NORTH EAST INDUSTRIAL ARCHAEOLOGY COUNCIL NEWSLETTER

Maker's Plate from the Ryhope Pumping Engine.

NORTH EAST INDUSTRIAL ARCHAEOLOGY COUNCIL.

NEWSLETTER NO.3 - SPRING 1973.

Editor's Notes.

As our last Quarterly Meeting was concerned with the Ironbridge Gorge Museum project it is appropriate that details of this scheme should be included in this edition. With summer approaching perhaps this will entice some of our members to visit the West Midlands area during their holidays.

Our other main feature is an article on the erection of the Britannia Tubular Bridge, which due to unfortunate circumstances was in the news a couple of years ago. This article had to be omitted from out last 'Bulletin', but we hope readers will be interested in a process of bridge building which is part of our industrial heritage.

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NORTH EAST INDUSTRIAL ARCHAEOLOGY COUNCIL

The Annual General Meeting of the North East Industrial Archaeology Council will be held on Friday, 13th April, in the Lecture Theatre of Durham Technical College at 19.30 hours (7.30 p.m.)

AGENDA

1. Apologies.
2. Minutes of previous AGM.
3. Chairman's Remarks.
4. Secretary's Report.
5. Treasurer's Report.
6. Editor's Report.
7. Election of Officers: Chairman
   Secretary.
   Treasurer.
   Editor.
   Auditor.

   Six executive Committee Members.
8. Any other business.

D. Wilcock.
Hon. Secretary.

The Meeting will be followed by a light-hearted quiz of IA interest, for the "Linsley-Smith" Silver Grip. Teams will consist of two members from each of the four constituent groups.

NEIAC ANNUAL CONFERENCE 1973

This is being held earlier this year, on Saturday 30th June, in the Durham Technical College. The theme will cover the Industrial Archaeology of Power and the speakers will be Mr. R.A.S. Hennessey, author of "The Electric Revolution," who will talk on the electric supply industry, Mr. T.T. Hay, who will take water power as his theme and give an international survey of water mills and water wheels; Dr. Alan Griffin, author of "Coalmining" in the Longman Industrial Archaeology Series, will talk on the I.A. of coal mining.

There will be space for display and there will also be a session devoted to contributions from the Groups.

Details will be circulated to all members, but please DON'T forget the date.

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"The Yesterday Show" BBC-tv North East. Transmitted Tuesday 20th March at 10.15 p.m. - This show has every chance of becoming popular with the viewers, it offers them a challenge in guessing the objects, and Frank Atkinson's presentation is relaxed and natural. The panel, all historians, were disappointing in their speculations, but as they are used to dealing with people and ideas, it is understandable that they were puzzled with the artifacts. The obvious choice for such a panel would be Industrial Archaeologists and the two members of the audience who spoke at length on water wheels and mining could be described as such.

There is to be a series of these programmes transmitted on Tuesday nights so watch out for them in the Radio Times.

Don.W.

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THE INDUSTRIES OF THE IRONBRIDGE GORGE.

The Ironbridge Gorge Museum has been established in an area of industrial activity which has spanned four centuries, starting with medieval coal mining and culminating in the activities of the Allied Ironfounders at Coalbrookdale.

The River Severn gave the coal owners of the east Shropshire coalfield an easy water-borne access to distant markets in both the midlands and the west of England and provided the necessary spur to the growth and development of the field. To facilitate transportation to the river primitive wagonways, the first being of wooden construction were built to link coal mines to the river.

Ironstone and limestone was also found in close proximity to the coal, and furnaces were erected, using charcoal as a fuel and water power for the bellows, in areas of woodland on fast flowing streams, on the edge of the coalfield. One such site was in Coalbrookdale where Abraham Darby established a furnace. It has been said that his use of coke in smelting in 1709 made but little difference to the growth of the industry, but when Abraham Darby II, his son, blew the first Horsehay Furnace in 1755, the success was almost immediate and this led to the rapid development of the iron trade and to the erection of further furnaces. The concomitant development of the steam engine led to its application in pumping and winding in the coalfield, which in turn led to deeper pits and greatly increased output. To link these with the river more railways and waggonways were laid, using the cast iron rails made locally.

In 1777, through an Act of Parliament, a group of trustees built a bridge across the Severn, and were granted leave to build wharves and warehouses on both sides of the river, upstream and downstream from this bridge. Further development was stimulated when the Shropshire Canal reached the river via the Great Hay inclined plane in 1793. At the foot of this inclined plane the canal ran parallel with the river bank for about $\frac{3}{4}$ mile to the bridge. To transfer coal from the twenty foot canal tub boats to river barges led to some very inventive devices, as well as giving the area the name - COALPORT. A host of new industries, including the famous china factory and chain works grew up in this area.

At the beginning of the 19th century there were blast furnaces on both sides of the river, including the famous Bedlam furnaces and also at Calcutts, where much of the iron was cast into cannons, and behind the furnaces were the coal and tar ovens of Lord Dundonald. Waggonways and railways constructed by the Coalbrookdale Company brought their products down to the river for export, while similar waggonways constructed from cast-iron rails supplied by the Company came down to the river on either bank in an area of about 4 miles, and three bridges spanned the river.

During the depression in the iron trade following the Napoleonic Wars a great number of the furnaces were closed down, especially along the Severn. In the 1820's and 1830's the increase in production and rise in trade led to greater and newer ironworks being constructed, but away from the river bank, on the edge of the coalfield, where the pits were deepened and the iron ore and coal mines were more productive. The only works to be built near the river were those at Blists Hill, which were opened in 1832.

The development and growth of railways, the improvement of the roads throughout the 19th century, rivalled the river as modes of transport, and as the Severn became less reliable for navigational purposes there was a shift of industrial emphasis away from the area of the Severn Gorge into the northern parts of the Shropshire coalfield.

Although the coal and iron industries declined during this period there was a growth in the clay industries in the Gorge. The

Coalport China Works became one of the most celebrated in Europe, exhibiting at all the international expositions with their dazzling wares. To meet the increased demand for tiles during the rapid expansion of industrial towns at this time, the tile industry of the Gorge expanded considerably. The leading firm of Maws moved into the area from Worcester in 1871, and grew into a large active works within a decade.

