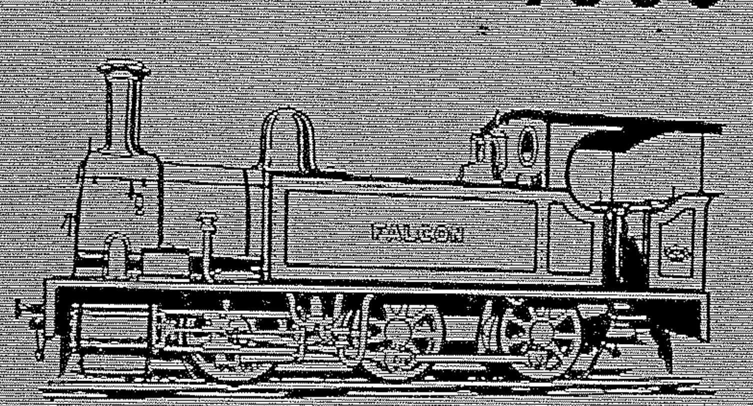
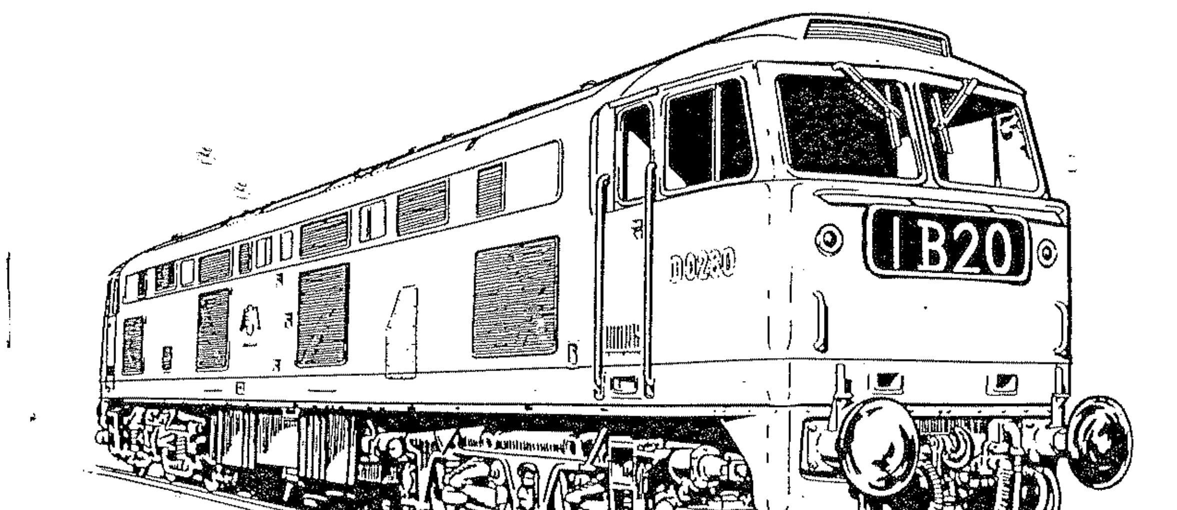
BRUSH TRACTION

1865





1965

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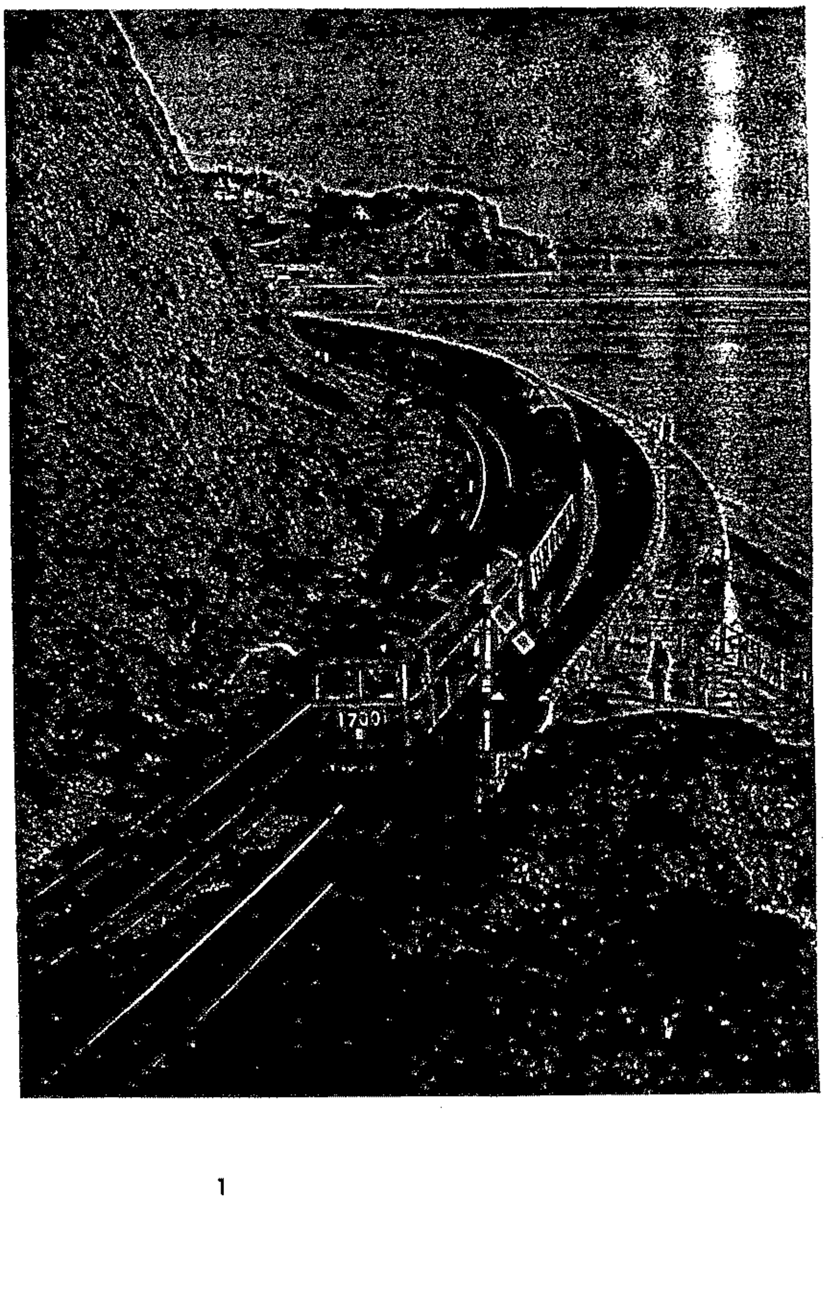


FALCON 2800 horsepower diesel-electric locomotive near Teignmouth in 1963 while undergoing trials on the Western Region of British Railways. This locomotive, capable of 100 miles per hour, had two high speed generators and engines each developing 1400 horsepower.

INTRODUCTION

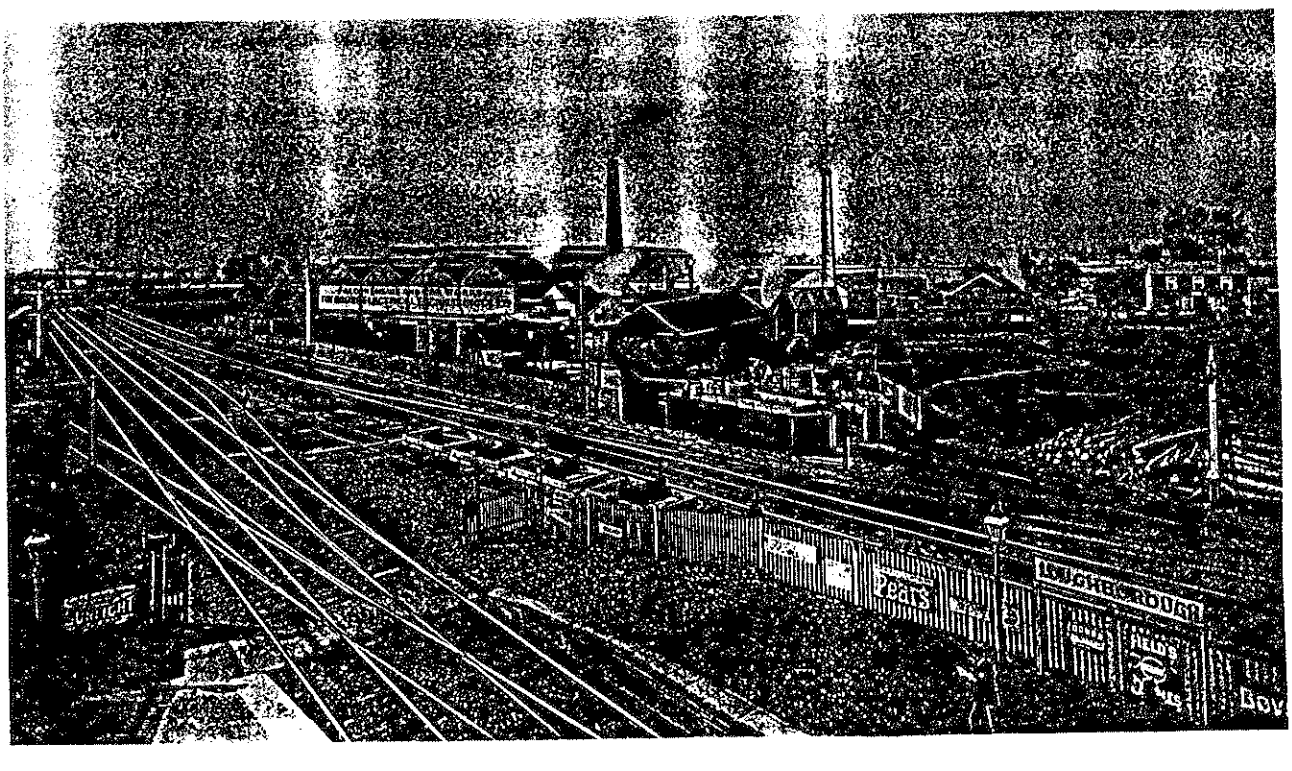
The material amenities of our modern civilisation have expanded with astonishing rapidity in recent times and in no field is this more apparent than in the growth of transport. This growth has affected not only the means of communication and the movements of people and goods, it has changed our entire pattern of living in less than two or three generations.

In this account of the foundation, rise and development of one branch of the activities of a famous industrial organisation will be found a part of the story of our national development and social advancement.

It is a record in the fields of traction and industrial enterprise of technical innovation, commercial and financial acumen, managerial resourcefulness and courage, hard labour and pride of work, adaptability to changing environment, of challenge and response that make a fragment of the wider scene of British history.

The end results of former pioneering work are now known. They are disclosed in the pattern of events that form the Brush Company's history. These ultimate results were not apparent to those who were involved in the problems of their times and who brought qualities of foresight, judgement, skill and knowledge in varying degrees to the challenges of changing circumstances. The way these problems were met will be evident in the following pages, and they may convey useful information to those who have to deal with the increasingly complex questions presented by current economic, social and technological changes.

Falcon Works in 1890. The house on the right was occupied by the manager and stands on the site of the present general offices. In the foreground is Loughborough Midland Railway Station.

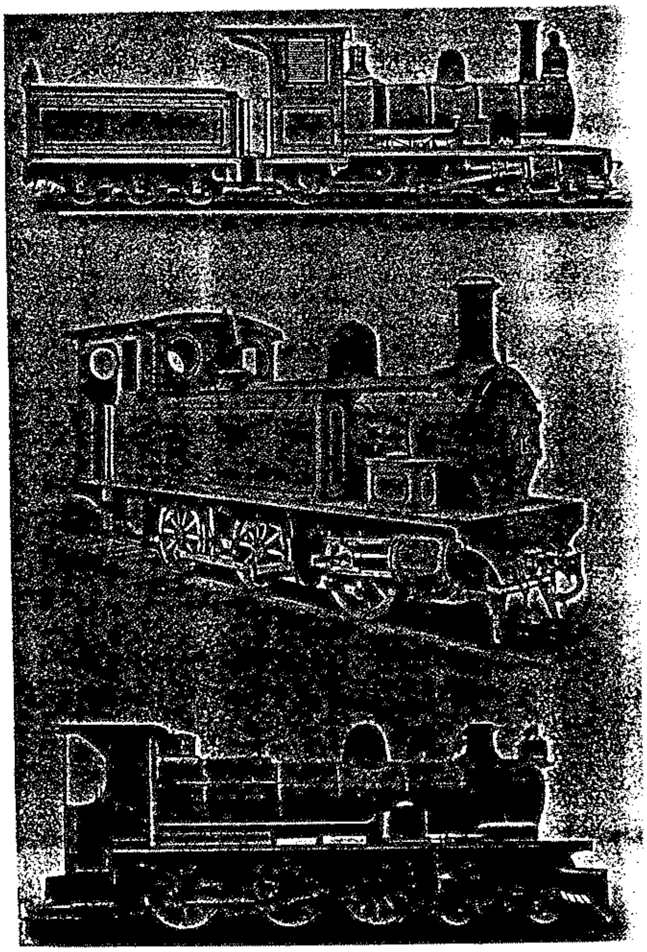


1. EARLY DAYS

The connection of the Brush Electrical Engineering Company with transport began in 1889 when the Anglo-American Brush Electric Light Corporation acquired the assets of the Falcon Engine and Car Works at Loughborough and a new company was formed with the present title to merge the activities of the two firms. This connection has been maintained to the present time. Persisting through many changes of products, and sometimes occupying a major part of the Company's business, the design and manufacture of transport vehicles has continuously been a significant feature of the Company's progress.

It was in 1865 that Henry Hughes, an engineer and timber merchant of Derby Road, Loughborough, founded the Falcon Works. He bought about seven acres of land adjacent to the Midland Railway station and the main road between Loughborough and Nottingham. After the erection of suitable buildings, manufacture commenced of rail coaches, wagons and horse-drawn tramcars. Their mainly wooden construction was a natural extension of Hughes' interests as a timber merchant. He and a partner Huram Coltman, lived in houses built on the site now occupied by the general offices. Walter W. Coltman born there in 1869, established a boiler-making business in the town and became Mayor of Loughborough seven times.

The vehicles produced at Falcon Works by Henry Hughes and Company found ready acceptance and within a few years about 200 people were employed.



Examples of steam locomotives designed and manufactured by the Company.

STEAM LOCOMOTIVES

Looking for means of expansion Hughes' attention turned to the development of steam locomotives. The Tramways Act of 1870 gave powers to local authorities to construct street tramways for mechanically propelled vehicles, and this was followed by a wave of installations in large towns and cities. The neighbouring City of Leicester opened its first section of tramways in 1874 and it was there on 6th March 1876 that the first Hughes Steam Locomotive was tried coupled to a trailing tramcar. Hughes' 'Patent Tramway Engine' weighed some four tons and contained a novel device for consuming its own smoke and condensing the steam. The price was reported to be £600. After a few months service the locomotive lost popularity at Leicester and was transferred to Govan near Glasgow where it worked in regular service until 1881.

Another steam locomotive named 'The Pioneer' was delivered in 1877 to the Swansea and Mumbles Railway Company for hauling carriages seating 80 passengers at 8 miles an hour.

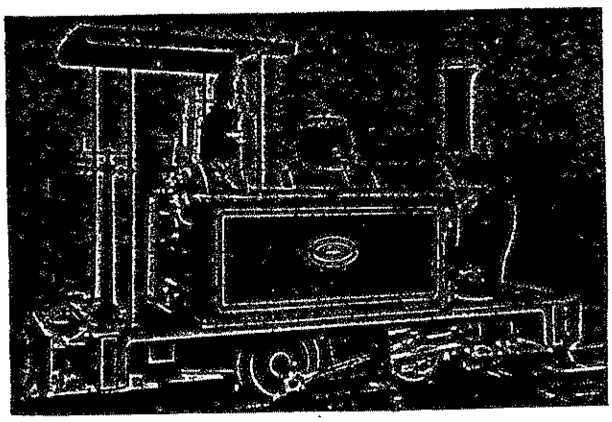
Trade recession in the late seventies and early eighties brought financial difficulties and the firm was reconstructed in 1883 as the "FALCON ENGINEERING AND CAR WORKS".

Control was taken over by Norman Scott Russell. Henry Hughes left the Company; it is said he emigrated to New Zealand and died there in 1896. As trade improved the Falcon Works flourished and the factory became fully engaged on the manufacture of locomotives and rolling stock for deliveries at home and abroad.

Russell developed an air condensing tramway locomotive which had, as another feature, a speed regulating governor driven by a fifth wheel running on the rails and kept in position by a spring. The air condenser consisted of 250 thin copper tubes arched traversely across the roof of the cab and communicating with each other through a box chamber running along each side. It was a forerunner of the modern car radiator.

About 42 Hughes Locomotives and 61 Russell Locomotives were built between 1874 and 1888 and the Brush organisation continued to make steam locomotives until 1914 supplying them to railway companies throughout the world. The last big contract was received in 1910 from the Siamese State Railways.

Reports continue to reach the Company of locomotives still working fifty years or more after their first installation. The Brush 'Broadside' No. 160 for May 1959 illustrates one example of a locomotive operating in Spain which is identified from the nameplate as being built in 1889, some seventy years earlier.



Built in 1889 this locomotive was in operation seventy years later.

Several causes contributed to the demise of the product at Loughborough. The growth of strong foreign competition particularly from Germany reduced profits, also the outbreak of war in Europe in 1914 restricted export business. Probably the most cogent reason was that productive facilities could be more profitably used for expanding the manufacture of steam turbines.

OMNIBUSES

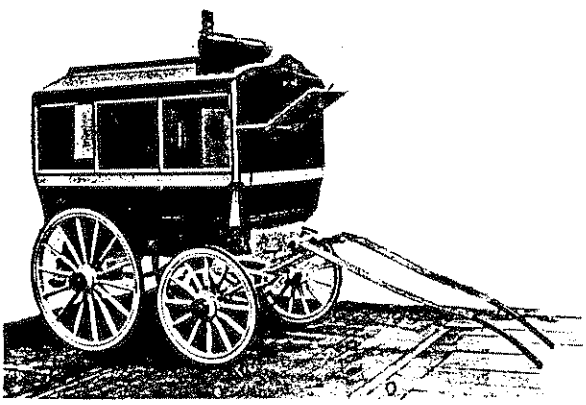
Horse-drawn omnibuses were first produced in 1885 and in spite of many disadvantages they had a vogue lasting thirty years. They appealed to small operators because of low first cost, though the operating expenses were higher than steam propelled tramcars. A bus hauled by four horses could maintain an average speed of only six miles per hour and even less in hilly districts. The necessarily light construction and limited size restricted the number of passengers, so that receipts were low, in some cases not more than a halfpenny per passenger for two miles. Also the heavy work was destructive to horses particularly when frequent stopping and starting were necessary. The pull required to start was four to five times that needed to maintain motion, and horses could be worked only a few hours a day. They were changed every four years on average.

Large numbers of buses were built at Falcon Works and when motor vehicles superseded the former types, early in the 20th century, the Brush organisation was placed by long experience in a good position to take advantage of the new trends, and indeed to pioneer new designs of vehicles.

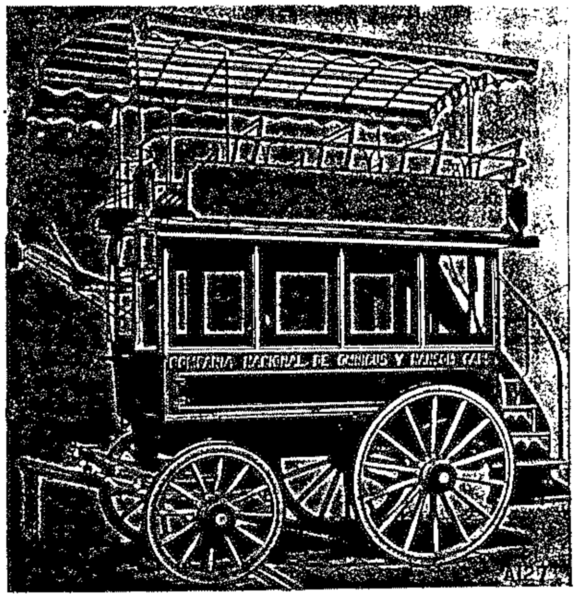
TRAMCARS

The introduction of steam traction from 1880 onward enabled larger and more comfortable vehicles to be used, with higher speeds and quicker acceleration. The economics of the new system quickly proved superior to animal traction, but in turn steam locomotion suffered the disadvantage of hauling considerable dead weight of the engine and accessories. The emission of smoke and dirt arising from coal fuel was also a drawback to extensive use in town streets.

Towards 1889 the era of electric tramcars began. Successful installations appeared in Germany in 1884 and in the United States in 1888. Faced with these trends the Loughborough management, hampered by little knowledge of electricity, sought ways of linking the business with electric traction. Currently, the young and fast developing Anglo-American Brush Electric Light Corporation manufacturing electrical machinery, stationary engines and ancillary equipment in London formed intentions of entering that field, and so resulted a merging of interests that had far-reaching consequences.

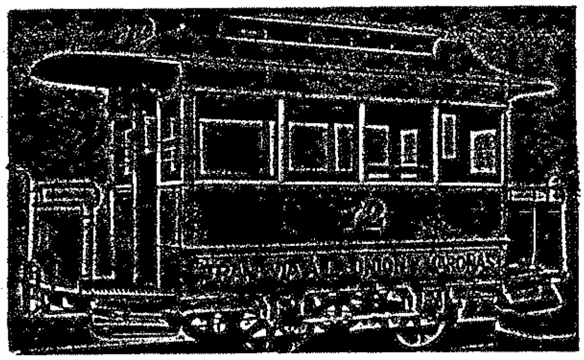


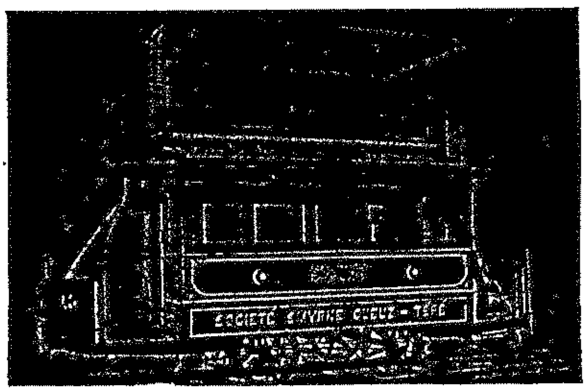
Horse drawn omnibus made in 1885.



One of the first double-deck vehicles, built in 1889. It was designed for four horses, and had a removable sun canopy. The brakes operated by friction blocks on the large rear wheels actuated from a foot pedal to the left of the drivers seat.

An early horse-drawn tramcar.





Double-deck horse tramcar manufactured in 1890. The spiral staircases were an improvement on earlier straight ladder types.

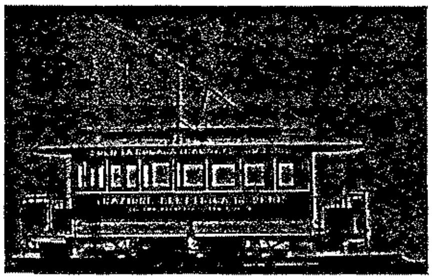
BRUSH ELECTRICAL ENGINEERING COMPANY

The history of the parent company began in London in 1879 when the Anglo-American Electric Light Company was formed to exploit inventions of the American physicist Charles Francis Brush (born 17th March 1849 in Cleveland, Ohio, and died 15th June 1929). He developed and patented in 1877 an improved form of arc lamp and dynamo, and sold the world rights outside North America to the London company. During the next decade an extensive business developed in the design, manufacture and installation of electric lighting systems and power supplies. The ever widening fields of power generation and utilisation brought new opportunities for expansion and the manufacturing capacity of the Company's works at Belvedere Road, Lambeth, became strained to an extent that it was imperative in 1889 to acquire larger productive facilities. These considerations coupled with a decision to extend activities into electric traction led to the acquisition of the Falcon Works, Loughborough and the Brush Electrical Engineering Company Limited came into being on 10th August 1889 to continue and develop the activities of the merged organisations.

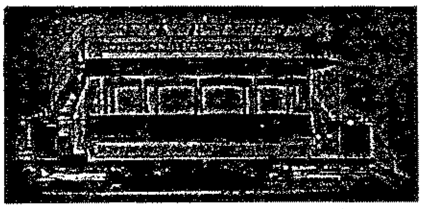
Charles Francis Brush
1849 – 1929

Three inventions of C.F. Brush of Cleveland, Ohio made an important contribution to the development of electric lighting and gave impetus to growth of the electrical industry. Described in British Patents 2003 of 1878, 947 and 3750 of 1879, they comprised a dynamo with new features for generating electricity suitable for carbon arc lamps, a simple method of regulating lamps as carbons burned down, and mechanism for prolonging the period of use of carbons between replacements.

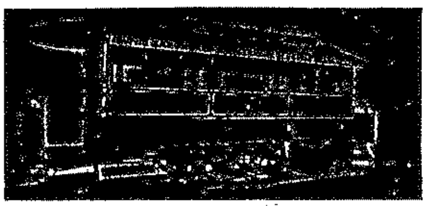
Operated on a constant current system with a number of lamps connected in series over long distances, the Brush method enabled lights to be used economically over large areas, and the system became widely adopted for street and factory lighting. Brush received many awards and honours for his scientific work, including degrees of Ph.D and LL.D from Western Reserve University in 1880 and 1900, Sc.D from the University of Michigan in 1912 and the Edison Medal of the American Institute of Electrical Engineers in 1913. In 1881 he was decorated by the government of France as a Chevalier of the Legion of Honour.



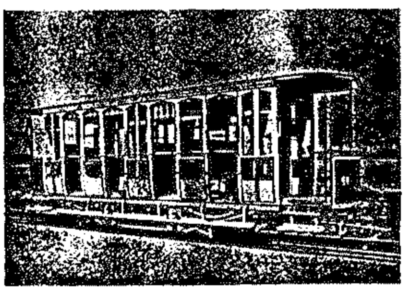
Electric car built in 1890. Long overhang of the body beyond the wheels required careful distribution of passenger weight.



Designed in 1898, many electric tramcars of this type were made. The life guard at each end complied with Board of Trade requirements.



Electric Car, with Accumulators, Built in 1890.



Convertible Car for Alexandria Tramways, seating when open 12 and when closed 16 of each class.

Mr. Edward Woods, C.E

Mr. Emile Garcke

Col. Fredk. G. Steuart.

Mr. Aymor H. Sanderson.

The Duke of Marlborough
(Chairman).

Mr. B. H. Van Tromp.

Mr. R. Percy Sellon
(Joint-Manager).

Mr. Joseph B. Braithwaite.

Mr. John S. Raworth
(Joint-Manager).

THE BRUSH ELECTRICAL ENGINEERING COMPANY, LIMITED. - PORTRAITS OF DIRECTORS AND MANAGERS
1892

2. THE EARLY MANAGEMENT

Among the important contracts for electric lighting installations successfully accomplished by Anglo-American Brush was one in 1888, to the order of His Grace George C. Spencer Churchill, Duke of Marlborough, for 1,000 lights with engines, generators and associated equipment at Blenheim Palace. Beside belonging to a family distinguished in British history, Marlborough was well known for his interest in scientific matters and particularly in the development of electricity. He joined the board of Brush in 1889 and succeeded Lord Thurlow F.R.S. as Chairman of the new Company in 1890.

EMILE GARCKE

The Manager and Secretary at this time was EMILE GARCKE destined to play a conspicuous part in the affairs of Brush over almost fifty years, and also in the development of Electric Tramways and Transport Undertakings in the United Kingdom.

