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Under the Hayle Estuary: A Tale of Two Tunnels

Arthur Fairhurst

The developments by ING Red on the North Quay of Hayle Harbour prompt a review of some of the work carried out on the last major project in that area, the building of the Bromine from Seawater Plant by ICI (Alkali) on behalf of the Air ministry in 1939-40. That story is covered in Trevithick Society Journals 26 and 29.[1,2]

This article deals with one particular feature, namely the construction of the tunnel connecting Carnsew Reservoir to the Power Station pump house to provide an adequate supply of sea water for future power generation and bromine manufacture.

Earlier articles relied heavily on one major source document, "The Technical history of Hayle Works 1939-54" published, for private circulation, by the then Associated Ethyl Co Ltd, London in 1958. Records of the actual construction were scant and subject to the Official Secrets Act. Bill Venn, the author, relied on the comprehensive notes prepared by the ICI. Site Engineer, John Cathie, 15 years after the event in 1955.

In more recent times a copy of the text of the Presidential Lecture to the Cornish Institute of Engineers, delivered by Mr B. Rees in September 1957 on "Tunnelling under the River Estuary at Hayle" became available to me.[3] The preparation was subject to similar constraints to those applying to John Cathie, relying on memory long after the event. The two documents appear to be the only two definitive source documents dealing with this project.

Rees provided detail on tunnelling problems, progress and techniques whilst Cathie dealt with the political and managerial issues. The two accounts complement each other and taken together they provide a more realistic perspective of this challenging and unique project.

The decision to site the bromine plant on the Hayle estuary was finally made in December 1938, influenced by the availability of warmer sea water from the Power Station cooling system. In face of continuing increases in Air Ministry requirements for bromine there was concern within ICI Alkali that the freshwater dilution from the Hayle River would significantly limit production. The issue was so sensitive that a plan to build a plant to extract bromine from Dead Sea salt was

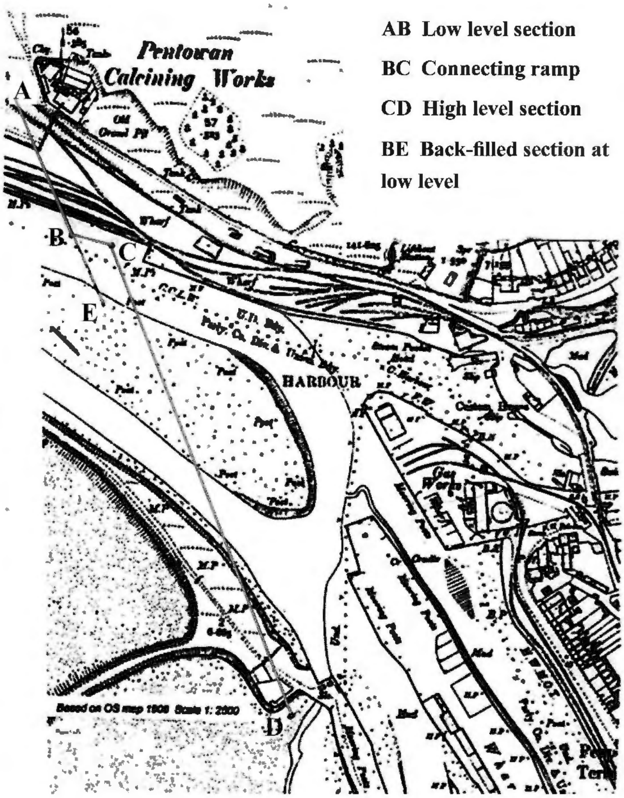

Figure 1. Lines of tunnels beneath the Hayle Estuary.

built at Randle Works in Cheshire, as a contingency. It was never used.

Edmundsons Electricity Corporation, owners of Cornwall Electric Power (CEP) had contemplated an enhanced supply of sea water for the Hayle Station and had developed the "Lelant Scheme".[3] The down side of this scheme was the high level of fresh water dilution so it was imperative that CEP should be persuaded to adopt the alternative " Carnsew Scheme". After discussion between CEP and Air Ministry the decision to source sea water from Carnsew was confirmed in early Spring 1939.

It was logical that CEP should be responsible for the tunnelling from Carnsew to the Station and for the ancillary works. Edmundson engaged Leighton, a London firm of civil contractors to undertake the work. They tendered for the work in April 1939 with a start date of 1 October and completion by May 1940. The plan was to drive a 7ft. diameter tunnel for 1,680 ft through rock at a depth of -100ft,O.D. the inlet shaft being on the bank at Carnsew and an outlet shaft and pump-house at the Station.

