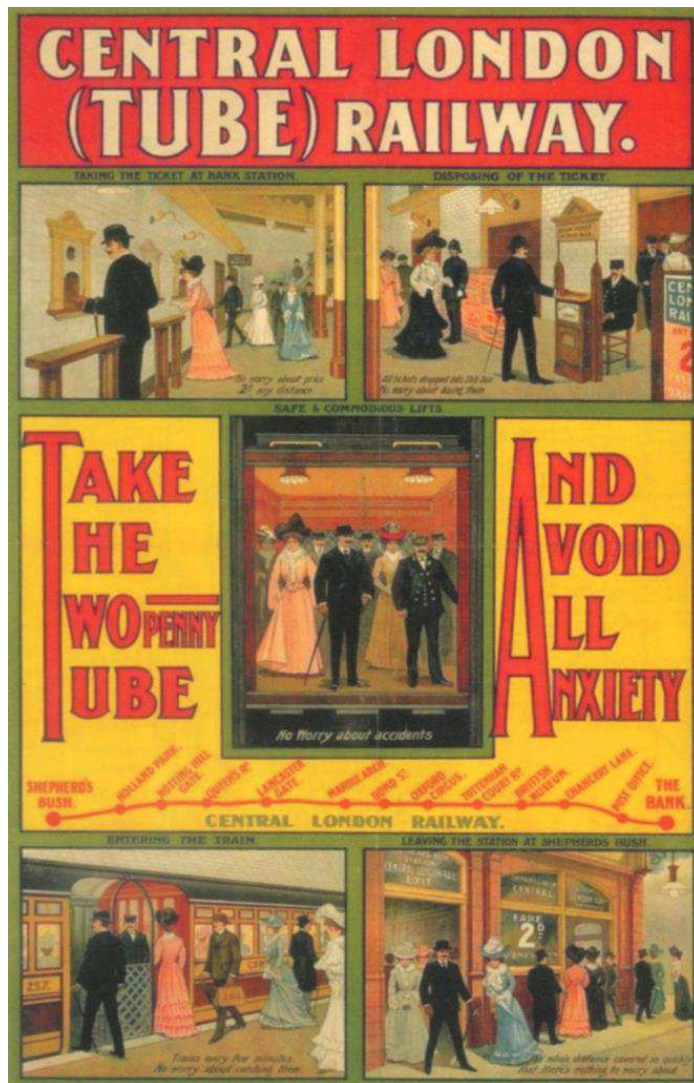


Central London Railway Construction

Contracts archive [1896-1902] of Electric Traction Co's

Managing Engineer: Ferdinand Huddleston MICE

By Roland Paxton

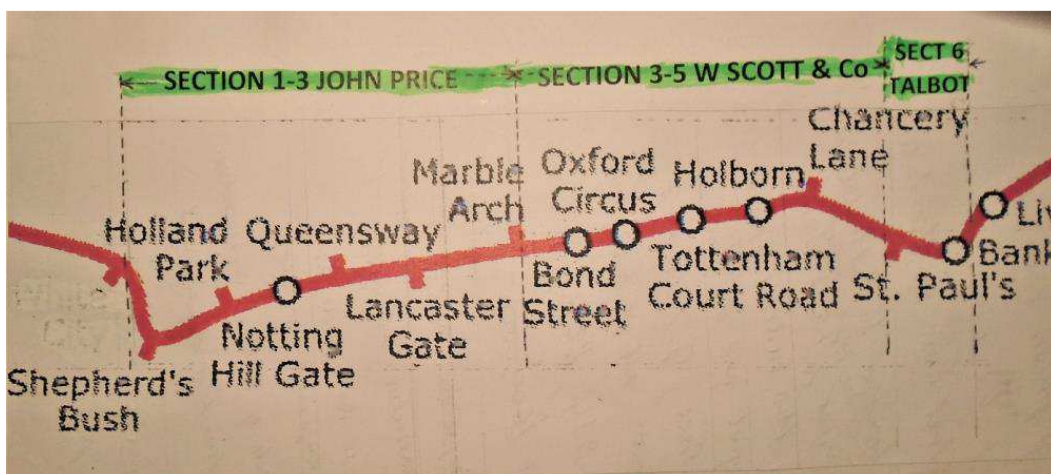


Early 'Two-penny' tube poster [not present in this archive]

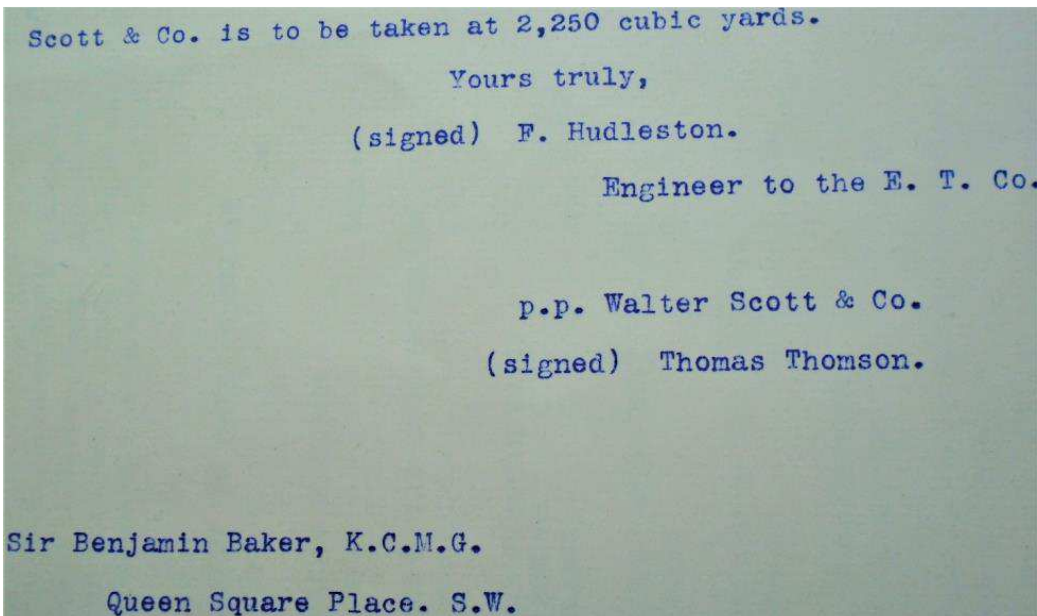
The Central London Railway was a deep level underground 'tube' railway. Its tunnels and stations now form the central section of London Underground's

Central Line. This railway company was established in 1889, funding for construction was obtained from a syndicate of financiers including Earnest Cassel, Henry Oppenheim, and members of the Rothschild family. In March 1894 the Railway Company appointed the **Electric Traction Company Ltd** to construct the railway at a cost €2.544m. The railway with its 13 stations ran completely underground in a pair of tunnels for about 6 miles eastwards from its terminus at Shepherd's Bush to the Bank of England, with a depot and power station at the western terminus. The project's technology was then state-of-the art, using Price's tunneling machine developed on this work to operate in the London clay and enable cast iron tube linings to be provided within shields, often under compressed air, improvement on the earlier brick-work construction exemplified by the Thames Tunnel and Metropolitan Railway [see Mott's map item 62], Even by 1907, no other railway of the size of the CLR had been completed in less time.

Following earlier proposals for the line that were not implemented the Central London Railway Act received its assent on 28 June 1892. The stations were to be at **Shepherd's Bush, Holland Park, Notting Hill Gate, Queens Road** [now Queensway], **Lancaster Gate, Marble Arch, Bond Street, Oxford Circus, Tottenham Court Road, British Museum, Chancery Lane, Post Office** [now St. Paul's] **and Bank.** The railway was opened by **HRH Edward Prince of Wales** on 27th June 1900. Soon afterwards it was dubbed by the *Daily Mail*, the **'Twopenny Tube'**, as this was the fare between any two stations. The service was very popular and within 6 months the railway had carried nearly 15 million passengers. During the first few years, patronage increased to around 45 million passengers per year.



To design the railway the Central London Railway employed leading engineers, **James H. Greathead** [developer of a tunnelling shield used for earlier tunnel crossings of the Thames], **Sir John Fowler**, [Engineer of the he earlier Metropolitan Railway, and **Sir Benjamin Baker**, [of London Underground, New York elevated railways and Forth Bridge engineering fame]. On **Greathead's** death in 1896, six months after work on the Central London Railway began, he was succeeded by leading engineer, **Basil Mott**. Electric Traction Company's engineer for constructing the railway was leading structural engineer **Ferdinand Hudleston**. Another notable tunnelling engineer [mentioned by Sir B. Baker in item 8 with an CLR Involvement was **Arthur Woodruffe Manton** [Engineer for major tunneling works, including Pennsylvania RR's Hudson East River Crossing, New York]. This archive comprises **Hudleston's** copies of contracts and specifications, priced documents, drawings, correspondence and notes relating to four contracts for the execution from 1896 of the basic infrastructure of the original line from Shepherd's Bush to Bank and Central Station [Bank], totaling more than **€1.1M**. It is of particular interest for its arbitration award copy correspondence with **Sir Benjamin Baker** (items 8, 33, 34 & 53 and 16, 27, 30, 31, 35) and a letter from **Mott** instructing the mode of completion of the tube lining within the shield and retention of two grout holes in the cast iron segments for future inspection (17)



Scott & Co. is to be taken at 2,250 cubic yards.

Yours truly,

(signed) F. Hudleston.

Engineer to the E. T. Co.

p.p. Walter Scott & Co.

(signed) Thomas Thomson.

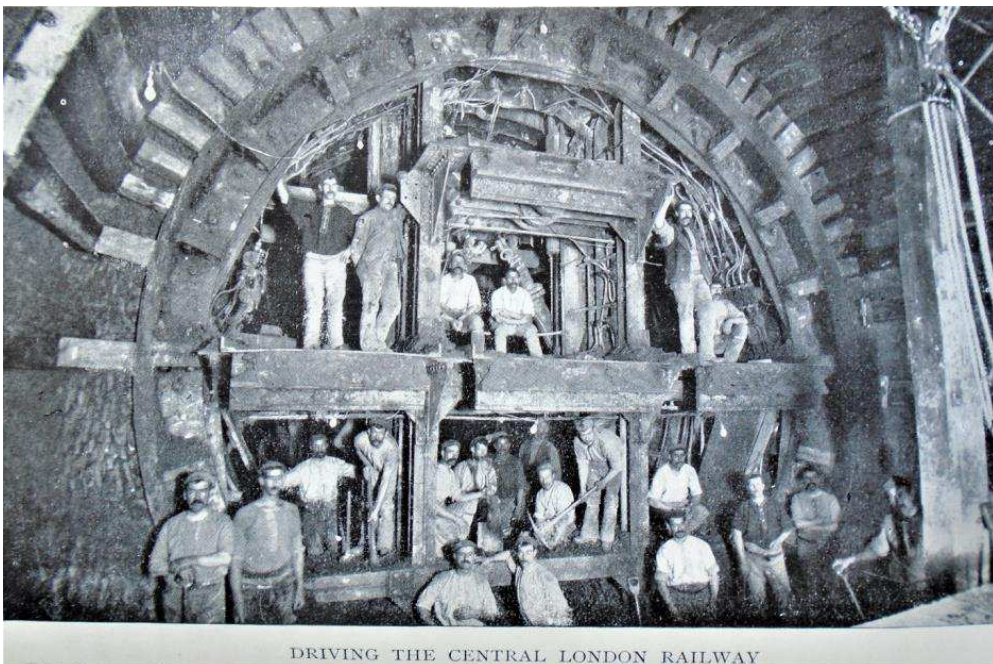
Sir Benjamin Baker, K.C.M.G.

Queen Square Place. S.W.

This part copy letter to Sir Benjamin Baker in 1900 indicates Hudleston's role as 'Engineer'

More time was required to construct the railway than was at first envisaged and an extension to 1899 was obtained. The work was sub-contracted by the Electric Traction Co. in three sections: [1-3] **Shepherd's Bush to Marble Arch**; [4-5] **Marble Arch to St. Paul's**; and on to [6] at **Bank**. Work began with the demolition of buildings at the Chancery Lane site in April 1896 and construction shafts started at Chancery Lane, Shepherd's Bush, Stanhope Terrace and Bloomsbury in August and September 1896. The short section east of **Bank** was used for sidings. A separate Contract was let for **Central [Bank] Station. Subways and Approaches**.