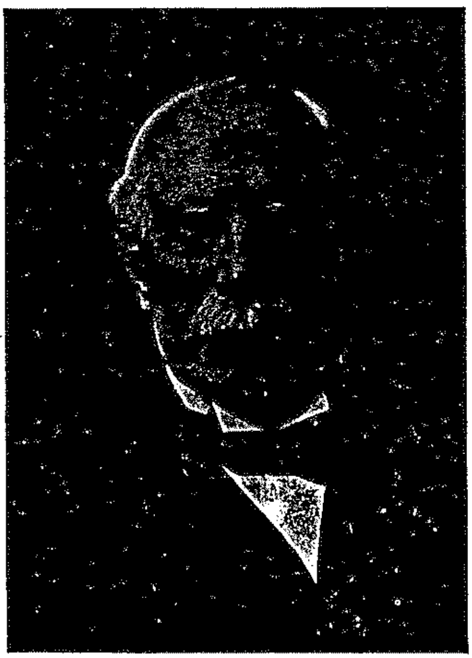
Born in 1856 he joined the Brush Company as Secretary in 1883, was appointed Manager in 1887, Managing Director in 1891, and Chairman in 1909, remaining Chairman until his death in 1930.

Garcke was an outstanding financier and administrator. He founded the British Electric Traction Company in 1895 as an organisation to promote Tramway Undertakers as public companies. This successful enterprise was responsible for the rapid growth of electric tramways as a means of public transport; more than eighty operating companies became affiliated, deriving financial and administrative guidance from the B.E.T. as it was called.

Through the Garcke links B.E.T. maintained a close association with Brush and became majority shareholder in 1901.

This connection provided a powerful stimulus to Brush in developing the design and manufacture of tramcars with their electrical equipment for undertakings within the Traction group, and a flourishing business resulted which grew to be the leading organisation of its kind in the world.

Another of Garcke's activities was the foundation in 1896 of "Garcke's Manual of Electrical Undertakings", a handbook and directory that provided a statistical record of the British Electricity and Allied Manufacturing Industries, and directory of executive personnel, directors and chief officers. Issued annually Garcke's Manual became a standard work of reference for more than sixty years when it ceased publication in 1960 consequent on the nationalisation of the electricity supply industry.



EMILE GARCKE
1856 - 1930

Among other directors at that time were MR. AYMOR H. SANDERSON, a former director of the Falcon Engine and Car Works and MR. EDWARD WOODS, an eminent civil engineer and past President of the Institution of Civil Engineers.

Senior members of the staff who were prominent in early technical progress were JOHN S. RAWORTH, the superintending engineer, W.M. MORDEY, chief electrician, and R. PERCY SELLON, assistant manager.

J.S. RAWORTH joined the Brush Company in 1886 from Siemens Brothers. He was responsible for technical design of the Company's products in the days when little experience existed and engineering methods were based on "cut and try" rather than precise calculation. Raworth's name was particularly associated with steam engines, which he developed as prime movers for electric generators. Steam engine generating units provided the main source of power for electrical installations at the end of the 19th century, and they had a vogue in the early part of the 20th century until they were superseded in the larger sizes by steam turbines and at the smaller end by diesel engines. Many hundreds of engines to Raworth's designs were made by Brush. He was appointed chief engineer in 1886 and elected to the Board in 1897 retiring in 1904. For many years he acted as Engineering Consultant to the Company.

W.M. MORDEY was appointed as "electrician" in 1881 from the Post Office Telegraph Service. He quickly made a mark as a successful designer of electrical machinery and achieved a high reputation along with Hopkinson, Kapp and a few others, making a notable contribution to progress in the art of dynamo design both practically and theoretically.

In those days it was the aim of most designers to evolve something different from other types, and to which they could connect their name. This led to many freakish designs appearing largely because of wrong ideas about magnetic circuits. By careful experimentation combined with accurate measurements and theoretical analysis, Mordey evolved designs which were entirely sound and practical and there followed the Mordey-Victoria dynamo, the Mordey-Victoria alternator and the Mordey transformer between 1885 and 1895, all of which became famous in their day, each embodying some significant invention. The term 'Victoria' arose from the name of the Brush Works at Belvedere Road, Lambeth.

Among other things Mordey was one of the first to prove the practicability of parallel operation of dynamos and alternators, and he also recognised at an early stage the losses caused by eddy currents in magnetic fields.

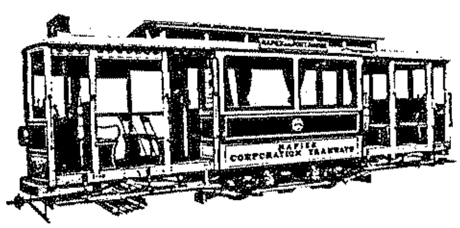
He left the Brush Company in 1895 to work as an independent consultant in which he had a distinguished career, becoming President of the Institution of Electrical Engineers in 1908. His death occurred 30 years later in 1938.

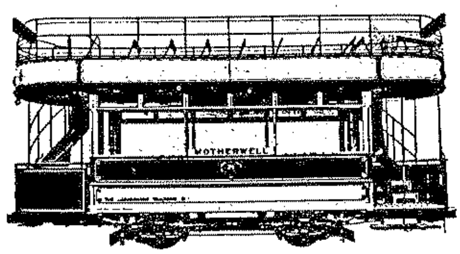
R.P. SELLON the assistant manager joined the technical staff of the Anglo-American Brush Company at the time of its formation in 1879 and was promoted to managerial duties in 1890. He later joined the Board and served as director until retirement in 1904. Sellon was responsible for manufacturing activities and took a prominent place in the establishment of productive equipment and methods for making the then novel items of electrical apparatus.

C.E. HODGKIN was superintendent, afterwards manager, of the Falcon Works at the time Brush acquired the business. From 1895 to 1900 he was responsible for the erection of new shops and building up the manufacturing capacity for complete tramcars including the main components, i.e. car bodies, trucks and underframes, as well as motors and controllers. The traction motor shop alone was capable of producing 1,000 motors a year. Several of these items, including the motors, had previously been exclusively of foreign manufacture and all-British built electric tramcars was a pioneering venture. Hodgkin was elected to the Board of Directors in 1901 and retired in 1904

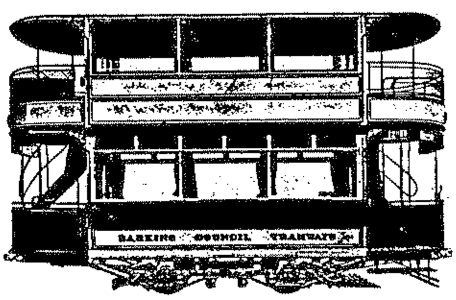
BEN BROADHURST was appointed Secretary in 1891 to succeed Emile Garcke on his appointment as Managing Director. He had been with the Company from about 1880 and developed an unrivalled knowledge of the commercial aspects of the electrical industry. Broadhurst carried responsibility for the detailed administration of the Company's affairs for some thirty years, becoming Joint General Manager in 1907 (with J.J. STEINETZ who dealt with engineering) and Managing Director in 1911. It was in that office he died in 1922. A loyal henchman of Garcke, he devoted himself untiringly to the development of Brush interests. Garcke and Broadhurst more than anyone else guided Brush from its beginning, steered it through a difficult infancy and brought the Company to full maturity as a leading industrial organisation.

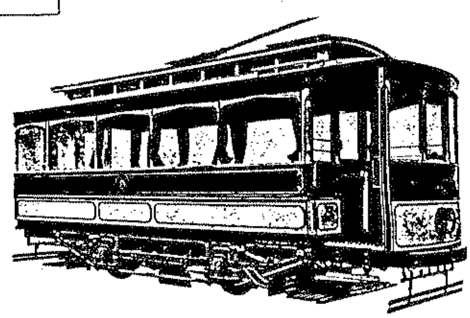
BEN BROADHURST.





TRAMCAR EXAMPLES
ILLUSTRATING RECENT CONTRACTS EXECUTED for NAPIER, BARKING, LANARKSHIRE, ABERDARE

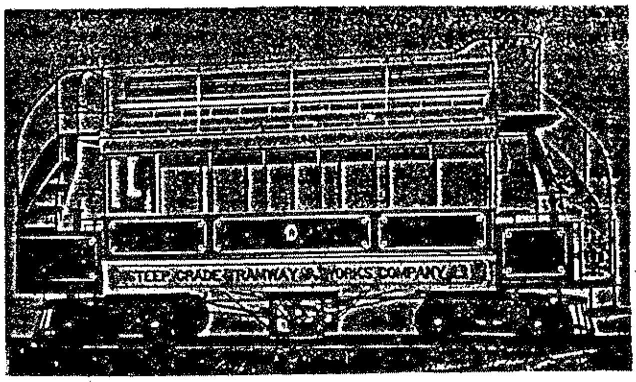




Completed in or before 1913.

EARLY TRAMCARS

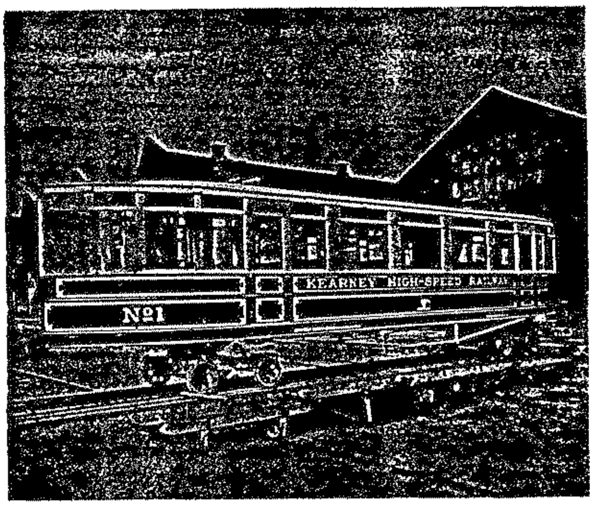
Some of the earliest electric cars used accumulators to supply power to the electric motors. These accumulator cars had a vogue in the 1890's before central generating stations and overhead street wires became accepted practice. Cars of this type were first tried in Birmingham in 1890 and other undertakings soon followed suit, but after several years of unsatisfactory working, they were abandoned in favour of systems using external power supplies. The storage batteries were costly to maintain and required charging at frequent intervals. With heavy loads the cells rapidly dropped in capacity. There was little reserve of power and the batteries added considerably to the dead weight of the cars. A car carrying 20 passengers weighed as much as 20 tons, the dead weight being one ton per passenger with a full load. The working costs exceeded those for horse traction and, although technically more advanced, the development failed to make headway for economic reasons. Public esteem for these electric cars was not increased by the spectacle of cars with discharged batteries being towed back to depots by horses.



The double bogie arrangement ensured good riding qualities for this open upper deck tramcar. Longitudinal seats were provided with access to the top deck by spiral staircases.

Other tramcars built in the same period used many parts imported from abroad including electrical equipment, trucks or bogies, largely because of the inexperience of British manufacturers. The trolley system with overhead wires supplying direct current at 650 volts came into favour and by 1899 Brush had constructed the first complete electric tramcar of this type made in England, the car, truck and electrical equipment were all made by the Company. It was supplied to the Liverpool Corporation Tramways.

About the same time Brush installed a complete tramway system, including a generating station with Brush engines, generators, tramcars, motors and controllers for the Kidderminster-Stourport tramway under the auspices of the British Electric Traction Company.



An unusual design of car intended for a mono-rail system, mounted on temporary trucks. Photograph taken at Falcon Works just prior to despatch.

1900 - 1940

By the year 1900 electric tramcars were being ordered in hundreds and the Company built large new shops to cope with the demand. A shop for making traction motors was erected with a capacity of 1,000 motors a year, while the car-building shop was enlarged to occupy 5 acres of floor space. Large buildings for the seasoning of timber and wood-working machinery were built, as well as a modern shop for the manufacture of trucks or bogies.

The electric tramcar era had fairly begun: it was to last for about forty years, enduring a lingering end in the closing years, but finally giving way to other forms of street transport, the trolley bus, the diesel bus, and the motor car.

In the decade 1918-28 a notable social trend was the flow of population from the centres of large towns to the outskirts. Huge housing estates were developed, some reaching the proportion of self-contained towns with shops, amusements and recreational facilities; residents had little occasion to visit the centre towns except for business purposes. Such communities posed considerable problems to transport undertakings because the load was concentrated into a few hours a day and it was unidirectional, inwards in the morning and outwards in the evening. Buses or cars would be practically empty on return journeys and idle for most of the day.

In Birmingham, 69% of the rolling stock stood unused between the hours of 9.30 a.m. and 4.30 p.m. and in London in 1930 nearly 50% of the tramway passengers were carried between the hours of 7 and 9 a.m. and 5 and 7 p.m.

The capital expenditure required to extend tramway tracks and wires to outlying districts combined with the short periods of effective use rendered such proposals eneconomic. Moreover, where motorbuses ran in competition with tramway services, the public showed marked preference for the buses, probably because of their superior speed and comfort.

So in many areas the popularity and remunerative operation of tramcars began to wane from about 1925 onwards, and the challenge of motorbuses with the advantages of flexibility, speed and comfort gathered momentum throughout the country, until by 1940 only a few tramcar services remained in operation.

3. ELECTRIC TRAMCARS

The first application of electricity to traction in the British Isles was made at Portrush in Northern Ireland in 1883 when a tramway six miles in length was opened to convey passengers to and from the Giants Causeway. This installation preceded by several years the construction of electric tramways or street railways in America.

It was in the United States that the most extensive early developments were made and where the formidable technical problems were solved largely by trial and error, and often by bitter experience.

For example, the motors were first attached rigidly to the car bodies with the result that mechanical shocks from the wheels were transmitted to the motors and breakdowns were frequent. It became apparent that some form of resilient mounting was necessary for the motors to protect them from road shocks. In due course trucks were evolved which carried the wheels, axles and motors supported by springs. The trucks also supported the main frame and bodywork by another set of springs. These trucks or bogies were the forerunners of subsequent standard practice. Detailed improvements steadily evolved over the next fifty years.

The early motors had primitive forms of insulation and the need for protection against dirt and moisture was not at first appreciated. Consequently some installations were almost unusable in wet weather because rain water containing various impurities splashed into the motors and caused insulation failures. The next step was to enclose completely the motor casings which of course interfered with ventilation of the motor windings. The result was burnt-out motors, and totally enclosed machines had to be made bigger and heavier to avoid overheating. The disadvantages of extra size and weight were accepted in the interests of reliability but over the years improvements in insulating materials and the techniques of their application led to the re-introduction of ventilated motors.

Endless difficulties were experienced with trolleys, gears, controllers and, in fact, every item had to be tested in actual operation to ascertain its suitability for tramway service.

After many false starts in several American cities the first really successful electric tramway was built in Richmond, Virginia, U.S.A. by Frank J. Sprague in 1887. The line had 13 miles of track and an equipment of forty cars. The broad principles used in this installation of overhead trolleys, 600 volt motors, the controllers and the various details of car construction set the standard for all future development.

An interesting side effect of the success of the Richmond installation was that the Sprague Electric Railway and Motor Company was absorbed by a combine of Edison Companies in 1889 and the Edison General Electric Company was formed. At the same time the Brush Electric Company was manufacturing arc lighting dynamos at Lynn, Massachusetts, where the Thomson-Houston Company founded in 1883 was also engaged in similar work. The Brush patents and manufacturing interests in electric lighting were taken over by the Thomson-Houston Company and in 1892 that company was merged with Edison General Electric to form the General Electric Company which has become one of the best known and largest electrical manufacturing organisations in the world.

In this way, the inventions and pioneering development work of Edison, Sprague, Brush, Thomson and Houston, were brought together in one great enterprise.

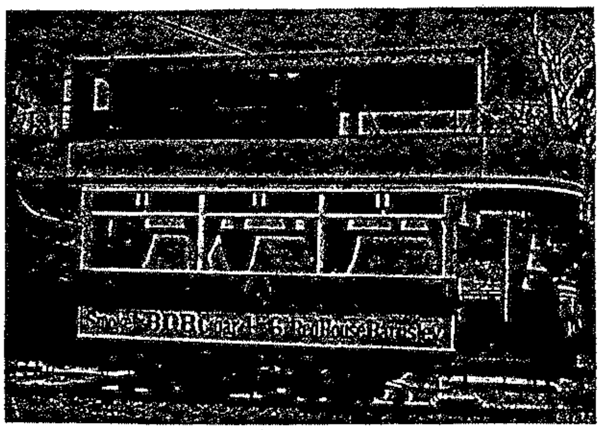
BRITISH DEVELOPMENTS

The Richmond tramways installation and others that followed attracted the attention of British engineers and tramway managements. In 1891 Mr. W.M. Mordey visited U.S.A. on behalf of the Brush Company (England) and made a thorough study of the state of electric traction in that country. As a result of this report and his recommendations the Brush directors resolved to commence the manufacture of electric tramcars and the associated electrical equipment. Progress at first was slow, largely because of the inhibiting influence of the Tramways Act of 1870. This legislation was made long before electric tramways were thought of and pertained mainly to horse tramways. The Act provided among other things for compulsory purchase by Local Authorities of tramway undertakings within their areas after a period of 21 years tenure by the operating companies. Since the undertakings could be acquired at practically scrap value there was no incentive to operators to improve or enlarge their systems, particularly in the later years of tenure, and investors were reluctant to provide capital that had little prospect of redemption.

Consequently, there were few customers for the conversion of horse or steam tramways to electric traction until about the year 1896 which may be regarded as the beginning of electric tramways in this country on a commercial scale. At that time there were only 80 route miles of tramways worked by electricity in the whole of the United Kingdom.

Expiry of the 21 year period of tenure, and the availability of finance by pioneer promotors such as Emile Garcke, led to the formation of many companies for the installation and operation of electric tramways. Local authorities in the principal towns and cities also became interested in the new form of public transport with the result that a surge of activity developed in designing, manufacturing and installing equipment to meet the new demand from 1896 onward.

Although Great Britain was about ten years behind some other countries in these developments, the delay was not all loss, because British manufacturers were able to avoid the expensive errors in engineering design which had been discovered and corrected by pioneers elsewhere. The Brush Company was well placed to take advantage of the situation with preparations extending over several years since 1890. With experience both of electrical equipment and of tramcar manufacture at Falcon Works, development into electric traction was a natural stage of evolution based on previously determined policies.



An early double deck electric tramcar. The long body in relation to the bogie caused considerable pitching and swaying.

TECHNICAL DEVELOPMENTS

Much discussion occurred on the relative merits of single and double-deck tramcars. Most foreign systems used single-deck vehicles and nowhere were double-deckers developed to the same extent as in this country. Controversy also raged over the relative advantages of closed or open upper decks. Some tramway managers claimed that passengers enjoyed the air and scenery sufficiently to prefer the open accommodation and closing the top destroyed the reason for its existence, it being a waste of time to climb a staircase to reach covered seats. The single-decker was easier to load and unload and the work of the conductor was less arduous. With no stairs to climb, he could handle more passengers.

Brush made both types, and a compromise single-deck type had open smoking compartments at each end with enclosed accommodation in between. The vestibule car became popular at a later date, the vestibule being an enclosed platform at each end for the driver and conductor, and for the public when entering or leaving the car. As car speeds were increased the effect of bad weather on the health and efficiency of drivers became more pronounced and the introduction of enclosed platforms by a few seaside towns in 1913 quickly attracted attention. Brush cars delivered to Wallasey included this feature and Coventry, York and Salford quickly followed the trend. The advantages were so marked that Brush adopted this feature as standard from 1914 onwards and similar steps were taken in the design of motor omnibuses.

One trouble experienced with early tramcars was skidding caused by fierce application of brakes particularly on wet or greasy rails. This was a prolific cause of accidents and a search was made for suitable remedies. One of the simplest and most effective solutions of the problem was made by Mr. C.W. Mallins, traffic manager of Liverpool Tramways, who invented a safety sanding gear. Brush promptly took a manufacturing licence from the patentee and placed the gear on the market with marked success. The sanding mechanism was operated by the driver's foot and trials at Liverpool in 1907 proved the device to be capable of halting a vehicle in a remarkably short distance when driven down a steep incline at sixteen miles per hour. About 300 vehicles of the Liverpool Corporation were fitted with Mallins Sanding Device and the fact was duly reported in the Manchester Guardian of 24th December, 1907 as a contribution to road safety.

Electric tramcar construction was at its peak in the years 1900 to 1910. During this period, traction and transport equipment was the most important activity of the Company and the principal source of income. Orders were received in large quantities, one customer alone, the London County Council had 250 vehicles under construction at Falcon Works at one time, and the output of vehicles exceeded 1,000 complete tramcars every year.

Rolling stock manufacture then occupied about one-half of the works area of 33 acres and employed rather more than one-half of the total number of 1,500 employees.

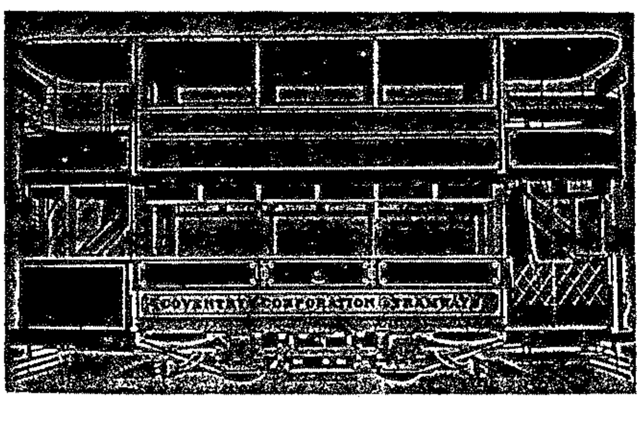
The Vestibule Car - 1914

Brush Deck Cover with Sliding Roof and Windows Closed.

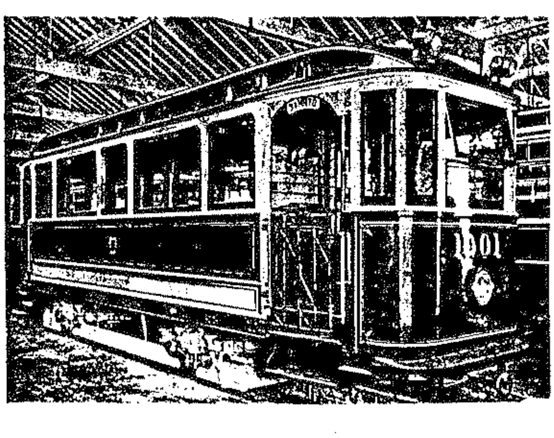
EXPORT

Among the important export installations were tramcars for Moscow (1905) and St. Petersburg (1908) now Leningrad, and Bombay (1908). Brush supplied the complete power house generating plant for Bombay specially designed to withstand the hot and humid climate. This also applied to the tramcar electrical equipment, particularly the motors which were totally enclosed. Reports made after a few years' operation indicated remarkably successful results which were attributed to the care with which the equipment was designed and made.

Large quantities of tramcars were also made for Shanghai, the Sudan, South America, Japan, New Zealand and in fact for countries in every continent of the world.



New car for Coventry with vestibule platform.



One of a substantial order for Electric Tramcars supplied to Russia in 1905.

METAL CONSTRUCTION

For tropical climates and other locations where the use of timber was unsuitable, 'All-Metal' body work was evolved, the first vehicle of this type being constructed by the Company in 1907. The use of metal instead of timber introduced radical changes of production techniques. New shops and equipment were set up to handle metal components and new skills and experience were added to vehicle construction.

It is interesting to notice that some forty or fifty years later, in the 1950's, the experienced craftsmanship of metal production became a valuable feature of the Company's production of diesel-electric locomotives.

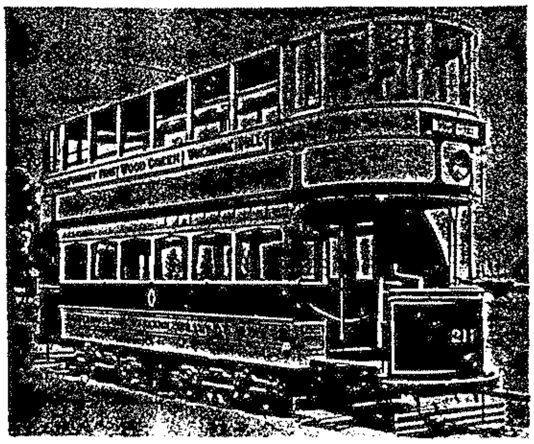
The expense of all metal construction for tramcar bodies was not justified in many circumstances and Brush designers introduced a composite type of body which used metal parts for strength combined with timber for lightness and ease of construction. This form of construction became the most popular type of all, completely superseding the old timber models for passenger vehicles. The style was well suited to the works' resources for it enabled the company to make the best use of metal working techniques combined with the extensive timber working facilities built up from the earliest days.

TIMBER

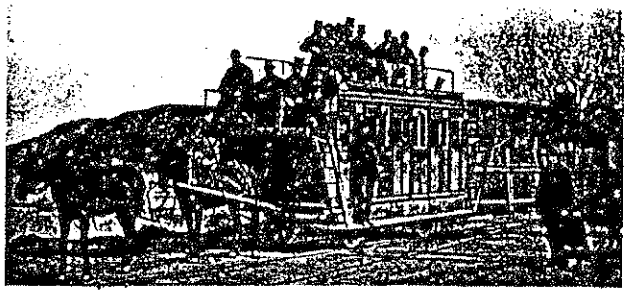
The selection, treatment and use of timber was a special feature of Falcon Works that lasted for some sixty years. At the height of this activity, 1900 to 1930, huge stocks of English and foreign woods, mainly of ash and beech, valued at tens of thousands of pounds sterling were stored in air seasoning sheds. There was also a large saw mill and woodworking shop equipped to carry out machining operations of every kind, including drills that would bore square holes, reproduce carving automatically, and other ingenious devices.

The study of woodlore occupied much attention of the designers of bodywork and as late as 1945 experiments were still being conducted to ascertain the best forms of chemical treatment to resist decay. Since 1885 when the first horse-bus was built, the search for immunisation of timber from fungal growths had continued unabated.

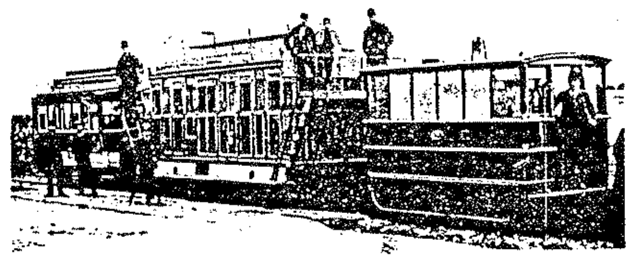
In addition, fire resistance, surface finishing and painting techniques all became matters of considerable expertise to the staff and workpeople enabling them to produce highly finished vehicles, weatherproof, rotproof, fireproof, and pleasing in appearance.



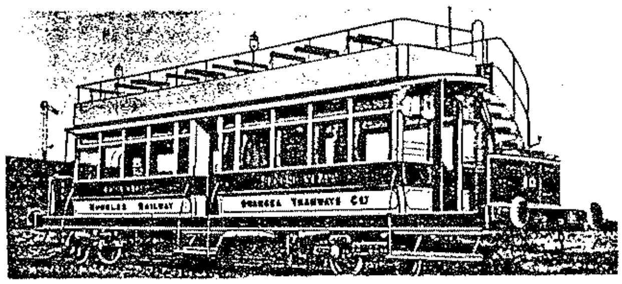
The latest type of Double-Deck Bogie Car (1908).



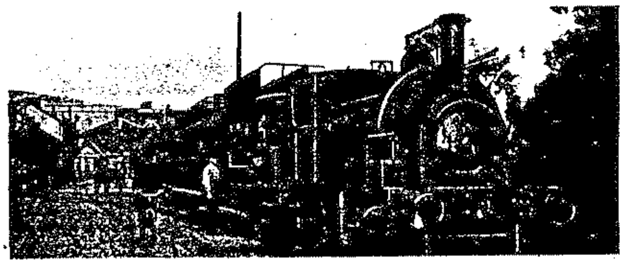
Horse traction at the Dunns, Oystermouth, about 1865.



Hughes patent steam tramway locomotive on the Swansea and Mumbles in 1877; it was built at Falcon Engine Works, Loughborough.