Commercial traffic on the Severn from the Gorge declined and completely disappeared by the beginning of the present century. Industrial development was confined to other parts of the Shropshire Coalfield where rail and road transport was easier, leaving behind in the Gorge derelict and overgrown sites. As these werenot subjected to development nor to "tidying up" they have remained unchanged and these combined with the natural sylvian beauty of the Gorge have given an ideal setting for the Museum, where the growth and achievement of this part of Great Britain can be shownto good effect.

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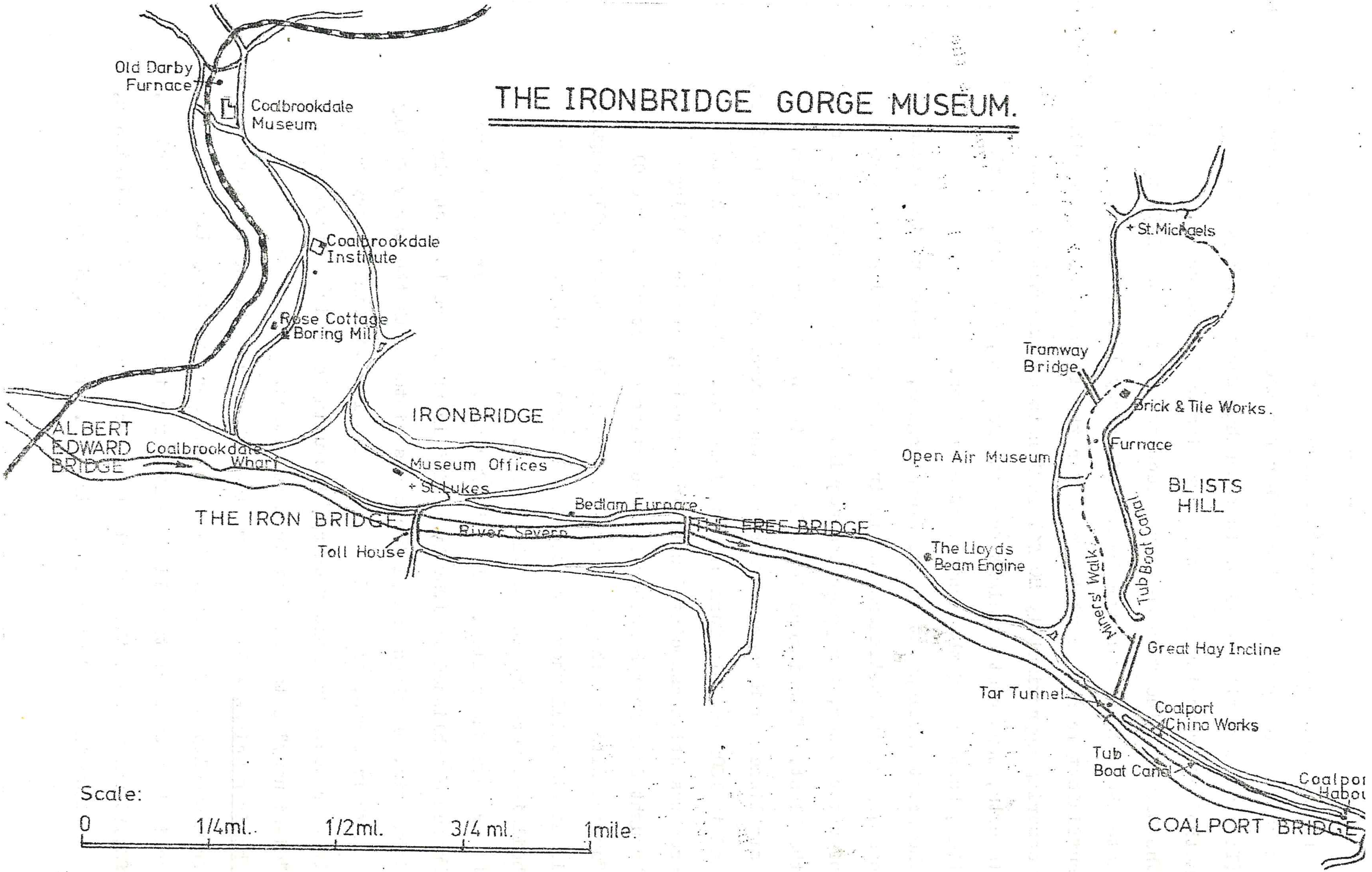
SITES AND SIGHTS IN THE IRONBRIDGE GORGE.

The visitor to the Ironbridge Gorge has to make the decision as to what must be the first on the tour. Either the Ironbridge itself, which gave its name to the town, or to the Old Furnace site in Coalbrookdale where the bridge was created and where the ribs were cast.

The Old Furnace - The site was excavated in 1958, when about 5,000 tons of rubble, dirt etc. was removed from the site above the foundry and the original Darby Furnaces were revealed. Abraham Darby, who came originally from Dudley, and had been casting brass in Birmingham, had developed a method of casting thin iron pots in sand, came to Coalbrookdale in the 17th century. This was an area which had abundant water power for working the

THE IRONBRIDGE GORGE MUSEUM.



bellows. Iron ore and limestone were being mined locally, and there was plenty of standing timber for the production of charcoal. (It was not until 1708/1709 that Abraham Darby developed his method of producing iron using coke instead of charcoal.

The beams of the furnace bear a succession of dates, 1777 was the date when it was enlarged by Abraham Darby III, in order to smelt sufficient iron to cast the ribs for the Ironbridge. These ribs measuring approximately 80 ft. in length and weighing 5 tons 15 cwts, were cast straight from the furnace, and must, at that time, been one of the wonders of cast iron.

The great development in the steam engine, partly due to better casting of the cylinders led to iron making becoming independent of water power, for power was required to drive the bellows for the blast. This independence led to the Darby Furnaces being established at Horsehay, nearer to the source of the raw materials, and in 1802 the old furnace was blown out. The Coalbrookdale area was still associated with iron working, pig iron being brought down from Horsehay for recasting and storing. The Old Furnace site and the associated water wheels were gradually engulfed in debris until they were completely buried. Stores and other buildings were erected on the debris.

