourists, who walked along a rough path from the First Basin and crossed the light suspension bridge to view the generating sets in the building. More recently the popularity of the motor car and the atrophy of the human leg muscles have restored its earlier seclusion.

In most years, floods of 20/30,000 cusecs are normal occurrences in the South Esk, and they provide a spectacle of natural power and grandeur that is justly famous and which has always attracted sightseers from far and near. In April, 1929, unusually heavy and prolonged rains all over the catchment created a flow of not less than 150,000 cusecs, and one of the many victims of this record flood was the original Duck Reach Power Station building. The structure as it stands today was erected after that disaster.

The power station and all associated works were vested in the Hydro-Electric Commission in 1944, and when the Trevallyn Power Development came into operation in 1955, the old station was closed down after sixty years of faithful service. Four of the machines have been preserved as historical relics, at the Trevallyn Dam and Power Station, in the Queen Victoria Museum in Launceston, and in the Engineering Department of the University of Tasmania.

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DUCK REACH – THE FIRST SIGNIFICANT HYDRO-ELECTRIC DEVELOPMENT IN AUSTRALASIA

H.H. McFie

1. THE DEMAND FOR POWER.

In the United Kingdom the industrial revolution provided the demand for and the means to supply energy in increasing quantities with the great surge of power beginning in the late 1700's. Bolton advised his partner James Watt to develop his stationary engines since "All England is crying out for steam". However in Tasmania water power was extensively developed for mechanically driven flour, timber and other mills. "From 1850 to 1860 there were some 80 flour mills of which 55 were water driven(1)". In his comprehensive world-wide studies, Dallas (2, 3) has shown that because of its lower costs and smooth, constant running, water-power has been the preferred motive force, where practicable, and a major influence on the profitable development of industries, particularly for remote works such as mining and underdeveloped areas. The water wheel was dominant until the 1880s, the mechanical direct turbine until c.1910 and hydro-electric power was well established by the early 1900s. Messrs Gilbert Gilkes and Gordon of Kendal, England, the turbine suppliers to Duck Reach, state "We manufactured our first water turbine in 1856" (private communication p.c.) and Siemens Bros. of London, the generator suppliers, produced the world-first practical dynamo (1865), (devised by M. Faraday c.1831).

In 1877/78 Lester Allen Pelton (1829-1908) Comptonville, California produced the "first successful impulse water wheel…The high efficiency was due to the use of the first splitter type bucket…" (4). By 1904 the Pelton Water Wheel Co. claimed 11,000 installations (9,000 in USA) totalling more than 1x 10^6 h.p. with their highest head more than 2,000ft and their largest installation 30,000 h.p. at Puget Sound (3).

Work by F.de Moleyns (1841), Starr & Wing (1845) and others culminated in Sir Joseph W. Swan's practical carbon filament incandescent lamp (1878), followed by T.A.Edison's (1879). Swan forced cotton wool dissolved in zinc chloride through a die into alcohol, the resulting thread being wound on to formers and baked; Edison chose bamboo and his patents led to a long law suit which was settled in favour of the Swan Electric Light Co. (of 1881). They joined forces in the U.K. (1887) adopting the USA 100 V. and by 1898 cheap British made 200/250 V. lamps were available (5,6).Sir Charles Parson's UK patents for his Steam Turbine and Electric generator were dated 28th April, 1884, the year the public supply of electricity began in both UK and USA. Electric lighting (carbon arc and direct current-d.c.) was in use earlier, for example, the British Houses of Parliament were lit by the equivalent of 3066 standard sperm candles from a steam driven Gramme dynamo (1875) and the New Zealand Parliament buildings were partly lit experimentally for £2254.10.11, using 300 Swan lamps at 5/- ea. and a 16 h.p gas engine and dynamo (1883) (6). The first recorded death from electrocution was in France (1879).

2. TRANSFORMATION AND TRANSMISSION.

Prior to W. Stanley's development of a commercial transformer (1886) d.c. was used, but its high transmission losses and costs, electrolytic corrosion and limited range were major disadvantages. George Westinghouse had purchased (1885) the English patents of Gaulard and Gibbs for a "series alternating current of distribution" (1881) and N. Tesla's patents for his polyphase A.C. System. Stanley worked with Westinghouse and its first alternating current (a.c.) was demonstrated at Chicago (1893) (7). Previously a.c. had been used elsewhere, Lowell (1889) transmitted 20 miles, a Frankfurt exhibition was lit by a.c. transmitted from Lauffen, Sweden, 100 miles away (1891) and from Hallsjon, near Ludvika, a.c. was transmitted eight miles to a mine (3).

The facility to transmit electricity over long distances cheaply and reliably gave access to the enormous potential of hydro-electric generation. However the technical and economic parameters were still developing as indicated by Read, " development of Great Lake hydro-electric power for use in Hobart would have been impossible before 1895, risky before 1903 and uneconomic before 1907" (7). The first stage of Great Lake (1916) transmitted 65 miles on 589 steel towers at 88kV and distributed at 6.6kV.

The pace of development in UK was severely hindered by public and government opposition to granting "monopoly" rights to developers and a long public enquiry resulted in the Electric Lighting Act (1882). This brought about the complete paralysis of the electrical industry in England. The "Electrician" claimed (Mar. 1884) "the fanatical dread of a monopoly has resulted in there being no business to monopolise". By contrast, the rapid response of private and largely uncontrolled developers in USA to electrical innovation is indicated by the application of electric traction to tramways with overhead trolley systems (street cars). After several years of trial and modification the first was successfully operated at Richmond, Virginia (1888) and 789 street railway companies were formed in American cities (by 1890) (8). Built by Siemens Bros. the Hobart tramways were the first successful system in Australia (21 Sept. 1893).

3. EARLY HISTORICAL HYDRO-ELECTRIC DEVELOPMENTS.

The following items are a few examples of historically significant developments which formed the genesis of the hydro-electric contribution to the relentless surge of power. Commencing in the late 1800's they and subsequent developments maintained its momentum until the present time. They have been selected to provide a comparative base for early Tasmanian power developments.

By 1897 the total hydro-electric power development was (x 1,000 h.p) USA 72, Switzerland 32, France 18, Norway & Sweden 20 & UK 4. The then assessed potential of Great Lake was 100 (Tasmanian Parliamentary Paper No. 59 of 1897) (9).The installed capacities of the five Tasmanian hydro-electric power stations on completion of Great Lake-Stage 2 (1923) was 63,000kW compared with Victoria's 94,000 (1924.5), the populations being 219,000 and 1,625,000 respectively.

