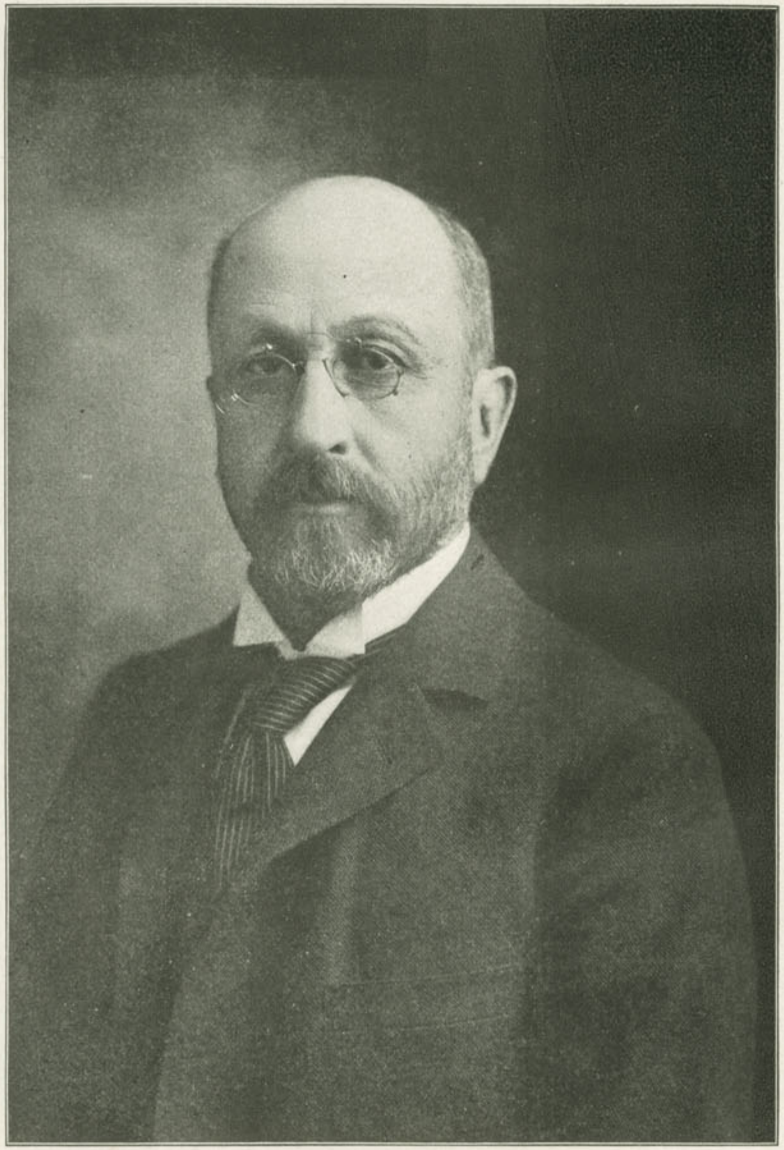

MARSHALL MONROE KIRKMAN.

RAILWAY EQUIPMENT.

FORMING ONE OF THE TWELVE VOLUMES OF THE REVISED AND ENLARGED EDITION OF

THE SCIENCE OF RAILWAYS.

BY

MARSHALL M. KIRKMAN.

RAILWAY EQUIPMENT

CONTAINS A CONCISE MANUAL OF THE LOCOMOTIVE AND ITS WORKING. TREATS OF THE ORIGIN AND EVOLUTION OF THE LOCOMOTIVE; OF THE EQUIPMENT OF DIFFERENT COUNTRIES; OF THE MANUFACTURE OF ENGINES AND CARS; OF THE ORGANIZATION AND ARRANGEMENT OF THE SHOPS AND ROUND-HOUSES OF RAILWAYS; OF THE AIR BRAKE AND ITS WORKING; OF THE ADAPTABILITY OF ELECTRICITY TO GENERAL RAILWAY PURPOSES AND OTHER MATTERS GERMANE THERETO.

THE WHOLE PROFUSELY EMBELLISHED AND ILLUSTRATED BY ENGRAVINGS, PREPARED EXPRESSLY FOR THIS WORK. DESCRIPTIVE OF RAILWAY CARRIAGE AND ITS APPLIANCES.

VOLUME I.

NEW YORK AND CHICAGO:
THE WORLD RAILWAY PUBLISHING COMPANY.
1900.

Entered according to Act of Congress of the United States,
in the years 1898, 1899 and 1900, by
THE WORLD RAILWAY PUBLISHING COMPANY,
in the office of the Librarian of Congress, at Washington, D. C.
Also entered at Stationer's Hall, London, England.

J. C. WINSHIP COMPANY, PRINTERS, CHICAGO.

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Revised and Enlarged Edition of

"THE SCIENCE OF RAILWAYS."

PUBLISHERS' NOTE.

The great and increasing demand for "The Science of Railways" due to its popularity with all classes of railway men, encouraged the author, after seven editions had been exhausted, to revise the work and enrich it by new and important books and treatises on various subjects connected with railways; among others by——

A detailed and carefully illustrated account of the Origin and Evolution of the Locomotive;

A portrayal and concise Manual of the Locomotive, for the information and guidance of beginners and others interested in such matters;

A detailed treatise on the Compound Locomotive, fully illustrated;

An account of the Manufacture of Engines and Cars;

An exposition of the Equipment of Different Countries;

A treatise on the Arrangement of Railroad Shops and Round-Houses, and the Care and Maintenance of Equipment;

An exhaustive and scientific account of the Workings of the Air Brake;

Treatises on Permanent Track Signals and Interlocking, as practiced on American railroads;

An exhaustive and scientific exposition, copiously illustrated, of the Workings and Appliances of Electricity and their adaptation to General Railway Purposes.

Organization of Equipment Department.

Engineers' and Firemen's Manual.

"The Science of Railways" has been further improved and enlarged by new chapters on the Civil Service of Railways, Financing, Fiscal Affairs, Construction, Operating, etc., etc., etc. Many other details of interest and importance conforming to present practices in connection with the Creation and Administration of Railroads, have also been added to the work.

The illustrations of primitive carriage scattered throughout each book of the early editions have, in this edition, been confined wholly to one volume, and while the number has been reduced (to give place to more practical matter) the volume in question contains over four hundred beautiful Engravings illustrative of Primitive Means of Transportation in every age and quarter of the globe. These, with the literary matter that accompanies them, portray in the most vivid and picturesque manner possible the Primitive Peoples of the World, and the successive steps by which transportation has been led up to its present high plane.

The binding, type, paper, and arrangement, it is proper to say, have also been improved and beautified to conform to the increased interest and permanency of the work. It has been further adorned and enhanced in value by the additionof seven hundred engravings (not embraced in the early editions) descriptive of Railway Appliances. These engravings have been prepared expressly for this work by the author, and no expense has been spared to beautify and perfect them.

Such are concisely some of the Improvements which have been made in "The Science of Railways" since the issuance of the firstseven editions.The original work everywhere met the commendation of railroad officers, employes and owners. For this reason the publishers feel assured that the Revised and Enlarged Edition, retaining as it does all that was good in the first issues, with so much that is new and valuable in the enlarged work, will be enhanced in value still further in the estimation of those for whom it is written.

RAILWAY EQUIPMENT.

INTRODUCTION.

This volume forms a part of "The Science of Railways." I embody it as a part of "The Science of Railways" because I know of no good reason why engineers and firemen and others connected with the machinery department of railroads should not desire to know something about railroads generally, as well as others in the service. Certainly, no body of men offers better material to select from in choosing the officers of railroads, provided they study the subject of railroading as a whole. The preparation of this volume occupied many months, and during that time the author submitted it for approval and revision to many men of eminent talent and great experience in connection with railway equipment and machinery Indeed, throughout the preparation of the volume, he actively sought the aid and advice of experts in such matters, so that he might confidently offer to the reader something worthy of consideration in that connection. The engravings the volume contains have been prepared expressly for it, and so elaborate and costly are they that it is no exaggeration to say that nothing so extended has ever before been attempted in connection with any railway publication of this character, nor can more be desired by those studying the subject as railroad men. In view of these facts, and because of the valuable aid and assistance the author has received, he begs to offer the volume to railway men, and to respectfully dedicate it to them.

Chicago, January, 1900.

INTRODUCTION TO THE REVISED AND ENLARGED EDITION OF "THE SCIENCE OF RAILWAYS."

I do not set out to write an exhaustive account of railway affairs, but rather to discuss those things which every railroad man may reasonably desire to form a part of his knowledge, if not of his experience. In the early history of railroads ignorance was general. This is no longer the case. Railway men now recognize that they must not only know thoroughly the particular work assigned them, but have more than a cursory knowledge of the duties of others. No man's experience is, in itself, wide enough to command this knowledge, and it is the object of this work, the result of forty years' practical experience and extended research, in some measure to supply.

The ancients believed the world ended where their vision ceased. Beyond was nothing; a void, simply. And so it is with ignorant men. They are insensible to the value of knowledge; to the accumulated experience of mankind. It lies beyond their vision or comprehension. Its invaluable treasures are to them as if they were not.

Not only this, but they resent knowledge in others. In the early history of railroads, books and treatises on the subject were angrily rejected by practical men, and the writers thereof held up to contumely. Fitness was based solely upon individual experience; upon the kaleidoscopic views of the needs of railroads which began and ended with particular persons. This is no longer the case. To-day knowledge in regard to railway operations is sought wherever it can be found. Men no longer rest content with their own experience. Books and treatises, which would in earlier days have been ridiculed or angrily resented as an impertinence, no longer irritate the egotistical nor excite outward expression of aversion upon the part of the obdurate and narrow-minded. Because of this spirit the railway world is ceasing to be a benighted region wherein men grope about in semi-darkness—the blind leading the blind. Its votaries are not only enlightened and tolerant, but anxious to avail themselves of the knowledge and experience of others. This spirit grows so rapidly that we may confidently look forward to the time when it will be everywhere recognized as necessary that railway men shall not only possess personal experience and skill, but also familiarity with the skill of others. Then an officer or employe, instead of being a

mere speck on the railway horizon, will be a center of light, familiar not only with his own department of work, but, in a general way, with the whole railway world. Thus his mind will be liberalized and his intelligence strengthened and deepened.

Railways are still in a state of evolution, and continue to take on each day the complexion of those who operate them. Every thing in which man is interested, like himself, advances or recedes. There is no stationary period. This is true of railroads. At this time they are on the upward plane. That which seems perfect to-day is bettered to-morrow. So that since the first edition of "THE SCIENCE OF RAILWAYS" was issued, in 1894, I have found it necessary to re-write much of it and otherwise add greatly to the matter it contains. When the work was first issued it did not appear especially deficient to me in any department, but further investigation, more careful study and greater experience, coupled with the progress which railways have made, made it appear to me very deficient in some respects. Accordingly, I took up the subject anew.

Railroads had their origin in the locomotive and the cars which it hauls, together with the machinery department organized for their construction and maintenance. These, as a whole, constitute the primary elements of the railroad world. A great defect in the early editions of this work was my failure to give the equipment and machinery departments the careful and analytical consideration they merited. This defect I now seek, and I trust, in a measure successfully, to correct. In this revised and enlarged edition several books, wholly new, are devoted entirely to the discussion and portrayal of this phase of the subject. They take it up from a standpoint which has been little discussed, and so conscientiously has the matter been prepared and so critically scanned by scientific and practical men that I am assured it will command the attention of men of the highest attainments in such matters. The new books will, it is hoped, commend themselves to the vast army connected with the machinery and equipment department of railroads. The books are not exhaustive, but practical and discursive. To those connected with other branches of the service they will be valuable as throwing light on a department about which it is difficult to gain practical information, but about which such information is necessary because of the intimate and vital association of the machinery department with other departments of the service. I have striven to treat the

subject in a manner which will commend it to railroad men as fully as other portions of the work seem, by their testimony, to have met their approval.

The new matter may be partially summarized as follows: Evolution of the locomotive; description of the locomotive; the locomotives and cars of the world; the manufacture of locomotives and cars; the machinery department; the care and maintenance of locomotives and cars; construction and operation of the air-brake; electricity and its laws and practicable application as a motive power for railways; organization of equipment department; manual of engineers and firemen. In addition to these subjects now for the first time extensively treated in "The Science of Railways," many other important and vital additions have been made to the work.

Wherever practices as portrayed in the first edition have been modified by subsequent changes, or the description has been found deficient, it has been my aim as new editions of the work have been issued to supply the deficiency. Among important subjects that have been elaborated in the new editions, not enumerated above, the following may be mentioned: Opportunities and requirements of the civil service of railroads; train service; details of track; car wheels; lighting cars; heating cars; fiscal affairs, financing, etc. In every instance where improved practices or more careful study have suggested changes, they have been made.

The illustrations and chapters on Primitive Carriers, which were scattered through the work in the first six editions, have been concentrated in one volume. They may thus be quickly and easily scanned without in any way interrupting the more serious theme of the work. The pictures of primitive carriers, while reduced in number, are still of surpassing beauty and attractiveness, and sufficient in number and careful selection to be thoroughly representative of primitive carriage in every age and part of the world. On the other hand, the literary account of primitive people, as associated with primitive carriers, both of our age and of the ages which have preceded it, has been greatly added to in interest in the enlarged edition.

While the engravings representing primitive forms of carriage have been restricted to such as are valuable from an artistic and practical point of view as illustrating the forms of carriage that lead up to railway transportation, the author has added seven hundred engravings representing the highest known forms of transportation. The value of these to railway men can not be over-

estimated, as with the text accompanying they form a panorama of the physical machinery of railroads of the greatest practical value and interest.

And in this connection it is proper to say that, while I make much of the new matter in the revised and enlarged edition, I do not wish to imply that I consider it more important than other and older portions of the work. I am led, however, to refer particularly to the new matter because it is here that the work has, by some, been claimed to be deficient. I have never heard similar criticism of it in regard to other departments of the service of which it treats. The new matter simply rounds out what was before lacking, and makes the work, as a whole, more nearly conform to what I desire it to be; namely, an exposition of THE SCIENCE OF RAILWAYS.

CHAPTER I.

EVOLUTION OF THE LOCOMOTIVE.

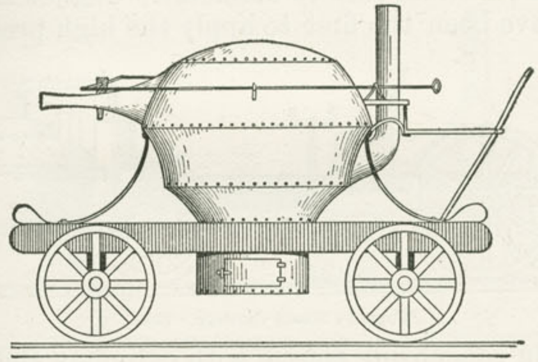
THE genius of the railway system lies in the locomotive; hence I make it the theme of my opening chapter. The pulsations of its heart carry to and fro the commerce and travel of the world, just as the action of the human heart sends the blood coursing back and forth through the body. It is for the moment the consummation of man's highest achievements and desires in this direction. His labors and speculations on the subject antedate our time by many hundreds of years, but not until the nineteenth century did his inventive genius sift from the myths of speculative fancy something he could control and direct at will; something insensible to labor and pain, and that could be made to carry the burdens before borne by him or his willing agents—the animals.

A history of the locomotive, however brief or imperfect, like all histories, is more valuable for the suggestion it affords thoughtful men than for the mere power to satisfy the curiosity of the multitude.

So many functions have grown up about the operation of railways, we constantly forget that the spark of life lies in the locomotive; that its fire warms the blood and is the cause of all the animation we see about us. The theme is one to excite admiration, and can not be considered mechanically. The conception, purposes and achievements of the locomotive must, each in its turn, be familiar to the engineer in order that his sympathies may be excited and his genius inspired. Without such inspiration how can he fully fathom its mysteries, comprehend its possibilities or aid in achieving its great future? To understand its mechanism or fathom its future he must have traced its growth. In order to go forward he must first be imbued with the inspiration of what has already been done. It is never enough in a world so great as that of railways, that men should comprehend only the mechanical thing; they must also understand its philosophy. It is for this reason that in describing the locomotive I preface what I have to say by an account of its origin and growth.

The discovery of the locomotive is, as a whole, the greatest achievement of man in the art of carriage. He speculated for many centuries on the utility of steam, but it remained for Trevithick, of our day, to demonstrate its ability to haul a load across the country and perform other acts of drudgery that before seemed incredible. With its introduction the horse and the ox henceforth became local incidents of carriage merely, and no longer factors.

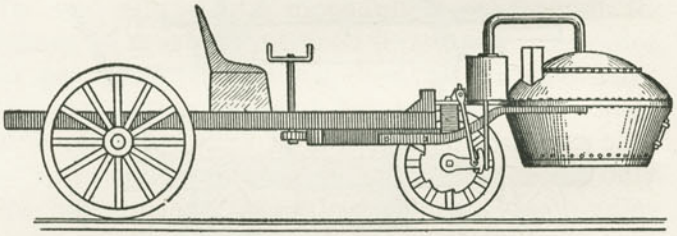
Who first discovered the possible value of steam we are not informed, but we know that as far back as one hundred years before the Christian era a more or less ingenious machine, operated by steam, had been constructed at Alexandria, Egypt, by Hero. It is clear that he understood the expansive power of steam and its possible utility. The advanced position he took, and the treatise he wrote on the subject, suggest



Newton's Experimental Engine. 1680.

that many experiments and cogitations of others, before his time, found expression in him. Discoveries of this kind do not spring full-fledged into existence, but are created little by little, and thus nurtured and grow.

Nothing of a useful nature grew out of Hero's speculations, and it was not until the seventeenth century that the practical value of steam for purposes of carriage assumed tangible form. In 1680 Newton sought to invent a machine by which the reactionary force of steam upon the air would propel the vehicle forward. His experiments, however, were not satisfactory. In 1769 Cugnot, an officer of the French army, invented a steam-propelled vehicle with three wheels. The front supported a frame which carried a steam boiler and other appliances. The machine was steered by a lever from the platform. The driving wheel was of wood; it was tired with iron, and about four feet in diameter. Cugnot is said to have been the first to apply the high pressure

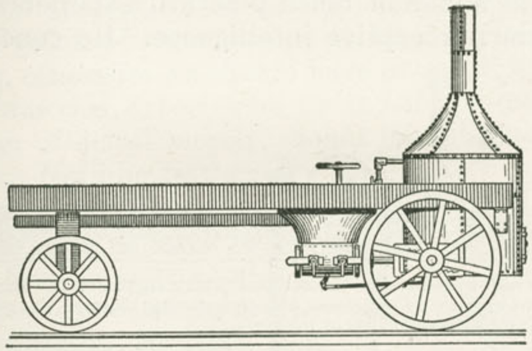


Cugnot's Steam Carriage. 1769.

or non-condensing engine with cylinders and piston to the production of rotary power, as well as to utilize steam for purposes of land locomotion. The limited size of the boiler of his engine, coupled with other defects, rendered its use impracticable. The first attempt to utilize steam for propelling carriages in America was made by Nathan Read of Salem, Massachusetts, in 1794. He is credited with having constructed the first multitubular boiler. The tubes were placed vertically. The forward wheels of the machine were placed on a swiveling axle, operated by a hand

wheel attached to a large sheave over which a rope was placed, the ends being attached to the axles. His engine was designed to travel only in one direction.

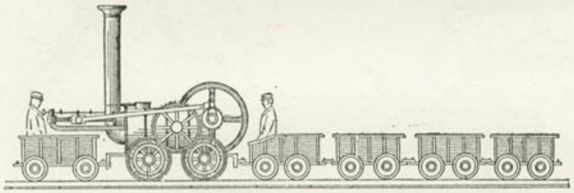
With the needs of the commercial world came the perfected locomotive. Forms of government had become fixed and, with them, the internal commerce of the world was rendered measurably secure. Trevithick's discoveries made the loco-



First Multitubular Boiler, Read's Steam Carriage. 1791.

motive practicable, but it was not until twenty-seven years afterward that the attention of the world was attracted to it and its possible future usefulness. It resulted from this neglect that when the subject was finally brought forward the person who happened to be immediately connected with the awakening was singled out as the central figure and hero of the event. And it follows from this chance association that George Stephenson will for all time be generally believed to have been the inventor of the locomotive and, therefore, the father of the railway system, instead of Trevithick.

From the accounts which have come down to us, it appears that in 1803 (twenty-seven years before Stephenson opened the Liverpool and Manchester railway with its procession of engines) Trevithick constructed a steam locomotive designed to run on a cast iron tramway. He was a man of much practical experience and singularly receptive intelligence. He conceived

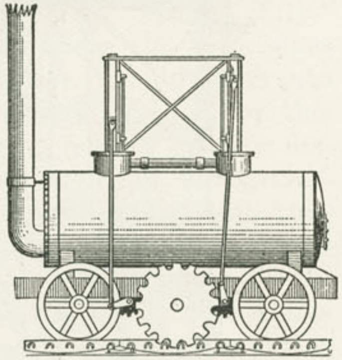


First railway train in the world. Trevithick's engine. 1803. The driving wheels are operated by cogwheels, directly connected thereto. The rails were smooth, as were also the tires of the wheels.

what had before been disputed, namely, that a smooth wheel acting on a smooth rail had the necessary adhesion to draw a load proportionate to the weight placed on the wheels and the power of the machine. This weight the attendant boiler with its load was intended to supply. In constructing his locomotive, the steam from the cylinder was made to escape through the chimney. This happy conception, whether its results were anticipated or not, created a strong draught, and it followed therefrom that one great object, namely, a good fire with which to

create steam, had at last been achieved. This simple expedient solved, in a measure, the practicability of the use of steam for purposes of land carriage.

Trevithick employed high pressure steam.* His locomotive contained every essential feature of the present machine, but was, upon trial, unfortunately, found to be more expensive to operate than horse power, and thus not a commercial success. This defect, fatal from a practical point of view, seems to have chilled his ardor, otherwise we should have expected him to continue his experiment until this obstacle, a matter of detail merely, should have been overcome. Nothing further appears of a practical nature in connection with the locomotive until the advent of John Blenkinsop, in 1811, when he put Matthew Murray to work to construct a locomotive that would haul coal over his railroad, or tramway, between Middleton and Leeds, three and a half miles. In consequence of the severe

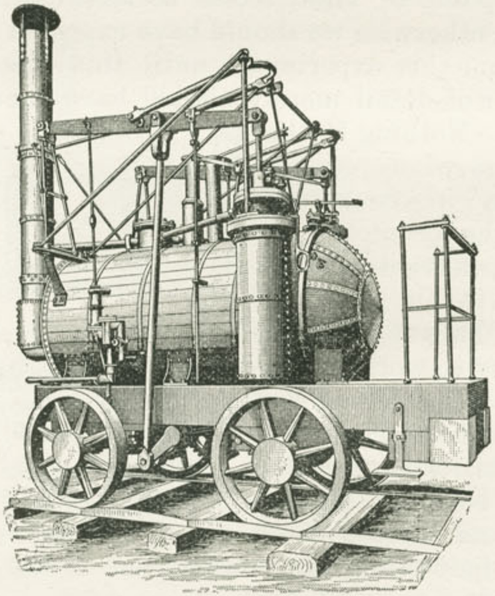


Blenkinsop's Rack Rail Locomotive, 1811. The wheel and rail were notched as shown.

*In this connection it is proper to say that high pressure steam is the only form used in connection with the locomotive, save in the case of compound engines, in which case the use of the steam the second time may be termed low-pressure.

gradients on the line, a notched or rack rail and a cog wheel were used. A trial of this machine was made in August, 1812, and, having been found to be an economical as well as a mechanical success, it was continued in operation.

During this interesting period many other experiments were being carried on, but, while they afforded much valuable information, were not in the main successful. In 1812 the locomotive known as the "Puffing Billy" was



"Puffing Billy." 1813. The so-called rails on which the engine stands, it will be noticed, are little more than plates, and it is from this fact that the trackmen of England are to-day still called plate-layers. This picture is an original, taken from the locomotive now at the Field Columbian Museum, Chicago. Many of the other illustrations in this volume are similarly taken from originals, or models thereof. All are perfect representations of the things they depict.

constructed by a Mr. Blackett, proprietor of the Wylam Colliery. William Hedley, one of his employes, assisted him. They used a smooth rail and wheel, demonstrated by Trevithick to be practicable. Blackett's locomotive, however, when put in operation in February, 1813, was found not to be entirely successful because of the difficulty of making steam. Afterward, however, in May, 1813, when rebuilt and the exhaust had been carried into the smoke stack, as devised by Trevithick, the difficulty was found to be overcome, and the locomotive proved to be a perfect success, financially and mechanically, and was continued in operation for many years. Blackett's locomotive was called "Puffing Billy," because of the noise made by the two pipes which carried the steam from the cylinders into the smoke-stack. The noise occasioned by this locomotive and the cars it hauled greatly disturbed the quiet folks who dwelt in the neighborhood; indeed, they went so far as to claim that it vitiated the lease of the land to the railroad company. However, eventually, "Puffing Billy" ceased to scare the cattle and distract the minds of the people on the line and so the railroad was allowed to stay.

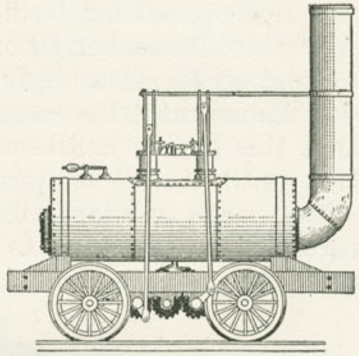
During the same year a second locomotive was built by Blackett for use on his line. In constructing his machines, however, due regard was not paid to the weight of the rail on which they were to run, and so it was found necessary to substitute for the four rigid wheels on which the machines were operated, two four-wheeled bogies.* This secured a more equitable division of the weight, while also permitting the machine to run around the sharp curves on the line. Afterward, when the road had been relaid with heavier rails, the four-wheeled bogies were removed and the engine again placed on four fixed wheels as in the first instance.

Middleton & Leeds Railway. 1812-13. Thirty cars were hauled in a train.

Up to this point in the introduction of the locomotive, George Stephenson, who afterward deservedly became so prominent, had not appeared prominently as an inventor or constructor. His attention, however, had been

*I use the term "bogie" in reference to the English custom rather than that of America. In England a four-wheeled truck with the bogie principle is called a bogie, but in the United States only two wheels are recognized as coming under this head. The English were slow to utilize or introduce the two-wheeled bogie. From time immemorial the rigid wheel-base was the fashion in that country. This prevented the sharp curves which are so common in America and which so greatly lessen the cost of railways. The railways in Great Britain have been constructed with a view to the avoidance of such curves, while the financial necessities of the American roads rendered them necessary. Because of this the bogie did not in England possess the value it did in America. That the English erred in this we may confidently believe from the fact that the bogie ultimately found favor on the English roads.

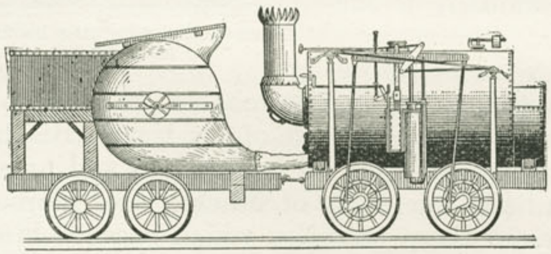
early attracted to the subject in connection with his patron, Lord Ravensworth. His investigations and reflections first bore fruit in the locomotive successfully constructed under his direction and tried in July, 1814, called the "Blucher."



Robert Stephenson's First Locomotive. "Blucher," 1814.

His engine was thus fourth in order of succession, or third in order of those proven to be commercially and mechanically a success.

Stephenson, however, did more, it is probable, to perfect the locomotive than anyone of his time. His mind was peculiarly open to impressions and quick to assimilate the ideas of others. He, moreover, possessed those qualities which enabled him to impress others with the practicability and value of his conceptions. He was not only a mechanical engineer, but a man of talent and affairs in other directions. He possessed a mind capable of considering intelligently and conservatively any problem brought to his attention, whether it were a financial project, a business detail or a mechanical idea. It resulted from this and the study he had given the subject, and the prominence he had attained meanwhile, that when in 1818 the owners of the Stockton and Darlington determined to construct a public railway, they employed him as their engineer; but, owing to obstacles in Parliament and elsewhere, the road was not opened for business until the twenty-seventh of December, 1825. The locomotive used on that occasion was designed by Stephenson and was known as "Locomotion." From the fact that this engine continued in successful operation until 1841, it is apparent that it embodied within itself substantially all the essential features afterward proven to be necessary to safety and economy of operation.

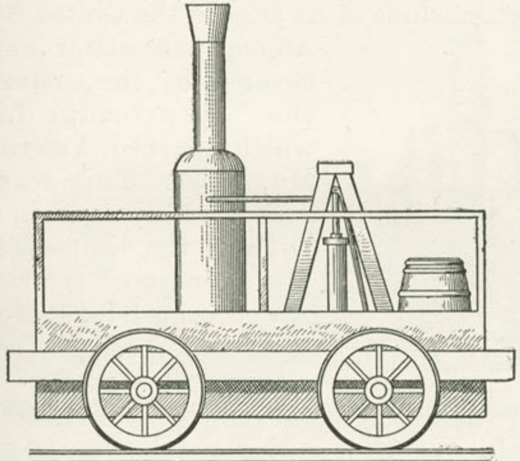


The first railway locomotive with multitubular boiler. Seguin's. 1828.

In 1827 Seguin, of France, is said to have converted a Stephenson engine into the first railway locomotive with a multitubular boiler. Previously the locomotive boiler had been a cylindrical shell with one tube placed lengthwise, with the exception of the one constructed by Read in 1791, referred to. Seguin proved that the evaporating power of an engine was greatly increased by the multitubular principle, and to

him is largely due the rapid development of the locomotive in this direction.

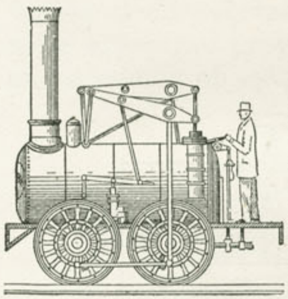
In 1830 the Stockton and Darlington had eleven locomotives in successful operation. Of these, eight were designed by Stephenson and three by Timothy Hackworth. The latter afterward became engine superintendent of the line. As an



"Tom Thumb." 1829. Built by Peter Cooper. The first engine to draw a car on the American continent.

indication of the power of the locomotive at this period, one owned by the Stockton and Darlington road had six coupled wheels and could draw thirty-two cars, or one hundred and thirty tons, of coal on a level at the rate of five miles per hour. The cylinders were eleven inches in diameter, and had a stroke of twenty inches. The driving wheels had a diameter of four feet.

The people of the United States having heard of the successful operation of the locomotive in England, the Delaware & Hudson Canal Company, in 1828, sent its agent to England to buy rails and contract for four locomotives. This was the inaugural effort of railway operations in America. Of the four locomotives, the "America" arrived in New York in January, 1829, and was the first machine of its kind in the United States.



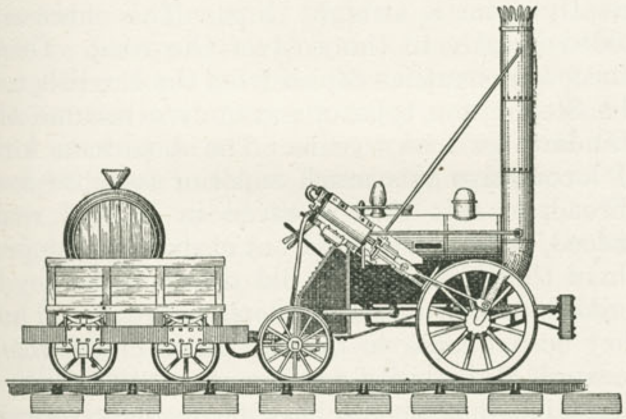
The "Stourbridge Lion." 1829. Delaware & Hudson Canal Railroad.

Among the other engines covered by the order was the "Stourbridge Lion," which reached America in May, 1829. This was the first locomotive put in operation in the United States. The event occurred on the 9th of August, 1829. Horatio Allen was the engineer.

Other locomotives were constructed and placed in successful operation in England during the period I have named; thus, one (in 1829) for the Shutt End Railway, at Kingswinford.

It was at this time—September 15th, 1830—that the event which so impressed the world occurred, namely, the opening of the Liverpool & Manchester Railway. So late as 1829 the owners of that property were still in doubt as to whether to use horses, or locomotives, or stationary engines with endless chains. To solve their doubts they determined to have a competitive

trial of locomotives. It occurred near Manchester in the latter part of the year 1829. The reward was twenty-five hundred dollars for the locomotive which should prove to be the most successful. Three machines competed, among them Stephenson's "Rocket," which deservedly received the preference. These experiments convinced those interested of the value of the loco-



Stephenson's "Rocket." 1830. This engine hauled the first train at the opening of the Liverpool & Manchester Railway.

motive, and they accordingly gave Stephenson orders for seven other machines, all of which took part in the great procession that attended the opening of the Liverpool & Manchester road, on the 15th of September, 1830. The "Northumbrian," which had a speed of thirty-six miles an hour, headed the procession as being in all respects the best of its type.

George Stephenson and his son Robert attained great influence in connection with railway subjects because of their ingenuity and talents. They are said to have improved the steam blast, which enabled the "Rocket" to make sufficient steam to haul a passenger train at the rate of thirty-five miles an hour.* The wheels of this locomotive had little side play and on this account it was necessary that the track should not vary greatly from a straight line. This necessity added greatly to the cost of the road. Other European countries copied from the English, and the Stephenson type of locomotive became the standard for many years. The American form of locomotive was much superior to those used abroad, in this that it saved in cost of road. Indeed, as I have pointed out elsewhere, the people of the United States did not have money to build the expensive roads adopted abroad, and had they been unable to operate their cheap roads because of inability to invent anything more adaptable than the Stephenson locomotive, railway construction in this country would have been very light.

About the time of which I have been writing Stephenson constructed the locomotive known as the "Planet," which became, in a measure, the standard for that period. It had inside cylinders, placed under the smoke-stack in front of the machine. In 1831 the necessities of the freight

* This speed is stated by Stretton not to have exceeded twenty-nine miles an hour. Authorities differ.

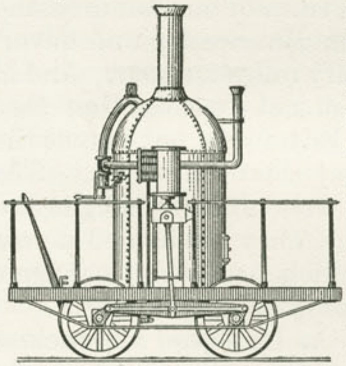
traffic of the Liverpool & Manchester Railway requiring locomotives with greater power, the "Samson" and "Goliath" were constructed to meet this requirement. The machines weighed ten tons and had cylinders fourteen by sixteen inches. The driving wheels were four feet and six inches in diameter.* This was justly esteemed a great advance over anything previously constructed. It is recounted of the "Samson" as a remarkable evidence of its strength, that it was able to convey a freight train of one hundred and sixty-four tons between Manchester and Liverpool at the rate of twenty miles an hour. And in this connection it must not be forgotten that freight trains in Great Britain do not run at the slow rate of speed they do in America. The freight or goods car of Great Britain is light and the load to correspond. They are hauled across the country at a rate which American managers have only permitted for passenger trains.

With the opening of the Liverpool & Manchester the railway system of the world was formally inaugurated. However, George Stephenson continued to be much sought after in opening new roads; as, for instance, the Glasgow & Garnkirk Railway, in 1831. The engines used at that time

* These engines had originally four driving wheels, but the oscillation when in motion necessitated the addition of two small trailing wheels back of the fire-box. Thus the first inside cylinder freight engine upon six wheels was constructed. Later, in 1834, the "Atlas" was built with six coupled driving wheels and cylinders sixteen by twenty inches, and became the first machine of this description with inside cylinders.

had cylinders eleven by sixteen inches, with driving wheels four feet and six inches in diameter.

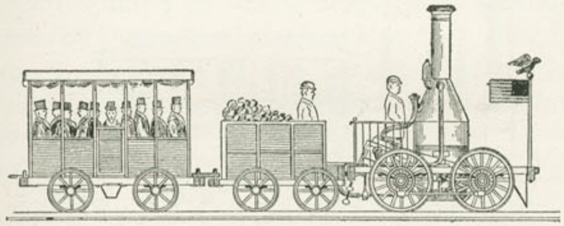
It was at this period—on the 4th of January, 1831—that the owners of the Baltimore & Ohio Railroad offered a reward of four thousand dollars to the manufacturer of the best American-built locomotive of three and one-half tons weight, capable of drawing fifteen tons at fifteen miles an hour on a dead level. It was stipulated, moreover, that it should burn anthracite coal, and have four wheels coupled together. The premium was finally awarded to Davis & Gartner, manufacturers, of Pennsylvania.* This firm first constructed what was known as the "grasshopper" pattern of locomotive some of which were in use on the Baltimore & Ohio Railroad



The "York." 1831. The winner of the Baltimore & Ohio prize of four thousand dollars.

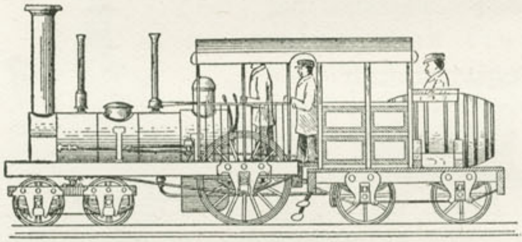
* The locomotive they constructed was known as the "York." Quite a number of manufacturers were meanwhile actively getting into position to meet the wants of the community in this new direction. It was with this thought that the Baldwin works were started, in 1832. Many manufactories in Great Britain, among others Stephenson & Company; Fenton, Murray & Company; E. Bury & Company; Galloway & Company; Sharp, Roberts & Company; Tayleur & Company; and Forrester & Company, destined to exert a most marked influence on the construction and value of the locomotive, had already been started.

as late as 1863. It is noted of the "Comet," built at this time, that its smoke-stack was thirteen feet in height. It was about this time in railway construction that there sprung up the question of the relative value of four and six-wheeled drivers. The advocates of each claimed superior qualities for their machine. For many years those who advocated the four-wheeled disputed the usefulness of the other, but ultimately the great value of the six-wheeled locomotive for particular uses was demonstrated beyond controversy.



Train on Charleston & Hamburgh Railroad, South Carolina. The locomotive was called "Best Friend." It was built in 1830, and soon after exploded through neglect of the fireman. When re-built it was called the "Phœnix."

If the public were slow to appreciate the value of the locomotive for commercial purposes prior to the opening of the Liverpool & Manchester railway, it was fitfully alive after that period. Indeed, from being coldly indifferent it became over zealous; from being loth to invest at all, it became insanely anxious to place its money at any risk. It thus came about that promoters had no difficulty in finding means to further their enterprises, no matter how wild or visionary they were. Little attention was given to the probable dividend-paying capacity of the venture, but everything offered was quickly taken. The result was as might have been expected, a great financial crash, which for the moment paralyzed ventures of all kinds, good and bad. Afterward, when confidence was restored, progress was carried on along more conservative lines. Speculation during the period referred to was not confined to railways, but characterized, more or less, everything that affected these properties, or that was used in connection with them. Thus



First Truck Engine, "Brother Jonathan." Mohawk & Hudson Railroad. 1832.

manufacturers of locomotives sprung up out of all proportion to the needs of the time. However, the hardship which befell these ventures was not so disastrous nor far-reaching as in the case of railroads, where thousands of people lost all they had.

At first every question which arose in connection with the operation of railroads was necessarily open to discussion. Nothing had been demonstrated, and in the haste and confusion of the moment the most visionary projects found advocates or acquiescent followers. This was the

case with questions regarding the most practicable gauge for locomotives and, therefore, for railroads. At first the gauge in England was uniformly four feet, eight and one-half inches, following that of the colliery tramways. In Scotland there were a few with a gauge of four feet six. However, when the Great Western Railway was built, Brunel, its eminent engineer, determined to adopt a gauge of seven feet, and invited the construction of locomotives on that basis. Parliament having permitted this gauge, many other variations occurred in quick succession until every variety of theory had been exhausted. One broad gauge locomotive of the Great Western had a driving wheel ten feet in diameter—the largest ever known.

At first it was maintained that the broad gauge locomotive was capable of greater speed and uniformity of operation than any other. This view remained uncontroverted until it was demonstrated that the four feet, eight and one-half inch locomotive was capable of even greater speed than the broad gauge engine, while in all other respects it was fully up to the broad gauge machine in convenience and serviceability. In 1846 a broad gauge engine of the Great Western Railway attained a speed of seventy-eight miles. In 1847 a standard engine of the London and Northwestern Railway made seventy-nine miles per hour. When we remember that our own period is thought to be peculiarly noted for the speed of its locomotives, the performances made in 1846 and 1847 must incline us to be more appreciative of early railway builders.* The driving wheels of the London and Northwestern engine were eight feet six—the largest ever put under a standard machine. Those of its rival, the Great Western, were eight feet in diameter. The cylinders of the latter were eighteen by twenty-four. It was said to evaporate three hundred cubic feet of water per hour and the minimum fuel it consumed was two and one-half pounds per horse power per hour.

When it was demonstrated that the locomotives of the narrow gauge of the London and Northwestern Railway could make as good or even better time than those of the Great Western, both the public and the owners of the railways were inclined to favor the former and to insist upon its being made the standard. This, because the conveniences of traffic required uniformity. Moreover, it was much cheaper, even relatively to construct and afterwards to operate the narrow gauge road than the broad gauge. These and other things, all potent in themselves, caused the broad gauge roads to rapidly fall into disrepute, but the idea was not completely and finally abandoned in England until 1892 when

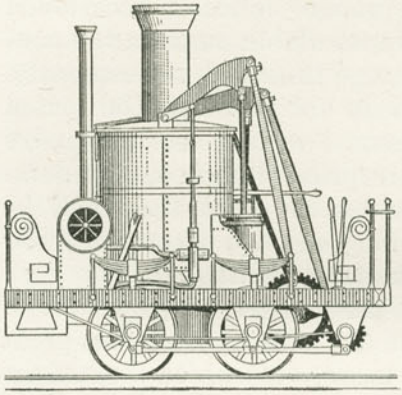
* In this connection it should not be forgotten that the track in 1846 and 1847 was much inferior to that of to-day. The fish plate had not then been introduced; moreover, the art of track laying, which has reached so high a plane, was in its infancy, comparatively. The absence of heavy rails and other appliances we consider so necessary to a perfect track rendered heavy locomotives, and fast running matters of great difficulty in 1846.

the Great Western railway changed the last of its broad gauge engines to conform to the standard system.

While the broad gauge delusion occasioned owners the loss of incalculable sums in the construction of broad gauge lines and, subsequently, in their operation, it is not probable the lesson could have been learned in any less expensive way. In all new enterprises, if men cannot demonstrate their ideas on the spot, they will be disputed, and thus time only can determine their accuracy. An incidental advantage that accrued from the battle of the gauges, or grew out of the sharp rivalry it occasioned, was the great improvement in the locomotive which the intense study of the situation and its needs and the effort to distance competitors suggested. This was some compensation to the public and to owners for the vast sums expended on the broad gauge roads. The struggle between the rival factions would have terminated much earlier than it did, it is believed, except for the lack of tact displayed by railway managers, notably Bury, of the London and Birmingham railway, who, running to the other extreme, insisted upon building and operating engines with very small driving wheels. These locomotives showed very poorly in comparison with the magnificent engines on the Great Western, and prejudiced people in favor of the latter. However, the struggle was unequal and, although the Great Western continued to operate some of its broad gauge locomotives as late as

1892, the superiority of the standard gauge had manifested itself many years before.

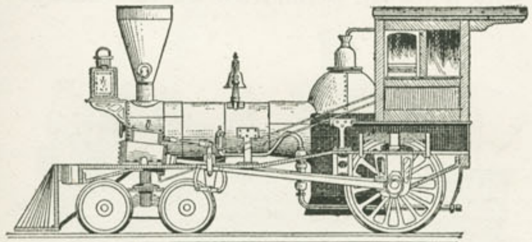
As another illustration of the difficulties in which the early projects were beset by the lack of precedent or experience, the case of boiler construction may be cited. Thus, the length of the boiler of the locomotive could not at the beginning be determined by known utility. It was only when the smoke-stacks of these machines were found to be quickly burned out, that it was surmised the escaping heat must be unduly great. Tests were accordingly made and this was found to be the case. To stop the waste the boiler was lengthened so as to secure increased heating surface and more complete consumption of the fuel.



The "Traveler." 1832. The first distinctive freight engine. It was built by Phineas Davis, and remained in service until 1893.

At the close of the ninteenth century we find that the growth of the locomotive is not yet ended. It is impracticable to give a minute account of its evolution with illustrations of the various locomotives upon which changes or improvements have been made. As a matter of fact, probably a locomotive has never been

manufactured that was not intended to be in some respects an improvement over those preceding it. The growth of the locomotive is, however, marked by a few great and important improvements. These it is not only possible, but will be interesting and valuable to notice. The series of pictures embraced in this chapter the reader will, upon examination, discover to be progressive in these practical details. I have not attempted to portray every representative engine



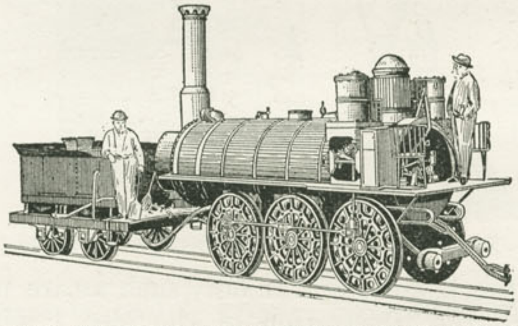
The "Pioneer." 1836. One of Baldwin's early engines.

from the beginning, but only such as are necessary to the illustration of the idea I wish to convey.

In regard to the details of locomotives, they represent, in a measure, their evolution. Some of these details I have incorporated in a table in the Appendix hereto, where particulars may be seen at a glance and quickly analyzed.* The table embraces a statement of the weight of particular locomotives, number of driving wheels, diameter and stroke of cylinders, and other

* See Appendix *A*.

important particulars relating to representative machines, commencing with that constructed by Trevithick in 1803. The table is not exhaustive, but sufficiently so for practical purposes. With the aid of this table the reader will be able to trace from year to year the vigorous growth of this great engine of civilization. He will, moreover, be grateful, I feel assured, for this condensation, which will enable him to escape the laborious delving through many dull pages of print which would otherwise be necessary.

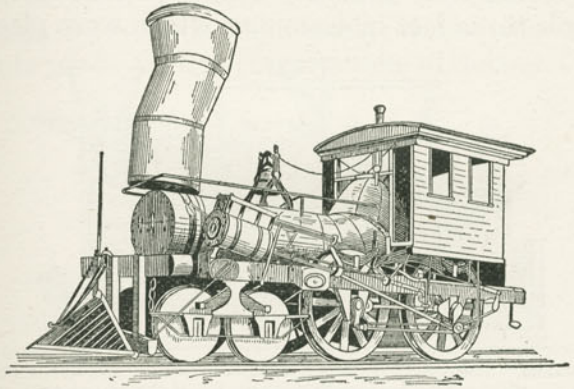


The "Samson." 1838. Built by Timothy Hackworth of England. In service in a coal mine in Nova Scotia over forty years.

With this brief explanation, I will take up the more important characteristics of the locomotives in the general order they have been evolved from time to time. It will not occupy much space in telling, while it is necessary to a knowledge of the growth of the machine.

To commence, then, the reader will not have failed to remark how exceedingly simple the locomotive was that Trevithick constructed in

1803. The wheels of this engine, four in number, were four feet, six inches in diameter; the boiler was six feet long and contained a return flue tube; the engine had one horizontal cylinder eight inches in diameter, with a stroke of four feet, six inches. This engine had smooth wheels which were made to run upon smooth rails, as already noticed.

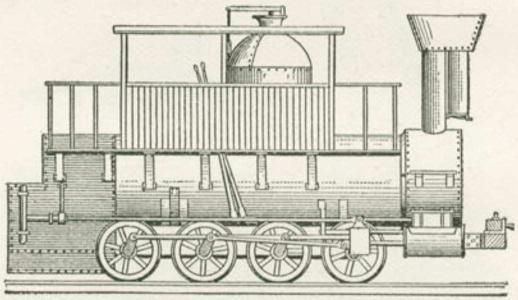


Matthews' Locomotive. Utica & Schenectady Railroad. 1840.

The locomotive constructed by Blenkinsop had a rack rail and cog wheel driving gear, and was supported by four wheels of three feet, six inches diameter; it had two vertical cylinders eight inches in diameter with a stroke of twenty inches. This engine evaporated eight cubic feet of water per hour, consumed seventy-five pounds of coal per hour, and could haul ninety-four tons on a level track at a rate of three and one-half miles an hour.

Hedley's locomotive, "Puffing Billy," had a wrought-iron boiler with a return flue, and two vertical cylinders; the piston rods were connected to beams and motion was communicated to the four smooth driving wheels by means of toothed-gear; the exhaust steam was discharged into the chimney by two blast-pipes.

The first locomotive built by George Stephenson, called the "Blucher," ran upon four smooth wheels three feet in diameter, which were placed

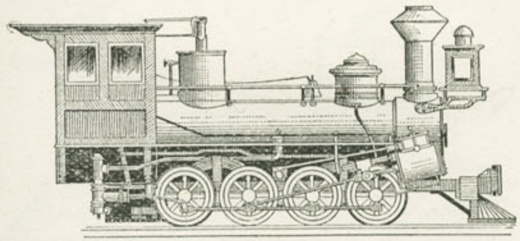


The "Camel." 1848. Built by Ross Winans of Baltimore. A chute was provided for feeding coal through the top of the fire-box.

five feet apart between centers. Its boiler was eight feet long, thirty-four inches in diameter, with a flue-tube passing through it of twenty inches diameter. It had two vertical cylinders eight inches in diameter with a twenty-four inch stroke, the power of which was communicated by cross beams and connecting rods to cranks on the spindles of spur wheels, which in turn acted upon the large cog wheels on the engine axles. This engine was without springs and the cog wheel gear soon became worn with use.

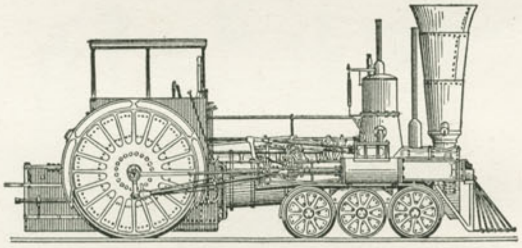
The pictures of these four engines, just described, accompany this, and, taking their machinery as a basis, we may go forward and note some of the more important changes which have since occurred in the evolution of the engine.

In following this description, or evolution, the reader is asked not to attach too much importance to dates or places. It must be remembered in this connection that many of the improvements made in the construction of locomotives



The "Dragon." 1848. The first engine built for burning Cumberland coal, and the first to have a rocking grate. The grate was operated from the footboard, which became the general custom afterward.

occurred almost simultaneously in different countries. In describing a change, therefore, that we will say occurred in the United States in 1846, it may be possible this change was made in England or Scotland in 1845. Whether this is so or not is of little account, or whether the discovery was made by an Englishman, an American or a Frenchman. It is the fact I seek. That has an interest and value to all mankind. The other is merely local and temporary. Let me illustrate this. The American locomotive has exceeded the English built engine in its ability to haul a big load at a high rate of speed. Why is this so? Because of its gigantic boiler, high steam pressure and enormous heating surface. This great boiler creates a vast storehouse for the generation of steam, unknown, until later years, in any other machines in the world, while the bogies enable it to wind in and out on a track which the rigid frames, so long the predominating pattern in other countries, would not have been able

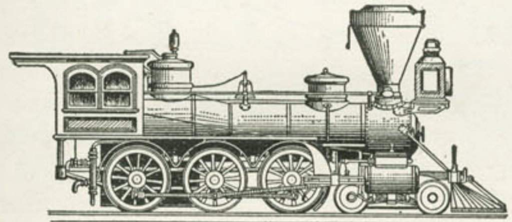


The "John Stevens." Camden & Amboy Railway. 1849.

to traverse. The superiority of the American engine in this particular is generally recognized. It grew out of the necessities of transportation in the United States, mainly our great distances, and heavy loads and sharply curved tracks. The only material fact in all this to the student of the world is to know there is such a locomotive in successful operation, what it is like, and wherein it is superior to others in the accomplishment of certain results. Whether this locomotive was constructed in Schenectady or Glasgow is of no importance to the world's student.

For these reasons, in my description of the evolution of the locomotive (and, indeed, of the machinery department generally), I shall strive to describe as nearly as I can the facts merely, without occupying too much space over unimportant details of place, and without straining to determine to whom the fact first became apparent.

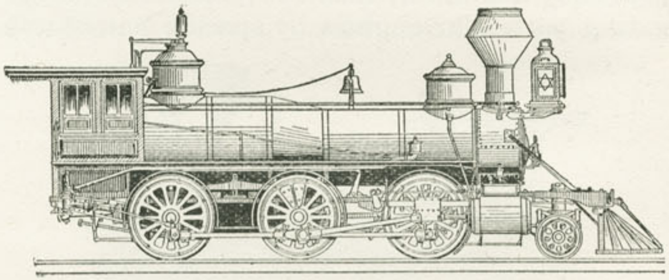
In this connection I will mention, what young men may not know, that the practice of designating particular engines by specific names was



First Ten-Wheeled Passenger Engine. "Thatcher Perkins." 1863.

followed in the early history of railroads. This has now given place to the use of numbers. Proceeding to details, let us first take up the cylinder. Surely there is nothing about the machine of greater importance than this.

CYLINDERS.—The first locomotive designed by Trevithick, in 1803, had but one cylinder, placed horizontally on the inside. Up to 1826 the cylinders were placed vertically, half within the boiler. In 1826, when the engine "Experiment" was designed by George Stephenson for use on the Stockton and Darlington Railway, inclined cylinders were placed outside of the boiler. The first locomotives with horizontal cylinders designed by Stephenson were built in 1830,—the "Northumbrian" had outside cylinders and the "Planet" inside cylinders.* In 1836 Tayleur and Company designed locomotives with cylinders fourteen inches in diameter with only a twelve-inch stroke, but the short stroke did not work to advantage.



The First Passenger Mogul. 1876. An engine with six drivers and a bogie truck. Built by the Baltimore & Ohio Railroad for exhibition at the Centennial exposition.

In 1878 Mr. F. W. Webb, of the London and Northwestern Railway, invented and constructed a compound locomotive having three cylinders. The introduction of this principle in connection with locomotives has caused much controversy. Those who favor the compound engine claim that by the utilization of the steam first in the high pressure cylinders and then again in the low pressure a saving of fuel is effected. On

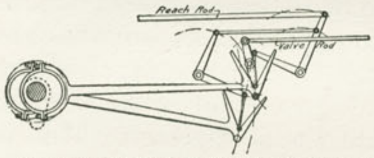
* "Inside" and "outside" cylinders are explained in detail in connection with the "Description of the Locomotive."

the other hand, those who do not favor the compound engine claim no saving whatever is effected, and that what the compound locomotive can do, the other can do as well, or better. However, invention did not stop with Mr. Webb, and compound locomotives with two, three and four cylinders, variously arranged, have been designed and built.* Others have taken it up and, believing in it, have gone on with their experiments; but, while many locomotives of this description are manufactured and under successful operation, controversy as regards the merits of the respective machines is in no wise lessened. The manufacturers of the compound locomotives are more explicit, however, than formerly, claiming that a certain percentage of fuel is saved, even going so far as to state the percentage. This is contradicted by those who claim nothing is saved. Moreover, the latter claim that the compound cylinder increases first cost and otherwise complicates the machinery of the locomotive. The advocates of the compound engine assert, among other things, that it will keep a train moving on a heavy grade where an ordinary high pressure engine would slip and be stalled; this, in the case of the former, because of the more uniform pressure on the crank pins throughout the stroke. Another advantage claimed for it is that, because of the better utilization of the steam, less demand is made upon the boiler, and in consequence of the mild exhaust required to maintain sufficient steam-pressure,

*The subject of Compound Locomotives is treated of in great detail and with profuse illustrations in Vol. XII.

no unconsumed fuel is carried through the flues, the necessary results being obtained with slower combustion. These claims are backed up by manufacturers by continued construction and improvement of locomotives of the compound type. Out of the controversy between the rival types much good may possibly accrue to the world as in the case of the war of the gauges.

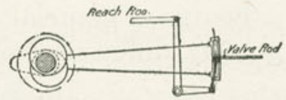
LINK MOTION.—The first locomotive in which the valve gear was fitted with the shifting link motion was designed by William T. James, of New York, in 1832. The valve gear of the Stephenson engines was known as the fork motion. The eccentric rods of this machine were provided with forks which engaged with the pins fastened to the arms of the valve rods. In 1842 William Howe, an employe of R. Stephenson and Company, devised a curved link to take the place of the forks.* This was the first introduction of the link motion in



Stephenson's Fork Valve Motion, or gearing attached to the driving axles of the locomotive, 1835.

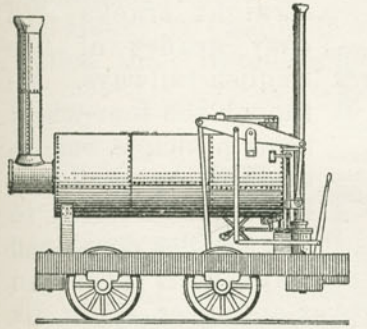
* "The link motion was a separate invention in England in 1842, and it was introduced by William Howe and fitted to the North Midland Company's engine. On the other hand, it is now equally certain that the 'James,' designed and built by W. T. James, of New York, was the first locomotive in the world fitted with the link motion. It had a vertical boiler, four wheels (not coupled), and inclined cylinders driving a spur wheel shaft directly above the driving axle, and was constructed in 1832, or ten years before the English invention."—*Mr. Clement E. Stretton.*

England. It also provided for cutting off steam at various parts of the stroke.



Howe's Link Motion, or gearing attached to the driving axles of the locomotive, 1842.

The "George W. Johnson" is said to have been the first engine having a double fire-box, built in 1831. The valve gear of this engine was also the first instance of what was afterward known as the "V" hook.



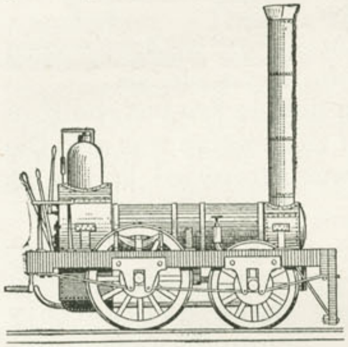
"Geo. W. Johnson." 1830. The first locomotive having a double fire box.

REVERSING GEAR.—New features, which were extensively copied, were introduced in this connection by the Baldwin Locomotive Works. It is noticeable in connection with the construction of its first engine, the "Old Ironsides," built in 1832, that Mr. Baldwin did most of the work himself, capable mechanics and suitable tools not being available.

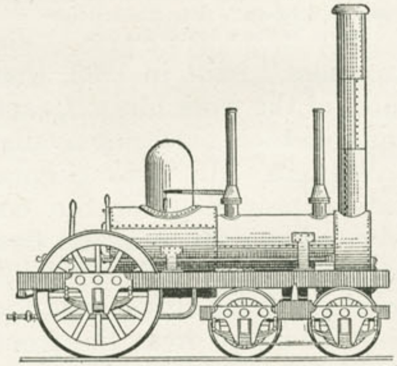
WHEELS.—In 1833 Stephenson took out a patent providing for the construction of six-wheeled engines, with no flanges on the middle pair of wheels. This was found to facilitate their passing around curves, and the practice of omitting the flange from the front or middle drivers on locomotives with six or more driving wheels is still in vogue.*

*For details regarding the manufacture of wheels, see volume "Train Service."

Bogie.—Financial conditions in America being greatly different from those in Europe, it soon became evident that money could not be obtained with which to to carry on the work of constructing railways and maintaining the straight tracks and easy grades of the English railways. Although the four-wheel bogie principle was introduced by Hedley & Blacket, as referred to elsewhere, it was not used, nor the idea developed afterward on English railways, until its use in America emphasized, over and over again, its enormous value in railway operations. In 1832 John B. Jervis built the locomotive "Experiment" with a four-wheel bogie truck, which enabled these machines to run around curves of very sharp radius, thus greatly lessening the cost of



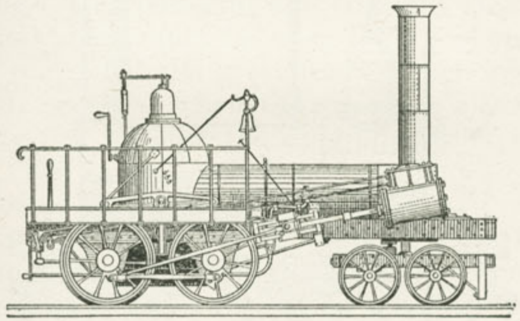
"Old Ironsides." 1832. The first locomotive built by Matthias W. Baldwin, founder of the Baldwin Locomotive Works.



The "Experiment," built by John B. Jervis, in 1832, and said to have been the first engine in America constructed with a four-wheeled bogie.

construction. Jervis believed engines should be made especially for light rails and crooked roads, and the adoption of the swiveling or bogie truck was the result. It was a great step, of enormous value to railroads, and its merits are now appreciated all over the world.

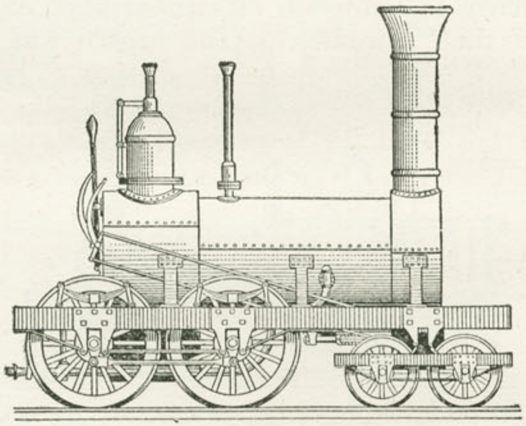
Equalizing Levers.—The first engine with equalizing levers are said to have been built by Henry R. Campbell of Philadelphia, in 1837, called the "Hercules." The engine was built with four drivers and a four-wheel truck in front, and under the rear end of the main frame a separate frame was placed for the two axles—one pair in front and one behind the fire-box. This frame supported the weight of the engine by means of strong springs and was held in position by a pedestal fastened to the main frame. The centers of the latter vibrated upon a journal sliding vertically in the pedestal. By means of the equalizing lever the weight of the engine is



The "Hercules." 1837. Built by Eastwich & Harrison. The first engine having equalizing levers.

equally distributed on all the driving wheels, even during their vertical oscillations when passing over imperfect track, thus greatly overcoming the tendency of locomotives to leave the track when the latter is rough.

BOILERS.—The early locomotive boilers were copied from vertical and horizontal stationary boilers and were not adapted especially to the



The "Campbell." 1837. The first standard American eight-wheel locomotive.

locomotive. Among other improvements came the locomotive type of boiler, with its special form of fire box. Undoubtedly the development of this type has had a very important bearing upon locomotive construction as a whole.*

FLUES.—In 1842 Robert Stephenson lengthened the flues of locomotives from nine to fourteen feet, in order to reduce the amount of heat going

* Mr. Robert Quayle.

out of the smokestack. By this means the heat in the stack was reduced from seven hundred seventy-three degrees to four hundred forty-two degrees, which overcame to a great extent the destruction of the chimneys and smoke boxes.

SAND BLAST.—An improvement in this connection was introduced by Messrs. Holt and Gresham, by which a jet of steam is admitted to the sand ejector, thus forcing a small and uniform supply of sand from the sand box and projecting it in a powerful and constant current to the point of contact between the wheel and rail. This prevented the great waste which had previously occurred when the sand was allowed to simply run through the sand pipe, from box to rail. The same result is now accomplished by the use of air instead of steam.

FRAME.—The matter of engine frames is also an important detail. In the first locomotive designs there was a disposition manifest to place the boiler and machinery of the locomotive upon a platform built over the running gear. Later in such engines as the "Sampson" we find frames and platforms dispensed with and the pedestals for the driving box attached directly to the boiler. Later the locomotive frame appears, and in this country has developed into what is known as the "bar" frame, while in Europe the "plate" frame is used.*

FUEL.—Early English locomotives were designed to burn coke for fuel. Early American

* Mr. Robert Quayle.

locomotives burned wood. Various experiments were made with a view to the use of coal. Between the years 1853 and 1860 numerous engines with complicated boilers and fire boxes and special forms of grates were constructed to this end, but experiments at length proved that all the changes necessary to the advantageous use of coal were a brick arch placed in the ordinary fire box, below the tubes, a deflector or baffle-plate within the door, a fire door by which the supply of cold air could be properly regulated, and a steam jet or blower in the chimney. In Russia, America and other countries, crude oil is more or less used. In localities where it can be obtained cheaply it has taken the place of all other kinds of fuel, and the fire boxes of the locomotives have been adapted thereto.

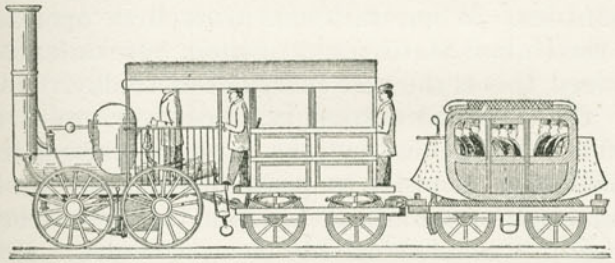
INJECTOR.—This device was first used in England, in 1859, on the London & Northwestern Railway engine "Problem." It was designed and patented by H. J. Giffard, a French engineer, who discovered that steam from the boiler rushing through an injector, had enough force to force water from the tender, with the condensed steam, into the boiler.* This was one of the greatest discoveries that has been made in perfecting the locomotive.

WHISTLE.—The steam whistle was first suggested to George Stephenson by the manager of the Leicester & Swannington Railway, in 1833, on account of an accident caused by one of the

* For illustrations of an injector, see pages 77 and 78.

company's engines running into a horse and cart at a crossing. Stephenson, on his attention being called to the need, had a trumpet, operated by steam, manufactured and placed on the engine. The present steam whistle is a development of the trumpet.

CAB.—The cab of the locomotive, which has always been considered an essential part of it in America, was not esteemed necessary in Great Britain. The reason of this difference, it is probable, was because the distances to be traversed in



The "DeWitt Clinton." It is said to have hauled the first passenger train ever run in America. The cab on the engine is the first one ever constructed. Mohawk and Hudson Railroad, 1831.

America are much greater and the fact that the thermometer falls much lower than it does in England. The English, moreover, looked upon it as an obstruction and an embarrassment to the engineer in the performance of his duty. This objection they are now inclined to believe not to be well founded, and as new locomotives are constructed the managers of the British lines will be induced to supply them with a cab something like that used in the United States and Canada. The first locomotive built with a cab is said to have been the "DeWitt Clinton," on the Mohawk and Hudson Railroad in 1831. The American style of cab was introduced into England in 1889, when Mr. T. W. Worsdell, locomotive superintendent of the Northeastern Railway, designed and built a locomotive fitted with a comfortable cab.

Cowcatcher or Pilot.—This device is considered a fundamental part of the locomotive on nearly every road in America. It is, however, hardly known in Great Britain and many other countries. When railroads were first operated in the United States many of them were unfenced. Indeed, this is the case more or less to-day. Most of the highway crossings, moreover, were at grade. Track obstructions were, therefore, frequent and in order to prevent them so far as possible from derailing the train, the cowcatcher, or pilot, was introduced to clear the track. It is, of course, a makeshift and, while it often fails to accomplish the purpose for which it was designed, it is in the main beneficial.

Snowplow.—This, like the pilot, has a specific object, namely, to clear the track of snow and ice. Many forms have been used for this purpose; but where there is great need for a device of this kind, the cylindrical or rotary form of snowplow carried on separate running gear ahead of the locomotive, is very generally favored by railroad managers. It is placed on the front end of a car containing a boiler and engine for operating the machine, and is encased in a sheet iron

box having an opening at the top. The engine in the car causes the machine or plow to revolve and its rotary motion forces the snow from the track through the opening in the top and thus entirely away from the track. The car is attached to the front of the train locomotive and propelled thereby. In ordinary cases, however, when the snow is not closely packed or very deep, the engine pilot or cowcatcher is covered with sheet iron and used as a snowplow.

Headlights.—Headlights were placed on locomotives as early as 1830, being at first crude affairs in the shape of a fire basket hung on the front of the engine. They were not, however, designed to afford the engineer a view of the track. Indeed, the general absence of grade crossings on English roads have rendered the use of headlights and cowcatchers less necessary than in America. In England to-day the small lights carried on the front of the locomotive are merely for the purpose of designating the different classes of trains. In the early history of American railways night trips were avoided as much as possible. When the carrying of the mails necessitated night service, it was considered a great hardship. Among the first provisions for a headlight in this country was a fire of pine knots surrounded by sand, built on an open platform car which moved in front of

Early English fire basket, attached to the end of the train as a signal.

the locomotive. When it was found that the transportation of freight by night was a great gain in time and diminished the chances of collisions, the Boston and Worcester railroad company prepared, in 1840, a bright headlight with reflectors for the locomotive which ran during the night. From this developed the silver-plated copper reflectors fitted with lamps and carried in front of the smokestack. Double headlights, so placed that the rays from the two lamps cross each other, are found advantageous for affording a view of the track in passing around curves. Electricity will doubtless in time take the place of other devices for lighting the track; but excessive cost, here as elsewhere, in connection with the use of electrical appliances by railways, is an obstacle which must first be overcome.*

BELL.—An improvement on the ordinary method of ringing the locomotive bell by hand with a rope, is the automatic bell ringer operated by air or steam. This ingenious invention, at once a measure of safety and a labor saving device, is now so generally used as not to attract notice.

Such are some of the more important improvements made in the locomotive. In another chapter I propose to take up the Modern Locomotive, and by descriptions and engravings, illustrate its important parts. This description will also serve in an important respect to further illustrate the evolution of the locomotive, as will be seen by comparing the diagram therein of a modern locomotive with that invented by Trevithick.

*Acetylene gas, more modern than the others, is more or less used for lighting passenger cars and headlights.

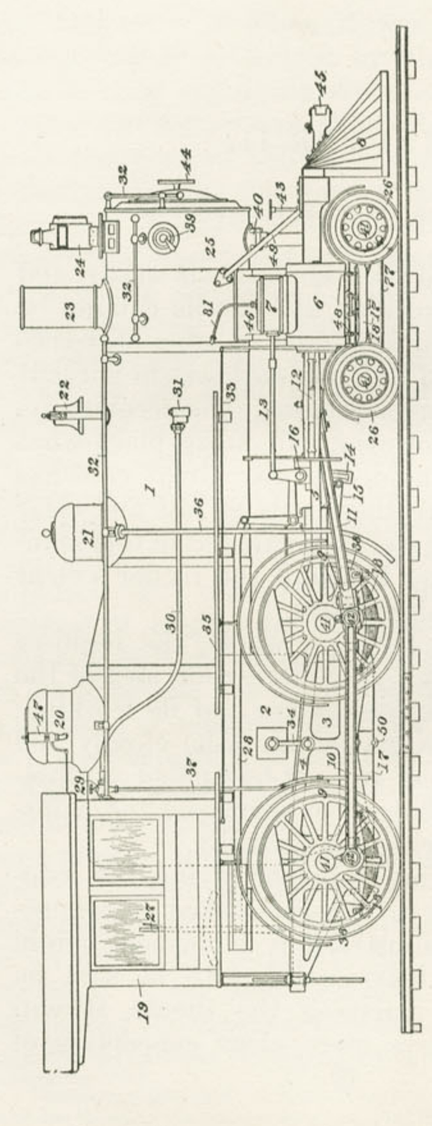
CHAPTER II.

DESCRIPTION OF THE LOCOMOTIVE.

The machinery of the locomotive is so vast and involved that its working and details can not be clearly explained in print, and to attempt it is to tire the reader and dull his enthusiasm without enlightening his understanding. The accompanying illustrations, however, will make plain what type is not able, unaided, to do. Great care has been taken to make these cuts so full and clear that nothing which can be portrayed in this manner may be wanting to afford the reader a clear understanding of his subject.

Taking the chapter as a whole, the inquirer may derive from it a very intelligent idea of the construction of the locomotive and its working; but to do this, the matter must be closely and exhaustively studied. It must be studied as scholars study their lessons—consecutively and painstakingly—not hurried nor cursorily.

The accompanying cuts portraying the locomotive (some fifty in number), taken in connection with other illustrations embodied herein (of locomotives), leave nothing to be said on the subject. In pursuing the theme, it will help the reader to a more clear conception of



Side View of Locomotive.

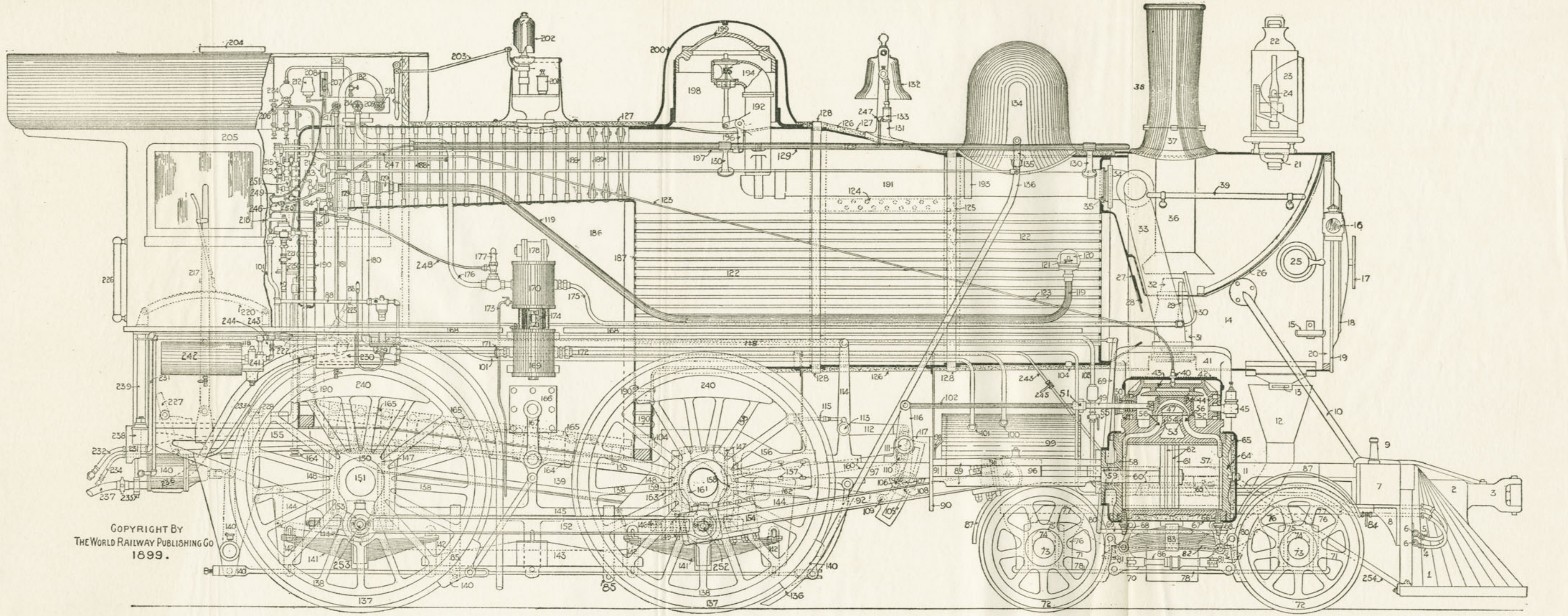
1 Main barrel of boiler. 2 Fire box. 3 Ash pan. 4 Rear section of frame. 5 Front section of frame. 6 Cylinder. 7 Steam chest. 8 Pilot. 9 Driving wheels. 10 Coupling rod. 11 Main rod. 12 Cross head. 13 Valve stem. 14 Link. 15 Eccentric rod. 16 Rocker shaft. 17 Equalizer. 18 Springs. 19 Cab. 20 Steam dome. 21 Sand box. 22 Bell. 23 Smokestack. 24 Head light. 25 Extension end for spark arrester. 26 Truck wheels. 27 Reversing lever. 28 Reversing lever reach-rod. 29 Injector. 30 Injector feed-pipe. 31 Check valve. 32 Hand rail. 33 Cylinder cock reach-rod. 34 Boiler hanger to frame. 35 Foot board. 36 Sand pipe. 37 Overflow pipe. 38 Spring hanger. 39 Hand hole. 40 Cinder gondola. 41 Axles. 42 Crank pin. 43 Headlight step. 44 Number plate. 45 Automatic coupler. 46 Saddle casting. 47 Whistle. 48 Cylinder cocks. 49 Forward brace. 50 Fulcrum to equalizer. 77 Truck frame. 81 Lubricator pipe.

NOTE.—In further illustration of the standard American locomotive the reader is referred to the graphic picture in chapter in this volume devoted to the "Locomotives and Cars of the World, and the Manufacturers Thereof." It particularizes the different parts of the locomotive and gives the technical names by which they are known among those connected with the locomotive department of railroads. It is at once a chart and an encyclopædia, each part of the locomotive being given a number so that it may be recognized and quickly referred to.

DESCRIPTION OF THE LOCOMOTIVE, AS PER DIAGRAM HEREWITH.

1. Pilot.
2. Draw Bar Plate.
3. Coupler.
4. Air Signal Hose.
5. Air Brake Hose.
6. Hose Hangers.
7. Buffer Beam.
8. Pilot Bracket.
9. Flagstaff.
10. Arch Brace.
11. Front Frame.
12. Cinder Chute.
13. Cinder Chute Slide.
14. Extension Front.
15. Headlight Step.
16. Signal Lamp.
17. Number Plate.
18. Smoke Arch Door.
19. Smoke Arch Front.
20. Smoke Arch Ring.
21. Headlight Bracket.
22. Headlight Case.
23. Headlight Reflector.
24. Headlight Burner.
25. Cleaning Door.
26. Netting.
27. Deflector Plate.
28. Deflector Plate Adjuster.
29. Air Pump Exhaust Pipe.
30. Blower.
31. Nozzle Stand.
32. Nozzle Tip.
33. Steam Pipe. (2.)
34. T or Nigger Head.
35. Dry Pipe Joint.
36. Petticoat or Draft Pipe.
37. Stack Base.
38. Smoke Stack.
39. Arch Hand Rail.
40. Oil Pipe Plug.
41. Cylinder Saddle.
42. Steam Chest Casing Cover.
43. Steam Chest Cover.
44. Steam Chest.
45. Relief Valve.
46. Balance Plate.
47. Balanced Slide Valve.
48. Valve Yoke.
49. Valve Stem.
50. Valve Stem Packing.
51. Valve Stem Connection.
52. Valve Seat.
53. Bridges.
54. Exhaust Port.
55. Front Train Line Cock.
56. Steam Ports.
57. Cylinder.
58. Back Cylinder-Head.
59. Piston Packing.
60. Piston Rod.
61. Piston Head.
62. Piston Packing Rings.
63. Truck Center Casting.
64. Front Cylinder-Head.
65. Cylinder Head Casing.
66. Cylinder Lagging.
67. Cylinder Casing.
68. Cylinder Cocks.
69. Cylinder Cocks Rigging.
70. Engine Truck.
71. Engine Truck Wheel.
72. Engine Truck Tire.
73. Engine Truck Axle.
74. Engine Truck Brass.
75. Engine Truck Box.
76. Engine Truck Pedestal.
77. Engine Truck Frame.
78. Engine Truck Pedestal Brace.
79. Engine Truck Frame Brace
80. Engine Truck Equalizer.
81. Engine Truck Spring Hanger.
82. Engine Truck Spring.
83. Engine Truck Spring Band.
84. Front Signal Line Cock.
85. Safety Hanger.
86. Truck Brake.
87. Wheel Guard.
88. Air Signal Pipe.
89. Guides.
90. Guide Yoke.
91. Guide Block.
92. Main Rod.
93. Main Rod Front Strap.
94. Key.
95. Crosshead Pin.
96. Crosshead.
97. Front Frame.
98. Air Drum Bracket.
99. Air Drum.
100. Pump Connection.
101. Train Pipe Connection from Main Reservoir.
102. Valve Stem Rod.
103. Train Pipe.
104. Wash Out Plugs.
105. Link.
106. Suspension Stud.
107. Link Block Pin.
108. Link Block.
109. Eccentric Connection, Back Up.
110. Eccentric Connection, Go Ahead.
111. Link Hanger.
112. Tumbling Shaft Arm.
113. Tumbling Shaft.
114. Tumbling Shaft Lever.
115. Counter Balance Spring and Rig.
116. Rocker.
117. Rocker Box.
118. Reach Rod.
119. Branch Pipe.
120. Check Valve Case.
121. Check Valve.
122. Flues.
123. Oil Pipe.
124. Horizontal Boiler Seam.
125. Circumferential Seam.
126. Boiler Lagging.
127. Boiler Jacket.
128. Jacket Bands.
129. Hand Rail.
130. Hand Rail Brackets.
131. Bell Stand.
132. Bell.
133. Air Bell Ringer.
134. Sand Box.
135. Sand Box Lever.
136. Sand Pipe.
137. Driving Wheel Tire.
138. Driving Wheel Centers.
139. Ash Pan.
140. Driver Brakes.
141. Driver Springs.
142. Driver Spring Hangers.
143. Driver Spring Equalizers.
144. Driver Spring Hanger Brace
145. Lower Rail of Frame.
146. Pedestal Brace.
147. Driving Box Shoe.
148. Driving Box Wedge.
149. Wedge Bolt.
150. Driving Box.
151. Driving Axle.
152. Side or Parallel Rod.
153. Rod Bush.
154. Main Rod Connection.
155. Main Frame.
156. Frame Brace.
157. Frame Splice.
158. Go Ahead Eccentric.
159. Back Up Eccentric.
160. Go Ahead Eccentric Rod.
161. Go Ahead Eccentric Strap.
162. Back Up Eccentric Rod.
163. Back Up Eccentric Strap.
164. Grate Shaking Rig.
165. Rocking Grates.
166. Expansion Pad.
167. Expansion Link.
168. Running Board.
169. Air Cylinder Brake Pump.
170. Steam Cylinder Brake Pump.
171. Air Strainer.
172. Delivery to Drum.
173. Drip Cock.
174. Pump Piston Packing.
175. Pump Exhaust Connection.
176. Pump Steam Connection.
177. Governor.
178. Pump Valve Case.
179. Injector.
180. Injector Overflow.
181. Water Pipe.
182. Steam Pipe.
183. Steam Valve.
184. Primer.
185. Water Valve.
186. Fire Box,
187. Tube Sheet.
188. Radial Stay Bolts.
189. Sling Stay.
190. Stay Bolts.
191. Dry Pipe.
192. Stand Pipe.
193. Dry Pipe Hangers.
194. Throttle Pipe.
195. Throttle Valve.
196. Throttle Bell Crank.
197. Throttle Stem.
198. Dome.
199. Dome Cap.
200. Dome Casing.
201. Safety Valves.
202. Chime Whistles.
203. Whistle Rig.
204. Ventilator.
205. Cab.
206. Air Pump Lubricator.
207. Air Gauge.
208. Steam Gauge.
209. Steam Turret.
210. Injector Throttle.
211. Blower Cock.
212. Gauge Lamp.
213. Signal Whistle.
214. Air Pump Throttle.
215. Throttle Lever.
216. Sand Lever.
217. Reverse Lever.
218. Engineer's Brake Valve.
219. Gauge Cocks.
220. Quadrant.
221. Cut Out Valve.
222. Fire Door.
223. Cylinder Cock Lever.
224. Sight-Feed Lubricator.
225. Oil Can Shelf.
226. Hand Hold.
227. Shake Lever Stub.
228. Ash Pan Damper Handle.
229. Whistle Signal Valve.
230. Brake Valve Reservoir.
231. Train Pipe.
232. Train Pipe Hose.
233. Signal Pipe.
234. Signal Pipe Hose.
235. Feed Pipe Hanger.
236. Feed Pipe.
237. Feed Pipe Hose.
238. Tail Piece of Frame.
239. Cab Bracket.
240. Counter Balance Weight.
241. Engine Brake Triple Valve.
242. Engine Brake Auxiliary.
243. Connection to Truck Brake Cylinder.
244. Driver Brake Cut Out Cock.
245. Truck Brake Cut Out Cock.
246. Bell Ringer Valve.
247. Air Pipe to Bell Ringer.
248. Air Pipe to Governor.
249. Main Reservoir Connection to Air Gauge.
250. Train Line Connection to Air Gauge.
251. Glass Water Gauge.
252. Main Crank Pin.
253. Back Crank Pin.
254. Pilot Brace.

PLATE I.



THE AMERICAN STEAM LOCOMOTIVE.—Prepared exclusively for Kirkman's "SCIENCE OF RAILWAYS."

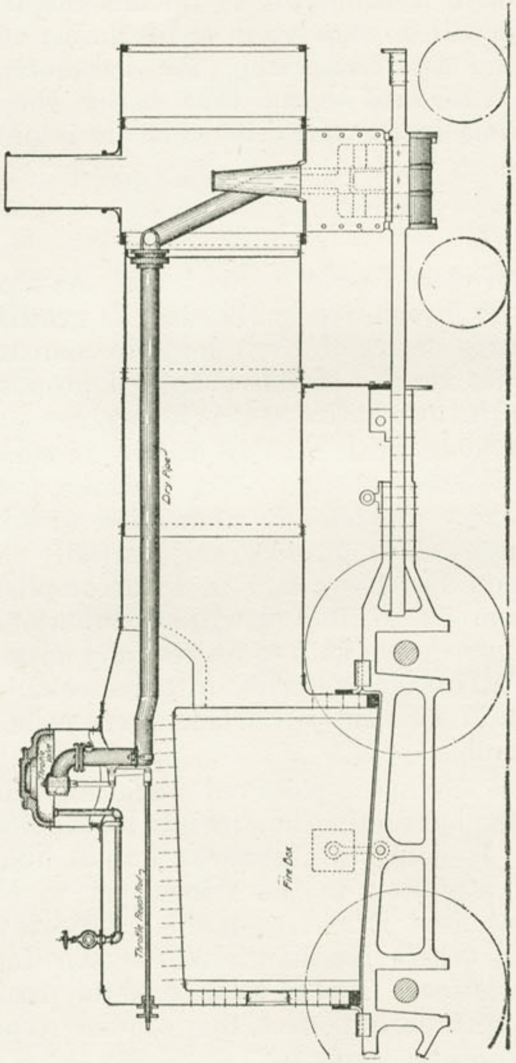
Particularizing the different parts of the locomotive and giving the names by which they are known to those connected with the Motive Power Department. It is at once a Chart and an Encyclopædia, each part of the locomotive being given a number so that it may be recognized and quickly referred to.

the locomotive if, before taking up this chapter seriatim, he will go through it and examine beforehand the cuts illustrating the locomotive in detail. Afterward he may take up the chapter as a whole in the order in which it is presented here.

In another place I have briefly traced the evolution of the locomotive, portraying its growth from the rude device of Hero down to comparatively recent times. In this chapter I propose to describe the locomotive as it is to-day.

Mankind looks upon the locomotive as complete—as a perfect entity. This, however, is a mistake. Many problems in connection with it are still unsolved, or, at least, only partially so. The difficulty has been, and is, to accomplish within a compass so limited, within confines so narrow, in connection with so restless and unstable a body, what the ingenuity of man seeks in vain to attain satisfactorily where every condition is favorable.

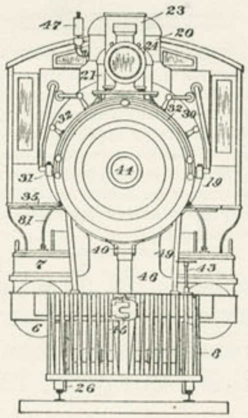
I shall not attempt to point out specifically the defects of the locomotive, but merely to describe it as it is. In doing this, however, I shall indirectly call attention to the things yet to be achieved; at least it will have this effect with experts and others familiar with the machine and its limitations. And in relation to the parts which are apparently perfect, they are but steps



Longitudinal Section of Boiler.

Showing throttle, dry-pipe and means of fastening boiler to frame. The steam from the dome above the boiler is let into the dry-pipe by the opening of the throttle. It passes thence into the live-steam channels, through which it is carried to the cylinders.

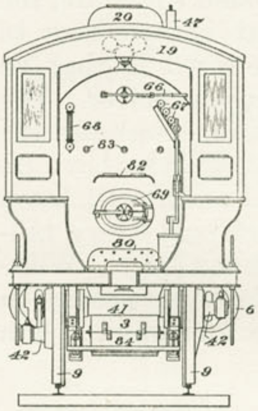
on the ladder leading to something better. It will, for this reason, do good to keep them prominently in mind. Man grows, and, with him, the appliances he uses. All that is necessary to ensure his utensils being bettered is that he should set to work to make them better. The second object I have in view in describing the locomotive is to familiarize those who have no practical knowledge of it (and never will have) with its construction and working. Every railroad man should possess this knowledge. Without it his education is incomplete. Its possession will broaden his intelligence and render him more valuable to the company he serves. This truth is so self-evident that it does not need argument or illustration.



Front View of Locomotive. For names of the parts shown above see side view of the locomotive preceding this.

The end sought in a locomotive is to draw the load desired with the least expenditure, including in the latter material and wear and tear. In the case of passenger engines speed is a factor. In Great Britain it is also a factor in connection with freight or goods trains. Many railroads are neither straight nor well constructed and ballasted. In such cases wear and tear are intensified.

In constructing the machine the builder calculates the cylinder power of the locomotive needed to move the load required, over and above the amount necessary to overcome weight of locomotive, friction, air resistance and the inertia of the machine. The ability of the locomotive driving wheel to carry forward a load (without slipping) is said to be equal to about one-fourth of the weight on the rail under each driver.* In order to secure tractive power, therefore, required weight proportionate to the load to be hauled must be placed on the driver. It must also be remembered that tractive resistance is dependent upon speed. In practice the weight placed on the axles of the driver, and so on the wheel and rail, must be proportionate to the strength of the rail; this limitation, therefore, influences and deter-

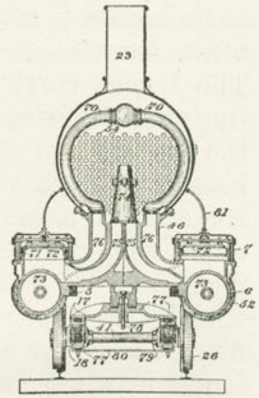


Rear View of Locomotive. The parts shown above, not included in the side view of the locomotive preceding this, are as follows: 66 Throttle lever. 67 Gauge or water cocks. 68 Water gauge. 69 Fire door. 80 Frame tie. 82 Oil-can shelf. 83 Plugs at arch support pipes. 84 Damper.

* The general practice of builders in America is based on the theory that for passenger engines the weight on the drivers is equal to four to one pound of tractive power; freight engines four and one-fourth to one, and for switch engines four and one-half to one; or, in other words, in the last case, four and one-half pounds of weight to every pound of tractive power. The Master Mechanics' Association of America endorses this formula.

mines the power of the machine. Speed is further a factor in this, that it increases the destructive force on the rails.

