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BRISTOL TRAMWAYS POWER STATIONS 1895 –1941

The story of Beaconsfield Road and the Counterslip power stations

by Marcus Palmén

Marcus has been working diligently with Peter Davey, the expert on the Bristol Tramways, and others compiling the histories of the various electrical tramways in the South West, culminating in these being posted on our web site. From these studies Marcus realised that Peter had not covered the electrical side of the story, which otherwise has been published in book and video formats. He therefore set about researching the electrical details, for which we are indebted and it is now given below.

The Bristol Tramways & Carriage Co

In 1887 the Bristol Tramways & Carriage Co Ltd was formed with a capital of £200,000 with Sir George White as Chairman. George White had as an 18 year old negotiated Parliament bills to reform Bristol's failing horse tramway. His entrepreneurial skills and life long interest in transport, whatever the medium, ensured that Bristol had the first conventional overhead electric tramways system in the UK, though four other different systems (Blackpool, Leeds, South Staffs and Isle of Man) preceded it.

George White's nephew, later Sir William Verdon Smith (1876--1957), early career was also in tramways in Bristol, but in 1894 he was appointed to the Board of London United Tramways. He worked closely with the legendary tramway engineer James Clifton Robinson, chairman Imperial Tramways Co, who no doubt also had a hand in the Bristol tramway development. In the picture below George White is at the controls of the first tram arriving at Old Market followed by James Robinson at the controls of the second!

The relationship between the Company and Bristol Council did not always progress smoothly. Following the introduction of electricity into the tramways these quickly provided a profitable income, while the Corporations Electricity Generation was running at a loss in this early period.

1. The first trams arriving at Old Market

When the company introduced a bill to extend the tramways system the Council stated they would oppose the bill unless the company would agree to obtain their electricity from the Council who would take over generation and combine it with that for lighting.

Mr. H.F. Parshall, M.Inst.C.E was at the time employed as a Consultant Engineer by the company and designed the power stations. The following is an extract from the "Railway World" of January 1897:-

"There is the underlying technical question whether the Council is right in the contention that current can be more cheaply generated where the traction and lighting plant is combined. Mr Preece, in his report to the Council, supports the opinion it can. Mr Parshall differs with him *in toto*, and no less eminent authorities than Lord Kelvin and Dr. John Hopkinson concur with Mr. Parshall, and advise the company not to enter such an arrangement."

The company withdrew the bill and expansion was delayed until 1899/1900.

The Tramways Development

The first trams in Bristol were pulled by horses commencing on 9th August 1875 running from Perry Road (Colston Curve) to Apsley Road, known as Redland Terminus. The horses were kept at the Colston Stables, wedged between the triangle of Perry Road, Colston Street and Griffin Lane (now Lower Park Row).

On 14th October 1895, the first electric cars ran from Old Market to Kingswood and were kept at the depot in Beaconsfield Road, St. George, which was also the power station. Eventually 17 tram routes existed which were reduced to 12 in the final pattern.

The growth of the electrical tramways system is illustrated by the total number of tramcars owned by the company at the end of each year :-

1895 – 11 cars (Built by Milnes)

1896 – 14 cars (Built by Milnes)

1897 – 31 cars (Built by Milnes and 1 by Brill)

1898 – 51 cars (20 American added)

1901 – 231 cars (Built by Milnes and 1 other)

1920 – 236 cars (Built by BTCCL)

The first electric trams in 1895 were powered by electricity generated at the Beaconsfield Road Depot. This held the first 25 cars built and contained the generating station. The site was in St. George about halfway along the route Old Market to Kingswood.

The basic design of the trams remained substantially unchanged throughout the 46 years of existence. I am told Bristol had the largest fleet of open topped trams in Europe.

2. The St. George Depot & Power Station at Beaconsfield Road

Two boilers supplied 3 - Willans 135HP 380 rpm steam engines coupled to three generators by rope drives. This first plant lasted only two years. In 1897 two new boilers was added making four in all and the original three units were replaced by four direct-drive ones.

During 1898-99 a new generating station was built at Counterslip to cater for the massive expansion to the system. The building was one of the first commissions for William Curtis Green RA - Architect and Draughtsman 1875 –1960. His later works included the Dorchester Hotel in Park Lane.

3. The Tramway Generating Station, Counterslip

The main plant at Counterslip in 1990 consisted of 4 steam vertical cross compound steam engines 750 BHP each direct coupled to 4 500v DC generators each with a 625kW capability.