3.1 U.S.A

The first hydro-electric plant in North America to supply both private and commercial customers was Edison's at Vulcan Street, Appleton, Wisconsin (Sept.1882, designated 1977) (4). His thermal Pearl Street Station, New York, was contemporaneous and is said to be the world's first central generating station (8). The Cataract Co. of Niagara awarded a contract (27 Oct. 1893) for the hydro-electric development of the fall and 100,000 h.p was installed with 5000 h.p units (1894/95). Also to G.E.C. for a 22 mile transmission line to Buffalo to supply 10,000 h.p- later 40,000 h.p (23 Jul.1894) (3)."The first system to provide long distance H.V-3 phase transmission for significant municipal and industrial multi-purpose power use" was Fulsom hydro-electric power system in California (1895) (4).The Snoqualmie Falls cavity generating station, Washington is " the first underground hydro-electric power station" (1899) and is still producing power (designated 1977) (4). The Sault-Ste-Marie, Michigan hydro-electric complex (1902) "was and remains the largest low head facility in the USA…canal capacity 30,000 cfs..." (4).

3.2 England

Up to 1894 there were eight known hydro-electric stations distributing electricity of which the City of Worcester's station on the R.Teme at Powick was the only one owned, built and operated by a municipal authority. It was opened on 11th October, 1894 when the load, which was mainly domestic and street lighting was 200kW a.c. Of its 4 x 125kW alternators one was driven by a water turbine, one by steam and the other two either by water or steam or both…"With an output of 400kW..(hydro-electric) it was the largest…built in the 19th century for public supply and for two years…the largest hydro-electric station of any kind in the country." It was sold in 1925, but its waterpower was used until 1945 (10).

3.3 New Zealand

The early application of hydro-electric engineering in New Zealand (N.Z) paralleled that of Tasmania, the common influences being suitably located water resources, remote mining activities and the pioneering demand for power. Their subsequent developments have made New Zealand a world leader with installed and potential hydro-electric power larger than that of Japan. N.Z legislative controls were more advanced than those in Tasmania when (1917/18) John H Butters (later Sir John) Chief Engineer and General Manager of the Hydro-Electric Department, (Commission 1930-HEC) was introducing the licensing of electrical contractors and recommending standards for electrical machinery and equipment. There were interchanges of information and experience and, for example, the Auckland Electric Power Board sought Butter's advice and the New Zealand Government requested a report from him on the Hydro-Electric Department's organisation and developments (1922)(11). Although N.Z proceeded under enacted controls there was strong regional independence and "Apart from minor involvement at Rotorua the Public works Department was not involved until their first station at Lake Coleridge was commissioned…" (1915)(12). The Electric Lines Act (1884) and the Counties and Municipal Corporation Acts (1886) gave public bodies special authority to promote the use of electricity, but the Water-Power Act (1903) reserved to the Crown the sole rights to use water power in lakes, falls, rivers and streams for the purpose of generating or storing electricity or other power. Never-the-less the Minister for Public Works (Hon.R.Mackenzie) stated (1910) that, "the Government considers that the time has now arrived to take up with vigour, the question of developing our abundant water power…until all our centres of population have been supplied with hydro-electric energy and until our principal sources of power have been turned to commercial advantage" (6). Much of the N.Z. data which follows relies on references 6, 8 and 12 with some of the sources giving different values and in several cases duplicated information.

The Phoenix Quartz Mining company's Skipper's Creek hydro-electric development is claimed to be the first in N.Z (early 1886). It is described in detail by H.A.Gordon F.G.S, Inspecting Engineer in his reports to the Minister of Mines which are appendices to the journals of the House of Representatives (1186 et. seq.). Since the mine only had secondary rights to the water, "Mr. Prince of Fletcher & Co. electrical engineers, Dunedin,…undertook to erect electrical machinery…now erected on the left branch of Skipper's Creek, about a mile and three quarters from the crushing battery…to generate the electricity. As this is the first time in the history of electricity that it has been employed…to drive extensive crushing machinery, a full description…will not be out of place". Water was diverted from Skipper's Creek via a cutting to the forebay and then to twin wrought iron penstocks each 22 inches in dia; decreasing to 6 then 2.5 inches at the nozzles, to two 6ft dia. Pelton hurdy-gurdy water wheels (manufactured in N.Z. under licence) under 165ft. head, situated at the foot of a near vertical cliff. From the Brush pattern dynamos of the "largest size yet manufactured" d.c. power was transmitted by a No.8 B.W.G.(1/8 inch) copper wire 1 3/4 miles across a 800ft. mountain ridge to the mine battery of 30 revolving stamps.(10x800+20x650 pounds) plus a rockbreaker and two compressors. The output of turbines was about 75 h.p delivering c.50 to the mine. Since the hydro-electric installation and the mine equipment was installed and varied over a period of several years, the operating date of early 1886 could have (effectively) extended into 1887, whilst the outputs are approximations by the Inspecting Engineer. It is not known how long the station operated, but in 1888 he reported the company "has worked out…now merely prospecting".

At Reefton, West Coast-South Island the Reefton Electrical Transmission of Power and Lighting Co.Ltd. "harnessed…the Inangahua River and installed and operated the first hydro-electric plant to be worked by a public body in the colony, supply being given to the town. Indeed it is claimed that it was the first such supply in the Southern hemisphere." (4 Aug.1888)(6). Its initial installation was a 200kW Crompton bipolar dynamo 30/110V, belt driven by a water turbine made by Scott Bros. of Christchurch. The water race was 1.5 miles long and provided 27ft. head at the station. A 110 h.p Boving turbine was installed (1908) and the station was burnt down (1911). A steam prime mover (1901) and replacement generators kept it operating until November 1946, but it is not clear how much of its output was hydro-electricity. It was listed as in operation under the Electric-power Boards Act (1918), but as a steam supply (31st Mar.1919). It was not a supply authority as at 31st Mar.1948, having been taken over by the Grey Electric-power Board (Nov.1946). Its first supply of filament lamps was carried to the works packed in a butcher's basket, but they were all burnt out by 11.00 o'clock.

With the Wellington City Council's agreement an English syndicate, the Gulcher Electric Light & Power Co. installed 4 "Vortex" turbines of 22h.p each, driven by water from the Council's supply, in two stations and lit 500x22 c.p. street lamps (June1889). They subsequently erected a steam station with four horizontal engines each of 75kW (1892) and extended the supply for private use. Their plant and rights were purchased by the Council (1907) and listed as steam (31st Mar.1919) with bulk supply from the Hydro-electric Department.(He-D). The Electrical Supply Co. installed a hydro-electric station to supply the town of Stratford (1898). In March,1919 the station is listed with 800 consumers, water and oil power of 90 and 145kW, a.c. respectively. The Council purchased the company's assets, including a diesel generating plant (1916).