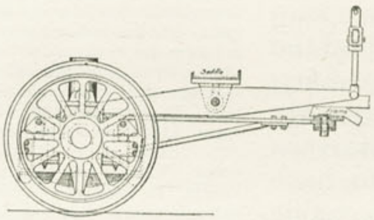
Locomotives may be divided into four classes, each especially adapted to the service it is designed to perform; namely, those used for switching cars at stations or yards, freight traffic, ordinary passenger traffic, suburban traffic. Switching engines usually have four or six driving wheels, upon which, in most instances, the whole weight of the locomotive rests. The drivers are made to bear the entire weight in order to afford the adhesion necessary for starting heavy trains quickly and at frequent intervals. These engines also have short wheel bases to enable them to go around sharp curves and over switches branching from the main track at sharp angles. The wheels are placed near together, usually between the smoke box and fire box. The short wheel base of the switching engine renders it unfit for general traffic, because of the unsteady



Sectional Views of Locomotive, through the exhaust chamber (at the left) and the live steam chamber (at the right). The parts shown above not included in the side view of the locomotive preceding this, are as follows: 52 Lagging. 70 Pipes carrying dry steam to live steam channel (76). 71 Slide valve. 72 Valve cover. 73 Piston. 74 Exhaust nozzle. 75 Channel carrying exhaust steam from cylinder to smoke-stack. 76 Live steam channel, carrying steam to cylinder from dry steam pipe. 78 Truck center pin. 79 Truck axle collar.

motion produced when running at a high rate of speed.

In the case of passenger trains the light load to be hauled permits placing a part of the weight of the locomotive on supporting wheels or trucks. The trucks carry the front part of the engine. One pair of driving wheels is usually placed behind the fire box and another pair in front. In many instances the drivers are increased to six, and, in some cases, to eight. This does not increase the adhesive power of the locomotive, but it does decrease the weight on each pair of wheels, thereby distributing the total weight on the rails over a longer wheel base, and thus making the locomotive less hard on the roadway. If the same weight were put upon one pair of driving wheels that is placed upon four or more, the locomotive would have the same tractive power and, with the same cylinder power, could pull a greater load than when more drivers are used, because the extra friction of the wheels would be avoided. While one or two pairs of drivers are generally sufficient for a passenger engine, three or four, perhaps five pairs will be used in the case of a heavy goods or freight locomotive. The driving wheels of

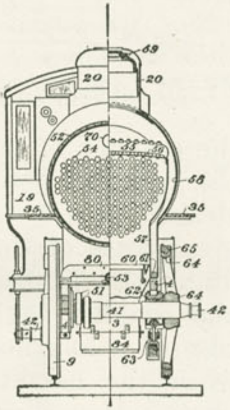


Side View of American Bogie (or Pony) Truck, supporting forward end of locomotive.

the latter are usually smaller than those of the former.

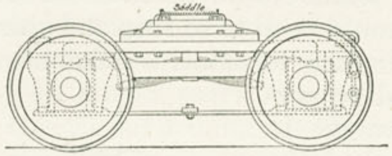
It is required of trains employed in suburban service that they should be able to stop and start quickly. To do this, the locomotive must have more than the usual proportion of adhesive weight to prevent its slipping, and the main valves must be so constructed as to quickly admit steam to the cylinders and exhaust it therefrom.

Speed is dependent upon the velocity of the pistons. This is achieved through multiplicity of reciprocations, that is, the reciprocations multiply the rapidity with which the steam acts upon the pistons; but, as this is limited, it becomes necessary to increase the size of the drivers in order to secure the maximum speed desired. This is why passenger engines have large wheels, while engines not required to make great speed have smaller ones.



Sectional Views of Locomotive, through the forward driver (at the left) and the fire box (at the right). The parts shown above not included in the side view of the locomotive, preceding this, are as follows: 51 Eccentrics. 53 Reversing gear spring case. 54 Flues. 55 Crown-bar. 56 Crown-sheet. 57 Inside shell of fire box. 58 Outside shell of fire box. 59 Dome castings. 60 Grate. 61 Mud ring. 62 Journal box. 63 Spring hanger to journal box. 64 Driving wheel castings. 65 Driving wheel tire.

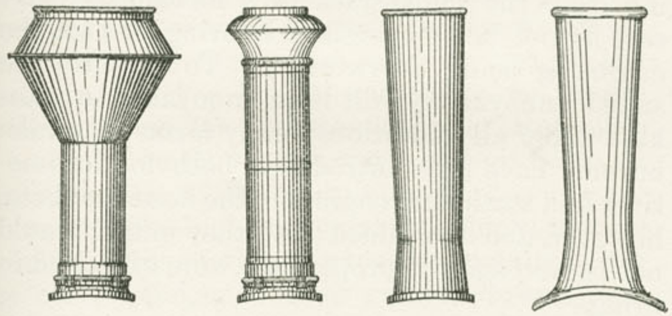
The velocity required in hauling a load is dependent upon the pressure of steam on the pistons. For this reason the power, it is apparent, must be proportionate. This, however, depends upon the steam producing quality of the boiler.* The steam generating capacity of a boiler depends, *a*, upon the size of the grate and fire box, *b*, upon the amount of heating surface provided, and, *c*, the draught produced by the blast or exhaust steam. In the case of stationary engines the great area of the fire box and the facility (or draught) afforded by a high chimney cheapen and amplify the production of steam. In the case of a locomotive the fire box is restricted, while the height of the smokestack is inadequate. How then is it possible to produce sufficient heat (consume sufficient fuel effectively) to generate the quantity of steam required; to maintain the water in the boiler at the desired temperature; to maintain, in fact, a steam pressure of, say, one hundred and sixty pounds to the square inch? It is through enforced consumption of fuel—by forcing the fire, so to speak. This is accomplished, in the main, by the draught occasioned by the escaping steam through the exhaust pipe into the smokestack. It is further assisted by dampers at each end of the ash pan



Side View of American Locomotive Truck, supporting forward end of locomotive.

* The formulas or rules governing these relations are found in the working tables used by constructors of locomotives.

(which latter is placed immediately below the fire box) to afford the requisite amount of air, and secure through the intervention of such dampers a due consumption of the gases and carbon. The escaping steam through the smokestack serves to create a partial vacuum which, the heat from the fire box hastening to fill, creates in turn a strong draught and in so doing hastens the ignition and consumption of the



Evolution of the Coal Burner Smokestack.

fuel. Some engines are provided with an appliance or lever which controls, from the cab, the intensity of the blast caused by the exhaust steam. In other ways, also, free steam from the boiler may, when necessary, be discharged through an auxiliary blast pipe into the chimney; but, while a strong draught is secured by exhausting steam into the smokestack, a serious difficulty is experienced, in the use of soft coal especially, in supplying the requisite air to the fire box. This could be drawn wholly from beneath were it not for the impossibility of thus securing due consumption of the carbon generated by the heat as it escapes through the unburned fuel on top of the fire. To obviate this a second damper is placed higher up in the fire box, usually in the fire door. The consumption of fuel is further heightened by careful, I may say scientific, firing. As a rule, we may assume, when we see great volumes of black smoke issuing from the smokestack of a locomotive, that care is not being exercised in firing or that the engine is being overworked. To obviate the smoke annoyance (for it is an annoyance to mankind under all conditions) many forms of smoke burners have been introduced, both for locomotives and stationary engines. The need for them, however, and the added cost they entail, would not be necessary if proper care were exercised in firing.

In working, the fire is regulated from the cab of the locomotive by levers attached to the ashpan dampers. Thus the quantity of air passing through the fuel is controlled. The door through which the fuel is conveyed to the fire box is also made use of to regulate the quantity of air.

The supply of steam required from a locomotive boiler is more irregular than from any other kind of a boiler. Thus, when a train is ascending a heavy grade the fire must be urged to its greatest intensity. When the top is reached

the demand measurably ceases and steam is generated less rapidly. The irregularity, however, is not so great in a large boiler as in a small one. The former may also be more economically used.

In order to create the required draught, when rapid combustion is required, in a small boiler, the exhaust nozzles must be contracted. By this means the back pressure on the pistons is increased and, if the blast becomes very violent, more or less unconsumed coal is carried through the flues and escapes through the smoke stack. In addition to this waste, more or less of the gases in the fire box escape, there not being sufficient time for their combustion. Moreover, a boiler so small that it must be worked to its maximum at all times cannot afford a reserve of water at a high temperature which may be brought into use when necessity requires. On the other hand, a boiler of greater capacity can store heat for such use when not working to its maximum capacity.

The heating surface of a locomotive is made up of the sides of the fire box, the flue sheet, crown sheet, and tubes or flues placed within the boiler. The quantity of water converted into steam by one pound of coal depends upon the quality of the coal used and the construction of the locomotive boiler. The average performance of an ordinary locomotive varies from five to seven pounds of water to one pound of coal. Locomotive boilers consume in the neighborhood of twenty-five hundred pounds of coal per hour, according to the work performed. The maximum amount of combustion per hour is, approximately, one hundred and twenty-five pounds of coal to each square foot of grate surface. This requires twenty square feet of grate surface to burn twenty-five hundred pounds per hour. For each square foot of grate surface from fifty to seventy-five square feet of heating surface are necessary. Quality of fuel, however, has much to do in governing the proportion of the heating surface to the grate surface. Wood and good bituminous coal do not require so large a grate as anthracite coal or poor fuel.

The limited surface of water possible to be heated directly by the fire box is overcome by the flues in the boiler of the locomotive. The draught occasioned by the steam blast through the smoke-stack draws the flames and generated heat into the flues and, as these flues are enveloped in water, the latter quickly becomes heated. This is, as is well known, the simple explanation of the generation of steam in the locomotive boiler. As it increases in force it finds its way (when the throttle is opened) into the cylinders and thus affords the power that, through the pistons, propels the machine on its way. The heating surface of the tubes, or flues, varies, of course, on different engines according to the size of the boiler and the power required. A large locomotive may have tubes with a heating surface of eighteen hundred square feet which, with

the heating surface of the fire box amounting to, say, two hundred feet, will afford a total heating surface of two thousand square feet. The approximate evaporation of such a boiler may be estimated at thirty-five hundred gallons of water per hour, or, say, four hundred and ninety cubic feet.

A small tube of a given length affords a greater amount of heating surface in proportion to the space it occupies than a large one, and as the size and weight of the locomotive boiler are necessarily limited and the required amount of heating surface must be obtained within that space, small tubes are employed. However, because of their liability to become stopped up with particles of unconsumed fuel or cinders, a tube of less than two inches diameter is not thought to give the best results. Moreover, small tubes may be made of thinner metal than large ones, and by their use the heat from inside is thus more rapidly conducted to the water in the boiler than when heavier metal is used. This, when rapid combustion is taking place, is, as may be supposed, an important advantage.

The number of tubes in a boiler is regulated with a view to affording the water sufficient space in which to circulate freely and the steam to escape. In this last connection it must be borne in mind that the rising steam produces a certain disturbance (ebullition) of the water, which, if adequate space is not provided, will result in particles of water being raised and carried with the steam into the cylinders, producing what is technically called "priming." Aside from the loss of power and inconvenience this engenders, the pistons, cylinders and cylinder heads are thereby endangered through the undue strain thus brought to bear.

The boilers of locomotives were formerly made of wrought iron, but soft steel has, to a great extent, taken its place. The latter is of more uniform quality than iron, and is thought to be better adapted to resisting the great strain upon it. Material used for boiler plate must be tough, ductile and tenacious, and of close and uniform texture, in order to satisfactorily meet the requirements of the situation. The plates of the boiler are fastened together with rivets which are inserted when red-hot into holes in the plates. When the rivets cool they contract and, in doing so, draw the plates more closely together. The seams are then tightened by calking. As the seams are manifestly the weakest portion of the boiler plate, it is necessary that care should be exercised to make them as strong as possible.

The boiler and other steam chambers of the locomotive are overlaid with wood or some plastic material which hardens and which is also, so far as possible, a non-conductor of heat, so as to prevent its loss by radiation. This covering is more or less commonly known as boiler lagging. It is covered with Russia iron or sheet steel in order to hold it in place and to present a better appearance as well.

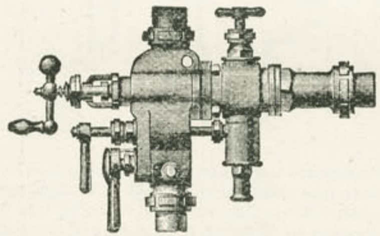
The cylindrical part of the boiler containing the water (through which the flues from the firebox pass) is required to be of sufficient strength to withstand the lateral and end strain. The formation of the boiler being a complete cylinder renders the former comparatively easy. The other is more difficult. The strain at the forward end of the boiler is overcome, in a measure, by the aid of the tubes and partly by longitudinal stay-rods. In connection with the fire box so many flat surfaces are presented that it is necessary to increase the bracing to make up for the lack of strength due thereto. This is done by means of stay-bolts passing through from the outer to the inside sheet and riveted over on both ends. The crown-sheet, of the old crown-bar type, is secured by crown-bars running across the entire width of the fire box, and the crown-sheet is supported by bolts running from the bottom of the crown-sheet to the top of the crown-bar and secured by bolts or rivets; the crown-bars are also re-inforced by braces which are secured to the dome and wagon-top of the boiler. The radial stay type of fire box is circular in form and is secured by stay-bolts. The type of firebox boiler known as the "Belpaire" is similar to the crown-bar fire box, with the exterior sheets flattened, the sides conforming to the shape of the crown-sheet of the fire box and secured by stay-bolts.

The practices by which the safety of the boiler is made secure are not uniform, because of the shape of the fire box, and for other reasons. These practices are not, therefore, susceptible of complete elucidation here. Moreover, the obscure nature of the obstacles to be overcome prevents the matter being clearly understood, except by the use of models or practical examination of the machine itself.

In practical working the boiler of a locomotive must contain sufficient water to cover every part of the metal exposed to the heat in and from the fire box, otherwise it will be quickly weakened and ruined through over-heating. It is practicable to keep the boiler filled with water to a height of six or eight inches above the top of the crown-sheet (i. e., the roof of the fire box). A steam space is provided in some designs above the water line by elevating the outer shell of the boiler over the fire box. A cylindrical dome projects from the top of the boiler, and it is from this reservoir that the steam is precipitated through the dry steam pipe into the cylinder. The reason the steam is first collected in this reservoir instead of being drawn directly from the space above the water, before described, is because dry steam is more effective than wet steam and, as dry steam rises above wet steam, the dome permits their separation.

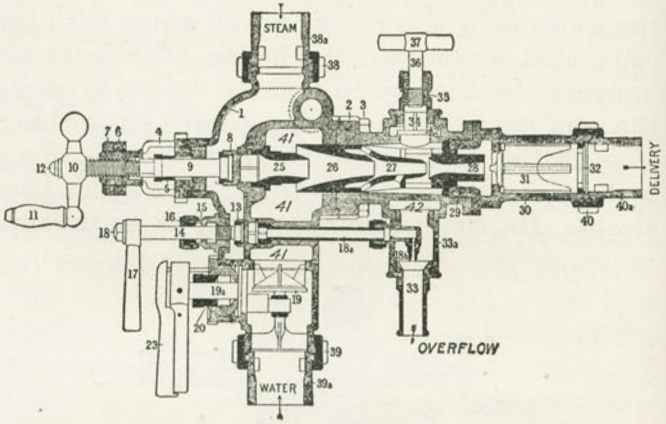
Water is supplied to the boiler, to take the place of that which has been converted into steam, by an injector. This is a device or force pump for supplying the boiler with water without the intervention of the machinery of

the locomotive farther than the introduction of a jet of steam from the boiler into the injector. The jet of steam is brought into contact with a supply of water from the tender and the water is by this means forced along with the condensed steam into the boiler. While simple in operation, the injector never ceases to excite the admiration of those who observe its working. It is to the unscientific mind very much like a man raising himself from the ground by his boot straps. Its working is, however, in accordance



Side View of an Injector.

with well known laws. (See "Engineers' and Firemen's Manual," Vol. XII.) The injector is usually placed inside the cab, where it will be under the immediate eye of the engineer. I have described the injector in connection with the supplying of the boiler with water before referring to any other method for accomplishing this end, because it is superior to all others. It is in very general use. However, as a precautionary measure, some locomotives are still supplied with the diminutive apparatus known as a donkey engine, operated by steam from the engine, by which the engineer may at will (in the event the injector should not work) force the water from the tank into the boiler.

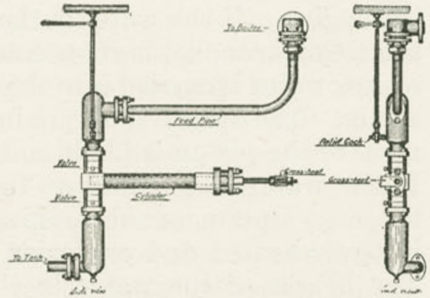


Section of an Injector.—Operation: Valve 19 is opened by means of lever 23, which admits water into chamber 41. Valve 13 is then opened by means of lever 17, which admits steam into tube 18a, escaping into overflow, thus creating a partial vacuum in chamber 41 by means of communication, through chamber 42, with valve 34 open, drawing water from tank into chamber 41, nozzle 26, and escaping at overflow. When water thus appears, valve 8 is opened by means of lever 10, admitting steam into nozzles 25, 26, 27 and 28, forcing check valve 31 open and forcing the water already in chamber 41 into delivery pipe, thus supplying the boiler. Water is regulated by valve 19. To shut the injector off, valve 8 is closed.

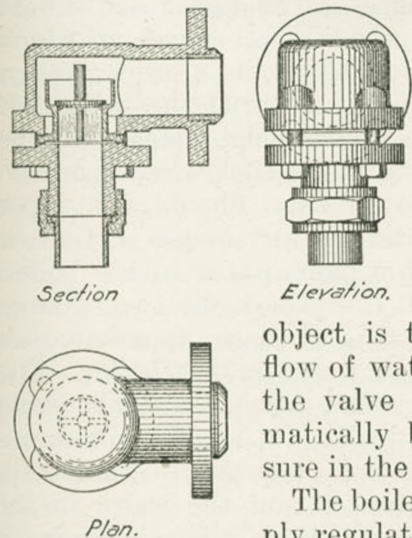
1 Body (back part). 2 Body (front part). 3 Body screw. 4 Yoke. 5 Yoke gland. 6 Yoke packing nut. 7 Yoke lock nut. 8 Steam valve disc and nut. 9 Steam valve spindle. 10 Steam valve handle. 11 Steam valve rubber handle. 12 Steam valve top nut. 13 Jet valve disc and nut. 14 Jet valve spindle. 15 Jet valve bonnet and nut. 16 Jet valve gland. 17 Jet valve lever handle. 18 Jet valve top nut. 18a Jet tube. 18b Lifting nozzle. 19 Water valve. 19a Eccentric spindle. 20 Water valve bonnet. 23 Water valve lever handle. 25 Steam nozzle. 26 Intermediate nozzle. 27 Condensing nozzle. 28 Delivery nozzle. 30 Line check. 31 Line check valve. 32 Stop ring. 33 Overflow nozzle. 33a Overflow chamber with nut. 34 Heater cock check. 35 Heater cock bonnet and nut. 36 Heater cock spindle. 37 Heater cock T handle. 38 Coupling nut—steam end. 39 Coupling nut—water end. 40 Coupling nut—delivery end. 41 Water chamber. 42 Vacuum chamber. 38a Tail piece—steam end. 39a Tail piece—water end. 40a Tail piece—delivery end.

NOTE.—The principle of the injector is fully described and illustrated in Vol. XII.

The boiler may also be supplied with water by a force pump operated by a plunger connected to the cross head of the locomotive, as shown by the illustration. Still other devices are known for supplying the boiler with water, but as they are now rarely, if ever, used, an explanation of them here is unnecessary. A check valve is usually placed at the end of the pipe where the water enters the boiler. Its object is to prevent a back flow of water from the boiler, the valve being closed automatically by the water pressure in the boiler.



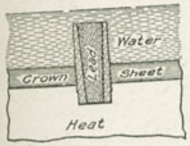
Force Pump.—Water is drawn from the tank into the cylinder through a valve which closes immediately when the motion of the plunger is reversed; at the same time another valve is opened through which the water is forced into the boiler.



Check Valve, for preventing water from returning.

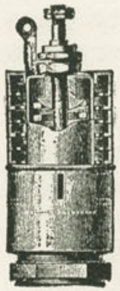
The boiler is fed and the supply regulated according to the amount of work being done by the engine. If the water in the boiler is too high, the steam space is thereby diminished and more or less water is carried into the cylinders with the steam. The strain thus produced by the movement of the piston is liable to break the cylinder. If the water is too low, on the other hand, the the crown-plate, or sheet, is in danger of becoming over-heated and explosion is liable to result. The height of the water in the boiler is ascertained by the use of gauge cocks and a glass water gauge. The former, usually three or more in number, are placed at the rear end of the boiler three or four inches apart. The lower one should be placed two and one-half inches above the crown-sheet. The upper one should be slightly above the highest point at which water is to be carried, which, it is proper to say, is determined by the diameter of the boiler. If the water is at the proper height, steam will be discharged from the upper cock when open and water from the lower one. Should the upper cock discharge water for any length of time, it indicates there is too much water in the boiler. On the other hand, if steam is discharged from the lower cock, it is at once apparent that there is not enough water in the boiler. The water gauge is a steam tight glass tube from twelve to fifteen inches in length, communicating by means of brass elbows with the steam in the boiler at the top and the water in the boiler at the bottom. Each elbow contains a valve worked by a handle and screw. When

both valves are opened, steam rushes into the tube at the top and water at the bottom, and the height of the water in the tube will be on a level with the surface of the water in the boiler. What are very generally known as safety plugs are used for guarding against the danger arising from not having enough water in the boiler. These plugs are hollow and made of brass or cast iron, and filled with some metal that will melt at a low degree of heat. They are placed in the highest part of the crown sheet. In case the crown sheet should become over-heated, the metal in the plugs melts and runs out, thus creating openings by which the pressure in the boiler is relieved and warning given by the escaping steam.



Section of Boiler Fuse Plug.

An important appliance of the locomotive is the safety-valve, designed to prevent the steam pressure in the boiler from exceeding a certain limit. There is a tradition in America that a captain on a Mississippi river steamer, who was racing with the boat of a rival line, sat on the safety-valve of his engine in order that no particle of the steam should escape. This is cited as the acme of daring and foolhardiness. Two valves with which the device is provided are placed in the top of the dome, so that in case one should get out of order the other may operate. They are so constructed that whenever the pressure of steam exceeds the limit which the boiler is supposed to be able to safely bear, the valve opens automatically and the steam is afforded a means of escape. The noise of the steam rushing through the safety-valve is lessened by dividing or breaking up the current before it emerges into the air. With the modern device for using steam in connection with the injector, already described, surplus steam which would otherwise escape through the safety-valve and be wasted is, in a measure, utilized by the engineer. There are various forms or patterns for the safety-valve. No device has received greater attention than this; yet, with all the thought given to the matter, it is still not satisfactory. A form very common in America is represented in the accompanying illustration.



Section of Safety-Valve.

The steam gauge is another important device. It is an instrument by which the number of pounds of steam pressure per square inch is indicated by an index or pointer on a dial.*

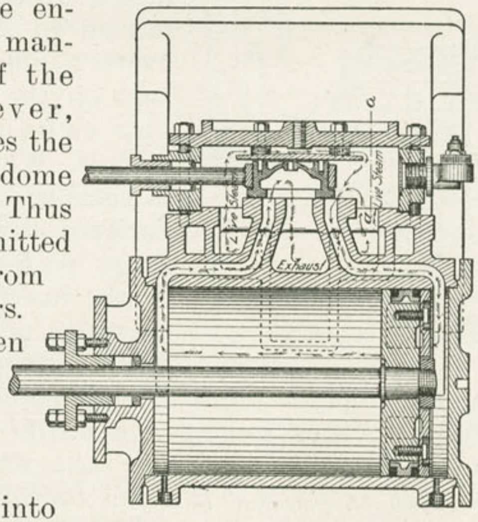
We often speak of a locomotive as an engine. This is proper in one sense, and improper in another. The locomotive is propelled by two engines fed from a common boiler. The steam cylinders operating these engines vary in size. A

Interior of Steam Gauge.

*The automatic lubricator has become an essential part of locomotives, and is fully illustrated and described in Vol. XII.

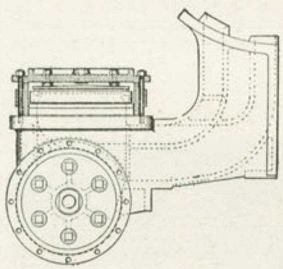
form very common in America has a bore of eighteen inches diameter, and a stroke of the piston of twenty-four inches. By the stroke of the piston is meant the distance it moves in the cylinder. This distance is twice the length of the crank, measured from the centers of the shaft and crank-pin. Absolute accuracy is required to be observed in boring the cylinder. Briefly summarized, the operation of the engine is as follows: The engineer, by the manipulation of the throttle lever, opens or closes the valve in the dome of the boiler. Thus steam is admitted or shut off from the cylinders. On pulling open the throttle the steam finds its way from the steam-chest into the cylinder through a passage (or port) devised for that purpose. The arrange-

Exterior of Steam Gauge.



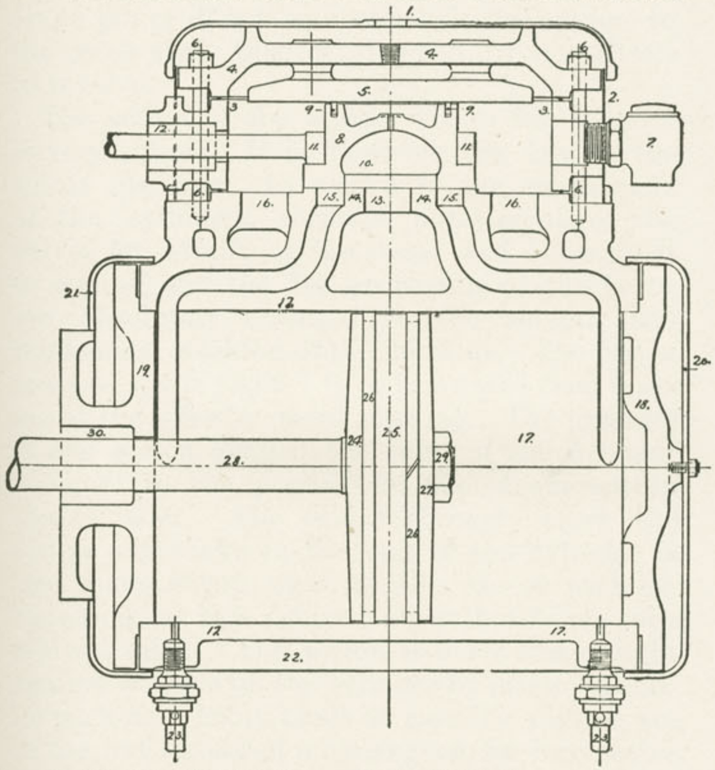
Section showing action of steam in single expansion cylinder. Piston shown in section.

ment of the valve and its movements are such that the ports through which steam is admitted into the cylinder are, alternately, each open during only a portion of the stroke of the piston. The steam enters the cylinder at one end, and in doing so forces the piston (which moves back and forth in the cylinder) to its opposite extremity. After the piston has made a part of its distance (stroke) the port through which steam is passing into the cylinder closes without allowing the steam thus admitted to escape until the piston has nearly reached the end of its journey. In operation, the expansive action of the steam admitted to the cylinder exerts a diminishing pressure on the piston until the exhaust port is opened. When the stroke is completed the steam escapes through the exhaust port into the air. At the instant the steam ceases to act (i. e., at the completion of the stroke) a new supply is admitted at the other end of the cylinder, thus forcing the piston back to the opposite extremity, when the exhaust steam escapes, as before. It is this constant action and re-action of the piston within the cylinder that transmits power to the piston rod and thence to the coupling rod, which in turn is attached to the



End View of Cylinder (cylinder head removed) with the steam chest shown in section at "a" "a" of preceding illustration.

CYLINDER AND ITS APPURTENANCES.



1. Steam Chest Top Casing.
2. Steam Chest Side Casing.
3. Steam Chest.
4. Steam Chest Cover.
5. Steam Chest Balance Plate.
6. Steam Chest Studs.
7. Steam Chest Relief Valve.
8. Slide Valve.
9. Slide Valve Balance Strips.
10. Slide Valve Exhaust Cavity.
11. Slide Valve Yoke.
12. Slide Valve Stem Stuffing Box.
13. Exhaust Port.
14. Bridge.
15. Steam Port.
16. Feed Port.
17. Cylinder.
18. Cylinder Head Front.
19. Cylinder Head Back.
20. Cylinder Head Casing Front.
21. Cylinder Head Casing Back.
22. Cylinder Jacket.
23. Cylinder Cocks.
24. Piston.
25. Piston Bull Ring.
26. Piston Packing Rings.
27. Piston Follower.
28. Piston Rod.
29. Piston Rod Nut.
30. Piston Rod Stuffing Box.

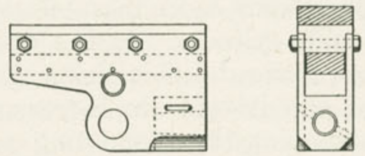
crank pin or (if it is an inside-cylinder engine) to the crank shaft, thus causing the driving wheels to revolve.

The action of the steam within the cylinder is very simple. It is, however, the key to the whole situation. In regard to the mechanism of the cylinders, accurate adjustment of the valves for admitting the steam and allowing it to escape, and the due proportion of the parts, are absolutely essential to the smooth and economical working of the machine. The piston must be steam tight. It is prevented from leaking at the sides by metal packing. The pressure of the piston against the sides of the cylinder is equal to the pressure of the steam within the cylinder. The orifice through which the piston rod works in the end of the cylinder is also made steam tight by the use of packing. Speaking on this subject, an authority on such matters says: "The piston is made steam tight against the side of the cylinder by elastic metallic packing. Many kinds of metallic pistons are in use, but I know of none so good, for locomotive purposes, as that simple one invented by Mr. Ramsbottom, which bears his name, and which consists merely of a few grooves (three commonly) turned in the piston body, into which are sprung pieces of D-shaped wire (for the rings are little more) which press outward against the interior of the cylinder, and bear upon it with steam-tight contact. It is, of course, desirable that while the piston should move steam-tight in the cylinder, it should also move with the least possible friction. . . . In order that a piston may be safe against leakage, it is necessary that the ring should bear upon the cylinder with a pressure at least equal to that of the maximum force of steam within the cylinder, because if this condition be departed from, and if steam leak in at any part between the surface of the ring and the interior of the cylinder, it will press upon the ring, drive it backward, and will pass on; but this pressure is a pressure per inch of surface, therefore the less surface there is in contact, the less will be the actual pressure, and the less, therefore, will be the actual friction; obviously, for these reasons, it is desirable to diminish the width of the bearing surface of the rings as much as possible in practice, and that it is which is done in the Ramsbottom piston. Moreover, the use of such a piston diminishes the wear upon the cylinder, while the wear of the rings is unimportant, as although they may require frequent renewal, say every six months, their total cost, even in a large locomotive, is only a few shillings."*

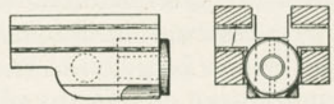
Continuing our description, the end of the piston rod farthest from the cylinder is attached to a square piece of metal or cross head which works back and forth in a rigid horizontal frame running parallel with the piston rod. In many cases the frame is on the side of the piston rod, but sometimes above it. This frame is called a

* Mr. John Wolfe Barry.

guide bar. Its purpose is to prevent the connecting rod, in the rotary motion given it by the crank pin, from deflecting the piston rod from the exact angle at which it enters and traverses the cylinder. In some instances the connecting rods of the locomotive are attached to the crank shaft between the driving wheels. In such cases the cylinders are also placed within the frame of the locomotive, i. e., between the wheels. These are called inside cylinders. When the connecting rods are attached outside of the driving wheels to the crank pin, the cylinders are called outside cylinders. Both forms have adherents, but the judgment of constructors and operators inclines more and more to the outside cylinder. The inside form has the merit of a shorter steam passage and greater facility in securing the cylinder and keeping it heated; also in more secure fastenings for the guide frame, and avoidance of interference with the bars which couple the drivers together. Other advantages might be named, but the crowded space within which the cylinders with their appurtenances must be placed, and the increased cost of constructing axles with the crank forgings, together with other

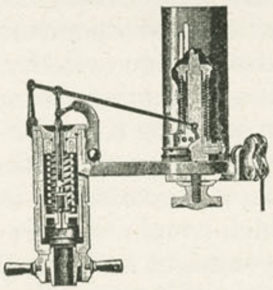


—Two Bar Cross-head.—
Guide bars in section.



—Four Bar Cross-head.—
Guide bars in section.

objections, more than offset the advantages of the inside cylinder. In the case of outside cylinders the natural difficulties which attend the coupling of the drivers are increased by the necessity of attaching the connecting rod to the outside face of the wheel. On the other hand, the slight resistance (friction) attending its working compared with the considerable resistance of the connecting rod when fastened to the axle between the drivers more than offsets any objections. By placing the cylinder outside, necessary space is left beneath the boiler for the gearings. Outside cylinders must, per contra, be set on brackets where they can not be kept hot. Moreover, the steam must travel a long passage, relatively, to reach them. These are serious objections. However, notwithstanding these objections and still others which might be named, the practice of putting the cylinders outside the wheels and frames is very general in America. In some parts of Europe, and especially in England, the inside cylinder is more favorably regarded.

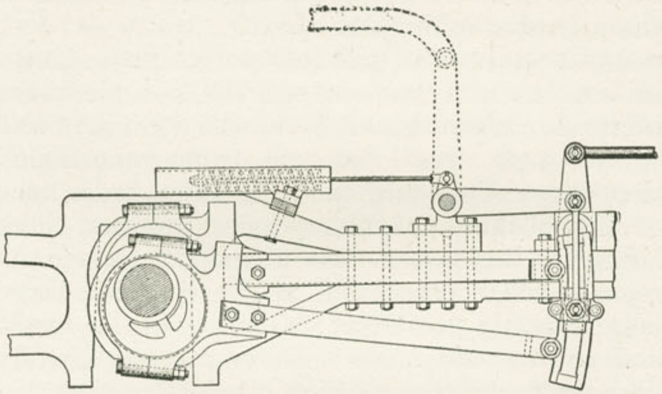

Section of Indicator.

The steam pressure in the cylinder may be known at the various points of the stroke of the piston by the use of an indicator designed especially for that purpose. In its practical working the steam acts upon a piston, upon which rests a spiral spring, which is

graduated to suit the pressure under which the engine is working. The piston is coupled to the pencil arm by means of a parallel motion, and the pressure in the cylinder is recorded upon a card which has been placed around the drum of the indicator referred to above.

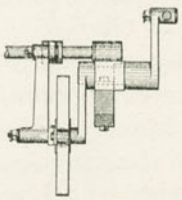
As the fixtures of the locomotive have grown in number and the size of the cylinders has increased, rearrangements of the cylinders and valves have from time to time been found necessary. This has, perhaps, been more true of inside than outside cylinder engines, there being in the latter case abundant space. As regards the construction of the cylinder, there is practically no difference between the inside and the outside forms. Reference has already been made to the packing used in connection with the cylinder, including that designed to prevent the escape of steam through the opening through which the piston rod works. The head of the cylinder (i. e., the forward end), is fastened on with bolts so it may be easily removed whenever necessary to remove the piston, or for any other reason.

A locomotive is enabled to run either backward or forward by having two contrary eccentrics for each cylinder; one is fastened to the shaft in such a position as to move the valve so the engine will run forward; the other is set so that the engine will move backward. These eccentrics are attached to the opposite ends of a link by means of eccentric straps and rods. The purpose of this link is to change the direction of motion of the engine by bringing the eccentric blade of the desired motion in contact with the rocker arm and for giving the required cut-off.



Side View of Eccentrics, Straps and Reversing Gear.

When a link is placed with the block at one of its ends, steam will follow the piston nearly to the end of the stroke and as the link is raised or lowered, so as to bring the link block toward the center of the link, the cut-off is shortened. The rocker arms are connected by rods, called valve stems, to the main valves.*



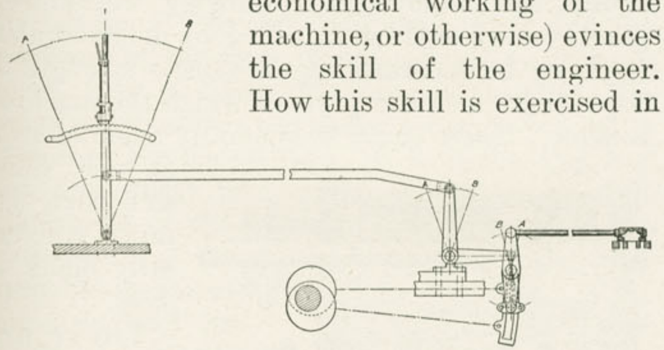
End View of Reversing Gear.

The links are suspended to the ends of arms by bars, called link hangers. These arms are attached to what is called a lifting shaft, which also has another upright arm attached to it on the right hand side

*For full description and illustrations see Vol. XII.

of the engine. This arm is connected by a reversing rod to a reversing lever, worked by the engineer in the cab of the locomotive. Its movement raises or lowers the link.

The method of governing the action of the slide valves and the admission of steam to the cylinders (and consequent smooth operation and economical working of the machine, or otherwise) evinces the skill of the engineer. How this skill is exercised in

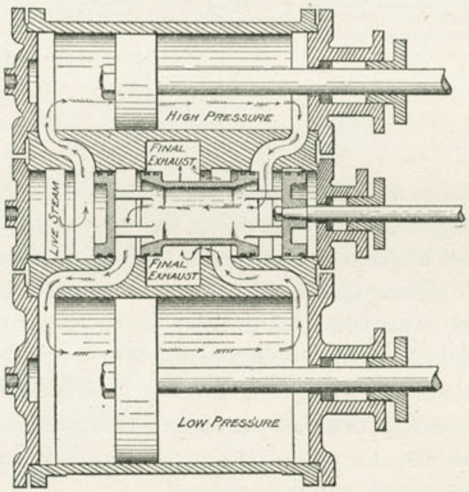


Engineer's Lever in Connection with Reversing Gear.

controlling the expansion of the steam in the cylinder rather than the opening and closing of the valve which admits steam into the cylinder, can not be explained with sufficient perspicuity to be of sensible aid to the student. The subject is pre-eminently one of practical knowledge, and what little can be gained from books by the new beginner is given in Vol. XII.

I do not esteem it necessary here to further describe the apparatus by which the action of the piston in the cylinder is brought to bear on the driving wheel, and so on the train.

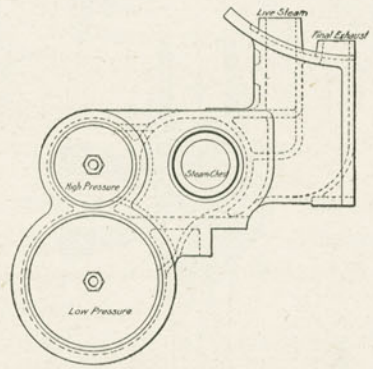
All the connecting rods and shafts must, it is apparent, be relative in length, size and strength to the other parts of the machine; harmony must exist throughout. This is true also of the boiler and cylinders, which must be proportionate to the load to be hauled and the speed to be attained. These details, incomprehensible to the novice, are achieved by following well-known practices of construction, aided by demonstrated formulas for ascertaining the tensile strength of the various metallic parts of which the machine is made. These parts, so generally made of iron at one time, are now almost universally made of steel.



Section showing action of steam in compound cylinder.

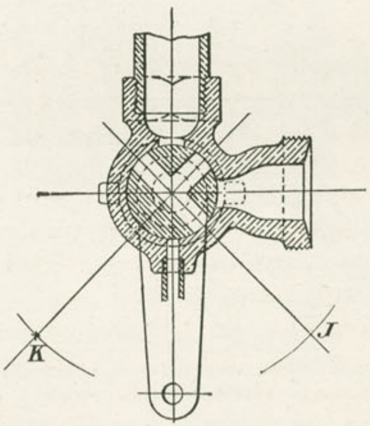
There are two forms of locomotives. One is known as the simple or single expansion locomotive; the other as the compound locomotive. Among the thingsclaimed for the last named is that it saves fuel because of the greater degree of expansion of the steam.

Its advocates claim that after the steam has acted upon the piston of one cylinder (the high-pressure) it is conveyed into a larger cylinder (the low-pressure), where it expands and acts again upon another piston before being finally exhausted through the smokestack. The four-cylinder compound locomotive has a high-pressure and low-pressure cylinder on each side of the engine. The two cylinders (high and low pressure) of the type illustrated, are cast in one piece, with a valve chamber and saddle. The valve which allows the steam access to the cylinders is of the piston type. It is double and hollow and works in a cylindrical steam chest in the saddle of the cylinder casting, between the cylinders and the smoke box. This valve controls the steam admission and exhaust of both the high and low-pressure cylinders. The steam which is exhausted from the high-pressure cylinder becomes at once the supply for the low-pressure cylinder. When the front bars of the locomotive frames are double, the low-pressure cylinder is placed on top, and the double rail prevents the use of the ordinary



Front View of Compound Cylinder (cylinder heads removed).

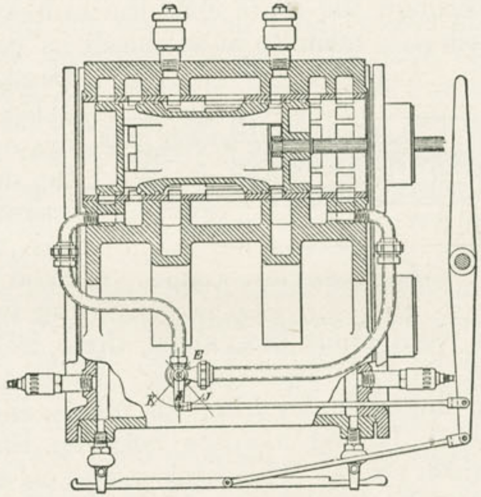
rocker shaft and box. The valve motion is then what is called direct acting, changing the location of the eccentrics on the axle in relation to the crank pin.* When the front rails are single bars, the low-pressure cylinder is under the other and the eccentrics are placed in the usual position. In such case the valve motion is called indirect acting. The most common method of transferring the motion from the links to the valve rod is by means of a rocker arm, the link block being connected with the lower end of the rocker arm, and the valve rod to the upper arm. Before starting the locomotive, steam is admitted to both the low and high-pressure cylinders. For this purpose a starting valve is provided, which is opened to admit steam to pass from one end of the high-pressure cylinder to the other, and thence through the exhaust to the low-pressure cylinder. It is operated by the same lever which operates the ordinary cylinder cocks. To secure harmony, however, and to prevent the locomotive becoming logy, this valve is kept closed as



Section of Starting Valve and Relief Cock, Compound Cylinder. Position "J" for starting; position "K" for high-pressure cylinder relief cock.

*See Vol. XII.

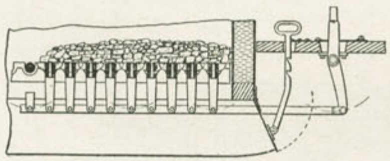
much as possible. Besides the usual air valves placed in the main passage of the high-pressure cylinder and also in the admission ports of the low-pressure cylinder, additional air-valves are placed in the low-pressure cylinders to prevent the formation of a vacuum which would draw cinders into the steam-chest and cylinders. To prevent rupture in case of excessive pressure, water relief valves are attached to the front and back cylinder heads of the low-pressure cylinder. The compound engine is generally similar to the ordinary single-expansion locomotive, except in the respects pointed out.*



Application of Starting Valve and Relief Cock, Compound Cylinder.

The grate of a locomotive usually consists of cast iron bars so arranged that they may be easily moved or shaken. Grates designed for

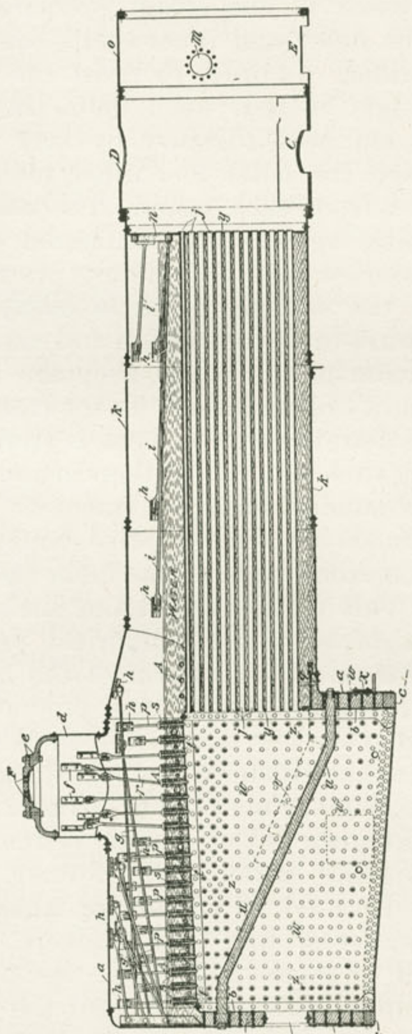
*The subject of compound-cylinder engines *versus* single-expansion cylinder engines is also referred to in the chapter on "The Evolution of the Locomotive" in this volume, but more particularly and in great detail, and with profuse illustrations, in Vol. XII burning anthracite coal are sometimes constructed of wrought iron tubes, through which a current of water circulates in order to prevent the grate from becoming over-heated. Cinders and burning coals are prevented from falling through the grate upon the railway track by an ash pan, made to fit as closely as possible inside. Dampers are provided for increasing or shutting off the draught, as required. The fire box, which affords room for the burning fuel, is usually a rectangular box, about three feet wide, made of iron or steel plates. These plates are so arranged as to form an inside and an outside shell, having a space between them, called a water space. This space varies on different locomotives from two and a half to four and a half inches. The inner shell in many cases is made of copper plates, and has a flat top called the crown-sheet, or crown-plate. In America soft steel has taken the place of copper. The top of the outside shell is generally arched. The two shells are united by what is more or less generally known as a mud-ring, which closes the water space between the two shells at the bottom. As the water in the cylindrical part of the boiler of the locomotive has free contact with that in the water space of the fire box, the shells of the



Section Showing Grate and Damper.

latter are exposed to the steam pressure, the strain upon the outer and inner shells being in opposite directions. In order to resist the pressure thus brought to bear upon them, they are strengthened and held together by stay bolts screwed through the outer and inner plates at short distances from each other. The ends of these stay bolts are securely hammered down after being inserted into the plates. As much depends upon the strength of these bolts, subjected as they are to the expansion and contraction of the steam in the boiler, they are made of the best quality of material. In the case of a crown-bar fire box, the crown-sheet is strengthened by strong iron bars bolted thereto and connected to the outside shell by braces or sling stays. The tubes or flues of the boiler are attached to the front plate of the inner shell of the fire box. This plate is called the flue sheet, and is rigidly stayed to the cylindrical part of the boiler by braces at the bottom of the latter. These tubes carry the smoke and products of combustion from the fire box to the smoke box and so on out at the chimney or smokestack.

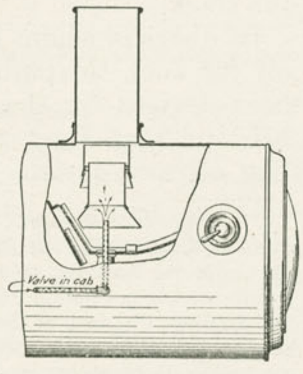
There are two main methods of firing a locomotive; one is known as the banking system, the other the spreading system. The former, it is thought, may be used to advantage when the coal is comparatively free from clinkers. The coal is banked or piled in the back part of the fire box and sloped downward toward the front of the grate where it is kept at a white heat.



Longitudinal Section of Locomotive Boiler Filled With Water.

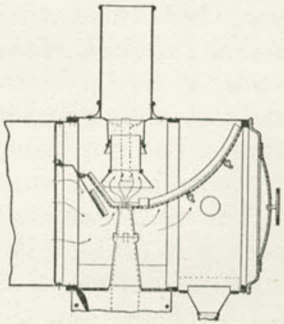
a Boiler shell. *b* Inside shell of fire box. *c* Mud ring. *d* Dome shell. *e* Dome castings. *f* Dome lugs. *g* Rear longitudinal stays. *h* Shell lugs. *i* Forward longitudinal stays. *j* Flues. *k* Barrel plates. *m* Manhole opening. *n* Dry pipe ring. *o* Extension end. *p* Sling stays. *q* Inside shell brace. *r* Dome sling stays. *s* Crown-bars. *t* Crown-sheet. *u* Arch support water pipe. *v* Brick arch. *w* Stay bolts (solid). *x* Frame tie. *y* Flue sheets. *z* Stay bolts (hollow). *A* Cross stays. *B* Fire door. *C* Saddle opening. *D* Smokestack opening. *E* Gondola opening. *F* Safety-valve connections.

The coal in the back part of the fire box gradually cokes and thus the gases are expelled. The consumption of these gases is aided by the admission of air at the furnace door, which mixes with them. When the bank of coal at the back of the fire box becomes coked, it is pushed forward onto the glowing fire and more coal put in its place to go through the same process. The spreading method of firing, referred to above, is used when the coal contains clinkers. The coal is evenly spread in a thin layer over the entire grate. The success and economy of this method depend upon the regularity with which the fire is fed and the layer of coal maintained; also upon the proper admission of air above the fire. The layer of coal is thicker when the engine is working hard than when it is doing light work. To obtain the best results, intelligence and observation must be exercised by those in charge here as elsewhere.



Part Section of Boiler, Showing Blower.

In order to create a draught when the locomotive is standing still, either before leaving the round house or at any other place, there is a device for letting steam into the smokestack directly from the boiler. This steam represents an expense, as it takes so much live steam from the boiler, while that from the cylinders, having already performed its office, does not. Because of this, or from a desire to husband the supply of steam in the boiler, or because of forgetfulness, the device in question for creating a draught is not always used.



Section Showing Spark Arrestor, used with Extension Front Ends.

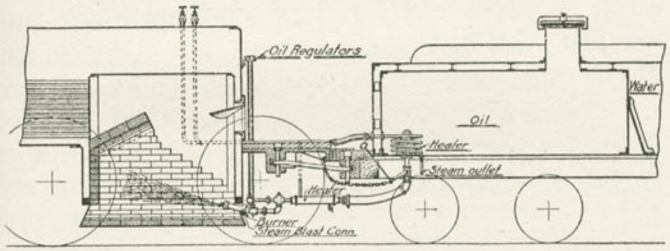
Another device of the locomotive is the spark arrester, placed below the smoke-stack above the flue openings. In some countries the use of this device is required by law. Besides abating a nuisance, it is useful as a precaution against setting fire to property along the track.

In districts where it is found desirable to use oil for fuel, adaptable grates or burners have been devised for the purpose.* However, it is believed that they are more or less imperfect, like all new devices introduced to supply com-

*In some investigations made during the coal strikes, a few years ago, an engine was fitted up with an oil-burning device. It was found, however, that it was not economical to use oil at a price of 1.7c per gallon unless coal cost more than $2.00 a ton. Dr. Dudley, Chemist of the Pennsylvania Railroad Company, made some extensive investigations in Russia in regard to oil for fuel in locomotives, and that company afterward fitted up an engine, finding that it was perfectly practicable to operate an engine with oil, but that it was no economy for the Pennsylvania road with the prevailing price of fuel and oil on their line of road.

paratively recent needs. They are, however, such as to effect a saving in cost compared with other kinds of fuel, but the pattern or form which the oil burner or grate will ultimately assume after experience has demonstrated what is needed, it is impossible to tell.

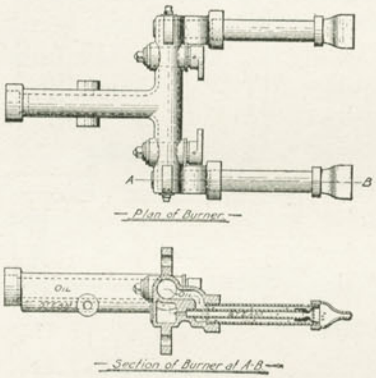
The devices now generally recommended for using oil contemplate the supply of liquid being carried in a reservoir. This is placed in the tank of the locomotive tender. The reservoir con-



Section Showing Fire Box and Tank Arrangement for the Use of Oil as Fuel.

taining the oil is thus immersed in water. By this means danger of the liquid igniting accidentally is reduced to the minimum. The convenience of this method and the necessity that precautions shall be observed are likely to fix this as the storehouse for the oil for all time to come.

When oil is used for fuel, the fire is fed by means of a pipe, a valve preventing the escape of the oil in case the pipe should by any means become disconnected. The utilization of oil (or the refuse thereof) for heating purposes usually contemplates its dispersion in the fire box in the form of a spray. To accomplish this, one pipe carries oil to the fire box while another pipe, entering directly below, carries steam. The escape of the latter breaks the stream of oil into spray. Both pipes have stopcocks. It is said that in practical use the flat flame or spray is superior to the conical flare or ring of jets.



Fuel Oil Burner.

Liquid fuel has many advantages over coal or other forms.* One important advantage is that it is more easily and cheaply handled. The danger of setting fires along the tracks by sparks from the locomotive is avoided by the use of oil. The absence of cinders and dirt, inseparable from the use of coal or wood, lessens the wear and tear of the machinery of the engine. The wastage which the use of

* Superintendents of railroads where it is used in southeastern Russia claim that the evaporation of from twelve to thirteen and one-half pounds of water is secured per pound of petroleum for locomotives. American experts claim that twelve hundred and fifty pounds of oil equal, in work, a ton of coal—two thousand pounds. It is said that the best results are obtained by adjusting the temperature of the oil before it reaches the fire box.

coal and wood entails is avoided in the case of oil. The comfort of travelers is also greatly heightened. The thing *per se*, however, in connection with the use of petroleum, is the saving it effects.*

Petroleum has been used for centuries as a substitute for other forms of fuel in the great basin of southeastern Russia adjacent to the Caspian Sea. Petroleum is produced there in abundant quantities, and is cheaper than all other forms of fuel. It is used exclusively on locomotives and for stationary and marine engines. The crude oil is not burned, however, but the residuum which is left after refining the crude product.†

It is said that petroleum has always been used for fuel in this region of the Caspian Sea, but in earlier times the demand was light and, in the absence of appliances or grates for burning the

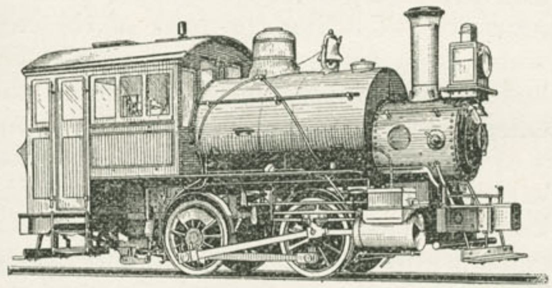
* The following statement of an American railway gives a comparison between the use of coal and oil for one month, viz.: Cost per mile, for all engines, for coal, 23.46 cents; cost per mile, for all engines, for oil, 14.24 cents; saving per mile, about 39.3 per cent. It should be remembered, however, in comparing the cost, the oil is found on the spot while coal is not produced in the locality, but has to be carried a great distance. Its cost to the railroad company is something like eight dollars per ton. In localities where coal is produced and sold at a low figure it is as a rule, probably, cheaper for fuel than oil.

† In numerous instances, however, in other countries the crude oil is used for fuel instead of the dregs. This will be changed with the introduction of appliances for refining the oil. A curious device adopted to keep the flues of the locomotive free from soot where oil is used is a sand funnel, the sand being carried through the flues by the draught from the fire box.

oil, the natives mixed it with cinders and other substances before igniting it. It is possible that the worship of fire in Persia was first suggested by the numerous gas wells which are to be found in the northern districts of that ancient and still primitive country.

Petroleum is used as a substitute for other forms of fuel in some parts of South America, particularly Peru. Its introduction in California is more recent. The supply of oil in the latter section is not yet determinable. In connection with the experiments of a California railway, the company reports that "steam at a pressure of from one hundred and fifty to one hundred and seventy pounds, applied direct to the atomizer, gives better results than superheated steam or superheated air, producing flame which is carried entirely through the flues. This could not be accomplished with superheated steam or superheated air, the latter acting more in the nature of a blowpipe, producing intense heat in the fire box, but not carrying the flame forward." This company reports that it is able to change its coal-burning engines to oil burners for less than one hundred dollars each. The cost, therefore, of introducing oil may be quickly repaid by the saving where circumstances favor its use. The statement, more or less credited, that oil is more severe on the fire box and flues than coal or other forms of fuel, is claimed to be unfounded. Directly the reverse is said to be the case. This, however, is a point upon which, it is probable,

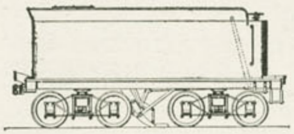
experience has not been sufficient to enable men to judge finally. We know, however, that the use of oil for fuel requires skill and care upon the part of the fireman; but every form of fuel requires these. The theory of the effective use of oil for fuel contemplates that the heat shall be uniform and well distributed in the fire box and flues, the former according to the service to be performed. Whether these are most effectively secured by the devices in use, or whether

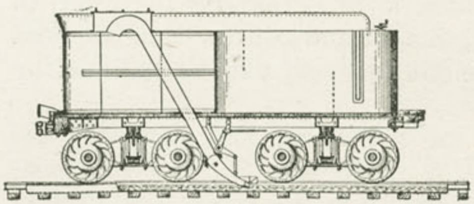


American Four-wheeled Saddle Tank Engine. Diameter of cylinders, 16 in.; stroke, 24 in.; diameter of driving wheels, 48 in.; wheel base, 7 ft.; weight of locomotive, 76,000 lbs.

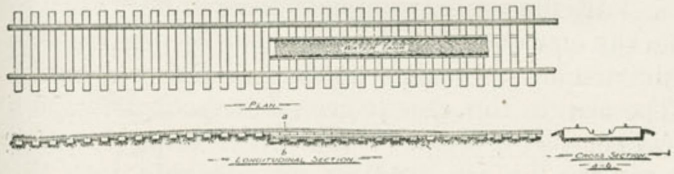
something else may be found to be better, time only can tell. I may say in conclusion, that in using oil for fuel, it is necessary, in order to avoid undue expansion and contraction, the heat should be sufficient in every case to exclude the cold air.

The method of supplying and carrying the water required for use in the boiler of the locomotive varies. In some instances the supply is carried above the boiler. In such cases the locomotive is called a tank engine. Usually, however, locomotives have a tender attached. It answers the double purpose of carrying fuel and water. The quantity of water and fuel varies according to needs. The maximum of the former may be generally stated at forty-five hundred gallons, and the latter at eight tons of coal. The customary way of filling the tank of the engine with water is by means of a water pipe or crane attached to the supply house, commonly called the water tank. In order, however, to secure a supply of water when the train stops only at long intervals, or otherwise to economize time, the well-known device of replenishing the water in the tender while the engine is in motion, from a sunken tank in the track, has suggested itself. The tank or trough is filled with water and varies in length. As the engine reaches the tank, the lower end of an inverted or curved pipe is lowered into the water. This pipe extends to the top of the tender and is provided with a hinge near the lower end so it may be easily

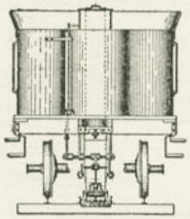

Side View of Tender (with Water Scoop dropped).


Section of Tender Showing Water Scoop in Track Tank.

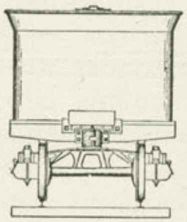
raised and lowered. The speed of the locomotive forces the water through this pipe into the tender, and in this way thirty-five hundred gallons of water may be taken up in a few seconds, according to the size of the pipe and the speed of the engine. The pipe is under the control of the engineer. However, in order to prevent accident because of dropping it too soon or raising it too late, the device is perfected by raising the rails at either end of the tank so that the end of the pipe will clear the road and trough if dropped before the latter is reached or left a second after the sunken tank is passed.


Water Tank. Approach to tank.

Water from the tender is conveyed to the engine by a piece of rubber hose attached to each side underneath the front end of the tank, the other end being connected to the pipe on the engine, which supplies water to the injector. The water is turned on and shut off from this hose by valves. In order that the tank on the tender shall be able to resist the pressure of the water, the flat sides of the tank are braced by rods or bars. To resist the violent motion of the water when the tender is started or stopped suddenly, transverse plates are placed inside; these are commonly called diaphragm plates.


Front View of Tender with Scoop in Track Tank.

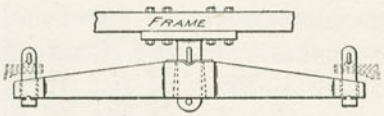
Fuel is supplied to the locomotive in various ways. It may be said generally to be dependent upon the quantity and the ability of the company to afford the most convenient arrangements. Coal is oftentimes shoveled from cars standing on an adjacent track. Sometimes iron buckets filled with coal, hoisted by cranes, are swung over and emptied into the tender. In other cases cars of coal are placed on platforms located high enough so the contents may be unloaded by gravity into the tender. Another method is the coal chute. The coal in this case is stored in pockets. Each pocket has a spout which, upon being lowered over the tender, empties its contents into the tender. A stationary engine for performing this work is common where the quantity of fuel to be handled justifies it.


Rear View of Tender.

In further reference to the locomotive, it is supported on either side by a frame, made of wrought iron bars or rolled iron plates. The frame is built in two sections. To the back section the driving axles are attached, and to the front section the cylinders are bolted.

The frame legs for receiving the axle boxes are usually connected longitudinally by means of two bars welded to the same. This forms the back section. To this section at the front end is attached a device (usually in the form of a jaw) provided for the bolting of the front section, the latter generally consisting of a single bar extending to the front end of the engine, where a heavy timber, called a bumper, extends from one side to the other. The cowcatcher or pilot (the device for removing obstacles from the track in front of the locomotive) is attached in front of this bumper timber. The cowcatcher is commonly made of wood, having a triangular frame at the bottom so supported that it is a few inches above the top of the rails. It is made of heavy strips of wood or iron bars attached to the frame, a few inches apart. Iron plates or scrapers, forming a snowplow, are oftentimes attached to the pilot to remove snow from the track when necessary or the snow is light. The locomotive is further supported by springs to protect it, so far as possible, from injury resulting from the jar to which it is subjected when in motion. The springs rest on saddles bearing on the top of the axle boxes. The frames are suspended to the ends of these springs by spring hangers. The boiler and other parts of the locomotive being also fastened to the frames, the weight of the locomotive is thereby suspended on the springs.

The weight of the locomotive is equally distributed upon the driving wheels by means of equalizing levers. These levers support each side of the engine so that the action is the same as if it were supported on one point. They are supported by a fulcrum in the center, and the fulcrum is attached to the frame of the locomotive.



Equalizer—Side View.

In reference to the construction of the wheels of the locomotive, including those known as drivers, the reader is referred to that portion of this work in which the subject of car wheels is especially referred to.*

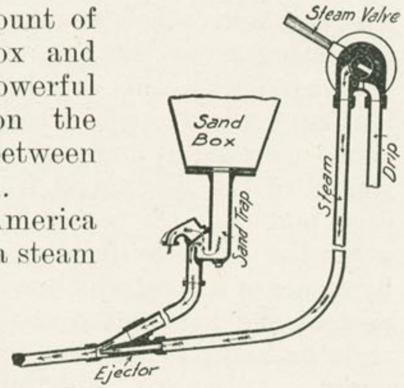
The air brake in use to-day covers a subject so important and vast that I have found it necessary to treat it apart in another place.†

The supply of sand needed for daily use is carried in a cylindrical receptacle placed on top of the boiler, called a sand box. From here it may be easily applied to the rails as needed, through a pipe on each side of the boiler. A valve operated by a lever in the cab of the locomotive admits the sand into the pipes. In order to ensure a uniform and continuous supply of sand on the rails, a device is employed for forcing the sand by a blast of steam or compressed air. This is accomplished by means of an ejector which

* See volume "Train Service."

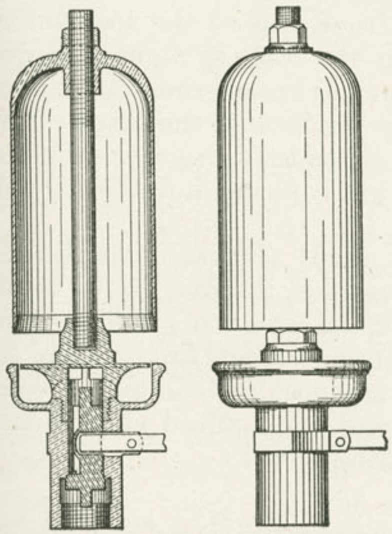
† See chapter "Construction and Operation of the Air Brake," in this volume, also "Engineers' and Firemen's Manual," Vol. XII.

draws a small amount of sand from the box and forces it in a powerful blast directly upon the point of contact between the wheel and rail.



Sand Pipe of Locomotive, Supplemented by Steam Blast.

Locomotives in America are provided with a steam whistle, a bell, and a gong, for giving and receiving signals. The whistle consists of an inverted cup or bell, made of brass or other metal, placed over a circular opening. It is fastened to a stem which is screwed into the top of the dome of the boiler. Inside of this stem is a valve which opens communication with the steam. This valve is opened or closed by a lever in the cab. When the valve is open the escaping steam produces the alarm or whistle.


Section. Side View.
Steam Whistle.

The locomotive bell swings from an iron frame projecting from the top of the boiler. It is connected with the cab by a rope with which it is rung when used for signaling. It is sometimes operated by compressed air or steam. The weight of the bell varies from fifty to one hundred pounds. On passenger trains, signals are given the engineer from every part of the train by means of a gong which is fastened to the upper part of the locomotive cab on the inside. The train bell cord is attached to the hammer of this gong. Automatic whistles operated by compressed air are, in some instances, substituted for the gong.

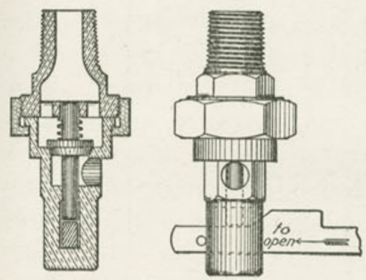
A large lamp or headlight attached to the smoke box at the front end of the locomotive is used to illuminate the track at night and give notice of the approach of the engine. A concave reflector is placed at the back of the lamp. This reflector is of such shape that the rays reflected from it (when the light is placed in its focus) will be in parallel lines.

On all American roads a covered apartment, called a cab, is provided at the rear of the boiler for the protection of the machinery and those in attendance on the engine. Seats are provided on either side for the engineer and fireman. Windows at the sides and front afford them a full view of the roadway and track.

In regard to details of working, before a fire is started in the locomotive the grates and ash

pan are freed from clinkers, cinders and ashes, and care taken to see that the boiler contains the necessary supply of water. The fire is started slowly, otherwise the undue expansion and contraction of the different parts will be likely to produce an excessive strain on the boiler.

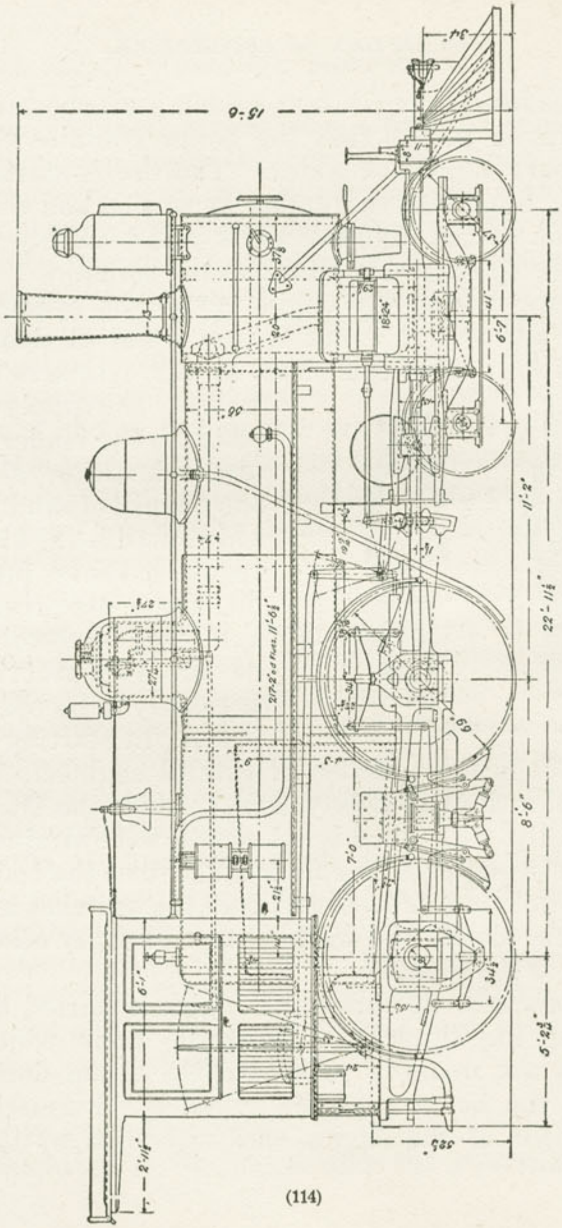
Before leaving the engine house the cylinder cocks are opened to allow any water or steam which may have condensed in the cylinders to escape. The supply of water in the tender is also looked after; also the quanty of sand in the sand box, the requisite tools, fuel, oil, waste, packing, and other accessories of the locomotive necessary to its operation. In starting a train, it is the practice of careful engineers to open the throttle slowly, so as to start the train gradually. Full speed is not sought to be attained until the engineer has ascertained that the train as a whole moves together, that the switches are properly placed, the track clear, and every other detail as it should be.



Section. Side View.

Cylinder Relief Cock.

In practical operation the engine is started by moving the throttle, opening the valve which allows the steam to pass from the steam dome above the boiler into the cylinders. Formerly the speed of the engine was controlled by the



Eight-Wheel Passenger Locomotive.

size of this opening, but as the link motion, already described, allows the expansion to be varied at will, the throttle-valve is kept open and the speed controlled by varying the amount of the expansion.

Such are the details of the modern locomotive.* The reader will notice that I have not attempted to exhaust the subject. To understand the locomotive requires intelligence, study and great practical knowledge. Nothing that can be said in books about the construction and operations of the locomotive is of particular value to an engineer or fireman; but a description of the locomotive, even so imperfect as that embraced in the foregoing chapter, is of the greatest possible interest and value to other railway men, who have neither the opportunity, time nor inclination to become practical engineers, but who have a desire, and it is to the interest of every railway company that they should have the power, to acquaint themselves with the various parts of the locomotive and the theory of its operation. It is for such people that I have written this chapter.

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* In further explanation of the locomotive, and as a key to many things impossible to write specifically of, I have embraced in the Appendix (B) to this volume, a list of the articles or different parts which go to make up a locomotive. The parts that the manufacturers of locomotives buy in the market from other manufacturers are indicated by an asterisk (*)

CHAPTER III.

THE LOCOMOTIVES AND CARS OF THE WORLD AND THE MANUFACTURERS THEREOF.

Elsewhere I have devoted a chapter to the growth of the locomotive. In another place I have described the modern locomotive and its workings in detail. Both of these chapters are so fully and carefully illustrated that a novice may by their aid become generally familiar with the subject. He may not, indeed, be able to act as an engineer or fireman, but he will have an intelligent insight upon which to quickly build up a practical acquaintance with the subject. The chapters in question depict so accurately the parts of the locomotive and their operation and relation to each other that they will also serve to refresh the minds of practical men, while those who hope to become practical men, such as machinists, engineers and firemen, will find they open a field of research which will hasten the schooling process through which every one must go. To railroad men not connected with the machinery department they will afford an opportunity of becoming familiar with the locomotive and its history without going into the shop to work, or mounting an engine to learn, little by little, its operation. Those who wish to become

AMERICAN PASSENGER, BUFFET-SLEEPING AND OBSERVATION CARS.

LIST OF THE VARIOUS PARTS OF THESE CARS. SEE ILLUSTRATION SHOWING SAME, PLATE II.

TRUCKS AND THEIR ATTACHMENTS.

1 Axle. 2 Axle safety bearing. 3 Axle safety strap. 4 Wheel. 5 Wheel center. 6 Outside wheel plate. 7 Retaining ring. 8 Retaining-ring rivets. 9 Steel tire. 10 Tread of wheel. 11 Flange of wheel. 12 Journal box. 13 Journal-box cover. 14 Journal-box cover-spring. 15 Journal-box cover-bolt. 16 Journal-bearing or brass. 17 Pedestal. 18 Pedestal bolts. 19 Pedestal tie-bar. 20 Pedestal stay-rod. 21 Pedestal brace. 22 Wheel-piece. 23 Outside wheel-piece. 24 End-piece of truck-frame. 25 End-piece plate. 26 End piece, or end sill corner-plate. 27 Outside transom. 28 Outside transom plate. 29 Transom corner-plate. 30 Transom truss-rod. 31 Transom truss-rod seat. 32 Transom truss-rod washer. 33 Transom chafing-plate. 34 Middle transom. 35 Middle transom plate. 36 Safety-beam. 37 Safety-beam iron. 38 Safety-beam tie-rod. 39 Middle safety-beam. 40 Center-pin. 41 Center-bearing arch-bar. 42 Center-bearing stool. 43 Body center-plate. 44 Truck center-plate. 45 Center-plate block. 46 Center-bearing beam. 47 Center-bearing arch-bar. 48 Center-bearing inverted arch-bar. 49 Center-bearing beam-plate. 50 Center-bearing beam-strips. 51 Truck-bolster. 52 Truck-bolster chafing-plate. 53 Spring-beam. 54 Spring-beam chafing-plate. 55 Bolster-spring cap. 56 Bolster-spring seat. 57 Bolster-spring. 58 Spring-band. 59 Spring-plank. 60 Spring-plank bearing. 61 Swing-hangers. 62 Upper swing-hanger pivot. 63 Lower swing-hanger pivot. 64 Swing-hanger pivot-bearing. 65 Swing-hanger staple. 66 Swing-hanger staple casting. 67 Truck side-bearing. 68 Side-bearing bridge. 69 Body side-bearing bridge. 70 Body side-bearing pillar. 71 Body-bolster. 72 Outside body-transom pillar. 73 Intermediate body-transom pillar. 74 Body-transom center-bearing pillar. 75 Equalizing-bar. 76 Equalizing-bar spring. 77 Equalizing-bar spring-seat. 78 Equalizing-bar spring-cap. 79 Equalizing-bar spring-block. 80 Check-chain. 81 Check-chain hook. 82 Check-chain loop. 83 Check-chain eye-bolt. 84 Check-chain chafing-plate.

AIR BRAKE, AIR SIGNAL AND HAND BRAKE APPARATUS.

86 Brake-hanger. 87 Brake-hanger carrier. 88 Brake-beam adjusting-hanger carrier. 89 Brake-hanger pin. 90 Trussed wooden brake-beam. 91 Hollow brake-beam. 92 Brake safety-strap. 93 Release spring. 94 Upper balance-spring. 95 Lower balance-spring. 96 Balance-spring rod. 97 Brake-head. 98 Brake-shoe. 99 Brake-shoe key. 100 Outside brake-beam fulcrum. 101 Inside brake-beam fulcrum. 102 Center brake-beam fulcrum. 103 Center-brake transom. 104 Center brake-beam. 105 Center brake-hanger. 106 Center-brake safety-hanger. 107 Center-brake release-spring. 108 Center-brake balance-spring. 109 Center-brake balance-spring rod. 110 Center brake-shoe. 111 Crescent link. 112 Crescent link-hanger. 113 Equalizing brake-lever. 114 Truck brake-lever. 115 Truck-lever fulcrum. 116 Dead truck-lever. 117 Live truck-lever. 118 Brake-lever stop. 119 Inside connecting-rod. 120 Outside connecting-rod. 121 Lower brake-connection. 122 Adjusting turn-buckle. 123 Upper brake-connection. 124 Hand brake-connection. 125 Brake-chain shaft. 126 Brake rachet-wheel. 127 Brake hand-wheel. 128 Rachet-brake. 129 Floating or Hodge-lever. 130 Hodge-lever connecting-rod. 131 Hodge carrier. 132 Cylinder lever. 133 Cylinder lever guide. 134 Cylinder lever connecting-rod. 135 Brake cylinder. 136 Cylinder front-head. 137 Cylinder back-head. 138 Automatic slack-adjuster. 139 Automatic pressure-regulator for High Speed Brake. 140 Piston-travel recorder. 141 Piston crosshead. 142 Auxiliary reservoir. 143 Auxiliary reservoir bands. 144 Auxiliary reservoir blocks. 145 Release-cock or bleeder. 146 Pipe to auxiliary reservoir. 147 Triple valve. 148 Check-valve case. 149 Branch pipe. 150 Cut-out cock. 151 Strainer tee. 152 Pressure retaining valve. 153 Pipe to pressure retaining valve. 154 Train brake-pipe. 155 Pipe hanger. 156 Tee fitting to conductor's valve. 157 Branch pipe to conductor's valve. 158 Conductor's valve. 159 Angle cock. 160 Hose clamp. 161 Air brake hose. 162 Armored brake hose. 163 Air-hose coupling. 164 Signal hose coupling. 165 Signal hose. 166 Armored signal hose. 167 Train signal pipe. 168 Train signal stop-cock. 169 Signal branch-pipe to car discharge valve. 170 Signal branch-pipe to car discharge valve. 171 Car signal-valve. 172 Signal cord. 173 Signal cord hanger. 174 Angle fitting.

AUTOMATIC WATER-RAISING SYSTEM.

175 Water tank. 176 Air tank. 177 Drip cock in air tank. 178 Air pressure governor. 179 Check-valve in air pipe. 180 Water tank filler. 181 Three-way cock. 182 Stem of three-way cock. 183 Main shut-off valve. 184 Air vent from water tank. 185 Water strainer. 186 Blow-off to clean strainer. 187 Cold water pipe.

LAVATORY FITTINGS IN SMOKING ROOM.

188 Hot water jacket. 189 Hot water pipe to bowl. 190 Cold water pipe to bowl. 191 Combined hot and cold water cock. 192 Wash-bowl or basin. 193 Basin plug. 194 Basin coupling. 195 Basin waste-pipe. 196 Slab. 197 Riser. 198 Towel-holder. 199 Towel-holder bracket. 200 Water cooler. 201 Water cooler faucet. 202 Water glass or tumbler. 203 Water glass bracket.

WATER CLOSET.

204 Floor pipe. 205 Iron hopper. 206 Cover for iron hopper. 207 Dump pan. 208 Porcelain bowl. 209 Drip tray. 210 Seat hinge. 211 Operating lever. 212 Sliding rod. 213 Supply pipe. 214 Vent pipe. 215 Water tank. 216 Toilet paper holder. 217 Coat hook. 218 Stained glass art-window.

HEATING SYSTEM—COMBINED HOT WATER AND STEAM.

219 Baker heater. 220 Expanding generator coil. 221 Inner coil. 222 Hot water pipe from heater. 223 Hot water pipe to car. 224 pressure gauge. 225 Fire pot. 226 Grate. 227 Grate shaker. 228 Ash-pit. 229 Ash-pit bottom. 230 Ash-pit door. 231 Ash-pit door handle. 232 Coal box. 233 Feed door. 234 Feed door handle. 235 Safety plate handle. 236 Outside casing. 237 Inside casing. 238 Smoke flue. 239 Smoke flue base. 240 Top of heater. 241 Ring for Russia-iron top. 242 Smoke pipe. 243 Damper. 244 Circulating drum. 245 Combination drip cock. 246 Filling funnel. 247 Safety valve. 248 Floor valve, direct steam heating. 249 Angle valve. 250 Steam jacket (no fire in heater). 251 Steam inlet to jacket. 252 Steam outlet from jacket. 253 Steam circulating pipe. 254 Hot water circulating pipe. 255 Seat Radiators. 256 Foot-guard over heater pipes. 257 Blow-off for water. 258 Blow-off for steam. 259 Handle for steam blow-off. 260 Automatic water trap. 261 Angle drip valve. 262 Return bend. 263 Steam hose. 264 Hose-band. 265 Steam hose coupling (Gibbs). 266 Steam hose coupling (Sewall). 267 End steam valve.

LIGHTING APPARATUS AND FIXTURES—GAS, ELECTRIC LIGHT, ETC.

268 Filling valve cover. 269 Filling pipe. 270 Holder valve. 271 Gas holder. 272 Gas holder supports. 273 Car gauge. 274 Regulator. 275 Pipe to lamps. 276 Main gas cock (in closet). 277 Bracket gas lamp. 278 Globe. 279 Globe holder. 280 Center suspension lamp. 281 Four-arm lamp. 282 Electric bulbs. 283 Vestibule lamp. 284 Glass bowl. 285 Glass dome. 286 Globe hinge. 287 Spring catch. 288 Reflector. 289 Cluster. 290 Plug for cluster. 291 Check screws. 292 Cluster stem. 293 Cluster stem-lock. 294 Burner tips. 295 Body casting. 296 Flues. 297 Ventilator. 298 Ventilating chimney. 299 Burner cock. 300 Roof casting. 301 Gas way. 302 Thimble. 303 Reducing elbow. 304 Smoke bell. 305 Gas pipe hangers. 306 Ventilator. 307 Electric connector. 308 Electric wires. 309 Electric switch-board. 310 Platform electric lamp. 311 Vestibule electric corner light. 312 Electric berth light. 313 Electric deck facing light. 314 Combined gas and electric chandelier. 315 Electric light shades. 316 Side lamp. 317 Side lamp bracket. 318 Side lamp chimney.

COUPLING APPARATUS AND DRAFT GEAR.

319 Miller coupler. 320 Automatic vertical-plane coupler. 321 Knuckle. 322 Knuckle pin. 323 Drawbar. 324 Shank. 325 Draft-spring strap. 326 Draft-spring strap-bolts. 327 Draft-spring. 328 Draft-spring followers. 329 Tail-bolt or stem. 330 Drawbar carry-iron. 331 Inner drawbar carry-iron. 332 Uncoupling lever. 333 Uncoupling shaft. 334 Uncoupling rod. 335 Draft timbers.

PLATE II.

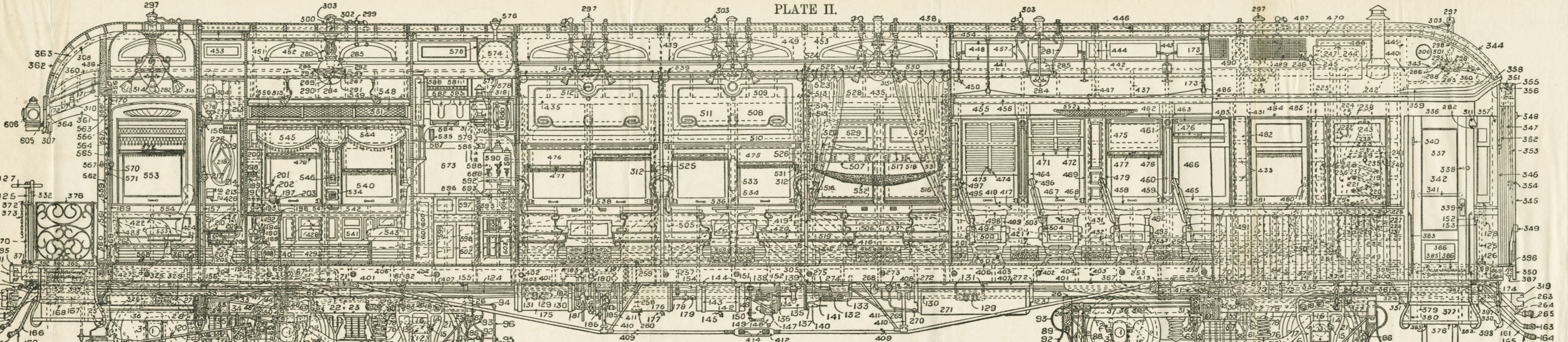


DIAGRAM SHOWING THE DIFFERENT PARTS OF PASSENGER, BUFFET-SLEEPING AND OBSERVATION CARS.

WITH VESTIBULE AND OBSERVATION PLATFORMS, GAS AND ELECTRIC LIGHT, BAKER HEATER AND STEAM HEATING, &C.

Particularizing the different parts thereof and giving the technical names by which they are known by those connected with the car department of railroads. It is at once a Chart and an Encyclopedia, each part of the car being given a number so that it may be recognized and quickly referred to, the whole being classified under sub-headings. The right hand portion of the chart illustrates the construction of a passenger coach having seats with reversible backs and a Baker heater room. The left hand portion illustrates the construction of a buffet sleeping car with berth sections and seats, the buffet kitchen, the smoking and toilet rooms, and an observation room and platform in the rear. The wide vestibule platform is added to the coach end of the car with a Pintsch gas lamp in the dome, and outside electric corner lights. The four wheel truck used in the coach end of the car is such as is used very largely in the construction of American passenger coaches, although six wheels are often used. The six wheel truck shown under the sleeping and observation end of the car is such as is used in the construction of these heavy modern cars.

VESTIBULE AND PLATFORM.

336 Vestibule end of car. 337 Vestibule door. 338 Vestibule door lock. 339 Vestibule door drop-handle. 340 Vestibule door hinges. 341 Vestibule door guard-plate. 342 Glass in vestibule door. 343 Vestibule dome. 344 Vestibule hood. 345 Diaphragm face-plate. 346 Inner face-plate. 347 Diaphragm. 348 Top face-plate guide. 349 Bottom face-plate guide. 350 Face-plate buffers. 351 Face-plate chains. 352 Back gravity-bar. 353 Front face-plate gravity-bar. 354 Gravity-bar fulcrum-bolt. 355 Chain-sheave brackets. 356 Chain sheaves. 357 End post. 358 Vestibule end sill. 359 Corner post. 360 Platform roof. 361 Roof-apron. 362 Platform hood. 363 Platform roof carline. 364 Platform roof end carline. 365 Platform hood and fitting. 366 Platform trap-door. 367 Platform sill. 368 Platform end sill. 369 Platform end sill iron. 370 Platform hand rail. 371 Socket for rail-post. 372 Platform end timber. 373 Platform sill. 374 Platform tie-rod. 375 End sill. 376 Step hanger. 377 Step riser. 378 Tread board. 379 Step iron. 380 Step hanger. 381 Step hanger brace. 382 Extension folding step. 383 Extension step hinge. 384 Side-stems. 385 Side-stem thimble. 386 Side-stem spring. 387 Side-stem pin. 388 Center-stem. 389 Inner guide center-stem. 390 Center-stem spring. 391 Center-stem pin. 392 Follower center-stem. 393 Pressure bar. 394 Short buffer-plate. 395 Threshold plate. 396 Foot plate. 397 Safety coupling chain. 398 Safety coupling hook.

CAR FRAMING, ETC.

399 End-sill. 400 Side-sill knee-iron. 401 Side-sill. 402 Sill tie-rods. 403 Sill and plate tie-rod. 404 Bridging. 405 Floor timber brace. 406 Car floor. 407 Deafening ceiling. 408 Crosstie timber. 409 Body truss-rod. 410 Body queen-post. 411 Body queen-post stub-ends. 412 Turn-buckle. 413 Truss-rod anchor-iron. 414 Truss-rod stub-ends. 415 Truss-rod saddle. 416 Truss-plank inside. 417 Belt rail. 418 Belt rail cap. 419 Compression beam. 420 Auxiliary compression beam. 421 Compression beam brace. 422 Counter brace. 423 Counter brace rod. 424 Hog-chain or overhang truss-rod. 425 Overhang truss-rod post. 426 Overhang truss-rod saddle. 427 Rafters. 428 Upper deck plate. 429 Free-cod. 430 Stud. 431 Window posts. 432 Sheathing rail. 433 Sheathing furring. 434 Plate. 435 Body end-plate. 437 Rafters. 438 Roof boards. 439 Clear-story. 440 Deck end-sills. 441 Deck sill. 442 Deck sill facing. 443 Deck post. 444 Deck panels. 445 Deck plate. 446 Upper deck carline. 447 Compound carline. 448 Deck sash. 449 Deck sash lintel. 450 Deck sash openers. 451 Deck sash pivot. 452 Deck sash rail. 453 Ceiling. 454 Inside deck cornice. 455 Inside lining. 456 Inside decorative panel. 457 Deck sash hinge. 458 Inside window frame. 459 Pilaster base. 460 Pilaster. 461 Pilaster cap. 462 Window cove molding. 463 Window casing. 464 Window sills. 465 Window sash. 466 Window glass. 467 Window lift. 468 Window lock. 469 Window stop. 470 Rafter cornice. 471 Window blind guide. 472 Window blind stile. 473 Window blind rail. 474 Window blind lift. 475 Window blind shade. 476 Bottom bar of shade. 477 Shade thumb latch. 478 Shade fixture. 479 Shade stop. 480 Outside window sill. 481 Window sill cornice board. 482 Window panel. 483 Outside window molding. 484 Letter board or frieze. 485 Fascia board. 486 Eaves molding. 487 Deck eaves molding. 488 Deck outside window-sash. 489 Deck window screens. 490 Deck screen-post. 491 Outside sheathing. 492 Upper wainscot panel. 493 Lower wainscot panel. 494 Cushion. 495 Back. 496 Head roll. 497 Back band. 498 Arm rest. 499 Seat end rest. 500 Seat end roll. 501 Base casting. 502 Foot rail. 503 Striker arm. 504 Seat lock. 505 Seat end.

SECTIONS AND SLEEPING BERTHS.

506 Lower berth. 507 Upper berth down. 508 Upper berth up. 509 Berth front panel, upper part. 510 Berth front, lower part. 511 Berth front panel. 512 Berth catch handle. 513 Berth spring frame. 514 Berth spring chain. 515 Berth chain pulley. 516 Berth safety rope. 517 Berth mattress. 518 Berth spiral spring. 519 Pillow box. 520 Berth pillow. 521 Berth curtains. 522 Curtain rings. 523 Curtain rod. 524 Curtain rod brackets. 525 Berth partition. 526 Head board. 527 Lower berth step. 528 Lower deck ceiling. 529 Bunk panel. 530 Bunk apron. 531 Hammock hook. 532 Hammock. 533 Mirrors. 534 Electric push-buttons. 535 Annunciator box. 536 Table. 537 Table leg. 538 Table hook-plates. 539 Hat hooks. 540 Smoking room. 541 Smoking room panels. 542 Wall camel seats. 543 Sofa. 544 Window curtain-rod. 545 Window drapery. 546 Match striker. 547 Ash receiver. 548 Continuous basket rack. 549 Seat rack brackets. 550 Basket rack end. 551 Basket rack netting. 552 Parcel and umbrella rack. 553 Observation end of car. 554 Revolving chair. 555 Chair base casting.

DOOR AND TRIMMINGS.

556 Door lintel. 557 Car door. 558 Top door-rail. 559 Middle door-rail. 560 Bottom door-rail. 561 Lower door panels. 562 Middle door panels. 563 Upper door sash. 564 Lower door sash. 565 Door sash-lift. 566 Door sash lock. 567 Door knob. 568 Door holder. 569 Door holder catch. 570 Escutcheon. 571 Door hinges. 572 Lambrequin.

BUFFET KITCHEN.