Lower down the valley, below the furnace, is the excellent Darby Museum established in 1959 by Allied Ironfounders Ltd. showing documents, drawings and pictures associated with the Darby family and their works, along with a fine display of 19th century cast iron products from the foundry, including cast iron fireplaces, "missionary" pots and cast iron furniture.

<u>The Iron Bridge</u> - It was to replace the ferry across the Severn from Madeley Wood to Benthall that led Abraham Darby II to activate a subscription list in 1775 for the erection of a bridge. £3,150 was raised, the principal subscribers being John Wilkinson, a partner in the Coalbrookdale Iron Co., the Rev. Harries and

Abraham Darby. In 1776 an Act of Parliament was obtained to construct a toll bridge across the Severn with abutments and approach road. The design of the bridge, a semi-circular arch, and the casting of the ribs and other parts, was carried out by Abraham Darby. The erection of the bridge took 3 months in 1779, without accident and without obstructing the river.

On the abutments of the bridge are iron plates with mortices in which stand two upright iron pillars. The main rib bears on the base plates against the foot of the inner pillar. The rib consists of two pieces connected by a dovetail joint in an iron key fastened by screws. The shorter ribs pass through the pillar at apertures left for that purpose and are morticed into the top bearers and into the base plate and pillar. The back rib is similar, but does not come down to the plate. Cross stays, braces, circular spandrils and brackets keep the whole structure steady while cross stays and a diagonal and a top plate connect the pillars and ribs together in the opposite direction.

The whole bridge is covered with top plates of iron projecting over the sides of the ribs, to which are fixed the balustrades. The structure is remarkable in that no bolted or rivetted joints are used on the bridge, the members being slotted into or through each other, wedges of cast iron, or dovetail boxes take up any play.

The bridge, which spans 100 ft. and is 40 ft. above the water level, was erected from a scaffolding across the river, each part of the rib was raised to above its height by ropes and chains, then lowered until the ends met in the centre.

The bridge, being a toll bridge, was placed in the hands of trustees in 1782, and in 1950 Major Rathbone, a descendant of the principal shareholder, Richard Reynolds, handed the bridge to the Salop County Council, who have now placed it in the hands of the Department of the Enviroment as a scheduled ancient monument.

The abutments of the bridge have been slowly sliding into the river putting the whole structure into a compressive strain. To relieve this strain and to solidify the whole unit of bridge and abutments, a major operation has been mounted to strap the whole together by an inverse arch under the river.

The Bedlam Furnaces - now under reconstruction, are to be found beside the road between the Ironbridge and the Free Bridge. Their recent excavation required the removal of tons of rubble and rubbish, and provided the volunteer excavators with a chronology of British rubbish.

The furnaces were erected in 1757/1758 and taken into the Darby Company by Abraham Darby III in 1776. In 1769/97 the possessions of the Coalbrookdale partnership were divided between the Darby and Reynolds families, and it was to the latter the Bedlam Furnaces passed. The Reynolds successors formed the Madeley Wood Iron Co., and when this company erected the Blists Hill Furnaces in 1832 it seems that the Bedlam Furnaces ceased operations.

A surviving plan of 1772 shows that the two furnaces were fed raw materials from a railway which terminated in a bank behind them. The bellows were operated by two water wheels, the water being re-cycled back to a higher level by a steam engine. Between the furnaces and the rivers there wasa casting room as well as two air furnaces for the re-melting of pig iron, and before these were the wharves on the River Severn, the wharf still surviving. The Bedlam furnaces were noted for the fine quality of their soft foundry iron, and the site was probably the first in Shropshire where coke was manufactured in ovens and not in open heaps.

The Tar Tunnel - The original tunnel was driven in 1787 to act as a ventilation and drainage level for the coal mines in Blists Hill, it was also intended to be a route for bringing coal from

lower seams down to the river for transhipment. By one of those rare and accidental incidents the tunnelers holed into a tar spring which proved to be highly profitable for not only was it used for lining the outsides of the boats, it was used for the lining of the insides of the ailing, being highly regarded as a medicine and sold as "Betton's British Oil". Samples of the tar are sold today, but the Museum Trust will not claim it to be a panacea, nor do they know of anyone who has sampled it!
The tunnel begins in the cellar of a private house, passes under the main road and runs straight for the accessible length of 2,240 ft. almost in line with the Coalport section of the Canal at Blists Hill. The beginning of the tunnel is brick arched about 6 ft. high at the centre and 6 ft. wide, a pipe and covered drainage channel runs to one side of the tunnel floor. At intervals there are large cavities on the east side of the tunnel, probably excavated in the 19th century to allow the tar to accumulate. One such cavity which has been fully examined lies about 2 ft. thick in sticky, black liquid tar. Throughout the length of the tunnel tar can be seen seeping out through the brick lining and collecting into pools on the path. The Museum intend to extend the tunnel by further excavation, and to link it with the shaft at Blists Hill. Visitors will descend the coal mine and be conveyed along the length of the tar tunnel viewing the pools of tar on the way to the outlet.
<u>Coalport Bridge</u> - This is one of the oldest iron bridges in the world still open to traffic, although subjected to a severe weight limit. It bears the date "1818" and the letters "J.O." in the centre of the parapet. It is generally accepted that these initials refer to John Onions owner of the furnace and foundry at Benthall where the bridge was probably cast.
The bridge stands on the site of an earlier structure, which

was known as the Wooden Bridge. Probably only the superstructure was made of wood and it was an iron bridge. The three brick filled slots on the stone abutment on the south side of the present bridge may have accommodated the ribs of the original bridge. Thus within the space of two miles were to be found the world's first -and second -iron bridges.

Coalport - As the name implies this was the main port for the shipment of coal, brought either by canal or the numerous rail- or waggonways down to the river.