Brush electric accumulator car, with two-class accommodation for 99, used under B.E.T. auspices in 1902 and 1903.



Steam train at Rutland Street in 1928, hauled by Avonside 0-6-0 saddle tank "Swansea".

Brush 106 seat electric car as operated from 1929; there were in all 13 cars by Brush Electrical Engineering, with B.T.H. electrical equipment.

4. THE SWANSEA & MUMBLES RAILWAY

Development of rail transportation in England is illustrated by the history of this undertaking incorporated on 29th June 1804 under an Act of Parliament granted in the 44th year of the reign of King George the Third and finally closed on the 5th January, 1960 after a useful life of nearly 160 years.

Originally designated the Oystermouth Railway or Tramroad, it was intended to convey iron and limestone from the mines and quarries at Oystermouth to the Swansea Canal and horse-drawn waggons began to carry goods in April, 1806. One year later, on 25th March 1807, a public passenger service was inaugurated and the Oystermouth line claimed to be the first passenger carrying railway in the world.

Horse-drawn vehicles were used for the first seventy years, the speed of travel and passenger comfort being primitive by present standards; hard wooden seats, exposure to the weather and ascent to the top deck by simple wooden ladders, were some of the features endured. The track rails consisted of angle iron in three feet lengths bedded in concrete. The car wheels were not flanged and derailments were commonplace.

A new form of locomotion appeared in 1877 with the introduction of Hughes patent steam tramway locomotive built at Falcon Works, Loughborough. The locomotive-hauled trains of tramcars revolutionised the operation of the line and the displacement of horses became inevitable. The original cars held ten persons, while steam trains hauled as many as 1,800 passengers. The effects on cost of operation, speed of travel, and passenger fares were overwhelmingly in favour of steam. Nevertheless, there was much public opposition and several prominent public men in Swansea led a campaign of strenuous resistance to the development, mainly because of smoke fumes and dirt nuisance, and out of consideration for the loss of livelihood caused by staff reductions among those dependent on horses.

To mitigate these consequences horsecars ran between steam trains for some time with much inevitable confusion.

In 1898 the line was extended to Mumbles Pier and one year later the Swansea Improvements and Tramways Company in which a controlling interest was held by the British Electric Traction Company (Emile Garcke) obtained a lease of the Railway for 999 years.

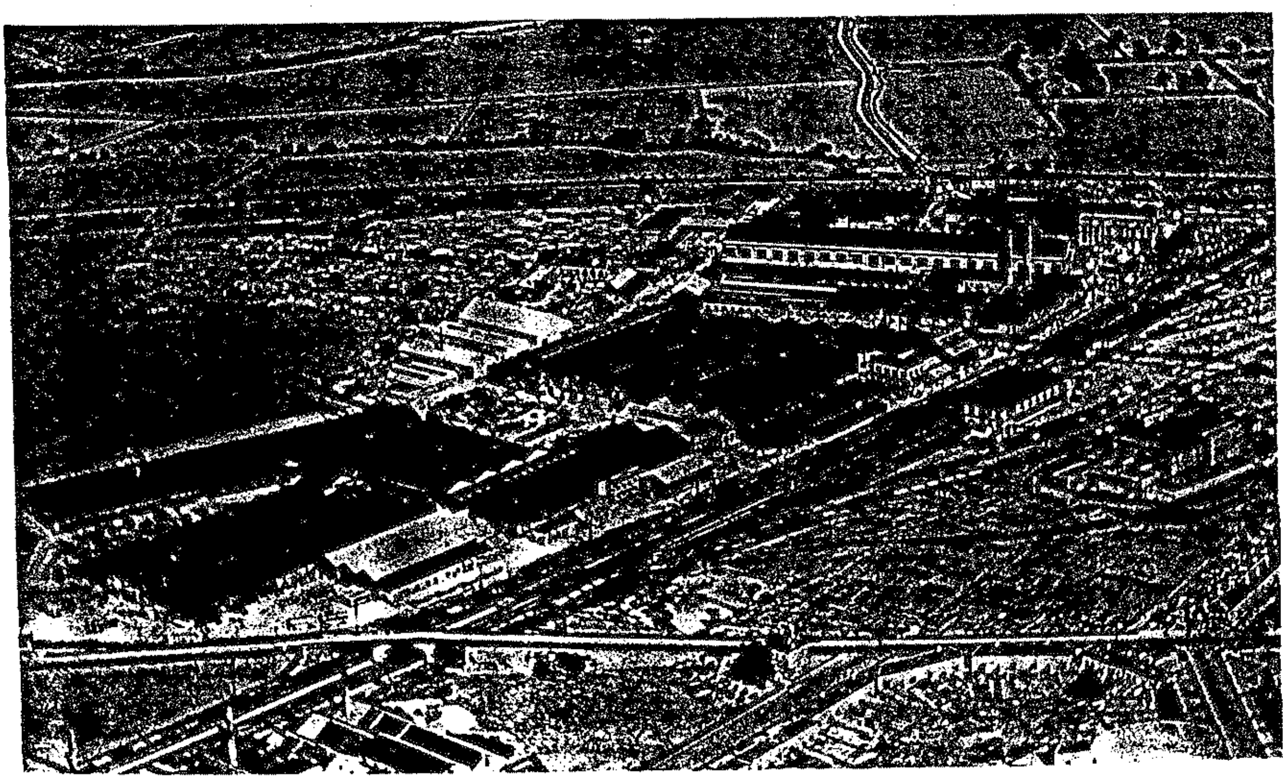
The B.E.T. Company introduced in 1902 an electric accumulator tramcar pioneered and made by the Brush Company. The car was propelled by electric motors supplied by batteries and had two classes of accommodation for a total of 99 passengers. Difficulties with accumulators and charging equipment limited the scope of this venture and the car was withdrawn from service after two years.

Steam traction prevailed until 1929 when the line was electrified with overhead wires at 650 volts direct-current and 13 Brush Electric Tramcars were put into service. These double deck vehicles each had two 60 horsepower electric motors and seated 48 passengers inside and 58 on the upper deck, 106 passengers in all. They were reputed to be the largest double-deckers in the world.

The new installation was highly successful for about thirty years but towards the end of that period, in the 1950's, diesel-driven road buses became highly competitive. When the time came for renewal of track and rolling stock at an estimated cost of £350,000 the expense was deemed to be not justified and a decision was made to close down.

On 5th January 1960 the last tramcar made a final ceremonial journey on the system and the end of the Swansea and Mumbles railway was officially solemnised at a luncheon held in the Swansea Guildhall.

Thus a railway system which a few years earlier had celebrated a 150th anniversary and which had witnessed the growth and decay of many forms of transportation in locomotion by horses, steam engines and electric motors, and which had been linked with the Brush Company in the development of the various means of transport, finally succumbed to the growing popularity of flexibility and economy of diesel buses operating on public roads.



The extensive buildings of Brush Coachwork Ltd. Aerial photograph taken in 1949.

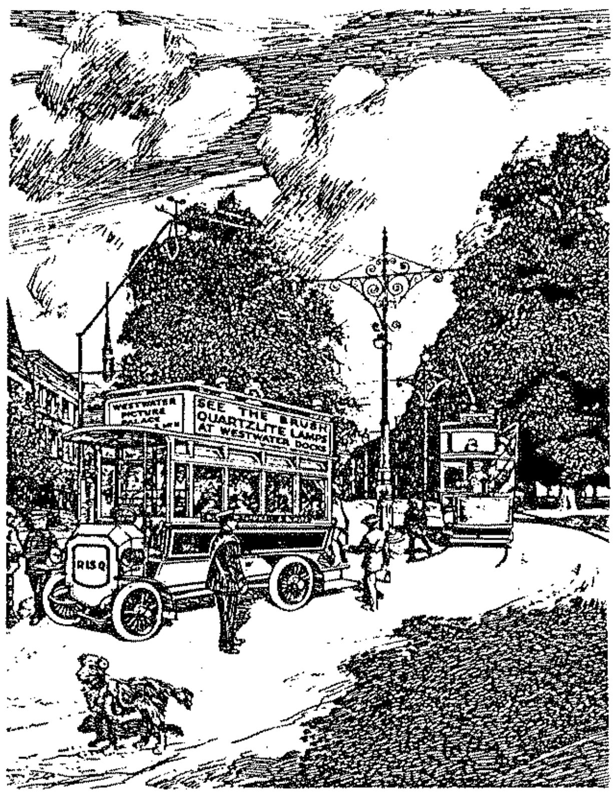
5. TROLLEY BUSES

As traffic increased in volume and speed tramcars caused increasing congestion in busy streets. Fixed rails with twin tracks meant that trams had to stop in the middle of the road to load and unload passengers and two trams passing could block the entire road if narrow. The resulting effect on other traffic gave rise to a public demand for the elimination of tramways in town centres and by 1911 the idea of using trolley buses in place of trams was promoted. Such a scheme had several attractions. A trolley bus using pneumatic tyres was quieter, it required no permanent way, and could readily draw up to the side of the road to load and unload Further, many tramway undertakings had substantial investments in electric power stations and plant using coal, an indigenous fuel. Trolley buses using electricity from overhead systems made full use of these resources. It was also easier to extend routes as no rails were required, only overhead wires and supports being necessary. As a compromise between motor buses and tramcars, providing the advantage of electric traction without rails, the trolley bus had many advocates and the Brush Company prepared itself to produce yet another form of transport vehicle.

As a first step the Company acquired British and Foreign rights to make and sell the 'Bremen' trolley omnibus and announced in September 1911 that it was prepared to deal with enquiries from most parts of the world.

The Bremen system had a unique form of current collector running along the overhead wires and arranged to be readily detachable from the bus trolley pole. This enabled a single pair of wires to be used instead of the conventional four wire system for vehicles travelling in opposite directions. In the Bremen system, when two buses wished to pass each other, the conductors exchanged current collectors, an operation which compelled the vehicles to to stop for about ten seconds.

The first installation in England was put to work at Stockport in 1912. It did not have a wide vogue.



HOW THE TROLLEY BUS WILL SERVE WHERE THE TRAMWAY ENDS

An artists's impression of the introduction of the Trolley Bus in 1911.

Two Trolley Omnibuses meeting and exchanging current collectors. This contrivance enables a single pair of Overhead Wires to serve for traffic both ways. (1912).

ELECTRIC MOTORS

At the outset, the Company did not make the electrical equipment because of various trading agreements, and the work was limited to making and assembling the body with proprietory electrical gear on chassis separately purchased by customers, but in 1930 Brush developed a series of trolley bus motors which broke away from conventional traction motor designs. Limitations of space and weight together with demands for higher power brought about intensive research into new features of motor construction and within a few years the nominal horsepower of trolleybus motors was increased from 30 to 80 without any appreciable increase of size or weight. This advance was made possible by use of improved insulating materials which enabled the motors to be operated at higher temperatures without damage, efficient ventilation by fans replaced the former total enclosures, light alloys were used for supporting parts of the structure, and high gear ratios were employed to enable high speed motors to be used. With buses running at 30 miles per hour, motor speeds attained 2,500 revolutions per minute which allowed good ventilation and economy of structural materials.

Another new feature was the introduction of compound wound motors to modify the conventional series characteristics, which made the motors more suitable for regenerative braking, a requirement of some importance on routes with gradients. Compounding also had the effect of countering the sensitivity of motor speed to changes of load so that a vehicle could be driven easily with light loads at low speed without constant notching and heating of resistances. This was a valuable feature in heavy traffic or in fog.

One experiment that failed in its purpose was the development of a motor with a specially boosted field that would enable it to regenerate with a vehicle speed as low as 4 miles per hour. Hitherto the lowest possible regenerating speed was 10 to 11 m.p.h.; below this speed mechanical brakes had to be applied. A vehicle fitted with this motor was tried in service on a trolley bus system near to Loughborough in 1935. The performance was exactly as required showing remarkable economy of energy consumption but the braking was so fierce that vehicles following in traffic could not pull up sharply enough to avoid collision. It became apparent that vehicles in traffic should have approximately similar braking capabilities so the new trolley bus had to be withdrawn.

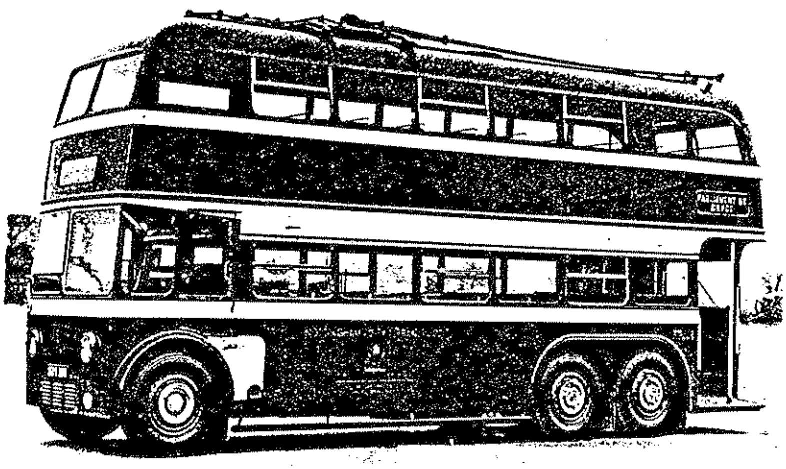
For various reasons largely concerned with intertrading agreements, the Brush business in electrical equipment did not grow to large proportions in the trolley bus field and manufacture was abandoned in 1936 when the volume of production became unremunerative and the prospects of expansion were remote. Also the Company was at this time in financial difficulties and unable to support the expense of further development.

It can fairly be claimed that the intensive development of trolley bus motors over a period of about seven years laid the foundations of improved traction motors of the future and marked a breakaway from the totally enclosed, heavy and cumbersome types of former times.

THE DECLINE

Body building activities, both of composite and metal construction, continued to flourish and large fleets were supplied, particularly to Municipal undertakings, notably the London County Council, Nottingham City Transport, Derby Corporation and many others. By 1949 the annual sales of all vehicle bodies reached a total of £1 million. From that peak the business of body building began to decline and in 1952 it was closed down.

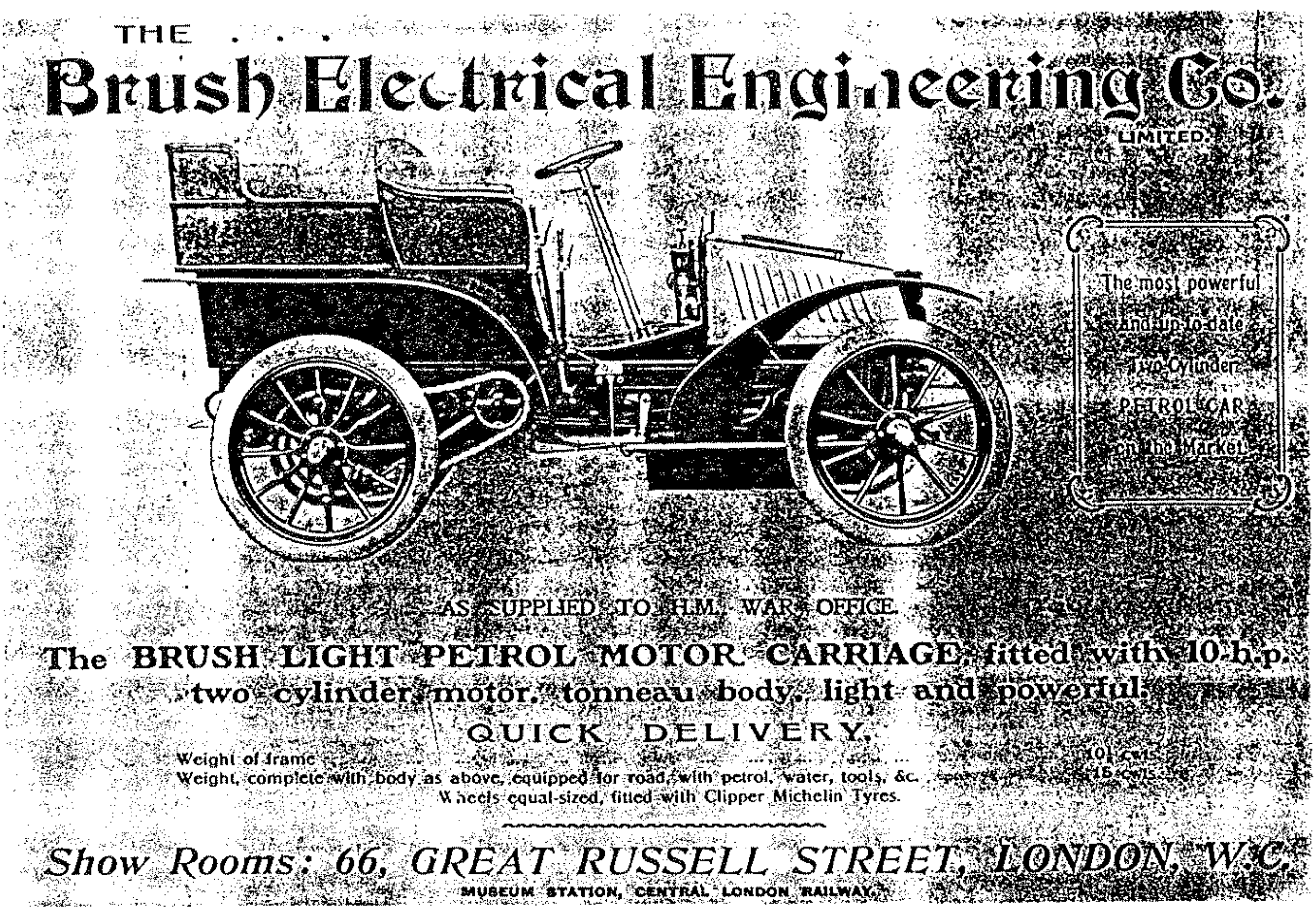
Although orders ceased for new vehicles, trolley buses continued to operate in many areas until they were finally superseded by diesel buses. The largest trolley bus fleet in the world of 1700 vehicles operated on the London routes. Beginning in 1931 with the introduction of "trackless trams", as they were called, on tramway routes, trolley buses replaced trams steadily until 1939. After the war remaining tram routes were taken over by diesel buses which also began to replace trolley buses in 1959. After three years the changeover was complete and the last remaining trolley buses numbering about 100 were finally withdrawn from service in May 1962: from start to finish, trolley bus services were operated in London for 31 years.



70 seater all metal Trolley Bus produced for Nottingham City Transport.

Trolley-Bus at Stockport (1912).

Large quantities of vehicles of this type were supplied to the London Transport undertaking. The six wheel arrangement became a standard form.



From a contemporary Brush publication about 1902.

6. MOTOR CARS & OMNIBUSES

About the year 1900 the Company turned its attention to the automobile field. Petrol engined motor cars were beginning to appear as practical vehicles for private motoring and forseeing the scope for a new industry, the directors formed an Automobile Department under the management of Mr. J.T. Critchley, M.I. Mech.E. There followed the development of two sizes of motor cars. One with a 10 h.p. engine was displayed at the Motorcar Exhibition at London in 1902. It was propelled by a two-cylinder petrol engine made by Brush and was claimed to be the most powerful and up-to-date two-cylinder petrol car on the market. The weight complete with petrol, oil, water and tools was 15 cwts. Michelin pneumatic tyres were fitted, and drive to the rear wheels was provided by open chains, one at each side of the body. An open tonneau body was provided with no weather protection. Later a 16 h.p. model was produced having a four-cylinder engine.

Although there was some initial success in which many customers were supplied with Brush motor cars, including H.M. War Office, it was recorded in the directors' annual report of 1904 that sales were disappointing "probably because of the wet season", and it was hoped that a spell of fine weather would improve the situation.

It is not unusual for new developments to decline after the first initial impetus; had the Company possessed the financial resources and perhaps the confidence to persist through a few years of depression, Brush might have become one of the leading pioneers of the motor industry. The development of motorcars was abandoned one year later.

THE OMNIBUS

The automobile department then applied its energies to motor omnibuses, these vehicles being in the Brush tradition for the manufacture of public service vehicles of all types, and petrol buses were just beginning to appear as another form of public transport.

It was recognised at an early stage that risks of damage by fire must be minimised in vehicles carrying petrol spirit and the first bus bodies were built of non-flammable wood, i.e. timber rendered fire-proof by chemical treatment, the materials were principally English ash for the framework, mahogany and aluminium for the panels, and red deal for floors.

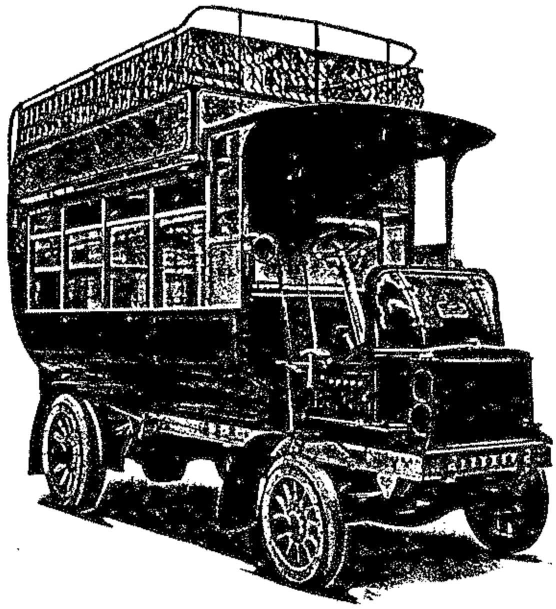
Vehicles were shown at the Automobile Exhibition and the Tramways and Light Railways Exhibition in London. One model, described as the Interurban One-Man Omnibus for providing road links between tramway and railway services had a four-cylinder 30 h.p. engine running at a maximum speed of 900 revolutions per minute and carried 32 passengers. Passengers entered by the drivers platform and placed the fare in a box near the driver before taking their seats, thus avoiding the need for a conductor.

A new form of patented gear box made by Brush under an exclusive licence from the inventor, Mr. King, was included in the construction.

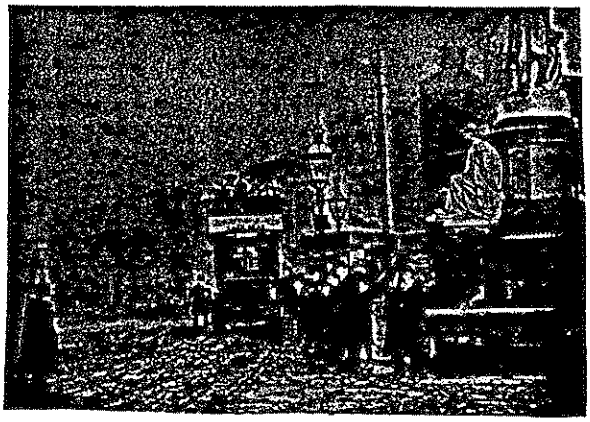
Experience in the manufacture of steel railway coaches was applied to bus construction and in 1907, the year of the first Commercial Motor Exhibition in London, Brush displayed at Olympia the first all-metal bus built in England.

The Company was now well launched in the motor-omnibus industry, and to cope with the rapid developments taking place, a subsidiary company was formed, the British Automobile Development Company Limited, with works adjoining the Loughborough factory, for the production of road motor vehicles for passenger and goods traffic.

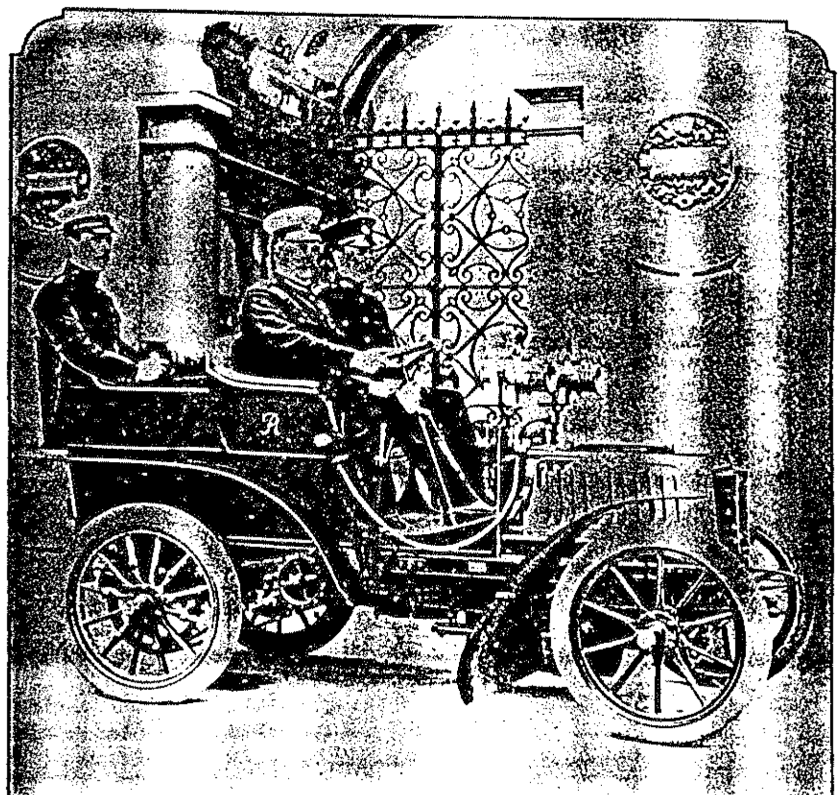
Founded in 1906 as an offshoot of the automobile department, this company made an important contribution to the early development, but for financial reasons it was later merged into the Brush organisation when the Company's interests were restricted only to the manufacture of bodies.



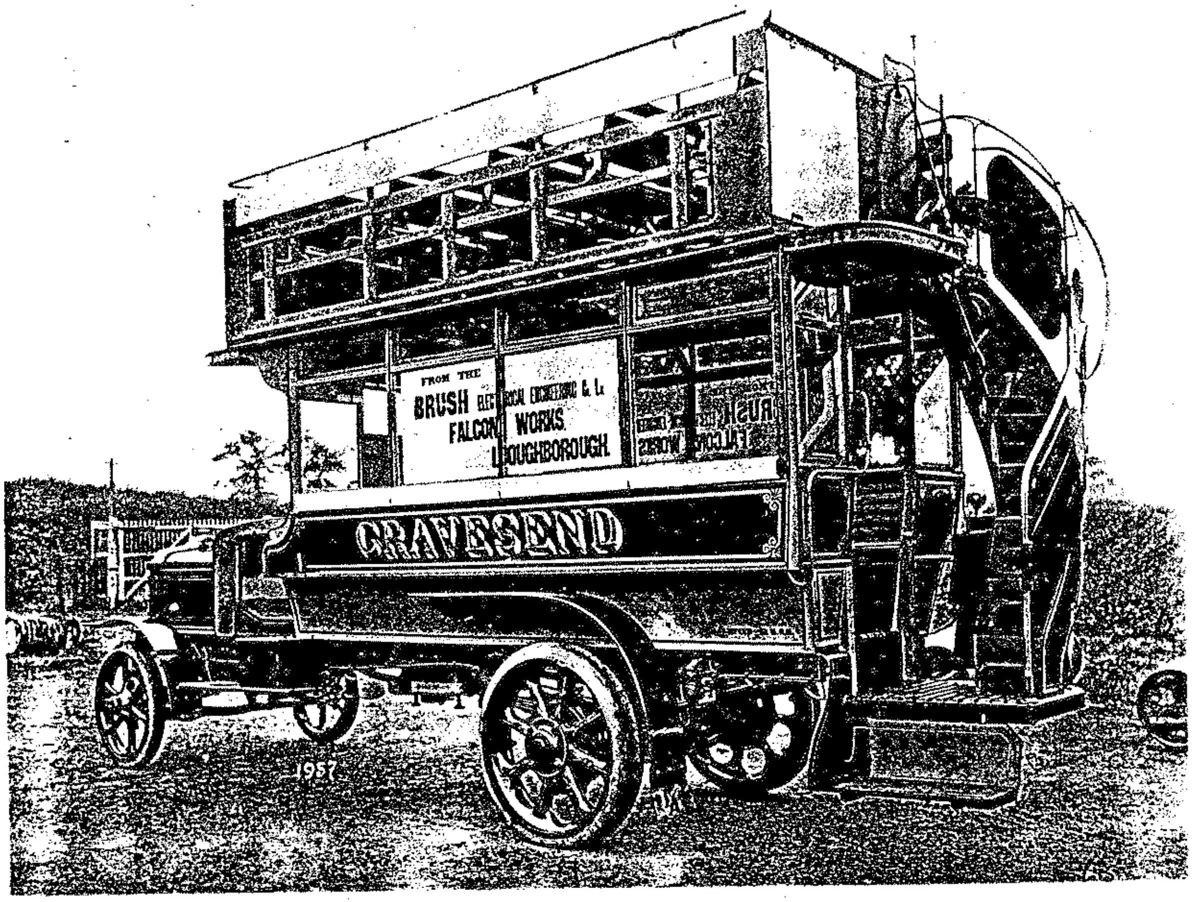
The first all-metal Motor Omnibus exhibited at Olympia in 1907. It had a maximum speed of 12 m.p.h. The wheel base was made shorter than usual by seating the driver above the engine and placing the radiator in front.