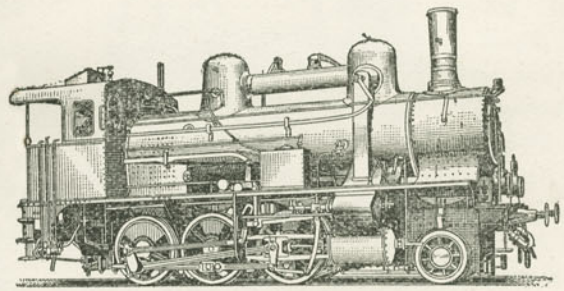
573 Buffet. 574 Overhead water tank. 575 Supports for overhead water tank. 576 Overhead water tank filler. 577 Pipe from overhead water tank. 578 Bread and pastry closet. 579 Cold water pipe. 580 Hot water pipe. 581 Tea and coffee urn. 582 Shelf for canned goods. 583 Plate rack. 584 Saucer rack. 585 Bread board. 586 Match safe. 587 China closet. 588 Shelves for glassware. 589 Urn. 590 Coffee pot. 591 Hot water pot. 592 Drip tray. 593 Cold water faucets. 594 Gas pipe. 595 Sink. 596 Carving table. 597 Ice box. 598 Refrigerator. 599 Ice cream closet. 600 Wine and beer locker. 601 Provisions. 602 Linen locker. 603 Locker door. 604 Locker panels.

MARKERS.

605 Flag and lamp holder. 606 Tail lamp.

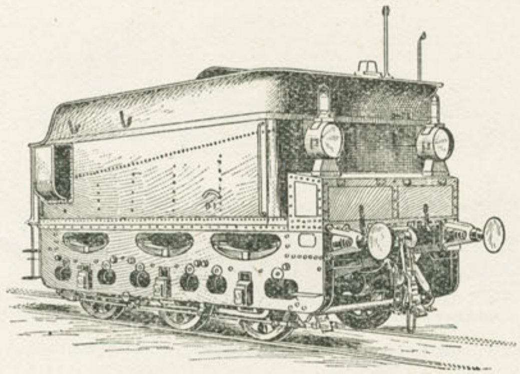
firemen, engineers, or machinists in a railroad shop, will in every case do well to first familiarize themselves with the theory of the subject. This work is intended to aid in this.

It was the practice at one time, and still maintains to a greater or less extent, to commence at the bottom as a boy and, by years of practical labor without study, evolve the experience necessary to a more extended field of work. This is still in a measure necessary, because nothing



This machine is of Austrian manufacture, and presents many unique and interesting features.

can fill the place of practical experience; but practical experience without research, study and thought, without delving into the philosophy of the thing, is not enough to base a career upon, whether a man be a fireman, engineer, machinist, or statesman. Men whose attainments are so limited show to great disadvantage compared with reading men. If they would grow to the height their Creator intended, they must add to their practical experience the experience and research of others. It is in order to aid in bringing a knowledge of the science of railroads within the reach of all, that I am led to write these books. I do not expect to be exhaustive. Books intended to exhaust a subject fail to do more than exhaust the reader. There is a natural growth in every department of the world's industry so certain and irresistible that for any one to say he will exhaust a subject is simply to

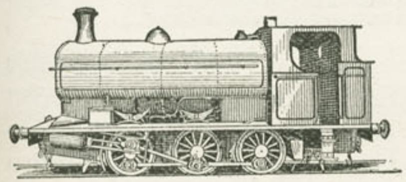


Engine Tender of Austrian Imperial Train.

become tedious—to belittle his subject, in fact. The most that men of talent need—and they are the only people worth instructing—is a hint. They require to be led along the road a little way in order that they may obtain better use of their legs and have opportunity to observe what there is going on in the world outside of the spot in which they were born. This is the purpose of books like these. They are not to fit men

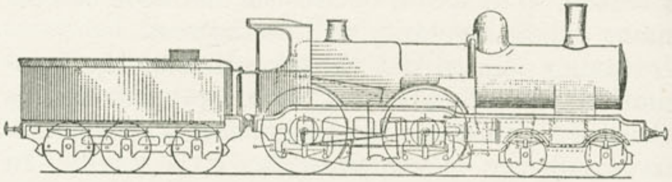
completely, but to help them; to lead them by suggestion to do what might not otherwise occur to them. It is only necessary to stimulate, touch a match, so to speak, to fire the ambition of real men. Their ingenuity will do the rest.

Having pointed out the evolution of the locomotive and described its parts, I propose in this chapter to illustrate the higher forms of locomotives and cars in use throughout the world. In selecting pictures for incorporation here, I have been led into correspondence with many of the great manufacturers of the world, and from this have acquired much interesting information of great value to myself, if not to the reader. The accompanying pictures represent standard forms of locomotives. It will not be long, however, before they will become obsolete, like the equipment of fifty years ago. When this period arrives I will, in new editions of the work, transfer them to the evolutionary period of growth. There they will be interesting and not misleading.



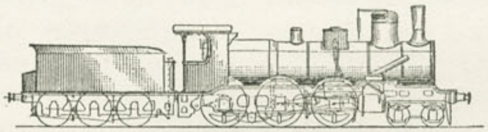
Locomotive on Siberian Railway. Diameter of cylinders, 16 in.; stroke, 22 in.; diameter of driving wheels, 46 in.; weight of locomotive, 31½ tons

In looking through the pictures embraced in this chapter, American readers will not fail to note the difference between the equipment of other countries and their own. It extends through the whole category of countries. There is, in fact, almost as much difference between the locomotives and cars used by different peoples as there is between the faces of those who

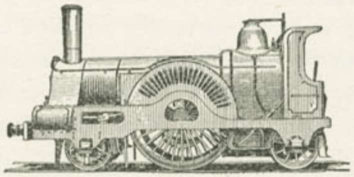


Outline of Italian Inside Connected Passenger Locomotive. The tender truck, it will be observed, has a rigid frame.

make up the different nations. The rolling stock mankind constructs is not only different in form, but in working and carrying capacity. The subject is more interesting than one would suppose at first glance. Details are strikingly different. Thus in the case of cars, we couple them together automatically; in other countries they are in the main attached to each other by chains and then drawn tightly together against projecting bumpers. The wheels also abroad, as a rule, are spoked, while with us they are, in the main, solid. In many

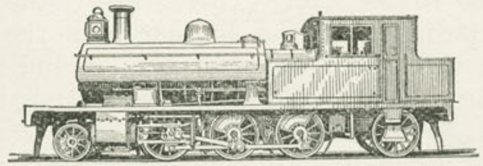


Outline of Italian Inside Connected Freight Locomotive.



Egyptian Locomotive. This passenger engine with a single pair of drivers is suitable only for very light work, but possesses remarkable speed.

cases there are only four wheels under foreign cars. This seems strange to us, but is not strange when we remember the number of wheels is intended to be proportionate to the load to be carried.*

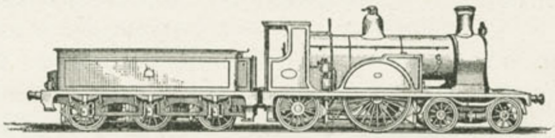


Locomotive on China Railway, the locomotive and tender being built in one piece. Diameter of cylinders, 16 in.; stroke, 24 in.; diameter of driving wheels, 4 ft.; total wheel base, 25 ft., 6 in.; weight of locomotive in working order, 117,700 pounds; capacity of tender tank, 1,550 gals.; fuel capacity, 107 cu. ft.

The machinery of different countries used in constructing and repairing railway locomotives and cars also differs. This is also true of skilled labor, the experience and talent of builders, natural facilities, and other details. The

*Differences in car construction and use are practically without limit. Four-wheeled freight cars are as common in other countries as eight-wheeled are in the United States. We may note one or two examples: The coal cars used on the Lancashire & Yorkshire Railway have four wheels and a wheel-base of nine feet. They weigh eleven thousand two hundred pounds when empty and thirty-three thousand six hundred pounds loaded. On the Eastern Railway of France the coal and coke and box cars have four wheels with a wheel-base of twelve and three-tenths feet. The flat cars are carried on six wheels and have a wheel-base of sixteen and four-tenths feet. The freight cars of the Saxon State railways of Germany have only two axles, and weigh, when loaded, about thirty-five thousand pounds. The maximum train load on the East Indian Railway is one thousand tons. The freight cars have four wheels, with a wheel-base of eleven and one-half feet.

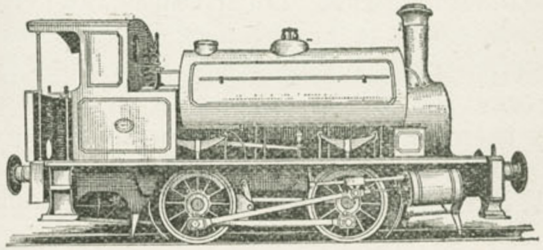
intrinsic merits of locomotives differ quite as much as steamships or other manufactured goods. No manufacturer will, however, admit that his machines are inferior to the best. They are, on the contrary, of the highest type and the best to be had. The greater the talent and experience of the builder and the more perfect the appliances he uses, including the labor he employs, the higher, of course, will be the results he attains. It is only by enquiry, observation and careful comparisons that we can form an intelligent opinion relatively of the



Caledonian Railway Passenger Locomotive, Scotland. This engine is designed for speed.

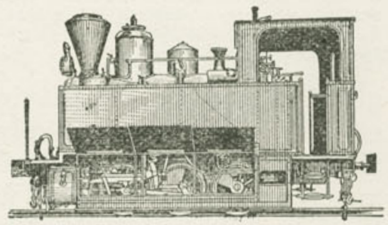
merits of different manufactories. It follows without saying that the machinery of railway shops must, to secure results at the lowest cost, be adequate and of the best type, and so grouped that it may be utilized with the minimum expense for labor and the handling of material. Repair shops require to be easily accessible to the lines they are designed to accommodate, but construction shops must, to obtain the best results, be located with reference to supplies and the obtainment of labor on the most advantageous terms and with the least likelihood of interruption from economic causes. In many

instances bounties are offered by cities and towns to influence the location of manufactories of locomotives and cars. Generally, however, it may be said that the location of these shops is not pre-



Mineral Tank Engine, Scotland. Engines of this character are known in America as "Saddle Tank" Engines. Diameter of cylinders, 14 in.; stroke, 20 in.; diameter of driving wheels, 44 in.; wheel base, 7 ft.; weight of locomotive, 41,800 lbs.; tank capacity, 750 gals.

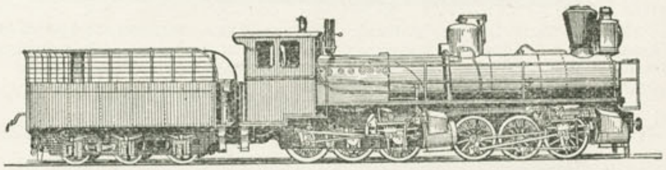
meditated. Their location, like their growth, has been natural, and in many cases not thought out in advance. Manufactories which thus develop from small beginnings are, as a rule, more prosperous than those created in their entirety out of hand. Success is usually the outgrowth of slow and natural growth, and this because men who grow up with the affairs of a great business are more competent to handle it than those hired to meet an emergency.



French Locomotive and Tender, for Switching Purposes. Diameter of cylinders, 11.81 in.; stroke, 14.17 in.; diameter of driving wheels, 35.43 in.; weight of locomotive, 32,606 lbs.; capacity of water tank, 463 gals.; capacity of coal box, 1,236 lbs.

It is probable that the conveniences of the railroad shops of the world and the experience and talent of those who manage them are not materially different as regards efficiency from other manufactories. Local causes intervene, as in other cases, to heighten or lessen results, to spur men on or deaden their effort, but in the long run the fittest survive in every country, while their unfortunate brethren go to the wall.

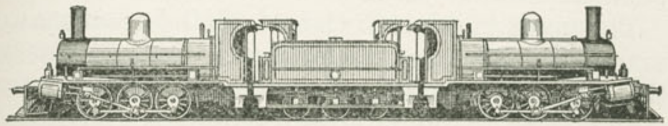
In order to construct cheaply, manufacturers must have continuous work and in sufficient



Russian Freight Locomotive. Designed for heavy work on steep grades, where conditions of bridges make it necessary to distribute the load on the drivers to the minimum. Diameter of cylinders, 12.99 and 18.11 in.; stroke, 21.65 in.; diameter of driving wheels, 43.31 in.; weight of locomotive, 92,075 lbs.; water capacity of tender, 2,360.9 gals.; wood capacity, 8,969 lbs.; weight of tender, 23,843 lbs.

quantity to keep the maximum amount of machinery and labor actively employed. If the work is irregular or insufficient to utilize needed appliances, there is waste which shows itself in the increased cost of the product. It is the same with the builders of cars and locomotives as it is with the operation of railroads. A company that has sufficient traffic to keep its property and force profitably occupied can do business at less cost and, consequently, with greater profit than a company not so fully engaged.

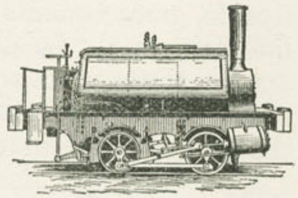
As a rule, manufacturers, it is probable, exercise about equal intelligence in the care of their machinery and property, in the selection and



Neilson's Twin Goods Engine, Scotland. The engine is designed to work equally well in either direction, where high power is necessary with low weight on the drivers. The use is, of course, special, and the distances to be run by it not great. Diameter of cylinders, 19 in.; stroke, 26 in.; diameter of driving wheels, 4 ft., 2 in.; weight of each locomotive, 87,000 lbs.; capacity of water tanks, 3,000 gals.; coke space, 384 cu. ft.; weight of tender, 43,800 lbs.

purchase of tools and material, in the handling of men and in the sale of goods, but there must be glaring exceptions to the rule. These latter represent the failures, their wastage constituting the difference between a loss and a profit on the thing manufactured.

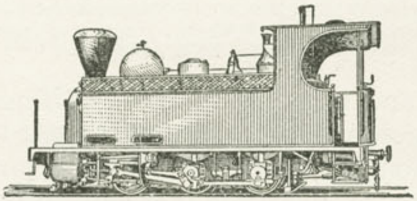
In reference to methods of business pursued by manufacturers, they are not, of course, uniform. They adapt themselves to the circumstances that surround each enterprise. Thus, in many, indeed, in the majority of instances, the work is carried on by day labor. In some cases, on the other hand, it is done by the piece. This last named method is the more desirable for both employer and



Scotch Tank Engine, for light switching purposes. Diameter of cylinders, 8 in.; stroke, 18 in.; diameter of driving wheels, 2 ft., 6 in.; fixed wheel base, 5 ft.; tank capacity, 220 gals.; fuel space, 11 cu. ft.; weight of locomotive, 17,580 lbs.

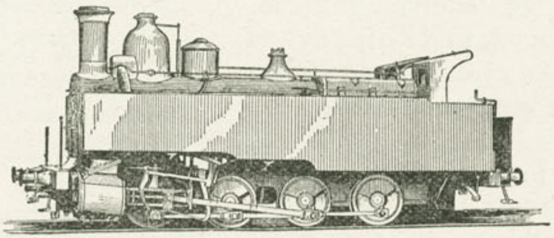
employe, when practicable, because it relieves the employer of undue anxiety, while it makes the laborer self-reliant by making him an independent manufacturer.

The great builders of the world, the great manufacturers of railway equipment included, possess the highest administrative talent which can be found—first, in the builders themselves, and afterward in those they employ. In regard to these latter, they have. as a rule, grown up with the work they look after, and thus understand its every need.



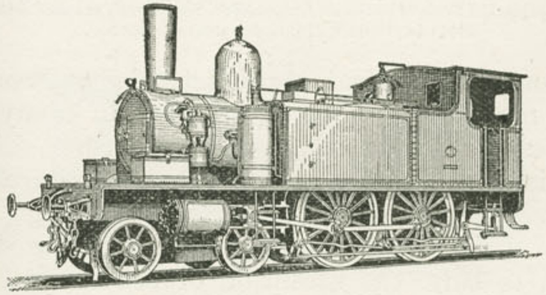
Belgian Locomotive and Tender Combined.

If it were practicable, great benefits to railways and individual interests would be derived by free consultation among those who build equipment. We have such organizations among those who maintain the rolling stock of railroads. The privilege of



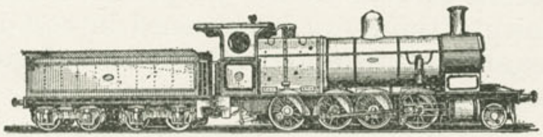
Belgian Locomotive-Tender, for pushing trains. Diameter of cylinders 18.9 inches; stroke, 21.65 inches; diameter of driving wheels, 51.34 inches; weight of locomotive, 89,287 pounds; capacity of water tank, 1,533 gallons; capacity of coal box, 3,531 pounds.

inspecting the great manufacturing shops of the world would, of itself, be a source of enlightenment and benefit. We may not hope, however, for this privilege. Men do not thus divulge the the secrets of their trade. To possess a method by which a thing can be lessened in cost is to possess an advantage over others not so favored. It is, consequently, jealously guarded.



French Locomotive-Tender (known in America as a tank locomotive).

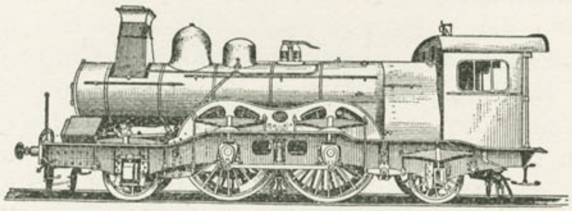
The great manufacturing plants of the world, as I have intimated, were started by practical men and developed under their immediate eye. With the lapse of time most of these men have died, or through the development of business have been compelled to divide their responsibilities with others. Thus a new element has been brought into the field. This new element is not only intensely practical, but, in the main, highly educated and scientific in its methods. In the sharp competition of trade personal experience no longer suffices. All the appliances which scientific knowledge, through its more comprehensive grasp of affairs, can add to practice must be brought into requisition. Where, therefore, formerly no scientific man was to be found in con-



Consolidation Freight or Goods Locomotive, New South Wales. Diameter of cylinders, 21 inches; stroke, 26 inches.

nection with a great manufacturing enterprise, such men are now common, and, in many instances, constitute the governing force.

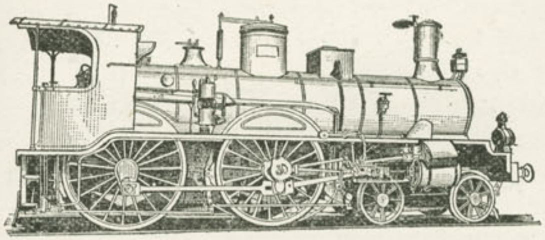
It is said that the Germans, whose education is less and less directed to classical things, and more and more to modern science, have done much to turn the attention of scholars to the



Express Locomotive of Chemins de fer de l'Etat Belge. It will be observed that the plate frame, so common to European engines, is shown here; also, a square smokestack, which is not used in America.

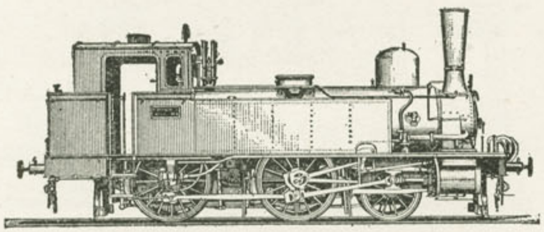
practical needs of manufacture and the wide field therein for scientific analysis and exposition. It is owing to this added force that the manufacturers of Germany have been able to

take the great forward step which they have. It is found in practice that the enlistment of scientific men in the great manufacturing plants of the world does not reduce the influence or value of other kinds of labor, either in management or minor details. One supports and supplements the other. The first named is, through its formulas, able to materialize what would otherwise be lost in idle speculations.



Italian Express Locomotive.

Education has thus become a part and parcel of trade and its devotees are now to be found among machinists and master mechanics, as well as in the professional walks of life. Its value will prove incalculable to trade, as its possessor is, by reason of his extended research, not only able to grasp the idea itself but the collateral ideas surrounding it. This is the advantage the educated man has over the uninformed; the trained mind over the untrained mind. The latter, because of lack of extended information, is only partially informed, and when an idea is grasped the thoughts this idea should suggest are not always awakened, but continue to lie dormant. It is in this respect that educated men have so great an advantage in practical business over those less favored, and it is this that is leading those identified with the manufacturing interests of the world to seek to add this new force to their business affairs. Nothing but good can come of it, for the further the educational process goes on without lessening man's interest in practical things, or his inclination to work, the better it

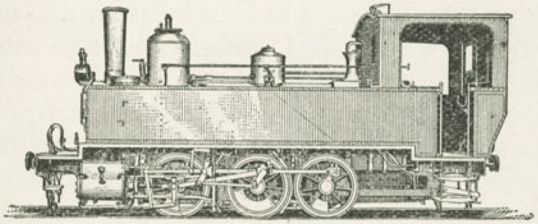


Locomotive and Tender Combined, Berlin-Hamburg Railroad. Diameter of cylinders, 16.53 inches; stroke, 24.02 inches; diameter of driving wheels, 62.68 inches; weight of locomotive, 70,765 pounds; water capacity, 1,188.78 gallons; coal capacity, 2,712 pounds.

will be for the industries of the world, and the greater the number of comforts that will be brought within the reach of mankind.

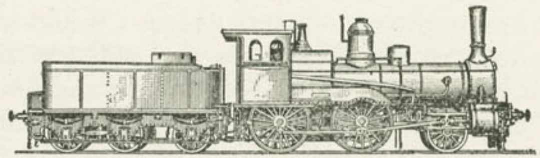
The manufactories of locomotives and cars in the great commercial countries of the world are the outgrowth of natural causes—represent, in fact, an evolution co-existent with the needs of railway transportation.

The first manufactories known to mankind in the early ages of the human race are believed to have corresponded to our blacksmith shops.



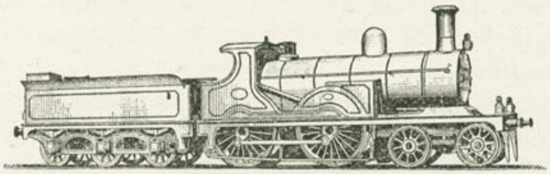
French Locomotive Tender (i. e., locomotive and tender combined). Diameter of cylinder, 10.62 in.; stroke, 18.11 in.; diameter of driving wheels, 35.82 in.; weight of locomotive, 34,184 lbs.; water capacity, 463 gals.; coal capacity. 1,766 lbs.

They were isolated and were carried on by individual men. There was little demand for their product. Their work related in the main to the manufacture of arms and rude appliances of carriage. The smith worked unaided at his primitive forge, but his occupation was surrounded by superstitions and the wonder and admiration of the people among whom he lived. His ability to reduce crude ores and model the melted metal afterward into necessary and ornamental objects, seemed to the rude denizens of that remote age as susceptible of accomplishment only through the aid of the gods. He was, therefore, if not



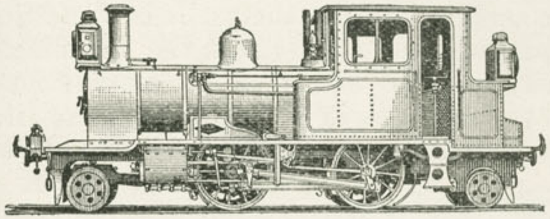
German Rapid Transit Passenger Locomotive, with Belpaire type of fire box, Warschau-Wien Railroad. Diameter of cylinders, 17 in.; stroke, 22 in.; diameter of driving wheels, 72 in.; weight of locomotive, 73,719 lbs.; water capacity of tender, 2,614.7 gals.; coal capacity, 8,828 lbs.; weight of tender, loaded, 59,500 lbs.

worshiped, at least looked upon as in communication with the Divine Being, and those sick or distressed eagerly sought his advice, as we do the physician or philosopher. He was the first carriage builder. It was he who constructed the primitive carts of ancient Mesopotamia, the very beginnings of vehicles. He first learned the value of ores and how to melt and mold them into weapons and articles of daily use. One of the earliest references we have to this primitive manufacturer is in the Odyssey, where the oracle describes the blacksmith shop with its bellows



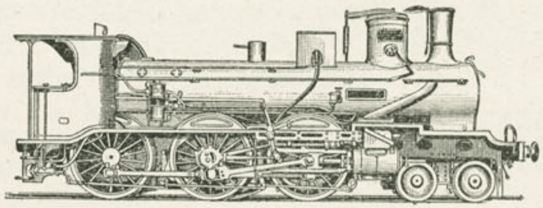
Coupled Passenger Bogie Engine, Scotland. Diameter of cylinders, 17½ in.; stroke, 26 in.; diameter of driving wheels, 6 ft., 6 in.; diameter of truck wheels, 3 ft., 6 in.; weight of locomotive, 88,000 lbs.; water capacity of tender, 2,550 gals.; weight of tender, loaded, 71,680 lbs.

and quickening fires, near which the body of Orestes will be found to lie. The Manufacturer, it will thus be seen, is at once the oldest and most honorable of industrial men. When letters were unknown and the arts and sciences things yet to be evolved, he was consulted and honored as a man whose calling was potential and had the favor of the gods. He still has that favor. In the evolution of time he has again become a principal factor in the world's affairs. Ours is the age of manufactories. In early times the



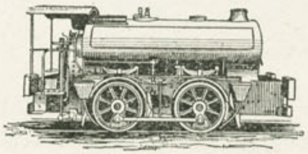
Madras Railway Engine.

builder worked alone and shaped, unaided, the complete article. Now sixty men are necessary to make a shoe. It takes an army of men to manufacture a car wheel, an air brake, the upholstery of a car, and, similarly, other appurtenances of this vehicle. One manufacturer gathers from other manufacturers the articles he needs and, putting them together with a skill peculiar to himself, makes a new thing which he offers for sale. Practices, however, differ with manufacturers in this respect, particularly those who construct railway equipment: one will himself manufacture many parts of the car or locomotive that another will buy in the open market. Thus one will make his own car wheels and axles



Breda, Milan, Ten-Wheeled Locomotive. The cylinders are placed behind the engine trucks, thus increasing the length of wheel base.

while another will buy them. It is a question of business interest merely. If the manufacturer can buy a needed article in the market for less than he can make it himself, he will buy it. If there is profit in its manufacture, he will manufacture it. No set rule, therefore, is laid down or observed. It is simply a question of ways and means—of money making. The situation is governed by many conditions, among them that of capital, labor facilities, questions of supplies and the capacity of the manufacturer. This last is all determining. Thus one man will achieve success and fortune while another will utterly fail. One man will be able to manufacture a great number of articles that enter into the makeup of the car or locomotive he builds, while another, because of his limited capacity for affairs, will find it advisable to buy everything he can in the open market. No set rule prevails.*



Quaint Locomotive without Smoke-stack, adapted to tunnel or mining purposes.

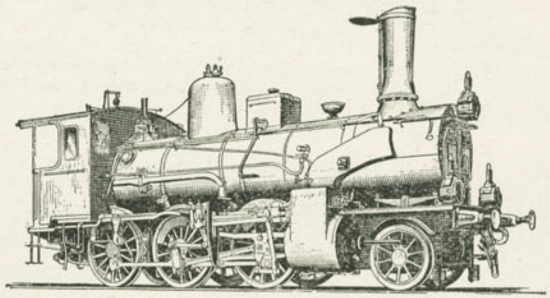
Our age is recognized as one of machinery. It also represents a more accurate division of labor than formerly. The claim is often made that

*In Appendix B to this volume will be found a list of the different parts of the locomotive. Those parts that the manufacturers of locomotives buy in the market from other manufacturers are indicated by an asterisk (*). Of course this rule does not prevail in every case, but, generally speaking, it does.

machinery is detrimental to labor. This cannot be so because the laboring man to-day enjoys many comforts denied him heretofore. He may

Scottish Double Header.

be more dissatisfied than formerly, but that is because he is more exacting, not that he has less. The use of machinery assures the laboring man both comfort and growth. Let him not be impatient. It is an old and true saying that "Everything comes to him who waits." It should also have been added that nothing ever comes to

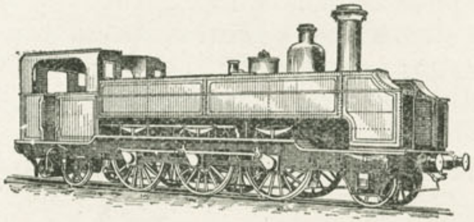


Austrian Locomotive. The square sand box is not found on American locomotives.

those who will not patiently wait. An eminent writer,* referring to the social question that surrounds the use of machinery in our day, says

*Dr. N. D. Hillis.

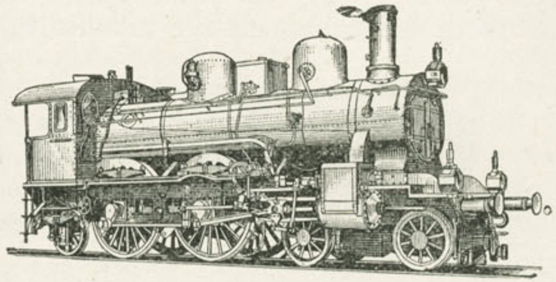
very appropriately: "Strangely enough, in this era when tools have emancipated men, it is asserted that they have created a new form of servitude. But analyzed, the statement is found to be far from the truth and calculated to disturb the happiness of the workman and embitter his life. Tools represent the uttermost of kindness and divine benefaction. It happens that very few men are possessed of genius and greatness. There are a few ten-talent men, a few five-talent



Belgian Passenger Locomotive and Tender. Diameter of cylinders, 17.72 in.; stroke, 23.62 in.; diameter of driving wheels, 69.93 in.; diameter of truck wheels, 41.73 in.; weight of locomotive, 97,003 lbs.; capacity of water tank, 2,572 gals.; capacity of coal box, 4,061 lbs.

men, more two-talent men, while most of all represent one talent. Now, in an age when civilization has become complex, and highly organized, the great multitudes representing one talent are in danger of falling out of the race. The strong and wise advanced so swiftly that the one-talent man could not keep up. Nor was he able to work with sufficient rapidity to hold his place. Now, in the interest of this one-talent man, inventors created tools. To make a modern shoe requires

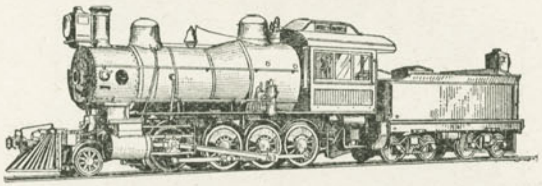
sixty different workmen. From these sixty different tasks the one-talent workman selects something he can do, and doing that one thing, he, too, becomes a creator, retains his self-respect by being a producer, and where without tools he would have been heart-broken, with his tools he stands upon his own feet and makes his own contribution to our civilization. Search all modern life through and there shall not be found



Austrian Locomotive. It will be observed that the Austrian engines have a damper attached to the smokestack, which is used to close the top of the stack when the engine is standing in the house, thereby preventing cold air from passing through the fire box and flues and injuring same.

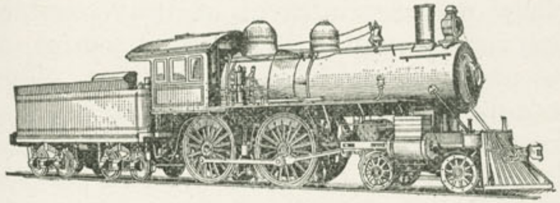
one single element that represents a form of ministry to the weak and the poor, that is so beneficent as the fact that machinery hath so divided toil as to enable the humblest man to become a self-supporting worker, and have his own place in civilized life. And when the tool has made a place for the one-talent man, it goes on to multiply the wages his father enjoyed, by means of which he purchases many things he wants that were before denied him."

The limited demand for locomotives and cars and the great cost of the plant required for their construction has tended to restrict the number of manufactories of this kind. It would be profitless to attempt to enumerate those in operation throughout the world, although the number is not large. The manufacturers of the different countries bear substantially the same relation to those of other countries that manufactures generally do. In other words, where capital seeks employment in the manufacture of



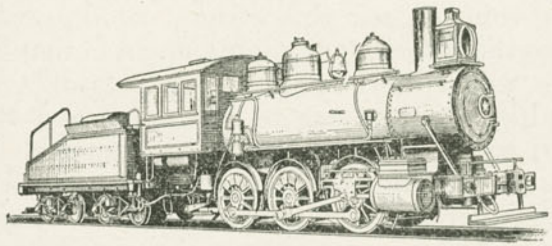
Brooks' Consolidation Freight Locomotive. Diameter of cylinders, 20 in.; stroke, 26 in.; diameter of driving wheels, 51 in.; driving wheel base, 22 ft., 8 in.; total wheel base, 50 ft., 3 in.; total weight of engine, 158,750 lbs.

miscellaneous goods, it finds a proportionate outlet in the construction of railway equipment. Local causes affect such enterprises and where there is little disposition upon the part of a people to manufacture goods, we find few or no manufacturers of locomotives and cars. In the past Great Britain has had substantially as many manufacturers of locomotives and cars as all the other countries of Europe combined. Her great capital and genius for business has easily enabled her to surpass her neighbors in this direction, but, while Great Britain has exceeded all other



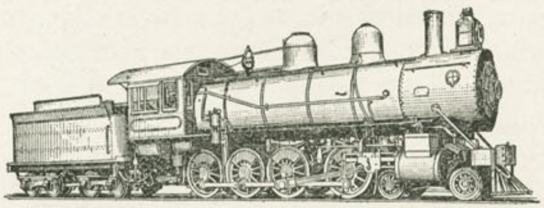
Schenectady (U. S. A.) Locomotive. Diameter of cylinders, 19 in.; stroke, 24 in.; diameter of driving wheels, 78 in.; weight on drivers, 77,000 lbs.; weight of locomotive in working order, 110 tons; driving wheel base, 8 ft., 6 in.; total wheel base, 23 ft., 11 in.; tank capacity, 4,500 gals.; weight of tender loaded, 98,000 lbs.

nations as manufacturers of steam locomotives and cars, Americans have been by far the greatest manufacturers of electrical apparatus relating to carriage. Their plant has from the first been extended and complete so far as science has been able to unravel its needs, while the skill of their designers and mechanics has been unequalled. This superiority has been so manifest, indeed, that those in need of electrical apparatus in every part of the world have sought, by preference, American manufacturers to fill their requisitions.



Schenectady (U. S. A.) Locomotive. Diameter of cylinders, 18 in.; stroke, 24 in.; diameter of driving wheels, 51 in.; driving wheel base, 11 ft.; weight of locomotive, 99,000 lbs.; water capacity of tender, 3,000 gals.; weight of tender, loaded, 61,300 lbs.

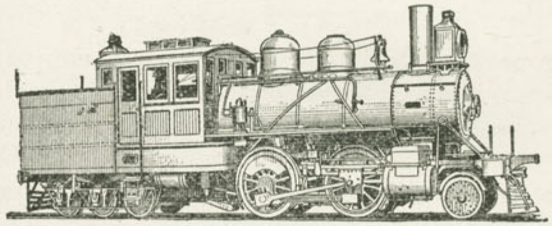
Every manufacturer of railway equipment strives for something that will recommend his wares above those of his competitors. Some of these devices are patented; others, again, are the outgrowth of combinations not always subject to exclusive use. The particular forms or devices which different manufacturers make use of, add greatly, of course, to the interest and picturesqueness of the subject. A collection of pictures portraying every kind of locomotive (i. e., loco-



Schenectady (U. S. A.) Locomotive. Diameter of cylinders, 22 in.; stroke. 26 in.; diameter of driving wheels, 55 in.; driving wheel base, 15 ft., 6 in.; total wheel base, 25 ft., 4 in.; weight on drivers, 147,000 lbs.; total weight of locomotive, 175,000 lbs.; water capacity of tender, 4,000 gals.; weight of tender, loaded, 92,900 lbs.

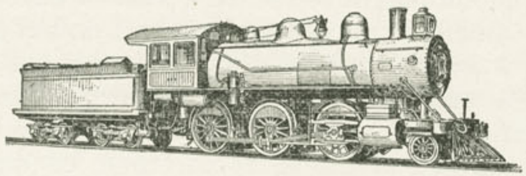
motives varying in some particular,) would fill a dozen volumes, and this without adding materially to the interest or enlightenment of mankind. If we would know what the natives of Arabia look like, we take one or two types and study them; and so it is in regard to locomotives. One or two forms are generally sufficient to illustrate the peculiar ideas or idiosyncrasies of a manufacturer. This is not always the case, however, and for that reason, in portrayals of this kind, it is difficult to know where to draw the line. I set

out to illustrate every form of locomotive and car, but quickly gave up the task as impossible and unprofitable. Types, I am assured, are all the student desires to see, but, while I have been led to modify my original purpose, I do not abandon it wholly; I restrict my portrayal to the locomotives and cars that manufacturers select as affording peculiar interest and instruction, or, if not of great practical value, then of curious interest, such as might be gratified by travel abroad.



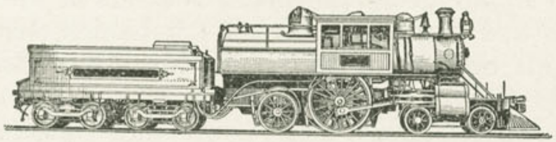
Rogers' Locomotive, U. S. A.

In enumerating the manufacturers of locomotives and cars, the railroad companies engaged in this business must not be forgotten. In the early days of railway enterprise, in the United States particularly, many companies constructed plants for the building and repairing of equipment. This on the supposition that they would build their own rolling stock. For a considerable period they did this, but, in the majority of cases, the practice was soon partially or wholly discontinued. It was found that locomotives and cars could, as a rule, be bought of private builders at less than railroad companies could construct them for. In going outside their legitimate business of manufacturers of transportation it was



Schenectady Locomotive. Diameter of cylinders, 20 inches; stroke, 28 inches; diameter of driving wheels, 63 inches; driving wheel base, 15 feet, 2 inches; total wheel base, 23 feet, 3 inches; weight on drivers, 124,400 pounds; total weight of locomotive, 144,200 pounds; tank capacity, 4,500 gallons; weight of tender (loaded), 98,400 pounds.

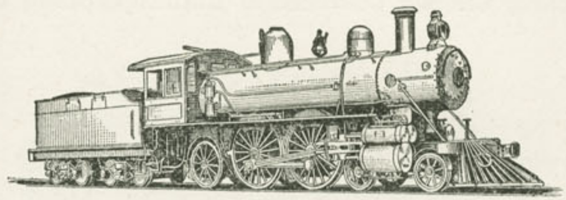
the genera. experience that railroad companies made a mistake. Their limited demand for locomotives and cars, and their method of organization, was not such as so generally enable them to carry on the business of manufacturers of goods efficiently or economically. I do not say that this was, or is, the experience of every com-



Baldwin Single Driver Passenger Locomotive, capable of great speed. Diameter of cylinders, high pressure, 13 inches, low pressure, 22 inches; stroke, 26 inches; diameter of driving wheels, 84¼ inches; total wheel base, 22 feet, 9 inches; weight on drivers, 48,000 pounds; total weight of locomotive, 115,000 pounds.

pany; I refer to the majority only. To be successful as a manufacturer, it is necessary that the manager or the person in charge shall possess the

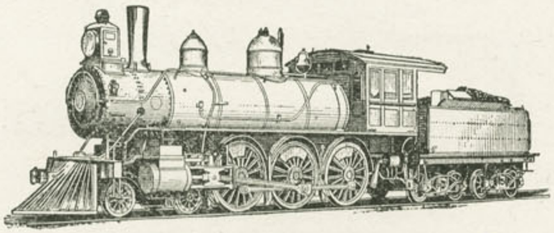
interest and the authority of a proprietor. Above all, he shall have absolute discretion in regard to the purchase of material, employment of labor, erection of shops, selection of machinery, and other particulars. How can he compete with private manufacturers otherwise? The responsibility is vast and indivisible Such an organization is not in unison with the genius of railway administration, however. In practice, when a railroad company manufactures locomotives and



Baldwin Locomotive ("Atlantic Type"). The trailing wheel behind the drivers reduces the weight on the latter. Diameter of cylinders, high pressure, 13 inches, low pressure, 22 inches; stroke, 26 inches; diameter of driving wheels, 84 inches, diameter of truck wheels, 36 inches; total wheel base, 25 feet, 6 inches; weight on drivers, 77,600 pounds; total weight of locomotive, 114,290 pounds; water capacity of tender, 4,500 gallons; fuel capacity of tender, 7 tons; weight of tender (loaded), 88,000 pounds.

cars, the work is entrusted to a subordinate, who has many superiors and coadjutors, who, each in turn, have much to say about the way business shall be carried on. The result is the energy and interest of the superintendent in charge is dulled and responsibility partially or wholly lost. It takes too long to act, and too many men have a voice who have no real responsibility. This the great majority of the railroad companies quickly discovered, and, having discovered it, made haste to abandon the field to private enterprise, using their plants thenceforth merely to repair and maintain their equipment.

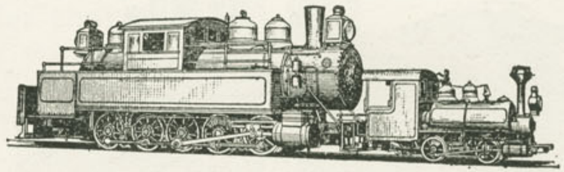
In referring, as I do, to a railway company's lack of success as a manufacturer, I do not wish my assertions to be too sweeping. There are many things railways are able to manufacture at their shops successfully. Moreover, the exceptional ability of particular men connected with such organizations is often such that they are able to carry on the business of manufacturing loco-



Richmond Locomotive, U. S. A.

motives and cars successfully in spite of all the obstacles in their way, but such men are exceptional, and systems can not safely be founded upon them. With their loss, the company employing them lapses into the condition of the unfortunate majority. If a railroad company would enter the field as a manufacturer of equipment it should adopt methods of organization, governing its shops in conformity therewith. Let it separate such plant from its plant for manufacturing transportation.

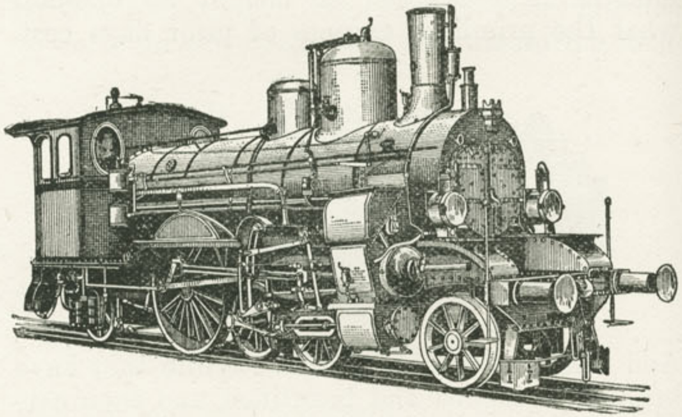
From the foregoing it will be seen that in enumerating the successful manufacturers of equipment throughout the world railroad companies must, generally speaking, be eliminated. We can not look to them either for superior excellence of work or great economy of execution. It is to private manufacturers, compelled to compete with each other in the open market, we owe the fact that the magnificent locomotives of to-day can be bought for one-half what the primitive engines of prior days cost.



Baldwin Locomotives—the big and the little—the St. Bernard and the Scottish Terrier.

And this is also true of cars. While they have been strengthened and beautified, and their carrying capacity greatly increased, the price per car has been much reduced. These gratifying results are due to the competitive struggle of private builders. Their efforts in this direction have, moreover, had a good effect on such railroad companies as manufacture their own rolling stock, by reducing its cost and adding to its beauty and utility.

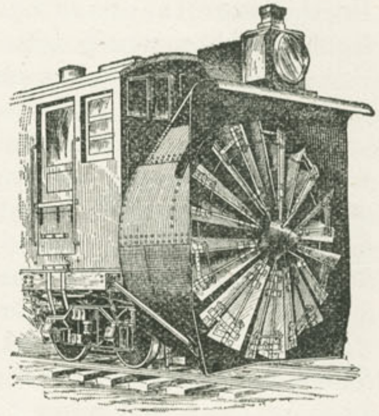
In reference to the particular merits of manufacturers of locomotives and cars, it is probable that the same degree of excellence, or lack of it, exists in this field of industry that exists in other things which the community needs and which men seek to make money out of by supplying. Certainly the intense rivalry which exists among manufacturers is highly beneficial to the railroad companies; it sharpens the wits of the manufacturer and makes the buyer more exacting. Its effect is to lessen cost while adding to the utility



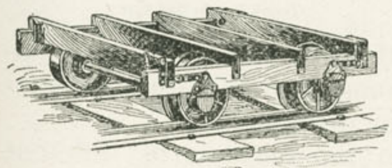
Compound Locomotive-Auxiliary Cylinders.

This is said to be the first engine of its kind constructed. It was built by Krauss & Co., Munich, for the Bavarian State railroads. Its builders aimed at combining the chief advantages of uncoupled wheels with the greater traction force which four-coupled engines afford in starting and in mounting gradients, while further they desired to secure a more perfect adaptability of the engine to the various requirements concerning speed and power that arise during ordinary working conditions. Very large cylinders, the account further states, while quite desirable in cases of great power being required at low speed give unfavorable results at high speed. The above design, it is claimed, enables its builders to adapt the dimensions of the cylinders to the conditions obtaining at high speed, while for low speed they bring into use an auxiliary engine, thus doubling their tractive power when needed, and exerting a great pull with early cut-off. The engine is claimed to perform satisfactory service.

of the product. The manufacturer also strives to beautify his goods in order that they may be more attractive to the buyer and the customers of the latter, and he selects those having natural tastes in such matters, to plan and adorn his goods in order that he may the more successfully accomplish this. In America the public owe the superb decorations of passenger cars and most of the superior conveniences of travel to the Pullman and Wagner companies. They are specialists and keep in their employ men who make a study of car construction and decoration, and so, little by little, have advanced in their calling, until the work they produce appears perfect in beauty and adaptability. Indeed, they have made travel so comfortable that a large part of the community enjoys greater luxuries when occupying their cars than when at home.

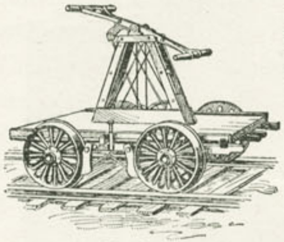


Steam Snow Plow. The boiler operating the snow plow is in the car attached. The rotary motion of the wheel precipitates the snow through the opening above.



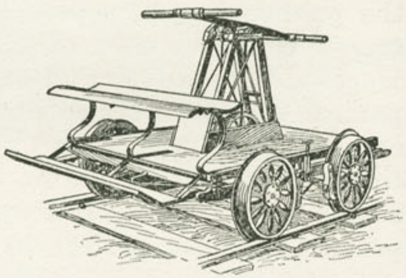
Light Push Car.

Furthermore, they have made travel so much a delight that those who possess in any degree the roving instinct, wish to travel all the time. No such state of affairs existed in the days of stages and the eras prior thereto. Modern travel has added a new wonder to the world's list. Its luxuries embrace everything the most fastidious can ask.



Hand Car.

These luxuries are, without doubt, destined to become, more and more, common; the drawing-room and palace car, with its compartments and state-rooms, the luxuriant service of the dining-car, the buffet smoker, and other conveniences and comforts of travel, are destined to soon come within the reach of a majority of mankind instead of a limited few, as at present. This is what the improved appliances of the future, brought about by the sharp wits of competitive endeavor among manufacturers and carriers, have in store for mankind.



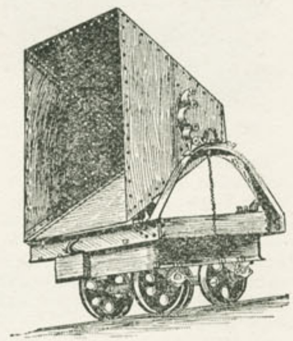
Track Inspection Car.

The differences in the customs of different countries in regard to humdrum things are observable in their contributions to the development

of railway carriage. The faces of men do not differ more than do the details of railway carriage, albeit the differences are not radical. The wealth, culture and surroundings of nations influence their constructive ideas in this field as they do in that of buildings and other concomitants of life. The illustrations embodied herein show this. Utility is, however, the predominant idea with all. Ideality does not enter into the subject or only in a minor sense.

Velocipede Hand Car.

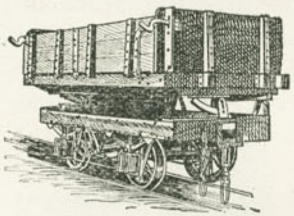
How best to meet the requirements of the service is the all-absorbing thought with every builder. The problem he sets himself to solve is to construct a machine that will do a given amount of work at the least cost for the machine itself; that will be economical above all others, according to the work it performs, as regards fuel and other incidentals which enter into its operations; that shall be durable and trustworthy; that can be easily operated; that will only require the minimum of repairs; that



Swinging or Dumping Car. Capacity, 15 bushels; weight, 7 cwt. It is light enough to be handled by two persons and short enough so it will turn on a small table or short radius. It is used in coal and ore mines to haul ore to the surface and permit dumping at end of car.

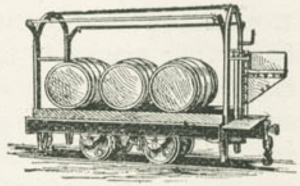
will not prove destructive to the track, and, finally, that will be popular with those who have to handle it, on the footboard, in the roundhouse and at headquarters.

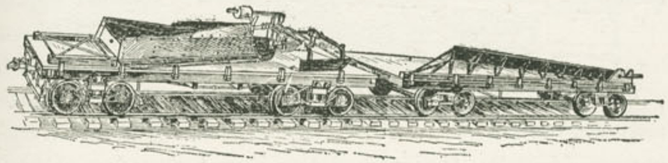
In looking over the accompanying illustrations, the reader cannot but be impressed with the beauty of the locomotive considered purely as a work of art. Who, moreover, has ever stood beside a modern locomotive without emotion; without admiration for its beautiful lines; its mammoth proportions, and magnificent possibilities? What, for instance, can be more beautiful than the locomotive of the Chemins de fer De L'Etat Belge portrayed elsewhere herein? It is a poem in iron, wherein artistic lines and proportions are faithfully observed throughout. Americans will especially note this engine because of its, to them, novel features. The Belgian, on the other hand, will be similarly impressed, it is probable, with the American locomotive, because of its, to them, peculiar features.


French Dumping Car for earthworks and mines. Length, 10 ft., 6 in.; height of sides, 2 ft., 1 in.; weight, 7,950 pounds; load, 17,700 pounds. It is so arranged as to dump its load to the side without shoveling. The side door is hinged at the bottom edge and held upright by hooks.

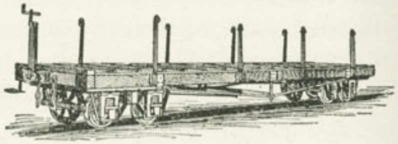
The characteristics of a people may in a measure be traced in their locomotives. Is not the strong personality of the Englishman and the Scotchman noticeable in the machines they build?

The lines are simple yet graceful, and strength and efficacy are apparent in every detail of their work. Who could doubt the nationality of the builder of the Neilson machine? Nothing could be more symbolical of power than this magnificent piece of mechanism. The beautiful Breda engine of Milan, like the French machines, represents very truthfully the artistic culture and dilettante taste of an extremely refined and highly bred people. On the other hand, locomotives constructed in different countries look so much alike sometimes that one is inclined to think at first glance they were built by the same man. The similarity is the genius of one builder reflected in another.

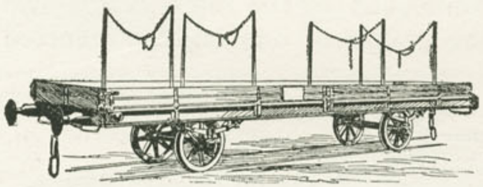

Belgian car for transportation of casks. Length, 7 ft., 7 in.; weight, 1,230 lbs.; load, 2 tons.


Devices, operated from the locomotive, for unloading ballast. One of the above devices is used when it is desired to unload material uniformly on either side of the car. The other is used where it is desired to unload wholly on one side.

No engine in the world is superior to the American machine in its combination of desirable qualities, such as economy of operation, power, speed, simplicity and effectiveness of working, durability and reasonableness of first cost. The necessities of railway operations in America, as I have had occasion to notice elsewhere, have been such as to compel manufacturers to build locomotives and cars that would stand rough and crooked roads, and in the case of engines, that would haul great loads at a high rate of speed, and, finally, that would come within the means of companies with very little money or credit. This much may be said without disparaging the locomotives of other countries. American manufacturers have no reason to fear comparison in any respect with the builders of Great Britain, Belgium, Germany, France, Italy, and the great centers of the world for the construction of railway rolling stock.



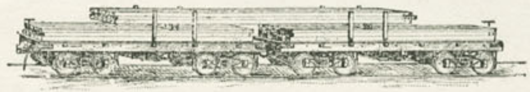
Brazilian Flat Car. Length 13 ft., 6 in.; weight, 5½ tons; load, 6 tons.



Wurtemberg Car with movable sides and extremities. Length, 32 ft., 10 in.; height of sides, 11 in.; weight, 7 tons; load, 12 tons.

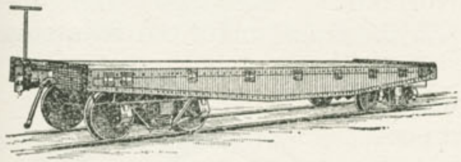
In connection with the accompanying pictures of locomotives and cars, such statistics are given as space permits or I have been able to procure. The dimensions given of locomotives indicate, in a general way, the capacity of the machine.

They are such as to enable the reader to form an approximate estimate of the capability of the locomotive. I have not attempted to describe each locomotive in detail, because nothing that could be said would add materially to the information the pictures themselves, with the accompanying description, affords.



Standard American Flat Cars Length, 34 ft. each; capacity, 60,000 lbs. The above cars are loaded with timber. In some instances three cars are necessary to support a load. The method of loading flat cars in America is prescribed by the Master Car Builders' Association.

A locomotive is a living thing, resembling in its defects the man who builds it. These defects, like those in man, can only be determined after trial. Admirers may portray to us the merits of some one they like, but whom we have not seen, but it is only when we look the person in the face that we become really interested; and preparatory commendation we observe goes for naught if his appearance does not please us. On the other hand, if we like his looks, we still defer coming to a decision until we see how he will act. This is as true of a locomotive as it is of a man—with



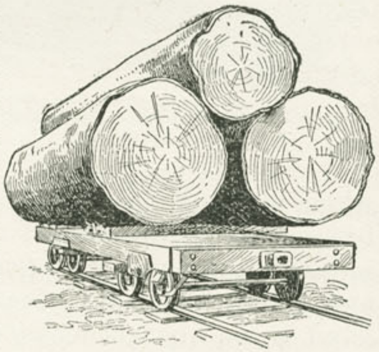
American Steel Flat Car. Weight, 25,900 lbs.; capacity, 40 tons.

the odds in favor of the locomotive. The poorest of these machines always does the best it can. This, alas! is not true of men in every case. Railway men cannot lead themselves to look upon the locomotive as a mere mechanical machine.

View of the under side of American Steel Flat Car. The under framing of other steel cars of the manufacturer is the same as the above.

Those in other walks of life in a measure participate with them in this.

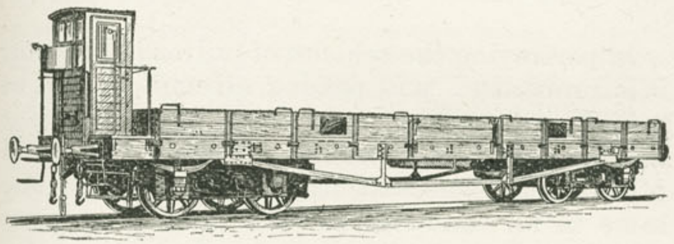
Who, that has ever seen a locomotive under headway, or as it stopped from its flight, has not felt that it was a living thing that gloried in its magnificent performance? It seems at such a time to stand upon the track under our admiring eyes with the glad consciousness which a gladiator might possess when his skill and strength were admired and commented upon. Nothing in the world is more inspiring than the flight of a railway train. Stand near to it and get its full inspiration, more than half made up of terror, as



American Logging Truck.

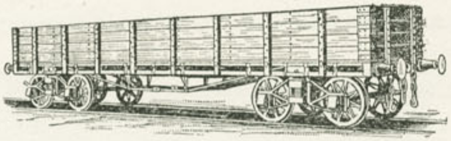
it rushes onward. Repetition will not dull the impression nor lessen the admiration. The coldest man at such a time has difficulty in restraining his enthusiasm.

Elsewhere I have explained the locomotive in detail and have commented on the shop arrangements of railroads. I have designed this chapter to be a panoramic view, so to speak, of the equipment of railroads, or such varieties thereof as will enable the reader to form an idea of its extent and versatility. Men build locomotives



Austrian Car.

and cars for particular purposes, much as they breed horses. One locomotive will be built to haul a maximum load at a minimum rate of speed; another to draw a similar load at the highest rate of speed; another to draw a light load at a high rate of speed; another to carry bundles, so to speak, that is, to do the switching (shunting) about passenger yards; another to do similar work about freight yards where heavy loads have to be moved quickly. There is equal or greater adaptability in the construction of cars. Every great manufacturer is prepared to answer every demand that may be made upon him. He asks what is required and in return makes his suggestions.

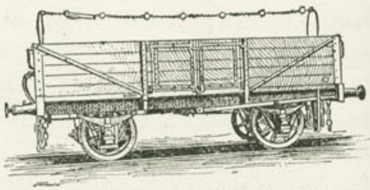


Half Box Car with Tubular Frame, Belgium, Length, 33 ft., 5 in.; height of sides, 35 in.; weight. 10⅜ tons; load, 29½ tons.

His adaptability is great in every emergency, and his expedients as exhaustless as those of an inn-keeper.

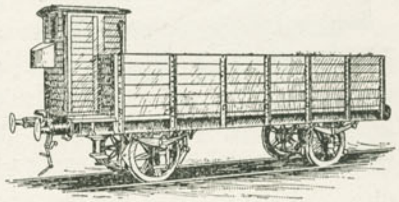
In portraying the vehicles of railroads I do not, it is proper to say in passing, attempt, except in a very limited way, to portray those used for handling freight, baggage, express, mail and other traffic about stations. These are much the same in all countries and do not in any sense belong exclusively to railway carriage, as similar vehicles are used wherever parcels are handled.

The evolution of vehicles has for the moment reached its highest development in the cars of railroads, and among these I class both passenger and freight. They are at once more capacious, more luxurious and in every way better adapted to rapid and safe carriage than anything before conceived by man. They



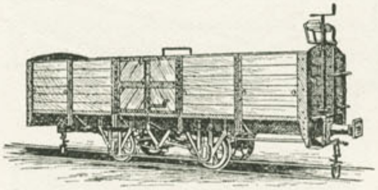
Victorian Railway Gondola Car. Length, 21 ft., 4⅛ in.; load, 22,400 lbs.

are also more costly: a vehicle freighted with lives or valuable property which it is designed to haul across the country at the rate of sixty miles an hour must, it is apparent, be very carefully constructed and of the best material. In view of this necessity, it would seem that in this age of iron and steel that one or both of these materials would be used exclusively in building cars. Yet such is not the case, except in a limited way. Inventors have devised and patented iron and steel cars and manufacturers have erected plants to build them, but the demand for their product is qualified to such an extent as to throw doubt, if not distrust, for the moment, on their ventures. This hitch is, however, thought to be temporary only. It is a common belief that in the end railway cars will be built of iron or steel. "Up to the present time there has not been any iron cars constructed that have met with very much success. I have made a personal examination of these cars and there certainly is much in their construction that is meritorious. They are as a rule constructed in special shapes,

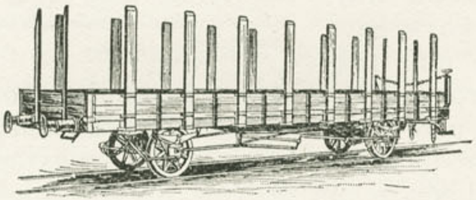


Varsovie-Vienna Railroad Car. Length, 19 ft., 8 in.; height of sides, 3 ft., 6 in.; weight, 7 tons; load, 12½ tons. The reader will not have failed to notice the care taken to protect the brakemen and attendants by awnings over the brakes, or shelter, as in the above instance. The caboose car which accompanies every freight train in the United States, illustrated elsewhere, is not generally used abroad.

however, and protected by letters patent, as is also the machinery for forming these shapes. This fact works very strongly against the universal use of the car. Among their features they have constructed the bottom framing of a flat car of standard shapes consisting of channel irons, iron beams, etc. I was very favorably impressed with this. There are a number of iron cars now being perfected which are being watched with a great deal of interest. I do not think that the time will come in the very near



Belgian Railroad Half Box Car. Length, 17 ft., 5 in.; height of sides, 5 ft., 3 in.; weight, 3½ tons; load, 10 tons.

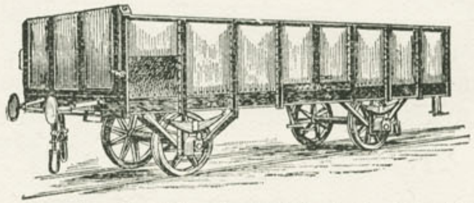


Wurtemberg Railroad Car. Length, 33 ft., 8 in.; height of sides, 16 in.; weight, 9½ tons; load, 15 tons.

future when an all iron car will be used, but I think the coming car will be constructed of iron in combination with wood. Wood will be used for floors, side, end, and roof framing; iron will be used for the sills and underneath framing of the car."*

* C. A. Schroyer.

In the art of carriage and in the uses of common carriers, the cars of railways especially engage our attention. It is from their contents that transportation companies derive their revenue. The various patterns that have been devised to meet particular needs, while not so great in number or varied in construction as those we see on our highways, are yet very numerous. Should their use continue as long as road carriages have existed, they may equal, if not exceed, the latter in variety and picturesqueness.



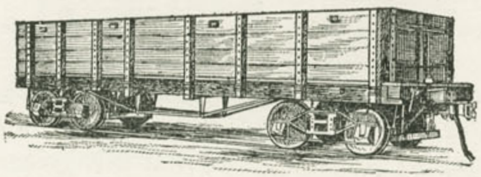
Iron Car. Length, 22 ft., 4 in.; height of sides, 3 ft., 11 in.; weight, 8 tons; load, 15 tons.

All kinds of vehicles are of comparatively modern invention. Man existed for many ages, indeed, for incalculable cycles of time, in a savage and semi-savage state before there was need of a vehicle or its use became possible. One of the first references we have to it is in connection with the Aryans, before their final separation, as I have noticed elsewhere in connection with the evolution of transportation.* These interesting people made a double use of their vehicles, namely, for carriage and a house in which to live. They

* See volume "Origin and Evolution of Transportation."

were, it is probable, great carts, such as still may be found among the Scythians of Asia. Once the need of a wagon was felt, its evolution kept pace with man's progress, but it was not until men had advanced far on their road that they could have had uses for such a thing. It presupposes comparatively high development to conceive of the manufacture of a vehicle, notwithstanding its simplicity. The North American savage, while he has for four hundred years been familiar with the wagon of the white man, has as yet never attempted its construction.

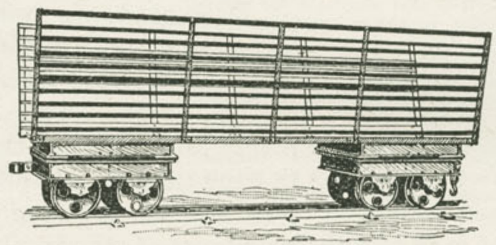
Italian Half Box Car. Length, 14 ft., 9 in.; height of sides, 36 in.; weight, 3 tons; load, 8 tons. This car, while supplied with a ridge pole, has no roof. It thus becomes what is known in the United States as a gondola car, and in other countries as a half box car.



Standard American Gondola Car. Weight, 31,000 lbs.: load, 30 tons. It is used for transporting such freight as coal, sand, gravel, crushed rock and lumber. It is constructed in all respects the same as a flat car. The sides in many cases can be readily removed, thus enabling the car to be used as a flat car or gondola, as the exigencies of business require.

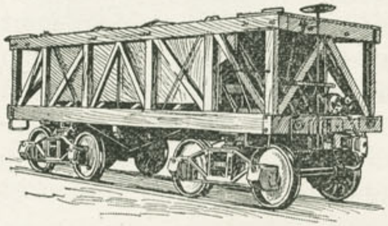
If these savages cannot in so long a period of time adopt an idea that is constantly before their eyes, how incalculable must have been the period required for primitive man to have conceived the idea of carriage and to have put it

into practical shape. Cultivated men and women learn quickly but the savage learns not at all, or so imperceptibly as to escape notice for long periods of time. A savage will look upon a picture of a house turned bottom side up without being conscious that there is anything wrong about it, although he himself for the moment may be surrounded by actual houses. His intelligence is so slight as not to be able to grasp an idea even when presented to him in this most

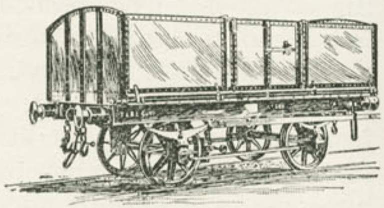


Car for the Carriage of Sugar Cane. Length, 13 ft., 1 in.; height of sides, 3 ft., 4 in.; weight, 1,570 lbs.; load, 4,480 lbs.

primitive of forms. Such vacuity can hardly be conceived of but it is the natural condition of the savage mind, or absence of mind. Man originally had no greater ability to think consecutively than the dog has, but he had greater capacity for development. Hence his emergence from savagery, and his busying himself in perfecting machinery whereby he might transport himself and his family and his rude effects from place to place across the vast plains of the then primitive world. This was the beginning of vehicles. Afterward, with slight alterations, he re-adapted them for purposes of war and the chase. His device was very simple, a wooden axle, at either end of which a rude wheel revolved. A platform resting on the axle afforded the occupant of the vehicle a footing. It was afterward enlarged so as to hold two persons, besides the driver. It had no seat. The introduction of this last device indicated the growing effeminacy of men and their downward step in physical strength. However, at first a luxury, the seat had no sooner been evolved than it became a necessity. It was but a step from the cart to the wagon, from two wheels to four. With the wagon, good roads became more than ever a necessity. Such a vehicle was less able to overcome obstacles than the cart. Its friction was greater. Moreover, with advancing civ-

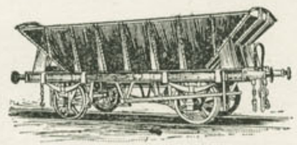


Ore Car. It is also adaptable for many other purposes, as will be apparent. It is unloaded into bins underneath the track or divergent therefrom by traps in bottom of car. Length, 22 ft.; height of body, 4 ft., 10 in.; weight, 24,000 lbs.; capacity, 60,000 lbs. This car is a favorite means of transporting ores to the various ports throughout the country to be loaded on to vessels. The car is run on the dock from whence the vessels are laden, either directly from the car or bins attached to the dock.



Baume-Marpent's Iron Car. Length, 14 ft., 9 in.; height of sides, 2 ft., 11 in.; weight, 6½ tons; load, 10 tons.

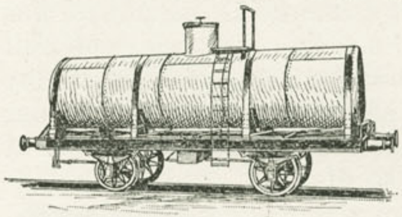
ilization, people desired to hasten their movements. To do this they were compelled to build better roads and to improve the running gear of their wagons. The Romans practiced the art of road building to a greater extent than their neighbors or predecessors. They not only perfected great military and commercial highways, but made considerable use of a species of rail upon which the wheel traveled and which, by natural evolution, has become the rail of our railroads. It was not then in the shape it is at present, nor indeed so effectively upheld, but the idea of a rail resting upon supports and that should form a bed for the wheel (with the minimum of friction) was, so far as I am aware, first developed during the Roman period. The idea, it is probable, did not originate with them. They stole it, we may confidently believe, as they did everything else they possessed, save the art of war, from their more versatile neighbors. The thought originated not with a Roman, we may believe, but with some cunning Semite or Greek. But wherever it originated, it was a step in the direction of the railroad of to-day. For many hundreds of years it was impossible to make use of the device except in a limited way in connection with the hauling of coal and ores for short distances. With the advent of the



Coal Car, Victorian Railway. Length, 21 ft.; weight, 10,975 lbs.; load, 10 tons.

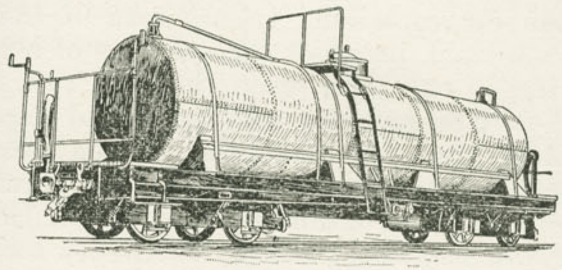
locomotive, it was found, after making many changes and improvements, to be what our great modern thoroughfare needed to support the tremendous loads it was called upon to carry.

We are still in the transition period of railway construction. But great progress has been made. The vehicles which in America at first carried only a dozen passengers, or were limited to a few tons of freight, now carry sixty passengers and forty tons of freight, respectively. Not only this, but they are hauled across the country at a rate of speed believed to be impossible at first; and this, without perceptible risk or deterioration. To this height has the art of constructing vehicles and roadways been carried. At one time sixteen by twenty-four inch cylinder engines handled a large portion of the traffic in the United States, while on heavy grades forty-five ton ten-wheel engines and fifty-ton consolidation engines were employed. Twenty thousand pounds was the maximum freight-car load. Cars having a capacity of eighty thousand pounds have since been put into effective use, while the modern



French Reservoir Car for Liquids. (The tank car used in the United States is generally similar to this.) Length of tank, 22 ft., 4 in.; diameter, 5 ft., 4 in.; weight of car, 8½ tons; load, 10 tons. This peculiar form of car was suggested, in the first instance, by the needs of the petroleum traffic. A vehicle was needed that could be easily loaded and unloaded, that was strong, and the contents of which could not be easily ignited by flying sparks or other cause.

refrigerator car, loaded and iced, carries about one hundred thousand pounds. A corresponding advance has been made in passenger equipment, track and bridges. The early sleeping-car, weighing sixty thousand pounds, was, in the opinion of many railway men, entirely too heavy. Day coaches weighing eighty thousand pounds, and sleepers weighing one hundred thousand pounds, have since been in common use. The light rail has been succeeded by one weighing

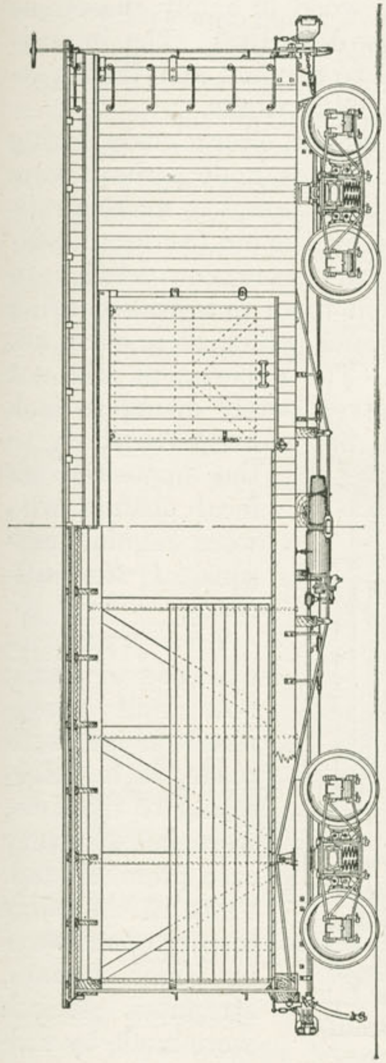


Austrian Car for Liquids.

ninety, and, in some instances, one hundred pounds. Engines weighing from sixty to one hundred tons have taken the place of the forty-five ton engines.

An interesting question, and one continually recurring in railroad practice, is whether locomotives are made to earn the maximum amount of which they are capable. Experiments with tonnage rating on grades show a general increase in the average number of cars per train. From the service rendered by locomotives the carrier derives his revenue. One important way, therefore, of increasing revenue, is to compel the locomotives to do more work. This is all the more important in view of the fact that reduction of rates caused by sharp competition has decreased the earning capacity of American railroads until the carrier receives less for hauling a car containing eighty thousand pounds of freight than was formerly obtained from a car containing twenty thousand pounds. In this connection a writer estimates that "an increase of one car containing twenty tons of freight, in each train, increases the earnings of a locomotive, in one year, seven thousand two hundred dollars, and the only additional expense is ninety tons of coal. Taking the average mileage of the locomotive at three thousand miles per month, or thirty-six thousand miles per year, we have the revenue of twenty tons of freight hauled the same mileage at one cent per ton per mile, or twenty cents per mile per car. There will have been no increase in the wages of the engineer, fireman, or trainman, or for repairs. The only extra expense has been five pounds of coal per car mile."

The evolution of cars, which from the first has been constant, has not been uniform. There have at times been what we may call epochs. Thus, within a short period, the railroads of America changed their light freight cars for those of stronger build, rapidly advancing the load from ten tons to forty tons. The substitution

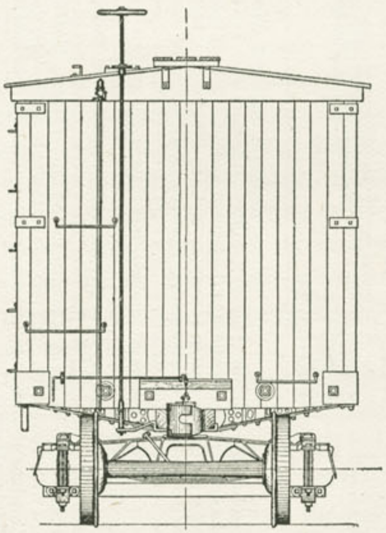


American Standard Box Freight Car.

Sectional View, showing inside lining and side elevation. For explanation of this car see accompanying drawings, and also the description elsewhere in the printed matter. This car is the most useful of all the forms employed in the United States for the transportation of freight. Many special forms of box cars are patterned after it, such alterations being made as the circumstances of the case require; among these may be mentioned the refrigerator car, furniture car, ice car, fruit car, beer car, boarding car, and so on. Cars of this character are also used for carrying grain, potatoes, and many other kinds of vegetables in bulk. Indeed, very little of the grain raised in the United States and Canada is handled in sacks, except on the Pacific slope. Cars loaded in bulk hold a greater quantity than they would otherwise. In the case of grain they are loaded by gravity from elevated bins in storehouses, and unloaded at their destination directly into warehouses or vessels by pipes brought into the cars. Thus much expense for labor that occurs under other circumstances is saved. This car is generally used for merchandise in the United States. The English use a flat car for this purpose, the goods being covered with a tarpaulin. The reader's attention is particularly directed to this car and the drawings which accompany it. The drawings not only show the construction of the car, but how it is strengthened so as to stand the trying vicissitudes to which it is subjected.

of iron and steel for wood in many directions also represented a new departure. The importance of these changes to carriers and their patrons cannot be portrayed in words.

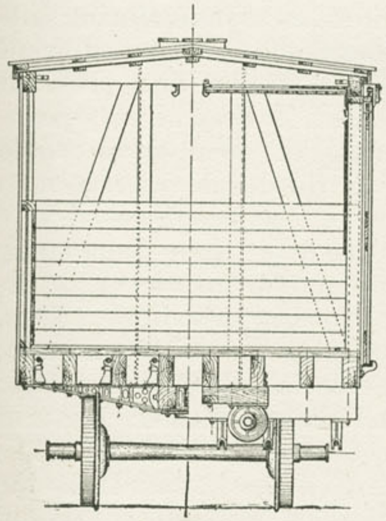
Of the many experimental efforts made during the early history of railroads, none perhaps were more ingenious than the attempt to make a railway car the substitute for the old fashioned pedlar's wagon. Thus, cars were converted into stores and moved from town to town according to pre-arranged programs which were duly advertised in advance. The experiment did not prove successful, however, partly owing to lack of facilities and cost, but more particularly to the opposition of local dealers who were regular patrons of the railroads.



End Elevation of American Standard Box Freight Car.

The various classes of traffic now well recognized on our railroads, it is interesting to notice, were not in every case premeditated. Thus, in the early history of railways in Great Britain, strenuous efforts were made by rail-

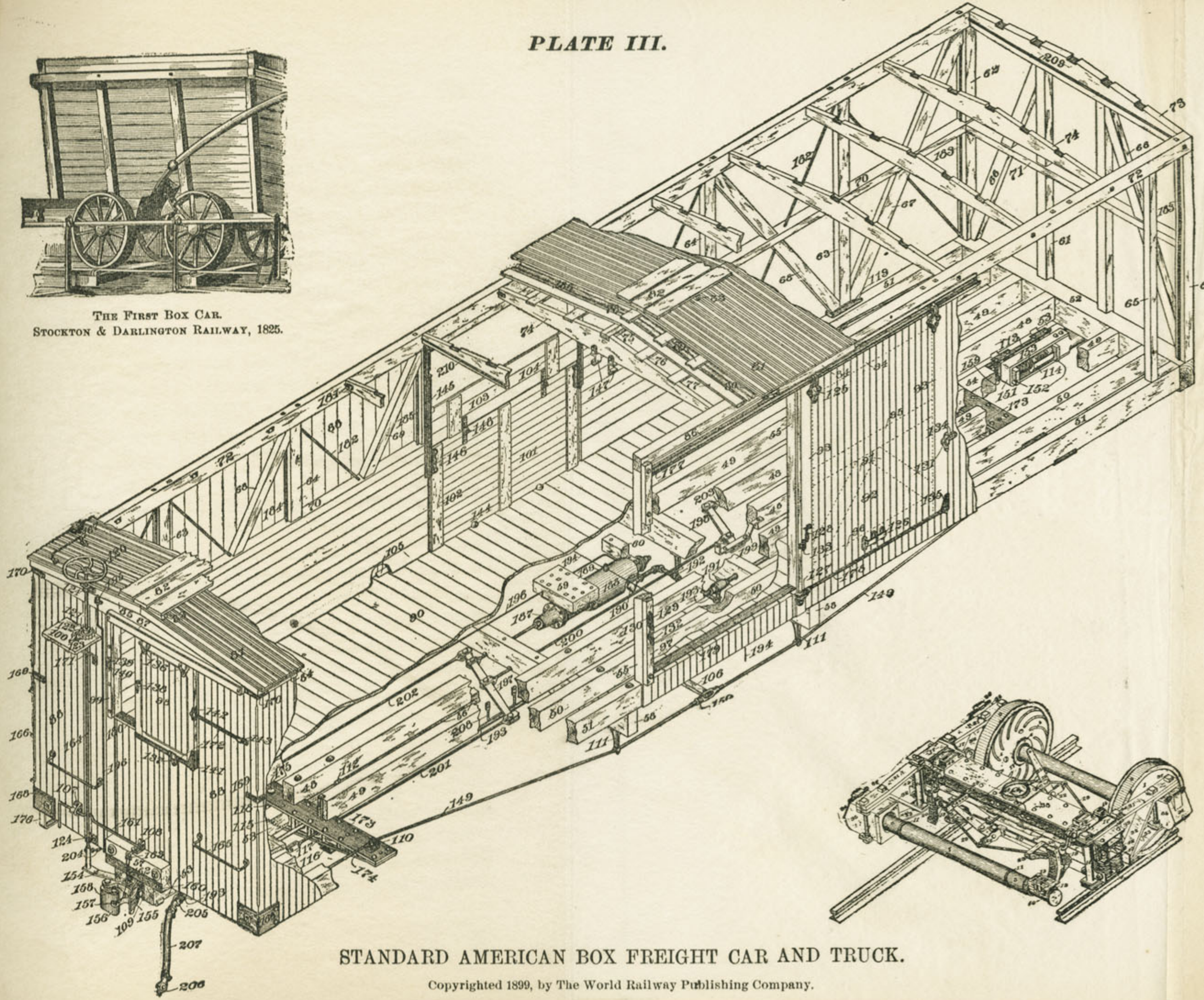
way owners and managers to discourage what is now known there as third-class traffic. They desired, for business reasons, to confine the traffic to first and second-class travel. In order the more effectually to do this, no effort was made to make the low-classed passenger comfortable or expedite his passage over the road. Cattle trucks and other rude conveyances without seats were used for his accommodation, while he was subjected to long delays on side tracks in order to allow other traffic the right of way. No indignity seemed to be too great to put upon him. Nevertheless, his desires could not be crushed out, but continued to grow, the companies meanwhile being subjected to the most biting comment on account of their policy. In the end the third-class passenger prevailed.



Cross Section of American Standard Box Freight Car.

The third-class fare in England at the time of which I write was about six cents per mile. The cars were conveyed on the same train with horses, cattle and empty freight cars. The sides of the vehicles were two feet high, without roofs or windows. The frequency with which passengers fell from the cars while trains were in motion led finally to an increase in the height of the panels. The carriage buffers were simply solid blocks of wood. There were no springs under the cars. In rare cases, third-class cars had seats. The speed of trains corresponded with the meager fare paid. When greater speed was suggested, carriers replied that passengers in third-class cars could not endure the exposure if they traveled too rapidly. On some lines in manufacturing districts, third-class passengers were ticketed by all trains. It is reported that one line provided covered cars of this class. It became very popular because of its foresight. Well-to-do people sometimes traveled in third-class carriages, to the great indignation of the people, especially the railroad people. To deter them from doing this, the management of one railway, it is recounted, adopted the soot-bag expedient. Thus, sweeps were hired to enter the third-class cars, which had been kept especially for the benefit of well-to-do persons and shake out the contents of their bags. A very offensive makeshift. The second-class cars were little better than the third-class. Many of them were not closed at the sides, and those who patronized them were not always sure of being in good company. The first-class English cars were small and cramped. This, after larger ones had been built in other

PLATE III.



THE FIRST BOX CAR.
STOCKTON & DARLINGTON RAILWAY, 1825.

STANDARD AMERICAN BOX FREIGHT CAR AND TRUCK.

STANDARD AMERICAN BOX FREIGHT CAR AND TRUCK.

The accompanying illustration particularizes every part of the car. The index thereto, which accompanies it, gives the technical names by which the different parts are known. The illustration with the index is at once a chart and an encyclopedia. Each part of the car, it will be noticed, is given a number by which it may be recognized and easily referred to. The following are the names by which the different parts of the car are known:

1 Master car builders' Washburn pattern double plate wheel. 2 Wheel flange. 3 Wheel tread. 4 Wheel rim. 5 Wheel brackets. 6 Wheel hub. 7 Axle. 8 Axle wheel seat. 9 Axle dust guard seat. 10 Axle journal. 11 Axle collar. 12 Axle journal bearing. 13 Journal bearing key. 14 Truck column. 15 Brake hanger hook. 16 Truck column guide. 17 Brake hanger arm. 18 Brake hanger pin. 19 Brake head. 20 Brake shoe key. 21 Brake shoe. 22 Brake lever fulcrum. 23 Brake lever safety loop. 24 Dead brake lever. 25 Live brake lever. 26 Brake lever connecting rod. 27 Dead brake lever guide. 28 Dead brake lever guide hook. 29 Brake beam truss rod. 30 Brake beam. 31 Arch bar. 32 Inverted arch bar. 33 Tie bar. 34 Column bolt. 35 Journal box. 36 Journal box lid. 37 Journal box bolt. 38 Truck bolster. 39 Truck bolster plate. 40 Truck bolster transom bars. 41 Truck bolster strut. 42 Truck bolster spring plate. 43 Springs. 44 Spring seat. 45 Truck bolster side bearing. 46 Truck bolster center plate. 47 Journal box dust guard. 48 Sills, center. 49 Sills, inside intermediate. 50 Sills, outside intermediate. 51 Sills, outside. 52 End sill. 53 Draft timber. 54 Draft timber filling block. 55 Door post. 56 Butting timber. 57 Deadwood. 58 Center cross tie. 59 Cylinder block. 60 Reservoir block. 61 Post, end. 62 Post, corner. 63 Post, transom. 64 Post, intermediate. 65 Post, ladder. 66 Braces, end. 67 Braces, transom and corner. 68 Braces, transom and intermediate. 69 Braces, intermediate and door post. 70 Side girts. 71 End girts. 72 Side plate. 73 End plate. 74 Carlines. 75 Lower ridge pole. 76 Lower intermediate purline. 77 Parting strip. 78 Center nailing strip. 79 Inside intermediate nailing strips. 80 Outside nailing strip. 81 Roof covering. 82 Running board. 83 Running board saddle. 84 Side fascia. 85 End fascia. 86 Side door furring. 87 End door hood. 88 Outside sheathing. 89 Inside lining. 90 Flooring. 91 Side door braces. 92 Side door sheathing. 93 Side door stile. 94 Side door top rail. 95 Side door middle rail. 96 Side door bottom rail. 97 Side door closed stop. 98 End door. 99 End door closed stop. 100 Hand brake platform. 101 Grain door. 102 Grain door battens. 103 Grain door leaf. 104 Grain door leaf battens. 105 Beveled grain strips. 106 Turnbuckle block. 107 Pin lifter bracket, end sill. 108 Pin lifter bracket, deadwood. 109 Draw bar chafe thimble. 110 King post. 111 Queen post. 112 Draft timber keys. 113 Draw bar check castings. 114 Draw bar spring cage. 115 Body center plate. 116 Body side bearing. 117 Body bolster wedge filling. 118 Body bolster center filling. 119 Post and brace pocket. 120 Hand brake wheel. 121 Hand brake ratchet. 122 Hand brake pawl. 123 Hand brake holder. 124 Hand brake rest. 125 Side door hanger. 126 Side door handle. 127 Side door bracket. 128 Side door hasp. 129 Side door seal pin. 130 Side door staple. 131 Side door open clasp. 132 Side door closed clasp. 133 Side door wedge. 134 Side door open stop. 135 Side door bracket wedge. 136 End door hangers. 137 End door bracket. 138 End door hasp. 139 End door seal pin. 140 End door staple. 141 End door bracket wedge. 142 End door open clasp. 143 End door open stop. 144 Grain door floor block. 145 Grain door guides. 146 Grain door guide arm. 147 Grain door hold-up hooks. 148 Grain door leaf hinges. 149 Longitudinal truss rod. 150 Turnbuckle. 151 Draw bar loop. 152 Draw bar followers. 153 Draw bar springs. 154 Draw bar carrier and brake step. 155 Draw bar. 156 Draw bar knuckle. 157 Draw bar knuckle pin. 158 Draw bar coupling pin. 159 Draw bar follower straps. 160 Deadwood angle iron. 161 Pin lifter rod. 162 Pin lifter chain. 163 Pin lifter clevis. 164 Hand brake staff. 165 End grab iron. 166 Side grab iron. 167 Roof grab iron. 168 Sill corner iron. 169 Girt corner iron. 170 Plate corner iron. 171 Brake platform bracket. 172 End door chafing strips. 173 Body bolster top plate. 174 Body bolster bottom plate. 175 King bolt. 176 Sill step. 177 Side door track. 178 Side door chafing strip. 179 Side door threshold plate. 180 End door threshold plate. 181 Carline strap bolt. 182 Counter brace rods. 183 Corner post rods. 184 Intermediate post rods. 185 Door post rods. 186 Corrugated iron roofing. 187 Brake cylinder. 188 Auxiliary reservoir. 189 Auxiliary reservoir release valve. 190 Triple valve. 191 Drain cup. 192 Cut out cock. 193 Train pipe. 194 Release valve rod. 195 Pressure retaining valve. 196 Pressure retaining valve pipe. 197 Cylinder lever. 198 Floating lever. 199 Floating lever fulcrum. 200 Cylinder lever and floating lever connection. 201 Cylinder lever and live truck lever connection. 202 Cylinder lever and hand brake connection. 203 Floating lever and live truck lever connection. 204 Hand brake chain. 205 Train pipe angle cock. 206 Train pipe coupling. 207 Train pipe coupling hose. 208 Brake lever guide. 209 End plate tie rod. 210 Carline tie rod.

countries. The Belgians had two deck cars, inconvenient and quaint in appearance. What was known as bogie cars were in use in Germany. The long open car was adopted in America almost from the very beginning.

On the pioneer railroad, the Liverpool & Manchester, when first opened, passengers rode in open, unsheltered cars, or in covered vehicles which were only a little more comfortable. Trains were few and far between and started at irregular intervals. It was some time before a time table was thought of. This road was expected to earn fifty thousand dollars from passengers the first year, but the receipts were ten times as great.

Trains in Great Britain were protected by distant signals in the early years of their operation. It was suggested at one time that there should be a third man on every engine, supplied with a small telescope, for keeping a sharp look-out ahead. The train force was entirely unprotected from the weather. The rear brakeman rode on the rear car facing forward, while the forward brakeman rode on the front car looking back to see that the train was not broken in two. The baggage was placed beside the brakemen, and for some time "strappers" were employed whose duty it was to keep the straps which fastened the baggage to the car properly greased, lest they should break and allow the baggage to fall off en route.

The brakemen carried with them a way-bill stating the number of passengers of each class, their point of departure and destination. Smoking was not allowed on trains. The rules were prolix and difficult to observe. Luxuries were highly rated, thus, the minimum charge for a lap dog was two dollars and fifty cents. People were strictly forbidden then, as now, to stand on the platform. Each passenger had a fixed place assigned him at the ticket-office—the seats being numbered. The ticket-office was usually closed some little time before the departure of a train. In some parts of Germany a ticket could not be obtained within fifteen minutes before the train was to leave. If not in the car ten minutes before starting time, passengers were locked out.

The capacity of the English freight car varies from four to eight tons. Only a small percentage of the freight equipment of English railways is made up of box cars. In many cases the roofs of the box cars were cut away opposite the doors and the open space covered with a tarpaulin, in order to facilitate work with cranes. Timber and other freight covering two or more cars, is transported on cars having a false bolster, the latter being pivoted in the center. The loads rest on the bolsters and thus permit the cars to curve. A three-link coupling is being substituted more or less generally for the five-link coupling formerly in use. What is termed a "shunter's stick," is used for coupling and uncoupling the cars. This stick is about five feet long and has a hook in the end with which to handle the chain.

The buffer acts as a fulcrum, on which the switchman rests the stick when raising the chain and throwing it over the hook, or when taking it off the coupling hook. When a freight train is stretched, there is a space of from seven to twelve inches between the buffers.

