ENGINEERS' AND FIREMEN'S MANUAL.

GENERAL INDEX.

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

THE SCIENCE OF RAILWAYS.

BY

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BOOK III.

GENERAL INDEX TO THE "SCIENCE OF RAILWAYS."

RESUMÉ OF THE WORK, AND DEDICATION.

With this volume I bring my account of railroads to a close. The subject is a great one and covers, incidentally, the science of political economy, the ethics of business and the methods, habits and morals of men. Economic questions that enter into the calculations of traders, merchants and manufacturers, and the principles that govern those who employ and manage men, form a most important part of it.

Naturally, in my books, practical questions that concern the operations of railroads take precedence of all others.

But those who would comprehend the subject in its entirety must understand the principles of political economy that permeate it throughout as well as more practical details. For this reason I have given the former such space as I have been able.

Railroads are affected in their operations by natural laws—physical, moral and intellectual. Each is a potent factor. In their solution those who own railroads, those who manage them, those who work for them and those who patronize them are concerned.

Each day it becomes more and more apparent that the greater the wisdom exercised in governing railroads, the greater success they achieve; the less friction there is between owners, employes and patrons; the more profitable railway property is; the more contented and happy employes are; the better the public is served, the more friendly it is. Everything that contributes to this end serves a good purpose. Books are as valuable here as in the practice of medicine, law, government, the art of war, or other subjects that are too great to be comprehended by one man.

If in my writings I express anywhere opinions unfavorable to existing methods it is not necessarily because I believe them to be wrong in practice. Managers of railroads are the creatures of circumstances. Railway corporations, like governments, are compelled to accept for the moment situations as they find them and adapt themselves thereto with the best grace possible. However high their aim, present methods must conform to what is practicable. With greater knowledge and better resources the high purposes of today that are merely speculative may become realities.

Many portions of my books are devoted to specific details; to recounting particular methods of administration. In being minute I have erred, if I have erred at all, on the safe side, for while the views of particular men may not be accepted unqualifiedly by others, they are none the less

valuable. In this as in other things, what we read is, as I have before had occasion to remark, very often more valuable for the ideas it suggests than the thoughts directly conveyed. Where so many things have to be considered, as in railroads, before it is safe to act, the more extended our horizon, the greater our knowledge, the safer guides we make. Hence the value of experience, observation, treatises, descriptive books, etc.

In regard to the foregoing eleven volumes, other men, I must believe, have, each in his particular place, given many of the subjects discussed more attention than I. Of their methods, so far as I have been able to gather them, I have been an attentive student all my life. From them I have sought to learn. I have nothing to say, it is probable, in regard to their several lines of thought, that will greatly interest them. On other subjects I hope it may be different. Those I write for, however, are that great class, growing greater each day, whose knowledge of railway operations is necessarily circumscribed and whose opportunities for learning are limited. To these I hope my books will be something more than an exposition of well known facts or possible eventualities. They will open up to them many complex and interesting questions that enter into the origin, working and destiny of railroads, which would otherwise forever remain a sealed book, and without a knowledge of which their prospects in life would be much restricted and their usefulness greatly lessened.

No business interest is so divergent as that of a railway. The corporation itself is perpetual. It is the creature of circumstances. It serves all alike. It is a repository of great and varied trusts. It is at once a manufacturer and trader. It employs myriads of men. Its duties are complex, its responsibilities manifold. In its proprietorship it possesses the conservatism and high constructive qualities necessary to the accumulation and retention of property. Herein it is fortunate, for men of this class are the natural rulers of the world and the highest and best friends of those who do not possess their peculiar attributes. It was through their combinations that men first achieved freedom and the comforts of life. These highly desirable acquisitions cannot be preserved without their assistance and guidance.

In considering the affairs of railways, every interest must be remembered, that of owner, patron, officer and employe. All their rights, ambitions, projects, prejudices, habits, weaknesses and ignorances must be severally weighed and considered. Not to do so would be to jeopardize, certainly to weaken, the whole structure. For these reasons the philosophy of the subject, quite as much as its practical details, finds a place in the accompanying volumes. The theme is the most important of our day, and may truly be called Scientific. I regret my inability to do it greater justice.

I have had many new and original cuts prepared for this edition of the Manual to show not only the details of parts or their working which are not generally well understood, but especially to show the proper method of procedure in case of many accidents. It is a well known fact that no words of explanation, however complete and explicit they may be, can convey the information that a picture instantly affords.

In concluding these volumes, upon which I have been engaged so long, I wish to dedicate them, however unworthy, to the officers and employes of the railroad corporation with which I have been connected during the whole of my business life, now over forty years. This association has bred in me far deeper sympathies than those of a business character merely; in the long years that have passed officers and employes have become brothers, and the property itself has become imbued with life.

MARSHALL M. KIRKMAN.

Chicago, January, 1900.

BOOK I.

ENGINEERS' AND FIREMEN'S MANUAL,

OR

COURSE OF STUDY FOR THOSE WHO SEEK TO BECOME ENGINEERS.

ENGINEERS' AND FIREMEN'S MANUAL,

OR

COURSE OF STUDY FOR THOSE WHO SEEK TO BECOME ENGINEERS.

THE LOCOMOTIVE ENGINE THE KEY TO THE RAILWAY WORLD: QUESTIONS REGARDING SELECTION, TRIAL AND WORK OF THOSE IN CHARGE. THE VALUE OF SYSTEMATIC STUDY AND CAREFUL EXAMINATIONS TO THOSE WHO WOULD BECOME EFFICIENT ENGINEERS.

The books that make up the "SCIENCE OF RAILWAYS," of which this is a part, have much to say, directly and indirectly, about the Equipment and Train Service of railways. Both these subjects bear directly on the duties and responsibilities of engineers and firemen. It is as impossible to afford a separate and connected account of such duties as it is to afford such an account of the duties of superintendents or comptrollers. Railway service laps and interlaps in every direction, and the engineer and fireman to fully understand their duties must also understand the things that are germane thereto. This requires that they should study railroading not piecemeal, but as a whole.

It was the impossibility of separating the duties of particular departments of the service and describing them apart that first constrained me to take up the subject as a whole. I started out to describe particular branches of the service, but quickly found that their connection with the others was so close as to render a description of the whole necessary. Thus I was led reluctantly and contrary to my original intention to take up the subject in its entirety. What I have been compelled to do, others, who seek to fully inform themselves in regard to particular branches of the service, will also be compelled to do.

While there are many engineers and firemen who take this comprehensive view of the subject, others believe their field lies more apart and that, therefore, it is susceptible of separate delineation and study. There is much interesting and valuable literature extant on the subject of the duties of engineers and firemen, but for the reason stated, it only partially explains their offices. This does not, however, lessen its value, so far as it goes. It is simply incomplete.

Knowledge of the locomotive and how it is operated is only one of many things engineers and firemen must know. They must also be familiar with train regulations, signals, methods of dispatching trains and kindred knowledge. Such things are fundamental. Moreover, as their duties bring them in daily contact with the equipment, they must know something of its construction, care and maintenance. The wider their knowledge, the greater the probability that they may some day become department directors instead of operatives merely.

Nor need their ambition be thus restricted. The nature of their duties affords an admirable opportunity for acquiring the knowledge required by superintendents and managers of railroads. All that is needed is that he who sets out to familiarize himself with the locomotive shall keep on until he becomes acquainted with the needs of other branches of the service. The task is difficult, but not insurmountable. The knowledge may be acquired by experience, study, observation, inquiry and the thousand and one devices ambitious men adopt to further their ends.

A man who seeks merely to be a fireman, and then an engineer, and afterward, perhaps, a foreman, may be satisfied with a mechanical or perfunctory knowledge of the railway world, but such knowledge is not sufficient even for this limited field. However, he can possibly get on thus without scandalizing the service, or seriously jeopardizing the interest of his employer, but if he expects to occupy a position of greater power and influence, he must study railroading as a whole. Only thus can he comprehend the spirit and practices that animate the service, or cope with the many men of talent who fill its offices.

To be an officer of a railroad, or to fill a position of responsibility in connection therewith, requires that the incumbent shall understand the science of government. This science is in essential things alike as regards public and private corporations. To know how to govern a country or city well, is to know how to govern a great railroad well with its vast army of employes and widely extended and complicated interests. The man who seeks preferment in either must understand how governments are formed and how best carried on for the common good. He must know much about the checks and safeguards that experience proves to be needed in order to secure a strong and pure government. Such knowledge, as I have said, constitutes a part of the science of railroads, and no man is fully capable of being an officer of a railroad or of holding a position where he must come in contact with the public, without possessing it. This feature of the situation I have sought to explain in my books as conscientiously as I have the basis of rates, safe conduct of traffic, or the faithful handling of a company's money, but the information is not to be found in any particular chapter or book. It permeates every part of the service and it is impossible to discuss any question without more or less reference to it. It is this fact which makes men familiar with the magnitude and homogeneousness of the subject, so impatient of those who think that there are departments and branches of the service that may be considered apart from the rest.

Those who work for railroads, no matter where, are interested in acquiring knowledge of every department of the service, and this not perfunctorily, but systematically. Their personal interests not only require that they should possess this knowledge, but the interests of their employer as well. The more the subject is studied, the more this truth will be apparent. I am not so presumptuous as to believe I have exhausted the science of railways in my books. If a book could be made exhaustive, there would never be but one written. The greatest value that any book possesses is the suggestions it affords the person who reads it. He may find many things upon perusing it, that he did not know before, or only surmised; others again that he had overlooked. He will be refreshed as by a bath, even though he has only acquired a morsel of original information from what he has read, for the reason that his knowledge will have been expanded by the thoughts to which his reading has given rise. Let railway men keep this in mind in reading books on railway and other subjects.

I have sought to treat my theme as fully as circumstances permitted. Where I do not wholly enlighten, I may be pardoned for believing that I have at least pointed the way.

There are few of the books that make up the "Science of Railways" that do not contain matter of more or less general interest and value to those who seek to be firemen and afterward engineers. However, if the latter position is the height of their ambition, then some of the books will not possess as much value as they would under other circumstances, but in every book may be found some account of the practices and philosophy of railroading with which it is desirable every one should be familiar.

Much of the information that books on the general subject of railroads contain is not necessary to a fireman to enable him to creep up to the place of engineer, any more than salt is absolutely necessary to a potato; but he like every railway man, if lacking in the niceties of his profession (that only general knowledge can supply), will lack flavor and will seek in vain to reach the highest positions in the service.

From the foregoing it will be seen that a consecutive and separate account of the duties of engineers and firemen is impossible. However, there are particular duties imposed upon them that may be described apart. These I shall embody here. While incomplete, the matter is not the less valuable on that account, as it is replete with suggestions. This I may say with the greater freedom, as I am the editor, rather than the author. What I shall have to say is probably known to accomplished railroad engineers, but it is not known to those less favored, and yet they should be familiar with it, in order to be able to look forward with confidence to preferment in their calling. Furthermore, if instead of treating what I have to say as final, the student in search of knowledge will look upon it as rudimentary only and supplement it with acquisitions of his own, he will not only add greatly to his prospects as a railway man (by adding greatly to his value to his employer), but he will increase immeasurably

his ability to secure a position, if through any untoward circumstances, he finds himself without employment.

As the engine is the key of the railway world, so those who operate it share in its supreme importance. While admirable in outline and usefulness, it is after all only an aggregation of metal fashioned into many curious forms, but dead and incomplete without the guidance of the engineer and fireman. Like the world in the beginning when clothed in stillness and death, awaiting the light of day, so the locomotive stands apart, cold and dead, but under the inspiring influence of the Engineer and Fireman pulsates with life, forming not only a magnificent picture in itself, but one of the most useful implements ever designed by men for the use of men.

The locomotive is still in a state of evolution, and, sympathetically, those round about it are changing not only in the particulars of their duties, but in their aspirations and lives. The engineers and firemen of early days bore little resemblance to their brothers of the present period. The latter have not only personally acquired greater skill, but they possess also the accumulated experience of those who have gone before them. It is no exaggeration to say that the fireman of to-day, even if a novice, is much superior in capacity to the engineers who had charge for a long time after railways were first operated. The first enginemen were by trade, blacksmiths and mechanics, who understood something about metals and machinery, but were ignorant of the uses of steam or the future possibilities of the locomotive. It was necessary to train men for the position. This process has been going on with ever accelerated speed from the first day up to the present moment. There is no end to the road. It grows wider and the horizon expands with each advancing step.

The firemen and engineers of railways constitute as highly a trained class of men as there are connected with the technical world of trade at the present time. Their knowledge and usefulness will increase with time and further experience. It is only reasonable to believe this because we know that possession of knowledge only intensifies the desires of men in this direction. Its acquisition by an ambitious man creates an unquenchable thirst for further light. His mind expands with his opportunities in this direction until the vacuum of the brain appears so much greater than its filled space that the wisest man becomes despondent at the meagerness and superficiality of his knowledge.

It is only the supremely ignorant man whose mind is at rest.

With each passing day, knowledge becomes more and more a necessity to men. The advantages the informed man has over his ignorant brother, are so great that the latter must likewise

acquire knowledge or confine himself to the common drudgeries of life. This is what competition is doing, and it is thus showing itself as useful in this department of life as it has in the production and interchange of material commodities.

Men have no inherent love of study, but the taste grows, and if one man studies, all must eventually study or be outstripped in the race of life. Thus the ambition of a particular man starts the whole forward. When men acquire a desire to learn, moreover, their ingenuity supplements the efforts of others, and in this way accomplishes a double purpose, at once encouraging and beneficent.

As the driftwood carried to the coast of Spain suggested to Columbus the unknown world of America, so the questions and answers embodied further on herein will suggest a host of collateral ideas of great value both to the student and his employer. These inquiries measurably dispel the darkness, but do not fully light up the horizon. And so it is generally in reference to books. A great good that they serve is the thoughts they give rise to in the minds of readers. The capillary attraction of the human mind thus exemplified, if I may thus characterize it, has this attractive feature, that above the water line of acquired knowledge it ever attracts to itself, all that is necessary to nourish or expand it. It is this feature of the brain reaching beyond original limits, that has made man the arbiter of the world, and that makes all things an open book to him. The only difficult thing in his case is to get his mind in motion; once under way, it never ceases its inquiries until death silences its action.

In the case of engineers and firemen many methods have been devised for adding to their knowledge so that they may better serve themselves and the great industries with which they are connected. In some of the old countries of Europe, and particularly in France, technical schools have been established near the great shops by railroad companies, so that the children of employes may early in life be instructed in the trade they design following, and this under the immediate eye of their father. Thus, as they grow up, they associate themselves with him and afterward, when he is too old to work, succeed him in his calling. In this way, the child is brought at the most receptive period of its life into direct contact with the things that are afterward to occupy its mind exclusively. The advantage of this cannot be overestimated, for we all know that there is a particular period in life that is illuminated more brightly than any other, when what we learn we do not forget nor undervalue. This period, to a great extent, forms the groundwork of every man's life. Consequently, if during such period light is thrown on the work that is afterward to occupy him, it exceeds in value knowledge acquired at any other

period. For this reason, the benevolent intentions of the corporations in providing schools for the children of employes, will, it is reasonable to believe, be followed by the best possible results to themselves. However, the schools are not intended for the children of firemen and engineers alone, but for all employes engaged about the shops.

Usually the effort to educate men for engineers and firemen does not commence until the men have entered the service. This is where the great bulk of the railroads of the world take up the work of instruction. The method they follow in carrying out their object is as diversified as it is in other things connected with the service. Formerly, applicants were put on the locomotive, and told to go to work, their preparatory instruction being of the simplest possible kind. This practice is still extensively followed. In other cases, the fireman is compelled to serve a brief apprenticeship in the roundhouse. In still other cases, the preparatory period is more extended and the labor prolonged. Some companies go so far as to require a man who seeks to become a fireman to commence emptying clinker pits, cleaning and wiping engines, and performing such mechanical duties in connection with the locomotive as occasion requires. If he shows adaptability and industry, he is after a while given an opportunity by being put on the Extra Firemen list. Here his action is carefully scrutinized. If he meets just expectation, he is in due course made a regular fireman, the assistant and second self of the engineer. Here, while he has his own work to do, and plenty of it, he has an opportunity to familiarize himself with the work of the engineer. The facility with which he does this, will depend upon his ability to learn and his desire to get on in the world, but assuming that he, not less than his older brother the engineer, is animated by an acute intelligence and a laudable ambition, he must also have, like the latter, good health, a strong body, and be free from intemperate habits. These latter qualities are more necessary to those connected with locomotives than to others in the service, although they are necessary to every man who expects to achieve success in life.

It goes without saying, that every man who seeks to be a fireman, or who expects to become an engineer, must have a good character.

The practice of examining into the qualifications of applicants before hiring them grows in popular practice every year. Men are scrutinized more carefully than formerly, and once having entered the service, greater intelligence is exercised in ascertaining their capacity and usefulness. This is especially true of those branches of the service where technical skill is required and perfect trustworthiness needed. In the early days it was sufficient that an applicant for the place of fireman was able to perform the work, which, under the most favorable circumstances, is very severe. Afterward, as experience taught

the necessity of it, railroad companies began to inquire into the antecedents of aspirants. By and by they got to inquiring about their habits, but railroads had been operated in America sixty years before it occurred to them to test the mental capacity and disposition of applicants by careful examinations. As this could not very well be done before applicants entered the service, it had to be done afterward. It took, in a general way, the shape of examinations such as characterize those of students of law and medicine. Meanwhile, the general trustworthiness of the employe was scrutinized and his mode of life, morals, temperament, steadfastness and general fidelity to duty carefully studied. If deficient in these latter respects, intellectual and physical endowments were not sufficient to outweigh objections. On the other hand, if he possessed all the moral qualities, and yet was deficient mentally and physically, he was not considered as affording good material for a fireman, and, prospectively, an engineer. Accordingly, if during the probationary period he broke down, or failed to answer the requirements of the service, he was told to go his way and in some field where his capabilities would be sufficient for the occasion fix his life occupation. This, instead of being a hardship or injustice, has been found to be a kindness to applicants, because it anticipates subsequent failure and saves them the waste of time and mortification that would otherwise ensue.

It also saves the company, and incidentally the public, from the mishaps that attend the service of men inferior in mental and moral qualities. It not only enables the employer to promptly separate the capable from the incapable, but throws around the general public a measure of safety that carriers are always bound to consider.

In order to pass the examinations, careful study and preparation, and experience as well, are required. Applicants must at least have a good common school education, because this is required of engineers. Once having entered the service it is manifest that the efficiency of the incumbent may be greatly heightened by requiring him to commence at once systematically to study the problems of the business with which he is identified, and not solely, be it remembered, with a view of performing his present duties properly, but with the further view of his being promoted to the responsible position of engineer, at a given time, or thereafter when opportunity occurs. Methods of procedure vary on different roads, according to men's views of the subject. Some roads do not make any examinations at all, but the tendency is more and more in that direction as their value becomes more and more apparent. The system which is elucidated further on, and which meets with the approval of some of the most experienced and talented Master Mechanics and Superintendents of Motive Power in the

world,* contemplates a careful and systematic course of study. First, however, the habits and antecedents of applicants are carefully inquired into, as I have intimated. Once the applicants have passed this ordeal, the full confidence of the company is accorded them and every facility afforded them to pursue their inquiries and studies so as to fit themselves for present and future work. Every official of the machinery department holds himself ready to answer questions or respond in other directions so far as it may be proper to aid applicants in this way.

After the applicant for the position of fireman has passed through the preliminary stages, whatever they may be, he is given a series of questions bearing directly on his future duties and responsibilities as an engineer. These he is expected to carefully study, and at the end of the time designated, go before the master mechanic or other authorized officer and answer them categorically, with such other questions of an incidental nature, as are pertinent to the occasion. However, the list of questions given him and the answers thereto constitute the examination in the main.

*Among these, Mr. Robert Quayle, who stands in the first rank in knowledge of railway machinery and equipment and in conscientious effort to make this great department of the service all it should be. He has no superior as a student or executive, and I desire here to thank him for valuable information and assistance. I am indebted to many others but to him especially and particularly. M. M. K.

Having passed the first examination successfully, he is furnished a further list of questions he will be expected to answer. This constitutes the second examination. Following this he is furnished the interrogatories which close the course of study.

In regard to the last examination, no one is ever sent to take it, whom the master mechanic above him is not willing to accept as an engineer provided he successfully passes it. Another condition and a very proper one is that men sent forward for this examination shall be in their order of service, other things being equal. The final examination, which is so important, is usually conducted by a board appointed for the purpose. This insures impartiality and thoroughness, though the same thing can, it is apparent, be secured by an examination made by the master mechanic and his associates.

All the examinations having been passed and the applicant's work meanwhile having proven satisfactory, he is ready to take charge of a locomotive—is an engineer in fact, ready to fill the first position of the kind that offers. This is the goal he has sought. Such is the procedure.*

Different roads vary the details. Its merit is that it affords a course of study, which, with the practical experience of the fireman meanwhile, makes of him a trustworthy engineer. This is what every fireman strives for and what his employer requires of him, for it is thus engineers are made.

If during the progress of the examinations candidates are unable to pass or answer the questions, it is generally thought well to extend the time a reasonable period.

If at the expiration of the time allotted the applicant is unable to pass, then the expediency of his seeking other employment naturally suggests itself, and this last for two reasons, as I have already intimated: First, that the service may not be clogged by men who cannot ultimately be promoted; and second, that applicants shall not be allowed to waste their time upon work not destined to be of lasting advantage to them. And in this connection it is not considered too much by those versed in such matters that applicants shall answer satisfactorily, both in

* It will not be forgotten, in this connection, that the applicant has long before this demonstrated his moral and physical fitness for the position of engineer. Sometimes the physical examination is conducted by the machinery department, and at other times by the surgical department of the railroad. As will be noticed farther on, each applicant before being passed is examined with a view to ascertaining whether he is perfectly familiar with the time table, or not; also with the signals. The examinations in regard to these last are sometimes conducted by the machinery department, but more frequently, perhaps, by the operating department. Upon many lines, the superintendent is not satisfied until he personally ascertains that those taking charge of engines are familiar with the rules, familiar with the time table, and familiar with the signals. The machinery department looks especially to the technical fitness of those in charge of locomotives: the operating department requires in addition to this, perfect familiarity with the the rules governing the movement of engines and trains over the road.

writing and orally, eighty per cent of the questions asked them in each of the examinations.

And in regard to applicants, every assistance possible is rendered them, as already intimated, and they are at liberty to go to master mechanics, foremen and others for information in regard to those things they do not fully understand.

It will be seen from the foregoing that in no sense will the course of study be forestalled by the questions that are propounded and the answers thereto that are contained herein. Both the questions and the answers applicants will find it useful to critically study, as students pursue their studies at universities; but they must not only know the correct answers to the various interrogatories (because every engineer must understand them), but must understand their purport, so that they can reply to each question in their own language and according to their understanding of it. They cannot use the answers embraced herein—these are intended to be merely instructive. They must frame answers for themselves. Thus it will be seen that, while the assistance this Manual affords will save them much inconvenience and many inquiries, it will not save them from the necessity of studying and framing an answer of their own to each inquiry that the examinations contain.

Parallel with the examinations, and along the same lines, it is a growing practice on many well managed railroads to maintain schools of instruction for the purpose of teaching train men, and

particularly engineers and firemen, in regard to the construction, use and maintenance of the air-brake, steam-heating apparatus, use of gas and electricity for lighting, and other implements of an intricate or scientific nature that are used on trains. The expense of this systematic course of instruction is more than offset by the increased efficiency of those thus instructed. The efforts of railway companies in this direction are everywhere actively seconded by their employes, as it adds to their usefulness and renders more certain their promotion, or if not promotion, then successful competition in the strife for place and its retention. Accurate and extended knowledge of their duties, aside from its present value, cannot, it is also apparent, but be of the greatest possible use to those who possess it, should they, through the cutting down of a force or otherwise, find it necessary to seek employment elsewhere.

The examination of firemen and engineers has been disregarded on many roads, but it needs little discernment to see that this state of affairs cannot continue always. Companies lacking this element of strength will not be able in the long run to make a showing as against companies whose force throughout has been carefully instructed in technical knowledge of the highest order in regard to their duties. The omissions and mistakes of the inefficient and the scandals they will create, to say nothing of the extra expense such men entail, will compel the companies employing them to adopt a more comprehensive plan of selection and instruction, first with a view of preventing inefficient men from entering their service, or in case they have such, to weed them out as soon as possible in the event they prove to be incompetent. In making these examinations the railroads will only forestall the act of the state, for it is only a question of time, and a short time at that, when firemen and engineers will be compelled to go before a State Board for examination as to their fitness, the same as steamboat engineers are required to do, unless the railroad companies forestall such action by themselves making the examination.

The questions that it is proper to propound to applicants for the position of engineer are many and intricate. The answer to each question, it will be observed, is of a nature to familiarize the applicant with his work and to make him of greater present usefulness, to say nothing of the future. The sooner, therefore, the applicant familiarizes himself with his present and prospective duties the better for him and his employer. The quality of service that the fireman renders while fitting himself for promotion, also operates for or against him finally. His work during this period is compared with that of others, as is also the care and intelligence he exercises in the use of oil, fuel and other supplies.

The position of fireman, it is proper to say, is not only one exacting hard work, but considerable knowledge of detail, so that he has an

opportunity to show fitness in this respect, which is all-important in the positions that he aspires to fill.

In propounding the questions that follow, it will be noticed that no fixed or predetermined formula is observed. They are, however, specific and such as are suggested by the practical experience of those versed in such matters. I do not seek here, any more than elsewhere, to be original, but rather useful; to supplement my limited knowledge wherever possible by the wider knowledge and experience of others. The particular form that an examination shall take is not material, if it is effective. The method I have followed is the commonplace one of interrogating the applicant by asking him questions. It is probable that with the growth of the service the list of questions will be extended. That would be of advantage to the applicant if it will extend his knowledge.

In reference to the answers to the various questions, it is not expected, as already intimated, that applicants will restrict themselves either to the scope or words I use. The answers I give, while correct, and such as to throw a clear light on the subject, are not exhaustive.

The fireman who passes an examination is expected to answer the questions correctly or at least eighty per cent of them. The information I give will help him, but it is also intended he shall give the matter exhaustive thought on his own account. The subject is a growing one and it is expected of firemen as it is of every man connected with railroads, be he high or low, that he will not be satisfied with what he knows, but will strive to keep on acquiring knowledge. I do not here any more than elsewhere seek to forestall personal research, but to add to the desire to acquire it by careful study and thought.

With these explanatory remarks I will take up the several examinations in their order, and first, the inquiries that every fireman (whether already in the service, or just entering it) may at any time expect to be put into his hands to be answered at the end of some specified time. A full knowledge of the questions propounded and the answers thereto will aid him, not only in the direct examinations to which he will be subjected, but in replying to collateral questions which will arise impromptu as the examinations proceed. Afterwards will be taken up the questions that in the natural order of things will be submitted to the fireman after the first examination has passed, to be answered at some specified time. Then those questions which constitute the final examination and upon which depends the appointment of the fireman as an engineer.*

* In the event a railroad company does not require an examination such as I refer to, still a study of the subject as here presented will, as already intimated, materially aid firemen and others in acquiring the knowledge they must possess in order to fit them to run an engine. The subject therefore, no matter how it presents itself, is of interest to them.

The questions and answers, constituting the three examinations are generally familiar to engineers. Nevertheless, in their aspect and grouping, they present new features that will prove interesting and instructive even to them. While designated for firemen seeking advancement, they cannot prove otherwise than useful to such engineers as may, in the natural order of things, be doubtful as to their ability to pass a critical examination, should one be instituted by the state or the railroad company.*

STEAM AND ITS APPLICATION TO THE LOCOMOTIVE.

Before formally taking up the examinations already referred to, it will be proper to preface them by a brief description of the simple and primary application of steam to the locomotive. I know that such matters are well understood by engineers and firemen, and are not, therefore, of value to them; but to those who are not familiar with the subject, they are interesting and instructive. Books and lengthy treatises have been written on the subject, but, stripped of padding and unnecessary words, there is very little to be said if we omit other matters relating to the locomotive, including that of the art of firing, which things I have fully pointed out elsewhere. What I wish

*They appeal especially, so far as they go, to engineers who are not familiar by practical experience with present methods of firing. The engineer not familiar with the needs of to-day and the exacting requirements in regard to the best (scientific) methods of using fuel must lose no time in becoming so, if he desires to maintain a place in the front ranks of his profession.

to say here, therefore, relates simply to the process of getting the locomotive under way.

The power that imparts motion to the locomotive is the expansive force of steam. This force, which has been known for thousands of years, was first utilized for purposes of carriage in the early part of the nineteenth century.

As stated elsewhere, steam is the vapor of water generated by heating water above the boiling point. Hence steam is water in a gaseous state and is colorless and imperceptible to the eye. Saturated steam is steam either in contact with the water from which it was generated or, if separated therefrom, is kept at the same temperature and pressure. Wet steam is steam not only saturated, but also holding in suspension unevaporated water in the form of minute drops; it holds this water in suspension mechanically, due either to the ebulition of the water from which it is generated or else from a rapid flow of steam from near the surface of the water, in a similar manner as the wind off a rough body of water is noticed to carry drops of spray. Dry steam is the term usually used for saturated steam in distinction from wet steam. Superheated steam is steam removed from contact with water and heated above the temperature of the water from which it was generated; it is variously called steam-gas, surcharged steam, or anhydrous steam. Steam more closely resembles a perfect gas when superheated than in any other state, and it is for this reason that in the locomotive the attempt is made to superheat the steam. The boiler has a

dome from which, and at quite a distance above the usual water level, reasonably dry steam is taken, passed through a pipe called the "dry pipe," and branching in the smoke-box or front end of the locomotive where the escaping hot gases have a tendency to superheat it, passes into the two cylinders in which its energy becomes useful.

In steam, as in other gases, there is a natural repulsion between its various particles, each particle trying to separate itself from the others, so that it will fill the receptacle in which it is placed, regardless of the quantity of steam or size of the vessel holding it. Its natural tendency is to expand and thus push out whatever resists expansion. If the steam is enclosed and superheated, therefore, as in the case of a locomotive boiler, the natural tendency of its particles to separate is intensified and we thus obtain, according to its quantity or volume, the steam pressure required.

The vapor seen escaping from a vessel of boiling water, or rolling in clouds from the exhaust pipe of a locomotive, is only a modification or diluted agent of the mighty force that does so much of the world's work. This vapor is steam that is resolving itself back into water; the change or condensation which is visible is caused by its contact with the cold air. Real steam, as just stated, is an invisible gas, or, rather, a transparent fluid, really water changed into gas by the action of heat. Accordingly, to make the steam that an engine requires water must be boiled. To hasten this and to lessen the cost, the boiler is permeated with tubes, or flues, connecting with the fire-box, into which the flames therefrom are drawn, thus multiplying the heating surface and, in so far as this is done, hastening the boiling of the water and the generation of steam.* As the water is transformed into steam it rises into the dome, as will be seen by reference to the diagram of the locomotive. From there it is released by opening the throttle valve and is thence conveyed, through what is known as the dry pipe and steam pipes, through the steam chest, thence to the cylinders.

It is, as is well known, the expansive power of the steam operating through the mechanism of the cylinders that affords the propelling power of the locomotive.†

In order to utilize this power there is connected with the cylinders a steam box which is commonly termed the steam chest, in which there is a slide valve, under which are three ports or openings, one leading to each end of the cylinder, and, the third leading to the atmosphere. The slide valve has a reciprocating movement whereby these ports are opened or closed. Motion to the valve is imparted by the revolving driving-wheel axles in various ways, the most common of which is by means of eccentrics and links with connections to the valve stems, as fully explained and illustrated elsewhere herein. The cylinder is

*This as well as other matters relating to the construction and appliances of locomotives is illustrated and described elsewhere herein.

†For diagrams of the various cylinders and the action of the steam therein, see various cuts contained in this work, both of the simple and compound patterns.

fitted with a piston. This is movable back and forth from one end of the cylinder to the other. Thus the steam from the boiler is introduced through the steam chest into one end of the cylinder and forces the piston to the opposite end; then the valve opens the port at the other end of the steam chest and allows the steam to enter at the opposite end of the cylinder, and at the same time connecting the other side of the piston with the atmosphere, thus allowing the steam just used to escape; this reversal of pressure upon it forces the piston back to the place whence it first started. The escape to the atmosphere takes place through the smokestack in order to create a greater draught on the fire. This action back and forth, at first slow, is almost inconceivably rapid when the locomotive is under full headway. The piston described is in its turn, attached to a rod which works through a closely fitting opening in the back end of the cylinder. In this way the motion is carried outside of and beyond the cylinder. To the end of the piston rod just referred to is attached the connecting rod which, in turn, is attached to the crank or revolving shaft of the driver. The backward and forward motion of the piston (called "reciprocating motion") is thus converted into a revolving or rotary motion. It is observed, however, that the connecting rod, when it has carried the crank backward or forward as far as it will go, loses its reciprocating motion and the piston will no longer produce a rotary motion. These positions of the crank are

CYLINDER AND ITS APPURTENANCES

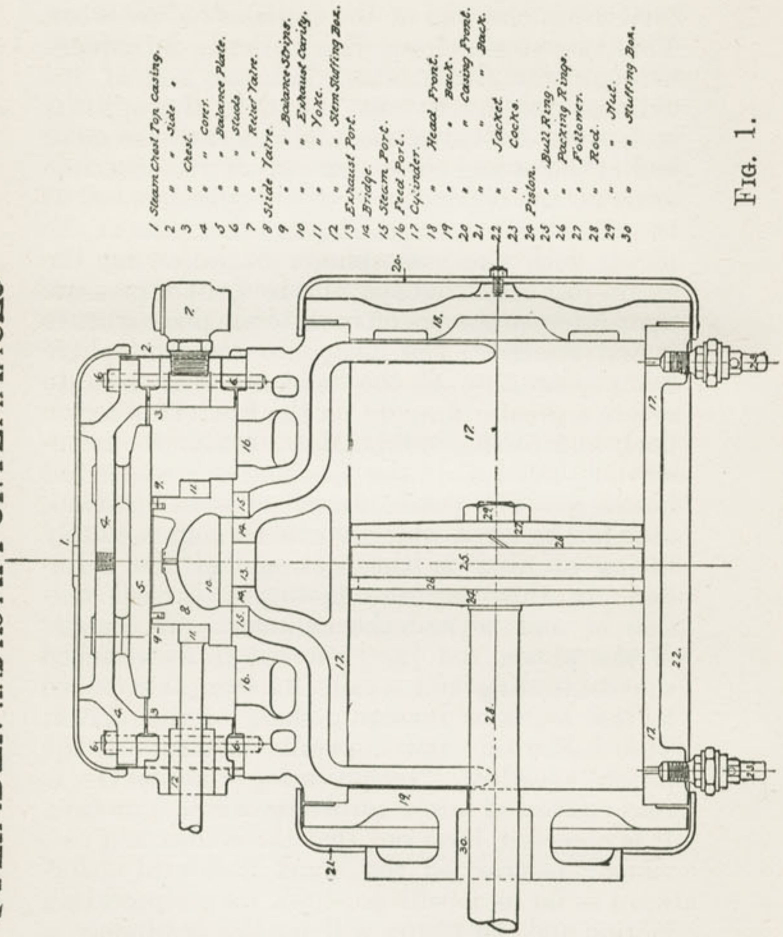

FIG. 1.

called its dead points. In the stationary engine this is overcome by a fly wheel, the momentum of which carries the crank past the dead points; then, too, stationary engines of one cylinder are not required to frequently stop and start with a load, as are locomotives. In the case of a locomotive the obstacle is obviated by having two cylinders with cranks, placed at right angles to each other and on the same axle; also, as the service demands the movement of the locomotive in either direction, backward or forward, the valve motion is so constructed that the engine is reversible.

It is thus that the steam is generated and its power applied. I would in this connection refer the reader to the chapter on "Description of the Locomotive."*

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*See "*Railway Equipment*," Vol. I.

DUTIES AND RESPONSIBILITIES OF ENGINEERS.

FIREMAN'S FIRST EXAMINATION.

How long have you been in the service?*

How long have you served as a fireman?

What should you do on arrival at the roundhouse previous to your departure therefrom with your locomotive? I should draw the necessary supplies and see that the lubricators, lamps, oil cans, tank and sand boxes are filled. If the coal be bituminous, I should see that it is broken and wet down, that the cab and its fittings are wiped, the ashpan cleaned, and the grates straight, so that coal will not drop through them.

When on duty, do you compare your watch with that of the engineer to see that they agree?

As it is the duty of the engineer to show you any train orders that he receives, are you particular to see that the rule is always observed?

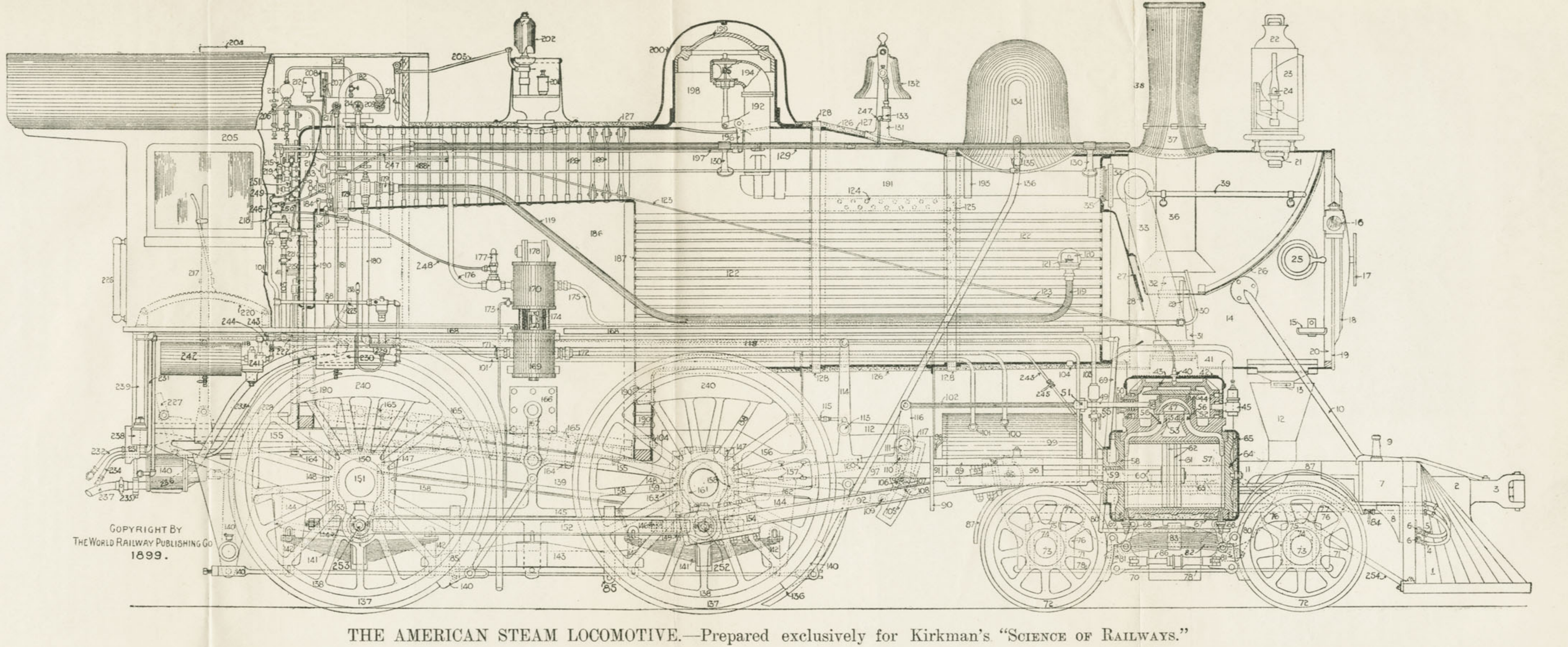
Are you familiar with the signals?