A 1948 return lists it as a Supply Authority with mixed generation as above, however, after its distribution system was changed to 3 phase supply (1926) the Council purchased power in bulk from the Taranaki Electric-power Board. At Outram, Otago a small generator driven by a Pelton turbine supplied the township (1899), it was not listed as operating in 1918 and no further details have been sighted. Hydro-electric plants were installed at Patea and Okere Falls, Rotorua by the He-D (1901) with 50kW a.c. and 70ft. static head and 200kW a.c. and 14ft. respectively. They were still operating as supply authorities at 31st Mar.1948 with 120 and 714 consumers respectively. Power was developed from the Waingorogoro stream by the Hawera County Electric Supply Co. (1903) with an installation of 145kW a.c. from a static head of 55ft. An oil fired unit of 154kW was also installed. The company was not a supply authority by 1948, but was operating as such in 1918.

Waipore Electric-power Co. Ltd, Dunedin constructed the first large hydro-electric station in the South Island (1907) to harness the Waipore Falls by a timber crib dam, 1¾ mile timber flume (replaced by a 4,700ft tunnel, 1909/1911), a 3ft dia. steel penstock under 665 ft.head and 2 Pelton turbines each driving 1000kW a.c. generators. It transmitted 28 miles to Dunedin. It was taken over by the Dunedin City Corporation (1907) before completion and the installation was increased to 4x1000 (1910) and 6x1000 (1913). The earlier machines were subsequently replaced and its capacity increased to 21,400kW (later than 1920). The first large hydro-electric project in the North Island was built and operated by the Waihi Gold-mining Co. Ltd (1913) at Hora Hora on the Waikato River. Capacity was 6,300 kW and transmission 45 miles to Waikato at 50 kV and 5 miles at 11kV to Waihi. It was purchased (1919) by the government and was the "pioneer of the large Government plants". It was submerged after 33 years by the filling of Lake Karapiro. Lake Coleridge, Christchurch &

Canterbury Province was the first hydro-electric development designed, constructed and operated by the Public works department. It initially had an installed capacity of 4,500kW a.c. (Mar.1915), but was subsequently increased to 6,000 (4x1500 in 1920) plus 2x3000 (1923) and 3x750 (1930), then to 34,500kW (by 1950). Static head is 490ft.

3.4 Mainland Australia

The early development of electricity in the mainland States was almost entirely thermal based. Since the main population centres were coastal, they had ready access to technology, equipment and coal. The tyranny of distance caused some of the inland towns to be late in achieving electrification. For example, Corin (see later) is credited with designing and installing electrical stations in “many…country towns. Amongst these…were Albury, Wagga Wagga, Wollongong, Orange, Cowra, Dorrigo and Mullumbinby,” that is after c.1910 (17) whilst their topography and hydrology was, in most cases, unsuitable for hydro-electric schemes. These factors, together with the advent of the railways resulted in thermal generation. Some early mining, flour and timber mills were operated by water wheels such as at Tumut, NSW and in the Australian Alps, also the 22ft dia. Garfield wheel near Castlemaine (15).The Moe-Walhalla railway line (1895) is photographed showing a large wooden water wheel supplied by a long elevated timber flume, (16, pp 54/5) and some such sites may have converted to hydro-electric power. However in his “notes on the electricity supply for Launceston” of May, 1958 (pc) the Director of the Queen Victoria Museum and Art Gallery, Launceston, F.Ellis, states that “Its claim as the first commercial hydro-electric generating station to be built in Australia has remained unchallenged and appears justified”. A counter claim from the township Thargomindah (Qld) for a small water turbine mounted on the outlet pipe of an artesian bore to operate (24 Jan.1893) two dynamos with d.c. supply to 200 street lights and total capacity 16kW, fails to upset the above statement (pc SEC Qld, Oct/Nov 1974).

The first use of electric lighting in Victoria was in Melbourne to celebrate the marriage of the Prince of Wales (1863) when Parliament House, the General Post and the Telegraph Offices were each lit by a carbon arc lamp supplied by adjacent chemical batteries. Using d.c. and overseas technology a number of small electric plants were built. The Victorian Electric Lighting Co. was formed (1881), later the Australian Electric Co.Ltd.(1883), by R.E.Joseph with Professor W.C.Kernot, Chairman and during the 1880s several similar small companies built and operated stations to provide street lights using reciprocating steam or (occasionally) gas engines driving by belt or rope arc lighting d.c. generators. Such companies were also manufacturing, selling or agents for arc and incandescent lighting. The above named company supplied the first electric lighting to Mt.Bishoff Mine (1883) q.v. Their distribution area was small and local, but the Melbourne City Council’s power station (1894) although of “formidable size and supply range… (also)…operated solely on public lighting”. The first significant hydro-electric installations in Victoria were the Sugar loaf-Rubicon System of five power stations (completed 1928) of which Rubicon contains 2x6,000h.p turbines under 1450ft. head (14).

Electricity from the tramway’s Piermont steam power station was used to light Sydney streets (from July,1904); however the influence of one of Australia’s outstanding pioneering engineers, William Corin (1867-1929) on the mainland’s hydro-electric developments occurred later. He was appointed Electrical Engineer to the Launceston Corporation (26th.Nov.1895-May, 1907) and was responsible for management, modifications and additions to the newly completed (December, 1895) Duck Reach hydro-electric power station and its rapidly growing distribution system. His design and supervision of the conversion of the wiring to a 3 phase-4 wire system was one of the “first in the British empire”. He was given leave (1906) to advise the Queensland Government on its Barron Falls hydro-electric scheme and his proposals were eventually adopted (1923/24). He travelled to Fiji for similar consultations (1906), New Caledonia (1920) and advised the New Zealand Government on its Lake Coleridge projects. He was consulted on the North Coast, Clarence et alia hydro-electric proposals (1919). Corin joined the NSW Public Works department (1908) and was appointed Chief Electrical Engineer (1913) and consultant to the Department of Mines. His paper to the Inst.C.E. (UK) “Efficiency Tests of a Hydro-electric Plant with observations upon the Water Power of Tasmania” Vol. CLXXXIII (1911) was awarded the Telford Premium. The Government sent him abroad for 12 months (late 1913/14) to study contemporary power engineering developments in UK, the Continent and USA, following which his paper, “Power Requirements and Resources of NSW” (1915) was the beginning of many important works which he carried out, notably the Burrinjuck, Dorrigo and Nymboida hydro-electric projects. Although his chief responsibility was for thermal installations, his hydro-electric knowledge was applied to these other developments. The three hydro-electric stations serving public supply had installed capacities of Nymboida 4,800kW, Wyangala 7,500 and Burrinjuck 2,000 (1950). He proposed and estimated the cost of a Snowy Mountain hydro-electric scheme (1920). He resigned (Dec.1923) and entered private practice as a Consulting Engineer, served on the Federal Capital Commission and his name was honoured by the Corin Dam on the Cotter River, Canberra (1966) (17). It is evident from the above that its timing, size, standards and pioneering hydro-electric development gave Duck Reach primacy and status in the mainland states and elsewhere, which together with Corin’s professional capacity was reflected in his post Tasmanian career.