Following this summary of development we now move to a more detailed review of the power stations and of the Beaconsfield Road Station in particular.

St. George Power Station - Beaconsfield Road

The power station in Beaconsfield Road, which was then outside the City boundary, was - a turning south of the main road, close to St. George's Church - was about equidistant from the extreme ends of the Kingswood – Old Market line. On leaving Old Market Street, the line continued in an easterly direction, via Lawrence Hill and Redfield Road, to Kingswood, a total distance of nearly four miles, the length of single track being about six miles. About one-third of a mile from its commencement, the horse line to Eastville, via Stapleton Road, branched off to the left, and three-quarters of a mile from the starting point the road crossed the South Wales branch of

the Great Western Railway. Up to this point the gradients were fairly easy, except for one short length of 1 in 32. After crossing the railway, there were several inclines of 1 in 30, 1 in 32, and 1 in 35. Just before reaching the points leading into the power station, there was an incline of 1 in 15 for a length of 220 yards.

After passing the depot, there were gradients of 1 in 17 to 1 in 20, and the road continued to rise till within half a mile of the Kingswood terminus, where it had an elevation of 300 ft. over the starting point in Old Market Street. The last half-mile was on a slightly descending gradient. This section was laid in 1895, but extensions in the form of branch lines had been made, and the electric tramways traversed some six miles of street, and their total length, measured in single track, was ten miles.

Plant 1

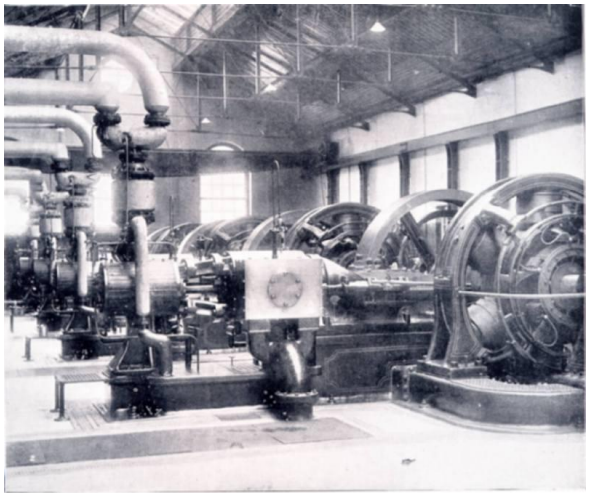
The plant, as originally laid down, consisted of two Lancashire boilers of Siemens-Martin steel, by Messrs. Daniel Adamson & Co., of Dukinfield, near Manchester. The length of these boilers was 30 ft., and the inside diameter 7 ft. 6 in., the furnace tubes being 3 ft. in diameter. The thickness' of the plates were 23/32 in. for the shell, 17/32 in. for the furnaces, and 11/16 in. for the ends. The boilers were fitted with Green's fuel economisers, and two pairs of Vicars' mechanical stokers. Two feed-pumps were supplied, each capable of delivering 16,000 lbs. of water per hour against a boiler pressure of 160 lbs. per square inch. The steam mains were 7 in. in diameter, the pipes leading from the boilers to the mains 6 in., and from the mains to the engines 5 in. All these pipes were of mild steel. The boilers were tested separately at the works to a pressure of 260 lbs. per square inch, and the steam pipes, stop-valves, etc., to a pressure of 300 lbs. The whole, including feed and waste pipes, when in position and complete working order, were tested by hydraulic pressure to 200 lbs.

The electrical equipment comprised three of the British Thomson-Houston Company's then standard type MP4-100-650 continuous-current traction generators. As indicated by their classification, these were 4-pole machines, developing 100 kilowatts (200 amperes at 500 volts) at a speed of 650 revs. per minute. They were rope-driven by Willans central-valve compound engines, with two cranks 180 degs. apart, giving 135 IHP. at 380 revolutions, with a steam pressure of 120 lbs.

As the traffic steadily grew, the Tramway Company, in order to meet the requirements, altered the arrangement of the power station. In the first place, the engine and boiler houses were been enlarged and re-roofed, and the car-shed extended. Two new boilers were added, making four in all. The new boilers, like the two previously installed, were Lancashire type, by the same manufacturers. Both of the new boilers were 7 ft. 6 in. In diameter, one measuring 30 ft. in length and the other 28 ft. They were also fitted with Green's fuel economisers and Vicars' mechanical stokers.