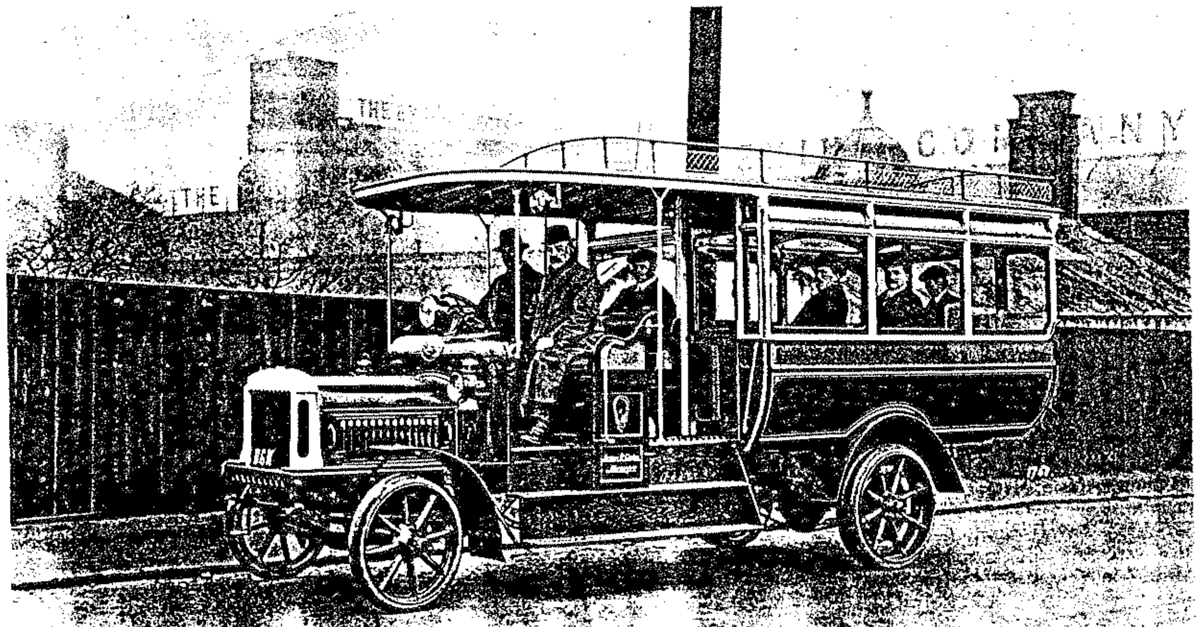


Brush Motor Omnibus in Birmingham (1907).



Supplied about 1902 this Brush Motor Car was among the first mechanical vehicles used by the War Department of H.M. Government.





Examples of early motor buses ready to leave the Works.

BODY BUILDING

Engines and Chassis became items of specialised manufacture and Brush found itself unable to maintain economic manufacturing facilities over the entire field.

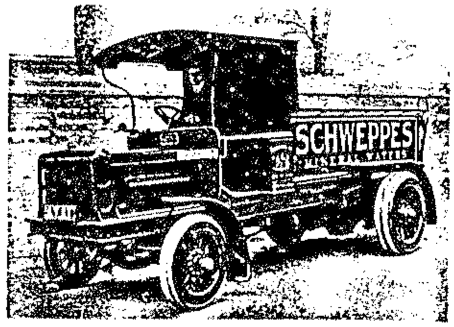
Considerable investments had been made in buildings and equipment for storing, seasoning and the treatment of timber for tramcar bodies, and railway wagons, as well as for bus bodies, so when the time for specialisation arrived the Company decided to concentrate on body work. Another factor in this decision was that municipalities and operating companies, who were the principal customers for motor omnibuses, in many cases preferred to buy chassis and engines separately, and have bodies fitted to suit particular conditions of public service.

The new arrangements developed rapidly and many types of bodies were evolved in a continuous sequence up to 1952 interrupted only by the 1914-18 war and again by the 1939-45 war when the coach building facilities were diverted to making vehicles for the armed services and to aircraft construction.

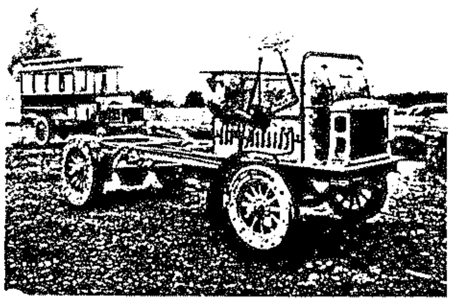
Early designs produced up to 1914 were still influenced by horse-bus design with engines mounted over the front wheels with the driver sitting behind the engine compartment and in front of the body. Many vehicles of this period were used as troop carriers in France to convey soldiers between base and forward positions.

The first breakaway from the horse-bus design occurred in 1924 when Brush built the first Top-covered Double-Deck Omnibus to be used in a provincial city. There was initially some police objection to covered top decks because of the height and instability of such vehicles. Brush designers overcame this by reducing floor height and obtaining a low centre of gravity.

Tilting tests were performed at the Works on all vehicles in which they were demonstrated to incline to an angle of 14 degrees from the verticle when fully loaded without falling over.

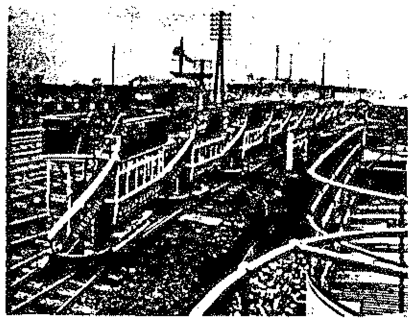


Brush 3-ton Motor Wagon of 30 H.P. (1906).



A four-ton Brush chassis. (1907). Built to the order of a well-known Brewery, and fitted with Hartridge non-slipping tyres.

The coachwork finishing shop



Fleet of Brush Motor 'Bus Bodies on the sidings at Loughborough, ready to leave for London. (1906).

A motor coach design of the 1950's for long distance passenger transport.

NOISE

The advent of the motor omnibus aroused public agitation against the noise introduced in hitherto quiet streets and roads. In London a 'Noise Committee' was formed, representative of West End residents, with power to inspect new buses for London streets and exercise a veto on their use if the noise was deemed offensive.

One such inspection in the Spring of 1907 included several new Brush buses and took place on Wimbledon Common. Each bus had to ascend a steep part of the road with the Committee stationed half-way. Then the vehicles were judged for noise and speed on a measured stretch of level road. The maximum permitted speed was 12 miles per hour. A decision announced the following day passed the Brush vehicles as fit for service but there is no record of the standards or criteria by which the performance was judged.

The industry generally regarded these incidents as typical pieces of legislature and interference directed against new technical developments, as was the case with railways, tramways and electric power supplies.

In the years between the two world wars, i.e. 1918 to 1939 public passenger transport expanded and motor omnibus fleets increased accordingly. During this period the demand for electric tramcars which at first increased, began to decline and finally came to a halt. The superior mobility of motor buses enabled long distance services to be introduced between towns and villages, as well as local transport services between factories and housing estates, and tramcars could only compete on fixed routes with dense traffic. Brush facilities were well adaptable to the trend as a result of earlier policies and the firm consistently contributed to the progress of passenger vehicle design and construction.

DESIGN

Some of the improvements now accepted as obvious, were startling innovations at the time, such as enclosed driver-cabs with the driver seated above or alongside the engine, upper decks extended full length of the vehicle, with enclosed stairways, seats placed crossways instead of sideways, upholstered seats and many other detailed features which have led to the "luxury" buses of today. One simple but controversial innovation was the introduction of individual passenger-operated window-ventilation. Many operators thought the bus should be ventilated as a whole by mechanism under the control of the conductor, so avoiding disputes and ill-feeling between passengers.

WORKMANSHIP

Another reason for the successful development of the Company's business beside technical innovation, was the careful and expert workmanship applied to each item of construction. Vehicles designed for reliability, comfort and endurance, were made so by the skilled work of experienced craftsmen who took immense pride in the products they created. Joiners, metal-workers, electricians, painters, upholsterers and others made painstaking efforts to ensure the quality of Brush bodywork was the finest possible. This was in accordance with a long standing tradition from the earliest days and passed down from father to son and to grandson, that Brush standards of quality were the best in the world and obtainable only by the highest standards of craftsmanship applied to proficient design and carefully selected materials with the aid of excellent productive processes and facilities.

As an example of the care taken to secure a pleasing and lasting external finish, as many as fourteen coats of paint were applied to outside bodywork, each coat dried and thoroughly rubbed down before the next coat was applied. The result was a mirror-like finish that withstood years of wear in all climates.

It was largely because of these built-in standards of quality that large operators placed order after order for their coachwork requirements with the Brush Company.

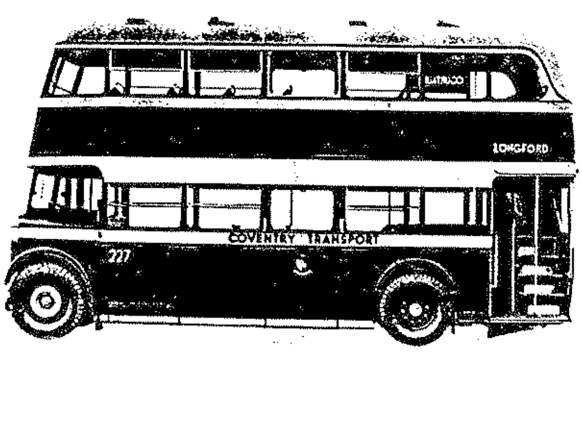
END OF COACHBUILDING

Naturally, the maintenance of such standards was costly and this had to be reflected in the price of the product. Many users were willing to pay the price before 1939 because they knew the first costs were then recovered in reduced maintenance and longer life. After the second world war the demand for first quality products subsided and many cut-price firms set up in the coach building business. Large operators faced with severe competition found it economic to build their own bodies as a means of cutting costs.

These factors among others led to dwindling trade at cut prices and by 1952 the business had become so unremunerative that the Brush directors decided to cease coachbuilding activities.

The facilities so released were devoted to the manufacture of battery electric vehicles, after space had been allocated for expansion of the Company's electrical products; mainly switchgear.

Examples of Bodies built by Brush.



7. RAILWAY COACHES & WAGONS

An article in the 'Engineer' of 22nd December 1905 contains a description of steel railway coaches under construction at the Falcon Works. At the time there were eighteen steel coaches in process of manufacture for the Great Northern and City Railway. Mounted on standard Brush trucks, the underframes, posts, pillars, floors and outside panels were made entirely of steel, all rivets being concealed in neat mouldings to improve the appearance. The inside panelling was 1/16" aluminium sheet. This type of construction was claimed to be absolutely fireproof, long-lasting, and safer than wood in case of accident.

Similar coaches were also supplied to the District and the Metropolitan Railway Companies. There was much comment on the superior quality of the Brush products compared with coaches imported from American and Continental sources. These were said to resemble girder bridges with the sides disfigured by rows of protruding rivet heads.

Each of the Brush coaches seated 64 passengers and weighed nearly 18 tons. The overall length was 41 feet.

Coaches built for the Metropolitan Railway Company and put into service in 1905 were the first steel railway coaches made in the United Kingdom and the efforts of the Company to maintain the eminence of British manufacture received favourable comment in the Press.

Owing to the lighter weight of steel coaches compared with wood in relation to seating capacity, marked economy of operation was obtained. It was estimated that the cost of steam or electricity required to propel each ton of rolling stock on the London underground lines amounted to £25 per ton per annum. As the reduced weight of each coach was of the order of three tons, substantial savings resulted.

Attention was given to the comfort of passengers in the provision of space, soft upholstery and pleasant decoration. The public demanded greater luxury of travel and were no longer willing to bear the discomforts of former days when the cheapest and plainest compartments were deemed sufficient. Railway companies found that traffic receipts increased when travelling was made pleasant and the Brush Company's designers applied much effort and ingenuity to the creation of luxury for passengers.

Other products under construction in 1905 included all-steel double hoppered four wheeled coal waggons of 20 tons capacity for the City of Birmingham Gas Department and similar designs of 40 tons capacity for the Buenos Ayres and Pacific Railway intended for carrying grain.

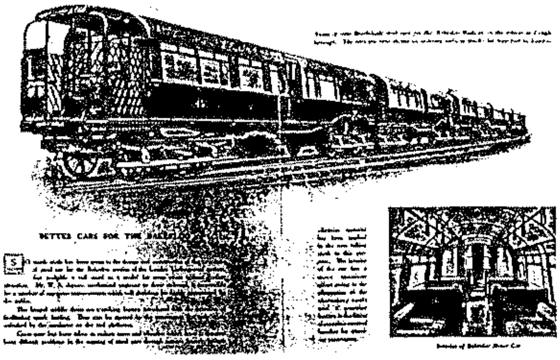
Another innovation was the steam motor coach in which a steam engine locomotive was attached to a single coach for frequent service on branch railway lines. Many of these vehicles were supplied to all parts of the world, but the steam engines were not of Brush manufacture.

The Sudan Railway placed large orders in 1906 for first, second and third class corridor coaches together with sleeping, dining and kitchen cars. The carriages were electrically lighted throughout and fitted with electric fans. The floors were covered with linoleum but first class coaches had carpets and interior finish of walnut.

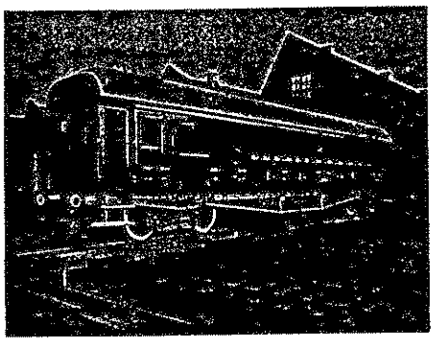
Other railways supplied included the Great Central Railway (1907), the Siam Railway (1907), the North British Railway, the Highland Railways, the Indian Railways and leading railways of South America and China.

Building of main line railway carriages and trucks was a major line of the business done by the traction sections of the works in 1912.

A consignment for the Egyptian State Railways in 1908 was designed specially to avoid the effects of shrinkage of timber caused by extreme heat and dryness of the climate. The body frames were entirely of teak sheeted outside with boarding of the same material and so arranged to show no joints if shrinkage did occur. Coaches were provided for 1st, 2nd and 3rd class accommodation. The former had harem compartments.

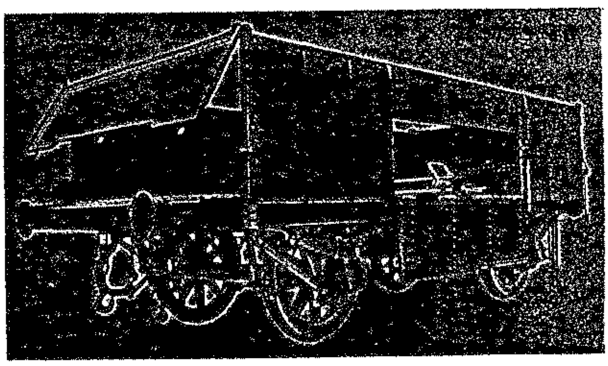


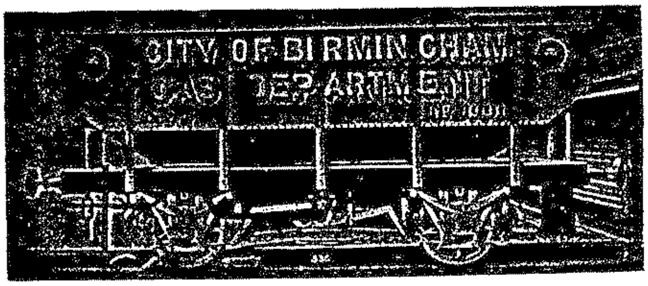
THE BRUSH BUDGET. 1914.



Brush Composite Coach for Egypt, including Harem Compartment.

Steel wagons for India 1913.





Brush 20-ton Double-Hopper Coal Wagon for Birmingham Corporation (1906).

8. TRUCKS & BOGIES

Considerable thought was given by designers and operators to improvements in the riding qualities of tramcars, not only from the point of view of mechanical reliability and ease of maintenance but also to increase passenger comfort. It was found that some passengers were made physically ill by the effects of vibration caused by uneven rails and joints, also by the lurching and swaying that occurred at rail curves. Further, the various strains and vibrations set up in wheels and axles by frequent stopping and starting, rounding curves and by rail-joints produced rapid wear and sometimes failure of wheels and axles in addition to destructive wear of the permanent way.

These difficulties were accentuated by increased speeds, also by increases in the size of cars and the power of the driving motors. Early tramcars had motors of 6 to 10 horsepower, developments led to the use of 50 h.p. motors by 1904.

The choice of materials and the disposition, design and construction of springs, brakes, wheels, bearings and body supports required mechanical engineering ability of high order to secure satisfactory results.

Much ingenuity was applied to the development of trucks and bogies taking into account these and other factors such as cost.

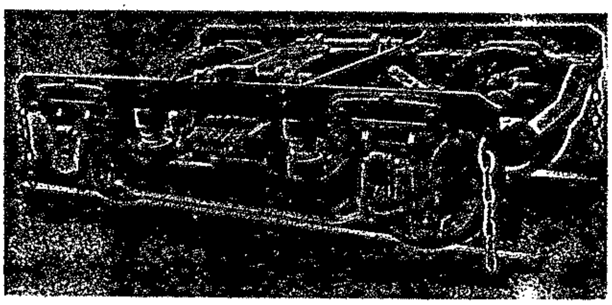
In an article "Electric Traction Trucks" which appeared in "Traction and Transmission", a supplement of the journal "Engineering" in October 1904, Elmer E. Cook states that no gradual process of evolution took place in the development of Trucks "it was scarcely more than two steps from chaos to creation".

MAXIMUM TRACTION TRUCKS

Chief among these was the so-called Maximum Traction Truck in which the motor was suspended between the outer end of the truck and an axle with large diameter wheels driven through gearing. Another axle with smaller wheels was located at the opposite end of the truck, these wheels were not driven but acted as guides and load carriers. The car body rested on radius plates between the axles. This type of truck was claimed to obtain the greatest traction effort from two motors when fitted to a car supported by eight wheels, i.e. by two trucks, each with four wheels, two axles and one motor. Several variations of this design were introduced to suit particular conditions of operation.

One disadvantage of the smaller wheels was that they easily left the rails, and many operators preferred trucks with equal wheels. Both types had adherents and they were in vogue for many years.

Truck for railway carriages built at Loughborough in 1912.



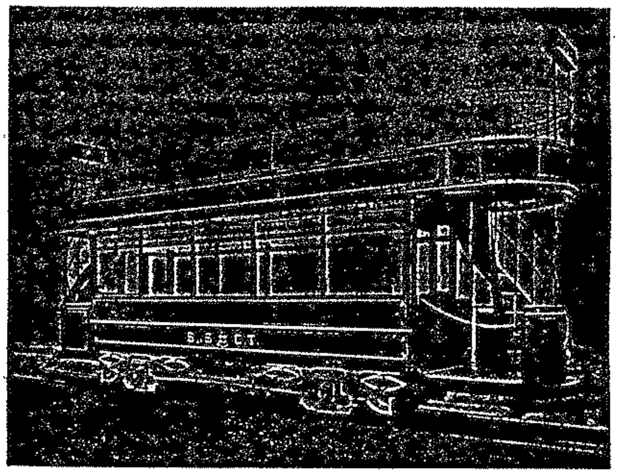
RADIAL TRUCKS

The invention of Lycett and Conaty, respectively of the City of Birmingham and of Birmingham and Midland Tramways, the manufacture of these trucks was taken up by Brush because of their merits as smooth riding units and economy of operation, i.e. minimum current consumption for the tractive effort required. Although more expensive than other trucks they could be fitted as single trucks to cars 22 feet long while 16 feet was hitherto regarded as the maximum length permissable for bodies with conventional single trucks.

Additional passenger accommodation allowed by extra length more than justified the extra cost of construction, as many as 65 could be taken in a 22 feet car, and this was found to be a satisfactory size for many operators.

A discussion on "Improvements in Trucks" at a meeting of the Tramways and Light Railways Association on 14th December 1905 was opened by Elmer E. Cook of the Brush Company, and the audience of tramway managers, consulting engineers and manufacturers confirmed the advantages of radial trucks for smooth riding. Leading authorities, Professor C.A. Carus-Wilson and Mr. J.B. Hamilton, manager of the Leeds Tramways spoke strongly in their favour. The manager of Chesterfield Tramways, Mr. R.L. Acland stated his undertaking had 12 months experience with radial trucks with highly satisfactory results. When the trams were ordered from Brush in 1904 the venture was regarded as courageous pioneering.

Notwithstanding these favourable opinions, there was need for further improvements. Efforts to increase the fare carrying capacity resulted in vehicles being made unduly long with consequent decrease of riding qualities.



The largest British Tramcar on four wheels (Southend). Brush body, seating 76 passengers, on Peckham truck, of 13-ft. wheel base.

LONGBASE TRUCKS

Introduced in 1908 to overcome difficulties experienced with trucks based on early American designs having maximum wheel base of 6 to 6½ feet, the Longbase truck enabled the wheel base to be extended by two feet and reduced pitching, rolling and swaying caused by long overhang of the body extended beyond each end of the truck supports. The effect was accentuated on double deck vehicles, some of them being 27 feet long, carrying 60 passengers. Unwanted movement racked the joints of woodwork, ground the track and wheels and caused unpleasant effects on passengers. In some cases damage to rolling stock and track, also the discomfort to passengers reached unacceptable limits and cars had either to be shortened or the riding qualities improved by the use of two bogies.

The Longbase truck successfully overcame the difficulties experienced with long bodies and single trucks and at the time was hailed as one of the most valuable improvements introduced since electric tramcars first came into service. Even so, the quest for improvements continued.

PECKHAM TRUCKS

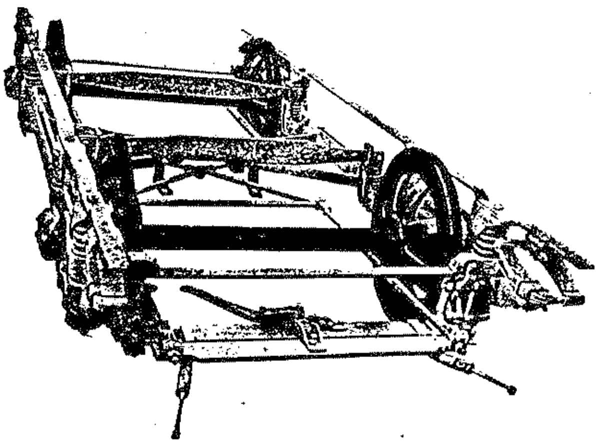
Manufactured by Brush under a sole licence arrangement with the inventor, the type was characterised by a pendulum form of suspension which absorbed side shocks and eliminated side swinging of the car. Flexibility of construction permitted easy negotiation of curves without grinding of wheels and rails. Longer wheel bases than for rigid axle trucks could also be used. A motor was mounted on each of the two axles, providing maximum traction efficiency. Rapid acceleration was also possible, an important feature on routes containing frequent stops.

The first tramcars with Peckham trucks were built in 1912 for Southend Corporation Tramways. They were the largest British Tramcars on four wheels, seating 76 passengers and having trucks of 13 feet wheel base, just double that of the first American designs.

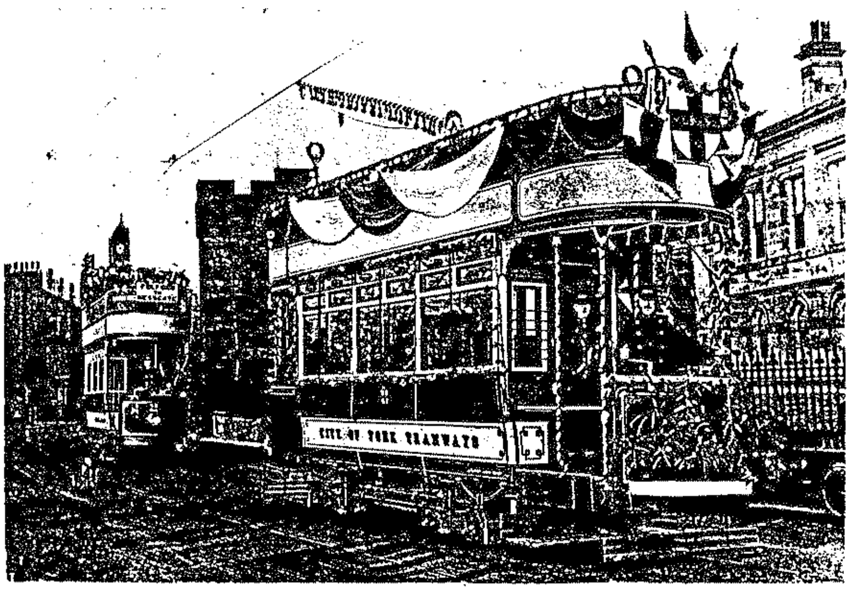
Eight-wheel tramcars with two four-wheel bogies were rendered obsolete by this development which gave smoother operation and reduced dead weight with beneficial effects on power consumption.

In addition to the types described many trucks and bogies were built for use with railway coaches and wagons made by the Company. A workshop erected in 1900 with equipment specially for the manufacture of trucks, rapidly became a business in its own right. Soundness of design and reliability of construction caused big orders to be attracted. Municipalities, Railways and other undertakings ordered substantial quantities for use with vehicles assembled in their own workshops.

Continued for nearly forty years, the activity declined in the 1930's and when it ceased the old Truck Shop was converted for use as a welding workshop, fabricating parts required by the engineering departments.



Brush-built Peckham Truck for Liverpool Tramways.



OPENING OF YORK ELECTRIC TRAMWAYS - CARS ON THE FULFORD ROUTE PASSING THE CASTLE. 1910
This illustration shows clearly the general design of the Brush Longbase truck of 8 ft. wheel base.

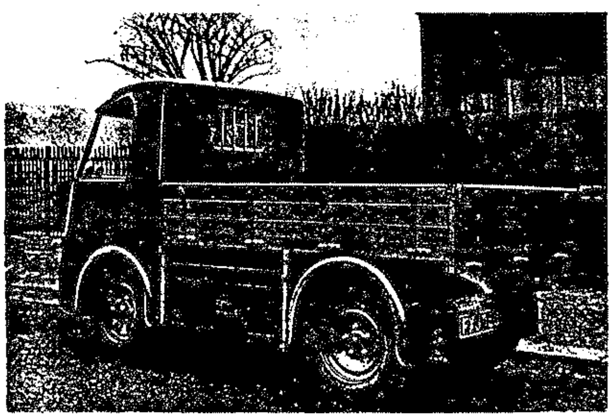
9. BATTERY ELECTRIC VEHICLES

The application of electric storage batteries to transport vehicles was tried in the early days of tramcars but excessive weight of the batteries was then found to be an insuperable obstacle to economic development of this form of transport. As batteries improved, particularly under the stimulus of the automobile industry, the attractions of battery-electric vehicles for short distance work with small vehicles, such as tradesmen's delivery vehicles, became more pronounced.