3.5 Tasmania

Mt.Bishoff Tin Mining Co. Waratah installed a Swan Electric Light d.c. System in their offices, workshop, and the Manager’s house (19thJune1883 et seq.) The dynamo was operated from one of their five water wheels. The company subsequently installed a dedicated Pelton turbine, two more dynamos and extended electricity to other equipment and plant, including d.c. from a rotary transformer to their locomotives, and 400 incandescent lamps at Waratah (1886) which is claimed to be the first town permanently lit electrically in Australia. The hydro-electric lighting of their works is considered to be the first in an Australian industry. The company also built and operated a significant hydro-electric power development (before Dec.1907) with two Escher-Wyss Pelton turbines under 500 foot head and Westinghouse alternators each 150kW. Two additional sets of Voith turbines and AEG 375kVA alternators were added (19th.Sep.1909 and 1912 resp.). The now neglected station and m/c’s are extant, but have been stripped of copper and other salvage items. The mine was effectively closed (1945) and the power station (c.1950) (19).

Waverly Woollen Mills, (1872) near Launceston used a 36ft. undershot water wheel and later three Gunther Garrad turbines, 35 and 50 h.p (1890) and 100 h.p (1922). Electric lighting was installed (5th July 1889) using an Anglo-American Brush Co. dynamo and a Leffels water turbine. The 120 year old mill is open daily and some of the plant is extant (p.c.). Pioneer Tin Mine, near Derby built and operated (Apr.1909) its Moorina hydro-electric power development including the large rockfill Frome Dam 720ft. long, 60ft. high which is the earliest in Australia (18) and one of the first in the world to be built with an upstream waterproof concrete membrane. The three Voith (of Heidenheim) turbines at 423 ft. static head and AEG 375kVA alternators are operating in original condition as also are the dam, canal, penstock and power house (19).

Mt.Lyell Mining and Railway Co.Ltd. built and operated the Lake Margaret hydro-electric power development (Nov.1914) initially with 4x1750b.h.p Pelton turbines directly coupled with leather flexible linked belting, to 4x1200kW (at 0.8 power factor) GE alternators. Two additional sets of Boving and Gordon turbines were added (1918) and a seventh (1930) to 8,400kW station capacity. A lower head downstream hydro-electric station was built (1928-32) with a Boving (Francis) turbine and 1,600kW alternator. Both stations are operating in substantially original condition, except that the penstocks to both have been replaced together with the control board, main buspipes and valves to the main station (19).

Great Lake- first stage hydro-electric development was commenced (Aug.1911) by the Hydro-Electric Power and Metallurgical Co., but due to the Great War and the resulting financial problems, the Government took over the Company's assets and the Hydro-Electric Department, now Hydro-Electric Commission, completed the first stage when power was formally switched on first at Waddamanna and then in Hobart by the Governor-General, Sir Ronald Crauford Munro-Ferguson (6th.May, 1916). Two Boving (Pelton) turbines under 1123 foot static head, coupled with 3,500kW Westinghouse alternators gave an output of 7,000kW. Power was transmitted 65 miles to Hobart at 88kV and distributed at 6.6kV. Great Lake-second stage included the construction of the 40 foot high concrete multiple (27) arch No.2 dam. It was the world's leading dam for its type and size at this time. Great Lake capacity was thereby considerably increased and the headwaters of the Ouse River were diverted into it by the Liawenee Canal. Waddamana canal and associated hydraulic works were similarly increased with additional penstocks plus 7x6000kW m/c sets of Boving Pelton turbines and Westinghouse alternators at Waddamana A power station, total output being 49,000kW with 9 m/c sets (Nov.1919 to Apr.1923). Transmission was increased with a second line to Hobart, extended to Electrona, and one to Launceston (1921/22). The development was made obsolete by the diversion of Great Lake northwards via Poatina and the power station withdrawn from service in its 50th year (30 June, 1965). It is conserved as an HEC museum in original condition. The Great Lake hydro-electric power development was justly described as the "first major works of this type in Australia". It was a product of the continuing search for power and was authorised by the Complex Ores Act of 1909. The electrolytic purification of such ores from the mainland and the West Coast of Tasmania required large electrical capacity at low prices. Indicative power costs at the time were £75 per h.p year, the major contracts with the HED in the 1920s were £2, and £2/10/- and New Zealand hydro-electric power costs were subsequently similar. (1)(19)(20).

The Duck Reach hydro-electric power development (10th Dec.1895) was built and operated by the Launceston City Corporation (LCC) on the South Esk River about 2 miles from Launceston. The South Esk is one of Tasmania's major river systems, with a catchment of 3400 square miles, yielding an average flow of 2450 cubic feet per second and in the late 1880's several proposals were made to develop its potential both for public water supply and energy. In the lower reaches of the deep turbulent Cataract Gorge, a timber aqueduct was built against the dolerite cliffs to supply the Cataract Mill (1834) later Richies (building extant). A syndicate sought to buy these water rights for the "Launceston Light and Motive Power Co." (May, 1887), but the LCC's rights to the lower 3 miles of the South Esk were enacted (51 Vict. 43 of Dec. 1887). After considering other private proposals and engineer's reports the Council decided to invite tenders for an hydro-electric supply from the South Esk and the lighting of the city (Jul. 1888). Their consultants were Messrs. G. Gordon, MInstCE, C.W.James, CE and W.C.Kernot, MA, Professor of Engineering, Melbourne. Mr. K.L.Murray, MIEE, was engaged to define and supervise the programme (July, 1891) and Mr. C. St. John David MSE was appointed Surveyor and Engineer (Mar. 1892). Following further consideration a firm scheme was adopted and as required by their Act, a poll of citizens was held, which despite a strong campaign by opponents resulted in 2173 in favour and 690 against. Although the main competitor to the proposal was the Gas Co. which supplied street lighting (5 Apr. 1860) plus the domestic and industrial demand, strong views were also expressed from those who doubted the adoption of the new electrical technology.

