ELECTRIFICATION OF THE BALTIMORE AND OHIO TUNNELS IN BALTIMORE

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ELECTRIFICATION OF THE BALTIMORE AND OHIO TUNNELS IN BALTIMORE

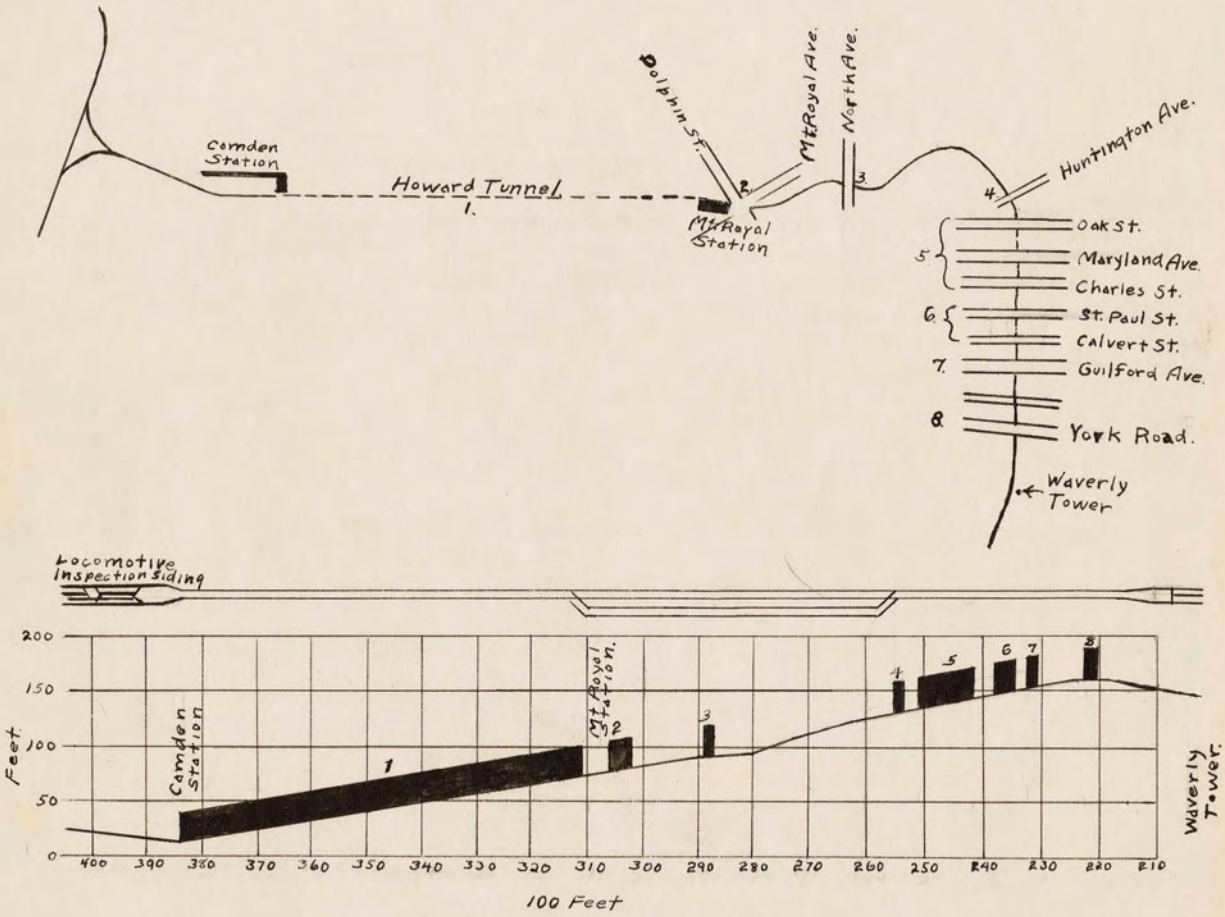
A PIONEER PROJECT.- The history of the electrification of the Baltimore and Ohio tunnels at Baltimore is of importance because it was the first application of electricity as a motive power on a trunk line. With no predecessors to lead the way and necessity demanding it, the Baltimore and Ohio Railroad went ahead and performed this engineering task and made it a success, thus paving the way for others and bringing the railroad up to a higher level of efficiency and service. Working in conjunction with them was the General Electric Company, which supplied them with electrical equipment. It is partly due to this company that the electrification was so well planned and executed. Since that time many railroads have resorted to electrification to abate the smoke nuisance, relieve main-line comjestion, conserve fuel and otherwise lower operating costs.

