THE VALTELLINA RAILWAY—THE FIRST STANDARD THREE-PHASE ROAD.

Readers of the SCIENTIFIC AMERICAN are more or less familiar with the electric railway built by Ganz & Co., of Budapest, along the shores of Lake Como. The road was opened for regular traffic on September 4 last, since which time it has been running faultlessly.

The Valtellina line is 66 miles long, and of standard gage. It runs along Lake Como and the River Adda, with three branches extending from Lecco to Colico, from Colico to Chiavenna, and from Colico to Sondrio.

The central power station is situated at Morbagno, the water power of the River Adda being utilized to drive the turbines. The effective head of the turbines is 30 meters (98.4 feet). There have been installed three turbine dynamos, each with a capacity of 2,000 horse power at 150 revolutions per minute. The three-phase alternating-current generators coupled directly with the turbines generate current at a tension of 20,000 volts at the terminals. This high-tension current is led to the primary conductors of the line through a switchboard, and is transformed into three-phase alternating current at 3,000 volts by means of step-down transformers situated along the line. This stepped-down current is led to the contact wires, and thence directly to the motors of the vehicle. The primary conductors are extended along the line on the same poles which carry the contact wires.

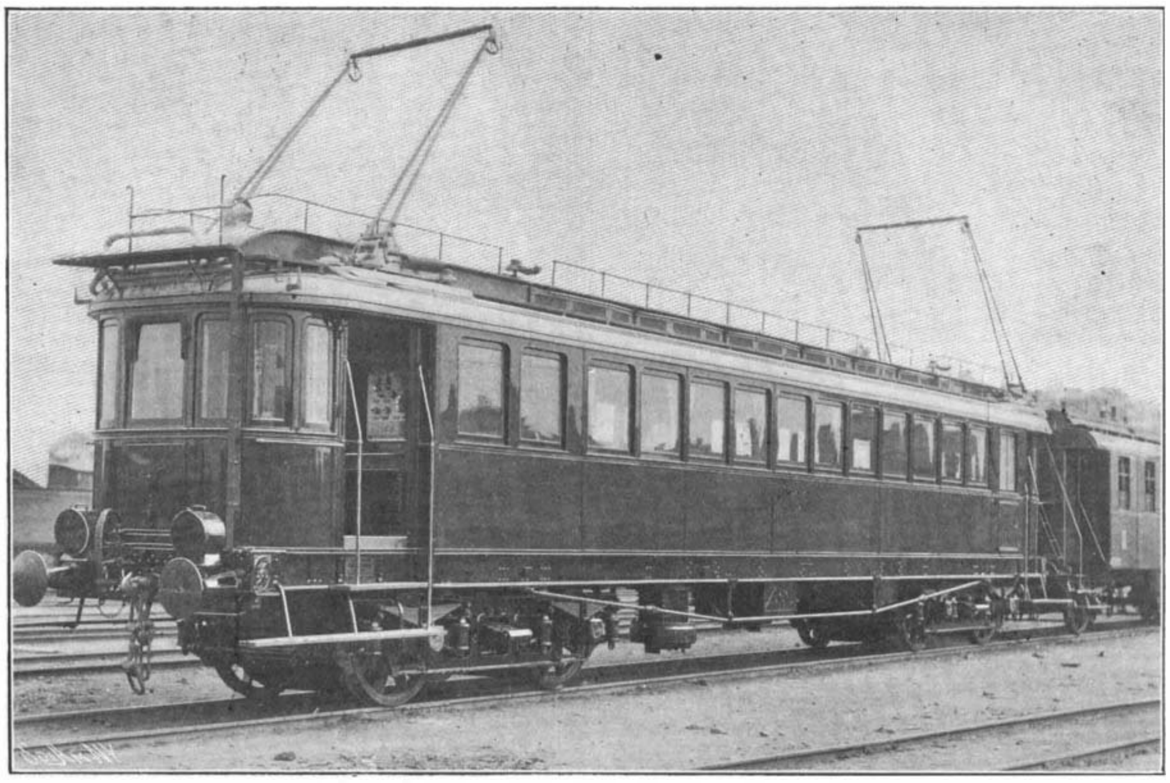
For the line at Lake Como the motor cars are 18.1 meters in the carriage body and 19 meters (62¼ feet) over the buffers. The cars rest on two bogie-trucks, each having a wheel-base of 2½ meters. Without passengers a car weighs 50 tons, including the motors. The wheels are 1.17 meters (3.8 feet) in diameter, while those of the electric freight locomotives supplied to the same line have a diameter of 1.4 meters (4.59 feet). The locomotive motor weighs 3.8 tons; its rotor about 1½ tons. The car-motors with a smaller size wheel weigh 3½ tons approximately. Each series pair of these motors develops a full-load horse power of 150, while the high tension motor itself, when running at full speed with the low tension motor cut out, yields about the same horse power. Thus, 300 horse power are developed in one truck carrying two pairs of motors, or 600 horse power (450 kilowatts) on one train with front and rear driving cars.