The layout consisted of a low masonry weir at the downstream end of "Duck Reach", a 5 foot 6 inch diameter tunnel 2763ft. long with the invert half-circumference concrete lined to 5 foot internal diameter, a concrete forebay delivering to a 5 foot decreasing to 4 foot, wrought iron penstock (¼ inch plate), a "receiver" or bus-pipe at the power house on the north (left) bank of the South Esk River. The machines (m/c's) were 3x158 h.p at 111 foot head, plus 5x21 h.p Thompson-Vortex type turbines by Gilbert, Gilkes and Co. Ltd, Kendall; coupled to Siemens Bros London, alternators 3x100kW a.c. and 5xd.c. dynamos (7 amp at 1750V) to light 125 carbon arc lights of 1250 candle power each. The power house was a substantial masonry structure, 105 x24 feet on concrete foundations with the front and end walls built of dolerite spalls excavated from the benching and pits (up to 35ft. deep). It was designed by David who was also responsible for the tunnel and other hydraulic works, the suspension bridge (1896) and cottages inter alia. A successful trial arc lighting of the city took place from 8.00-10.00pm on 10th December, 1895 and continuously from the 17th. Within five months 5000 incandescent lamps were installed.

William Corin, MInstCE (q.v) was appointed City Electrical Engineer (Nov.1895-Mar.1907) and designed and supervised the expansion of the power development resulting from the rapid increase in demand. Two additional 100 kW m/c's were installed (1899) and a contract awarded to Kolben and Co. Prague (1903) for 4x445 h.p at 100ft net head Francis turbines coupled with 4x300 kW, Siemens alternators. Their installation and related works were completed (1906) by the conversion to a 3 phase 4 wire systems, except to arc lights. The power station alterations raised the machine hall roof to two storeys throughout and the control panels and switch boards were refitted. A large substation was built in the city. A second penstock was constructed and the bus-pipe divided by a 4ft diameter isolating valve. The new Kolben exciters were coupled to the old 21 h.p turbines. The intake weir was raised (1910) and "horizontal gratings" (trash racks) installed. Since the smaller units were replaced the net increase was c.1000 e.h.p. to 1600 e.h.p.

Headworks storages were increased at Arthur's (each approximately 6 square miles) Woods (3.5-4.5) and Tooms Lakes. At Arthur's Upper Lake the stop boards controlled a spillway of about one foot six inches by 67 foot six inches. The lower lake had seven steel sluice gates, each three foot by three foot three inches, set in a long low rock-armoured bank, with puddle clay core and about six feet of the lake's surface was controlled. Woods Lake rockfill dam was about 190 feet long by 6 foot above the sill sluice gates (7 off) set in two outlets. These works which, were built to augment the low summer flows at Duck Reach were done in two stages. HED were contracted by the LCC to build a 27 foot high dam at Arthur's Lower Lake, but this work ceased when Council accepted the proposed bulk power supplied subsequently by Waddamanna to Launceston by 88kV transmission (on-line Sep.1921).

Launceston was connected to the State Grid (1 Jan.1923) and its supply upgraded, 240 volts from 110 (1 Apr.1924). Schemes were put to the LCC by David (City Engineer) and R.J.Strike, City Electrical engineer to more fully develop the potential of the Gorge. Three proposals (1909) included one with an intake about 2 miles further up-stream and later a layout with tailwater the Tamar River tidal high water (1919), but they were not proceeded with. However a flume was built (1919-1921) consisting of 11 chain of masonry aqueduct from the intake weir plus 84 chain of six foot by four foot deep timber fluming set on timber trestles to the forebay. To develop the extra flow a new generator set was installed (1921) of 1180 h.p-800kW. Other than the damage caused by the 1929 flood the machinery operated without significant change until the station was closed down (Dec.1955) after 60 years of service, when the HEC's Trevallyn Power Development was commissioned. It had been compulsory acquired by HEC (1 Jul.1944) together with the LCC's supply system for £244,000. There were five m/c's under 113 foot static head and its rated capacity was 2000 kW.

Historic flood maxima occurred across the northern half of Tasmania in April 1929 when on the 5th. And 6th the South Esk River was said to be 10 foot deep in the station, i.e. at SL 280, the "usual" level being SL 240 and their design flood level SL 265. Station floor is SL 271.32 ft. The front and end walls collapsed and a major part of the roof was carried away. The machines were not seriously damaged and rebuilding in reinforced concrete, drying out and rewiring continued until recommissioning (mid 1930). The cable suspension foot bridge including pylons was rebuilt, but again washed away in a lesser flood (1969). The pylons are extant, but the decking and cables were not replaced (1, 7, 19, 21). The HEC offered (1957) the then obsolete development to the LCC without cost, but it was not accepted. Inaccessible and neglected it now consists of the bare powerhouse with several large diameter truncated pipes and damaged roof cladding, the winder house including gears and steelwork, large masonry pylons (2 off) and the original Corin Street staff houses built of dolerite spalls from the powerhouse foundations (1896/97). Several of the early turbines, alternators, exciters and valves were placed in safe keeping including at the Queen Victoria Museum, Launceston and others are displayed at Trevallyn power development. In the early 1980's strong public support was given to proposals to partly restore or reactivate the station, but since costs of ten million dollars were indicated for a site of very difficult access, the movement failed.

4. CONCLUSIONS.

The hydro-electric power developments at Appleton (1882), Niagara (1894/95) and Fulsom (1895) USA, were earlier than Duck Reach as was the (UK) City of Worchester's mixed thermal and hydro-electric station at Powick (1894) and New Zealand's Skippers Creek (1886), Reefton and Wellington (1889). Never-the-less the Launceston City Corporation's enabling Act (Dec.1887) and electrification (Dec.1895) place Duck Reach amongst the world's leaders of hydro-electric development, both in time and technology. The New Zealand projects were much smaller than it, but also lacked its potential for growth, both in demand and supply.

No significant early hydro-electric developments have been located on the Australian mainland, but in Tasmania both Mount Bischoff (1883 lighting of works, 1886 lighting of Waratah) and Waverly Woollen Mills (1889) precede Duck Reach. These electrical installations, however are comparable with New Zealand's first two projects, but for similar reasons, not to Duck Reach.