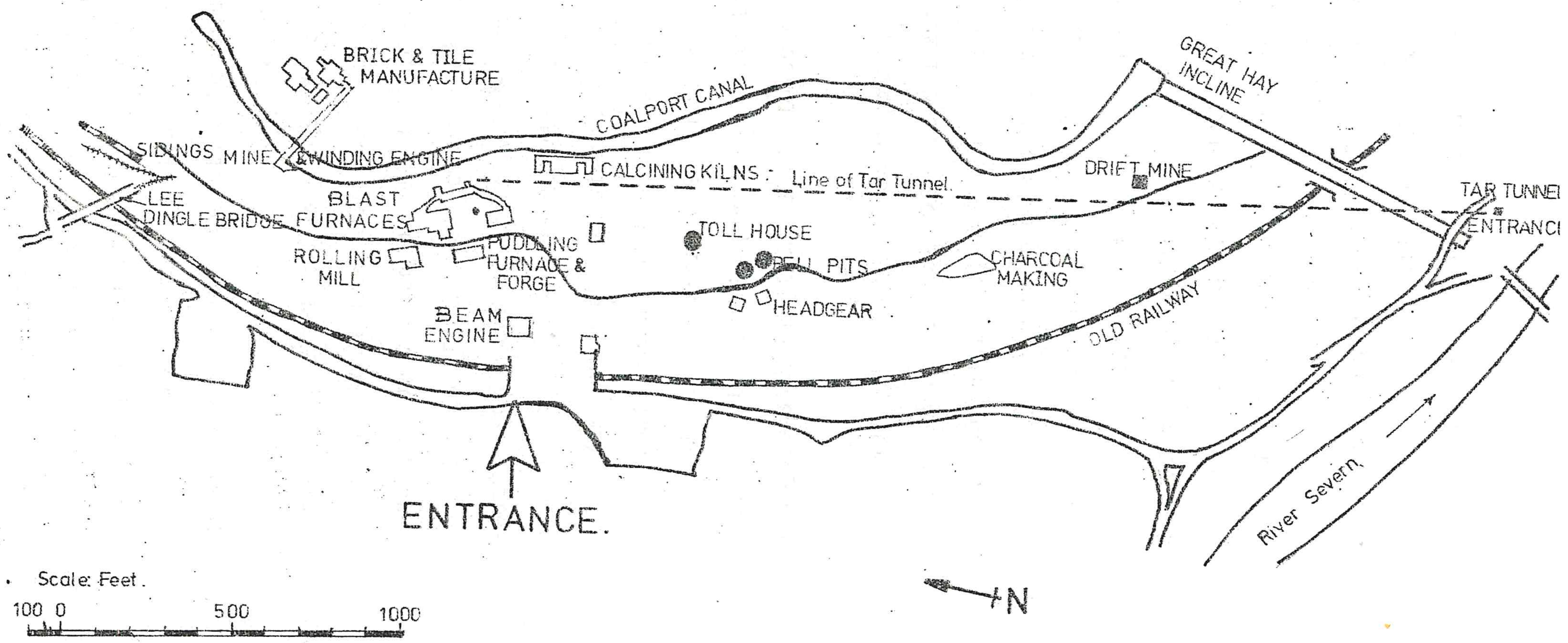
The Shropshire Canal ran from the foot of the Great Hay Inclined Plane alongside the river, but above the flood level, to terminate near Coalport bridge. A number of wharves were built on the river bank, and the area attracted many industries, including a china works, a chain maker, a rope walk and a second pottery, making this one of the busiest industrial areas in Shropshire, as well as the busiest interchange, canal-to-river port in Great Britain.

Along the canal and riverbank were a series of seven self-acting inclined waggonways running from canal to river, terminating onto a structure not unlike a modified coal-drop or drawbridge, hanging out over the river. The foundations of a number of "drawbridges" are clearly visible, they look like rather small slipways. As the whole area is to be landscaped, no doubt other remains will be revealed when the overgrowth is cleared.

Blist Hill Industrial Museum - The Museum occupies a site of some 200 acres (see map) which contains the remains of the Madeley Wood Co's Blist Hill Ironworks, including a blowing engine house, remains of a narrow-gauge tramway system, and a tramway bridge, Lee Dingle Bridge, across the Madeley-Coalport Road. A steam winding engine, now fully restored, for the small colliery, a brick and tile works, and the only remaining portion of the Shropshire Canal leading to Coalport, and on

THE IRONBRIDGE GORGE MUSEUM.

BLISS HILL INDUSTRIAL MUSEUM.



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which now floats a recently discovered and restored tub boat. It is on this site that the Ironbridge Museum proposes to establish those industrial relics relating to the industries of the area, which are at present in isolation and cannot be preserved "on-site," and by virtue of their position are more likely to be destroyed than preserved.

The Canal will be fully restored as a portion of the Shropshire Canal and will have added an arm which will contain the iron acqueduct designed by Telford in 1795 and at present at Longden-on-Tern. A lock system will be connected to this level using the guillotine lock from Wappenshall and it is hoped other types of locks will be included in the stretch of canal.

To present the development of coal mining the "Miners Walk" will be established through the length of the museum site, passing by the bell pits and a drift mine, horse and engine driven gins, and wooden and iron headgears, with the intention of showing the visitor the chronological and logical development of coal mining.

The Blists Hill Ironworks began operating in the early 19th century and continued to work for over 100 years. During this time several new types of furnace must have been introduced, culminating with the partially iron cast furnaces.

Two engine houses are standing and it is hoped to restore both and to house blowing engines in them. In this setting two blast furnaces will be reconstructed from the remains available at the old works at Hinkshay and Stirchley. Should a metal cased furnace become available this will be incorporated into the site. Cast houses, pig beds, puddling furnaces and a forge and rolling mill will be included in the iron-producing section.

A complete set of buildings from the old tile works stands at Blists Hill, and on and around this site will be arranged as comprehensive collection of items relating to this important industry as can be found, which will illustrate the principles and methods of the clay industry. The wealth of manufactured products is amazing and these will be exhibited showing the various periods of the development of the industry.

The Museum is within reach of the North East, the Sunderland Group with the Ryhope Pumping Engine Trust arranged avvisit last September, and although it was a long day it was very rewarding. From Easter onwards the Museum is open to visitors for the Summer.

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BRITANNIA BRIDGE by D.W. PATTENDEN.