The current generated at the central station has a frequency of 15 per second. When running synchronously the high tension motors make 300 revolutions per minute. In the rotor of the same motor the periodicity currents vary according to the slip. During the start, when the high tension is switched into series connection with the low tension motor, after the speed has risen to "half speed," or 150 revolutions per minute—above which speed the series connection ceases—the periodicity of the currents in the rotor of the high tension and in the stator of the low tension is about 7½ per second. The speed of the locomotive motors is 125 revolutions per minute. The Valtellina locomotive motors are not geared in series; they are all high tension.

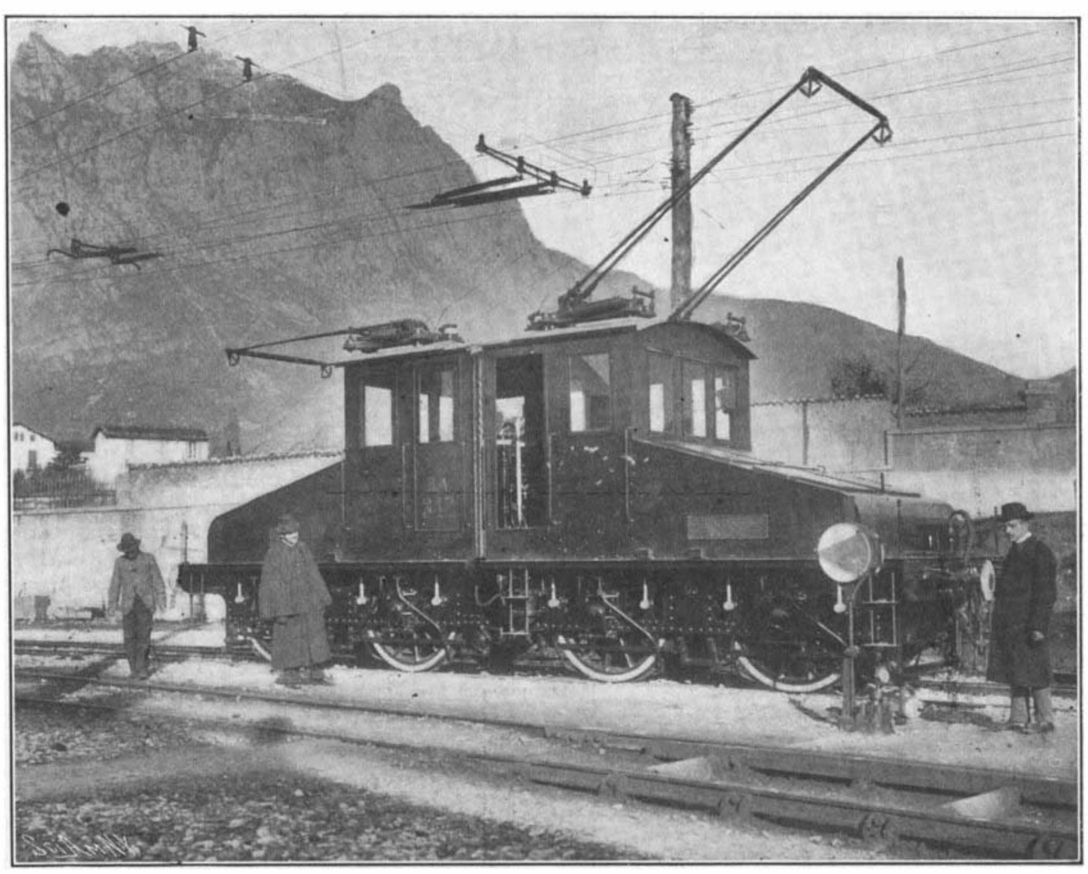
The line will be used for the transportation of both passengers and freight. Passengers are carried by the cars at a speed of 60 kilometers (37½ miles) per hour. The electric locomotives are used for hauling freight trains. Each train has a net weight of 250 to 300 tons. The speed attained is about 30 kilometers (18½ miles) per hour.