To minimize the risk of subsidence, the routing of the tunnels largely followed the roads on the surface and avoided passing under buildings. Usually, the tunnels were bored side by side 60-110ft below the surface, but where a road was too narrow to allow this, the tunnels were aligned one above the other, so that a number of stations have platforms at different levels. To assist with the deceleration of trains arriving at stations and the acceleration of trains leaving, station tunnels were located at the tops of slight inclines.



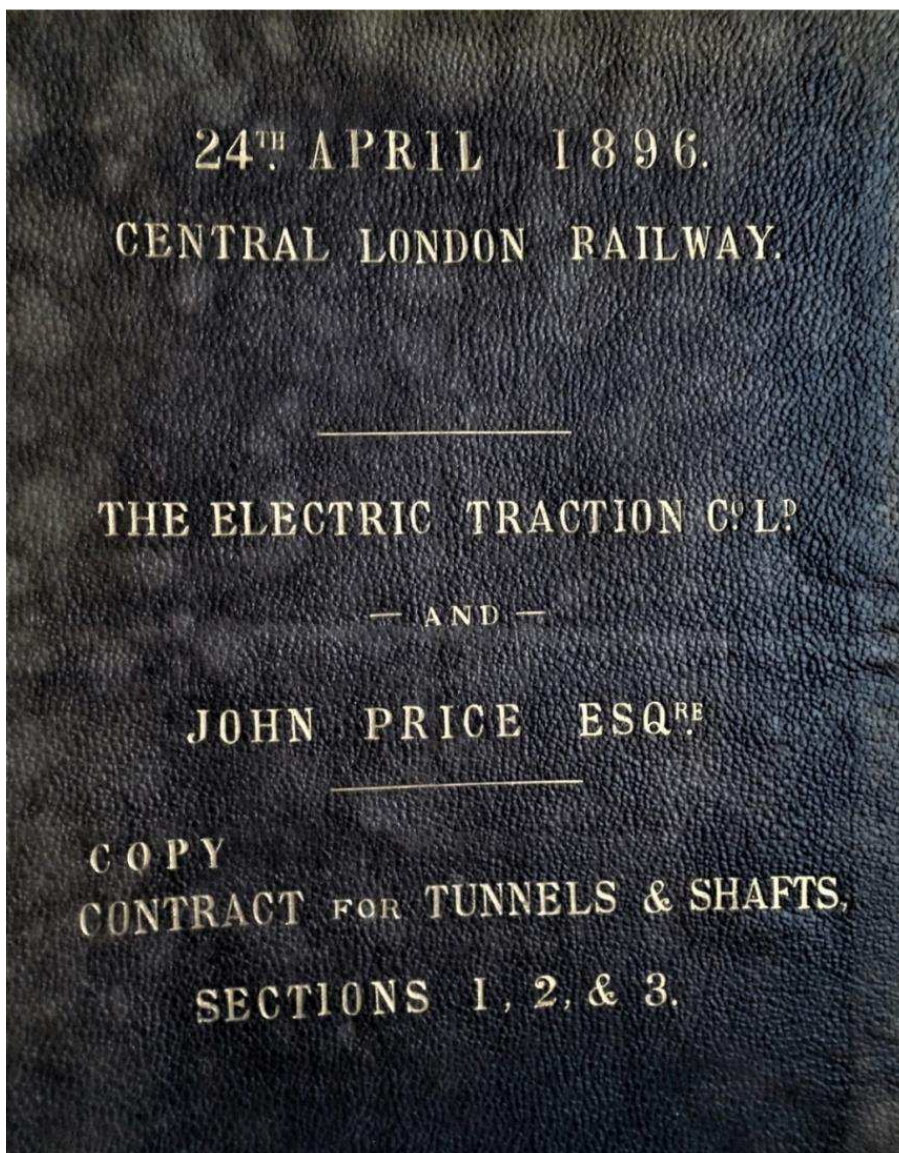
DRIVING THE CENTRAL LONDON RAILWAY

Photograph c.1898 from Hall C. *Conquests of Engineering* [see item 63]

Tunnelling was completed by the end of 1898 and because a planned concrete lining to the east iron tunnel rings was not installed, the internal diameter of the tunnels was generally 11ft 8¼in. For Bank station the company negotiated with the City Corporation to construct the ticket hall beneath a steel framework under the roadway and pavements of Threadneedle St. and Cornhill. This involved diverting pipework and cables into ducts beneath the subways linking the ticket hall to the street. Delays on this work were so costly that they nearly bankrupted the company. An extension to 1900 was approved.

[Some of the above data is by courtesy of the '*Central London Railway*' Wikipedia entry]

Archive Part 1: Tunnels & Shafts from Shepherd's Bush to Marble Arch



1. **Priced contract** dated 24 April 1896 between **The Electric Traction Co. Ltd** and **John Price Esq.** Fo. 47pp, ms title. *Leather- cloth, gilt titling.* Printed form of Contract priced at **£420,008** [£460.613],

Specification, Bill of Quantities, Schedule of Prices, Form of Bond.

Neatly priced in manuscript with details and copy signatures.

The specification required the railway to consist mainly of two tunnels lined with cast iron and circular in section, with enlarged tunnels of similar construction for the 13 stations. Also, tunnels of large diameter for cross overs at or near Shepherd's Bush, Queens Road, Marble Arch, British Museum and Bank Stations. This contract was for Sections 1, 2 & 3. The contractor was to provide at his own cost, all labour, tools, plant and suitable materials for carrying out and maintaining the works. He was also to fix, use and work such compressed air plant as may be required to enable the works to be carried out. These and other requirements are set out in 47 clauses of 'General Conditions'. Then follow 40 'Works' clauses i.e. for: order of execution; small and large shields; line and levels of tunnels and shafts; supply of shields and appliances for 11ft.8½in to 25ft diameter tunnels; hoisting engine with cage; staging and loading appliances; air compressing engines and receiver for working grouting apparatus and for ventilation; air or electric locomotives; small tunnels - items 7-12; cast iron lining joints, cast iron, wrought iron, steel – items 13-33; shields and appliances; grouting; station tunnels; cross-over roads; stations; shafts – cast iron lined, lifts – items 30-33; concrete [using approved Thames ballast aggregate and clean, broken brick]; cement [must be Portland – details specified – briquettes of 1" x 1" section after 7-days in water must bear a strain of at least 400lbs - testing machine to be supplied by the contractor; brickwork; mortar; list of 24 contract drawings.

2. Ms. Computation of **Contract price per yard lineal** fo. 2pp.

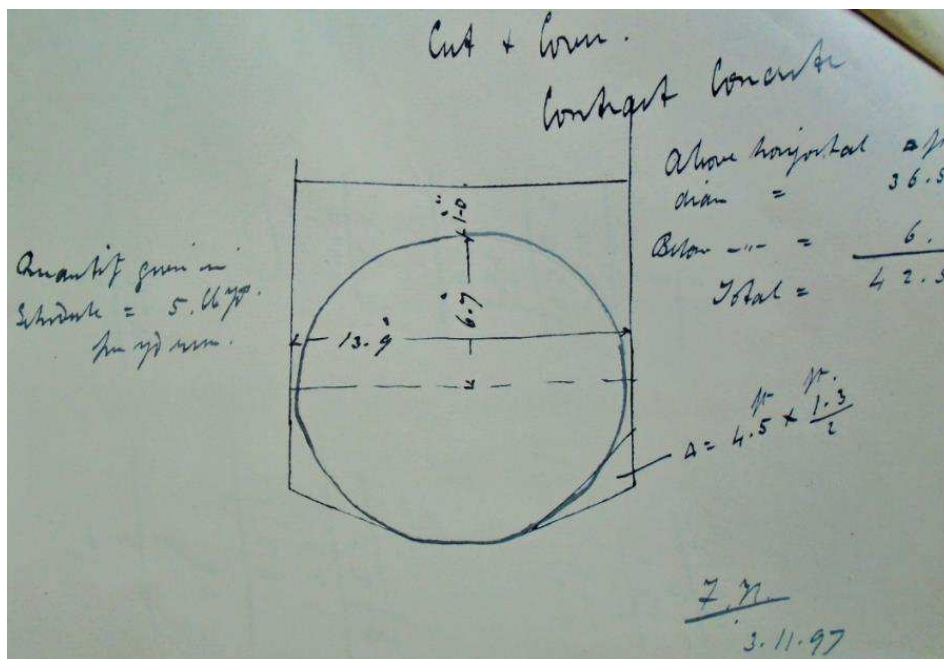
Calculated from Price's rates for various diameter tunnels and shafts e.g. **11ft 8¾in Tunnel** [£28/12/-]; **12ft 5in Tunnel**; **12ft 7in tunnel**; **21ft 2½in Station Tunnel**; **25ft Crossover Tunnel** [£123/4/6d] and shafts various sizes. [see image at item 40 for the format of these composite prices]

3. Ms. **Estimated cost of Labour at the Face**. In Hudleston's hand? 29/10/97. Fo. 1p. Gangs paid £24-15s for a 54 hour working week – a gang comprised 1 ganger @ 1/-[per hour]; 4 miners @ 9½d; & 8 labourers @ 7½d.

4. Ms. Cont typed copy letter of 17 June 1897 from **Price to Hudleston on 'Open Cutting at Woodhouse Park'**. 4to. 2p. Agreeing to accept

the E.T. Co's prices with modifications regarding gravel used for concrete, grouting to keep the tunnel dry, and the cost of cartage of surplus excavation, which if agreed would cover the cost of the work up to the entrance of Woodhouse Park ... any work under Caxton Road an extra ... does not think we should risk driving the shield with a less cover than 4 feet of clay. I have arranged to put a bore hole near the end of Caxton Road to give some idea of the nature of the ground [See Price's tunneling machine developed on this contract - item 62]. Whilst working on it, Price took T.J. Reeves into partnership soon after this contract started, and in the next few years the firm became renowned for constructing Rotherhithe Tunnel by 1908. They also worked on the Charing Cross, Euston and Hampstead underground lines and later on projects in Belgium, Kenya, Australia and India. [with]

5. Ms. Cont. typed copy of Hudleston's instructions for a **12ft 7in Tunnel at [Shepherd's Bush] Depot** - to be laid in open cutting and then filled. Fo. 1p. With Hudleston's sketch entitled '**Cut and Cover Without Concrete**' dated 3.11.97 [note: trench width for iron tube at 13ft 9in].



6. Contract for Tunneling Sections 1, 2, and 3. **Mr Price's Explanatory Notes of the 65 Items of his Final Claim, with the Electric Traction Company's comments thereon.** Fo. 108pp. orig. printed wrapper bearing Hudelston's initials. Of particular interest for numerous arbitration additions and alterations neatly inscribed in red ink [as advocated by Sir Benjamin Baker].
7. Proof No. 2. Central London Railway. Contract for Tunnelling Sections 1, 2, and 3. **Mr John Price's Supplementary Claims for September and October 1898, with the Electric Traction Company's comments thereon. Appendix to Final Claim.** Fo. 7pp. Hudleston's initials and the date 12.12. 1898 inscribed on front cover. With pencil list of claims.
- 8.

2, Queen Square Place,
Queen Anne's Mansions, Westminster.
22nd. December 1898.

Dear Sir Richard,

Central London Railway.

I think it would be well for Mr. Hudlestone and Mr. Manton to amend in red ink my copy of the Explanatory Notes relating to Mr. Price's final claim in accordance with the various suggestions made at the Arbitration.

It seems to me the following Items are affected:-

- Item 6. The amounts £89.12.0 and £17.8.3 to be discussed and agreed.
- Items 13,46,47,48,49 & 60. relating to measurements to be discussed and agreed.
- Items 14 & 32. to be withdrawn on the iron becoming the property of the Traction Company.
- Item 33. to be reduced to one half.
- Item 36. to be modified and arranged.
- Items 40 & 63 to be withdrawn as dealt with under the Award to damage to property.