CAUSE OF ELECTRIFICATION.- The B&O tunnels at Baltimore consist of a main tunnel called the Howard Street Tunnel and a series of smaller ones. Previous to their electrification, it was necessary to ferry the trains across an arm of the Patapsco River instead of running them thru the city. There were two reasons for this: first, an ordinance of Baltimore governing the construction of the line thru the city required that the trains be operated

electrically inside the city limits and secondly, the number and length of the tunnels was too great for steam locomotives to operate in them due to difficulties in removing the gas and smoke from them. Such were the conditions when the B&O decided to electrify the tunnels.

DESCRIPTION OF THE ELECTRIFIED ZONE.- The B&O electrified a section 3.75 miles in length. It included all the tunnels and was located wholly within the city. The zone extended from Camden Station on the west to Waverly Interlocking Tower on the east. This space is occupied by the eight tunnels to the extent of 48% of the total length. The longest tunnel has a length of 7300 feet. The map shows the location and length of the tunnels which are numbered in order that they may be readily found on the profile chart. As may be seen, the entire section has two tracks except that part which lies between Mt. Royal and Huntington Ave. This place has four tracks making the total length of track about 8 miles long. The profile shows that the entire section is upgrade from west to east.

THE SERVICE.- On June 27,1894, the first trial trip was made although regular operation was not begun until May 1,1895. The equipment consisted of 3 96-ton gearless locomotives, designated as class LE-1, which handled the east bound upgrade trains. As the downgrade to the west is rather steep, no electric hauling was done in that direction; the steam locomotives handling their own trains down the grade. This method has been used up to the present without any great difficulty. This service



MAP, TRACK CHART AND PROFILE OF THE ELECTRIFIED TUNNEL ZONE AT BALTIMORE

differs from the so called "helper service" in that the electric locomotive receives no aid from the steam engine whose load it is pulling. In other words, when a train arrives at the west end of the electrified zone, the electric locomotive attaches itself to the steam locomotive and its train and drags them up the grade thru the tunnels. Due to the grade in this zone, the electric engines must develope approximately twice the tractive effort that the steam locomotives, which they drag thru the tunnels, develope in running from Baltimore to Philiadelphia. Although the west-bound trains operate thru the tunnels under their own power, electric assistance is given to start them. Under these conditions, the electric locomotive returns, after each haul, without a load.

THE ORIGINAL POWER SYSTEM.- At that time all the power was supplied to the line directly from five generators at the west end of the electrified section. The power station was built especially to supply electricity to the zone under discussion and consisted of five 500-K.W. 700 volt direct current generators which were direct-connected to tandem compound non-condensing Corliss engines. These were the largest direct-connected generators then in use. In order to reduce the cost of operation and improve the voltage on the line, a storage battery substation was erected, at a later date, near Mt. Royal; a distance of one and three-quarters miles from the power house. The generated or bus-bar voltage was lowered to 500 volts so

that the excess current could be used for industrial purposes. This made necessary the use of a booster system of control to give the locomotives sufficient power for efficient operation during the period of peak load. The power available for the train service was limited to 900 kilowatts by the capacity of the booster set. This maximum power was sufficient to handle one freight train of 1,500 tons weight and a light passenger train. A overhead distribution system was used. The contact conductor was made by placing two Z bars together to form a box-like structure with a slot in the bottom. This was supported in the tunnels by direct current hangers and outside of outside of them by towers and catenery supports. A collector shoe was mounted upon a pantograph and allowed to slide in the slot of the conductor. This type proved to be very defective due to the action of the gases in the tunnel upon the metal at the point of contact and consequently was replaced at a later date by a third rail system.

CLASS LE-1 LOCOMOTIVE USED.- The first electric locomotives used in this zone were of a design that followed the common locomotive practice in the United States. The B&O was supplied with three of them by the General Electric Company. Each was capable of hauling a 2,300-ton freight train at a speed of ten miles per hour, a 1,800-ton train at twelve miles per hour or a 500-ton train at thirty-five miles per hour. They were the

heaviest locomotives built for electric service in the world at that time; each weighing 87 metric tons. They were rated at 360 horse power at 300 volts and had a total tractive effort at full load of 2,800 pounds although their starting tractive effort was 4,800 pounds. It is interesting to note that, in spite of their great weight, they were only one-third as powerful as those used on the New York Central Railroad.