The commercial merits of the system are many. The initial outlay was not inordinate. The cost of maintenance is said to be comparatively small. For railways of considerable length and heavy traffic, less maximum power is required in the central station with the Ganz high tension distribution than with the necessarily low tension of continuous current distribution, the ratio of maximum to average load at the central station being less.

The electrical merits of the system are no less noteworthy, especially when the length of transmission from one central station is considered. By reason of the high voltage no large currents are used. The loss involved in converting to continuous current by rotary converters is eliminated. The use of pure induction motors without commutators, and the coupling of these in series pairs, results in a high motor efficiency.



A PASSENGER CAR OF THE VALTELLINA ROAD.



FREIGHT LOCOMOTIVE OF THE VALTELLINA LINE.

The French Patent Office has granted a patent for the "penetration" process of glass coloring. Applications for patents have also been made in other countries of Europe, so we are informed. The process is described thus: Silver salt is put on the surface of the glass, which is then heated to 500 deg. or 550 deg. Cent. The excess of salt having been removed, the surface appears yellow, the color penetrating to a depth of 0.17 mm. when the baking has lasted for about five minutes. After an hour, a layer of double that thickness would be colored; after eighteen hours the color would have penetrated through a glass plate 1.6 mm. in thickness. In reflected light this yellow displays a beautiful greenish or bluish fluorescence. Silver and copper give a red. Gold and iron salts have also been used. When the baking is continued for a long period, the coloring matter is renewed from time to time, say every six hours.

THE HON. SALEM H. WALES.

It is with sincere sorrow that we record the death on the 2d instant in this city of our old associate and partner, the Hon. Salem H. Wales.

Mr. Wales was born in Wales, Mass., on October 4, 1825. At the age of twenty-one he came to New York and entered a mercantile house in this city. In December, 1848, he became a member of the firm of Munn & Co., and became associated with Mr. O. D. Munn and Mr. Alfred E. Beach as one of the managing editors of the SCIENTIFIC AMERICAN. He continued to be identified with the publication until 1871, when he retired from business.

In 1855 he was appointed Commissioner to represent New York at the Paris Exposition of that year, and also served on the Executive Committee of the Christian Commission during the civil war. After his retirement from business he became interested in several public institutions and served New York city in a number of positions.

In 1873 he was appointed president of the Board of Park Commissioners, and again in 1880 and 1888 was a member of the same board. In 1874 he received the regular Republican nomination for Mayor of New York. He was not elected, but in the same year he was chosen president of the Board of Commissioners of Docks and in 1895 he was appointed one of the Commissioners of the new East River Bridge, which position he held for several years.

He was a director in the Hanover Fire Insurance Company, in the National Bank of North America, in the Southampton (L. I.) Bank and the Southampton Water Works. He was a charter member of the Union League Club, organized in 1863, and had always been one of its most prominent and active members. Mr. Wales was also a member of the Century, Press and Church Clubs, the Meadow Club, the Golf Club of Southampton, the New England Society and the Metropolitan Museum of Art, and a member of the Executive Committee of the latter. He was prominent in promoting the success of the New York Homeopathic Medical College, and of the Hahnemann Hospital, and was president of both institutions for a number of years.

Mr. Wales was a man of sterling integrity, possessed a most amiable character, and was widely known and esteemed. His loss will be mourned by a large circle of friends and acquaintances.

He leaves two children, Mrs. Elihu Root, wife of the Secretary of War, and Edward H. Wales. Mr. and Mrs. Wales celebrated the fiftieth anniversary of their marriage on February 12, 1901.

The Scientific American Building Monthly.

There is probably no better illustrated or printed architectural periodical than the SCIENTIFIC AMERICAN BUILDING MONTHLY. In its pages the architect will find photographs and plans of houses, of all styles and costs. To the man who is not an architect, but desires simply to build, it is a treasure-house of suggestions. By glancing through each number he is sure to find a picture of the very house which meets his ideas. A page of bright comment discusses current architectural topics. The "Talks with Architects" are not the least valuable feature of the paper; for often enough the architect interviewed gives information by which even the experienced designer of houses may profit. Each month there appear notes under the captions "The Garden," "The Country House," "The Household," "Legal Decisions" and "New Books," in which new information is presented in an attractive manner. Especial attention is given to formal gardening as an adjunct to the modern mansion.

Electric Traction on Long Distance Railways.

BY ALTON D. ADAMS.

After a long series of experiments, electric railways reached the present standard type at Richmond, Va., in 1888, a type that includes essentially a stationary, continuous-current dynamo connected to car motors by a single circuit made up of the trolley wire on one side and the rails on the other. On the Richmond railway the dynamo voltage was approximately 500, while the motor voltage ranged downward from this figure according to line loss. This pressure remains standard at the present day and is varied from only to the extent of using dynamos up to about 600 volts where long lines involving a large loss of pressure are to be supplied.