Yours faithfully,
(Signed) B. Baker.

- Ms. Cont. typed copy letter of 22 December 1898 from **Sir Benjamin Baker to Sir Richard Farrant writing:** *'that it would be well for Mr Hudleston and Mr Manton to amend in red ink my copy of the explanatory notes relating to Mr Price's final claim in accordance with the various suggestions made at the Arbitration ...'* [re items 6, 13, 46-49, 60; 14 and 32, 33, 36/ 40 & 43 - see his letter below and details in document 4 where his recommendation has been acted on.
9. Ms. Copy typed letter dated 2 January 1899 from the London Central Railway Secretary T. Davidson Esq. to Hudleston? 4to. 2pp. **Confirming that Sir Benjamin Baker had sent in his arbitration award and that Sir Richard Farrant** [has asked him to send this copy]. Pencil note, 'Similar letter sent to G.E Warburg Esq.
 10. Ms. An account of work charged to Mr John Price by the Electric Traction Co., initialed by F. [Hudleston] dated 19.1.1900. Fo, 6pp, cont. leathercloth wrapper. Regarding £869 for clearing spoil at Holland Park, Notting Hill Gate, Queens Road and Westbourne; Making good to brick arches at Shepherd's Bush and other work all quantified and priced.
 11. **Contract for Tunnelling Sections 1, 2 and 3. Classification by the Electric Traction Company of the 64 items of Mr. John Price's Claim showing the amounts allowed and disallowed.** Fo. 8pp. F. Hudleston's initials on front cover. Includes iron lined passages. Neat manuscript alterations and additions in red ink, including 11 items additional to 24 printed ones.
 12. Ms. Copy typed letter dated 13.1.99 from F. Hudleston to John Price giving him an account of Sir Benjamin Baker's arbitration award, which is here totaled at £460,036, and enclosing a cheque for the balance owing. With a note in Hudleston's hand dated 15.2.1902, 'I have agreed that E.T. Co pay Price half of 1153.9.5d, 577.14.8½.' i.e Total £460,036.
 13. Ms. Mr John Price's Contract. Typed copy **Report of Meeting on 18 Feby 1900** to try to reach a final settlement, with Sir Richard Farrant and Hudleston representing the E.T. Co. and Messrs Price and others the Contractor, with Hudleston's record of the meeting. Fo. 2pp. Gives details of the Award and further supplementary claims. After deducting the 'amount admitted by E.T. Co. as per Mr Hudleston's Certificate of 12 January 1899, the payment agreed was £460,806,

£1155 short of what Price was prepared to accept. Hudleston agreed to split the difference. See part of document below for more details.

MR JOHN PRICE'S CONTRACT

A meeting was held the 15th February 1900 to endeavour to arrive at a final settlement of Mr Price's Contract, when the following gentlemen were present:-

re presenting the E.T.Co. -----	representing the Contractor -----
Sir Richard Farrant	Mr John Price
Mr William Morris Junior	" Perks
Mr Hudleston	" Connory

The following are Mr Hudleston's notes as to what took place at the Meeting:-

Amount of Sir Benjamin Baker's Award re Mr Price's claim dated 30th Aug 1898	460,403: 0:0
Add Mr Price's Supplementary Claims	
30th Sept. 1898	609: 6: 2
31st Octr. "	106: 9: 3

	715:15: 5
Mr Price's claim for staircase shaft Plates and bolts left upon ground (Items 42 & 43 of original claim)	72:15:11

	788:11:4

	461,191:11:4
Deduct	
Amount admitted by E.T.Co. as per Mr Hudleston's Certificate of 12th January 1899	460,036: 1:11

	£ 1,155: 9:5

**Archive Part 2: Central London Railway. Tunnels & Shafts
[Marble Arch to St. Paul's]**

CENTRAL LONDON RAILWAY.

THE ELECTRIC TRACTION CO^LD

— AND —

MESS^{RS} WALTER SCOTT & CO

COPY
CONTRACT FOR TUNNELS & SHAFTS.
SECTIONS 4, & 5.

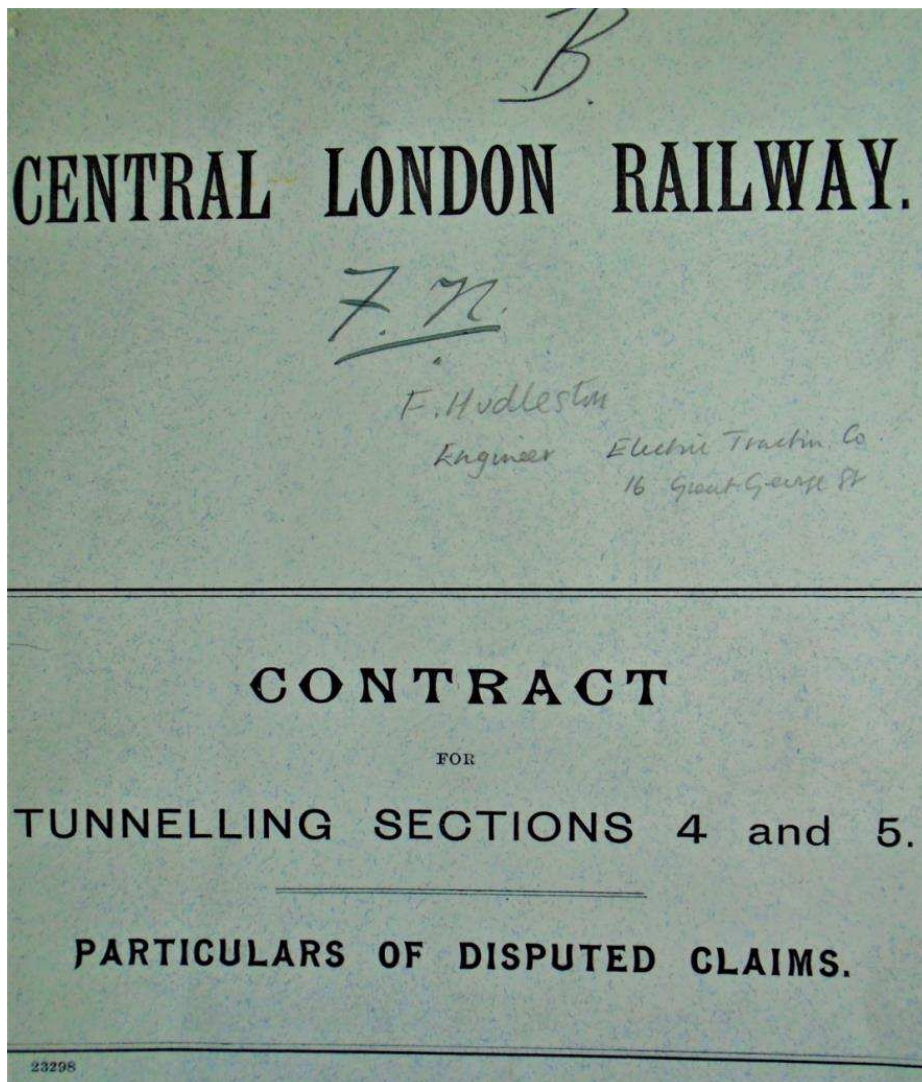
THE ELECTRIC TRACTION CO., LD,
16, GREAT GEORGE STREET, S.W.

14. Priced contract of 29 April 1896 between The Electric Traction Co. Ltd and Messrs Walter Scott & Co. Fo. 45pp, ms title, Form of Contract priced at **£500,000**, Specification, Bill of Quantities,

Schedule of Prices Form of Bond. *folio, leather-cloth with gilt titling.*

All neatly completed in manuscript with details and copy signatures.

The specification required the railway to consist mainly of two tunnels lined with cast iron and circular in section, with enlarged tunnels of similar construction for the 13 stations. Also, tunnels of large diameter for cross overs at or near Shepherd's Bush, Queens Road, Marble Arch, British Museum and Bank Stations. The works for all the tunnels and shafts were divided into six Sections of which this contract was for Sections 1, 2 & 3. The contractor was to provide at his own cost, all labour, tools, plant and suitable materials for carrying out and maintaining the works. He was also to fix, use and work such compressed air plant as may be required to enable the works to be carried out. [These and other requirements are set out in 47 clauses of 'General Conditions' [then follow 40 'Works' clauses i.e. for: order of execution; small and large shields; [line and levels of tunnels and shafts; supply of shields and appliances for 11ft.8¼in to 25ft diameter tunnels; hoisting engine with cage; staging and loading appliances; air compressing engines and receiver for working grouting apparatus and for ventilation; air or electric locomotives; small tunnels - items 7-12; cast iron lining joints, cast iron, wrought iron, steel – items 13-33; shields and appliances; grouting; station tunnels; cross-over roads; stations; shafts – [cast iron lined, lifts – items 30-33]; concrete [using approved Thames ballast aggregate and clean, broken brick}; cement [must be Portland – details specified – briquettes of 1"x 1" section after 7-days in water must bear a strain of at least 400lbs - testing machine to be supplied by the contractor; brickwork; mortar; list of 28 contract drawings.



15. **Contract for Tunnelling Sections 4 & 5. Particulars of Disputed Claims** [22 items] **23.2.98.** Fo. 41pp. orig. printed with Hudleston's initials. numerous arbitration additions and neatly inscribed in Hudleston's hand? [as recommended by Sir Benjamin Baker.] See excerpts from item 14 below relating to the use of compressed air plant at Chancery Lane. With copy letters from Hudleston to Sir Benjamin Baker; also from Basil Mott to Hudleston tipped in at to items 1 & 17

we have agreed the total cost of labour at ... £12,045 9 10
 and the total cost of materials ... 4,707 18 1
 and measured work at Contract prices... 182 3 0
 To these must be added the charges for plant, supervision, profit, &c.,
 which are in dispute as well as the credit.

1. Charges for Plant

In charging for use of plant and depreciation, Messrs. Scott divided their plant under the two heads of ordinary and special as follows:—

	Ordinary.	Special.
	£	£
20 H.P. portable engines—2 at £350 ...	700	...
Dynamos, 100 amp. 200 volt.—2 at £180 ...	...	360
Belting and countershafts ...	...	45
Hydraulic lift, cage, guides, &c. ...	...	390
Air compressor ...	180	...
Air receiver ...	35	...
Staging and plates ...	...	110
Temporary buildings ...	...	80
Cables to shaft bottom ...	...	20
Piping do. ...	...	40
Ladders do. ...	...	25
Steam crane ...	350	...
Plates, bottom shaft and cross over roads ...	...	45
Temporary staging in shaft ...	...	25
Winch hauling muck on incline ...	...	200
	£1,265	£1,340

See Cont. page 22 claim

*Refer to
 a/c. Quarter
 ending 30 Dec 1907
 The E.C.C. supplied
 all the real
 Air Compressing
 Plant, Locks etc*

Their claim for ordinary plant is 30 per cent. for the Contract plant and 80 per cent. for special, and as they take the Contract time at 20 months, these rates work out 1½ per cent. per month and 4 per cent. per month respectively, and on to this Messrs. Scott claim a further 10 per cent. and 15 per cent.

We contend that the actual time of working, which was 30 months, must be the time over which depreciation is spread. We think that 30 per cent. is a fair depreciation for ordinary plant averaging monthly 1 per cent. ... £629 16 4

As regards special plant, we contend that 50 per cent. is a liberal depreciation on the class of plant shown above which is necessary in any

Item 15. Charges for Compressed Air use.

Plant

<i>This should be subdivided thus</i>	<i>Scott & Co.</i>	<i>E.C.C. acc.</i>
<i>Depreciation on Station Plant</i>	<i>1141-0-9</i>	<i>629-16-4</i>
<i>" on Plant used for the Compressed Air Work only</i>	<i>746-10-2</i>	<i>412-10-0</i>
	<i>1,887-10-11</i>	<i>1042-6-0</i>

Note. Hand Arbitrator's Summary Sheet.