It quickly became apparent that Leighton was a firm of no high reputation and with limited expertise, technical and financial resources. The actual work on the outlet shaft started on 3rd September and at the inlet shaft on October 5th. It was on October 3rd that Mr Ewbank of Edmundson informed Leighton that he was dissatisfied with the rate of progress. On November 8th he requested the presence of Mr Ellis, Leightons M.D., to personally supervise the work as stipulated in the contract. In the meantime ICI (Alkali) had engaged C. S. Melk and Halcrow, Consulting Engineers, as advisors. A site visit took place on November 25th when it was confirmed that the planned date of completion would be exceeded.

On December 11th Christopher Hinton, ICI Chief Engineer reported to Halcrow on the slow rate of progress reported by his site engineer John Cathie. In early January he took the law into his own hands and ordered Leighton to remove all their equipment from the intake area.[4] It is fortunate that relationships between Hinton and Ewbank were cordial because in a letter from Edmundson to Leighton on January 8th Mr Ewbank supported the action taken by Hinton and further informed them that they had, by their actions, repudiated the contract. Then followed considerable legal consultation between the parties culminating in ICI (Alkali) negotiating a new contract with John Mowlem & Co.

There can be no doubt that the ground work undertaken by Messrs Cathie and Rees (Site Engineer for CEP) helped towards this pragmatic outcome. Mowlem immediately took over the tunnelling work whilst Leighton proved to be in an extremely bad financial situation. This clearly contributed to the absence of adequate and suitable technical equipment on site. They subsequently went out of business.

After many challenges the tunnel was finally commissioned on January 27th 1941 but in quite a different configuration to that originally intended. The low level (LL) tunnel through rock only ran for 380ft from the outlet shaft at -100ft O.D. whilst a ca 1220ft long tunnel was driven through sand, shale and soft rock at -40ft O.D. being constructed of iron tubing, lined with concrete. The two sections were connected by an 85ft ramp at an angle of 45 degrees and brick lined.

It is reasonable to assume that a project of this nature would have been planned

Figure 2. Aerial view of tunnel location beneath the Hayle Estuary. Note that this orientation is opposite to that of figure 1.

in some detail but the reality appeared to be a "seat of the pants "trial and error operation. In the contract between CEP and Leighton responsibility for surveying the site lay with the contractor. With the benefit of hindsight this was a flawed judgement because the initial survey was woefully inadequate. There was a dearth of knowledge about the nature of the local terrain and its geology which made it difficult to have confidence in the planning. To say that it became a "high risk" project is an understatement.

Leighton sank boreholes along the proposed line of the tunnel using a Banks drill loaned from the Camborne School of Mines. It was only suitable for depths up to 40ft. When that depth was reached a Climax Macintosh drill was used to drive a 2-inch diameter pipe a further 9ft before it collapsed. It was then assumed that the bedrock had been reached and further surveying ceased. Later, in March 1940, Mowlem engaged Le Grand, Sutcliff and Gell to carry out further surveys. At a distance of 760ft from the outlet shaft, still along the line of the planned tunnel, rock was only reached at -103ft O.D.

An understanding of all subsequent, recorded, developments is best achieved by following the developments section by section, starting from each shaft.

Outlet Shaft and Low Level Tunnel

Leighton started sinking the outlet shaft at the Station on September 3rd 1939, an ominous day. Their lack of experience, expertise and good equipment soon became apparent from the slow rate of progress. However, progress was quicker than at the inlet shaft on Carnsew where an inability to apply standard civil engineering techniques aroused much concern.

The first 20ft of the 12ft diameter shaft was through sand and required shuttering with timber. Thereafter, broken skillet, getting progressively harder with increasing depth, was encountered. Jack hammers were being used by inexperienced Irish labourers with little idea of where they should be placed but the problems were compounded by unreliable pumps, equipment failures and inadequate systems for removing spoil. A depth of 109ft was reached by November 26th, an average of only 1.3ft per day.

The first holes were drilled in the tunnel face on November 26th with a platform type of hoist being installed to remove the spoil. Continuing failure of the Beresford pumps meant that progress in the 7ft diameter rock tunnel was slow and interrupted. Jack hammers were still being used. Within one month the tunnel had been driven only 144ft. Mechanical means of removing spoil were not successful nor was the platform style of hoist,

On January 8th with 202ft of tunnel drive Leighton was replaced by John Mowlem & Co. Tunnelling did not resume until February 8th, wherupon problems of a different nature were encountered. The new contractor removed the hoisting equipment from the shaft and built a tubular scaffolding hoist tower from the base of the shaft. The work on the adjacent pump-house by a local contractor made it impossible to fix headgear in any other way.