Two-ton electric lorries for local deliveries of such household commodities as bread, milk, groceries, etc. began to appear about 1935 and quickly became established in large numbers in the following years. The outbreak of war in 1939 put a stop to further development but toward the end of the war in 1945 it became apparent to those in the industry that the use of battery electric vehicles would receive a further impetus in peacetime conditions because of the chronic shortage of petrol for civilian needs. The scarcity was expected to persist because of the lack of shipping capacity to import petroleum oils to the United Kingdom. Emphasis was therefore placed on the use of home produced fuel.

It was at this point that the Brush Company decided to enter the field as manufacturers of battery-electric vehicles and at the end of 1945 three models were put on the market having four-wheeled chassis suitable for loads of half, one, and one and a half tons respectively. The maximum range of these vehicles was about 50 miles of continuous running, but with frequent stops and starts of about 8 times per mile the range was reduced to 35 miles.

Typical battery-electric delivery vehicles.



Electric motors of 10 and 12 horsepower were fitted which permitted maximum speeds attainable on the level when fully loaded of 18 miles per hour. These vehicles with bodywork by Brush Coachworks Limited had a considerable vogue for about seven years and hundreds were supplied to organisations concerned with local deliveries, e.g. dairies, laundries, bakers, grocers, departmental stores, coal merchants and the like.

They were used by some municipalities for refuse collection.

The following is a calculation of operating costs made in 1945:-

OPERATING COSTS OF "BRUSH" BATTERY ELECTRIC VEHICLES

(Based on prices at 31.12.45)

Batteries - 10/14 cwt. 30 cells 193 amp.hrs.
18/22 cwt. 36 cells 226 amp.hrs.
25/30 cwt. 36 cells 290 amp.hrs.

10 years life assumed for Vehicle and Charger. 3 years life assumed for Battery. Allowance made for scrap value of Battery.

MODEL	10/14 cwt.	18/22 cwt.	25/30 cwt.
CAPITAL OUTLAY:	£. s. d.	£. s. d.	£. s. d.
Chassis complete	353. 0. 0.	473. 0. 0.	573. 0. 0.
Body	106. 0. 0.	115. 0. 0.	125. 0. 0.
Charger and Relay	59. 14. 0.	75. 15. 0.	111. 6. 0.
Total including battery	518. 14. 0.	663. 15. 0.	809. 6. 0.
Total excluding battery	424. 9. 0.	535. 4. 0.	650. 0. 0.
STANDING CHARGES:	£. s. d.	£. s. d.	£. s. d.
Interest 3% of total cost	15. 11. 3.	19. 18. 3.	24. 5. 7.
Deprec. 8.72% of Vehicle Charger	37. 0. 0.	46. 13. 5.	56. 13. 7.
Deprec. 32.4% of Battery	27. 12. 0.	37. 8. 0.	46. 8. 0.
Licence	15. 0. 0.	15. 0. 0.	20. 0. 0.
Insurance	10. 5. 0.	11. 5. 0.	14. 0. 0.
Total per annum	105. 8. 3.	130. 4. 8.	161. 7. 2.
Total per week	2. 0. 7.	2. 10. 1.	3. 2. 0.
RUNNING COSTS:	d.	d.	d.
Electricity @ ½d	.24	.33	.48
Tyres	.27	.40	.47
Repairs & maintenance	.30	.34	.40
Oil	.03	.03	.03
Total pence per mile	.84	1.10	1.38
COST/WEEK - 175 miles	£. s. d.	£. s. d.	£. s. d.
Standing Charges	2. 0. 7.	2. 10. 1.	3. 2. 0.
Running costs	14. 0.	18. 4.	1. 3. 0.
Total	2. 14. 7.	3. 8. 5.	4. 5. 0.

NOTE: *Tyre costs are based on pre-war rubber tyres. Synthetic rubber would probably increase the tyre cost per mile to the region of .50, .70 and .80d for the 10/14, 18/22 and 25/30 cwt. models respectively.*

The success of this venture is indicated by the fact that four years after commencing the business, Brush had supplied about one third of all the electric vehicles in use in the United Kingdom, although they were in competition with fifteen other manufacturers.

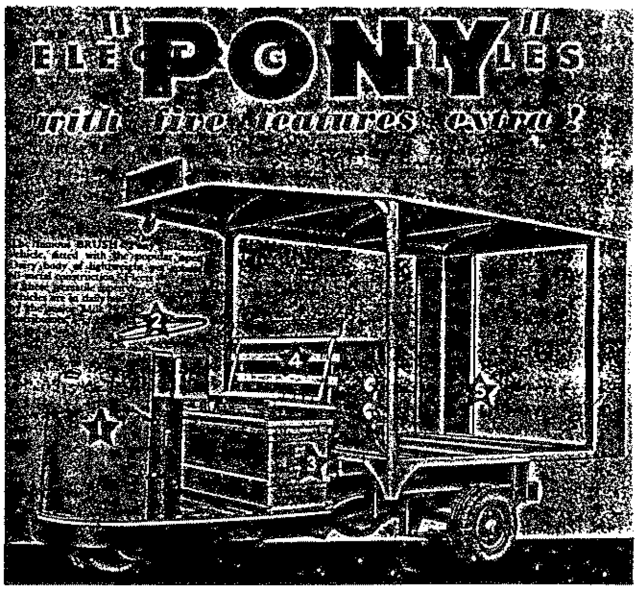
Gradual easing of restrictions on the use of petrol and developments in the mass production of petrol motor vehicles changed the economic advantages of electric vehicles and in 1952 the Company ceased to make four wheeled models, preferring to concentrate on a cheaper three-wheeled type which embodied the Brush 'PONY', a recent development aimed at the growing market for industrial electric trucks.

THE BRUSH PONY

This name was given to an ingeniously designed power unit comprising a single front wheel chain driven by a geared electric motor of 2¼ horsepower and mounted directly above it. Above the motor was a four-speed controller built round a steering column which projected vertically through an enclosure to a steering wheel. Close behind was the battery box which also provided a seat for the driver. The entire assembly was supported by a steel underframe adapted for connection to a trailing two-wheeled truck providing a three-wheeled vehicle.

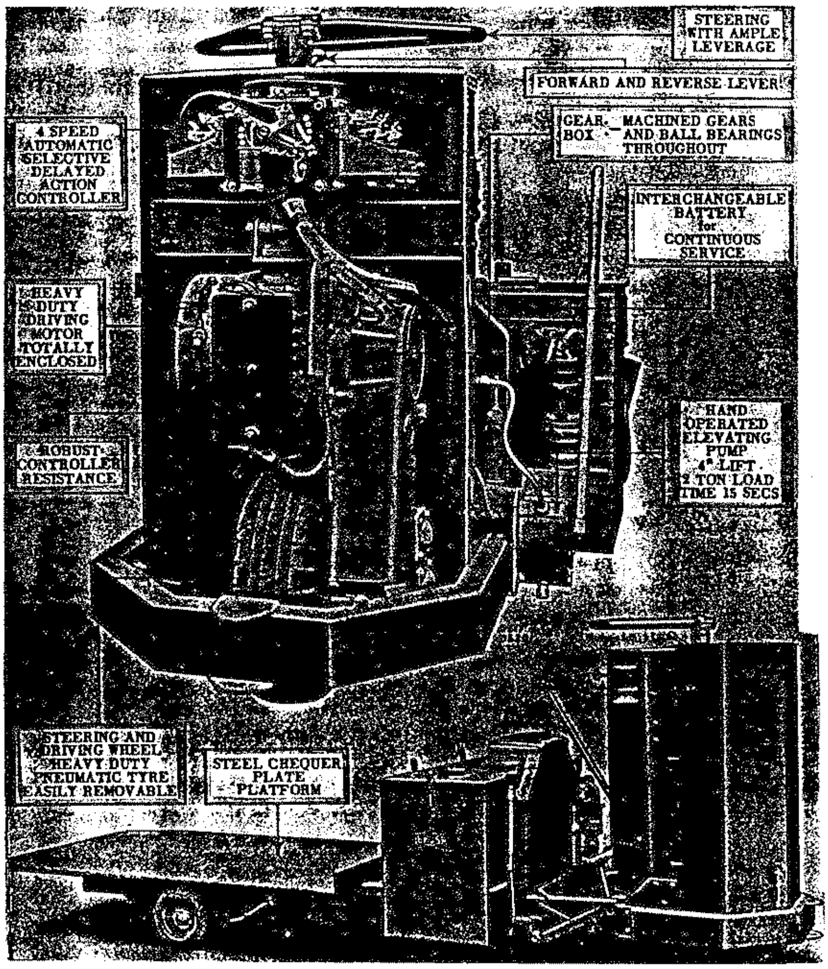
For industrial purposes trucks were made to carry loads up to 2 tons and loading platforms on the trucks could be elevated and lowered by hydraulic means from a hand operated pump located near the drivers seat. This feature made the vehicles particularly suitable for pallet loading in factories, while the steering column being capable of turning through 90 degrees angle allowed easy manoeuvrability in confined spaces.

Introduced in 1947 the Brush Pony was an immediate success. At that time there was much wasteful use of manpower in industry by the employment of men to carry or haul goods and materials. The movement of materials increases their cost without adding to the value, and as appreciation grew of savings in time and cost that could be effected by the use of power driven trucks the Brush business expanded from a small beginning to become a substantial activity.



Special features illustrated are:-

1. Enclosed power unit, with dust and waterproof cover.
2. 180° steering lock, facilitating quick turn round.
3. Heavy duty battery guaranteed for 4 years.
4. Bench type drivers seat under cover.
5. Pay-load capacity up to 18 cwts.



Industrial truck with carrying capacity up to two tons.

Capable of a normal days work at 5 miles per hour on a single battery charge.

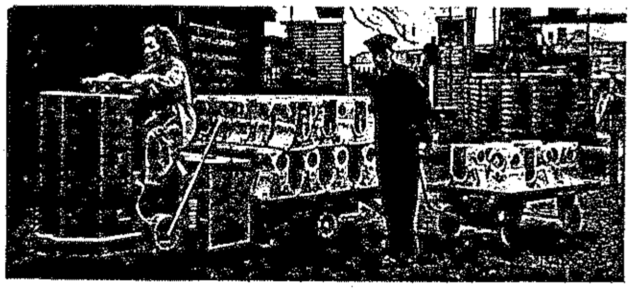
Removal of the front cover provided ready accessibility to the working parts of the Pony.

This vehicle could be turned in a radius of six feet, little more than half its overall length.

Electric trucks had to compete with petrol engined types but many customers favoured the electric models because of their freedom from noise and fumes which made them particularly suitable for use in clean environments, exemplified by the application of Pony battery electric vehicles to hospital services also for food carrying and ambulance vans, dairy work and the like.

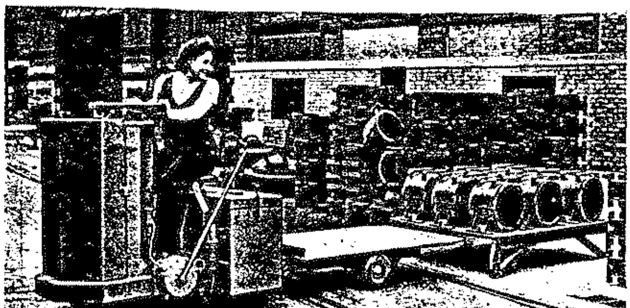
These three-wheeled vehicles were the only products that remained of the former Brush Coachwork Limited which closed down in 1952 and by 1957 battery electric vehicles employing 24 people with 8,250 square feet of floor space comprised the smallest department of Brush.

Nevertheless there was a steady and persistent demand and seeking to extend and improve their range of products of this type the Company made an arrangement in 1960 with the Barrett Cravens Company of Illinois, U.S.A., to manufacture designs of battery electric vehicles. The franchise included world manufacturing and selling rights except North and South America, Japan and the Caribbean.



Contrast between new and old methods of handling materials.

Pallet loading of materials and components saves hours of man handling.



THE BRUSH OX

More strictly known as the Brush-Barrett Powerox the first products of the collaboration were demonstrated at the Mechanical Handling Exhibition at Earls Court, London, in May 1962. The exhibits comprised two forms of industrial vehicles, one a stand-up rider tractor with a speed of 3¼ miles per hour when hauling a rolling load of 10,000 lbs., and the other a pedestrian controlled platform and pallet truck for loads of 4,000 lbs.

The tractor was about four feet long and 27½ inches wide. It had three wheels, the front wheel being power driven. The driver stood on a platform behind the battery box. Being a self-contained vehicle it was capable of hauling a variety of trailing loads including trains of trucks coupled together. The other vehicle, a platform truck had rear wheels set further back as in the conventional industrial truck and a standardised power head with a single front wheel. It was suitable for fixing to trucks and platforms in a range of sizes. Manual controls were operated on the handle from a walking position.

In May 1961 the B.E.V. Department, which operated within the organisation of the traction Division moved out of Falcon Works to Cliff Works, Burton-on-the-Wolds, about 4 miles from Loughborough. Buildings were taken over previously occupied by Petters Service Department. The premises provided increased manufacturing facilities to cope with expanding production and also gave scope for further development.

10. DIESEL-ELECTRIC LOCOMOTIVES

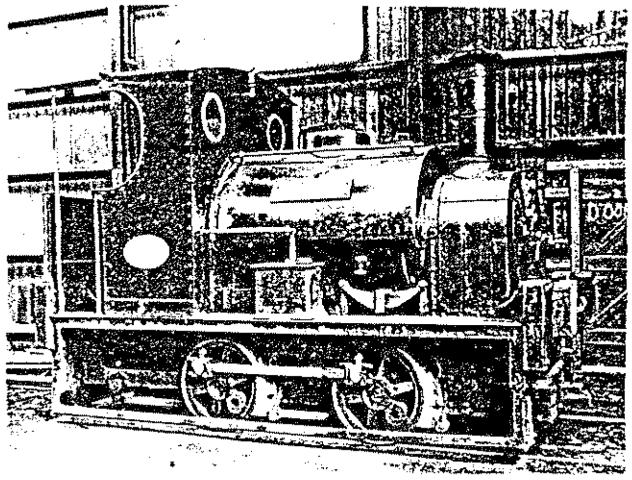
Brush commenced to manufacture oil engines in 1933. They were low speed (300 r.p.m.) engines with horizontally opposed cylinders designed by H.V. Senior who joined the Company to take charge of a newly established Engine Department. A useful business was built up during the next few years and much experience was gained of the design, construction, installation and operation of diesel-electric generating sets.

About this time the application of oil engines to the propulsion of locomotives was gaining ground and railway systems in the United States, also in Germany, introduced locomotives of this type on a large scale. In England, the London, Midland and Scottish Railway put into service a number of diesel-electric shunting locomotives with engines of 350 h.p., which proved to have several advantages compared with steam locomotives, in availability, economy of operation and cleanliness.

This promising new field was one which Brush by its tradition and experience was well qualified to enter but the period 1930 to 1938 was a time of intense industrial depression and the high cost of development with little prospect of quick returns was a serious obstacle.

The first venture was a conversion of an old steam locomotive named "SPRITE" used for shunting and haulage duties on the works internal transport system. Built at Falcon Works in 1899, this locomotive was in daily service for about forty years and had a single driver named Yates for most of that time. Toward the end of 1938 Yates became ill, and by a curious affinity between locomotive and driver, Sprite broke down a few days later, indicating a need for extensive repairs.

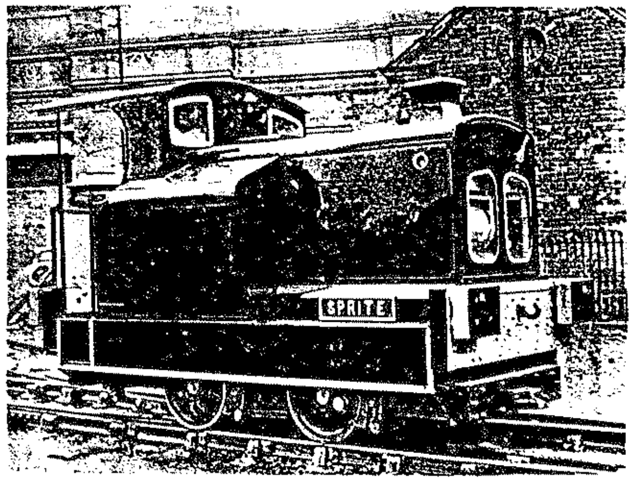
It was decided to rebuild "Sprite" as a diesel-electric shunting locomotive for experimental purposes. A direct-current generator and two old traction motors were found in the Works, a 50 h.p. engine was taken from stock, simple control gear was made, and early in 1940 the locomotive re-entered service in its new form. The reconstructed "Sprite" operated successfully for about ten years before it was finally withdrawn from service.



The first experiment with diesel-electric traction at Falcon Works.

ABOVE: A 40 year old steam locomotive used for yard shunting and haulage.

BELOW: The same locomotive after conversion to diesel-electric propulsion in 1940.



SHUNTING LOCOMOTIVES

Based on this success the next step was to build a prototype shunting locomotive to a specification approved by the British Railway Companys. Negotiations with the London and North Eastern Railway Company resulted in an agreement for a Brush built locomotive to be accepted for trial in the shunting yards of the Railway and paid for only if extensive operation on regular duties proved the locomotive to be entirely satisfactory.

Construction was hindered during the war of 1939-45 because of the shortage of labour and materials and the need to concentrate on war effort, but when the war ended in 1945 rapid progress was made and the completed locomotive was delivered in 1946.

The power unit was a Petter superscavenge two-stroke oil engine, started by compressed air and rated at 400 h.p. direct coupled to a Brush traction generator of 190 kW continuous rating at 600 r.p.m. A rigid 0–6–0 frame, had three axles with two motors, each motor driving an outer axle through double reduction spur gearing. Both motors were ventilated by a separate motor driven fan, mounted on the frame. All the power equipment was made at Loughborough including the Petter engine, the Petter business having been acquired by Brush in 1938.

A similar set of equipment was supplied to the Great Western Railway Company for use in a locomotive constructed in the railway workshops at Swindon.

The complete locomotive as delivered to the London and North Eastern Railway weighed 51 tons in full working order. It was capable of a maximum speed of 20 m.p.h. and specially fine speed control was provided between 2 and 5 m.p.h. for hump shunting.

After extensive trials in various railway yards, and the correction of a few small teething troubles, the locomotive was bought by the L.N.E.R. in 1948 and put into regular service.

CORAS IOMPAIR EIREANN

During the 1939-45 war the Irish State Railways (C.I.E.) experienced grave difficulty in obtaining fuel for locomotives because of the virtual cessation of coal exports from Britain. Some locomotives were fitted with oil burners for raising steam and some had recourse to the use of wood as a fuel, with poor results in each case. The railway authorities resolved to install diesel-electric locomotives as quickly as possible to assist the shunting and mixed haulage work around Dublin.

Brush were called in to advise, in collaboration with Associated Locomotive Equipment Limited, a sister firm in the Alan Good complex of companies, with many years of railway locomotive experience. As a result arrangements were made in which A.L.E. and Brush assisted the Irish Railway Company to build five locomotives in their own workshops at Inchicore, Dublin using Brush power equipment and including Mirrlees diesel engines. Rated at 535 h.p. the six-cylinder four-stroke engines were pressure charged, and direct coupled each to a 290 kW Brush direct-current traction generator.

This was the first occasion a power exceeding 500 h.p. had been installed on an 0-6-0 wheel arrangement; the high power being dictated by the need for main line transfer work as well as heavy shunting.

The first unit went into service early in 1948 and on 21st March, 1948 the locomotive experimentally hauled a train of 350 tons non-stop from Dublin to Cork, a journey of 165 miles in 8 hours, 40 minutes. Steam locomotives required 11 hours 50 minutes for the same journey. Fuel cost for this test was only a quarter the cost of steam. This result was all the more remarkable because the locomotive was designed for shunting and short hauls with heavy intermittent loads rather than for continuous main line work.

The remaining locomotives were completed at intervals and by the end of 1948, all five were in full operation.

SHUNTING LOCOMOTIVES

The characteristics of diesel-electric locomotives proved to be particularly suitable for heavy shunting duties in steel works and over the next few years the Company supplied a number of locomotives specially designed for these duties. The electrical transmission enabled high torque to be obtained at low speeds combined with accuracy, smoothness and flexibility of speed control. Also by observation of simple instruments drivers could obtain accurate measurement of the load on the engine at any time. These were useful qualities for handling heavy loads of steel and the like.

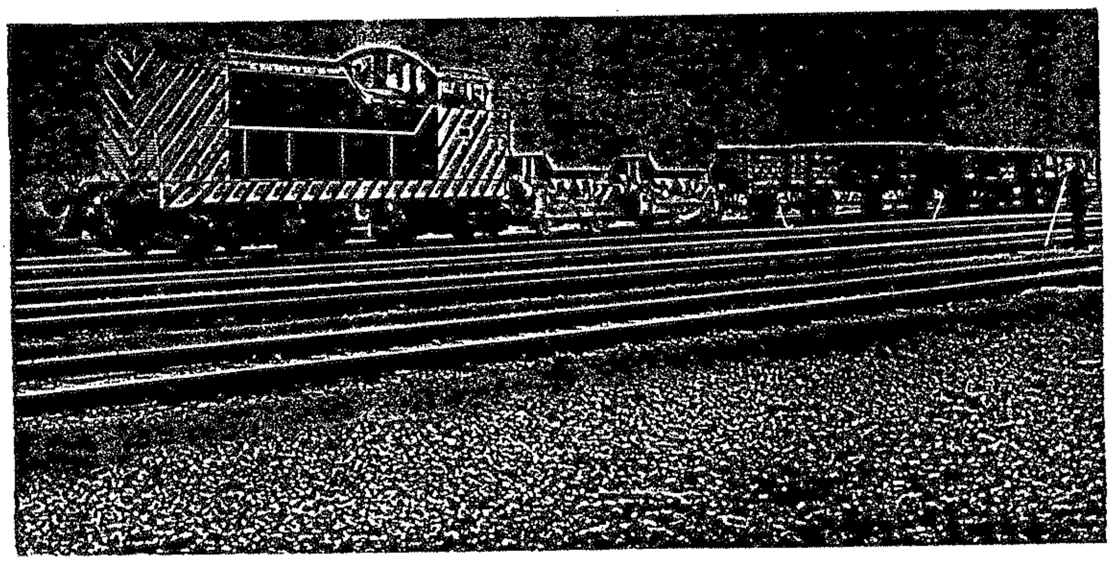
Robust mechanical construction was necessary to withstand high stresses caused by shocks from uneven rails and the bumping of buffers.

Between 1948 and 1962 a series of shunting locomotives was supplied to important steel works in the United Kingdom, a substantial number going to the Steel Company of Wales. This organisation experimented with American built vehicles just after the war but a first trial order with Brush resulted in highly satisfactory performance and they placed several repeat orders. Three 660 horse-power weighing 90 tons each were, at the time of their delivery in 1955, the most powerful diesel-electric shunting locomotives in the United Kingdom.

The rail tracks being unguarded and open to works personnel were a possible source of danger to people walking over them if they failed to observe oncoming locomotives. To obviate such accidents the vehicles were fitted with piercing syrens and also made conspicuous by vivid yellow diagonal stripes and black bands painted on the superstructure, an effect which is noticeable in the photograph. These audible and visible warnings of approach proved effective in their purpose and were applied generally to similar locomotives.

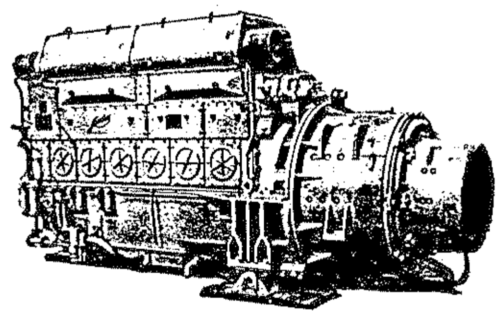
Most of the locomotives had rigid underframes with four or six wheels, but the larger vehicles each had two four-wheeled bogies to spread the axle load and reduce track wear. They were designated Bo–Bo type.

70 ton 515 B.H.P. Locomotive supplied in 1953 for Steel Works duties.



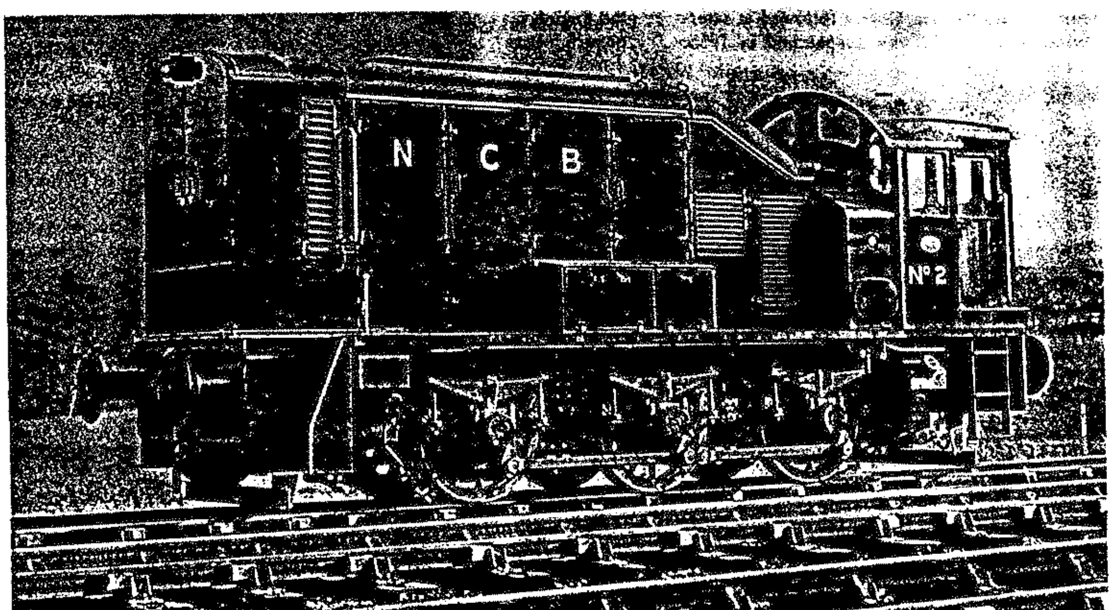
LIST OF DIESEL ELECTRIC SHUNTING LOCOMOTIVES SUPPLIED 1948-62

CUSTOMER	SUPPLIED (Date)	TYPE	ENGINE OUTPUT BHP	ENGINE MAKE	MAX. SPEED MPH	WEIGHT (tons)
Steel Co. of Wales	1948	0-6-0	480	Mirrlees	20	51
Lever Bros.	1950	0-6-0	355	Mirrlees	20	51
Consett Iron	1950	0-6-0	355	Mirrlees	20	51
Steel Co. of Wales	1952	0-6-0	355	Mirrlees	20	51
- do -	1953	0-4-0	300	National	28	45
- do -	1953	Bo-Bo	515	Mirrlees	28	70
National Coal Board	1953	0-6-0	366	National	20	48
Steel Co. of Wales	1955	Bo-Bo	660	Mirrlees	28	90
- do -	1955/6	0-4-0	300	National	28	45
Stewarts & Lloyds	1956	0-6-0	400	Mirrlees	20	51
Steel Co. of Wales	1956	0-4-0	220	National	18	30
- do -	1956	Bo-Bo	515	Mirrlees	28	75
B.R. Eastern Region	1957	0-4-0	200	McLaren	18	30
National Coal Board	1959	0-6-0	400	National	20	48
Parkgate Iron & Steel Co.	1960	0-4-0	200	McLaren	18	34
Renishaw Iron & Steel Co.	1962	0-4-0	200	McLaren	18	30



Power Unit comprising Brush main and auxiliary generators coupled to a MIRRLEES J6 diesel engine arranged for three-point suspension. The engine developed 515 b.h.p. at 875 r.p.m. This unit was typical of many supplied with shunting locomotives.