The great development of electric railways since 1888 has consisted almost entirely of the application of principles and methods then in use or well understood. Dynamos of much greater capacity have been applied to street railway work, longer lines have been built, and larger cars driven by more powerful motors have been put into operation. In spite of all this extension, almost every electric railway in the United States includes substantially the continuous current dynamo and motor and the single circuit uniting them, working at a pressure of approximately 500 to 600 volts or less.

If the purpose of electric railways had remained merely what it was in 1888, to furnish transportation in city streets, there would be little reason to depart from present standard practice. Instead, however, of a series of tracks in city streets, none of which are more than five miles from the generating station, a single electric railway system now often extends between cities and towns that are 25 to 50 or more miles apart. An electric railway of such length cannot be economically operated from a single generating station when the pressure of transmission or distribution is not above 600 volts. High pressures running into thousands of volts for a distance of 25 miles, and into tens of thousands of volts for a distance of 50 miles are absolutely necessary for efficient transmission of energy, if the cost of conductors is to be held at permissible figures.

Besides the demands of extending street railways for higher voltages, there is a similar demand from quite a different source. Steam railways have suffered a great diminution in their suburban business through the competition of electric lines. Many of these steam roads are ready to adopt electric traction on parts of their systems if it can be shown that the resulting advantages would warrant the expense.

A number of expedients have been adopted to provide for electrical distribution on long railway lines. One of the first solutions of the problem was to build additional generating stations at intervals along an extended railway line, and supply a section of the line from each station. This plan of several generating stations spaced along an electric railway line has been carried out in a number of instances, each station delivering continuous current at 500 to 600 volts. The great objection to this arrangement lies in the fact that such stations must each have a capacity much below that required for the highest economy of operation, because the low voltage permits each station to supply the motors on only a few miles of railway. The voltage at continuous current dynamos, between the trolley wire and track and at the car motors might be increased somewhat, say to 1,000, but there are legal objections to the use of this voltage in city streets, and the difficulty of insulation at car motors would thereby be much increased. Moreover, a pressure of 1,000 or any other number of volts that could be made reasonably safe in the streets and practicable at the motors would be far below the requirements for efficient transmission to long railway lines. Another plan for transmission and distribution to long-distance electric railways involves the development of alternating current at any desired voltage, its transmission to substations each of which contains transformers and rotary converters, and the supply of continuous current at about 500 volts from these converters. This plan has already been put into operation on a number of long-distance electric railways. It should be noted that this adoption of alternating generators and transmission does not avoid the use of continuous current dynamos, distribution lines and motors operating at the old pressure of about 500 volts. The rotary converters are simply a special type of continuous current dynamo in which alternating current may be used for driving, instead of mechanical power. In some cases alternating motors and ordinary continuous current dynamos are used at sub-stations to furnish current at 500 volts for electric railways. The rotary converter simply combines the motor and dynamo in one machine.

Obviously the converters at sub-stations must have capacities at least equal to those of the continuous current generating stations which they displace. It follows that the system just considered adds to the capacity necessary for continuous current dynamos in any event the entire electrical equipment of the alternating station, the transmission lines and the transformers at the sub-stations. On many long-distance electric railways this large increase in capacity of operating machinery is warranted by the high economy of a very large generating station and by the advantage of any desired voltage on the transmission lines. The distance from the generating station at which cars may be operated by this system of combined alternating and continuous current equipments seems to correspond to the limits of electrical transmission at any practicable voltage. At the present time such electric railways are operated that extend more than fifty miles from their generating stations. Though American practice has clung to continuous current motors for electric traction, induction motors have been adopted on a number of railways in Europe. Where the generating station is so far from parts of the railway line that the permissible voltage at motors is not great enough to allow economical transmission, rotary converters may be avoided by the use of induction motors. Furthermore, when converters are not used, the expense for the operation of sub-stations disappears, because mere transformer stations do not require the services of attendants. On European railways where the induction motor is used, the generating station is operated at any voltage desired for the transmission and the alternating current is delivered at a number of transformers spaced at suitable intervals along the tracks or carried by the cars. These transformers lower the voltage to as little as 400 in some cases and as much as 3,000 in others for distribution over trolley wires and tracks to the car motors. Ordinary single phase alternating motors lack sufficient starting power for railway purposes, for which reason three-phase motors are employed on these European roads. With three-phase motors the single trolley wire must be abandoned and two trolley wires with the rails, or three wires without the rails as a conductor must be employed. This use of two or three trolley contacts is a disadvantage in operation compared with a single trolley, but it may be worth while in some cases to add one or two trolley wires and do away with rotary converters. A generating station at high voltage, transformer sub-stations, and distribution from these sub-stations at 400 to 3,000 volts to three-phase car motors make it possible to operate a railway at any distance from the power station that can be economically covered by high voltage transmission. As to the length of railway that may be operated from a single generating station, it thus appears that the system with transformer and converter sub-stations using continuous current motors is on a par with the system having only transformers at sub-stations and using three-phase motors. The Bergdorf-Thun Railway in Switzerland is 25 miles long, its most distant end is 31 miles from the generating plant which operates at 16,000 volts, 14 transformer sub-stations reduce the voltage to 750, and the three-phase current at this pressure is distributed to the car motors.