Item 15. Compressed air plant costs

16. Ms. Copy typed letter from Hudleston to Sir Benjamin Baker regarding W. Scott & Co's contract dated Oct 2nd 1900

L ELECTRIC TRACTION COMPANY, LIMITED.
 51 WESTMINSTER.
 IC ADDRESS.
 E. LONDON.

*16, Great George Street,
 Westminster, W.*
 Oct. 2nd. 1900.

Dear Sir,

C. L. Ry.- W. Scott & Co's Contract.

With reference to the question of amount passed by me in connection with Station Openings, (Item No. 1 in my particulars of disputed claims) I have looked into the matter and find it should be as follows:-

70 Station Openings @ 227 - 3 - 6	£1902 - 8 - 0
6 " " (materials only)	
@ 216 - 13 - 6	100 - 1 - 0
1 Special " at Davies Street	
@ 250 - 0 - 0	50 - 0 - 0
	<hr/>
	£2,052 - 8 - 0
	<hr/>

and this figure should therefore be taken as the amount passed instead of £2,006 - 12 - 0 shown on the left of page 3.

The amount disallowed should therefore be shown as £2504 - 19 - 6 instead of the printed figure £2650 - 13 - 6 on the right hand of page 3.

Yours truly,

17. Ms. Copy typed letter dated 3.4.1897 from Basil Mott [CLR Engineer] to F. Hudleston saying that he did not consider Mr Price's proposal for using shield skin for part of the cast iron lining would be satisfactory, and to instruct him 'to complete the cast iron lining

throughout within the shield skin'. Mott also stated 'it is important that two grout holes should remain in the cast iron segments as at present as I have found the second hole of great value for purpose of inspection and should not like it to be given up.' [see below] 4to. 3p. At p. 30 of item 14: "Item 17. Refers to lining skins of 21ft 2½in Tunnels with Cast Iron Segments".

CENTRAL LONDON RAILWAY.

Engineers Office,
8, Queen Anne's Gate,
Westminster
April 3rd. 1897.

Dear Sir,

Proposed use of Shield skin for part of Cast-Iron Lining. - In reply to your letter of the 31st. March, I am sorry to say that I do not consider Mr. Price's proposal would make a satisfactory job. Kindly instruct him to complete the cast iron lining throughout inside the shield skin.

Grout Holes. - I think that it is important that two grout holes should remain in the cast iron segments as at present as I have found the second hole of great value for purposes of inspection and should not like it to be given up.

Yours truly,
(Signed) Basil Mott.

F. Hudleston Esq.,

18. **Contract for Tunnelling Sections 4 & 5. Summary of Items in Dispute between The Electric Traction Company.** Fo. 7pp. F.H[udleston]'s. Initials. Comprises Sheets A to D. The items in dispute include Marble Arch shaft, excavation, tunnel, brickwork,

station passages, shield chambers 11ft 10¼in & 21ft and lining at shield skin.

19. **Contract for Tunnelling Sections 4 & 5. Supplementary Claims by Messrs. Walter Scott & Co.** Fo. 4pp. Relating to items at Marble Arch shaft, Oxford Circus Yard, Tottenham Court Road, Chancery Lane and Davies St. Moving hoarding; shoring; Removing spoil &c.
20. Ms. Fo. 5pp. **Computation of Contract price per yard lineal** computed from Scott & Co's tender for **11ft 8¾in Tunnel** [£31/17/0]; **12ft 5in Tunnel** (€34.3.1d); **12ft 7in tunnel**; **21ft 2½in Station Tunnel**; **25ft Tunnel** [crossover] (€ 162.19.3d) and for various **shafts** from 18-30ft deep.
21. Ms. Fo. 5pp. Working calculations re. lin. yd rates computed in item 20
22. **Walter Scott & Co. Cost of using Compressed Air at Chancery Lane** [€24,911]. 17 July 1899; Fo. 8pp. cont. leather-cloth, brass studs. Under the headings of: Labour at Depot – in Tunnel, Station wages & insurance; Materials; measured work; depreciation of station plant and plant used on work only; supervision and profit; credit for 490.3yds if driven without air; extras and nuisance claims. Plus 7 pages of further details and the E.T.Co's explanation of "Walter Scott & Cos CLAIM"... They claim that the depreciation on ordinary plant is 30% during the contract which they take at 20 months... Special Plant they estimate at 80% depreciation in 20 months ... more including the E.T.Co's opinion and the sums allowable
23. Duplicate of 22.
24. Duplicate of 22.
25. **Contracts Nos. 4 & 5. Final Accounts. Counterclaim by Electric Traction Co.** Pink wrapper with F. [Hudleston]'s initials [see below]. Fo. 20pp. **Six items totalling €1033 not allowed**; for spoil removal; making good to arches between platforms at Marble Arch, Oxford Circus; Tottenham Court Road and British Museum Stations; Sundry alterations at these stations; Breaking up engine beds &c. &c. Details of labour rates and costs, material costs and dates provided.

F.N. "E."

CENTRAL LONDON RAILWAY.

.....
CONTRACTS Nos. 4 & 5.
.....

FINAL ACCOUNTS.

Counterclaim by Electric Traction Company,
with Walter Scott & Co.'s replies thereto.

WALTER SCOTT & CO.
CONTRACTORS.

AND AT
VICTORIA BUILDINGS,
NEWCASTLE ON TYNE.

TELEGRAMS:—DISLodge, LONDON.
TELEPHONE:—NO 693, WESTMINSTER.

28, Victoria Street,

Westminster, S.W.

11th May 1900

Dear Sir,
Central London Rly
Final account

Herewith we send you three
copies of your counterclaim
against us on the above contract
with our replies thereto. You
will notice we have slightly
rearranged the order of the items
so as to bring all of one class
together, but the total £1062.10.11
is the same.

Yours truly

Walter Scott

26. A.L.S. from Walter Scott to E.T.Co. 11 May 1900 tipped in sending 3
copies for your counterclaim against us on the above contract with

- our replies sheets, A slightly rearranged so as to bring all items of one class together ... total €1062.10.11.[with] [with]
27. Copy joint letter **from Hudleston & Walter Scott & Co to Sir Benjamin Baker KCMG** 2 Oct. 1900 tipped in. Regarding spoil left in basements of stations.
28. **Central London Railway. Contract for Tunnelling Sections 4 & 5, Summary of Contract Items and Extras. [1900].** Blue wrapper with F.H[udleston]'s initials. Fo. 9pp. Useful descriptions of the various diameter tunnels and shafts stations, cast iron linings, driving tunnelled through marl and rock, compressed air Chancery Lane. Ms. Additions and notes. Total €585,556. €74,238 claimed; €25813 disallowed.
29. Ms. **Davies Street- Damage to Property. Mr Hudleston's Remarks.** 3 Aug 1890. Fo. 2p cont. typed copy '*... As regards Messrs. Scott's argument that these station tunnels should certainly have been made under compressed air, I deny that there is any very special difference in the blue clay at this point from that along the rest of the route. The top of the blue clay was about 24ft below street level; the top five or six feet was softist, then came 22ft of hard stiff blue clay, and at 52ft below the surface the clay got rather softer, but I do not consider that there was any great difference between it and the clay found at other places along the line, and certainly not sufficient to justify Messrs. Scott in asking for the use of Compressed Air. I am opinion that the great damage to property at this point was due to the fact that the old Tyburn Stream flowed across Oxford Street just at our Station on the top of the blue clay and had softened the surface, the result being that the older houses which did not go down into the solid blue clay, were ready to slip on the slightest disturbance of the ground, just as they did about 40 years ago when the Middle Level sewer was carried past. This I consider to be obviously a contract risk. It must be remembered that Scott & Co. disturbed surface property at every station they made, and the occurrences at Davies Street were merely on a larger scale than the rest. The sinking of the shaft at an earlier date would not have told us anything more about the state of the clay than we know from driving the small tunnels, which were actually in this rather softer stratum. Again when Scott's made their 25ft shield chambers they*

had a full section of the clay before them; yet no suggestion was made about Compressed Air until after the 32ft Tunnels had been driven and the damage to the property had actually occurred. Even if the Tunnels had been carried out under Compressed Air, the additional expense to us would not have been anything like the €32,400 which they state, as the Compressed Air plant we supplied to them and the headwalls built for driving the upper passages were ample to drive the Tunnels as well. In similar work we have had to carry out, the additional cost we were put to in labour at the face and coals did not amount to more than €40 per lineal yard, say €9,000 for the two Station Tunnels at Davies Street. ...' [F.Hudleston]

30. Ms. Cont. typed copy **letter from F. Hudleston to Sir Benjamin Baker** dated 2nd October 1900 re. **W. Scott & Co's Contract**. **'With reference to the question of amount passed by me in connection with Station Openings, (item No. 1 in my particulars of disputed claims) I have looked into the matter and find it should be as follows [details of 77 Station Openings ... €2052.6.6] ...The amount disallowed should therefore be shown as €2564 instead of the printed figure €2330.13.8d.** [image below]

THE ELECTRIC TRACTION COMPANY, LIMITED.

TELEPHONE N° 551 WESTMINSTER.

TELEGRAPHIC ADDRESS.
"TRACKAGE, LONDON."

*16, Great George Street,
Westminster, W.C.*
Oct. 2nd. 1900.

Dear Sir,

C. L. Ry.- W. Scott & Co's Contract.

With reference to the question of amount passed by me in connection with Station Openings, (Item No. 1 in my particulars of disputed claims) I have looked into the matter and find it should be as follows:-

70 Station Openings @ £27 - 3 - 6	£1902 - 9 - 0
6 " " (materials only)	
@ £16 - 13 - 6	100 - 1 - 0
1 Special " at Davies Street	
@ £50 - 0 - 0	50 - 0 - 0
	<hr/>
	£2,052- 6 - 0
	<hr/>

and this figure should therefore be taken as the amount passed instead of £2,006 - 12 - 0 shewn on the left of page 3.

The amount disallowed should therefore be shewn as £2664 - 19 - 6 instead of the printed figure £2630 - 13 - 8 on the right hand of page 3.

Yours truly,

Engineer.

Sir Benjamin Baker K. C. M. G.

31. Cont, typed copy of joint letter of 2nd Oct. 1900 from **F. Hudleston & Thomas Thomson of Walter Scott & Co. to Sir Benjamin Baker** regarding spoil left in basements of stations by W. Scott & Co. 4to. 1p. Agreeing that this spoil is to be taken as amounting 2250 cubic yards.
32. Ms. list [in Hudleston's hand?] 2 Oct 1900 re. 24 claim items. Fo. 4p.
33. Ms. Cont. typed copy of letter of 18 October 1900 from **Sir Benjamin Baker to The Electric Traction Co. and Messrs Walter Scott and Co.** 4to.1p. *'... I have examined the different items of disputed claims Nos. 1-24 in the printed documents submitted to me & amended during discussion as regards certain item and I have also examined the Items of Counterclaim Nos. 1-6 similarly amended. I am of opinion that in respect of the above claims and counterclaims as amended Walter Scott & Co. are entitled to be paid a sum of €8,260 beyond that which would be due to them on the basis of the Electric Traction Co's figures as set forth. As regards disputed Property claims I am of opinion that the damages and costs in respect of Frascati should be paid by Messrs Walter Scott & Co. and the Electric Traction Co. in the proportions of 2/3 by the former and 1/3 by the latter company...'* [with 34] [image below]

Queen Anne's Mansions,
Westminster, S.W.

18th October, 1900.

Central London Railway
Contract for Tunneling - Sections 4 & 5.

The Electric Traction Co.
and
Messrs Walter Scott & Co.

Dear Sirs,

I have examined the different Items of disputed claims Nos. 1 to 24 in the printed documents submitted to me & amended during discussion as regards certain items and I have also examined the Items of Counterclaim Nos. 1 to 6 similarly amended.

I am of opinion that in respect of the above claims and counterclaims as amended Messrs Walter Scott & Co. are entitled to be paid a sum of £8,260 beyond that which would be due to them on the basis of the Electric Traction Co's figures as set forth in the above documents.

As regards disputed Property claims I am of opinion that the damages and costs in respect of Frascati should be paid by Messrs Walter Scott & Co. and that those in respect of Davies Street should be paid by Messrs Walter Scott & Co. and the Electric Traction Company in the respective proportions of 2/3 by the former and 1/3 by the latter Company.