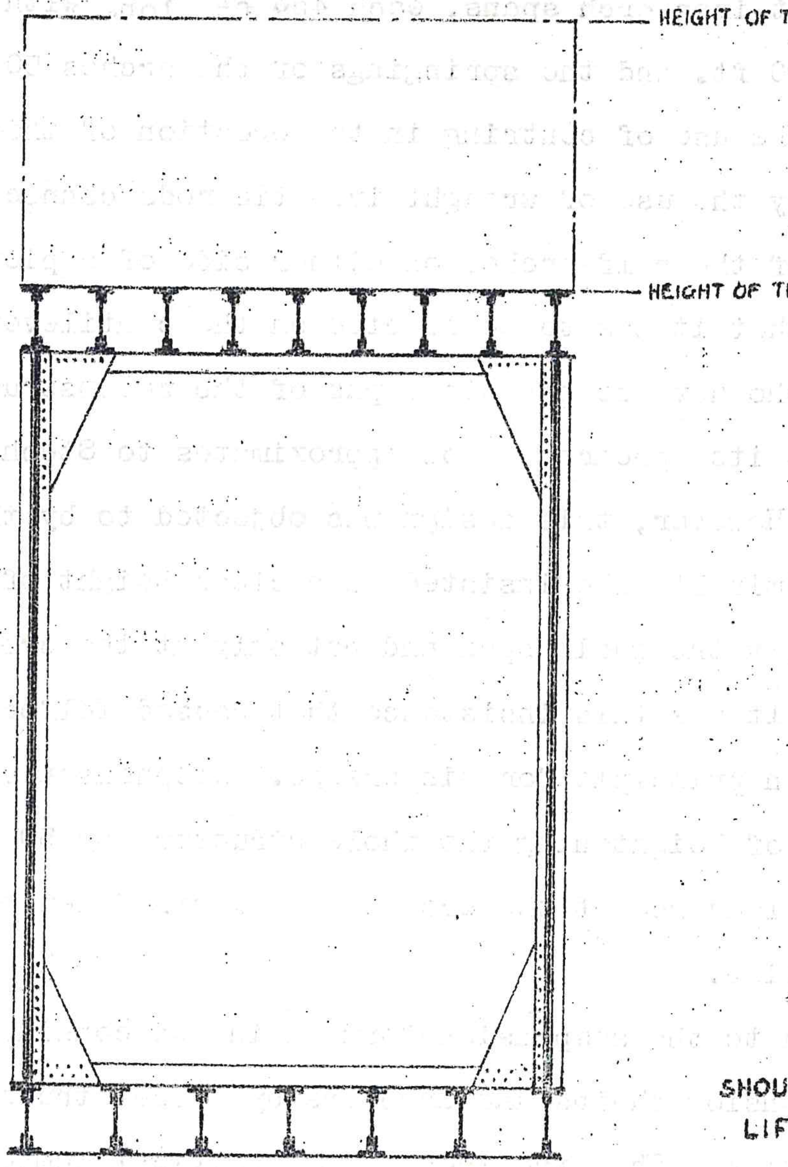
The Britannia Tubular Bridge over the Menai Straits between Anglesey and Caernarvonshire, although situated well outside our territory, is of interest because it was designed by that great northern engineer, Robert Stephenson, and has recently been reconstructed by the Cleveland Bridge & Engineering Co. Ltd., of Darlington, following the disasterous fire in 1970.

In the late 18th and early 19th centuries the Holyhead Road, linking London & Dublin by the shortest sea crossing, became the most politically important road in the British Isles, but was in a bad condition in many places. The Government therefore, set up nine special Commissions to survey and improve this road. Thomas Telford was associated with many of the improvements which followed, the greatest being his Suspension Bridge over the Menai Straits about a mile eastwards of the Britannia Bridge. Telford's bridge, which replaced a ferry across the treacherous Straits, was opened in 1825, and is still the only road link between Anglesey and the mainland. However, the development of a nationwide network of railways made it inevitable that rails replace road on this important route.

It was realised that the greatest difficulty in engineering the Holyhead Line would be, as it was with Telford, the spanning of the Menai Straits. After a preliminary survey in 1838, George Stephenson proposed laying a single line of rails on one carriage-way of Telford's bridge and using horses to draw the trains across. The failure of Captain Brown's suspension bridge, carrying the Stockton & Darlington Railway's extension to Middlesbrough over the River Tees at Stockton, had dramatically demonstrated the unsuitability of this form of construction for trains drawn by locomotives. Until Robert Stephenson replaced the S.&.D.R. bridge in 1842, with a rigid cast iron structure it was only possible to use horse or rope traction across the Tees. When the Chester & Holyhead Rly. Co., was formed in 1844, with Robert Stephenson as Engineer-in-Charge, further thought was given to the problem of a rail crossing of the Menai Straits. Up to that time the suspension principle was the only known method of spanning such great distances and a further difficulty was the considerable traffic of sailing vessels, many of large size, using the Straits. This precluded the use of any form of centring or scaffolding which would obstruct the passage of ships during the construction of the bridge. At the site chosen by Stephenson the Menai Straits are about 1100 ft. across at high water and are most conveniently divided almost exactly in the middle by the Britannia Rock which gives the bridge its name. Although covered to a depth of 10 ft. at high water, this rock provides a good foundation for the central pier. At this point the rise and fall of ordinary tides is 20 ft. and the velocity of the tidal flow sometimes exceeds 8 mph. The shores are precipitous on the Caernarvon side and steeply shelving on the Anglesey side.

Robert Stephenson's first design for the Menai Bridge employed two cast iron arch spans, each 450 ft. long with the crown of the arches 100 ft. and the springings of the arches 50 ft. above the water. The use of centring in the erection of the arches was to be avoided by the use of wrought iron tie rods connecting each section of the half-arches on either side of a pier, i.e it appears that it was to be erected on the cantilever principle. Readers who have seen photographs of the reconstructed bridge will note that its appearance now approximates to Stephenson's original design. However, this design was objected to by the Commissioners of the Admiralty who insisted on a clear height of 100 ft. over practically the whole span and not only at the crown of the arches. It was this insistance that caused Telford to adopt the suspension principle for his bridge. Stephenson rejected the solution of heightening the whole structure by 50 ft. to give 150 ft. clearance at the crowns and examined new methods of construction.