*In the army and navy, fitness being the same, promotion is dependent on length of service. Promotion in the railway world also depends on length of service, provided the qualifications of applicants are alike. Continued and trusted service, it will thus be seen, in the employ of a particular railroad company is a matter of the greatest importance to those who seek preferment.

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.

Please describe them.*

In addition to the danger signals enumerated, is there any other signal that you consider a danger signal? Yes, any violent motion made in front of a train.

What is the source of the power of a locomotive? Heat.

What is steam? Vapor, generated by heating water above the boiling point.

What do you understand by the pressure indicated by the steam gauge? The pressure of steam in pounds per square inch above atmospheric pressure.

What is meant by atmospheric pressure? The weight or pressure of the atmosphere, namely: about fifteen pounds per square inch at sea-level.

Has a locomotive a natural or a forced draught while working? It has a forced draught.

Why? Because of the exhaust steam escaping through the smokestack.

How does the exhaust steam create a draught through the fire? By forming a partial vacuum in the smoke-box and in the flues, which the hot air from the fire-box rushes in to fill, thus creating a draught.

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*The hand signals that employes use, also the signals that are carried on locomotives and cars (indicating particular things), also the signals connected with the track, are fully described and illustrated in the book on "Train Service" in the *Science of Railways*. Any one seeking to be an engineer, or to answer the questions connected therewith, is respectfully referred to the book in question, as it will without doubt facilitate their research and knowledge of railway practice.

What good effect is produced by opening the fire-box door when the engine is at work? By partially opening the door black smoke and popping are prevented.*

What bad effect is produced by opening the fire-box door when the engine is at work? The chilling of flues and sheets, and thereby, through contraction, causing them to leak and warp.†

Is it necessary to have a large quantity of air to generate steam rapidly? It is, as the air supplies more than half the elements for combustion.

Does this apply to a heavy fire as well as a light one? Yes, the heavier the fire the greater the quantity of air required.

Has improper firing any tendency to cause flues to leak? Yes, in so far as it permits the cold air to strike the flues unnecessarily.

Define black smoke. Black smoke consists of a mixture of gases and carbon. The greater part of it is carbon, which is unconsumed fuel.

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*Popping. Locomotive boilers are constructed to hold a steam pressure of a certain number of pounds per square inch (the maximum is about 200 pounds), and are fitted with two safety valves, regulated by springs, to hold that number of pounds. When the steam pressure exceeds that amount the valves open and allow the steam to escape until the pressure is reduced. The escape of steam through the (pop) valve is called "popping" or "blowing off."

†The reason flues leak when exposed to cold air is that the fire expands the flues and flue sheet (to which the flues are fastened), and when the cold air strikes them they contract, and the flues being lighter than the flue sheet, they contract faster, leaving an opening between the flue and its hole in the flue sheet. Pumping a great quantity of cold water rapidly into a hot boiler will have the same effect.

How can black smoke be avoided? By careful and scientific firing.

Why should black smoke be prevented? To save fuel and avoid dirt and annoyance to the public.

Has it been proven in practical service that proper firing will prevent black smoke? It has.

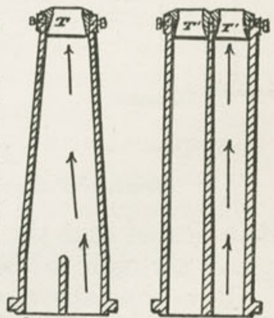
How is such firing accomplished? By the single shovelful process, or never putting into the fire-box, at most, but two shovelsful at one time.

Is this manner of firing productive of economy of fuel? It is; a saving of between 15 and 20 per cent. has been obtained in actual service. It will also cause a more nearly uniform temperature to be maintained in the fire-box, thus lengthening the life of the flues as well as improving the steaming qualities of a locomotive.

Does the size of the exhaust nozzle affect the fire?* Yes, by affecting the draught on the fire.

When the amount of fuel burned is greater in the front end of the fire-box than in the back end,

Fig. 2. Fig. 3.



Single Double

—Exhaust Pipes—

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*The exhaust pipe, as its name implies, is a pipe for carrying the exhaust steam from the cylinders to the smoke-box of the engine and so through the smokestack. Suitably attached to the upper end of the exhaust pipe is the exhaust tip or nozzle, the size of which is altered in accordance with the draught requirements of the engine—a small exhaust creates a powerful draught, and *vice versa*. (See Figs. 2 and 3.) The steam is carried to the smokestack for the purpose of creating a forced draught through the fire-box.

what does it denote? It denotes that the greatest amount of draught passes through the bottom flues.

When the amount of fuel burned is greatest under the fire-box door, what does it indicate?

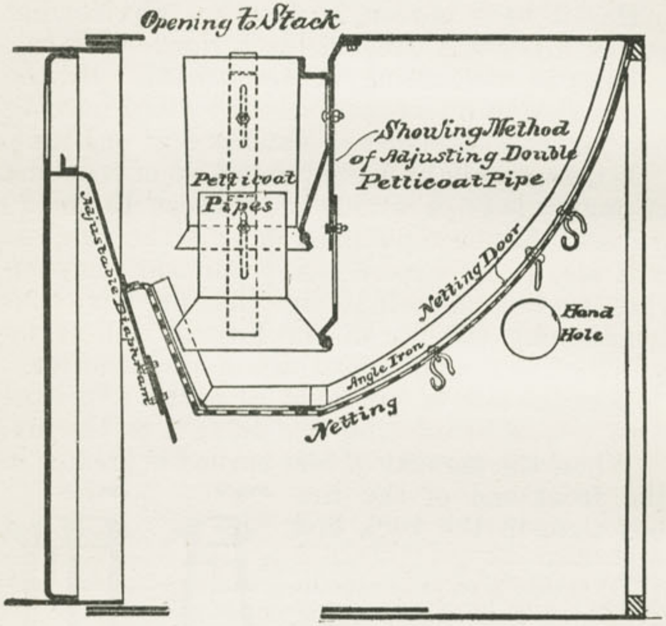


Fig. 4.
Draught Appliances in Smoke Box

It indicates that the greatest amount of draught passes through the top flues.

How can these defects be remedied? By adjusting the draught appliances in the smoke-box of the engine.

What is meant by the "draught appliances" of a locomotive? The diaphram, the petticoat-pipe or pipes, the exhaust pipe and nozzle, and the netting. (See Fig. 4.)

How often should grates be shaken? They should be shaken as often as is necessary to keep ashes and clinkers from forming on them; it depends very much upon the kind of coal used.

What causes an excessive "pull" on the fire-box door?*

What is the result of opening the fire-box door when the engine is working? The temperature is lowered in the fire-box and flues.

Why is it important that bituminous coal should be broken into the size of an ordinary apple before it is put into the fire-box? Because it increases the exposed surface and can be better spread over the fire.

Why should the coal be wet? To prevent dust and dirt and to give weight to fine coal.

What should be the condition of the fire when a stop is made at a station or when the bottom of a long down grade is reached? The fire should be burned down so as to prevent the engine either blowing off or emitting black smoke.

What is the proper method of using dampers? The dampers should be closed when the engine is not working. The back dampers should at all

*A "pull" on the fire-box door is caused by the partial vacuum always existing in the fire-box and smoke-box when there is a forced draught. This draught pulls the door shut, or holds it when it is sought to open it. If the fire-box is not kept free of clinkers and ashes, thus permitting the passage of air through the fire, there will be a stronger pull on the fire-box door.

other times be used solely (if possible) when the engine has a single ash-pan.

If the engineer keeps the injector working after the engine has been shut off, in what condition should the fire be kept? The fire should be kept burning brightly, using the blower lightly (if necessary) in order to keep the boiler at the proper temperature.

Is blowing off at the pop valves wasteful? Yes. It causes a waste of steam, and consequently a waste of fuel.

Describe a blower. It consists of a cock on the boiler-head with a pipe coupled to it, leading to and terminating in the smoke-box, and pointing upward toward the stack near the nozzle. (See Fig. 5, also Plate I.)

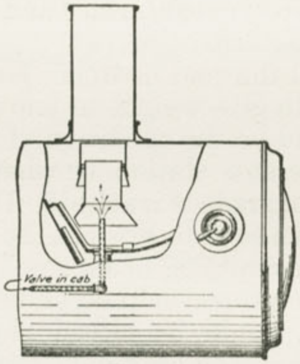


Fig. 5.

What is the use of a blower? Its use is to create a forced draught on the fire when the engine is not working.

Explain how the blower may be used improperly. By using it too strongly while the fire-box

and grates are being freed from ashes and clinkers, or while the door of the fire-box is open, when there is only a light or poor fire, thus forcing cold air through the flues, causing them to contract and leak.

Are you studying the subject of combustion?

In what way are the draught holes in the fire-box door and the deflector inside of the furnace a benefit? By permitting the oxygen to come in contact with the carbon and hydro-carbons, thus creating a more perfect combustion.

Do you, in the interest of the company, and for your own benefit as well, aid and assist the engineer in the performance of his duties whenever you can?

How much coal do you burn per engine mile and per mile per unit of tons hauled?*

What is the comparison in this respect between your record and others in the same service?

How do you account for any differences there may be?

If your engine runs two round trips over a division of 109 miles with one filling of the lubricator, how far are you running to the pint of valve oil, if the lubricator holds 3 pints? 109x2=218, round trip. 218x2=436 miles to 3 pints. $436 \div 3 = 145\frac{1}{3}$ miles run to the pint of valve oil.

If you use 8 pints of engine oil in the same distance what is your mileage per pint of engine oil? 436 (miles)$\div 8 = 54\frac{1}{2}$ miles per pint of engine oil.

*Statistics of companies are sometimes based on the engine mileage and sometimes on the pounds of coal burned per *100-ton-miles, i. e.*, in hauling 100 tons one mile or one ton 100 miles.

What is your mileage per pint of lubricating oil (both engine and valve oil)? 3+8=11 pints; 436 (miles)÷11=39.64 miles per pint lubricating oil.

Should you burn 18 tons of coal per round trip, what would be your engine mileage per ton? 218÷18=12.11 (Answer).

If you hauled 1,000 tons each way over the division on this trip, burning 18 tons or 36,000 pounds of coal, how much coal would you burn per *100-ton-miles?* 1,000x218=218,000 ton miles or 2,180 *100-ton-miles.* 36,000 (pounds)÷2,180=16.52 pounds coal burned per *100-ton-miles.*

Suppose that you should pull only a caboose car weighing 20 tons and burn 3 tons for the round trip, how many pounds of coal would you burn to the *100-ton miles*, and would this increase or reduce your average for the month? 3 tons=6,000 pounds. 218 (miles)x20 (tons)=4,360 ton-miles or only 43.6 *100-ton-miles.* 6,000÷43.6=137.6 pounds of coal per 100-ton-miles. It is evident by comparison with the preceding example, where a full train was hauled and only 16.52 pounds burned per *100-ton miles*, that this one trip, requiring 137.6 pounds, or over eight times as much, will make your monthly record higher than it would be otherwise. Heavy trains every day in the month make the best showing on the *ton-mileage* basis.

How would this trip affect the records if taken on the *engine mileage basis?* If you made 218 miles with 3 tons of coal that would be 72 2-3 miles run per ton of coal. But, in the former example, as your engine mileage with a full train was only 12.11 miles per ton of coal, it is evident this trip of over 72 miles per ton would increase your monthly average.

Can you locate the different parts of a locomotive and give their proper names?*

Do you keep the engine which you fire in as clean a condition as circumstances permit?

What are your views regarding the use of fuel, coal, and other supplies and tools? They should be used carefully, with a view to the greatest possible economy consistent with effective service.

Do you comply cheerfully with all orders emanating from your superiors in the service?

What is of supreme importance to an engine or train when on the road? Their right to be there and their due and proper protection.

If you should discover that a fixed signal was missing or imperfectly displayed, what would it be your duty to do? It would be my duty to notify the engineer at once.

The foregoing constitutes the first examination. It is very simple and easily learned. However, it is desired that the student should meanwhile extend his knowledge in other directions. Among other things, he should familiarize him-

*The reader will note that the fine engraving of the locomotive (Plate I.) used in *Railway Equipment*, Vol I., has been introduced into this volume as well, in order that reference thereto may be the more easily had. This complete chart, naming each and every part of a locomotive, will be found extremely valuable to any one who seeks to familiarize himself with the intricate machinery and the names of the different parts of a locomotive. The reference numbers throughout this manual which are inclosed in brackets, refer to the number of the part designated by Plate I., and should be carefully studied.

self in a practical way with the construction and working of the locomotive.*

*It is proper to repeat here that the inquiries and replies as embodied in this and the succeeding sections will vary more or less on the different roads that take up the system of progressive examinations, but whatever they may be, the knowledge embraced in these inquiries and the replies thereto will not only greatly facilitate the fireman in passing his examination, but will be a benefit to him in all his subsequent career.

DUTIES AND RESPONSIBILITIES OF ENGINEERS.

FIREMEN'S SECOND EXAMINATION.

NOTE.—As indicated in a preceding foot note, the book on *Railway Equipment* of this series, will be found to contain a carefully prepared diagram of the locomotive in which the different parts are numbered. These parts are frequently referred to in the examinations which follow. By reference to the number indicated, the reader will be able to locate the particular thing referred to. This reference, while possibly not necessary in every case, will, nevertheless, make the examination more easily understood.

The questions that suggest themselves in connection with the second examination, and the answers thereto, are as follows:

What has been the average amount of coal (or wood) consumed per mile run, or per mile per unit of tons hauled, by the engine fired by you during the past year?*

How many firemen, if any, have done better than this?

What are your relations with your engineer? (They should be of an amicable nature, so that you may freely and fully discuss with him every matter pertaining to your duties.)

What are your views in reference to the use of intoxicating liquors? (The occasional use of

*Upon many roads statistics of this kind are based upon the miles run by the locomotive. A much better basis, however, when it is practicable, is the tons hauled by the locomotive.

intoxicating liquors, if continued, results finally in their frequent and habitual use. This is not always the case, but as a rule tippling results finally in the participant becoming a drunkard. No one, of course, who indulges in the use of liquor ever believes such will be his case.)

Do you work to the best of your ability for the interests of your employer, and are you economical in the use of tools, fuel and supplies? Yes, I consider the interests of my employer as my own, and therefore economize in the use of supplies as if paid for by myself.

Do you understand the principle of combustion?

What is it? It is the uniting with oxygen of any combustible material that has been heated to the point of ignition.

What is carbon? It is the element which forms the chief part of every kind of solid fuel.

From what is oxygen obtained? From the atmosphere.

What other gas does the atmosphere contain? Nitrogen.

Which element forms the greater portion of the atmosphere? Nitrogen has a volume of four parts to one of oxygen, but by weight is only double the latter.

To cause complete combustion of one pound of coal, how large a volume of air is required with the forced draught of a locomotive? About 300 cubic feet; and as each shovelful of coal contains 15 to 20 pounds, the necessity of free admission of air to the fire is apparent.

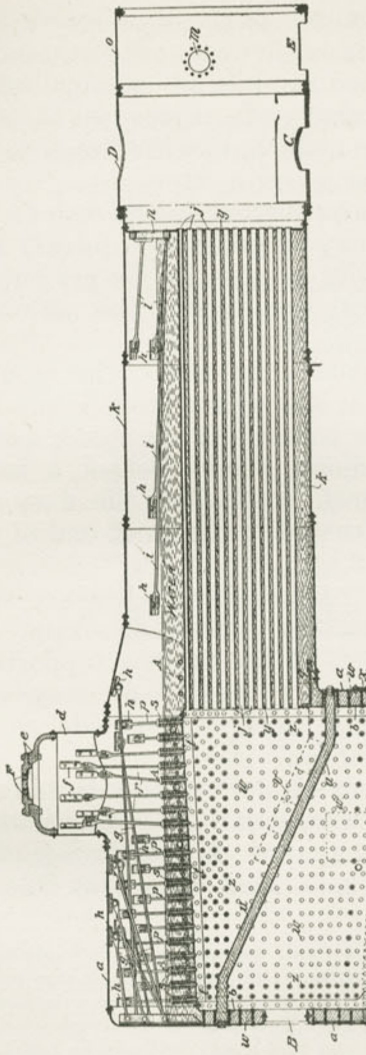


FIG. 6.

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* Hand hole. *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* Water tubes for supporting arch. *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* Cinder chute opening. *F* Safety-valve connections.

Describe the general form of a locomotive boiler? It is cylindrical in form. It has, usually, a rectangular shaped fire-box at one end and a smoke-box at the other end. Flues run through the cylindrical part, which, like the fire-box, are surrounded by water.

Why are these parts surrounded by water? In order that steam may be generated quickly and in as large a quantity as possible, by presenting the greatest practicable surface to the action of the heat.

Describe a locomotive fire-box. The modern form is a rectangular shaped structure located at the back end of the boiler. It has a door and is composed of side-sheets, a crown-sheet, a back-sheet and a flue-sheet from which the flues run to the smoke-box located in the front end of the engine. (See Fig. 6.)

To what kind of a strain is the fire-box subjected? It is subjected to a crushing strain.

How are the sheets of the fire-box supported? They are supported by means of stay-bolts screwed through the inside and outside sheets and are riveted together. (See Fig. 7.)

What is the object of hollow stay-bolts or of "detector holes" in stay-bolts? To immediately indicate by the escape of steam through this small (detector) hole that the stay-bolt is broken.*

*A "detector hole" is a small one-eighth or three-sixteenth inch hole drilled in the center of the outer end of a stay-bolt to a depth somewhat greater than the thickness of the outside sheet of the fire-box. (See Fig. 7.) This practice is based upon the fact that it is at the outer end that a stay-bolt usually breaks.

In what manner is the crown-sheet supported? By means of crown bars or radial stay-bolts. (See Fig. 6.)

What annoying feature is there connected with crown bars? They are hard to keep clean, and cause "mud-burnt" crown-sheets.*

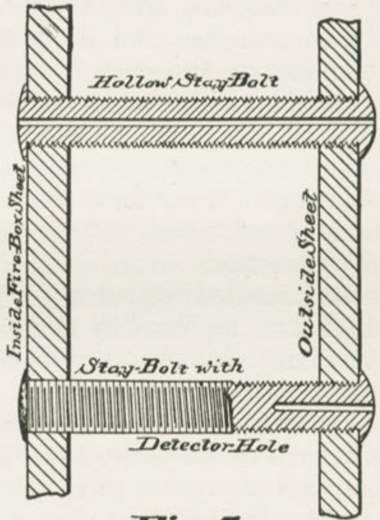


Fig. 7.

What is the advantage of the radial stayed crown-sheet? It is comparatively easy to keep clean and cheaper to repair.

*When crown bars are used, the top of the fire-box is flat and hence offers a considerable surface for the settling of mud and other incrustating matter. With the radial stayed fire-boxes the top of the fire-box is the arc of a circle and consequently less of such matter can settle thereon. If a layer of mud or other poor conductor of heat settles upon the crown-sheet, the water is kept from contact with it and the sheet is overheated and becomes burned.

How are the inside and outside sheets of the fire-box secured at the bottom? They are riveted to a wrought iron ring called the mud-ring. (See Fig. 6.)

What are below this? The grate-frame, ash-pan, grates, lever for shaking grates and dumping the fire. (Nos. 139, 164 and 165 of Plate I.)

Describe the ash-pan and its uses? It is a receptacle secured to the bottom of the fire-box and is provided with two or more dampers designed to regulate the admission of air to the fire. It collects the ashes dropped from the fire-box and thus prevents their setting fire to bridges, cattle-guards and other property elsewhere along the road.

What is the so-called wagon-top boiler? It is a boiler which has the fire-box end made larger than the cylindrical part in order to provide more steam space.

Why are boilers provided with steam domes? In order to furnish more steam space, obtain dryer steam, and provide a place for the steam-pipe (191), throttle valves (195), safety-valves (201) and whistle (202).

What must be the condition of the boiler in order to give satisfactory results? It must have a good circulation and be clean and free from incrustation of any nature, such as scale, mud, etc.

What is meant by the "circulation" of a boiler? The free movement of the water, so that it may come in contact with the heating surfaces, and after being converted into steam, be immediately replaced by fresh supplies of water.

What would be the effect if the leg of the boiler became filled with mud? There would be no water in contact with the heated sheets and they would in consequence quickly become blistered or "mud-burnt."*

What would be the result if the sheets should become overheated? They would be forced off the stay-bolts and an explosion would occur.

What effect is occasioned by the stoppage of one or more flues? The heating surface and draught are decreased by just so much.

Why are the boiler check valves (121 and Fig. 9^{A}) placed so far away from the fire-box? In order to introduce the water into the boiler as great a distance from the fire as possible. This permits the water to become somewhat heated before coming in contact with the fire-box and also tends to better circulation.

Where is the steam generated, and in what manner is its power transmitted to the locomotive? It is generated where the water comes into contact with the heated surfaces and afterward rises to the top of the boiler. It passes thence through the throttle valve (195) and dry pipe (191) into the steam pipes (33) in the front end (14) and so on to the steam chests (44). From there it passes through the steam ports (56) at each end of the cylinders (57) when uncovered by the valve (47), and coming in contact with the piston (61), pushes it away from the cylinder head (64) until the opposite steam port (56)

*The narrow water space between the inside and outside sheets of the fire-box is termed the "leg" of a boiler.

is uncovered by the valve, and at the end of the stroke the reverse motion is induced by the steam entering the opposite side of the valve (47) and pushing against the piston in the opposite direction. Simultaneously the first steam port is brought into connection with the exhaust opening (54), and thus the steam that has been used escapes into the atmosphere through the exhaust pipe (31 and 32) and smokestack (38). (See Plate I. and Fig. 6.)

What quantity of water ought to be evaporated in a locomotive boiler to a pound of coal? Six to eight pounds, according to circumstances.

What are the advantages of the arch in the locomotive fire-box? It induces a more perfect combustion by retaining the gases in the fire-box until they have reached the igniting point. It thus prevents, partially at least, black smoke by giving the fire time to consume the carbon and gases. It also partially heats the cold air before it enters the flues, and otherwise acts as a deflector on the fire.

What is the advantage of extending the front end (14) of the boiler? (See also Figs. 4 and 6.) It serves as a receptacle for sparks, which, if not confined, would be ejected through the smokestack, thus causing discomfort to the public and danger to property.

What provision is made in this extended front end (14) for the regulation of the draft? It contains the exhaust nozzle (32), the so-called petticoat-pipe (36), and an adjustable deflecting plate or diaphram (27). (See also Fig. 4.)

What is the purpose of the safety valve (201) and how does it operate? Its purpose is to relieve the boiler of excessive pressure by allowing the steam to escape into the air. The steam, after attaining a certain pressure, pushes up a stem and spring and thereby unseats a valve and thus allows the steam to escape into the atmosphere until the pressure becomes normal, when the spring again seats (closes) the valve.*

Of what use is the second safety valve? It is valuable as a measure of safety, in the event the first valve should stick or otherwise become inoperative.

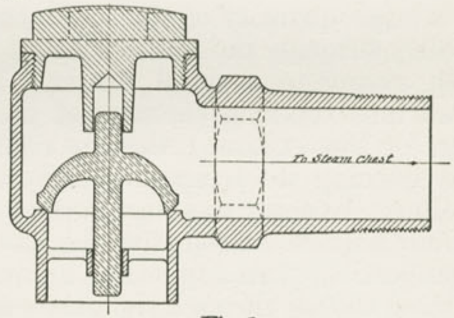


Fig. 8.
—*Steam Chest Relief Valve*—

Why are suction or air relief valves (45) †placed on the steam chest of many locomotives? In order to admit air into the steam chest and thus prevent a vacuum therein, when the engine is running with steam shut off.

*American locomotives are fitted with two safety valves with the steam pressure usually set at from three to five pounds difference between them.

†Fig. 8 shows one style of steam chest relief valves.

What is the object of safety valves on the steam chest or dry pipe of a locomotive? To prevent bursting the steam chest or knocking out a cylinder head in case the engine were reversed with the throttle closed.

If, upon opening the fire-box door (222) what is called a red fire should be discovered, what would be the probable cause? That the grates had become filled with ashes and clinkers and the fire was not getting sufficient air.

If the fire was not getting air enough through the grates (165), why would you not open the fire door? Because if the door was even partially opened, a large quantity of air would enter and pass directly through the gases without uniting therewith, except to a small extent. Thus, it would pass into the flues (because of the powerful action of the exhaust) thereby cooling the flues and reducing the temperature of the water in the boiler. In order to secure perfect combustion, the air must be mixed with the gases in the proper proportion. This can be best accomplished by admitting the air through the grates and having it pass thence through the fire.

How can the theory of the proper mixing of the air and the gases be demonstrated? By inverting a shovel in the fire door at an angle toward the fire. The air will thus be deflected into the fire in a wide sheet and will be more thoroughly mixed with it, thereby insuring greater combustion as will be shown by the increased brightness of the fire. Under such circumstances, the entire grate area may be seen,

and the fireman can examine all parts of the fire-box to ascertain whether he is distributing the coal to conform to the draught arrangements of the engine.

If a hole is formed in the fire, what will be the result? Heat will be lost, as cold air will enter the fire-box and cool the gases below the point of ignition.

Why is it necessary to keep a "heavier," or deeper fire on one engine than another? Largely because of the influence of the draught appliances upon the fire.

What is the best way to fire a locomotive? The fuel should be applied frequently and in small quantities. It should be distributed evenly over the fire. The coal should be broken into pieces about the size of an apple.

How can too much air be admitted? By opening both dampers when the engine is working lightly and there is only a light thin fire. Air admitted above the amount required for combustion cools the gases below the igniting point.

What constitutes perfect firing? Providing fuel and air in exactly proper proportions.

How can this end be most nearly attained? By observing attentively the results of different methods of firing and being governed by that which is best.

In the case of an engine working hard and using bituminous coal, is it possible to admit too much air through the fire? No, not if the fire is sufficient to consume the gases.

Does the draught from an open cab window or otherwise, affect the working of lubricators (224)? Yes, the cold air chills the oil and thereby retards its flow—causes it to "feed" irregularly.

What else would cause irregularity? Dirt in the lubricator (18). If the choke plugs were too large, such a result would follow.*

If a lubricator feeds faster when the engine throttle is closed than when it is open, what is the trouble? The choke plugs are too large. (See detail cuts and explanation of lubricators. Appendix *C* of this volume.)

Will bad results be caused by filling a lubricator full of cold oil? Yes, when the oil becomes heated, it will expand. It may thus cause the lubricator to burst or bulge.

How can you clean the sight feeds when they become filled with dirt? By removing the regulating valve and blowing out the nozzle, or by running a fine wire or straw through it.†

How can choke plugs be cleaned? By disconnecting the oil pipes and running a wire through them.

When waiting on sidings, etc., should the feed valve or the water valve be closed? The feed valve, as the water valve may not be tight.

*The choke plug is the nozzle, through the small hole in which the oil feeds in passing from the lubricator (224) to the cylinder supply pipe (123). See also cuts in Appendix *C*.

†The sight-feed is the nozzle inside of the lubricator feed glasses of what is known as the "Sight Feed Lubricator." It is thus called because of the fact that the oil that is feeding (i. e., being supplied to the part needing lubrication), is doing so in plain sight of the engineer. See appendix *C*.

Should oil be used as fast for a speed of fifteen miles per hour as for a speed of thirty miles per hour? No.

Explain how to modify the friction of oil. By making the oil thin by adding kerosene, or other light oil, rather than by heating it. If it is heated, the cold surface congeals it, making it a poor lubricant and occasioning internal friction.

Please describe any new signals introduced since your last examination.

How many changes have been made in the old signals?

What tools should a locomotive be supplied with? Those that the company's rules and regulations require.*

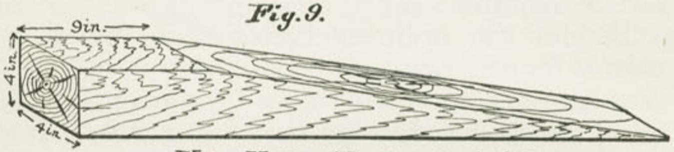
Besides the ordinary tools, what should be carried for use in case of break-downs on the road? A valve-stem clamp, blocking for the crosshead, two hardwood wedges (as shown in Fig. 9), a few pieces of pine board, a small coil of wire or strong cord, and a miscellaneous assortment of bolts

*These rules and regulations are not, of course, uniform on different roads. Indeed, some roads do not specify what they should embrace. However, generally speaking, the list may be said to include the following items: Axe, pinch bar, flue plugging bar, small steel bar, blocking, bolts and nuts, broom, tallow bucket, water bucket, one gallon oil-can, one quart oil-can, squirt can, engine chain, cape chisels, cold chisels, clinker bar, clinker hook, coal pick, cushions, dipper, green flags, red flags, white flags, frogs, machinist hammer, soft hammer, ash hoe, 9-inch jack, 24-inch jack, jack levers, blizzard lamps, white lanterns, packing hook, packing iron, flue plugs, front-end poker, saw, scoop shovel, tallow pot, torch, torpedoes, 12-inch monkey wrench, 15-inch monkey wrench, eccentric set screw, oil cups, steam chest nut wrench, air-pump spanner, large injector spanner.

and nuts. Many times considerable delay will be avoided if these tools are readily at hand.

What should the engineer do before attaching his engine to a train? He should comply with any regulations there may be in regard to registering; examine the shop book to ascertain whether or no the repairs have been made that have been ordered; look over the engine carefully and remedy any defects there may be; try the gauge cocks (219) and both injectors (179), and see that the engine is supplied with the tools, supplies and blocking it requires. He should also ascertain whether the fireman has attended to his duties or not.

Fig. 9.



Wedge Made of Hardwood—4"×4", 3ft. long.
For Use in Case of Broken Spring or Hanger, Tire or Axle, Equalizer, &c.
Two of These should be on Every Engine

What precaution should be taken if work or repairs, such as having valves faced, brasses filed, etc., have been done to the locomotive? The engineer should examine to see that the work has been properly done and whether the parts require lubrication or not. In any event, they require to be given special attention, as new parts are always liable to run hot and cause rough bearings.

When everything is ready, how should the engine be started? In full gear. The throttle

(195) should be opened slowly and carefully in order to start the train without a jerk. This lessens possible injury to draw bars, and in the case of passengers and freight minimizes the annoyance and danger.

Is the engineer required to see that his entire train is attached? Yes.

Should the bell (132) be rung before starting? Yes, always.

In what manner should water be supplied to the boiler? Continuously, except when starting the train. The quantity should be regulated according to the work the engine has to do.

After the engine is started, what particular thing will especially facilitate its economical working? The use of a full or wide open throttle (195), except when the engine can do the work with less than a six-inch cut-off; also, by regulating the speed by means of the reverse lever (217).

When an engine is to be taken over the road without a train, what should be done before starting? If the rules permit an engine passing over the road without a conductor, it would be necessary to make such entries as the rules require in the train register; also secure running orders; also see that the engine is supplied with necessary lanterns, flags, torpedoes, etc.

If the engine should break down between stations, what should be done? The line should be protected at once by the use of the danger signals prescribed by the company. Afterward the engineer should investigate as to the extent of the damage and repair same if possible, so that he might at least go forward to the nearest siding, from whence he would report the matter to the proper official.

What is meant by the "total wheel base" of a locomotive? The distance from the center of the front to the center of the back wheel.

What is meant by "rigid wheel-base?" The distance between the centers of the front and back driving wheels.

Why is the top rail of the frame not made straight? (See Plate I. and cuts on pages 62 and 114 of *Railway Equipment*, Vol. I.; also Figs. 22 and 23.) To give slope to shallow fire-boxes, so that the flues will be further above the grate.

Why are the piston rods frequently extended out through the front cylinder head, as shown in Fig. 139? In order to better guide the piston and produce more uniform wear of the cylinders. This is the practice, noticeably, with the large cylinders of compound locomotives.

DUTIES AND RESPONSIBILITIES OF ENGINEERS.

THIRD EXAMINATION OF FIREMEN.

NOTE.—The questions propounded, and the answers thereto, that constitute the third examination are given below. It will be remembered that this is the final examination and the fitness shown by the applicant, together with the general character he has established, determine whether he will be thought competent to be promoted to the position of engineer or not. It will be observed that this examination is much more elaborate than those that have preceded it. However, study and experience will enable the applicant to pass it without difficulty. A perusal of the questions and the responses thereto strengthens the suggestions previously made that many engineers who have never been critically examined in regard to the construction, maintenance and working of the locomotive will greatly strengthen their position by familiarizing themselves with the points this and the other examinations bring out. It will be noticed that the duties indicated are such as belong to the engineer to perform or that he is responsible for. I also wish, in this connection, to again call particular attention to the accompanying diagram of the locomotive; also to the description of the locomotive embraced in the companion volume to this on *Railway Equipment*. The description in question is accompanied by forty-four engravings prepared especially for this work, and representing the main features of the machine, namely: Longitudinal section of boiler; front view of locomotive; rear view of locomotive; sectional views of locomotive through the exhaust chamber and the live steam chamber; side view of American bogie (or pony) truck, supporting forward end of locomotive; sectional views of locomotive through the forward driver and the fire-box; side view of American locomotive truck, supporting forward end of locomotive; evolution of the coal burner smokestack; side view of injector; section of injector; force pump; check valve for preventing water returning; section of boiler fuse plug; section of safety valve; interior of steam gauge; exterior of steam gauge; section showing action of steam in single-expansion cylinder; end view of cylinder; two and four bar crossheads; section of indicator; side view of eccentrics, straps and reversing gear; end view of reversing gear; engineer's lever in connection with reversing gear; section showing action of steam in compound cylinder; front view of compound cylinder; section of starting valve and relief cock, compound cylinder; application of starting valve and relief cock, compound cylinder; section showing grate and damper; longitudinal section of locomotive boiler filled with water; part section of boiler, showing blower; section showing spark arrester; section showing fire-box and tank arrangement for the use of oil as fuel; fuel oil burner; side view of tender with water scoop dropped; section of tender showing water scoop in track tank; front view of tender with scoop in track tank; rear view of tender; equalizer, side view; sand pipe of locomotive, supplemented by steam or air blast; steam whistle; cylinder relief cocks; side view of locomotive; eight wheel passenger locomotive; chart of standard American locomotive.

Notwithstanding the exceptionally large number of engravings in the volume *Railway Equipment*, I have had many original engravings of a more special character prepared for this edition of the Manual. Hence it is that I feel justified in thinking that, while many so-called catechisms and progressive examinations have been published and are very well in so far as their limited scope permits, the combination of this Manual together with the other volumes comprising the *Science of Railways*, will be of untold advantage to students of railway matters.

The book *Railway Equipment* also contains a technical and exhaustive account of the working of the air brake, illustrated by thirty-two expressly prepared engravings. It also further contains a detailed and scientific account of the practical application of electricity as a motive power to general transportation, illustrated by eighty engravings prepared expressly for the volume in question.

In the event the injector (179) should not work while on the road, what action would you take? If the tank valve was open and the tank contained water, I should look for the stoppage in the hose (237) or strainer. If I found them all right, I should conclude there was something the matter with the injector (179) and act accordingly.

What should be done in regard to the water level meanwhile? It should be watched, and the fire-box door opened so as to prevent the engine blowing off. If the water should get low, I would bank the fire.

To what cause, as a rule, is the failure of the left-hand injector to be attributed? Non-use.

What should be done to obviate this? Both injectors should be used daily.

In what way can both injectors be kept in good order? By their alternate use, say, one used on the out-trip and the other on the return trip, or by using one at terminals and the other while running.

What is the difference between "priming" and "foaming" of a boiler? Priming is caused by contracted steam space or the boiler being too full of water. Foaming is caused by foreign substances, such as oil, soap, etc., getting into the water.

What would you do in the case of foaming? I would shut off the throttle and injectors and ascertain the true level of the water, by allowing it to settle; then I would open the fire door so that the engine would not blow off. If the water should drop too low, I would open the throttle and apply the injectors. If there was a surface cock, I would open it, if there was none I would handle the engine carefully until reaching a point where the boiler could be washed out.

What would you do if you discovered that the water in the tank contained oil? I would proceed as in the case of foaming, until I reached a water station, when I would flush the tank, using the heaters in the tank to bring the oil to the surface. *

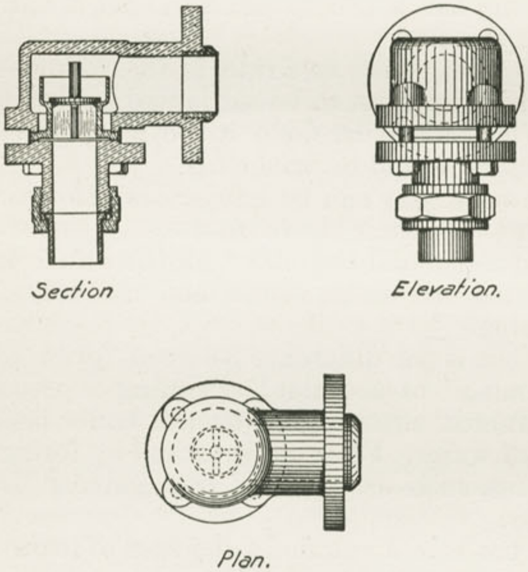


FIG. 9A.

Check valve, for preventing water from running.

What attention should be given to boiler attachments, such as the gauge cock (219), water

*Brown sugar put into the hose and forced into the boiler will generally counteract the effect of the oil.

glass, etc.? They should be looked after to see that they are in good working order and are not clogged or filled up.

What should you do if a wash-out plug (104) was blown out, or a blow-off cock could not be closed or was broken off? I should dump the fire, plug up the hole and re-fill the boiler. If I found it impossible to plug up the hole, I should send for assistance to take the engine to a place where it could be repaired.*

If the check valves (Fig. 9A) remain open after the injector stops working, how would you proceed to close them? I would tap the valves gently on the top or bottom of the valve case, preferably with a piece of wood, being careful not to hit the sides of the valve if it is made of brass.

If you could not re-fill the boiler, what would you do? I would disconnect the engine and arrange to have it hauled to some place where it could be repaired.

What parts would it be proper to disconnect? It would be proper to disconnect the valve stems (49) and take down the main rods (92).

How can a disconnected tank valve be opened without stopping the engine? By closing the water valve (185) and injector overflow (180) and blowing steam through pipe (236) and hose (237) suddenly.†

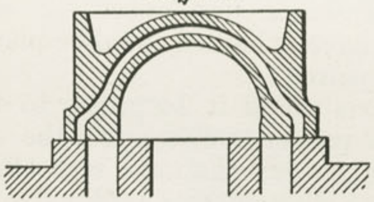
*Blow-off cocks are located in parts of the boiler where mud or other incrustating matter is liable to settle. By their means such sediment is ejected from the boiler.

†This will generally blow the tank valve out of its seat, but steam should be shut off quickly to prevent bursting the hose (237).

What would you do if you stopped the engine working and the water in water glass dropped out of sight? I would open the throttle so as to raise the water above the crown sheet, deaden the fire if necessary, and immediately set both injectors to work.