Plant 2

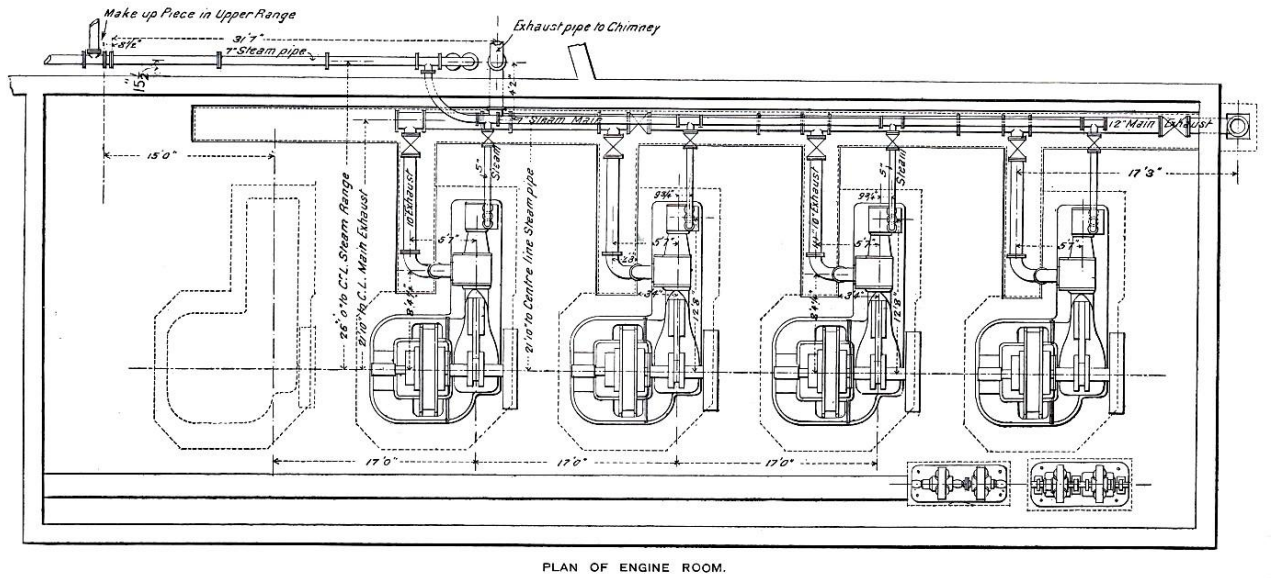
The most noteworthy alteration, however, took place in the engine-room, the three rope-driven sets, above described, having been taken out and four direct-coupled sets substituted. The old plant had been in service less than two years and its removal calls for some explanation. The advantages of direct drives had then become so generally recognised that it is not surprising that the Tramway Company should have made the necessity for enlargement an occasion for a thorough-going alteration.



4. The New Plant at Beaconsfield Road 1897

In the new equipment the flywheel-pulley and ropes were done away with, the generators being keyed instead direct to the engine shafts. There were four of these sets, as shown in the plan of the engine-room with foundation space for a fifth set. Each consisted of a 250 HP. Mclntosh & Seymour engine, driving one of the British Thomson - Houston Company's type MP 6-150-200 traction generators. The total capacity of the station had thus been increased from 405 to 920 HP. The engines were of the horizontal compound type, with high-pressure cylinder 13 in. in diameter, low pressure, 23 in., and stroke of 17 in. The speed was 200 revolutions per minute, and the steam pressure 160 lbs. The economical load was 230 HP. at one-third cut-off.

The design of this stage of development was due to Mr H.F.Parshall, who was called in by the Tramways Company, and his was the choice of the McIntosh & Seymour engines, which were highly successful in America. This design ensured that this tramway power station was one of the foremost in Europe at that time. Parshall as a consultant engineer designed many tramways power stations, installed the Central London Railway and acted for Glasgow Corporation and many other corporations. In 1927 he designed Kearsley Power Station for the Lancashire Electric Power Company. He was known in the USA for his work on the third rail electrification.



PLAN OF ENGINE ROOM.