Launceston's Municipal Electric project provided a large increase in its commercial and industrial development when its advertisements for cheap electricity attracted overseas manufacturers, including Patons and Baldwins, Kelsall and Kemp, Rapson Tyre Works, plus municipal tramways, pumped water and wastewater services. Corin (q.v) was photographed with his 43 staff, also with 12 power station staff (1907) whilst the construction and fabrication activities, employing many more, helped the recovery from the severe 1890's depression. From a small population base (23,370-1895) LCC's bold initiative and foresight led Tasmania firmly into major hydro-electric developments, with their low unit prices, low maintenance costs and long economic "lives". Moorina (83 years) and Lake Margaret (78 years) are still operating with original machines, Duck Reach and Great Lake –Stages 1 & 2 (each 50 years) were bypassed by larger hydro-electric projects, whilst Bischoff (43 years) was made obsolete when the mine was worked out. Although the Great Lake hydro-electric power development (1916-Stage 1 - 7MW and 1923-Stage 2 - 49MW) was much larger and ultimately made a much greater contribution to the Tasmanian economy, Duck Reach (1895, 5 m/c's and 2MW) fully deserves the claims made by the Launceston City Corporation and by the available evidence now cited herein that it was "The First Significant Hydro-Electric Power Development in Australasia".

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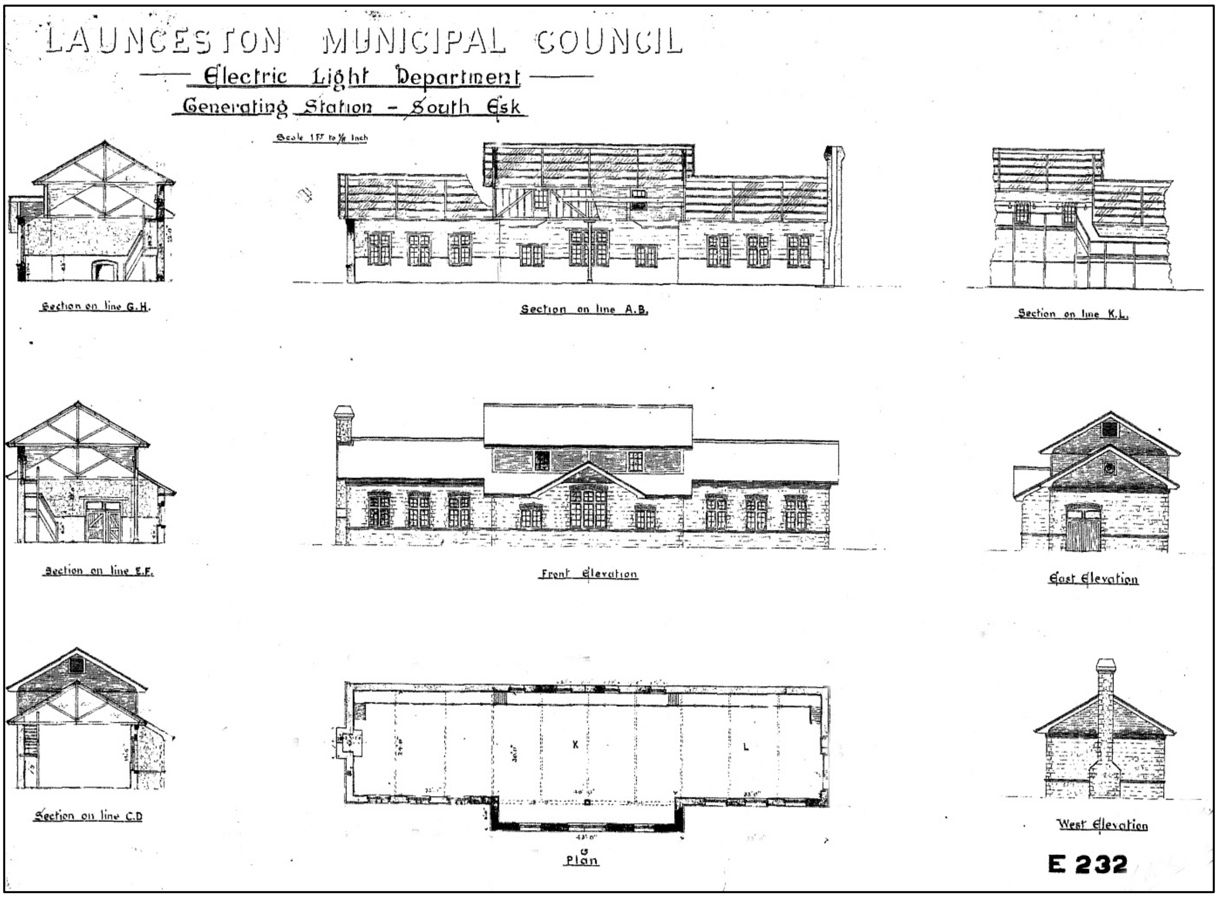
SUMMARY

When the street arc lights were activated by the Duck Reach Power Development at 8.00 pm. on 10th December, 1895, Launceston saw the beginning of an era of hydro-electric power in Tasmania, which has continued for nearly 100 years. Built on the South Esk River two miles from Launceston the development consisted of a diversion weir, tunnel, penstock and power station situated in a steep dolerite gorge. The capacity of the station was increased (1899/1906/1921) and it operated until 5th December, 1955 when the Trevallyn Power Development (80,000 kW) was completed. The latter used the full head of the gorge to the upper tidal reach of the Tamar river estuary and in so doing, bypassed the old 2,000 kW station. The paper examines the significance of Duck Reach in the history of hydro-electric engineering, particularly in Australasia.