CONSTRUCTION OF THE CLASS LE-1 LOCOMOTIVE.- The truck of this type of locomotive was built up of wrought iron bars welded together to form a trussed frame which rested on four wheels and carried two gearless motors. Two of these trucks were coupled together to form the under frame of the locomotive. The motors were of the General Electric type A X B 70 railway motor. The armature was spring-suspended upon a quill surrounding the axle. A spring-supported field was centered upon this quill by means of bearings. The power was transmitted from the motor to the wheels by the use of a sprocket and rubber driving cushions, thus eliminating gears entirely. Since that time many types of geared electric motors have been developed but the good qualities of this type are shown by the fact that at present gearless motors are used for passenger service on the Coast Division of the Chicago, Milwaukee and St. Paul Railroad. The principle difference in the motors is that the former are operated on a lower voltage than the latter.

CLASS LE-2 LOCOMOTIVE.- In 1903, the B&O bought

two new two unit locomotives from the General Electric Co. for use in the tunnels at Baltimore. They were known as Class LE-2. Each weighed 146 tons or 73 tons per unit and developed 4600 horse power since they were made in two sections having 4-200 horse power motors per section. It was required that each two unit locomotive should handle a train of a weight of 1,450 metric tons in addition to the weight of the locomotive itself on the B&O trunk line thru the tunnels over a 1.5% grade at a speed of 9 miles per hour on a 625-volt circuit. This performance required a a tractive force of 92,000 pounds per motor.

CONSTRUCTION OF THE CLASS LE-2 LOCOMOTIVE.- The cab was of the box type, having two sets of controls located in diagonally opposite corners of each cab. Glass doors and large glass windows permitted the operator to see in all directions from within the cab. There was ample space under the cab floor to inspect the motors and truck gear. The motors were operated thru a multiple unit control system so arranged that each section might be operated independently or in conjunction with two or more sections coupled together. Four heavy pieces of cast steel, two side frames and two end pieces, formed the main body of the truck. Strength and rigidity was obtained by machining the parts at the ends where they were fitted together. The ends of the frames were used as buffer beams. To them was attached draft gear which was capable of withstanding a tractive force of 100,000 pounds. This gear was so designed as to allow both

lateral and longintudinal motion. The truck frame was supported by equalisers at four points. The equalizers rested on half-elliptic springs, the ends ofwhich rested on journal boxes. The constriction of the brasses was such that they might be readily removed without moving the wheels and axles or other parts of the truck. The motors were of the General Electric type 65 B, developing 200 horse power at 625 volts. They were geared to the driving wheels with a 81/19 ratio. The eight motors supplied the power thru sixteen driving wheels.

THE THIRD RAIL SYSTEM INSTALLED.- In 1908, the third rail system was installed. Most of the original installation is still in use, although, after ten years of service, it was necessary to renew the third rail in the Howard Street Tunnel due to the effect of locomotive gases and electrolysis upon it. A new type of insulator and board support was used to improve the third rail system in this tunnel.

CHANGE IN SOURCE OF POWER.- The demand upon the electric service grew so rapidly that, in 1909, the great weight and number of trains made it necessary to increase the electric power capacity of the system. A complete change in the method and location of power generation was made. The railroad decided to buy their power from the Con. Gas, Electric Light and Power Company. Since this power was in the form of three phase, 13,000 volt, 25 cycle current, a rotary converter substation was necessary to

supply the line with direct current. A rotary converter substation was consequently constructed at Mt. Royal inwhich 3-1000 K.W., 650 volt syncronous converters with auxiliaries were installed. The building was made of such size that additional converters could be added whenever it became necessary to increase the capacity of the plant. The battery unit was retained to aid economical service at peak load. After the Mt. Royal substation went into operation, the power plant that had been used up to this time to supply the total power was neither necessary nor desirable so it was dismantled.

CLASS OE-1 LOCOMOTIVE.- Another addition was made to the locomotive equipment in 1910 when the railroad secured two new electric locomotives of the Detroit Tunnel type. They were made by the General Electric Company working in conjunction with the American Locomotive Company and consist of a main cab with a sloping auxiliary cab on each end. Their design is such as to make them worthy of a detailed study.