He turned to the suspension form again and considered replacing the suspension chains and droppers by a deep trussed girder construction. Then the idea of the vertical members being built up from wrought iron plates occurred to him. In section the bridge platform would be a box without a lid. In an effort to further stiffen the structure he considered the effect of putting a lid on the box and so the tubular form, with the trains running through the tube was born. This was a completely novel form and Stephenson sought the opinion of two leading experts, Professor Eaton Hodgkinson, FRS, and William Fairburn, a famous engineer and shipbuilder. The experts differed, the scientist recommended that suspension chains be retained as an auxiliary to the tube, otherwise a great thickness of metal would be required to give adequate stiffness and strength. The practical engineer declared that the chains could be omitted provided that the



SHOULDERED LINK OF LIFTING CHAIN

SECTION OF TUBES
BRITANNIA TUBULAR BRIDGE

plates were properly proportioned and well rivetted. After much pondering Stephenson accepted Fairburn's advice and commenced an extensive series of experiments at Fairburn's shipyards at Millwall on a large model of the proposed bridge tubes to establish the required dimensions and thicknesses of the plates. No doubt the shipbuilder's experience of building and launching large wrought iron ships influenced Stephenson's decision to dispence with chains.

The same design was then chosen for the smaller bridge needed over the Conway estuary. This was built first and so became a dress rehearsal for the larger and more difficult Menai Bridge. The Conway Bridge consists of a single span of 400 ft. clear with a mere 18 ft. clearance at high water. There are two tubes, one for the 'up' and one for the 'down' lines and each weighs about 1,000 tons. The Britannia Tubular Bridge is symmetrical about the tower built on the Britannia Rock. There is a clear span of 460 ft. each side to similar towers built on the shore, and a further 230 ft. clear span from each shore tower to the abutments either side. Again there are two separate tubes, one for the 'up' and one for the 'down' line and when the bridge was completed the four spans of each tube were joined together inside the towers to form continuous tubes, or beams, each 1,513 ft. long. The tubes are fixed at the Britannia Tower and are allowed to slide at the shore towers and at the abutments under thermal expansion or contraction. The clearance at high water to the underside of the tubes is 102 ft.

The towers are constructed of a hard carboniferous limestone, known as Anglesey Marble, and quarried at Penmon at the eastern extremity of the island. The stone was worked to shape with heavy steel picks and some blocks are up to 20 ft. in length and weigh up to 14 tons. The interior masonry is a soft easily worked, but durable red sandstone from Runcorn in Cheshire. The Britannia Tower has a maximum height from the bottom of the foundations of 230 ft. and measures 62'0" x 52'5" at the base tapering to 55'0" x 45'5" at the level at which the tubes enter it. It contains 148,625 cu.ft. of limestone, 144,625 cu.ft. of sandstone, together weighing nearly 20,000 tons and has 387 tons of cast iron beams and girders built into it. The foundation stone was laid in May, 1846.

The shore towers taper from 62'0" x 52'5" at the base to 55'0" x 32'0" at the level of the bottom of the tubes. Their summits are 190 ft. above high water and they each contain 210 tons of cast iron beams and girders. The abutments are ornamented with statues of lions in the Egyptian style, each weighing 30 tons. They are 25 ft. long and 12 ft. high, and each contain eleven pieces of limestone. The additional height of the towers above the tops of the tubes was required for the lifting gear to get the tubes into place. It has been suggested by some that the 'windows' in the top sections of the towers were to enable suspension chains to be added later, if found necessary. It is more probable that the towers were designed before Stephenson had completed the Millwall experiments and retained the extra height to house the lifting gear.

Turning now to the tubular beams, it will be seen from the sketch that Stephenson adopted a cellular construction. The eight cells at the top of the tubes are each 1'9" square and the six cells at the bottom are each 2'4" wide by 1'9" deep. The walls of these cells are connected to the horizontal plates by rivetting to angle irons weighing 45 lbs per yard for the top cells and 27 lbs per yard for the bottom cells. The external height of the tubes varies from 30'0" at the centre of the Britannia Tower to 22'9" at the abutments. In fact the top forms a true arch, although the bottom is horizontal. The clear internal height, due to the double top and bottom thus varies from 26'0" at the centre to 18'9" at the ends. The external width of each tube is 14'8" and the clear space for the passage of trains is 13'5". The length of each of the main tubes which span the water is 472 ft. that is 12 ft. longer than the clear span between the towers, to give a 6 ft. bearing length on each tower entablature. By joining the four sections of tube together, as mentioned above, to form a continuous tube fixed at the centre and free to move at the ends, Stephenson introduced the cantilever principle and so greatly increased the strength of the structure.

The boiler plates used to form the top, bottom and sides of the tubes were obtained principally from Staffordshire and vary in thickness from 3/8" to 3/4". They are up to 12 ft. long and 2'4" wide, the largest size it was possible to roll with the then existing machinery. The technique of rolling wrought iron plate or section was then in its infancy and nearly every plate and rib had to be laboriously flattened or straightened by hand before it could be punched for rivetting and erection. 40 lb. sledge hammers were required for the heavier plates! The largest plates are in the bottom of the tubes and are 9/16" thick at the centre of the long tubes and 7/16" thick at the ends, and are arranged in a double layer with the joints staggered. The plates forming the top are 6 ft. long and 1'9" wide, 3/4" thick in the middle of the tubes and 5/8" thick at the ends. The top and bottom plates are laid longitudinally whilst those in the sides have their long dimension vertical. The side plates are alternately 6'6" and 8'8" in length, laid so that their joints do not coincide, and 2 ft. wide and 1/2" thick. They are joined together and stiffened by being rivetted to 'T'-shaped rolled section. Triangular gusset plates rivetted in the corners further stiffen the tubes. The total weight of wrought iron in one of the 472 ft. long tubes is 1,600 tons, of which 600 tons is in the sides and 500 tons each in the top and the bottom. They contain 327,000 one inch diameter rivets at 4" pitch in the top and bottom and 3" pitch in the sides. The weight of each of the shorter tubes is 660 tons, so that the total weight of iron in the bridge is nearly 10,000 tons.