Immediately tunnelling restarted the Beresford submersible pump failed and both tunnel and shaft were flooded. However, from February 12th progress increased to between 81ft to 96ft per week. By February 21st, at 320ft the rock began to deteriorate with water spurting from the drill holes. This immediately raised doubts about the surface level of the rock through which the tunnel was being driven. It was at this stage that Le Grand, Sutcliff were engaged to make borings ahead of the advancing face and along the line of the tunnel. The initial boring was on March 14th but driving continued in the meantime. Pump trouble continued to be a hindrance but progress was reasonable. The tunnel was making up to 7,000gph of water but by March 9th 455ft had been driven through rock of varying quality.

At 499ft a very soft seam of rock was encountered requiring timbering back to 447ft. Holmans were asked to bore a 100ft hole ahead of the face but after 30 ft the exercise had to be abandoned because of problems with clay seams. Tunnelling continued but with timbering close to the face. On March 19th, at 582ft, the rock suddenly ended in a vertical face running at an acute angle to the line of the tunnel. As the spoil was cleared there was a considerable inflow of water. When timbering was complete there was a large cavity in the crown. The face was immediately cleared and a 16ft length of the tunnel was filled with concrete. A further bulkhead, 5ft thick was constructed 6ft closer to the outlet shaft. It was determined that at this point there was a 72ft cover of clay, sandy soil and sand below the harbour bed.

The first Le Grand boring was put down at 178ft ahead of the tunnel face and only reached rock at -103ft O.D. Further bore holes were put down. At the end of March, taking into consideration also the experience in the inlet Shaft it was decided to abandon further low level driving and proceed with a high level drive through sand and silt, in compressed air, at -40ft O.D.

Inlet Shaft

The inlet shaft was initially sited on the banks of Carnsew where drillings had indicated that it would have to pass through sand and silt before reaching clay at -30ftO.D. Work started on October 5th using 25ft long interlocking steel piling. Due to the pocketing of fine sand under the piles a depth of only 24ft had been reached by November 1st. Pile driving was abandoned on December 8th to be replaced by a process of cementation of the sand below the piles. This also failed and all attempts to sink the shaft in this location were abandoned on December 26th with the shaft only reaching 31ft.

Following the failure of simple civil engineering methods it was decided to attempt to sink the shaft through wet sand, using cast iron tubing with a cutting edge, grabbing out the sand from within the tubing until the cutting edge reached rock.

John Mowlem, as with the Outlet Shaft, took over this work and their experience and expertise quickly became apparent when they started work at the end of January. The new site for the shaft was off shore, 50ft into Carnsew. Timbers were initially driven in to support an 80ft long gantry from the shore to shaft. Rail-track was laid to allow access for a 5ton crane.

The 12 ft diameter iron for the shaft was obtained from London Transport Board, each ring being 1ft 8in wide comprising 12 sections bolted together including a key section. Mr B Rees describes the cutting edge assembly admirably in the text of his lecture. An extract is reproduced below:-

> The steel cutting edge was assembled on 16 boards, 2ft 6in long x 7in x 1in, evenly spaced and radial to the centre of the shaft lying level on the sand a 1.84ft O.D. between the guide piles. Into this cutting edge were bent 26 nozzles for jetting purposes fed from six 2-in diameter pipes. Fourteen rings