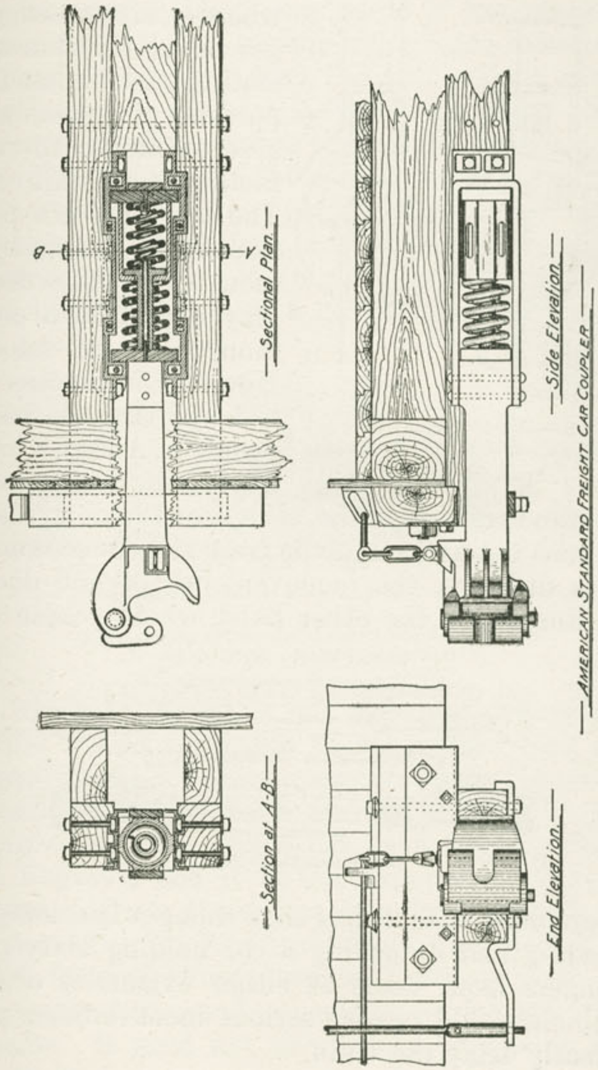
Delivery of freight at the place of business of the consignee is quite common in the large cities and many of the villages of Great Britain. Railway companies also haul merchandise from the stores to the stations. When the consignee unloads freight from the cars a demurrage charge is usually made after a limited time. Horses, turntables and capstans are still used for switching purposes to some extent, although new yards are arranged for the use of locomotives.

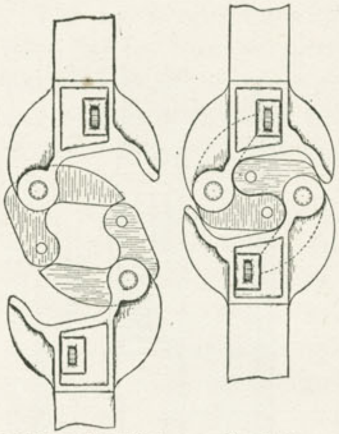
Foot warmers are a common means of heating passenger cars in England. They are usually made of heavy tin and are some two feet long, twelve inches wide and four inches thick. They are charged with acetate of soda and put into a tank of boiling water before being placed in the car. Within each can is a cast-iron ball. When the water cools and the soda begins to form into crystals, the heater is shaken and the crystals broken by the ball. The effect is to produce more heat, and the warmer is thus made good for some two hours longer, after which it must be re-heated in the tank, as before. Dining and sleeping cars are sometimes heated with hot water. In some cases, sleeping cars are heated with oil gas.

The passenger cars of France have a seating capacity for four persons on each side of the compartment. Smoking is generally allowed in every car, although the law requires that one compartment on each train shall be reserved for this practice.

In Spain the trains travel at a very moderate rate of speed. The stations are usually built of stone—solid-looking, but heavy in appearance. The railways are broken up into many sections so that passengers must change cars frequently, and oftentimes make long waits for trains at junctions. This will be remedied in time. The train force of Spain is kind, patient and obliging but very deliberate in its movements.

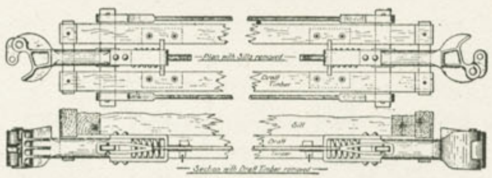
As the enclosed, or what is known as the box freight car, is the principal freight vehicle in America, so the common first-class passenger coach is the principal vehicle in connection with our passenger service. It carries most of such traffic; those who use parlor and drawing-room cars being but a small fraction of the whole. These latter, however, while not great in number, pay very much more than the others. The accommodations afforded them conform, in a general way, to what is known as first-class travel in other countries. It was at first designed that passenger cars should be arranged with entrances and exits at the sides so as to be quickly loaded and unloaded. In connection with local traffic, and more particularly suburban business,





Making a Coupling. Coupled.
Automatic Coupler.

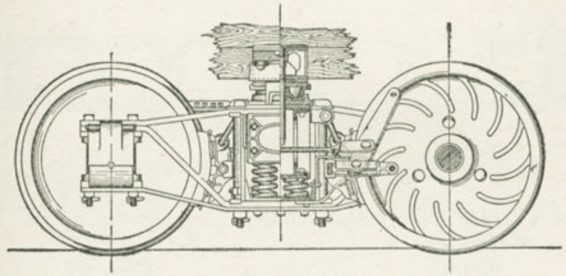
where many passengers get on or off at every station, time is an important element, and side entrances to cars facilitate movement. The cars need not necessarily be compartment cars. The doors may open into a common room or saloon. However, in practice, it is found that the habit people in America have of leaving their seats to stand waiting in the aisle near the door, ready to rush out as soon as the train stops, overcomes, in a measure, the inconvenience of end doors. In Europe, on the other hand, where people are



Continuous Draft Rigging.

more deliberate, it has been thought the delay of loading and unloading a car holding sixty passengers from doors at either extremity of the vehicle would prove a serious inconvenience and greatly delay the train.

The compartment car, while it has much to recommend it, has serious objections; so serious, indeed, that where used, the public show strong inclination to abandon it for the American form, or some kind of vehicle that shall be more public. The seclusion of the compartment car affords opportunity for the perpetration of so many crimes and impositions that travelers have grown distrustful of it. Within its secluded precinct the blackmailer finds a convenient opportunity

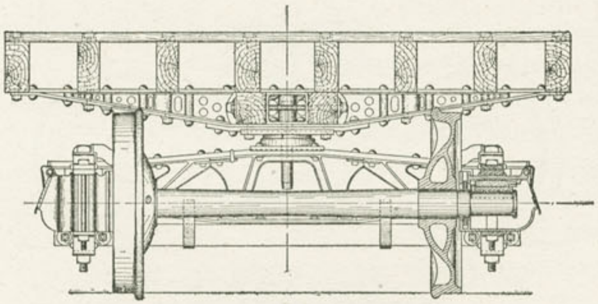


Side elevation and section at center bearings of Truck of American standard freight car.

in which to ply his or her nefarious occupation, while the Dick Turpin of other days long ago transferred his field of operations from Hounslow Heath to the more secure and productive precinct of this car. Such has been the experience of England, and it is the experience of every country where the compartment car is used.

A car that may be loaded and unloaded at the sides from platforms level with the car floor, is a desirable form, and especially so, for suburban traffic. It need not necessarily be cut up into compartments; the room may be a general one, so far as the opportunity for passengers to observe what is going on is concerned. Thus the danger and annoyance of the isolated compartment may be avoided.

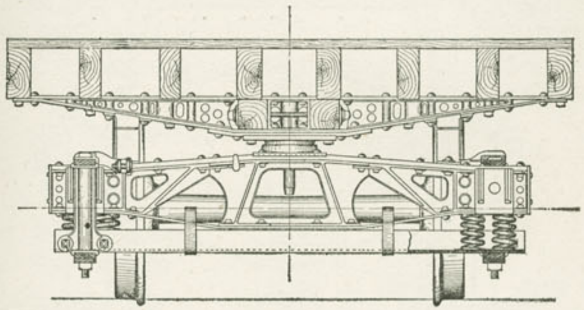
While there are many details regarded as important in the construction and maintenance of a passenger car, those things upon which the safety of passengers rests, outweigh, of course, all others. They are vital. Among these, and



End Elevation and Section Through Journal Box of Truck of American Standard Freight Car.

first to be considered, are the wheels of the car. These, it is apparent, must be stable and not likely to prove defective with wear and tear. A broken wheel is, of all calamities, one to be especially dreaded. Next, the body of the car must be looked after, and here it is apparent great care must be exercised, first, in constructing and afterward in maintaining. Not only must a car be strongly built, but constant care must be exercised afterward to maintain its

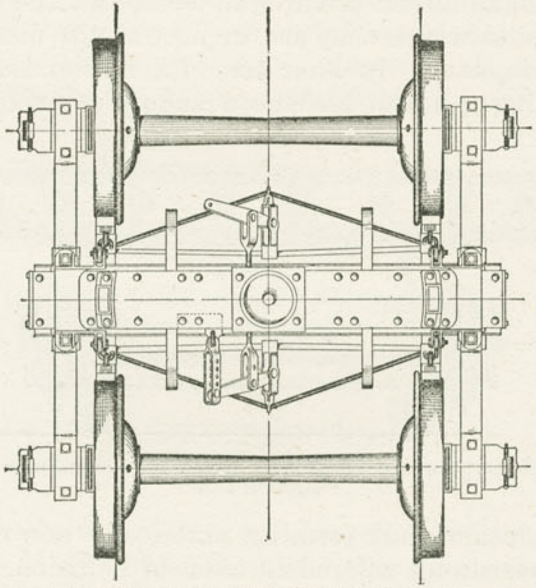
strength by needed repairs and renewals. For it will often fall out that the lives of the occupants of a car or train will depend upon the parts of the car, including the woodwork, being strong and sound, and the whole carefully cemented and bound together. Only vehicles thus constructed and maintained are able to withstand the rough usage to which they are, or may at any moment, be subjected. In later years the sills of the cars making up a train have been made to coincide with



Section Showing Body and Truck Bolsters of American Standard Freight Car Truck.

each other, thus forming practically one car in the resistance offered in cases of collision. The telescoping of cars at one time a thing of frequent occurrence, is thus happily prevented or minimized.

While every part of a car is important and the safety of the train dependent upon the discovery and correction, in time, of defects in vehicle or fixtures, the things that go to make up the difference between efficiency and inefficiency are relative here as in other branches of the service. When the safety of the car has been assured, the builder, according to his tastes and the price he gets for his work, gives his attention to minor details, among others, those intended simply to add to the comfort of passengers. These are

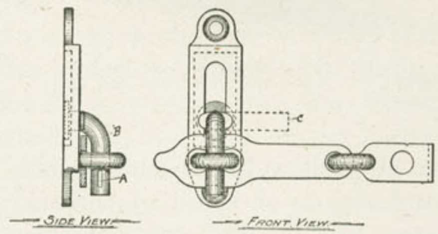


Plan of Truck of American Standard Freight Car.

never appreciated by travelers at their true worth, because we are, as a rule, totally unconscious of the efforts put forth in our behalf in this direction. We can only be able to appreciate these and other details of car construction by taking up the parts one by one, and by inquiry and surmise estimate the thought, direct and

incidental, that they have received both from operators and builders all over the world, every moment of the day since railroads were first operated. Every detail has been modified or wholly changed many times to reach its present degree of perfection.

Among the things those who operate railroads regard as of especial consequence in a passenger car are, cleanliness, a good light, proper temperature, adequate ventilation, comfortable seats, careful adjustment or balancing of the vehicle, good springs, well kept toilet rooms and, finally, an abundant supply of wholesome drinking water. This last is not thought worthy of attention in Europe, where people seldom drink water. The Americans are the water drinkers of the civilized world, and as their drinking water is often contaminated, many ills grow out of it, such as typhoid fever, which their brethren in other countries do not experience.*

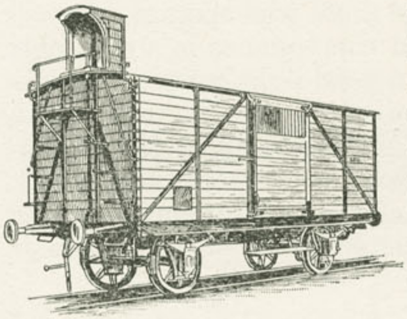


Freight Car Door Fastening. Seal is passed through opening A. To open, latch B is raised and thrown in dotted position C.

The higher class passenger cars in America possess, so far as they are available for day use, few conveniences which are not to be found in

* On some English railways, drinking water for passengers is carried in bottles in the lavatory.

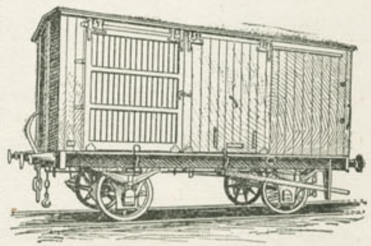
the common coaches. Their fixtures are not better than those of the common car, but more ornate. It is this feature, with the attendant service, that the high-class passenger seeks and pays for. The palace cars are also quieter than common cars. This is an attraction. However, the comforts of palace cars are variable, as is everything else about a railroad. On one line they will be ample, on another, inefficiently looked after. Their service is, however, in every case designed to be such as to conduce to the especial comfort and repose of mind of the traveler. In furtherance of this, well trained servants attend upon him, while the furnishers of woods, metals and cloths have ransacked the storehouses of the world in their effort to furnish builders material with which to make their cars attractive.



Turkish Box Car. Length, 21 ft., 6 in.; height, 7 ft., 4 in.; weight, 8 tons; load, 12½ tons.

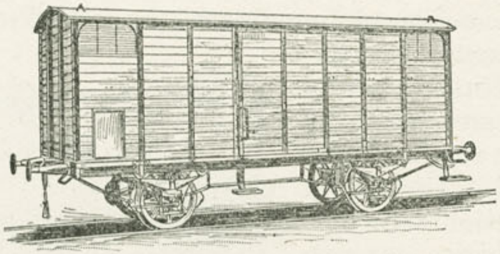
Money is not spared in preparing cars for use where traffic is likely to follow therefrom. It is noticeable, however, that what constitutes a high-priced car (a luxury in little demand), at one period, becomes a thing of common use later on. The vestibule train and buffet smoker, at

one period associated only with long distances, limited trains, and wealthy passengers, will sooner or later become common to all. It is so in every walk of life, the luxuries of to-day are the necessities of to-morrow. In regard to mail and baggage cars, several illustrations of these are embraced herein so that they may be viewed in connection with other vehicles making up a passenger train. The baggage car, it will be noticed, still maintains its primitive simplicity, while the mail car has, under advanced methods of handling the mail, become a great workhouse fitted with appliances needed to conform to the many wants of those engaged in handling this line of railway traffic. The service is still in its infancy, like many others.



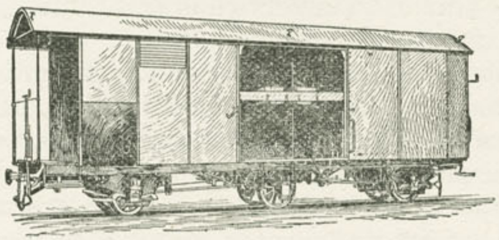
Victorian Box Car. Length, 21 ft., 4½ in.; load, 17,900 lbs.

In studying car construction it is noticeable that many of the differences existing between the cars of this or that country are due to accident, or pre-existing methods, rather than design. Thus, the English compartment car was not intended originally to cater to any idea of exclusiveness peculiar to the English people, because they are not noticeably exclusive among themselves. It was due rather to the accident of putting a number of old fashioned stage coaches on a platform and then putting the platform on wheels and the whole on to the track of a railroad. Forgetting the origin of their car and its



German Box Car. Length, 22 ft., 9 in.; height of sides, 8 ft., 1 in.; weight, 9½ tons; load, 12 tons.

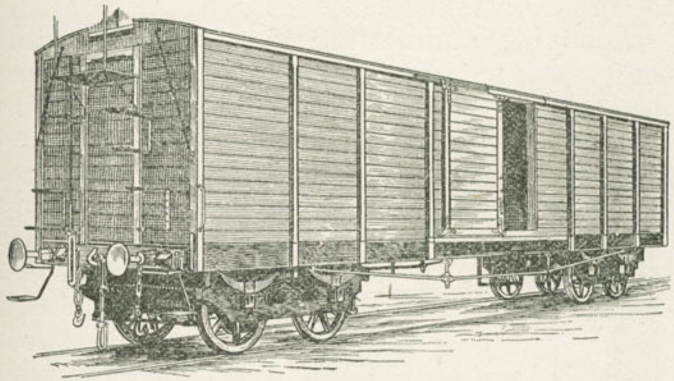
disadvantages, the English people have been inclined to comment unfavorably on the common coach of America with its single great saloon in which all the passengers sit. These saloons, however, have very great compensating advantages. One of them is they render it prac-



Austrian Goods Car.

ticable to have toilet rooms easily accessible to passengers at all times. This is a great accommodation. The traveler in Europe who sees

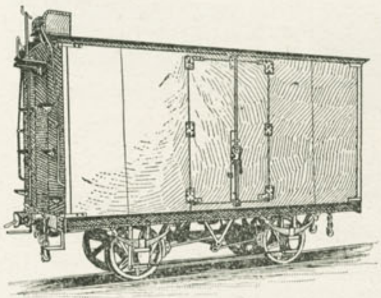
women speeding away across the station platforms pell-mell to remote toilet rooms, beseeching conductors and guardmen as they fly not to let the train go off without them, has a lively sense of personal sympathy awakened within him, mixed up more or less with indignation that women are compelled to put up with such treatment. However, when a people are accustomed to a thing like this they do not notice it.



Austrian Box Car for Transportation of Glass.

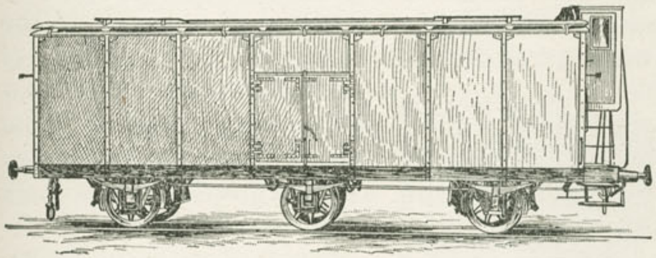
The inconvenience grows out of the situation. It is not practicable to have toilet rooms in connection with each compartment, and so, while high-class passengers may be accorded conveniences of this nature, abroad, others are necessarily denied it. Hence the running to and fro of men and women whenever a train stops at a station. It has always been so, and the natives do not therefore notice it. Habit is everything in life. Thus, when we travel in remote countries, it seems at first glance horrible that men should buy their wives as they do horses, but where such customs prevail, a high-spirited woman would drown or hang herself, if she were given away or did not bring a good price; and so it is possible that men and women in England and on the continent find agreeable and healthful exercise in the oft repeated excursions they are compelled to make across the station platforms while the train waits.

Among other interesting things connected with the passenger service of railroads, a chapter on the evolution of the car seat might be written. It was at first merely a plain wooden board, rude in design and hard to sit on. Following its use many experiments were made in different directions. The situation was thought to be very simple. Oil cloth and leather were among the first things tried as a covering for the seat. They were found to be cleanly, but very cold in winter. Moreover, passengers oftentimes experienced great difficulty in maintaining an upright posture when the car was going around curves or the train stopped suddenly, and in early days it used always to stop suddenly. Cloth,

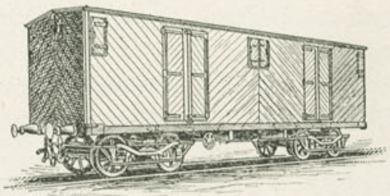


Brazilian Dynamite Car. Length, 14 ft., 6 in.; height of sides, 6 ft., 3 in.; weight, 5 tons; load, 6 tons.

carpet, cane and perforated wood were also tried but in vain. The problem as successive things were tried became quite exciting. Seats stuffed with tow, straw, shavings of wood and excelsior were in turn experimented with, but still without success. How little we appreciate this struggle today as we sit securely and comfortably back in a luxurious seat watching the flying fences and trees! In the end a satisfactory solution of the subject was found. In this connection it is to be remarked that Americans dislike very much to ride backward. I do not know why unless it has the appearance of waiving for the moment that feeling we have that we are the equals of the best and the superiors of all others. I do not believe the claim so often put forth that

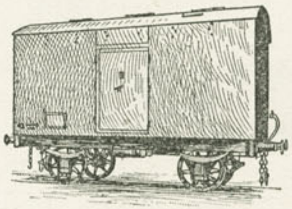


German Beer Car.



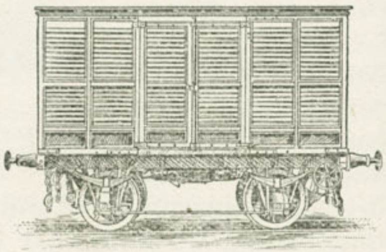
Refrigerator Car, New South Wales. Length of body, 34 ft.; height of sides, 6 ft., 9½ in.; weight, 35,840 lbs.

riding backward causes sick headache, to be tenable. However, the weakness of the American stomach or whatever it may be, made a reversible seat a necessity. Thus every one might face the front. This was not difficult of attainment when once the inventive genius of the country was directed to the subject. Myriads of devices successively saw the light. All of them were more or less satisfactory but not quite up to the exacting requirements of railroad managers; and so the struggle still goes on, and will continue to go on till the end.



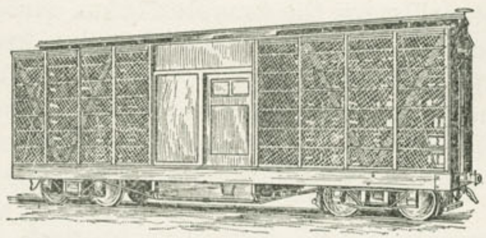
Insulated Car for Dairy Products, Victorian Railways. Length, 21 ft., 4½ in ; weight, 17,100 lbs.; load, 10 tons.

The sleeping car is one of the most conspicuous features of the passenger service. It is an American conception. Its accommodations were at first as rude and cramped as those of a sailing vessel of two hundred years ago, but, through the energy and tact mainly of one man, aided in later years by others, its conveniences have been developed until to-day it is a model of elegance and comfort. It seems now to be perfect,



Perishable Goods Car, New South Wales. Leng'h of body, 15 ft.; height of sides, 7 ft.; weight, 14,570 lbs.; load, 22,400 lbs.

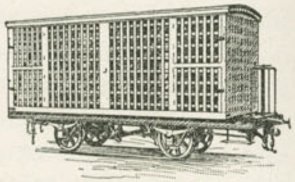
but, as a matter of fact, is, like everything else connected with railroads, still in a state of evolution. From a simple shelf or rude couch upon which the wayfarer rested, amidst noisome smells and the dust and smoke of travel, the passenger now enjoys a comfortable bed or, if he desires, the luxury and seclusion of a private compartment fitted up with every convenience, save, possibly, a bath, that the best hotel affords. The only substantial difference between them is that the traveler's quarters are cramped. If some-



American Poultry Car.

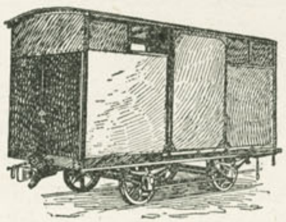
thing still more exclusive is desired, the traveler may hire a private car for his exclusive use. The price charged is not excessive when it is remembered that this is one of the greatest luxuries wealth or position can command.

The immense distances traversed in America suggested the idea of the sleeping car. It is said to have been first introduced in a rude way on the Cumberland Valley road in 1836. The car was divided into four sections by transverse partitions. Each section contained three narrow berths, one above the other, and it was a matter of not infrequent occurrence for the traveler occupying the upper berth to be hurled out of his bed as the train passed around some unusually sharp curve. Afterward, when the sleeping car had been perfected, the upper berth continued to be a source of anxiety, as it sometimes closed up unexpectedly on the traveler, thus smothering him in his bed. This defect has, however, now been remedied.



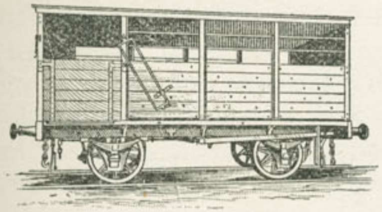
Peloponnesus Railroad (Greece) Car for Small Cattle. Length, 16 ft., 11 in.; height of sides, 6 ft., 5 in.; weight, 4½ tons; load, 8 tons.

Some of the experiments with the sleeping car took the direction of fitting up berths similar to those on steamboats, but as no bedding, save a coarse mattress and pillow, were supplied, it did not meet with success. In 1838, rude sleeping cars were put on the line between Philadelphia and Baltimore. They are thus referred to by the Baltimore Chronicle in its issue of October 31, 1838: "Cars intended for night traveling between this city and Philadelphia will be used for the first time to-night. They are of beautiful construction. Night traveling on a

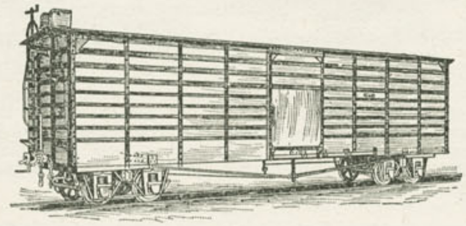


Italian Cattle Car. Length, 14 ft., 9 in.; height of sides, 6 ft., 9½ in.; weight, 3½ tons, load, 8 tons.

railroad is, by the introduction of these cars, relieved of all irksomeness. A ride to Philadelphia may now be made without inconvenience, discomfort or suffering from the weather. You can get into the cars at the depot and, if you travel in the night, you go to rest in a pleasant berth, sleep as soundly as in your own bed at home and, on awakening the next morning, find yourself at the end of your journey. Nothing now seems to be wanting to make railroad travel complete, except the introduction of dining cars, and these, we are sure, will soon be introduced." The advanced methods foreshadowed by the Chronicle proved delusive, as later accounts tell us. The cars were not successful. Similar



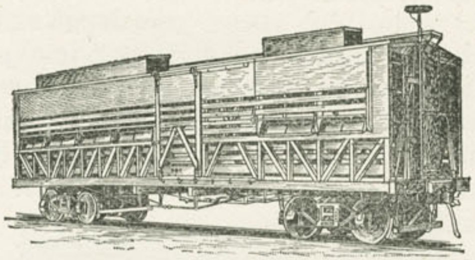
Cattle Car, Victorian Railways. Length, 23 ft., 4½ in.; load, 22,400 lbs.



Brazilian Cattle Car. Length, 31 ft., 6 in.; height of sides, 6 ft., 9½ in. No form of car designed for the transportation of cattle equals the standard in use in the United States, which is at once roomy and well ventilated, besides being supplied with water and facilities for feeding.

attempts were made about this period by other lines, but with like results.

Reference is made in the early chronicles to sleeping cars with seats so adjusted as to form rude beds, the space between the seats being filled in with a platform of boxes. During the day these were carried into the baggage car or were stored in the end of the sleeper. At night the back of every alternate seat was removed,

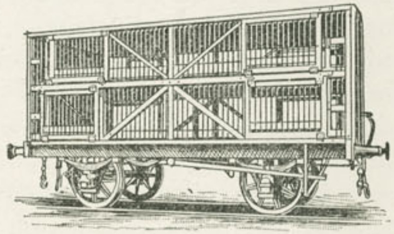


American Standard Stock Car. Capacity, 60,000 lbs.; weight, 30,000 lbs. This car is used very largely in America to transport cattle. It is provided with hay bars and racks, water troughs and, in some instances, gates on the inside to prevent cattle from moving about the car. The springs for the trucks are given special attention so as to insure ease in movement of the car while in rapid transit.

the boxes were brought in and put in place, a mattress was spread over the whole and curtains hung around the bunk thus made up. This was one of the most primitive forms.

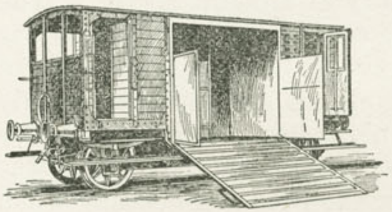
In 1859 the needs of railway travel in America had advanced to a point that warranted inventors and capitalists turning their attention to the subject of providing suitable sleeping-car accommodations for railroads. What was wanted was a car which should be commodious and pleasant

during the day and easily arranged with comfortable beds for the night. It was at this period that the attention of George M. Pullman was first called to the matter. His biographer, referring to the matter, says: "It is his special distinction that he conceived the correct solution of one of the most momentous problems in the history of modern travel." The circumstances of the case required an "ideal car for long-distance travel which, without loss of carrying capacity, could be quickly and readily transformed from a night into a day coach. The great difficulty in accomplishing this result was to provide a place for the beds and bedding when not in use. That was the key to the whole situation. Pullman's principle of construction provided the necessary place for the beds and section furniture, when not in use, without taking up an inch of space necessary for day travel, or in any way interfering with the comfort of the passengers." Mr. Pullman's first venture was to have two old day coaches remodeled into sleeping cars, according to his plan, after a patent which he bought, supplemented by improvements of his own. These were merely make-shifts, however, and accordingly he determined to construct such



Victorian Sheep Car. Length 23 feet, 4¼ inches, weight 15,400 pounds, load 8 tons.

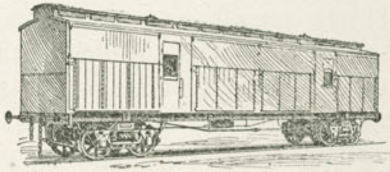
a car as he believed the situation required. This vehicle he aptly named the "Pioneer." Here for the first time the space above the windows or upper berth was utilized, through his device, for the storage of bedding and furniture. This car, when completed, in 1865, cost eighteen thousand dollars. The figure, while seemingly exorbitant, was greatly exceeded by the vehicles which were subsequently constructed by him at the car manufactories which he established. The "Pioneer" was a foot wider and two and a half feet higher than the ordinary day car then in service. It was the most stately and elegant equipage of its day, and when President Lincoln was assassinated it was used to convey his remains from Chicago to Springfield. In order to accommodate the car, however, because of its increased width and height, it was found necessary, in some instances, to reduce the width of station platforms and increase the width and height of bridges along the line over which it ran. The car proved to be popular with the traveling public and became the standard for all passenger vehicles as regards width and height.



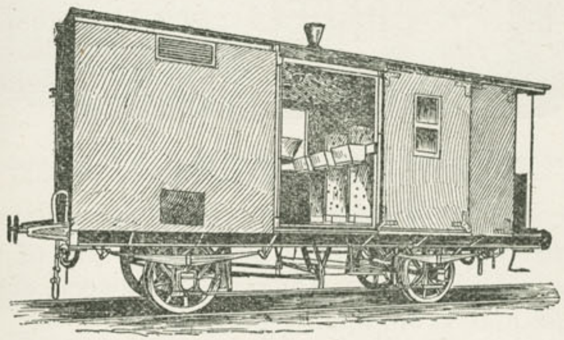
Belgian State Railroad Horse Car. Designed to accommodate three animals. Length 19 feet, 1 inch; height of sides 6 feet, 8 inches.

The parlor and drawing-room car afterward

introduced for high-class passengers, was intended particularly for day travel. It afforded comforts not provided for by the common day coach. Its popularity in America clearly evinced a desire on the part of the traveling public for a high-grade passenger service. It now forms an essential part of the equipment of every great railway line. Provision for serving meals on trains next attracted attention, but not until forty years after the Baltimore "Chronicle" called attention to the subject. The outgrowth of this desire was the hotel or dining car. The meals were served on tables placed between two seats facing each other. The car

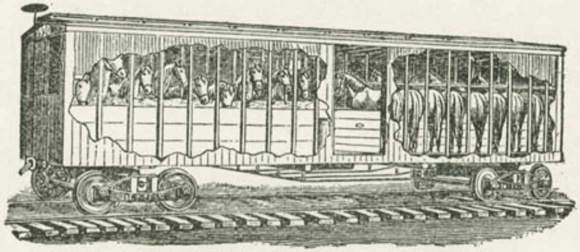


Victorian Railway Horse Car. Designed to accommodate twelve animals. Length 48 feet, 2¼ inches.



Austrian Horse Car. For fine animals.

is a restaurant in itself—fitted with kitchen, closets, and ample storage accommodations. Thirty people can be served simultaneously in one of these cars. Where traffic does not warrant a dining car, a buffet car is sometimes used. It has only a limited cuisine, but ample to meet restricted needs. Another popular car in America is the buffet smoker. It forms a part of the service on limited or very high-grade trains. It accommodates some twenty-five persons comfort-

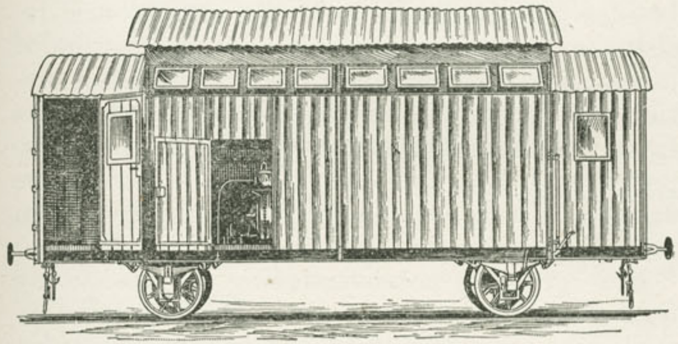


American Horse Car.

ably. It is provided with luxurious seats, and an attendant who looks after the wants of passengers and supplies them with tobacco, cigars, liquor, and so on, upon their order.

There are two great manufacturers of cars in the United States that originated with the palace car companies. The Pullman was the first of these. Many years afterward the Wagner company went into the business. These companies do not confine themselves enclusively to the construction of palace and sleeping cars, however,

but build other cars on order. It is, however, in connection with the passenger car that their great and peculiar service to railway travel consists. Their business as carriers has from the first required careful attention to detail, as the traffic they cater to is exacting to the last degree. Its comfort not only involves superior conveniences, but embraces, incidentally, the decoration of the vehicles in which it is moved.



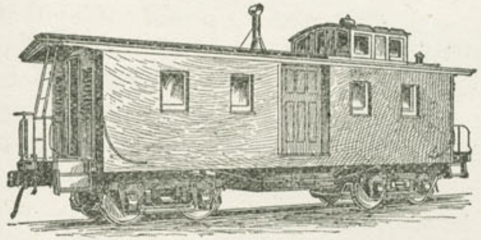
Austrian Car for creosoting or impregnating wood.

Every part of the car has thus received their constant and intelligent thought. The cars of the palace companies are not only more strongly built and conveniently arranged than others, but more carefully and elegantly decorated. "Invention has followed invention, improvement after improvement has been added, until the 'Pioneer' of 1865 has expanded into the traveling hotel palaces of to-day." The vestibule train, continues the authority I have already quoted, is intended to perfect this purpose. "In its latest application the vestibule is extended to the locomotive tender, thus extending its protection not alone to the passengers, but to the employes in baggage and postal cars. In this recent application of the principle, the car body extends over, and completely incloses the platforms; this, in combination with the Pullman vestibule and anti-telescoping devices, adds great strength to the ends of the cars, rendering telescoping impossible, besides greatly diminishing the atmospheric resistance to trains in motion. The vestibuled locomotive tender gives the trains steadier motion and increased cushioned resistance to shocks from the engine, affording greater protection to postal and baggage cars, and minimizing the dangers to engine men by preventing cars from mounting the engine in case of collision."*

It is probably not overstating the case to say that many of the most valued luxuries and conveniences connected with the passenger service of railroads have originated with the Pullman Company. They have grown out of the thought given the subject and the exacting needs of the service it caters to. The world owes the development of the sleeping car interests of railroads, particularly and especially to George M.

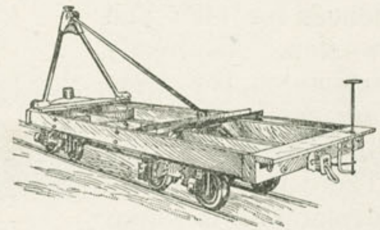
* The Pullman Palace Car Company was organized in 1867, with a capital of one million dollars. In 1897 it had a capital of thirty-six millions dollars. The number of its sleeping, parlor, and dining cars operated amount to two thousand, four hundred and eight, of which nine hundred and sixty-three are buffet and dining cars.

Pullman. For many years he upheld and fostered the evolution of this great feature of modern travel alone. Others have since come into the field and have become with him great and permanent factors; but primarily the development of the sleeping and palace car interest owed its growth to his sagacity, executive talent and genius for affairs.



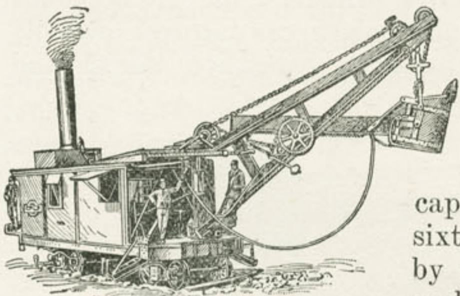
So-called Caboose Car, with observation tower. This car in the United States is generally attached to every freight train. It contains the implements which convenience and the vicissitudes of operation require, besides accommodations for the conductor and his crew. It is sometimes equipped with several sections, similar to those in sleeping cars, for the use of stockmen who accompany shipments.

The capacity of American apartment cars are not uniform. Some of them have ten staterooms; others less. There is an upper and lower berth in each room. Each berth is capable of holding two persons, making forty in all. Every room is fitted with washstand and closet facilities. There are also toilets at each end of the car. A door in the bulkhead allows two or more apartments

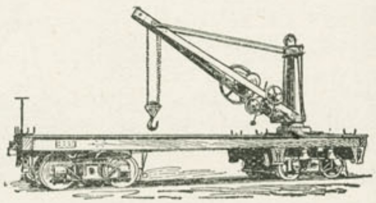


Frame-Work of Steam Shovel Car.

to be thrown together when desired. The common American sleeping car (the pioneer sleeping car, in fact), has from twelve to sixteen open sections. There is an upper and lower berth in each section. There is usually one stateroom at each end of the car. The car is capable of holding sixty odd persons by putting two in each berth. However, in practice, two people seldom occupy one berth either in this or in the apartment car. There are toilet rooms at each end of the sleeping car, one for women and one for men. The American drawing room or parlor car has seating accommodations for thirty-eight to forty-four persons. There is an enclosed smoking room at one end of the car. In some cases these cars have private rooms, also a buffet, and the accessories that belong to it. The car also has suitable toilet conveniences for men and women. As already intimated, the sleeping car is distinctly an American idea. There is little or no demand for it where



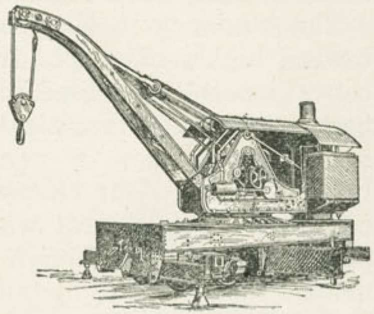
Steam Shovel Car.



Wrecking Car.

the distances to be traversed are short. The palace car proper is, however, everywhere growing in popularity. In England, where cars are shorter than in America, one of the sleeping car patterns is divided into four compartments designed to accommodate eight persons. In each compartment are two small brass bedsteads. No upper berths are provided. An aisle extends down one side of the car into which each compartment opens. This form of car enjoys more or less popularity wherever compartment cars of the pattern popular abroad are used.

Details of railway transportion are variable in other countries as they are in America. Facilities conform, as they do here, to public needs. If there is a wealthy or luxury-loving clientage, cars are run to accommodate it. If there is not, the vehicles conform to public safety and common usage. Everywhere railway companies adjust their methods of transportation to conform to the convenience, comfort and safety of their patrons. The form of the car throughout the world denotes the demand. In some cases public need necessitates palace cars; in others, vehicles of the plainest possible description.

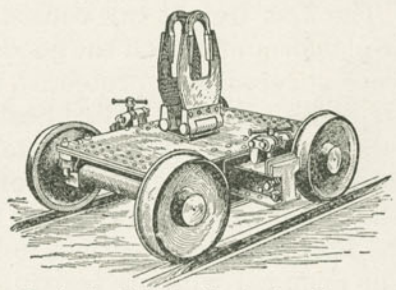


Steam Wrecking Car.

It is, however, undoubtedly true that in Europe and the far East, and in Mexico as well, many seek cheap rates and plain accommodations which Americans of corresponding social position would not put up with. There is a rivalry more or less ugly in the latter country that leads every man to desire to travel, irrespective of his means, on a par with every other man. How could he be equal with the best if he did not? Because of this and for other reasons there is little demand for anything in America but first-class transportation. The emigrant, newly arrived, is content to travel as cheaply as possible, following the custom of his own country, but when he has become Americanized, nothing short of a first-class carriage, in many instances, is acceptable to him.

The tendency in Europe is, however, steadily toward higher classes of travel; toward greater conveniences and added luxuries. What was at first esteemed impracticable is now, in many instances, deemed a necessity. Upon many lines there are four classes of travel. The first conforms in a general way to our high grade palace car travel, though perhaps not as luxurious. There are instances where it equals the Pullman and Wagner service, but as a rule it does not. The second-class coach in Europe is quite as comfortable as the common day car in America. In the third class, the seats are uncushioned and comforts in other directions are restricted. In the fourth class, the accommodation is yet more meager. Trains are made up

of the locomotive, baggage car, mail car, and respectively, of fourth, third, second and first-class cars. In the majority of instances there are only three classes of travel. Sometimes all the various classes are carried in one car. Thus, if traffic is small and divided, a car may be apportioned to accommodate first, second, third and even fourth class, a compartment being set apart for baggage. The apportionment of cars to the different classes of travel is made to conform to actual needs. If there is demand for a first-class car, it is allotted; if only a portion of a car is needed, then only a portion is set aside for this purpose. Thus the cars conform to requirements. In the higher grade of compartment cars of recent construction, lavatories are provided, but these luxuries are not general in compartment cars of the lower grades. The passenger coaches used in Europe and, indeed, throughout the world, are in the main of the compartment form. American manufacturers have not constructed any cars of this pattern either for use at home or abroad. In Germany and Austria, the American form of coach, with an entrance at either end, is taking the place of the compartment car. The higher grade of trains in



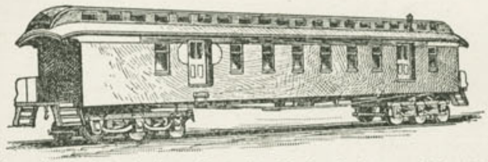
Device for Changing Trucks from Narrow Gauge to Wide Gauge, and Vice-versa.

these countries are vestibuled, as in America. What we call the vestibule car, they designate, because of its form, the Harmonica or Accordion. The air-brake is very generally used by the railways in Europe. It is destined to become universal in its application because of its convenience and value as a safety appliance. In many instances, especially in central and eastern Europe, steam from the locomotive is utilized for heating purposes. Oftentimes, however, the old-fashioned warming pan and hot water bottle are made to do service. The method of coupling cars by chains, so generally practiced abroad, is much inferior to the automatic coupler generally in use throughout America. In some cases, Pintsch lights and electricity are used in other countries, as they are in America, but in many instances a candle or oil lamp serves, as in primitive days of railroading, to light the coaches.

The first freight car consisted simply of a bed or platform on which the goods were piled. They were covered, and protected in a measure, by a tarpaulin. In the United States, however, where cars are moved immense distances, and goods remain therein for days, and oftentimes, weeks, it was found necessary not only to securely protect the load from the weather, but also from thieves. The open car with its tarpaulin cover was found to answer very well in Great Britain where the distances are not great and the freight is moved

with much greater celerity than in the United States.

For sixty years after railroads were opened in America stringent regulations designed to prevent overloading cars were enforced. The maximum load was ten tons, and this long after the roadbed had been strengthened and the weight of the rails had been increased to the heaviest pattern known. This persistence illustrates the force of habit. Because ten tons was a reasonable load for the light rail, and unstable bridges and track, of the earlier roads, it did not occur to



Standard American Postal Car. Length, 60 ft., 9 in.; width, 9 ft., 10 in.; height from rail, 13 ft., 11 in.; weight, 62,000 lbs.

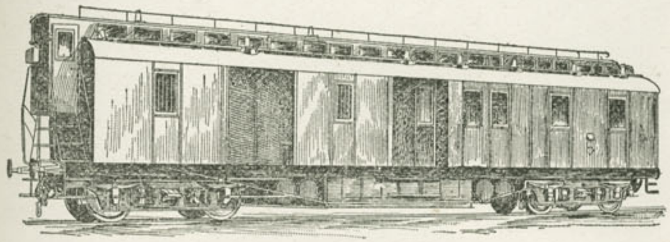
any one to change or increase it for fully sixty years. Then it suggested itself to the managers of American roads that thirty or even forty tons might be hauled in a car more advantageously than ten. Accordingly all new cars were built to conform thereto. The change will be highly beneficial, as it will effect great saving in the number of cars and the relative cost of hauling and handling. The new car, it is to be remarked, is little, if any, larger than the old one, but it is stronger and its body is supported by a substantial truss on either side, as shown in the illustration.

The freight car load in England and on the continent is very light compared with ours. The cars used are much shorter than the American pattern and correspondingly weaker. Our cars have uniformly eight wheels; theirs, as a rule, only four. Moreover, the practice so general in America (and in a measure the secret of our successful operation) of requiring a relatively full load for each car in a train, is not so rigidly ob-

Interior of American Postal Car.

served abroad, but more particularly in Great Britain, where single light shipments, in many cases, constitute a load, just as one or two passengers may, by judicious tips, occupy a compartment in a car to the exclusion of every one else. The great loads hauled by engines in America at a low rate of speed is an economic feature that may well be studied by railroad managers everywhere.

The box car in America and the flat car in Great Britain easily lead all others in number and importance. They form the key to the situation. The box car is the only car in use in America for carrying general merchandise. Soon after railroads were opened here half box cars were constructed to carry coal and similar freight. For a long time only three kinds of freight cars were in use, namely, the flat, box, and coal or gondola car. In recent years many new forms for special purposes have been added,



Austrian Postal Car.

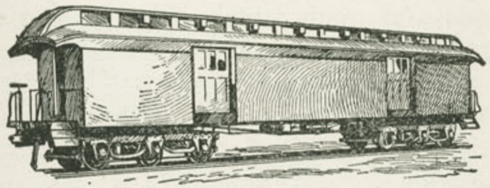
but as the illustrations accompanying this portray them in every substantial respect I will not tire the reader by attempting their description.

Writers and observers, especially Englishmen, in speculating on the causes which enable American railroads to carry freight at so low a rate per ton per mile, concur in ascribing them to the great carrying capacity of our standard freight car and the fact that, as a rule, it is loaded to its full limit. For this reason I have felt it desirable to illustrate this car somewhat at length, so that the reader may study it in detail. It is in a great measure descriptive of all other freight cars and meets every requirement of the American Master Car Builders' Association, an organization of prominent and experienced officers in charge of the cars of railroads. The construction of the freight car, indeed, may be said, at this time, to be

Interior View of Austrian Postal Car.

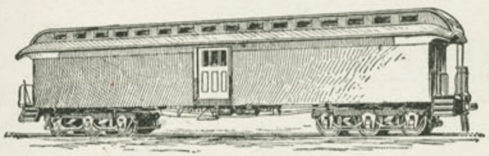
dictated wholly by them. For these and other reasons I desire particularly to invite the reader's attention to the illustrations of the car contained in this chapter. Different manufacturers, it is proper to say, vary the patterns they use somewhat, but in every substantial particular the standard box freight car is uniform throughout

the country, and as I describe it.* Its dimensions are: Length inside in the clear, 34 feet; width inside in the clear, 8 feet, $2\frac{1}{2}$ inches; height inside in the clear, 7 feet, 1 inch; width



Standard American Suburban Milk Car. Length, 50 ft.; height above the rail, 14 ft.; weight, 62,200 lbs. Some railroads line the floors of these cars with sheet iron; the milk cans may then be slid over the floor with very little effort. Side shelves are often provided for additional cans.

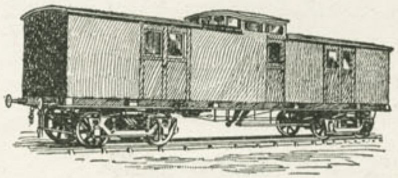
of side door opening, 5 feet; width of end door opening, 2 feet. The sill timbers of the standard car are as follows: Two center sills, $4\frac{1}{2}$x9 inches; 2 outside sills, $4\frac{1}{2}$x9 inches; 4 intermediate sills, 4x9 inches; end sills, 7x10 inches; draft timbers, $5\frac{1}{2}$x$7\frac{1}{2}$ inches; center cross timbers, $4\frac{1}{2}$x9 inches.



Standard American Baggage Car. Length, 50 ft.; height above the rail, 14 ft.; weight, 52,350 lbs. A portion of the car is frequently set aside for the express or parcel traffic. The mail also is frequently carried in this car on irregular trains where the business is not sufficient to warrant a messenger. In the early history of railways the baggagemen handled all the mail matter which railways carried.

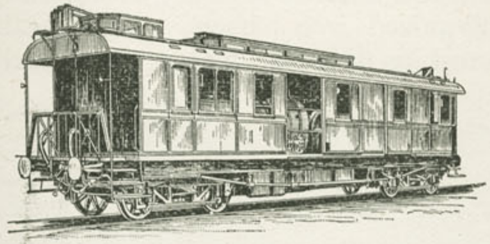
*I am indebted for the description which follows to Mr. J. H. Barker, a prominent car builder.

The body bolsters of the car are open hearth steel; top bar, 10 x $\frac{5}{8}$ inches; bottom bar, 10 x $\frac{3}{4}$ inches; filled in with malleable iron flanged castings, securely riveted together. The truss rods are six in number, of $1\frac{1}{8}$-inch round iron, with $1\frac{3}{8}$-inch ends and open turnbuckles in the center. The draft rigging is a double, or tandem, spring device with malleable iron cheek castings on either side, thoroughly secured by locking into the draft timbers $1\frac{1}{2}$ inches and each bolted with eight $\frac{3}{4}$-inch bolts. By the use of a malleable iron cage, encircling the rear spring, and a malleable iron plunger which gets its bearing on the front follower, this spring takes the blow in buffing and, simultaneously, the front spring, bearing on the front follower and front end of the cage, which gets a bearing on the back follower, causes the front spring also to take the blow. And by the use of the draw bar pocket, which bears on the rear follower, and the rear follower on the rear spring, communicates, through the plunger, a bearing on the front follower. And the rear follower, bearing on the cage communicates to the front spring and front follower. Thus, the strength of both springs is brought into service in draught as in buffing. In



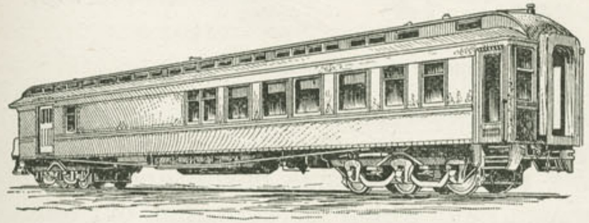
Victorian Baggage and Compartment Passenger Car. Length, 43 ft., 2¼ in.; weight, 40,000 lbs; accommodation for twelve passengers.

buffing, the springs are protected by the front follower having $1\frac{3}{4}$-inch travel and then coming to a stop on the cheek castings, as also on the deadwood angles. In draught, the rear follower



Baggage Car and Electric Lighting Plant, Austrian Imperial Train.

has $1\frac{3}{4}$-inch travel and then comes to a stop on the cheek castings. Each spring is manufactured with $2\frac{1}{4}$-inches motion. There is, therefore, $\frac{1}{2}$-inch motion left in each spring when the stops are reached in buffing, or in draught, and by this means the breakage of springs is practically eliminated. The roof is made of sheets of cor-



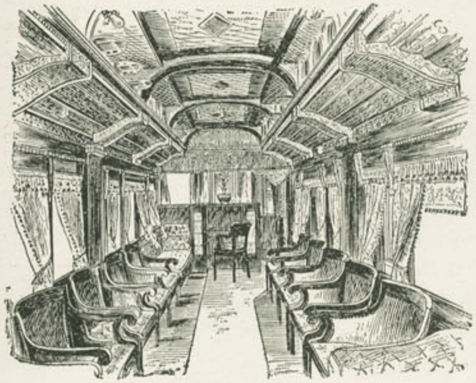
Standard American Baggage and Buffet Smoking and Library Car. Frequently fitted with barber shop and bath room. Length, 72 ft.; width, 9 ft., 8 in.; height above the rail, 14 feet; passenger room seating capacity, 23 persons. An attendant is usually found with these cars, who looks after the comfort of the passengers. He has for their use, generally, cigars, tobacco, mineral waters, and kindred articles, which he sells at a small profit. One end of the car is used for baggage and in some cases for mails.

rugated galvanized iron, No. 26 gauge, the edges of which are turned up underneath ½ inch into parting strips, as shown in the illustration. These parting strips come directly over the carlines and are secured thereto, without injury to the galvanized iron sheets. Underneath, the sheets rest on the side plates, ridge purlin and

Interior of American Buffet Smoking Car.

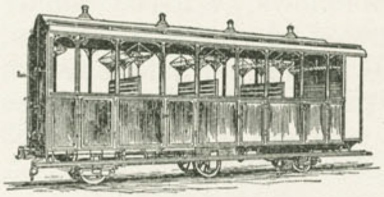
two intermediate purlins. On the top of parting strips, as shown in the illustration, there is a center purlin, an outside purlin and two intermediates, on which a covering of tongued, grooved and guttered roofing is thoroughly secured. This construction makes a thoroughly water-tight roof, even though the upper roof boards should leak. Each carline is secured to

the side plate at ends with a 1½ x ⅜-inch strap bolt with a stem of ⅝-inch round iron. The axles are the master car builders' standard for a car of 60,000 lbs. capacity, as follows: Extreme length, 7 feet, ¼ inch; diameter of center, 4⅝ inches; wheel seat, finished, 5⅜ inches; journals, finished, 4¼ x 8 inches; collar, ⅝ inch. The wheels are the master car builders' standard, double plate, 33 inches in diameter, weight, 600 lbs. The brasses,

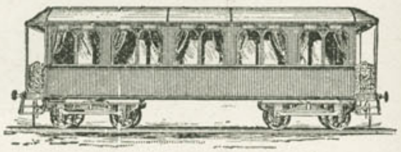


A Smoking Compartment in an American Car.

wedges, oil boxes and oil box covers (the last made of malleable iron), are all the master car builders' standard. The cross transoms and spring bearings are channel irons, 13 inches wide, ½ inch web, 4-inch flanges. The truck bolsters are of open hearth steel. The top bars are 11 x ⅞-inch, the lower bars, 11 x ½-inch. The bridging from end to end of same is of flanged malleable iron castings, the bars and castings being securely riveted together. The center plates, side bearings and columns are of malleable iron. The compression members of the brake beam are of 2 x 1-inch iron. The tension rod of 1-inch round iron. The brake heads are of malleable iron made to take the master car builders' standard Christie brake head. The brakes are hung from malleable iron arms, which are secured to the truck frame by the column bolts, thus retaining the brakes in the same position always. The brake levers and connections are master car builders' standard. Finally, it may be said the end and side doors of the car are locked and sealed when the car is loaded. The roof and sides of the car are water tight. Altogether, the vehicle is as secure as good construction and locks can make it.



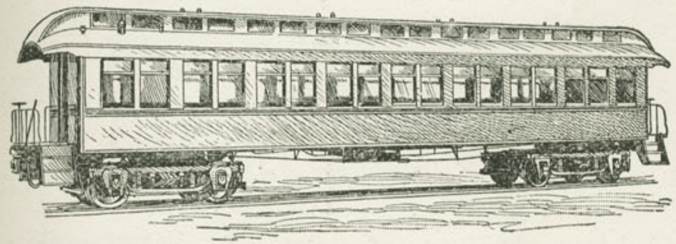
Bosnian Railway Compartment Car.



German First-Class Passenger Car.

While the fact is not generally known nor commented upon it is nevertheless true that there are specialists among car manufactories as there are in every business and profession in the world. Thus there are manufactories devoted

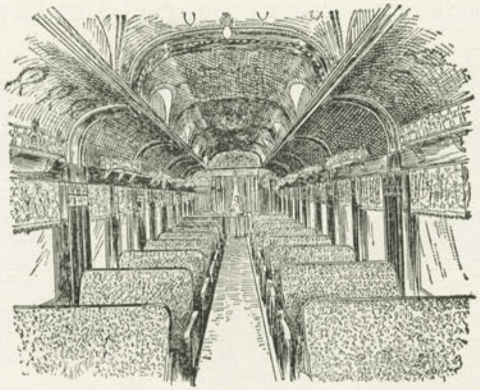
wholly to the production, in a complete form, of cheap, light, portable railroads and the equipment connected therewith. I have, by way of illustration, gone to some trouble to familiarize myself with the details of one of these companies—the Decauville, at Petit-Bourg, France.* It is quite interesting and instructive. The proprietor of these works (M. Paul Decauville), it appears, started in life as a farmer, albeit, a highly educated one, as many of the farmers of Europe, and more particularly of France, are. It is said that he first introduced into France the idea of plowing by steam. He made it highly successful on his estate. There being occasion for the transportation of stone from a quarry located on his farm, to the river Seine, it occurred to him that a narrow gauge, portable railroad would be desirable for handling it; but upon inquiry he



American Standard Railway Passenger Car. In some cases these cars are provided with safety gates, so that passengers cannot get on or off except at the instance of the brakemen or on the proper side. Its length is 52 ft.; height, 14 ft. above the rail; weight, 58,200 lbs.

*In 1897 this concern was carried on by a company with a capital of seven million francs, under the style of Societe nouvelle des Etablissements, Decauville, aine.

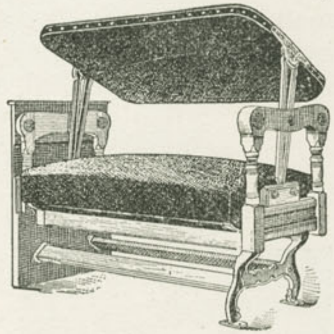
found the cost so excessive as to preclude the idea. Upon examination he discovered the cause of this excess to be due to the fact that such roads were constructed the same as other railroads; namely, by purchasing the different parts, here and there, from manufacturers, and carrying on the work in the same way in which standard railroads were built. This suggested the



American Standard Passenger Coach. The furniture of this car consists of double seats for sixty passengers, toilet rooms at either end, for ladies and gentlemen, respectively; drinking water, fire extinguishers, tools needed in case of disaster, lights and steam-heating apparatus, supplemented by stoves.

thought to him that if a manufacturer devoted himself wholly to the construction of the patterns used for narrow gauge, portable railroads, he might be able to greatly lessen the cost of the items, and, by doing so, create a demand for the road, that did not then exist. Accordingly, he started the Petit-Bourg works, which his genius

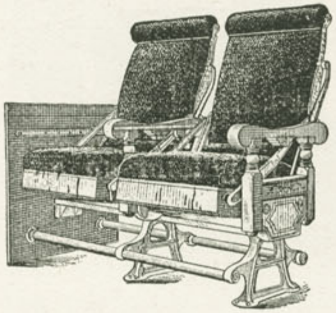
served to make a success from the first. Curiously enough the location of his manufactory formed at one time a part of the grounds surrounding the magnificent chateau of Mme. de Montespan, the last of the mistresses of Louis XIV. of France and the mother of his children. Thus, from being a place of illicit love, it became the seat of one of the greatest industries of the world. Decauville's plan was to take the raw material and, with the aid of suitable machinery and labor, make it into the various things that are essential to a complete narrow gauge, portable railroad, including the equipment. He designed his railroads to be used for handling stone at quarries, hauling sugar cane, lime, logs and other forest products, material and dirt about great works, public and otherwise, and particularly for military purposes in the mountain and unimproved districts and on the frontiers of Asia, India, Africa, and similar isolated localities. In those cases where his



American Reversible Seat.

American Reversible Seat. The back is raised sufficiently to clear the seat and then shoved across.

roads were to be used in remote or inaccessible parts of the world, his plan contemplated their manufacture from metals and other practically indestructible materials. Thus, the ties of his railroad were of metal, according to the general design of such devices, only much lighter. It was necessary, above all things, that his railroad should be easily put together on the ground. This required that it should be light and portable. To be readily salable, it must also be cheap, but at the same time, capable of hauling very heavy loads. The Marquis d'Andelarre, in presenting a medal of honor to M. Decauville for his devices, spoke of him as the manufacturer of a lilliputian railroad, able to move mountains. This is not an exaggeration, for Decauville's railroad was based upon the principle of a division of the burden over a number of wheels proportionate to the load. Thus, when the load could be divided, as in the case of earth, brick, lime, or the products of the farm, the weight was split up into parts, varying from two hundred and fifty to five hundred kilograms, each part being placed on a small car with four wheels. If, on the contrary, the load was indivisible, like a cannon, or the trunk of a great tree, the weight

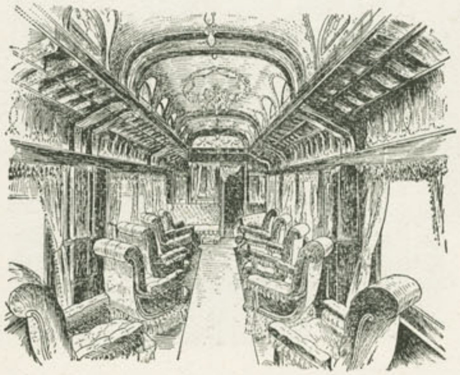


American Reclining Chairs.

American Dining Car.

was distributed over a proportionate number of trucks.

An important thing in connection with the narrow gauge portable railroad is that the rails form but one piece with the ties, which are riveted to them. The rails and the ties resemble a

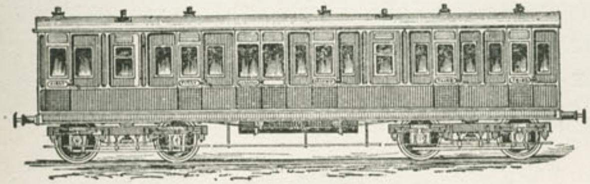


American Parlor Car.

Roumanian State Car.

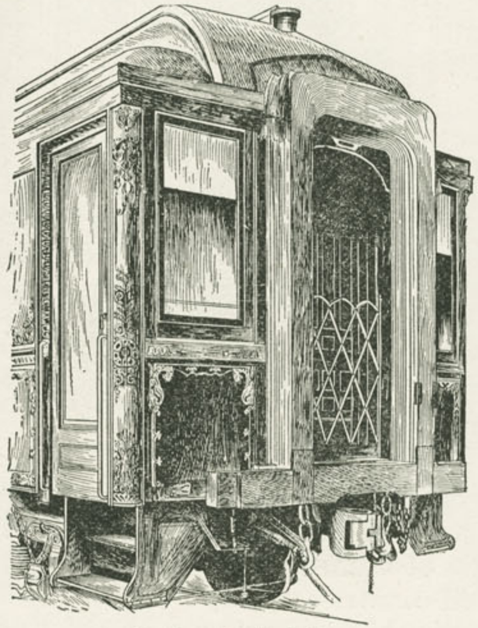
ladder. The track is furnished curved or straight as the needs of railway construction require. The weight of a section of four metres, (Of 50 gauge) is forty-six kilograms, including the ties, so that a section of the road may be easily carried by a man of ordinary strength. The road may be laid anywhere upon level ground without the intervention of experts or the use of technical appliances of any kind. Indeed, it is so simple that it is possible in many cases (a majority of cases, it is said), to lay it as fast as an

Austrian Imperial Saloon Car.



Joint Service Compartment and Passenger Car.

ordinary army marches. The practicability of this appears easier of fulfillment when it is known that the manufacturers of these ready-made railroads deliver them complete, ready for use, boxed, very much as manufacturers do a

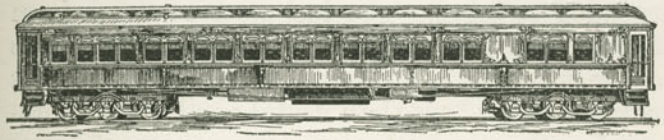


American Vestibule Car.

cooking stove. The success of manufactories of portable narrow guage railroads was assured the moment it was demonstrated that they could be built cheaply and were, in all respects, durable

An Apartment in a Palace Car.

and serviceable. A demand at once sprang up for them, not only for handling the industrial products of the world, but for military purposes in far-off countries. They were thus used by the English in Afghanistan and by the Russians in

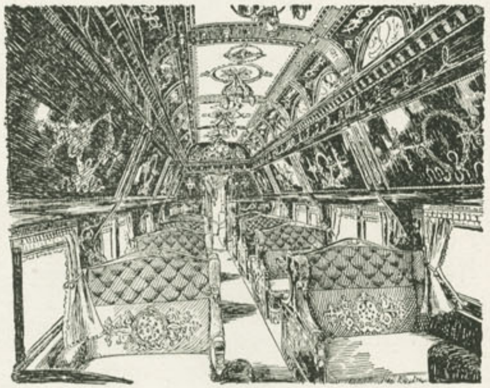


Standard American Sleeping and High-Class Passenger Car.

Central Asia. In India the railroads were carried ready for use on the backs of elephants, and in Turkestan on the backs of camels. These animals marched along the proposed line distributing their burden where needed. The animal carrying the track was followed by one carrying a locomotive, another with cars and another with fuel and other appurtenances. The locomotives used on these roads are in some cases propelled by compressed air; on others again by electricity. Steam, however, is generally used as in the case of standard railroads.

Apartments in an American Palace Car.

The manufacturers of portable railroads not only construct the track, turnouts, switches, and everything pertaining thereto, but the locomotives and cars needed by the industries they are intended to serve. The locomotives weigh from three to ten tons, according to the requirements of the situation. The cars of portable railroads look more like toys than useful implements compared with standard cars. There are vehicles especially built for use in handling earth, stores, stone, brick, wood, sugar cane, grain, garden truck, fertilizing matter, and for every other purpose that the requirements of the case de-

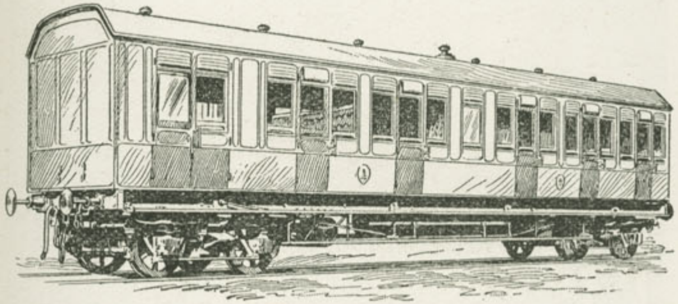


American Palace Car for Day and Night Use.

mand. The vehicles intended for military uses are generally constructed of metal. They are thus practically indestructible. Military cars are, moreover, adaptable for the carriage of either men or munitions of war. The cars are packed and shipped ready for use, just as croquet sets are packed by manufacturers. It is this feature, namely, that the railroad is ready for use

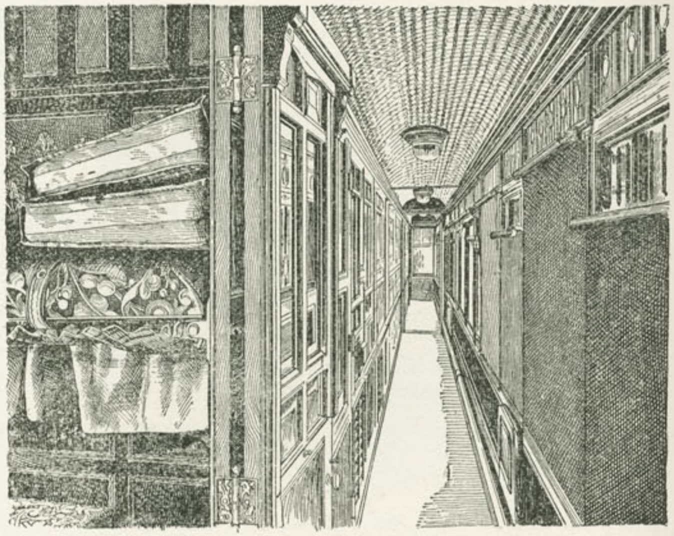
when delivered and does not require experts to construct it which makes it so attractive to those who have use for such a contrivance.

Before concluding this chapter on manufactories, I am led to say a word in regard to a practice that has grown up to a certain extent at railroad shops (manufactories), of officers and employes associating themselves together for the



Compartment Car, New South Wales. Accommodation: 24 first-class day passengers or 14 first-class night passengers; 20 second-class passengers. Length of car, 46 ft.

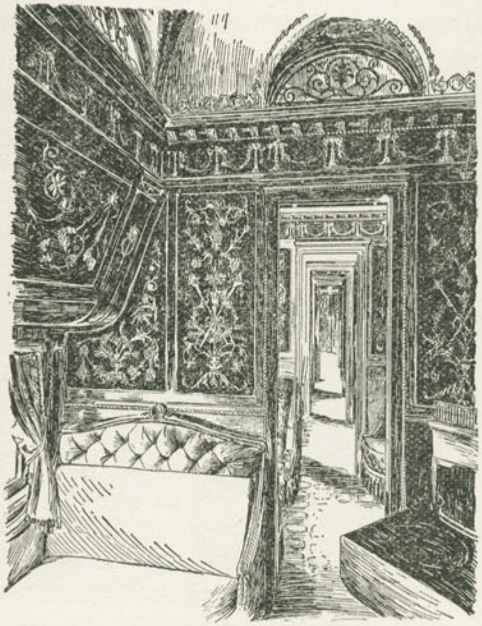
purpose of discussing matters connected with their daily work. I have not myself had sufficient acquaintance with the needs of the situation to be familiar with all its requirements, but some of those who have achieved deserved distinction in connection with the manufacturing and maintenance of railway equipment are earnest advocates of such associations or groupings as that referred to. They believe that the discussions these meetings will call forth will have the effect to aid in arriving at a better understanding of the many questions that arise in connection with the daily work in shops and about which men differ and continue to differ mainly because they do not have the benefit of each other's experience and wisdom. Those who



Austrian Compartment Sleeping Car. The apartments off this passageway are distinct and capable of accommodating two people and are supplied with the accessories common to toilet rooms.

advocate these associations believe in them as an educational medium highly beneficial to those immediately concerned, and to the employer as well. They believe that these meetings will not only disseminate knowledge but give birth to a spirit of emulation. Every ambitious, growing

man is benefited (I do not say pleased) by having his ideas reviewed and criticised. He is thus shown the weak points in his makeup. Opposition has the effect also to spur him on to renewed



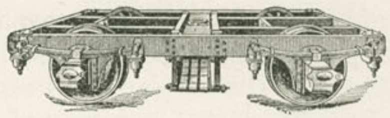
American Apartment Car. The doors between the compartments, as shown in the perspective, close, making each a distinct room with a door opening into a common passage way. What is known as a compartment car in other countries has a distinct entrance from the station platform for each compartment. In many cases each car has compartments for first, second and third-class traffic.

efforts. Man's pride as well as his energy and ambition push him on through life. For these and other reasons monthly meetings of those engaged in shop work, it is thought, will prove highly advantageous both to them and the company they work for. These weekly or monthly meetings, made up as they will be of many small groups of men engaged in analogous work, may in turn be supplemented by general meetings of all the groups, or of delegates selected therefrom.

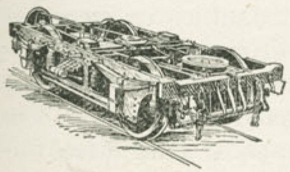
American Observation Car.

At some shops there has been introduced in connection with such associations as those referred to what is known as a question box. Any information anyone desires he propounds in the shape of a question and drops it into the box. When a meeting occurs, the question is read and discussed and, if necessary, a committee appointed

to give it needed consideration. As a rule meetings of employes of shops for discussion, such as I have referred to, are not common on railroads. Many companies, however, require such meetings of their managers and superintendents. Those who advocate the extension of the practice believe that those who work in shops and about roundhouses and locomotives will also be benefited by such meetings. They contend, as already pointed out, that such associations will have the effect to stimulate and enlighten men. We all know that it is only by intercourse with those about us we can be impressed with the smallness of our own knowledge compared with that of men collectively. The man who lives apart from his brothers is always more or less of an egotist. He is filled with silly notions of the value of his own ideas, when as a matter of fact they are usually of little or no account. For these and other reasons it is believed that the organization of railroads about their shops may be heightened by such associations of employes for purposes of discussion and mutual enlightenment as those referred to.



Steel Bogie Truck.



Passenger Truck, Austrian Railway.

CHAPTER IV.

THE MACHINERY DEPARTMENT.—CARE AND MAINTENANCE OF LOCOMOTIVES AND CARS. ARRANGEMENT OF RAILROAD SHOPS AND ROUNDHOUSES.

Before proceeding to discuss the questions that properly come under this chapter head, I may say, in parenthesis, that the varied duties and great responsibilities inseparably attaching to those immediately in charge of the machinery department of railroads, grow each day in the estimation of railway owners and managers. This is because the subject is better understood each day. With the evolution of railroads, it becomes more and more apparent that the machinery department, embracing equipment and shops, must be in charge of those who, by experience, education and mental faculties, are fitted to understand and direct the vast interests involved. In the early history of railroads, men were thought fit to be master mechanics or superintendents of cars if they had been good blacksmiths or master carpenters, respectively. For a long while it was very hard to disabuse the minds of managers of railways of this false impression, but now there is a marked tendency to rank those in charge of the machinery department with the highest operating officers, and to

expect of them corresponding talent. This just distinction is destined to be permanent and to increase, rather than diminish, with the progress of railway development. The questions involved in connection with the equipment and shops of railways, and the vast number of men of varied temperament and ability employed, require men of the highest possible talent and experience to wisely direct. I have not attempted, either in this volume or elsewhere, to enter into anything like a detailed account of the duties and responsibilities of the superior and minor officials of the machinery department. The subject is too complex to be taken up by itself. To understand it, one must understand everything connected with the equipment of railways and, as this is the subject of the present volume, I leave it to the reader himself to judge, as here portrayed, how great and varied must be the responsibilities of those in charge of the machinery of railroads.

The care of the locomotives and cars of railroads after they have been completed is one of the greatest industries of the world. The wear and tear of these vehicles, while largely dependent upon the nature of the roadbed and the speed of trains, are very great under the most favorable circumstances. Exposure and hard usage soon necessitate repairs which multiply until the locomotive or car finally collapses, requiring to be rebuilt or replaced. It may have lasted ten years, even longer, but its final destruction is only a question of time.

The repair and renewal of locomotives and cars require adequate shops, convenient tracks and much costly and complicated machinery. Moreover, the improvements which are daily made in connection with locomotives and cars, add greatly to the outlay of capital connected with shop work.

The force engaged about the shops and roundhouses of railroads constitutes a vast and intelligent army. Its technical skill is of the highest order, and anything that throws light on the construction, care and maintenance of cars and locomotives, it carefully studies. No class of men, it is probable, is more eager to acquire useful knowledge. It was this fact that suggested the necessity of incorporating in the "SCIENCE OF RAILWAYS" a volume devoted to "Railway Equipment," and the organization of shops and the regulation of the forces connected therewith. There are a great many men of talent and enterprise engaged in the machinery department of railroads, but there are few understanding the subject in all its bearings, who can be induced to write down what they know for the benefit of others less favored. The officials connected with this branch of the service are not only very busy, but, like all men of talent and affairs, modest about exploiting their knowledge. Yet there is no one whose opinion is of marked value in regard to the equipment of railroads and the

shop work connected therewith; except those who, by their daily occupation, are familiar with the varied requirements of this branch of the service. Because of this, information, when obtainable from such authoritative source, is invaluable.*

The machinery department of railroads is, as I have already remarked, growing in the estimation of railway owners and managers. It was never so highly esteemed as at this moment. Its great importance impresses itself more and more upon the railway world. We see clearly, with the growth of business, that the highest class of talent is required to manage its great and diversified interests.

The value of a railroad is dependent, it may be said, not only upon the stability of its track, station and train service, but upon the fitness of its locomotives and cars and the efficiency displayed in their construction and care. This branch of the service is one of supreme importance and, as we progress, we see men of higher and higher education, talent and experience, selected to fill its offices. These officials, embracing Superintendents of Motive Power, Master Mechanics, Superintendents of Cars and their assistants, are consulted more than formerly and are better rewarded. Their great usefulness and discretion can no longer be ignored.

* This is why I have sought in every way throughout this volume to supplement what I write with the direct advice and assistance of those who have daily practical knowledge of the workings and needs of the machinery departments of railroads.

It is said that with the introduction of steam in the navy the engineering department thereof has become an adjunct of the greatest possible importance, but because of the oversight of those who are at the head of some of the navy departments of the world, and the opposition of those immediately in charge of the ships (born of prejudice and jealousy), no adequate recognition of the engineering department has occurred, and, in consequence, the navy is much crippled thereby. This can not now be justly said of the machinery department of railroads, or, at least, of all railroads. In early days men skilled in the technicalities of machinery, and especially educated to fill supervisory positions in connection therewith could not be found, and, consequently, railroad companies were compelled to put up with such service as they could secure. This condition of affairs no longer exists. Men are more and more qualifying themselves for position by scientific instruction in polytechnic schools, and elsewhere by private instruction and practical observation and experience. There is, therefore, no longer the clumsiness, ignorance and stupidity displayed as in the first days of railroad operations, when shops were built without reference to continuity of work or the economical handling of machinery, material and men.* To-day, as far as new enterprises are projected, or it is possible to remedy the faults of earlier times, shop facilities are such as to secure expedition and economy.

*This important phase of railway equipment, namely, care and housing of material, I discuss in the volume "Disbursements of Railways."

An adequate description of the care and maintenance of locomotives and cars, while of the greatest possible necessity and value to railroads and to railroad men, is yet a thing unknown, so far as we have anything emanating from those directly engaged in this field. We have many able and valuable books and essays written by those who have been engineers, or who possess great capacity of observation and description, but nothing from the masters themselves—from those who not only understand the forces and principles which underlie the organization of the machinery department, but are actually in direction thereof, because of their talent, experience and worldly knowledge. Such an account as this I have been so fortunate as to obtain through the co-operation I have received in the preparation of this chapter. It is from a gentleman who is everywhere recognized as a potent force in railway operation; a man at once practical and scientific; a philosopher, and yet a daily worker and manager. Because of these varied accomplishments, what he has to say has the force of reflection as well us of practical knowledge. The gentleman I refer to is Mr. Robert Quayle.* My own experience, while considerable and extending over some forty years of service, is not such as to enable me to discuss the subject of machinery authoritatively in all its bearings. There are many things connected with organization and

*President of the American Railway Master Mechanics' Association.

needs, however, which my knowledge makes familiar to me and with which it is not necessary to couple technical information in regard to machinery and its ramifications to make useful. This knowledge, while of little technical value, is yet necessary as a corollary.

The gentleman referred to above who has so kindly come to my aid is, as I have intimated, well known throughout the railway world by superintendents of motive power, master mechanics, superintendents of cars, and others connected with the machinery department of railroads. He has had many years of practical experience, first in connection with the technical details and routine work of the machinery department and afterward in charge of the organization and arrangement of the equipment of a great and well-managed railway. He has not only experience, but talent of a very high order. What he advocates is practicable. This chapter is, moreover, greatly enhanced in value, in my estimation, by the highly practical suggestions it contains from Mr. G. W. Rhodes, generally recognized throughout the world as one of the foremost men connected with the machinery department of railroads. He has charge of such a department for a railroad, comprising some eight thousand miles of line. This, added to his long practical knowledge of details, eminently fits him to judge of the shop needs of railways.

With the foregoing explanations I will proceed, without further introduction, to take up

the subject matter of this chapter. In it I design to point out the methods by which certain fundamental objects connected with the machinery department of railways may be obtained in an efficient and economical manner. In connection with the question of the locomotive, I shall first take up the location of roundhouses and shops, and incidentally, the location of the machinery they contain; afterward, the question of repairs of locomotives while they are in use. Then repairs of a more extended nature will be referred to.

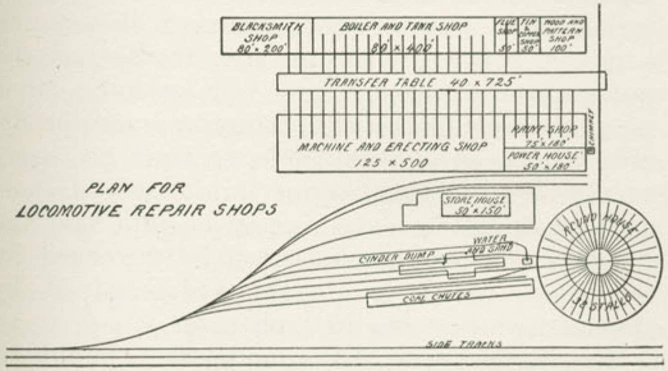
While locomotives may be made to perform efficient service for a long period of time by carefully attending to petty repairs from day to day, sooner or later they wear out and, when this becomes the case, it is necessary to withdraw them from the service for substantial renewals. Under this latter head this chapter treats of the location, design and equipment of repair shops and the organization of labor and the supervisory force connected therewith. Following this it takes up the care and maintenance of cars in the same order, describing first their care and afterward explaining the methods of keeping them in repair while in daily use. This is followed by an account of appliances for renewing or rebuilding cars, including the organization of the shops and the labor and superintendence connected therewith And in connection with these subjects it must not be forgotten that the equipment of a railroad requires constant and minute inspection and daily, even hourly, repair. This watchfulness extends over the whole period during which it is in active use, from the time it is constructed until it is finally worn out. Incidentally, it may also be said that the care and maintenance of the rolling stock of a company require, in order to carry on the work effectively and economically, needed facilities and appliances of the highest order, embracing adequate grounds, suitable buildings and machinery, convenient storehouses, faithful and skilled workmen, and a supervisory force of the highest order. These things are fundamental.

Taking up the subjects which I have briefly summarized, comes first the

Care of Locomotives.—In operating the locomotives of a company, suitable buildings arranged for their shelter must be provided at needed places along the line of road. These must, moreover, be fitted with such appliances as may be necessary to enable those in charge to perform such work on the locomotives housed therein as the necessities of daily service require.

In the United States the buildings I refer to are usually of a circular or partially circular form, and so located as to be readily reached from the main line. They are provided with a turn-table connecting with all the tracks in the house. These buildings because of their shape are known as "roundhouses." Such a house is needed at places where the requirements of the service render it necessary to station engines or

to keep them temporarily, say at the junctions of divisions, at the termini of particular trains and other places where engines must be housed. While the locomotives are thus protected they receive the simple repairs which the exigencies of the service require. So that while these buildings may be called roundhouses and are, in the main, designed simply to house locomotives overnight or temporarily, they are also, in a



The dimensions will, of course, be increased or decreased according to the amount of work to be done.

measure, repair shops, where such appliances are kept in the way of machinery and skilled workmen as the needs of the service require. In view of this, it is proper to call them machine shops.

At important centers there are one or more buildings, apart from the roundhouse, especially provided with the machinery needed for making repairs. In any event, however, many repairs are made in every roundhouse. There it is intended the engine shall be cleaned, inspected and fitted for the road. It is, therefore, it will be seen, a place of the greatest importance in the machinery department.*

When in the suburban service of a railroad locomotives run to several adjacent stations on schedules which necessitate their being held over at two or more points, it may be economical to locate the roundhouse at an intermediate station rather than the terminal, running the engine back and forth between the roundhouse and the points from which it starts. By so doing, labor may be concentrated and, therefore, more profitably employed and at the same time necessary furnishings and accessories minimized. Generally speaking, however, it may be said that the location of roundhouses must be governed by conditions which can only be determined by special investigation in each case.

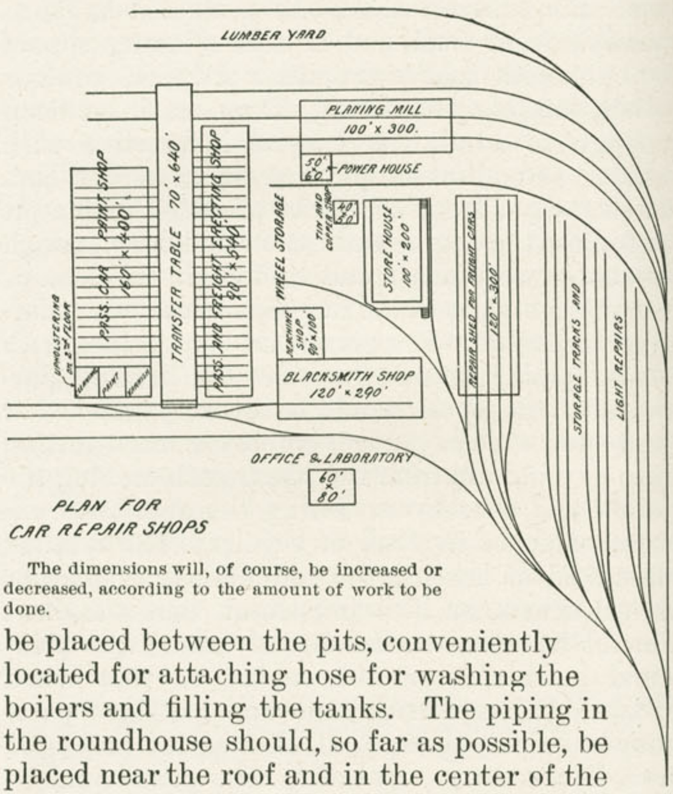
The ground for the roundhouse should be selected with a view to drainage and should be amply protected in this respect. If there are repair shops apart from it, convenient tracks connecting the two should be arranged.

* "In order that the work may be done effectively, it is important that the roundhouse shall be well lighted. This can be done in the daytime by plenty of windows and at night by electric lighting when practicable. The light will be much improved by reflection from whitewashed interiors. As roundhouses contain much valuable property, it will be well to make provision against fires by building fire walls every ten or twenty stalls."—*Mr. G. W. Rhodes.*

The design of the roundhouse and its arrangement give little scope for artistic display. The important things to be considered are first, cost, afterward, expense of maintenance and, finally, convenient and economical arrangement for use. Roundhouses should be protected as far as possible from frost, and in cold climates should be built with that view, either of brick, stone or other suitable substance. They must be deep enough to admit the longest locomotive with tender and allow ample margin at either end. Each stall or track should be provided with a pit as long as the engine and tender and deep enough to enable workmen standing therein to clean or repair such parts of the machine as are not otherwise accessible. The pit should be provided with steam piping around its sides for heating purposes. This piping should be securely fastened or protected so as to prevent employes, when getting into or climbing from the pit, from loosening the joints and thereby rendering the appliance unserviceable or in need of repairs. The method described of heating the roundhouse is superior to all others, as it is important that the heat should be concentrated directly under the principal machinery of the engine, so that when frozen or covered with snow and ice these parts may be quickly thawed out, cleaned and inspected and, if necessary, repaired.* The pits should be

* "In cold climates low, flat roofs are very generally used. Such construction largely reduces the square feet of area which it is necessary to heat."—*Mr. G. W. Rhodes.*

provided with adequate draining facilities and sewer connections. Especial attention should be given to sewerage, also the provision for carrying off the sediment and incrustation from the boilers without blocking the drains. Hydrants should



The dimensions will, of course, be increased or decreased, according to the amount of work to be done.

be placed between the pits, conveniently located for attaching hose for washing the boilers and filling the tanks. The piping in the roundhouse should, so far as possible, be placed near the roof and in the center of the building. The steam pipes, while carefully protected, should be exposed throughout, so as to facilitate inspection and repair.

The floor of the roundhouse is an important matter. It should be built of material that will stand the wear and tear of heavy trucks and the blows received from falling pieces of machinery. It should be sufficiently substantial to resist the pressure of the jacks used in raising the locomotives.

Light may be provided by windows in the rear of the building and, if necessary, by inserting panes of glass in the doors. Skylights, if necessary, may be used. The doors of the roundhouse should open outward. They should also be strong and securely hung. They require to be provided with catches for fastening them when open and holding them when closed. The building should have a substantial roof, so constructed as to evade, as much as possible, the corroding action of the smoke and gases from the locomotives. Funnels for carrying the smoke and gas above the roof will be found valuable devices in this connection.

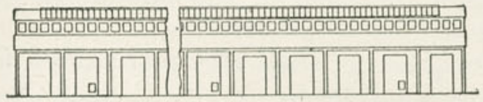
The roundhouse should be equipped with such assortment of wrenches, bars, ratchets, jacks, air motors, tools and work benches as the service requires. Except at very small roundhouses, necessary tools for drilling, turning and planing should be provided. At large roundhouses these should be supplemented by tools for facing valve seats, boring cylinders, drilling out and replacing stay-bolts, and other work of like character incident to daily service. When there is not a central power plant, the roundhouse should be provided with a boiler for generating steam for heating purposes and providing needed power. If very high water pressure is not available, a steam pump of sufficient capacity to afford ample water at high pressure should be provided for boiler washing. The advantages afforded by use of compressed air in connection with roundhouse work make an air compressor a valuable part of the equipment wherever considerable work is done. A sufficient reservoir for air storage should be provided.

Drop pits with power lifts for removing trucks and driving wheels are necessary where much work of this nature is to be performed.* These may be operated to advantage by compressed air.

* "Driving box brasses and journals, it is to be remarked, can only be thoroughly inspected and examined by dropping out the wheels. When round-houses are not equipped with these facilities a thorough inspection of the parts named is neglected, resulting in a continuation of the difficulties with the engine in place of removing them. An engine was recently cut off of an important train on the line under my charge with a hot box. The cellar was removed and the journal examined as well as it could be without going to the expense of jacking the engine up, the roundhouse not being fitted with a drop pit. Nothing was discovered seriously wrong, the cellar was repacked and oiled, and the engine again put into service. The engine continued running hot and it was found its condition was not bettered. The next roundhouse the engine stopped at was fitted with a drop pit, operated by air. It took but a short time to drop the wheels out and make a thorough inspection of both journal and brass. It was then found that the brass had been so badly cut it would be impossible for the engine to run cool until it was equipped with a new brass. The result of this experience was that a drop pit was at once ordered for the roundhouse that was without one. I think pneumatic drop pits for engine drivers and truck wheels should be in every roundhouse on the main line of important roads."—*Mr. G. W. Rhodes.*

Provision should be made at every roundhouse for the stores it is necessary to keep on hand. In small houses space which would otherwise not be used may be utilized for this purpose, but at large and important places a storehouse is needed. This may sometimes be advantageously attached to the buildings. In other cases it will be more convenient to have it apart.

The foreman's office should, generally, connect with or be immediately adjacent to the storeroom. All material requiring protection



SIDE ELEVATION, ERECTING SHOP, LOCOMOTIVE DEPT.

from weather or thieves, excepting oils, should be kept securely locked in the storehouse. At large roundhouses a separate building, as nearly fire-proof as possible and arranged with reservoirs or tanks, should be provided for oils. If located below the level of the ground, the oil may be drawn by pumping it directly from the tanks, or compressed air may be used. The latter is, however, considered preferable. The oil house should be built at a sufficient distance from the other buildings to prevent the fire spreading in the event of a conflagration.†

† For further reference to storing material, etc., see volume "Disbursements of Railways."

A pit in which to dispose of ashes and other refuse of the ash pan should be located near the turn-table; the closer it is the better, so as to prevent, as far as possible, the injury which accrues to the flues by cold air passing over the grates after the fire has been drawn. The clinker pit should be large enough to accommodate all the locomotives using the roundhouse. As the cinders which thus accumulate must be removed, a depressed track, whereon the cars intended for their removal may stand, will be found an economical appliance. It should be so located that by opening the door of the clinker pit the cars may be loaded by gravity.*

The coal house, with its contrivances for supplying locomotives by gravity, the supply of sand and the water tank, while not necessarily appendages of the roundhouse, may be so conveniently situated in its vicinity as to be highly desirable. Local conditions will necessarily govern their location. Care should be taken, however, to so group these supplies that the labor each

END ELEVATION, ERECTING SHOP, LOCOMOTIVE DEPT.

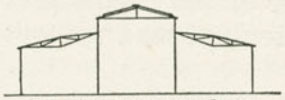
* "At some shops the ashes are handled very economically by the use of air hoists, which avoids the necessity of a depressed track. Portable pans are placed in the clinker pit into which the clinkers and ashes are dumped. These are lifted by air hoists suspended to an overhead traveler and their contents dumped into a car. At some locations, on account of poor drainage, especially in low countries, depressed pits are not practicable. Where air hoists are used the expense of the depressed track may be avoided."—*Mr. G. W. Rhodes.*

requires may be concentrated so as to be utilized to its fullest extent. For instance, the sand and water cranes should be in such relation to each other that the man in charge of the engine may take on a supply of both water and sand without moving the engine.