Yours ~~xxx~~ faithfully,

(signed) B. Baker.

34. Ms. Cont typed copy 'Messrs Walter Scot & Co's Contract. Sir Benjamin Baker's Award - 18th October 1900 ... (details - total £536,81610:11d. 2pp. fo. Includes 'Note. There is also the question of Damage to Adjacent Property in certain areas where Messrs. Scott & Co. have agreed to pay two thirds... Account due to Messrs Scott & Co... say £21,000.' Balance due £16,000, against which will be charged 2/3 of any further amounts the E.T.Co. may pay in respect of Damage to Davies St. Property

Benjamin Baker's Award - 18th October, 1900.

The Electric Traction Co's allowance as set forth in the document submitted to Sir Benjamin Baker	535,556:10:11
Add Arbitrator's Addition to the above allowance in respect of disputed Contract Items (Messrs Scott & Co's Claim was £25,813:3:3)	8,260: 0: 0
	543,816:10:11
Deduct Damage to Property Davies Street (Total amount estimated @ £13,000 to £15,000) Arbitrator's Award is that Messrs Walter Scott & Co. pay two thirds. At present the Expenditure has been about £10,500 only. Two thirds of this	7,000: 0: 0
	536,816:10:11
Add Amount paid by Messrs Scott & Co. out of the £10,500, the rest having been paid by the E.T.Co.	900: 0: 0
	£ 537,716:10:11

Note.

There is also the question of Damage to
Adjacent Property in certain cases

35. Cont. typed copy of a draft proposed letter to **Sir Benjamin Baker**
[post Oct. 1900] from the Advisers of **The English Traction Co. &**
Walter Scott & Co] - Contract for tunnelling Sections 4 & 5. Fo...as

to the construction to be placed upon your letter of 18 October. 1p fo. '... Messrs. Scot and Co. maintain that on your letter referring to the claims and counter claims submitted to you and amended during discussion. They are entitled to €8260 beyond the amount which would be due to them on the basis of the Electric Traction Co's figures as set forth in the documents as so amended whereas the Electric Traction Co's contention is that they are entitled only to pay €8260 in addition to the figures on the documents as originally submitted to you. The agreed difference between these two ways of reading your letter is the sum of €277.16.0. and the Electric Co. and Walter Scott & Co. sill feel obliged if you will kindly state which is the correct view to take of your letter ... This difference of opinion had arisen between the Advisers of The Electric Traction Co. and the Advisers of Walter Scott & Co as to the construction to be placed upon your letter of 18th October 1890 relating to the sum of €8,260 and reiterating the substance of Electric Traction Co. and Walter Scott's joint letter of October 1890 [item 33] [envelope addressed to F. Hudleston Esqr]

36. **Initialed note in Hudleston's hand** on Electric Traction Co's headed paper dated 10 July 1901 relating to a claim of €2,000 subsequently reduced to €750 in respect of damage to 'The Vicarage. Christ Church' [near St. Paul's?]. 4to. 1p.

THE ELECTRIC TRACTION COMPANY, LIMITED.

16, Great George Street,
Westminster, S.W.

TELEPHONE NO 551 WESTMINSTER.

~~TELEGRAPHIC ADDRESS.~~
~~"TRACKAGE, LONDON."~~

10-7-01

The Vicarage, Christ Church
near St. Paul's station

Oct 24, 1900.

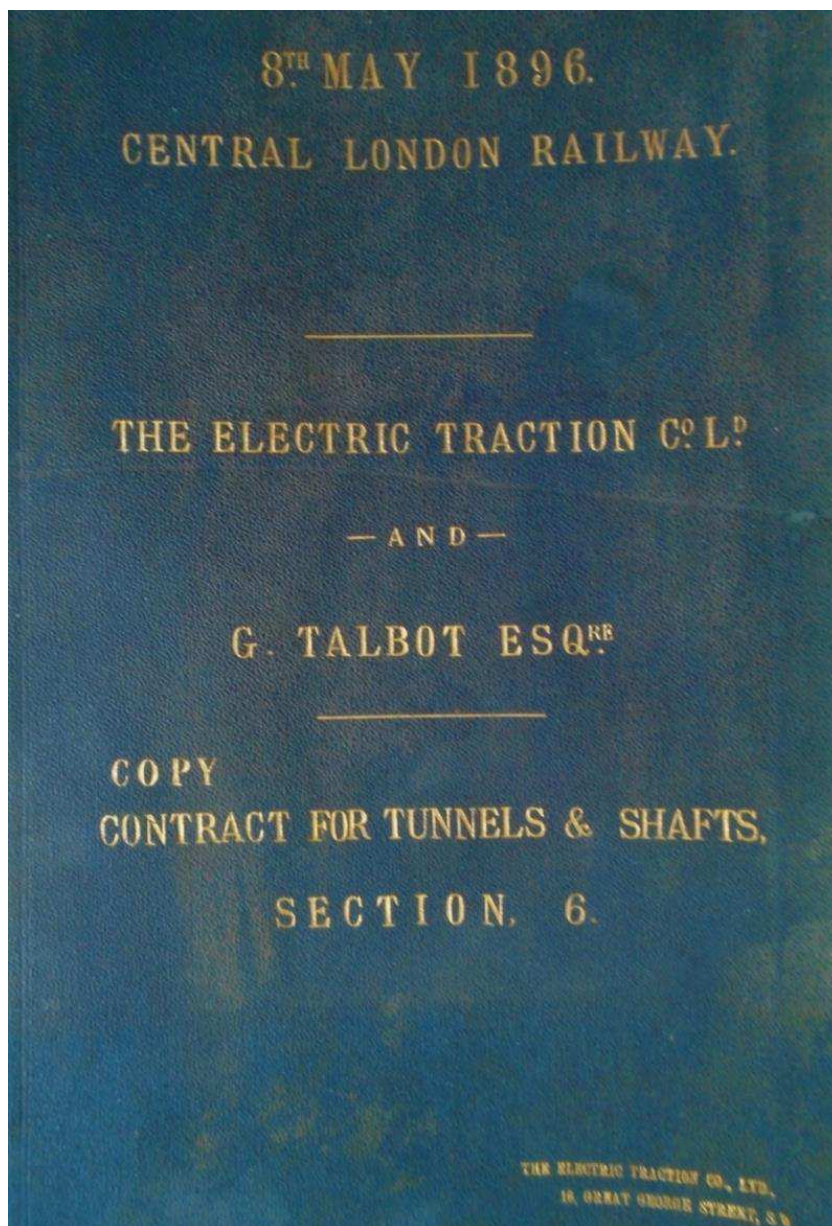
A. M. C. & Co. received a letter from
Banks & Co. demanding £2,000 in respect of
damage done & premises repaired.

The claim was ^{Jan 1901} afterwards returned
to £750/0/0 for the Arbitrator. Mr Daniel
Wadby & Mr Wadby's demand was £64-8-0

The E.T.C. paid Wadby fees of 50-14-0. J.M.

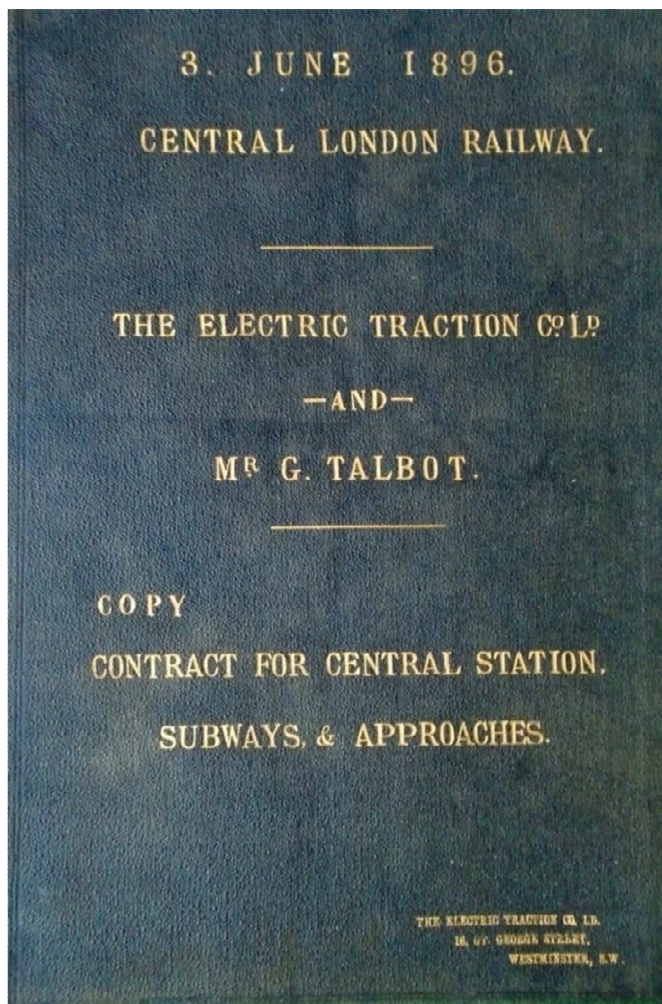
37. Cont. typed copy letter from **Ashurst, Morris and Chrisp** dated 21 Feb. 1902 re. **Central London Railway. Walter Scott & Co. to H.E. Upton. Fo. 1p.** *'...Messrs. Stanton, Atkinson & Hudson have sent us a draft of a proposed letter to Sur Benjamin Baker with reference to their claim to €277.16.0 more than they have been paid. We enclose a copy of the draft letter and shall be glad if you will submit it to Sir Richard Farrant. Sir Benjamin Baker will not understand it from the enclosed letter. In fact we do not see how he can be made to understand it without a long and detailed letter or personal explanation. He will not be pleased at having to spend on so small a matter the time necessary to examine into it. Mr William Morris rather thought when we went into the matter with Mr. Hudleston and yourself some time ago that the decision would be probably be against the Traction Co. on the strict reading of the Award. It would perhaps be better to offer to Messrs. Scott and Co. to halve the amount rather than trouble Sir Benjamin Baker with it.'* [original envelope addressed to Hudleston - attached]

Archive Part 3: Central London Railway. Tunnels & Shafts [St. Paul's/Post Office] to Bank and Central Station [Bank] Subways and Approaches. [two contracts]



38. Central London Railway. Priced contract of 8 May 1896 between The Electric Traction Co. Ltd & G. Talbot Esqr. for Tunnels & Shafts. SECTION 6 [St. Paul's - Bank]. Fo. 45pp, ms title, Form of Contract priced at £139,780, Specification, Bill of Quantities, Schedule of Prices Form of Bond. Cont leathercloth, gilt titling [see below]. All

neatly completed in manuscript with details and copy signatures. The specification required the railway to consist mainly of two tunnels lined with cast iron and circular in section, with enlarged tunnels of similar construction for the 13 stations. Also, tunnels of large diameter for cross overs at or near Shepherd's Bush, Queens Road, Marble Arch, British Museum and Bank Stations. The works for all the tunnels and shafts were divided into six Sections of which this contract was for Sections 1, 2 & 3. The contractor was to provide at his own cost, all labour, tools, plant and suitable materials for carrying out and maintaining the works. He was also to fix, use and work such compressed air plant as may be required to enable the works to be carried out. [These and other requirements are set out in 47 clauses of 'General Conditions' [then follow 40 'Works' clauses i.e. for: order of execution; small and large shields; [line and levels of tunnels and shafts; supply of shields and appliances for 11ft.8½in to 25ft diameter tunnels; hoisting engine with cage; staging and loading appliances; air compressing engines and receiver for working grouting apparatus and for ventilation; air or electric locomotives; small tunnels - items 7-12; cast iron lining joints, cast iron, wrought iron, steel – items 13-33; shields and appliances; grouting; station tunnels; cross-over roads; stations; shafts – [cast iron lined, lifts – items 30-33]; concrete [using approved Thames ballast aggregate and clean, broken brick}; cement [must be Portland – details specified – briquettes of 1" x 1" section after 7-days in water must bear a strain of at least 400lbs - testing machine to be supplied by the contractor; brickwork; mortar; list of 28 contract drawings.