Whether continuous current or induction motors are employed, a voltage as low as 500 or even 750 for distribution from sub-stations to car motors implies a large expenditure for conductors on long railways. Though it is not thought advisable to exceed the voltages just named at continuous current motors, the same limitation does not apply to induction motors. Hence there is a movement in Europe toward higher voltages at car motors. An illustration of this fact is seen in the Valtellina Railway in northern Italy. This line has 65 miles of track, the voltage at the generating station is 20,000. Twelve transformer substations along the line reduce this pressure to 3,000 volts, three phase, and current at this voltage goes directly to induction motors on the cars.

A further effort to utilize high voltage for distribution right up to electric cars has been made on the European railway from Marienfelde to Zossen, fifteen miles long. On this railway the voltage of transmission and distribution is 10,000, and three-phase current at this pressure is received at transformers carried on the cars and there reduced to a low voltage for the induction motors. But in the new locomotive built for this road, the transformers have been discarded. On another page will be found a full description of this locomotive.

Though little has been done with induction motors for electric traction in the United States, especial attention has recently been turned here to the use of single-phase alternating current for railway work. The Oerlikon Works in Switzerland are building a 44-ton locomotive to be operated by single-phase current on a system devised by an American engineer. This locomotive, which is to develop 700 horse power, is fitted with continuous current motors for driving, and also with a single-phase alternating motor connected to a continuous current dynamo. This locomotive is going into service on a railway in Europe where single phase current will be distributed along the single trolley line and rails at 15,000 volts. After entering the locomotive at this pressure the alternating current will drive the single phase motor, and this motor the dynamo Continuous current from this dynamo will then pass to the motors that do the work of traction. In this system any desired voltage may be employed for the distribution without regard to the continuous current motors.

On a railway now under construction in Michigan single-phase current is to be distributed to the cars at 15,000 volts and there reduced by transformers to 200 volts for the single-phase motors. On each car the motor operates constantly, doing traction work when the car is in motion and compressing air when the car is standing still. The compressed air is used to start the car and also to aid in its operation on heavy work or grades. Like the previously named single-phase system, this one using compressed air permits any desired voltage to be employed between the single trolley wire and track.

A third and apparently very important plan for the operation of railways with single-phase current is soon to go into operation on a road extending from Washington to Baltimore, a distance of 31 miles, with a branch 15 miles long to Annapolis. Single-phase alternating generators working at 15,000 volts will furnish the energy to operate this railway, and current from these generators will be reduced in pressure to 1,000 volts at nine transformer substations along the line. At each car a regulator and transformer will receive the single-phase current at 1,000 volts and deliver pressures ranging from 200 to 400 volts at the motors. This range of voltage will give all necessary motor speeds from starting to 40 miles per hour for the cars. The motor to be used for this work is the most notable feature of the system. This motor is substantially a continuous current series-wound machine with its magnetic circuit laminated throughout. It has long been known that a continuous-current series motor if supplied with alternating current of single-phase will start and operate as though supplied with continuous current, except that very destructive sparking usually occurs at the commutator in motors of large capacity. It is claimed that this trouble has been overcome by a new method of construction, and one of the large electrical manufacturers has contracted to furnish the motors mentioned for the Washington and Baltimore line. Each motor is rated at 100 horse power and there are to be four motors on each car.

It thus appears that while Europe is trying to solve the problems of electric traction on long railways with induction motors and three-phase current, America is going about the work either with a combination of three-phase and continuous currents, or with single-phase current alone. As to the important feature of high voltage for transmission the three-phase and single-phase systems are equal. In the delivery of energy at very high voltages to cars the single-phase current has a great advantage because of the single trolley wire required. On the other hand the development of power with the single-phase current is not yet certainly solved for traction work.