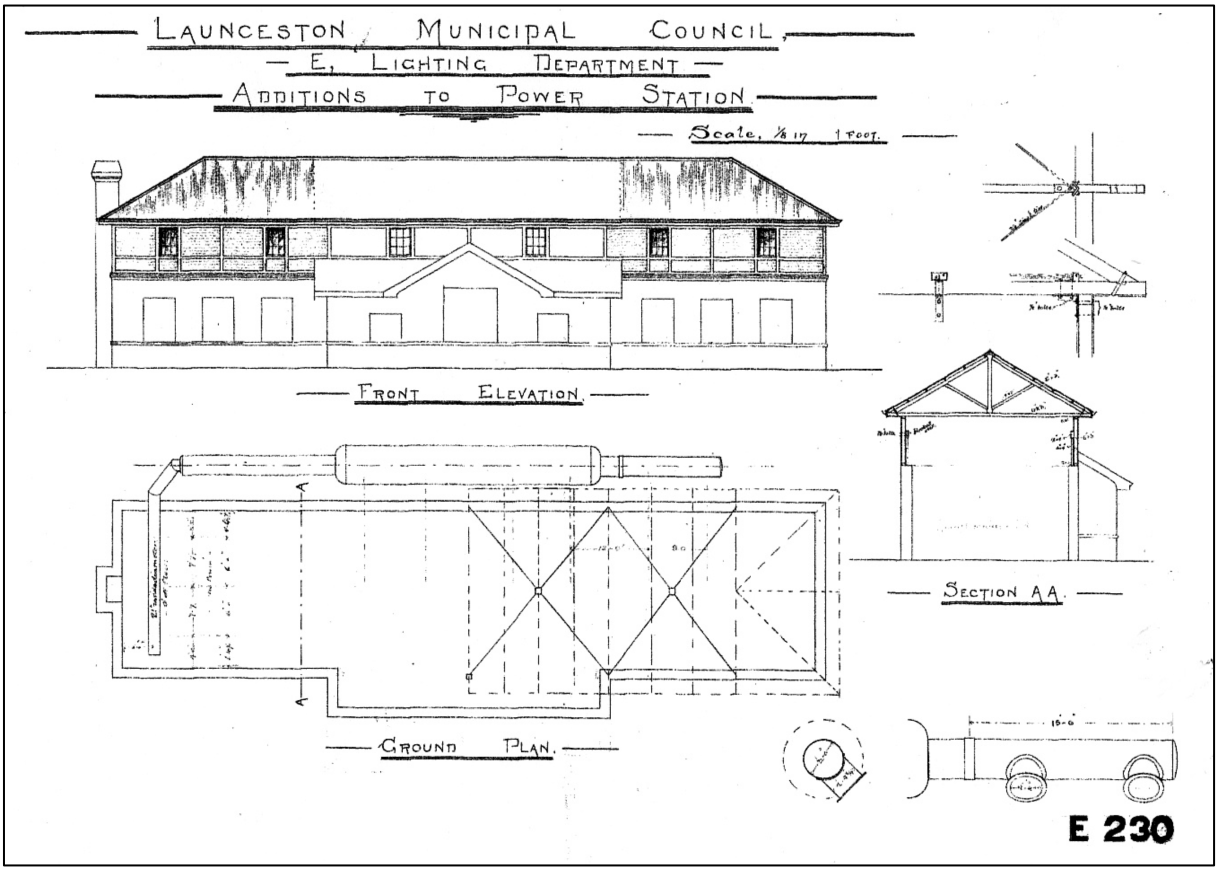
Dimensions have been given their historical values, mainly Imperial Units, including the customary use of Watts for electrical outputs.

Transcriber's note: Some abbreviations in the original have been reproduced in full for greater clarity and the two illustrations, Figures 1 & 2, have been omitted. The symbols for the electrical units have been retained as written in the original.