MECHANICAL CONSTRUCTION OF THE OE-1.- This locomotive was built for great weight and strength. The runmung gear is formed by two four wheel trucks connected together thru a massive hinge which allows lateral motion although the trucks support and guide each other. Great weight was the ruling factor in designing the framing; the side pieces consisting of steel castings five inches thick, which were bolted together thru steel end frames and bolster

to form the frame structure are a proof of this. The draft gear and buffers were carried on both ends. The wheels are steel tired and fifty inches in diameter, having gears mounted near their hubs. The weight of the locomotive is carried on cast steel journal boxes which are mounted on pedistal jaws between nine inch shoes. The weight is carried to the boxes thru semi-elliptic journal box springs designed to give as uniform a distribution of weight as possible over groups of springs. This construction relieves the platform and cab of most of the operating stresses.

ARRANGEMENT OF APPARATUS.- The main air reservoir is located well up in the end of the auxiliary cab. Behind this in order named is the sander for the forward wheels, a set of rheostats and the contactors. Perforated side sheets provide ventilation for the rheostats. The Contactors are banked facing the main cab and are available from it. Ordinarily asbestos lined doors shut them off from the main cab. This auxiliary cab is so constructed that in can be removed as a unit from the locomotive. In the main cab are the sand boxes on the sides and the air compressor in a central position. This compressor has a capacity of 100 cu. ft. of air per minute when pumping against a pressure of 130 pounds. In going from the low pressure to the high pressure cylinder, the air passes thru 35 feet of 2 inch pipe on the roof to cool it. It is cooled in a like manner in passing from the high pressure cylinder to the reservoir.

A blower unit next to the compressor supplies the motors with forced ventilation. The control apparatus is provided in duplicate at each end of the cab. It is located at each end of the cab in the right hand corner, and consists of the master controller, air brake valves, air gauges and ammeters. The handles for the bell and whistle ropes, the switches for headlights and valves for sanders are within reach of the operator.

MOTOR EQUIPMENT OF THE OE-1.- This locomotive has four motors designated as G.E.209. They are of the six pole commutating type. The rotor shaft is geared to the wheels at both ends. Great care is taken to have absolute alignment of the pinion and gear teeth, thus reducing the strains on the gear teeth to a minimum.

OPERATION OF THE OE-1.- The maximum tractive effort developed by this locomotive is 46,000 pounds at a speed of 14 miles per hour; giving an output of 1,700 horse power. At starting it will exert a tractive effort up to the slipping point of the wheels. As all its 90 tons weight is upon the driving wheels as is not the case with a steam locomotive it is capable of exerting a greater tractive effort without slipping than a steam locomotive of the same weight. It is a good freight locomotive and at the same time is fast and well adopted for passenger service in the tunnels. By coupling two of these units together they can be operated by the engineer in the forward one thus doubling the power.

FOURTH PURCHASE OF LOCOMOTIVES.- A second pair of locomotives of the Detroit Tunnel type were provided for the tunnel service in 1912 so that this type may now be considered as standard for the present electrification.

ALTERATIONS IN POWER SYSTEM.- In 1914 purchased power was used for all the light and power requirements of electricity for the railroad at Baltimore. This extension of electric service so improved the load factor that the Mt. Royal battery was not necessary and was consequentdismantled. A 2,000 K.W. rotary converter was then installed in the substation giving it enough capacity to supply power to two trains of a trailing weight of 2,840 tons each. All the rotary converters mentioned were secured from the General Electric Company and are in use at present so that the equipment of the substation consists of 3-1000 K.W. and 1-2000 K.W. rotary converters, giving the plant an output capacity of 5000 K.W.

OPERATION IN 1921.- The maximum traffic over the Belt Line in 1921 was about 2250 tons including the steam locomotives of about 230 tons. These trains can be hauled up the maximum grade by two OE-1 or OE-2 locomotives at at about 15 miles per hour. This about twice the speed ofwhich the Mallet steam locomotive is capable under similar conditions.

A BUSINESS ASSET.- The B&O looks upon this electrification as a business asset. They want the public to know

about it. They have gone so far as to advertise this electrification on car cards showing one of their Detroit tunnel type locomotives in service at the tunnels. Their statements concerning the electrification leave no doubt in the readers mind that they are justly proud of this engineering feat.