Supplied to the National Coal Board in 1959 this locomotive was rated at 400 B.H.P. The maximum track speed was 20 miles per hour.



CEYLON GOVERNMENT RAILWAYS

Until 1950 the Brush interests in diesel-electric rail traction were confined to building shunting locomotives up to 500 horsepower but the Company's engineers had closely studied the developments in main line locomotives occuring in several countries notably in U.S.A.

The Technical Director of Brush, Mr. J.H.R. Nixon, made an extensive visit to North America in 1948 and reported favourably on the prospects for diesel-electric traction after studying the operating records of American railways equipped with diesel-electric locomotives for main line services, and also after visiting several manufacturing concerns.

Accordingly, the Company and its Associates decided on a policy of entering this expanding market and they were successful in obtaining in 1950 a first order for twenty-five 1,000 horsepower locomotives from the Crown Agents for the Colonies for the Ceylon Government Railway at a cost of over £1,000,000.

These locomotives were literally sold off the drawing board in the face of keen competition and the order was accepted as a tribute to the technical ability of the Brush-Bagnall team. It was a challenge to the engineering and productive resources of the group.

In view of the importance of the order and the special operating conditions in Ceylon which included tracks with gradients of 1 in 40 rising to an altitude of 6,000 feet with difficult curves as well as tropical humid climatic conditions near the sea coast, two Brush engineers, J.H.R. Nixon and E.P. Hubbard made a complete survey of the entire railway system in Ceylon. They travelled on every mile of track, visited the workshops and in collaboration with the Chief Mechanical Engineer of the Railways, Mr. B.D. Rampala, made detailed notes of every possible feature of operation to be taken into account in the final design of the locomotives.

Speedy delivery was of urgent importance and so a new erecting shop, with an area of 17,000 square feet was constructed at the Loughborough Works, capable of producing 36 main line locomotives a year. In addition a test track was laid down with a separate test house. These facilities materially expedited the completion of locomotives and on 20th November, 1952 with appropriate ceremony the first finished locomotive was formally handed over by Sir Ronald Matthews, Chairman of the Brush Group, to Sir Velubillai Coomaraswamy deputising for His Excellency the High Commissioner for Ceylon.

The first five locomotives went into service in 1953 for proving trials and training drivers and other staff. Others followed at intervals and the last locomotive, the 25th, was despatched in 1955.

Taken from a contemporary publication the locomotives described in the following pages were built within the Brush Group to the order of the Ceylon Government Railways and the Companies cooperating are listed below:

Design and Erection	-	Brush Traction Limited, Loughborough.
Electrical Equipment	-	Brush Electrical Engineering Co. Ltd., Loughborough.
Diesel Engines	-	Mirrlees, Bickerton & Day Ltd., Stockport.
Mechanical Parts	-	W.G. Bagnall Ltd., Stafford.

GENERAL DESCRIPTION

"The locomotive is of the type designated A1A–A1A, the superstructure being mounted on two bogies, each bogie having three axles of which two outer axles are motored whilst the centre axle is for carrying purposes only.

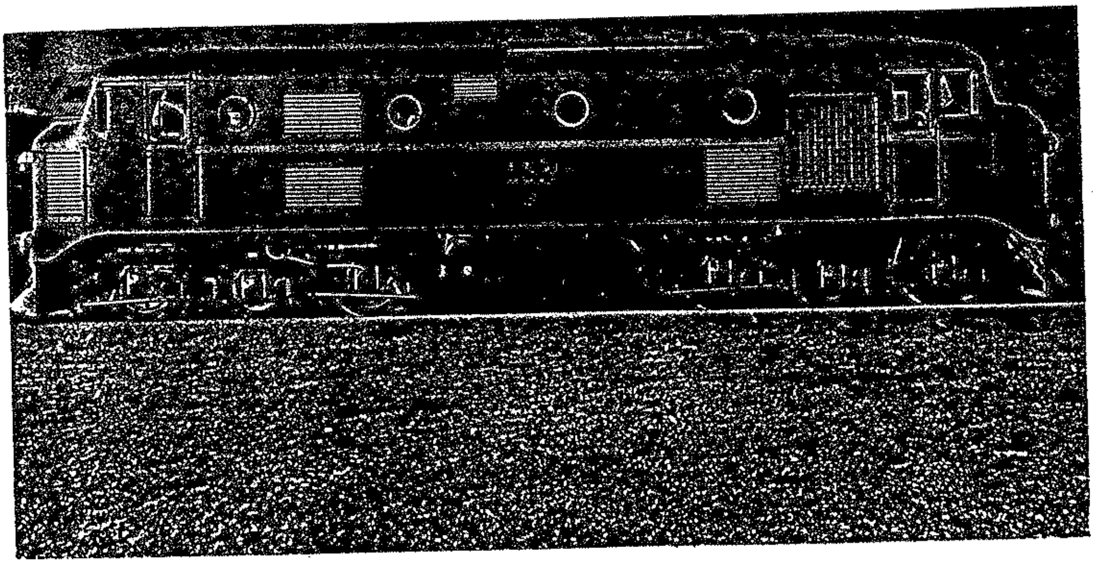
The locomotive superstructure has a driving cab at each end mounted behind a short, streamlined, nose end compartment. The power unit with its auxiliary equipment and control gear is mounted in the main body of the locomotive. A partition separates the engine from the generator and control equipment, and unobstructed walk-ways are provided on both sides of the power unit.

Both driving cabs are fitted with a driver's position and controls on the left-hand side of the cab with an assistant driver's position on the right-hand side of the cab. All instruments essential to the driver are mounted on a panel in front of the driver and his assistant. Unobstructed vision for both men is provided by large driving windows, fitted with pneumatically operated windscreen wipers. A powerful headlamp is fitted into the nose at each end of the locomotive.

Immediately behind No. 1 cab is the main radiator ducting carrying the radiator fan motor and runner. Air is drawn through the radiator panels, which are mounted vertically on either side of the locomotive, and after passing through the twin branches of the ducting is ejected upwards through a grille in the roof.

Access to the main body of the locomotive is provided by doors in the cab bulkheads. At No. 1 end, the centre walk-way through the radiator ducting branches on either side of the diesel engine; the generous loading gauge of the Ceylon Railways allowing sufficient space between engine and locomotive sides for the withdrawal of the engine pistons and connecting rods from the sides of the crankcase."

1000 B.H.P. Locomotive in Ceylon



"Doors are provided in the partition separating the engine and generator compartments and the walk-ways continue on either side of the main and auxiliary generators, exhausters, compressor and control equipment cubicle. Doors in No. 2 cab bulkhead give access into No. 2 driving cab.

The nose end compartments in front of each driving cab contain a traction motor blower, electrically driven which supplies filtered air to the two traction motors in the bogie beneath. Access to the nose compartment is by removable panels inside the cab and by hinged louvre panels on the outside of the locomotive nose.

All auxiliaries are electrically driven with the exception of the engine cooling water circulating pump, which is belt driven from the free end of the crankshaft and the engine lubricating oil pumps, which are gear driven from the crankshaft. Power for the auxiliary machines is taken from the auxiliary generator, which is mounted on an extension of the main generator shaft.

The main fuel tank and batteries are slung beneath the locomotive between the bogies. A separate fuel service tank is mounted in the roof of the locomotive.

Due to the bad weather conditions encountered in Ceylon, which include tropical rain and heavily corrosive salt atmosphere, special care has been taken to make all ventilating and air inlet louvres waterproof and anti-corrosive materials have been used throughout the construction of the locomotive."

DIESEL ENGINE

"The locomotive is powered by a Mirrlees, Bickerton and Day, Vee-type 12 cylinder, turbo-charged four-stroke oil engine, with a rating of 1,254 B.H.P. at 850 r.p.m. under normal temperature and altitude conditions.

Under site conditions in Ceylon, the engine developes 1,000 h.p. at 850 r.p.m.

Lead acid batteries of 192 ampere-hour capacity are provided for starting the main power unit and for supplying the necessary auxiliary power when the diesel engine is not running.

The driving axles are fitted with tubes for the axles suspension of the traction motors, the nose of each traction motor being suspended by a flexible link from the centre transom.

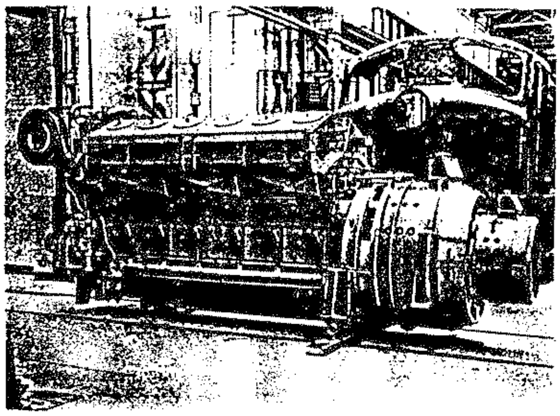
The traction motors are fitted with roller bearings for both the armature and suspension bearings. The drive from the motors to the axles is taken through single reduction gearing; a pinion on the armature shaft meshing with a resilient gear wheel on the road axle."

BRAKE EQUIPMENT

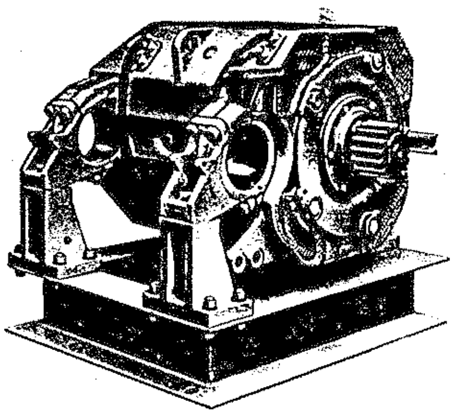
"The locomotive is fitted with twin Westinghouse reciprocating exhausters, electrically driven to provide vacuum for the train brakes. The locomotive itself is braked by compressed air brakes, four brake cylinders being fitted to each bogie and operating clasp brakes on all wheels. A Westinghouse compressor provides compressed air for the locomotive brakes, and also for the control and other auxiliary equipment.

The driver's brake controls consist of a vacuum brake valve which operates the train brakes and automatically operates the locomotive brakes through a proportional valve. This valve ensures that the locomotive air braking is applied in direct proportion to the vacuum braking on the train. A separate brake valve is supplied which gives independent braking on the locomotive when required.

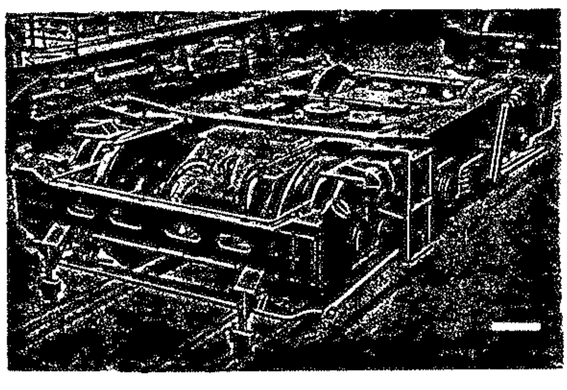
A hand brake for the locomotive is also provided in each driving cab."



Power Unit for 1000 B.H.P. Locomotive.



One of the driving motors.



Bogie with motors assembled.

CONSTRUCTIONAL DETAILS

Underframe

"The underframe is constructed of four main rolled steel 'I' sections which are reduced in depth over the bogies by means of flame cutting and welding along the neutral axis, in order to provide clearance for the bogies between underframe and rail head.

The two outer main members terminate at the bogie centre cross members, to which they are welded, but the inner main longtitudinals continue and are welded integral with the fabricated drag box.

Cross members, which are riveted to the main longtitudinals at various points along the underframe, carry channel section sole-bars and an unbroken deck of steel plate covers the underframe skeleton."

Superstructure

"The superstructure is constructed in sections comprising the two cab ends, two sides, and three roof sections.

All the superstructure is constructed of 14 gauge steel sheet welded to frameworks of angle and top hat section.

Entrance doors to the locomotive are provided on each side of both driving cabs. Top hatches in the roof section permit easy access to the cylinder heads of the diesel engine, and the roof itself is easily removable for major overhauls or complete removal of the power unit.

Port-hole type windows are provided in the sides of the engine and generator compartments, and full drop windows are provided in the cab doors and side windows."

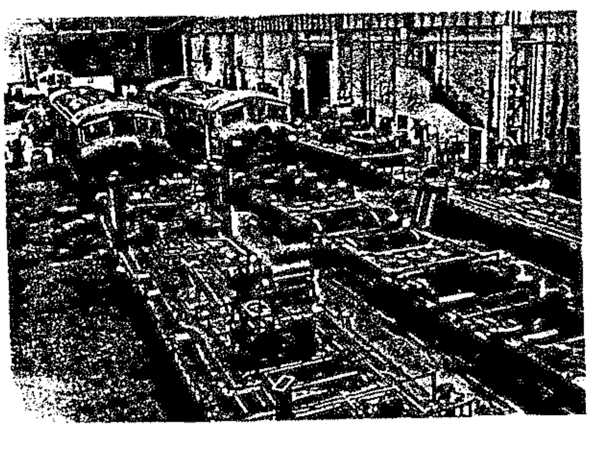
Bogies

"The bogies are constructed from box type side frames of welded construction joined by a heavy fabricated steel centre transom, and by two channel members as headstocks.

The weight of the locomotive is carried on the centre bolsters of the bogies. Each bolster rests on eight nests of coil springs carried on two spring planks, one on each side of the centre carrier axle of each bogie. The spring planks in turn are suspended by swing links from the bogie side frames.

The leaf springs for the axles are carried internally in the hollow side frames, suitable openings being provided for inspection and withdrawal, whilst the coil springs are situated below the bogie frames.

Roller bearing axle boxes are fitted in manganese steel horn guides, which are replaceable."



A part of the erection shop with locomotives for Ceylon being constructed.

PRINCIPAL DATA (CEYLON LOCOMOTIVES)

Locomotive Details

Locomotive weight	87 tons
Track gauge	5' 6"
Maximum height	13'3½"
Maximum width	10' 3.7/8"
Length over buffers	50' 9"
Bogie wheel base	10' 6"
Bogie centres	27' 0"
Minimum curve negotiable	5 chains
Clearance from Gearcase to Rail Head	4½"
Capacity of fuel tank - main	775 gallons
- service	75 gallons
Wheel diameter - motored	3' 7"
- carrier	3' 0"

Locomotive Performance

Maximum speed	55 m.p.h.
Starting Tractive Effort (26% Adhesion)	33,700 lbs.
Tractive Effort (1 hour rating)	30,000 lbs at 9.2 m.p.h.
Tractive Effort (continuous)	24,600 lbs at 11.7 m.p.h.
Estimated range with Full Fuel Tanks	750 miles

Diesel Engine Details

Maker	Mirrlees, Bickerton & Day
Type	JS12VT
Output at Sea Level and normal temperature and Humidity conditions	1,254 H.P. at 850 R.P.M.
Developed continuous power at site	1,000 H.P. at 850 R.P.M.
Bore	9¾"
Stroke	10½"
Number of Cylinders	12
Superchargers	Two, Napier type TS200/1
Exhaust Temperature (Cylinder outlet full load)	750°F/850°F
Lubricating oil pressure	30 lbs/sq. inch.

Electrical Equipment Details

Main Generator	Brush Electrical Engineering Co.
Continuous rating	850 r.p.m., 652 kW, 630 V, 1,035 A. 850 r.p.m., 652 kW, 750 V, 870 A.
Auxiliary Generator	Brush Electrical Engineering Co.
Continuous rating	850 r.p.m., 35 kW, 110 V, 318 A.
Traction Motors	Brush Electrical Engineering Co.
Number per locomotive	4
Continuous rating	196 h.p., 315 V, 517.5 A.
1 hour rating	226 h.p., 315 V, 610 A.
Gear Ratio	82:16
Radiator Fan Motor	Brush Electrical Engineering Co.
Continuous Rating	110 V, 3.1 h.p./12.6 h.p. 32/115A 600/960 r.p.m.
Traction Motor Blower Motors	Brush Electrical Engineering Co.
Continuous rating	110 V, 5 h.p., 1980 r.p.m.
Exhauster Motors	Brush Electrical Engineering Co.
Continuous rating	110 V, 3/6.05 h.p., 19/55 A. 600/1,115 r.p.m.
Compressor Motor	Westinghouse Brake & Signal Co.

Auxiliary Equipment Details

Compressor	Westinghouse Brake & Signal Co.
Working Pressure	85/100 lbs/sq. inch
Exhausters	Westinghouse Brake & Signal Co.
Type	4-cylinder reciprocating (4V110).
Normal speed	600 r.p.m.
"Release" speed	1,115 r.p.m.
Batteries	D.P. Battery Co. Ltd.
Number of cells	48
Capacity	192 amp. hours @ 5-hour rate
Traction Motor Blower	Sturtevant
Output	2,940 cu.ft. per min. 2,170 r.p.m.
Radiators	Serck Radiators Limited
Axle Box Bearings	The Skefco Ball Bearing Co. Ltd.

BRITISH RAILWAYS

The British Transport Commission announced in 1955 an extensive plan for the modernisation and re-equipment of the national railways system, at an estimated cost of £1200 million.

The Plan included a programme for the replacement of steam motive power by electric and diesel traction which required the electrification of large mileages of route, and the introduction of several thousand electric and diesel locomotives. The development was in line with railway experience elsewhere, particularly in North America and Europe where the introduction of newer forms of motive power rendered steam locomotives obsolescent after more than one hundred years steam dominance of railway traction. No steam locomotives were built in the United States since 1953, and one of the largest manufacturers stopped building them in 1948. Apart from the technological advances inherent in these changes the end of the steam locomotive was hastened by social factors such as an insistent demand for greater cleanliness and reduced air pollution, the revulsion of labour to heavy and dirty work of shovelling coal on fires and aversion to firebox and boiler cleaning. Cheap coal, low wages and a plentiful supply of labour were necessary conditions for the continued use of steam for motive power and these factors no longer existed.

Technical advantages to be gained from dieselisation and electrification included improved utilisation of fewer locomotives, better acceleration and smoother riding, more convenient handling of fuel, and general improvements in the economy and efficiency of services.

Electrification of the main lines suffered an initial disadvantage. Extensive engineering works were necessary for the erection of overhead lines, modifications to signalling and tele-communications, and the like, before a single locomotive could be run on the track. In contrast, diesel locomotives could be put into operation immediately when received from the constructors.

Emphasis was therefore placed on the speedy delivery of diesel locomotives, and in meeting this requirement the Brush Company played a notable part.

TYPE 2 LOCOMOTIVES

Successful completion of the Ceylon contract and the experience gained established Brush as constructors of large diesel electric locomotives. Also by 1955 the Traction Division had a well integrated design team and manufacturing unit ready for new assignments. The Ceylon design substantially fitted the specification for 'Type 2' locomotives required for British Railways so the Company was well placed at this time to make a good start to the modernisation 'Plan'.

The first order on this account received in November, 1955, was for twenty 1250 horsepower locomotives designated A1A–A1A for the Eastern Region of British Railways. It was valued at more than £1.5 million. The locomotives were powered by Mirrlees vee-type 12 cylinder oil engines coupled to Brush direct current generators. There were 6 axles with four 250 horsepower Brush Traction motors. Each locomotive weighed 104 tons and had a maximum speed of 75 miles per hour.

A stipulation of the contract was that delivery of the first locomotive should be within two years with others to follow at regular intervals. In fact the first locomotive was finished five weeks ahead of schedule and on Thursday, 31st October, 1957, a ceremony took place in the locomotive erecting shop at Loughborough when Mr. Geoffrey Eley, Chairman of the Brush Group formally handed over the locomotive numbered D5500 to Sir Reginald Wilson, member of the British Transport Commission, and Chairman of the Commissions Eastern Area Board. He accepted on behalf of British Railways Eastern Region, and afterwards drove the locomotive on the test track.

Further deliveries followed regularly and on time. As the locomotives entered service exactly as planned and gave a good account of themselves operationally the Brush reputation grew among railway men for high quality of production, sound design, efficient operation, and strict adherence to delivery schedules.

In consequence further orders were placed for this type of locomotive, with successive increases of power. After the first twenty at 1250 horsepower, the next batch of 226 were rated at 1365 horsepower and a further 17 were uprated to 1600 horsepower. In all, 263 'Type 2' locomotives were made for British Railways to comprise the greater part of the Eastern Regions diesel electric fleet - the largest number supplied by a private contractor.

Sir Reginald Wilson receiving the first locomotive built at Loughborough for British Railways Eastern Region on 31st October, 1957.
Seated in the middle is Geoffrey Eley, Chairman of the Brush Group, on his left Mr. R.C. Bond of the British Transport Commission, and Maurice Tattersfield (standing) then Managing Director of Brush, Loughborough.
Immediately to the right of Sir Reginald is Ian T. Morrow, Managing Director of the Brush Group and standing is F.H. Wood manager of Brush Traction Ltd., afterwards Chairman and Managing Director of Brush in 1964.

Twenty were built in 1958, sixty in 1959, one hundred in 1960, and the remainder in 1961. Punctually at midday on Thursday of each week British Railways drivers collected one or two new locomotives from the sidings at Loughborough and took them under their own power to the Chief Mechanical and Electrical Engineers department at Doncaster. There, they were checked and subjected to acceptance trials, one trial was to haul a ten coach passenger express to Peterborough and back and another was a 750 ton freight trip to Spalding. On these runs every aspect of performance was checked. Within six days Brush received their acceptance certificates and the new locomotives were handed over for immediate service.

Description of 1365 horsepower A1A–A1A Type 2 diesel electric locomotives from a contemporary brochure.

These locomotives were built to the order of the BRITISH TRANSPORT COMMISSION and the Companies co-operating are listed below:

DESIGN AND ERECTION
(Traction Division)
Brush Electrical Engineering Co. Ltd., Loughborough, England.

ELECTRICAL EQUIPMENT
Brush Electrical Engineering Co. Ltd., Loughborough, England.

DIESEL ENGINES
Mirrlees, Bickerton & Day Ltd., Stockport, England.

MECHANICAL PARTS
W.G. Bagnall Ltd., Stafford, England, and Beyer Peacock Ltd., Gorton, Manchester.

The locomotives were of the type designated A1A–A1A, the superstructure being mounted on two bogies, each bogie having three axles of which two outer axles were motored whilst the centre axle was for carrying purposes only.

LOCOMOTIVE PERFORMANCE

Maximum speed	90 m.p.h.
Starting tractive effort	36,000 lbs.
Tractive effort (1 hour rating)	21,200 lbs. at 18.8 m.p.h.
Tractive effort (continuous)	18,800 lbs. at 21.5 m.p.h.
Estimated range with fuel tanks full	500 miles.

Electrical Equipment Details

Main generator	Brush Electrical Engineering Co.
Continuous rating	900 r.p.m., 900 kW, 750 volts, 1,200 amps. 900 r.p.m., 900 kW, 900 volts, 1,000 amps.
Auxiliary generator	Brush Electrical Engineering Co.
Continuous rating	450/900 r.p.m., 30 kW, 110 volts, 273 amps.
Traction motors	Brush Electrical Engineering Co.
Number per locomotive	Four
Continuous rating	275 b.h.p., 375 volts, 600 amps, 530 r.p.m.
One hour rating	270 b.h.p., 340 volts, 660 amps, 460 r.p.m.
Gear ratio	19 : 60
Traction motor blower motors	Brush Electrical Engineering Co.
Continuous rating	110 volts, 7.3 b.h.p., 1,740 r.p.m.
Exhauster motors	Brush Electrical Engineering Co.
Continuous rating	110 volts, 3/6.4 b.h.p., 29/59 amps., 600/1,200 r.p.m.
Compressor motor	Westinghouse Brake & Signal Co.
Control equipment	Brush Electrical Engineering Co.

Locomotive Details

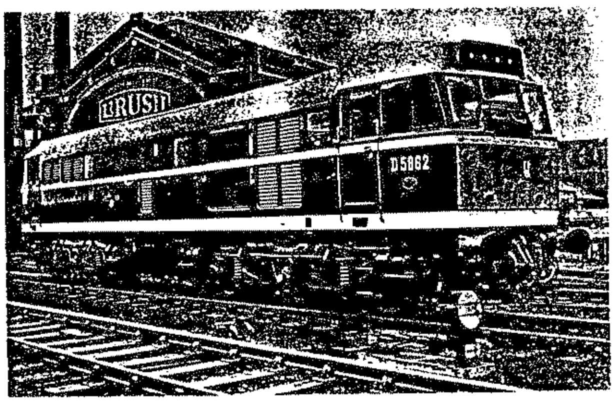
Locomotive weight	104 tons
Track gauge	4' 8½"
Maximum height	12' 7"
Maximum width	8' 9"
Length over buffers	56' 9"
Bogie wheel base	14' 0"
Bogie centres	28' 10"
Minimum curve negotiable	4½ chains
Clearance from gearcase to rail head	6½"
Capacity of fuel tank - Main	500 gallons
Service	50 gallons
Wheel diameter - Motored	3' 7"
Carrier	3' 3½"

Diesel Engine Details

Maker	Mirrlees, Bickerton & Day Ltd.
Type	JVS12T
Output at sea level and normal temperature and humidity conditions	1,365 h.p. at 900 r.p.m.
Bore	9¾"
Stroke	10½"
Number of Cylinders	Twelve
Superchargers	Two, Brush
Exhaust temperature (Cylinder outlet full load)	750°F./850°F.
Lubricating oil pressure	45 lbs./sq. in.

Auxiliary Equipment Details

Compressor	Westinghouse Brake & Signal Co.
Working pressure	85/100 lbs./sq. in.
Exhausters	Westinghouse Brake & Signal Co.
Type	4 cylinder reciprocating (4V110)
Normal speed	600 r.p.m.
"Release" speed	1,200 r.p.m.
Batteries	D.P. Battery Co. Ltd.
Number of Cells	Forty-eight
Capacity	192 amp. hours @ 5 hour rate.
Traction motor blower	Sturtevant
Output	4,400 cu.ft. per min 1,740 r.p.m.
Radiators	Serck Radiators Limited.
Axle box bearings	Hoffman Manufacturing Co. Ltd.



Type 2 Locomotive ready to leave the Works.

TYPE 2 LOCOMOTIVES IN SERVICE

The locomotives became the mixed traffic "work-horses" of the Eastern Region, regularly hauling named trains such as the "Fenman", "East Essex Coast Enterprise", the "Lea Valley Enterprise", and sometimes heading the "Broadsman", 'East Anglian', and 'Norfolkman'.

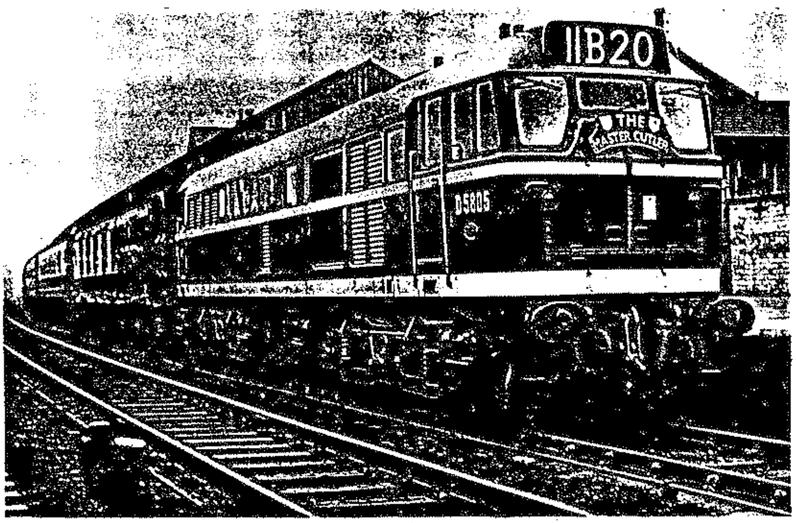
Drivers accustomed to the foot plates of steam locomotives found a new elegance in the cabs provided for them. Seated on cushioned seats, protected from weather and with a clear view of the track before them, they manipulated one control lever and two brake handles while observing a few dials denoting speed, current and voltage. The cabs were electrically heated and contained an electric cooker with grill, hot plate and oven.