To Our Subscribers.

The Scientific American is fast nearing the completion of its fifty-seventh year. During that time it has faithfully chronicled the scientific progress of the times and has described new and important discoveries and inventions. From the first number to the last which has so far appeared, the Scientific American may be regarded as a weekly history of the world's progress in science, industry and invention.

With the close of the year many of the subscriptions will expire. In order that the paper may be received uninterruptedly, subscriptions should be renewed promptly. An expired subscription will not be continued. To those familiar only with the Scientific American, it may be well to speak of the purpose of the Scientific American Supplement. The Supplement presents papers and articles too long for insertion in the columns of the Scientific American, and contains translations of scientific articles in foreign tongues, which would otherwise be inaccessible to those who read only English. By subscribing both to the Scientific American and the Scientific American Supplement, it is possible to obtain a most complete survey of scientific work on both sides of the Atlantic. By taking both papers the subscriber obtains the benefit of reduced rates.

The Current Supplement.

The current Supplement, No. 1406, contains a wealth of varied information. The opening article deals with the new augmented water supply and reservoirs of London, and is very fully illustrated. The Pacific cable is made the subject of an article accompanied by sectional views of the cable at various points. The Berlin-Zossen Road, now famous in electrical history for the high-speed tests carried out upon it by the two great German electrical companies, has for its counterpart in this country the Aurora, Elgin and Chicago Railway. In the current Supplement an article is published which fully describes this American road. Francis J. FitzGerald continues his discussion

of the conversion of amorphous carbon into graphite. A brief resumé of Prof. J. J. Thomson's lecture before the British Association on Becquerel rays and radioactivity will doubtless be welcomed. How the oxides of nitrogen could be reduced directly by the contact process is likewise told. We have, from time to time, published accounts of the efforts of Americans to exterminate mosquitoes. In Europe no less activity has been shown. It may, however, not be without interest to our readers to learn from Dr. Louis W. Sambon, of Naples, something of the life history of *Anopheles maculipennis* (Meigen), and the methods employed in Europe for its extermination. Prof. Edwin G. Dexter describes interestingly quaint superstitions and proverbs relating to weather influences.

AIR BRAKES

The compressed air brake bears a very important relation to the subject of railway transportation; for it has a direct effect upon the economical operation and speed of trains, as well as upon their efficiency as carriers of merchandise, live stock and passengers. Without the general adoption of the air brake in the past few years the long, heavy, fast freight trains and speedy passenger trains, so comfortable, luxurious, and safe, would not now be running. For the most important consideration is the safe transport of passengers and merchandise, and this requires a brake of great power and always reliable, to control the speed of the train or stop it in a short distance with comfort and safety.

Few people realize the enormous energy stored up in these trains, giant catapults as they are, moving through space with tremendous force and speed. A very reasonable example is a train of freight cars loaded with grain, the total weight of which is about three million pounds. The energy stored up in such a train, when running twenty-five miles per hour, is greater than that which can be imparted to a projectile by the largest of modern guns. It takes a very efficient brake to check this enormous inertia in a short distance, smoothly and safely.

With the air brake, these trains are perfectly controlled. The air brake has kept pace with the great increase in weight, length, and speed of both freight and passenger trains. Much that is interesting could be said about the magnitude of the air brake business, and the details of construction, manufacture, and use under the different circumstances of operation. The employes of railways who have to do with the air brake apparatus are carefully instructed how to handle and care for it, through the publication of instructive literature. There are scattered all over the country, instruction rooms maintained by the railways, where illustrative samples of air brake apparatus are available to the men, and in which traveling air brake inspectors frequently give lectures. There are also instruction cars traveling from place to place in which sample brakes are set up, explained, and operated.

While the subject is technical and of considerable detail, the principles of the air brake can be described in few words. Briefly, the air brake comprises a pump for compressing air, a reservoir on each car for storing the air, a brake cylinder on each car in which the air is allowed to exert its force when it is desired to have the brakes act upon the wheels, and a triple valve on the car, connected with both reservoir and cylinder and controlling the flow of air in and out of each.

The triple valve piston is normally subjected to air pressure of equal intensity on both sides. A reduction of pressure in the train-pipe side moves the piston one way, and restoring the pressure in the train pipe pushes it back again. The former opens connection between reservoir and brake cylinder; the latter discharges brake cylinder air and allows the reservoir pressure to be replenished. An engineer's valve in the cab of the locomotive enables the engineer to cause the rise and fall of train pipe pressure referred to. The rest of the apparatus is the piping, cocks, and connections.