Methods of organization covering the care of locomotives merge with those connected with petty repairs. The force engaged consists of bodies of skilled and unskilled workmen in and about the roundhouse. The skilled workmen comprise machinists and boilermakers and their helpers, respectively. The unskilled workmen embrace wipers and laborers. At large roundhouses the boilerwashers and helpers may constitute a distinct body. All receive instructions from, and are responsible to, the foreman in charge. The latter is subordinate to the master mechanic, and usually reports to him.

If the number of roundhouses on a division is large, they may be grouped. In such case the foreman of each roundhouse will, perhaps, report to and receive instructions from a general foreman for the section, who, in turn, will report to the master mechanic.

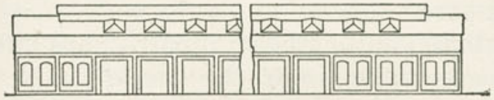
Repairs of Locomotives.—When locomotives become much worn with service or, in other words, need many repairs, the limited facilities of the roundhouse will not suffice. The engine must then be withdrawn from service and taken to the general repair shops where facilities are provided for such work. It is oftentimes difficult to determine just when this transfer should



CROSS SECTION, ERECTING SHOP, LOCOMOTIVE DEPT.

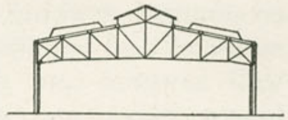
be made. Much depends upon the character of the service in which the locomotive is engaged; something upon the character of the repairs. If life or property is not jeopardized by continued use of the locomotive, it becomes simply a question of dollars and cents: if saving may be effected by making the repairs, they should be made forthwith; otherwise not. The nature of the water supply determines, very largely, the length of time an engine can be kept in service. If the water is unsuitable, its impurities, precipitated by heat, accumulate in the flues and upon the sheets of the boiler; thus it may be necessary to remove the flues as often as two or three times a year, whereas, if the water is free from impurities, the flues may last for ten years. Therefore, in order to prolong the usefulness of the flues and boiler sheets, and thus minimize cost, pure water should be obtained whenever possible. First cost is unimportant compared with expense of maintenance afterward; yet unfit water is often obtained by sinking wells, or other device, in order to save present outlay, when by a little larger expenditure a permanent supply of good water could be obtained from a running stream, or in some other way.

Much is to be said in reference to the character of the service in which engines are engaged. In the early experience of railroads in the United States small engines were able to haul heavy trains, because the speed was slow and stops infrequent. Now, however, the speed of trains has been increased, while the growth of the country and with it the towns along the line of railroads necessitate more frequent stops. This is true of all new countries and of many old ones. Heavier



SIDE ELEVATION, BOILER, TIN, FLUE, WOOD & BLACKSMITH SHOPS. LOCOMOTIVE DEPT.

END ELEVATION



SECTION

locomotives have thus become necessary with the result that the durability of the machinery is lessened, as it wears out more quickly in heavy service where a large amount of coal is necessarily consumed than where the contrary is the case.

Judicious location of the repair shops for locomotives requires consideration of many varied interests. Among those to be mentioned are accessibility to locomotives to be repaired; proximity to skilled and unskilled labor; facilities for obtaining material and supplies; and, finally, the securing of adequate grounds for buildings, yards and tracks. In this connection the growth of the service, i. e., future needs, must be taken into account.

There are two kinds of repair shops: those arranged for heavy work, such as the thorough overhauling of a locomotive requires, and those for lighter repairs. As the arrangement of both is generally similar, i. e., differs only in degree, only those designed for extensive repairs are considered here.

The location of these repair shops must be easily accessible from the main track. The shops must also have ample yard room with switching tracks suitable for convenient and economical working, including the handling of material and supplies. The grounds should be well sewered and drained, and provided with fences, gates, etc., so they may be completely enclosed. The terminus of a division or the common terminus of several divisions of a road is the natural place for general repair shops such as those described.

As it sometimes becomes necessary to transfer to the roundhouse the skilled labor of the repair shop, it is desirable that the roundhouse should be located as near to the repair shop as practicable.

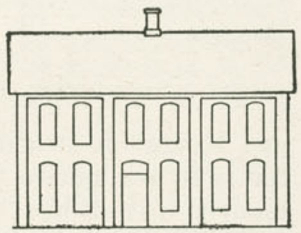
Repair shops, such as those referred to, necessarily consist of a number of buildings in which different parts of the work are done. The arrangement and location of the buildings require

careful study. The following observations thereon are offered as tending to reduce cost of repairs by minimizing labor and loss of time in handling material and in making repairs.

The largest and most important building of the group is the machine and erecting shop. In the case of very large plants the erecting building is separate from the machine shop. In other cases the two are placed under one roof. The building, or buildings, must be located so as to be conveniently reached from other shops.

The boiler shop should be located in the immediate vicinity of the erecting shop, so that the boilers may be moved conveniently from one building to the other.

The tank shop, i. e., the shop for the repair of the water tanks of locomotives, should be a part of, or immediately adjacent to, the boiler shop, so that work of a similar nature may be concentrated as much as possible.



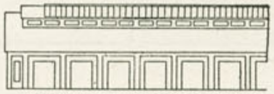
SIDE ELEVATION, TIN AND COPPER SHOP

The forge and blacksmith shops are usually consolidated under one roof. The location should be convenient to the machine and erecting shop and the boiler and tank shops.

The paint shop should be conveniently located for moving locomotives and tenders from the erecting shop. It should be provided with tracks leading to the roundhouse or main line.*

It is, as a rule, advantageous to locate the foundry some distance from the other buildings so as to have room for supplies stored in its vicinity. The heavier castings should be stored conveniently between the foundry and the machine shop, where the castings are to be used. In some cases it may be better to store them near the general storehouse. This latter should be conveniently located for the distribution of material to the shops with as little expenditure of time and labor as possible. Spacious platforms and other conveniences should be provided to facilitate the transfer of castings from one part of the house to another.

If the shops are very extensive they should have a power plant. It should be as centrally located as possible. How far this will be practicable, like other problems, can only be determined on the spot. The boilers should, however, be grouped in one building, and steam for heating purposes distributed directly to the entire plant, according to the best modern inventions.


SIDE ELEVATION, PASSENGER AND FREIGHT CAR REPAIR SHOP

* "Much less time and care are spent on locomotive painting than formerly, so much so that many important lines do not consider a locomotive paint shop essential. The cabs are built and painted in the coach shop, and the tanks and engines in the machine shops, as they are being completed about in the same way as is generally followed in contract shops."—*Mr. G. W. Rhodes.*

A suitable engine, able to furnish the amount of power needed, should form a part of every power plant for the purpose of driving the dynamos which generate the electrical force used to operate the machinery of each shop. The cost of attendance may thus be reduced.*

The design for shop buildings should, in a general way, follow the lines accepted as best for such plants. The foundations and walls should be strong and of well-laid masonry, with pilasters and strengthening buttresses wherever necessary to carry the load attached to the roof, or needed to support the tracks for traveling cranes. The walls should be sufficiently high to afford headway under the cranes. As abundance of light is needed in every shop the windows and skylights should be ample.

When there are no traveling cranes, the roof trusses should be strong over the entire floor space, as it is often advantageous to attach to the roof appliances which will greatly increase the weight on the trusses. The roof of the building should be substantial, durable and as nearly fire-proof as possible. Slate is preferable.

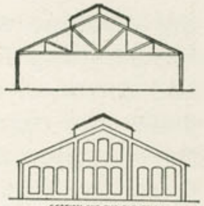
The foregoing applies with more or less force to every building connected with the repair of locomotives. Each building, however, possesses

* "Owing to improvements in the working parts of stationary engines, improvements in continuous sight-feed lubricators, etc., it has become the practice in shops of even considerable importance to do away with the stationary engineer and to make the supervision of the stationary engine part of the duties of the leading fireman."—*Mr. G. W. Rhodes.*

certain features peculiar to itself. These may now be taken up.

In planning the erecting and machine shop, either of two plans may be followed. Each has certain advantages or disadvantages, depending largely upon climatic conditions. Both designs, however, contemplate a building varying in width from one hundred to one hundred and twenty-five feet, arranged with a machine shop on one side of a line drawn lengthwise through the center, and an erecting shop on the other side. The length of the building may vary to suit special requirements, but one end should be so located that it may be extended when necessary. In one design tracks run at right angles to the length of the shop. They are spaced from twenty-two to twenty-five feet apart from center to center of track. Each track is provided with a pit deep enough to enable workmen to perform the work required on the machinery and fittings from beneath the engines. Cranes sufficient to lift the heaviest locomotives traverse the entire length of the shop immediately over the pits. This design requires a transfer table close to and extending lengthwise of the shop, accessible to tracks connected with the main line, for moving engines to and from the erecting shop. In the other design the erecting tracks run lengthwise of the shop. One track is usually placed on each side of the allotted floor space, with another track extending lengthwise through the center, upon which locomotives enter and leave the

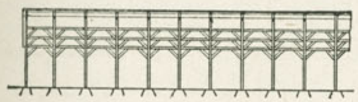
shop. The same provision is made for traveling cranes as in the first instance, so that locomotives may be lifted from the center track to the erecting tracks, and vice versa, as well as on and off their wheels. Pits extending the entire length of the erecting tracks are required as in the other case.



SECTION AND END ELEVATION
PASSENGER AND FREIGHT CAR REPAIR SHOP

When scrap furnaces are used, the shop boilers may be placed immediately above the same in order to utilize the heat for the purpose of generating the steam required in operating the steam hammers and for other purposes. If coal is used for fuel, the furnace may be fed through a chute connecting directly with the cars on which the supply is loaded. If oil is used in the furnace, the supply should be in close proximity to the building, so that the distance the oil will have to flow may be reduced as much as possible.

A boiler shop rarely needs to be more than eighty feet wide. The height of the walls should be the same as for the erecting shop. The arrangement of tracks in the boiler shop should also be the same as in the erecting shop. Adequate crane facilities for moving and turning boilers are required. The boiler shop should be equipped with a hydraulic rivet-



LONGITUDINAL SECTION, REPAIR SHED FOR FREIGHT CARS.

ing machine with accumulator* and tower-lift† for handling locomotive boilers, with a machine and tower, or extension, which will permit a lift under the crane that will support the boiler of the riveting machine at a height of at least thirty-five feet in the clear; and an oil furnace for annealing.‡

The blacksmith shop may, if thought desirable, be arranged with a forge shop in an annex, or "L." In this way facilities for storing material without interfering with ready access to the blacksmith shop may be secured. The walls of the building should be substantially constructed, with large openings for ingress and egress. The light should be abundant. Capacious ventilators should be inserted in the roof. The trusses should be strong enough to support such posts, cranes, overhead runways or tracks for transferring material as may be necessary.

* An accumulator is a long cylinder in which a piston is set in vertical position, the cylinder being attached to a large iron drum filled with scrap iron, sand or other heavy material in order to obtain the pressure necessary to operate the machinery. By means of a pump, liquid is forced into the cylinder, which causes the piston and the drum containing the load to rise, thereby obtaining the required pressure.

† A tower-lift is a long cylinder with piston coupled to a crane at the top of a tower, directly over the machine, and is used for holding boilers in suspension while being riveted and in handling other work to be performed at the machine.

‡ The annealing furnace is a large furnace with a door extending across the entire front, in which boiler plates are heated to a red heat and allowed to cool before being placed into the boiler in order to make the metal more pliable.

Among the prime requisites for a paint shop are light, heat and ventilation. "The last two are best accomplished by what is known as the overhead hot-air system. The large fan which forces the hot air through the pipes in winter is available for inducing a circulation of air in the shops in summer. The best results in drying in a paint shop are obtained when the air circulates freely."* Besides the windows in the walls of the building, the skylights should be fitted into the roof as may be consistent with good construction. The ventilators should be provided with adjustable appliances for preventing waste of heat. The floor should be smooth and made of cement or similar substance so that it may be easily washed and quickly drained.

The foundry building should be substantially built and arranged for traveling cranes when necessary. The core rooms and core ovens should be convenient to each other and the latter provided with adequate heating facilities.†

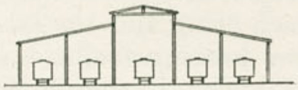
Where there is a brass foundry, it should be adjacent to the main building and should be provided with a good chimney with which the brass melting furnaces should be connected. The cupolas should be located outside of the side

* Mr. G. W. Rhodes.

† The core room is a room in which cores are made, usually of sand, for the castings made in the foundry. In order that the cores may not break easily or run off easily when molten metal is poured around them, they are baked hard in an iron oven, heated by a mild fire. The oven is provided with iron shelves upon which the small cores are placed to be baked.

wall near the center of the length of the building. Provision should also be made for an ample charging floor and elevator.* "In constructing a brass foundry it should be designed so that the raw product will come in at one end and the finished brass, ready to be loaded into a car and shipped away, come out at the other. This can be accomplished by having the heating furnaces, molders' floor, rattler, grinder, boring machines and lead-lining machines follow each other in close succession so that the completion of each operation places the brasses without additional handling into a position available for the next operation."†

A good form of storehouse is a building two stories in height. To facilitate loading and unloading material and supplies the lower floor should be elevated to a level with the floor of a freight car. The building should be surrounded by a platform of suitable width on a level with the floor, the platform inclining to the ground at the ends of the structure. Enough



END ELEVATION, REPAIR SHED FOR FREIGHT CARS.

* The cupola referred to is practically a cylindrical furnace made of sheet-iron and lined with fire brick, which usually extends up through the roof of the building so as to allow the free escape of gases and flame. The charging or filling door is near the top, through which all the iron and fuel are fed. The charging floor is a floor built conveniently to the charging door, on which the fuel, iron and such other material as is used in the process of melting and making iron or steel are placed.

† Mr. G. W. Rhodes.

doors should be provided for convenient use. The second story floor should be well supported in order to bear its burden of stores. The building should be fitted with one or more elevators. Good light is necessary and the building should be provided with bins, racks, and other necessary appliances so arranged as to interfere with the light as little as possible. The first floor and the supports for the second floor should rest on a good foundation of masonry.

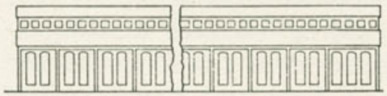
The power house, containing the boilers and other accessories, including engines and dynamos, should be designed with reference to the economical handling of fuel and ashes.* The building should be ample, but provision should be made for extending it when necessary. It should be located with reference to the easy and economical distribution of steam for heating and (if required) power purposes. The room in which the boilers are located should be well ventilated, and the engine and dynamo rooms provided with a high roof and good light.

The equipment of a shop requires careful study in order that it may meet practical and scientific needs. The tools should be of improved design and construction, though first cost may be considerably enhanced thereby. The arrangement must be such that work passing through the shop

* "Fuel, when unloaded, should pass into a hopper-formed receptacle, constructed so it will supply itself sufficiently and may be passed with one additional handling into an automatic 'feed,' or, where automatic feeds are not used, shoveled into the fire box without additional handling."—*Mr. G. W. Rhodes.*

will require to be moved as little as possible and the least possible distance. If the tools are not arranged with this view, much unnecessary expense will be incurred thereby for labor and on other accounts.

Traveling and swinging cranes should be provided in all shops where needed. The efficiency of traveling cranes may be greatly enhanced by equipping them with electric motors. Overhead runways* should also be introduced in shops when they can be utilized. Pneumatic hoists (lifting machines operated by compressed air) suspended from trolleys (trucks), the latter being mounted on overhead runways, are also useful in shops. Careful estimates require to be made, however, of the expense attending the use of power cranes, including cost, before introducing them, lest their practical working value does not justify the outlay.†



SIDE ELEVATION PLANING MILL CAR DEPT

* Tracks for lifting and moving machinery and other articles by pulleys.

†"A useful form to measure the value of such improvements may be mapped out as follows:

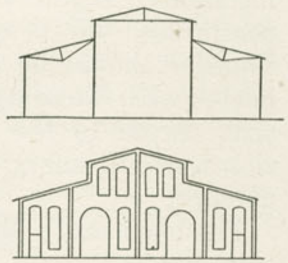
HANDLING CINDERS AT ROUNDHOUSE.

	Value.	Wages Per Month.	Saving Per Month.	Saving Capitalized at 6 per cent.	Number of Men Employed.	Saving Per Month.
Ash Pit (Old Method)...		$175.20	....	....	10	....
Ash Hoist (New Method)...	$674.78	288.00	$187.20	$37,440.00	6	40.00%"

—*Mr. G. W. Rhodes.*

The heating appliances of shops should be so designed and arranged as to accomplish in the most satisfactory and economical manner possible the object intended, namely, the free and full circulation of the heated air throughout the space where it is needed. In the case of steam heat especial care is required in order to derive the full benefit from the steam—in other words, the utility of the steam in the pipes should be exhausted before introducing a new supply.

A drop table—a machine for removing driving and truck wheels from locomotives going into the shop and replacing them on engines going out—should be located somewhere on the track by which the engine enters and leaves the erecting room. It should also be easy of access to the machine shop. At the drop table, a lye tank for cleaning the material stripped from the locomotives, should be provided, in order that the material may be cleaned before being taken to the machine shop. If the tracks run lengthwise of the erecting shop, the drop table is not necessary, as the engine may be lifted directly from its wheels by the traveling cranes.



SECTION & END ELEVATION, PLANING MILL.

The machinery for cleaning the boiler tubes of the locomotive should be located at some place easily accessible by push (small platform) cars from the erecting shop tracks. The arrangement of the cutting off, scarfing, welding and tube testing machinery, should be such as to reduce the labor of handling to a minimum.*

Economical operation requires that power facilities shall be provided at every point in a shop where it is required to drive tools, such as drills, taps, reamers, calking and chipping implements, cylinder boring bars, facing and sand-papering machines, and so on. This work may be performed by compressed air or electricity more satisfactorily than in any other way.

Portable riveting machinery should be provided in the boiler shop and, if new boiler work is done to any extent, an hydraulic riveting plant is highly desirable.

An economical air compressor of sufficient capacity is necessary to the equipment of the locomotive repair shop. If a large amount of compressed air is required, a storage reservoir therefor should be located near the shop, connected with the compressor by piping of adequate size. Leaks in the piping and reservoirs occasion waste of energy and are consequently to be avoided.

The blacksmith shop should be equipped with

*"This is accomplished by concentrating operations so that the finishing of one operation places the material in a position for commencing the next operation without intermediate handling."—*Mr. G. W. Rhodes.*

a bulldozer,* forging press† and drop hammer, if needs demand, or with any one of the three that may be profitably used. Attention given to establishing standard details of devices for replacing hand work in forging by machinery fitted with proper dies, will also prove profitable.

Heating furnaces (both large and small) should be designed and adjusted so as to give the best possible results in the way of abundant, rapid and uniform heating. Thus, much valuable time may be lost if the furnace in the blacksmith shop is not adequate to keep the hammersmiths going. Especial attention should be given to the construction and arrangement of furnaces. The use of oil for fuel may be more economical than coal, not as regards relative quantity consumed, but in increased work accomplished.


SIDE ELEVATION, BLACKSMITH SHOP CAR DEPT

The equipment of the power plant should be selected and arranged after a careful study of surrounding conditions. It should be of the highest type. When impure water must be used,

*A bulldozer consists of a heavy bed with a strong cross head to which suitable dies and formers are secured, by which bar iron is pressed into different shapes.

†A forging press is a machine for forging iron, when heated to a white heat, into any shape which dies can be made to squeeze it into. The work is usually done by one operation of the machine.

provision should be made for turning the water, after condensation, into sumps (reservoirs).

The transfer tables necessary in repair shops may, like traveling cranes, be profitably operated by electric motors. They should be strongly built so as to reduce cost of maintenance.

The labor in the repair shops of railroads, like that in roundhouses, comprises skilled workmen as well as a body of unskilled laborers. It, however, includes a greater variety of tradesmen and, unlike roundhouse work, affords opportunity for employing apprentices in various lines of mechanical work. A practicable plan of organization of labor in this important division of mechanical work may be described as follows:

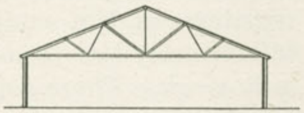
The workmen in each shop should report to a common foreman from whom they receive instructions. If the works are not too extended, one foreman for each shop will be sufficient. The foremen of the various shops should report to a general foreman, who thus becomes responsible for the practical operation of the entire works. He is immediately subordinate to the master mechanic. Where the works are very extended, the foreman of each shop has assistant foremen, who have charge of particular parts of the work in hand. For example, it may be desirable to have two foremen in the machine

END ELEVATION. BLACKSMITH SHOP. CAR DEPT

and erecting shop—one in charge of machine work, the other in charge of erecting work. In subordination to these will be gang foremen on the erecting floor, each having charge of a body of workmen and personally looking after a certain number of erecting tracks. The work in the machine shop may also, in many cases, be divided between two or more foremen, each being responsible for the output, tools and men, of a certain portion of the shop. There should be a foreman in charge of hand tools, standard gauges, and so on. He may be responsible to the foreman of the machine shop, and is held accountable for the safe keeping and maintenance of the tools under his charge. He requires such workmen as may be necessary, also the machine tools, such as lathes, milling machines, grinders, and so on, needed for keeping the tools in repair.

In giving out implements, a simple but effective plan is to require a numbered ticket to be deposited by the workman who receives the tool. When he returns the implement, the ticket he has deposited is given up to him. This avoids book-keeping and yet is an effective safeguard.

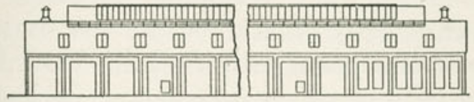
Arrangements are also necessary for keeping the time of men. The system must be effective, first, that every man may receive what is due him and, second, that he shall not be credited with time he has not worked. The "check" system



CROSS SECTION BLACKSMITH SHOP

may be used in this connection to advantage. Under this plan each man is given a number. He passes through the check room when commencing work in the morning and afternoon, at which times he is given a metal check corresponding to his number. The checks used in the forenoon are marked "A.M.", those in the afternoon "P.M." No checks are given out after the hour for commencing work has passed. If a man is late, he receives what may be termed a "late" slip from his foreman in lieu of a check. It shows the time he commenced work. Each workman is visited twice a day by the timekeeper, who collects the checks and slips, and at the same time he also obtains the data he will require to enable him to distribute the labor, i. e., charge it to the account upon which the work is performed. Another method of keeping time may be called the "clock" system. Each employe has a number, as in the check system. He is given a key corresponding with his number, and when commencing work he registers his number and the time of day by inserting the key in a clock provided for that purpose; upon quitting work he passes through the check room and registers in the same manner: the clock thus tells exactly the time he began and the time he quit work. These references in regard to keeping the time of men, it will be understood, are general and wholly superficial. The subject is one of importance because of the vast number of men employed, and the necessity that methods

should be adequate thereto. These methods, it is unnecessary to say while they may be general, yet require modifications to meet particular circumstances and, in any case, the utmost elaboration. The subject does not properly come up



SIDE ELEVATION PASSENGER CAR PAINT SHOP

here. It is discussed in the volume "Disbursements of Railways," in which the whole question, including such matters as keeping the time of men, reporting same, pay-rolls, distribution of work, and the accounts, statements and statistics connected therewith, is explained.

The plan outlined for organizing the labor of the locomotive repair shops contemplates careful and constant supervision. If, however, the work is done by the piece instead of by the hour, inspection of it when completed becomes necessary in order to insure satisfactory work and determine the amount due the laborer. If their duties permit, the foremen usually do the inspecting; in other cases inspectors are employed in the different shops. They are responsible to the foreman for the character of the work.

Care of Cars.—Cars, unlike locomotives, are too often not kept under cover, but placed on open tracks spaced and conveniently located for storing and light repairing. They are called repair tracks. These tracks are located at the terminals of the road and near the car repair shops, as convenience and economy dictate. If for freight cars, they should be in the immediate vicinity of the principal switching yard, because there usually the cars which are in bad order are to be found. If the repair track is for passenger cars, it should be near the storage yard for such cars and arranged conveniently for switching cars to and from the latter. Repair tracks thus located will minimize the cost of transferring cars to and from trains and avoid, as well, unnecessary delay in other directions.

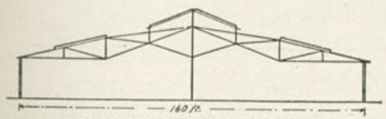
Repair tracks are so spaced as to permit ample room for workmen and afford adequate facilities for handling the implements and material needed in making the repairs.

As the fluctuations of traffic will, in a majority of cases, necessitate frequent rearrangement of the repair tracks, they should be located with this thought in view. This is true also of the buildings necessary in connection with these tracks. The buildings are rather storehouses than shops. They are required for storing tools and such supplies as would be damaged by exposure to the weather or would be likely to be stolen if left unprotected. The buildings should

also afford facilities for storing wheels and axles and a supply of oils. They should be provided with convenient benches for working in metals and wood. Compressed air and convenient connections for testing air brakes are also required in connection with these tracks.

END ELEVATION. PASSENGER CAR PAINT SHOP

In caring for passenger cars, ample facilities for cleaning the cars inside and out are needed. This necessitates hot and cold water. Compressed air affords a convenient and economical method of cleaning upholstery, carpets and involved wood work. This and the uses to which compressed air is put in connection with the air brakes require that repair tracks should be supplied with it. If possible, the repair yards should be located near the roundhouse or machine shops so that steam, compressed air and oil supplies may be obtained therefrom. Air jacks are another convenience which may be advantageously used. When steam is used for heating cars, a supply is required in the yard so that the cars may be warmed before being put into the train. If conveniently located, this supply may be most economically obtained from the roundhouse or machine shop.

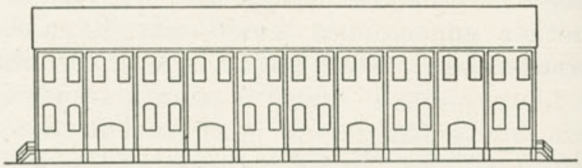


CROSS SECTION. PASSENGER CAR PAINT SHOP

The articles required in making petty repairs to cars are obtained from the nearest storehouse, and in order that work may be done effectively and the cost of labor reduced to the minimum, standard details of car construction are required to be established and maintained.

Stations are established at junctions with other roads and at convenient intervals along a line for the purpose of making such light repairs as the needs of the service demand. Inspectors at these points examine every car in transit with a view to discovering and correcting defects, those requiring repairs not provided for at the inspecting station being sent to the general shops or repair tracks.

The organization that looks after the care of cars may be separated from that provided for repairs and renewals. The service is divided into skilled and unskilled labor, like that for locomo-



SIDE ELEVATION. STORE HOUSE. CAR DEPT.

tives. It is employed in and about the repair yards and is made up of car repairers, inspectors and laborers, including cleaners. These report to and receive instructions from the foreman. The latter is directly subordinate to the superin-

tendent of cars or the master mechanic; in some cases to a general foreman who reports to the general officer in charge.

The supervisory force for the care of cars is generally similar to that for locomotives; in one case it is over car repairers, in the other over roundhouse employes.

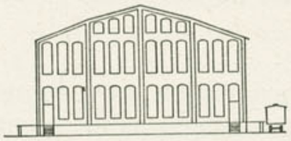
Repairs of Cars.—The principles governing the repairs of locomotives as distinguished from their care also apply, generally, to cars. In the case of the latter, however, where climatic conditions permit, repair sheds with only a roof covering are often made to answer the purpose of more enclosed buildings.

It is desirable, when practicable, that the repair shops for cars and locomotives should be contiguous. The advantages of combining the two plants are too valuable to be overlooked and far outweigh any disadvantages that such union engenders. In what follows it is assumed the buildings comprising the two kinds of work are located in convenient, neighborly relation.

The car repair shops may be said, briefly, to comprise a planing mill, erecting shop for passenger cars, erecting shop for freight cars, passenger car paint shop, freight car paint shop, blacksmith and forge shop.* The storehouse is general.

*If the road is a small one, these buildings will be consolidated to conform to actual needs. Indeed, this adaptability of the plant to what is required by local conditions will occur in every branch of the service. My description in this chapter may be said to apply to roads of maximum size in 1899.

The planing mill must be easily accessible to the lumber yard and dry kiln. At the other extremity of the building the finished material is distributed to the erecting shops. It should also be convenient to the power house, as the planing mill makes large demands in this respect.



END ELEVATION, STORE HOUSE, CAR DEPT.

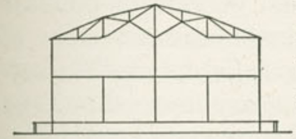
It is thought the passenger car erecting shop, the freight car erecting shop, and the paint shops may be advantageously located parallel to each other, yet separated sufficiently for a transfer table to be placed between them. The dimensions of the transfer tables must be sufficient to hold cars of the maximum length.

The machine shop, blacksmith shop and forge shop may be consolidated under one roof, but should be separated by permanent partitions of masonry running parallel with the end walls. This building should be located so that it may be easily reached with cars loaded with material. Provision for storing car wheels, mounted on axles, and unmounted, should be made near the machine shop.

In that part of the machine shop contiguous to the blacksmith shop, bins and racks should be provided for storing damaged articles, such as bolts and rods, so that they may be repaired and made serviceable in the blacksmith shop with the least expense for handling.

Fuel supplies should be of suitable nature and conveniently located for use.

It is thought that the storehouse serving in common the locomotive and car departments should be located with reference to the convenient handling of material for the latter rather than the former. This is true also of the location of the power plant. Owing to the large amount of power required in the planing mill, the necessities of this building require that the power should be located as near to it as possible.



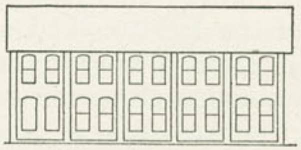
CROSS SECTION STORE HOUSE, CAR DEPT.

The buildings of the car department should be well lighted and ventilated. This is easier of accomplishment than in the case of locomotives, as the machinery is lighter and the dirt and soot less.

The walls of the car repair shops need not be of heavy construction, as it is not necessary to provide for traveling cranes. They should, however, be substantial and covered with a well-braced, durable roof.

The floors of the machine shop, erecting shop and planing mill should be substantial and adapted to resist the wear and tear inseparable from the handling of heavy material. The floor of the paint shop should be of cement, or like substance, finished with a smooth surface and provided with good drainage and sewerage facilities.

The planing mill may be built two stories in height, the upper floor being fitted with machinery for use by cabinet and patternmakers. Both floors should be well lighted and ventilated. The removal of the sawdust and shavings by what is known as the exhaust process of conveyance makes ventilation and cleanliness easier of accomplishment. The second story floor should be well braced and sufficiently strong to carry the shafting for the machinery on the lower floor without serious vibration.



Office and Laboratory.

The erecting and paint shops should be provided with movable platforms and racks for use as scaffolding in working on the upper parts of the cars.

A paint and oil stock room for daily current supplies should be located conveniently to the paint shops. It should be fireproof and kept scrupulously clean.

An upholstery room is necessary in or near the passenger car shop. It must contain facilities for upholstering, dyeing, repairing curtains, hangings, linen, bedding, and so on. Compressed air will be found useful and economical in renovating curtains, cushions and carpets. It may also be found desirable to do electroplating work in this branch of the department.

The equipment of the planing mill and car shops requires to be handled with a view to

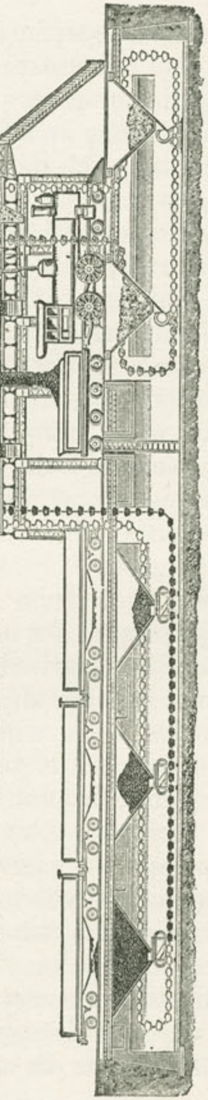
securing the greatest results with the least outlay. This refers both to the nature of the tools used and their arrangement and care. The subject is one of supreme importance and, because of the improvements occurring each day, requires constant attention.

Pneumatic hoists suspended on trolleys operated on overhead runways should be provided when circumstances warrant it. These hoists may also be used to advantage in handling trucks, wheels, axles, and so on.

Office and Laboratory.

Portable air-jacks with sufficient capacity to raise one-half the weight of a car—or more if need be—will also be found to be convenient and labor-saving devices.

The repair tracks should be provided with ample yard room, arranged for making repairs on such cars as may be handled to advantage out of doors. A good arrangement of tracks is thought to be in pairs, with wider spacing between each group of two so as to facilitate the handling of material, supplies and tools by workmen. The ground between the repair tracks should be suitably paved. A narrow gauge track should be laid between each pair of repair tracks for handling heavy material, wheels, truck timbers and drawbars on push cars. "With suitable turntables this narrow gauge track may be connected through the car machine shop, blacksmith shop and storehouse, so as to allow the raw



Locomotive Supply Station. This plan is arranged so as to coal, sand, water, and dump the ashes of four locomotives simultaneously. The coal, sand and ashes are carried in pockets, so arranged that when the engine stands in position the coaling chute comes over the tender and the sand over the sand box. The fire box of the locomotive is immediately over a hopper into which the ashes are dumped.

product from the store to be transferred direct to the blacksmith fire or to the machine shop without additional handling. By using an empty vehicle in connection with the loaded vehicle the raw material may be passed from the loaded vehicle to the machine and from the machine to the empty vehicle, thus avoiding the extra handling which takes place when the material is thrown on the floor from the machine."*

The labor organization of the car repair shops is the same as that noted for repairs of locomotives. All workmen report to gang foremen; these latter usually to

* Mr. G. W. Rhodes.

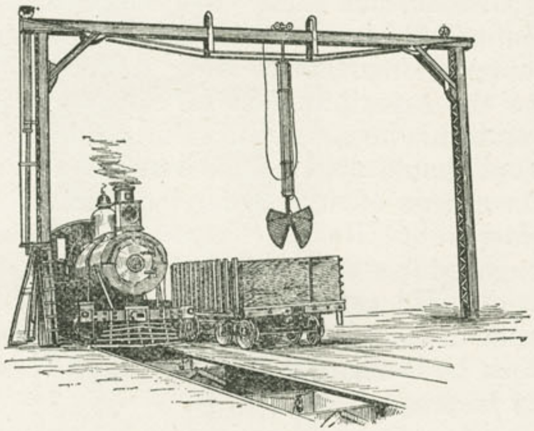
departmental foremen. These in turn report to a general foreman who is responsible to the superintendent of cars or the master mechanic, as the case may be.

In general, local master mechanics have charge of the repair of locomotives and cars on the various divisions of a road: all these divisional officers report to the heads of the car and mechanical departments as their work suggests, to the superintendent of motive power (general master mechanic) on matters relating to locomotives, and to the superintendent of cars on matters relating to his department. The machinery department should also include a mechanical engineer in charge of designs for locomotives, cars, machinery, etc. He has charge of the draughtsmen engaged in work connected therewith, drawings, etc. He reports to the general master mechanic or superintendent of cars, according to the work he is engaged upon, or to either solely, as may be prescribed.

A well-appointed physical and chemical laboratory, equipped with suitable machinery and fittings for making physical and chemical tests of iron, steel, springs and so on, and chemical tests of other materials, such as oils, paints, water, etc., is a necessary accessory of the machinery department of a railroad.

The laboratory should be in charge of an engineer of tests. He will require such assistants as may be necessary to make tests and analyses promptly, and also to inspect such material as car wheels, tires, axles, round and bar iron, steel, boiler plate, etc., all of which kinds of supplies should be bought under specifications.

If a special building is prepared for the laboratory, it may be built two stories high, with the draughting, blue printing and mechanical engineer's office on the second floor.



Pneumatic Hoist for Emptying Clinker or Ash Pits.

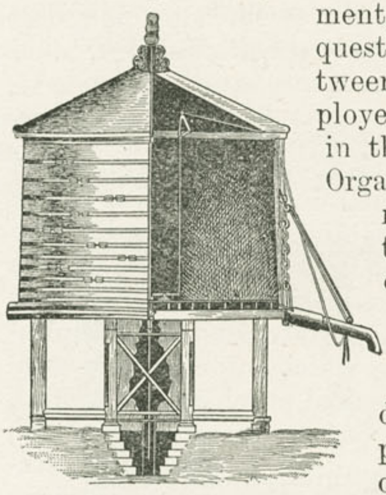
The building used for a laboratory will afford, in many cases, desirable headquarters. Here may be grouped the offices of superintendent of motive power (general master mechanic) and superintendent of cars, with their assistants and clerical forces. These varied and important uses require that the building should be centrally located, ample, well lighted and heated, and carefully ventilated. This association of different offices

in one building near to valuable sources of information will tend much to simplify business and expedite work. It renders co-operation easier and, therefore, more likely to occur.*

Important features which relate to shop and attendant work are those questions connected with the handling of material and keeping of the time of workmen and others. In regard to the first, it is referred to very fully in one of the accompanying volumes entitled "Disbursements of Railways." I have there discussed the disciplinary and other questions which enter into the careful, prudent and economical purchase of material, its inspection when bought, its care afterward, its disbursement in connection with the operations of a road, and, finally, the accounting involved, embracing, among other things, the charging of the material to the thing upon which it is expended.

*"The concentration of offices, in my judgment, is just as important as the grouping of various parts of the work so as to avoid the labor which will occur if they are separated. The introduction of telephones has made this grouping of offices perfectly practicable. With a good shop telephone system each head of a department can be in close communication with his various shop foremen, and it is a great advantage in having the head men in the same building. A central building of this kind should always have a convenient meeting room. We believe that the most economical management of railroads is where there is the closest co-operation of departments. This co-operation is best accomplished by periodical meetings. The same benefit that the head officials obtain by such meetings, subordinates obtain."—*Mr. G. W. Rhodes.*

In regard to the principles which govern those connected generally with the machinery department, so far as relates to questions of labor as between employer and employee they are discussed in the volume "Railway Organization." Other and more practical features, such as those connected with the keeping of the time of employees, payment of wages, distribution of the pay-roll to the various accounts upon which the labor has been expended, are discussed in the volume on Disbursements.



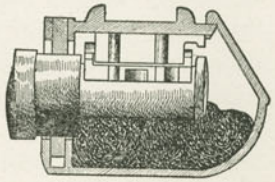
Water Tank.*

Many things of the greatest possible importance, as everyone recognizes, enter into questions of labor. In the first place, the principles which govern it, as between employer and employe, must be rightly understood by both, in order that justice may be done and neither party suffer through ignorance or inadvertence. I have taken up this phase of the subject at considerable length in the book referred to above and, while I feel that I have not been able to do it justice, I have endeavored to throw such light on it as my experience and research enable me to do.

*The best practice, at terminals and water stations, is to erect a tank similar to this illustration, only higher, or an iron standpipe, at a distance from the track and at a considerable elevation. Connection is then made thereto with water-cranes or "penstocks," located on convenient points of the yards. Thus a large point will have a complete waterworks system supplied from one reservoir, instead of employing several tanks, like the illustration, which render the grounds unsightly, take up valuable trackage space and obscure the vision, if on curves.

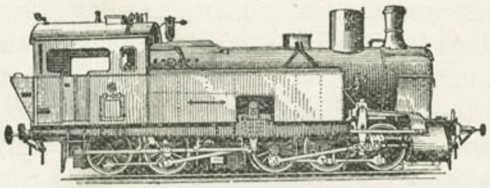
In regard to the hum-drum of daily life on a railroad, the appliances must be such that those who work in the machinery department or elsewhere shall surely be allowed the full time they work. This requires that the accounts shall be kept accurately and that returns thereof shall be rendered to headquarters and payment made accordingly. This in the interests of the employe. On the part of the employer it is required that he should know exactly what the labor has been expended upon and the cost thereof, so that he may, at his leisure, classify it month by month, or in detail, as his interests suggest. All these things are matters of routine, and provision is made therefor, both as regards wages and the accounting connected therewith, in the volume referred to on "Disbursements of Railways."

Questions of accounts relating to material and labor do not affect directly the care and repair of locomotives and cars, but, incidentally, they do, so that in studying the theme as a whole they must be considered. This proves, if proof were necessary, which it is not, what I have so often called attention to elsewhere throughout this work, namely, that in order to understand a particular department of railroad work, one must be generally familiar with all departments. It is not enough to know how a shop should be located, what machinery it should contain and how such



A Lubricating Device.

machinery shall be used. We must have knowledge concerning questions collateral thereto. which questions, one by one, will be bound to reach out and overlap others until, finally, they cover the whole railway world.



CHAPTER V.

ARRANGEMENT OF SHOP LABOR—SPECIALIZATION OF WORK—COMPARISON OF COST, ETC.

Each year's experience, it is apparent, affords valuable information in regard to the location, arrangement, machinery and government of the shops of railroads. In other words, we are learning from our experience. One marked tendency is in the direction of a reduction in the number of repair shops; in concentration, so to speak, so far as it is practicable. Too great conçentration is both inconvenient and expensive. Light repair shops must be located where mishaps are likely to occur. The daily value of an engine or car is too great to warrant sending it a long distance to effect some slight repair that may be made quickly and at small cost at a shop conveniently located.

So that while there is a tendency in the direction of centralization, it is being carried on intelligently and with a view to the best results.

An examination of the organization and workings of shops of railroads show an ever-growing knowledge of the needs of the service and a disposition to make use of the best known and most economical methods.

Another tendency in connection with the care and maintenance of the locomotives and cars of railroads is the disposition to concentrate responsibility in the hands of particular men in charge of these two great departments. At one time there was a master mechanic and master car builder on every division of a railroad, each acting more or less independently of the other. The result was multiplicity of patterns and devices, costly supervision and more or less clashing. With greater concentration of authority, or more systematic co-operation between responsible heads in its absence, we find that the devices used in connection with the equipment and shop machinery are made to harmonize over the whole extent of a property, as new equipment or appliances take the place of that which is worn out. This effects a saving to a railroad not only in the quantity of material it carries, but also in machinery and labor. It is also apparent that concentration, or, in its absence, perfect co-operation, is necessary to secure the maximum efficiency that is possible in connection with the use of locomotives and cars by having repairing and storing done at the most available points and in the best way.

Another tendency of shop organization on railroads is in the direction of piece work, or in the absence of such method, of having particular men do particular things. Where piece work is practicable under competitive influences, great savings are oftentimes possible compared with

the old method of working by the hour. Under this plan (so long practiced by private manufacturers), the man who is skillful and hard working derives the whole benefit thereof. He is not handicapped by lazy or inefficient companions. The manufacturer is also protected and emancipated. If a workman occupies two days in doing one day's work, the loss is his under the piecework system. Moreover, when men are hired by the hour, compensation must be fixed for the whole force on the basis of the average amount that is accomplished. This decreases the wages of the good man and increases those of the poor man. Nothing could be more unjust. Piecework being based on individual effort, the tie that under the old system bound the good and the bad together is severed.

It is noticeable that the distribution of shop labor of railroads, as well as the labor of other manufacturers, is in the direction of particularizing or specializing the work. Thus, a machinist instead of occupying himself in common, according to his impulse or the order of the foreman, on different parts of a locomotive or tender, concentrates his efforts on particular things, such as the valves, guides, driving boxes, steam pipes, boiler trimmings, wheels, and so on.*

* The minuteness of the division will, of course, depend on the amount of work to be done at the shop. Where this is little, great diffusion will be necessary. Where there is a great amount of work, men may be occupied almost exclusively with particular things. One experienced writer on the subject, Mr. L. L. Smith, suggests that the valve gang of laborers shall have charge

The value of specializing the work of shop laborers and others engaged on locomotives is measurably the same in regard to repairing and renewing cars. In fact, a minute subdivision of labor is being enforced more and more each day throughout the railway service. Men everywhere and in every department of life are becoming specialists. Where Humboldt set out to describe the universe, men are now content to study and portray a blade of grass. Particularizing work is not only true of railroads, but it is true of manufacturers and business men generally. At one time in the experience of railroads a minute division of work, such as that mentioned, was not possible; there were not enough locomotives

of the valve motion work and the taking down and putting up steam chests, rockers, links, eccentrics, tumbling shafts, reverse levers, and setting the valves; that the guide gang shall have charge of the guide, crosshead and piston work and taking down, fitting and putting up cylinders, saddles and frames; that the driving box gang shall fit up the driving boxes, shoes, wedges, and also repair and fit up the engine trucks; that the steam pipe gang shall fit up, test, and put in the steam pipe, dry pipe, dome, and throttle rigging; that the boiler trimming gang shall have charge of the cab and engine trimmings, injectors and pipes, also the clamping of the frame and finishing of the engine; that the wheel gang shall strip, take out and put in driving wheels, and fit up driver brakes, grates and grate rigging; and, finally, the general laborers shall clean the work and distribute it to and from the machine shop and make themselves generally useful. Of course, this division that Mr. Smith suggests will depend upon the amount of work. He probably has in mind some particular shop where such a division of labor as he suggests will most advantageously occupy the force required. No two shops, it is probable, will be exactly alike in this respect.

and cars to warrant it, but with the equipment railroads now generally possess, there is sufficient shop work to keep men occupied advantageously on special things.

The tendency to subdivide work will increase rather than diminish with the passage of time and, taken in connection with the system of piece work I have referred to, will effect great reductions in the shop outlay of railroads, compared with early and more primitive methods.

However, in order that a railroad company shall be certain that full advantage is derived by it from the best known methods, comparisons of outlay must be made; thus, a company must keep an account of the cost in hours of different kinds of work so as to compare results with other shops on the same system and with similar work on other railroads. It is only by such comparisons that it is possible to determine the measure of efficiency and economy exercised. Every company possesses or may possess facilities with which to make comparisons of work carried on at different shops on its own system. Co-operation among railroads in this direction will afford them knowledge of what other companies are doing. In this way progressive men will be encouraged to push forward, while the sluggards will be spurred on as they could be in no other way. Much of the efficiency that characterizes the handling of passengers and the ticketing of the same in America is due to the periodical meetings of the officials in charge of passenger traffic and the comparisons they have made and the suggestions and betterments that free discussion among them has brought out. Great advantages have similarly accrued to the accounting department of railroads. For many years those in charge of locomotives and cars have had similar meetings, and it is not too much to say of these meetings and others of a like tenor, that railway progress has been advanced by them one hundred years or more. The discussions they evoke are frank and full, every person in attendance being animated by a desire to acquire knowledge of what is best in connection with the construction, maintenance of equipment, and the arrangement and systematization of shops and shop work, and as the views promulgated are not those of theorists, but the result of practical experience and observation, the result is a wide diffusion of useful knowledge.

A new idea that is promulgated at one of these meetings, if it is good, is sure to be accepted in the long run. Opposition only serves to broaden it, so that finally, when accepted it is like beaten gold. The truth of this is evinced so far as uniformity exists in America in connection with shop work and the equipment of railways. A conception, to be generally adopted, must be faultless, or, at least, the best that is practicable. In this manner we are little by little creeping away from primitive methods to higher ground.

It will be seen, therefore, that in suggesting that railroads generally shall compare the cost of different outlays in connection with equipment and shop labor and shop implements, I am not advocating, except, perhaps, in this particular direction, anything new. It is probable that in making the comparisons I refer to, the number of hours occupied in doing a particular thing will not be the same on different roads, and cannot be made so because of inherent differences in the quality of the labor and more particularly the relative facilities different companies possess or can afford in the way of machinery, tools and shop facilities; but, taking into account the differences of this kind that will exist, immense good will result from the comparisons I speak of. The differences will serve to excite inquiry and suggest further comparisons. Ways and means will thus come to be discussed. This will bring up questions not only regarding the supervision and division of labor, but also questions regarding the implements with which men work, their tools, the machinery of the shops, its arrangement, utility, highest adaptability, care and so on. Comparisons of this kind will never grow old and will never cease to be valuable in business affairs.

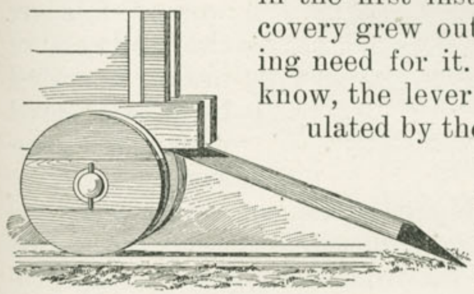
The benefits that accrue to railroads through interchange of views between officials in regard to matters relating to equipment and shop work, as I have had occasion to state elsewhere, may be supplemented to advantage by encouraging the various groups that constitute the engineering and mechanical forces connected with the rolling stock and shop work to meet and interchange views in regard thereto. Such discussions are constantly going on between individual employes. They may, in many instances, it is probable, be made more effective by enlarging their scope. It does not matter particularly how this is brought about. In some cases such results may be secured by having stated meetings at which matters relating to equipment, machinery, tools, arrangement of shops and kindred topics, are criticised and discussed, and questions asked and answered in relation thereto. The great object to be attained is to elicit interest and investigation on the part of the skilled men connected with equipment and shop work as to what is practicable and best. To what extent this can be done and just how it can be most effectively accomplished will depend upon circumstances, of which the officials immediately in charge will be the best judges. There cannot be any fixed rule. Of one thing there can be no reasonable doubt, however, namely, that the employe who is led to seriously consider and discuss the best way to care for machinery and tools, or the most effective way to utilize shop labor, will be more likely to give such things consideration in his everyday life than those who do not think of such matters except inconsequentially, or in an abstract way only. This is human nature.

CHAPTER VI.

CONSTRUCTION AND OPERATION OF THE AIR BRAKE—THE BRAKE SHOE—HISTORY AND EVOLUTION OF THE BRAKE.

NOTE.—The pages of this chapter depicting the evolution of the brake, are contained in the fifth and sixth editions of this work. Otherwise the matter is new.

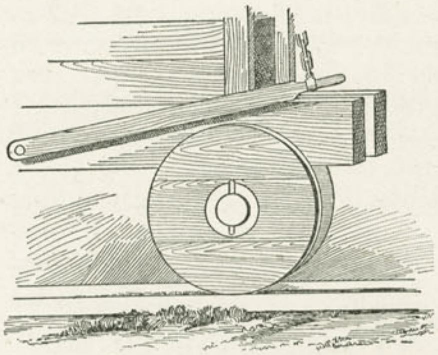
In discussing the practical uses of the brake in connection with railways, a brief reference to its origin and evolution is interesting. Like every other object of utility it was exceedingly simple in the first instance. Its discovery grew out of the pressing need for it. So far as we know, the lever brake, manipulated by the hand or foot, was the first formal device of this nature. Applied originally to road wagons it was afterward found equally adaptable to the vehicles of railroads.



Early Lever Brake. 1630.

Another almost equally simple form of brake was that used at New-Castle-on-Tyne in the seventeenth century. However, there have been many forms of primitive brake quite as archaic as either of these. Some of them are illustrated herewith.

Among these crude devices may be mentioned the "Le Caan" brake, so-called. This was operated by dropping the lever. When this was done the shoe of the brake, falling to the ground, formed a wedge, thus retarding the revolution of the wheel.



New-Castle-on-Tyne. 1630.

Among other primitive makeshifts there were various forms of chain brake, and later the devices in which steam was used; also, the hydraulic brake, operated by liquids stored under high pressure.

Reaching a higher grade, comes the so-called plain vacuum brake, operated by an ejector, which withdraws the air from the pipes, thereby producing a vacuum more or less perfect.

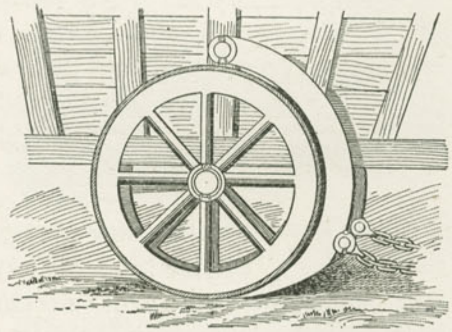
Then the automatic vacuum brake, operated by the application of air at atmospheric pressure to a vacuum cylinder.

Also the compressed air brake, worked by an air pump, forcing air into the pipes, the air being stored in a reservoir under the vehicle.

Still other forms and modifications might be

enumerated, but those given are sufficient to represent, substantially, the progressive steps in the evolution of the brake, and direct attention to the practices observed and the principles involved.

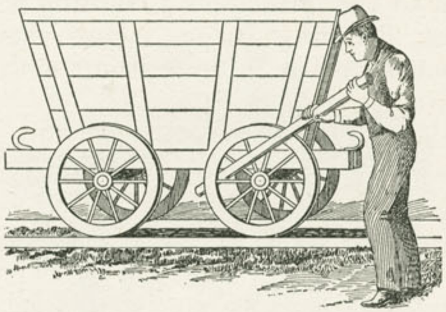
Among the writings of the ancients we find mention of the use of the brake, coupled with vague references to the principles governing it. Nothing, however, definite. Indeed, there was little use for such a device in connection with the chariots and rude carts and wagons used in the primitive ages of the world. For a long period the axle and wheel were one and revolved in unison. Such was the primitive cart. When this was the case there could have been little need of the friction afforded by a brake to stop the vehicle.



The "Le Caan" Brake, 1796.

Indeed, the difficulty was to make the wheel revolve at all. Later on, as the class of road vehicles improved and the highways became more passable, rude brakes, as we have seen, came into use. They were operated by a lever, applied with the hand or foot in a general way, as shown in the accompanying devices.

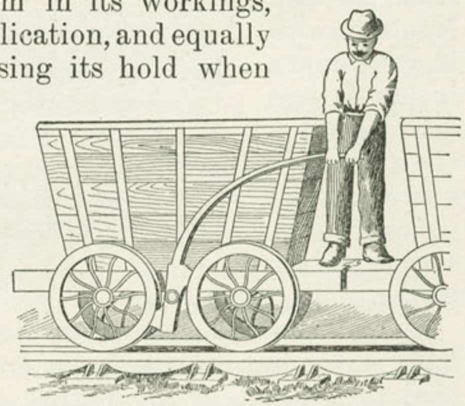
With the advent of the smooth and comparatively level track of railways, some means of controlling the movement of vehicles became a matter of prime importance; hence the universal adoption and use of a brake. Through the introduction of air brakes trains when moving at a high rate of speed can be stopped quickly without undue strain on the machinery or wear and tear on the track. Formerly they were compelled to slow up gradually, thus losing much time and, in many instances, occasioning accidents that railways are now happily free from.



A Primitive Device, Known as the "Sprag" Brake.

The evolution of the railway brake is both interesting and instructive. It has at last reached a stage of great complication, as well as of great efficiency. The sum total of railway machinery at the time the first railroad was opened, from Liverpool to Manchester, in 1829, was not greater than the machinery of the brake and its concomitants at the present day. The scientific features of the first locomotive were exceedingly simple, while the machinery of the air brake is anything but simple.

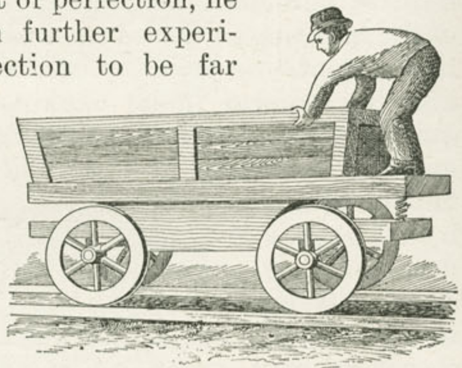
One of the most important devices in connection with the operation of railroads, and one that grows in importance each day with the added weight and speed of trains, is the brake; the device by which their movements may be controlled at will, either by persons on the locomotive or by those who fill the cars. An acceptable brake requires that it should control absolutely the train under every circumstance as regards its weight and speed; also, as regards weather and grade, not forgetting, moreover, such mishaps as the separation of the train while in motion. To fulfill these conditions it is apparent that the device must be automatic and self-applying in the case of the breaking in two of the train, or other similar accident. To be of the highest utility it must also be uniform in its workings, quick in its application, and equally quick in releasing its hold when the brake is no longer needed. It is also highly desirable that it should be durable and reasonably economical as regards construction and maintenance. These last features, like others that are necessary and desirable in connection



Lever Brake. 1825.

with the device, will be more and more fully attained as the needs of the situation are studied and railways have had greater experience in the use of the device.

The brake of the present day is so perfect in its working and control of the train that it is justly considered one of the greatest safety devices of railways. Another feature is the saving it effects in the wear and tear of machinery and track through the smoothness and certainty of its operation. That its development is still incomplete, however, goes without saying. What man exhausts himself upon to-day, what seems to him to be the height of perfection, he discovers upon further experience and reflection to be far from perfect. Man's growth is ever shown in his devices —his evolution in his successful striving after something better.

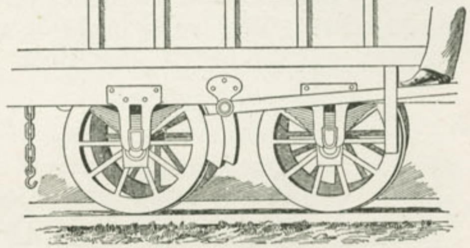


Early Form of Brake.

One of the first railway brakes of which we have particulars consisted of a wooden lever, pivoted to the side of the vehicle at one end and supported at the other by a short chain or strap. It is illustrated herewith. This was some time in the seventeenth century. In applying it the chain

was slipped off the lever and the latter pressed downward. This primitive device, manipulated wholly by the strength of the person in charge, contained the underlying principle from which all subsequent improvements have been evolved.

Robert Stephenson is said to have invented a steam brake for the driving wheel of the locomotive about 1833.* However, it was applied only to one side of the machine. It is said to have contained primarily the elements of the brake used since on the driving wheels of locomotives, viz.: Cylinder, toggle-joint and suspension links. The idea that a similar brake might be used, with extended appliances, on the cars attached to locomotives, also occurred to him, it is said.



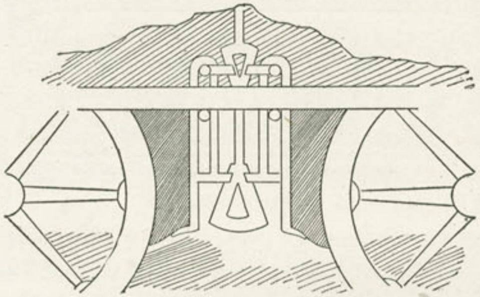
Lever Brake, 1832.

Among the devices for checking and moderating vehicles, the hand chain brake so generally used at one time was a most effective invention. Everyone is familiar with its operation. It consisted of a chain or rod running under the car attached to a frame swinging beneath and hanging

*His steam brake must not be confounded with the air brake, which latter uses steam to obtain the air pressure required.

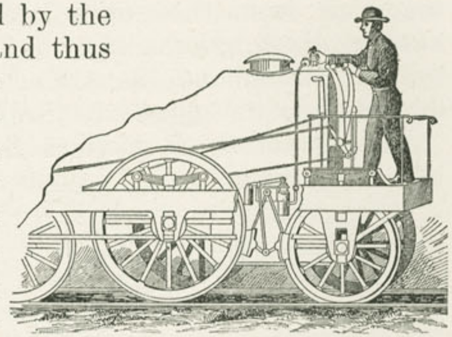
at right angles to the vehicle. The end of the rod was attached by a chain to the brake shaft, where the power was applied by a wheel worked by hand.

Another form of chain brake is that applied to the train as a whole. The end of the chain is attached to the brake shaft or lever where the power is applied, and the other end to the rear of the last car. When the brake is applied the tendency of the chain is to draw into a straight line, thus swinging the brake frame under the car, which in turn pulls rods attached to it and connecting with the brake beams, thus applying the brakes. It is, however, a sectional rather than a continuous brake, and is valuable only on short trains.

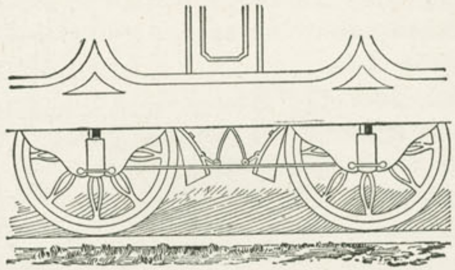

Steam Brake for Tender, 1832.

Another early invention was the hydraulic brake. Water, or other liquid, was stored under pressure, and operated by a continuous pipe carried along the train, with cylinders for applying the force beneath the cars. The steam pump on the engine generally supplied the pressure. A serious objection to the hydraulic brake is the susceptibility of the liquid to the cold. This is an objection also to steam. In cold weather the

water generated by the steam freezes and thus destroys or lessens the application of the power by clogging the brake shoe or by obstructing the apparatus itself. In addition to this fatal obstruction, steam is also objectionable for use on engines because of obscuring the view of the engineer when the exhaust escapes.

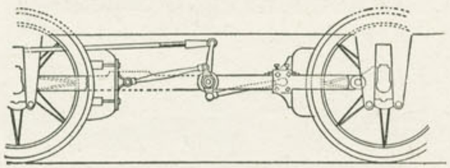

Stephenson's Locomotive Steam Brake for Driving Wheels, 1833.

The vacuum brake is in some sense a competitor of the compressed air brake referred to else-

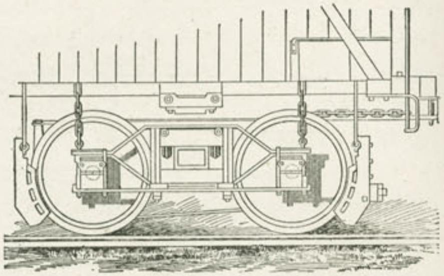

Car Brake Operated by Steam, 1839.

where. It consists of an ejector for producing the vacuum (i. e., exhausting air from the pipes); a continuous line of pipe; diaphrams; and, finally, couplings between the cars. The force is applied from the engine. In its operation the ejector takes air from the entire train pipe and the various diaphragms, and in doing this sets the brakes throughout the train.* As air is readmitted to the pipes the brakes are released.

Various forms of vacuum brake have been invented. This brake enjoys considerable favor because of its simplicity. Particularly is this true on roads where the trains are light and short and the stops frequent.


Gearing of Brake Operated by Steam, France, 1840.

The vacuum brake has some features not possessed by the automatic air brake, thus it may be operated so as to only partially release the brake; moreover, frequent and rapid application of the brake does not reduce its available braking power. When long and heavy trains are used, however, the vacuum brake does not meet the demands of the service. This is principally owing to the necessity of having abnormally large apparatus


American Modern Hand Brake, 1865

*Only sufficient air is taken out to produce the result desired.

(pistons, levers, etc.), in order to get sufficient resisting power upon the wheels; and also because it is in such cases slow to act. However, the vacuum brake is constantly undergoing improvements and the objections to it will doubtless in time be overcome for all classes and kinds of service.

An important consideration, it may be said, in connection with the brake is that part of the apparatus commonly called the shoe, or device that is applied directly to the wheel, and against which the friction is produced that retards the latter. It is manifest that the tenacity of the shoe depends not only on the force with which it is applied, but also upon the kind and quality of the material of which it is made. Another thing of great importance in connection with the shoe is the durability of the material used. The power with which this apparatus is applied and the tremendous friction consequent thereon must, it is apparent, quickly destroy the device unless the material is of the most durable character.

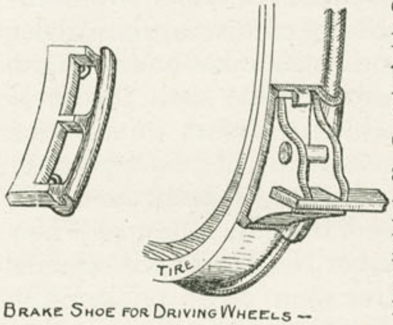
One of the devices in the early history of the brake, by which it was made more effective, was the covering of that portion of it which touched the wheel—the sole, in fact—with several thicknesses of strong leather. This material may be said to have been used generally before the days of railroads. With the latter highways came heavier loads, moving at a higher speed. This required quicker and more effective application of the brakes. The heat resultant from this necessitated not only that the shoe should be of metal, but also the parts connected therewith.

Many different kinds of material have been used in connection with the brake shoe, according to the needs of the service and the skill of manufacturers. In the case of railroads a common device is made of cast or wrought iron; sometimes of cast steel, or combinations of iron and steel, wood, leather, cork, even paper. It is very desirable, in order to secure proper application, that the material, whatever it is, should be uniform.

An expert on the subject of brake shoes for railroads, a man of intelligence and a successful manufacturer,* writing on this subject, says: "The same air pressure throughout a train of cars on which shoes of different hardness are are used, will apply a widely different friction on the wheels of the different cars. It is then impossible to obtain the maximum braking power for hard shoes without sliding those wheels to which soft shoes are applied. It is highly desirable to fix upon a standard mixture for foundrymen making cast iron brake shoes. Brake shoes are made for three kinds of service: on chilled wheels, on steel-tired driver wheels, and on steel-tired coach wheels. Those designed for the first mentioned service are made of cast iron, or cast iron with wrought iron pieces in

*George M. Sargent.

the face, or cast iron with chilled sections. . When cast iron is used a strong, tough metal soft enough to grip the wheels is economical, although its first cost is greater than a burnt grate bar scrap mixture. A mixture of number two foundry car wheels and heavy cast scrap has given good results. The combination cast and wrought iron shoe is much more durable than the plain shoe, and more desirable in respect to uniformity, because the same amount of wrought iron, forming one-half the surface of each shoe, will be nearly of the same hardness. . . . When two surfaces rub together the harder will abrade the softer and the latter wear away quicker, but we are limited in the hardness of the shoes by the co-efficient of friction necessary. They must be of a uniform hardness, sufficient to grip the tire without scoring it, and afford friction necessary to make the stops. It is evident that for the different classes of engines different kinds of shoes will be required. The suburban passenger engine, making frequent stops, should be equipped with shoes less hard than applied on a through passenger engine. The combination cast iron and steel shoe has the advantage that the proportion of each metal may be varied to suit the requirements of the service. Brake shoes for steel tired coach wheels are applied under entirely different conditions. They are made either plain or flanged. The plain cast shoe should be soft and tough. Whatever kind of metal is used in the flange coach shoe, care should be taken that the shoe is a good fit to the tire, and so hung that the flange grooves in the shoes are directly opposite to the wheel flange, and above all that the brake beam be free to move laterally as the wheel and axle move. Experiments have proved that a brake beam hung rigidly from the truck, in combination with the flange brake shoes, forms a grinding machine capable of turning a V-shaped flange, and that even with the plain shoe, lateral motion is of decided advantage in protecting the flange."



Brake Shoe and Its Application to the Driver.

In connection with the use of the brake shoe, it may be said that its application to the flange of the wheel was not discovered until long after it had been applied to the tread. This application was a new departure and a valuable one in many directions, as it added, it is manifest, greatly to the power of the brake. Its importance will grow with increased use and ability to handle it. The application of the flanged brake shoe to the drivers of locomotives is general. This because the flanged brake shoe tends to

keep both tread and flange in the original form and by reason of the additional grip over the flange. One objection that has been made to the use of the flanged brake shoe on cars is that its use in connection with the tread creates a pressure so great that the wheel is inclined to slip. This, it is apparent, is not so much an objection to the brake as a lack of proper adjustment of the power that manipulates it. It is claimed by manufacturers of flanged brake shoes that where the device is not used the tread wears away, while the flange of the wheel remains the same, thus creating a dangerous disparity.*

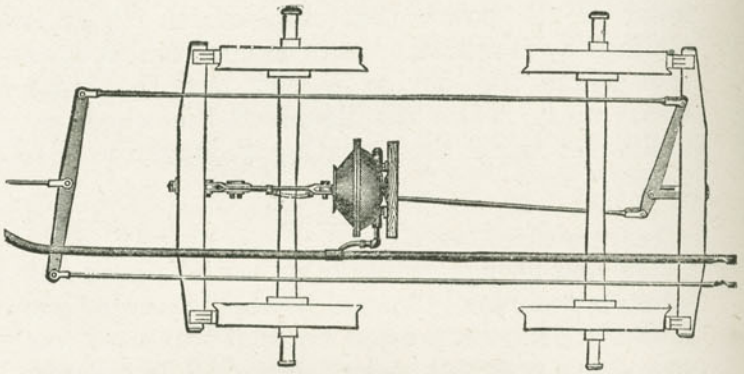
The first form of air brake successfully used was what is technically known as the "straight" air brake.† The compressed air that was used was stored in a reservoir under the engine. In order to set the brake the engineer's valve was turned and the air forced back through the pipe. It thus filled the cylinders under the car, and in doing so forced out the pistons, which brought the brake shoes against the wheels. To release the brakes, the air from the engine drum was cut off and the

*Further reference to the brake shoe will be found in the volume "Train Service," under the head of "Car Wheels."

†The air brake must not be confounded with the old-fashioned steam brake. In the latter case steam was forced through the pipes and used as the power, while in the case of air brakes air is used, steam being employed merely to furnish the power for compressing the air.

air in the pipe and cylinders allowed to escape into the atmosphere, through the engineer's valve.

The invention of the air brake occurred about 1869. Although an improvement over the continuous chain brake and other inventions of early days, it was still too slow in releasing (letting go its hold on the wheel), as all the air in the pipe



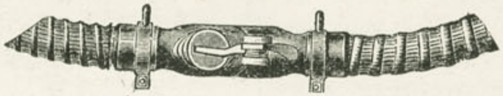
The Vacuum Brake. The diaphragm (the semi-oval device shown above) consists of a kettle-shaped iron casting with a loose disc of heavy rubbered duck fastened over its mouth (where the two half sections come together in the center) by means of a ring and cap-screws; the center of the disc, or diaphragm, being provided with washers and an eye-bolt for attachment to the brake lever. When the air is exhausted from diaphragm, the pressure of the atmosphere from without forces the rubber disc into the iron shell and, pulling on the brake levers and connections, sets the brakes.

and cylinders had to escape through the engineer's valve, the longer the train consequently the slower its operation. Another fault was, if a hose or pipe burst the brake was rendered useless. Moreover, if a train became parted the brake had no effect whatever upon the rear section.

These objections rendered it apparent that a wholly satisfactory brake required that the force (air) for applying it should be stored on each car, and so arranged that it could be used (i. e., the brake set) by those in the car, independent of the engineer. Also, that it should be automatic in its action, i. e., that any breakage or defect of the apparatus would set the brake. The most primitive conception of this idea was a design in which the operative force was a spring, so arranged as to be held under compression by the air in the pipe, and brought into action when the air escaped. The next improvement involved the necessity of a reservoir auxiliary to the engine for storing the power on each car; the next was to provide a way by which the stored pressure in the reservoir might be automatically admitted to the brake cylinder whenever the pressure in the train pipe escaped. These improvements were covered by a patent issued in 1872.

The device employed is known as the "triple valve." Like nearly all inventions of a mechanical nature, the first design was incomplete and passed through several stages before reaching a point where it was of simple and practical use. The valve in question, which is of a complicated nature, is located, in conjunction with the auxiliary reservoir and brake cylinder, beneath the car. Upon the reduction of the pressure in the train pipe (through which the compressed air is supplied to the auxiliary reservoirs from the engine) this valve allows the compressed air in each auxiliary reservoir to pass into the brake cylinder, thus applying the brakes. Upon the pressure in the train pipe being restored the valve allows the air in the brake cylinder to escape to the atmosphere, thus releasing the brake, and opens the ports for the passage of air from the train pipe to the auxiliary reservoir, recharging the latter.

The perfection of the hose coupling between the cars also plays an important part in the development of the stored-air brake. A satisfactory automatic coupler is a desideratum of the greatest importance.



Vacuum Brake Coupling.

An air pump was patented in 1870. An objection to it was its complicated valve motion. One difficulty was in keeping the square piston rod properly packed in order to prevent friction and wear. Many of the changes in devices had relation to the reversing valve mechanism, but up to the year 1875 no satisfactory result had been accomplished. First, a horizontal rotary valve was used, then a double poppet valve, then a vertical rotary valve, and, finally, a simple slide valve, the latter proving by far the most effective.

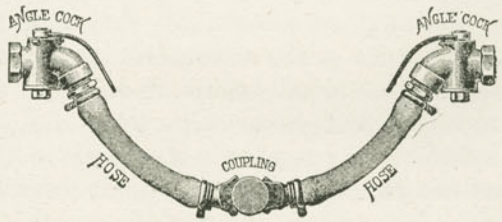
Many of the objects sought as necessary were finally covered by the pump of 1875.

After the introduction of the automatic brake it was discovered that to secure satisfactory results

some plan for maintaining a uniform pressure of air without attention from the engineer was needed. The outgrowth of this was the pump governor, which automatically closes the steam pipe leading to the pump when the desired maximum air pressure is attained, opening it again when the pressure has been reduced.

Thus we see, in connection with the brake, every requirement substantially met as it arises.

The first form of engineer's brake valve used in connection with an air brake was composed of



Air-Brake Hose Coupling.

three openings controlled by a conical shaped rotary plug. The general principle by which this valve worked is retained in the engineer's valve of later designs. The engineer's valve, manipulated by the engineer, opens communication between the main reservoir and the train pipe, to charge cars or release brakes, closing the connection and opening the train pipe to the atmosphere when the brakes are to be applied. The equalizing discharge feature of this valve is a device brought out prominently in 1886, being made necessary by the application of automatic brakes to long trains of cars. This device automatically regulates the discharge of the air from the train pipe in setting the brakes, and also gradually closes the exhaust opening, thereby equalizing the pressure remaining in the train pipe, thus overcoming the difficulty experienced with the earliest forms of valves arising from the sudden opening and closing of the exhaust opening, which produced a violent recoil of the air in the train pipe, thus releasing some of the brakes on the forward cars.

An important feature in connection with the subject is what is known as the quick-action brake. While the plain automatic brake answers, in a measure, on short trains, it does not answer the purpose on freight or other long trains. The head brakes being set some time before those in the rear are affected, a severe shock occurs to the rear cars of the train. A remedy for this was a device with a local vent for quickening the discharge from the long pipe. The "automatic relief valve" and the "cut-off and relief valve" are also inventions designed to hasten the application of the brake.

In the evolution of railway traffic the tendency to increase the speed of trains developed a demand for a brake of greater efficiency than was afforded by the common quick-action brake. This demand was sought to be met by what is known as the "high-speed" brake. It is practically the quick-action brake under a very high pressure. It stops the train in about two-thirds

the ordinary distance: thus, a train moving at the rate of sixty miles an hour that would otherwise make a stop in sixteen hundred feet, will be brought to a stand, say, in about eleven hundred feet.

As the distant signals of any block system must be placed far enough from the home signals to permit of the train being stopped, it is apparent that the former would have to be moved farther away with the increase of speed of trains, except for the high-speed brake.

Before describing this improvement, it will be well to state the theory of resistance upon which it is based. It is known that a brake shoe that presses against the wheel sufficiently to cause the wheel to slide at a low rate of speed will not do so at a high rate of speed. Technically, the co-efficient of friction increases with the reduction of the velocity of the surfaces in contact.

The quick-action brake, under the emergency application, causes the shoe to press against the wheel with a force equal to ninety per cent. of the pressure of the wheel upon the rail. This is as high a percentage of braking power as is practicable without sliding the wheel at a slow speed. The "high-speed" brake, however, nearly doubles this braking power when first applied and then automatically reduces it as the speed of the train is reduced. This form of brake originally contemplated, on each car, an additional valve and cylinder, which were made operative by a greater reduction of pressure than the engineer should use except in cases of emergency. The piston of this extra cylinder produced additional force upon the ordinary levers after the regular cylinder had acted. As the speed of the train was reduced, it rested with the engineer to gradually release the pressure from the additional cylinder. Two objections to this form or device were, first, that the engineer might use the "re-inforce" cylinder when not intending to do so, by the use, inadvertently, of too much air, thus sliding the wheels and running by the stopping point as well; and, second, in case of impending danger, say, ahead, if the engineer should leave his post, the brake would not automatically regulate itself, but would either lose its "re-inforce" power immediately or else lock all the wheels as the speed reduced and, by sliding the whole train, precipitate it into the danger it was sought to avoid. The especial advantage it afforded was that on a loaded freight car the "re-inforce" valve could be "cut in" and on an empty car "cut out," and thus regulate the holding power of loaded and empty cars respectively, to a much greater extent than is otherwise done.

The high-speed brake, a modification of the re-inforce brake, consists of an automatic graduated relief valve screwed into the brake cylinder, and also the increasing of the standard train line air pressure is increased to nearly double the normal quantity.

The relief valve referred to is set at sixty pounds pressure, and in the ordinary use of the

brake allows all air above this amount to escape to the atmosphere; but when it is applied in an emergency, the cylinder receives the extra pressure so quickly that the relief valve is forced to its extreme position, thereby opening a smaller escape which increases in size as the speed diminishes and finally closes when but sixty pounds remains in the cylinder. (See Fig. on page 384.)

This brake has been in use on many fast trains and has demonstrated its advantages and put to rest the fear at first expressed that sliding of wheels would ensue upon its use. It has other advantages over the ordinary quick-action brake, in this, that the cylinder pressure is limited to sixty pounds without reference to the adjustment of the brake piston and that several service applications can be made with equal effect without re-charging. As the use of sand upon the rails is essential to the attainment of the best results with this brake, it is desirable that locomotives should be equipped with automatic air sanding appliances which sand the rail when the handle of the engineer's valve is put in the emergency position. Some engines that alternate the handling of this brake with the standard brake have double governors and feed-valves for regulating to either the high or standard pressure, according to the equipment of the train.

In concluding the foregoing brief resumé of the "Evolution of the railway brake," it may be said that at first but one wheel of a vehicle had a brake; later, both pairs of wheels composing the truck to one end of a car were braked; still later, when six-wheel trucks were required for heavy equipment, only the two outside pairs of wheels on each truck had brakes; later still, every pair of wheels under a passenger car was supplied with a pressure upon their brake shoes equal to ninety per cent. of the weight of the wheels upon the rail. A still greater change is noticeable on locomotives. While it was at one time questionable as to the advisability of applying a brake to locomotive driving wheels, afterward it was made a requirement by law in America to equip engines and tenders as well as cars with power brakes. This renders every car and engine so nearly equal in stopping power that the greatest safety is had, and the minor jerking occasioned by the unequal braking power of the different vehicles is avoided.

HOW TO USE THE AIR BRAKE.

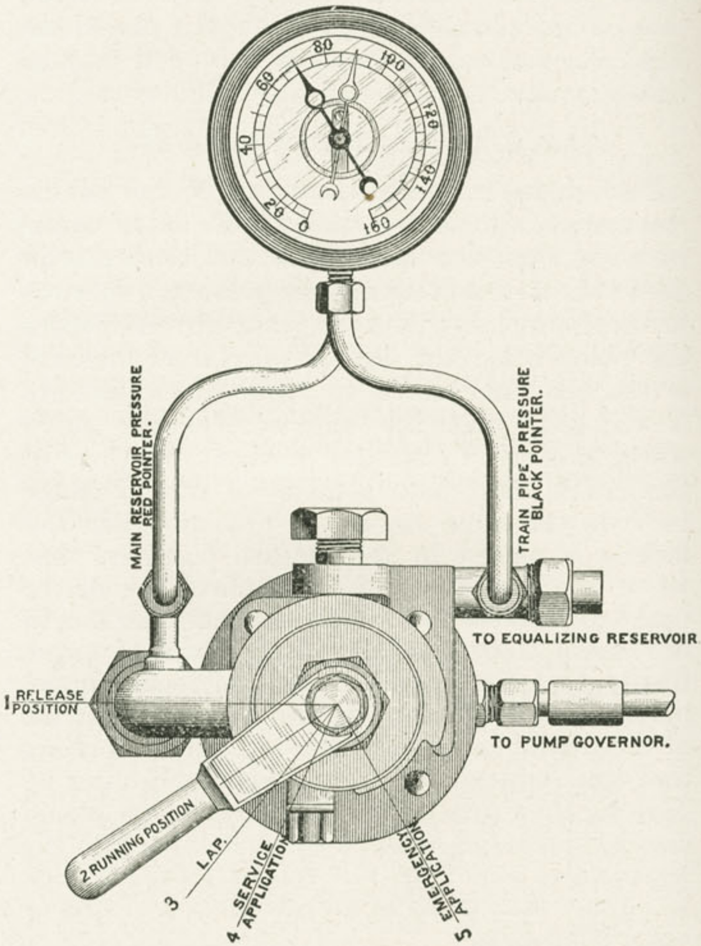
The complicated machinery the use of air necessitates requires to be so constructed, maintained and handled that when in use it will, in every case, stop the train within the distance it is expected to. In furtherance of this, those who have manufactured the brake and, again, those who have handled it, have instituted carefully prepared rules and regulations governing the use of the brake. They are thus not the product of any man or time, but cumulative in their growth. I have carefully consulted these authorities in

preparing the accompanying regulations, not attempting to do more myself than to make changes in phraseology and supply omissions. The rules and regulations thus compiled may be stated generally and specifically as follows:

GENERAL INSTRUCTIONS TO ENGINEMEN.

The engineer, when assuming charge of his locomotive, should see that the air brake apparatus, on both the locomotive and tender, is in good order: thus, that the air pump and lubricator work properly; that the pump governor stops the pump when the desired maximum pressure is reached, and starts it again when pressure is reduced;* that the engineer's brake valve works properly in all the different positions of the handle; that both pointers of the air gauge indicate the same amount of pressure when the handle is placed in full release position; that when the brakes are fully applied, the driver brake pistons do not travel less than one-fourth nor more than one-half of their stroke; and, finally, that the engine truck and tender brake pistons travel between one-half and three-fourths of their cylinder length. Moreover, the reservoirs and drain cups should be drained of all water by opening their drip cocks. The train pipe should also be blown out through the rear hose, with the brake valve handle in full release (position one), to be sure that there is no obstruction of dirt or other substance.

*It should be borne in mind that with the different types on engineers' valves, the pump governor regulates different pressures.



Engineer's Brake and Equalizing Discharge Valve and Duplex Air Gauge, known as the D 8 or 1889 Valve.

Engineers should also report to the roundhouse foreman, or other authorized official, at the end of each run, any defect they may have detected in the air-brake apparatus.

On Making Up Trains and Testing Brakes.—There should be seventy pounds train pipe pressure on the engine before connecting to the train, with the handle of the engineer's valve standing in position two. When the locomotive has been coupled to the train and the latter has been charged with an air pressure of seventy pounds, the engineer should, on a signal from the proper person, apply the brakes fully and leave them thus until the brakes on the entire train have been inspected, after which, upon signal, the brakes should be released; but the engineer will not leave the station until all the brakes are released and he has been advised by the proper person that they operate all right. These tests should be made after each change in the makeup of a train, also before starting down such grades as may be particularly designated. In passenger trains, when the train air signal is used, the signal to set the brakes in testing should be given from the rear car of the train, to show that the signal connections are properly made. The engineer sets the brake as answer that the air signal works properly.

Application of the Air Brake in Service.—In applying the brakes to steady the train upon a descending grade, or to reduce the speed for any purpose, care should be taken not to make too great a reduction of pressure at first, as the speed of the train would be too quickly checked and, also, to a greater degree than desired, thus necessitating a release of the brakes and their application again, perhaps even requiring a repetition of the operation.

The brake should be applied lightly at a sufficient distance from the stopping point, increasing the force gradually, as it may be found necessary, so as to make the stop with one application of the brake, or at most two.

In the case of freight trains which are only partially equipped with the air brake, after shutting off, the slack of the train should first be allowed to take up; the brakes should then be applied with a reduction not to exceed six to eight pounds, and with such further reductions thereafter as may be necessary. This will prevent shocks to the train which otherwise might be serious.

In making a regular stop in the case of a passenger train, the brakes should (except on heavy grades) be released a short distance before coming to a standstill, so as to prevent a shock at the instant of stopping. On a moderate grade it is best to do this and then after releasing apply the brakes again lightly, in order to prevent the train starting of its own volition and that when it is ready to start the release will take place immediately. In the case of freight trains the brakes should not be released until the train has come to a full stop.

Application of the Brake in Emergency.—The emergency application of the brake should never be used except when an emergency exists, and then the brake valve should be thrown to the emergency position, number five, no matter where it may have been before.

When Brakes are Applied from an Unknown Cause.—If at any time it is found that the train is dragging without a rapid fall of the black pointer indicating the fact, the handle of the engineer's valve should be moved into the full release position for an instant and then returned to the running position.

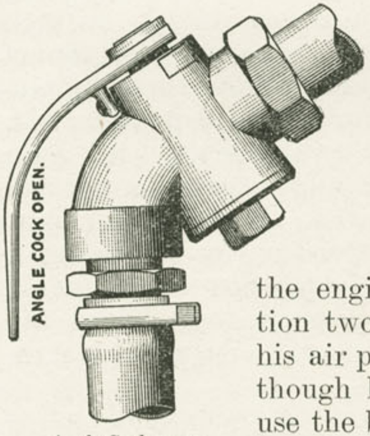
If, however, the brakes are applied suddenly with a fall of the black pointer, it is evident that a conductor's valve has been opened, or that a hose has burst or a serious leak occurred, or that the train has parted. In such event the handle of the engineer's valve should be immediately placed in position three, to prevent escape of air from the main reservoir. It should be left there until the train has been stopped and the brake apparatus examined and a signal to release given. If a hose or pipe has burst, it may be necessary for the engineer to place his handle in position two (running position), that the trainmen may detect the escape of air from the hose or pipe while searching for it.

Braking by Hand.—The air brake should never be used by the engineer when it is known that the trainmen are operating the brakes of air-brake cars by hand, as there is danger of injury to the trainmen by so doing.

Cutting Out Brakes.—The brakes on the drivers and tender should, unless defective, always be used automatically at every application of the train brake, except upon grades that may be particularly designated.

When necessary to cut out either the driver or the tender brake because of any defect, it should be done by turning the handle of the four-way cock, in the triple valve, down to a position midway between horizontal and vertical, leaving the bleed cock open.

Double Headers.—When two or more engines are coupled in the same train, the brakes must be connected to, and operated from, the head engine. For this purpose a cock is placed in the train pipe just below the engineer's valve. The engineer of each engine, save the head one, should close this cock and place the handle of the engineer's valve in position two. Then he will start his air pump and let it run as though he were intending to use the brake. This is for the purpose of maintaining air pressure on nis engine and enabling him to



Angle Cock, open.

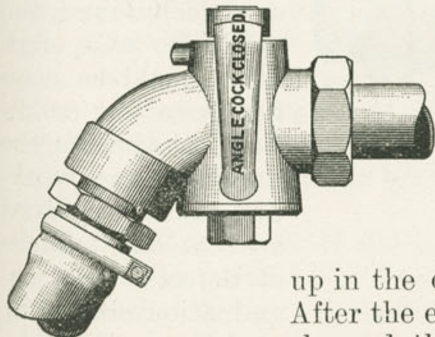
assume charge of the train brakes should occasion require it.

Extra Hose.—An extra air-brake hose and coupling should be carried on each engine in order to make repairs in case hose bursts. Upon engines having the air signal, an extra signal hose and coupling should also be carried for like purpose.*

Sliding Wheels.—To avoid the sliding of wheels (and consequent loss of two-thirds of the retarding force, and the damage to the wheels as well), engineers should use sand freely when the condition of the rail is doubtful. The sand should be applied to the rail before the brake is operated, and should be shut off only after the brake has been released.

GENERAL INSTRUCTIONS TO TRAINMEN.

Making Up Trains and Testing Brakes.—When an engine has been coupled to a train, or when two sections have been brought together, the brake couplings should be united. The cocks in the train pipes should then all be open, except at the rear end of the last car. This should be closed and the hose properly hung up in the dummy coupling. After the engineer has fully charged the train with air

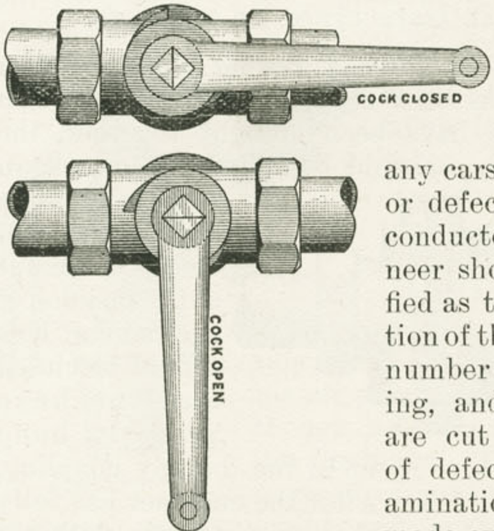


Angle Cock, closed.

*Some railroads carry all extra hose in the baggage or caboose cars.

he will then be signaled to apply the brakes. When the train air signal is to be used, the signal to the engineer to apply the brakes should be given by means of the air signal from the rear car of the train. When he has done this, the brakes of each car will be examined to see if they are properly applied. When this is ascertained to be so, the engineer will be signaled to release the brakes. The brakes of each car should then be examined to see that each is released. The longer the brakes can be left applied, it should be remembered, the more thorough will be the test of their stopping power.

If any defect is discovered, it should be remedied and the brakes applied again, the operation being repeated until everything is righted. In the event any cars are cut out or defects found, the conductor and engineer should be notified as to the condition of the brakes, the number of cars working, and those that are cut out because of defects. An examination should be made every time any



The Plain Straightway Cock.

change is made in the makeup of a train, also before starting down such grades as may be particularly designated. At points where there are no inspectors, trainmen will carry out these instructions.

A passenger train should never start from an inspection point with the brakes upon any car cut out or in a defective condition without orders from the proper official.

Use of Hand Brakes.—The air brakes on a freight train should not be wholly relied upon to control the train if there is a smaller proportion of cars with the air brake in service than the regulations of the company specify. When hand brakes are also used, they should be applied upon the cars next behind the cars with air brakes, except when backing up, in which case the braking should, in the main, be done by hand brakes at the rear of the train.

Detaching Engine or Cars.—When the engine or a car is detached, the cocks in the train pipes at the point of separation should first be closed, the one nearer the engine last. The couplings should then be parted by hand. If the brakes have been applied, the cocks should not be closed until the engineer has released the brakes upon the whole train.

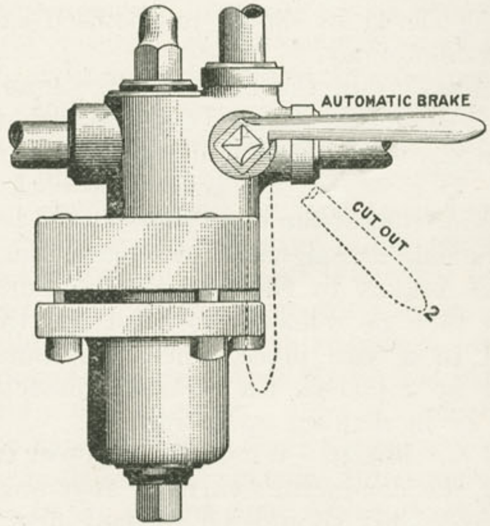
Frozen Couplings.—If the couplings should at any time be found to be frozen together or covered with ice, the ice should first be removed and the couplings then thawed out by a torch or by dipping into a pail of hot water, so as to prevent injury to the gaskets.

Brakes Sticking.—If the brakes should be found sticking, the engineer should be signaled to release them. If he cannot do so and calls for release, or if brakes are applied to detached cars, the release may be effected by opening the small cock in the auxiliary reservoir until the air begins to release through the triple valve, when the reservoir cock should immediately be closed.