What should be done in the case of a disconnected throttle?* If the throttle becomes disconnected and remains open, the steam pressure should be reduced so that the engine can be handled with the reverse lever (217). The trainmen should be notified of the mishap and a report made of it at the first telegraph office. If the throttle becomes disconnected and remains closed the engine should be disconnected.

Fig. 10.



—Allen Ported Valve—
—Central Position—

What should be done with a flue (122) that leaked badly or had burst? It should be plugged,

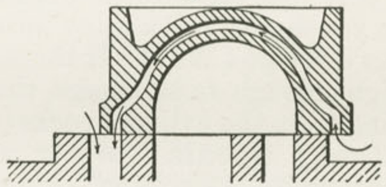
*A disconnected throttle signifies that either the throttle valve (195) has become disconnected from the throttle bell crank (196) or that the latter has become disconnected from the throttle stem (197). It will readily be seen that in either event the movement of the throttle lever (215) will not open or close the throttle valve.

and the engine should be provided with tools suitable for that purpose.

What should be done if the whistle (202) or one of the safety valves (201) blows out? They should be plugged with soft wood, tied or otherwise secured.

What would you do if the engine was stalled in the snow and the water in the tank was low? I would shovel snow into the tank and melt it with the heaters.*

Fig. 11.



—Allen Valve—
—Early Admission Period—

How low would you allow the water in the tank to get before shoveling in the snow? Not lower than one foot.

Can the boiler be filled with water through the injectors by towing the engine with another locomotive? Yes.

How is this done? Close all openings from the boiler except those from the tender, open the engine throttle and both injectors, leaving the

*The term "heater," as usually applied to a locomotive, signifies the supplying of steam to the tank through the feed pipe (236) and hose (237) from the injector (179) after closing the heater valve, as shown in the supply pipe (119) above the overflow (180).

reverse lever in the ordinary position for that direction in which the engine is being towed. The pistons will form a partial vacuum in the boiler, and water from the tender will be drawn in. It is evident that any air suction valves (Fig. 8) on the steam chest must also be closed in some way.

If the throttle was closed and steam still came out of the cylinder cocks (68) what would you do? I would see if the oil pipes (123) from the lubricator (224) were closed, If they were, then I should report that the throttle (195) leaked.

How can you distinguish a leaky throttle (195) from a leaky dry pipe (191)? If the water in the boiler is high enough to submerge the dry pipe, steam issuing from the cylinder cocks (68) would indicate a leaky throttle. Water and steam would indicate a leaky dry pipe. If the dry pipe is not submerged, the location of the leak cannot be determined.

How should a hot bearing be treated? It should be lubricated and packed, and cooled so far as practicable before going ahead.

How would you proceed with a cracked steam chest (44)? I would loosen the steam chest cover (43) and insert iron wedges or nails between the steam chest bolts and sides of the chest, and fasten down the steam chest cover.

How would you disconnect if you had a broken steam chest (44)? I would disconnect the valve stem (49), cover the admission ports (56), take down the main rod (92) and block the cross-head (96).

How are the steam chests and covers usually ruptured? By reversing the engine at high speed without opening the throttle.

With a totally demolished steam chest and cylinder on one side, what would you do? I would put out the fire, disconnect both sides of

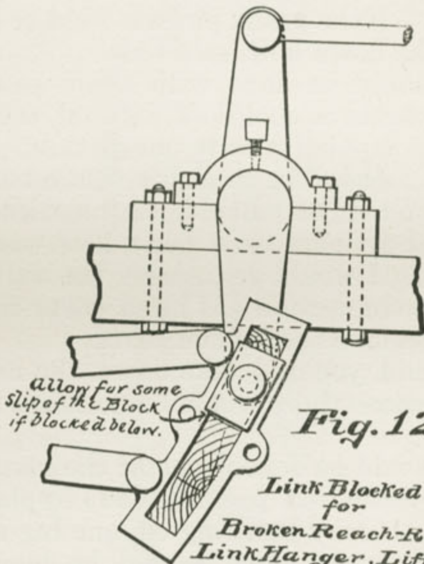


Fig. 12.

Link Blocked Up for Broken Reach-Rod, Link Hanger, Lifter, or Saddle Pin.

the engine and ask to have it hauled to the shop. Repairs might be made by putting a solid gasket in the steam pipe, but as a rule this is not practicable.

What can be done if the lifting shaft (112), reverse lever (217) or reach rod (118) break? The links (105) can be blocked up to the point at which the engine should cut off, as illustrated in Fig. 12. It must be remembered, however, that it is impossible to reverse until the block is changed.

If the piston (60 and 61), crosshead (96), connecting rod (92) or crank pin were bent or broken, what would you do? I would disconnect the engine. If the crank pin was bent or broken, I would take down both side rods.

What should be done with a hot piston rod (60)? It should be cooled off with oil, the engine being kept moving slowly meanwhile. Water should not be used in cooling a piston rod.

If a piston rod (60) should break and knock out the forward cylinder head (64), how would you disconnect? I would disconnect the valve stem (49) at the connection (51) and cover the ports (56) and remove the broken parts.

Why would you not take down the main rod (92)? Because there would be no harm in leaving it up.

What should be done if one of the glands that holds the piston rod packing (59) in place was blown out, thereby breaking off one lug and one bolt? The piston gland should be blocked or secured, if possible; if not, the engine should be disconnected on that side.

What will indicate that an eccentric (*BB* Fig. 12) has slipped on the axle (*A*)? The irregular sound of the exhaust.

How can you determine which eccentric has been displaced? By running the engine slowly with the link first in full forward motion, then

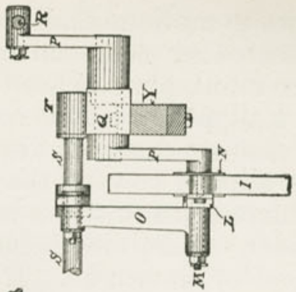


Fig. 14. End View.

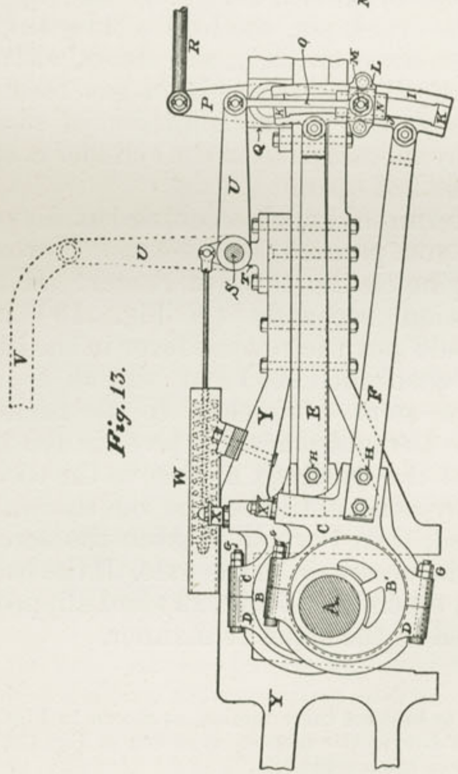


Fig. 13. Side View.

Eccentrics, Straps and Reversing Gear.

A—Axle.
BB'—Eccentrics.
CC—Front half of eccentric-strap.
DD—Back half of eccentric-strap.
E—Forward motion eccentric-rod.
F—Back motion eccentric-rod.
GG—Eccentric-strap bolts.
HH—Eccentric-rod bolts.
I—Reversing-link, front half
J—Reversing-link, back half.
KK—Reversing-link filling pieces.
L—Reversing-link saddle.
M—Saddle pin.
N—Link-block.
O—Link-lifter.
PP—Rocker-arms.
Q—Rocker-shaft box.
R—Valve rod.
S—Reversing or tumbling shaft.
T—Reversing shaft box.
U—Reversing-arms.
V—Reach-rod.
W—Spring counter-balance.
XX—Eccentric oil-cups.
Y—Frame of engine.

in full backward motion, and observing if the steam is admitted at each end of the cylinder just before the crank pin reaches the dead points. The effect of a slipped eccentric on the valve is either to increase or diminish the lead. If the eccentric has slipped toward the crank pin, the lead will be increased and steam will be admitted to the cylinder sometime before the piston reaches the end of its stroke. If it has slipped away from the crank pin, the lead will be diminished, or taken away entirely, and steam will not be admitted until after the piston has reached the end of its stroke.* The admission of steam is indicated by its escape from the cylinder cocks, which must be left open.

Having determined which eccentric has slipped, how would you proceed to reset it? I would place the engine on the forward center. If the forward motion eccentric (*B* Fig. 13) had slipped, I would put the reverse lever in the back notch of the quadrant (220) and scratch a line on the valve stem (49) close to the packing gland. Then I would place the lever in the forward notch of the quadrant and move the eccentric around by hand until the line on the valve stem appeared; then I would tighten the screws that fasten the eccentric to the axle. If the backward motion eccentric (*B* Fig. 13) had slipped, I would proceed in the opposite manner.

*This applies to indirect valve motion, as shown in Figs. 13, 14 and 15. With direct valve motion, as shown in Fig. 123, the reasoning would be the reverse.

What is the position of the eccentric when the crank pin is on the forward center? With the standard type of rocker arm (*P*), which gives indirect valve motion, the forward motion, (go-ahead) eccentric always follows, and the back-up eccentric always leads the crank pin at right angles, less the amount of lap and lead, when the engine is moving forward, see Skeleton Fig. 15.

INDIRECT VALVE MOTION
WITH ROCKER ARM

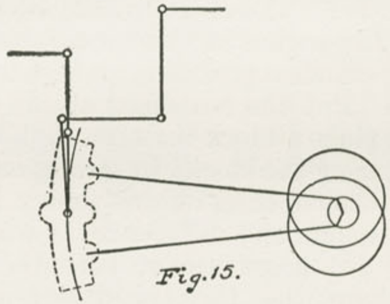


Fig. 15.

In the event of a valve (47), valve yoke (48), or stem (49), becoming broken inside of a steam chest (44), how can the breakage be located? To test one side, place the piston at half-stroke and admit a little steam to the cylinders, then move the reverse lever (217), from full forward to full backward gear. If the steam escapes alternately from both cylinder cocks (68) it may be concluded that the defect is in the opposite steam chest.

Having located the defect, how would you put the engine in safe running order? By taking off the steam chest cover (43), and blocking or fastening the valve (47) centrally as shown in Fig. 16, or by plugging the ports (56) with soft wood boards if the valve was broken. The defective side should then be disconnected and the cross-head (96) securely blocked.

If the valve seat (52) is broken, what should be done? Take off the steam chest cover, cover both steam ports (56) as shown in Fig. 16 and disconnect the engine.* In some cases the false valve seat may be removed.

Is it necessary when disconnecting to block the crosshead (96)? Yes. It is the safest thing to do in case the ports (56) become uncovered.

How and in what position is it best to block the crosshead? Put the crosshead at one end of the stroke and place a block between it and the guide blocks, securing the blocks by strong cord or wire, to prevent their falling out, as shown in Fig. 17.

Does it make any difference at which end of the stroke you block the crosshead? Yes. On engines where the forward driver is opposite the guides, the crosshead must be blocked clear ahead so that the forward crank pin will not strike it.

If a disabled engine is being handled on one side, what is the best method of stopping so that

*Disconnecting one side of an engine, as in this case, means the removal of the main rod or rods on one side, securing the crosshead (preferably at the back end of the guides (89), as shown in Fig. 17, if it will clear the crank pin in that position) by means of a crosshead clamp or hardwood blocks, well secured, and setting the valve in a central position so as to cover all steam ports, and securing it there by a valve stem clamp or by cocking the valve stem gland and setting the gland nut tight on one side. An engine may still be operated if only one side of it is disconnected.

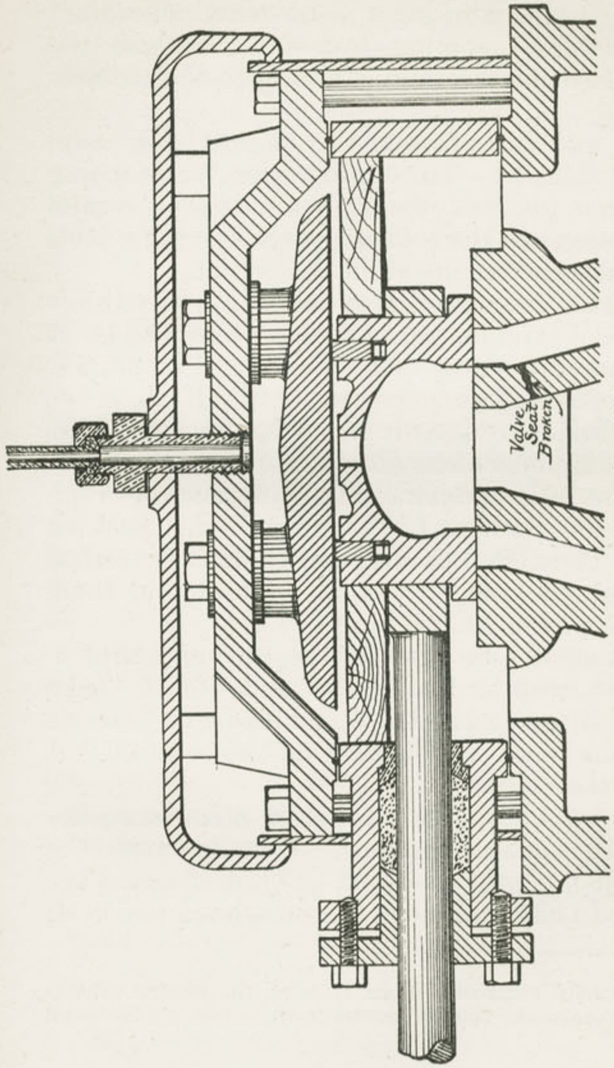


Fig. 16.
Richardson Balanced Slide Valve
Also showing Method of Blocking any Slide Valve for Broken Valve Seat or Other Breaks Inside of the Steam Chest—

the side that is working will not stand on center? Shortly before coming to a stand, release the brakes, reverse the engine and open the throttle slightly.

Why will this prevent the engine from stopping on center? The final power for stopping comes from the back pressure against the piston and this acts against the rotation of the driving wheels only when the engine is off the center.

How can you distinguish between a valve blow (47) and a cylinder piston packing blow (62)? A valve blow is generally continuous and a cylinder piston packing blow intermittent. If it arises from cylinder packing it will blow the strongest at the commencement of the piston stroke.*

Do you fully understand the difference between piston rod packing (59) and cylinder packing (62)? The piston packing rings (62) are termed "cylinder packing," to avoid confounding them with the piston rod packing (59).

What should be done in the case of a broken eccentric strap or blade (160 and 162)? Take down both eccentric straps and blades on the side where the break was located, and disconnect that side of the engine.

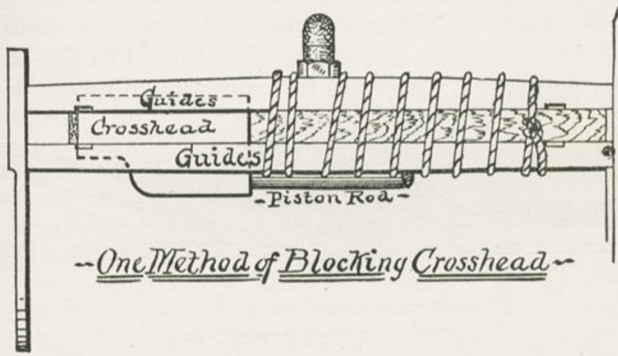
How would you disconnect if a lower rocker arm (116) became broken? I would cover the ports (56), clamp the stem (49), disconnect the main rod (92) and block the crosshead (96). If

*A wasteful escape of steam through the engine exhaust nozzle is termed a "blow" in contradistinction to the usual "exhaust."

the broken lower arm did not strike anything I would allow it to remain as it was.

What can be done in case a link saddle pin (107) breaks? The hanger (111) can be taken down and the top of the link (105) blocked up with a piece of wood to the point at which you wish to cut off.

Fig. 17.



—One Method of Blocking Crosshead—

If the link hanger (111) or lifting arm (112) should break, what would you do? I would do the same as in the case of a broken saddle pin.

Would you reverse the engine under these conditions? No.

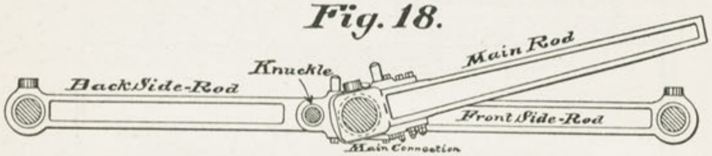
If you should lose a rod key, what would you do? If it was a main rod key, I would substitute a side rod key, if the engine had one, and put a wooden key in its place.

How would you disconnect in the case of a broken crosshead (96)? The same as for a broken cylinder head. I would disconnect the engine on the side on which the break was located.

If the engines have six or more connected driving wheels, what side rods should be taken off, if opposite ones are broken? If the knuckle is back of the pin, as in Fig. 18, and the back section is broken, the corresponding side rods on the opposite side should be taken off. If the forward section is broken, all side rods should be taken off.

How would you disconnect if you broke a main crank pin close to the wheel? I would take off all side rods (152) and disconnect engine, and fasten the crosshead (96) and valve (47) (with steam ports (56) covered) on the broken side.

Fig. 18.



—Rods &c.—
—For Mogul or Ten-Wheel Engine—

Which are the main drivers of a locomotive? That pair of wheels to which the main rods are attached.

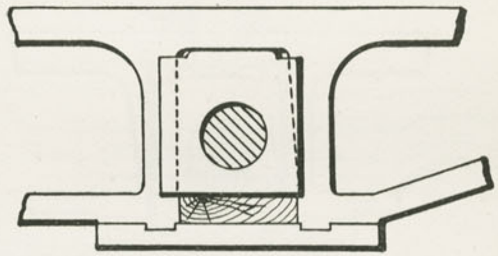
On which axle is it customary to place the eccentrics, and why? On the main axle, so that the engine can be run, even with all the side rods taken down.

Describe the difference between a standard, mogul, ten-wheel and consolidation engine. A standard engine has four drivers, connected, and a four-wheel truck. A mogul has six drivers, connected, and a "pony" or two-wheel truck. A ten-wheel engine has six drivers, connected, and a

four-wheel truck. A consolidation engine has eight or more drivers, connected, and a "pony" or two-wheel truck.

If one of the forward tires (137) of a ten-wheel engine should break, what would you do? I would run the wheel with broken tire up on wedges (see Fig. 9) placed on the track, so as to raise the tire above the rail and insert in place

Fig. 19.



Wheel Blocked Up
For Broken Tire or Axle

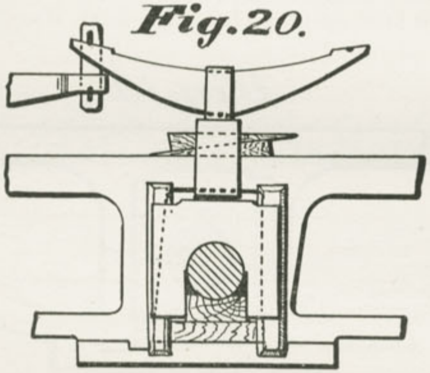
of the cellar a block thick enough to hold the tire off the rail, as shown in Fig. 19. Then, if the rods were not sprung, I would go ahead with the train.

What would you do in the case of the tire on a rear driving wheel breaking? I would proceed as in the case of a broken front tire, running very carefully, especially around curves.

What would you do in the case of a broken main driving wheel tire (137)? I would block up the wheel to the thickness of the tire, loosen the side rod keys and proceed carefully without the train.

How would you proceed to run a mogul engine with the back tire off? I would remove the cellar and insert a block between the pedestal and

Fig. 20.



~~ Driving Axle Broken Outside the Box ~~

journal so as to hold the wheel center off the rail and then take off both back sections of the side rods.*

*The cellar of a journal is a hollow, box-like casting placed beneath the journal. In conforming as nearly as possible to that portion of the journal not covered by the brass, it serves a double purpose—to keep dust and dirt from the journal, and, being packed with waste, wool, hair or other similar substance saturated with oil, greatly assists to a proper lubrication of the journal. The bolts or keys that secure it in place are termed cellar bolts.

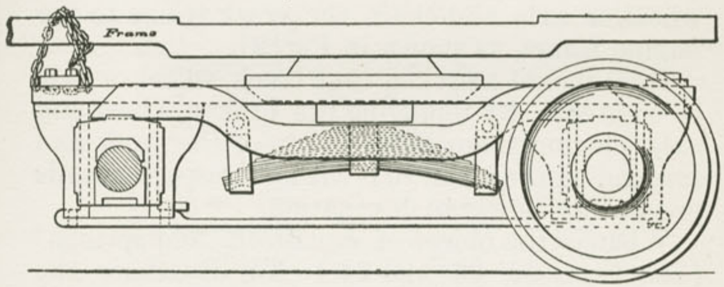
The pedestals are the jaws of the frame of a locomotive, between which the driving boxes (150) are held.

What would you do under similar circumstances with an eight-wheel standard engine? I would endeavor to run the engine to the shops, by placing wedges between the tank and engine, thereby blocking up the engine so that the weight will be against the flange of the good wheel.

How fast would you run in that condition? Not exceeding five or six miles per hour, and very slowly on curves and switches.

Fig. 21.

—For Broken Eng. Truck Wheel or Axle—



If the back tire of an engine were off, how could you fix the engine so as to safely back around curves, if necessity required? With standard (eight-wheel) engines, by blocking as for broken rear tire on a mogul; that is, relieve all possible weight from rear drivers. With a mogul, you would have to block with soft wood between engine and tender on the inside of the curve.

In case the axle of a driving wheel should break, how should the axle be blocked up and part of the weight relieved from that box? Hardwood blocks should be used to block the axle up level; blocking under the spring saddle will take part of the weight from the box, as shown in Fig. 20.

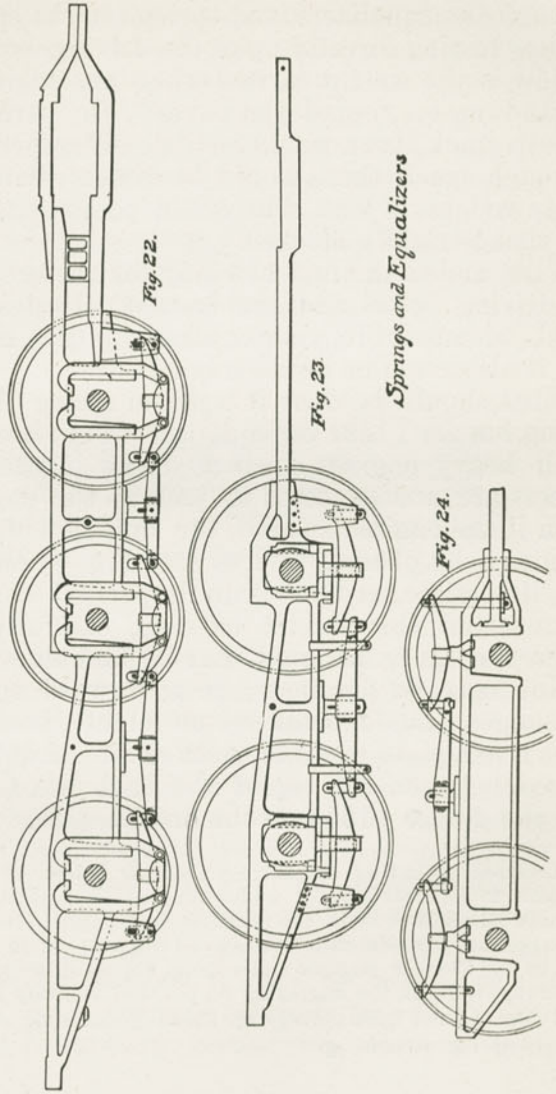
What would you do in the case of a totally demolished tank truck? I would go to the nearest siding and send for help. In case of necessity I would substitute a car truck.

What should be done if an engine truck wheel (71) or axle (73) breaks? Remove the broken wheel or axle and chain the truck frame to the engine frame, as shown in Fig. 21.

How should a broken tank truck, wheel or axle be treated? By removing the broken wheel and axle, placing a cross tie on top of the tank and suspending the truck to it with chains, afterwards proceeding slowly to destination.

What is the object of equalizers and springs? (See Figs. 22, 23 and 24.) To distribute the weight of the locomotive more equally upon all the bearings and to make the engine ride easier, thereby lessening the wear and tear on the machinery as well as affording greater comfort to the enginemen.

When the springs and equalizers are in order, where is the weight of the engine carried? The frame and the boiler resting upon it is supported at the engine truck center in front and at the fulcrums of the equalizers and, from these latter points of suspension, the weight is transferred



Springs and Equalizers

through the equalizers and springs to the spring saddles resting directly upon the driving boxes.*

How is the weight carried when an engine is blocked up on top of the boxes? On perfectly smooth track there would be little difference, but on rough track there would be times when the whole weight of one side would come upon the box that is rigidly blocked.

What makes the best blocking for use between the driving boxes and the frame? Good hardwood, because of its greater elasticity than metal and it also remains in place better.

What should be done if a driver spring (141), spring hanger (142) or equalizer (143) breaks? With heavy engines such as those in use, engineers are not expected to jack up the engine. Even if the engine is small, the quickest way is to raise it by placing wedges (see Fig. 9) on the rail, if possible, as time is an important consideration; but this should be done carefully, as other springs or hangers may be broken or the engine may be derailed. If a forward spring or hanger should break on an eight-wheel engine, a fish-plate or other piece of iron should be placed between the top of the back box (150) and the frame (155) on the broken side. This

*Locomotives having the springs above or below the frame are said to be over-hung or under-hung, as the case may be. There is no difference in the principle, but simply in its practical application to the various classes of engines. Plate I. and Figs. 22 and 23 show engines under-hung, Fig. 24 shows springs over-hung, while in the engraving on p. 114 of *Railway Equipment* (Vol. I.) the back springs are shown under-hung and the forward springs over-hung.

will save raising the wheel that much higher and will permit the use of a smaller wedge. Then a wedge should be placed on the rail and the back wheel run up on it. This will take the weight off the forward box. I would then block solid with wood between the top of the forward box and the frame and remove the spring saddle, if necessary, as in Fig. 25; then let the engine down, remove the fish-plate from the back box and run the forward wheel up on to the wedge, which will take the weight off the back box and

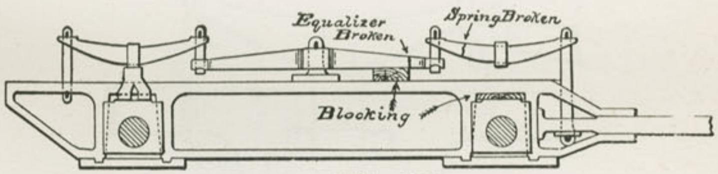
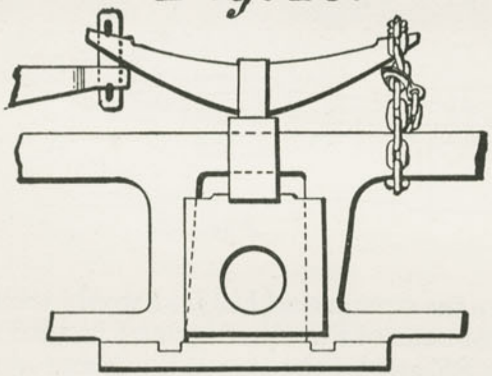


Fig. 25.

relieve the equalizers (143). I would then pry up the front end of the equalizer and block it solid, as in Fig. 25, and let the engine down and remove all loose parts. If the back spring or hanger is broken, the reverse should be done. If it is a mogul or ten-wheel engine, I would run the forward wheel up on the wedge in order to raise the weight off the main wheel, or run the main wheel up in order to raise the weight off the forward wheel. If it is a mogul engine, and a forward spring or hanger breaks, it may be necessary to remove both forward springs and block on top of both forward boxes; but if it is only a hanger that is broken, a chain may replace it, as in Fig. 26. When both forward driving boxes are blocked, the intermediate equalizer to the truck should also be blocked. When the springs and hangers are below the frame, I would proceed in the same manner, and then block or chain up the equalizer (143) until level and remove or secure the broken springs or hangers. When the spring hangers (142) straddle

Fig. 26.



Broken Hanger Replaced by a Chain

the frame (155) it is sometimes possible to block between the hanger and the frame. If the large spring (141) below the frame (155) and between the drivers (138) should break, I would block the top of both boxes (150) or block between both long hangers and the bottom of the frame, securing or removing the broken parts. If the small coil spring back of the rear drivers

breaks, it may be necessary to remove one of the small equalizers which ride the box. If it is necessary to do so, I would block on top of the box. If it is not necessary to do so, and the spring hanger cannot be held in any other way, I would chain the back end of the small equalizers to the frame; otherwise I would let the frame ride the box and run the engine very slowly. With equalizers broken, I would raise the engine the same as in the case of a broken spring or hanger if it is possible to do so. If an equalizer or a stand-

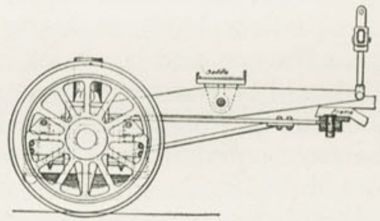


Fig. 26A.

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

ard on an eight-wheeled engine breaks, I would block on top of one box and block up the loose end of the equalizer the same as for a broken spring or hanger, if possible; if not, I would block on top of the driving boxes. If the forward equalizer on a ten-wheeled engine breaks, I would block on top of the forward and main boxes and block up the forward end of the back equalizer.

What should be done if the pony truck center pin or long equalizer of a mogul engine is broken?

If it is the cross equalizer on a mogul, block on top of both forward boxes and block on top of the back end of the long intermediate equalizer that goes to the truck; if it is an intermediate equalizer, block between the boiler and cross equalizer; if it is the cross equalizer on a four-wheeled pony, block on top of both forward boxes. If the equalizer is below or between the frames, it might be possible to block between the hangers and the frames. If it is a small equalizer that rides the back box, block on top of the back box and chain up the back end of the bottom equalizer. If it is the truck equalizer, block on top of the truck boxes between the box and the truck frame. All loose parts should be removed or secured. If a pony truck center pin breaks, replace it, or block between the cross equalizer and the boiler.

If the front end (18) should break, what should be done? Board it up, using the studs (bolts with threads cut on both ends), if possible; otherwise brace it. A wet blanket will do for a short time.

If you lost the smokestack (38) of your engine, what would you do? Substitute something that will create a draught, such as a barrel or long box.

How can you make temporary repairs to a hole punched in the engine tank, so that the engine can run to shops? By stopping the leak with burlaps, waste, or cab curtains used as a gasket, secured by means of boards inside and outside.

Why should the bottom joints (13) of a cinder hopper be kept tight? To prevent the air from

getting into the front end and causing the cinders to ignite; thus cracking or otherwise injuring the front end of the engine and weakening the draught.

If the grates (165) were burnt out or broken, while on the road, how would you manage? I would block them with brick, wood, the water pail, or other available substance, if they were not too badly burnt or broken.

Which is generally considered to be the better direction to move a derailed engine in order to get it back on the track? Retracing the path it took in leaving the rails.

What precautions should be taken to prevent the engine from emitting live sparks from the smokestack? Care should be taken to see that the netting (26) is in good condition, and that the ash-pan and its protecting screens are also in good condition. If an engine throws fire, it should be worked as light as possible and slipping the driving wheels avoided. The matter should be reported to headquarters at once.

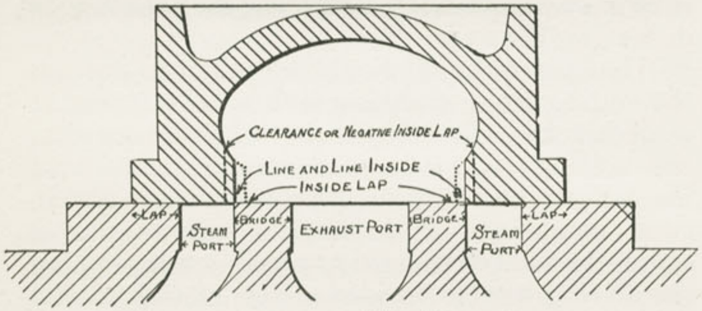
After the train has started, why should the reverse lever (217) be hooked towards the center of the quadrant (220)? To cut off the supply of steam from the boiler to the cylinders at a shorter point of the piston stroke.

What is meant by working steam expansively? Allowing the steam that is in the cylinder (57) when the supply is cut off to perform the remainder of the stroke by its expansion. Saving of fuel is thus effected.

What is meant by the "lead" of a valve (47)? The width of the opening of the steam port (56) when the piston is at the beginning of its stroke. When there is no "lead" an engine is called "blind."

What is meant by "outside lap"? The distance that the valve (47) projects over the outside edge of the steam ports (56) when it is in the center of the seat. See Fig. 27.

Fig. 27.



~Graphic Definitions of Valve Dimensions~

Why are locomotives given lap? For the purpose of enabling the engine to work steam expansively: thus the steam is held in the cylinder and expanded while the valve is traveling the distance of its lap.

What is meant by "inside lap"? The distance that the inside edges of the exhaust cavity of a valve overlap the outside edges of the bridges when the valve is in the center of its seat; negative inside lap is termed "clearance." See Fig. 27.

What effect would be produced on the lap and lead by changing the length of the eccentric blades (161 and 163)? The total lap and lead of both ends would be unchanged: what would be taken from one end would be added to the other.

Why are the eccentric blades (161 and 163) made adjustable? In order to equalize the travel of the valve (47).

Does lead increase by "hooking up" the engine, or shortening the cut-off, when the ordinary link motion is employed? Yes, the earlier the cut-off, the more lead.

How can the total lap of a valve be changed? Only by cutting off or adding to the edges of the valve.

How can lead be changed? Only by moving the eccentrics on the axle.

If lead can only be changed by moving the eccentric on the axle, how does "hooking up" an engine increase the lead, as stated above? Because hooking up throws the whole motion back around the eccentric, which acts the same as throwing the eccentric ahead through the motion.

Is it the engineer's duty to adjust the valve motion of an engine? No, except in case of derangement on the road; at all other times it should be done by shopmen.

What work about the engine should the engineer do before the engine in attached to the train? See that the wedges, nuts and bolts are tight, tighten the rods by means of the wedge keys, see that the journal oil boxes are well packed, see that all frictional parts of the engine are properly oiled and look after the headlight.

How would you proceed to tighten the driving box wedges (148)? I would block the tank wheels and place the engine on upper back eighth (see diagram) on the side to be adjusted.* I would then push the lever ahead once or twice, leave the lever forward with the steam behind the pistons and then push the loose wedge up. I would commence at the main drivers.

What are the proper positions in which to key up the main rod? The positions in which the wrist pin is the largest through the length of the main rod.

What is the necessity of keeping the brasses keyed up properly? If they are not thus keyed up, they will become loose in the straps and pos-

*For the purpose of particularizing the various positions of the driving wheel crank (when occasion requires), the 360 degrees through which it passes are divided into eight parts; the "upper quarter" represents the crank pin when directly above the main axle; the "lower quarter" when directly below it; the "forward center" locates the crank pin on a straight line between the main axle and the cylinder, the "back center" 180 degrees from there. The "eights" are the upper, lower, forward and back, as shown by diagram.

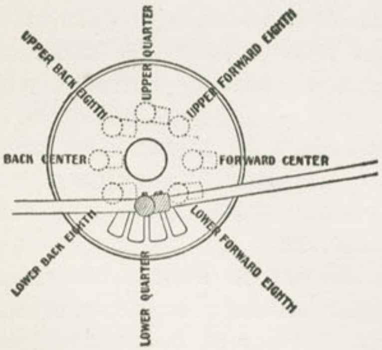


FIG. 28.

sibly break, as well as loosen everything about the engine.

How would you proceed to key up the side rods (152) on a mogul and a consolidation engine? I would first see that the wedges were properly adjusted, then place the engine on forward center on the side to be keyed, loosen all the keys on that side, key the main connection (See Fig. 18) first, and then adjust the front and back ends in the same manner.

Why is it necessary to place the engine on dead center while keying up the side rods? In order to insure the keying of the rods at the proper length and to avoid a strain in passing the dead centers.

Why should the side rods of a six-wheel connected engine be keyed from the main connection first? In order to get the proper length of all the rods.

Can the length of a side rod of an engine be altered by keying in any other position than on the center? Yes, but any other position might throw the engine out of tram.

What provision should be made in the rods for the uneven movement of the boxes on the pedestals? The rods should be made as long as possible, but still remain free on the crank pins during a full revolution.

If an engine pounds when steam is shut off, what does it indicate? That something is wrong —that the drivers are flat; that the main rods are too long or too short, or that the follower bolts (i. e., bolts for holding together the parts of the piston on the front side of the packing rings) or something in the cylinder is loose.*

Why will engines usually pound worse in full gear than when hooked up? Because in full gear the lead is the least and there is very little cushioning of the pistons.

What are most frequent causes of pounding? (1) Broken or loose driving boxes or (2) driving box brasses; (3) loose or broken main-rod brasses or (4) side-rod brasses; (5) main-rod too long or too short, causing either the crossheads or pistons to strike; (6) worn guides; (7) spider loose on the piston-rod; (8) follower bolts loose; (9) piston rod loose in the crosshead; (10) flat spots in the driving wheel tires.

What would you do in order to locate a "pounding" in the driving box (150), rod-brasses, etc. I would place the engine on the top quarter (see diagram), block the driving wheels on the opposite side, stand down by the side of the engine, and have the fireman work the reverse lever back and forth by the center, with steam in the cylinder. Then I would try the opposite side in the same way.

In what manner would you give an engine a thorough inspection on arrival at your destination? I would inspect the bearings, wheels, eccentrics, springs, hangers, and all parts of the engine that could be seen. If any defects existed I would notify the proper parties of the fact in writing.

*The blow felt on an engine from flat wheels, loose brasses, etc., is termed a "pound."

What is meant by friction? The resistance of two bodies in contact with each other; that which in any way opposes the mechanical motion or sliding of one upon the other.

Upon what does the amount of friction depend? It depends upon the pressure of one body bearing upon another, independent of the area in contact; the nature of the materials brought into

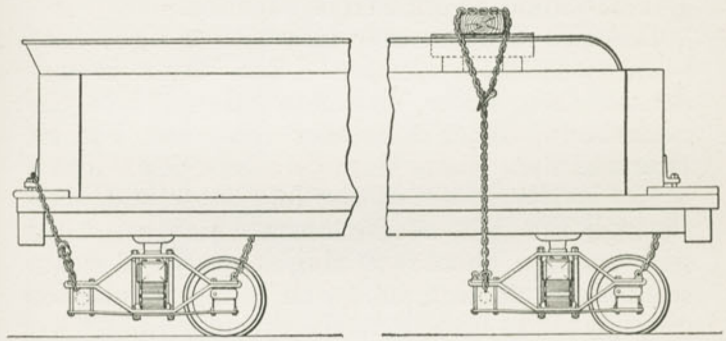


Fig. 29. Fig. 30.

— Two Methods of Chaining up Truck for Broken Wheel or Axle —

contact; the efficacy of the lubricant used; speed and temperature.

What is the effect of introducing oil or any other lubricant between frictional surfaces? The generation of heat is prevented, and the surfaces between which there is friction are prevented from coming together, thus minimizing the friction.

What rule should be observed in regard to oiling an engine? All parts requiring it should be oiled, using no more oil than is necessary. The amount of work the engine has to do, the temperature and the weather must to be taken into consideration.