5. Plan of Engine Room

Subsidiary Station Plant

In addition to the four traction generators, there was a British Thomson-Houston motor-generator which supplied current for the lighting of the

station, and a negative booster for reducing the difference of potential on the rail return circuit

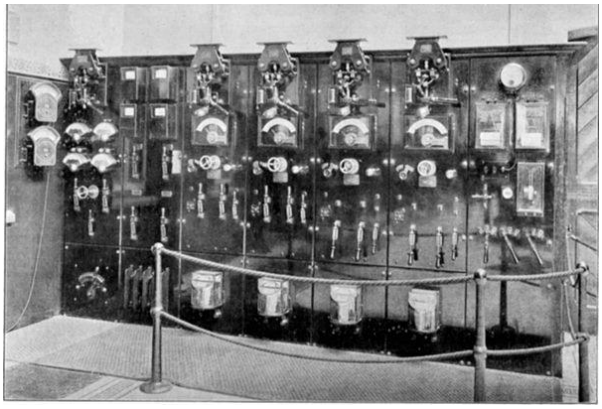
There were also four electric motors, of which two drove the feed-pumps, while one served for the coal conveyor and economisers, and one for the machinery in the repair shops. Each of these motors would give up to 20 HP., if necessary. The motor-generator was capable of developing on its secondary terminals an output of 230 amperes at 135volts; its general construction was similar to that of the large generators. The motor portion of the machine was compound-wound in such a manner that the E.M.F. at the secondary terminals remained constant. The compounding of the field however, was done entirely from the motor armature, and not from the secondary armature, so that this latter could be used in connection with the accumulator battery. The primary terminals of

the machine were connected to the main station bus bars, and had, therefore, to work at a potential of 500 volts. A regulating rheostat in connection with the shunt winding of the fields enabled the potential between the secondary terminals to be varied between 135 and 105 volts.

One special feature of this installation was the use that had been made of accumulators for station lighting, etc. The battery consisted of 58 cells, with 21 plates in each cell. They were of the Chloride type, and each cell had a capacity of 546 ampere-hours, when discharged in six hours. The motor-generator described above furnished the low-tension current for charging these cells, and from them current was taken for lighting the station when that machine was not running. As power may be required for the station motors when the traction generators are shut down, arrangements had been made by which the current from the battery could be used to drive the low-tension side of the motor-generator, so as to give a high-tension current for the motors.

Switchboard and Accessories

The main switchboard, shown in the following illustration, was composed of a series of panels of black enamelled slate, viz.: four generator panels, one feeder panel, a panel for the control of the negative booster, and a special panel arranged to meet the requirements of the Board of Trade.



6. The main Switchboard

Each generator panel was furnished with one of the British Thomson-Houston Company's automatic circuit breakers, main ammeter, positive and negative main switches, shunt field regulating rheostat with pilot lamp and discharge resistance, field switch, magnetic blow-out lightning arrester, and Thomson Recording Wattmeter.

The automatic circuit breaker, Form K, placed at the top of the panel, was in effect a main switch capable of adjustment to automatically open the circuit at any desired current. Its function was to protect the generator and other apparatus from damage due to excessive overloads, or short-circuits, by limiting the current to a predetermined amount.

The ammeter used was of the British Thomson-Houston Company's square-cased pattern. It was practically dead-beat, and had a scale so graduated as to be easily read.

The voltmeters (of which there were two - Weston illuminated Dial pattern) were placed on a

separate swinging crane or bracket, so as to be set at any desired angle with the face of the switchboard. One of these instruments was connected permanently across the bus-bars. The other, serving for the whole range of panels, had leads carried along the back of the board from which it could be put in circuit with any generator by means of a flexible cable and plug connection on each generator panel.

The regulating rheostat and field switch enabled the E.M.F. of the generator to be raised or lowered 50 volts by the insertion of a resistance in series with the shunt winding of the field. The pilot lamp, in series with the rheostat, field switch and discharge resistance, was used to indicate the condition of the generator field, the arrangement being such as to protect the field winding against the inductive effect produced when the field circuit was broken. The rheostat itself was mounted on the back of the board, the hand wheel only being on the front.

The Thomson Recording Wattmeter was mounted at the bottom of the panel, the current from each generator passing through one such instrument, thus providing a continuous record of the total amount of energy supplied to the line and forming a basis for the economical operation of the station.

The panels for the control of the motor-generator (for charging the accumulators, etc.) and station motors formed a separate switchboard, situated at the opposite end of the engine-room.