Train Breaking Into Two or More Parts.—The cock in the train pipe at the rear of the first section should first be closed and the engineer signaled to release the brakes. After having coupled to the second section the rule for making up trains should be observed, first being sure that the cock in the train pipe at the rear of the second section has been closed in case the train has broken into more than two sections. When the engineer has released the brakes on the second section, the same method should be employed with reference to the third section, and so on. When the train has been re-united, the brakes should be inspected on each car, to see that all are released before proceeding.

Cutting Out the Brake on a Car.—If, through any defect of the brake apparatus while on the road, it becomes necessary to cut out the brake upon any car, it may be done by closing the cock in the cross-over pipe near the center of the car when the quick-action brake is used, or by turning the handle of the cock in the triple valve to

a position midway between horizontal and vertical when the plain automatic brake is used. When the brake on a car has been thus cut out, the cock in the auxiliary reservoir should be opened and left open upon passenger cars, or held open until all the air has escaped from the reservoir upon freight cars. The brake upon any



The Plain Automatic Triple Valve.

car should never be cut out unless the apparatus is defective, and when it is necessary to do so, the conductor should notify the engineer and also send in a report to the proper official, stating the reason for so doing. Some form of noticeable defect tag tied to the defective part is very effective. This tag should give the car number, initials, state the defect, and be signed by the conductor, giving the date.

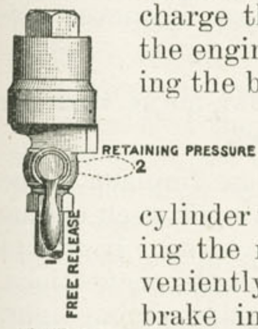
Conductor's Valve.—Should it become necessary to apply the brakes from the train, it may be done by opening the conductor's valve, which is placed in each passenger equipment car. The valve should be held open until the train comes to a full stop, and then closed. This method of stopping the train should not be used except in case of emergency.

Burst Hose.—In the event a brake hose should burst, it should be replaced and the brakes tested before proceeding, provided the train is in a safe place. If it is not, the train pipe cock immediately in front of the burst hose should be closed and the engineer signaled to release the brakes. All the brakes to the rear of the burst hose should then be released by hand and the train moved to a safe place, where the burst hose should be replaced, the brakes connected and tested as in making up a train.

Call for Brakes.—When the engineer calls for brakes, the conductor's valve or rear angle-cock (if convenient) should be opened first. Each trainman should then set the brakes nearest to him, whether the air brake is applied on the car or not.

Brakes not in Use.—When the air brakes are not in use, either upon the road or in switching, the hose should be kept coupled between the cars or hung up properly in the dummy couplings.

Pressure Retaining Valve.—In descending long grades, owing to repeated applications of the brakes, the stored pressure may become so reduced as to make it necessary to re-charge the auxiliary reservoirs. This the engineer cannot do without releasing the brakes, but the retaining valve is designed so that the trainmen may hold a pressure of fifteen pounds in each brake cylinder while the engineer is re-charging the reservoirs. This valve is conveniently located up near the hand brake in a position accessible on a moving train. A pipe from the bottom of the retaining valve connects it with the triple valve exhaust. When it is desired to retain fifteen pounds pressure in the cylinder, the handle of the retaining valve is changed from position one to position two before the brake is released by the engineer. At the foot of the grade the handles should all be turned downward again to position one. Special instructions are issued as to the grades upon which these valves are to be used.



The Pressure Retaining Valve.

Reporting Defects to Inspectors.—Any defect in the air brake apparatus discovered upon the road should be tagged and reported to the inspector at the end of the run; or, if the defect be a serious one in passenger service, it should be reported to the nearest inspector and remedied before the car is again placed in service.

Extra Hose.—Each conductor should keep two extra air-brake hose on hand. Passenger crews should also have extra air-signal hose. To insure this, inspectors are authorized to exchange new hose for old defective hose whenever presented.

GENERAL INSTRUCTIONS TO ENGINE-HOUSE FOREMEN AND INSPECTORS.

It is the duty of engine-house foremen to see that the air-brake equipment upon each engine is properly inspected after each run. It should be ascertained that all pipe joints, connections, and all other parts of the apparatus are air tight, and that the apparatus is in good working order. Air pipes in the engine house which may be coupled to the rear of the engine are very convenient for this inspection, as engines are not always under their own steam when desired.

Air Pump.—The air pump should be tested under pressure and, if found to be working imperfectly in any respect, should be put into thoroughly serviceable condition.

Pump Governor.—The pump governor should cut off the steam supply to the pump when the desired maximum pressure has been reached. In the event it does not, it should be regulated to do so.

Engineer's Brake Valve.—This valve should be kept clean and in perfect order. It should be tested with the handle in positions four and three to see that the equalizing piston responds

promptly and that there are no leaks from port to port under the rotary disc valve.

Adjustment of Brakes.—The driver brakes should be adjusted so that the pistons will travel not less than one-fourth nor more than one-half of their stroke. When the cam brake*is used, care should be taken to adjust both cams alike in order that the point of contact of the cam should be in line with the piston rod. The tender brake must be adjusted by means of the dead truck levers, so the piston will travel not less than five nor more than six inches when the air brake is applied and the hand brake released. This adjustment should be made whenever the piston travel is found to exceed eight inches. The engine-truck brake should have a piston travel of not less than one-half nor more than three-fourths of the length of its cylinder, and must be adjusted alike on both sides.

Brake Cylinders and Triple Valves.—The brake cylinders and triple valves should be examined and cleaned once every six months and the cylinders oiled once in three months. If the driver brake cylinders are in a position to be affected by the heat of the boiler, they must be oiled more frequently and the pistons given a one-half turn. Record should be kept of the date of each cleaning and oiling.

Draining.—The main reservoir and also the drain cup in the train pipe under the tender should, after each trip, be drained of any accumulation. The auxiliary reservoirs and triple

*See illustration on page 539.

valve should also be drained frequently, daily in cold weather, and the train pipe under the tender blown out.

GENERAL INSTRUCTIONS TO CAR INSPECTORS.

It is the duty of all inspectors to see that the couplings, pipe joints, conductor's valves, and all other parts of the brake apparatus are in good order and free from leaks. For this purpose they should be tested under a full air pressure of seventy pounds and all defects remedied. No passenger train should be allowed to leave a terminal station with the brake upon any car cut out or in a defective condition without special orders from the proper official.

If a defect is discovered in the brake apparatus of a freight car which cannot be held long enough to repair such defect, the brake should be cut out and the car properly carded, so as to call the attention of the next inspector to the repairs required.

Making Up Trains and Testing Brakes.—In making up a train, the couplings should be united and the cocks at the ends of the cars opened, except at the rear of the last car where the cocks should be closed and the couplings properly hung up in the dummy couplings. After the train is charged, the engineer should be signaled to apply the brakes, using the train air signal from the rear car for passenger trains. The brakes upon each car should then be examined to see that they are properly applied. This having been

ascertained, the inspector should signal the engineer to release the brakes. The brakes should again be examined to note that each is released. If any defect is discovered, it should be corrected and the testing of the brakes repeated until they are found to work properly upon each car. The inspector should then inform both the engineer and conductor as to the actual condition of the brakes.

Cleaning Cylinders and Triple Valves.—The brake cylinders and triple valves should be kept clean and free from gum. For this purpose they should be examined as often as once in six months upon passenger cars and once in twelve months upon freight cars. The cylinders and triple valves should be thoroughly cleaned after removing all movable parts and the piston leathers and cylinders well coated with a heavy oil or light grease which is but little affected by changes of temperature and will not gum. The dates of the last cleaning and oiling should be marked with paint upon the cylinder in the places provided opposite the words stenciled with white paint in one-inch letters upon the cylinder, as follows:

Cyl. oiled .... (Date) ....
Cyl. / Triple } Cleaned .... (Date) ....
(Place) ....

It is well to give the pistons a one-half turn when replacing them in their cylinders.

The triple valves and auxiliary reservoirs should be frequently drained, especially in cold weather, by removing the plug in the bottom of the triple valve and opening the small cock in the reservoir.

Adjustment of Brakes.—The slack of the brake shoes should be taken up by means of the dead truck levers or the turn buckles. In taking up such slack, it should be first ascertained that the hand brakes are off and the slack all taken out of the upper connections, so the live truck levers do not go back within one and one-half inches of the truck timber or other stop, when the piston of the brake cylinder is fully back at the release position. If, when under full application, the brake piston travel is found to exceed eight inches upon a passenger car or nine inches upon a freight car, the slack of the brake shoe should be taken up and the adjustment so made that the piston shall travel not less than five inches nor more than six inches.

Braking Power.—When the cylinder lever has more than one hole at the outer end, the different holes are for use upon cars of different weights. It should, therefore, be carefully ascertained that the rods are connected to the proper holes, so the correct braking power shall be exerted upon each car.

Repair Parts.—Inspectors should keep constantly on hand, for repairs, a supply of all parts of the brake equipment that are liable to get out of order.

Hanging up Hose.—Inspectors should see that, when cars are being switched or are standing in the yard, the hose is coupled between the cars or properly secured in the dummy coupling.

Responsibility of Inspectors.—Inspectors are held responsible for the good condition of all brake apparatus upon cars placed in trains at their stations. They should also make examinations of brake apparatus and repair the same whenever called upon by the trainmen to do so.

[NOTE.—It is proper to say here that after preparing this chapter on the air brake, greatly aided therin by Mr. E. W. Pratt, an expert in such matters, Mr. G. W. Rhodes, Superintendent Motive Power, Chicago, Burlington & Quincy Railroad, and Mr. Robert Quayle, Superintendent Motive Power and Machinery, Chicago & North-Western Railway, both eminent men in their profession, were so kind as to examine it with a view to the discovery and correction of inaccuracies and omissions. It has thus passed under the eye of men pre-eminently fitted to judge of its merits.]

THE MODERN AIR BRAKE.

For some time after the adoption of the air brake it was common to attribute to it many of the train accidents that occurred; the opinion prevailed that it did not work uniformly—that it was capricious, that its action could not be accurately foretold. It is now known, however, that its operations under like conditions are always the same.

Doubtless many improvements remain yet to be introduced in connection with the air brake, but it has become so important a factor in the operation of trains as to be standard, and every one concerned with the operation of railroads is interested in an account of its workings. Such an exposition it is designed to give here, omitting those details which would add prolixity to the statement without tending to make its workings more clearly understood.

Air brakes are of two kinds, viz.: "straight" and "automatic," but in both cases the power used is compressed air. The air is compressed by a pump on the locomotive, and is stored in a reservoir on the engine called the main reservoir. The brake is applied by admitting compressed air to a brake cylinder, which, through the action of connecting rods and levers, pushes out a piston and forces the brake shoes against the wheels. When the air in the cylinder is allowed to escape, the piston is shoved back by a spring in the cylinder, and the brake is released. On passenger cars springs on the brake beams generally serve to release the brake shoes from the wheels, but on freight cars the inclination of the hangers, by force of gravity, causes the shoes to drop away from the wheels.

In the first or simplest form of air brake, termed "straight air," now practically obsolete, the pressure for applying the brakes was all stored in the main reservoir. To apply the brake, the air passed through a valve on the engine, called the engineer's valve, to the train line which was connected directly to the brake cylinder of each car.* This method proved unsatisfactory, because if a breakage, such as a burst hose or

* The train line consists of all the pipes and their connections from the engineer's valve to the rear cock of the last car.

pipe, occurred in any portion of the apparatus, the compressed air escaped, releasing all the brakes. Moreover, the brake could be applied only by the engineer, and, as the pressure was supplied directly from the main reservoir only, the more cars there were in the train the less pressure there would be in each brake cylinder when the brakes were applied.

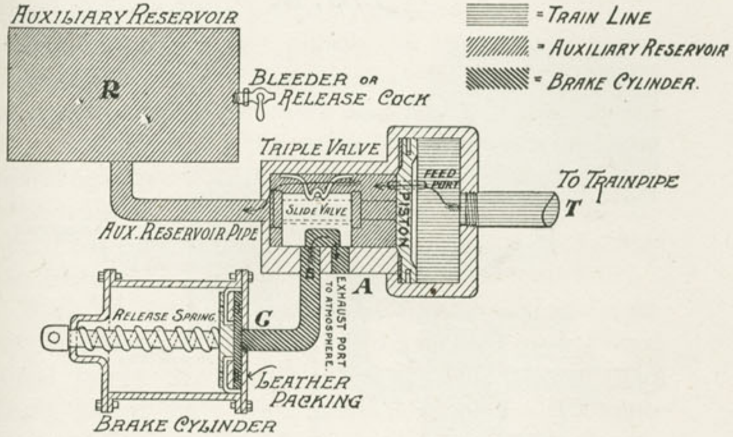
The automatic air brake, which has generally superseded the straight air brake on railroads of this country, is so called because it is applied automatically by any derangement reducing the air pressure in the train pipe, such as excessive leakage, a parted train, burst hose, and so on. The straight air brake requires but two essential parts on each car, namely, a cylinder and train line, while the automatic brake requires two additional parts—a triple valve and an auxiliary reservoir. The purpose of the triple valve is to divert the air into its proper channel and prevent its escape from the auxiliary reservoir and brake cylinder when the brake is set. The purpose of the auxiliary reservoir is to store a proper volume of air on the car for supplying the brake cylinder. In the application of the brake the entire pressure which the cylinder receives comes from the auxiliary reservoir on the same car. Hence, each cylinder having its own auxiliary, an increase in the number of cars in a train does not reduce the braking power, as we have seen it does in the case of straight air. The capacity of the auxiliary reservoir on each car should be about three times the capacity of its cylinder when the piston has a travel of two-thirds the length of its cylinder—or standard travel. Although locomotives and cars of different weights require different sized brake cylinders (from eight to fourteen inches in diameter), the auxiliary should, in each instance, be proportionately larger.

The essential parts of the automatic brake system are the air gauge and pump governor; air pump and main reservoir; train line with its hose, couplings and branch pipes; triple valve, auxiliary reservoir and brake cylinder.

The operation of the air through the automatic system is, briefly, as follows: The air pump takes air from the atmosphere and compresses it into the main reservoir; it then passes through the engineer's valve (in release position) to the train line. From the train line the air passes through the branch pipe, cut-out cock and triple valve of each car into its auxiliary reservoir. When the brakes are to be set, a movement of the triple valve allows the air to pass from the auxiliary to the brake cylinder, applying the brake. When the brake is to be released, the movement of the triple valve to its original position allows the air in the brake cylinder to escape to the atmosphere. When a retaining pressure valve is applied to a car, the triple exhaust is piped to the retainer, which must, of course, be open to allow the free escape of all air from the cylinder. The train pipe under each car is connected by its branch pipe to a triple

valve. The latter derives its name from the fact that it performs the three operations of charging the auxiliary reservoir, setting the brake and releasing it; and, as each operation depends directly upon the triple valve, it becomes the most important feature of the automatic brake,

FIG. A.



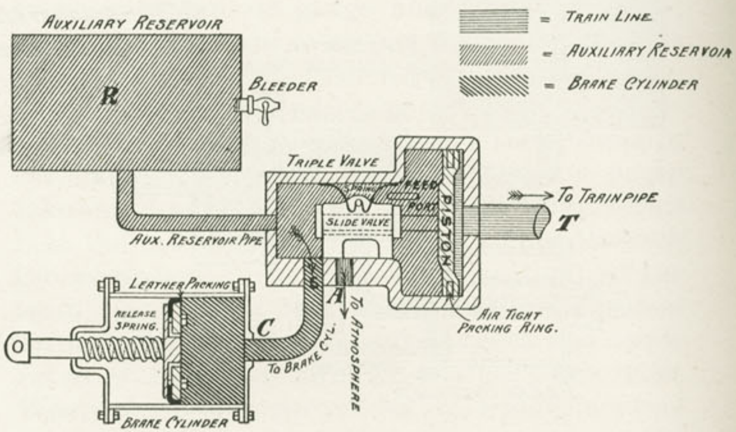
AIR BRAKE MECHANISM. RELEASE OR CHARGING POSITION
SHOWS T&R AND C&A CONNECTED, R&C CLOSED.

and is, perhaps, the most difficult of comprehension. For the purpose of clearly showing the fundamental functions of this complex mechanism, Figs. *A* and *B* are introduced.

It will be noticed, by reference to the above illustration, that the triple valve has four connections: train line (at *T*), auxiliary reservoir (at *R*), brake cylinder (at *C*), and the atmosphere (at A). Communication between these various connections is opened or closed as follows:

To release the brake, communication is opened between the train line and auxiliary reservoir, closed between the auxiliary reservoir and the brake cylinder, and opened between the brake

FIG. B.



AIR BRAKE MECHANISM. SET POSITION.
SHOWS T & R AND C AND A CLOSED, R AND C CONNECTED.

cylinder and the atmosphere. On the other hand, to set the brake, communication is closed between the train line and auxiliary reservoir, opened between the auxiliary reservoir and brake cylinder, and closed between the brake cylinder and the atmosphere.

The triple valve contains a piston which by its stem moves with it a slide valve. Fig. A

shows the piston in such a position that the train line pressure (T) can pass by it through the feed-port and charge the auxiliary reservoir (R). Here the brake cylinder (C) has an opening to the atmosphere (A) on account of the cavity under the slide valve. It also shows how the slide valve prevents the auxiliary (R) pressure from entering the brake cylinder (C).

Fig. B shows the piston of the triple valve moved away from the feed-port, thereby closing communication between the train line (T) and the auxiliary (R), the slide valve has closed the opening from the brake cylinder (C) to the atmosphere (A) and has opened a port from the auxiliary (R) to the brake cylinder (C), admitting air from R to C.

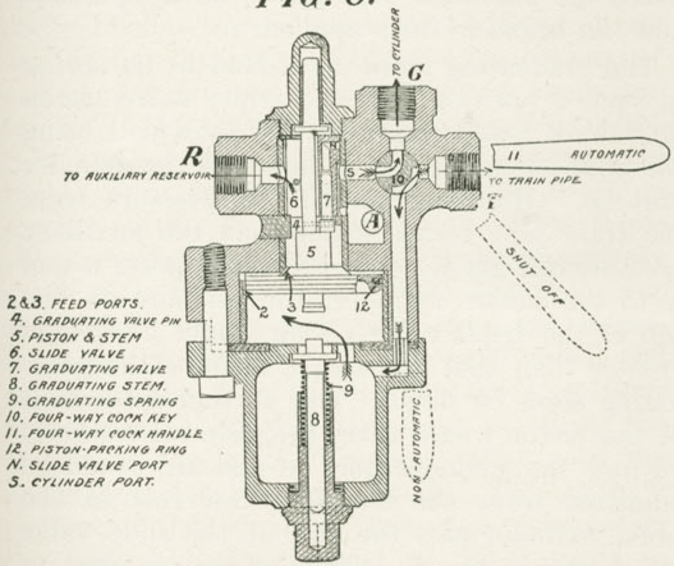
Figs. A and B show the triple valve in its two extreme positions. If after the piston and slide valve are as in Fig. B, they be moved back about half way until the port s between the auxiliary (R) and the cylinder (C) is closed, whatever pressure had already passed into the cylinder would remain there and no more could enter; and a slight movement of the triple again to position shown in Fig. B would admit more air to the cylinder. This can be repeated until the two pressures in R and C are equal. The operation of the triple valve in this manner is what is termed its graduating feature, whereby a small amount of the auxiliary reservoir pressure is admitted to the brake cylinder and communication closed, repeatedly. For example, suppose in

Fig. *A* the train line and auxiliary reservoir are charged to the standard pressure of seventy pounds. The triple piston having equal pressure on each side is balanced. If five pounds train line pressure be drawn off leaving sixty-five, the auxiliary being left at seventy will force the triple piston, and with it the slide valve, to position shown in Fig. *B*. It would remain there until about six pounds had gone to the brake cylinder from the auxiliary reservoir, leaving it sixty-four as against the train line's sixty-five, when the train line pressure would push the piston and slide valve back just enough to close port *s* and prevent further escape of air from the auxiliary reservoir. Another five pound reduction would be followed by a like reduction from the auxiliary reservoir, which would add still more to the cylinder pressure. Although some difference of pressure is required between the two sides of the triple piston to move it, this difference is so slight that in graduated applications it may be said that whatever reduction is made in the train line is followed by a like escape from the auxiliary reservoir.

Fig. *C* shows the plain automatic triple valve. To comprehend this valve it is but necessary to see how the graduating feature is performed by the addition of a graduating valve. The latter (7) is fastened to the piston stem (5) by a pin (4) and moves immediately with the slightest movement of the piston (5), while the slide valve (6) in which it seats has a small free movement

lengthwise on the piston stem. When a reduction of five pounds is made in the train pipe pressure (the under side of piston), the auxiliary pressure (on top of the piston), being greater by five pounds, pushes down the piston, pulling with it the graduating valve (7) and the slide valve (6)

FIG. C.



PLAIN AUTOMATIC TRIPLE VALVE.

until the slide valve port (*n*) is opposite the cylinder port (*s*). It remains in that position until a little more air than five pounds of auxiliary pressure has gone to the brake cylinder, when the piston is moved up enough to seat the graduating valve (7), but not enough to move the slide valve.

Further light reductions from the train pipe will require but the easy movement of opening and closing the graduating valve to apply the brake with more force. When sufficient air is taken from the train pipe to hold the graduating valve open until the auxiliary has supplied a pressure to the brake cylinder equal to that remaining in itself, the pressures are said to have equalized and the brake is fully applied.*

The graduating stem (8) is held by its spring in such a position that the triple valve piston (5) cannot readily move farther than will bring the slide valve port (*n*) in line with the cylinder port (*s*). However, should the pressure from the train pipe escape faster than the auxiliary pressure can get through the small ports *n* and *s*, to the brake cylinder, the pressure on the top of the triple valve piston would be enough greater than that beneath it to force the graduating stem (8) down. This further movement of the piston would carry the slide valve wholly beyond the cylinder port (*s*) and air would be admitted from the auxiliary reservoir to the brake cylinder past the end of the slide valve (as shown in Fig. *B*). This extreme movement of the triple valve is called its emergency position.

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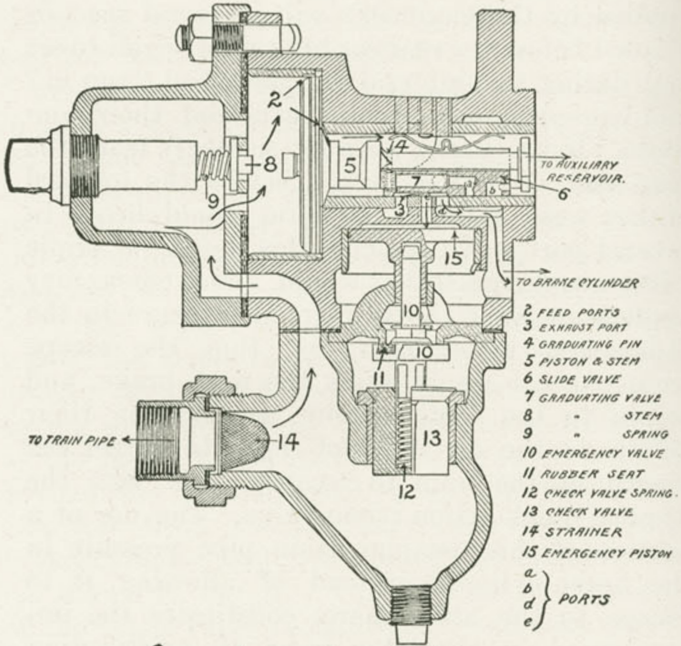
* This is but a passing word regarding the equalization of pressure. The subject is largely misunderstood, as it seems to many to be governed by no simple law. It is clearly explained and illustrated elsewhere in connection with "piston travel."

With the plain triple valve, as with all previous automatic valves, all the air drawn from the train line to apply the brakes must escape from the engineer's valve or the opening where the reduction is made. When trains of fifty air-braked cars were used, it was found that if a hose burst on the first car or emergency was applied by the engineer's valve, several seconds elapsed before the rear car brake had begun to set and during this interval the slack had "run in" and caused damage to the cars and their contents. If the brake were set suddenly from the rear end of a long train, before the forward brakes were applied, the train would break in several parts. To remedy this defect a triple valve was designed that would, under emergency application, vent the train pipe pressure to the atmosphere under each car; thus the escape from one car would apply the next brake, and so on to the last, thereby accelerating their action as the air did not have to travel the length of the train to escape. This was the original quick-action triple valve. The use of a portion of this escaping train pipe pressure in the brake cylinder, instead of allowing it to escape to the atmosphere, constitutes the improvement in the later form of quick-action triple valve shown in Fig. *D*.

The plain triple valve is now applied to locomotives only. The quick action triple valve has the same parts as the former, with more parts added. In an ordinary application of the brake, only the same parts are brought into action and cars equipped with one kind of valve will work properly with those equipped with the others. When a rapid reduction of the train line pressure

FIG. D.



QUICK ACTION TRIPLE VALVE.

is made, as in the case of the plain triple valve under like circumstances, the triple valve piston (5) compresses the graduating spring (9) and pulls the slide valve (6) into a position farther than

that of ordinary service. Thus the graduating port(a*) in the slide valve is carried past the cylinder port(d) and registers with port e, allowing auxiliary reservoir pressure to pass to the top of the emergency valve piston (15), which shoves down the emergency valve (10) and allows the train line pressure beneath to flow through to the brake cylinder.† At the instant port a comes opposite port e, the small port b in the slide valve is in register with the cylinder port d, admitting auxiliary reservoir pressure to the brake cylinder.

Although the auxiliary reservoir pressure is thus opened to the brake cylinder simultaneously with the train pipe, the emergency valve (10) is so much larger that the greater part of the pressure at first received by the cylinder comes from the train line. When the train line and the cylinder pressures equalize, as they will at about fifty pounds from an original seventy, the train line check (13) closes, preventing the return of the air to the train line, and then the auxiliary reservoir and the cylinder pressure equalize through the smaller ports (b and a). With an original pressure of seventy pounds, the resulting brake cylinder pressure will be about sixty pounds—or twenty per cent. more than can be obtained with any triple valve other than the quick action; a similar increase in train line pressure is also required to release the brake.

When the train line and all the auxiliary reservoirs of a train have a pressure of seventy pounds

*In reality it is a port just back of port a.

†Check valve 13 is raised by the train line pressure under it

per square inch, they are said to be fully charged. The feed port in the triple valve is so small that about two minutes are required to charge an auxiliary, if seventy pounds pressure be maintained in the train line continually.

The two pressures, train line and auxiliary reservoir, control the movements of the triple valve by the preponderence of the one over the other. The law governing the triple valve is as follows: The triple valve moves to *set* position when the train line pressure is reduced to *less* than that pressure in the auxiliary reservoir, and to *release* position when the train line pressure *exceeds* that in the auxiliary reservoir.

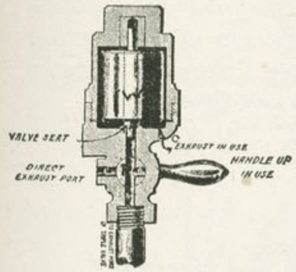
Venting the auxiliary reservoir pressure to the atmosphere by the release valve, or "bleeder," is termed "bleeding" a car. The brake releases through the triple valve as soon as the auxiliary reservoir pressure is less than that of the train line. The principle is precisely the same as when the engineer releases by increasing the train line above the auxiliary reservoir pressure.

The pressure retaining valve is a valve connected by a pipe to and directly controlling the triple valve exhaust. It can be used with either kind of triple valve. Its purpose is to slowly release the brake until it holds about the same as a lightly applied hand brake, retaining that pressure while the train is being recharged on a descending grade. It is conveniently placed at the end of a car near the hand brake and may be operated from the top of a freight car or the

platform of a passenger car of a moving train. The pressure retaining valve is shown sectioned in Fig. E. While simple, it is yet the most liable of any valve to misuse by trainmen. A handle controls the plug (P) of a three-way cock. When the handle is turned to point downward, the plug (P) will be turned one quarter turn, bringing port a opposite b, thus connecting the triple valve exhaust with the atmosphere through the direct exhaust port. In that position the triple valve has as free an exhaust as though the retainer were removed from the pipe. When the retainer is to be used, the handle is turned up to a horizontal position, as shown in figure E, before descending a grade. The plug (P) connects the port b with the under side of a weighted valve (W) which it must raise to let pressure escape at c. About fifteen pounds are required to raise valve W, and when raised, all in excess of that amount slowly escapes through the small port c, the fifteen pounds being retained in the brake cylinder while the engineer releases the triple valves and recharges the auxiliary reservoirs.

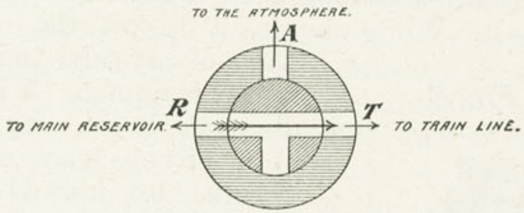
FIG. E.

PRESSURE RETAINING VALVE.



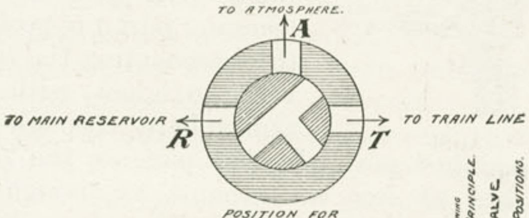
The engineer's valve is the valve on the locomotive used to operate the brake. It is, therefore,

FIG. F.



POSITION FOR RELEASE AND RECHARGING
MAIN RESERVOIR & TRAIN LINE CONNECTED

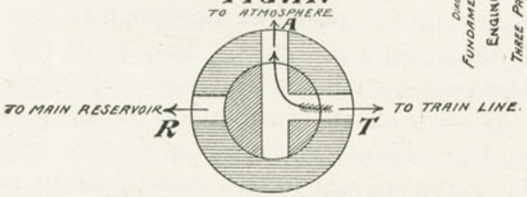
FIG. G.



POSITION FOR HOLDING BRAKES APPLIED
"ON LAP" ALL PORTS CLOSED.

DIAGRAMS SHOWING FUNDAMENTAL PRINCIPLE OF ANY ENGINEERS VALVE IN THE THREE PRINCIPAL POSITIONS.

FIG. H.



POSITION FOR APPLYING
TRAIN LINE OPEN TO ATMOSPHERE.

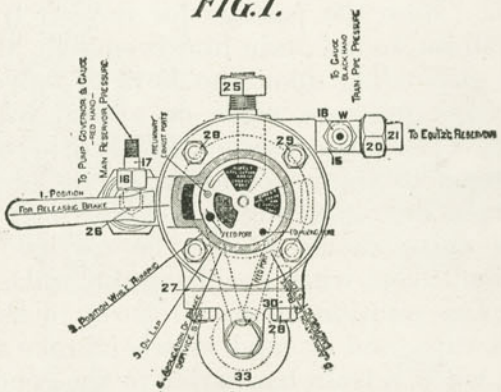
THE THREE WAY COCK.

the connecting link between the train line and the atmosphere for setting the brakes, or between the main reservoir and the train line for releasing, but it cannot connect the three

simultaneously. The first engineer's valve used was the three-way cock.

Figs. *F*, *G* and *H* clearly illustrate the three positions of a three-way cock. The outside represents the body of the valve and the inside circle the plug that can be turned one-fourth way around by the handle, bringing the necessary ports into communication (Figs. *F* and *H*) or closing everything (Fig. *G*).

FIG. I.



Engineer's Brake and Equalizing Discharge Valve with Feed Valve Attachment and Duplex Air Gauge, known as the F 6 or 1892 Valve.

The engineer's brake and equalizing discharge valve with feed valve attachment and duplex air gauge is the fifth valve of a series of improvements during fifteen years. The main features of the "three-way cock" are still retained, however. This valve (Fig. *I*) has two other positions, *running* and *service application*, making a total of five positions, beginning on the left, namely, *release, running, lap, service application,* and *emergency.* (See Fig. on page 316.)

(1) *Release,* or *full release* as it is frequently termed in distinction from running position, brings the main drum pressure, by means of the rotary valve, in direct communication with the train line into which it flows. This position is for quickly charging the train line and auxiliary reservoirs, also for releasing brakes.

(2) *Running* position is but a modification of *release.* Here the passage for the air from the main drum to the train line is smaller and contains (depending upon the form of valve used) an excess pressure valve or a feed valve and spring. The main reservoir pressure is thus held at fifteen to thirty pounds in excess of that in the train line according to the adjustment. The brake valve should always be carried in this position except when operating the brakes.

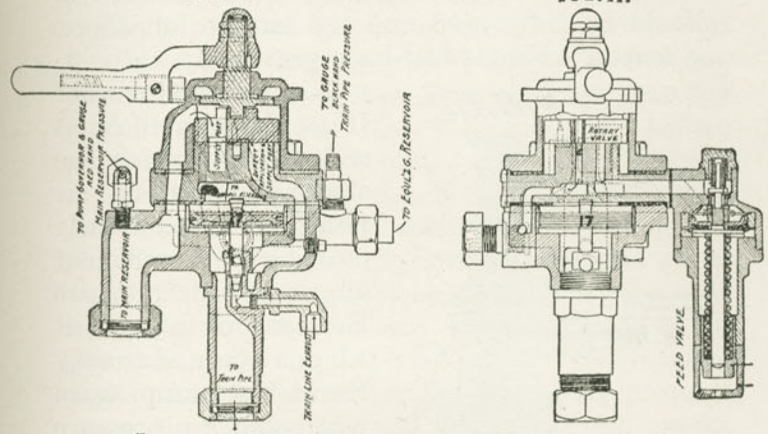
(3) *Lap* position closes all ports in the engineer's valve and is used between brake applications, when a train has parted or the conductor's valve opened, and also when coupling to air-braked cars.

(4) The *service application* position is but a modification of the direct application or emergency position, having a smaller opening of the train line to the atmosphere, and therefore being less severe. The engineer, by means of the rotary valve and handle, does not directly vent the train line pressure, but simply draws pressure from the top of a piston (17, Fig. *J*) operated on from

below by the train line pressure. The piston (17) being balanced in positions 1 and 2, if in position 4, five pounds of pressure be withdrawn from the top of the equalizing piston (17), this piston will move upward, carrying with it its stem (which forms the train line exhaust valve) and will remain open until five pounds have gone from

FIGS. J AND K

FIG. J. FIG. K.



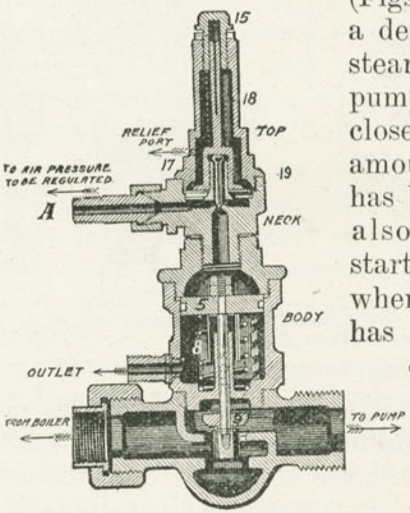
ENGINEERS BRAKE AND EQUALIZING DISCHARGE VALVE.
WITH FEED VALVE ATTACHMENT.

beneath it—the train line. The stem of this piston does all the braking in service, and the opening it forms to discharge the train line pressure to the atmosphere is so small as to preclude the possibility of setting the brakes in quick action. The position just described should be always used, except in the case of actual emergencies.

(5) *Emergency* or *direct application* position brings the train line wide open to the atmosphere directly through the rotary valve.

When, by some defect in the engineer's valve, service application position does not apply the brakes, position 5 may be resorted to; then the handle should be gradually moved toward the position so as not to set any quick action triple valves that are in the train in emergency; but when an actual emergency arises, position 5 should be fully used and the handle left there, no matter where it had been previously.

FIG. L.



PUMP GOVERNOR.

The Pump Governor (Figs. *L*, *M* and *N*) is a device by which the steam supply to the air pump is automatically closed when a sufficient amount of air pressure has been obtained; it also automatically starts the pump again when the air pressure has receded from that desired point.

All the steam from the boiler to the pump must pass through the bottom portion of the governor containing the steam valve (9). This valve is closed

[NOTE.—The Air Pump is fully explained and illustrated in Vol. XII.]

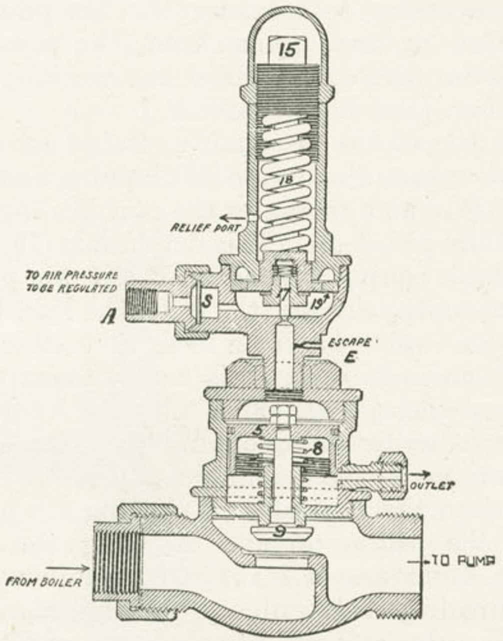
by a piston (5), operated upon by air pressure above it. When there is no pressure above this piston (5) it is held open by a combined action of the spring (8) below it and boiler pressure beneath the steam valve (9). As the spring and boiler pressure act constantly, it is only necessary to see how the air pressure is admitted to, and taken from, the top of the air piston (5) to understand the working of the governor. (See Figs. *L* and *M*.)

The top of the governor contains a very thin flexible copper diaphragm (19), holding a small pin valve (17) which regulates the port leading to the top of the piston (5). This diaphragm (19) has an adjustable spring (18) above it and air pressure on the under side of it. With the 1892 form of engineer's valve, having a feed valve attachment, the air connection at *A* is from the main reservoir and the spring (18) is adjusted by the nuts above to withstand about ninety pounds of air pressure under the diaphragm (19) before it raises and opens the pin valve (17) letting air pressure upon the piston (5) and stopping the pump. When, from use or leakage, the main reservoir pressure drops below ninety, the diaphragm closes the pin valve (17) and the air pressure above the piston (5) escaping, allows it to raise the steam valve (9) and start the pump.

With all former engineer's valves, the air connection to the governor (at *A*) is from the train line, which pressure it regulates, similarly, at seventy (70) pounds per square inch.

Figure M shows the improved pump governor, working on the same principle, but sufficiently altered to render it more sensitive to the slightest variations.

FIG. M.

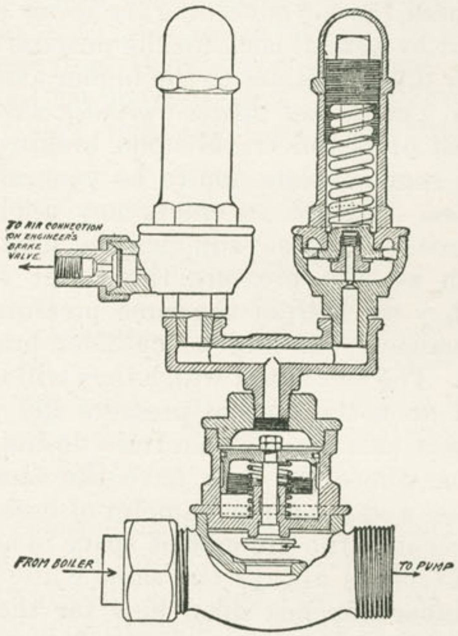


IMPROVED PUMP GOVERNOR.

Fig. N illustrates a governor with a double top, which is successfully used with engineer's valves not having the feed valve attachment and also on locomotives equipped for either the standard or the "high-speed" brake. When used for

the first purpose, one of the tops is connected to the train line and adjusted at seventy pounds as usual while the other top is connected to the main reservoir pressure and set at ninety pounds

FIG. N.



DUPLEX PUMP GOVERNOR.

or more, the object being to prevent too high a pressure from accumulating in the main reservoir when the brakes are held applied on long descending grades or in making stops requiring the brakes to remain set a long time.

When this double governor is used on locomotives hauling both the standard and the high-speed brakes alternately, both tops are connected to and govern the same pressure, but the one is set at standard amount and the other at twenty to thirty pounds higher. If the high-speed brake is to be used, the top governing the lower pressure is cut out by a small cock for the purpose and the governor then regulates to the higher amount.

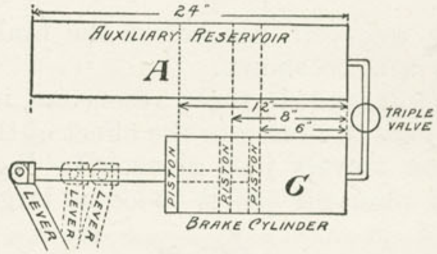
Piston Travel and Brake-Cylinder Pressure.—The effect of piston travel upon braking power requires some explanation to be generally comprehended. Except in emergency application, the auxiliary reservoir supplies the brake cylinder with all the pressure the latter receives. When they are both of the same pressures—i. e., have equalized—the limit of cylinder pressure is reached. The amount at which they will equalize is based upon the laws of pressure and volume. The reason that brakes on a train do not all set the same where the cars have the same sized auxiliaries and the same diameter of brake cylinder, is because the amount of space in an auxiliary reservoir is always the same while that of the cylinder depends upon how far the piston travels, as the piston practically forms one end of the cylinder.

If Fig. O be referred to, it will be seen that while the auxiliary reservoir (*A*) has a cubic capacity always limited by its fixed walls, that of the brake cylinder (*C*) has one end fixed but the piston forms the other end of the cylinder.

The piston can only travel as far as the brake levers will allow according to the amount of slack in their adjustment; the wear of the brake shoes continually increases this slack and consequently the travel of the piston.

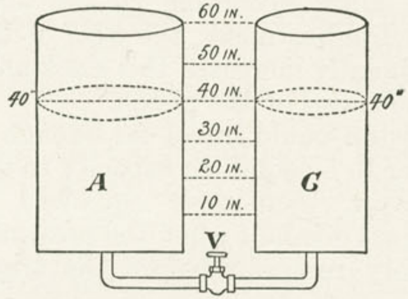
If the piston could travel far enough to cause the cylinder to be equal in capacity to the auxiliary reservoir, then their equalized pressure would be just one-half what the pressure was in the auxiliary reservoir before the triple valve

FIG. O.



opened communication to the cylinder. As Fig. *O* shows, the brake piston can travel but 12 inches, while the auxiliary reservoir has a capacity equivalent to about 24 inches of the length of the cylinder. Thus with a full piston travel of 12 inches the auxiliary reservoir is twice the size of the cylinder; with an 8-inch piston travel, it is three times as large; with a 6-inch travel, it is four times as large, etc. Hence their equalizing points are respectively at two-thirds, three-fourths, and four-fifths the pressure the

FIG. P.

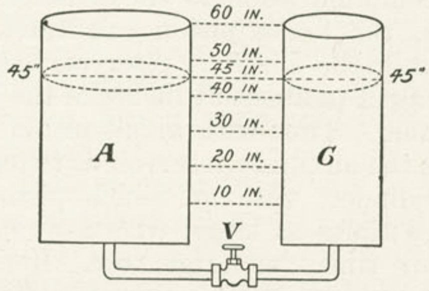


RATIO OF AUXILIARY RESERVOIR (A) TO CYLINDER (C) IS 2 TO 1.
REPRESENTING LONGEST PISTON TRAVEL 12 INCHES.

auxiliary reservoir has before the brake is applied, as will be shown.

Figs. *P*, *Q* and *R* show reservoirs in which water is used to illustrate the effect of the different piston travels just given. In Fig. *P* the auxiliary reservoir (*A*) is twice as large as the

FIG. Q.

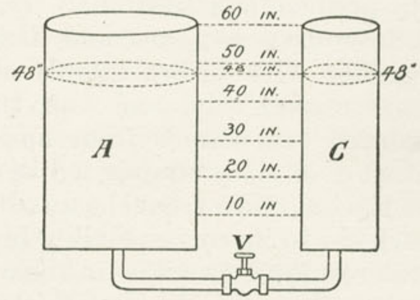


RATIO OF AUXILIARY RESERVOIR (A) TO CYLINDER (C) IS 3 TO 1.
REPRESENTING STANDARD PISTON TRAVEL 8 INCHES.

cylinder (*C*); in Fig. *Q* it is three times as large, and in Fig. *R* four times—all the reservoirs (*A*) are of the same size, the difference in the cuts being in the size of the cylinder (*C*).

In Fig. *P* if *A* be filled with say sixty inches of water (*C* being empty) and valve *V* opened, twenty inches of water will flow from *A* to *C*, making forty inches in *C*, as *A* is twice as large,

FIG. R.



RATIO OF AUXILIARY RESERVOIR (A) TO CYLINDER (C) IS 4 TO 1.
REPRESENTING SHORT PISTON TRAVEL 6 INCHES.

and leaving forty inches in *A*. Hence their equalizing point is at forty or two-thirds the original amount in the auxiliary reservoir (*A*), and the necessary reduction from *A* to cause this equalization is 20-60, or one-third of its original amount.

In Fig. *Q*, if the experiment be repeated, but fifteen inches of water will flow from *A* to *C*, making forty-five inches in *C*, as *A* is three times the size of *C*, and leaving the same in

A (45). Thus forty-five or three-fourths the original is their equalizing point, and one-fourth is the necessary reduction from *A* to cause equalization.

In Fig. *B* only twelve inches of water will flow from the auxiliary reservoir *A*, making forty-eight inches in *C*, as *A* is four times the size of *C*, and leaving forty-eight remaining in *A*. Here 48-60 or four-fifths the original is their equalizing point, and one-fifth is the necessary reduction to produce equalization.

Now, if three cars *one*, *two* and *three* were coupled together with piston travels of 12, 8, and 6 inches respectively, and the train-line pressure reduced ten pounds from an original charged pressure of sixty pounds, a like amount, or ten pounds, would flow from the auxiliary reservoir of each car to its corresponding brake cylinder, but the resultant pressures in the cylinders would be twenty pounds in car *one*, thirty pounds in car *two*, and forty in car *three*. Although these brakes would hold so much differently, yet they would all be released with a slight increase of train pipe pressure.

With auxiliary reservoirs and train line of these three cars charged to a pressure of say sixty pounds, a train line reduction of one-fifth or twelve pounds fully applies the brake on car *three* with forty-eight pounds cylinder pressure. A further reduction of three pounds (making 15 in all) is necessary to fully apply or equalize the pressure on car *two* with but forty-five pounds,

not at all affecting the forty-eight pounds of brake *three*, while it takes a total reduction of twenty pounds to fully equalize brake *one* with but forty pounds in its cylinder—leaving *three* and *two* at their equalized points as above. The train line pressure is now at forty, or twenty below what it was. If this pressure be slowly increased, they will release in the opposite order from that in which they equalized, that is, brake *one* lets off first when the train-line pressure is over forty, *two* releases when it exceeds forty-five, and *three* not until above forty-eight pounds is had in the train pipe.

It will then be plain why uniform braking cannot be accomplished where the piston travel of cars in a train differs widely and also why, in such a case, it is better for an engineer to make under rather than over-reductions that he may be able to release all cars together.*

Automatic Slack Adjusters.—Many devices have recently been invented, several of which have proven practicable, by means of which the slack is automatically taken up on the brake rigging as the shoes wear, thus keeping the piston travel uniform. Their desirability is apparent and all the adjustment necessary with them is to let out

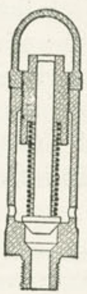
*A full reduction is the necessary amount that must be taken from the train line to equalize the auxiliary reservoir and the brake cylinder pressures on a car; an under-reduction is a less amount than this; an over-reduction is more than is necessary and its effect is to waste air and render it frequently impossible for an engineer to release all brakes simultaneously.

the slack sufficiently or more than enough when putting on new brake shoes.

Train Air Signal.—The train air signaling apparatus on a passenger car consists of a pipe running the length of the car with a stop cock at each end and a branch pipe leading up to a discharge valve which is operated by a signal cord placed similarly to the old-time bell cord. The signal pipes on the cars are connected to each other and to the locomotive by hose and couplings differing sufficiently from those of the train line to avoid a wrong connection being made. (See Figs. *Z* and *Aa.*)

The apparatus on the locomotive comprises a reducing valve, which supplies the signal system with main reservoir air but at a reduced pressure—about forty pounds—and a signal valve which causes a blast of air to blow a small whistle in the cab when any sudden reduction of the signal line pressure occurs, as when the discharge valve in some car is opened or a break-in-two occurs.

FIG. S.



SAFETY VALVE FOR HIGH SPEED BRAKE.

The High-Speed Safety Valve herewith shown (Fig. *S*) is for the purpose of attachment of cars ordinarily equipped with the standard brake to a train wholly equipped with the "high-speed" brake. This valve is screwed into the oil hole of the standard cylinder and its spring is set to relieve the cylinder slowly of all pressure over

the standard maximum pressure, and thus prevent wheel sliding.

ADDITIONAL INSTRUCTIONS TO ENGINEERS.

Test of Brakes.—The brake test should never be omitted under any circumstances, and must not be considered a waste of time on freight trains; they have less rights, and consequently less protection on the road than passenger trains, and every precaution should be taken to know that the brakes are working properly. It would seem almost needless to say that a long freight train, having a close meeting point at the next station, should have brakes tested before starting; and it would appear equally absurd to omit the brake test before leaving a terminal "because it was up grade a long ways, and brakes are not needed to stop the train." One brake dragging on a grade may stall a train.

While nothing can be done by the engineer to take the place of the terminal test of each car that the trainmen should make while the train is standing, yet there are several ways in which an engineer of a moving train can tell, approximately, the number of air-braked cars to which he has connection. This may frequently be instrumental in discovering cases where, through malicious intent or carelessness, many or all of the train brakes have been rendered inoperative from the engine by the turning of a hose cock.

The best method of making a running test of the brakes is to make a service application of from four to five pounds, say, two miles from the next stopping or meeting point, railroad crossing, draw-bridge, or system of interlocking switches, and then notice the amount and length of the blow from the train line exhaust nipple of the engineer's valve. To an experienced man the length of this blow will reveal very closely the number of cars of standard piping he has in connection with his engine. If an engineer wishes to note the holding power of the brakes as a running test, then he should make a much heavier reduction after the first, for it should be borne in mind that, on account of the leakage grooves three inches long in each car cylinder, so light an application as four or five pounds will be felt to hold the train better with a very few cars working than if all were working.

Another but inferior method of making a running test a safe distance from danger points, is to throw the handle of the engineer's valve to full release position (having previously had, say, twenty pounds of excess pressure) and note the number of pounds that the main reservoir hand of the gauge drops back before the two pointers meet. On short trains, with average-sized main reservoirs, if free from water, the drop may be about one pound to the car, but a little experimenting on an engine will determine. If the train line exhaust of the engineer's valve blows when the handle is thrown to full release, there are probably no cars at all connected to the engine. As this form of running test tends

to overcharge the train, it may cause brakes to set and drag therafter when a stop is not made.

Defective Car.—One defect in a single quick action triple valve will cause the brakes on a whole train to apply in emergency when a service stop is desired. On a moving freight train this may cause considerable damage to cars and their contents. Such action can be determined and the car cut out before starting if the engineer will but watch the train line exhaust from his engineer's valve. If this exhaust stops suddenly before he has had time to reduce the full twenty pounds from the gauge, he will know the brakes have gone into emergency. They are not applying in emergency when the train line exhaust blows properly for the length of train.

Running Position.—Always carry the handle at this position with any engineer's valve. When releasing brakes ordinarily if the handle is immediately returned to running position before the engineer takes his hand from the valve, no trouble will be had from brakes dragging. Excess pressure, which is obtained in this position, is very like insurance—handy when adversity arises and then is too late to obtain it.

Clean Valves.—Frequently clean the governor pin valve, the excess pressure or the feed valve, and the rotary—oiling the latter only, when replacing. If very little oil be used in the air cylinder of the pump, these valves will seldom become gummed and defective. No engineer can do perfect braking with any of them defective.

Pump Stopped.—Pumps frequently stop from lack of oil in the steam end and fail to compress air from heating at the air end due to their being run unnecessarily fast. It is well to remember that a few drops of oil from the lubricator to the steam cylinder when starting the pump and a few minutes more time taken to charge a train on a hot day may prevent a pump failure. If the air cylinder of a pump be excessively hot, allowing water to be sucked in will cool it and should be practiced before inserting oil. Cylinder oil is more annoying in its after effects, and hence a lighter oil is advisable—applying it always through the cup provided for that purpose and not through the air suction. Details could be given as to the proper procedure where a pump has stopped on the road, but the proper tools are generally lacking and, excepting in a few cases, the repair cannot be made by the engineer without long delay. It is better for enginemen to know how to treat a pump so as to prevent its stopping and to act accordingly than to be able to repair it on the road.*

Air Signal.—Extra passenger engines equipped with the air signal when it is not in use should have their reducing valves cut out by closing the stop cock for that purpose, so as to prevent the accumulation of dirt and oil, rendering it defective when next wanted for use.

Handling Trains.—In handling freight trains, either partially or wholly equipped with air brakes, allow ample room for making the stop

*The principle and working of the air pump are fully described and illustrated in Vol. XII.

and wait, after shutting off, for what slack there is to be taken up. Then a reduction of seven or eight pounds should be made and another wait also made for the slack to come up.* After the slack is taken up ("bunched") the engineer may reduce further as circumstances and his judgment dictate, bearing in mind that the brakes should not be released until a full stop is reached. If it is necessary to release the brakes on a freight train while moving slowly, it should be done quickly and with as little air as possible and the valve lapped until ready to re-apply. This is the most essential point in making more than one application.†

To release a part air train while moving is a most skillful operation, and should only be employed when necessary. To do this without breaking the train in two or jerking the rear end, an engineer should place the engineer's valve in running position for a fraction of a second and then return it to lap, awaiting the release of any triple valves this movement may have affected. He should continually repeat this until probably

* With less than ten cars of air five pounds should be used for the first reduction; with ten to twenty cars of air, five to six pounds should be used; with twenty to thirty cars of air, six to seven pounds; with thirty to fifty cars of air, seven to eight pounds. This is required to get the pistons of all cars past their leakage grooves.

† From the time the brakes are applied until they are released, no matter how many reductions, is one application; after they have been released and are re-applied, is the second application.

all brakes have released, a few at a time, finally placing his handle in full release a few seconds to be sure all are off.

Train Parted, Etc.—When the brakes are applied suddenly from some unknown cause, such as hose burst or train parted, the engine should be shut off immediately and the engineer's valve lapped. When a train has parted between air-braked cars, it should never be attempted to pull away from the rear section. If, after coupling up, all the brakes do not release at once, lap the valve and secure excess pressure; never try to "pump them off."

Avoiding Over-Reductions.—A reduction of more than one-third of the auxiliary reservoir pressure is always an over-reduction; with piston travel not over eight inches, more than one-fourth is an over-reduction. Freight trains are handled more uniformly well if no over-reduction is made on any cars of the train—even those with the shortest travel of piston, which require but a one-fifth reduction.

Passenger Trains.—On account of the slight amount of slack on a passenger train, an engineer should bear in mind that there is no excuse for jerking with the air brakes. If the brakes be released properly before coming to a dead stop and emergency not used when the train is moving slowly, the train will not be jerked by the brakes. Careful handling of the throttle and keeping the engine brakes in good order will prevent jerks due to the engine.

In making water-tank or other "chalk-line" stops, it is best not to attempt to make the stop with one application on a passenger train. Reduce to a very slow speed, releasing all brakes and immediately lapping the engineer's valve until ready to re-apply lightly for the desired stopping point. As the brake is so slightly applied, little or no shock is occasioned now by holding the brakes on to a full stop.

To Avoid Sliding of Wheels on a slippery rail, two applications may be employed in making a stop on passenger trains. A heavy application should then be made when the train is moving fast and the wheels are least liable to slide. The brakes should all be released when the speed has been reduced to fifteen or twenty miles per hour and, finally, a light application made—as then wheels will slide most easily. The rails should also be continuously sanded.

ADDITIONAL INSTRUCTIONS TO TRAINMEN.

Blow Out Hose.—Dust, dirt and cinders are the greatest enemy of the air brake. Since the air brake is the trainman's best friend, trainmen should do everything possible to keep dirt out of the air brake apparatus by blowing out or shaking dirt from all couplings before uniting them. Setting quick action should be avoided by opening cocks slowly, as quick action throws sand and dirt into the triple valves and cylinders and causes many leaks.

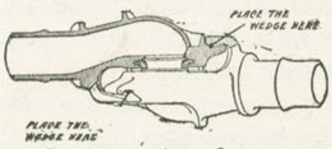
Coupling and Uncoupling.—After coupling the hose, the hose cock nearer to the engine should first be opened and the hose tested; then the other cock should be opened slowly to prevent setting the brakes in emergency.

In uncoupling, the farther hose cock from the engine should be closed first.

The hose should always be cut by hand before uncoupling the drawbars.*

Discovering Leaks.—This should always be done before any test of the brakes is made and while the train is being charged. When there is a strong wind and leaks cannot be heard, yet the pump indicates excessive leakage, all communication between the engine and train should be closed and the engine thus tested. The engine being found tight, the rear half of the train should then be cut off, thus testing the first half with the engine connected. Whichever half of the train now is proven to have the leakage should be again divided—the one part connected to the engine and the other detached. Continuing this division of the defective part until the leakage is located and repaired. If leaks occur between hose couplings

FIG. T.



STANDARD HOSE COUPLING.

* Before coupling an engine to a train or in picking up uncharged air-braked cars, it should be ascertained that the cocks on all the cars are right, otherwise all the air may be thrown away through some open angle cock.

on account of worn gaskets, a wooden wedge, such as a match (preferred) or a nail, placed between the lugs of the coupling will generally prove effective (Fig. *T*). Paper gaskets should not be used nor the coupling lugs bent down by pounding. Leaky hose or pipes can often be temporarily fixed by covering the part with a piece of old hose split open and then wound tightly with wire or string.

Emergency When Service is Intended.—Whenever brakes, being properly tested, set quick-action, it is due to some triple valve in the train being defective. The car having the defective valve can be located by dividing the train into parts as described for locating leaks, each time having the engineer charge and apply the brakes fully in service application the same as testing. When the car is found it should be cut out and its air released and the whole train again tested.

Charging.—Trainmen should bear in mind that two minutes is practically the shortest time in which an auxiliary reservoir can be charged; that the brake will not set until this is done; and that if they attempt to test the brake sooner than this, they are simply wasting time, as the car is not charging as fast with the train line pressure thus reduced.

In charging long freight trains with small leakage, an eight-inch air pump should require about one-half as many minutes as there are cars; a nine and one-half inch pump should charge in about half the time.

Air Cocks.—There are two varieties of air cocks in use, as illustrated—the straight-way cock and the angle cock. As a handle changed from one style of cock to the other and bent or straightened to correspond in appearance would produce an effect just the opposite of what its position would indicate, notice should be taken of the groove in the top of all air-cock plugs. This groove always stands *lengthwise* with the pipe to be *open* and *across* the pipe to be *closed* immaterially of how the handle points (see Figs. *U* and *V*).

FIG. U.

THE ANGLE COCK.

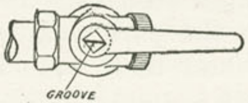


Fig. 1.
Angle Cock Open—Top View.

THE ANGLE COCK.

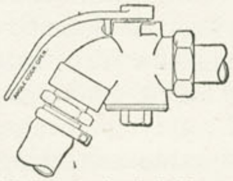
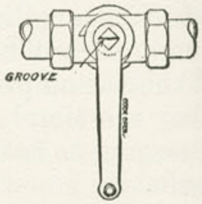


Fig. 2. Angle Cock Open.

On account of its construction, when an air cock sticks, the top of the plug should be tapped down; if too loose, pull up on it by means of the handle.

FIG. V.

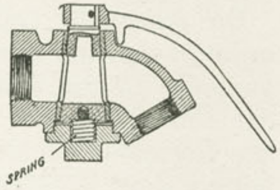


THE PLAIN STRAIGHT-WAY COCK.

Cars Cut Out.—When two or more engines are coupled to a train it should be seen that the first

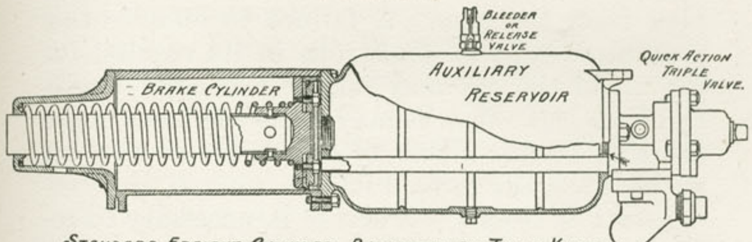
car is equipped with a quick-action brake in working order. (Fig. *X* shows the appearance of a freight brake with a quick-action triple valve attached.)

FIG. W.



No more than three piped cars* or cars equipped with the plain triple valve (see Fig. *C*) should be placed together in a train, as quick action may not skip these cars and apply the brakes behind them properly in emergency.

FIG. X.



STANDARD FREIGHT CYLINDER, RESERVOIR AND TRIPLE VALVE.
8 IN. DIAMETER BY 12 IN. STROKE.

Disabled Cars.—Whenever it is necessary on a freight or passenger train to place a disabled air car behind the air-braked cars in use, the hose should be coupled to the next car ahead, the angle cock opened on the car ahead, but the angle cock on the disabled car closed. This keeps pressure in the hose coupling, and, if the train

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* A car with the brake cut out is the same as simply as a piped car.

should part there, the brakes on the head section would apply before the parts were far separated.

On passenger trains, when a change in the order of the cars would materially affect the convenience of the train, if the train line on any car should become disabled, the signal pipe of the car could be used as the train line by utilizing a short combination coupling at each end of the car. Such a coupling is formed by a short piece of hose with a signal coupling on one end and a train line coupling on the other.

Hand Brakes on Air-Braked Cars.—In setting out air-braked cars, where safety requires that the hand brakes be set, all the air should first be bled from the cars. A failure to observe this precaution may be disastrous in its results; for the air of the car may release the hand brake, and then leak off, or it may cause the hand brake chain to break—either of which leaves the car without a brake to hold it.

Releasing Brakes.—When it is necessary to release a brake by the release valve or "bleeder," it should be held open only until the air commences to escape from the triple valve. If held open longer, it has a tendency to set brakes on other cars with which this car is connected.

Triple Valve Blowing.—A constant blow from the exhaust port of a quick-action triple valve can generally be stopped by tapping on the heavy flanges of the triple valve, or by setting this car in emergency. To do this latter, the car should be detached from others, else the stopping

of this one blow may cause several other triple valves to act similarly—as emergency is what usually gets the dirt into the triple valve in the first place.

A continuous blow from the retaining pressure valve is a triple valve blow and should be treated accordingly; the retaining valve should never be turned up or its exhaust be plugged to stop such a blow, as then there is no way for the brake to release after it is once set.

A Retainer Stopped Up can be overcome by removing from the triple valve the small plug that is opposite the point where the retainer pipe enters the triple. The plug should be left out until the retainer is repaired.

Leaving Train at Terminals.—The engine should not be uncoupled from the train until all the air brakes have been released. If a few seconds be allowed after releasing, they are less liable to re-apply after the engine is detached.

Test Brakes After Any Change.—Although the air signal and train line couplings are not interchangeable, when the gaskets are worn they can sometimes be forced together. Hence, a test of the air train signal and the brakes on a passenger train if any coupling has been made or changed should always be made. In passenger service of to-day, with its high speeds, the safety of passengers and property depends upon the air brake, and a test of the brakes once too often is better than to omit it. Forgetting to open an angle cock has caused more so-called "air brake failures" than anything else. Every one is liable to mistakes of this kind on freight as well as passenger trains, but a failure to test thereafter may be criminal carelessness.

Operating the Train Air Signal.—In using the train air signal care should be taken to give sudden, full openings of at least one full second to the car discharge valve and then allow an interval of at least two seconds between pulls. Signal apparatus in quite a defective condition can usually be operated successfully by making even a longer blast and interval.

A leak in the air signal pipe on a train will permit more perfect signals to be given forward of the leak than to the rear of it, thus often locating it to the car.

(See Fig. *Z*, showing the arrangement of the Train Signaling Apparatus, and Fig. *Aa*, showing details.)

ADDITIONAL INSTRUCTIONS TO SWITCHMEN AND YARDMEN.

Cause of Leaks.—Pulling hose apart instead of uncoupling them by hand and knocking cars together hard in coupling draw bars are the causes of many broken and leaky pipes on air-braked cars. If badly leaking, it may necessitate the switching of them out of the air braked portion of a train—the trouble thus reverting to those who caused it.

"*Bleeding*" *a Train.*—If yardmen have to "bleed" a train in order to switch it, there are

three ways of doing it, and the amount of time required is in the order in which they follow:

(1) Couple the train to an air-equipped switch engine and have the brake set and released repeatedly in service application until the pressure is exhausted from the auxiliary reservoirs.

(2) Slowly open an angle cock at one end of the train and leave it open; then "bleed" each car by the "bleeder." If the angle cock be opened quickly instead of slowly and the brakes thus applied in emergency, it will take twenty per cent. longer to "bleed" the train, as there will be about ten pounds more air to release from each auxiliary.

(3) If the train is not to be switched for half an hour or so, make a slight leak at one end of the train line—so slight that the air will escape through the leakage grooves in each cylinder without setting the brake. These leakage grooves are about three inches long, and hence if the air does not enter the brake cylinder fast enough to push the piston past these grooves the brakes will not apply.

CAR DESIGN.

Brake Cylinders.—Large brake cylinders are advisable so that the required leverage of the car will not exceed ten—that is, the power exerted by the brake piston would not require to be increased more than ten times by the levers in order to give the necessary power at the brake shoes.

The cylinders should always be placed in as protected a position as possible without being inaccessible for cleaning and oiling or other repairs. On freight cars constructed for special service it is often advisable to alter the usual freight brake arrangement by separating the auxiliary reservoir from the brake cylinder or even employing two cylinders—one for each truck of the car.

Where the auxiliary reservoir is not placed centrally on a car, the release rods, being of different lengths, should be so supported that their jarring while the car is in motion will not release the brake.

Stiff Brake Rigging is essential to good brake construction, as light levers and brake beams will cause a not inconsiderable loss in brake power due to excessive piston travel and cause the car to pull very much harder on account of the small brake shoe clearance when the brake is not applied.

Hand Brake.—It is desirable to design the hand brake on freight cars to work *with* the air brake piston instead of *against* it, so that the air brake would not throw the trainmen from the cars if they were using the hand brake at the time the air brake was applied.

Braking Power.—All wheels should have brakes applied to them. The leverage should be proportioned to the light weight of the car (except cars be for some service where they will carry always a constant load, as wrecking cars, pile drivers, tool cars, etc.) and the same class of equipment should have a like percentage of braking power. Where these rules are not observed, wheel sliding and rough handling of trains are more than likely to occur without the engineer being able to detect it.

Brake Hangers should be so placed on freight cars that the brake shoes will naturally leave the wheels when the brake is released. When this is not done, a large amount of brake shoe friction will be had on moving trains.

Style of Brake.—The outside hung brake (i. e., brake beams hung outside the truck) has been found more desirable than the inside hung (i. e., brake beams hung inside the truck), as the former is the more accessible for inspection and the repairs are generally less.

The dead-levers should preferably be fastened to the car body instead of to the truck, as the latter causes flange wear due to the slewing of the truck.

Piping.—On passenger cars with air signal hose the same length as train line hose, the signal pipe should be inside the train pipe and dropped to a plane four inches below the latter and secured by a suitable bracket, to prevent the hose rubbing together when coupled.

All pipes on both freight and passenger cars should be rigidly secured to the body of the car in such a way as to prevent their loosening when the car timbers become more thoroughly seasoned. Too little attention is often paid to the proper security of piping.

LOCOMOTIVE DESIGN.

The Main Reservoir should be securely fastened to the engine frame and be of large capacity, especially for freight service. If one large reservoir cannot be employed, two or more smaller ones of such shape as to be hung in convenient positions may be used.

The Steam Brake is now seldom applied to road engines and there are many objections to its use, most of which are equally applicable to the use of the independent air brake for engines. If the engine brakes be independent of the train brakes, accidents may result from any sudden application of the brakes on the train, burst hose, parting of train, etc.

Brake Cylinders.—As the air brake is superior to the steam brake on locomotives for road service, so is the push-down or push-out form of air brake cylinder superior to the pull-up, and requires much less repairs to keep in good order.

Braking Power.—The braking power of locomotives should be as high as for average cars. To accomplish this the tender should be braked to its full light weight, with the driver and truck brake at seventy-five per cent. their weights.

Piping.—Good work in the piping of a locomotive is essential to light and economical repairs. Whenever possible, pipes should be bent and few angle fittings—and those of the best quality—used. Low bends in piping which will form traps for condensation or other accumulations

should be avoided. Sufficient unions to enable the parts requiring most frequent repairs to be readily accessible are necessary, and these should be placed where oscillation of the pipes will be the least liable to loosen them and cause leaks.

Metallic Gaskets should be used in all the steam unions of air pumps to lessen the liability of pump failures caused by pieces of destructible gaskets obstructing small pump ports.

Location of Air Pumps.—To avoid dust and dirt in the air pump, it should be so placed that the air suction is above the running board. If it be not practicable to place the pump entirely above the running board, the suction ports should have a pipe leading to a clean cool place for receiving the air.

Pump Packing.—The piston rods of air pumps should be packed with some of the many successful forms of metallic packing. This will greatly reduce the liability of the packing burning out and minimize the cost of repairs.

Tender Brake.—Outside hung tender brakes are much preferable to brake beams hung inside the truck, although theoretically the latter are superior. The brake should be equalized by levers and not "chain equalized." As a properly designed tender brake will be a powerful one, it is advisable to employ standard freight car sizes of rods, pins, and levers; brake beams as stiff as those for use of passenger cars may be necessary, however.

REPAIRS ON LOCOMOTIVES.

In repairs to *brake cylinders*, only the best oil-tanned leather should be used; if it is exposed to the heat of the fire box it should be frequently oiled.

The driver brake should be kept in excellent condition as it is probably the most powerful and most frequently used brake on the train, and also serves to dress the steel tires, thereby saving repeated turning of tires and damage to switches, frogs, and track.

Air Signal.—The reducing valve and the whistle should be frequently cleaned, as with the former usually lies any defect that may cause false signaling. The reducing valve should always be placed in a warm (not hot) position on a pipe coming from the main reservoir, so that the air will be free from dirt and moisture—its two enemies.

REPAIRS ON CARS.

Yard Testing Plants.— Large terminal points should have their yards equipped with air pipes between every other track for testing purposes, and should be supplied with air at a pressure of not less than seventy nor more than ninety pounds.

Triple valves that have defective slide valves and seats should be sent to the general repair shops where a special tool for planing off the seat and a facing plate for the valve will be productive of better work, and at one-third the cost of hand work.

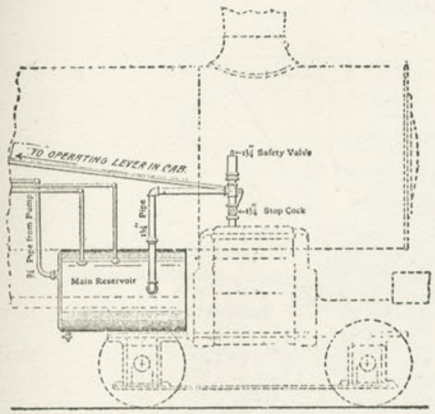
THE SWEENEY BRAKE.

The device termed the "Sweeney Brake" is really but the conversion of one of the cylinders of a locomotive into an air compressor when the air pump is insufficient or has stopped entirely. It has been used mainly on heavy descending grades, but can also be used for making a stop on level road when necessary.

Fig. *Y* shows its application to a locomotive. Tapped into the steam chest is a pipe leading to the main drum. On this pipe is a plug cock operated from the cab by a lever, a safety-valve and a check valve (not shown).

When this device is to be used the engine's reverse lever is placed in the back motion and this stop cock opened. Thus the engine cylinder is converted into a powerful compressor, taking air from the engine nozzle and charging the main reservoir, and from thence the train.

FIG. Y.



THE SWEENEY AIR COMPRESSOR.

COMPRESSED AIR FOR SHOP PURPOSES.

When the amount of air necessary for shop purposes is small, and it is found more convenient to use air pumps than a compressor, although more wasteful of steam, air pumps can be arranged to do work with considerable saving by compounding them with an inter-cooler. One six-inch pump, water-jacketed, will form a sufficient high pressure pump for two eight-inch pumps as low pressure compressors if a water cooled reservoir be placed intermediately. The saving thus, over direct high compression, will be something considerable, and the pumps keep cooler and last longer.

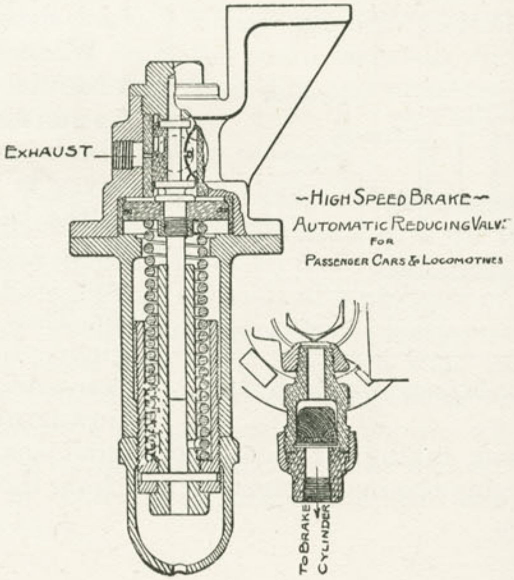
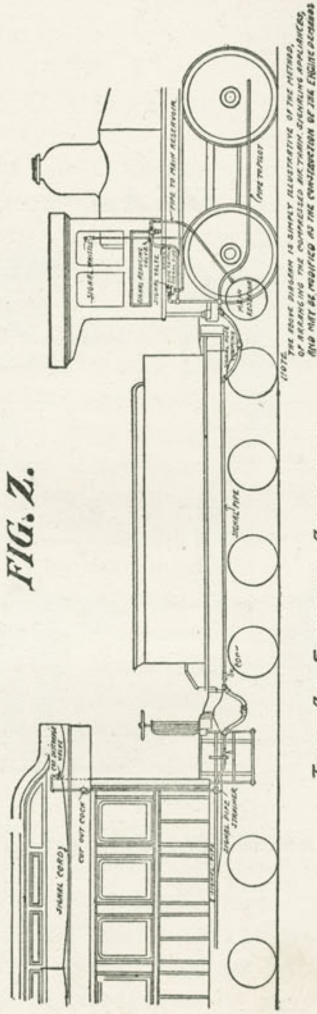
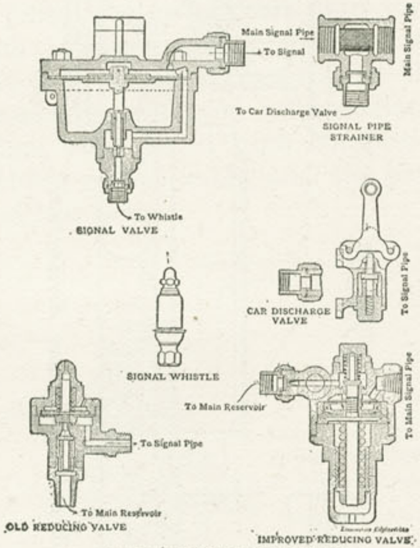


FIG. Z.



TRAIN AIR SIGNALING APPARATUS.

FIG. Aa.



TRAIN AIR SIGNALLING APPARATUS.

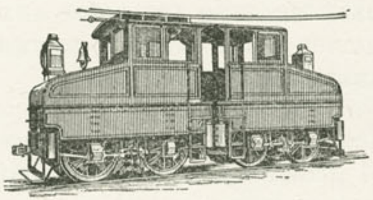
NOTE.—For further reference to the automatic air brake see Appendix D.

CHAPTER VII.

ELECTRICITY AS A MOTIVE POWER FOR RAILWAYS, EXPLAINING AND ILLUSTRATING ITS LAWS AND PRACTICAL APPLICATION AS A MOTIVE POWER FOR GENERAL TRANSPORTATION PURPOSES.

Elsewhere I have described the steam locomotive and its origin and growth, giving with great minuteness the particulars connected therewith. The cuts and engravings which accompany the account make the whole plain to the reader and add much to the practical and romantic interest of the subject. While exhaustive, apparently, as regards railway carriage, it is yet incomplete. A new way has arisen for transmitting power. Steam is no longer the only force for propelling the locomotive. Something still more attractive, electricity, looms on the horizon to compete with it. How far this competition will prove successful, we can only surmise. Only the future can determine the true place which electricity is to occupy in the evolution of general railway transportation. The desirability that its extended use should prevail no one will question, as electricity is in many particulars much more attractive than steam. When power can be furnished through this medium as cheaply as by steam, then indeed, will it be recognized and hailed as a distinct step forward in the progress mankind has been making for thousands of years toward a perfect system of carriage.

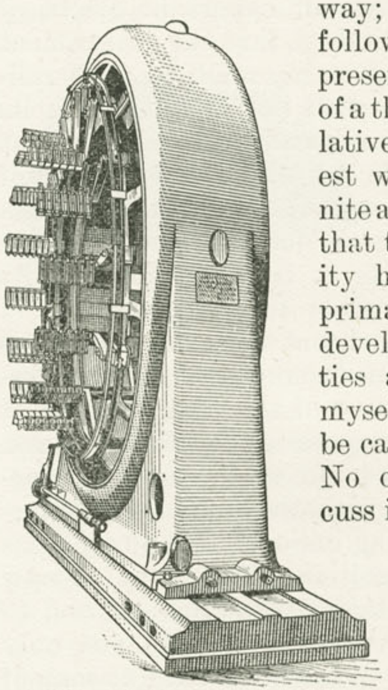
Of all subjects that relate to transportation and to the medium of power in connection therewith, none, it is probable, excites more general interest than electricity; but about none is mankind so generally ignorant. We see cars and trains flying along our streets and on our elevated railways through the medium of this agency, but to all except a few experts the details are a profound mystery. We know in a general way that power is transmitted along a wire to be utilized as the vehicle progresses or, according to another method, it is husbanded in mysterious packages, or storage batteries, on the vehicle itself, to be utilized as needed in the progress of the journey; but what the storage battery is, and how power thus confined is utilized, we are only vaguely informed upon. How is this wonderful agent, invisible and intangible, yet powerful and compliant, gathered and dispersed? Through what intricate and subtle medium is its power held in suspension, to be conveyed, at the will of the attendant, to the wheels and so to the load they carry? Only experts can answer, and they not



Electric Locomotive. Baltimore & Ohio Railroad Tunnel.

always so a layman can understand. I am free to confess myself lacking in many practical details, although I have been familiar with electricity and it uses for forty years. When young, I was, for those days, an expert in electrical matters, so much so, indeed, that the government sought to have me sever my relations with railroads and connect myself permanently with its signal service. Acquaintance with electricity at that period of my life has led me to keep myself more or less in touch with it since; but it has been the touch of an amateur, not such as to properly enable me to teach or to trace scientifically its generation or application to transportation. I understand the subject, but not exhaustively, as it demands, or as an instructor should understand it. It was because of this that I did not at first contemplate incorporating in "The Science of Railways" an account of the uses of electricity in connection with the problem of transportation. Its growing importance, however, has compelled this recognition, albeit, late. I now find it necessary to take up the subject, and to take it up in a manner that will not only prove instructive to students, but also to men of the highest attainments in this interesting field of thought and to those who are familiar with the methods and operations of ordinary steam railway practice as well.

My first connection with railways was partly associated with the telegraph department of the service, and in this way I became interested and familiar with electrical enterprises and ambitions, as intimated above. Electrical science was, however, in an embryotic state when I ceased to concern myself with it in a practical way; but, while ceasing to follow it, I continued to preserve an interest in it of a theoretical and speculative nature. This interest was, however, indefinite and unsubstantial. So that to-day after electricity has passed beyond primary conditions and developed wide possibilities and uses, I confess myself hardly worthy to be called even a student. No one who cannot discuss it at once practically, scientifically and theoretically, is worthy to handle the subject in such a treatise as I desire to incorporate as a part of my work on railways, which I have sought from the first to make comprehensive and practicable. For this reason I have called to my aid in the preparation of this part of my work a gentleman of world-wide celebrity in



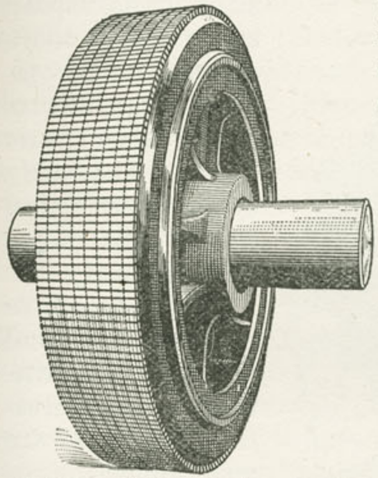
1500 Kilowatt (2000 Horse Power) Engine Type Railway Generator Field with Brush Holder. (A kilowatt equals one and one-third horse-power.)

electrical mechanism, Mr. Charles F. Scott, an honored member of the American Institute of Electrical Engineers, and the electrician in chief of one of the few great electric manufacturing industries of the world. It may be said of him that he holds a high rank as regards the theory and practical application of electricity, and there are few who may with any plausibility claim to be his superiors in presenting its application to railways. His long association with the great electrical institution I have referred to has made him familiar with the secrets and progress of electricity, while his scientific education and rare attainments enable him to understand perfectly its most subtle phases. As a teacher he is so exhaustive and clear in his statements that all he says may be comprehended. However, the subject is a scientific one and, like all scientific subjects, requires intelligent, careful and discriminating study to understand. Because of the vast scope of the theme and its technical nature I have found Mr. Scott's assistance fundamental rather than accessory. What he has to say is so conclusive that after he has spoken I have been unable to add anything that seems to me to be of particular value. The engravings of electrical apparatus which accompany the matter, I have prepared especially for this work. They are practically exhaustive of the subject at this time, and form, with the printed description, a complete exposition of the theme. With this explanation I will, without further introduction, proceed to take up the question of electricity in the order in which it naturally presents itself for investigation. Before doing this, however, I may pause long enough to say that while railway carriage, as it has been known in the past, pre-supposes steam as a motive power and the uses of Stephenson locomotives, the theory of such carriage (its science, I may say) would not be changed in any important respect by the use of electricity. This the reader will see upon reflection. It will involve changes in machinery, but not in organization or methods of business. All the departments of railway service and the subdivisions thereof, with their principles of business and methods of application, will go on just as they do to-day without change of any kind—at least from this source. The men who now operate our steam locomotives would be transferred to those operated by electricity. That is about the only change in the personnel of the service there would be. Therefore, in taking up the subject of electricity in its application to railways, the reader may dismiss all side speculations of a less interesting nature.

THE RELATION OF ELECTRICITY TO TRANSPORTATION.

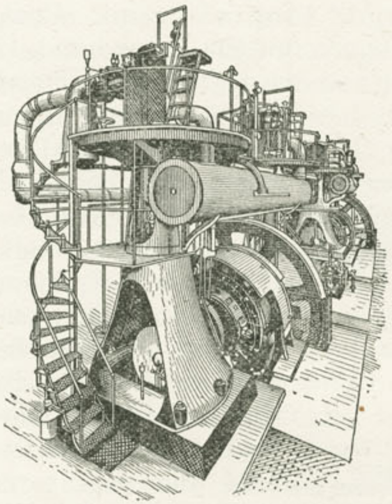
Power.—The fundamental problem in transportation is the production and application of power. The cost of transportation depends largely upon the cost of power, and its limitations in speed and flexibility are determined in

great degree by the source of power. There are two ordinary sources of power, fuel and falling water. The latter has been useless for transportation purposes as it could not be conveyed and applied to the moving of trains. Coal, on the other hand, is easily transported and can be carried upon the moving train; its energy of chemical combustion can be transformed through the agency of steam into mechanical energy which can be applied directly to the moving of the train. In the cable road the engine is stationary and the power is conveyed to the car by a rope. This system finds its limitations in the short distances to which the cable can extend owing to its low efficiency.



1500 Kilowatt Generator Armature Core, showing longitudinal slots for winding and radial openings between the thin iron plates for ventilation.

Electricity.—Electricity is not a source of energy. It does not replace the falling water nor the burning coal nor the street car horse. It is the harness for connecting the engine or turbine to its work, and it replaces the cable as a means for conveying power from a stationary engine to a moving car. One can scarcely imagine a simpler and more direct method of moving a street car than by a cable drawn by a stationary engine unless indeed it be the street car horse harnessed directly to his car; but the street car horse could scarcely have been swept away more quickly by an epidemic than he has been by the electric motor. The costly cable is destined to follow the horse into obscurity.


1500 Kilowatt Generator, driven by a vertical engine. Metropolitan West Side Railway, Chicago.

The locomotive replaced animal power for long distance transportation, but there are many objections to it for hauling small cars at frequent intervals through the streets of towns and cities. For this service animal power continued in use until the cable and the electric current enabled us to harness the car to a stationary engine or a turbine. The electric car has replaced the horse car and has also revolutionized street railway service. By it speed and comfort have been increased and operating expenses reduced.

The Problem Presented.—Whether the electric motor is to continue its widening range and take

the place of the steam locomotive is a very interesting and important question. While the locomotive is not adapted to the conditions of street railway traffic, it is possible that long distance transportation cannot be met as economically by the motor as by the locomotive.

It is often asserted, and possibly truly, that electricity is in its infancy and that it only awaits further comprehension of its mysteries to enable it to be applied to the solution of every kind of problem. A little further development, many believe, will relegate the steam locomotive to the past and add unprecedentedly to the speed of trains. Some even predict that the motor will completely supplant all steam engines.

Intelligent consideration of the subject requires an examination of the functions of electrical action, the characteristics of electrical apparatus and the conditions of electrical transmission, so that we may from these determine in some measure the possibilities and the limitations of electric traction.

The problem will be thus generally treated in the following pages, namely, the electrical principles and laws which underlie the subject; the application of these in electric machines and in transmission; the systems of transmission and the apparatus suitable for railway service; the specific elements which go to make up an electric railway system, illustrated by descriptions of electric roads representing the varieties of service performed by motors;* and, finally, an examination of the application of electric traction to the conditions which prevail in steam railways, the whole being concluded by a comparison of the present state of electric traction with that which has preceded it, followed by a forecast of the probable development of the future.

ELECTRICAL PRINCIPLES AND LAWS.

What Electricity Does.—The function of electricity in the operation of railways is to receive energy from an engine (or other prime mover) and to deliver it upon the moving car in mechanical form. The elements in the system are: (a). A prime mover (an engine or water-wheel) for the supply of mechanical energy. (b). An electric generator or dynamo for receiving the mechanical energy and transforming it into electric energy. (c). A transmission circuit for conveying the electric energy to the point where it is to be used. (d). An electric motor for receiving the electric energy and transforming it into mechanical energy, suitably regulated and controlled.

*In these references the question of the utilization of electricity for the operation of railroads, other than those for city and suburban service is referred to. Indeed, the whole question of electricity from the standpoint of railroad men is, how far will electricity be able to supplant steam in the operations of railroads for handling general traffic? This, in its place receives the attention which it merits, as it is with relation to this phase of the subject that the whole question receives consideration here.

The Sources of Electric Currents.—Electricity may be produced in a number of ways. Heat also may be derived from several sources, from mechanical energy—by friction or percussion; or from chemical energy—by combustion; or from electrical energy—by the passing of a current through a wire. Electricity may result from the expenditure of mechanical energy—by friction of certain substances; or through the agency of the dynamo; or from chemical energy—by the dissolving of zinc in a battery; or from heat energy—in thermal batteries. The two ordinary sources of electricity are the dynamo and the battery. The currents from the two sources are of similar nature. The only reason the battery is not used for supplying current for lighting and power is its high cost.

The two conditions necessary for the flow of current are, first, a force for sending or "pushing" the current through the circuit called electromotive force, and second, a complete circuit through which the current may flow. The circuit is usually of copper wire, supported and protected by wood, glass, rubber or other insulating materials through which current does not pass. In both the dynamo and the battery there are two terminals between which there is electromotive force which will send a current through a circuit if its ends are connected to the respective terminals. The strength of the current is determined by the intensity of this force and by the resistance of the circuit. This is analogous to the flow of water in a pipe—the flow depends upon the pressure and the resistance of the pipe.

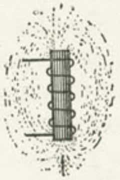
What electricity is, the cause of electro-motive force, the nature of the electric current, are topics which do not directly concern us here; neither do the causes of chemical affinity and combustion, nor the reason that liquid water is changed to invisible steam under the influence of heat. It is enough to know the facts and to apply to a useful purpose the principles and laws which have been deduced from scientific investigation and experience.

The Effects of Electric Current.—When an electric current flows through a circuit several phenomena may be observed, notably certain heating and magnetic effects.

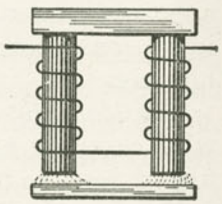
The Heating Effect.—Heat is produced in all parts of the circuit by the passage of the current. The quantity of heat depends upon the strength of the current and upon the resistance to its flow. The resistance depends upon the material and size of the conductor. If the same current pass through a copper wire, an iron wire and a carbon rod, all of the same diameter, the copper will remain comparatively cool, the iron will become warm and the carbon quite hot. If the same current pass through a heavy wire and a fine wire of one-third the cross section, the heat produced in the fine wire will be three times as great as in an equal length of the heavy wire. Loss of heat is loss of energy. Conductors are, therefore, made large and of material of high

conductivity (copper), except where heat is desired, when the opposite course is followed. In incandescent lighting, the lamp filament—the part of the circuit wherein heat is to be generated for producing incandescence, is made of a fine carbon thread, while the wires to the lamp are made of copper wire of sufficient size to prevent the waste heat in the wires from exceeding a small per cent. of the useful heat in the carbon. If the distance to one lamp be twice as great as it is to another lamp, the length of wire must, of course, be twice as great. The same size of wire would involve twice the loss. The same loss is secured in the two cases if the cross section of the wire in the larger circuit be doubled, making its weight four times that of the wire required for the lamp at half the distance. In a system for the electrical transmission of power the heating effect of the current is not useful. There is not only the loss of power, both in circuits and in machines, but the rise of temperature which results may cause damage to apparatus unless adequate precautions are taken in its construction and operation to avoid undue heating.

The Magnetic Effect.—The space surrounding a wire carrying current is a magnetic field. Iron filings tend to take a definite position, and do so quite strongly if the current is a large one. The effect is increased if the wire is in the form of a coil so that the current in each of many successive turns may act upon the same space. It is still further increased if the coil surrounds an iron core, as iron is much better than air as a conductor for the lines of magnetic force. The lines of force may be detected outside of the core by iron filings, as is shown in the accompanying illustration. If an ordinary pivoted compass needle be placed in the field it will take a direction parallel to the lines of force at that point. If the core be of soft iron, and the current be interrupted, the magnetic field vanishes. If the direction of the current through the wire be reversed the magnetic field also reverses, the form, as indicated by the filings, remains the same, but the end of the compass needle which was attracted before is now repelled, so that the needle will find stable equilibrium when it has turned completely around and its direction is reversed. In general the strength of the magnetic field, or the magnetic induction, is increased by increasing the proportion of iron in the magnetic circuit and decreasing the length of air space. A double magnet is illustrated here in which the upper ends of the iron cores are joined by an iron yoke. A keeper or armature of soft iron is placed near the other ends of the



Electro Magnet. A current through a wire coil around an iron core makes it a magnet. The magnetic field causes iron filings or a compass needle to take a definite position.