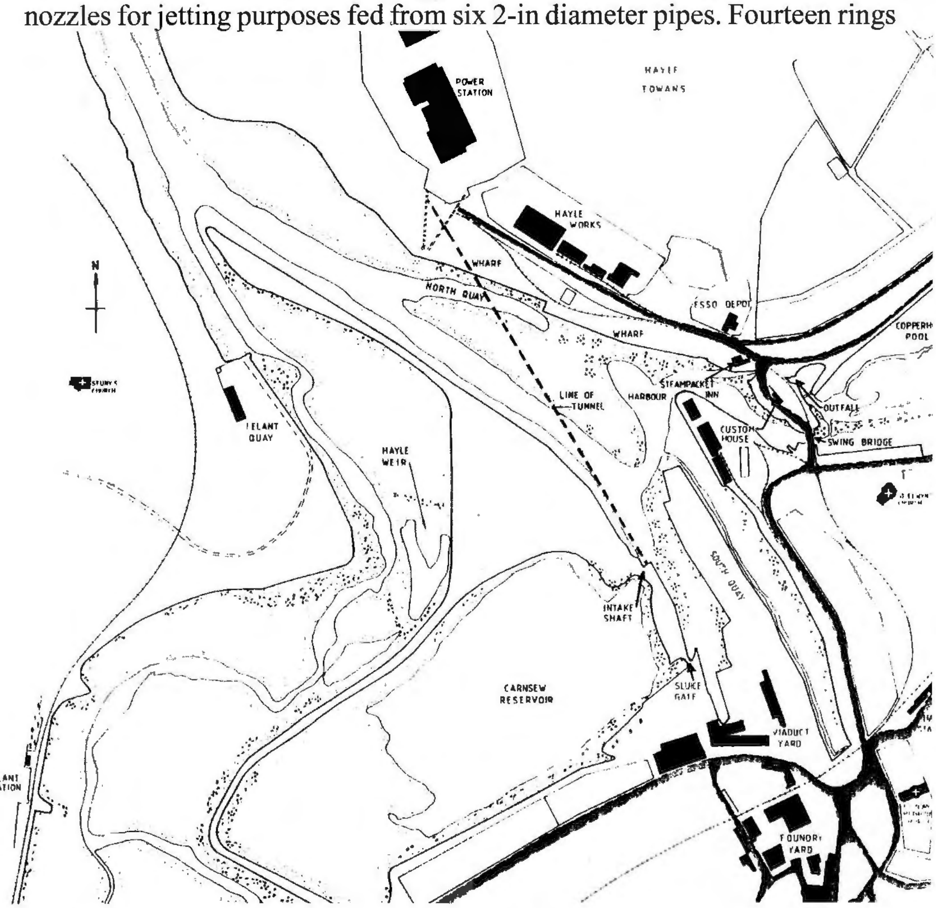

Figure 3. Detailed map of the Hayle Estuary showing the tunnel location.

of shaft iron were then built in the cutting edge using two strands of yarn soaked in red lead in each cross joint, the machined circumferential joints having an insertion of canvas soaked in red lead through the whole width of the joint. After these were bolted up, the caulking grooves were caulked with lead rod.

The six no 2 end pipes were extended to the top and twelve 1 in diameter grouting pipes were also extended up to the top from the grout holes in the bottom ring. All these were boxed in to guard them from injury by the grab. A square steel frame (Kentledge frame) of 'H' section girders were then built on top of the 14 rings already assembled and on to this rested equally spaced 3 ton cast iron Kentledge blocks.

With approximately 30 tons, resting on the cutting edge the edge had only cut into the boards on which it was resting by 0.25in. A few holes were then bored through the boards close to the cutting edge, care being taken to do this symmetrically and opposite round the circle. After boring about three holes in each, the boards gradually cracked and the cutting edge slowly sank 6 ins into the sand before coming to rest.

Grabbing inside the shaft with a half yard "orange peel" at the rate of 10 cu yards per hour, took the shaft down at the rate of 2ft per hour until it reached a depth of 10ft 10ins.

With the addition of further rings to the shaft and progressive increases in weights on the cutting edge progress was steady through the sand and silt. Clay was reached at -30ft O.D at which point water inside the shaft was 12 ft below the level outside, rather than 1 ft previously. Further progress was somewhat problematical. Further rings were added and the weight on the cutting edge was increased to 260 tons. Attempts were made to disturb the clay with jetting pipes but to little effect; trying to break the clay with a pointed iron rail did not succeed either.

The shaft had been full of water due to jetting but when baling reduced the level the shaft started to sink again. By using the grab the cutting edge reached -40ft O.D. When the water level inside the shaft was high grabbing was almost useless until baling out restarted. This procedure was repeated with more rings added and the weight on the cutting edge increased to 300tons. When -53.5ft O.D. had been reached the material removed was fine quarry sand and clay.

On March 21st this work stopped whilst a bore hole was sunk along the centre line of the shaft. After four days drilling, to a depth of -112ft O.D. no rock had been reached. The profile of the material removed was:-

Cutting Edge -55ft O.D.

6ft	Sandy Clay
4ft	Clean ground
7ft	Sandy Clay
18ft	Blowing yellow sand with 2in bands of clay interspersed
4ft	Very fine clean gravel and sand
18ft	Dirty sandy clay

On March 29th a major rethink took place and the decision taken to abandon further driving in the LL tunnel but to drive a high level tunnel (HL) at -40ft O.D. in compressed air as near as possible to the original line using a Gateshead Shield, starting at the inlet shaft.

It is appropriate, at this stage to review progress by reference to the following time-line collated from the available information.

Change of level

Inlet shaft

Bank Site

5 Oct 39	Piling started
30 Nov	Piling abandoned
8 Dec	Cementation process started
26 Dec	Site abandoned Leighton departs site

Pool site

Late Jan	Mowlem begin preparatory work
21 Mar	Shaft at -55ft O.D. driving stopped
21-25 Mar	Bore hole sunk no rock up to -112ft O.D.
29 Mar	Low level tunnel driving abandoned
	Bottom of inlet shaft sealed with 8ft concrete

Outlet Shaft Tunnel

26 Nov1939	Low level tunnelling started
8 Jan	Leighton leave site
8th Feb	Mowlem start tunnelling
21st Feb	320ft Rock Deteriorating Heavy ingress of water
9th Mar	455ft driven Soft rock encountered
14th Mar	Le Grand S & G make borings ahead of face
19th Mar	Major fault in tunnel at 582 ft.