How great a distance should an engine run to a pint of engine oil, or a pint of valve or cylinder oil, and how should an engine be oiled to effect the greatest economy? The best record made by any engine of a similar class and doing similar service should be equaled or excelled.

Describe the manner in which a sight feed lubricator (224) operates? The steam is condensed into water and flows down into the reservoir, as water is heavier than oil. The oil rises and then passes through a tube down into a cavity in the bottom of the lubricator, and then through the sight feed glasses, which are filled with water. There it is caught by a jet of steam from the equalizing tube and is taken into the oil pipe (123) leading to the cylinder (57).

Describe the principle upon which injectors (179) work? The action of injectors is due to the fact that the velocity of steam escaping from a boiler at a certain pressure greatly exceeds the velocity of water under the same pressure, and consequently, when the water is brought in contact with the steam, the steam imparts its velocity to the water, and, by mixing with it, is condensed.

The following explanation of the accompanying engraving of a rudimentary injector, Fig. 31, will make clear the principle: In Fig. 31 the steam pipe terminates in the nozzle *N*, inside of a cone *C* on the end of the feed pipe. When

steam is admitted through valve *V* to the steam pipe it escapes through the nozzle *N* and the cone *C*, and this current of steam produces a partial vacuum in the latter and in the feed pipe, thus drawing water up from the water tank into this cone *C*, where it encounters the jet of steam

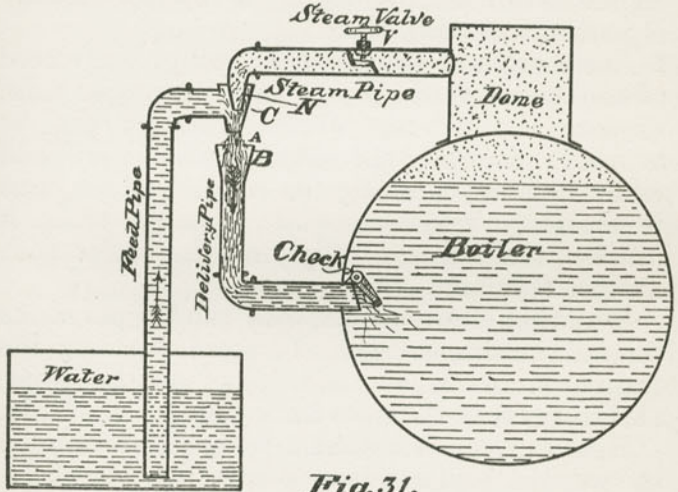


Fig. 31.
Injector Principle

from the nozzle *N*, both escaping at *A*. But when the water mingles with the current of steam in the cone *C* the steam is condensed, imparts its velocity to the water, and the jet escaping from *C* consists of water only. This at first overflows at *A*, but after a few seconds its velocity has become so great that the momentum of the water forces the check valve open and flows into the boiler against the pressure therein. By closing the steam valve *V*, the injector ceases to work and check is closed by the pressure from within the boiler. The actual construction of an injector is shown in *Railway Equipment*, Vol. I., p. 78.

Will an injector sometimes work better and an engine steam more freely if the injector throttle is partially closed? Yes.

Name some of the principal things considered as an abuse of the engine? Lack of proper care; slipping the driving wheels when it can be avoided; catching the driving wheels on sand while slipping; working the engine harder than is necessary; reversing while running, when it can be avoided, and supplying the boiler with water irregularly.

Why should sand from both sand pipes strike the rail simultaneously? To avoid straining the engine more on one side than on the other; also to prevent the tires from wearing unevenly.

How can you tell when a wedge is stuck? By the way the engine rides. Wedges are placed between the pedestal and the driving box; the box moves up and down on faces of wedges; when it does not, or becomes rigid by being cut, it is termed "stuck."

How would you proceed to pull down a wedge that had become stuck? By running the wheel over a nut on the rail or by causing a downward strain on the wedge bolt. Being wedge shape, by pulling it down it increases the space between the pedestal and driving box and releases the latter.

What is the principle of the compound locomotive? This is fully explained under the chapters on the Compound Locomotive hereinafter contained.

Explain the working and operation of each class of compound locomotive used on this road. (See chapters in this volume referred to.)

Should the fireman conform to your views of what is best while on the engine? Yes, but matters should be talked over and explanations given when necessary.

In case of accidents on a busy main line of the road, what is of first consideration? After protecting the train, to get the main line clear as soon as possible.

What circumstances will govern procedure in such a case? If the engine can be cautiously moved to a nearby siding, there would be the proper place to disconnect and make temporary repairs; if a wreck occurred on double track, one track should be cleared first to permit trains to pass around the wreck and facilitate the work of the wrecking car.

To repeat a former inquiry, wnat is the proper method of firing? Firing light and often and having the coal broken into fine pieces and evenly distributed over the fire.

AIR BRAKE EXAMINATION.

NOTE.—In the book on *Railway Equipment* great pains have been taken to describe the air brake and how it is worked: It was intended to be exhaustive or at least more complete than anything hitherto written on the subject. What follows is embodied here, because it forms a part of an examination of "would-be" engineers that I am describing for the benefit of those concerned. The account of the air brake in *Railway Equipment*, referred to above, covers nearly a hundred pages and is profusely illustrated. I would recommend it to firemen who seek to be engineers, and all others who wish to post themselves in regard to the construction, maintenance and operation of the air brake.

In regard to the particular air brake referred to (the Westinghouse), I adopt that, not because I have any interest whatever in the brake or its owners, but simply because it is more generally used than others, and is therefore of greater general interest. To understand it thoroughly will enable the student to quickly familiarize himself with other forms, because while details differ in many essential things, yet the object and general means of attainment are the same. M. M. K.

Can you trace the air through the air brake system? Yes. The air is received from the atmosphere through the air cylinder (169) of the pump; from there it is carried through the discharge pipe (172) to the main drum (99); then through the engineer's valve (218) to the train line (231); through the branch pipe, cut-out cock and triple valve to the auxiliary reservoir (to charge the cars); then through the triple valve to the brake cylinder (to set the brake); then through the

triple valve to the atmosphere (to release the brake). When a retainer is used, the final exhaust has to go through the retainer.

Are Westinghouse air pumps single or double acting? They are double acting.*

Under what circumstances will a pump compress air in but one direction? When any one of the four valves in the air cylinder are fast or broken.

How should an air pump be started and lubricated? It should be started slowly and should be lubricated by putting eight to ten drops of cylinder oil in the steam cylinder (170) as soon as the water has worked out. The harder the pump's service the greater should be the amount of oil supplied thereafter.

At what speed should a pump be run? It should be run at a uniform medium speed not sufficient to cause excessive heating.

What kind of oil, if any, should be used in the air cylinder (169) of a pump and where should it be applied? Engine oil should be used, and it should be applied through the cup on top of the air cylinder and not through the air valves. If a pump becomes very hot, it may be necessary to use valve oil for temporary relief. The pump should be cleaned out with lye at the end of the run. The best method for cooling it is to allow it to draw in some cold water through the air suction ports, and then a teaspoonful of engine oil. if necessary. The oil and condensed water drained

*See full explanation and illustration of Air Pump, Appendix B.

from the steam cylinder (170) of a pump while it is being started are good for the air cylinder (169), if it does not contain too much oil. The air cylinder, it may be remarked, is a very important matter, as the sensitiveness of all the air parts of a locomotive depends upon the proper treatment of the air cylinder.

What objection is there to the use of kerosene or valve oil? Kerosene is liable to explode and valve oil gums that with which it comes in contact.

Should a swab be used on a pump rod? Yes, metallic packing should always have a swab.*

What causes water to get into the main drum (99)? Compression of the atmosphere (containing moisture) causes precipitation of water.

How often should the main drum and tender drain cup be drained? Daily in freezing weather; at other times, every few days, according to the weather.

What damage does water do? In summer it rusts the pipes, and the scale falling therefrom stops the strainers and cuts the valves. In winter, if the water freezes, it bursts the pipes, or they are clogged with frost, thus preventing the working of the brakes.

What train-line pressure should be carried on an engine? That which the rules and regulations prescribe. Seventy pounds, ordinarily, is the rule.

*A "swab" is the term applied to the cotton wick or other absorbent material wrapped around a piston rod or valve rod for the purpose of lubricating the rod in its packing gland. This "swab" is kept continually saturated with oil.

The engineer is responsible, although the engine may be in his charge for only one trip.

How is the train-line pressure regulated with an 1889 valve (*D 8*) on an engine? By means of the governor (177).*

How is it regulated with an 1892 (*D 5*, *E 6* or *F 6*) engineer's valve? By means of the feed valve, when the governor is set above the required train-line pressure.†

What is excess pressure? The amount of pressure in the main drum over the train-line pressure.

When should excess pressure be carried? At all times, except when charging a train at terminals or recharging on heavy grades.

What is the value of excess pressure? It insures prompt and certain release of the brakes, especially on long trains. It is also used to charge cars quickly.

How much excess pressure would you carry with an 1889 valve? Fifteen pounds for a passenger or short train, and twenty pounds for a freight or long train.

*The 1889 valve is so designated to avoid the confusion of letters and numbers. I call it thus because it was introduced in 1889. It is more generally known as *D 8*. In 1892 another valve was introduced, and this is also designated by letters and numbers. I designate one the valve of 1889 and the other the valve of 1892.

†The 1892 valve is variously designated in different catalogues. The reason I designate it as the 1892 valve is because it was introduced in that year, and in order to avoid the confusion that the various numbers and letters cause to railway men. In some cases it is called the 1892 valve in others *D 5*, *E 6*, or *F 6*. They all refer to one and the same valve.

How much excess pressure would you carry with an 1892 valve? Twenty pounds for a passenger or short train, and twenty-five to forty-five pounds for a freight or long train.

Why would you carry a different amount of excess pressure for a freight than for a passenger train? Because freight cars have a larger train-line piping, and there are usually more cars than in passenger trains. Consequently, to insure prompt release, more excess pressure is necessary. Besides uncharged cars are often introduced (picked up) by freight trains; such trains also frequently break in two, necessitating a large quantity of air to release the brakes.

How do you regulate excess pressure with each kind of engineer's valve? With the 1889 valve in running position, the excess pressure is regulated by the tension of the spring in the excess pressure valve; with the 1892 valve, if the feed valve is properly set, the excess pressure is regulated by adjusting the governor.

What does air blowing out of the little hole in the neck of the top of the new governor indicate? It indicates that the pin valve (or diaphragm valve) is off its seat, either on account of dirt or on account of the tension of the governor spring having been reached.

If the pump stops before the maximum pressure is attained, what should be done first? Shut the pump off entirely for a minute, and then open it quickly; if it then fails to start, it is probable that the main valve is broken and cannot be fixed without protracted delay. If the pump

starts, but stops frequently, remove one of the caps of the pump (the side one preferably) and put in some cylinder oil, replace the cap and start the pump slowly. If this does not suffice, remove the reversing piston (side cap) and ascertain if the packing rings are broken. If they are, remove the broken pieces and wrap with candle wicking and oil. Next remove the center cap, pull out the reversing valve and stem, noticing as you do so that the reversing plate is not loose.

If these parts are found to be all right, put them back (being careful to put the valve in facing the reversing piston), and push the stem completely down, replacing the cap. Then if the pump starts and makes one complete stroke, up and down, the trouble is with the reversing valve plate (to get at which it is necessary to remove the top head of the pump,) or with the air piston —the piston nut has probably worked loose—to remedy which, remove the bottom air head.

NOTE.—If rubber or asbestos gaskets are used instead of copper to connect the pump, pieces of them lodged in the small ports in the top head will stop the pump. When the side cap is off, it is a good plan to turn on some steam in order to test some of these ports.*

Should the conductor be notified if the pump does not work? Yes, at once, even if the engineer expects to get the pump working before the next stopping point is reached.

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*The above description only applies to the 9½-inch pump where it has parts in common with the 6-inch or the 8-inch pump. See Appendix B.

What are the essential parts of the automatic brake for cars? The train-line, the triple valve, the auxiliary and the cylinder.

How can you distinguish between the two kinds of triple valves? The plain triple valve has a cut-out cock in the triple valve casting, or has one-half inch piping. The quick action triple valve has no cut-out cock in the triple valve casting; it is in the large one-inch or one and one-quarter-inch branch pipe.

What are these cocks for? They are to cut in or cut out the brake—that is, they are used to let the air enter a particular brake apparatus or to cut out such brake. In the case of the four-way cock in the old style triple valve, it also may be used to cut in to straight air.

Where is the compressed air kept stored for use? For all purposes, in the main drum, train-line and auxiliaries; for applying brakes, in the auxiliary, and (with the quick action triple valve) in the train-line.

How does it get there? The answer to the first question in the air brake examination describes this, also.

How rapidly does an auxiliary charge? At the average rate of about half a pound a second, when the train-line is kept at its maximum.

When should you bear this in mind particularly? When charging uncharged cars, or when recharging on descending grades.

How can you tell the pressure in the auxiliary? In a practical way by lapping the valve (position 3) and noting the black hand of the air gauge

when it stops dropping—i. e., with the brakes not set. When the brakes are applied the train line and auxiliary pressures are equal if an over-reduction has not been made.

Where does the air that enters the brake cylinders come from? It comes from the auxiliary, if service application is used; and from the train-line and auxiliary if emergency application (with quick action triple valve only) is used.

What is the office of the triple valve? It charges the auxiliary and sets and releases the brake.

How is the automatic brake applied and released? By the triple valve, which allows the air to enter and leave the brake cylinder. The triple valve is moved by increasing the train-line pressure above, or decreasing it below the auxiliary pressure.

When the train-line pressure exceeds that of the auxiliary, what is the effect on the brakes? They are released by the triple valve.

When the auxiliary pressure is higher than the train-line pressure, what is the effect on the brakes? The triple valve sets them.

In making a service application with any given pressure, what proportion of it should you reduce to get a fully applied brake? One-fourth of the auxiliary pressure, for the standard piston travel of eight inches. This because the cylinder is at that travel about one-third of the standard auxiliary's capacity.

How much should the first reduction be? From four to eight pounds, according to circumstances.

Up to ten cars of air, four or five pounds; from ten to twenty cars of air, five or six pounds; above thirty cars of air, seven to eight pounds.

Why are there leakage grooves in cylinders? To prevent a slight leak from applying the brakes. Driver brakes have no leakage grooves.

How long are these grooves? They are long enough to allow the piston to move three inches before covering them.

After making a full service application, how much pressure is there in the cylinder? The same as in the auxiliary, i. e., three-fourths of what the auxiliary had before the brake was applied, for standard eight-inch piston travel.

When and how can you obtain greater pressure than this? By using emergency (with quick action triples) before you have made much or any service application.

What is meant by an over-reduction? The further reduction of the train-line pressure after the pressures of the auxiliary and cylinder have equalized (that is, become equal).

What is the result of making an over-reduction? It is a useless waste of air and results in an irregular and oftentimes difficult release of the brakes.

If you do not make an over-reduction, how much air is it necessary to restore to the train-line in order to release all of the brakes? If an over-reduction is not made on any car, the brakes will all release together by a sudden increase of but a pound or two, even though the cars have an unequal piston travel.

How many applications are necessary to make a stop? One, usually, but not more than two.

What is the objection to more? Each application reduces the reserve pressure in the auxiliary reservoir.

When would you make more than one application in making a stop with a passenger train? When at yard limits, draw bridges, railroad crossings, meeting points, or other places of danger; also when a slippery road crossing is reached just before a stop is to be made, or at a place where sand cannot be depended upon.

Why is it dangerous to repeatedly apply and release the brakes? Because each application reduces the auxiliary pressure, and, if there is not sufficient time between the applications to recharge, the braking power is greatly weakened.

How would you handle the engineer's valve in releasing the brakes ordinarily? I would move it to full release (position 1) and bring it immediately to running position (position 2) before removing my hand from the handle.

What separates the main drum from the train-line pressure? The rotary valve of the engineer's valve when the handle is at any place except on full release. Also the feed valve of an 1892 valve or the excess pressure valve of an 1889 valve separates these pressures in running position only.

Explain the effect of a cut or leaky rotary valve or seat? It generally causes a loss of excess in running position and releases the brakes on lap. While a rotary valve might be cut in many ways, usually the leak is from the main drum to the train-line, as the seat between the two is only a quarter of an inch broad.

How would you do good braking with a leaky rotary? "Good'—the word is comparative. Rough handling of the train or jerking could be avoided if the train-line exhaust was allowed to blow out as much air, or more than the leaky rotary was putting into the train-line.

Is a leaky rotary considered dangerous? Yes, and a proper test before taking the engine out of the house would have determined the defect.

Why is it necessary to keep the rotary, feed and excess pressure valves clean? Because gum or dirt will cause them to open or leak when they should be closed, or will cause them to close when they should be open. Excellent work cannot be done if these valves are not kept clean.

Where are these valves located? The rotary valve is located under the handle key of both engineer's valves. The feed valve is located on the side of the 1892 engineer's valve. The excess pressure valve is located on the side of the 1889 engineer's valve.

What is the purpose of the engineer's brake valve drum? It enlarges the cavity above the equalizing piston without taking up space inside of the cab and making a bulky valve. This space being large, permits a preliminary exhaust opening large enough not to become easily stopped up, and yet a very slight reduction in the pressure can be had.

If this drum should spring a leak on the road, what would you do to accomplish good braking? I would plug the connection to it, plug the train-line exhaust, and use the handle in direct application (position 5), opening it carefully so as to avoid quick action, and closing it slowly so as to prevent the surge of air ahead from releasing the head brakes.

State the different positions of the engineer's valve. Full release (1), running (2), lap (3), service stop (4), and direct application or emergency (5).

What harm is causea by ieaving the 1889 engineer's valve on lap a long time and then releasing? With this valve the governor will allow a high main drum pressure to accumulate, if the train-line is below standard when the handle is on lap. Putting this into the train-line upon releasing, a burst hose will result, auxiliaries be overcharged and governor injured.

Would you run a pump fast with an 1889 valve when on a grade? Not unless there was a long train which had to be recharged frequently on account of leakage.

What is the function of the air pump governor? It automatically shuts off the supply of steam to the pump when the maximum air pressure has been obtained and readmits steam to the pump when the air pressure it is regulating falls below the standard amount.

What might prevent the governor from shutting off the steam when the maximum pressure had been obtained? The drain or waste pipe being stopped or frozen up; stoppage of the relief port in the spring cap; too long a diaphram valve; excessive leakage by the governor piston or above it; with new governors; the spring under the diaphragm valve head, broken or missing.

If the governor became inoperative, what would you do to get it in working order? I would try to adjust it by adjusting the spring. Then if it failed to work, I would relieve it of pressure and clean the diaphragm valve and valve seat with soft wood or something that would not scratch or cut them.

What would you do if the governor did not allow you more than thirty or forty pounds of air, although you had adopted the above means of repair? I would disconnect the air pipe leading to the governor and plug it up, using the pump throttle to regulate the pump for the remainder of the trip.

What is the cause of gum or dirt in the governor? Oil from the air cylinder, or the running of the pump over an ash-pit or other dirty or dusty place.

Why should the brakes on a passenger train be released before the train is brought to a full stop? To avoid the disagreeable lurch which is caused by the trucks being tilted when the train stops. The greater the amount of air in the brake cylinder at the instant of release, the longer it will take it to escape, and this must be allowed for in order to get a release at exactly the right time.

Why should you not release the brakes on a freight train before coming to a full stop? It is not necessary to do so, because the brakes on freight cars are generally hung differently from those on passenger cars, and the train may break in two.

When would you use the emergency application of the brake? Only when necessary to prevent the loss of life or property.*

Does the emergency jerk most when going fast or when going slowly? When going slowly.

How should the brakes on a freight train, with only a part of the cars having air brakes, be applied and released? They should be applied lightly at first, increasing the pressure when necessary. They should not be released until the train has stopped.

If necessary to release a part air brake train when moving, how do you handle the engineer's valve? Place the handle in running position (2), and then move it back to lap quickly, repeating this several times until nearly all of the brakes have been released, each time leaving the handle in a running position a little longer than the previous time; finally, throw the handle to full release and then back to running position.

When should the hand brakes be set on the rear of a train? Only upon a call for brakes, or when a part air brake train is backing up. In the latter case, most of the braking should be done

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*Reference to Appendix A will show that a locomotive should not be reversed after applying the brakes in emergency.

by using the hand brakes at the rear. When the engineer requires assistance, because of too few air cars, the hand brakes immediately behind the air brake cars should be used.

If you find the brakes dragging, how can you release them? By using excess very quickly, if you have it. If not, by setting the brakes enough to get excess, and then releasing quickly.

Why is it necessary to test the air brake apparatus before starting? To insure the safety and celerity of trains upon the road.

Describe the proper method of testing brakes on a train. Beginning at the rear, the brakeman should couple all the hose, open all the angle cocks except the one at the rear, see that all the cars are cut in (except such as are marked defective), see that all the hand brakes are off, and the retainers open, with the handles pointing down. The engine should be cut in last. While the engine is charging the cars, the brakeman should pass along the train and inspect it carefully to ascertain if there are any leaks. In charging a train, the pump should be run according to the temperature of the weather, in order to charge the train reasonably fast without overheating it. Where there are the average leaks, an eight-inch pump should charge a train in about one-half as many minutes as there are cars; a nine-and-one-half-inch pump twice as quickly. After the train is charged and the engineer is satisfied that it is reasonably free from leaks, the head brakeman (stationed at the head air brake car) should signal the rear brakeman (stationed at the rear air brake car), who should repeat the signal. After the engineer gets the signal from the rear man, he should apply fifteen to eighteen pounds in service application and place the engineer's valve handle on lap. The brakemen should now walk toward each other, inspecting each car, to see that it sets and holds —noting the piston travel as well. After this has been done, they should signal the engineer to release. Then the brakemen should pass each to his respective end of the air brake cars to see that all the brakes have been released, and, in winter, see that no shoes are frozen to the wheels. The head brakeman should then advise the engineer as to the number of air cars that are in good working order, and the tonnage or length of the train.

In testing brakes, why is it not advisable to use the emergency application? Because the use of service application is the ordinary method of stopping a train. Some defective brakes will set in an emergency application that will not set in service application.

Why should a full reduction be made, and not five or six pounds? Because some cars may charge five or six pounds faster than others, if charged rapidly. A proper test must insure the setting of every car that is in fair condition.

In making a test with a train standing, if any brake in the train sets quick action, how can it be detected? By noticing the train-line exhaust from the engineer's valve. If it stops suddenly while the brake valve is in service position (it may start again or not, according to how much reduction is made), it shows that the train-line pressure has suddenly dropped faster and lower than the pressure above the equalizing discharge piston. Emergency does this by venting the train-line pressure directly to the brake cylinder suddenly.

How would you proceed to ascertain in which car the trouble was? One method is to set about five pounds in service application and then find out which cars having the quick action triple valve are not set; have some one watch each car while increasing three to five pounds more in the service application. The car that sets in quick action first is the defective one, but as emergency travels at the rate of about twenty-three cars per second, it is best to cut out one of the cars that did not set at the first reduction, and have the application continued; if this proved not to have been the one thus defective, test the train again, cutting out another car that failed on the first application, until the defective car is located. Another and ordinarily shorter method is as follows: Cut the air cars in two equal sections and repeat the test for trying brakes. This will tell which half of the train is defective. Then take one-quarter or three-quarters, according to whether the defective car is in the front half or back half of the train, and continue in this way (never trying with less than three car lengths of piping) until the defective car is found and cut out. A broken graduating pin in the quick action triple valve will cause a brake to set quick

action, and although this rarely occurs, no train should be taken out of the station until the defective car is located and cut out. It should be done before damage occurs.

If one triple valve goes to emergency, will the others follow? Yes, if it is a quick action triple, all the other triples of either kind will go to emergency. Rare exceptions to this rule may occur where a large number of plain triples or cars having brakes cut out are placed together in a train.

Before starting from a terminal station, or where a change is to be made in a train, is it the engineer's duty to find out how many cars there are in his train with and without air brakes? Yes, it is his duty to find out how many cars there are with air brakes. To know the tonnage of a train is more valuable than to know the number of cars.

In making a careful test, why is it necessary to hold the brakes applied for a minute or longer? Because the longer the brakes can be left applied the more certain it is that they will hold for a long and difficult stop.

Where else, except at starting points, should a terminal test be made? When changing engines, or adding a double header (another engine) after long delays have occurred on the road, and at the summit of very heavy descending grades. When air brake cars are added to a train, a terminal test of such cars should be made by the forward brakeman, while the rear brakeman should see that the rear air brake car can be applied and released from the engine. When the engine is cut off, or the train cut in two at a crossing, or elsewhere, it should be ascertained that the engineer can set and release the rear air brake car.

When the brakes apply suddenly without the action of the engineer, what is the cause? The train has parted, the hose has broken, or a valve has pulled open.

What should be done in such a case? The engine throttle should be shut off and the air brake handle should be put on lap (position 3) as quickly as possible.*

If you find that the train has broken in two, what would you do so as to be able to get under way again promptly? When the train has been brought to a stop, I would place the handle in running position to see if the train pipe is still open. If I thought it was a burst hose, I would keep the handle moving from lap to running position and back, so that the trainmen could hear the air escaping from the burst hose. If I find that the black hand is gaining in running position, I would know that the trainmen had found the defect and had closed the angle cock ahead of it. I would then release the head brakes and lap the valve so as to pump up excess ready to release the rear cars when the hose had been replaced, or the train recoupled if it has been parted.

*No attempt should be made to get away from the near portion of the train. Increasing the distance of separation between the parts will only increase the violence of their finally running together.

If, after recoupling, you could not release all the brakes at once, how would you handle the engineer's brake valve in order to do so the most quickly? I would lap the valve and, after getting about twenty pounds of excess, I would try to release with this, repeating the operation until all the brakes were released. I should never leave the engineer's valve handle in release position expecting the action of the pump to release all the brakes.

How should you handle the engineer's valve in backing up a train where a "tail hose" is being used at the rear end?* Leave it in a running position all the time, running the pump a little more slowly than usual. Before backing out of the yard, as a test, the rear man should set the brake while the train is moving, and stop it against the working of the engine.

When two or more engines are coupled together, which engine should do the braking? The forward engine.

What would you do on the other engines? I would close the stop cock in the train-line under the engineer's valve and run the pumps, keeping the engineer's valve handles in running position.

*A "tail hose" or "back up hose" is a long hose to be coupled to the rear air brake hose of the last car, and has on its extreme end a valve by which the trainman operating it may allow air to escape from the train-line to apply brakes. This hose is used where passenger trains are backed any considerable distance. In conjunction with the valve, it frequently has an air whistle with which to sound warnings on approaching street crossings, etc. The tree end of the "tail hose" is fastened to the platform hand railing, so as to be readily accessible to the operator from the platform of the rear car.

All the engines should be equipped with such stop cocks.

Would you do any differently in cold weather than you would in warm weather? Yes, in winter the pump on the rear engine must be kept moving, even if it is necessary to break some pipe joint to cause a leak.

What variation is allowable in the brake piston travel on cars, tenders, drivers and engine truck? Generally speaking the piston travel should be kept between one-half to three-fourths the length of all kinds of brake cylinders except drivers. It is advisable, however, that freight cars be taken up to five inches when empty and drivers are best kept between two and four inches. It occurs in the practice of some companies, that engine trucks and ore cars or other cars of special construction have cylinders but eight inches long.

How is the slack taken up in each case? In passenger cars it is taken up by the turn buckles or dead levers. In freight cars and tenders it is taken up by the dead levers, or bottom rods for inside connected brakes. In cam driver brakes, it is taken up by lengthening the arms, and in truck brakes by lengthening the outside arms.*

How can brake shoes be kept from rubbing against the tires continually on eight-wheeled

*The cam driving brake is placed between two adjacent driving wheels--mainly on locomotives having but two pair of drivers. Formerly it was largely applied to the two rear drivers of moguls and ten-wheel engines. The more modern form is "the outside equalized brake" as shown in the chart of the Standard American Locomotive (Plate I.).

engines? By adjusting the screws of supporting rods or by adjusting springs.

How are the outside equalized brakes adjusted? Both the steam and air brakes are adjusted by tightening the adjusting screw located near the rear driver on each side.

How does the variation of piston travel affect the braking power? The braking power is increased by the shortening of the piston travel, and *vice versa*.

With the same piston travel, can loaded and empty cars be stopped alike? No, they will neither hold nor stop alike on account of the variation of weight to be stopped, but the brake itself exerts about the same force in both cases.

Why should the brakes be released before uncoupling from a train? In order that the cars can be switched and car repairers can tap (test) the wheels or jack up a journal box; also to prevent the shoes from freezing to the wheels, and especially because a brake that is applied leaks so rapidly that in changing engines it may be found that much of the air has escaped.

What should be done with the air hose at each end of an engine before coupling to the train? Air should be blown through them, or they should be shaken out by hand to clear them of dirt and dust.*

What is the pressure retaining valve? It is a weighted valve which the triple exhaust has to

*The rules of some roads require that whenever air hose are not coupled together they shall be hung up in dummy couplings provided for that purpose.

raise in order to escape it when the retainer handle is turned up, and has to be turned up before the brake is released.

What is its use? It retards the release and finally holds from fifteen to twenty pounds of air in the brake cylinder while the auxiliary is being recharged.

In descending a grade, what is the best way to keep a train under control? The best way is to apply the air lightly while the train is moving slowly, keep the train at a slow speed, and the train-line pressure as high as possible all the time. To do this, if it is necessary to recharge, reduce the speed below the average just before recharging. To recharge, handle the train as though a flagman had been sent half a mile ahead, i. e., go slow and exercise caution.

In switching with an air brake train and picking up uncharged cars, how should the engineer's valve be handled? As a high main drum pressure will release a low auxiliary pressure, this condition should be obtained before coupling to the uncharged cars. Then the pressure should be released, and the handle left in full release until the pointers of the air gauge commence to rise.

Do you consider a good light on the air gauge as important as on the steam gauge? Yes, more so, as steam is indicated by the working of the engine, while, until ready for its use, there is no certain indication of the amount of air pressure except by the gauge, which must be clearly seen. Clear vision of the air gauge at night is very important and should be given proper attention; the light from the fire-box when the door is open is not sufficient.

How often should the air gauge be observed? When whistling for road crossings, or similar places, and about two miles from all dangerous places or places where the train is to stop.

Can one tell approximately how many air brake cars are attached to the engine by a five or six pound reduction? Yes, the length of the blow from the train-line exhaust indicates this approximately. It is easy to discern a few from many cars.

How far from important stops, meeting points, railroad crossings, etc., should the first brake application be made? Not less than a mile on freight trains, and on passenger trains the distance should be far enough to insure safety in case the brakes fail to work satisfactorily.*

For what purposes and in what way is air taken from the main drum? For many purposes. It is taken by the train-line, air signal, air bell ringer, air sander, air blow-off cocks, and air flanger.

Will a ten pound reduction from seventy pounds set a brake any harder than a ten pound reduction from fifty pounds initial train-line pressure? No, not with a standard piston travel, or greater than the standard.

If you had but forty pounds of air, how much would you reduce to obtain full power? One-

*Some railroads require a running test at least two miles from all such points and at the summit of heavy grades.

fourth with standard eight-inch piston travel would be a full application.

Why is it important to keep the driver brakes in good order? Because they are the most powerful brakes on the train and the most costly. They keep the tires worn down, prevent the engine from pulling away from the tank, and prevent the train from parting near the head end.

How do you test for leaks in driver breaks? First, apply them. (Emergency application will hold longer than service application and the straight air will supply loss from leakage.) Everything from the triple valve to both cylinders, and all the parts of both cylinders should then be examined with a torch. A gauge screwed into the oil hole of the cylinder also affords an accurate test.

When do wheels generally slide, at high or at low speed? At low speed.

Which is the more likely to slide, a freight or a passenger car? A passenger car, as it has a braking power of ninety per cent of its weight under quick action, while a freight car has seventy per cent or less.

How would you stop a passenger train when the track was slippery? Apply the sand a train length before applying the air, and only shut off the sand when the train had come to a stop. Less air should be used than at other times, as the sand helps the brake shoes to hold as well as the rail.

When is the rail most slippery? When there is a frost, or the rail is lightly sprinkled. When

cinders or coal screenings are used for ballast, the rail is rendered more slippery.

If it is impossible to depend upon sand, as in the case, say, with a side wind, or if the sand pipes should stop up, how should the braking be done? To make a sudden stop, from ten to fifteen pounds should be applied about the same distance from the stopping point as in the case of a good rail. When the train is reduced to a speed of from fifteen to eighteen miles per hour, all the brakes should be released and then five to eight pounds applied, or not enough pressure to make the wheels slide.*

Does the black hand of the air gauge show the train-line pressure at all times? No; only in full release or running position, or on lap at the instant the train-line exhaust starts or stops. It always shows the pressure in the cavity (and little drum connected thereto) above the equalizing discharge piston.

Are the train-line pressure and the auxiliary pressure always the same? No. While releasing or charging, the train-line pressure is greater than the auxiliary pressure. While setting, or after making an over-reduction, the train-line pressure is less.

With an 1889 engineer's brake valve can you supply a leak in the train-line with the handle in running position? Yes, if in releasing after

*The speed curve in Fig. 32 shows clearly that it is the reduction of the high velocity that requires the severest application, while a low speed can easily be overcome by a light application, and it is then that wheels are most liable to slide.

brake applications you move the handle to full release and bring it immediately to running position before letting go of it.

What is the result of leaving the handle of the engineer's valve in full release too long and then returning it to running position? Any leak in the train will set the brake, and the engineer's valve is not ready to overcome it.

What is indicated by noticing the discharge from the train-line exhaust nipple? About the number of cars in the train; also, when applying service application it will indicate whether the brakes will act with emergency application or not. When the handle is placed in release position, a blow from the train-line exhaust indicates few or no cars.

If the air signal whistle blows every time the brakes are released, what is wrong? The pressure reducing valve needs cleaning, as it does not reduce the main drum pressure.

When the weather is cold is it desirable you should examine the tank wheels before starting, to see if the shoes are frozen to them, and, if so, to effect their release? Yes, particularly so, as there is great liability of water dripping from the tank.

Should a passenger train going at high speed be steadied by the brakes while on a curve or rough place? Yes. The brakes should be applied a little before reaching the place, and held on until the whole train has passed.

If short of air, how can you distinguish whether the trouble is with the pump or with the gov-

ernor? By reducing the pressure that the governor regulates or by letting it all out. Then, if the pump works all right, the trouble is probably in the governor. If the pump does not work all right, the trouble is probably in the pump.

Would the air brake on a car work properly with the retainer broken off? Yes, if not plugged up.

How many air-brake cars should be operated by one engine? To the extent of the train-limit. If the brakes leak, complaint should be made forthwith and the defects remedied.

With an independent brake on the engine, if you were backing up, which would you apply first, the automatic brake, or the independent brake? The automatic train brakes.

How often should you report defects in the engine, that need repairs? Daily, and at every roundhouse your engine enters.

Do you appreciate the fact that the proper handling of the air brake on trains is one of the most difficult tasks that an engineer has to perform, and that its proper handling so as to secure the comfort of passengers and the safety of life and property requires close attention and the exercise of good judgment? Yes.

Is it not a fact that the failure of the air brakes to work is almost invariably due to the neglect of some one to do the right thing at the right time? Yes.

Is it the duty of an engineer to observe and study with painstaking care any and all new fixtures and appurtenances introduced from time to time in connection with the air brake or other features of the engine? Yes; his imperative duty.*

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*In closing this examination the attention of the reader is again respectfully called to the detailed description of the locomotive and the air brake, together with the numerous engravings illustrating the same, to be found in the book on *Railway Equipment*. The information in question will prove of value to all students of the subject treated on.

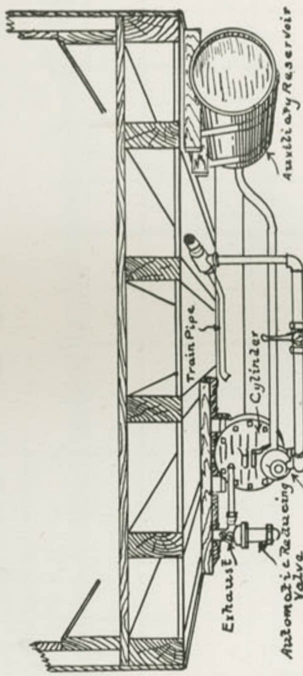

Fig. 32.

~Passenger Car Equipped~ ~with~ ~HIGH SPEED BRAKE~

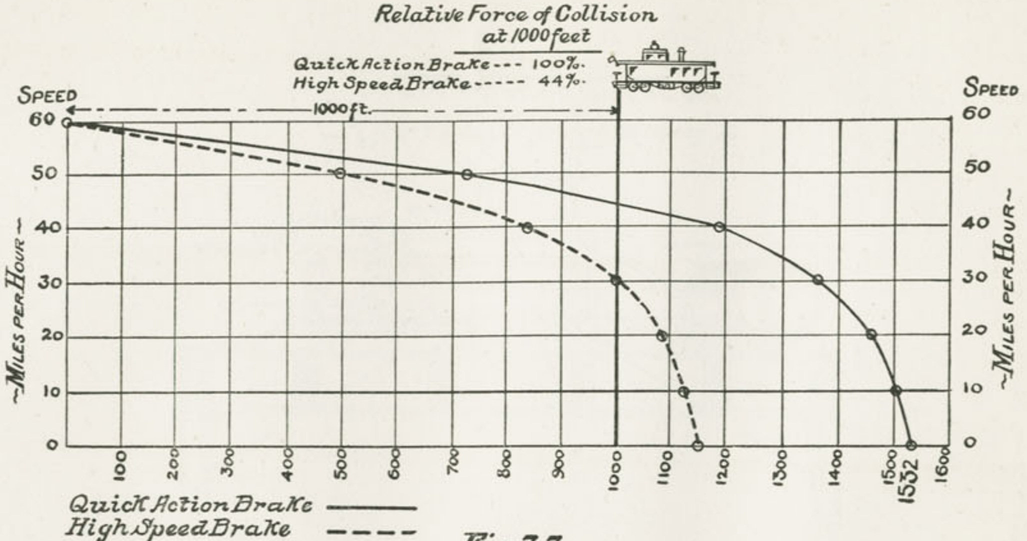

Fig. 33.

~ Speed Curves for Stopping ~

~ With Quick Action and High Speed Brakes ~

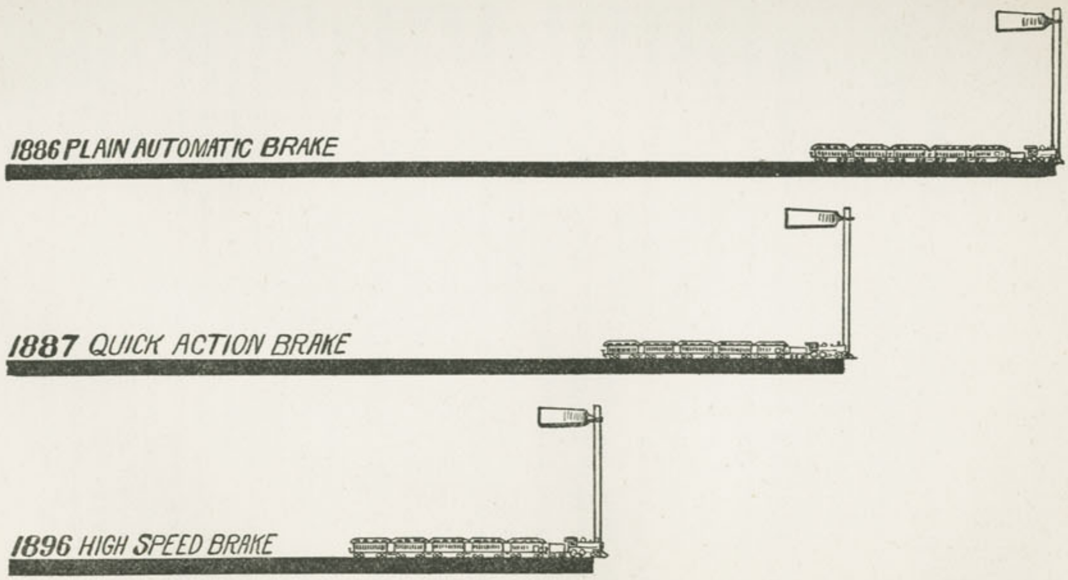

Fig. 34.