Double Electro Magnet. The path or circuit of the magnetic lines is almost entirely in the iron cores, yoke and armature.

cores. When current flows through the coils the iron becomes a magnet and the armature is strongly attracted toward the cores in the coils. This form of electro magnet is in common use in electric bells and telegraphic apparatus. If the cores in the coil were removed the armature would still be attracted, but very weakly. The magnetic effects of currents and the reactions between currents and magnets are utilized in the dynamo and the motor.

Electrical Units.—Current is measured in amperes. The ampere (corresponding to gallons per minute in hydraulics) is the current which flows through one ohm resistance when the pressure is one volt. The current required by ordinary incandescent lamps varies from about one-half to one ampere. The current taken by an ordinary street car averages twenty to forty amperes, and is usually much more in starting and on grades.

Pressure, or electro-motive force, is measured in volts. The volt (corresponding to pounds per square inch in hydraulics) is the electro-motive force required for sending one ampere through a resistance of one ohm. The electro-motive force of an ordinary cell of gravity battery is about one volt. Incandescent lamps are usually made for about fifty or one hundred volts. The ordinary electro-motive force on street-railway circuits is five or six hundred volts.

Resistance is measured in ohms. The ohm is the resistance through which one volt will force one ampere. One ohm is approximately the resistance of one thousand feet of copper wire one-tenth of an inch in diameter (No. 10 B. & S. gauge—weight, thirty-one pounds*) or of one mile of copper wire .23 inches in diameter (No. 3 B. & S. gauge—weight, eight hundred and forty pounds).

Ohm's Law.—The current in a circuit is found by dividing the electro-motive force by the resistance.†

The Energy of Electric Currents.—Energy is required for the production of an electric current. In the battery, chemical energy and in the dynamo, mechanical energy are converted into electrical energy. The electrical energy reappears in other forms—as heat in wires and lamps and electric heaters; as mechanical energy in motors, or as chemical energy in electroplating. In an ordinary electrical power system part of the heat produced by the burning of coal is wasted and part makes steam; part of the

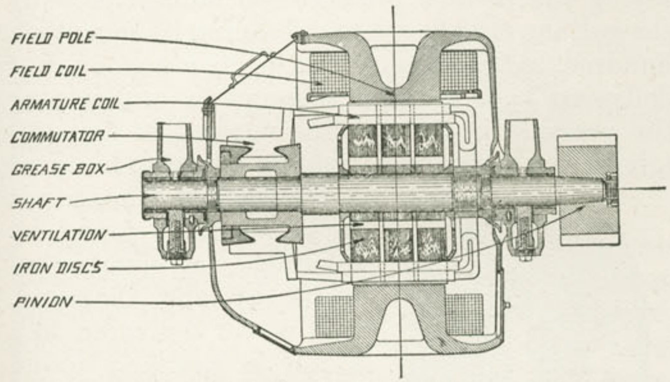
* B. & S. (Brown & Sharpe) gauge represents the American standard gauge.

† $\text{Current} = \frac{\text{Electro-motive force}}{\text{Resistance}}$, or $C = \frac{E}{R}$, or $\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$. Also, $\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$, and Volts = Amperes × Ohms.

Therefore, if it is required to find what resistance will allow fifty volts to produce a current of three hundred amperes, divide the volts by the amperes.

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}} = \frac{50}{300} = \frac{1}{6} \text{ Ohm.}$$

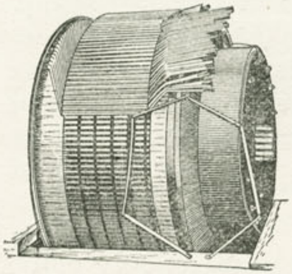
energy of the steam is wasted and part produces mechanical energy in the cylinder; part is lost in friction and part reaches the dynamo; part is lost in heat in the dynamo and part is delivered as electrical energy to the circuit; part is wasted in heating the wires and part reaches the motor; part appears as useless heat in the motor and all that is left of the energy of the coal after loss at



Cross Section of a Railway Motor.

every step appears as mechanical energy delivered by the motor shaft. The energy at any point in the system is of course exactly equal to the sum of all the parts into which it is subsequently divided.

Mechanical energy is measured in foot-pounds and mechanical power in foot-pounds per minute, or in horse-power. Electrical power is measured in horse-power, or in watts. Seven hundred and forty-six watts equal one horse-power. A kilowatt is one thousand watts, or practically one and one-third horse-power. The electric power which is being delivered by a dynamo depends upon two things, the pressure (electro-motive force) and the current. An exact analogue is found in a force pump where the power depends upon the pressure and the quantity of water pumped, and the horse-power is found by multiplying the pounds pressure per square inch by the gallons per minute and dividing by seventeen hundred and fourteen. The electric horse-power delivered by a dynamo is found by multiplying the pressure in volts by the current in amperes (giving the watts) and dividing by seven hundred and forty-six. The output in kilowatts is found by dividing the number of watts by one thousand. The power delivered to a motor is similarly found by multiplying the electro-motive force by the amperes. In this case, however, the current flows against the pressure and the power is delivered to the machine instead of by it. A small current at high pressure will deliver the same power as a large current at a low pressure. Five amperes at one thousand volts is equivalent in power to ten amperes at five hundred volts, or fifty amperes at one



Winding a Railway Generator Armature.

hundred volts, as the product is in each case five thousand watts, or six and two-thirds horse-power. The power which appears as heat in a wire is similarly found by multiplying the amperes by the electro-motive force measured between the ends of the wire. The power is equal also to the square of the number of amperes multiplied by the ohms resistance, or,

Watts = amperes × volts = amperes^2 × ohms = $C\,E = C^2\,R$.*

If twenty amperes flow through two miles of No. 3 B. & S. copper wire (two ohms) the

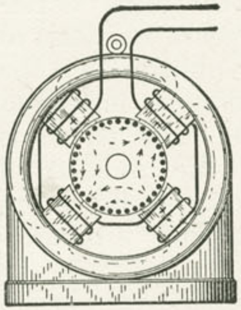
Watts = $C^2\,R = 400 \times 2 = 800 = 1.07$ horse-power.

ELECTRIC MACHINES.

How Current is Produced in the Dynamo.—There is a reciprocal relation between electricity and magnetism. On the one hand, a current of electricity passed around an iron core will make a magnet of the iron; on the other hand, if under proper conditions a wire be moved in a magnetic field or near a magnet, a current will be produced in it. In an ordinary dynamo the magnetic field is produced by a "field" consisting of a number of poles or magnets of iron, which are surrounded by coils of wire through which currents are passed. The magnets are joined at one end by a solid and heavy iron yoke, and at the other they confront the armature. The armature contains an iron core on which wires are placed parallel to the armature shaft, and shown in the cross section

* *C* stands for Current, *R* for Resistance and *E* for Electro-Motive force.

of the armature as black dots in the accompanying illustration. The movement of a wire in front of a pole and through the magnetic field which lies between it and the armature, induces in the wire a pressure or electro-motive force which will produce a current if the ends of the wire be joined. The lines of magnetic force pass from alternate poles to the armature, and pass *from* the armature back to the field in the intermediate poles. As a wire passes in front of a pole, the course of the electro-motive force will be in one direction if the pole be positive, and in the other direction if it be negative, and as the poles are of alternate signs, the electro-motive force will be first in one direction and then in the other, alternating as each pole is passed. If a wire be laid on the armature in front of one pole and is carried back on the armature opposite the next pole, so that the two free ends of the wire are at the same end of the armature, the electro-motive forces which are induced by the two adjacent poles under which the wires simultaneously move will be added together and the electro-motive force on the turn of wire will be the sum of that on each of the two parts. If the wire be wound in the form of a coil of several turns, it is



Section of a Dynamo, showing electro-magnets or fields and the armature within, which carries wires (shown in cross section) at the surface. The magnetic lines are shown by dotted lines.

evident that the electro-motive force upon the coil will be the sum of the electro-motive forces in the several turns.

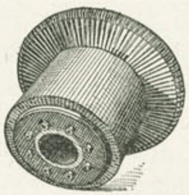
The field is designed to have great magnetic strength with small magnetizing current by making the magnetic circuit of iron, which is an excellent conductor for the magnetic flux, and by making the air gaps small. The speed of the dynamo is usually made as high as the mechanical conditions permit.

The electro-motive force induced in a coil of wire, as has been explained, reverses in direction whenever the coil passes in front of a new pole. the electro-motive force in the wire reverses in direction, and the current which may flow in it is an alternating current, corresponding to a reciprocating motion. The two ends of the coil may be connected to two separate rings, on which brushes rest for conducting the current to an external circuit.

A direct or continuous current is secured from the dynamo by placing on it a large number of coils and connecting them to a commutator. The coils occupy many successive positions on the armature so that at all times there are some coils in which a high electromotive force is being developed, while other coils are in a position in which little or no force is being developed, owing to their intermediate position

A Single Segment of a Commutator, showing groove at top of neck for attaching wires from armature.

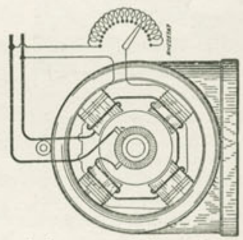
with respect to the field poles. There is a position with respect to the fields in which a coil produces its maximum force, and, as the armature turns, all the coils successively pass through this position. The ends of the coils are connected to bars of the commutator on which rest brushes for conducting the current to the external circuit. As the armature turns, the brushes make successive contact with the various commutator bars, and, through them, to the coils of the armature. The brushes are placed at the proper angle for connection to the coils which are giving an electro-motive force, and as the angular position of the brushes is not changed, they are continually connected with the coils which are in the same position with reference to the poles, and are, therefore, giving the same electro-motive force. The current in the individual armature coils is an alternating current, but current in the external circuit is a direct current flowing constantly in the same direction.



Commutator, showing segments to which armature wires are connected.

Dynamos may be designed to give either an approximately constant current or an approximately constant electro-motive force. The latter, or constant potential dynamo, is ordinarily run at constant speed, and with a constant field current. If this field current is derived from the dynamo itself the dynamo is said to be self-

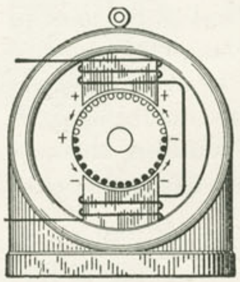
excited, and if from a separate source, separately excited. The electric-motive force of a dynamo is determined by the strength of field, the speed, and the number of wires which are in series. The latter element is fixed when the machine is designed, the speed is fixed by the driving power, and the method of adjusting the force on a machine in operation is by variation of the strength of the field by changing the current through the field. When a dynamo is delivering current, the electro-motive force upon its terminals decreases as the load increases, owing to the resistance of the winding of the armature and to certain magnetic reactions. The force at full load may be made equal to, or greater than that at no load by an increase in the exciting or magnetizing current around the fields. This is ordinarily accomplished by compounding the machine, i. e., placing upon the field a second winding through which the main current flows for the purpose of adding the magnetizing effect of this current to that of the regular shunt winding. This is shown in the diagram of a compound wound dynamo. The current from one brush which rests on the commutator passes around a few turns upon the field poles before going out to the circuit. The fine wire "shunt" winding of many turns is



A Compound Wound Dynamo—two field windings. In the fine wire the current is nearly constant and is varied by the rheostat. The heavy winding carries the current to the load, and therefore varies as the load varies.

taken in a "parallel" connection from the circuit and passes through an adjustable resistance or "rheostat" by which the field current may be varied.

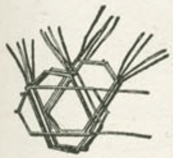
How Motion is Produced in the Motor.—It is well known that the opposite or unlike poles of two magnets attract, and that like poles repel. The production of motion in the electric motor may be readily understood when it is seen that the field and armature are in reality two electro-magnets, which are retained in such a position and relation that a constant force exists between them. In the accompanying figure is shown a two pole motor in which the field currents magnetize the field poles, making the upper pole positive and the lower pole negative. Currents are passed through the armature wires in such a way that the wires on the upper half of the armature (shown as circles in the figure) carry current in one direction, and those on the lower half in the opposite direction. This magnetizes the armature, giving a positive pole at one side and a negative pole at the other. The attraction between unlike poles and the repulsion between like poles will produce a tendency to rotation. As the armature revolves the connection between



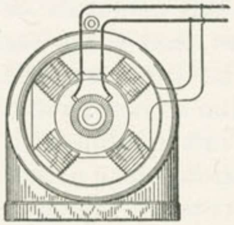
A Motor. The signs (+ and —) show poles formed by currents in field coils and in armature wires. Arrows show attraction and repulsion between poles, and the resulting rotation.

the circuit and the wires on the armature is changed (at the commutator), so that the wires which are on the upper half of the armature still carry current in the same direction as before, and the magnetic poles remain fixed in the same position with respect to the field, although the armature itself revolves. In a multi-polar machine there are a number of magnetic poles formed by the armature currents midway between the field poles.

The armature of a direct current motor is wound similar to that of a direct current dynamo and the connections to the commutator are made in the same way. As the armature revolves in front of the field poles of the motor, an electro-motive force is generated in its coils similar to that which is generated in the coils of a dynamo. If two machines be driven at the same speed and are excited by equal field currents, so that equal forces are produced, connections may be made between like brushes and no current will flow between the machines. If the field current of one of the machines be increased, its electro-motive force will be increased above that of the other machine, and it will send a current back through the other machine and drive it as a motor. If the relative field strengths of the machines be changed, the second machine will run as a dynamo, and the first machine as a motor. The

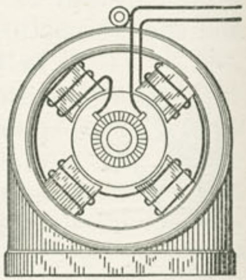


Armature Coils for Railway Motor.



A Shunt Machine. The field current is independent of the main current.

motor fields may be adapted for connection across the circuit, in which case they are termed "shunt motors" and are adapted for running at constant speed. The fields may be connected in series with the armature so that the field strength varies with the current flowing, in which case they are termed "series motors" and are adapted for variable speed work.



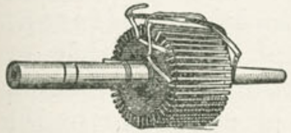
A Series Machine. The main current is the only current around the fields. This is the ordinary connection in railway motors.

Alternating current motors are of several types, the most practical of which are: the synchronous motor, which has little or no torque except at a definite speed (related to the speed of the generator by the ratio of the number of motor poles to the number of generator poles) and which runs at that definite speed, whatever be the load upon the motor within its capacity, and the induction motor, which may have considerable torque at all speeds and which decreases in speed as it is loaded.

TRANSMISSION.

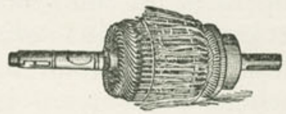
General Characteristics.—Electrical energy is transmitted by a current under pressure, which

has many close analogies to the transmitting of energy from a pump to a water motor by the flow of water in a pipe. The quantity of energy delivered depends upon the intensity of the pressure and the quantity of the flow. The pressure may vary over a wide range, and the current required is inversely proportional to the pressure for the delivery of given amount of energy. The electric current, moreover, may be continuous, corresponding to the continuous flow of water through a pipe, or it may be alternating, corresponding to reciprocating motion or the flow of water in a pipe backward and forward in response to a piston at the end. This alternation of current may take place slowly or rapidly.



Armature of Railway Motor. Shaft with core or body of thin circular iron discs slotted on the circumference. Two coils are partly in place.

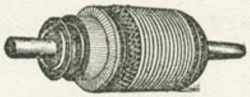
The different pressures which may be employed in a continuous current system or in an alternating current system, the range in frequency which may be used with alternating current, together with the different number of phases which may be employed, evidently give rise to a wide variety of possible electrical systems. Practice has adopted a few combinations, which may be regarded as



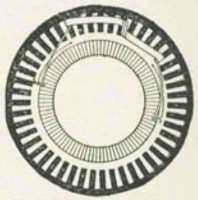
Armature with Coils in Place. Ends of wires are bent back over armature; they will be bent forward and connected to the commutator.

standard systems, which meet most of the ordinary demands.

Electrical energy may be distributed, either by constant potential or by constant current. In the constant potential method, the pressure is kept constant, and the demands for different amounts of power, either by the variation of the number of lamps or motors, or by the variation of power demanded by a motor, are met by a variation of current. Lamps or motors are connected in "multiple" or "parallel" when operated on this system. In the other system the current is kept constant, and the demand for additional power is met by an increase of pressure. Lamps or motors are connected in "series" so that the same current passes through all the devices when operated on this system. The constant current series system finds its common application in arc lighting, where the current is maintained constant and the pressure of the circuit is made proportional to the number of lamps to be supplied. Power can be supplied from circuits of this character, but this system is not in general use for power service and finds practically no application in railway work.

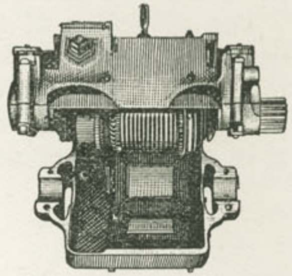


Armature complete. The coils are held firmly in the slots by bands of strong wire.



Armature Disc, showing slots, diagram of commutator and one coil in place connected to the commutator.

Losses in Circuits.—The passage of an electric current through a wire is accompanied by a loss of power and a reduction in pressure. Loss of power is objectionable, as it increases the amount, and, consequently, the cost of the power which must be generated; excessive reduction in pressure is to be avoided as it may cause variations in pressure beyond the limits which are admissible for constant potential motors. If the pressure be too low the power available may be too small, or the speed may be too low; if the pressure be too high the speed may be too great, or there may be flashing at the commutator.



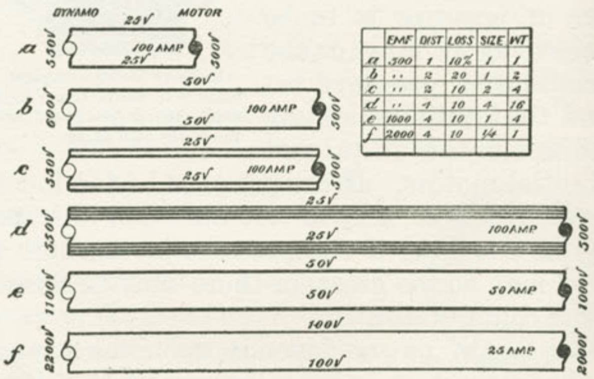
Railway Motor, complete; armature in fields, lower half of field opened downward, showing lower field poles.

The loss of power depends upon the strength of the current and the resistance of the circuit. The resistance of a copper circuit, in turn, depends upon the size of the wire and the length of the circuit. The loss in power increases, therefore, as the strength of the current increases and as the length of the circuit increases, and it is decreased if the conducting wire be made larger. The loss does not vary directly as the current,

Motor ready for mounting on axle.

but it increases as the square of the current; thus, the loss of power in a given circuit when the current is doubled is increased four-fold.

The reduction of loss of pressure in a circuit depends directly upon the current strength and upon the resistance of the circuit. The loss in pressure is illustrated in the accompanying figure *a*, in which a dynamo delivers current through a



	EMF	DIST	LOSS	SIZE	WT
a	500	1	10%	1	1
b	..	2	20	1	2
c	..	2	10	2	4
d	..	4	10	4	16
e	1000	4	10	1	4
f	2000	4	10	1/4	1

The relative cross section of copper for delivering to motor the same power under different conditions of distance, loss and electro-motive force, is indicated by number and thickness of wires.

circuit consisting of two wires to a motor. The current delivered is one hundred amperes, and the resistance of each of the wires is one-fourth of an ohm. The pressure required for sending one hundred amperes through one-fourth ohm is twenty-five volts. The pressure required at the dynamo is therefore five hundred and fifty volts for delivering five hundred volts at the motor

and overcoming the line resistance. If the length of the circuit be doubled, as is shown in figure *b*, and the motor still receives one hundred amperes at five hundred volts, it is evident that the pressure on the dynamo must be increased to overcome the additional line resistance. The resistance of each wire now becomes one-half an ohm, for which fifty volts is required. The dynamo pressure must now be increased to six hundred volts, and the loss in the wires is doubled. If the section of the conductors be doubled by placing another wire of the same size in multiple with the first, then the pressure required for overcoming the line resistance is one-half of that required in figure *b*, and is but twenty-five volts in each side of the circuit. The conditions now, as shown in figure *c*, are similar to those in the first case. It will be noted that the same pressures prevail in figures *a* and *c*, the difference being that when the distance is doubled, the section of the conductor must also be doubled, thus increasing the weight of the copper four times. If the length of the circuit be increased to twice that in figure *c*, the section of copper must again be doubled in order to secure the same drop in pressure between the dynamo and the motor. The weight of copper is now (figure *d*) increased to sixteen times that in the first case, while the distance is increased but fourfold.

In each of the above cases the motor receives one hundred amperes at five hundred volts, or fifty kilowatts. If the pressure at the motor were one thousand volts, the current required for the same power is fifty amperes. In figure *d* the drop in pressure is a total of fifty volts when one hundred amperes pass through four wires in parallel. If one wire only were used, the drop would be four times as great, or two hundred volts. The drop for a current half as large, or twenty-five amperes, will be one hundred volts. In figure *e*, where the current delivered to the motor is fifty amperes at one thousand volts, the use of a single conducting wire will therefore involve a loss of one hundred volts, and will require a generator pressure of eleven hundred volts, which is ten per cent. greater than the pressure at the motor, which is the same percentage as in figure *d*. Doubling the voltage, therefore, enables the same power to be delivered with the same per cent. loss in pressure and consequently with the same loss in power, with the use of only one-fourth of the weight of copper. If the pressure of the motor be increased to two thousand volts, the current required for the same power will be twenty-five amperes. The same per cent. drop will result, if the drop in each wire be one hundred volts instead of fifty volts as in figure *e*. The section of wire in figure *f* may, therefore, be one-fourth the size of that in figure *e*. The weight is also one-fourth and is, therefore, the same as that in figure *a*. A comparison of the first and last figures shows that the same power may be delivered at four times the distance, with the same weight of copper and

the same loss, if the pressure be made four times as great. It is evident that an increase in the amount of copper used under any conditions will result in a less loss of power in the conductor. Increased investment in copper, therefore, leads to a less loss of power in the circuit. The best economic result is secured by increasing the investment in copper until a further increase will not be compensated by a saving in power. This condition is secured when the interest on the investment in copper equals the cost of the power lost in circuit.

General Conclusions.—The following conclusions may be drawn from the illustrations which have just been given, showing the relations between pressure and distance, and pressure, distance, cost and loss in the circuit (it is assumed in each case that the same power is delivered by the circuit):

For the same loss and electro-motive force, the cost of copper increases as the square of the distance. Distances should, therefore, be as short as practicable. A station should be located at the middle of a territory which it serves.

For the same loss and distance, the cost of copper varies inversely as the square of the electro-motive force. Therefore, the electro-motive force should be as high as practicable.

For the same loss and cost of copper, the distance varies as the electro-motive force. The distance to which electrical power can be transmitted depends, therefore, upon the electro-motive force which can be used upon the circuit.

The energy lost in the line when one hundred horse-power is transmitted for one hour is twice as great as it is when fifty horse-power is transmitted for two hours. It follows, therefore, that a line can transmit a given quantity of energy most efficiently when it is delivered uniformly. Also, if a given quantity of energy is to be transmitted with a given line efficiency, the copper required is less if it is delivered uniformly.*

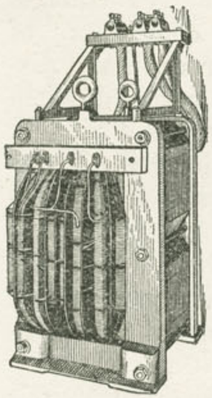
Continuous or Direct Current.—In a direct current the flow is constantly and uniformly in one direction, corresponding to the ordinary flow of water. Direct current is used almost entirely in electric railway work. For constant potential distribution continuous current is commonly used at one hundred and ten volts, two hundred and twenty volts and five hundred volts. The principal limitation of the one hundred and ten volt system is distance, as the cost of copper becomes very great in the large conductors which are required if the current is to be carried to any considerable distance. The two hundred and twenty volt system is commonly used for operating lamps on the three-wire plan, in which one hundred and ten volt lamps are placed between the middle and each outside wire. This system can be extended in general three or four times as far as the one hundred and ten volt system with

*For further reference to electrical energy and the cost thereof, see tables embraced in Appendix C of this volume.

the same cost of conductors. The five hundred volt continuous current system is that commonly used for street railway and general power distribution. This pressure, which is often increased to six hundred or even seven hundred volts, is sufficiently high to render the conductors of moderate cost for operating over ordinary distances. These pressures may be handled without much difficulty in the generators and motors. The commutator, by means of which the current is taken from the armature of the dynamo and introduced into the armature of the motor, is at best difficult and costly to construct. It is the part most likely to wear and give trouble, and the difficulties increase very rapidly if the pressure is much above five hundred volts.

Alternating Current.—An alternating current is one which reverses in direction with a frequency equal to the product of the number of poles in the dynamo multiplied by the speed. A twelve-pole machine running at two hundred and fifty revolutions, produces current with a frequency of twelve times two hundred and fifty, or three thousand alternations per minute. The frequencies in common use for power work range from three thousand to seven thousand two hundred alternations, and for lighting work may be as high as sixteen thousand alternations per minute.

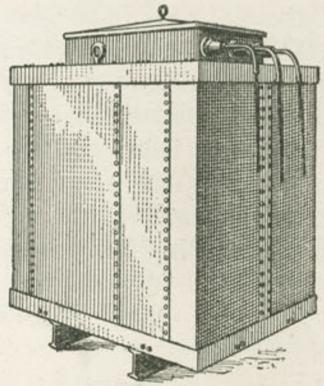
Alternating current possesses a characteristic which is of great utility in the transmission of electrical energy to considerable distances. It is impracticable for many uses to utilize high pressures; for instance, in incandescent lighting the lamp cannot be readily made for a pressure higher than about one hundred volts. On the other hand, the cost of conductors for delivering current at one or two hundred volts becomes very large if the distance be more than a few thousand feet. The desirable system is one in which the energy can be transmitted at high pressure and utilized at low pressure. The direct current does not admit of any ready and convenient transformation. The alternating current, on the other hand, through the agency of the transformer or converter, enables this to be accomplished.



Three Hundred and Seventy-Five Kilowatt (500 horse-power) Raising Transformer. Wires from generator are connected to large terminals on marble block at rear end: wires to high tension line (15,000 volts) are connected to terminals at front. The flat coils are placed side by side and spread apart at the ends to allow circulation of oil between the coils.

An alternating current transformer in its essential elements consists of two windings, each of one or more coils of copper wire wound around a core of iron, usually of thin plates. If one of the windings or sets of coils be connected to a circuit on which the pressure is, say, one thousand volts, an alternating magnetism is produced in the iron, which, in turn produces an electro-motive force in the other, or secondary winding. The electro-motive

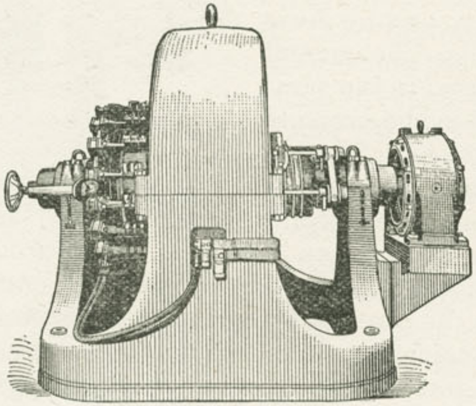
force produced in this winding is proportional to the number of turns of wire in it. If the turns be one-tenth of those in the primary windings, the electromotive force is one-tenth of that on the primary, or one hundred volts. The current is increased in the same proportion the pressure is decreased. Thus, if the primary current be five amperes at one thousand volts the secondary current will be fifty amperes at one hundred volts. The product of the current and pressure giving the energy in watts is the same in the primary and secondary.* The transformer, therefore, supplies a means by which a small current transmitted at a high pressure may be transformed into a large current at a low pressure. The transformer has no moving nor open contacts, there is no mechanical motion, it requires no attention, and is simple and efficient in operation. The alternating current system has given a wide extension to incandescent



Raising Transformer Case.

* There is a slight reduction, both in pressure and in current, which renders the number of watts delivered from the secondary slightly less than those supplied to the primary. The ratio at full load is usually from ninety-five to ninety-eight per cent.

lighting where the service is extended or scattered, as the direct current low voltage system is economical only over a short distance. Almost all of the installations for delivering power in large quantities from water power employ alternating current. The alternating current transformer may be used in connection with the generator for increasing the pressure. It is often most con-

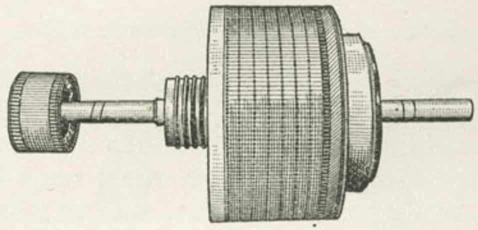


Four Hundred Kilowatt (535 horse-power) Rotary Transformer, showing small starting motor on end of shaft for bringing armature to normal speed; collector rings, on right end, for receiving alternating current; commutator, on left end, for delivering direct current to railway circuits.

venient to wind the generator for an electromotive force of a few hundred volts and then raise the pressure by raising transformers to several thousand volts, depending upon the distance of transmission, then reducing it by other transformers for supplying light or motors.

The alternating current system may involve one or more currents differing in phase. Two

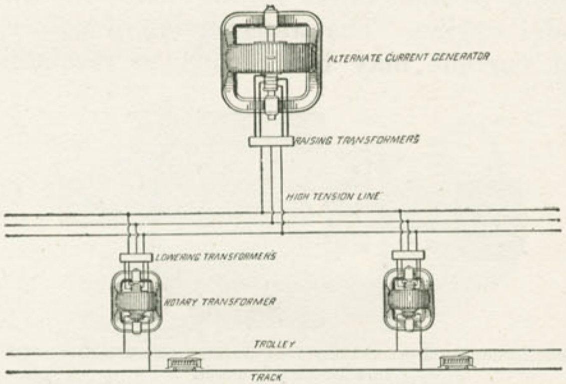
alternating currents are said to differ in phase by ninety degrees when the maximum value of one occurs at the time of the zero value of the other. This has a mechanical analogy in two cranks at right angles. This system is also termed a two-phase system or quarter-phase system. In a three-phase system there are three currents differing equally in phase and corresponding to the cranks on the shaft of a three-cylinder engine. The transmission of power by direct current may be likened to mechanical



Four Hundred Kilowatt Rotary Transformer Armature, with armature for starting motor.

transmission by a belt which is in continuous motion in the same direction. Alternating current may be likened to a reciprocating motion acting upon a crank. A single-phase system corresponds to a single crank, while a polyphase system corresponds to a mechanical system in which two or more cranks are used. The analogy may be carried further, as the increased facility in starting and the uniformity of action which is found when several cranks are used also characterize the use of polyphase currents. Three or more wires are required for carrying polyphase currents.

Alternating Current and Direct Current.—The advantages of alternating current for transmission can be secured for the operation of direct current apparatus by the use of a machine for transforming alternating into direct current. This transformation could be made by employ-



Alternating Current System supplying rotary transformers which deliver direct current to the trolley system.

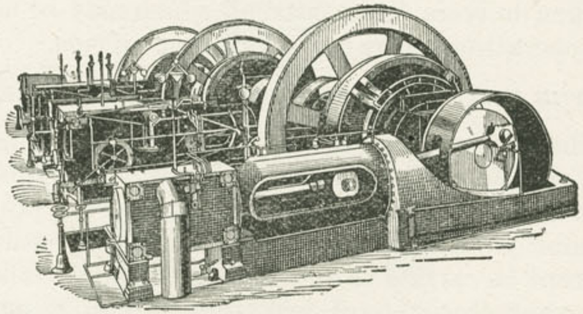
ing an alternating current motor which drives a direct current generator. The two machines may be simplified by placing the two windings upon one armature running in one field. The arrangement may be further simplified by having but one machine with one winding and making suitable connections to rings for supplying the alternating current and other connections to a commutator for delivering direct current. A

machine with this double function is termed a rotary transformer or rotary converter. A system of this kind is shown in the accompanying illustration in which an alternating current generator delivering current at a low pressure supplies raising transformers which deliver a high electro-motive force to a transmission circuit. At the distant end of this circuit the pressure is reduced by lowering transformers and alternating current is supplied to a rotary transformer. This in turn delivers direct current, which may be used for operating railway cars or other service.

THE LIMITATIONS OF ELECTRICAL APPARATUS.

The query often arises, what it is that limits the capacity of electrical apparatus; why is it that dynamos and motors built for a given power cannot yield a greater power; and why cannot current be carried to any distance desired. There are characteristics of machines and of circuits, depending primarily upon the properties and characteristics of the materials of which they are composed and the electrical principles upon which they are based, which place positive limits upon the performance which can be secured from them.

The Dynamo.—The dynamo is limited in its output by several conditions. The output is equal to the electro-motive force multiplied by the number of amperes. The first depends upon the field strength and upon the speed. The field strength is limited by the magnetic saturation of the iron of which it is composed. Iron possesses a fairly definite limiting capacity for magnetic induction and, beyond a certain point, the induction increases in strength very slowly as the field current is increased. The strength of the field is, therefore, limited by the magnetic characteristics of the iron. The speed is fixed by mechanical limits, such as connection to the driving power and strength of materials. The limitations of



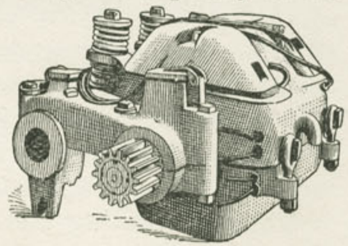
Three 800 Kilowatt Railway Generators, connected to horizontal engines. North and West Chicago Railway.

the dynamo in electro-motive force are encountered in the design of the machine, i. e., by speed and by the properties of iron. The limitation in the current, which is the other element which determines the output of the dynamo, is fixed not by the design, but the operation of the machine. As the current in the dynamo increases, the loss in the armature conductors increases, thus raising the temperature. An increase of current beyond a certain amount will affect the

commutation of direct current machines. It is essential, therefore, in operation, not to load the dynamo so that an unsafe temperature is reached, or bad sparking on the commutator occurs.

The Motor.—The limitations of the motor are very similar to those of the dynamo. In design, the permeability of the iron limits its capacity as a magnet, so that a certain definite cross section and weight of iron are required for developing the required electro-motive force. The speed must be within limits which are readily utilized. In operation the electrical limits are commutation and heating. Excessive current will be destructive to the machine by overheating the conductors and burning the insulation, and by causing sparking and burning at the brushes.

Speed.—The speed of trains is limited by the power available and by mechanical conditions which are largely independent of the source of power used; for example, the strength of materials and safety. The amount of power which can be used is dependent upon the co-efficient of friction and upon the weight upon the drivers. The power is also limited by the capacity of the motors, and the size of the motors is often limited by the size of the trucks on which they are placed. Speed also enters into the problem of delivering current to the car. At



Street Railway Motor.

very high speeds the mechanical connections for carrying current to the car are difficult to maintain especially with the large currents which are required for heavy work.

The Line.—On a line the elements which limit the power that may be transmitted are loss of power and loss of pressure. The loss in power depends principally upon the mean load upon the station, while the loss in pressure is greatest during the maximum load. It may occur that a greater loss of power is permissible than is practicable on account of the drop in pressure which would occur during the maximum load. Transmission is limited by the cost required for long distances. The distance which can be economically traversed depends upon the pressure which can be used in the receiving apparatus. This in turn is limited by the capacity of the receiving apparatus in point of insulation and safety. An electric current can certainly be conveyed over any distance for transmitting any amount of power, provided no limit be placed upon the cost of conductors.

ELECTRICAL SYSTEMS FOR RAILWAY SERVICE.

The electrical systems which are in use or are available for railway work are:

The Direct Current Systems, viz.: direct fed systems; the booster system; the three-wired system, and storage batteries.

The Alternating Current-Direct Current System.

The Alternating Current System.

The elements and the characteristics of these various systems will be considered in regular order.

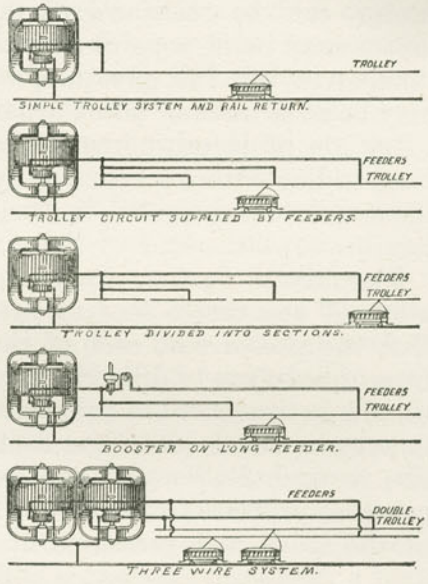
Direct Current Systems.

In direct or continuous current systems both generators and motors are wound for direct current; the motors on each car receive current in parallel from the line. Variations may be used in the transmission by adopting one of several arrangements.

Direct Feeding.—The generators supply current to two conductors or systems of conductors which lead directly to the motors. This is the ordinary system in street railway service and on suburban roads. The generators in the station are usually connected in multiple to two conductors or bus bars, one of which is connected directly to the track and the other supplies the trolley line through heavy wires called feeders. The generators are compounded to give an increase in pressure or electro-motive force on the bus bars as the load increases, thus compensating for the drop in pressure on the lines with heavy load and maintaining a fairly constant pressure at the motors. If there were but one car in operation it is quite possible to adjust the electro-motive force of the generator so as to maintain a constant force at the car, although the current varies and the distance from the station is constantly changing. It is evidently not possible if there be more than one car on the line to maintain a constant pressure at each, for if the pressure at the station be properly adjusted for one car it will not be correct for the other cars. If the conductors are single wires, it is evident that the sections near the station must carry current for all the cars, and that each section carries current for the cars which are beyond it. The pressure becomes less and less on the successive cars as they are farther from the station. The pressure may be raised at the distant cars by running a separate conductor from the station to the trolley line at the distant point. If there be two cars at distances of, say one and two miles respectively, it is evident that the cross section of the longer wire should be twice as great as that of the shorter one in order that a uniform electro-motive force of five hundred volts may result from a station electro-motive force of five hundred and fifty volts.* This uniform drop of fifty volts occurs only when the currents on the two feeders are equal and of a definite amount. If the currents are less the drop is less than fifty volts, and a less station pressure is required. If the motors take a variable current, then it is impossible to keep the pressures constant or equal unless the station pressure is suitably varied for each feeder. The ends of the feeders may be connected to a common trolley line or to separate sections of trolley wire, as shown in the accompanying diagrams. When a car passes away from the feeding point so that the current is carried by the trolley line, the resistance of the circuit increases and a greater

* See *a* and *c* in illustration on page 416.

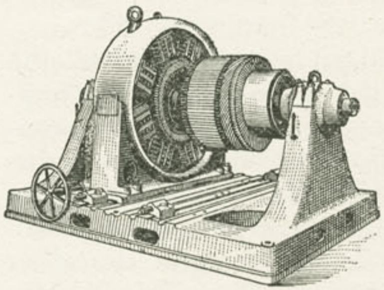
drop results. It is, therefore, impossible to secure an absolutely uniform pressure at a number of cars which are continually changing in location and in demands for current. The pressure can be kept, however, within practical limits by compounding the generators to give an increased electro-motive force as the load increases and by running feeders each of proper size for the average load it carries directly to the different sections of the line.



Direct Current Feeder Systems.

Not only does the load change, due to the wide variations in the current taken by individual cars, but the position of the cars is continually shifting. They may be uniformly distributed at one time, and then bunched together at one part of the line, thus greatly overloading the feeders to that point while the other feeders are comparatively idle. This system is simple and effective; its limitation is the short distance to which it can be economically extended. It may be observed that the maximum drop or loss of pressure allowable in the conductors cannot exceed the limits within which the motor can be satisfactorily operated; for one motor may be at a point near the station where it receives the full pressure, while another car may be at a distant point where the maximum reduction of pressure results. A motor therefore, is liable to receive any pressure between the maximum supplied to the system and the minimum at the end of the circuit.

The Booster System.—In the preceding explanation of the direct feeding system, it is evident that the pressure on each of the feeders running from the station to different points in the system should be increased in proportion to the current flowing in that feeder, thus compensating for the loss in each feeder and causing it to deliver a constant pressure to the trolley line, independent of the loads and pressures upon other feeders. This could be accomplished by supplying each feeder from a separate dynamo compounded to compensate for the losses in it. This is, however, objectionable for several reasons. Among them may be noted



Three Hundred Kilowatt Booster driven by motor; fields on same bed plate and armatures on same shaft. The field of the motor is removed in order to show its armature.

the division of the station into a number of small units, instead of a few large ones, and the increased generator capacity demanded, as the dynamo for each feeder must have a capacity for the maximum load upon that feeder. The load is not usually equally distributed throughout the systems, but the maximum is first on one section and then on another, so that if separate dynamos are provided for each section their aggregate capacity would be much in excess of the average load upon the station. In the booster system, a separate machine is placed on a feeder which increases the pressure in proportion to the current. The field winding and the armature of this machine are connected in series with the circuit so that an increased current increases the field strength and consequently also the electro-motive force upon the armature. The proportions are made such that the increase in pressure is just sufficient to overcome the losses in the circuit, so that a constant pressure is maintained at the end of the feeder. Power sufficient for the motors is generated in the main machines in the station, which may be similar to those in a station in which no boosters are used, while power equivalent to that lost in each feeder is supplied by the booster in that feeder. The booster system makes practical the use of much greater loss in conductors than is otherwise permissible. It has been explained that in the direct fed system the drop in pressure cannot exceed the allowable variation of pressure upon the motors.

In the booster system the pressure upon the bus bars in the station is kept practically constant, also the pressure upon the trolley line. The booster machine may introduce an electro-motive force equal to fifty or one hundred per cent. of that on the bus bars, and if this pressure is lost in the conducting system, the pressure at the motors does not vary beyond narrow limits. If the range of voltage allowed upon a motor is, say, between five and six hundred volts, then the maximum drop allowable is one hundred volts in the direct fed system. If a booster be used, the drop on a long circuit may be two or three hundred volts, in which case the pressure at the station would be raised to, say, seven or eight hundred volts, in order to give five hundred at the motor. The size of the feeder could be reduced to one-half or one-third of that which would be required for one hundred volts drop. The best relation is that in which the saving in the cost of feeders is just balanced by the cost of installation and operation of the boosters. These elements involve a number of conditions, such as distance, quantity of power, cost of copper, cost of apparatus, fuel and attendance, which vary in different cases. In general, however, the booster system is more economical than the direct fed system when the distance is more than five to ten miles. The booster may be driven from the same source of power that operates the main dynamos, or it may be driven by a motor which is supplied with current from the main generators.

The load upon the booster varies approximately as the square of the current strength in a feeder with usually sudden fluctuations. Its mean load is generally small, say, twenty to fifty per cent. of its maximum load. These characteristics make it usually inefficient to operate a booster from a separate engine on account of the low efficiency and the poor speed regulation of the engine under this service. It is best, therefore, to make the booster load part of the load upon the main engines, either by supplying the power directly from them or by receiving it through the main generator and a motor. A booster motor and dynamo may be direct coupled and placed upon one bed plate, thus making a simple and compact arrangement.

The Three-Wire System.—The three-wire system is in common use in direct current central station plants. Three conductors are run from the station. The pressure between two of the conductors in such plants is usually two hundred and twenty volts, and between the third conductor and either of the others, one hundred and ten volts. In a three-wire railway system there are really two ordinary systems, involving two sets of generators and two systems of circuits, each at about five hundred volts. The pressure between the two trolley wires is double this amount, or about one thousand volts. If the two circuits are equally loaded the current will pass from one trolley wire to the rail, through the motors which may be connected to that circuit. It will then be returned through the motors connected to the other system to the second trolley wire. The current flowing from the station for the two sets of motors is, therefore, of the same strength that would be required for operating one set only, and the pressure is one thousand volts. The theoretical saving in conductors is seventy-five per cent. as two instead of four conductors are required, each of half the section. In practice, however, the advantages are not so much as would appear. The rail return circuit which exists without additional cost is but slightly utilized, so that the actual saving in copper investment is much reduced. The complication of having two sets of generating apparatus and two conducting systems, and the tendency to unbalance an inequality on the two circuits in a railway system, in which the cars on the two systems are constantly varying in position, introduce practical difficulties which often more than compensate for the reduced cost.

Storage Batteries.—The storage battery in an electrical system is similar to a reservoir in a gas plant. Each may be used while production and consumption are both in progress for maintaining a constant supply to the service during variations in output of generating plant, or it may supply a varying service from a generating plant of constant output. On the other hand, it may receive its charge at one time and supply the service when the generator is not in operation. In an electrical system the storage battery may

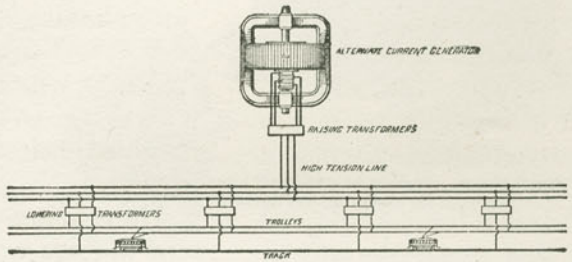
be placed in the central station, or at sub-stations, or on the cars. Its function in the main station is to provide for wide fluctuations in load with a power plant having a capacity equal to the average instead of the maximum demand of the system, and also for supplying current in case of accident to the generating apparatus. In the sub-station its function is similar to that in the main station, the transmission line being considered as a part of the generating apparatus. It is evident that when a battery is used the circuits may be installed for conveying the average load continuously. A line which is to deliver a certain number of horse-power hours continuously and uniformly is much smaller than one which delivers the same aggregate energy but in fluctuating amount. If one hundred horse-power is delivered continuously for twenty-four hours, the size of conductor for the same loss is only about one-fourth as large as would be required for delivering an average of two hundred horse-power for twelve hours if the load is varying during that time between naught and four or five hundred horse-power. The storage battery on a car effects similar advantages in generating station and transmission circuits, and also enables the car to be self dependent in case of accident to generating station or transmission lines, also for short distances where the trolley wire cannot be run. The theoretical advantages of the storage battery are very considerable as an auxiliary in a railway system. The cost for installation, attendance and repairs, and the weight, are the main points which have prevented its wide use in railway plants.

Alternating Current-Direct Current System.

This system finds its field where distances are greater than can be economically covered by simple direct-current systems. An alternating current generator supplies a current which may be transmitted at high pressure, reduced to low pressure and transformed by rotary transformers in sub-stations into direct current, which is then supplied to the motors precisely as it would be if the direct current had been produced by an ordinary direct-current generator. Thus, the energy for the various sub-stations is supplied from one central station in preference to generating it in several stations. This system is, therefore, of advantage when the cost of producing power at a main central station and transmitting it through the alternating current apparatus to the sub-stations is less than it would be to generate the power separately in the several stations. There may be conditions, such as the existence of water power, which render the cost of the power at the main station much less than it would be if produced in the several sub-stations. This system is in operation in a number of plants, notably at Niagara Falls, where the five thousand horse-power generators of the Niagara Falls Power Company supply rotary transformers for railway service both at Niagara Falls and Buffalo.

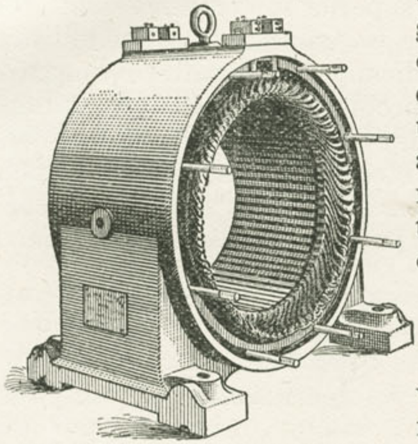
Alternating Current System.

General Characteristics.—The alternating current system is far superior for transmission. Its extension, however, in practical lines for railway work has been handicapped by the alternating current motor. The problems involved in the alternating current motor may be appreciated by referring again to the mechanical analogies to which attention has been called. An alternating current system of one or more phases may be likened



Alternating Current System supplying polyphase current by two trolleys and rail return to alternating current motors on the cars.

to a uniformly revolving shaft with one or more cranks which are to impart motion to a second shaft. The mechanical difficulties which would be involved in starting, in running and carrying load at variable speed upon the second shaft from the cranks upon the first shaft, can readily be appreciated, especially when comparison is made with a belt connection between pulleys on the two shafts, in which case a tightening of the belt, although it may be attended by momentary losses, involves no serious difficulty. It is also evident that the operation with two or more cranks is much more feasible than with a single crank. The analogies hold with the corresponding electrical apparatus, although the alternating current is much more tractable than the cranks, as there is an elasticity in the electrical apparatus which is wanting in the mechanical analogue.

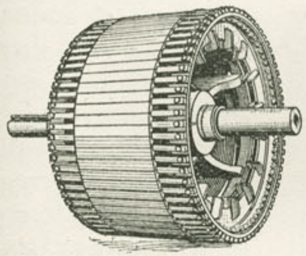


Induction Motor; primary, or stationary element, showing coils for receiving the current from the circuit.

Alternating current motors are in general of two types—the synchronous motor and the induction motor. The synchronous motor cannot be used for speeds less than its normal or synchronous speed and has usually not sufficient power to bring itself up to this speed, but must be provided with some auxiliary arrangement for starting and gaining its proper speed before it is able to run itself and carry a load. In operation it runs at a constant speed, and when overloaded its speed falls and it comes to rest. The synchronous motor is not directly adapted to railway work as it runs at a constant speed. It is theoretically possible to introduce some

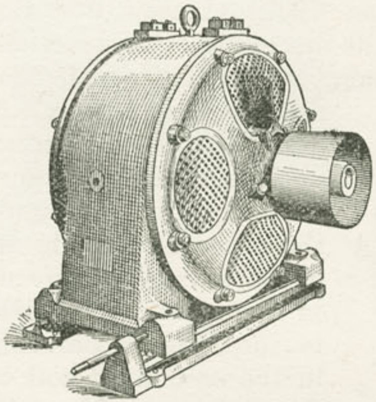
method of variable speed transformation by which the motor running at a constant speed may operate the car axle at a variable speed. Another objection to the synchronous motor is its tendency to fall from synchronism if the source of power be removed for a moment, through a bad contact or break in the circuit.

The Induction Motor.—The induction motor is extremely simple in its mechanical construction. It consists of two elements, one of which is connected to the supply circuit and receives current in its windings. The current in the winding of the other element is induced from the current in the primary, similar to the induced currents in the secondary coil of a transformer. The coils on the secondary element are completely closed or short-circuited and there is no electrical contact with the supply circuit. One of the windings, usually the primary, is placed upon the outside or stationary part of the motor and in one type the secondary or armature requires no commutator or contact of any kind for making electrical connection. In one method of regulation of this motor, a resistance is placed in the circuit of the secondary which may be varied with corresponding changes in the speed or power of the motor.



Induction Motor; secondary, or revolving element, showing copper bars in which current is induced by the current in the primary.

The resistance is usually placed outside of the motor and connected with it by suitable wires. In this case, connection is made to the windings of the armature by brushes resting on rings connected to the winding. The mechanical simplicity of the induction motor in its absence of commutator and usually of all open or moving contacts is particularly desirable in railway work. The induction motor has, however, met but little progress in the practical railway field. The reason for this is found in its electrical characteristics. It requires for its successful operation two-phase or three-phase currents. There are methods of operating an induction motor by single-phase currents, but in general they add considerably to the quantity of apparatus, reduce the output of the motor, lower the efficiency and greatly impair the performance at low speeds. The currents of more than one-phase require more than two conductors, so there must be at least two conductors besides the rail return for supplying the required currents to a car. This



Alternating Current Induction Motor Complete.

requirement has been especially disagreeable in street car work in cities and cannot be conveniently met on suburban lines where the cars are to run through the city streets. In cross-country and heavy work these objections do not hold. A double trolley line can be adopted with success, except, possibly, at very high speed. If the current is conducted by additional rails, it is, of course, necessary to add two rails. This increases the difficulties at crossings and in repairs to the track.

The theoretical and practical evolution of the alternating current motor has been slow and difficult in comparison with direct current apparatus. Much labor has been expended upon a single-phase motor with no practical outcome as far as railway service is concerned. The induction motor is essentially a constant speed motor. Its tendency is to run at a certain definite speed, depending upon the ratio of the number of its poles to those of the generator from which its current is derived. Without load the speed is practically the synchronous or theoretical speed. As the motor is loaded the speed falls, slowly at first and then more rapidly. The characteristics at low speed can be varied by design in different motors. For operation at variable speeds, as is required in railway work, there are two ordinary methods of regulation; one is the introduction of a variable resistance in the secondary element of the motor, the other is a change in the pressure or electro-motive force supplied to the motor with no change in the secondary element. In regulation by change of secondary resistance, an increased starting torque is secured by the introduction of a resistance in the secondary element. The torque at any speed depends upon the amount of this resistance, which is, therefore, varied according to the requirements. The efficiency of the motor cannot exceed the percentage which the actual speed bears to the synchronous speed. At one-third speed, for instance, the efficiency cannot exceed thirty-three per cent. Moreover, as the current and electro-motive force are not in phase, that is, their maximum values do not occur at the same time, but the current lags behind the electro-motive force, the true energy delivered to the motor is less than the product of the current and volts. This renders the apparent efficiency less than the true efficiency. It is, therefore, obvious that the motor is not adapted to running at low speeds, as is required if the motor must be frequently started.

In the second method of regulation, in which no resistance is introduced in the secondary, the electro-motive force supplied to the motor is varied. The motor is so designed that the torque is greatest at starting and constantly decreases as the speed is increased, when the voltage is maintained constant. The starting torque may be four or five times the full load torque and the starting current is increased in a greater ratio. The starting torque and current are, therefore, much greater than are desired. They

are reduced by a reduction in the pressure applied. A variable voltage may be secured from a transformer arranged to deliver a variable voltage to the motor. In this manner the motor may be adjusted to give any desired torque at any speed over a wide range. The same general characteristics of apparent efficiency, or the ratio between the output in horse-power and the apparent horse-power supplied, and also the true efficiency of the motor, or the ratio between the output and the actual horse-power supplied, are found with this method of regulation that belong to the motor regulated by secondary resistance. The efficiency and the apparent efficiency are, however, in general greater in the motor constructed without an adjustable secondary.

What has been said concerning the inefficient performance of the induction motor applies particularly to low speeds. When running near its synchronous speed an induction motor shows a performance about equal to that of the best direct current motors. The characteristics of the induction motor, therefore, adapt it to those classes of railway work in which starting is not often required and in which a high and fairly constant speed is required during a large portion of the time, so that the motor is operated at high and constant speed where its efficiency is high. Special methods have been proposed for improving the operation at low speeds. Among these are the operation of two motors, one being connected to the line and the second being supplied from the secondary of the first motor. In this arrangement both motors tend to run at half their normal speed. This connection is used until half speed is reached, when both motors are directly connected to the circuit. The regulation is secured by an adjustable resistance in the secondary of the second motor when they are connected in tandem and by resistance in the secondaries of both motors when they are operating in parallel. Another method of favorable operation at low speed is an arrangement of the windings of the motor so as to secure different numbers of poles. If, for example, a four-pole motor be changed to an eight-pole motor it will tend to run at half speed. If changed to a twelve-pole motor, it will tend to run at one-third speed. Such a motor would, therefore, be arranged to operate by many poles for slow speeds and changed to few poles for high speeds. Other special methods are theoretically possible, such as a device for changing the number of alternations of the current to correspond with the speed required. No apparatus for accomplishing this has, however, been presented. These methods of securing a reduced speed are in a measure effective. The current and the power required for producing a torque under given conditions are materially reduced. There is, however, a sacrifice in the simplicity of the apparatus and in the controlling devices. The ideal arrangement is a gearing of variable ratio, by which the axle could

be run at any desired speed from a motor running at a constant speed.

Conclusions.—There appears to be no fundamental obstacle to the use of the alternating current induction motor for railway work. It secures the advantages of the lower cost of alternating current generators and transmission circuits and in general a simpler construction of motor. The electrical characteristics of the motor adapt it for operation where a fairly constant speed is required and the proportion of the time employed in starting is small. This is usually the condition where distances are great and the high tension transmission circuits which are practicable with alternating currents are especially desired. One of the principal mechanical disadvantages is that a double system of conducting circuits must be employed.

There is little doubt but that the alternating current motor would be largely used in railway work had not the direct current motor secured the field first. At the present time the direct current motor has the prestige and the advantages of practical experience and evolution during many years of wide and varied service. It fills its field so well that the requirements of the alternating current motor are not merely that it shall equal what the direct current motor was in its early days, but that it shall now perform better than its rival the most difficult and exacting classes of service.

COMPARISON OF SYSTEMS.

The choice of a system for operating a given railroad cannot be definitely stated, as there are so many local conditions which affect in different degrees the cost of the various systems. For example, the booster system maintains a proper pressure at the end of a distant line by raising the pressure at the station and allowing a very large loss in the conducting wire. The aggregate amount of power lost in the wire depends of course, not upon the maximum, but upon the average current which is carried. If the service be intermittent, so that the average load is not more than half the maximum load, the loss of power in the wire is only about one-third or one-fourth what it would be if the maximum load were delivered continuously. The cost of the power lost in the wire depends upon the cost of producing power. It may be large if expensive coal is used, or it may be negligible if water power is available. If the load were constant and the cost of power high, it may be more economical to put in large conductors, so the loss would be small, and feed directly from the main machine without using boosters. The following general rules are laid down as being helpful in forming a general idea of the field covered by the different systems of distribution, with a full appreciation of the variations which different local conditions may demand. The direct fed two-wire system should be used for distances from the power house not exceeding five to eight miles.

The booster system should be used for distances from the power house of five to ten miles, where the service is heavy and power cheap; and for distances of fifteen to twenty miles where the service is light and intermittent. The high tension alternating current transmission, with rotary transformer sub-stations and direct current distribution, should be used for distances greater than those named above. The high tension alternating current transmission and distribution, finds its best field in operating roads where trains are run between distant points, making few stops.

For long distances and heavy service the cost of the systems using high tension alternating current, should be compared with the cost of operating two or more stations by the direct fed or the booster system. The items of expense between the dynamo and the car in the several systems are as follows:

Direct Current-Direct Fed System.—Interest on investment in copper conductors and cost of power lost in conductors.

Booster System.—Interest on cost of booster dynamos and copper conductors, and the cost of the power lost in conductors.

Alternating Current-Direct Current System.—Interest on the cost of raising transformers, high tension line, rotary transformers and sub-station building and copper conductors for supplying the direct current to the trolley, together with the cost of power lost in the copper conductors, the raising and lowering transformers and the rotary transformers, and the cost of attendance at the rotary sub-station. The cost of an alternating current generator is slightly less than that of a direct current generator, which favors this system.

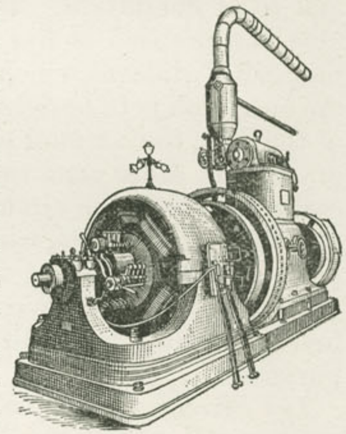
Alternating Current System.—Interest on investment in raising transformers (unless the dynamo be wound for high tension), high tension line and lowering transformers, and copper conductors in the trolley system, together with the cost of power lost in the transmission system. In this system it is necessary to install lowering transformers at numerous points along the line in order to avoid high cost of copper in the low tension trolley system. Unless the service is frequent this will require a sufficient capacity in lowering transformers in each of the main sections of the line for the whole load which may come on that section, so that the aggregate capacity of lowering transformers may greatly exceed the average power which is to be supplied.

High Tension System with High Tension Trolley Line.—Interest on investment in raising transformers (if they be used), high tension conducting circuit, extra cost of installing double trolley line for high tension and additional cost of lowering transformers for car equipment, together with cost of power lost in transmission. The extra cost of installation for high tension circuits and the increased liability to break-downs in carrying high tension to the car must be charged against this system.

For roads of thirty to forty miles in length, with a fairly heavy service, it will probably be found that the cost of operation, including interest on investment, will not differ widely whether the operation be by one station with rotary substation; or one station with high tension transmission and low tension distribution to alternating current motors; or one station with high tension distribution to the cars; or two power stations with boosters. Within certain limits, therefore, the choice of the system for use depends upon the exact and definite schedule of service and the cost of materials and of power.

THE ELEMENTS OF AN ELECTRIC RAILWAY.

A consideration of the elements in an engineering plant should logically deal primarily with the established best practice. But in electric railway service the practice of the present is new, the conditions, the methods, and much of the apparatus, have been evolved within the past few years. Not only have the new electric elements undergone rapid development, but even the steam engine, the oldest and best-established part of the



"Kodak" Engine direct connected to generator. Fitchburg & Leominster Street Railway.

system, has been greatly modified in design to meet the new requirements of higher speed, closer regulation and increased economy over wide ranges of load. The application of electricity to railway work will be set forth by considering in detail the various elements of the system in order, depending largely upon the present practice in large stations, and in other cases stating the engineering conditions and requirements.

The direct current system will be considered first, and then the modifications which result if alternating current is used in part or in whole.

The Power Station.

Location, Etc.—The number and location of power stations depend upon the source of power and local conditions. If water power is available, the position is fixed; if steam is used, the number of stations which will secure the cheapest operation is to be determined from the length of the line, the amount of traffic, the location of grades and other conditions which influence the cost of transmission circuits. The exact location of a station, which electrical considerations would place at the middle of the line to be operated, may be determined by convenience of obtaining fuel and water for both steam and condensing purposes.

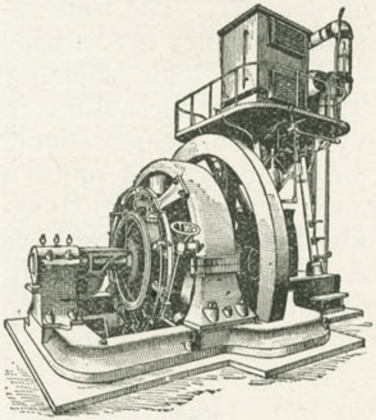
The Size of Unit to be used in the station is a mechanical rather than an electrical question. The cost is in general less per horse-power the

larger the size of engine and dynamo; the operating expense is also less, and the efficiency greater. It is usual to have at least three or four units, one of which may be held as a reserve. The dynamo can be made for any output at any speed within very wide limits, the cost per horse-power decreasing as the output is larger or the speed is greater. The dynamo is not generally the element which is first fixed, but its size and speed are adapted on one hand to the requirements upon the station, and on the other hand to the speed and capacity of the power by which it is to be driven. Close speed regulation of a railway generator is very important for good service. The speed governor should act quickly during the continual fluctuations of load, and must protect against excessive speed even when an overload is thrown off instantly. The wide variations in load make good efficiency over a wide range of more importance than high efficiency simply, at full load. The sudden fluctuations in load necessitate a heavy fly-wheel, which should preferably be located near the dynamo or be a part of it. The five thousand horse-power dynamos of the Niagara Falls Power Company have a revolving element of eighty thousand pounds, nearly twelve feet in diameter, which makes two hundred and fifty revolutions per minute. A sudden load acts directly upon this great fly-wheel. If the fly-wheel were placed elsewhere enormous strains would be brought upon the shaft.

The Generator.

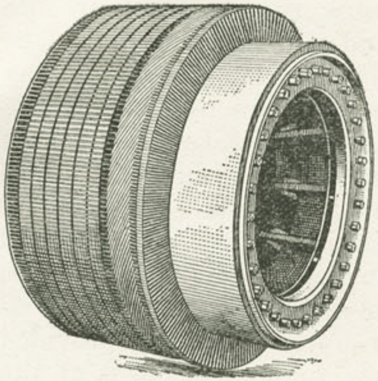
Types.—The dynamo may be connected with the engine by belt or rope, or it may be direct coupled, either by a flexible or fixed coupling between the dynamo shaft and the driving shaft, each shaft having its own bearings, or the dynamo armature may be mounted directly upon the extended end of the driving shaft with or without additional bearings. Until within a few years almost all dynamos for railway work were belt-driven, running at a speed higher than the driving shaft. Frequently several dynamos were run from one main or jack shaft. At the present time it is the almost universal practice to employ direct connected machines.

Engine Type.—The armature of the modern engine-type railway generator is mounted directly upon the engine shaft. The machine has a diameter which is large in proportion to its length, so that only a short extension of the shaft is necessary. The poles vary from four or six in small sizes to twelve or more in large sizes, and are usually of cast steel, bolted or cast into the yoke,



Four Hundred Kilowatt Generator Direct Connected to Vertical Engine. Brooklyn Bridge Power Plant.

or of sheet steel plates riveted together into compact pole pieces and cast into the yoke. The field is split vertically into halves, which may be removed from the armature by sliding them directly back from it. The armature is built on a substantial open cast hub, which is keyed securely to the engine shaft and carries on its outer circumference laminated iron plates, placed in planes at right angles to the shaft. These laminated plates are dove-tailed or otherwise fastened to the iron hub. They are provided with longitudinal slots, or deep grooves at the circumference, in which the copper conductors, either of wire or copper strap of suitable form, are placed. The coils are insulated separately by a covering of insulating material before they are placed in the slots. The conductors are connected to the commutator, which may be built on a separate bush and forced on to an extension of the hub or spider forming the central part of the armature. Around the commutator are placed brush-holders equal to the number of field poles. Each brush-holder carries a number of brushes, usually of carbon, which rest with a moderate tension against the commutator. Alternate brush-holders are connected to the positive lead and the remaining ones to the negative lead. The brush-holders are supported from a common ring, which may be rotated slightly, thus adjusting the angular position of all the brushes simultaneously. The mechanical elements of a large generator are extremely simple compared

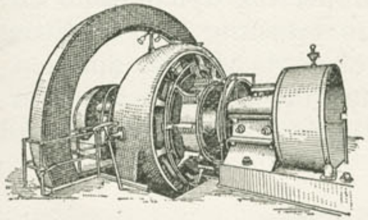


Armature of Engine Type Railway Generator, showing winding connected to commutator.

with the elements of other apparatus, such as an engine. The construction is of iron and copper, with insulating material which has been developed to a degree of perfection that renders it ample for standing very severe conditions. There is no moving part except the rotating armature and nothing to wear except the brushes and commutator. The brushes are readily adjusted and replaced when worn, and a commutator which receives proper treatment should run for a long time without becoming worn or uneven. When necessary it may be turned off and given a new and perfect surface.

Electrical Characteristics. — The requirements upon an electric generator are severe, as it is subject to a fluctuating load. The cars operated by a generator are individually fluctuating in their requirements for power. When the occasion comes that many cars require a large amount of power simultaneously, the load upon the station will increase greatly above the mean. The generator must, therefore, be able to stand for a short time, without overheating of armature or commutator or brushes, a load much greater

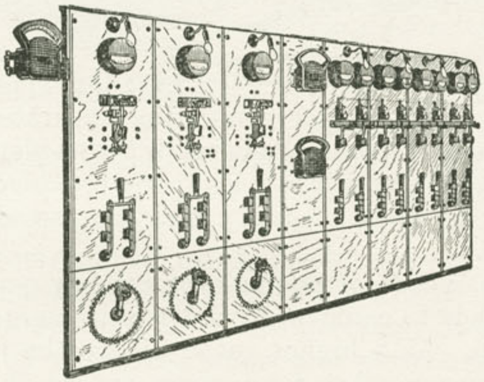
than the average load, and in case of overload or short circuit must be able to have the total load, which may be double the normal load, thrown off instantly without injury to the machine. This requires exceptionally good commutation, as there is a tendency to spark at no-load when the brushes are adjusted properly for carrying an overload, and it also requires excellent speed regulation of the power generating apparatus. The mechanical strains produced by the sudden throwing on of a very heavy load are provided for by large fly-wheel capacity and the use of heavy shafts.



Eight Hundred Kilowatt (1070 horsepower) Railway Generator in motion.

The speeds of engine-type railway generators are made to conform to the requirements of the engine. As a higher speed allows the use of a smaller generator for a given output, the speed is usually made as high as that at which the engine can be safely run. Railway generators are compound-wound, so that the main current passing around the field strengthens it, thus increasing the magnetization and consequently the electromotive force as the load increases. This also compensates for fall in engine speed as the load increases. The efficiency of engine-type generators varies from ninety-one or ninety-two per cent. to ninety-five per cent. at full load, depending upon the size of the machine. The efficiency at half load is within a few per cent. of the efficiency at full load.

The Switchboard.—The switchboard is provided with apparatus for connecting dynamos to circuits for adjusting the pressure, for indicating the pressure and the current, and for automatically opening the circuit in case of heavy overload. Usually a separate panel of the switchboard



Railway Station Switchboard for Three Generators and Eight Feeders.

is provided for each generator, for the total load and for each feeder circuit. A generator panel is supplied with a rheostat—an adjustable resistance in series with the field winding by which the strength of the field current and consequently the electro-motive force of the machine may be varied; a main switch for connecting the wires from the dynamo to the bus bars to which all the dynamos may be connected; a circuit

breaker for opening the circuit, either automatically in case of too great an overload, or by hand at other times; an ammeter for indicating the current, and a voltmeter for indicating the electro-motive force. One voltmeter is usually supplied for several dynamos, and is provided with a switch by which it may be connected to any one of them. When a machine is to be connected to the bus bars, it must be at the pressure which is indicated by a second voltmeter. The load panel

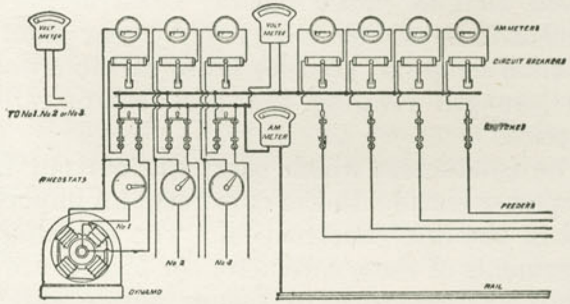


Diagram of Connections Between Dynamo and Feeders in Switchboard.

is equipped with an ammeter for measuring the total output of the station, and often with a recording wattmeter which registers the total kilowatt-hours, or the output in energy. Each feeder panel is supplied with a switch, an automatic circuit break and an ammeter. Such a switch-board enables any or all of the dynamos to supply any or all of the feeders, and the distribution of the load may be read instantly on the ammeters.

The Road Equipment.

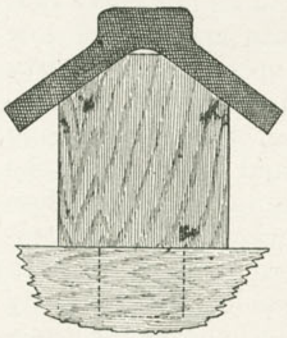
The Track.—In an electric railway the road-bed and track are determined by the weight and nature of the rolling stock and the location of the line. In general the requirements are the same as for steam railways. Inter-urban and some suburban roads, therefore, employ T-rails of the standard weight and form, while in city streets a suitable girder rail is used, such as will permit of paving between tracks and not interfere with regular street traffic. It may be observed that in street railway construction the rail has increased steadily year by year from the old-time strap rail used for horse cars to a weight and strength rivaling the best steam railway practice.

The conductors which carry the current from the power station to the cars form an important part of the line construction. The essential requirements of these conductors or feeders are low electrical resistance to secure ample carrying capacity, and insulation from other conducting bodies. It is, therefore, customary to use copper wires or cables, secured to glass or porcelain insulators mounted on poles. Where over-head wires are prohibited the feeders are usually of insulated cables laid in an under-ground conduit beneath or along the track. The rails of the track are equivalent to a copper conductor of a section about one-sixth that of the iron, and are commonly used for returning the current to the power station. The high resistance of the rail

joints is eliminated by bonding the rails with heavy copper wire or connectors riveted or otherwise connected to the rails near the joints in such a way as to conduct the current from rail to rail around the high resistance joints. Devices for transmitting the current from the feeders to the car are of three general types—overhead, surface and underground.

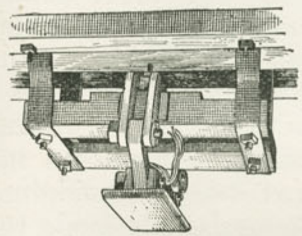
The Overhead System.—This system, commonly known as the trolley, is now used more than any other. A single bare copper wire suspended over each track is connected at frequent intervals with the feeder. A grooved wheel on the end of the trolley pole carried by the car makes contact with the under side of the wire, conducting the current to the car. This trolley has been almost universally adopted by street railways when overhead wires are not prohibited, and has an advantage over all its competitors in its low cost. It is limited, however, to moderate speeds and low current capacity. When the speed exceeds thirty to forty miles per hour the tendency of the trolley wheel is to leave the wire, thereby damaging the over-head construction and interrupting the service. Heavy trains require more current than can be collected by a single wheel. This necessitates mounting two or more trolleys on each motor car, which is objectionable. The necessity of turning the trolley around whenever the direction of the car is reversed is a serious inconvenience in switching and yard work. Poles placed between tracks for supporting the wires become dangerous to the employes of railroad yards and sidings. When a suitable over-head structure is already provided, some form of rail may be substituted for the wire, whereby amply carrying capacity may be secured and the objections to high speed eliminated. The Baltimore & Ohio Railroad has adopted this plan for operating its large electric locomotives in the Baltimore tunnel. A trough of steel beams is suspended from the upper wall of the tunnel, through which a heavy iron shoe is drawn by the locomotive. The shoe cannot leave the trough, and operates equally well in either direction.

Surface Conductors for collecting current, of which the "third rail" is the most common example, have some very marked advantages. Substantial construction is secured by placing the rail on strong insulating blocks secured directly to the ties on which the track rails are laid. This permits of any speed for which the track may be constructed. The cost of repairs is low. Accessibility for inspection, repairs and adjustment is an important factor in securing reliable service. Ample and reliable contact between the shoe and the rail permits an uninterrupted supply of current required to



Third Rail supported on special wood blocks which are dowelled into the ties. Nantasket road.

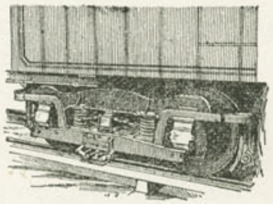
operate heavy trains. Any number of shoes may be added and an unlimited capacity secured without complication or inconvenience. The shoes work equally well running in either direction and require no special thought or attention. There are, however, certain objections to this system which in some cases may be sufficient to exclude its use. "Live rails" are inadmissible in city streets, therefore, this system cannot be used for street railways. They may also become objectionable in yards where many tracks intersect in a complicated manner, as they thus become dangerous to yardmen and trainmen. The third rail must be omitted at all grade street crossings. This cuts off the source of power and the lights from the train whenever a crossing is passed unless the rear car is also provided with shoes and connected with the motor car by a sectional cable running through the whole length of the train. The third rail may be placed between the track rails or on either side of the track, as may be desired. It must always be raised several inches above the track rails so the shoe will clear at switches and crossings. The shoe is usually of cast iron, simple in form and of low cost. It is suspended from the truck in



Shoe for Third Rail Between Main Rails. Cast iron, five by twelve inches; weight, twenty pounds. Nantasket Beach Railway.

such manner as to reduce shocks and be easily adjusted or renewed.

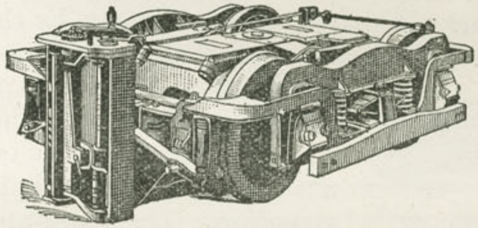
Underground Systems for collecting current are of two general types, the open conduit and the closed conduit. The open conduit system employs some form of trolley wire or rail laid in a conduit having a slot or groove in the upper portion through which a suitable bar is drawn by each car, making contact with the wire or rail and conducting the current to the car. Foreign substances, such as water, snow, ice, dirt, etc., getting into these conduits impair the insulation of the conductors and clog the conduit, making its operation under some conditions unreliable and unsatisfactory. In the closed conduit system the conductors are completely inclosed in water-tight conduits. Connection is made to sectional rails or contact blocks laid along the track, through switches which are closed by electro-magnets operated from the car. Hence the contact rails or blocks are charged only while the car is passing over them. This system possesses many advantages, especially for street railway work and yards and sidings where nearly all other systems are excluded.



Shoe and Third Rail. Brooklyn Bridge terminal.

The Electric Motor Car or Locomotive.

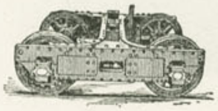
The development of the electric motor car nas been a continuous evolution. The first form was that of the old horse car with motors mounted on the trucks. This soon proved inadequate and heavier and stronger cars were constructed, requiring larger motors. Double truck cars of still greater weight and power were next adopted for suburban and inter-urban service. Some of these cars are now constructed of thirty to forty tons weight and are equipped with a motor capacity of from two hundred to four hundred horse-power.



Truck with Motors and Controller. Brooklyn Bridge Motor Cars.

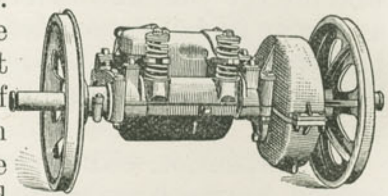
The Frame.—The chief requirements of the frame are stiffness and strength for resisting shocks and drawing trains. The frame of a double truck car is relied upon to tie the trucks together and transmit their combined effort to the draw bar. It is therefore customary, for heavy service, to construct the frame of iron or steel beams, suitably braced and stiffened with plates and rods in accordance with good engineering principles. The superstructure may be adapted to any service whatever. For passenger service only the main body of the car is designed to carry passenger and the controlling devices are mounted on either end. Combination passenger and baggage cars have one end partitioned off for carrying baggage, while for express and freight work the greater part of the motor car is reserved for baggage and freight. The latter class of motor cars, as well as those provided with a cab for the motorman only, are termed locomotives, since their chief function is to pull the train.

The Truck.—The axles of the ordinary car truck are not driven but are drawn by the locomotive. When, however, these axles are driven by motors the stress on the transom of the truck becomes quite different, requiring a stronger and more rigid construction. The boxes and journals must also be of proper form and size to give adequate wearing surface, and must be so fitted as to resist shocks transmitted to them without being thrown out of line. The axles and wheels should possess the qualities of durability, stiffness and strength. When but two motors are mounted on a double truck, there may often be an advantage in using maximum traction trucks. These trucks are constructed with one pair of heavy driving wheels and one



Truck for motor cars for suburban railroads.

pair of small wheels. The truck frames are so proportioned that the greater part of the weight on each truck is borne by the heavy axle and wheels, to which the motors are connected, and a high tractive effort is obtained without slipping the wheels.



Railway Motor, spring mounted.

The Motor.

Mechanical Requirements.—Since the service required of railway motors is especially severe, particular attention must be paid to certain mechanical points:

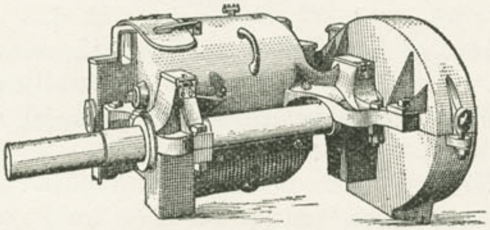
(1) Weight.—The motor should be as light as possible, to lessen wear and tear on track; to avoid carrying the extra weight; to facilitate handling. The armature, especially, should be light.

(2) Size.—The external dimensions are fixed by the truck, the wheel base, the gauge and the diameter of wheel. Motors of special shapes are frequently required for certain classes of work. For example, motors of large powers to be mounted on trucks with very short wheel base must be rectangular in form in order to be suspended between the axles and bolster of the truck. These mechanical limitations often determine the electrical design and type of motor.

(3) Strength.—The entire motor should be able to stand the tremendous strains and shocks, as

well as the continued vibration which are unavoidable in railway service. Steel motors combine strength and light weight so advantageously that they are now generally used for heavy railway work.

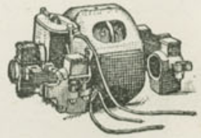
(4) Suspension.—The motor should be suspended as much as possible by springs, which will prevent sudden shocks and shield the car axles from undue strains. In the case of geared motors the weight of the motor is divided be-



Thirty-five Horse-Power Railway Motor, with Gear Case and Car Axle.

tween the frame of the truck and the axle. Single reduction gearing has superseded the older double reduction type and admits of a simple and effective spring suspension for the motor. Gearless motors, which must be constructed to run at a low armature speed, are more difficult to suspend properly because of the greater weight and size for a given output, and because the entire weight of the motor is centered at the axle. Shocks on axles and wear and tear on track are, therefore, greatly increased unless a hollow sleeve suspension with flexible spring connections is

used. The armature must be mounted on the axle before one of the wheels is pressed on, and cannot be removed for repairs except with considerable difficulty and expense. The gearless



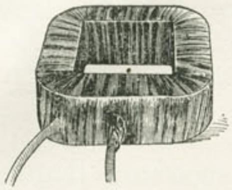
Railway Motor.

motor, on account of its lower speed and larger size, has a greater first cost than the single reduction motor of the same power. Geared motors should be suspended between the axle and the bolster. If the motors are mounted on the side of the axles opposite the bolster, shocks and vibrations are increased; the inertia effect on short curves at high speeds is also objectionable and may often be dangerous.

(5) Protection from Weather.—Motors should be enclosed so as to be practically water-proof up to the axle and entirely dust and oil-proof.

(6) Accessibility.—The motor should be so arranged as to afford easy access to all parts. The upper and lower halves of the field should be hinged, to allow them to be swung open for inspection or removal of damaged armature or field coils, bearings, etc. A covered opening should always be made in the upper field for easy access to brushes and commutator.

(7) Simplicity.—The motor should involve the smallest possible number of parts and especially few wearing surfaces. This is necessary to reduce liability to get out of order, to permit ease of replacing and to reduce the number of repair parts which must be kept in stock. Motors with



Field Coil for Railway Motor. The coil is thoroughly covered with insulating tape.

very small clearance between field and armature require more frequent renewal of bearings, because of the small amount of wear in bearings, before causing the armature to rub against the field poles. The electrical parts, such as field coils and armature, should be so simple that any ordinary mechanic can repair them.

The evolution of the railway motor has reached the point where nearly all manufacturers have settled down to practically one type, a four-pole or six-pole field and slotted drum armature with machine-wound coils. The differences appear in the number of field coils, the material in the field and the many necessary details that go to make up a complete motor. The four-pole motor for ordinary sizes and the six-pole motor for large sizes are adopted chiefly because they fulfill the conditions of lightness, compactness and strength. They are easily made "iron-clad," water and dust-proof. This type facilitates the use of machine-wound armature coils and provides for better ventilation of field winding; it also possesses electrical advantages. When the space is limited and circular motors of large size cannot be used, the form of four-pole motor fields is changed by being made narrower in one direction. This is done by making two opposite field poles short and putting no field coils on them.

Such a motor is called a "consequent pole" motor.

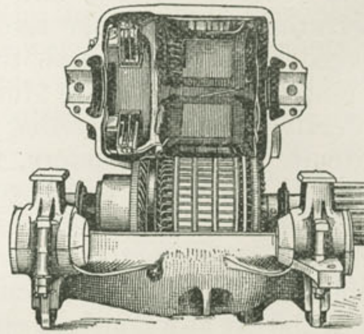
The toothed armature is better adapted to railway work on account of the danger of injury to the winding of the surface-wound armature, also on account of the fact that the excessive torque on the wires laid on a smooth core has been found to shift the winding. The coils on a toothed armature are mechanically protected by the teeth.

Electrical Characteristics.—The service required of the railway motor is different from that of almost any other motor. The average work of the motor is small, while the maximum may be several times greater. For this reason the motor is designed and rated differently from stationary motors. The motor usually receives a rating which corresponds closely to the average power developed by the motor while running. If rated in horse-power, the drawbar pull is fixed by the speed for which the motor is geared. If rated in drawbar pull, it must be at a definite speed in order to fix the capacity of the motor in horse-power. With any two of three terms—horse-power, speed, or drawbar pull—given, the third is fixed, so it matters little whether the motor is rated in horse-power or in drawbar pull. The railway motor must run without sparking, otherwise it will give trouble at the commutator from blackening, cutting, burning, or flashing, and the commutator will heat and wear rapidly. The motor must have the field coils and the armature so insulated as to protect them not only from the line voltage and the momentary voltages produced by opening the circuit, but from lightning discharges. The efficiency will not be as high as in a stationary motor, owing to the gear and extra friction losses, but in the best motors all losses are reduced to a minimum, and the maximum efficiency is obtained at about the average running load, which gives the best all-day efficiency. The same motor may be used for high speed and light load and for low speed and heavy load by simply using gears with a different ratio.*

The Series Motor operated on a constant potential circuit is now almost universally used for traction purposes. In this motor the field winding is placed in series with the armature. A variation in current, therefore, affects both elements, field and armature. This relation has its strong practical advantage in securing a heavy torque at low speeds and in giving good running conditions over a wide range of speed. The torque of a given motor depends upon the field strength (or field current) and upon the current in the armature. The torque is

* This is made clear by the following relation: Horse-power = Drawbar pull × Miles per hour × .00267. By changing the gear ratio a motor (itself exerting the same torque and revolving at the same speed) may be used for exerting twice the drawbar pull at half the speed. If the drawbar pull required be five thousand pounds and the speed be thirty miles per hour the horse-power required is 5000 × 30 × .00267 = 400 horse-power, or 100 horse-power each for four motors. The same motor will give a drawbar pull of ten thousand pounds at fifteen miles per hour if properly geared.

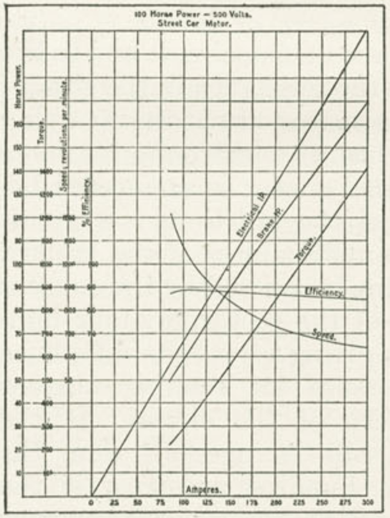
always the same for a given current, independent of the speed. The electro-motive force at the terminals of the motor depends principally upon the field strength and the speed. The speed depends principally upon the electro-motive force and is (broadly speaking) independent of the current. The current flowing depends upon the difference between the electro-motive force on the circuit and in the motor, and also upon the resistance in the circuit.



Motor with Upper Field raised, showing Armature and Upper Field Poles with the coils surrounding them.

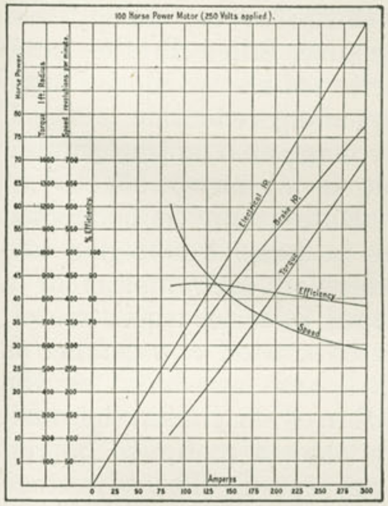
More precisely, the motor armature revolving in a magnetic field has an electro-motive force induced in it. When a motor is connected between the trolley and the rail there is a circuit in which the electro-motive force of the trolley, say five hundred volts, is opposed by the counter electro-motive force of the motor, say four hundred and fifty volts, giving fifty volts difference as the effective pressure for sending current through the resistance of the circuit. If the resistance of the circuit be one-half ohm the current will be one hundred amperes; if the resistance be increased to one ohm, the current will decrease; but a decrease in current means a decrease in torque. If the motor is propelling a car, the speed will necessarily become slower. The reduced current and the decreased speed both tend to reduce the electro-motive force produced in a motor, and the lowering of this counter electro-motive force, gives a greater effective force for sending current through the circuit. When, therefore, the resistance is increased the speed will become less and less, the counter electro-motive force will become less and less until the effective electro-motive force is just sufficient to cause enough current to flow to maintain the car at a constant speed.

Motor Curves.—The relations between the speed, torque, current and electro-motive force under various conditions may be determined by brake tests upon the motor before it is mounted on the car. When certain of these elements, as speed and current, are given, the others may be determined from characteristic curves plotted from the preliminary tests. The



Horse-power, torque, speed and efficiency diagram, at 500 volts for 100 horse-power motor.

accompanying diagrams show the characteristic curves for one hundred horse-power motor. These diagrams show the electrical horse-power (the horse-power received by the motor), the mechanical horse-power (the power delivered by the motor), the torque, the efficiency and the speed for different currents for pressures of five hundred, and two hundred and fifty volts on the terminals of the motor. By examining the diagram which gives the relations when the electro-motive force is five hundred volts, the conditions when one hundred amperes are flowing may be found on the vertical line corresponding to one hundred. The speed is ten hundred and seventy-five, the output is fifty-eight horse-power, and the torque is three hundred pounds. If increased torque is required, say, a grade is reached requiring three times the draw-bar pull, then a current corresponding to nine hundred pounds torque is required, which is two hundred and ten amperes,



Horse-power, torque, speed and efficiency diagram, at 250 volts for 100 horse-power motor.

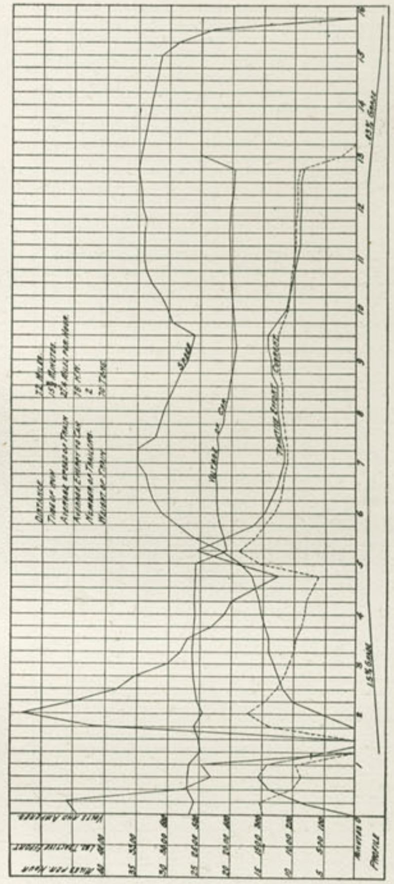
the speed falls to seven hundred and ten, and the output increases to one hundred and twenty-three horse-power. The efficiency falls from about eighty-nine to eighty-six per cent. The curve, when the electro-motive force is two hundred and fifty volts, shows the same torque for the same current, but at a decreased speed. The speed corresponding to one hundred amperes has decreased to five hundred and thirty-five, or one-half, and the output has, of course, fallen in the same ratio. A further reduction of electro-motive force would cause a corresponding reduction in speed.