27th Mar	Le Grand S & G reach rock at -103ft O.D. 750 ft from shaft

At this point there were two focal points, the driving of the high level tunnel and the connection between the two levels. The original Leighton plan was for the inlet shaft to be completed by 17th February and for the lining to be completed by 17th May. The tunnel was planned for completion on 10th May.

The bottom of the inlet shaft was sealed with an 8ft depth of concrete prior to the start of preparatory work for the tunnelling. Mr B. Rees describes the situation as follows:-

"Some 10ft above the centre line of the proposed H.L .tunnel a frame of H section joists were fixed across the shaft to which was bolted a 0.5in thick steel plate forming the air deck. The steel circular airshaft 8.5ft diameter was built upwards from the deck in 8ft lifts, the annular space between being filled with concrete. At surface level the soil and man airlocks were fixed to the shaft. The air shaft was divided into three compartments, one of approx 4ft diameter for the spoil bucket, the second of 2.5ft diameter fitted with a steel ladder as a man-way and the space between was used to take various air pipes, water pipes, etc.

The plant for the low pressure air installation commenced arriving on 13th April and consisted of two Bernard compressors of 500cfm. and 1000cfm capacity with 77hp and 120hp motors respectively. A Reavall compressor of 1800cfm capacity driven by a 224hp diesel was also installed to act as a stand-by in case of a failure in the electrical supply. The plant including a medical decompression chamber and the necessary cooling equipment for the air was ready for use on 23rd May.

During the period taken to erect the equipment, the eye of the tunnel had been drilled in the side of the shaft in free air and only required breaking out after the air pressure been put on the evening of 23rd may. A pressure gauge screwed into one of the grout plug holes at the axis level of the tunnel indicated that the full hydrostatic pressure was present on the skin of the shaft, the pressure varying with the height of the tide.

After stopping air leaks through the air deck and air shaft, the breaking out of the shaft iron, sufficient to permit driving 4ft by 5ft box heading irons, was started on 24th May. It was decided to put in three 8.5ft diameter rings to form a chamber 6ft long outside the shaft, within which the cutting edge of the shield was to be built. After this heading had been driven two feet, a break up was made from its end for the second and third rings of 8.5ft iron. After these rings had been built and grouted, the heading was widened ring

No 1 of the 8.5ft iron was built, and the junction to the shaft was concreted. All this work was in tough' hoggin 'which was very hard to excavate. Air pressure varied with the tide between 20 & 26 psi. The building of the shield then started in compressed air, the segments and skin of which had been stacked on the stage below the air deck before the deck was put in"

The Gateshead Shield used was of the hooded type, 8ft in diameter and 9.5ft long. To the heavily reinforced cutting edge was welded a 7ft long cylinder of 0.5in steel plate with welded joints. The outside of the joints were reinforced with a 9in plate. Within the shield was a steel plate with a 4.25ft x 3ft rectangular opening reinforced around the edges with six 3in channels. Bolted to this plate was a 2.5ft wide iron ring carrying the fixed portion of the hydraulic rams and control valves.

The mode of operation, as described in the lecture text, was as follows;-

Assuming that the rams had been drawn in and the last ring of iron built and that the face behind the forward bulkhead was timbered with horizontally placed poling boards, the first operation would be to remove the top poling has been board and dig out under the top hood of the shield for a distance of 1ft 8in, throw pug clay against the vertical face exposed to prevent excess loss of air. This operation is repeated until the whole of the face has been moved 1ft 8in. The rams are now extended to press against the against the last ring of iron built, the lower rams being used first to prevent sinking of the front edge of the shield due to the extension of the hood and the shield pushed bodily forward the 1ft 8in. The direction of the shield could be controlled by the operation of the ram and it was possible to correct misalignment as the tunnel progressed. The bottom two rams were than withdrawn and the bottom two segments of tunnel iron put in place and bolted to the existing iron. The bottom two rams were then retightened against the iron and the adjacent two rams above withdrawn to allow the placing of the next two segments of iron. This operation is repeated until the remaining segments had been built in with the key segment at the top. This completed the operation of one cycle of the shield.