~ Progress in Train Stopping During a Period of Ten Years ~

OTHER MATTERS RELATING TO THE DUTIES AND RESPONSIBILITIES OF ENGINEERS.

The foregoing examinations, with what follows, prepared with a view to ascertaining the fitness of firemen to become engineers, treat of things that it is desirable engineers should know—should have at their fingers' ends — in order to fill their places to the best advantage. If they are not familiar with them they should lose no time in becoming so. They are primary in their nature.*

The vast resources at the engineer's disposal, the result of experience, while much of it may be particularized in print, much of it cannot be. The beginner does not possess this fund of information and it is not expected of him. He is,

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*While we must believe that it is desirable that the engineer should not only understand his own duties perfectly, but those of the fireman as well, it is nevertheless true that this universality of knowledge is not possessed by all engineers. This renders manuals all the more necessary. One reason why engineers do not possess the knowledge in question is that methods change after they cease to be firemen; thus we will say, the kind of fuel may have changed, from wood to coal. Whatever the occasion of the lack of knowledge, the lack exists and is recognized by railroad companies and excused because unavoidable, but in so far as engineers are deficient in the knowledge of the duties of firemen, manuals that throw light on the duties of the fireman are not only of value to the latter latter but to the engineer as well.

however, expected to attain it as quickly as possible. If he is ambitious and adaptable he will soon acquire it. The time required will be dependent upon the thought that he gives the subject and his ability to learn. Nothing connected with his business will be too small to escape his observation; nothing too trifling if it affords him information; he will avail himself of the literature, however scant, that dwells upon his duties or that has any relation to the train service; he will observe and study the actions of those about him; question with untiring zeal, all from whom he can gain light. He will not be satisfied with the fact that he has been found worthy to have charge of an engine; he will not stop until he understands the anatomy of his machine and its working as the surgeon does that of his patient.

After his examinations he will go on with even greater zeal than before, because his ambition will by this time have led him to aspire to even higher things. For these and other reasons I have thought it well to supplement what I have said with other things that relate to the responsibilities of engineers, and that must be known to firemen in order to enable them to run an engine. What I add is not new nor especially ingenious. It is, however, useful to engineers and a help to others. I cannot claim to be more than the compiler and editor, for others before me have given it expression in one form or another. It is of the common sense kind, and

partakes, like all corporate regulations, of a practical nature. I shall try to avoid as much as possible repeating anything concerning the duties and responsibilities of engineers already given.*

With this explanation, I proceed to enumerate such things as occur to me at this time as forming a part of the subject.

To begin, then, it may be said of engineers, that amiability, quickness of perception, skill and promptness of action mark those of the highest attainments. The fireman who hopes to become a good engineer must possess similar characteristics.

It is also a characteristic of such engineers that they are stirred by an ambition to excel in every way.

While the fireman is the subordinate of the engineer, the latter should seek to further his advancement by teaching him everything connected with the construction, maintenance and operation of the locomotive that his time and capacity for learning permits of.

The fireman on his part should show his appreciation of the kindness and interest of the engineer by his industry, amiability and willingness to obey orders.

The engineer and fireman must work together, each recognizing his dependence upon the other, if the best results are to be attained.

*I shall, however, be only partially successful in this, but while there will be more or less going over ground already traversed, it will be in connection with new ideas and a fuller development of old ones.

In reference to details, it is becoming more and more the practice for the engineer to have charge of both injectors. This notwithstanding the efficiency of the fireman in this direction. If, however, the fireman miscalculates in regard to the requirements of the engine, and, in consequence, finds his fire too low, and the steam pressure dropping unduly because of it, he must call the engineer's attention to the fact, that the injector may be shut off and the supply of water reduced so that the pressure may be the more quickly regained.

It is a truism that economical firing is impossible where the engine and injector are started simultaneously, or both shut off at the same time on approaching stations.

A fact to be remembered is that the cause of leaky boilers is not necessarily the result of overworking the engines, but too often due to poor management of the fire and injectors, combined with injudicious use of the throttle.*

It has been estimated that when steam escapes at the safety valves, the loss amounts to about one-fourth of a pound of coal each second, or a shovelful of coal per minute, or, as an authority ingeniously puts it, "It is the same, or worse, than an engineer allowing the fireman to throw

* In relation to the promotion of a fireman to the position of engineer, it is claimed by many experts that a fireman who has been out of freight service for several years should not be promoted to the position of engineer without again firing a freight engine for three or four months.

a shovelful of coal off the engine each minute without taking steps to stop the waste." Severe critics claim they have seen engineers sit calmly by on such occasions and hear the escape of steam from the safety valves with indifference.

In reference to the art of firing, there are two systems of supplying coal to the engine. One is the banking system, used principally with certain grades of coal having few or no clinkers; the other is the spreading system, which is followed where anthracite coal and some grades of bituminous coal, having more or less clinkers, are used. Where the banking system is followed, a large quantity of coal is placed in the rear of the fire-box until the gases and hydro-carbons have been expelled and it becomes a coke. Then it is pushed forward onto the incandescent coals by a slash bar or rake and a fresh supply of coal placed near the door. This method is little used and does not require much skill. Where the spreading system is used the coal is broken into pieces not larger than an apple. While many companies require that the coal shall be thus broken before being placed on the tender, it is, perhaps, more generally the custom to have it broken by the fireman. However this may be, he is expected to see that it is so prepared before being placed in the fire-box.

Coal broken into pieces of the proper size offers greater surface area to the heat and permits of being scattered more uniformly over the fire

Except in very cold weather coal should be wet to prevent dust and dirt. This gives increased weight to the fine particles which otherwise would be drawn directly into the flues, causing not only a waste of fuel, but stoppage of the flues.

At starting, the fire should be sufficient to carry the train out of the yard, so as to permit the fireman to give his attention wholly to the signals and switches.

If the locomotive is supplied with a smoke burner, it should be carefully looked after, and if there are any flues in the sides or rear of the fire-box for admitting air above the fire, they should be kept open, as it will tend to more perfect combustion and help to abate the smoke nuisance.

When the train is under way and normal pressure of steam has been attained, two or three shovelfuls of coal should be placed in the fire-box at a time, but in doing this the fire-box door should be kept open only so long as may be absolutely necessary. The coal having been broken in advance, the shovel should be filled and drawn forward within reach ready for the coal to be placed on the fire; this before the fire-box door is opened.

In firing, coal should be placed along the sides of the box and in the corners thereof, so as to exclude the cold air, which has a tendency to lower the temperature and chill the flues and fire-box.

Care should be taken not to throw the coal so that it will strike the flues or fall on top of the arch, if the engine has one.

A fire requires to be frequently replenished with small quantities of fuel in order to keep it bright. Heat is greatest when there is a rapid state of combustion. If there are clouds of smoke in the fire-box, heat will not readily penetrate them, and so poor results will be attained.

In case it is found necessary to maintain a very heavy fire in order to generate sufficient steam, it indicates that there is something wrong with the front end of the engine; either the nozzle is too small or may have become choked, or the draft appliances are not properly adjusted.

The temperature required to ignite carbon (of which coal is chiefly composed) is about eighteen hundred degrees. If, therefore, a large amount of coal is placed on the fire at one time, the temperature is reduced until the coal supplied can be brought up to the required temperature. The result is, first, contraction of the metal surrounding the fire-box, followed by expansion, thus subjecting the boiler to a great and unnecessary strain.

The importance of making proper use of the dampers is not always appreciated. With single part ash-pans, one damper, and that ordinarily the rear one, will be found most economical. By opening both dampers when the engine is working lightly with a thin fire, too much air will be admitted, and as air drawn through a fire in excess of the amount required for combustion tends to cool the gases below the point of ignition, waste of fuel results. Closing the dampers prevents the admission of air through the fire. This stops combustion and leaves the fire-box and flue sheets to gradually cool off. Opening wide the fire-box door will only partially prevent the draft through the fire, while it admits cold air directly onto the flues and sheets surrounding the fire-box, thereby cooling them so suddenly as to cause leaks.

In firing, the requirements of the service should be anticipated. A heavy fire should not be maintained when steam is to be shut off wholly or partially. A hard pull, on the other hand, should be anticipated.

In starting, the coal should be well ignited so that there will be no occasion for opening the fire-box door until the train has gained considerable headway and the lever has been hooked up, with consequent lighter pull from the exhaust.

On approaching a stopping point, the dampers should be shut down, and if bituminous coal is used, but little, if any, fresh fuel supplied to the fire. If, however, fresh coal has been applied through misjudgment or otherwise, the blower should be opened and the fire-box door left slightly ajar to prevent smoke and injurious gases escaping.

Choking volumes of coal smoke and gases often find their way into passenger cars, causing

great discomfort, when careless or unskillful firing is exercised.

It should be borne in mind, in approaching a stopping place, that a saving of fuel will result from letting the steam drop back a few pounds, rather than to allow it to escape through the safety valves. When it is found necessary to reduce the steam pressure, the dampers should be closed, rather than the fire-box door opened. The injector may also be started if the boiler is not already too full; if it is, the steam may, in many cases, be utilized by turning it into the tank to warm the water therein.*

The ash-pan (139) and the front end (14) should be cleaned whenever opportunity presents itself. A set rule cannot be laid down asto the frequency with which these duties should be performed. No great amount of labor will be required in cleaning the front end of cinders if the draft appliances are good and there are no steam leaks.

In regard to the ash-pan, it will fill up more or less quickly according to the grade of coal and the amount used. With a poor grade of coal, it may become necessary to clean the ash-pan on the road. The better steaming of the engine will more than compensate for time thus lost, and it may result that failure to perform this duty will necessitate the consumption of two or three additional tons of coal on a trip.

When sufficient air is not admitted through the body of the fire, there is a loss through the smoke-stack of about two-thirds, or more, of the

*Practical experiment has demonstrated that every 11 degrees (Fahr.) increase in the temperature of the feed water produces about one per cent. economy in the locomotive boiler.

heating properties of coal. This shows the importance of keeping as thin a fire as is consistent with the working of the engine.

While it is possible for a man to become an adept without having studied the laws of combustion, it is nevertheless true that if he be thus skilled, he is obeying those laws. To such a one the study of combustion may be more interesting than beneficial, but to others study will open up an avenue to the knowledge they should possess if they would serve their employer acceptably. Men ignorant of the laws of combustion, who stumble into the right path, would attain it much easier and more quickly by study. All, therefore, should study the subject, and this both practically and scientifically.

Extended observation leads to the knowledge that lack of steam-making power in the engine is too often the result of over-firing. Especially is this true in the case of new firemen, or where the engine has a reputation of making steam poorly.

As already pointed out, perfect firing means the admission of fuel and air in exactly proper proportions, but as no fixed rule can be accurately followed, the fireman may hope to approximate it by watching closely the results of different methods of firing, remembering that, in many cases, by saving the shovelfuls of coal, the ton is saved.*

* While the foregoing instructions in regard to firing apply in the main to all classes of fuel, yet it is true they refer par-

Among many other things appertaining to engineers, the study of friction and the knowledge of what is dependent thereon is essential. Economical and effective use of oil cannot be attained without it.

Aside from information relative to more practical things, the engineer and fireman must know what clothing to wear, and the food best suited to their requirements.

They must study particularly the best methods of doing repair work: packing glands, cellars and boxes; removing brasses; keying rods; setting wedges, and work of a like nature about the engine and tender.

No one is qualified, it may be said, to operate an engine, who does not know in advance what to do in every emergency of train service. He must be able to act quickly and in the light of the best practices. In the cases of delays and mishaps, there is no time to study up questions or situations. The man in charge must be able to act instantly. There are, in the generality of cases, preferred methods of procedure in the case of break-downs and other mishaps. With these the engineer should be familiar. He is also

ticularly, in several instances, to bituminous coal. Where anthracite coal or wood is used therefor, modifications will be required according to the nature of the fuel and the class of fire-box and engine. However, the general rule requiring that the fuel shall be so used as to burn most freely and create the maximum intensity of heat with the least fuel possible, applies in every case. This is also true in regard to keeping the grates free of clinkers and ashes.

expected to be able to make such repairs on the road as are possible under the circumstances; to be able to temporarily adjust eccentrics or the front-end appliances, set wedges, and disconnect the engine; to be skillful in the treatment of hot journals or bearings, and have an ear so trained as to be able to detect and locate a blow or a pound that may cause a break-down.

The faculty of observation is to be cultivated by engineers and firemen. Some men, without apparent effort, are ever conscious of what is going on about them, while others see nothing. It is necessary that the defect of the latter should be corrected if they would become valuable in their places. Everyone ambitious of preferment should seek information from the better informed men about them, and should not be rebuffed or discouraged if replies to their questions are not always courteous or direct. Practice and reading will do the rest.

In the operation of railroads, men engaged for years on a particular class of engine, have been known to remain in ignorance of other classes about them. This may be remedied by study and observation. Certainly any engineer thus handicapped labors under great possible disadvantages.

As it is becoming the custom of many well managed roads to keep a record of the fuel and other supplies used by each engineer and fireman, questions of economy on such roads, it will be seen, have a personal application not known elsewhere.

It is a duty required of engineers, in many cases, that they shall reach the engine-house while their engine is over the pit, that they may thus be enabled to examine it from underneath, to better advantage. They are also expected to inspect the packing of truck cellars, see that the bolts and nuts are tight, look after the eccentrics and see that the oil holes are clear and oil cups filled. As the engineer is responsible for the fulfillment of the fireman's duties, he is also required to see that they are not neglected.

When the engineer does not know in advance the engine he is to run (that is, when the engines are pooled or worked in common), he must, upon taking charge, exercise greater care than he would otherwise, to see that it is provided with necessary tools, blocking and other appliances. He should also examine the work-book in such cases, to see what repairs were last reported as being necessary and what has actually been done. Parts that have been repaired always require more attention than others, because of the friction that intervenes in such cases. The inspection of the engine and tender by the engineer, it is apparent, is the first thing to be done on taking charge. The work should be systematic and thorough. In those instances where the roundhouse force looks after the packing of the driving boxes, tank boxes, truck cellars, and so on, the engineer must still see that the work has been done properly. Many engineers insist on doing it themselves, as they feel greater confidence that they will get over the road promptly and without mishap than they would if the work was performed by an employe of the roundhouse.

Among the further duties of the engineer these may be briefly summarized: To see that the water supply in the boiler is ample — this he does by trying the gauge cocks and noting the indication in the water glass; to try the gauge cocks frequently when on the road, using the water glass as an auxiliary or indicator merely; to look from time to time into the fire-box for leaks, and if the engine has an arch, to see that it is in place; to inspect the air pump and its lubricator, the guides, guide bolts, crosshead and piston rod packing, bearings, rods and rod bolts, keys and set screws, wedges and wedge bolts; to see in filling oil cups that the amount of oil required indicates that there is no stoppage of the feed or oil hole; to examine the wheels and flanges for breaks, chips or cracks, and the driving wheel centers and tires to see that they are not working loose; to see that the sand pipes are open, that the headlight is filled and trimmed and the reflector cleaned, that the cinder hopper is tight and that no leaks appear in the front end; to blow out the steam heating pipes in winter lest they be clogged with ice; to ring the bell a sufficient length of time before starting to enable any one who may be working under or about the machine to escape;* to see before leaving the

*Numerous accidents to life and limb have resulted from a neglect to observe this precaution.

engine house that the cylinder cock is opened; to start the engine slowly and under no circumstances to slip the engine for the purpose of throwing the water out of the cylinders; in backing the engine to the train, to see that the lubricator is started and all parts of the engine working in good order; to lubricate all parts of the engine before starting a train; to place the reverse lever in starting in the "corner" and open the throttle slowly and carefully so as to avoid jerking the train or slipping the wheels; to be particular if the rails are slippery or the load requires it; to sand the track before the wheels begin to slip; to be careful not to "catch" the engine when slipping on sand, as it is a severe strain to the machinery, and pins and rods frequently break under such circumstances; to use in sanding the rail only so much sand as is necessary to keep the wheels from slipping, as a train pulls harder on a sanded rail; to see when headway is attained that the reverse lever is pulled back to prevent unnecessary waste of steam and undue disturbance of the fire by too strong a draft; in starting (and also at other times) to look back and exchange such signals with the rear end ot the train as may be necessary to be assured that the train is intact and in proper working order; to use full opening of the throttle except where a simple engine can do the work required with less than one-fourth cut-off, in which latter event it is economical to leave the cut-off at one-fourth and regulate the steam by the throttle;* to see that water is supplied the boilers in as nearly a continuous flow as possible, to see that the water is, so far as practicable, kept at a uniform height, not losing sight of the fact that water in the boiler at a high temperature (or indeed warm water in the tank) represents so much heat energy available when the normal capacity of the boiler is inadequate to supply the demand;† to remember that the time to favor an engine by reducing or entirely stopping the supply of water to the boiler is when moving rapidly towards an ascent or heavy grade;‡ to see, when approaching dangerous places, drawbridges, railroad crossings, interlocking switches, yards, etc., that the train is under such control that a stop may be made, if necessary, before reaching the

*To illustrate: It would not be economical to use one-half to two-thirds cut-off and throttle the steam pressure when the work could be done with one-fourth or one-third cut-off with a full throttle opening, while one-eighth cut-off with full throttle is less economical than one-fourth throttled, due to increased cylinder condensation, where the temperature of the cylinder has too wide a range.

†The capacity of water for storing heat is great, and this fact should be taken advantage of. When it is not, engines will too often be found standing at stations or descending grades with light throttle, and with steam blowing off; or blowing off when the water in the tank is cold, or there is but half a glass of water in the boiler. At such times the injector should be at work or the surplus heat should be used to warm the water in the tank.

‡After speed has been reduced (even though the reverse lever has been dropped down), the engine is using a less amount of steam and the injector may then be started.

danger point;* to see, in stopping, that steam is shut off a sufficient distance to permit slowing down easily; to see that the link is hooked down to give the valves more travel and keep the valve seats in better condition.†

It is the duty of the engineer to see that the air brake is used with care, bearing in mind that it requires the nicest judgment and skill at all times to prevent mishap or jarring of the train. In the event the water in the boiler gets low (through failure of the pumps, or otherwise) the fire must be banked or drawn.‡ It may be necessary in some instances to detach an engine and proceed to the nearest station for water when the supply is exhausted. It can, however, sometimes be dipped from pools or streams along the track, or, in winter, snow may be shoveled into the tank and melted. Everything should be done in such cases that is consistent with safety to

*The speed limit in such cases is usually placed at six miles an hour, or as fast as a man can walk a short distance.

†This will also prevent the raising of the valves by compression from the cylinders, and where there are no relief valves on the steam chest, it will partially prevent the drawing of the smoke and hot gases from the front end into the cylinder. With some engines, having very long eccentric blades, it is unsafe to hook the links down to the lowest point while running fast, as in such cases a broken eccentric strap might follow.

‡"Banking" a fire usually means covering it with fine coal, well wet down, but sometimes it is advisable to cover with ashes or sand, which will practically extinguish it. "Drawing" or "dumping" the fire means knocking it through the grates and extinguishing it entirely.

keep the engine alive, but it is considered highly discreditable to "burn" an engine.

If the engine is priming or foaming, the cause thereof must be ascertained and the necessary remedies applied.*

In the care of the locomotive it must be remembered, among other things, that water projected from the smoke stack injures the paint on both the engine and cars. It looks bad moreover. In summer, after filling the tank with cold water, the heater should be applied long enough to prevent the tank sweating. Failure to observe this simple precaution may greatly injure the paint on the tank.

An important duty of the engineer is to see that the safety valves are regulated according to the steam pressure allowed the engine. Many companies undertake to make periodical tests of safety valves, gauges and air governors independently of the engineer. It should be a duty of the latter, however, to order a special test made

* Priming is generally caused by keeping the boiler too full of water. This can, as a rule, be prevented. Foaming is due to foreign matter in the boiler and may be relieved by a surface cock, or a blow-off cock, with which most engines are supplied. If the water used is of poor quality, the tank may be cleansed by flushing at the water station. In cases of priming or foaming, the true water level can only be determined by shutting off the engine and letting the water supply in the boiler settle. This should be done frequently under such circumstances. From an economical standpoint, the effect of working water into the cylinders (aside from the liability of knocking out a cylinder head and cutting the valves) may be appreciated by remembering that a cubic inch of water (which is not expansive) will make one cubic foot of steam, which is expansive.

whenever he may have reason to believe there is anything defective therewith.

At water and coaling stations, the engineer should utilize the time to inspect the bearings and running gear of the engine and tender and supply needed lubrication.

It is a duty of engineers to carefully inspect their engines at terminals, and notify the official at the engine-house what work is required to fit them for economical and effective use. Hot bearings should also be reported so that they may be examined at the shop, and in the event another person is put in charge of the engine, that he may be notified of the same.

Returns giving an account of delays, overtime, accidents, and for other purposes, should be made and transmitted to the proper officer as soon after arrival at the terminal station as possible.

In order that there may be no unnecessary loss of time in communicating with engineers and firemen when off duty, their addresses should be left with the foremen of engine-houses, or other designated officials.

In closing these instructions, it will be proper to again call attention to the necessity of wise and economical use of tools and supplies. Engineers and firemen cannot hope to make satisfactory records otherwise. Questions affecting the use of tools and supplies grow more and more important every year because measures for ascertaining the care exercised are becoming more and more effective each year. The subject is therefore, it will be seen, one of supreme importance to the employe as well as to the employer.

The foregoing account of the duties and responsibilities of engineers and firemen, while complete so far as it goes, is, as I have already explained, necessarily limited. At least two of my books treat almost wholly of matters with which the engineer must be more or less familiar in order to perform his work intelligently. It has been my particular endeavor here to group certain specific things that master mechanics and superintendents of motive power consider especially important to the safe and economical working of engines. The account, however, as already intimated, is incomplete, because the duties of engineers and firemen cannot in many things be treated apart from those of other train and station men. It was this universality of duty and interest running through the whole railroad world, that led me to take up the subject in its entirety in the "*Science of Railways*" as I have already explained.

What I have written in regard to engine men, while applying particularly to American railroads, refers in the main, it is apparent, to the railroads of the whole world, for the reason that construction, maintenance and operation are substantially the same everywhere.

BOOK II.

COMPOUND LOCOMOTIVES.

FORMING A PART OF THE
ENGINEERS' AND FIREMEN'S MANUAL.

CONTENTS.

Book II.

Compound Locomotives.

CHAPTER I.

ENGINEERS' AND FIREMEN'S MANUAL, CONTINUED—COMPOUND LOCOMOTIVES—INTRODUCTORY.

Note—In regard to the merits of the compound cylinder as compared with the single-expansion, I do not desire nor profess to express any opinion. I merely wish to describe the compound cylinder in what follows, and, if in some places preference seems to be expressed, it is the claim of builders and not mine. Those who use locomotives must themselves be the judges of the respective merits of single-expansion and compound cylinders and of the particular pattern they want.

January, 1899. M. M. K.

In view of the fact that the Compound Locomotive is of comparatively recent introduction as compared with the single-expansion cylinder, its construction and working are less understood by those connected with the equipment department of railroads. These particulars I have, for that reason, thought it best to embody here in connection with the "Engineers' and Firemen's Manual." More and more attention is being given to the expansive use of steam in connection with the locomotive. It is claimed not to be unreasonable in view of the triple and the quadruple expansion of steam (expansion in three and four cylinders) in the most approved stationary and marine engines that it should be possible to devise practical means of obtaining double expansion, at least, in a locomotive. Because of the more or less general introduction of compound cylinders, some account of the working of the compound locomotive is becoming every day more and more necessary to those connected with the machinery and equipment of railroads. Indeed, practical familiarity with the working of compound engines may be said to have become, in a measure, a necessary part of the knowledge of every engineer and fireman, for the reason that their duties may at any time, through promotion or otherwise, take them to roads where some form of compound locomotive is extensively used. Moreover, it is well that their attention be especially directed to the subject in order that it may have the consideration and scrutiny at their hands which its growing importance justifies and their practical knowledge is likely to render so valuable.

It is not surprising, inasmuch as the opinions of engineers and firemen respecting the operation of simple engines differ so widely, that there should be much controversy among them in regard to the operation of compound locomotives. Experience on the part of those operating the compound locomotive will tend to its better service and consequently greater development. Many prejudices against it are due to lack of acquaintance with its operation. This is true of every new thing. Especially is it true in the case of compounds where a railway has few locomotives of this kind. The feeling is but natural, if we remember, as we should, that in the handling

of their engine the reputation of the engineer and fireman is at stake. The opportunity afforded them for handling and studying any odd engine, compound or otherwise, is necessarily limited. Moreover, in the operation of such locomotive, it is possible they may be impressed with the unhandy, because unusual, cab arrangements. Naturally, they are filled with apprehension, lest some accident might occur and they be found ignorant of what should be done to temporarily repair the engine and bring it in. If a considerable number of the locomotives of a railroad are compounds of similar class, the men handling them become accustomed to their operation and this fear disappears. It is with a view to the practical usefulness these pages may have for engineers, firemen, and others interested in the operation of compounds, that the descriptions herein are elaborated to the extent they are.

The plan followed with each class of compound locomotives is, first, to give a general description of its operation, succeeded by a detailed description of its technical parts. This is done that the reader may, in the first instance, if he desires, learn of the general arrangement of each class without the details, and afterwards, at his leisure, he may apply himself to the particular class or classes that most interest him. Following the description of each class of compounds will be found, in catechetical form, information relating to its operation in case of any ordinary derangement of its parts when the methods of procedure will differ from those in case of similar accidents to simple locomotives, as outlined in the manual. It is said that reforms must pass through three stages: ridicule, argument, and adoption. The compound has been subjected to the first and second of these epochs, and it may be assumed to have reached the last stage mentioned. Like every part of a railroad, it is still in a state of evolution. I know of no preference in regard to compounds that is proper to express here. The order of description has, therefore, no significance. In the description of the various types I have endeavored to eliminate all matter that does not pertain directly to the practical application of the principle of compounding, as descriptions relating to other parts of the locomotive are to be found elsewhere in "THE SCIENCE OF RAILWAYS." In relation to the descriptions of the compound, I wish to say that I am indebted in a marked manner to Mr. E. W. Pratt, whose familiarity with the construction and working of locomotives and the appliances of the latter makes him an authority of the highest order in regard to all such matters. I am indebted to him in many other ways and it affords me much gratification to be able to acknowledge it thus conspicuously.

CHAPTER II.

ENGINEERS' AND FIREMEN'S MANUAL — COMPOUND LOCOMOTIVES — GENERAL DESCRIPTION — COMPARISON WITH SIMPLE LOCOMOTIVES.

A compound locomotive is one in which the exhaust from one or more cylinders is passed into one or more other cylinders and made to do more work by further expansion before it is allowed to escape to the atmosphere. In stationary and marine service the principle of compounding has long since passed its experimental stage and, following the replacement of the single-expansion engine by the double-expansion type, came the era of high boiler pressures with triple and even quadruple-expansion engines in marine service. It was long thought by many, and is still held by some, that, although compounding of steam in marine and stationary engines was a great economy due to the use of the condenser,* on locomotives where condensers were impracticable, the compound locomotive would not be able to gain sufficient advantage over the simple engine to warrant their general use.

Without any attempt to pass judgment upon the relative value of the points put forward for and against compound locomotives, I will out-

*A condenser is a chamber into which the final exhaust of an engine takes place and in which the steam is cooled and condensed, either by a jet of water or by contact with sheets or tubes having cold water circulation on their opposite sides. These two forms of condensers are termed "jet condenser" and "surface condenser," respectively.

line some of the claims made by their advocates and also some of the practical objections met with in their use, many of which objections have been largely overcome in the later designs.

It should be remembered that the locomotive is not a steam engine merely, but consists of a boiler as well, and must also carry water and fuel for its own demands.

The first advantage of the compound over the simple locomotive comes from its greater economy in fuel, resulting primarily from the saving in steam. There is, however, a secondary saving, produced by the less violent effect of the exhaust upon the fire and also the economical use of high boiler pressures in compound engines.

Experiments have shown that high boiler pressures, say above 180 pounds, which have been found very economical (especially in the space occupied per horse power developed) in stationary and marine engines, are not a source of economy with the type of single-expansion locomotives in use in this country, due to the extreme ranges of temperature within a single cylinder and the consequent condensation. Also, locomotive cylinders and their steam ports are not well protected, and compounding the cylinders renders the variations of temperature in each cylinder less wide, and thus makes practicable the use of higher pressure. With the use of steel in place of iron for boiler construction, and also on account of the excellent care and inspection given all locomotive boilers, there is no material increase of first

cost or for maintenance of high-pressure boilers. In simple locomotives the exhaust produces such a violent draft upon the fire that great quantities of unconsumed fuel are drawn from the fire-box and thrown from the stack. This is not alone a waste of fuel, but cinders entering the open car windows are a source of great annoyance to passengers, while, before the use of the compound locomotive in the service of suburban railways, the noise of the exhaust had to be overcome by means of mufflers, which became quickly choked up and produced a high back-pressure on the pistons, resulting in the loss of from 15 to 20 per cent. of the power.

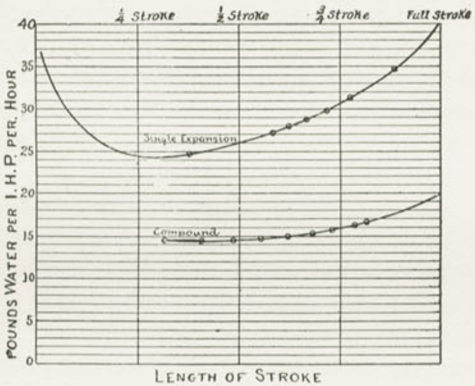
The throwing of sparks from the stack is not only a source of annoyance, but frequently results in heavy losses from damage by fire in timber and agricultural districts, and this is largely, if not entirely, overcome by the compound locomotive.

The heating surfaces of any given boiler absorb heat from the fire and deliver it to the water at a certain rate. If the rate at which the products of combustion are carried away exceeds this rate of absorption, there will be a continual waste that can only be overcome by reducing the velocity of the products of combustion. In the compound locomotive this is effected by the milder exhaust. It has been clearly demonstrated by experiment, that a milder exhaust and consequently a slower rate of combustion produces a greater evaporation of water per pound of fuel.

The milder exhaust is, of course, the result of a lower back-pressure and thereby permits a greater effective power on the piston.

There is also found to be considerable reduction in cylinder condensation, owing to the relatively small variation of temperatures in each cylinder as compared with single-expansion engines. In any engine the walls of the cylinder, one cylinder-head, and one side of the piston are cooled to the temperature of the exhaust steam during each stroke, and the live steam, again entering, must

Fig. 100.



reheat them to its own temperature, thus condensing and requiring additional steam to flow in and take its place. In the compound this total range of temperature is divided between the high and the low-pressure cylinders, and thus the variation and consequent condensation in each cylinder is less.

The saving of steam results in the saving of

both water and fuel. The economy in fuel can be directly reduced to dollars and cents, while that resulting from the saving of water is more indirect. In bad water districts, the reduction of from 15 to 20 per cent. in the amount of water used, necessitates less frequent washings-out of the boiler and must result in greater life and diminished repairs to boiler and flues. Moreover, as its carrying capacity of water limits the distance that a locomotive can run without stopping (or slowing up, where track-tanks are used), it is evident that the compound locomotive would have an advantage in this respect. Fig. 100, besides showing the most economical point of cut-off for simple and compound engines, as far as the use of water is concerned, clearly shows the relatively smaller amount of water used by the compound per indicated horse power.

No locomotive can haul more than its adhesion to the rails will permit, and hence the tractive power of an engine is based upon whatever the adhesion to the rails may be. This is determined by practical experiment. With a fairly dry rail, a turning force of more than one-fifth, or 20 per cent., of the weight of the drivers on the rails, will cause the wheels to slip; a perfectly dry rail will permit of a tractive power of about one-fourth, or 25 per cent., of the weight on the drivers; a well sanded dry rail will allow one-third, or 33⅓ per cent., while a bad frosty rail will permit less than half this last amount. Where all the driving wheels are connected, it matters not, of course, whether this force is applied by one or many cylinders, but, if the power is not uniformly distributed throughout the revolution and becomes sufficiently excessive at any one point to cause the wheels to slip, a very much less power will thereafter keep them slipping. It is a well known fact that adhesion, and consequently the tractive power of a locomotive, is very much reduced after the wheels begin to slip.*

It is claimed for the compound, that, as the average cut-off is later in both cylinders than for simple engines, the turning power is more uniform throughout the revolution, and hence heavier trains can be hauled than with the single-expansion engine. Then, too, while it would be uneconomical at other times to design a simple engine with cylinders sufficiently large to develop so high a tractive power as 33⅓ per cent. at slow speeds, this can be done with compound locomotives of the "convertible" type without loss in economy under ordinary speeds of service, when working compound.

A saving of oil has been one of the minor economies claimed to be incidental to the use of compound locomotives. It is generally thought that from six to ten drops of valve oil per minute are required to be supplied with the steam in order to properly lubricate a valve and cylinder. This

*Every engineer knows this and puts his knowledge into practice when on a very slippery rail by opening the throttle very slightly and leaving the valve in full gear, thus distributing the pressure more uniformly throughout the stroke than would be the case with a shorter cut-off.

oil is supplied to the high-pressure cylinder only, and hence, in the two-cylinder class of compounds, a saving has been effected in many cases.

Comparative tests of greater or less duration have been made by various railways, between compound and simple locomotives of otherwise similar construction, and the results obtained by the different experimenters are widely at variance. In general, it may be said that the reported saving in fuel with the compound is about ten per cent. in fast passenger and 20 per cent. in heavy freight service, although figures double the latter have frequently been given.*

Later designs of compound locomotives, arranged to be worked simple at the will of the engineer, will temporarily pull a heavier train than a simple engine of otherwise like design. When it is considered that the ruling grade on a division is the governing factor for the maximum rating of through trains over the whole division, it will be seen that a locomotive capable of enough greater power to haul an additional car or two up that grade, produces more economical service for the whole division.

Leaky valves and cylinder packing are less wasteful in a compound than in a simple engine. Steam leaking by the valve or packing of the high-pressure cylinder is still worked expansively

*Fast freight service will more nearly compare with express passenger service and the saving will be less than in heavy slow freight service, on account of the simple engine using steam more expansively in the former service than in the latter. This is more fully brought out elsewhere.

in the low-pressure cylinder. Then, too, the difference of pressure between the two sides of the valves and pistons is less than for simple engines, and the wear should be consequently less.

On the other hand many serious practical objections have been raised. The large cylinders greatly increased the weight of the reciprocating parts.* This must be followed by heavier counter-balance† weights and their accompanying evils.‡ Also larger ports and consequently larger valves must be provided for the large cylinders. Inasmuch as considerable difficulty was formerly experienced in obtaining admission and exhaust ports of sufficient size for the cylinders of large high-speed single-expansion engines, it is not remarkable that there should have been considerable trouble experienced from this source in designing ports for the much larger cylinders of the compound locomotive.

In connection with these last two points, the weight of reciprocating parts and the port re-

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*By the reciprocating parts is meant those parts that have a forward and back (or reciprocating) motion. This includes the pistons and piston-rods, the cross-heads and a certain part of the main rods.

†The counter-balance is the balance weight placed in the wheel at a point opposite the crank pin. (See No. 240, Plate I.)

‡The counter-balance weights act at all points of the revolution, having an outward or centrifugal tendency from the center of the wheel that is great at high speeds, and is only counter-acted when the engine is passing the front and back centers. At other points it produces an upward tendency upon the engine when moving up and a downward blow upon the rails when moving down.

quirements, let us see for one moment what the requirements for high speed are. Take an engine with a five foot driving wheel and a twenty-four inch stroke, traveling at the not unusual rate of a mile a minute. This requires 336 revolutions per minute, and means that the piston starts and stops 672 times, and with all its stopping and starting travels 1344 feet per minute. At mid-stroke the piston speed is about 35 feet per second or 24 miles per hour. To the average railway man high speeds are so common that I can think of no better way to show the full meaning of these figures than to compare them with those of a falling body acted upon by gravity. A falling body at the end of the first second is traveling at the rate of 32 feet per second, or about 22 miles per hour, and in gaining this speed the body has fallen some 16 feet, through which distance the continued action of gravity has produced this not inconsiderable acceleration, while in the case of the piston of the locomotive in question, the still greater speed of 24 miles per hour must not only be attained by the time the piston has reached the middle of its stroke, or in one foot, but also it must be exerting great additional propelling power on the crank pins. The steam in front of this rapidly moving piston must be exhausted freely or there would be no effective power to maintain the speed. Where the reciprocating parts weigh nearly a thousand pounds, it will be seen what enormous power is required to stop and start them without jar or shock to the locomotive, and also the size of ports required to freely exhaust the pressure ahead of and freely supply steam behind the very large pistons of compound locomotives. With any of the several types of valve gear used in locomotive practice to-day, it goes without saying that no compound can be relatively so efficient, in comparison with single-expansion engines, in express passenger as in freight service, for the reasons hereinbefore described. When many single-expansion locomotives with moderately large ports require a velocity of steam through their ports of over 1,000 feet per second, it can better be imagined than told what the port requirements are for the large low-pressure cylinder on a compound. It is generally considered that for express passenger service the low-pressure cylinders should not be so large in proportion to the high-pressure cylinders as for freight service.

Many of the earlier compounds in this country suffered in comparative tests with simple engines of otherwise similar design, by having cylinders of too small a size to do the same work as the simple engine. While they did their work with economy, they would not haul the heavy trains of the simple engines, and their supposed capacity had to be reduced, to the annoyance of those engaged in the operating of trains. Since then, with the advent of larger cylinders and the "convertible" class of compounds, the conditions have become altered.

With any locomotive, when steam is shut off, as in running down grade, the pistons act as air compressors, causing thumping, rough riding, and

cooling of the cylinders, as well as a strong draft in the stack at a time when no steam and little draft are required, and thus produce a waste of fuel. The large low-pressure cylinders of the compound have greatly magnified this evil, and several builders have overcome it by the use of automatic valves on the low-pressure cylinder, by which the two sides of the low-pressure piston are connected whenever the locomotive is drifting.

After closing the throttle, an engine working compound will make several strokes before all steam is finally exhausted. This delay in clearing the cylinders of steam, placed compound locomotives to considerable disadvantage in switching or like service; also, in such service, accustomed to gauge the speed by the exhaust of the engine, trainmen were often deceived by the less frequent exhaust of the two-cylinder compound. The employment of the separate high-pressure exhaust, whereby the engine can be run simple at the will of the engineer, it appears, has overcome these objections from an operating standpoint.