A reduction of the voltage on a motor operated on a five hundred volt circuit may be effected in either of two ways. Motors may be connected in series (two motors in series would give two hundred and fifty volts on each motor) or a resistance may be placed in series with a motor. When a motor is to be started a resistance is placed in series with it and is reduced as the speed increases. Within wide limits the variation of resistance enables a motor to be run with any torque at any speed. The advantage of connecting motors in series may be appreciated by noting the current which will be required for producing a torque of three hundred pounds on each of two motors at a speed of four hundred and thirty-five revolutions when the motors are in separate circuits, each in series with a resistance, and when they are in series in one circuit. In the first case each motor requires one hundred amperes, and two hundred amperes

are taken from the trolley line. The two hundred amperes pass through resistances which reduce the pressure to one-half, thereby wasting one-half the energy received from the circuit before the motors are reached. In the second case, the motors being in series, only one hundred amperes are taken from the trolley, and no power is lost outside of the motors. In running below half speed, motors are commonly connected in series and the pressure is still further reduced at starting by a resistance in series with both motors. If four motors are mounted on a car it is similarly advantageous to connect all four in series for starting, then pairs in series between quarter and half speed, and then all in parallel for full speed running.

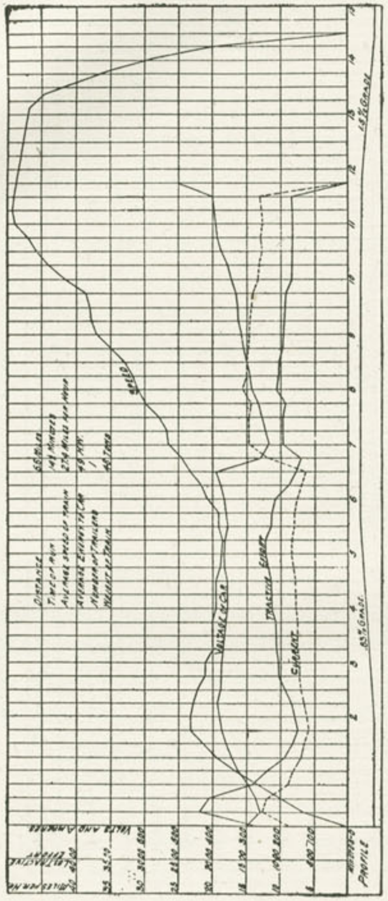
The use of the diagram is further illustrated by determining the requirements if a train weighing two hundred and fifty tons is to be hauled up a one per cent. grade at a speed of twenty miles per hour. If friction be seven pounds per ton the pull required to haul two hundred and fifty tons on a level is seventeen hundred and fifty pounds. The resistance per ton due to a grade of one per cent. is twenty pounds; the resistance for two hundred and fifty tons is five thousand pounds. The total resistance is sixty-seven hundred and fifty pounds. Now, twenty miles per hour is seventeen hundred and sixty feet per minute; sixty-seven hundred and fifty pounds pull through seventeen hundred and sixty feet per minute is eleven million, eight hundred and eighty thousand foot-pounds; this when divided by thirty-three thousand, gives three hundred and sixty, the horse-power. If the efficiency of gears be ninety per cent. the power required from the motors is four hundred horse-power, or one hundred horse-power from each of four motors. The diagram for five hundred volts shows that the one hundred horse-power motor, when developing one hundred horse-power, requires one hundred and sixty-five amperes and runs at a speed of eight hundred revolutions. If the diameter of the driving wheel be a little over thirty-six inches the circumference is ten feet, and the number of revolutions required to travel seventeen hundred and sixty feet per minute is one hundred and seventy-six. The gear ratio required is, therefore, eight hundred to one hundred and seventy-six, or about seventy-seven to seventeen. The series motor possesses a high efficiency over a wide range of load. In fact, the efficiency is always high so far as the motor itself is concerned. The low efficiency at starting is due to resistances in circuit for supplying the motor with reduced voltage.

Tests on Motor Cars.—Performance curves of three motor cars obtained from tests made while the cars were in regular service are given in the accompanying figures. Each diagram records the conditions of grade, current, tractive effort, voltage and speed during a run. The first diagram shows the performance of a motor car geared to



First Diagram. Performance Curves for Motor Car and One Trailer.

make a maximum speed of sixty miles per hour, pulling one trailer. The motors are first connected in series and a resistance is placed in the circuit. The resistance is reduced by the motorman as the speed increases. The current and tractive effort are high at first, falling to a minimum as the car reaches the maximum speed at which it can run when the motors are connected in series. At this point the car begins to ascend a grade, the speed is consequently reduced and the current increases to give the required torque for propelling the train up the grade at this reduced (but practically constant) speed. To obtain a higher speed, the motors are now



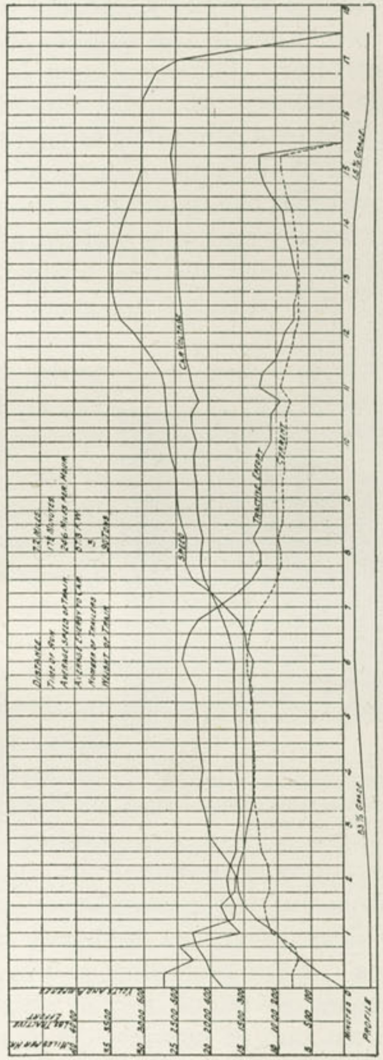
Second Diagram. Performance Curves for Motor Car and Two Trailers.

connected in multiple, the current becomes twice as much as before, while the torque, which is about the same as it was when the car was on the grade, is now effectual in accelerating the train to full speed, or until it becomes necessary to shut off the current and apply the brakes in order to make the next stop. The drop in voltage is greatest when the current is greatest, and is rather excessive in this case, due to the inadequate size of feeders supplying this portion of the road. The best action of the motors would be obtained from constant voltage of five hundred.

In the second and third diagrams similar curves

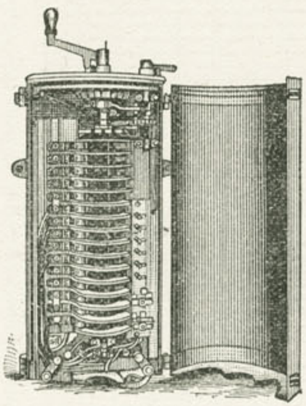
are given of motor cars geared for moderate speed and drawing heavy trains.

The Controller.—The controller is to the electric motor car what the throttle and reversing gear are to the steam locomotive. Through it the motive power of the car is made obedient to the will of the operator. The current is admitted to the motors at a low pressure, reduced through a resistance. As the torque developed by the motors depends upon the current flowing through them, the torque in starting may be increased or



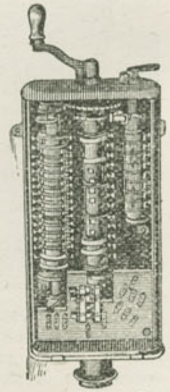
Third Diagram. Performance Curves for Motor Car and Three Trailers.

decreased at will by suitably varying the amount of resistance in the circuit. This is done in the controller. The resistance is usually made of wire or strips of metal wound in coils. This is divided into a number of sections which are connected to the controller, which is a form of switch for varying the quantity of the resistance between the trolley and the motors, and for cutting out the resistance entirely when the controller handle is moved to the full speed position. The controller is divided into two parts; the first consists of the switches for changing the resistance, and the second of the switches for making the changes in the motor connections. The latter determines the direction of motion of the car—forward or backward—and also connects the motors in series or in multiple as desired, whence the term "series-multiple" or "series-parallel" controller. It is convenient and more economical in space to place the switches of the controller on a drum, so that as the drum revolves different combinations are made. Each controller is provided with cut-out switches, by which any or all the motors may be thrown out of service. It is essential that con-



Controller for Two 50 Horse-power Motors; open, showing interior. The small handle on top is the reversing switch.

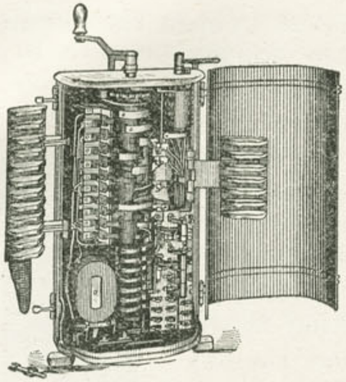
trollers be constructed so as to open the circuit when heavy currents are flowing without the serious arcing or flashing which is liable to occur when a current is broken. If arcing is permitted the switches and contacts soon become burned and destroyed, so that the controller is rendered inoperative. Arcing is reduced either by inserting in the circuit a high resistance, thereby reducing the current before finally breaking it, or by the "magnetic blow-out." This is a device by which the circuit is opened in a strong magnetic field, the action of which is to dissipate and blow out the arc which would otherwise establish itself.



Controller for two Railway Motors. Current is broken on auxiliary drum or switch and not on the central drum.

ADJUNCTS.

Brakes.—Motor cars for heavy service are equipped with air brakes similar to those used in ordinary railroad service. The air compressor is driven by an electric motor. In the usual type the air pump is direct connected to a series motor. The motor is provided with an automatic governor, which cuts off the current and stops the motor when the pressure reaches the maximum limit and starts it again when the pressure falls. Electric emergency brakes have been devised whereby a car may be stopped electrically even



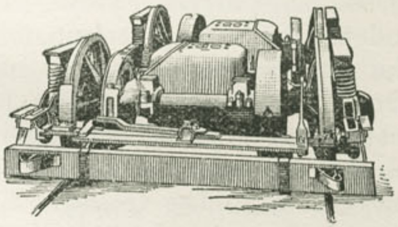
Controller for Electric Motors; open, showing Drum and Fixed Contacts. Motion of handle in one way increases speed, and in the opposite direction throws on the Electric Brake.

when the external source of power is cut off. The current for operating the electric brake attachment is obtained from the motors working as generators, deriving their energy from the moving car. The brake is a friction brake operated by a powerful electro-magnet.

Light and Heat.—Motor cars are lighted by electricity, usually in groups of five, one hundred volt lamps connected in series across the circuit. Cars may be electrically heated. The quantity of coal which must be burned in the power station to produce a given amount of heat in the car is probably twenty times as great as would be required in a stove in the car. The electric heater furnishes the ideal method of heating in convenience, cleanliness, safety, the uniform distribution of heat and in its perfect control.

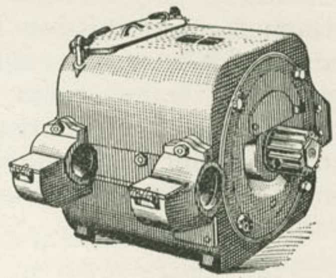
Alternating Current Modifications.—When alternating current is used, either in part or in whole, some of the foregoing elements are modified to conform to the new conditions. These will be considered separately under the two general systems which involve the use of alternating current.

The Alternating Current-Direct Current System.—In this system the power station may be located at a considerable distance from the road to be operated when water power, cheap fuel, or other advantages make such a location desirable. The arrangement and selection of units and other questions of design and operation of the station do not differ greatly from those in direct current stations.



Truck with motors geared to axles; electric brakes. An iron plate fastened on the armature at the end opposite the gear case is drawn against affixed plate by an electro-magnet. The pressure produces great friction.

In this system the alternating current is either generated at a high voltage, or the low tension current from the generators is raised to a high pressure by step-up transformers, and the current is transmitted over a line of comparatively small wires to several sub-stations located at convenient points along the railroad. At these sub-stations step-down trans-



Narrow-gauge Motor.

formers and alternating current-direct current rotary transformers are installed for the purpose of converting the high tension alternating current into direct current for the ordinary railway system. From this point the feeders, trolley line and motor car equipment conform with the standard direct current practice already described, the rotary transformer taking the place of the dynamo for supplying current.*

The Alternating Current System.—The power station and the high tension transmission line remain the same in this system as in the alternating current-direct current system. The step-down transformers, however, are more in number, are placed closer together and supply polyphase alternating current to the trolley. Two trolley wires are required over each track, the rails serving as the third wire of a three-phase or three-wire two-phase circuit. Each car is provided with two trolley poles, a suitable alternating current controller and polyphase motors.†

In this system advantages may be secured by operating the trolleys at high tension (using them for transmission line when the generator station is near the railroad), and carrying the reducing transformers on the cars instead of placing them at intervals along the track.

The use of polyphase motors for operating railroad trains is at present an experimental problem.

* This system is shown in diagram on page 426.

† The elements of this system are shown in diagram on page 441.

What place this system may eventually hold in long distance high speed service therefore remains to be determined by a practical demonstration of its scope and advantages.

ELECTRIC ROADS.

The range of work which is being done by the electric motor beyond the limits of ordinary street railway traffic, is very great, as is also the variety of conditions which present themselves. At first, two fifteen horse-power motors constituted the standard equipment of an electric car. The extent and magnitude of the development which has taken place are illustrated by the large number of roads which are now in operation and under construction, including inter-urban, elevated, suburban, passenger service on general railways, tunnel lines and long distance transmission and alternating current railways. Brief reference to some of these roads will be interesting.

The Akron, Bedford & Cleveland Railway.—This road is some thirty miles long, mostly single track, extending from Akron, through Bedford, to Cleveland, Ohio. The cars run to the center of the city on the street railway lines. The track is of fifty-six pounds per yard T-rails laid on wooden ties. The gauge is four feet eight and one-half inches. The trolley wire of (No. 0000 B. & S. gauge) hard drawn copper. The power stations are two in number, each of five hundred kilowatts capacity, so located that no part of the line is more than nine miles from a power station. Two hundred fifty kilowatt belt-driven generators are installed at each station. A unique feature of these generators is that they are constructed to generate either five hundred volt direct current or polyphase alternating current at three hundred and eighty volts. The direct current only is used. These machines may, when desired, be used as alternators to operate rotary transformers to supply the distant parts of the road or for lighting purposes. The motor cars resemble in general appearance those used on steam railways. About one-half of these cars are built with baggage compartments, the passenger compartment seating about thirty-two persons. The remainder of the cars are full seated with a capacity of forty-two passengers each. The cars have cross reversible seats, upholstered in plush, with center aisle; are provided with electric heaters and lighted with twenty electric lights. Cars are equipped with air-brakes.*

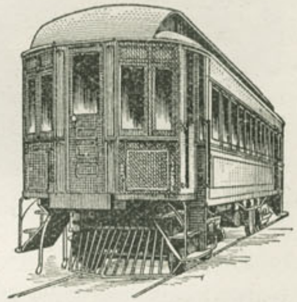
Burlington and Mt. Holly Branch of Pennsylvania Railroad.—The Pennsylvania Railroad has substituted electricity for steam on the branch line

*The following gives the general dimensions and performance of the cars:

Length of car, 40 feet; weight, 20 tons; maximum speed, 35 miles per hour; average speed including stops, 20 miles per hour; number of trucks, 2; number of driving wheels, 4; number of motors, 2; size of each motor 50 horse-power. Both motors are mounted on the rear truck, the controller is in the front vestibule and the cars always run in one direction. The maximum train consists of motor car and two trailers.

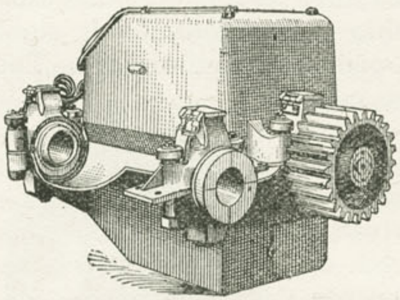
operating between Burlington and Mt. Holly, New Jersey. The following is a brief statement of the equipment of the line:

A four hundred horse-power boiler supplies steam at one hundred and twenty to one hundred and fifty pounds pressure to a non-condensing compound engine, which runs at a speed of two hundred and fifty revolutions per minute. The generator is a two hundred and twenty-five kilowatt, five hundred fifty to six hundred volt, eight pole machine, direct-connected to the engine. The track and roadbed construction is the same as that of the single track steam roads of that division of the Pennsylvania Railroad. The length of this branch is about seven miles. The trolley wire is of (Number 00 B. & S. gauge) hard drawn copper suspended between wooden poles. There is a continuous trolley wire over the entire length of the main track. Frogs and switches are avoided at turn-outs by changing the trolley wheel from the main trolley wire to a separate trolley wire suspended parallel to the main wire and about a foot from it. The generator station is located at the Mt. Holly end of the line. Double truck combination baggage and passenger motor cars are in use. The furnishings are similar to those of most railroad coaches.



Motor Car, Mt. Holly Road.

The total weight of each of these cars equipped is fifty-two thousand pounds. Trailers are standard coaches and weigh forty-two thousand pounds. One motor car is equipped with four fifty horse-power railway motors; two series-parallel controllers (one on each platform of car); two trolleys operating in tandem on the same wire; electric heaters and complete air-brake outfit. This car is geared to make a speed of forty to forty-five miles per hour. Other motor cars are similarly equipped, except that each has two one hundred horse-power motors, which are geared to give speeds of forty-five to sixty miles per hour respectively. Electricity has been in use on this road since 1895.


One Hundred Horse-power Motor with Pinion, Mt. Holly Road.

Nantasket Beach Branch of the New York, New Haven & Hartford Railroad.—This company began the operation of its Nantasket Beach Branch by electricity in 1895. The first installation was nearly seven miles, which was extended the following year three and one-half miles. The first year the double track line was equipped with a special trolley wire which had the shape of the figure eight. The extension is provided with the third


Trolley Wire, full size.—Nantasket Road.

rail instead of the trolley. The third rail is laid in the center of the track and is supported on white ash blocks four inches square and five and one-half inches high, doweled into the ties.* These blocks were especially treated by extracting the moisture in vacuum pans and thoroughly saturating them in an insulating composition. The third rail is rolled with a special section and weighs ninety-three pounds per yard. Rails are connected together by fish plates and by duplicate flexible ribbon bands of copper.† The third rail is not laid at stations, but an overhead trolley (connected to the third rail by cable) is used for a short distance. At road crossings the rail is simply left out and an underground cable connects the two sections of the third rail. The train crosses this gap by its own momentum. The road is an exceedingly difficult one on which to attain a high rate of speed as there are a great number of curves, there being twenty-nine curves in ten miles of track, and only one piece of tangent track, about a mile in length, which is level. The generator station is equipped with two five hundred kilowatt generators direct connected to compound, condensing engines, which have been at times called upon for a load fifty per cent. greater than normal. The motor cars are equipped with two motors, gear ratio, three and eighteen-

*See illustration on page 464.

†The contact shoe is shown in illustration on page 465.

hundredths mounted on trucks having thirty-six inch wheels. The cars are furnished with circuit breakers on each end, automatic air brakes, with air pump, direct connected to an electric motor, carrying a pressure of ninety pounds; also with a large whistle operated by air from the brake reservoir. The motor car complete without load weighs thirty-four tons. It is an open car, having sixteen benches, each bench accommodating six persons, making a total seating capacity of ninety-six, although a great many times there have been as many as one hundred and fifty persons on a car. Cars are fifty-five feet over all in length. Trailer cars are of the same size, weighing approximately twenty-eight tons. The usual train consists of a motor car and one trailer, but at times there have been as high as four trailers in addition to the motor car. The trains make a schedule speed of twenty miles per hour, including stops, of which there are fourteen and two flag stations. There have been few or practically no delays or stoppages caused by any electrical defect. A train of two cars can easily attain a speed of thirty miles per hour within a minute after starting, and in special tests a speed of sixty-five miles per hour has been attained. The station load is naturally a fluctuating one, as at times four or five trains leave Pemberton at the same time on the arrival of the Boston boats. Notwithstanding this, it is stated that the power is produced at the rate of eight-tenths of a cent per kilowatt hour. The motor-

men who operate this branch are firemen taken from the main line during the season when the electric line is operated.

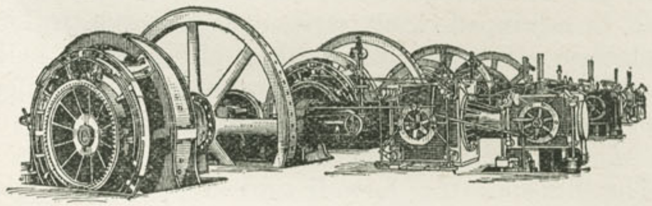
The New Haven System is exceptional in having a very large mileage within a small and densely populated territory. Its passenger traffic is the source of a large part of its revenue and much of this is from local traffic. These are the conditions most favorable for electrical operation. The success of the Nantasket Beach Line assures extensions to other parts of the system. Two lines, Hartford to New Britain and New Britain to Berlin, a total of twelve and three-tenths miles are already equipped with apparatus very similar to that used on the Nantasket branch.

The Metropolitan Elevated Railway, Chicago.— This road consists of twenty miles of double track on elevated steel structure. Standard T-rails weighing ninety pounds per yard are used for the track (gauge four feet, eight and one-half inches) and a forty-five pounds per yard T-rail for the contact rail of the third-rail system. This rail is placed on insulators on the left side of the track, about twelve inches from the center of the left-hand track rail and is raised six inches above the level of the main rails. The track rails are bonded together and to the main girders of the elevated structure, the whole being used as a metallic return. The feeders consist of old track rails suitably bonded and placed in a wooden box between the main tracks. One power station of four thousand six hundred kilowatts capacity supplies the whole road. The engines are direct-connected to five hundred volt direct-current generators of eight hundred kilowatts and fifteen hundred kilowatts capacity. Each motor car pulls three trailers. The total weight of train is ninety tons. Air-brakes supplied by an electric air-pump, electric heaters and electric lights are used.*

The Baltimore & Ohio Railroad Tunnel.—The largest electric locomotives which have been built are in use on the Belt Line of the Baltimore & Ohio Railroad in the city of Baltimore. This line runs through a tunnel one and one-fourth miles long, and then through cuts and short tunnels to the outskirts of the city. There is a grade of eight-tenths per cent. for nearly the whole length of the tunnel, and beyond it a long grade of one and one-half per cent. The steam locomotive is not detached from the train, but the complete train is hauled through the tunnel by the electric locomotive, and the two locomotives are available for the heavy grade outside the tunnel. In the station there are four seven hundred and fifty horse-power engines driving generators of the same capacity, giving a pressure of six hundred

*The dimensions of the motor cars and conditions of service may be generally stated as follows: Length, 45 feet; weight, 30 tons; maximum speed, 25 miles per hour; average speed, including stops, 13 miles per hour; number of stops, 3 per mile; number of trucks, 2; wheel base of trucks, 54 inches; diameter of driving wheels, 33 inches; number of motors per truck, 1; size of motors, 100 horse-power each; number of series-parallel controllers, 2.

volts. The ordinary trolley was impracticable, both on account of the limited space available in the tunnel and the very heavy currents required. The tunnel is low in places and the overhead conductors are placed between the two tracks, seventeen feet above the rails. Outside the tunnel they are raised to twenty-two feet. The conductor consists of a heavy plate below which is riveted two Z-bars, between which there is a slot of one inch. The contact is a brass shoe traveling in the trough and connected to the locomotive by a flexible



Five hundred Kilowott Railway Generator. Baltimore & Ohio Railroad.

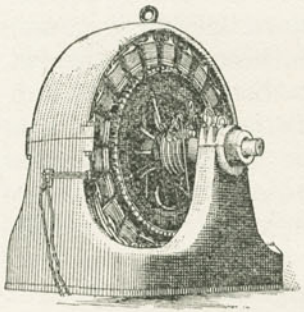
sawbuck arrangement which has great freedom of movement. A heavy copper cable carries current to the motors, which returns by the rails to the station. The locomotives weigh ninety-five tons each and rest on eight driving wheels, which makes the full weight useful for preventing slipping of the wheels. Each locomotive is made up of two units, each of which consists of a forged iron truck frame supported upon four wheels. There are four motors of about three hundred horse-power each, one on each axle. The motors have six poles and are placed on the axles which extend through hollow sleeves on which the armatures are built. The motors are supported independently of the axle and transmit their power by projections on the armature which move between lugs cast on the wheels. This flexibility prevents the violent jarring which would otherwise occur on an uneven track. There is a sheet iron cab on the locomotive with ample windows and provided with trap doors through which the motors can easily be reached whether the locomotive is standing still or running. The locomotive can run in either direction. It is equipped with series parallel controller, electric air pump, air brakes, air whistle, bell, and safety devices, and has an automatic coupler of the Master Car Builders' type at each end.*

Lowell and Suburban Street Railway Company.—The lines of the Lowell and Suburban Street Railway Company are so long that the cost of copper prohibits their operation from one station. The power, however, is generated at one station and is transmitted by alternating current at five thousand volts. It is reduced to a low voltage at a sub-station and then transformed into direct

*The following are some of the principal characteristics of the locomotives: Weight, 190,000 lbs.; draw-bar pull, 42,000 lbs.; starting draw-bar pull, 60,000 lbs.; length over draw-bars, 34 feet, 6 inches; height over all, 14 feet, 3 inches; width over all, 9 feet, 6¼ inches; wheel base each truck, 6 feet, 10 inches; diameter of drivers, 62 inches; number of drivers, 8; maximum speed, 70 miles per hour; maximum speed full draw-bar pull, 15 miles per hour; maximum speed half draw-bar pull, 30 miles per hour. Motors are wound for 250 volts and are connected 2 in series.

current by a rotary transformer or rotary converter. There were at first two sub-stations but the two have been combined into one. This involves greater losses in the lines but is more economical in running expenses. There are two generators each of two hundred and fifty kilowatts capacity, which deliver current at three hundred and thirty volts to raising transformers which supply the line with five thousand volts. There are three (No. 0, Brown & Sharpe gauge) wires for transmitting the three-phase current. The sub-station is ten miles distant. In the sub-station there are lowering transformers, and four machines which receive the alternating current and deliver direct current. Some fifteen miles of this line are operated through the rotaries. The direct current averages three hundred amperes and reaches a maximum of eight hundred amperes. In the city of Lowell the trolley wire from the rotaries is connected to the trolley wire which is fed by the Lowell central station, so that both sources of current supply one system. The load upon the rotaries varies greatly during different seasons of the year, being excessively heavy in summer time. This road attracts attention as it is one of the first roads in which alternating current was used for transmission.

The Utah Power Company.—This company utilizes a water power thirteen miles from Salt Lake City, Utah, by placing its generating plant at that place, transmitting the energy at high tension to Salt Lake City and supplying power to the lines of the Salt Lake City Street Railway Company. The The generating plant consists of one seven hundred and fifty kilowatt, four hundred volt, seventy-two hundred alternation, two-phase alternating current generator, direct-connected to water wheel. The power station is built to accommodate two more of these units as soon as the demand for power shall require an extension of the present plant. Two three hundred and seventy-five kilowatt two-phase-three-phase step-up transformers are used to raise the pressure to fifteen thousand volts for three-phase transmission. The high tension line consists of three (No. 2, B. & S. gauge) bare copper wires twenty-four inches apart, and is thirteen miles long.

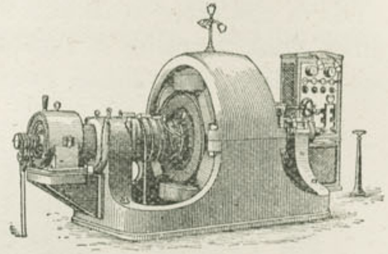


Six hundred and fifty Kilowatt (870 horse-power) Two-Phase Alternating Current Generator.

The step-down transformers at the Salt Lake City sub-station are the same as the step-up transformers at the generating station, and deliver two-phase current at four hundred volts to two four hundred kilowatt rotary transformers for transforming the alternating current into direct current. These rotaries supply the trolley lines with current at five hundred and fifty volts pressure.

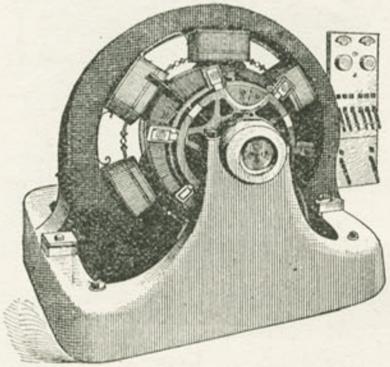
Niagara Falls Power Company.—A part of the power of the Niagara is utilized for electric rail-

way purposes, both at Niagara Falls and at Buffalo. The alternating current-direct current system is employed here to good advantage, since high tension transmission is essential to the use of Niagara's power in Buffalo. The hydraulic features of the power station are generally familiar. The generators are each of five thousand horse-power capacity and deliver two-phase current at twenty-two hundred volts. The armatures are stationary while the fields revolve in a horizontal plane, being supported upon the upper ends of the vertical turbine shafts. The high tension transmission line to Buffalo is twenty-six miles long, three miles of which are in Buffalo. Five miles of the line are along the Erie Canal and the remaining eighteen miles occupy a special right of way. The poles are thirty-five to sixty-five feet high, depending on the locality, and are set sixty to seventy-five feet apart and six to eight feet deep in good ground, or in concrete where the ground is soft or unreliable. Each pole carries three arms, two for transmission lines and one for telephonic purposes. The former are each twelve



Five Hundred Horse-power Rotary Transformer, Niagara power house. Alternating current from the 5,000 horse-power dynamos is transformed into direct current for railways.

feet long by four and three-quarters inches thick by five and three-quarters inches high, and are constructed to support three wires on each side, giving the present pole line a capacity of four three-phase transmission circuits of three wires each. Iron wires are suspended along the outer ends of the cross-arms and are grounded at every fifth pole, forming a lightning arrester for the entire line. At sharp curves double poles and double cross-arms are provided. The three conductors are of three hundred and fifty thousand circular mills bare copper cables, supported on large porcelain insulators, and have a capacity of five thousand horse-power at eleven thousand volts, which may be increased to ten thousand horse-power by doubling the transmission voltage. They are completely transposed every five miles. In Buffalo these conductors are run through an underground subway forty-two hundred feet long. At the Buffalo end three-phase step-down transformers are used to lower the voltage for supplying rotary transformers in the power station of the Buffalo Street Railway Company. These rotary transformers are two in



Rotary Transformer at Buffalo.

number, each of five hundred horse-power capacity, and deliver five hundred volt direct current to the feeders of the street railway. In the large power house at Niagara Falls three five hundred horse-power rotary transformers have been installed for supplying direct current to the local railways and to the Niagara end of the Buffalo and Niagara Falls Electric Railway. In this case

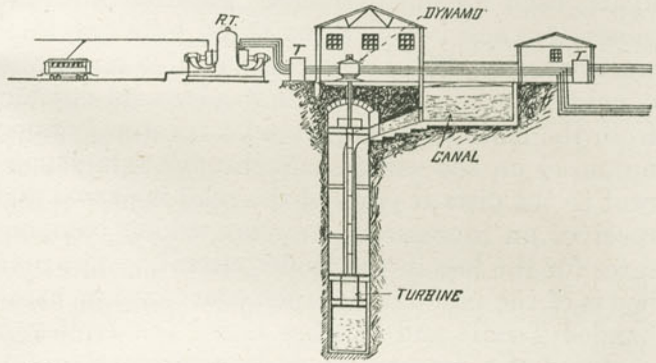


Diagram showing utilization of Niagara power. R. T. is a Rotary Transformer, receiving alternating current and delivering direct current. The circuit to Buffalo is shown at the right.

step-up transformers and high tension line are unnecessary, but step-down transformers are required to reduce the pressure from twenty-two hundred volts (the electro-motive force of the large generators) to that required by the rotary transformers for delivering direct current to the railway circuits at about five hundred and fifty volts. These rotary transformers are six-pole, two-bearing machines, running at five hundred revolutions per minute. The generators have a capacity exceeding that of any other electrical machines that have ever been made.

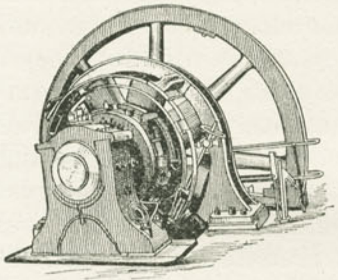
The Columbia & Maryland Railway.—This road lies between Baltimore and Washington, a distance of nearly forty miles, with a branch four miles long. The booster system for operating long roads with direct current is employed. Two power stations are located twenty-three miles apart, each having four eight hundred kilowatt generators and two or three three hundred kilowatt boosters. The boosters are double machines, consisting of a motor which receives its current from the main generators and a booster dynamo mounted on the same shaft through which current to the distant parts of the road is passed and receives an increase of pressure which compensates for the loss in the feeder circuit.* The road bed is of the best double track construction, using bonded T-rails and wooden ties. The trolley is operated at a pressure of six hundred to six hundred and fifty volts. The maximum grades are two and five-tenths per cent. in the country and five per cent. in the city of Baltimore. Each motor car† pulls two trailers, or a train of fifty tons total weight, equipped with electric lights and heaters, also complete air-brake outfit, including electric air-pump, reservoir and engineer's valves. The schedule includes through express trains, through local trains and suburban service at each end of the line. The maximum speed is sixty miles per hour.

*One of the machines is shown in illustration on page 434.

†The dimensions and performance of the motor cars are as follows: Length of car, 35 feet; weight, 25 tons; maximum speed, 60 miles per hour; number of trucks, 2; number of driving wheels, 8; number of motors, 4; size of each motor, 100 horsepower; number of series parallel controllers, 2; number of trolleys (tandem) 2.

The City & South London Railway.—Although European countries are backward as compared with America in the use of electricity as a motive power for the operation of railroads, and its use is, in the main, confined to street service, yet this road has been in operation since 1890. It is an underground road, the track being laid in an iron tunnel about eleven feet in diameter and six and a half miles long. The gauge is four feet, eight and one-half inches (standard), while the maximum grade is three and one-third per cent. The third rail and sliding shoe are used for supplying direct current to the locomotives at five hundred volts pressure. The locomotive has a fixed wheel base. On each axle is mounted a fifty horsepower motor armature. The motor fields are of the two-pole type, which is no longer in common use. The average speed of trains is thirteen and one-half miles per hour, with a maximum speed between stations of twenty-five miles per hour. The power station is equipped with eight boilers, four vertical compound engines and four four-hundred horse-power belt driven direct current generators.

The Lugano, Switzerland, Electric Tramway.—This road is of interest because of the use of the polyphase alternating system throughout. A water power at Maroggia is utilized. A three hundred horse-power horizontal shaft turbine drives a one hundred and fifty horse-power, five thousand volt three-phase inductor type generator. The frequency is forty periods per second, or four thousand eight hundred alternations per minute. The transmission line is seven miles long and consists of three copper wires one-fifth of an inch in diameter. A single transformer sub-station is located at the middle point of the railway supplying the trolley with four hundred volt three-phase current. The road is three miles long, single track, running through the streets of Lugano. Two trolley wires one-fourth of an inch in diameter are suspended ten inches apart over the track. The rails are bonded and serve as one of the conductors of the three-phase circuit. Each car carries two trolley poles and is equipped with a twenty horse-power three-phase motor and a controlling device operated from either end of the car. The motor is provided with a transfer gear attachment, whereby the speed may be changed in the ratio of one to four. The normal speed is nine miles per hour. This road has been in successful operation since it was installed in 1895.



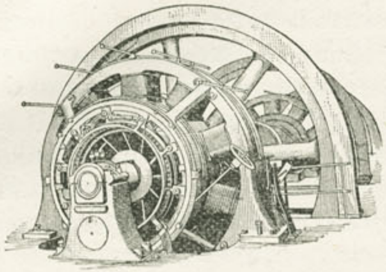
Four Hundred Kilowatt Railway Generator.—Hestonville, Mantau & Fairmount Passenger Railroad.

ELECTRIC TRACTION FOR GENERAL RAILWAY PURPOSES.

The application of electricity to general service under existing conditions gives rise to a number of important inquiries. Is it practicable? If it is practicable, what are the advantages that make it desirable? What are the requirements and forms of apparatus and methods of operation? If it is feasible, is it economical?

There is no question as to the possibility of generating electric energy in any quantity, of transmitting it and supplying it to electric motors in capacities much greater than those for which steam locomotives have ever been built. There is no doubt as to the ability of an electric system to perform the duties of a steam locomotive, and there are numerous points of advantage possessed by the electrical system. The steam locomotive performs several fairly distinct classes of service; namely, passenger traffic, both suburban and through, and freight traffic. There are also special and peculiar conditions to be met, such as those in tunnels, cities and on heavy grades. The application of electricity to these different requirements may be separately considered.

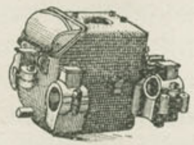
Local Passenger Service.—Local or suburban passenger trains in general run for comparatively short distances, the trains are small and the schedule provides trains at frequent intervals. Moreover, the desideratum on local lines is more frequent service, which will naturally involve a greater number of trains of smaller sizes. Noise



Eight Hundred Kilowatt Railway Generator.

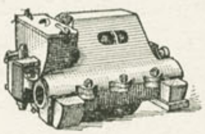
and dirt are particularly to be avoided in cities and suburbs where local passenger trains are run. The conditions of moderate distance, of small trains and frequent service are most favorable for electrical operation. The electric motor can be built cheaply and economically for small power (which is not the case with the steam locomotive), and a schedule in which small units are operated in frequent succession maintains a fairly constant load upon generator station and conducting lines, so that they operate at the best efficiency and may be installed at much less first cost than would be required if the same aggregate energy were to be delivered during a part of the time to a few trains. The conditions best adapted to electric traction are, therefore, identical with the requirements of local passenger and suburban service. The advantages of the use of electricity are found in the flexibility and economy of the electric system; the increased comfort in transit; the frequent service and convenience in some cases of an increased number of stations, all of which tend to increase traffic. The avoidance of noise, smoke and dirt is a distinct advantage. The wide extension of suburban railways connecting large cities with

surrounding towns is the best proof of the success and the economy of the application of electricity to this class of work. The adoption of electricity for elevated roads is demonstrating its superiority over the steam locomotive in a class of service closely related to suburban service on steam roads. The types of apparatus in use are referred to elsewhere. The motor car will probably retain its supremacy for short roads with trains of moderate size, to the exclusion of the electric locomotive, devoted entirely to the production of power and not admitting passengers or freight.

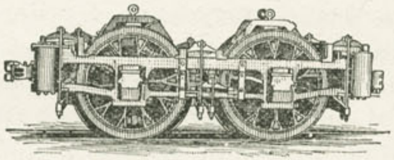


Motor for Heavy Street Railway Service.

Through Passenger Service.—If electricity is to replace the steam locomotive for heavy service, it is possible that the electric power must be supplied to the train in the same manner and under the same conditions as steam power is applied. It would, of course, be possible to mount motors on each car of a train. This would deliver directly to each car the power it requires; would remove the enormous strains on coupling attachments, by which the power is conveyed from the locomotive to the train; and would take advantage of the weight of the train for tractive effort. On the other hand a large number of small motors are more costly to install and keep in repair and they operate at a lower efficiency than a few large motors. Moreover, the construction of railway cars is the outcome of a long evolution in which the bearings, trucks, springs, etc., have found their present form. If a motor be placed on the car axle, an entirely different arrangement of trucks would be required for accommodating the motor and the power would be applied to the car from its truck, causing very different forces to act from those which now exist, and requiring radically different forms of car construction. Even if it were practicable to use the ordinary type of construction used in street car work for operating a train of self-propelled cars at moderate speeds, other conditions are involved at high speeds. Trucks of heavy passenger cars are very different from those of street cars. The mounting of a heavy motor and its connection to an axle is a difficult and delicate matter when very high speed is to be used. In the steam locomotive there are reciprocating parts, but they are comparatively light and are accurately balanced, so that the weight of the parts which give a pounding action on the rails is not great. The electric motor is heavy and its armature must be in close mechanical connection to the axle which it drives. The steam locomotive is built upon a heavy strong frame, capable of resisting ordinary obstacles and affording a fair protection to the train which follows it. For equivalent protection, an electrically operated train should have a heavy and substantial locomotive at its head. In an electric locomotive a motor may be connected to the axle which it drives in one of several ways.


Eighty Horse-power Railway Motor.

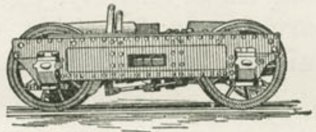
For instance, it may be connected by gearing. This possesses the advantage of cushioning the motor by supporting it on springs and also allows the motor speed to be greater than the axle speed, which is desirable except at high train speeds. In the gearless motor a method of connecting the armature with the shaft by springs or flexible coupling is usually necessary in order to prevent the weight of the armature from resting directly and solidly upon the wheels. Neither of these methods of connection between the armature and the axle relieves the pounding action which occurs on a rough track, or on a fairly good track at high speed, due to the vertical motion of the axle, which necessarily tends to produce a variable speed in the armature. These effects may not prove very serious in operation at moderate speeds and with moderate sizes of apparatus, but they demand careful consideration when weights and speeds are increased. It may, however, prove necessary to mount the motor entirely separate from the axles and make connection with the driving wheels through side rods similar to those now in use on locomotives. This would avoid the shocks by supporting the motor entirely from the frame of the locomotive, and would also have the advantage of preventing slipping of one pair of wheels. When motors are connected in series they are free to run at different speeds, and if one pair of wheels slips they may turn rapidly, while the others not only do not revolve but have the torque of their motor reduced, as the higher speed of the motor with which it is in series will reduce the current through the motors. The problems in the electric locomotive are mechanical rather than electrical. The final form of apparatus and the best method of proportioning and arranging it must be determined by practical experience.



Truck, Baltimore & Ohio R. R.

The advantages of electric traction aside from the question of cost are not radical. There is an absence of dirt and smoke, which are especially objectionable in cities and tunnels and are great annoyances in the summer season. The changes in the present method of operating steam roads, which would be most favorable for electrical operation, are those which tend to preserve a uniform load distributed along the line, thus placing a uniform average load upon the power station. Another change from present methods of running steam roads which may give electricity an advantage is in high speed. The absence of reciprocating parts in the electric motor, the uniformity of its torque and the large horse-power for which it is capable of being built may give the electric locomotive a marked advantage over the steam locomotive for special high-speed service.

It may be noted that in street railways the adoption of electricity on car lines was begun by using as much of the old material as could be utilized without the modifications necessary for the new conditions which the electric motor brought with it. The electric car and electric railway track have been evolved by many successive steps from the old street railway apparatus. In the steam railway this experience will not, it is probable, be lost sight of. The ordinary tendency is to make the fewest changes possible in methods, material and equipment, which may be unsuitable under the new conditions.



Truck for Electric Locomotive.

Freight Service.—The requirements for freight service involve most of the elements found in through passenger service which are unfavorable for electric traction. The tendency in railway operation is toward heavier trains, even when this involves the necessity of heavier track, stronger bridges and more expensive rolling stock. The frequent trains which, to a certain extent, are desirable in passenger service and more favorable to electric traction and very high speeds, which may make electric traction advantageous, are not generally required in the freight service.

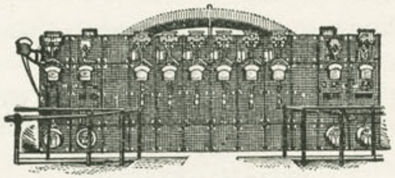
Special Conditions.—Electricity offers many advantages for the operation of railroads under special conditions, such as in tunnels, in cities and towns where smoke is to be avoided, on bridges where the iron work is injured by escaping smoke and gases, and also in switching and handling cars where cables or other forms of traction are used. The electric locomotive can be built for great power and may find special application even on general railways in assisting at points where such power is demanded. For example, electric locomotives may be used on very heavy grades for assisting steam locomotives or for relieving them entirely. The conditions would be particularly favorable where water power is available for supplying the electric energy.

RELATIVE COST OF OPERATION BY STEAM LOCOMOTIVES AND BY ELECTRICITY.

The cost of operating a railroad by steam locomotives and electricity is practically the same in almost all items except those belonging distinctly to the generation and application of power. For example, the cost of road-bed and track, stations, terminal facilities and cars is practically the same, while the charges for maintenance and operating expenses are practically identical except in relation to the power equipment. The principal elements in which there is a difference between the cost of electric traction and steam traction may be stated in brief, as follows:

ELECTRICITY.	STEAM.
CONSTRUCTION.	
Power Houses.—Building, power apparatus, including dynamos and switchboards, car barns.	Round Houses.—Water stations, coaling stations, etc.
Lines.—Overhead or third rail, feeder system, track bonding, etc.	
Locomotive.—Motors, controllers, etc.	Locomotive, tender.
MAINTENANCE.	
Power plant, line, motors, etc.	Locomotives, tenders, etc. Greater wear on track and rolling stock.
OPERATING EXPENSES.	
Wages.—Train attendants, power house attendants, linemen, etc.	Wages.—Train attendants, round house men, water.
Coal or water power.	Coal.

A comparison between the cost of electric and steam traction indicates very clearly their respective variations as the character of the service to be rendered is changed. With a given total service to be performed, the adoption of many small units instead of a few large ones will affect the costs by both methods; it will decrease the first cost of the electric power station and electric lines, as it insures a more constant load; it will increase the cost of the steam locomotives much more than that of electric locomotives; it will increase the cost of maintenance much more rapidly for steam than for electric locomotives; it will increase the wages for train attendants more rapidly for steam than for electricity, as a greater amount of work is required to be performed upon the steam locomotive; it will reduce the cost of coal in the electrical system, by securing a more uniform load which can be transmitted at greater efficiency while it will increase the cost of coal for steam locomotion.



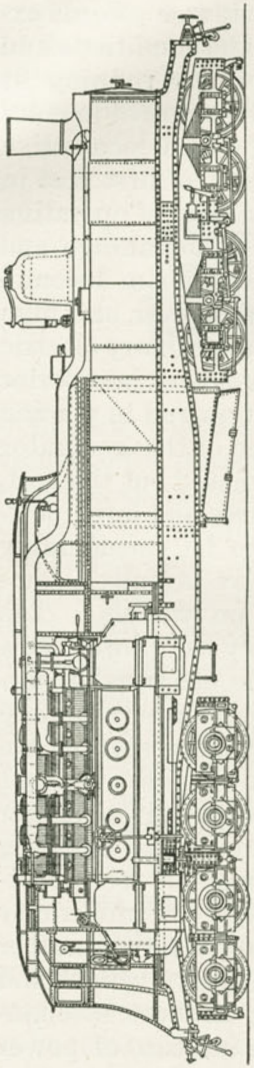
Switchboard.—Metropolitan Elevated Railway, Chicago.

Electric traction may through its greater convenience for passenger traffic lead to an increased business and an increased income. This is especially true of local and suburban service, but does not as yet apply to any great extent to through traffic. Short distance and frequent service with light trains favor electric service, while long distances and heavy trains favor steam traction. The relative cost of electricity and steam for each kind of service, depends very largely upon local conditions, such as the amount of service and size of trains, cost of apparatus, cost of power and distance over which the trains are to be operated.

THE HEILMANN ELECTRIC LOCOMOTIVE.

The Heilmann locomotive merits notice here as it attacks the problem of locomotion in a new way, and seems to combine different elements so as to secure, apparently, the greatest output and

highest efficiency from each. It also affords excellent means of investigating the conditions and measuring the power required for running at high speeds. The fate of this locomotive in competition with the best types of steam locomotive hinges largely upon the question of first cost in which it is greatly handicapped, and of operating expense in which it has a decided advantage, and in its ability to exceed what the steam locomotive is able to attain in hauling power and high speeds. In comparison with the ordinary electric locomotive the Heilmann locomotive is superior in requiring no conducting system and in placing both the speed and the voltage of the generator under the control of the motorman; but the cost, except possibly for long distances and large powers, will probably be found to be considerably greater. This electric locomotive is really a complete electric power system on wheels. The boiler and engine which supply the power are a part of the locomotive, and the electrical apparatus is used as a flexible transmitter between the engine and car-axles. The advantages which are aimed at are increased power of engine over that which is practicable in the locomotive; higher efficiency in boiler and engine, thus reducing coal consumption; perfect balance of reciprocating parts in the engine, securing great uniformity in the motion and draw-bar pull; a great number of driving wheels supporting a heavy weight and giving uniform tractive effort; in short, mechanical conditions for securing an increase of power



The Heilmann Locomotive, showing general arrangement of boilers, engines, electrical apparatus, trucks, etc.

over that obtainable from the steam locomotive, which may be utilized for drawing heavier trains or attaining higher speeds. A locomotive of six hundred horse-power was built and tested. It developed four hundred and fifty horse-power at the rims of the drivers when running at sixty-two miles an hour. The entire weight of the locomotive was one hundred and fifteen tons, carried upon sixteen driving wheels. The maximum observed speed was sixty-seven miles per hour. The locomotive was mounted upon two bogie trucks each having four axles, upon each of which was mounted a motor. The data furnished by this locomotive has formed the basis for the design and construction of two larger locomotives of one thousand five hundred horse-power each. The new pattern weighs one hundred and fifteen tons and is provided with a Willans engine with six cranks, direct

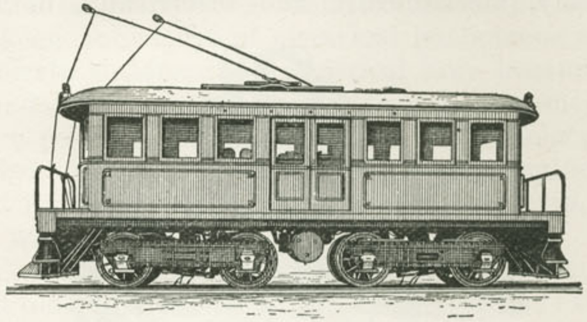
connected to two generators. The French type of locomotive boiler is used. The field circuits of both generators and the eight motors are separately excited from an additional dynamo, thus placing the electrical operation under complete control. The motors are four-pole, and the axle passes through the center of the sleeve carrying the armature. The total length is fifty-two feet, the length of truck fourteen and one-half feet, the distance from axle to axle between the trucks thirty-seven feet, and the height of the stack above the rail nearly fourteen feet. The indicated power of the engines is one thousand three hundred and fifty horse-power, and the efficiency to the car axles is seventy-five per cent. The engine can run with a cut-off which will insure high efficiency and the combustion under the boiler is practically complete. These characteristics adapt the locomotive for use in tunnels and for switching purposes. This locomotive is referred to at length as it without doubt represents in important particulars, a permanent step in the progress of electrical transportation.

PRESENT AND FUTURE OF ELECTRICITY.

History.—The history of practical electric traction is short. The idea of operating moving cars by electricity dates back a number of years. The electric motor may probably be dated from the invention of the Barlow wheel in 1826. Within the next ten or fifteen years several inventors worked on the application of the motor to the movement of a car, notably among them being Thomas Davenport, of Brandon, Vermont, who constructed a small car which carried batteries for operating the little motor which drove the car around a circular electric road. Cars which would carry passengers were constructed later, driven by batteries. It was soon found that, however possible it might be to construct motors, the cost of batteries for operating them prohibited any commercial application. A new impetus was given to electrical apparatus upon the invention and development of the dynamo. Electric lights, both arc and incandescent, were well known in principle many years ago, but awaited practical development and useful application until the dynamo, a cheap source of electric energy, became available. The first electric railway was operated by Siemens and Halske, at the Industrial Exposition in Berlin, in 1879. A small electric locomotive pulled a platform car which would carry eighteen or twenty persons at a speed of about eight miles an hour. During the succeeding years experiments were carried on both in Europe and America. The first electric system to be actually operated in competition with horses on street railway lines was by Bentley & Knight, in July, 1884, in Cleveland, Ohio. The road was about two miles long.* In 1888, the Union

* In 1887 a catalogue was issued, entitled, "The Van Depoele System of Electric Railways," which gave a list of Van Depoele roads, six in all, operating a total of fourteen and three-quarters miles, and adds, "As the matter now stands we have more miles of electric railway now in successful operation than all the other electric railways in the world combined."

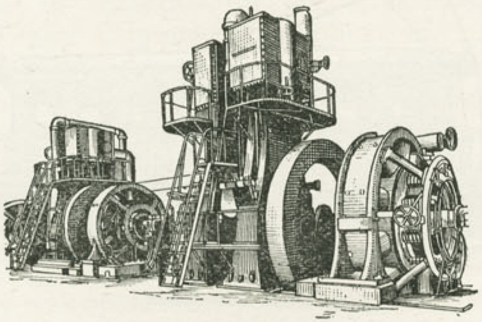
Passenger Railway, of Richmond, Virginia, began operation with electric motors. This was the first large road to adopt electricity. It served to overcome much of the ignorance and prejudice against electric traction, and since that time the progress of the electric motor has been so great that it is reasonable to suppose electricity will soon entirely supersede old forms for street railways.



Electric Locomotive.

The electric roads already far surpass the old horse-car roads in cities, and have, moreover, extended their limits to suburbs and outlying districts and towns impossible under old conditions.

The electric railway occupies a new field between that occupied by the horse railway and the steam railway. It has grown into this field by development. The steam railways which are adopting electrical apparatus are doing so in the parts of their traffic which come nearest the new field which electric traction has made its own. The rapid extension of the motor in practical lines is accompanied or preceded by rapid advance in other lines. The dynamo and motor of early days are entirely inadequate to-day. The electric systems used, the types of apparatus, the development and perfection, theoretically and practically, mechanically and electrically, of the



Four Hundred Kilowatt and Eight Hundred Kilowatt Railway Generators.

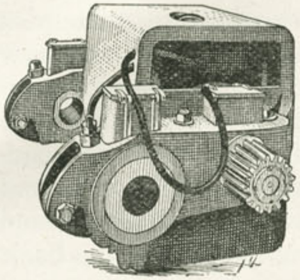
dynamo, the motor and the controlling apparatus, together with improvements in boilers and engines and track and line construction, testify to the amount, variety and excellence of the engineering work which has been put forth with such marvelous results.

Electrical Progress.—Electricity does not work by magic; it is not ready at a motion of a wizard's hand to appear in new forms, to change wild fancies and visionary schemes into actual useful realities. Development has been made

possible by the fact that electrical action is not by chance, but that there are definite principles and laws of electrical action. These are now known. As long as electrical phenomena were isolated and disconnected there was little advance but when scientific investigation had been carried on in the field of electricity and what had been discovered was generalized and expressed in the language of mathematics, then this basis of keen knowledge of electrical phenomena and accurate statement of electrical laws became a foundation upon which practical achievements were possible. The development of the electric railway is the work practically of the engineer, and its future development will, in the main, be his work also.

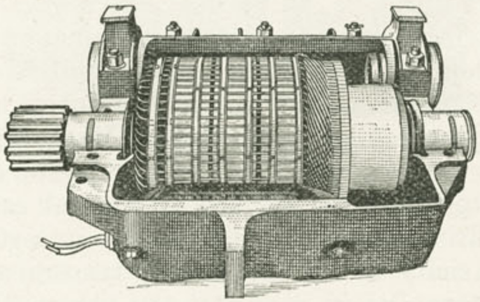
Electrical apparatus is not based upon vague and indefinite theory, but upon definite and exact laws, albeit difficulties and uncertainties arise in the application of these laws. Many undetermined elements appear in the application of electricity to the heavy service of general railways. These arise, however, not from the uncertainties of electricity in its generation, transmission or application, but in many of the other elements which are involved. For instance, the introduction of higher speeds than those which have been attained involves no fundamental electrical question, but it does involve innumerable mechanical problems.

The extension of electricity into new fields of electric traction is, therefore, dependent more



Railway Motor.

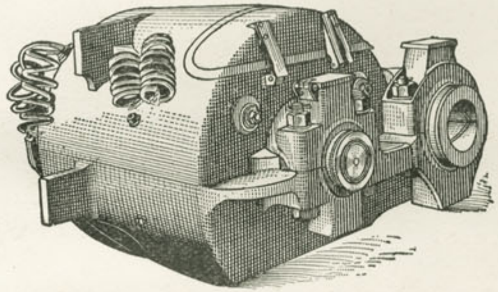
upon mechanical than electrical conditions, assuming the electrical engineer has no new elements with which to work. If, however, he has new material or new property presented to him, such as a higher magnetic permeability, or a higher conductivity for current, he will utilize it in cheaper and more efficient machines and circuits. If a new source of electric energy be discovered, some method of trans-



One Hundred Horse-power Railway Motor. Top Field removed, showing Armature in position.

forming directly the latent energy of coal into electrical energy, then the whole problem of electric traction will be revolutionized, as the cost of power is one of the prime elements in the problem of transportation.

In conclusion it may be said, a few years has sufficed to develop insignificant and experimental electric roads into completed railway systems which fill the streets of cities and towns and send out radiating lines in every direction into the surrounding country. A new field of transportation has thus been evolved which rapidly encroaches upon an important branch of general railway service. The motor created new conditions, and led to new methods. Its possibilities



One Hundred Horse-power Railway Motor complete.

and limitations are now fairly defined. Its present field in connection with general railway business is confined to local traffic over short distances. It is possible that it may develop new methods of operating which will be superior to those now existing. Who can doubt this in view of what has occurred? Taking all the circumstances of the past and the present, we may confidently look forward to the occupancy by electricity of an ever widening field in the general transportation interests of the world.

APPENDIXES.

APPENDIX A.
EVOLUTION OF THE LOCOMOTIVE.

					DIMENSIONS OF													
					Cylinders.			Heating Surface.			Wheels.				Weight.			
Year.	Designer of Engine.	Builder of Engine.	Name of Engine.	Class of Engine.	Inside or Outside.	Diameter in Inches.	Stroke in Inches.	Fire Box Area in Sqr. Feet.	Tubes Area in Sqr. Feet.	Total Fire Box Tubes in Sqr. Ft.	Number Driving Wheels.	Diameter Driving Wheels in Inches.	Number Truck or Bearing Wheels.	Diameter Truck or Bearing Wheels in Inches.	Weight on Driving Wheels in Lbs.	Weight of Engine in Running Order in Lbs.	Steam Pressure in Boiler. Lbs. to Sqr. Inch.	Length of Boiler. Ft. In.
1803	Trevithick.... ..	....	.. ..	Freight	Inside	8	54	......	......	......	4	54	..	...	...	.....	...	6- 0
1812	M. Murray......	M. Murray......	Blenkinsop......	"	"	8	20	......	......	......	..	....	4	42	....	.....	...	....
1814	G. Stephenson...	G. Stephenson...	Blucher...	"	"	8	24	......	......	......	4	36	..	...	....	.....	...	8- 6
1825	G. Stephenson...	Stephenson & Co.	Locomotion.....	"	"	10	24	......	......	......	4	48	..	...	.....	13000	25	10- 4
1826	Stephenson & Co.	Stephenson & Co.	Experiment.....	"	Outside	9	24	......	......	......	6	48	..	..	.....	.....	...	10- 4
1828	Stephenson & Co.	Stephenson & Co.	Lancashire Witch	"	"	9	24	......	66	......	4	48	..	...	.....	.....	...	9- 0
1829	G.&R.Stephenson	G.&R.Stephenson	Rocket..........	"	"	8	$16\frac{1}{2}$	20	$117\frac{75}{100}$	$137\frac{75}{100}$	2	$56\frac{1}{2}$	2	...	...	8500	50	6- 0
1830	Stephenson & Co.	Stephenson & Co.	Invicta	"	"	10	18	......	......	......	4	48	..	...	.....	.....	40	10- 0
1830	Stephenson & Co.	Stephenson & Co.	Northumbrian...	Pass'ger	"	11	16	......	......	$411\frac{75}{100}$	2	60	2	...	8025	14675	...	....
1830	G. Stephenson...	R.Stephenson&Co	Planet.	"	Inside	11	16	$37\frac{25}{100}$	$370\frac{41}{100}$	$407\frac{66}{100}$	2	60	2	36	10250	16000	...	6- 6
1830	Stephenson & Co.	Stephenson & Co.	Mercury	"	"	11	16	$37\frac{25}{100}$	$370\frac{41}{100}$	$407\frac{66}{100}$	2	60	2	36	10250	16000	...	6- 6
1832	G. Stephenson...	R.Stephenson&Co	Comet..........	Freight	"	12	16	$37\frac{30}{100}$	$302\frac{99}{100}$	$340\frac{29}{100}$	4	60	..	...	.....	18950	...	7-12
1832	T. Hackworth...	R.&W.Hawthorn	Wilberforce.. ..	"	Outside	$14\frac{3}{4}$	16	......	......	......	6	48	..	...	.....	.....	...	....
1833	Carmichael & Co.	Carmichael & Co.	Earl of Airlie....	"	"	11	18	......	......	......	2	54	4	...	.....	19000	...	....
1834	Stephenson & Co.	Stephenson & Co.	Patentee.........	Pass'ger	Inside	12	18	......	......	......	2	60	4	...	.....	.....	...	....
1834	Stephenson & Co.	Stephenson & Co.	Atlas..	Freight	"	16	20	......	......	......	2	54	4	54	.....	24000	...	....
1834	G. Forrester.....	Vaughan F'dy...	Swiftsure.......	"	Outside	11	18	......	......	......	2	60	4	...	.....	.....	...	....
1835	Hawthorn & Co..	Hawthorn & Co..	Comet No. 1.....	Pass'ger	Inside	12	16	35	237	272	4	48	..	...	.....	.....	60	....
1837	R.Stephenson&Co	R.Stephenson&Co	North Star......	"	"	16	18	......	......	......	2	84	4	48	.....	.....	...	....
1838	Haigh Found'y Co	Haigh Found'y Co	Grand Jct. Ry...	"	"	$13\frac{3}{4}$	18	58	480	538	2	72	4	48	.....	.....	...	....
1838	T. E. Harrison...	Hawthorn & Co..	Hurricane.. ...	"	"	16	20	108	516	624	2	120	..	...	.....	.....	...	....
1839	Haigh Found'y Co	Haigh Found'y Co	Hector..... . .	"	"	16	20	......	......	688	2	54	4	54	.....	.....	120	....
1846	D. Gooch........	Great Western Co	Great Western..	Express	"	18	24	......	......	1767	2	96	6	. .	.....	.....	...	....
1847	F. Trevithick . .	London & N.W.Co	Cornwall...	"	"	$17\frac{1}{2}$	24	......	......	......	2	102	6	...	.....	.....	...	....
1848	T. R. Crampton..	Bury, Curtis & Kennedy..	Liverpool	"	Outside	18	24	154	2136	2290	2	96	6	48	24000	70000	...	12- 6
1859	J. Ramsbottom..	London & N.W.Co	Problem.	"	"	16	24	......	......	......	2	$91\frac{1}{2}$	4	...	.....	54000	...	....
1861	J. E. McConnell..	London & N.W.Co	Delaware	"	Inside	18	24	$242\frac{30}{100}$	$980\frac{80}{100}$	$1222\frac{80}{100}$	2	$91\frac{1}{2}$	4	...	28000	69400	150	....
1870	M. Kirtley.. ..	Neilson & Co....	Midland Ry. 800.	"	"	17	24	103	993	1096	4	80	2	...	.....	71850	140	....
1871	M. Kirtley... ...	Midland R'y.....	Midland Ry. 890.	"	"	17	24	92	1020	1112	4	80	2	...	.....	73400	140	....
1885	S. W. Johnson...	Midland R'y.....	Midland Ry. 1738	"	"	18	26	......	......	1261	4	84	4	...	30000	85475	160	10-$10\frac{3}{16}$
1886	Nielson & Co....	Nielson & Co....	Caledonian 123..	"	"	18	26	......	......	......	2	84	6	...	34000	83800	150	....
1889	T. W. Worsdell..	North Eastern Co	N. E. Co. 1518...	"	"	20&28	24	......	......	1139	2	$91\frac{1}{2}$	6	...	35500	93350	175	....
1891	Wm. Dean.. ...	Great Western Ry	G. W. Ry. 3010..	"	"	20	24	$123\frac{88}{100}$	$1321\frac{34}{100}$	$1444\frac{22}{100}$	2	92	4	...	38000	88200	160	....
1892	P. W. Webb......	London & N.W.Co	L. & N. W. Co...	Freight	"	$19\frac{1}{2}$	24	$114\frac{30}{100}$	$1130\frac{40}{100}$	$1245\frac{30}{100}$	8	$53\frac{1}{2}$	..	...	.....	93675	160	15- 6

APPENDIX B.

PARTS OF THE LOCOMOTIVE.

The parts which manufacturers of locomotives buy in the market from other manufacturers are indicated by an asterisk (*).

[NOTE.—See chapters, "Description of Locomotive"; "Locomotives and Cars of the World."]

Air Pump Exhaust Pipe.
Arch Brace.
*Air Cocks.
*Air Signal Hose.
*Air Brake Hose.
Arch Hand Rail.
*Air Pump Lubricator.
*Air Gauge.
Ash Pan Damper Handle.
Air Drum Bracket.
*Air Drum.
Ash Pan.
*Air Brake Pump.
*Air Cut Out Valve.
*Air Pump Governor.
*Air Strainer.
*Air Pump Throttle.
Buffer Beam.
Blower.
Balance Plate.
Balanced Valve.
Bridges.
Back Cylinder Head.
*Boiler Lagging.
*Boiler Jacket.
*Boiler Sheets.
Bell.
Bell Stand.
Back Up Eccentric.
Back Up Eccentric Rod.
Back Up Eccentric Strap.
*Blower Cock,
*Brake Valve Reservoir.
*Branch Pipe.
Cinder Chute.
Cinder Chute Slide.
Cleaning Door.
Cylinder.
Cylinder Saddle.
Cylinder Head Casing.
Cylinder Lagging.
Cylinder Cocks.
Cylinder Cocks Rigging.
Cylinder Casing.
Cross Head Pin.
*Cross Head. (If steel, they purchase.)
Counter Balance Spring and Rig.
*Check Valve.
*Check Valve Case.
Circumferential Seam.
Crown Bars.
*Chime Whistles.
Cab.
Cylinder Cock Lever.
*Cylinder Lubricator.
Cab Bracket.
Counter Balance Weight.
Dry Pipe Joint.
*Draw Bar.
*Draw Head.
Deflector Plate.
Deflector Plate Adjuster.
Draft or Petticoat Pipe.
*Driving Wheel Tire.
*Driving Wheel Centers. (They purchase if steel; if cast iron, they make.)
*Driver Brakes.
Driver Springs.
Driver Spring Hangers.
Driver Spring Equalizers.
Driver Spring Hanger Brace.
Driving Box Shoe.
Driving Box Wedge.
Driving Box.
Driving Axle.

*Delivery to Drum.
*Drip Cock.
*Dry Pipe.
Dry Pipe Hangers.
Dome.
Dome Cap.
Dome Casing.
Extension Front.
Exhaust Port.
Engine Truck.
*Engine Truck Wheel. (If cast iron they make; if wrought iron or steel they purchase.)
*Engine Truck Tire.
Engine Truck Axle.
Engine Truck Brass.
Engine Truck Box.
Engine Truck Pedestal.
Engine Truck Frame.
Engine Truck Pedestal Brace.
Engine Truck Frame Brace.
Engine Truck Equalizer.
Engine Truck Spring Hanger.
Engine Truck Spring.
Engine Truck Spring Band.
Engine Truck Spring Pocket.
Eccentric Connection. Back Up.
Eccentric Connection. Go Ahead.
Expansion Pad.
Expansion Link.
*Engineer's Brake Valve.
Flagstaff.
Front Frame.
Front Cylinder Head.
*Flues.
Frame Brace.
Frame Splice.
Fire Door.
Feed Pipe Hanger.
*Feed Pipe.
*Feed Pipe Hose.
*Fire Box Sheets.
Guides.
Guide Yoke.
Guide Block.
Go Ahead Eccentric.
Go Ahead Eccentric Rod.
Go Ahead Eccentric Strap.
Grate Shaking Rig.
Gauge Lamp.
Gauge Cocks.
Hose Hangers.
Headlight Step.
Headlight Bracket.
*Headlight Case.
*Headlight Reflector.
*Headlight Burner.
Horizontal Boiler Seam.
Hand Rail.
Hand Rail Brackets.
Hand Hold.
*Injector.
*Injector Overflow.
*Injector Throttle.
Jacket Bands.
Key.
Link.
Link Block.
Link Block Pin.
Link Hanger.
Lower Rail of Frame.
Main Rod.
Main Rod Front Strap.
Main Rod Connection.
Main Frame.
Number Plate.
Netting.
Nozzle Stand.
Nozzle Tip.
Nigger or T Head.
Oil Pipe Plug.
Oil Pipe.
Oil Can Shelf.
Pilot.
Petticoat or Draft Pipe.
Piston Packing.
Piston Rod.
Piston Head.
*Piston Packing Rings.
*Pump Connection.
Pedestal Brace.
*Pump Piston Packing.
*Pump Exhaust Connection.
*Pump Steam Connection.
*Pump Valve Case.
*Primer.

Parallel or Side Rod.
Pilot Bracket.
Quadrant.
Relief Valve.
Rocker.
Rocker Box.
Reach Rod.
Rod Bush.
Rocking Grates.
Running Board.
Reverse Lever.
*Signal Lamp.
Smoke Arch Door.
Smoke Arch Front.
Smoke Arch Ring.
Stack Base.
Smoke Stack.
Steam Chest.
Steam Chest Casing Cover.
Steam Chest Cover.
Steam Passages to Chest.
Steam Ports.
Safety Hanger.
*Signal Pipe.
Suspension Stud.
*Steam Bell Ringer.
Sand Box.
Sand Box Lever.
Sand Pipe.
Side or Parallel Rod.
*Steam Cylinder Brake Pump.
*Steam Pipe.
*Steam Valve.
Sling Stays.
*Stay Bolts.
Stand Pipe.
*Safety Valves.
*Steam Gauge.
Steam Turret.
*Signal Whistle.
Sand Lever.
Shake Lever Stub.
*Signal Pipe.
*Signal Pipe Hose.
T or Nigger Head.
Truck Center Casting.
*Truck Brake.
*Train Pipe Connection.
*Train Pipe.
Tumbling Shaft.
Tumbling Shaft Arm.
Tumbling Shaft Lever.
*Tube Sheet.
Throttle Pipe.
Throttle Valve.
Throttle Bell Crank.
Throttle Stem.
Throttle Lever.
*Train Pipe.
*Train Pipe Hose.
Tail Piece of Frame.
Valve Yoke.
Valve Stem.
*Valve Stem Packing.
Valve Seat.
Valve Stem Rod.
Ventilator.
Wheel Guard.
Wash Out Plug.
Wedge Bolt.
*Water Pipe.
*Water Valve.
Whistle Rig.
*Whistle Signal Valve.

APPENDIX C.

COST OF ELECTRICAL CONDUCTORS.

TABLE I.

Cost of copper for outgoing and return circuits (without rail return) for delivering one horse-power on axle of car; volts delivered, 500 to 15,000; volts drop in line equal one-tenth of volts delivered; efficiency of motor and gearing, 80%; cost of copper, 15 cents per pound.

Miles.	500 V.	600 V.	700 V.	2000 V.	5000 V.	10000 V.	15000 V.
1	$ 20.70	$ 14.40	$ 10.60	$ 1.30	$ .21	$ .05	$ .02
2	83.00	57.60	42.40	5.20	.83	.21	.09
3	186.00	130.00	95.20	11.70	1.86	.47	.21
4	332.00	231.00	170.00	20.86	3.32	.83	.36
5	518.00	360.00	265.00	32.50	5.18	1.29	.57
6	......	518.00	380.00	46.80	7.45	1.86	.83
7	... ..	716.00	520.00	63.80	10.10	2.52	1.12
8	......	922.00	678.00	83.20	13.25	3.30	1.36
9	......	1164.00	860.00	105.00	16.70	4.17	1.85
10	.....	1440.00	1060.00	130.00	20.70	5.15	2.30
12	......	......	......	187.00	29.80	6.80	3.30
14	......	......	......	255.00	40.50	10.10	4.50
16	......	......	......	333.00	53.00	13.25	5.90
18	......	......	......	421.00	67.20	16.80	7.35
20	......	......	......	520.00	82.80	20.70	9.20

TABLE II.

Cost of copper in outgoing conductor for delivering one horse-power on axle of car; volts at car, 600; volts drop in outgoing conductor, 60 to 300 (for total drop add drop in rail return circuit); efficiency of motor and gearing, 80%; cost of copper, 15 cents per pound.

Miles.	60 V.	90 V.	120 V.	180 V.	240 V.	300 V.
1	$ 3.60	$ 2.40	$ 1.80	$ 1.20	$ .90	$ .72
2	14.40	9.60	7.20	4.80	3.60	2.88
3	32.40	21.60	16.20	10.80	8.10	6.48
4	57.60	38.40	28.80	19.60	14.40	11.52
5	90.00	60.00	45.00	30.00	22.50	18.00
6	129.00	86.00	65.00	43.20	32.50	25.90
7	176.00	117.00	88.00	48.00	44.00	35.10
8	231.00	153.00	115.20	76.50	57.60	46.10
9	......	194.00	146.00	97.00	73.00	58.20
10	......	240.00	180.00	120.00	90.00	72.00
12	......	......	259.00	173.00	124.50	103.60
14	......	......	.. ...	235.00	176.00	141.00
16	......	......	......	......	231.00	184.40
18	.....	......	......	......	291.00	232.80
20	......	.....	......	... .	......	288.00

TABLE III.

Approximate volts drop in rail return for delivering 100 to 1,500 horse-power on car axle; weight of rail, 80 pounds per yard (for other weights the distance for same drop varies as the weight); single track (for double track the distance for same drop is doubled); volts at car, 600; efficiency of motor and gearing, 80%.

Miles.	100 H.-P.	200 H.-P.	400 H.-P.	600 H.-P.	800 H.-P.	1000 H.-P.	1500 H.-P
1	3 volts.	6 volts.	12 volts.	18 volts.	24 volts.	30 volts.	45 volts.
2	6 "	12 "	24 "	36 "	48 "	60 "	90 "
3	9 "	18 "	36 "	54 "	72 "	90 "	
4	12 "	24 "	48 "	72 "	96 "		
5	15 "	30 "	60 "	90 "			
6	18 "	36 "	72 "				
7	21 "	42 "	84 "				
8	24 "	48 "	96 "				
9	27 "	54 "					
10	30 "	60 "					
12	36 "	72 "					
14	42 "	84 "					
16	48 "	96 "					
18	54 "						
20	60 "						

TABLE IV.

Cost of copper for delivering 400 horse-power and 200 horse-power on car axle; complete copper circuits without rail return, also copper circuit with rail return (single track); volts at car 600; total drop in pressure, 100 volts; efficiency, cost of copper per pound, etc., as in preceding tables.

Miles.	400 H.-P.		200 H -P.	
	Without Rail Return.	With Rail Return.	Without Rail Return.	With Rail Return.
1	$ 34.50	$ 9.84	$ 17.25	$ 4.60
2	138.00	45.60	69.00	19.00
3	310.00	121.60	155.00	47.40
4	552.00	266.40	276.00	91.00
5	863.00	504.00	431.00	154.00
6	1240.00	810.00	620.00	244.00
7	1690.00	1180.00	845.00	364.00

Table I. gives the cost of a complete copper circuit for transmitting one horse-power under definite conditions. It will be noted that the cost decreases rapidly as the voltage is increased, and that with the same cost the distance increases directly with the voltage. Twenty dollars and seventy cents is the cost for five hundred volts one mile, for five thousand volts ten miles and for ten thousand volts twenty miles. If the loss in the conductors be twice as great—twenty per cent. instead of ten per cent.—the cost of copper will be reduced one-half. If three phase alternating current is used, the cost is three-fourths of that given in the table.

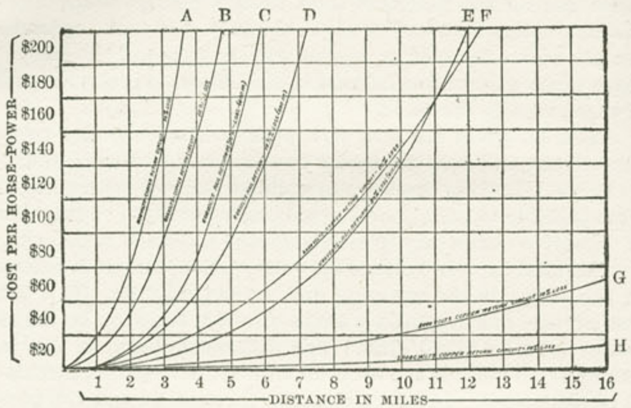
Table II. gives the cost of copper in the outgoing copper conductors, and does not take into account the return circuit.

Table III. gives the drop in volts in the rail return circuit This is liable to variations due to bonding of rails. Insufficient or defective bonds may greatly increase the track resistance.

The total drop in voltage between station and car is the sum of the drops in the outgoing and return circuits. If a total loss of, say, one hundred volts is allowed, the drop in the rail return is to be found first. The difference between this and one hundred volts is the drop for which the outgoing circuit is to be calculated. If the distance be three miles and the power one hundred horse-power, the rail drop is but nine volts, and ninety-one volts is allowed inthe copper outgoing circuit. If, however, the power is six hundred horse-power the rail drop is fifty-four volts and sufficient copper must be placed in the feeders to reduce the drop to forty-six volts. The drop in the rail should not exceed that in the outgoing circuit. When this would otherwise occur it is to be prevented and the two drops kept practically equal by supplementing the rail circuit with copper feeders. If the current is small the rail greatly reduces the cost of outgoing copper. For very light loads it is reduced to nearly one-fourth of what it would be if the rail were not effective as a conductor

Table IV. shows the effectiveness of the rail return circuit. The cost of copper for transmitting four hundred horse-power and also for two hundred horse-power is given both with and without rail return. In the latter the conditions would be filled if there were two trolley wires with feeding systems, one for outgoing and the other for the return circuit. It will be noted that the rail return reduces the cost for short distances to nearly twenty-five per cent. and that at five miles it is reduced nearly one-half for four hundred horse-power and to nearly one-third for two hundred horse-power.

Some of the above values are shown graphically in the following diagram:



Curves of cost of copper for different distances with and without rail return circuit:

A—	600 volts,	Copper	Return	Circuit	......................10%	Loss	
B—	600	"	"	"	......................16⅔%	"	
C—	600	Rail	"	"	......................16⅔%	"	(400 H.-P.)
D—	600	"	"	"	......................16⅔%	"	(200 H.-P.)
E—	600	"	"	"	......................50%	"	(400 H.-P.)
F—	2000	Copper	"	"	......................10%	"	
G—	5000	"	"	"	......................10%	"	
H—	10000	"	"	"	......................10%	"	

On the vertical line corresponding to three miles it will be observed that the loss with copper return circuit is reduced from $130.00 per horse-power when the loss is ten per cent. to $78.00 when the loss is allowed to reach sixteen and two-thirds per cent. When the rail is the return circuit the cost reduces to $30.00 per horse-power, when the power transmitted is four hundred horse-power, and to $23.00 when the power is two hundred horse-power. The cost at two thousand volts for complete copper circuit and ten per cent. loss is $11.70 and the cost at ten thousand volts is but 47 cents. The cost of copper for

three phase alternating current is three-fourths of this, or 36 cents at ten thousand volts. The cost of copper when there is rail return, single track, and when there is a loss of fifty per cent. of the voltage delivered (*i. e.* three hundred volts, equal thirty-three and one-third per cent. of the voltage at the power house), is given on the basis of four hundred horse-power delivered. It is comparatively low at first, but increases rapidly beyond a distance of nine or ten miles.

APPENDIX D.

EXPLANATION OF A POPULAR FORM OF AUTOMATIC AIR BRAKE.

The Westinghouse Air Pump consists of an air compressing piston in the lower cylinder driven by direct connection with the piston of a steam engine in the upper cylinder. The air is delivered to the Main Reservoir.

The Pump Governor closes the steam pipe leading to the pump when the desired maximum air pressure is attained, and opens the steam pipe again when the air pressure has been slightly reduced, so that no attention is needed from the engineer.

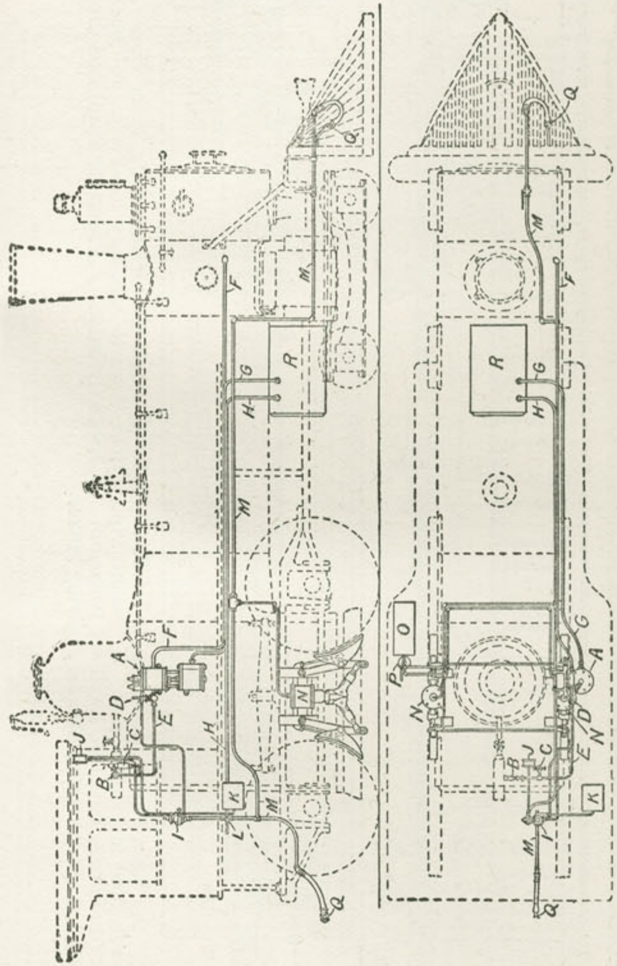
The Engineer's Brake Valve is manipulated by the engineer, as desired, to open communication between the main reservoir and the train pipe, or to close this opening and open the train pipe to the atmosphere when the brakes are to be applied.

The Triple Valve contains a piston engaging by a stem with a slide valve for opening and closing ports. The outer side of this piston is exposed to the train pipe pressure and the side toward the slide valve is exposed to auxiliary reservoir pressure; it is moved one way or the other by a slight preponderance of pressure on either side. When train pipe pressure is the greater the piston and slide valve are moved so as to open a small port from the train pipe to the auxiliary reservoir for charging the latter, and a larger port from brake cylinder to atmosphere to release the brakes. When auxiliary reservoir pressure is the greater, the piston and slide valve are moved in the opposite direction so as to close both the openings above mentioned, and then to open a passage from the auxiliary reservoir to the brake cylinder to apply the brakes.

The normal condition when running, is with the main reservoir, train pipe and auxiliary reservoirs charged with compressed air and the brakes off. A reduction of pressure in the train pipe by escape to the atmosphere at engineer's valve, or at the conductor's valve, or by the bursting of a hose or other breaking of train pipe, applies the brakes. A restoration of pressure in the train pipe from the main reservoir by proper moving of the engineer's valve, releases the brakes and recharges the auxiliary reservoirs for further use.

The Cut-Out Cock in the branch pipe and the release Valve on auxiliary reservoir are for use only when the brake on any car is out of order and must be cut out of service. The Release Valve is for releasing the brake on that car in such case by bleeding the auxiliary reservoir.

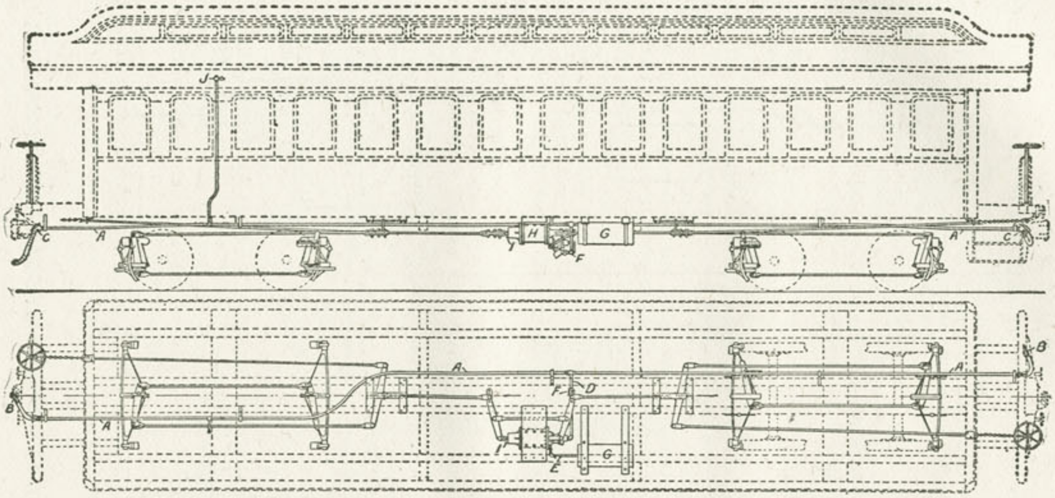
The Pressure Retaining Valve is connected by a pipe to the exhaust port from the brake cylinder. It is left wide open for free escape of air ordinarily, but is turned up by hand before descending long, heavy grades, so as to retain about fifteen pounds pressure in the brake cylinder, and thus keep the brake slightly applied while recharging the train.



A, Air Pump. *B*, Steam Valve. *C*, Oil Cup for Pump. *D*, Pump Governor. *E*, Steam Pipe to Pump. *F*, Exhaust Steam Pipe. *G*, Air Delivery Pipe from Pump to Main Reservoir. *H*, Air Pipe from Main Reservoir to Engineer's Valve. *I*, Engineer's Equalizing Brake Valve. *J*, Air Pressure Gauge. *K*, Equalizing Reservoir for Engineer's Valve. *L*, Cut-Out Cock in Air Pipe under Engineer's Valve. *M*, Train Pipe. *N*, Driver Brake Cylinders. *O*, Auxiliary Reservoir for Driver Brakes. *P*, Triple Valve for Driver Brakes. *Q*, Couplings for Train Pipe. *R*, Main Reservoir.

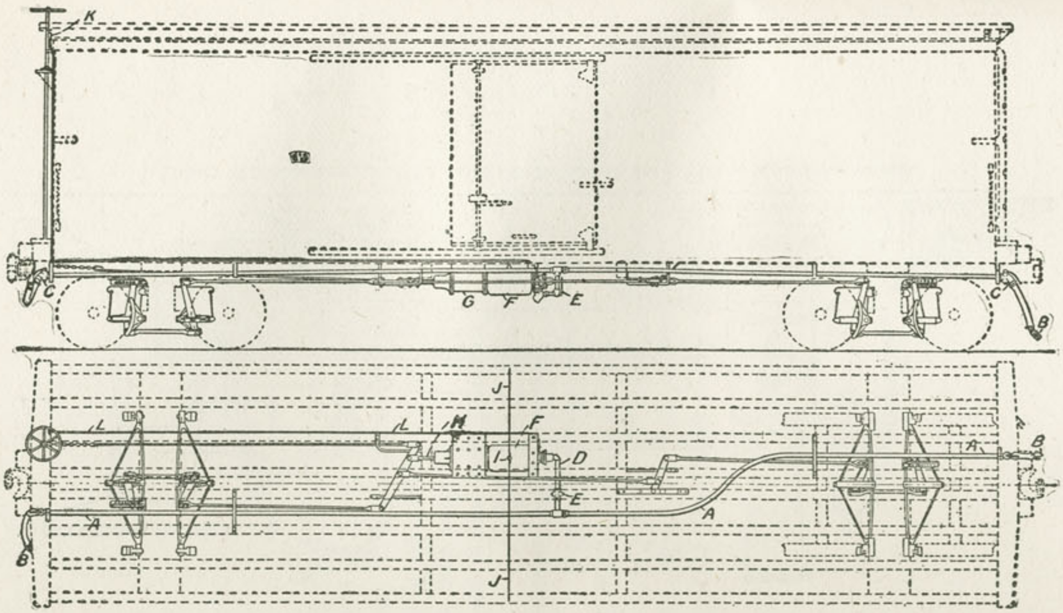
AUTOMATIC BRAKE, LOCOMOTIVE EQUIPMENT.

AUTOMATIC BRAKE, PASSENGER CAR EQUIPMENT.

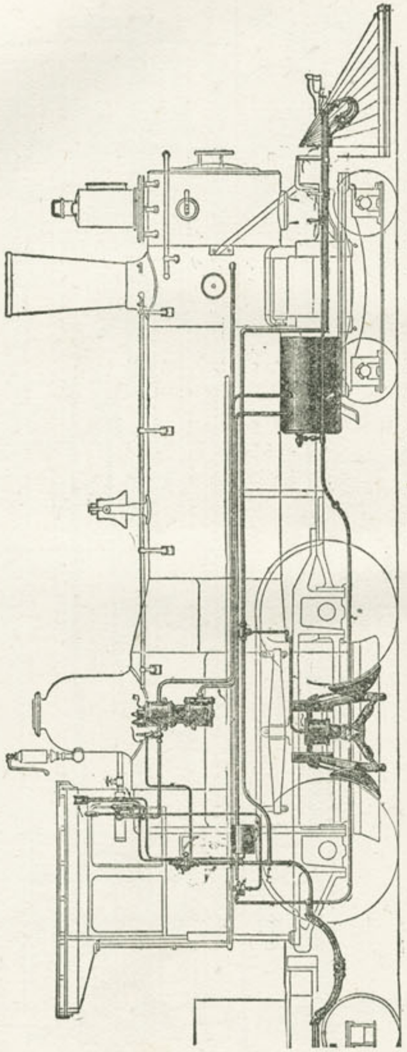


A, Train Pipe. *B*, Couplings for Train Pipe. *C*, Angle Cocks for closing Train Pipe. *D*, Branch Pipe to Triple Valve. *E*, Branch Pipe, Triple Valve to Auxiliary Reservoir. *F*, Cut-Out Cock in Branch Pipe. *G*, Auxiliary Reservoir. *H*, Brake Cylinder. *I*, Piston (or Push) Rod Cross-Head. *J*, Conductor's Valve for applying brakes.

AUTOMATIC BRAKE, FREIGHT CAR EQUIPMENT.



A, Train Pipe. *B*, Couplings for Train Pipe. *C*, Angle Cocks for closing Train Pipe. *D*, Branch Pipe. *E*, Cut-Out Cock in Branch Pipe. *F*, Auxiliary Reservoir. *G*, Brake Cylinder. *H*, Push Rod. *I*, Release Valve. *J*, Operating Rod for Release Valve. *K*, Pressure Retaining Valve. *L*, Pipe to Pressure Retaining Valve.



Theory of the application of the Automatic Brake and Brake Shoe to the driving wheels.

INDEX.

This volume is carefully Indexed, but for the convenience of the reader and to render the book easier to handle, the Index is included (with a full Index of the whole work) in volume Twelve under the title "GENERAL INDEX." This "GENERAL INDEX" is also, in a measure, an Encyclopedia of Railway Knowledge.

In all previous editions of the work each volume contained an Index, but as this was already embraced in the Twelfth Volume, it has been determined to change it in this edition (as indicated above) thus reducing the bulk of each volume, and making it more convenient for the reader to handle.

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