The tunnel iron was made up of six equal segments with a small key piece always kept at the top of the tunnel. The depth of iron across the flange was 4.875in and the thickness of the iron between the flanges 1in. Bolt holes were provided through the flanges for bolting the iron together. Hardwood packing was used to form a gasket between the joints. The bolts holding the iron together were grummetted and after final tightening the wood packing were cut back to the bolt and the joints pointed with cement. In each iron segment was a 1in diameter tapped hole fitted with a plug. As the face progressed and the tunnel iron built cement grout was forced through each plug hole to fill as far as possible the 1in thick annular space left by the skin of the shield.

High Level Tunnel

Following the carefully planned and engineered connection between tunnel and shaft driving the tunnel began on 8th June. A summary of the progress and the nature of the ground traversed is presented below in tabular form, The cutting edge of the Shield had to deal with many conditions from tough "hoggin" at the outset through dirty ballast& rock to open ballast and boulders until a full face of rock was reached after 1200ft. Air pressure was maintained at between 15psi and 25psi although at times loss of air was excessive, up to 3000cfm on occasions.

The initial rate of progress was 71.5 ft per week, but following the introduction of an incentive payment scheme 85ft per week was achieved. A careful and disciplined adjustment to the scheme was necessary when particularly and unique difficult driving conditions were encountered. With the Bromine Plant completed and commissioned by early August there was considerable pressure to maintain a good rate of progress.

Much attention had to be paid to grouting, particularly to grouting the annular skin, around the iron tubing. On more than one occasion re-grouting was necessary. The spaces between the flanges were also filled with concrete to achieve the smoothest possible flow through the tunnel and reduce the pressure drop along the tunnel at full flow.

A very significant moment in the tunnelling experience occurred at 1,190 ft when a full face of rock was reached. Picks and breakers were used to move forward. Between 1,214ft and 1,224ft explosives were used with the loose rock removed and the area timbered. It was on 25th October that the shield was used for the last time after which a temporary ring of iron was inserted. The tunnelling was to within 5 ft of the face of the rock in the cavity in front of the headwall, built when the ramp was driven upwards from the LL tunnel.

At 1240ft the cavity in front of the headwall was grouted. A 2in hole was drilled through the concrete and a 1.5in diameter tube was inserted in order to equalise the pressures on either side.

Tunnelling progress

Date	Distance (ft)	Air Pressure	Nature of ground traversed
8:6.1940	Start	18-23 psi	Tough hoggin
24.7.1940	468	20-25psi	Dirty ballast with lumps of rock
23.8.1940	717	14-19psi	Pebbles & sand under hoggin; difficult
12.9.1940	867		Open ballast & boulders with silt

17/26.9.1940	908-993	Loss of air	Open seam of boulders with black slime
1.10.1940	1035		Dirty ballast
6.10.1940	1076		Clayish with lumps of blue elvan rock
15.10.1940	1165		Loose rock in invert
18.10.1940	1190		Full face of rock
20.11.1940	1250	15-19psi	Cavity above Headwall reached
1.12.1940			Tunnel cleaned out and completed

Connecting the Two Levels

It was decided that the optimum way to make the connection between the two levels was to drive a ramp, at 45deg to the horizontal and 45deg to the east of the line of the tunnel from a point 382 ft from the outlet shaft. The remainder the tunnel already driven was filled with rock and spoil from the ramp.

Before this work started a test bore was drilled up the centre line of the proposed ramp. The results were:-

Height from LL tunnel	Quality of ground
0-16ft	Ground Elvan hard and fairly solid
16-38ft	Ground Elvan softening. Jointed & broken with clay at 36ftl
38-55ft	Ground Elvan, jointed & broken, softening with increased water content
55-60 ft	Ground Elvan, jointed in places. Joints carrying clay. Rock harder and more consolidated

Drilling a few feet further would have indicated only 5-6ft of rock cover above the crown of the high level tunnel at this point On the basis of these results it was decided to proceed to build the ramp on 21st May. Driving was carried out between 22nd and 28th May the last section was in soft and badly jointed rock under the overlying hard rock. Work to secure the top continued for a further week. The whole exercise was critical, there being two falls but only minor injuries were incurred.

Much care was taken with the upward drive to avoid suddenly running out of rock again. The system adopted was to drill ahead for 20ft, one hole to the left and one to the right at such an angle that at the end of the 20ft the hole would be 10ft outside the side of the tunnel and 10ft above the crown. If satisfactory the ramp would be driven for 13ft.

On 13th June a further drive brought the roof in with it, which was only 5ft

Figure 4. Aerial view showing Hayle Power Station, Associated Octel Works and Esso Oil Depot.

thick. Water flooded in and a cavity formed overhead due to the collapse of sandy clay and pebbles. (See above). Immediately a 3ft concrete headwall was put in place just inside the solid rock and completed by 13th June. The remaining section of the LL tunnel was back filled and the usable tunnel was trimmed to shape.