As one driver is reported to have remarked, he could now go to work in his best suit and cook and eat a four course dinner on the journey. It was the end of soot and greasy overalls, coaldust and flying sparks.

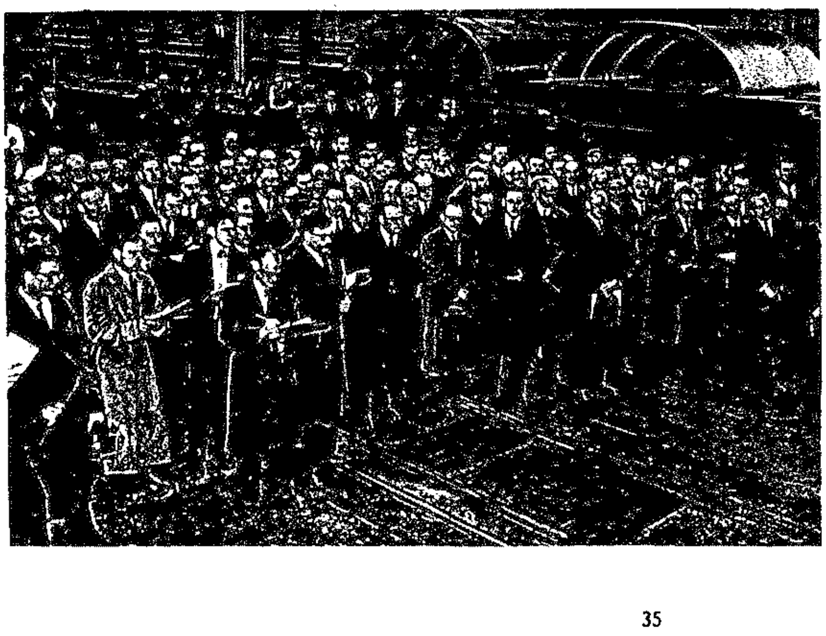
Maintenance of regular schedules day in and day out attracts no attention except from the operating staff and the manufacturers concerned for the good performance of their products, but one disturbing incident occured on 11th January, 1961, that caused much public comment and large headlines in the newspapers. It happened to one of the latest 1600 horsepower Brush locomotives hauling the 'Fenman' express from Liverpool Street, London to Kings Lynn. Attached to the rear of the train was a royal coach conveying H.M. Queen Elizabeth to Sandringham, and 45 minutes after leaving Liverpool Street Station the engine broke down. The train was stationary for nearly one hour until a steam locomotive arrived to enable the journey to be continued.

The Press made much of the incident, calling into question the general reliability of diesel locomotives, but investigation showed that the trouble was caused by the failure of a lubricating oil pump, a proprietary article not made by the Company. A letter of apology and explanation was sent by the Brush Chairman to Buckingham Palace. A generous reply closed the incident but not without much unwelcome publicity.

This exceptional event did not affect the respect of railwaymen for the overall performance of the locomotives. Available for traffic 22 hours each day, they were employed on a full range of duties from prestige express trains to loose-coupled freight, and drivers had nothing but praise for their smooth riding qualities and ease of control.



Locomotive in daily service hauling "The Master Cutler" train between London and Sheffield.



A group of visitors, journalists, staff and work-people at the handing over ceremony in a locomotive erection shop at Loughborough, 1957. Many of those present were responsible for the design and construction of the locomotives and equipment.

THE FALCON LOCOMOTIVE

Heavy demand for locomotives and electrical traction equipment was met by steady increases in the production capacity of all the departments concerned. A locomotive superstruction shop was erected with a floor area of 48,000 sq. ft., the erecting shop, testing facilities, and space for traction motors and generators were enlarged, while a section of the switchgear shops was laid out for the specialised assembly of control gear. Part of a large shop formerly used for the manufacture of steam turbines was also used for locomotive assembly.

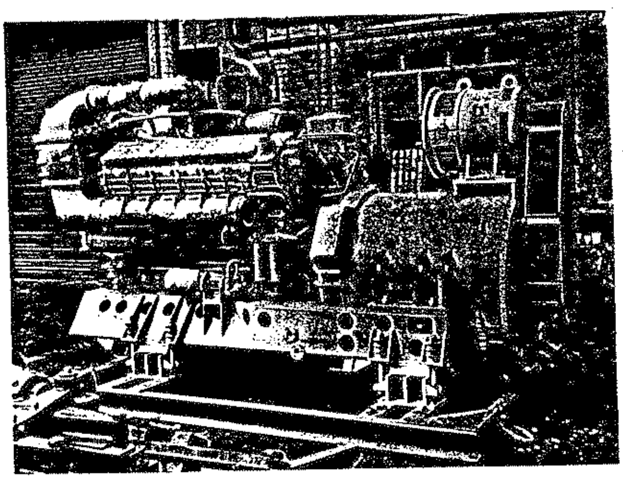
These additional facilities came into use in 1960 when the Company gave attention to schemes for building still larger locomotives and equipment.

Substantial orders were received in 1959/60 for separate power equipment comprising generators, motors and control gear for 2500 horsepower locomotives being built in the workshops of British Railways at Derby, also for auxiliary electrical equipment used on diesel-hydraulic locomotives of 2700 horsepower being built at Swindon and Crewe railway workshops.

Much thought was given to producing the Company's own design of locomotive in this class particularly as it was desired to demonstrate the advantages of high speed diesel engines made by an associated company Bristol-Siddeley based on Maybach designs. The engines developed 1440 horsepower continuously at 1500 r.p.m. It was decided to build a prototype locomotive at the Company's own expense having two engines to give 2800 horsepower, each coupled to a high speed direct current generator supplying three motors i.e. six motors in all, with a Co–Co wheel arrangement and all six axles motored. Each engine, generator and three motors were capable of operating as independent or as combined units on one frame.

High speed engines and generators enabled economies of weight to be obtained and the 115 ton locomotive was designed to have a power/weight ratio of 24 horsepower per ton, only slightly less than that of comparable diesel-hydraulic locomotives using diesel engines of the same type.

The new locomotive designated the 'Falcon' was ready for trials in 1961 and after thorough works tests and trials on the main railway system it was taken on regular main line services of the Eastern Region in 1962. During the trials, carried out over a variety of routes and gradients with both freight and passenger loads, the Falcon exceeded 100 miles per hour on several occasions and on the famous Lickey incline having a gradient of 1 in 37.7, it successfully accelerated from a standing start a train of 628 trailing tons.



Bristol-Siddeley "Maybach" engine coupled to Brush main and auxiliary generators.

The FALCON LOCOMOTIVE 1962

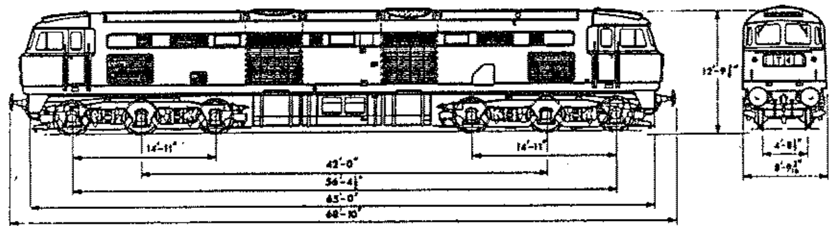
LEADING PARTICULARS OF THE FALCON LOCOMOTIVE

Gauge	4ft. 8½ in.	1.435 m.
Wheel arrangement	Co–Co	
Engine continuous traction rating (each)	1,400 b.h.p.	
Engine speed at continuous tracting rating	1,500 r.p.m.	
Maximum tractive effort	60,000 lb.	27.22 kg.
One hour tractive effort	31,500 lb.	14.29 kg.
Speed at one hour tractive effort	25.5 m.p.h.	41.03 km/hr.
Continuous tractive effort	28,500 lb.	12.93 kg.
Speed at continuous tractive effort	28.5 m.p.h.	45.85 km/hr.
Maximum speed	100 m.p.h.	160.9 km/hr.
Wheel diameter	3 ft. 7 ins.	1.092 m.
Bogie wheelbase	14 ft. 11 in.	4.547 m.
Distance between bogie pivots	42 ft. 0 in.	12.80 m.
Total wheelbase	56 ft. 4½ in.	17.18 m.
Length over buffer beams	65 ft. 0 in.	19.81 m.
Overall length	68 ft. 10 in.	20.98 m.
Overall width	8 ft. 9 ins.	2.667 m.
Overall height from rail	12 ft. 9.7/8 in.	3.907 m.
Minimum clearance to rail (new tyres)	6½ in.	16.51 cm.
Minimum curve negotiable	4 chains	
Weight in working order	115 tons	116.8) metric
Weight without supplies	105½ tons	107.2) tons
Axle load (maximum)	19¼ tons	19.55)
Fuel tank capacity	1,400 gallons	6,365 litres
Boiler water tank capacity (scoop fitted)	800 gallons	3,638 litres
Train heating boiler steam capacity	2,500 lb/hr.	1,134 kg/hr.

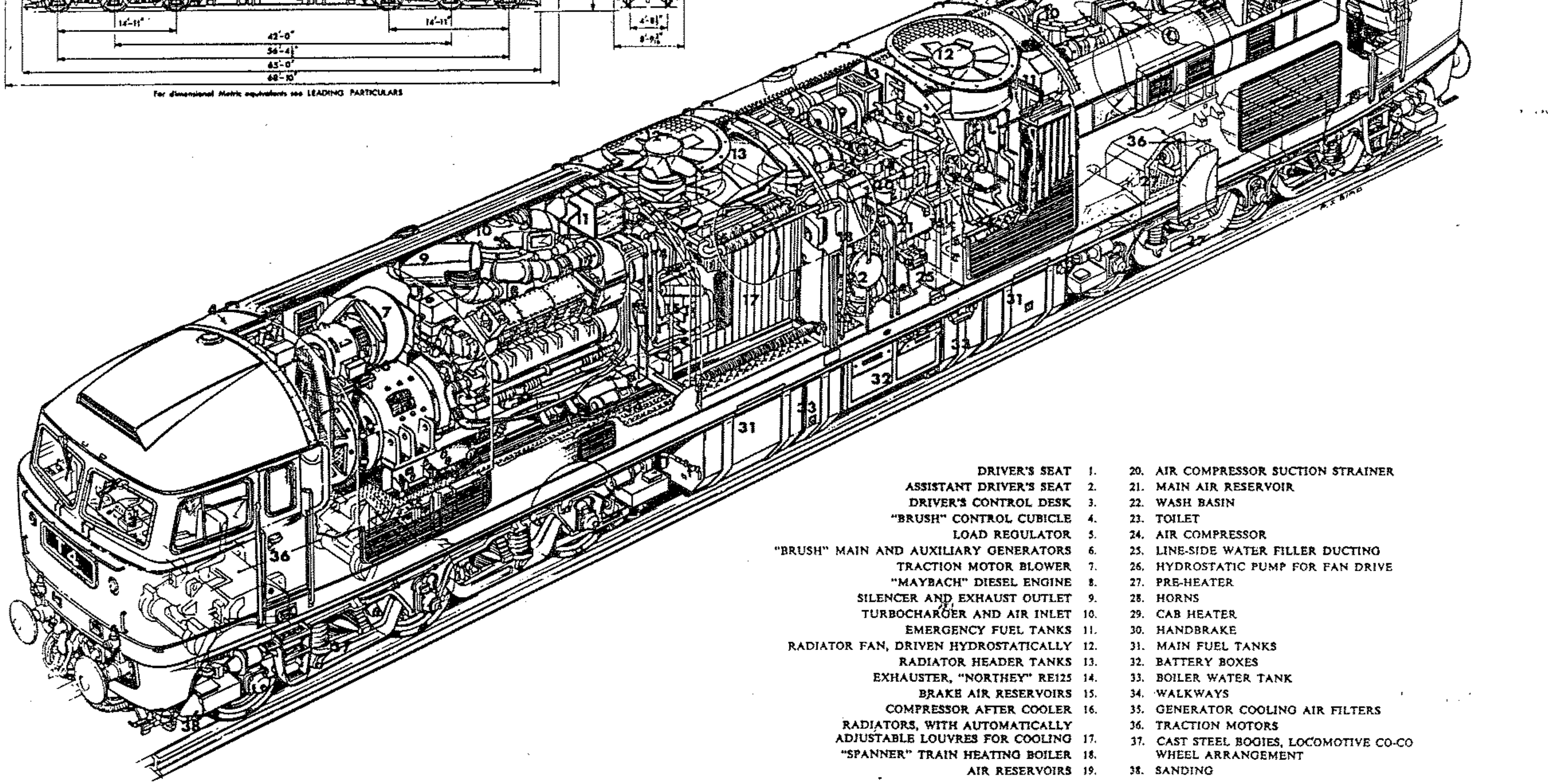
Diesel Engine

Bristol Siddeley Maybach	MD.655	
Vee form	12 cylinders	
Available continuous h.p.	1,440 h.p. at 1,500 r.p.m. to B.S. 2953:1958.	
Pressure charged and intercooled		
Bore	7.28 in.	(185 mm.)
Stroke	7.88 in.	(200 mm.)
Compression ratio	15.5:1	
Swept volume	5.375 litres per cylinder	
Brake Mean Effective Pressure at continuous traction rating	193 lb/sq.in.	13.57 kg/cm^2

FALCON 2800 h.p. Diesel Electric Locomotive.



For dimensional Metric equivalents see LEADING PARTICULARS



DRIVER'S SEAT	1.	20.	AIR COMPRESSOR SUCTION STRAINER
ASSISTANT DRIVER'S SEAT	2.	21.	MAIN AIR RESERVOIR
DRIVER'S CONTROL DESK	3.	22.	WASH BASIN
"BRUSH" CONTROL CUBICLE	4.	23.	TOILET
LOAD REGULATOR	5.	24.	AIR COMPRESSOR
"BRUSH" MAIN AND AUXILIARY GENERATORS	6.	25.	LINE-SIDE WATER FILLER DUCTING
TRACTION MOTOR BLOWER	7.	26.	HYDROSTATIC PUMP FOR FAN DRIVE
"MAYBACH" DIESEL ENGINE	8.	27.	PRE-HEATER
SILENCER AND EXHAUST OUTLET	9.	28.	HORNS
TURBOCHARGER AND AIR INLET	10.	29.	CAB HEATER
EMERGENCY FUEL TANKS	11.	30.	HANDBRAKE
RADIATOR FAN, DRIVEN HYDROSTATICALLY	12.	31.	MAIN FUEL TANKS
RADIATOR HEADER TANKS	13.	32.	BATTERY BOXES
EXHAUSTER, "NORTHEY" RE125	14.	33.	BOILER WATER TANK
BRAKE AIR RESERVOIRS	15.	34.	WALKWAYS
COMPRESSOR AFTER COOLER	16.	35.	GENERATOR COOLING AIR FILTERS
RADIATORS, WITH AUTOMATICALLY ADJUSTABLE LOUVRES FOR COOLING	17.	36.	TRACTION MOTORS
"SPANNER" TRAIN HEATING BOILER	18.	37.	CAST STEEL BOGIES, LOCOMOTIVE CO-CO WHEEL ARRANGEMENT
AIR RESERVOIRS	19.	38.	SANDING

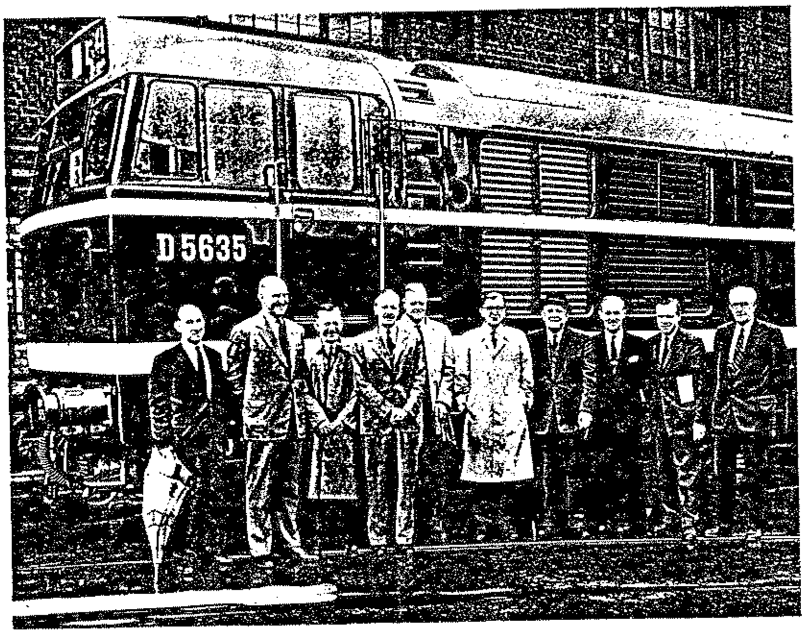
TYPE 4 LOCOMOTIVES

In the early stages of the railways modernisation plan the British Transport Commission ordered a large variety of locomotives and equipment as it was considered operating experience in actual service would prove more than paper estimates and arguments the types of equipment best suited to the requirements.

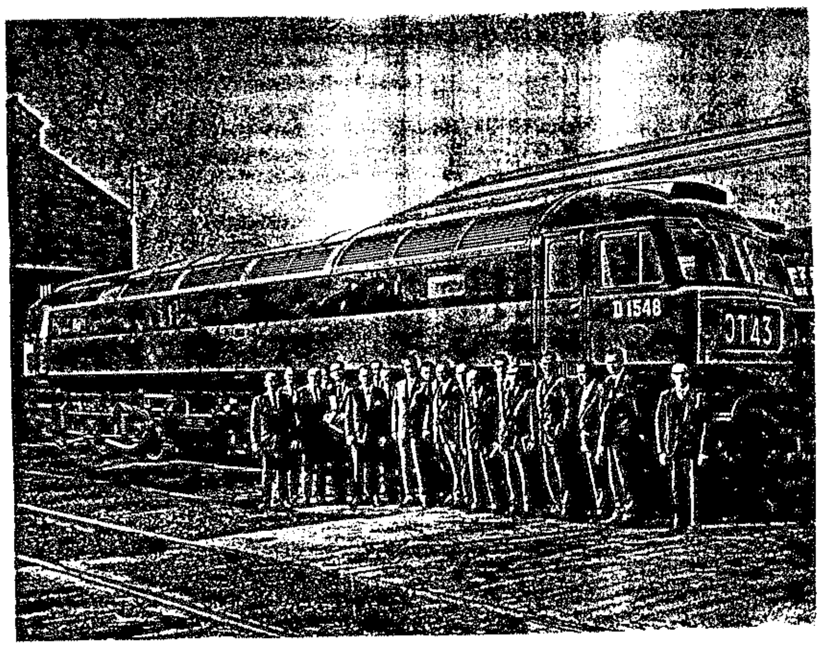
As experience was gained, the views of railway engineers took a definite form in favour of certain types of equipment in standard sizes of locomotives. Among these was a "Type 4" locomotive designed by Brush engineers in conjunction with the Chief Mechanical and Chief Electrical Engineers of British Railways Board. It was a 2750 brake horsepower Co—Co 114 ton vehicle having a single Sulzer engine with Brush electrical equipment i.e. generator, motors, control gear and auxiliaries. The single engine enabled the designers to make the locomotive five feet shorter than the Falcon. Attention was given to reduction of weight by the use of cast steel bogie frames of high tensile strength, aluminium alloy driving cabs, fibre glass for the roof canopy and a general choice of light materials in place of heavy steel sections conventionally used.

The Company was entrusted with a large order for these locomotives and the first deliveries were made in September, 1962.

Quantities of separate power equipments comprising generators, motors, control equipment and auxiliaries were also delivered to the Crewe workshops of British Railways for inclusion in locomotives built there to Brush designs under license from the Company.



Members of the British Transport Commission and Brush officials at Loughborough, 1961.



Visiting railway men with a Type 4, 2750 B.H.P. Locomotive, 1963.

Adopted by British Railways as their standard high powered locomotive, several hundreds of the Type 4 units were built and put into service. Some features of their design were described in a paper to the Institution of Locomotive Engineers in 1962 by Mr. F.H. Wood then Traction Director and later Chairman and Managing Director of Brush. The paper also referred to other Brush diesel-electric locomotives and Mr. Wood showed that although Types 2 and 4, and the Falcon locomotive had different basic characteristics, several features had a family relationship. (Journal of the Institution of Locomotive Engineers 1962-3 Vol 52). More details were also published in "Diesel Railway Traction" in March 1963.

This continuing pattern of similarities despite differences in specification was a notable feature of Brush locomotive engineering based on successful experience allied to technical progress. For example, the main traction generator was among the largest of its kind at the time it was built, having a continuous rating of 1800 kW at 970 Volts 1860 amps. Such a generator, having many proved features found to be successful in earlier and smaller machines, could not have been designed and made satisfactorily without long and progressive experience with traction electrical machinery.

Mechanical components and structures also followed evolutionary trends mainly characterised by steady reductions in the specific weight of each new type of locomotive. Some comparisons are given in these tables taken from Mr. Woods' paper.

1. Weight of components in tons

	Type 2	Falcon	Type 4
Diesel Engine	15.5	13.8	22.3
Electric Transmission	25.3	32.5	28.5
Mechanical Parts - Bogie	26.3	27.0	25.2
Superstructure and Cab	18.4	21.5	17.0
Brake Equipment	2.6	2.0	1.7
Radiators	1.5	2.6	2.0
Piping	1.8	1.8	1.5
Boiler, Tanks, etc.	7.4	4.9	7.9
Supplies, Fuel, Water and Sand	5.2	8.9	7.9
TOTAL	104	115	114
HORSEPOWER	1250/1600	2800	2750

2. Weight of structures in tons

	Weight	Length over Buffer Beams	Weight/foot
Type 2	18.4	53 ft. 1 in.	0.347
Falcon	21.5	65 ft. 0 in.	0.330
Type 4	17.0	59 ft. 10½ in.	0.285

By the middle of 1964 more than 100 Type 4 locomotives were in regular service and delivery from Falcon Works was taking place at the rate of ten per month.

Total orders received required the delivery from Loughborough of 310 complete locomotives of this class and additional power equipments to the number of 182 for inclusion in Railway-built locomotives.

This was on top of Type 2 of which 263 in all were made and put into service.

Brush power equipment was used in 56 locomotives of an earlier 2500 horsepower Type 4 diesel electric design.

A contribution was also made to the control systems used on diesel-hydraulic locomotives by supplying 74 control equipments for 2700 horsepower, 101 for 1700 horsepower, and 56 for 650 horsepower locomotives of that type.

Altogether, the situation in 1964 indicated that the completion of current orders would provide more than 1000 diesel locomotives on British Railways with Brush equipment of various kinds - or some 35% of the total main line diesel fleet.

LEADING PARTICULARS TYPE 4

Gauge	4 ft. 8½ in.	1.435 m.
Wheel arrangement	Co–Co	
Engine continuous traction rating	2,750 b.h.p.	
Engine speed at continuous traction rating	800 r.p.m.	
Maximum tractive effort	55,000 lb.	24,948 kg.
One hour tractive effort	33,000 lb.	14,969 kg.
Speed at one hour tractive effort	24 m.p.h.	38.6 km/hr.
Continuous tractive effort	30,000 lb.	13,608 kg.
Speed at continuous tractive effort	27 m.p.h.	43.5 km/hr.
Maximum speed	95 m.p.h.	152.9 km/hr.
Wheel diameter	3 ft. 9 in.	1.143 m.
Bogie wheel base	14 ft. 6 in.	4.190 m.
Distance between bogie pivots	37 ft. 0 in.	11.277 m.
Total wheelbase	51 ft. 6 in.	15.697 m.
Overall length	63 ft. 6 in.	19.354 m.
Overall width over body	8 ft. 9¾ in.	2.686 m.
Overall width over handrails	9 ft. 2 in.	2.794 m.
Overall height from rail	12 ft. 9.3/8 in.	3.902 m.
Minimum clearance to rail (new tyres)	6½ in.	165 mm.
Minimum curve negotiable	4 chains	
Weight in working order	114 tons	115.8) metric
Axle load maximum	19 tons	19.305) tons
Fuel tank capacity	850 gallons	3,862 litres
Train heating boiler steam capacity	2,500 lb/hr.	1,134 kg/hr.
Boiler water tank capacity	1,250 gallons	5,679 litres
Engine type	12 LDA 28C double bank, in-line pressure charged, inter-cooled four-stroke.	
Continuous rating	2,750 h.p. at 800 r.p.m. (B.S. 2953:1958)	
Lowest regulated output	120 h.p. at 325 r.p.m. approx.	
Idling speed (no auxiliary load)	340 r.p.m.	
Generator speed	1.44 x engine speed i.e. 1,150 r.p.m.	
Engine weight complete with heat exchanger, filters, pressure charger intercoolers, etc. but not including exhaust silencer and air filter box	dry: 20.7 tons wet: 22.2 tons	
Engine air consumption	7,650 c.f.m.	
No. of cylinders	12	
Bore	280 mm.	
Stroke	360 mm.	
Swept volume	266 litres	
Mean piston speed	1,888 ft/min.	
Inlet valves per cylinder	1	
Exhaust valves per cylinder	1	
Main bearings	Trimetal type	
Big end bearings	Trimetal type	
Pressure charger	Exhaust gas turbine type (Sulzer)	
Intercooling	By air/water heat exchanger	
Lubricating oil cooling	Heat exchanger on engine	

RHODESIA RAILWAYS

Another valuable export order was received in 1961 for fourteen locomotives for Rhodesia Railways. This batch was the first design by Brush for use on a 3'6" gauge railway system. The allowable axle load of 15 tons was met by a compact unit carried on six motored axles, giving a total locomotive weight of 90 tons.

The diesel engine, manufactured by Mirrlees National Ltd., rated at 1730 B.H.P. at site was developed from the twelve cylinder 'J' type engine employed successfully in service on British Railways, in the Brush Type 2 locomotives.

Intended to work on the 257 miles route between Bulawayo and Malvernia, maximum flexibility was assured by provision of a control scheme allowing multiple unit working with existing locomotives supplied by another Company.

The following description of the locomotives and equipment was published at the time.

Leading Particulars

Gauge	3'6"
Wheel arrangement	Co–Co
Weight with full supplies	90 tons
Engine rating	1,730 b.h.p.
Maximum operating speed	60 m.p.h.
Maximum tractive effort	57,800 lbs.
Continuous tractive effort	37,500 lbs at 13 m.p.h.
Overall length between Coupling faces	54'5"
Length over Buffer Beams	51'1"
Width over Framing	9'9"
Overall Height	13'4"
Bogie Pivot Centres	27'3"
Bogie Wheelbase	13'0"
Minimum curve negotiable	275'0"
Fuel capacity	1,000 gallons.

Equipment Layout

"A full bodied two cab design with a centrally mounted engine-generator unit has been adopted. The space between No. 1 end cab and the free end of the engine is occupied by the cooling group, with roof mounted radiator panels and two fans mechanically driven from the engine. One traction motor blower is also fitted in this compartment. At No. 2 end, the control cubicle is mounted centrally with one end flush to the cab bulkhead, an arrangement which allows access to the equipment in the cubicle from both sides. Two exhausters, a compressor and the other traction motor blower are fitted along the sides of the control cubicle compartment. Air intake louvres and filters for the engine charge air generators and auxiliary equipment are all roof mounted and this had led to smooth clean bodyside lines externally. Fuel tanks and battery boxes are supported underneath the body structure, taking up the space between the bogies."