We give a more detailed description of some parts of the brake, selecting those that are representative of the most modern construction and in general use.

The air pump, mounted upon the engine, just forward of the cab, is operated by steam from the locomotive boiler, and compresses the air required for the air brake system throughout the train. The air compressed by the pump is delivered into the main reservoir, which is a large tank mounted somewhere about the engine and storing sufficient air to relieve the pump from excessive work, when more air is suddenly required in the brake system. Otherwise the pump would be subject to violent fluctuations; at rest one moment, and in violent operation the next.

The engineer's valve, or "brake valve," mounted inside the cab of the locomotive, permits the engineer to control the movements of the train by applying and releasing the brakes as the operation of the train may require. This valve controls the flow of air from the main reservoir into the brake apparatus upon the other vehicles, and also controls the discharge of train pipe air when the train is to be stopped, or its speed reduced. The engineer has perfect control of all brakes in the train by moving a small handle. The positions of this handle are: "running," "lap," "service applications," "emergency,"

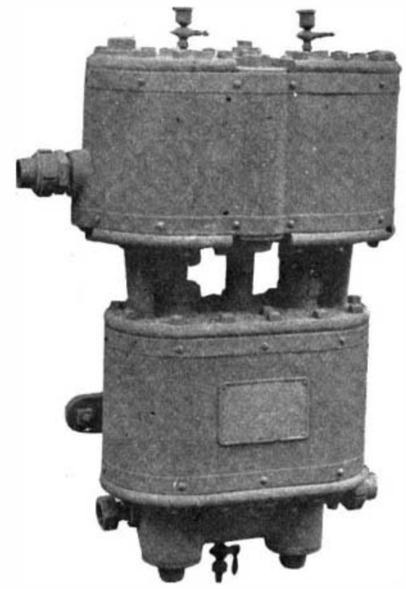


Fig. 1.—THE DUPLEX PUMP.

and "release." "Running" is the normal position of the handle while the train is speeding along and the brake system is charged with air at the proper pressure. In this position, air from the main reservoir, generally about twenty pounds higher in pressure than the rest of the brake system requires, is slowly fed through the engineer's valve into the rest of the system, thus taking care of leaks and keeping the air pressure up to standard.

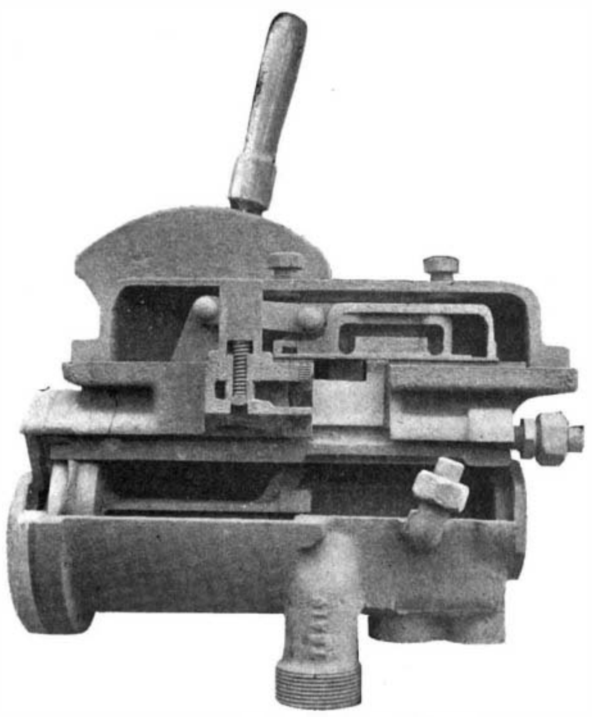


Fig. 2.—THE ENGINEER'S VALVE.

The other positions for the handle are explained by the names given them. The several positions for service applications, set the brakes with different degrees of force. With the handle in emergency position, brakes are instantly set with their greatest power. In release position, air that has been used to set brakes, is replenished from the main reservoir and pump, restoring all parts of brake system to normal condition. A modern type of engineer's valve is illustrated on this page.

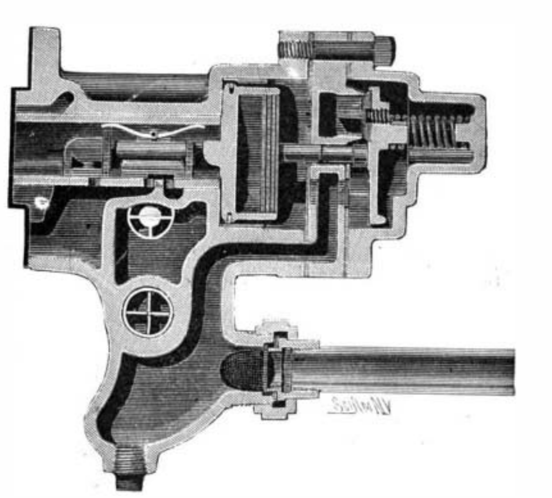


Fig 3.—THE TRIPLE VALVE.