Many of the earlier forms of intercepting valves were of the poppet type and hammered badly in opening or closing. It will be noticed that these valves in the later designs are of the piston type and are almost invariably cushioned by dash-pots connected thereto, or some other equally effective means.

It is also claimed that the breakage and loosening of the large low-pressure cylinders have been considerably done away with by the use of proper reducing valves and a better attachment of cylinders to the frame, the use of double front rails for the latter being particularly noticeable in modern construction of large locomotives.

Thus it is that improvements in design and construction are continually taking place, and the upholders of the great principle of compounding will certainly witness their more extensive adaptation to all classes of service.

CHAPTER III.

ENGINEERS' AND FIREMEN'S MANUAL—CLASSES OF COMPOUND LOCOMOTIVES AND THEIR GENERAL CONSTRUCTION.

There are many classes of compound locomotives in use. First, the *strictly plain compound*, where no live steam is admitted to the low-pressure cylinder, even in starting. The Webb three-cylinder compounds (with cylinders arranged as outlined in Fig. 106,) which are usually without connecting rods—the two high-pressure cylinders turning the rear pair of driving wheels by two outside cranks while the low-pressure cylinder turns the forward drivers by means of an inside crank—belong to this class and are used in considerable numbers on the London & North-Western of England. They are not powerful in starting, as the driving wheels acted upon by the high-pressure cylinders must turn, either by slipping or moving the train, before steam enters the low-pressure cylinder.

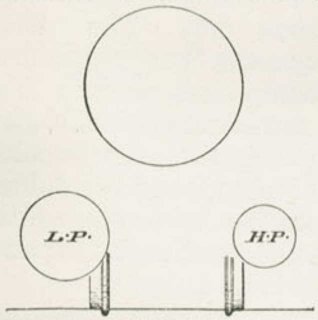


Fig. 101.

Second, *automatic compounds*—those using live steam in the low-pressure cylinder in starting only, automatically changing to compound with the first stroke, and thereafter cannot be run except as compounds.

The third class can be run simple or compound at any time at the will of the engineer and will be termed *convertible compounds.*

Each of these principal classes may have two, three, or four cylinders. The two-cylinder or "cross-compound" always has an intermediate receptacle, called a receiver,* between the high and low-pressure cylinders, while the four-cylinder engines may or may not have receivers—those with both pistons attached to the same crosshead generally have not. The three systems of four-cylinder compounds used in this country are the Baldwin (Vauclain), the Brooks (Player), and the Johnstone. Of these, the Brooks has receivers, while the remaining two are of the continuous expansion† type and have no receivers.‡

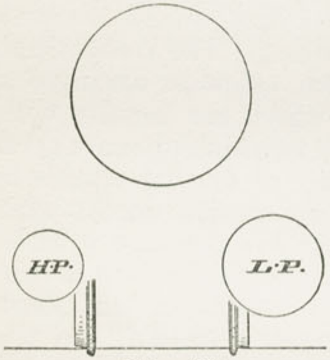


Fig. 102.

*The receiver is for the purpose of receiving the exhaust from the high-pressure cylinder and holding it until the engine gets to the point in the revolution where it is admitted against the low-pressure piston. Incidentally, the receiver may act as a re-heater, if located in the smoke-box, as is usually the practice.

†Meaning expansion without any pause or interruption as is the case when a receiver is interposed between the high and the low-pressure cylinders.

‡In Europe the Hurgarian State Railways employ four-cylinder tandem compounds with one receiver into which both high-pressure cylinders exhaust and from which both low-pressure cylinders receive their supply.

The arrangement of cylinders is quite varied, as shown by the several skeleton cuts. There may be two cylinders, one high-pressure and one low-pressure, as outlined in Figs. 101, 102 and 103; one high and two low-pressure, as in Figs. 104 and 105; two high-pressure and one low into which they both exhaust, as in Fig. 106; two high, each exhausting independently into a low-pressure cylinder on the same side of the engine, shown in Figs. 107, 108, 109 and 110; or two high exhausting into a common receiver from which both low-pressure cylinders draw their supply, as in Figs. 111 and 112. Aside from the varied arrangement of cylinders, many of the European designs employ three and four cranks and use no side rods. Some French constructions, retaining the use of side rods, employ for the high-pressure cylinders two inside cranks on one driving axle at an angle with the low-pressure cranks on a second driving axle, the angle between the cranks

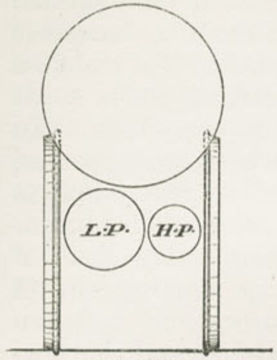


Fig. 103.

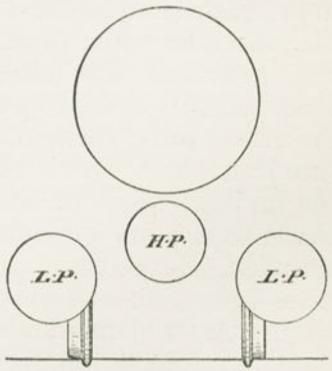


Fig. 104.

being such as to give as large a turning power as possible, for all portions of the revolution.

It is, perhaps, needless to say that the wide variations in the service of American locomotives demand that they have a large starting power at all points of the stroke. To obtain this starting power, all the earlier designs used a device called an intercepting valve that, if closed in starting, cut off communication between the receiver and the low-pressure cylinder and at the same time admitted live steam to the low-pressure side, but after the first exhaust from the high-pressure cylinder to the receiver took place, the pressure in the latter automatically shoved open the intercepting valve and simultaneously shut off the further supply of live steam to the low-pressure cylinder. Hence these engines belong to the automatic class of compounds.

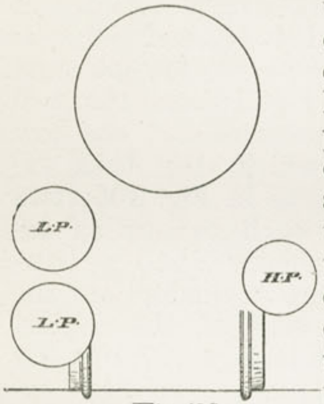


Fig. 105.

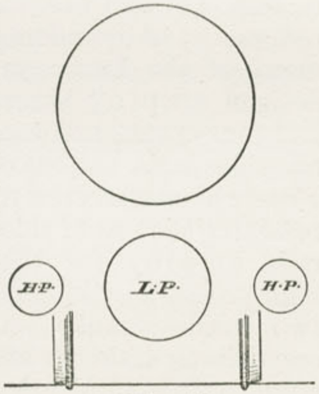


Fig. 106.

Mr. Anatole Mallet, who was the designer of the first practical compound locomotives in Europe

in 1876, was also the first to devise a means by which a compound could be worked as a simple locomotive for any desired period at the will of the engineer. This was accomplished by adding a separate exhaust valve through which the exhaust from the high-pressure cylinder could escape to the atmosphere without accumulating in the receiver. This relieved all back pressure on the high-pressure piston and admitted of greater power at slow speed than was otherwise obtained.*

Many objections were raised to placing the operation of the engine either as a simple or as a compound in the hands of the engineer, and the fear was freely expressed that the average engineer would run the locomotive to its disadvantage in simple position more than enough to offset the saving when operated as a compound. However, one prominent railroad officer, in placing the operation of the valves at the will of the engineer, seemed to express the now settled conviction of all, when he said: "To argue that an

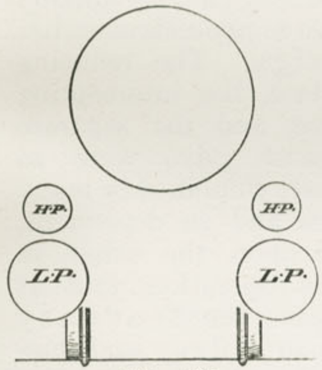


Fig. 107.

*It should also be stated that not only were the automatic compounds less powerful, at slow speeds after starting, than simple engines, but, except in the case of four-cylinder engines having one high and one low-pressure cylinder on the same side they were practically helpless in case of a broken steam chest on either side. The use of the separate exhaust valve has greatly altered the conditions in these cases.

engineer is likely to work simple any longer than absolutely necessary, is about the same as saying that an engineer with the ordinary engine cannot be trusted to pull the reverse lever up as soon as possible."

Later practice interposed, within or near the intercepting valve, a reducing valve, which is used to admit live steam, at a reduced pressure only, into the low-pressure cylinder when starting or when working simple. This reduced the abnormal shocks that were produced when starting large compounds of earlier design. The reducing valve, the intercepting valve, and the separate exhaust valve were so closely combined in many cases and so dependent, one upon the other, in their operation, that it became the tendency among railway and mechanical men to refer to the whole mechanism simply as the "intercepting valve."

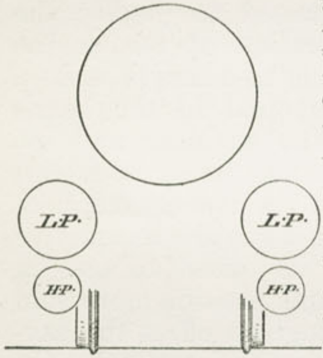


Fig. 108.

While the limit to the size of the ordinary locomotive may be considered to have been reached when the largest practical boiler that can be placed on a given gauge track has been attained, the limit to the American two-cylinder, or cross-compound, with outside cranks will be the maximum width allowable for locomotives. However, again Mr. Mallet, the father of the present era

of compound locomotives, has seemingly solved the problem by dividing the low-pressure cylinder into two cylinders, as shown in Fig. 105, of smaller size attached to the same crosshead. With such a construction it would appear that the boiler would still be the limiting feature of the size of the compound as well as the simple locomotive.

The proper cylinder ratio of compounds for all varieties of service is still somewhat undetermined. By the cylinder ratio is meant the proportion between the volumes of the high and the low-pressure cylinders, not including the clearance

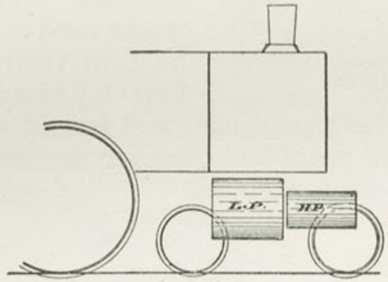


Fig. 109.

spaces. In American practice where the length of stroke is the same, the cylinder ratio would be as the areas of the two pistons, and it can readily be found by multiplying the diameter of each cylinder by itself and comparing the two products. For instance, to find the cylinder ratio of an engine with a 20 inch high and a 30 inch low-pressure cylinder, multiply 20x20 equals 400; 30x30 equals 900; 400 goes in 900 two and one-fourth times, which is the cylinder ratio.

The early practice in this country with two-cylinder compounds gave a ratio of two to one or even less, but extended experiment has demonstrated that a greater proportion than this is advisable and many compounds of this class have a low-pressure cylinder from two and one-half to two and three-quarters times larger than their high-pressure cylinder. The Baldwin works used a ratio of 3 to 1 in their Vauclain four-cylinder compounds for both passenger and freight service for a number of years and consider the results eminently satisfactory, while the builders of the Brooks tandem four-cylinder compound advise a ratio of between 2.8 and 3 to 1. However, the whole problem of cylinder ratios for compound locomotives is based upon the desirability of dividing the work as equally as possible between the high and the low-pressure cylinders, and without going into details, it is apparent that no given ratio will keep the work equally divided

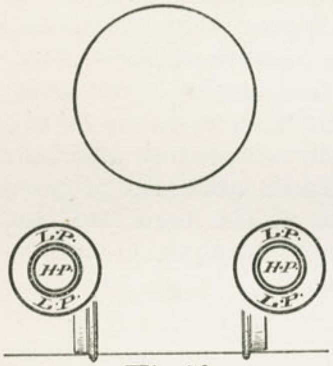


Fig. 110.

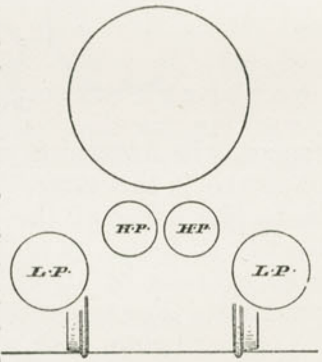


Fig. 111.

for different service and different points of cut-off, nor should this equal division of power between the cylinders be given anything but secondary consideration in comparison with the total economy of the locomotive. To partially equalize the power of compounds, the amounts of lap and lead are not the same for both cylinders; one builder uses a separate lever in the cab for independently adjusting the travel of the low-pressure valve, as fully described elsewhere.

There seems to be no general rule followed by builders in this country as to which cylinder of a two-cylinder compound should be placed on the right-hand or engineer's side of the engine. Generally the intercepting valves are located on the engineer's side to make their connections as simple as possible, and hence, according as the design contemplates the placing of this valve adjacent to the high or the low-pressure cylinder, that one is placed on the right-hand side. But even this rule is not without exception.*

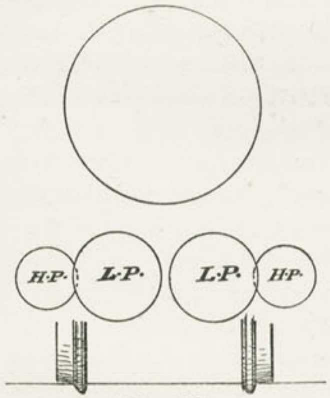


Fig. 112.

*It would seem as though the intercepting valve, if placed between the high-pressure cylinder and the receiver, would cause less wire-drawing of steam to the low-pressure cylinder than if located between the latter and the receiver.

Some compounds have cylinder casings both of the same size, but with the advent of the thirty-four or thirty-five inch low-pressure cylinder it seemed to many advisable to place it on the engineer's side with the thought of its better protection from damage if within his vision, and, furthermore, that the high-pressure cylinder casing be made no larger than necessary for reason of its better protection from accident.

It is becoming the general practice on compounds of any size to place combination safety and relief valves on the receiver and the low-pressure chest and cylinder heads to avoid damage in case of broken reducing valve or other accident that might produce unsafe pressure on that side.

CHAPTER IV.

ENGINEERS' AND FIREMEN'S MANUAL — QUESTIONS AND ANSWERS ON THE OPERATION OF COMPOUND LOCOMOTIVES IN GENERAL.

In what respects should the instructions for firing compound locomotives differ from those for single-expansion engines, as described in the Manual? On account of the effect of the milder exhaust on the fire, the fireman should carry the fire as light as possible and yet keep a thin layer of coal in a well ignited state over the entire surface of the grates.

Should the engineer observe any difference between the operation of a compound and a simple locomotive? Perhaps the most important thing is that the engineer must accustom himself to use the reverse lever for what it is intended, not hesitating to increase the valve travel whenever necessary, and converting the engine to "simple" only at low speeds and after the maximum power of the engine working compound is found insufficient. There will be no such waste of steam from lack of expansion (see Fig. 100) nor such serious injury to the fire by working the valves full gear as is the result with single-expansion engines. Do not expect to find the best running position of the reverse lever as near the center of the quadrant as with a simple engine. The engine will do better work with the lever nearer full gear, just how far depending, of course, on the varying conditions of train, grade, and speed; but, in general, do not cut the lever back too far. The engine throttle should usually be run as wide open as possible, but judgment must be used in this respect according to the existing circumstances. An engine designed for heavy freight service may do better under very light work or in passenger service, if throttled.

In order to move and stop engines quickly when desired, as for engine-house or turn-table work, how is it advisable that compound engines be handled? Their valves should be kept in simple or starting position whenever their construction will permit, in order that the engines may be moved with the least necessary opening of the throttle and that, when the throttle is closed, the pressure remaining in the pipes will the sooner escape.

In starting, why are compounds more likely to slip than other engines? If they are started working simple, their power temporarily is considerably greater than that of simple engines of the same weight, hence great care should be exercised by the engineer to avoid slipping; but at any rate the cylinder cocks should be left open as long as there is any liability of water being in the cylinders.

Why is it, that, under these circumstances, compound locomotives frequently slip only a part of a turn instead of spinning around, as many simple engines will do unless steam is immediately shut off? Because, while they are more

powerful at slow piston speeds, the ports used for starting are generally so small that a rapid movement of the piston will so greatly reduce the effective pressure on the piston as to cause the slipping to cease, many times without closing the throttle.

What harm results from frequent slipping for only a part of a revolution? This will occur each time at that part of the stroke where the turning power is the greatest and finally wear the tires out of round, so that the wheels will pound badly at high speeds, thus causing damage to the machinery and track besides making the engine ride hard.

Wherein does the lubrication of their cylinders differ from that of simple engines? Oil need only be supplied to the high-pressure cylinder or cylinders, when the engine is working compound. Hence a four-cylinder compound would be lubricated, as usual, on both sides of the engine, but a two-cylinder, or cross-compound, would require oil only in the one high-pressure cylinder when working in compound position. In this latter class, valve oil should be supplied to the low-pressure cylinder, however, when the engine is starting or running simple, but immediately shut off as soon as the change is made to compound working.

What are apt to be the injurious consequences of feeding oil to the low-pressure side when the engine is working compound? There being then no supply of live steam through the reducing and the intercepting valves, the oil would settle there and gum these valves so as to cause them to stick and, possibly, become inoperative.

When is it advisable to work the compound as a simple engine? In starting very heavy trains, and also on heavy grades when it is seen that the power as a compound with the valve in full gear is insufficient.

When the engine can be run simple for any period at the will of the engineer, above what speed is it impracticable to do so? Above a speed exceeding six or eight miles an hour.

What is the reason for this? Because, as outlined elsewhere, the special ports for use when the compound locomotive is working simple are usually purposely designed too small to permit of much speed.

If special valves for use when the engine is drifting are not provided, what is it advisable to do? Work a little steam all the time in order to keep the large valves and pistons somewhat lubricated.

Why is it more difficult to detect leaky valves and cylinder packing in compound than in simple engines? In the first place it does not so seriously affect the good working of the engine, and, in the second place, because the high-pressure cylinder does not exhaust to the atmosphere where a blow could be heard, and also the pressure behind the low-pressure piston is very much lower than with a simple engine and, consequently, a blow does not sound as loud.

What general rule will apply to compound as well as simple locomotives where one side has to

be disconnected in cases of accident? On the disabled side, always block securely at both ends of the crosshead and firmly secure the valve, under all ordinary circumstances, in the center of its seat?

What is usually the cut-off in the high-pressure cylinder with the reverse lever hooked up? Some builders cut no notches higher up in the quadrant than would give a cut-off at one-half stroke, while others notch the quadrant all the way up to the center.

Why is it not necessary to have notches in the quadrant for shorter cut-off than one-half? A shorter cut-off than one-half for a compound locomotive is generally inadvisable for reasons analagous to those hereinbefore urged against a shorter cut-off than one-fourth for a simple locomotive; also it prevents damage that might ensue from excessive compression. With a ratio of 2 to 1 between the sizes of the low and the high-pressure cylinders, one-half cut-off gives practically four expansions, a three-fourths cut-off gives two and two-thirds expansions; with a cylinder ratio of 3 to 1, one-half cut-off gives about six, and three-fourths cut-off about four expansions. Fig. 100 clearly shows, that, while the most economical cut-off (as far as the amount of steam used is concerned) is about one-quarter of the stroke for single-expansion engines, it is about one-half stroke for compounds. Lighter work than is produced by full throttle and one-half cut-off in the high-pressure cylinder can best be obtained by throttling the engine.

In what way does the use of a separate exhaust valve give greater power to the two-cylinder compound at slow speeds? Assuming 200 pounds boiler pressure and a cylinder ratio of $2\frac{1}{2}$ to 1, the high-pressure exhaust reaches about 57 pounds when the engine is working compound. This pressure is the receiver pressure and becomes the initial pressure (at slow speeds) in the low-pressure cylinder. When working simple, the reducing valve permits about 80 pounds of live steam to pass into the low-pressure cylinder, thus considerably increasing the power in that cylinder. The high-pressure piston also exerts an equally increased power when working simple, as the back pressure of 57 pounds is removed by the separate exhaust valve.

THE BALDWIN FOUR-CYLINDER COMPOUND.

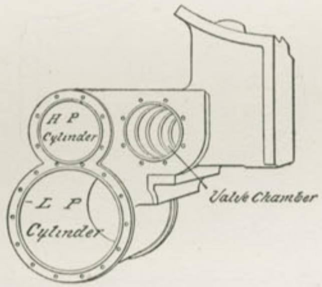
The builders of the "Vauclain" four-cylinder compound locomotives claim a design productive of the greatest efficiency with the utmost simplicity of parts and the least possible deviation from existing practice; that they also develop equal power on each side of the locomotive, thereby preventing the racking of the machinery resulting from an unequal distribution of power; and that, in their method of handling by the engineer, there is but slight departure from that of single-expansion or non-compound locomotives. They may be started, and run for any desired length of time, either simple or compound, at the will of the engineer, and can be changed from the one to the other at his discretion by the

movement of a small lever in the cab which also operates the cylinder cocks.

The principal features of construction are as follows:

The cylinders consist of one high-pressure and one low-pressure cylinder for each side, the ratio of their volumes being as nearly 3 to 1 as the employment of convenient measurements will allow. They are cast in one piece with the cylindrical valve chamber and the saddle, the cylin-

Fig. 113

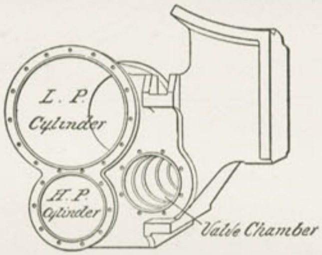


Baldwin Four-Cylinder Compound.
Cylinder Arrangement.

ders being placed one directly above the other and as close together as they can be with adequate walls between them. Figs. 113 and 114 show the proximity of the two cylinders, while in Fig. 115, which shows the arrangement of the cylinders in relation to the valve, the actual construction is distorted for illustrative purposes.

The valve used to distribute the steam to the cylinders is of the piston type, working in a cylindrical steam chest located in the saddle of the cylinder casting as close to the cylinders as possible and between them and the smoke-box, as shown in the figures. This chest, having steam passages cast larger than required, is bored out enough larger than the diameter of the piston valve to permit the use of a hard cast iron bushing. Fig. 122 shows this bushing and one method of forcing it into place so that steam tight joints will be had between all ports; it

Fig. 114.



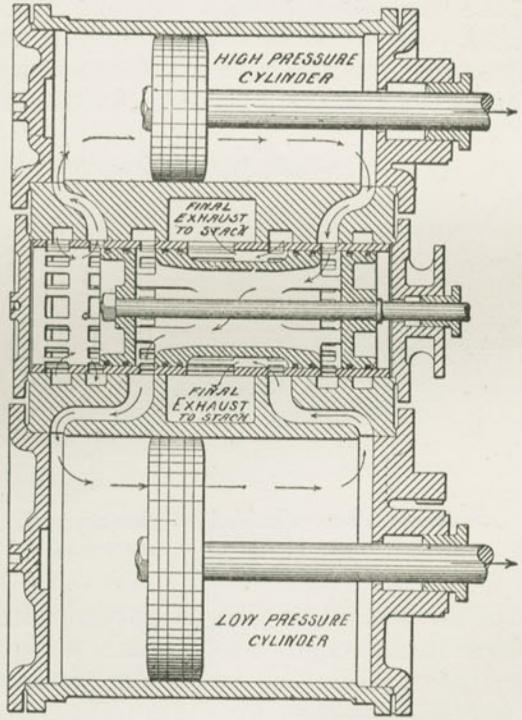
Baldwin Four-Cylinder Compound.
Cylinder Arrangement

also shows the narrow bridges across the steam ports which prevent the eight packing rings of the valve (shown in Fig. 116) from entering the ports. These cast iron packing rings form the edges of the valve.

The valve is of the piston type—double, and hollow between the two inside pistons—but having two solid ends, as shown by Fig. 116, and controls the admission and exhaust of both cylinders. The exhaust steam from the high-pressure

cylinder becomes the supply steam for the low-pressure cylinder and is transmitted from one side of the high-pressure cylinder to the opposite

Fig. 115.

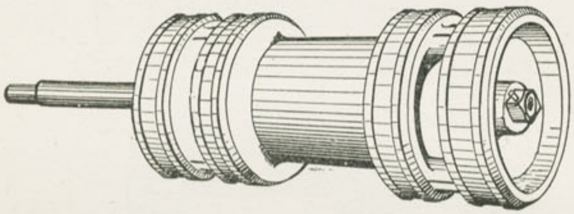


Baldwin Four-Cylinder Compound.
Steam Distribution with Piston Valve

side of the low-pressure cylinder through the hollow portion of the valve, as indicated by arrows, Fig. 115. The supply steam for the high-pressure cylinder enters the steam chest at both ends, thus balancing the valve with the exception of the area of the valve-stem at the back end.

The more common slide valve action being so much better understood by the average railroad man than the piston valve, I will liken this four-piston valve to one slide valve within another having external admission and internal exhaust in both cases. Thus it will be seen that the outside

Fig. 116.



Baldwin Four-Cylinder Compound. Piston Valve.

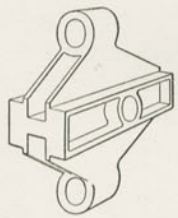
edges of the two outer pistons govern admission and their inside edges the exhaust of high-pressure cylinder, while the two inner pistons similarly regulate the flow of steam to and from the low-pressure cylinder, all of which will be evident by a reference to the arrows in Fig. 115.

Where the front rails of the frame are single bars, the high-pressure cylinder is usually put on top, as shown in Fig. 113, and in that event, with

the usual rocker-arm, indirect valve motion is used.* When the low-pressure cylinder is put above (Fig. 114) on account of the double front rails of the frame, they also prevent the use of the rocker-shaft and box and the valve motion is then termed direct-acting, which necessitates a different location of the eccentrics on the axle.*

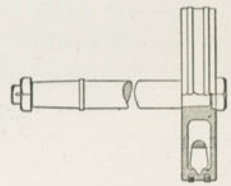
Engineers and those employed in shops and round-houses for setting valves and eccentrics should thoroughly understand the difference between the position of the eccentrics with relation

Fig. 117



Baldwin Four-Cylinder Compound Cross-Head

Fig 118



Baldwin Four-Cylinder Compound Hollow Steel Piston

to the crank-pins for direct and indirect valve motion, as given fully elsewhere in the Manual, and further brought out in the Catechism on Accidents to Baldwin Four-Cylinder Compounds hereinafter contained.

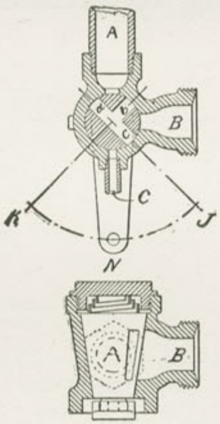
The style of crosshead is shown in Fig. 117. It is made of cast steel, to insure the greatest strength with a minimum weight, the wearing surface being lined with tin. The piston, shown

*Direct and indirect valve motion will be found fully illustrated and explained in the earlier chapters of the Manual.

in Fig. 118, is also preferably made with cast steel heads, the object in both cases being to reduce the weight of the reciprocating parts to a minimum.

It is obvious, that, in starting these locomotives from a state of rest with heavy trains, it is necessary to obtain a greater power than that exerted by the high-pressure piston alone, for there would

Fig. 119



Baldwin Four-Cylinder Compound.
Combined Starting Valve and Drip Cock.

be no pressure on the low-pressure piston until the high-pressure cylinder had made one exhaust; hence it is necessary to admit steam to the low-pressure as well as the high-pressure cylinders. This is accomplished by the use of the starting

valve (Fig. 119).* This is simply a plug-cock which is opened by the engineer by means of suitable levers from the cab, to admit steam from one end of the high-pressure cylinder to the other, and thence, as if it were the ordinary high-pressure exhaust, into the low-pressure cylinder. This same valve acts as a cylinder cock for both ends of the high-pressure cylinder and is operated by the same lever that actuates the ordinary cylinder cocks, which are in this case on the low-pressure cylinder, thus making, probably, the most simple starting device used on any compound locomotive and one not easily deranged. The operation of the starting valve in conjunction with the cylinder cocks is clearly shown in Fig. 120. The starting valve should be kept closed (position *N*) as much as possible, as its indiscriminate use reduces the economy and makes the locomotive "logy."†

Air valves, to prevent a vacuum, are placed in the steam passages of the high-pressure cylinder,

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*This is sometimes called the "By-Pass" valve, as it connects the two sides of the high-pressure piston, but for an entirely different purpose than that to which the by-pass valves are put in connection with the low-pressure cylinder as described hereinafter under the Richmond and the Rogers compound, and for that reason I have not called it a "by-pass" valve. Two earlier forms of starting valves have been used with Vauclain compounds, but, inasmuch as they have been superseded by this form of valve, it is not deemed necessary to illustrate and describe them herein.

†An engine which should be capable of high speed but is not, and in which the pressures work against themselves in the cylinders, is said to be "logy."

a practice now generally followed on all locomotives, either simple or compound. Additional air valves, marked *C* and *C'* in Fig. 120, are placed in connection with the ports in the valve chamber leading to the low-pressure cylinders. Air valves of somewhat different shape have been described and shown in detail heretofore in the Manual.

Water relief valves *W W*, Figs. 120 and 121, which are nothing more nor less than pop valves, are applied to the low-pressure cylinders and attached to the front and back cylinder heads to relieve excessive pressure of any kind, steam or water. The spring in the water relief valves on these engines is made to carry a pressure enough greater than the boiler pressure to prevent their discharging steam and water ordinarily in starting the engine simple.

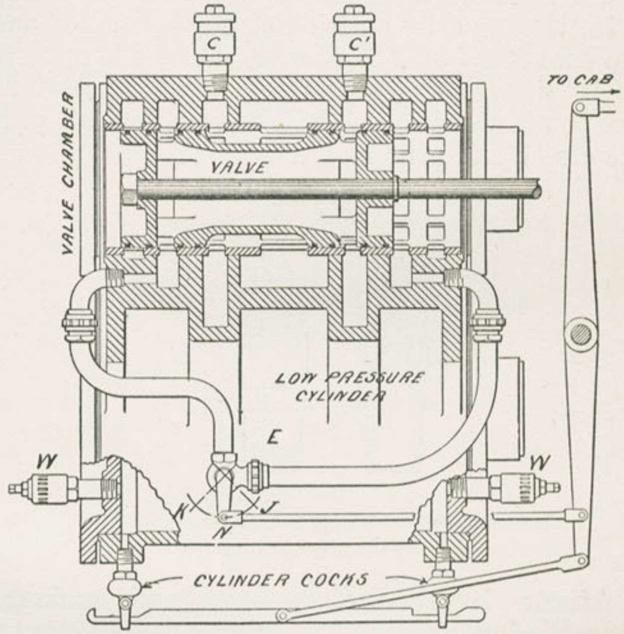
In all other respects the locomotive is the same as the ordinary single expansion locomotive.

Operation of the Baldwin Four-Cylinder Compound.—When starting the locomotive, the engineer should, ordinarily, pull the cylinder cock lever way back and thus open the cylinder cocks in order to relieve the cylinders of condensation, and, as the starting valve is opened by the same movement, steam is thus admitted to the low-pressure cylinder and the locomotive started quickly and freely.

In case the locomotive is at a platform of a crowded station, or in any other place where it is

undesirable to open the cylinder cocks, the engineer should move the starting lever in the opposite direction from that usually given it,

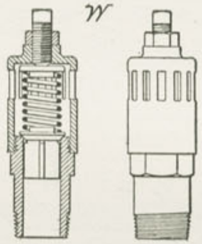
Fig. 120.



Baldwin Four-Cylinder Compound.
Showing operation of Starting Valve and Cylinder Cocks.

placing the starting valve handle in position *J*, Figs. 119 and 120; that is, he should push forward the lever in the cab, thus allowing steam to pass through the starting valve without opening either the low-pressure cylinder cocks or the drip *C* of the starting valves. By further reference to Fig. 119, it will be seen how, when the handle is in position *K*, ports *A*, *B*, and drip *C* are all connected by the ports *a*, *b*, and *c* of the plug; but if the handle is in the opposite position *J*, ports *A* and *B* only are connected, as *b* is now at *a* and *c* is opposite *B*; in its central position *N* (normal position for compound working), it will be seen that all ports are closed as in the figure.

Fig. 121.



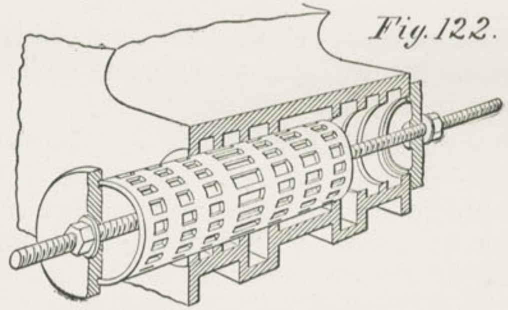
Baldwin Four-Cylinder Compound.
Cylinder Relief Valve

After a few revolutions have been made and the cylinders are free from water caused by condensation or priming, the engineer should move the cylinder cock lever into the central position, *N*, causing the engine to work compound entirely. This should be done before the reverse lever is disturbed from its full gear position.

Ordinarily, the reverse lever should not be "hooked up," thereby shortening the travel of

the valve, until after the cylinder cock lever has been placed in its central position, but it is often necessary to open the cylinder cocks when at full speed to allow water caused by priming or foaming to escape from the cylinders, and in such cases no disadvantage is experienced, and the reverse lever need not be disturbed.

The starting device is simply designed for use in the starting of the train and should not be used at any other time unless there is imminent danger of stalling and the lever has been previously dropped to full gear. In other respects,



Baldwin Four-Cylinder Compound
Valve Bushing, Showing Method of Pressing in

aside from these here noted, the rules governing the operation of compound locomotives in general should be clearly understood by any engineer who is liable to be called upon to run a compound locomotive of this or other design.

REPAIRS.

The builders of the Vauclain four-cylinder compound claim an advantage in it over the two-cylinder or "cross-compound" locomotive in simplicity of parts, there being no intercepting valve,* and a similarity to all the parts of a single-expansion locomotive. Thus its repairs will be similar to those of simple locomotives. To carry out this simplicity of parts, the piston rods of the high and low-pressure cylinders are of the same diameter and designed strong enough to withstand the severest strains of service.

The packing rings in the valves are easily replaced and the valve chest bushing can be cheaply and easily renewed. In extracting old bushings it is best to split them between the ports with a narrow chisel. The new bushings can be pressed in by some such handy device as that shown in Fig. 122.

Accidents to Baldwin Four-Cylinder ("Vauclain") Compounds.—For all ordinary accidents, such as broken main rod or pin, or a broken valve stem, what should be done? The same as for non-compound or simple locomotives, as described fully in the earlier chapters of the Manual.

With a low-pressure cylinder head knocked out, would it be necessary to disconnect that side? Not for a short distance.

In that event, how many exhausts would there be during one revolution? There would be three

*The intercepting valve is the valve which prevents the live steam which is admitted from the boiler to the low-pressure cylinder at certain times, from passing through the receiver to the high-pressure cylinder where it would produce back pressure on the piston.

in the stack and one through the open cylinder head and the latter exhaust might obstruct the engineer's view, if on his side, and render the procedure inadvisable.

With the Vauclain Compound, at what position of the reverse lever is work of the two cylinders most nearly equalized? At a cut-off of about one-half the stroke in the high-pressure cylinder.

When is the work most unequal and the strains on the crosshead consequently the greatest? In starting with the engine working simple, as then the high-pressure piston is nearly balanced by live steam on both sides and the low-pressure cylinder obtains approximately boiler pressure.

What results would be likely should the rigging of the cylinder cocks and starting valve become bent or disconnected? Should one starting valve fail to properly close, the exhausts would be of unequal intensity. If one of them failed to open when required in starting, the engine would be weak on that side as it would have to start compound, that is with steam for the first stroke in the small high-pressure cylinder only.

In this latter event, when would the first exhaust from that side take place? Not until the completion of the return stroke.

If the cylinder cocks open and close with the same rigging as the by-pass valve, why would not the engineer know thereby that the by-pass valve was in position desired? From the previous description of this rigging, shown in Figs. 119 and 120, it should be remembered that the cab lever pushed clear ahead opens the by-pass valve, but not its drip nor the cylinder cocks.

Before altering the valve motion, what else should be examined if the exhausts were of unequal intensity? Examine for broken packing rings in the piston valve or the low-pressure cylinder.*

In case a valve-stem broke off inside the chest or the valve itself broke, would it be certain of discovery at once, as with an ordinary slide valve? Possibly it would not. Instances have been cited where compound locomotives of this system have hauled passenger trains long distances with broken valve-stems and broken valves. The two ends of the valve being unbalanced by the area of the valve-stem (see Figs. 115 and 116) accounts for the first possibility, while live steam from the induction ports acting on each end of the valve would explain the case of an undetected broken valve.

How can it be found if the cylinder packing in the high-pressure cylinder is blowing? Put the engine on the quarter, block the wheels, and test as usual for leaky slide valve; then, with the starting valve closed (in compound position) and the low-pressure cylinder cocks blocked open,

*A case is cited by the builders where an engineer ran his locomotive two days without any piston head at all in one of the high-pressure cylinders, and even then could not tell what was the matter except that the intensity of the exhausts were unequal and the engine did not make good time. Machinists put to work to locate the trouble, found it to the great surprise of the engineer.

drop the reverse lever into full gear. Steam passing the high-pressure piston will appear at the open cylinder cock of the low-pressure cylinder, but at the opposite end that would be expected with a simple engine.

How can it be found if the packing in the low-pressure cylinder is blowing? Put the engine on the quarter and open the starting valve and cylinder cocks and look for any escape of steam from the low-pressure cylinder cock on the end that should be in exhaust, as with a simple engine.

DIRECT VALVE MOTION
WITHOUT ROCKER ARM.

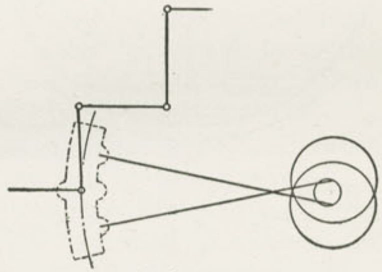
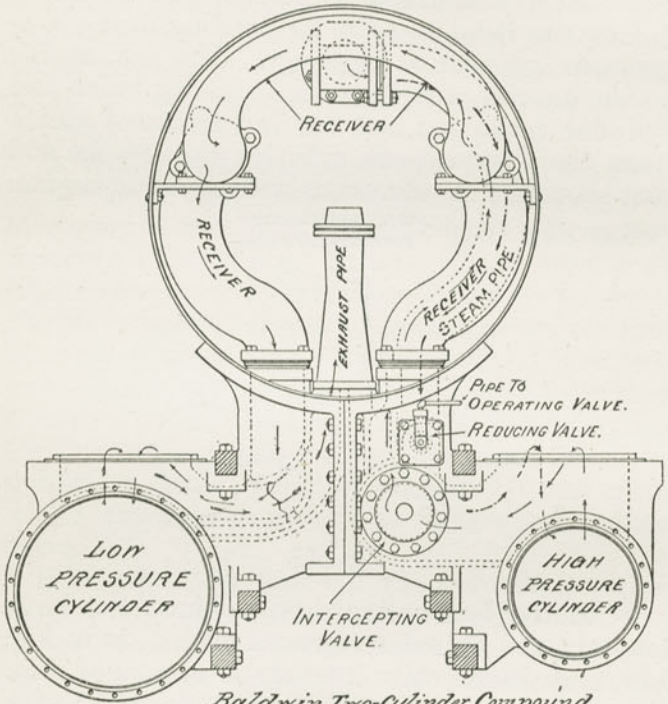


Fig. 123.