Body Construction

"The locomotive body is constructed as an integral unit. It consists basically, of bodysides connected by cross-stretchers, deckplates, bulkheads and roof sections terminated at each end by dragboxes, and end trusses. With the exception of the roof sections over the engine and generator, minor brackets and supports, all structure members and panels are load bearing. Traction and vertical loads are transferred from the bogie pivots and power unit mountings to the bodysides by cross-stretchers, which also incorporate four lifting and jacking points. The structure is fabricated from rolled sections and plates, stiffened with folded steel sections and panelled with steel sheets. A hatchway is provided, below waist level, at the centre of each bodyside enabling filter panels or other small items to be removed from the locomotive without passage through the driving compartments."

"Removable roof sections are provided throughout the length of the equipment compartments except for the radiator section which forms a welded load carrying assembly of mild steel sheet and folded sections between the cab bulkhead and the engine partition. The aluminium engine roof sections include four hinged doors for inspection and engine top maintenance and a further section of aluminium and fibre glass allows access to the generators and engine charge air coolers. Since the roof section above the control cubicle compartment is load carrying, particular attention has been paid to attachment to the body structure and here shear fasteners have been used. Again, this section is manufactured from fibre glass and aluminium. Roof mounted air intake louvres, of a monsoon types, also in aluminium, are divided at intervals along the equipment compartment by glazed roof lights which provide a degree of natural illumination inside the locomotive. The cabs, framing, panels and roof are constructed in aluminium."

Driver's Compartment

"The interior design of the roomy cabs shows a high regard for the personal comfort of the driver and his assistant. The driving position is on the right hand side and brake valves, selector and power control handles have been placed so that the driver is subjected to minimum strain during operation. Both driver's and assistant's seats, which are of the swivel type, allow adjustment for height and for distance from the foot rests. The driver's desk forms a compact self-contained unit fabricated in aluminium and in addition to the normal pressure gauges, ammeter etc., the desk carries a Hasler speed/distance measuring device as required by Rhodesia Railways.

Interior heating during colder weather is provided by three 650 watt heaters fitted in each cab. Fire protection equipment includes carbon dioxide cylinders of 10lb. capacity each. A small electric hotplate is mounted in a convenient position to one side of the assistant driver's seat.

Each cab has access doors from both sides of the track, the door windows being fixed while droplights are fitted to correspond with the driver's and assistant's seats. Hinged quarter lights open outwards, into the direction of motion, so that a sharp draught can be directed into the cab but for normal ventilation a constant flow of air is taken through a grille built into the leading curve of the cab roof. An extraction ventilator with a conventional "hit and miss" adjustment is positioned in the roof towards the rear of the compartment.

The interior of the cab is lined throughout with aluminium sheet and the space between the roof panel and ceiling lining is packed with fibre glass insulation. A similar insulation is employed between the double skin cab bulkheads in order to protect the crew from as much noise and heat as possible."

Bogies

"The bogies are of the cast steel Commonwealth type, frames and bolster being supplied by English Steel Castings Corporation Ltd. The superstructure weight and horizontal traction forces are transmitted to the bolster by a central pivot arrangement through low friction self-lubricating load liners. The bolster itself is carried on the bogie frame via four swing links mounted externally so that the bolster straddles the frame and traction forces are transmitted by "traction bars" connecting bolster and frame, thus eliminating the rubbing faces normally associated with this function. In turn, the bogie frame is carried on four spring nests, each of three concentric coil springs mounted on forged steel equaliser beams bearing on the tops of the axleboxes. In order to stabilise the suspension, hydraulic dampers are fitted across each spring nest."

"The axleboxes are of SKF design incorporating twin spherical roller bearings and arranged for grease lubrication. Cast steel is used for the box castings but the wearing faces are lined with manganese steel and the axlebox guides, which are fitted with manganese steel liners, are restrained from any tendency to spread by use of robust horn clips. Road wheels of the built-up type, incorporating steel disc centres have been used, with renewable tyres shrunk into position and secured by conventional retaining rings.

The bogie design has been arranged to accommodate nose-suspended, axle-hung traction motors and wheel spacing has been kept to a minimum by fitting two motor nose suspension links to a single pin assembled longitudinally through a bogie transom, such that each suspension link head is actually carried within the transom.

The centre motor,wheel and axle set moves as a complete assembly as the bogie is displaced during running and a lateral damper, attached between motor yoke and the bogie frame is fitted. In this way the centre pinion can remain in the same position relative to its gear wheel while ensuring that excessive oscillation and rapid displacements of the axle assembly are avoided.

Brackets are included on each inner bogie headstock to enable the fitting of an inter-bogie control device should this be necessary from the rates of wheel flange wear in service. The control would be of the torsion tube type, mounted on the locomotive underframe, with torque arms connected via a spring box to the bogie frame and, of course, the underslung fuel tank has been shaped with this provision in mind."

AIR AND BRAKE EQUIPMENT

"The locomotive air scheme includes an electrically driven Westinghouse type 3HC50 compressor, governed between 85–100 p.s.i., which provides an air supply for locomotive brakes, warning horns, and control details, including a Davies and Metcalfe Ltd. vigilance unit, while two Northey 125RE Exhausters provide vacuum for operation of train brakes. Thus the driver's brake control consists of a vacuum brake valve, operating train and locomotive brakes and an independent air brake valve operating locomotive brakes only. Application of the vacuum brake valve energises the locomotive brakes via a proportional valve which ensures that the vacuum braking on the train is matched by the braking applied to the locomotive. Four Comprestall type brake cylinders are fitted to each bogie and slack adjustment is made manually by a telescopic screw device in the bogie brake rigging.

As an aid to starting the locomotive under difficult conditions an anti-slip valve allows a light brake application to be made at the driver's instigation. However, should a wheel spin occur at any time, the same application is made automatically and the driver is warned by a buzzer and a warning light in the cab. In addition, rail sanding via two electro-pneumatic valves can be applied by a footswitch."

DIESEL ENGINE

"The medium speed power unit fitted is the Mirrlees National Ltd. 12 cylinder four stroke Vee engine, pressure charged and intercooled, rated under N.T.P. conditions at 1,920 b.h.p. at 1,000 r.p.m. Operating conditions altitude 4,500 ft. 95°F and relative humidity 50% combine to restrict the rating at site to 1,730 b.h.p."

ENGINE CONSTRUCTION

"The main engine bedplate, which is extended to carry the generator, is constructed from steel castings and plate and incorporates a traction type sump designed to prevent excessive surging of the lubricating oil when the locomotive is in motion. Stress relieved steel plate fabrications are used for the cylinder housing and upper part of the crankcase with inspection covers provided to allow access to the main bearings, big-end bearings, and camshaft gear. Quick release covers give access to the fuel pumps. The "wet" cylinder liners are of close-grained cast cylinder iron, with continuous uninterrupted bore, free to expand downwards.

Both main journals and crankpins on the crankshaft, which is machined from a forging of 40 to 50 ton tensile steel, are induction hardened and drilled passages carry oil from the main bearings to the crankpins. Automotive type connecting rods are made from H-section steel forgings, fitted with copper-lead lined shells. The lower half bearing cap is located, via serrations, by four high tensile steel bolts. The small-end bearing, which is pressure lubricated from the big-end bearing by a drilled oil-way through the connecting rod, is a phosphor bronze bush. Placed on either side of each crank throw is a steel shell type, copper-lead lined main bearing and in addition, a location bearing at the generator end is designed to carry the considerable overhung masses.

A special lightweight alloy has been used for the pistons. Four compression rings and two oil control rings are fitted, one oil ring above the gudgeon pin and the other below. Oil from the lubrication system is led up the connecting rod for cooling purposes to the underside of the piston crown, in which the combustion chamber is formed. Separate heads cast in cylinder iron, with the injectors positioned centrally between two exhaust and two inlet valves, are used for each cylinder.

Contained in the cylinder housing at its air intake side is the gear-driven camshaft, made from carbon steel ground bar with hardened cam sleeves, located so that the entire camshaft assembly can be removed sideways from the engine. Roller type tappets are used to work the fuel pumps and the air and exhaust cams operate overhead valve gear via hardened steel rollers and push rods, the above levers being carried by a two bearing bracket attached to the cylinder head. All levers are fitted with adjustable line contact tappets and the whole gear is pressure lubricated and totally enclosed."

PRESSURE CHARGER

"The engine is pressure charged by two exhaust gas driven turbochargers and these are single stage axial flow turbines, each driving a single stage centrifugal air compressor on a common rotor shaft. Compensation for altitude is operative up to 4,500 ft. above sea level. The shafts are fitted with removable hardened steel journals running in plain lead-bronze bearings and a built-in gear driven pump feeds the lubrication system of the pressure feed recirculation type."

GENERATOR UNIT CONSTRUCTION

"The main and auxiliary generators are insulated throughout with Class F materials, except in certain parts such as armature conductor insulation and main generator shunt field coil conductor insulation which is Class H; the two generators are mounted on a common hub, solidly coupled at the main generator end to the diesel engine through a light barring disc. The hub is supported by a Hoffman single row alignable roller bearing, mounted in the auxiliary generator end-frame and both inner and outer races are clamped in position. A lipless inner race allows axial movement of the rollers with expansion of the armature whilst labyrinth type seals are used to exclude foreign matter and prevent loss of lubricant. The auxiliary generator armature is built separately on a cast steel hub, with tapered bore, which is keyed to the main hub and the complete assembly is dynamically balanced.

As mentioned earlier, the generator magnet is foot mounted on the engine bedplate extension arms. The endframe of the main generator is combined with the auxiliary generator magnet and both machines are ventilated by means of a fan at the drive end which is mounted on the engine barring disc. Air inlets are provided in both generator endframes. In addition to the normal access to commutator and brush-gear allowed by openings in the magnet frames, the main generator air inlet covers are also removable. All cables and leads including those for the traction motors have an oil resistant polychloroprene sheath over varnished cambric insulation and external leads are arranged for ready disconnection and replacement.

The main generator is an eight pole compensated machine having separately excited and self excited shunt windings and a series decompounding winding, which is also used for engine starting. At 1,000 r.p.m., the continuous ratings of this machine are 1,122 kW, 680 volts, 1650 amps and 1,112 kW, 530 volts, 2,100 amps. High permeability steel laminations, assembled with an interference fit and keyed on to the main armature hub, form the armature core between two endrings; axial ducts allow the passage of cooling air through the core.

Over the required load and speed range the nominal 110 volts of the auxiliary generator is maintained by an automatic voltage regulator. The rating of the auxiliary generators, which is a six pole shunt wound machine, is 37.2 kW, 110 volts, 338 amps."

Built by British Railways at Derby this 2750 B.H.P. Locomotive seen at Loughborough station contains Brush electrical equipment for motive power (1963).

TRACTION MOTORS

"The traction motors are of the four pole, series wound, force ventilated, axle hung type and each is rated continuously at 222 h.p., 265 volts, 700 amps at 556 r.p.m. The one hour rating is 216 h.p., 239 volts, 770 amps at 477 r.p.m. and cooling air at the rate of 2,500 cu.ft./min. is supplied to each motor. Class F insulation materials are used for the armatures and the series field and interpoles are fully Class H insulated.

Armature bearings of the Skefko roller type, lubricated by high melting point grease, have been adopted with a location bearing at the commutator end. In order to allow for expansion of the armature shaft the pinion end bearing is used with a lipless inner race. Special attention has been paid to the labyrinth to avoid the entry of foreign matter into the bearings and grease into the motor.

The motors are resiliently suspended from the bogie frame by vertical links, incorporating rubber bushes allowing movement from spring deflections as well as cushioning the gears against starting shocks and a safety nose forms part of each cast motor yoke."

CONTROL EQUIPMENT

"A series-parallel arrangement has been adopted for the locomotive power circuits, the main generator being connected across three parallel branches of two motors in series. Each branch incorporates an electro-pneumatic contactor, traction motor field reversing contacts, an isolating link and an overload relay. For engine starting the battery supply is connected across the main generator via the battery isolating switch and two electro-magnetic contactors. In order to control the output of the main generator to that of the diesel engine, variation in the generator separate field strength is provided by a commutator type, oil vane motor driven regulator which receives its signal from the engine governor, adjusting the resistance of the separate field circuit to the value required for the load conditions prevailing. Three stages of traction motor field weakening have been used to cover the locomotive speed range and each automatic field shunting sequence is instigated by auxiliary contacts as the load regulator moves towards the maximum excitation position. The corresponding field strengthening sequence commences as the motor current rises to be detected by a relay in the power circuit. The selection of the particular engine speeds and power levels is relayed from the driver's power controller to the governor by means of air pressure signals. Supply for the main generator separate excitation, ancillary machines, lighting and control circuits is provided by the auxiliary generator at 110 V."

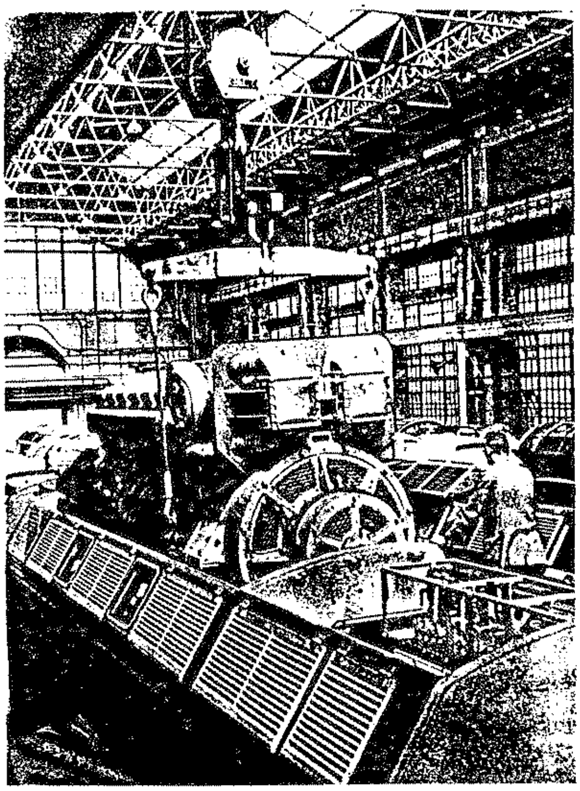
RHODESIA RAILWAYS

At a ceremony at the Brush Works on 9th August, 1963, the first of the fourteen 1730 horsepower locomotives for Rhodesia Railways was handed over to Mr. A.M. Hawkins, the assistant general manager of the Railways by Mr. M.C. Clear, at that time managing director of the Brush Company. Mr. Hawkins afterwards drove the new locomotive on the works test track.

The locomotives are described in the previous pages. They are designed for operation on the 3' 6" narrow gauge system between Bulawayo and Malvernia. Some of the sections of this line have considerable gradients and curves, also high altitudes, and these features combined with high ambient temperatures, made considerable demands on the performance and reliability of the locomotives.

In accepting the locomotive on behalf of Rhodesia Railways, Mr. Hawkins referred to an early connection between the Railways and the Brush Company. Some steam locomotives type 4–4–0 of 2 ft. gauge were supplied by the Falcon Works as long ago as 1895 for the Biera Railway Company. Several other locomotives of the same type were ordered in subsequent years, and it was reported in 1900 that Brush had built all the locomotives in service on the Biera Railway.

One last survivor was recently restored to its original condition and after exhibition at the Central African Trade Fair it was given to the museum at Umtali, the Rhodesian terminal of the old Biera Railway.



Mirrlees-National engine coupled to Brush 1122 kW main and auxiliary generators being lowered into the locomotive.

1730 B.H.P. Locomotive for Rhodesia Railways ready for delivery. 1963.

11. THE ORGANISATION

Activities in the field of transport passed through many administration and organisation changes over the years largely for reasons connected with changes of management and financial control, also to meet different circumstances in the nature of the products and their relative importance to the overall business of the Company.

Although these activities were at all times since 1889 under the control of the Brush Company's Board of Directors, detailed operations were sometimes delegated to subsidiary companies.

Prior to the 1914-18 war several departments operated under the general title of Falcon Railway Carriage and Wagon Works. They were prepared to accept contracts for the complete equipment of traction undertakings anywhere in the world.

The period 1918 to 1938 was occupied with the production of tramcars, trolley buses and coachwork, the separate departments concerned with sales, design and manufacture forming an integral unit occupying the "Meadow Lane" end of the works, and working under the direction of Mr. William Johnstone, formerly the rolling stock manager and in 1922, Managing Director of the Brush Company.

Generally known as the "car side", the unit underwent a major change in 1938 when the Brush Company was completely re-organised and re-financed, following several difficult years in which trading losses were made.

Sir Ronald Matthews and Mr. Alan Paul Good then joined the organisation as Chairman and Deputy Chairman respectively, with Mr. Thomas B. Keep as Managing Director. (Mr. Johnstone resigned in 1936).

The rolling stock departments were formed into a subsidiary company "BRUSH COACHWORK LTD.", the main products being single and double deck bus bodies. Later, Brush Coachwork became a selling organisation. Manufacturing operations were conducted as a Coachwork Division of Brush under the direction of Mr. William Good, (brother to A.P. Good), from 1942 to 1945.

During those years of the second European War, production was geared to vehicles for war purposes, including General Service Wagons, Radio Location Vehicles, Gun carriers and the like. Some 10,000 of these vehicles were made in all besides several thousands of bodies for motor buses.

An aircraft department was set up to build Dominic aeroplanes. This aircraft was originally the Rapide 79 designed and built by De Havillands, having two Gypsy Queen Engines each of 200 horsepower. It was selected by the Government for training radio operators in flight, and Brush assisted to produce the large numbers required.

Another war effort was concerned with the repair of Hampden and Lancaster bomber aircraft damaged by enemy action or by accidents. The process comprised the removal of sound parts from the damaged aircraft, repairing the damage where possible and fitting salvaged parts in reconstructed assemblies. In this way, many hundreds of aircraft were made fit for service.

Mr. William Good left the organisation soon after the termination of the war in 1945 and the traction work branched in two different directions. The Coachworks Division resumed normal work on building bus bodies, to which were added caravan bodies, and also the manufacture of battery electric vehicles.

By 1949 the Division was contributing a turnover of about £1 million per annum, but in the following years, business and profitability declined to such an extent that in 1952 work was stopped on all products but battery electric vehicles which had a steady annual turnover of about £150,000. The space released by the cessation of body building was taken over for the expansion of switchgear products.

In the meantime a new and important transport was growing in the development of diesel electric locomotives.

Impelled by Mr. Alan P. Good who had associated Brush with the oil engine firms of Petters; Mirrlees, Bickerton & Day; National Gas and Oil Engine Company and J. & H. McLaren Ltd., the development showed such potential that it was deemed desirable to co-ordinate the sales, engineering and manufacturing resources of Brush and associated companies concerned with rail traction by a single organisation.

ALAN PAUL GOOD
1906 - 1953

Founder and Deputy Chairman of the Brush Group of Companies 1949.

Managing Director of Brush (Loughborough) 1941 – 1949.

Accordingly BRUSH BAGNALL ELECTRIC TRACTION LTD. was formed and incorporated on the 4th December, 1945.

The Bagnall interest was derived from the firm of W.G. Bagnall, Stafford, an established firm of steam locomotive builders, founded in 1875 and acquired in 1945 by interests connected with Mr. A.P. Good. The firm had a high reputation as mechanical engineers and brought to the consortium the skill and resources needed for the design and construction of mechanical parts for complete locomotives carrying the specialised equipment of Brush and other partners.

This organisation had a major influence in building up the rail traction business of the Brush Company. Links with oil engine builders were strengthened in 1949 by the formation of the Brush Group Ltd., which controlled the engine firms financially, and administratively. Then came a big success in 1950 when a contract was obtained for supplying 25 main line 1000 horsepower diesel electric locomotives to the Government of Ceylon. They were the first main line locomotives of the diesel electric type to be built at Loughborough.

Mr. K.N. Eckhard was appointed General Manager of the Brush Bagnall organisation in 1951. He had considerable experience of railway operation gained in Argentina, and applied much practical knowledge to the advancement of the work, but resigned in 1954 because of failing health.

Soon after, the name of the organisation was changed to BRUSH TRACTION LTD., as the Bagnall interest receded following the death of Mr. A.P. Good in 1953. The separate firms continued to co-operate although they belonged to different groups. By this time Brush had developed a mechanical engineering department capable of designing the largest locomotives.

Further changes occurred when the Hawker-Siddeley Group acquired the share capital and assets of the Brush Group in 1957. The work of Brush Traction Ltd. was merged into the Traction Division of the Brush Company at Loughborough under the management of Mr. F.H. Wood. Mr. Wood became director of the Brush Company in 1960 responsible for Traction and Rotating Machines. At the same time, Mr. F.H. Beasant was appointed manager of the Traction Division. The chief mechanical designer was Mr. J. Simnet, the chief engineer, (electrical) was Mr. G. Smith who had been responsible for the design of every traction motor and generator for diesel electric locomotives made at Loughborough from the beginning. Mr. P.E. Batchelor was Chief Engineer for Control Gear.

Overall executive responsibilities throughout the diesel-electric period was carried by the Managing Director of the Brush Company.

Mr. A.P. Good held that position from 1941 to 1949 assisted for a short period in 1945/6 by Mr. F.S. Mitman, and by Mr. Sydney Lane in 1947/49.

When the Brush Group Ltd. was formed in 1949, Mr. Good and Mr. Lane transferred their activities to the Group Board in London, and Mr. J.W.C. Milligan was appointed Managing Director at Loughborough. He resigned in 1954 and Mr. M. Tattersfield succeeded him. Mr. Tattersfield in turn, transferred to duties with the Group Board in 1957.

On 1st December, 1957, Dr. B.L. Goodlet, Director and Chief Engineer was appointed Managing Director and held the position until shortly before his death in 1961. Later in that year Mr. M.C. Clear became Managing Director.

Other directors responsible for executive duties in 1962 were:-

Mr. H.T. Chapman	Chairman
Dr. L.R. Blake	Director of Engineering.
Mr. R.A. Grierson	Switchgear and Transformer.
Mr. R.L. Oddie	Secretary.

Mr. F.H. Wood was appointed Chairman and Managing Director of the Brush Electrical Engineering Company in 1964.

A group at Loughborough in 1957. Left to right are:-

Mr. M. Tattersfield, Mr. F.H. Wood, Mr. G.C. Eley, Sir Reginald Wilson and Mr. R.C. Bond (British Transport Commission), Mr. I.T. Morrow, Mr. H. Ivatt (formerly Chief Mechanical Engineer L.M.S. Railway) consulting engineer to Brush Traction Ltd.

12. PRINCIPAL DATES IN THE HISTORY OF BRUSH TRACTION

1865 Falcon Works, Loughborough, established.

1876 Hughes Patent Steam Tramway Locomotive.

1879 Anglo-American Brush Electric Light Corporation founded.

1885 Horse drawn omnibus manufactured.

1888 Steam locomotives made for railways.

1889 Falcon Works acquired by Brush Electrical Engineering Co.

1898 First complete electric tramway system installed.

1899 First all-British electric tramcar built at Loughborough.

1901 British Electric Traction Company acquired majority shareholding in Brush.

1902 Brush motor car constructed.

1904 Motor omnibus construction began.

1907 First all-metal bus displayed at Olympia Exhibition.

1909 Emile Garcke appointed Chairman.

1910 Tramcars main speciality of Falcon Works.

1912 Trolley bus vehicles manufactured.

1914 Steam locomotives and railway coach manufacture discontinued.

1914/18 Aeroplanes, seaplanes and military vehicles supplied.

1924 First top-covered double-deck bus body supplied.

1930 Trolley Bus motors developed and made.

1933 Oil-engine manufacture began at Loughborough.

1938 Brush Company re-financed, Mr. A.P. Good joined the Board.

1938 Brush Coachwork Ltd. formed.

1940 First diesel electric locomotive made for local shunting.

1945 Brush-Bagnall Electric Traction Ltd. formed.

1945 Battery electric vehicle business began.

1946 First diesel-electric shunting locomotive delivered to London and North Eastern Railway Company.

1947 Brush 'Pony' electric vehicle introduced.

1948 Shunting diesel electric locomotives supplied to Irish State Railways.

1949 Brush Group Ltd. founded.

1950 First order received for main line diesel electric locomotives.

1952 Body building for public service vehicles discontinued.

1953 Main line locomotives entered service in Ceylon.

1957 First deliveries of 1250 horsepower locomotives for British Railways.

1957 Hawker-Siddeley Group acquired Brush Group.

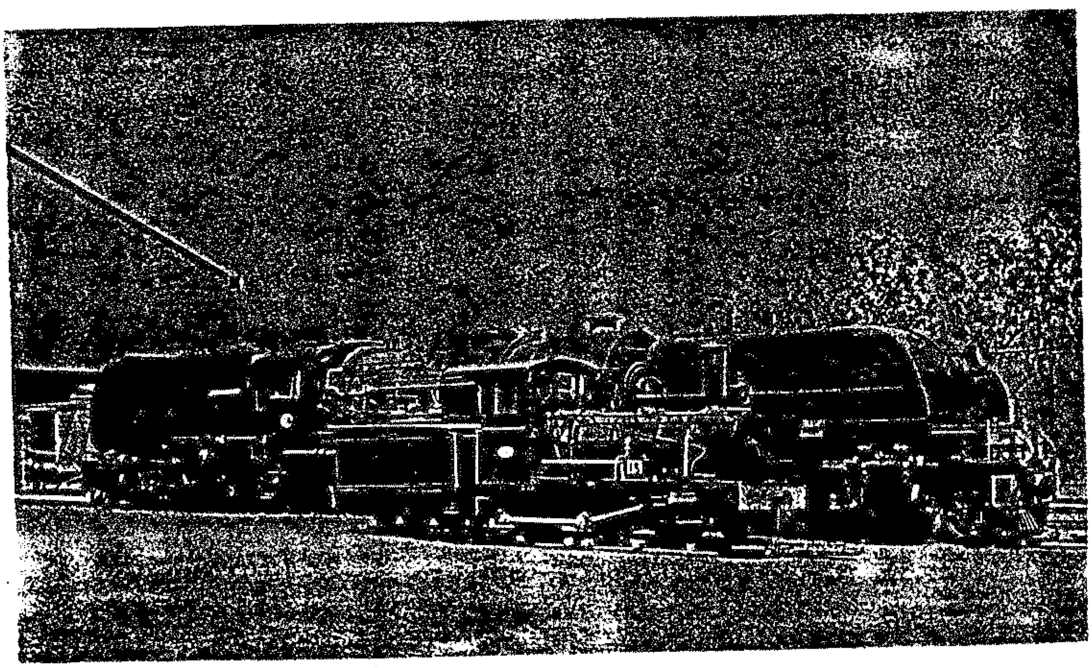
1961 Falcon 2800 horsepower demonstrated in service.

1962 Brush Powerox electric vehicles first exhibited.

1962 First deliveries of Type 4, 2750 horsepower locomotives for British Railways.

1963 Rhodesia Railways accepted first of fourteen 1730 horsepower locomotives.

In the foreground is a steam locomotive type 4-4-0 for the 2 ft. gauge of Biera Railway on exhibition at UMTALI in 1964. The locomotive was built at Falcon Works in 1895 and was the forerunner of many of a similar type supplied to the Biera Railway Company in Central Africa around the year 1900.



BOARD OF DIRECTORS, 1964.

Seated L to R

Mr. D.S. Young. Director (Fuller Electric Company Ltd.)
Mr. P.H.W. Everitt. Director (Fuller Electric Company Ltd.)
Mr. F.H. Wood. Chairman and Managing Director.
Mr. R.A. Grierson. Director.
Dr. L.R. Blake. Director of Engineering.
Sir George Briggs. Director.

Standing L to R

Mr. R.D. Taylor. Sales Director.
Mr. D.J. Hawkins. (in attendance).
Mr. A. Devereaux. (in attendance)
Mr. R.L. Oddie. Director and Secretary.