39. **Central London Railway. Priced contract 3rd June 1896 between The Electric Traction Co. Ltd & G. Talbot Esqr for Central [Bank] Station. Subways and Approaches** Fo. 45pp, ms title. Form of Contract priced at **£139,780** [£166,334] Specification, Bill of Quantities, Schedule of Prices Form of Bond. Cont leathercloth, gilt titling [see above]. All neatly completed in manuscript with details and copy signatures
40. Ms. Compilation. Fo. 3 sheets. **Contract prices per yard lineal** for 9 works computed from Talbot's tender e.g. for an **11ft 8½in dia. Tunnel** [€34/1/5; as compared with Walter Scott's £31/17/0]; **12ft 5in Tunnel; 12ft 7in tunnel; 21ft 2½in Station Tunnel; 25** and various **shafts**.

Talbot

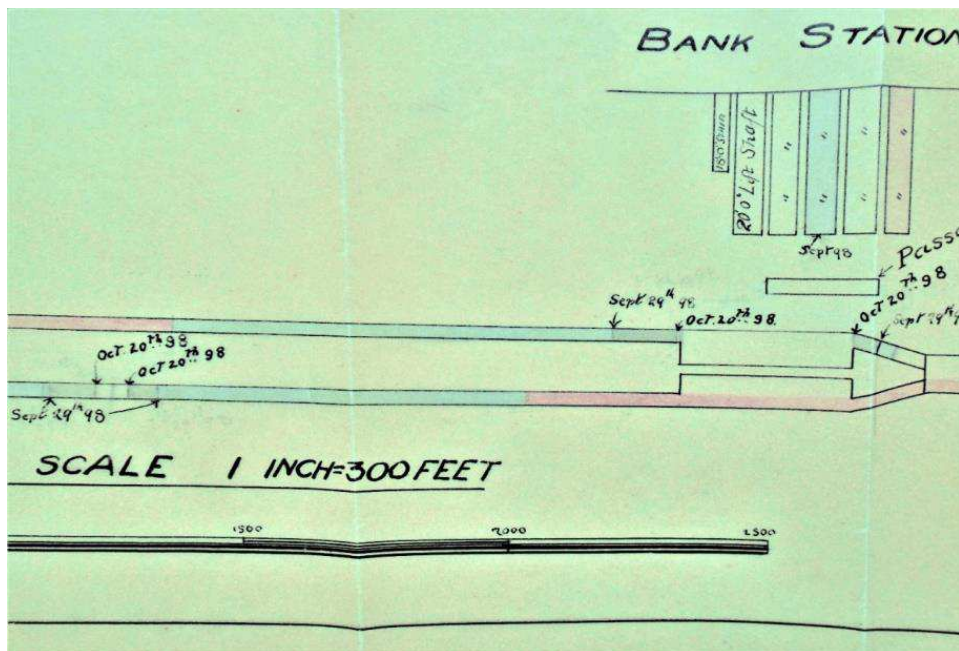
Contract 1. per yard Lineal

Tender from
11th 8th Tunnel Excavations

	Quantities	Price
Cast Iron Segments	14.0 Cords	15/-
W.I. Bolts Nuts and Washers	2.17.0.2d	6/7/2.
Crowded Timber in Joints	1.3.2d	14/10/-
Less Lime Grouting and Pointing.	0.15.0.3d	12/-
Concrete in Lining Sides.	13.09.8.7d	1/4
Bearers and Drains	1.26.0.7d	1/7/6
Total price per Yd Lineal		

Including for excavation, cast iron segments, wrought iron bolts, nuts and washers. e.g. for a 23ft shaft £67.8.6d.

41. **Chancery Lane. Working expenses in Tunnel** January to March 1898. Totaling Materials to and from face £182/2/5d and Loco and rope Runner. £172/16/9d. Fo. 1p.
42. Duplicate of 41.
43. Ms. **Station Openings. Mr Talbot's contract** 29th Novr 1898. Fo. 1p. Details of amounts paid to Smith Patterson & Co; Newton Chambers & Co. regarding a set of special cast plates round an opening, 1 set of steel girders at the top and flat bar at the bottom of an opening, and carting and storing cast iron segments.
44. Duplicate of 43.
45. **Abstract of claims, paid to date and award.** 20/12/1898. E.T. Co. Fo. 1p. For clay fully removed,, excavation, 3 types brickwork and concrete in passages.
46. Cont. 27in x 10in tracing with Electric Traction Co. stamp [p.38]: Scale 1" to 300ft. **'Position of Work on Talbot's Section, June 1st 1898.'** About 1¼ miles to east of Bank. Work completed by 1st June is shown red; between June and Sept. 31st in blue; and the state of work when air pressure was started on October 17th 1898 is shown grey.]Railway shown from 3000ft west of Post Office Station to about 600ft east of Bank [see part image].



47. Pencil *aide-memoir* [in F.H.'s hand] dated 15/2/1900. 8vo. 1p. Difficult to read, but seems to relate to getting a price for claims for Queen's? Road Mansionside ... [&] Connaught Place. [other matters ... cost of passages]. On reverse – printed blank memo of 'The Atrizans', Labourers' and General Buildings Company, Limited.
48. Ms. **Bank Contract. A.** 12.12. 1900. Summary of claims [£2075] and allowances [£51,071]. Initialed F.H. Fo. 3pp. Claims mainly for property damage and the allowances, mainly for measured work.
49. Ms. **Bank Contract. B. Mr. Talbot's Remarks** [written by R. Spence] to Thomson 28th December 1900. Initialed F.H. Fo. 14pp. Including insertions with Hudleston corrections and a supplementary report by contractor Talbot/Spence on '**Repairs to Streets**'. In his remarks Talbot wrote: *'On commencing operations I found obstacles not contemplated in my estimate and not sufficiently clearly set forth in the specification to enable me to consider them thoroughly, presented themselves to an extent which made the carrying out of the work under the conditions set forth in the specification an almost impossible task. Pipes of all sizes, Water, Gas and Electric and rivers running throughout the area to be excavated in very large numbers and in every direction had to be carried, supported and maintained, in position and existing sewers kept open the closing of which in*

accordance with the meaning of the specification opening up from the surface and maintaining a temporary roadway or roof could not be accomplished except at a very great risk in every direction and at such a rate of progress as would delay work completion far beyond the requirements of the Act obtained for such. In face of such obstacles that the work could not be well carried out under the conditions specified and arranged to deviate therefrom by carrying the existing surface of the street on timber instead of opening from the top and excavating and building below. This could only be done at a considerably increased cost and when such was brought to the notice of The Electric Traction Coy. they agreed to meet me in the matter and after a time. costs were got out of work then done and submitted to them. They amended the schedule figures to an extent which it was hoped would meet the expenditure. As time went on I found that even the amended rates fell sort of covering the cost and pointed out to Sir Richard Farrant and Mr. Hudleston at different times, that I could not undertake to go on and finish the work at the amended figures ...'. [with]

50. **Talbot Contract - Bank Station. F. Hudleston's holograph notes dated 28/12/1890.** Fo. 1p. neatly holograph 'Talbot's Statement that we increased his prices after he had shown us his expenses is not correct. We raised his rate for excavation from 9/6d to 12/6d and made a further allowance of 7s/6d on the concrete excavated in September 1897. It was not until May 1898 that he submitted his figures from which it appeared that although he was slightly out of pocket on the Bank [Station] Contract, he was making a profit of about 16% on the Tunnel Contract. The figures being as follows as at April 30th 1898. Talbot's expenditure on the Bank Contract £23,760 and on the Tunnelling Contract £50,829. Total £74,690. Hudleston's certificates for the work done totaled £80,870.
51. Ms. **Mr. George Talbot Contracts. C. Sections 5 & 6.** 12.12. 1900. Fo, double-page. E.T. Co's counter claim for damage submitted to Sir Benjamin Baker 9th August. Details of claims and E. T. Co's allowances. Neatly annotated in red with the amount of Sir Benjamin Baker's Award, i.e. €166,334. [with]

52. Ms. E.T. Co's Counter claim for damages to property. Submitted to Sir B. B. 7th August 1901. Neat notes in red relating to damage to the Bank of England and Sir Richard Farrant and Christchurch Vicarage

7.7.
his copy

2, Queen Square Place,
Queen Anne's Mansions, Westminster, S.W.
8th. August 1901.

Central London Railway - Sections 5 & 6.
The Electric Traction Co. & Mr. George Talbot.

Dear Sirs,

I have examined the different Items of claims and counter-claims submitted by the parties at the Meetings on January 2nd. and on the 7th. inst. and am of opinion that as a matter of convenience the several cases of damage or alleged damage to property undertaken by the Traction Company and Mr. Talbot respectively should be completed by each of them at their own costs and charges, and on this basis I consider that the gross amount of the original Contract sum and of the additions and deductions may be taken at £166,334.

Yours faithfully,
(Signed) B. Baker.

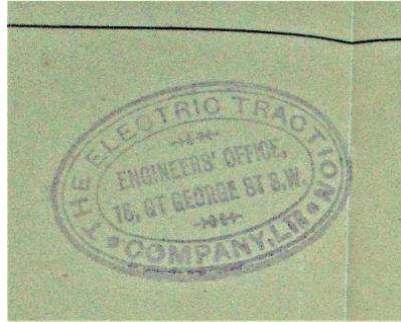
Messrs The Electric Traction Co., Ltd.

53. Ms. Typed copy of letter from Sir Benjamin Baker to the Electric Traction Co. Ltd regarding Sections 5 & 6 claims dated 8th August 1901. 4to. 1p. Initialed in red 'F.H. his copy'. 'I have examined the different items of claims and counter-claims submitted at the

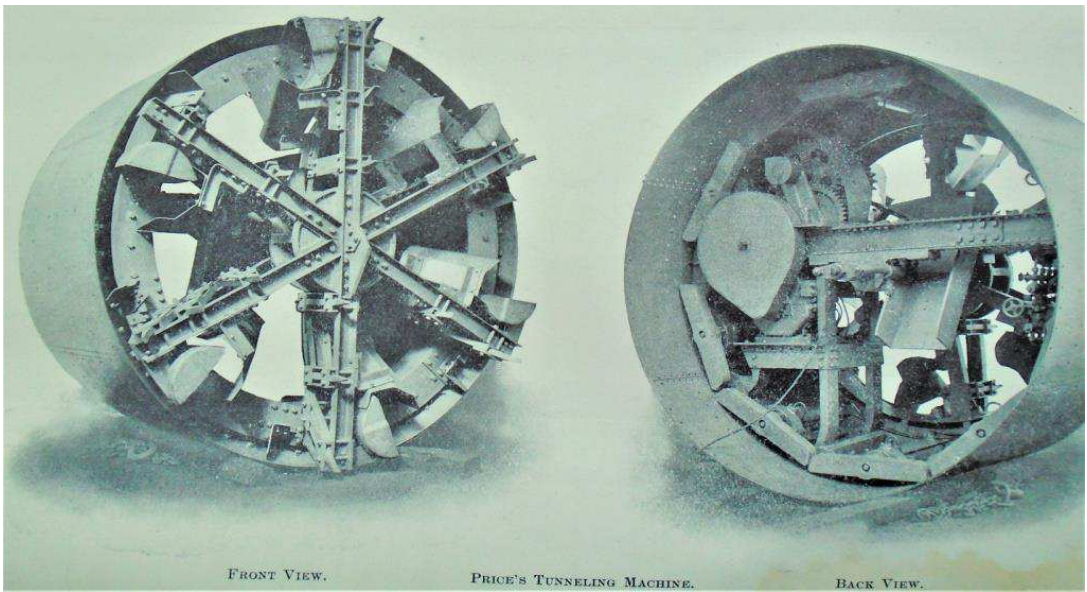
meetings on January 2nd and on the 7th inst., and am of opinion that as a matter of convenience the several cases of damage or alleged damage to property undertaken by the Traction Company and Mr. Talbot respectively should be completed by each of them at their own costs and charges, and on this basis I consider that the gross amount of the original contract sum and of the additions and deductions may be taken at €166,334. Note Hudleston's initials in red on the image.