Problems with the Beresford pumps continued. On 4th July the motors on two of the pumps burnt out and they had to be removed before the tunnel flooded. A 3-inch Sykes pump was rigged up in the cage within the outlet shaft in order to control the level of water in this shaft. It was considered unsafe at this stage, given the state of the tunnel at the top of the ramp, to pump out the water thus creating a vacuum and increasing the pressure in the ramp by a further 15psi

An interesting situation existed. The water level in the shaft was not allowed to fall below the level of the top of the cavity at the high point. It was eventually decided to sink a tube from the harbour bed at low water, over the top of the ramp and then drill through the 5ft of rock into the top of the tunnel. When the exact spot had been located a 3in tube was jetted down with compressed air on to the top of the rock. A 1in tube was inserted, through which compressed air was blown, whereupon the water level rose in the outlet shaft. The 1in pipe was grouted into the 3in tube and brought up the side wall of the Wharf.

On 6th August pumping out of the LL tunnel commenced and was complete by 9th August. Laying down sub drains was completed by 4th September followed by brick lining. The entire job was completed on 5th October. All the hoisting gear was then removed from the Shaft.

The sump was cleaned out and deepened to take the pump which had been sited in a sump inside the tunnel. Following this the shaft was lined with 7ft diameter reinforced concrete rings, each 3ft deep. Lining, up to the pump suction level, was completed by 16th Nov when the tunnel and shaft were allowed to fill with water, thus forming a water seal in order to retain the air pressure in the HL tunnel after breakthrough.

The 30ft section of shaft from -10ft O.D. and its connection with the pump suction was lined with 12ft diameter reinforced concrete rings by 18th December.

High Level "Break through"

The junction of the HL tunnel and ramp occurred between 1238 and 1252 ft from the Intake following the sealing of the LL tunnel. When the face of the HL tunnel was opened up there was a pressure of 10psi between the headwall and water seal due to air escaping through rock fissures. On 20th November, at 1246ft, a hole was broken through the headwall. Much air escaped between the brick lining and loose rock in the lower tunnel, causing much consternation on the Wharf above. Considering the crisis conditions under which the headwall was built it was in a good state and quite tough. The final section of this iron tunnel was installed On 24th November and the alignment of tunnel and ramp was practically perfect. Cleaning out of the tunnel invert then progressed after which the air pressure was

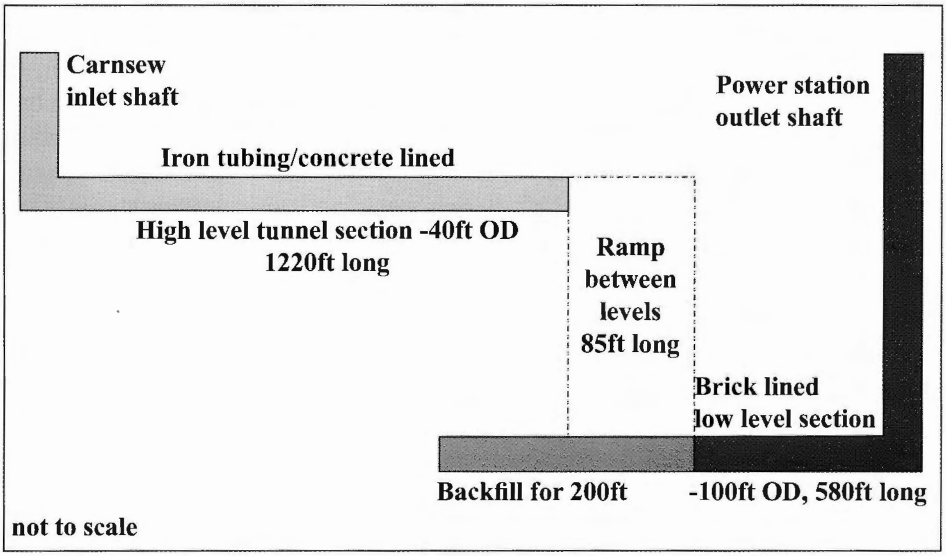

Figure 5. Tunnel levels under the River Hayle.

allowed to fall to 4psi. in order to test the pointed joints for leaks. the worst being caulked with lead.

From 3rd December any leaking joints were fixed whilst in the inlet shaft that section below the air deck was rebuilt and lined with finished concrete rings like the rest of the shaft. The remaining intake works, originally started in May, being the pen-stocks and lead-in apron, were completed by 20th January 1941.

During the last three months of the project there was every indication that the sense of urgency had waned but it is significant that the Bromine plant, in its start –up phase since August, had operated on a sea water supply from the existing Power Station system without establishing a need for an augmented supply.