With the four-cylinder type, where the large low-pressure cylinder is placed on top, as in Fig. 114, and direct valve motion is employed, how should the eccentric rods on one side stand with the same side of the engine on the forward center? They should be crossed, as shown in skeleton Fig. 123. A slipped eccentric should be set the same as for similar valve motion on a simple engine, as fully described heretofore in the Manual under "Third Examination of Firemen."

THE BALDWIN TWO-CYLINDER COMPOUND.

The original Baldwin two-cylinder compound, built in the year 1892, was of the cross-compound receiver type and, after the first stroke or two,



Baldwin Two-Cylinder Compound
Fig. 124

or as soon as the receiver had attained a pressure of 100 lbs., the engine automatically changed to compound and could not be operated otherwise. It belonged, therefore, to the automatic class of compounds. The reducing and the starting valve

then employed were changed materially in the later design of the two-cylinder compound herewith illustrated and described.

Their later two-cylinder compound locomotives belong to the class of convertible compounds, as they can be operated either simple or compound for any length of time by the movement of a small valve in the cab, as shown by Fig. 128.

Fig. 124 shows a front view, giving the general arrangement of cylinders, steam, exhaust and receiver pipes in the front end, and the location of the intercepting and reducing valve in the saddle of the high-pressure cylinder. The low-pressure cylinder derives all its pressure from the receiver when running compound, as is usual in two-cylinder compounds.

The office of the intercepting valve is two-fold. It acts as an intercepting valve by opening and closing communication between the two cylinders, and also as a separate exhaust valve, by connecting the low-pressure cylinder with the exhaust to the stack. This it does by diverting the exhaust from the high-pressure cylinder either into the atmosphere, when working single-expansion, or into the receiver, when working compound, and is operated at the will of the engineer.

The office of the reducing valve is to admit live steam at a reduced pressure into the receiver and thence to the low-pressure cylinder, when the engine is working single-expansion, and also to close simultaneously with the changing of the intercepting valve to the position which causes the engine to work compound, so that the receiver will obtain no live steam from boiler when taking the exhaust from high-pressure cylinder. The performance of the first above-mentioned function—that of reducing the pressure of live steam delivered to the receiver—is necessary in order

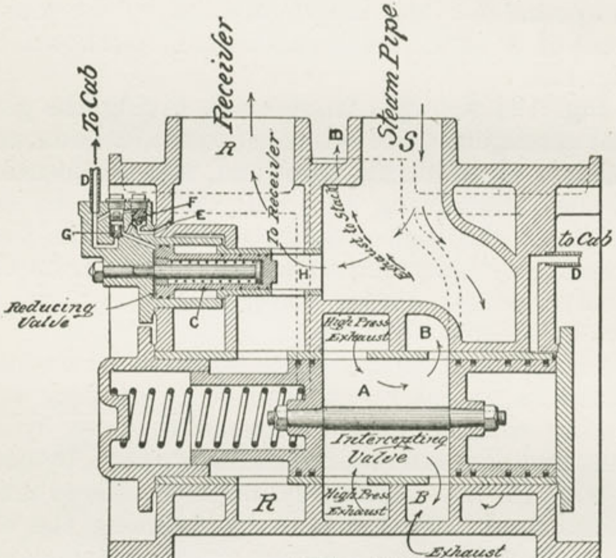


Fig. 125.

Baldwin Two-Cylinder Compound Engine Working Simple

that the total pressure on the large low-pressure piston shall not be greater than that on the high-pressure piston, and thus the low-pressure side kept from jerking the train and producing unequal strains on the two sides of the locomotive when working as a simple engine.

Operation of the intercepting and reduction valves.—In Figs. 125 and 126 the intercepting valve is marked *A* and the reducing valve *C*. It will be seen that they are both cylindrical in

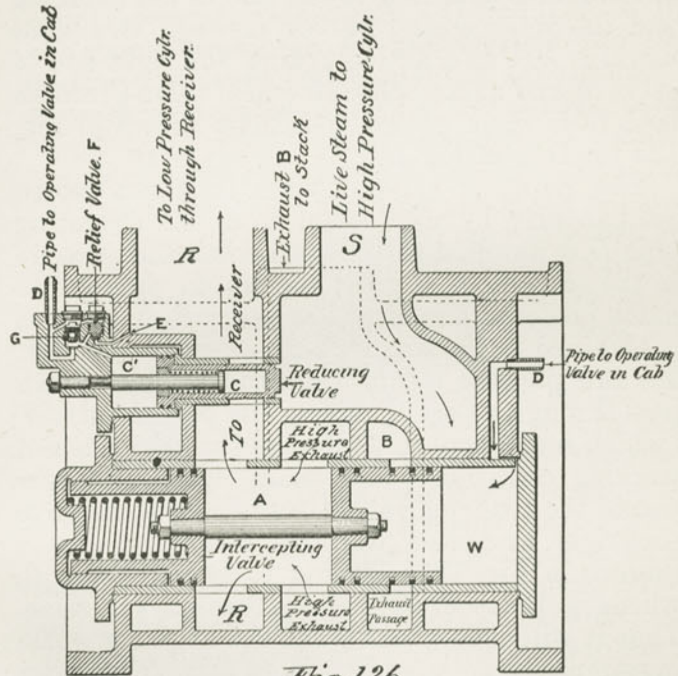


Fig. 126

Baldwin Two-Cylinder Compound Engine Working Compound.

form, are placed in bushings having suitable ports, and that coil springs hold them in their normal positions when no pressure is acting against them to overcome these springs.

In the cab of the locomotive is placed an operating valve, shown in Figs. 127 and 128, having two positions, marked "SIMPLE" and "COMPOUND." Through this operating valve a pressure of air or live steam is admitted to one side of the reducing and the intercepting valves through two pipes marked *DD*, and, acting against the right end of valve *A* and against the left end of valve *C*, moves both from their normal positions shown in Fig. 125 to those of Fig 126.

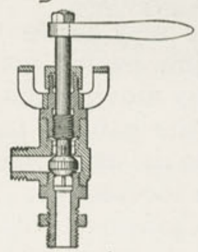
The reducing valve *C*, when it is not closed permanently by live steam from the operating pipe *D*, is automatically closed when the pressure in the receiver *R* is great enough to produce as much power in the large low-pressure cylinder as is obtained in the smaller high-pressure cylinder. For this purpose steam from the receiver *R* can pass through a port *E*, raising the poppet valve *F* (which remains open as long as the engine is not working compound) and bears upon the larger end of the reducing valve *C*, causing it to move to the right and close the live steam passage *H* (shown in Fig. 125) leading to the receiver *R*, whenever the receiver pressure becomes excessive. Thus it will be seen that when the engine is working simple there must be a close balance between the left-hand larger end of the reducing valve, being acted upon by receiver pressure, and the right-hand smaller end of the reducing valve, being acted upon by live steam from the main steam pipe *S*. In this way is the receiver pressure kept as much lower than the boiler pressure as the large end of the reducing valve is greater than

the small end. This proportion is relative to the respective sizes of the high and the low-pressure cylinders and hence equal cylinder power will be given both sides of the engine in working simple. When the engine is standing, the lever of the small operating valve, Figs. 127 and 128, in the cab should be placed at position marked "SIMPLE," and the valves are then in position for the engine to work as a single-expansion locomotive, as the steam pressure is relieved through this cab valve from the large end of the reducing valve and the right-hand end of the intercepting valve, allowing these valves to assume (by the action of their springs) their respective positions shown in Fig. 125. The arrows in this figure illustrate clearly how the steam can pass from the high-pressure exhaust through the intercepting valve *A* to the independent exhaust *B* leading to the stack (see dotted lines and arrows). At the same time the passage of live steam to the receiver—from which the low-pressure cylinder receives its supply—takes place through ports *H*, as shown by other arrows. The receiver pressure is governed by the automatic action of the reducing valve, as previously explained.

Fig. 127.

Dial

Fig. 128



Operating Valve
Baldwin Two Cylinder Compound

Thus the engine can be used as a single-expansion locomotive in making up and starting trains, and then, at the will of the engineer, the operating valve, Figs. 127 and 128, in the cab can be moved to the position marked "COMPOUND." This will admit live steam through the two supply pipes *D*, thence to the cylinders marked *W* and *C'*, Fig. 126, changing the intercepting and the reducing valves quickly, and, as the ports are small, noiselessly, to the position shown in the latter figure. With the intercepting valve in this position it will be seen that the independent exhaust *B* is closed and steam from the high-pressure exhaust must follow the course of the arrows to the receiver, passing around the small reducing valve bushing and its valve *C* which is kept closed by the live steam from pipe *D*.

At any time the engineer may desire to increase the power of the engine as, for instance, when in danger of stalling, by moving the lever of the operating valve in the cab to position marked "SIMPLE" the engine is again changed at once to a single-expansion locomotive.

Accidents to Baldwin Two-Cylinder Compounds.—With one side disabled, what should be done in order to safely run the engine in? Disconnect the disabled side, as advised for simple engines, place the intercepting valve in position for working simple so as to open the separate exhaust port, and run in with one side.

Should the small pipes *DD* leading to the reducing valve *C* and the intercepting valve piston be broken off, how could the engine be worked? With single-expansion only, unless the back head of the separate exhaust chamber *W* were removed

and the piston blocked in the position shown in Fig. 126; then the engine would become an automatic compound, that is, would start simple but automatically go to compound after a revolution or so.

What would it be advisable to do in case of a broken reducing valve? Use very light throttle at slow speeds, or run with a reduced boiler pressure.

Should the small valves *F* and *G* be frequently inspected and cleaned? Yes. These valves and the reducing and the intercepting valves become gummed by the injudicious use of cylinder oil on the low-pressure side.

THE SCHENECTADY COMPOUND.

Locomotives built by the Schenectady Locomotive Works are oftentimes styled by the older railway men as "McQueen" engines, although the name of the builders has been as at present for many years.

These builders have constructed many compound locomotives, and, including the original valve design, have employed three styles of compound mechanisms, but all engines built have been of the two-cylinder variety of compounds.

Original Schenectady Type.—The original design by their then superintendent, Mr. A. J. Pitkin, consisted of an intercepting valve and a reducing valve. The stem of the intercepting valve was connected by levers to an index in the cab, which showed its position to the engineer. These engines belonged to the class of automatic compounds.

In starting the engine, a small pipe from the boiler through a reducing valve supplied steam to the low-pressure cylinder at a reduced pressure. When the receiver had accumulated sufficient pressure by the exhaust into it from the high-pressure cylinder, the intercepting valve would automatically be thrown to its normal position for working compound; then the supply of live steam to the low-pressure cylinder was cut off and the receiver pressure admitted, and thus the engine worked compound.

The following modification of this valve arrangement was afterwards made by Mr. Pitkin and applied to many locomotives by the Schenectady Locomotive Works.

Design of 1892.—With this construction of 1892, the opening of the throttle admits live steam at the same time to both the high and the low-pressure cylinders, closes the intercepting valve and allows the engine to start with its full power as a simple engine. After a few strokes the receiver pressure automatically opens the intercepting valve and cuts off the passage of live steam to the low-pressure cylinder and the engine works compound. The special valves are located in and behind the saddle on the low-pressure side and are operated automatically and beyond the will of the engineer. Fig. 129 shows the general appearance of that portion of the intercepting valve projecting back of the saddle; Figs. 130 and 131 show the valves and pistons removed from their encasing chambers. Upon opening the throttle, a small connection from the

steam pipe admits live steam through suitable valves to an actuating piston, the movement of which opens a poppet valve, supplying live steam to the low-pressure cylinder, and also places the intercepting valve so as to close connection between the receiver and the low-pressure steam

THE INTERCEPTING VALVE.
SCHENECTADY—DESIGN OF 1892

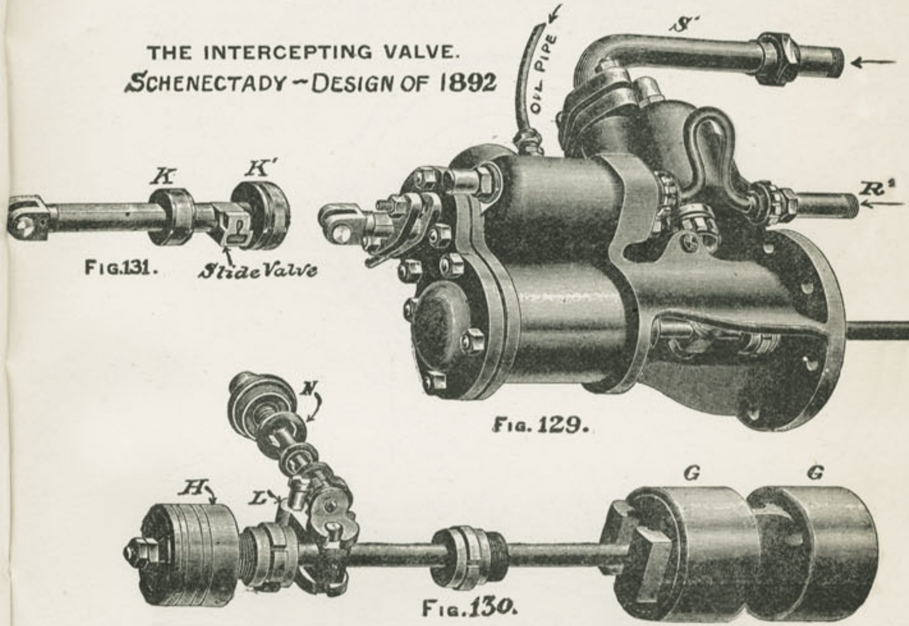


Fig. 131. Fig. 129. Fig. 130.

chest. Thus the low-pressure cylinder exhausts to the atmosphere and the high-pressure cylinder into a closed receiver. Sufficient pressure will accumulate in the receiver after a few strokes to move the small valves, thereby moving the actuating piston and with it the intercepting valve, to such position as will close off live steam to the low-pressure cylinder, and instead admit the receiver pressure, thus working the engine compound.

For the benefit of those interested in the details of this device, a more thorough description of the accompanying figures follows:

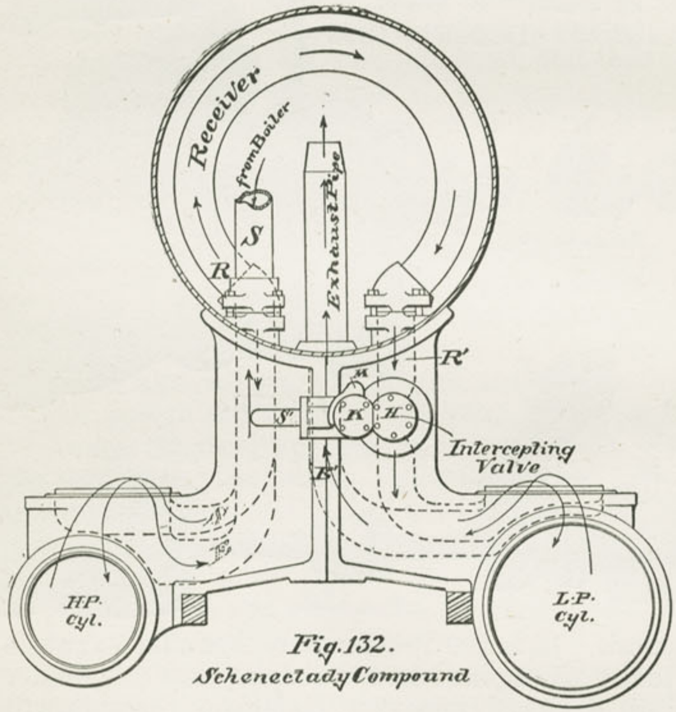


Fig. 132.
Schenectady Compound

The front view, Fig. 132, shows the general arrangement of cylinders, steam passages, and the intercepting valve. Figs. 133 and 134 both

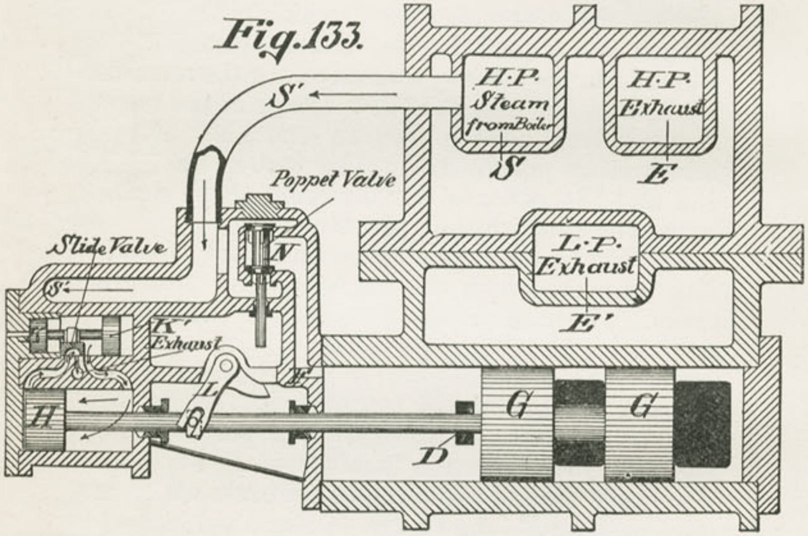
show the same horizontal section through the saddles and show the intercepting valve and the actuating valves, Fig. 133 showing them in position for working compound, and Fig. 134 for starting. Fig. 135 gives a vertical section, better showing the passages between the receiver and the low-pressure steam chest, which passages are opened and closed by the double pistons *GG* which form the intercepting valve. Of the remaining figures, 136 and 137 show details of the regulating valve, and Fig. 138 an end view of the intercepting pistons *GG*. The arrows in Figs. 133 and 134 indicate the direction of the steam in passing through the apparatus.

Fig. 132 shows a smoke-box mounted on saddles connected with the high and low-pressure cylinders located on opposite sides of the engine and having the necessary admission and exhaust ports. The exhaust port of the high-pressure cylinder is connected by a passage *E* (see dotted lines in Fig. 132 and full section of port in Figs. 133 and 134) with the receiver at *R*, Fig. 132. The other end of the receiver connects with the inlet passage R^1 (shown also in Fig. 135) leading to the low-pressure steam chest, and in this passage the intercepting valve *GG* is located and travels across it to open or close this passage.

The intercepting valve and the mechanism for operating it are mounted on the saddle of low-pressure cylinder, as before stated, while the live steam pipe *S* and the high-pressure exhaust passage *E* are situated in the high-pressure saddle. The low-pressure exhaust passage E^1 is formed by the two saddles being bolted together, see Figs. 133 and 134.

The intercepting valve consists of two pistons GG (having several small holes g through them in order to balance them, see Figs. 135 and 138) mounted at one end of a long piston rod, which

Fig. 133.

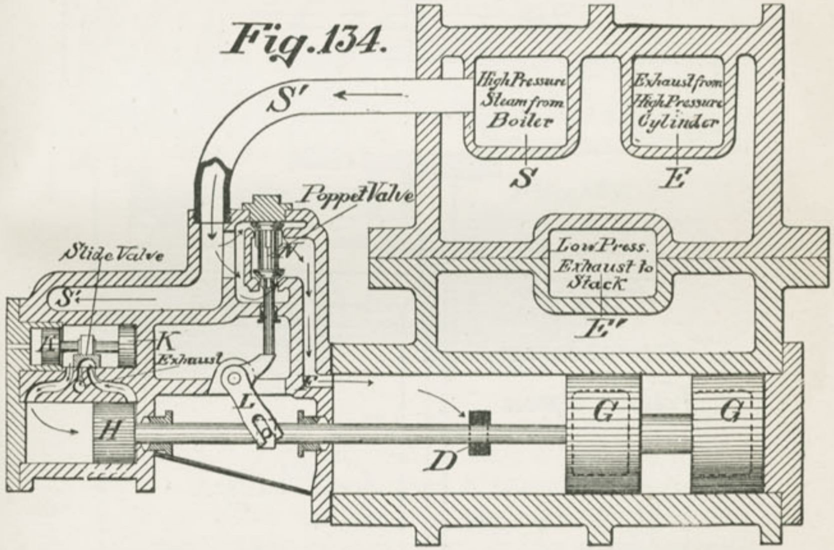


Intercepting Valve Open
Engine Working Compound

moves to and fro in a cylinder having four openings. The two large openings shown lead from the receiver to the low-pressure steam chest (see Fig. 135) and are closed by the two intercepting pistons GG when the engine is to be started, so that live steam may be admitted to the low-

pressure cylinder without producing a back pressure in the high-pressure cylinder through the receiver. Of the two remaining openings in the valve cylinder, port D leads to the low-pressure steam chest and port F admits steam from the boiler when the apparatus stands in position as shown in Fig. 134.

Fig. 134.



Intercepting Valve Closed
Engine Working Simple

The back end of the intercepting piston-rod passes through suitable stuffing boxes to a small cylinder provided with a piston H, which actuates the intercepting valve. This cylinder has a small steam chest, slide valve and admission and exhaust ports so similar to those of an ordinary locomotive cylinder, that its operation will be made plain by referring to the Figs. 133 and 134, if the movements of its slide valve are explained. This

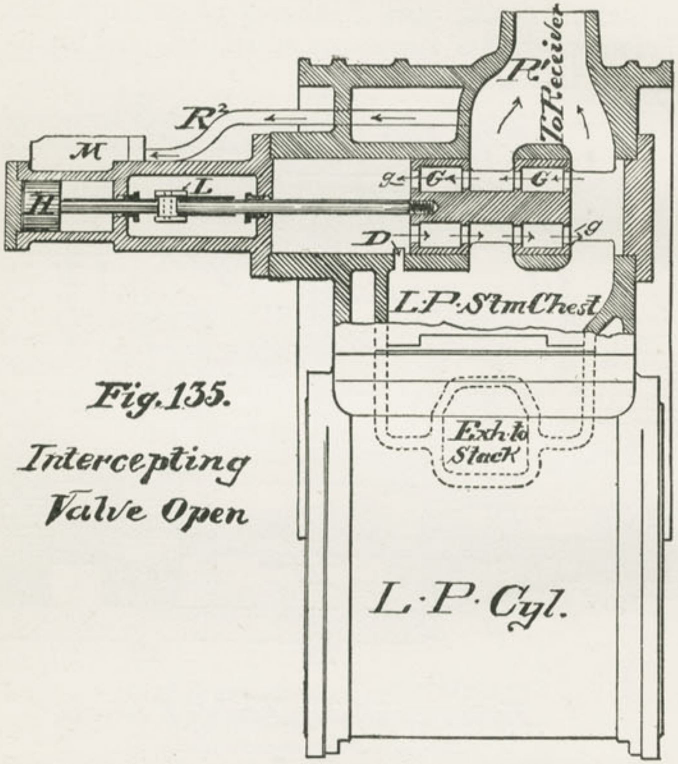


Fig. 135.
Intercepting Valve Open

small slide valve, Fig. 131, is moved by a stem connecting two pistons, K and K^1, of unequal diameter in order to insure their movement in the proper direction at the proper time. The actuation of these pistons, and with them the slide

valve, will be made clear by the figures. From Fig. 135 it will be seen that a small pipe R^2 leads from the receiver connection R^1 to this valve mechanism, and from Figs. 133 and 134, that a pipe S^1 comes from the live steam passage in the saddle and has a small port leading to the actuating valves as well as to the poppet valve N. These live steam and receiver connections come to opposite sides of a small piston valve M (Fig. 137), which is called the "regulating valve" and travels across two ports leading to the slide valve beneath it, as shown.

Fig. 136.

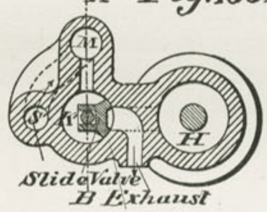
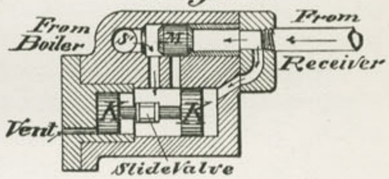


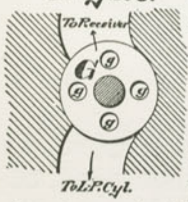
Fig. 137.



The remainder of this mechanism consists of a balanced poppet valve N, which, when open, admits live steam from pipe S^1 through the intercepting valve to the low-pressure cylinder in starting. This poppet valve N has a projecting stem on the lower side and is opened and allowed to close by a rocker-arm or bell-crank L, its two positions being shown in Figs. 133 and 134, respectively.

The operation of the apparatus is as follows: The normal position of the parts when the engine is working compound is shown in Fig. 133, in which position steam for the low-pressure cylinder comes entirely from the high-pressure exhaust through the receiver. To start the train, the engine throttle is opened as usual. This permits steam to pass to the high-pressure side and also through the pipe S^1 (Figs. 133 and 136) to the left side of piston valve *M* (Fig. 137) and down through the adjacent port (as indicated by arrows) to the slide valve chamber, there acting between the two pistons *K* and K^1 (Figs. 131, 133 and 137). The right-hand piston, being the larger, causes a movement of the slide valve from its position shown in Fig. 133 to that shown in Fig. 134, thereby uncovering the steam port to the left of piston *H*, which it forces with the intercepting valve *GG* to the right. In this position, as shown in Fig. 134, the receiver openings are closed by the pistons *GG* and the poppet valve *N* has been opened by the bell-crank L, thus admitting live steam through the intercepting valve cylinder and port *D* to the low-pressure steam chest, as indicated by the arrows. Hence it is possible to obtain the full pressure of live steam in the low-pressure cylinder in starting.

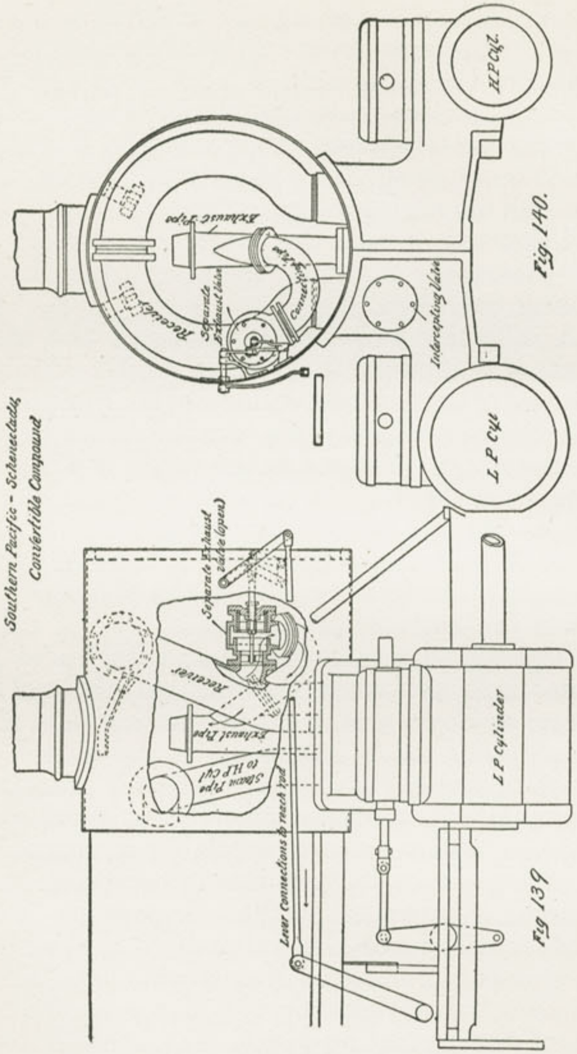
Fig. 138.



After one or two revolutions the pressure in the receiver, passing down through the small connecting port to the right of the larger piston K^1 (Fig. 137) overbalances the pressures between the pistons, thus moving the slide valve to the left, the position shown in Figs. 133 and 137. According to the ordinary action of a slide valve this reverses the pressures on the actuating piston *H*, forcing it

to the left and opening the intercepting valve. This return movement of the actuating piston *H* detaches the bell-crank *L* from the poppet valve *N* and allows the latter to close before the intercepting valve opens. After this the locomotive works compound, the passage of steam being through the high-pressure cylinder to the receiver and thence through the intercepting valve and low-pressure cylinder to the atmosphere, as previously described.

A difficulty met with in many of the earlier forms of compound mechanism, and to which the reader's attention was called at the beginning of this chapter, namely, the accumulation of dangerously high pressure in the receiver when running with the throttle closed, was overcome in this device by an automatic action of the piston valve *M* and the differential pistons *K* and K^1 (Fig. 137), as follows: When the engine is using steam the regulating valve *M* is always against the right-hand seat, as shown, and this valve only comes into use when running without working steam, as down a long grade. In this case, if the intercepting valve happened to be closed, the action of the engine would cause air-pressure to accumulate in a closed receiver as there would then be no live steam available to cause the actuating device to open the intercepting valve. Hence it is arranged so that air-pressure in the receiver will force the valve *M* to the left and itself take the place of live steam by passing to the slide valve chamber and down to the right side of the actuating piston *H*, moving it to the



Southern Pacific - Schenectady Convertible Compound

Fig 139

Fig. 140.

left and opening the intercepting valve, as shown in Fig. 133. Thus the small valve *M* acts as a safety valve, insuring the opening of the intercepting valve when live steam is not being used, and preventing the danger of excessive receiver pressure or the lifting of the high-pressure slide valve off its seat when the engine is running with steam shut off.

SCHENECTADY 1892 DESIGN, WITH SOUTHERN PACIFIC MODIFICATION.

To render it possible to run the engine "simple" for any desired period in starting, or to obtain a maximum power in case a train were stalling on a heavy grade, the Southern Pacific Co. in 1893 added to many of their Schenectady compounds of the 1892 design, a separate exhaust valve located in the smoke-box, as shown in Figs. 139 and 140. The reverse lever in the cab, when placed in either of its extreme positions, caused this valve to open and thereby connect the receiver directly with the main exhaust pipe, thus permitting the high-pressure cylinder to exhaust through the receiver directly to the atmosphere, as indicated by arrows in Fig. 139. As the receiver pressure was thus kept down it will be readily understood from the preceding description of the intercepting valve that the latter will remain in starting position as in Fig. 134, and hence the locomotive will work as a simple engine until such time as the engineer pulls the reverse lever higher up on the quadrant and thereby closes the separate exhaust valve. Then the intercepting valve automatically assumes the compound position, as in Fig. 133, for reasons hereinbefore explained.

This modification of the two-cylinder or cross-compound is of especial note inasmuch as it was one of the first in this country which permitted the working of the locomotive as a simple engine for any desired length of time, at the will of the engineer. Its results in practical operation were to greatly reduce the jerking of trains in starting (then a very serious objection to many compounds); it gave a greater maximum power at critical periods, and was withal so eminently satisfactory that the reader will notice the majority of the builders of two-cylinder compounds in this country have embodied a separate exhaust valve in their later designs.

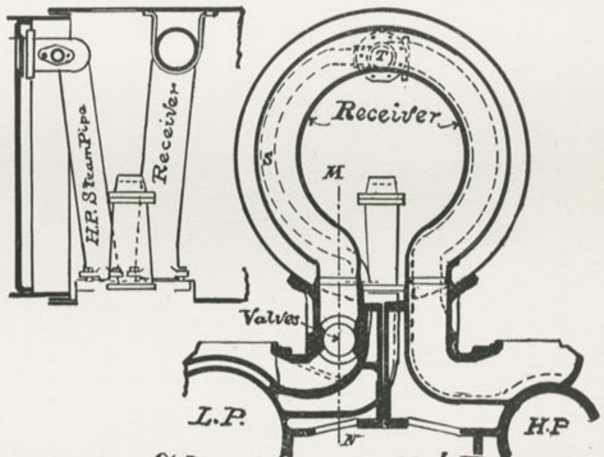
SCHENECTADY COMPOUND—DESIGN OF 1896.

The valve arrangement designed in 1896 by Messrs. A. J. Pitkin, Vice-President and General Manager, and J. E. Sague, Mechanical Engineer of the Schenectady Locomotive Works, and used as their standard construction for two-cylinder compound locomotives, will be made clear by what follows.

In general it may be said that this so-called "intercepting valve" consists of four separate parts, namely: (1) An intercepting valve proper, which allows steam to pass to the low-pressure cylinder from either the receiver or the boiler, according to its position. (2) A reducing valve allowing live steam at only a reduced pressure

to enter the low-pressure cylinder when working simple. (3) An independent or separate exhaust valve which, when open, vents the exhaust from the high-pressure cylinder to the atmosphere through the exhaust pipe and stack. (4) A small valve K inside of the separate exhaust valve, by the use of which the latter can be opened more easily and gradually.

Fig. 141. Fig. 142.



—Schenectady 1896 Design—

By the arrangement of these valves the engine can be started and run either compound or simple and can be changed from compound to simple, or the reverse, at the will of the engineer, with the throttle and the reverse lever in any position; the engineer has only to move a small three-way cock in the cab and the working of the engine changes very smoothly and without jerking the train.

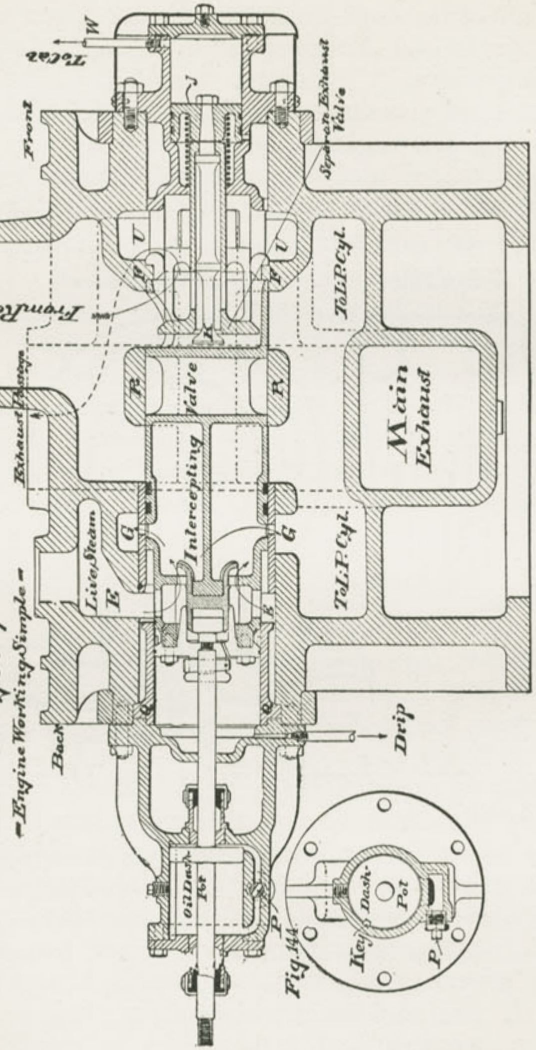


Fig. 143. Schenectady Compound —Engine Working Simple—

Fig. 144.

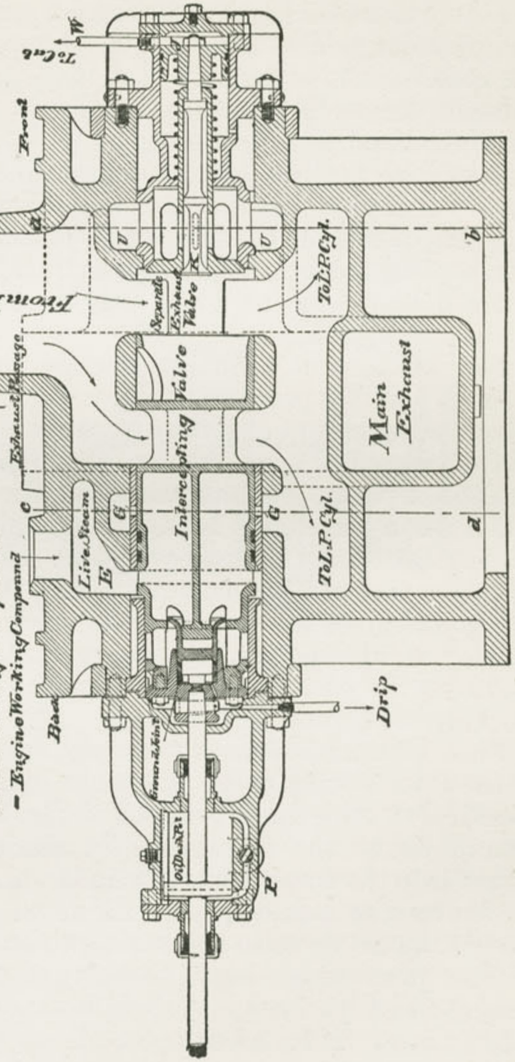


Fig. 145. Schenectady Compound — Engine Working Compound

Figs. 141 and 142 give sections of smoke arch and cylinder saddles and show the steam passages, the receiver and the location of the intercepting valve in the saddle of the low-pressure cylinder on the right-hand side of the engine.

It will be noticed by the dotted lines behind the receiver pipe that there are two steam pipes as in a simple engine, but the one (S) leading to the intercepting valve on the low-pressure side is much smaller than usual, as it will only be required for use at low speeds.

Fig. 143 shows a vertical section lengthwise through the low-pressure cylinder saddle and the intercepting valve (as if they were cut through at MN of Fig. 142) and shows the intercepting and the separate exhaust valves in the position taken when the engine is working simple and receiving live steam in both cylinders. Fig. 144 is a section through the dash-pot of Fig. 143.

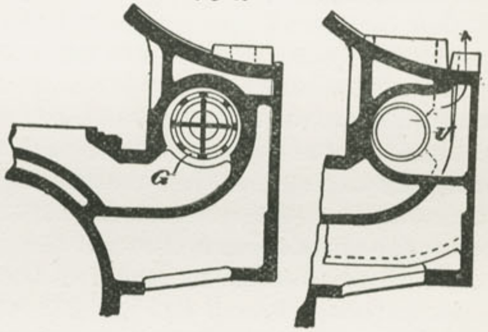
Fig. 145 gives the same section as Fig. 143, but shows the intercepting and the separate exhaust valves in the position taken when the engine is working compound.

Figs. 146 and 147 show two sections crosswise of the intercepting valve at points indicated respectively by the lines *cd* and *ab* of Fig. 145. Section *cd* shows the passages G for admitting live steam into the low-pressure cylinder, and section *ab* shows the outlet passage U from the separate exhaust valve to the main exhaust pipe.

The part which each portion of the valve arrangement performs is as follows: The separate exhaust valve, when open, allows the steam

to exhaust from the high-pressure cylinder to the atmosphere without going through the low-pressure cylinder, thus working the engine simple; when it is closed, the high-pressure exhaust must pass through the low-pressure cylinder, thus working the engine com-

Fig. 146 Section c-d Fig. 147. Section a-b



Intercepting Valve Passages

pound. The intercepting valve closes the passage between the two cylinders when the separate exhaust valve is open, so that steam cannot go from the high-pressure cylinder to the low-pressure cylinder; thus doing away with back pressure on the high-pressure piston when the engine is working simple; it also admits live steam direct from the dry-pipe through the reducing valve to the low-pressure cylinder. When the separate exhaust valve closes, the intercepting valve automatically opens the passage between the two cylinders and cuts off the supply of live steam from the dry pipe to the low-pressure cylinder. The reducing valve works only when the engine is working simple and throttles the steam passing through it, so that the pressure of steam going to the low-pressure cylinder is about one-half (or, less, according to the proportionate sizes of the two cylinders) of that admitted from the boiler to the high-pressure cylinder.