54. Ms. **Talbot's Contracts. Sections 5 & 6. D. Disputed Items.** 28 December 1900. Fo. 19pp. hand stitched. Neatly presented on vellum. 'F.H's copy'. A detailed account of 9 items, with neat annotations in red. A key final document relating to items totaling €15,426. The claim for labour driving under compressed air was €14,899. €10,061 was allowed. Other disputed items were for shield driving, use of compressed air, concreting tunnel invert, damage to property, street repair &c. Details provided.
55. Ms. **List of extra works relating to Talbot contracts** 17/12/1900. Fo. 3pp – damage to property including reinstating roads and names of contractors and costs, tunneling, &c.
56. Ms. Completed Standard **final measurement** form. **Central London Railway. Electric Traction Company and Mr. George Talbot. Measurement from commencement to completion of Contract. 27th 12. 1900.** Fo. 4pp. Details of operations, quantities and costs totaling €10,083 [for Section 5] and €141,456 [for section 6]; total £151,539] [with, 2pp]
57. George Talbot. **Compressed air accounts final**, for 7th Nov 1899 and Jan 1900 amounting to €8,263. [with, 3pp]
58. Central London Railway. **Electric Traction Company and Mr. George Talbot. Measurement from Commencement to Completion of Contract for Central [Bank] Station - Subways & Approaches** €43,693. Fo. Pp2. Prntd doc. With quantities, rates and prices in a neat ms. hand.
59. Ms. **Tunnelling Contract 2.1.1901.** Pencil notes in Hudleston's hand re outstanding matters. 1p. Fo. [with]
60. Ms. Talbot's Tunneling Contracts with quantities and rates extended 19.1.1901. Fo. 2pp.

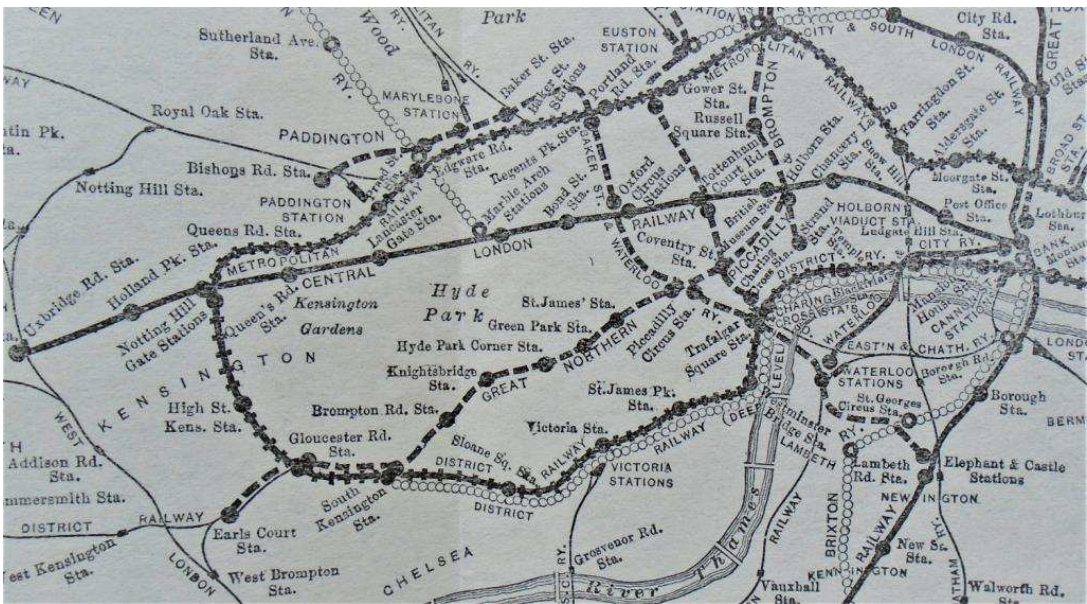
61. Ms. **C.L.R. Talbot Tunneling Projects**. Aug. 14th 1901. Fo. 1p.
Itemising a difference of €4677 between parties?



62. Mott, Basil & Hay, David. **'Underground Railways in Great Britain'**. Paper 89, Intl Engineering Congress, American Society of Civil Engineers. St. Louis. 1904. Original excerpt. pp. ii, 325-348, 10 text illu. & 4 fldg plts, inclg **'London Underground Railways'** map [see below] + photo: **'Price's Tunnelling Machine'** [See below [Price's priced contract for the Central London Railway on which his machine was developed forms Part 1 of this archive]. Original excerpt from *Trans. ASCE*. LIV. Pt. F. New York: 1905. 8vo. Cont marbled wrapper Mott took over from J.H. Greathead [d. 1896] as Engineer to the Central London Railway which he lists in this paper under 'Deep level tube railways' [See his copy letter item 17]. Mott was a leading authority on underground tunnelling. Greathead's mode of operation and illustration of a shield in use on this railway can be seen in:
63. Hall, *Cyril Conquests of Engineering*, Blackie & Son, Undated. Early 19th cent. See pp.161-182 -, 2 full-page illustrations. Orig.cloth.



Mott & Hay image: Tunneling Machine developed for use in clay by Price on this C.L.R. contract. Further developed and widely used later by Price and Reeves.



Mott & Hay Map. Central London tube line extends from Uxbridge Rd [l] - Bank [r]

Listed by Prof. R.A.Paxton, Institute for Infrastructure & Environment, Heriot-Watt University 9.6.2022

APPENDIX Biographical material on Ferdinand Hudleston 1857-1951

From: [mike chrimes](#)

Sent: Wednesday, May 11, 2022 11:33 AM

To: [Dr. Professor Roland A. Paxton](#)

Subject: Re: F. Hudleston: Engineer for constructing Central Underground Tube Railway 1896-1900

Hi Roland

This is Ferdinand Hudleston. I thought I wrote him up for the BDCE3 and am puzzled. I'm away to Berlin and not got time now but Carol should be able to find his membership docs. He transferred MInstCE 22 March 1898. He was consultant for the steelwork on the ICE building **and was a leading structural engineer in the early 20th century.**

He is in pike' engineering biographies c. 1908 etc.

Great to hear from you

Mike

LIVERPOOL ENGINEERING SOCIETY.—The first meeting of the seventeenth session of the above Society was held on Wednesday evening, the 29th October, at the Royal Institution, Colquitt-street. After the usual routine business, Mr. Henry H. West, M. Inst. C.E., the retiring President, introduced to the large assembly of members present Mr. Ferdinand Hudleston, Assoc. M. Inst. C.E., the new President, who in the course of his inaugural address congratulated them upon the flourishing condition of the Society. He then proceeded to describe in detail the general engineering features of the Mersey Dock Estate. Dealing first with the old dock, for which the Act was obtained in 1709, and which was opened in 1715, and touching on the fact that the datum of the Ordnance Survey of England was based upon the level of the old dock sill, he followed out the various additions to the Dock Estate during the last century in the shape of the Salthouse, George's, King's, and Queen's Docks. He next dealt with the period when Mr. Jesse Hartley was engineer to the Dock Board, during which all the great extensions of the Dock Estate were made, and then to the period when Mr. G. F. Lyster became engineer. He then described the various kinds of masonry and mortar which had been employed in the construction of the earlier docks, which were built solely of this material. Masonry, however, had gradually given way to Portland cement concrete. First the backing became concrete, and ultimately in the latest North Dock—the Hornby—the whole wall was concrete, with granite coping and granite face at the angles, and projecting corners. Hydraulic lime from Halkyn Mountain is still used for the setting of all true masonry, but the backing is Portland cement concrete. The shape of the newer docks then received his attention, and their advantages were discussed. The various depths of the dock sills, and the improvements which have been effected in order to deepen them were then considered in detail. The various pumping stations were described, attention being drawn to the Coburg pumps, consisting of three independent centrifugal pumps with 54in. diameter suction and delivery pipes, each pump driven by a compound condensing engine, and the three sets together delivering about 1200 tons of water per minute and indicating about 2000-horse power when pumping with their full lift. Their work is to keep eighty acres of old docks at a high spring tide level. This system of pumping was first adopted by Mr. Lyster at the Sandon Dock. A description of the sluices of the various docks followed. Mr. Hudleston described all the dock gates in Liverpool as being made of wood, the earlier gates being of oak, many of which are still in use, but the later ones being of green heart. Iron gates are cheaper and lighter on their roller paths if worked as lock gates on a low tide, but greenheart stands an amount of knocking about which would spoil an iron gate. Greenheart, too, is practically everlasting in the waters of the Mersey. An arrangement of the heel posts of the gates peculiar to Liverpool was then described in detail. Mr. Hudleston then passed on to a description of the graving docks, dock quays, and dock warehouses, including the large grain storage warehouses at the Waterloo dock and at Bootle, which together are capable, he said, of holding about 90,000 tons of grain, and he also dealt with the various kinds of machinery used in the warehouses, and with the special arrangements made for dealing with the foreign meat trade, coal trade, and the petroleum carrying trade. He concluded his paper by describing the two lighthouses at the mouth of the river, and referring to the attempts made to abate the nuisance caused by the two bugbears of the Mersey, viz., the Pluckington Bank and the Bar. A vote of thanks to the President for his paper terminated the proceedings.

Comment [r1]:

HUDLESTON, FERDINAND.

DISCUSSIONS :

- Waterloo and City Railway.* cxxxix.—Tunnelling on the Central London Railway, 127.—Carriages and motors, 127.
- Moving Loads on Underbridges and the Floor System of Girder Bridges.* cxli.—Possibility of increasing the weight of locomotives, 67.
- Nilgiri Mountain Railway.* cxlv.—Resistance of pushed vehicles, 36.
- Electrical Traction.* cxlix.—Efficiency of the Central London Railway, 156.
- Tonnage-Laws and Assessment of Harbour-Dues.* clvii.—Relation of the cost of dock-entrances to their depth and breadth, 23.
- Alfreton and Moncreiffe Tunnels.* cxli.—Instances of the deterioration of iron in lime mortar at Liverpool, 153, 156.
- Simplon Tunnel.* clxviii.—Steam-haulage and ventilation in tunnels under construction, 89.—Method of ventilation adopted on the Central London Railway to free the tunnel from fumes due to steam-haulage during construction, 90.—High velocity of air through single headings in the Simplon tunnel, 91.—Work under compressed-air, 91.—Quantity of air supplied in the Simplon, 91.—High temperatures in the tunnel, 91.
- Construction of Overhead Electric Transmission-Lines.* clxix.—Wind-pressure on wires, 232.

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tion and water-spraying, etc.

Mr. F. HUDLESTON had been unable to make out from the Paper Mr. Hudleston. whether the haulage had been done by steam-locomotives or not, and if the Author could tell him that it might affect the remarks he wished to make on the subject of the ventilation of the tunnel during construction.

The AUTHOR replied that the haulage had been done by steam- The Author. locomotives which fired up outside the tunnel; they travelled up to within 2 kilometres of the working-face with their fires damped. From this point the traffic was worked by compressed-air locomotives.