The feeder panel had four single-pole switches, controlling the four feeder lines, with fuse cut-outs and maximum indicating ammeters. The feeder panel, like the generator panels, was protected by a magnetic blow-out lightning arrester, mounted on the back, with a reactance coil of heavy copper.

The Board of Trade panel was in permanent connection with the trolley circuit, with the rails, and with a test wire to the extreme ends of the line. It was provided with two 50-ampere main switches and one recording ammeter, reading from 2 to 25 amperes. These two switches were arranged to receive the conductors from the two earth connections, and on their other sides they were joined to the ammeter which was connected to the negative bus bar. There was also a current indicator, reading from one twentieth of an ampere up to 3 amperes and from half an ampere up to 10 amperes. This current indicator was connected up on one side to the line bus bar, and on the other side it had a flexible cable and plug, enabling it to be placed in circuit with any one of the generators, when disconnected from the main switchboard. The test wire already referred to, which was connected to the extreme ends of the rail return at Staple Hill and Kingswood was used to record the difference of potential. The polarity indicator furnished a continuous record of the direction of the current.

Owing to the extensions which had been made to the system since the first section was designed, from Trinity Church to Eastville, and from Eastville onward to Staple Hill, the drop in the rail return on this section exceeded, under normal conditions, the Board of Trade limit of 7 volts.

This was corrected by the use of a negative booster utilising a 500 volt motor, direct-coupled to a separately excited, series-wound generator, having a maximum capacity of 300 amperes at 50 volts.

Tramcars and equipment

The rolling stock consisted originally of 12 motorcars, but this number was increased from time to time, as extensions of the system have been made, the total number of motor cars in use was 52 before the introduction of the Counterslip generating station. The trucks used were of the Peckham cantilever type, with a wheel base of 5 ft. 6 in., and Brill solid forged frame type, with wheel base of 6 ft. The platforms were slightly longer than on the horse cars; so as to allow the motor man to stand in front of the steps leading to

the roof deck, and manipulate the controller without hindrance. Each car was fitted with a powerful hand brake, and by means of special contacts arranged on the cylinder of the controller, and operated by the regular reversing handle, the motors can be short circuited, and so made to act as emergency brakes.

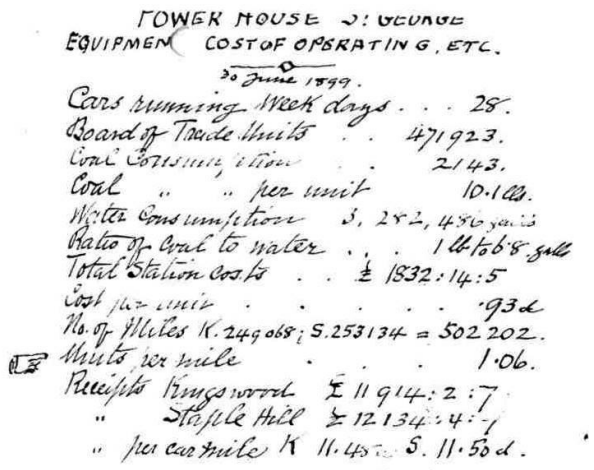
The older cars are equipped with two motors of the British Thomson-Houston Company's GE-800 type, developing nominally 27 H P in total, while for the newest lot of tramcars motors of the GE-52 type were used with same nominal capacity but designed to meet the conditions of heavier service.

The motors (two on each car) drove the axle through a single reduction gear, consisting of a cut steel pinion on the motor shaft, and a cast iron gear wheel on the car axle. This gear was completely enclosed in a cast iron box partially filled with oil, with the object of reducing the wear and tear on the gears to a minimum. On each platform was fitted one of the British Thomson-Houston controllers. Forming part of the controller, and mounted in the same case was a reversing switch, arranged in the same manner as the main controller cylinder, and also used for short-circuiting the motors, when it was necessary to use them as "emergency" brakes. The reversing switch and the main controller cylinder were interlocked so that neither could be used improperly in combination with the other. One feature of this interlocking arrangement was that when the two handles of the controller were removed, it was a physical impossibility for anyone to tamper with the controller. A magnetic blow out lightning arrester was connected in the controller circuit for the protection of the controller and motors.