The engine equipment includes a gage for showing the air pressure in both train piping and main reservoir, the pressure in the latter being kept higher than in the rest of the brake system; and a simple governor which controls the working of the air pump, automatically stopping the pump when standard air pressure has been accumulated in the brake system, and automatically starting the pump when the air falls below the desired standard.

The principal parts of the brake apparatus, mounted upon each car, are an auxiliary reservoir, for storing upon each vehicle sufficient air to operate the brakes thereon; a brake cylinder, ordinarily open to the atmosphere (through a port in the triple valve), and a quick-action triple valve.

When air brakes are applied, the triple valve allows air from the auxiliary reservoir to flow into the brake cylinder in sufficient quantity to give the brake-force intended by the engineer. The piston-rod of the brake-cylinder is connected to the levers and shoes by which the power delivered by the brake cylinder is evenly distributed to the wheels of the vehicle. When the brakes are released and the triple valve opens the port that lets the air escape from brake cylinder to atmosphere, a spring, surrounding the piston rod of the brake-cylinder, pushes the cylinder piston back to normal position, the forward movement of the piston having compressed this spring.

Fig. 1 is an external view of the duplex air pump, which is a construction peculiar to the New York Air Brake. The pump is constructed in a very simple manner and delivers sixty-seven per cent more air than other air brake pumps do with equal consumption of steam. The lower half of this pump is comprised by the steam cylinders, the upper half by the air cylinders, quite the reverse of former air pump construction. Thus the drainage of the steam cylinders is collected at the lowest point. The casual observer of this pump might suppose that it was merely a pair of ordinary pumps connected together, side by side, and that the total volume of air would simply be twice as much as would be delivered by one of the pumps alone. Closer inspection shows that this is not the case and that the pump compresses three volumes of air with two similar volumes of steam. One of the air cylinders has twice the volume capacity of any one of the other three cylinders. Its contents are compressed into half their original volume and delivered into the smaller air-cylinder. The smaller cylinder, which has the same volumetric capacity as the steam cylinder below it, will then contain three volumes of air, viz., the free air originally confined within it, plus the two volumes just received from the larger cylinder. The final compression of these three volumes of air is caused by the steam cylinder on that side of the pump, the air being delivered into the "main reservoir."

All working parts of this pump can be examined and replaced without taking the pump off the engine.

Fig. 2 is a photograph of the New York Air Brake Company's engineer's valve cut in half longitudinally. The novel feature of this valve is, that it discharges a definite quantity of train pipe air in each of the several positions for applying brakes, and is therefore called a "positive discharge" valve. An engineer having this valve on his engine, can apply brakes throughout the train with exactly the force that he knows, from experience, should be applied to the wheels to give the retarding power wanted at just that moment, and is not obliged to watch the pressure gage, in the cab of the locomotive, but can keep his eyes upon the rails, signals, or crossings ahead of him.

Fig. 3 is a sectional view of the quick-action triple valve. One is used upon each freight or passenger car. It is by the perfect working of this ingenious, yet very simple valve, that the brakes are all applied at the same moment on the long freight trains, of fifty to one hundred cars, now in use. The quick-action triple valve is really two valves combined in a single casing, one portion operating to make the brakes apply instantaneously and with maximum force throughout the train, as required in emergencies, and the other portion moving to produce a more gentle action and of varied force, as required by slow-downs, station stops, and other conditions of ordinary service operations. In service action the emergency parts remain inert. They are always at rest, except when emergency requires stopping a train at once and in the shortest distance possible.

The action of the brakes is transmitted from the engine to the first car, and from car to car, by an impulse that travels like a sound wave. When the engineer moves his brake handle so as to cause the brakes to apply for emergency, this wave, or impulse, travels through the air brake piping, from car to car, with great rapidity. A train of fifty freight cars of the standard box type is about a third of a mile long, yet brakes upon the last car apply within two seconds of those at the front end, and, therefore, instantaneously with all other brakes in the train. This is quite necessary, for if the emergency action was slow in reaching the rear cars, the forward part would be stopping, with the rear cars running into them. One can imagine the shocks that would result.