Assembly of the ironwork commenced on 10th August, 1847. The shorter tubes in the land sections of the bridge were assembled in situ on temporary timber platforms which were removed as each tube was completed. The longer tubes which span the water were constructed on special timber platforms extending nearly half a mile along the beach on the Caernarvon shore, just above high water level. To allow for the deflection of the tubular beams due to their own weight, when supported at the ends, the platforms were built with a rise of 9" in the middle. As each of the longer tubes were completed the tinber platforms were cut away and 6 ft. at each end allowed to rest on temporary stone piers so that the alignment could be checked. The first tube to be completed showed a deflection of 10" due to its own weight, but it was also noted that the tube rose one inch in the centre during the day and bowed sideways one inch towards the direction of the sun, due to differential thermal expansion, thus confirming Stephenson's calculations.

Having dealt with the design and construction of the tubular beams and the towers we will now see how Stephenson solved the problem of elevating the tubes to their final position on the towers. Every detail of this operation was pondered with minute care and, to supplement the experience gained at Conway, a model to the scale of 1" to 6 ft. was made. The tubes were floated down the Straits from the assembly platforms to the bridge site. To do this, as each tube was completed and resting only on the temporary stone piers at the ends, two groups of four pontoons were marshalled under the tube, one group near each end. Six of these pontoons were of wood and had been used at Conway, the other two were of iron and built at the further end of the tube platform. They were all 98 ft. long, 25 ft. wide and 11 ft. deep, and would support 400 tons each. When carrying the tube they drew 5 ft. of water. The sea-cocks of these pontoons were kept open until the appointed day and then closed at low tide. As the tide rose the pontoons lifted the tube off its temporary piers about 1½ hours before high water. Hawsers from the end pontoons to powerful capstans on the opposite shore then pulled the tube into mid-stream where the current was running at about 4 mph.

Three further hawsers, each 4" in diameter, were attached to the towers and to strong points on the shore and passed through "cable stoppers" on the pontoons to guide the tube as it was carried down the Straits on the tide. Cable stoppers are devices for gripping the hawsers and to further control the speed of the passage a number of lighter cables were attached to capstans, each worked by 50 men, at various points on the shores. The time of floating was arranged so that the tube just reached the towers when the tide became slack some 15 minutes before turning. During the 15 minutes the tube had to be manoeuvred into prepared recesses in the base of the tower. This was expected to be the most difficult part of the operation.

The first tube to be floated was the one destined for the 'up' line on the Anglesey side of the Britannia Tower and the chosen day was 19th June, 1849. No civil engineering undertaking of such magnitude had ever been attempted before and enormous crowds gathered to witness the event. Grandstands had been erected on the three remaining tubes on the Caernarvon shore. At 6.0 pm. Stephenson gave the signal, but unfortunately, due to over enthusiasm on the part of its crew, the capstan on one of the pontoons gave way and the event had to be delayed until the next day. The following morning Stephenson and Captain Claxton RN, who was in charge of the floating operation, found a strong wind blowing and the tide running through the Straits very strongly. However, at 7.30 pm. they decided to try again. The huge tube was floated safely and drawn into the tideway, but when the screw cable stoppers were applied to control the speed, one of them failed to grip. Disaster loomed when a 12" cable, which was to guide the tube to the base of the Anglesey tower, over-rode its capstan, which jammed and was pulled from its foundations. The vast crowd of men, women and children then seized the huge cable and the weight of numbers was able to check the progress of the monster. The tube was then soon brought into position, the bands struck up and the cannon fired their salute. Fortunately there were no casualties and the other three tubes were floated and positioned without difficulty.

As previously mentioned, the tubes were 12 ft. longer than the clear span between the towers, so recesses were left up the face of each tower to allow the tubes to be lifted up. To get the tube into these recesses a further section of masonry was left out of one side of the shore tower and was built up before lifting commenced. When the tube was in position the pontoons were flooded, allowing the tube to settle onto soft timber fenders at the base of the towers, and the pontoons were towed away. To enable the tubes to be lifted three heavy cast iron frames were built into each end of the tubes. To these were attached three cast iron lifting beams. The weight of each set of frames and lifting beams was about 100 tons, so that the actual weight to be lifted was about 1,800 tons. To do this chains similar to those used for suspension bridges were attached to each lifting beam. The chains consisted of flat links of 6 ft. pitch, 7" wide and 1" thick. They were bolted into sets of 8 and 9 links alternately and were made by Howard & Ravenhill of London, each chain weighing about 100 tons. The links of these chains had square shoulders adjacent to their upper ends under which screw clamps were located during lifting. Hydraulic presses, mounted vertically on the towers about 30 ft. above the final position of the tubes, provided the lifting power. The press on the Britannia Tower had a 20" diameter ram and a 6 ft. stroke; the cylinder was of cast iron and the walls were 11" thick. The two smaller presses which had been used to elevate the tubes of the Conway Bridge, were mounted side by side on the shore towers. These also had a 6 ft. stroke, but had 18" diameter rams. The pressure in the hydraulic system was said to be 8,000 to 9,000 psi. The force pumps for the presses consisted of 1.1/16" diameter rams each end of the piston rod of 40 hp. steam engines, steam being raised in locomotive type boilers.

The screw clamps under the uppermost links of the chains were attached to very thick cast iron crossheads on the tops of the rams of the hydraulic presses. When the tube had been lifted 6 ft. further screw clamps gripped the chain at a point 12 ft. from the top of the chain. The clamps on the crosshead of the presses were then removed, the rams returned to their lower positions and reclamped below the head of the second 6 ft. link, and the top set of links discarded. When the tube reached its proper level, three cast iron beams, each 24 ft. long, 4 ft. deep and weighing 11 tons, which had been housed in cast iron boxes in the masonry, were slid under each end of the tube, which was then allowed to rest on them.

It took about 30 minutes to lift the tube 6ft. and a further 30 minutes to reclamp the chains and lower the rams before the next stroke. It was originally intended to lift continuously in 6 ft. steps, as were the Conway tubes, so that the whole operation could have taken only 18 hours. However, when the second Conway tube was being lifted and was only 2'3" from the correct height, a crack appeared in the crosshead of one of the presses and only hasty underpinning with timber avoided disaster. When the Menai tubes were being lifted Stephenson prudently insisted in closely following the lift with masonry. This was a wise precaution because when the first tube had been lifted 24 ft. the cylinder of the press in the Britannia Tower broke and fell, together with the crosshead and chain tackle weighing all together some 50 tons, onto the tube. Repairing the damage to the tube and waiting for a replacement cylinder from the Bank Quay Foundry in Warrington caused a six weeks delay, and the first tube did not reach its full height until 13th October, 1849.