The trolley was of the swivelling type, specially adapted for use on top-seat cars, and of the latest pattern developed from experience on this and other lines equipped with the British Thomson-Houston Company's apparatus. It was supported on a cast-iron standard 6 ft. in height from base to centre of axle, upon which the trolley was mounted, and provided with a cast-iron door affording access to the connections within the standard. The trolley pole consisted of a tapered steel tube 12ft long and insulated in its entire length. It was supported on the standard by means of two sets of ball bearings which allowed the trolley pole to reach the trolley wire whatever its position in relation to the track. The trolley head was of Mr. Wood's patent improved spherical type. This obviated any danger of either head or wheel catching in span or trolley wire, or on bracket arms; this trolley head also possessed the advantage of allowing of the ropes being hung up, without risk, to trolley pole and standard.

Running Costs

Charles (Chas) Challenger who by 1914 was the Manager of the company provides in his notes details of the cost of operating the tramways system in the half year ending 30th June 1899 based on the St. George power station.


POWER HOUSE ST GEORGE
EQUIPMENT COST OF OPERATING, ETC.
30 June 1899.
Cars running Week days . . . 28.
Board of Trade Units . . 471923.
Coal Consumption . . 2143.
Coal " " per unit 10.1 lbs.
Water Consumption 3, 282, 486 gals
Ratio of Coal to water . . 1 lb to 8 gall
Total Station Costs . . £ 1832:14:5
Cost per unit 93d
No. of Miles K. 249 068; S. 253134 = 502 202.
Units per mile . . . 1.06.
Receipts Kingswood £ 11 914:2:7
" Staple Hill £ 12 134:4:7
" per car mile K 11.45 S. 11.56 d.

Here are some more extracts from Challengers notes:-

- GE 800 15 H.P. Kingswood & Staple Hill motors are “6 wound” for slow speed.
- GE 800 15 H.P. American used motors are “4 wound” for higher speed
- Commutators Kingswood motors replaced 2¾ yrs

- Wood, Engineer St. George Employs 20 fitters and cleaners for 25 cars - 1¼ car per man

- Concrete takes 36 hours to set.

- St. George Power House. 9 lbs coal consumed to Each B.T.Unit

- Electric Horse Power 746 watts

- Week End 14 May 1896, Board of Trade Units 12261 (12,261,000 Watts) Average Cost per Unit 1.055d Coal consumed per Unit 8.6 lbs

The notes on motor windings refer to 6 pole or 4 pole arrangements. The American motors were obtained at reasonable prices. At this time there was a realisation that these motors were under powered for cars towing trailers so the American cities with single deck trams and trailers were replacing these cars with higher-powered ones. Trailers were originally occasionally used with the double deck tramcars in Bristol but this was soon abandoned. LA was one of the cities that sold motors of this type.

The Counterslip Tramways Generating Station

The main power station, which delivered power for the Bristol tramways from the start of the 20th century until Good Friday, April 11th 1941, when a bomb hit St Philips Bridge and cut the power cables. Trams never ran again in Bristol.

7. The End of Bristol Tramways 1941

The original installed plant consisted of :-

4 - 750 BHP steam engines vertical cross compound with cylinders 22 & 44 in diameter, 42 in. stroke 90 rpm steam pressure 150 psi.

4 - 500 volt direct coupled generators capable of 625 kW continuously

Flywheel 37 tons 16 ft diameter capable of 120rpm

2 - 75 BHP steam engines - direct coupled to 50kW 500 volt 6 pole lighting generators running at 400 rpm.

Further research into the details of this plant and its installation is required – and may form the subject of a future article.

For now I will be content with a quote from Chas Challenger on the working of the plant:-

"I have run 230 cars (capacity 53 passengers) on holidays with 4 engines. Three engines can just manage 170 cars on an ordinary day."

- *William Curtis Green - http://www.clocktower.demon.co.uk/stockgrove/.*
- *Thomas Parker (re H.F.Parshall) - http://www.localhistory.scit.wlv.ac.uk/geneal ogy/Parker/MetRailway.htm*

8. The Tramways Centre

References:

- *"The Railway World" - Jan.1897 & July 1897*
- *"Bristol Tramways", Peter Davey, Middleton Press.*
- *"Tramways Remembered – West & South West England", Leslie Oppitz, Countryside Books.*
- **Bristol Electric Tramways" Pamphlet No. 30 British Thomson-Houston Company Ltd.*
- *"Tramlines to the Stars": George White of Bristol by George White*

From the Internet:

- *LRTA History & Heritage Page - http://www.lrta.org/hh/histheritage.html*
- *Sir George White Bt., (1854-1916). http://www.bristol-aeroplane.com/page3.html*