Mr. HUDLESTON remarked that 210,000 cubic feet of air per minute Mr. Hudleston. was a very large quantity. With steam-locomotives, even when the fires were damped, there was generally a good deal of steam, and much trouble was caused in a long tunnel. The tunnels with which he had been connected were chiefly "tubes," which, he was sorry to

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Hudleston. see, the Author said were during construction the worst ventilated of all tunnels. A tube was not an easy thing to ventilate while it was under construction, for there was not much room in it. But there were not more than about a dozen men at the face of a tube, and as a rule in London there was no contamination of the air of the tube with the steam from the haulage-engine. Practically what had to be dealt with was the foulness due to the men themselves. No doubt it was better for the men to have fresh air, but the ordinary navy did not care much about it, and on the few occasions when ventilation to some extent had been tried, the men had generally objected to the draught. As a rule, the ventilation effected by the amount of air given off by the air-driven pumps at the face—pumps which were now almost universally used—was sufficient to cool the face. He admitted that a person who was not used to such conditions generally felt the effect of the bad air, but when a navy had got used to it he did not mind it much. If a steam-locomotive were put into a tube it was necessary to be very careful, and it might be interesting to mention an occurrence during the construction of the Central London Railway, when for a time steam-locomotives were in use. The tunnel had been driven, the railway was practically completed from end to end as far as the lining went, and it became necessary to lay the permanent way and finish the stations. The tube was constructed under high pressure; he believed no other tube railway of that magnitude had been completed in less time. When the permanent way had been partly laid, it became necessary to use light engines for the haulage of the material, and soon the workmen in the tunnel were affected by the foulness due to both the gases from the coal and the steam. A good deal of trouble was caused, and a method of ventilation was then adopted such as was generally carried out in colliery practice. At every other station a 5-foot Blackman fan was put up, and in one case, where there was an awkward arrangement of intakes, a 6-foot fan. All the passages were blocked at the uptake shafts, except where the fan ran, and doors were made through these bulkheads. The intermediate station-shafts were downcasts, and the fans sucked up all they could. By these means the tunnel had been kept practically free from fumes and steam in spite of the engines running. Trouble had occurred occasionally with the heavier engines afterwards, but still, things had gone on fairly well under steam. He had found that the quantity of air pumped out of the tunnel was about the same as the Author said was pumped out of the Simplon tunnel. The fans were driven by electric motors of about 10 HP., though as a matter of delivery

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of all six fans was about 285,000 cubic feet per minute. He did not suppose that delivery had been obtained, because the passages were constricted; but it was a very large amount, and the tunnel was ventilated fairly well. The draught was not appreciable because there were in reality six separate installations. One thing about the Simplon tunnel that struck him was that an enormous amount of air had to be taken through a single heading, which, according to one of the illustrations of the Paper, was about 70 square feet, though he thought the Author had said it was about 60 feet. If it were 60 square feet the velocity of the air would be about 60 feet per second through that small heading, and if it was the larger size, $7\frac{1}{2}$ feet by 11 feet, which one of the illustrations of the Paper scaled, the velocity of the air would be 40 feet per second. No man could work in that hurricane with comfort. Although most of the work would be done in the break-ups, where the area was much larger and the velocity less, still it did seem a very large amount of air to pass through. Of course, if the 210,000 cubic feet was the total supply to both ends of the tunnel, these velocities would be approximately halved, but even then were extremely high. At the face they did not get the full quantity. The very ingenious arrangement whereby a current was induced up to the face gave a good deal of air, but how much he did not know: he supposed it could easily have been measured, but it could have been nothing like 210,000 cubic feet per minute, for no man working hard and perspiring freely could stand a gale of that sort; he would quickly be in the doctor's hands. The changing of clothing, etc., on the part of the men was of course practically a necessity in a long tunnel. The same precautions were taken in England in all compressed-air tunnels, where they were more necessary than in a free-air tunnel like the Simplon. In compressed air men perspired much more profusely than in the open air, and became practically drenched, and in the Simplon and other Alpine tunnels he supposed the men working at the face were in much the same condition; but the worker in compressed air had to face the chilling effect of the air-lock when leaving his work. Some attention was paid to those matters in England, but it was not possible to treat the men in the same fatherly way they were treated in Italy and elsewhere, for the ordinary English navy did not care to be nursed. The Paper stated that for every foot of air blown into the St. Gothard tunnel, 25 feet were supplied to the workmen in the Simplon. In the Arlberg tunnel the supply was said to have been about 8,000 feet per minute, but he did not think any very special ventilating-arrangements were provided there. The temperatures mentioned in the Paper were

Hudleston. extraordinary, and were never met with in ordinary tunnelling. In tube work the temperature seldom rose much above 75° F.: in compressed air it might reach 80°, but hardly beyond that. It was only in compressed air that the higher temperature was reached, generally at the top of the working-face, where, owing to the extraordinary quantity of heat given out by the grouting lime put in at the back of the iron lining, the iron was often too hot to put the hand upon. In the lower parts of the tunnel that temperature was seldom reached; even 80° was quite high enough, and necessitated special precautions in cooling down. It would be interesting to know how long the men had worked in such temperatures as 129° to 134° F., and whether they had found it very trying; also approximately how much air per man had reached the face. He would be glad if the Author could state also the total number of men working in the tunnel, because that would give an idea of what air-supply the 210,000 cubic feet represented.

Hudson Mr. C. W. F.

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of the larger central span with only two river piers would have proved more economical than the three piers with the smaller spans which had been adopted.

Mr. F. HUDLESTON, who had advised Messrs. Price and Reeves in the matter of their contract for the construction of the Rotherhithe tunnel, observed that the capacity of the installation of air-compressing plant in subaqueous tunnelling was a very different matter to that needed in shaft sinking. In the case of the Rotherhithe tunnel the capacity was determined from consideration of what would be needed in the event of a "blow" at the tunnel face of the river section, where the cover was only 8 feet, and during the construction of this section little more than one-third of the plant sufficed to give a supply of 5,000 cubic feet to 6,000 cubic feet of free air per man per hour, and keep the proportion of CO₂ in the workings under the percentage of 0·1 (at atmospheric pressure) which was in practice the limit allowed by the engineers of the London County Council with a pressure of 20 lbs. per square inch, above the atmosphere. A "blow" in a caisson or shaft-sinking chamber was a trifling matter compared with a blow in a tunnel face under a river bottom, and the former class of work did not require any great reserve of capacity beyond the simple precaution of not relying upon a single unit in the plant. He could not comprehend why air compressors of about 4,000 cubic feet of free air capacity should have been supplied at Newcastle for a shaft-sinking job when only one-third of that quantity was considered enough for the men. With regard to the quantity of air per man in compressed-air work, it would appear from recent statements¹ that medical men considered the standards of purity set up by engineers in the last 10 years were excessive; but, in Mr. Hudleston's opinion, there was no question that in compressed-air tunnelling much more work could be performed by men, and cases of "bends" were much less frequent, when the air was kept reasonably pure as was done in the Rotherhithe tunnel, than when the percentage of CO₂ was habitually kept two or three times higher than that, as appeared to have been the case in the work described in the Paper. The physical

¹ Admiralty Report on Deep-Sea Diving, 190.

Hudleston. exertions of men at work in a tunnel face or shaft bottom were generally a very different thing from those of a diver in diving dress or from what took place in an experimental chamber. The length of the shifts under air at Newcastle seemed unduly great—12 hours, even with two breaks, was far too long a span under a pressure of 25 lbs. per square inch above the atmosphere. With regard to details, Mr. Hudleston considered the working-chamber adopted at the bridge was a decided improvement on that originally proposed. A flat roof only 7 feet above the cutting-edge of a caisson was an extremely disagreeable thing to work under, and the saving of a few cubic yards of somewhat expensive concrete was not worth the extra risk to the sinking gang. The men's air-locks, on the other hand, appeared to be absurdly small for a gang of thirty men; and if five men came out together in one lock, the air must have become very foul. To go out through an air-lock was a disagreeable undertaking at the best, very much worse than coming up in diving-dress, and there was no reason to make it unnecessarily trying since the air lost in the operation was generally a negligible quantity when compared with the actual necessary exhaust of foul air, especially with the cubic contents of the working-chamber.

Mr. Moir. Mr. E. W. MOIR observed that the air-locks possessed more than one lock were said

the traps were designed by the contractors.

Mr. F. HUDLESTON thought there were one or two things in connection with the plant which he might explain a little more fully than the Author had done in the Paper. The first and most important was the capacity of the machinery for obtaining the air-pressure. That had been criticized a good deal at various times. In a subaqueous tunnel, as had been said by Mr. Brown and others, the air-capacity required was governed by what would be necessary if a blow occurred at the face. The amount given to the men was not exactly a secondary point, but it was not the first thing to be considered in determining the capacity of the plant. In the case under consideration, the London County Council's requirement of 8,000 feet per man per hour—afterwards reduced—had to be met. It was found that if that figure was multiplied by the number of men in and about the shield, a quantity was obtained which was thought to be a fair amount to have actually supplied in case of any trouble at the face. By the contract, also, the contractors had to supply double the quantity with which they intended to work, and that rather rough and ready method had to some extent settled the amount of plant laid down. The contractors were convinced that, with a plant for about 1 million cubic feet of free air per hour, they would be able to take charge of any reasonable blow in the face. A big sudden blow, of course, no amount of plant would stop; it was

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Q 2

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quantity for getting most work out of men under moderate pressures up to, say, 20 lbs. per square inch. In very high pressures it was another thing, and he had not had much experience beyond 20 lbs. In other large tunnels, especially the New York tunnels, he thought they gave a very much larger amount of air to each man than the scientist nowadays would consider sufficient. The next feature of the plant was the arrangements for bringing the air to the face. There the contractors followed one principle all through; they duplicated everything, and took every possible precaution to prevent themselves from being "caught out" by an accident. The duplicated air-mains were rather larger than some people would think necessary, but the size was purposely chosen to get a very small drop. There were two large trunk mains at the top of the engine-house, and every engine could deliver into either of them. They generally ran three engines as a rule—two into one trunk and one into the other. Each trunk supplied an independent main right up the face, so that, in case of accident, there would be one to go on with until the other was got into working order. There were the ordinary non-return valves, and so forth. The method of driving the rams in the main shield required some consideration. In many places they had been content to pump the water at the surface up to the full pressure, but that was not done at Rotherhithe. Hydraulic pumping-plant was put at the surface to work hoists and shields, pumping up to about 1,100 lbs., and that was intensified at the face by means of air-driven pumps such as had been introduced on the Central London Railway. There were two sets of pumps with cylinders of about the same size but different-sized plungers, and one of them could pump straight up to the full pressure, 3 tons per square inch, with 60 lbs. pressure of air. The other could pump half that. It was found that they could be worked perfectly well on the exhaust, and they were generally worked in series when on the exhaust. Afterwards still larger pumps were used on the second shield, and the whole of the pumping was done on the exhaust air. A great deal was gained by that way of obtaining pressure, because a long range of mains with anything like 3 tons pressure was a very awkward thing to keep right, whereas 1,100 lbs was child's play. That low pressure could be easily carried right up to the face through the bulkheads, and there was so much less to worry the men in the office. The bulkhead was very simple and did its work thoroughly well. The leading idea was due to Mr. John Price. When he first designed a bulkhead of that kind for Mr. Price the beams went straight across from one side of the tunnel to the other. Mr. Price, being a man of much experience, said: "If

Mr. Hudleston, you prop those things in the middle, you will do much better with half the trouble." That was done, and a very simple bulkhead was obtained, extremely flexible, and giving thoroughly to all deformation. As with all bulkheads, there was a little leakage at first, but a squirt of lime from a grouting-pan put that right. With regard to the shield, some people criticized large trapped shields and said they were useless when in gravel. They would, of course, not help much when completely in gravel, for in a face of gravel the shield had to be forced through as at Blackwall. No one had yet arranged differential pressure in a shield. How could a pressure-difference of nearly 3 lbs. per square inch be maintained in gravel between the bays of any large shield? In a face of wet gravel the only plan was to force the shield forward and scratch out the material in the best way possible. All the shield really required in such a case was a sufficient number of platforms and compartments to work in. But a whole face of gravel was not met with at once; generally the work ran into gravel at the top. The danger arose when the gravel first appeared at the roof. It would be noticed that the top compartment of the shield was 7 feet or 8 feet deep, and it was seldom that the work ran into 8 feet of gravel suddenly. If such a shield had been used in the blow at Blackwall only the first compartment would have been immediately affected, and it would have checked the effect of the blow. Nothing would keep all the air in so large a shield if there was once an opening into the river, but a trap would stop the muck from running into the shield and give time to raise the pressure again and blanket the floor of the river. It was impossible to get through gravel with a big shield unless the floor of the river was blanketed. With a small shield it was another thing, for with a single trap it was possible to get through by means of a good many dodges, especially the one alluded to by Mr. Hay of putting clay round the edge; but that could not be done in a shield of many compartments.

Mr. Tripp. Mr. W. B. Tripp, referring to the blow at Blackwall, said that Mr. Francis Fox

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Roland Paxton

June 2023