The second tube was floated on 6th December, and raised into place by 7th January, following. It was placed in line with the first tube and the four tubes of the 'up' line joined together so that a single line of railway could be laid across the Straits. On 5th March, 1850, an enormous train consisting of 45 loaded coal wagons and carriages seating 700 passengers, including Robert Stephenson and other prominent engineers, and weighing over 500 tons was drawn across the bridge by three locomotives. The bridge was opened to public traffic on 18th March. The work of floating and raising the other two tubes continued apace without, as far as I know, any further mishaps, so that on 19th October, 1850, both lines of the iron road to Holyhead were complete. The successful conclusion of the greatest bridging project up to that time and the novel techniques employed re-established Robert Stephenson's reputation as one of the leading civil engineers of the day and led to the design and construction, under Stephenson's supervision, of other tubular bridges, notably two for the Alexandria and Cairo Railway and the great Victoria tubular bridge over the St. Lawrence at Montreal.

The construction of the Britannia Bridge inevitably upset the peace and quiet of this rural corner of Wales for over four years. Three large workshops were erected along the tube building platforms and were equipped with cutting, punching and other machinery driven by six steam engines. There were 48 rivet hearths spread along the platform from which there was a continuous rain of white hot rivets as the rivet boys tossed them 40 ft. into the air to the rivet gangs on the tops of the tubes. The clamour of the straighteners' and rivetters' hammers carried far over the waters for months on end. An average of 1,500 men were employed in the work. 700 of them being engaged on the stonework and 800 on the ironwork. 700 men were required for the floating of the tubes. Temporary wooden cottages were erected to accommodate 500 workmen and their families. There was also a day school, a clergyman and a medical man to look after the community. At least 7 men lost their lives in the construction of the bridge. We are also told that shops selling provisions increased their prices considerably during this period.

Stephenson appointed Edwin Clark to be the Resident Engineer for both the Conway and the Britannia Bridges and fortunately for us Clark kept in a diary a definitive account of their construction. The contractors for the masonry and scaffolding were Nowell, Hemmingway and Pearson. One of the longer tubes for the Britannia Bridge was fabricated by Garforth of

Dukinfield near Manchester, who were the contractors for the Conway tubes. The contractor for the remaining seven tubes was Charles Mare of Ditchburn & Mare, the Blackwall shipbuilders whose yard later built the "Great Eastern". It should be noted that at this date shipbuilders were the only firms to have extensive experience of large scale wrought iron construction. The cost of the ironwork was rather more than £300,000 and the total cost about double this sum, a very large figure in those days. The fact that the bridge remained for 120 years without structural modification and carries the vastly heavier and faster trains of today speaks well of the quality of its design and construction.

Stephenson planned an arched roof of thin corrugated zinc to protect his bridge from the weather and also possibly from the direct rays of the sun which would cause differential expansion. At some later date the zinc was replaced by timber coated with pitch and it was this which was set on fire in 1970. The heat from this fire badly buckled the tubes and necessitated the recent reconstruction. Fabricated steel spandrel braced arches have been built under the longer tube sections and longitudinal steel girders supported on two reinforced concrete portal frames have replaced the land spans. The wrought iron tubes will eventually be removed and a roadway built above the railway lines to reinforce Telford's road link with the island. The cost of this reconstruction was about £3,000,000 including £400,000 for provision for the future road way.

For the information contained in this article acknowledgement is made to the following :-

(a) "General description of the Britannia and Conway Tubular Bridges on the Chester & Holyhead Railway" by "A Resident

Assistant" and published with the permission of Robert Stephenson, Civil Engineer, by Chapman & Hall in 1849 (i.e. before the bridge was completed). There is a copy in the library of the Cleveland Scientific Institution at Middlesbrough.

(b) "George & Robert Stephenson - The Railway Revolution" Chap.15, by LTC Rolt. Pub. Longmans, Green & Co. Ltd 1960.

(c) "Steel News" - Leading article in Issue 63 dated 3rd February, 1972. Published by British Steel Corporation.

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INSTITUTION OF ELECTRICAL ENGINEERS

WEEK END CONFERENCE ON "THE HISTORY OF ELECTRICAL ENGINEERING

13th/15th July 1973 at BIRMINGHAM UNIVERSITY.

The Institution's Professional Group Committee on the History of Technology has decided to organize this conference in the belief that there is a growing interest in the history of electrical engineering. As there has been no conference on the subject before, so far as the Committee is aware, an attempt has been made to make the programme of gneral interest to those interested in industrial history and industrial archaeology as well as to electrical and other engineers. The majority of the lectures will be of the survey type, but a few will deal with recent historical research. Subjects covered will include early electric telegraphs, electric power supply, illumination, electrical machines and control systems. On the Saturday afternoon there will be visits by coach to some interesting local (and normally inaccessible) private collections of early electrical equipment.
Residential accommodation will be provided at a University Hall of Residence, and the inclusive fee, covering all meals, accommodation and visits, from dinner on Friday evening to

lunch on Sunday, will be around £10 per person.

The Organizing Committee comprises Prof. DG Tucker (University of Birmingham), Mr. K Gravett (Polytechnic of the South Bank) and Mr B Bowers (Science Museum, London).

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BOOK REVIEW.

"Ryhope Pumping Station" - A History & Description by S.M. Linsley, pub. by the Ryhope Trust, 40p. Available from Ryhope and good bookstalls.

Complimenting the work of the preservationalists at Ryhope is this very readable and informative book by Stafford Linsley, illustrated with drawings from Harry Beavis.

This is the story of the need for water for the growing communities in N.E. Durham, the search for water, the development of the Sunderland & South Shields Water Co., its waterworks & pumping stations, and the story of Ryhope. The construction of the building and the installation of the engines, and their daily operation is fully described. To the visitor to Ryhope this book would complete the visit and if you get the book before going then the book will certainly encourage you to visit Ryhope.

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