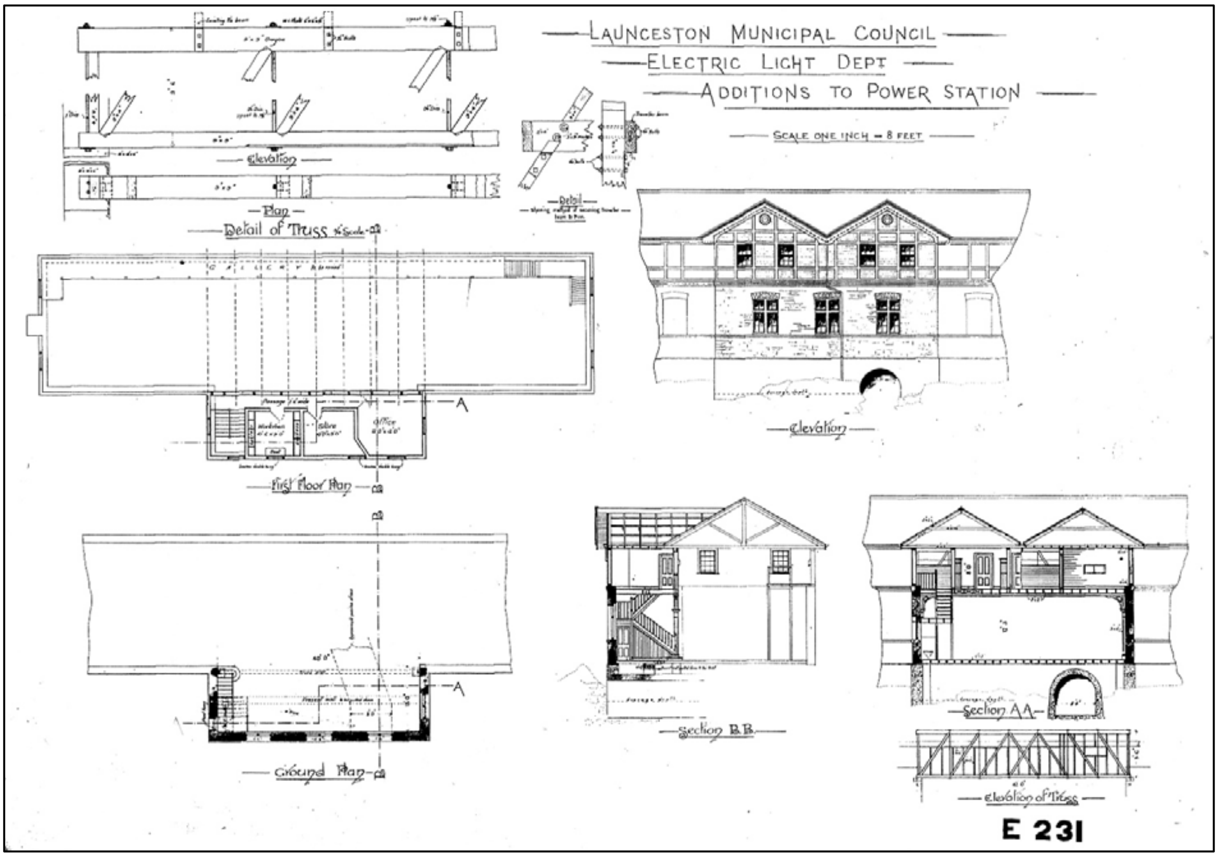
DRAWINGS



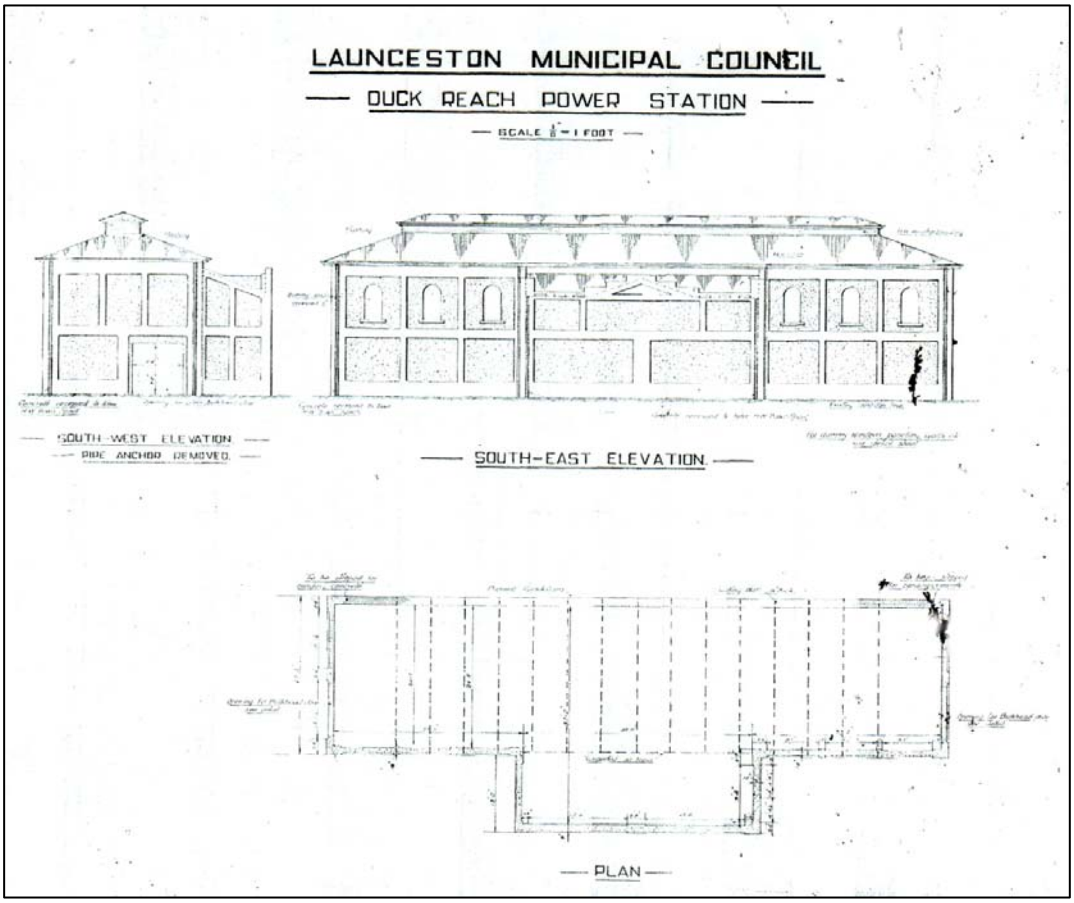
Original Power Station 1895



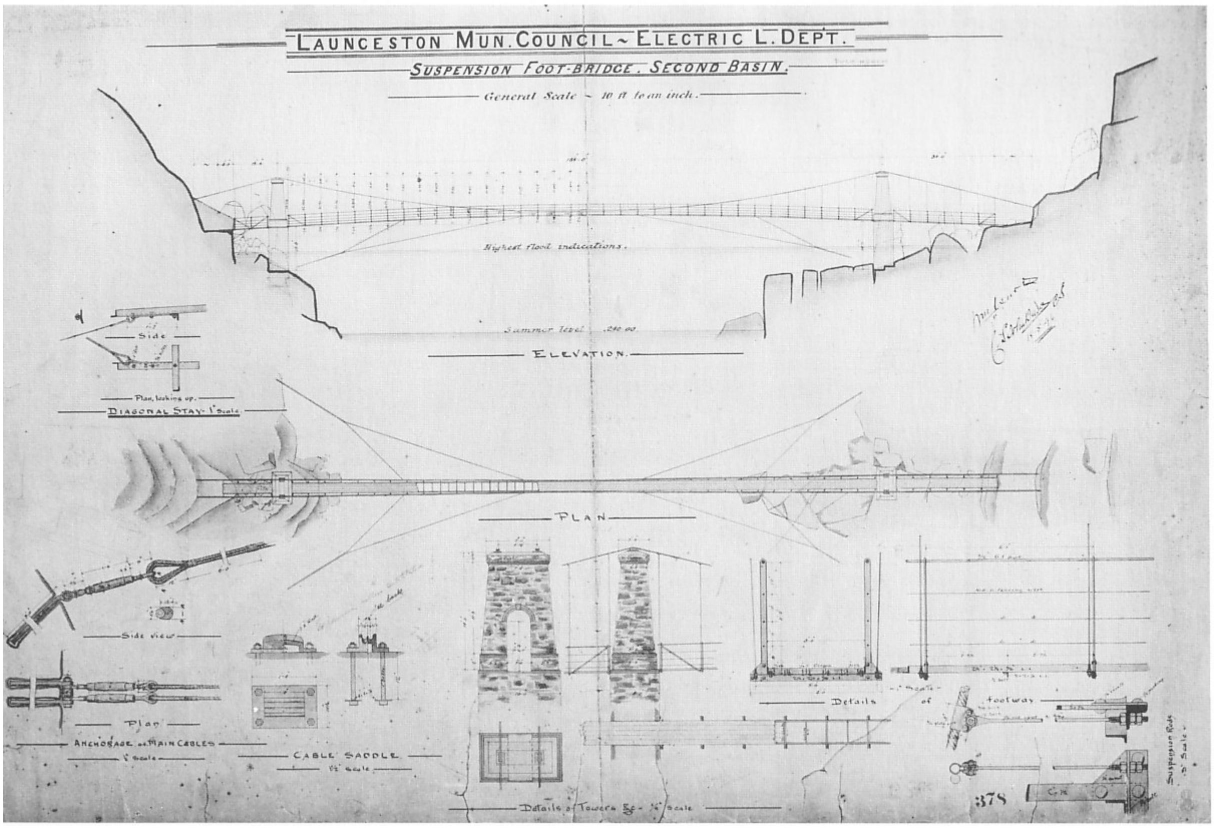
Additions to Power Station 1905
(roof ends raised)



Additions to Power Station 1907
(two gables over enlarged switch room)



Power Station after reconstruction in 1929.



Duck Reach footbridge – access from Corin Street
Designed by Charles St John David