The eventual commissioning of this unique two level tunnel without any problems on 27th January was due in no small way to the cooperation, between the site Engineers of ICI and CEP, Mr J. Cathie and Mr B. Rees. Their management and leadership skills, combined with a pragmatic approach, enabled them to overcome many challenges. A retrospective critique is both relatively easy and interesting but progress on site depended on these two senior engineers. The tunnel continued in operation until 1975 with any problems.

In 1970 there was a hiatus in the supply of sea water to the station when a section of the main under the harbour collapsed. Recent research and reliable anecdotal evidence from eye witnesses confirmed that the collapse was in the section of the original tunnel from the "boxers" at the end of the sandbank off North Quay. The site of the repair was well off the line of the LL tunnel and accessible from the estuary.

Comment

Time was of the essence in this project due in the main to the frequent changes in demand on the part of the Air Ministry. The impact of government policy was discussed fully in the article "Mining the Sea. The Race against Time"in Journal 29, 2002.[2] Preparation and planning time was at a premium.

Whilst CEP had prepared their own " Lelant" scheme, to augment sea water supplies to meet their future needs persuasion , at a late stage, by the Government to switch to the alternative " Carnsew " scheme was critical. There was clearly a shortage in the local area of sufficient skill and expertise to undertake such major works making it essential to find resources from elsewhere.

Edmundsons, owners of CEP, selected Leighton of London, a firm apparently of no high reputation. They contracted for the work in April 1939, barely 3 months after the final decision was made to site the Bromine plant at Hayle. There was little time for due diligence otherwise CEP would have discovered that their chosen contractor lacked adequate technical and financial resources to undertake the work in a satisfactory manner.. Their management must have been pre occupied with the survival of the Company.

The most significant contributory, technical, factor creating the very challenging situations was the inadequate surveys undertaken by the Contractor. CEP charged Leighton with undertaking this work and accepted their findings in good faith. It is a reasonable assumption that the work done by CEP on the original scheme led them to believe that a tunnel could be driven through rock at -100ft O.D. because experience showed that there was rock at this depth closer to North Quay and in the area covered by the "Lelant" Scheme. What we may regard as both naïve and unforgivable is the paucity of information and lack of rigour of the limited survey carried out by Leighton. We could also argue that more research should have been undertaken on the geology of the area. Fortunately the more detailed surveys carried out in the spring of 1940 provided the necessary information and data to move forward with more confidence. Relevant and more extensive experience together with robust leadership combined to recover the situation and overcome the daunting challenges.

From the outset CEP and ICI (Alkali) expressed concern about Leighton's performance but it was Christopher Hinton, Chief Engineer of Alkali Division who grasped the nettle and ordered them off site. The substitution of John Mowlem & Co quickly highlighted the inadequacy of their predecessors by their methodical and professional approach. However, precious time was lost!

ICI, as a whole, had 30 Government contracts associated with the war effort. They had the confidence, experience and resources in project management to take firm action. CEP was fortunate to have their support and whilst ICI were not initially responsible for the tunnel contract the cordial relations between them were maintained. They had the experience that CEP needed in the circumstances.

Once established on site Mowlem Engineers were decisive in their response to the various crisis situations. The decision to abandon the low level tunnelling and drive a high level tunnel under compressed air was bold and prompt. We may now regard the solution as obvious but on the ground, at the time, such a major change of plan required decisive action. Their cautious yet urgent approach thereafter drew upon a considerable body of expertise and confidence. Some of their solutions were imaginative.

Man management must have been of a high order to maintain control in the circumstances whilst the introduction of an incentive payments scheme to encourage a higher rate of progress was imaginative in 1940. The pressures on the Site Engineers were obviously considerable having to achieve results but following a cautious approach in often dangerous situations. The successful, if late, completion of the project was a tribute to the work of Messrs Rees and Cathie. We owe both men a debt of gratitude for putting on record the story of this fascinating project.

Sources of Documents

"The Technical History of Hayle Works 1939-1954" H. J. P. Venn Associated Ethyl & Co

Ltd 1958
"Tunnelling under the River Estuary at Hayle" Mr B. O. Rees
Presidential Address to the Cornish Institute of Engineers, 28th September 1957

References

1. Fairhurst, A., 1999. Mining the Sea: Extraction of Bromine from Sea Water *Trevithick Society Journal* No. 26, pp3 ff.
2. Fairhurst, A., 2002. Mining the Sea: A Race against Time. *Trevithick Society Journal* No. 29, pp96 ff
3. Fairhurst, A., 2007. Mining the Sea: An additional Note. *Trevithick Society Journal* No. 34, pp33 ff.
4. Fairhurst, A., 2002, *op. cit.*

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