The reducing valve is quite heavily cross-sectioned, while the long, intercepting valve appears next lighter, in order to render their outlines in Figs. 143 and 145 readily distinguishable. Examining the two ends of the intercepting valve, it will be seen that the left end, exposed to the pressure of the atmosphere through the drip, is only about three-fourths as large as the right end (between the bridges *R R*, Fig. 143), exposed to the receiver; hence, if the receiver has little or no pressure, the boiler pressure on the shoulder of the intercepting valve automatically carries it to the right, as shown in Fig. 143. The reducing valve is automatically opened because of the difference in area of its two ends also. The movement of each of these valves is cushioned by dash-pots, as shown. The separate exhaust valve is operated by the engineer by means of a three-way cock in the cab. To open the separate exhaust valve the handle of the three-way cock is thrown so as to admit a pressure of steam or air through the pipe *W* against the piston *J*. Pulling the handle back relieves the pressure

against piston *J* and the spring shuts the valve, as in Fig. 145. All the engineer has to do in connection with the operation of the valves is to pull the handle of the three-way cock in the cab one way or the other, according as he wishes the engine to run simple or compound. The engineer uses the handle under the following conditions:

To Start Simple.—Under ordinary conditions this is not necessary, but if the maximum power of the engine is needed to start a heavy train, the engineer pulls the handle of the three-way cock so as to admit pressure from the cab through pipe *W* against the piston *J*, Fig. 145. This will force piston *J* into the position shown in Fig. 143, opening the separate exhaust valve and holding it open. The engine throttle now being opened, live steam at boiler pressure enters the chamber *E* from the small steam pipe *S* before mentioned and forces the intercepting valve to the right against the seat *FF*, as shown in Fig. 143. The exhaust steam from the high-pressure cylinder now passes through the receiver and is exhausted through the separate exhaust valve to an annular chamber *U* connected with the main exhaust to the stack, as indicated by the arrow in Fig. 143. (See also Fig. 147.) Steam also enters the low-pressure cylinder from chamber *E* through the reducing valve and the annular ports *G* in the intercepting valve (See Figs. 143 and 146), and is exhausted in the usual way. The reducing valve prevents the full boiler pressure from reaching the low-pressure cylinder. As will be seen from

Figs. 143 and 145, the reducing valve is partly balanced by its smaller left end being open to the atmosphere through a small groove leading to the chamber having an open drip, and thus the boiler pressure acting on the unbalanced area throws the valve open—to the right. When the pressure in the intercepting valve cavity on the right of the reducing valve becomes high enough, it will throw the valve to the left, because it acts on the whole area of the valve; the result is that the steam is throttled to the proper pressure desired for the low-pressure cylinder.

To Work Compound.—Having started the train, when the engineer wishes to change the engine from simple working to compound, he pushes the handle of the three-way cock to its first position which, relieving the pressure on piston *J* through pipe *W*, allows the spring to act to the right and close the separate exhaust valve, as in Fig. 145. As soon as this valve is closed the pressure in the receiver, having no outlet, rises and presses the intercepting valve to the left against the pressure from chamber *E*, which acts only, as stated, upon the shoulder of the intercepting valve. The receiver pressure holds the intercepting valve to the left, as shown in Fig. 145, thereby closing the ports *G* and opening a free passage from the receiver to the low-pressure cylinder as indicated by the arrows, and the engine works compound. While working compound, which is the usual way of working the engine, both the reducing and the intercepting valves are held to the left against ground joint seats. This should prevent any

steam which might leak by the packing rings from constantly escaping at the drip.

To Change from Compound to Simple.—With the engine running compound, if the engineer wishes to change to simple because of a very heavy grade, he has only to pull the three-way cock handle to the same position as for starting simple. Then piston *J* first opens the small valve *K* and then the separate exhaust valve. The small valve *K* relieves the pressure more gradually than if the larger valve were opened at once. As soon as the separate exhaust valve is opened the pressure in the receiver escapes through it and becomes so low that the intercepting valve is again forced to the right (as in Fig. 143) against its seat *F* by the steam pressure from chamber *E*, and the engine works simple as in starting.

To Start as an Automatic Compound.—If the separate exhaust valve is left closed, as in Fig. 145, the engine will start as an automatic compound when the throttle is opened, for the pressure from chamber *E* will force the intercepting valve to the right, as in Fig. 143, thus admitting live steam through the reducing valve and ports *G* to the low-pressure cylinder, while at the same time the high-pressure cylinder exhausts into a closed receiver for a few strokes. This pressure, accumulating in the receiver, will then automatically close the ports *G* by moving the intercepting valve to the left, as in Fig. 145, and the engine thereafter runs compound.

Accidents to Schenectady Compounds—the Automatic Compound of 1892. What should be done in case of a break-down on the road, necessitating the disconnecting of the high-pressure side? If but a short distance to go and a slow speed would suffice, clamp the high-pressure slide valve in center and permit the engine to run by the admission of live steam through the small pipe S^1 and the poppet valve N to the high-pressure cylinder (Figs. 133 and 134). If the intercepting valve is out of order, block the poppet valve N open, that is, up. If it were required to run at considerable speed, this small pipe S^1 would give insufficient supply, in which case the high-pressure slide valve should be blocked clear back (much farther than its ordinary travel carries it), so as to uncover the exhaust port, thus admitting live steam direct to the receiver. If the steam chest is large enough to place the high-pressure valve as described, and the intercepting valve is not deranged, the engine would run at full speed with the low-pressure side. If out of order, the intercepting valve should be held open (in the position as shown in Fig. 133) by clamping the stem between the stuffing boxes. In all cases the throttle should be handled easily to prevent a too rapid flow of boiler pressure to the large low-pressure cylinder and the consequent liability of jerking the train or causing damage to this cylinder.

What should be done if it becomes necessary to take down the low-pressure side of the engine? The engine could be moved a short distance with the cylinder cocks open or the indicator plugs removed on the high-pressure side, but as most en-

gines of this class have either a large steam chest or an "Allen"* ported slide valve, the valve can be clamped back far enough to uncover the low-pressure exhaust port, and thus run at full speed. If this cannot be done, block both the low-pressure crosshead and valve clear back and unscrew the relief valves or take off the front cylinder head on that side to make an exhaust opening from the receiver. If the intercepting valve is out of order, it must be securely clamped open, as in Fig. 133, otherwise the opening between the receiver and the low-pressure steam chest would be closed.

In this last procedure, with the exhaust other than through the stack, would the engine steam with much of a train? No; but a limited amount of steam could be maintained by the use of the blower for creating draught.

What would be the effect of the removal of the slide valve on the disabled side? This would give a free port opening under all circumstances, but would generally consume too much time to be practicable.

What prevents the leakage of live steam into the receiver when the intercepting valve is closed, as in Fig. 134, there being no packing rings in the two pistons GG? The live steam pressure acts from below when starting, so as to hold these pistons tight against ports of the receiver. Fig. 135 illustrates this clearly, if the intercepting

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*See illustrations in Part First of the Manual, showing the "Allen" slide valve.

valve were there shown closed, as live steam would then be below pistons *GG*.

What would be the result if the wiper *L* would strike the poppet valve *N* (Figs. 133 and 134) before the intercepting valve pistons *GG* closed their ports? Live steam would blow through to the receiver and produce a back pressure on the high-pressure side.

How can this be prevented? Pistons *GG* have sufficient lap to allow of their closing before the wiper *L* strikes the poppet valve *N*, and the adjustable tappet on the intercepting valve stem should be set so as to cause this. If the tappet is set too far back, valve *N* would not be opened at all and, as a consequence, no live steam would be admitted to the low-pressure cylinder in starting.

If the operating piston *H* should break, what position would the intercepting valve probably take? On account of the unbalanced area of the stem, it would probably move open to the left as for compound working, Fig. 133.

Accidents to Schenectady design of 1892, with Southern Pacific Modifications.—If it became necessary to disconnect the high-pressure side of the engine, what should be done? The same as with the 1892 Schenectady system.

Would there be any difference in case the low-pressure side broke down? Yes; disconnect the broken side as usual (see instructions for simple engines in Part First of the Manual) and run with reverse lever in full gear, if for a short distance or a low speed only is required. If it is necessary to run for a considerable distance at a good speed, it

would be advisable to disconnect the separate exhaust valve levers from their connection to the reach-rod and properly secure them in either extreme position, so as to hold the valve open. The engine can then be "hooked-up," that is, the reverse lever pulled up toward its central position, to correspond to the demands of the service.

Accidents to Schenectady Compounds—design of 1896.—What should be done in case the high-pressure side had to be disconnected? Ordinarily, open the separate exhaust valve * and do nothing different than with a simple engine; but to obtain greater speed than the supply of live steam to the low-pressure cylinder through its small steam pipe would permit, the high-pressure valve should be secured in such a position, if possible, as will uncover its exhaust port, thereby admitting live steam to the receiver and thence to the low-pressure cylinder. In this case leave the separate exhaust valve closed and handle the throttle easily so as not to cause constant opening of the safety valves on the low-pressure side.

What is necessary with the low-pressure side disconnected? Open the separate exhaust valve and allow the high-pressure cylinder to exhaust to the stack through its connection. While considerable train could thus be handled, it would not be done at anything but a slow speed, unless the low-pressure slide valve were placed so as to

* While not absolutely necessary to open the separate exhaust valve for this case, it is best to do so that there may be no accumulation of pressure in the receiver should the high-pressure valve leak.

uncover its exhaust port and the separate exhaust valve left closed.

What is done to prevent full boiler pressure from reaching the low-pressure cylinder in case the reducing valve becomes defective or broken? Pop or safety valves are placed on the chest and both heads of the low-pressure cylinder and they are set at about one hundred pounds, the highest pressure deemed advisable in so large a cylinder.

In case of a broken intercepting valve what precautions should be taken? Run the engine compound only and do not stop the engine with the low-pressure side on center.

Why must the oil dash-pot be kept filled with oil? The flow of oil from one side of the dash-pot piston to the other prevents sudden movements of and serious jars to the intercepting valve.

How can the rapidity of this movement be regulated? By a greater or less opening of the valve *P*, Figs. 143 and 144, as this valve regulates the flow of oil from one side of the dash-pot piston to the other. A slight opening causes a slow movement, while a wide opening makes possible a too rapid movement.

What would be most liable to cause breakage to the intercepting valve? Allowing the oil dash-pot to become partially or wholly empty.

What kind of oil should be used in this dash-pot? Only mineral oil, thinner, if anything, than ordinary engine oil.

What is the purpose of the key shown in the dash-pot (Fig. 144)? To prevent the intercepting valve from turning around.

With this compound, what pressure from the cab is used to operate the separate exhaust valve? Either air or steam.

Why is air pressure generally considered preferable? On account of the absence of moisture therein. As the separate exhaust valve piston *J* and its cylinder (Figs. 143 and 145) project from the front of the cylinder saddle and are exposed to currents of cold air, the use of steam therein and a lack of proper drainage might cause them to freeze in cold weather.

What objection is there to the use of air? Should the air pump stop or the pressure otherwise become exhausted, as in switching and picking up a large number of air-brake cars, there might be insufficient pressure to hold the valve open against the receiver pressure.

How is this objection overcome when air is used for this purpose? Besides the air connection to the three-way cock in the cab, there is a steam connection; closing the one and opening the other, quickly furnishes an alternative pressure for operation.

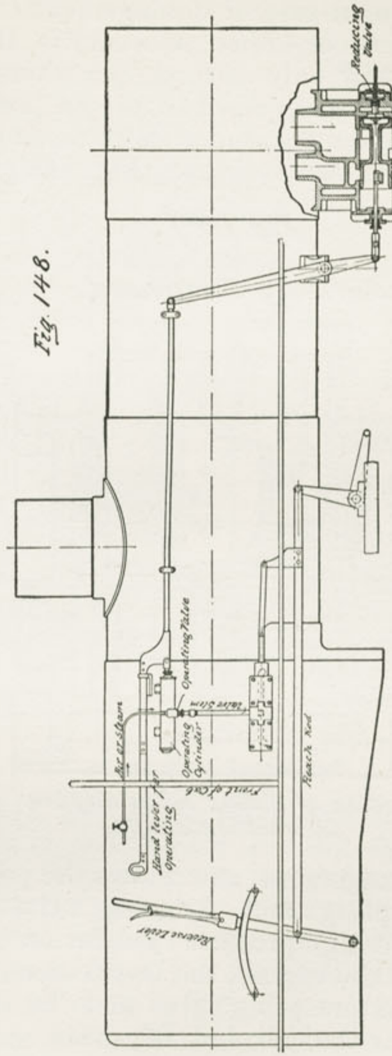
What would be the result if both the steam and the air connections were left open? There would be no effect upon the engine itself, but the steam would fill the whole air-brake system with water and seriously affect the operation of the brakes.

THE PITTSBURG COMPOUND.

The Pittsburg Locomotive Works have been one of the largest builders of two-cylinder or cross-compound locomotives in this country. Their location of the intercepting valve in the saddle of the high-pressure cylinder instead of the low-pressure cylinder is an arrangement which obviates the necessity of a second steam pipe for admitting live steam to the intercepting valve and low-pressure cylinder when it is desired to work the engine non-compound.

With the valve mechanism which will be shown and described in what follows, when the reverse lever is either in full forward or back-up gear and the throttle opened, the engine starts by the admission of live steam into both cylinders and with an open exhaust passage from each cylinder to the stack. The live steam admitted to the low-pressure cylinder is sufficiently reduced in pressure by passing through a reducing valve to cause the engine to have the same power that a simple locomotive would have with two cylinders the size of the high-pressure cylinder. When the reverse lever is "hooked-up," or drawn toward the center, one or more notches, it mechanically works an operating valve and piston near the cab, which throws the intercepting valve into position for compound working. There is a hand lever in the cab, as shown in Fig. 148, which can be used to move the inter-

Fig. 148.

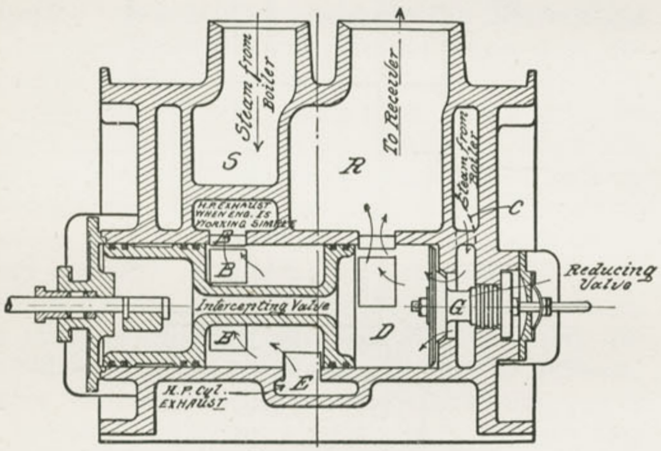


Pittsburg Compound.—Operating Device.

cepting valve in case of derangement of the operating device, or other necessity. However, the engine will only start simple when the intercepting valve is placed in proper position, as this valve does not automatically assume simple position of its own volition. Fig. 148 gives the

Fig. 149.

Pittsburg Compound.



Position of Valves when Engine is working simple

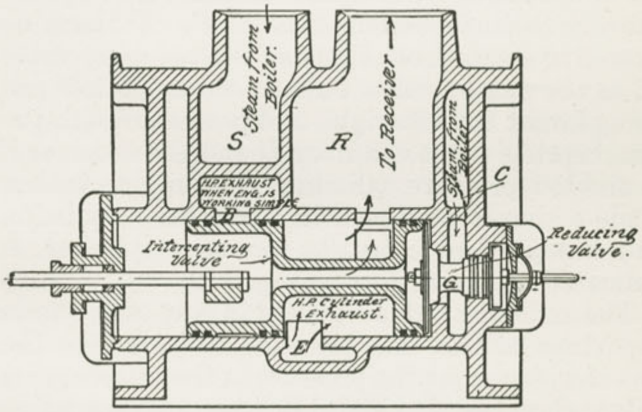
general arrangement and shows the position of the intercepting and reducing valves in the saddle of the high-pressure cylinder on the right-hand side of the engine, the lever connections between the intercepting valve and the operating cylinder near the cab, and the means of moving

the operating valve by its attachment to the reach-rod. The operating piston can be actuated either by air or steam pressure, the former being preferable, especially in cold climates.

Figs. 149 and 150 show on a larger scale the same section through the valves in the saddle.

Fig. 150.

Pittsburg Compound



Position of Valves when Engine is working compound.

In Fig. 149 the intercepting and the reducing valves are in position for working simple, while in Fig. 150 they are shown in compound position.

Port S is the passage from the steam pipe to the high-pressure steam chest, and port E the exhaust passage from the high-pressure cylinder; port R is the opening into the receiver; port B leads to the atmosphere through the stack, being an independent exhaust for the high-pressure cylinder. Port *C* is a branch from the main steam port *S*, and carries live steam to the reducing valve *G* for use in the low-pressure cylinder when needed.

When the intercepting valve is moved to the left in position for working simple, as shown in Fig. 149, steam from the high-pressure exhaust *E* passes through the intercepting valve (between its two piston ends) and to the atmosphere through the independent exhaust *B*. At the same time live steam from *C* opens the reducing valve *G*, as the valve is then unbalanced by its left end being larger than its right, and passes through the intercepting valve chamber *D* and the receiver *R* to the low-pressure cylinder. The engine is thus made a simple engine with live steam admission and independent exhausts for each cylinder, as indicated by the arrows in Fig. 149.

The reducing valve *G*, when in use, only allows a portion of the full pressure to pass into the receiver, for, when the pressure in the intercepting valve chamber *D* (Fig. 149) becomes equal to about half that of the boiler, it acts against the larger left-hand end of the reducing valve and forces it closed—to the right—thereby throttling the steam.

The intercepting valve moved ahead, or in compound position, as in Fig. 150, holds closed the reducing valve *G*, thus shutting off the live steam supply to the low-pressure cylinder. At the same time it closes the independent exhaust opening *B*, instead opening the ports to the receiver *R* and connecting the high-pressure exhaust *E* therewith around the stem of the intercepting valve. As the other end of the receiver leads to the low-pressure steam chest, the high-pressure exhaust thus becomes the supply steam for the low-pressure cylinder and the engine works as a compound, the flow being indicated by the arrows, Fig. 150.

From the above description it will be observed that the office of the intercepting valve is to convert the locomotive from simple to compound, or the reverse. The duty of the reducing valve is, when the engine is working single-expansion, to reduce the live steam from the boiler to a pressure inversely proportional to the ratios of the two cylinders before delivering it to the receiver and low-pressure cylinder, thus making the crosshead loads equal on each side of the engine.

Accidents to Pittsburg Compounds.—If the engine broke down and it became necessary to disconnect either side, could the engine be run successfully on one side? Yes, it would be more powerful than a simple engine under similar circumstances and could develop good speed, inasmuch as the independent exhaust ports *B* (Fig. 149) are of considerable size.

With the high-pressure side disconnected, how should the engine be run? The intercepting valve should be placed in simple position (as in Fig. 149) by leaving the reverse lever in full gear. Live steam would then pass through the reducing valve to the low-pressure cylinder and exhaust in the usual way. The high-pressure valve should, of course, be clamped in the center.

If the low-pressure side were disconnected, how could the engine be run? Clamp the low-pressure valve in the center so as to cover all ports and work simple, with engine in full gear. Steam would then be admitted as usual through the steam pipe to the high-pressure cylinder and exhausted through the intercepting valve cavity and the independent exhaust *B*, Fig. 149.

In both of these cases what would be necessary in order to run at considerable speed? To close the small valve which supplies steam to the operating device. The hand lever can then be used for operating and thus the reverse lever hooked up to a shorter cut-off. The intercepting valve levers should be securely fastened in simple position.

With a demolished steam chest on the low-pressure side, could the engine be fixed to run in any way different from such an accident to a simple locomotive? Yes. Proceed the same as before described when the low-pressure side is disconnected, except that the reducing valve must now be held closed. This could be done by tightening up the nuts on the outside stem of the reducing valve, or by inserting washers or a block under them. This same procedure could be followed for broken valve yoke, or valve stem broken off inside of steam chest, under which circumstances it is difficult to cover ports without taking up the steam chest cover.

What should be done if the reducing valve became broken? Endeavor to start compound, that is, with the lever hooked up three or four

notches, but if necessary to run simple, use very light throttle or reduce the amount of boiler pressure carried.

If the packing rings in the intercepting valve blew badly, how could it be detected? First see that the slide valves are tight, then shut off the supply of air or steam from the operating cylinder by closing the small globe valve in the cab, pull the intercepting valve clear back (by means of the hand operating lever) into simple position, as in Fig. 149, and open the throttle, still leaving the valves in the center. The blow would show in the stack. However, it is an easy matter to remove the intercepting valve, by taking off the back cap, and examine the packing rings, and this should be done frequently, that no broken pieces may catch in the ports.

With this design of compound, is it necessary to caution the engineer against the bad practice of operating the engine in simple position for too great a length of time, or at high speeds? No; for, if the small valve in the cab which supplies pressure to the operating device be open, to run the engine simple, requires that the reverse lever be at full stroke, and no competent man would work the engine thus longer than necessary.

In starting, where should the reverse lever be placed? In full motion to allow the intercepting valve to close and the reducing valve to open and admit live steam to the low-pressure cylinder.

RICHMOND COMPOUND.

The Richmond compound locomotive (sometimes termed the "Mellin" system, as it is built under those patents) is also of the two-cylinder or cross-compound type and belongs to the class of

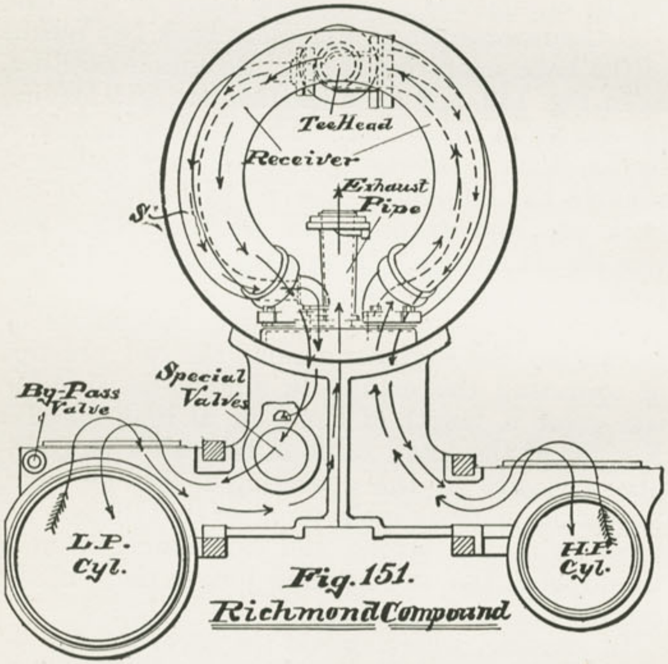


Fig. 151. Richmond Compound

convertible compounds. The large low-pressure cylinder is placed on the right-hand side of the engine, and within its saddle, as shown in Fig. 151, is located the special valve mechanism by which

the engine starts with the admission of live steam to both cylinders and thereafter automatically changes to compound, or may be converted back to simple any time at the will of the engineer. Without any movement of valves by the engineer, the locomotive is an "automatic" compound, that is, changes to working compound after the first stroke or two; but the movement by him of a three-way cock in the cab, causes the opening of a separate exhaust valve (sometimes called the "emergency valve") for the high-pressure cylinder, and thus the engine can be run simple as long as he thinks it advisable, or, if disabled, can be brought in with one side like a single-expansion locomotive.

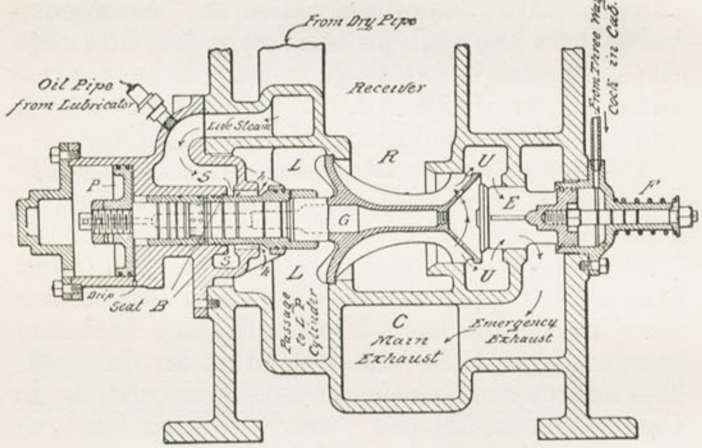
The device called the intercepting valve really consists of three separate and distinct valves, as shown in Figs. 152 and 153.

The intercepting valve proper is marked *G* and is a double poppet valve with its two seats of unequal areas, and has a stem extending back and connecting with the piston *P* of an air dash-pot. The intercepting valve moved, or opened, as in Fig. 153, connects the receiver *R* with the low-pressure steam-chest port *L*, while if closed, as in Fig. 152, it cuts off this communication and opens the receiver *R* to the cavity *U*.

The reducing valve is a long annular valve surrounding the intercepting valve stem and closes by moving to the left. When open, it admits live steam from chamber *S* to the low-pressure steam chest cavity *L;* when closed, it cuts off this communication.

The separate exhaust or "emergency" valve *E* is an ordinary bevel-seated wing-valve with its right-hand end in the form of a piston. Steam pressure from a three-way cock in the cab, if admitted against this piston, forces the separate exhaust valve open, thereby connecting the cavity *U* with the main exhaust cavity *C;* without pressure on this piston, the spring *F* again seats the valve.

Fig. 152



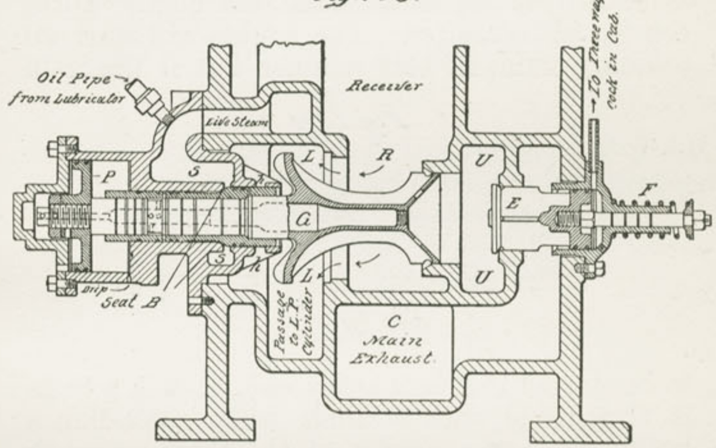
Richmond Compound
Valve Positions, Engine working simple.

The reducing valve is shown heavily cross-sectioned, the intercepting valve is next as dark.

The operation of the valves is as follows: Suppose the engine to be at rest after running compound with the valves in position as shown in Fig. 153. Upon opening the engine throttle, steam passes not only to the high-pressure side in the

usual manner, but also through a branch steam pipe *S* (Fig. 151) to the annular cavity *SS* (Fig. 153), bears against the shoulder *e* of the reducing valve at the seat *B* (Figs. 153 and 154) and forces the latter valve to the right, and with it the intercepting valve, to the position in which they are shown in Fig. 152. As soon as the enlarged end of the reducing valve passes the edge *h* of the

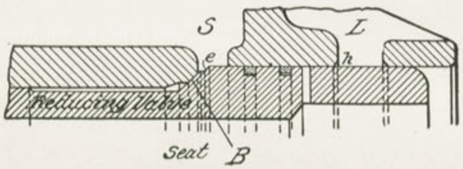
Fig. 153.



Richmond Compound
Valve Positions, Engine working Compound.

port *L* (see also Fig. 154), live steam is admitted to *L* and thence to the low-pressure cylinder, as indicated by the arrows. As we assumed the engineer had not opened the separate exhaust valve, it will remain closed instead of open, as Fig. 152 shows it; otherwise that figure would show the valve positions at this stage. Thus, while the receiver *R* is in communication with the cavity *U*, there is no outlet from the latter, and one or two exhausts from the high-pressure cylinder into the closed receiver *R* will produce sufficient pressure to act against the larger left-hand face of the intercepting valve *G* and cause it to move to the left, shoving with it and closing the reducing valve, as shown in Fig. 153. Now the receiver pressure becomes the supply for the low-pressure cylinder as shown by the arrows, and the engine works compound thereafter. The engine will start all ordinary trains in this manner but if the train

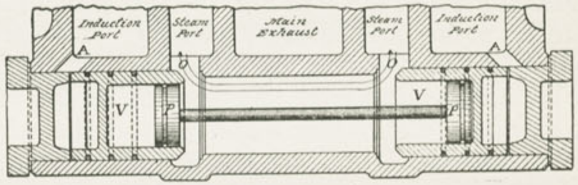
Fig. 154



to be started is a very heavy one, or such a train is threatened with stalling while ascending a heavy grade, the handle of the three-way cock in the cab should be turned to open the separate exhaust valve *E*. This would vent the pressure in chamber *U* to the main exhaust *C*, as indicated by the arrows in Fig. 152. If the engine were starting, no pressure could accumulate in the receiver *R* on account of this vent to the atmosphere, and hence all valves would remain as in Fig. 152 and the engine would continue to work simple until such time as the engineer closed the separate

exhaust valve *E* by means of his cab valve. If, however, the engine were stalling working compound (Fig. 153) and the engineer opened the

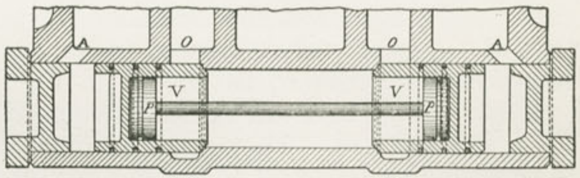
Fig. 155.
The Richmond Compound
By Pass Valve



Position when Running
Steam shut off

separate exhaust valve *E*, the removal of pressure from chamber *U* would cause the intercepting valve to close, assisted by the live steam pressure on the reducing valve shoulder, and thus all valves

Fig. 156.
The Richmond Compound
By Pass Valve



Position when running
under steam

would remain as in Fig. 152 until the engineer desired to work compound again. Then he would simply close the separate exhaust valve *E* and permit the valves to automatically assume compound working by the accumulation of pressure in the receiver *R*.

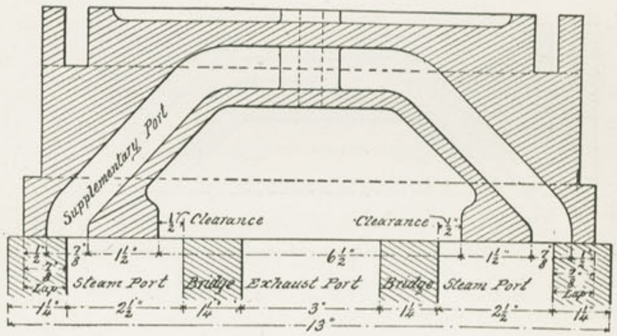
The annular shaped reducing valve appears so much like an inoperative sleeve around the intercepting valve stem that the separate sketch is made on a larger scale in Fig. 154, in order to illustrate its principle the more clearly. Live steam from *S* bearing against the shoulder *e* would force the reducing valve from the position in the cut to the right until shoulder *e* had passed the edge *h* of the chamber *L* and live steam thus be admitted to *L* and the low-pressure cylinder. As soon as the pressure in *L* became sufficiently great, say about half that in *S*, the valve would close partly so that only the desired proportion of the full boiler pressure would be admitted to the low-pressure cylinder.

The injurious action of large pistons in pumping air when the engines are shut off, as previously mentioned under "Classes of Compound Locomotives and their General Construction," is prevented in compound engines of the Richmond type by the use of "by-pass" valves located in the casting of low-pressure cylinder, as shown in Fig. 151, and further shown in detail in their two positions by Figs. 155 and 156. They work automatically by the opening and closing of the engine throttle, their construction and operation being as follows: The outer ends of the two piston valves *VV* are connected by the passages *AA* with the induction ports of the low-pressure cylinder and their inner ends are connected by the passages *OO* with the

steam ports. The pistons *PP* simply act in the cavities of the valves as dash-pots to prevent slamming of the valves.

Open the engine throttle, and live steam from the induction ports through the passages *AA* drives the valves *VV* toward each other against their seats and communication between the two steam ports *O* and *O* is closed, as in Fig. 156. With the throttle closed, the least vacuum in the

Fig. 157.



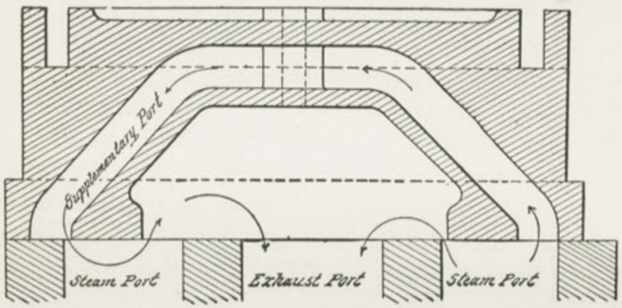
Brooks Patent Slide Valve, In Central Position

steam chest, acting at *AA*, is aided by compression in the cylinder through ports *OO*, and the "by-pass" valves move outward to the position shown in Fig. 155. In this position the two steam ports *OO* are connected and air passes freely from one side of the piston to the other—the purpose for which they are applied.

The necessity for very large port openings for the large low-pressure cylinders was mentioned under the general discussion of compound locomotives and it was there stated that auxiliary ported valves of the "Allen" type were used to give a double port opening to the cylinders in the early part of the admission period.

One Richmond design of slide valve employs this auxiliary port not only for double early admission, but also to give a double opening in the early exhaust period. Fig. 157 shows the design and gives the dimensions. It will be noticed that

Fig. 158.



Early Exhaust Period

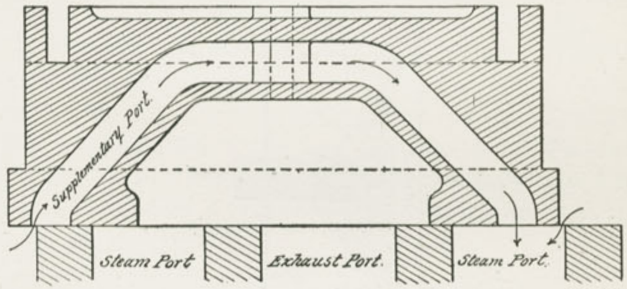
the "Allen," or supplementary, port is much wider at the seat than usual.*

To clearly show the features of novelty in this valve over the ordinary slide valve, Figs. 158 and 159 are given. The arrows in Fig. 158 indicate the double exhaust from the right-hand end of the cylinder during the early exhaust period. In Fig. 159 the arrows indicate similarly the ordinary

*Letters patent have been granted for this valve.

action of an "Allen" ported valve in giving double admission to the same end of the cylinder during the early steam period. This style of slide valve has been in use on locomotives and given only a six-inch extreme travel of valve and has proven very successful in keeping down the back pressure, especially at high speeds.

Fig. 159.



Early Admission Period

Accidents to Richmond Compounds.—In case of accident on the road requiring the engine to be run in with one cylinder, what should be done? Ordinarily, open the separate exhaust or "emergency" valve and do nothing otherwise differently than with a simple engine.

In case the engine was running with the low-pressure side only, why do you instruct to open the separate exhaust valve? So that there shall be no accumulation of pressure in the receiver which might occur in case of a leaky slide valve or balance strips leaking on the high-pressure side.

As the emergency port openings are small, what could be done in order to obtain considerable speed in case the break-down occurred in passenger service? Try to block the slide valve on the disabled side in an extreme position so as to uncover the exhaust port.

What should be done in case the reducing valve stuck open or became broken? Care should be used in starting by opening the throttle very

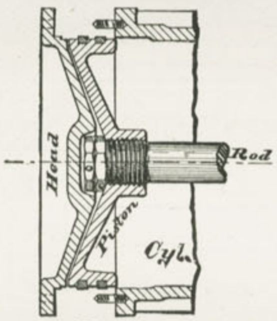


Fig. 160.
–Piston for Lightness & Strength–

slightly and the engine should be run as a compound only. If it had to be run simple, the boiler pressure should be reduced about one-half.

What might cause the reducing valve to stick? Feeding valve oil to the low-pressure side when the engine is working compound and there is consequently no flow of steam through this valve.

What precaution would it be advisable to observe in case the intercepting valve became broken? The engine should be run compound

only and it would be safer not to stop with the low-pressure side on center. If this latter precaution were not observed, the high-pressure piston might have considerable back pressure upon it from the receiver, should the intercepting valve break in such a way as to permit live steam from the reducing valve to enter the receiver in starting.

What prevents slamming of the intercepting valve? The air dash-pot connected thereto.

In this class of compounds, why are the cylinder neads sometimes dished, or not flat, as is usually the case? In order to give a maximum strength with a minimum weight of piston, these builders frequently use a piston such as is shown in Fig. 160; hence the cylinder heads conform to the shape of the piston.

ROGERS COMPOUND.

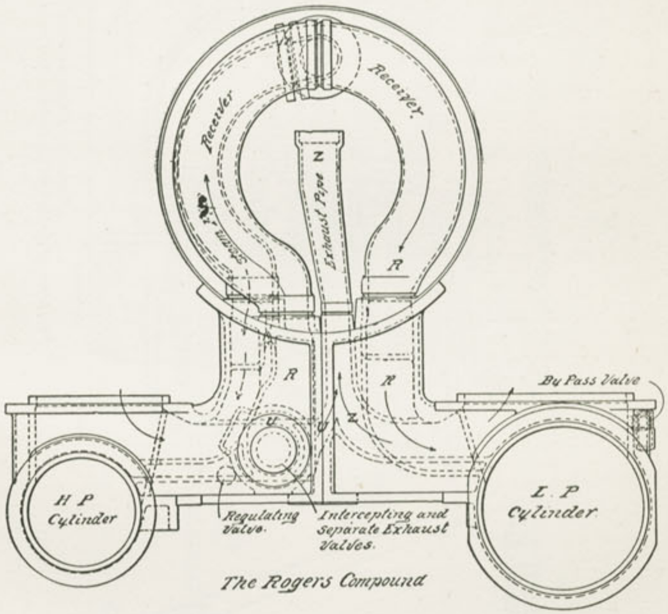
The intercepting valve originally employed by the Rogers Locomotive Works for their system of two-cylinder compound, was placed in the smoke-box and was controlled automatically and beyond the will of the engineer. In starting, by placing the reverse lever in either extreme position, a separate reach-rod with suitable levers was made to open the reducing valve and admit live steam from the boiler to the low-pressure cylinder, and close communication between the latter and the receiver, so that the high-pressure cylinder exhausted into a closed reservoir or receiver. After one or two strokes sufficient pressure accumulated in the receiver to automatically throw the intercepting valve into position for working compound and the hooking up of the reverse lever closed the reducing valve.

The succeeding arrangement used by these builders is fully described and illustrated in what follows. The device is for a two-cylinder or cross-compound locomotive, and is placed in the high-pressure saddle on the right side and connected to a lever in the cab having three notches, and is operated by the engineer at will. As long as this lever remains in the forward notch the engine works as a single expansion locomotive; the back notch places the intercepting valve in compound position, while the middle notch makes an automatic compound, that is, the inter-

cepting valve works the engine simple for a few strokes and then the valves automatically assume the compound position. Thus this engine belongs to the class of convertible compounds.

The component parts of the device are: A regulating valve (positively controlled by the cab

Fig. 161



The Rogers Compound

lever above mentioned), an intercepting and a reducing valve (controlled either positively by the regulating valve or at times automatically by the pressure in the receiver), and a separate exhaust valve (controlled by the operating valve). The

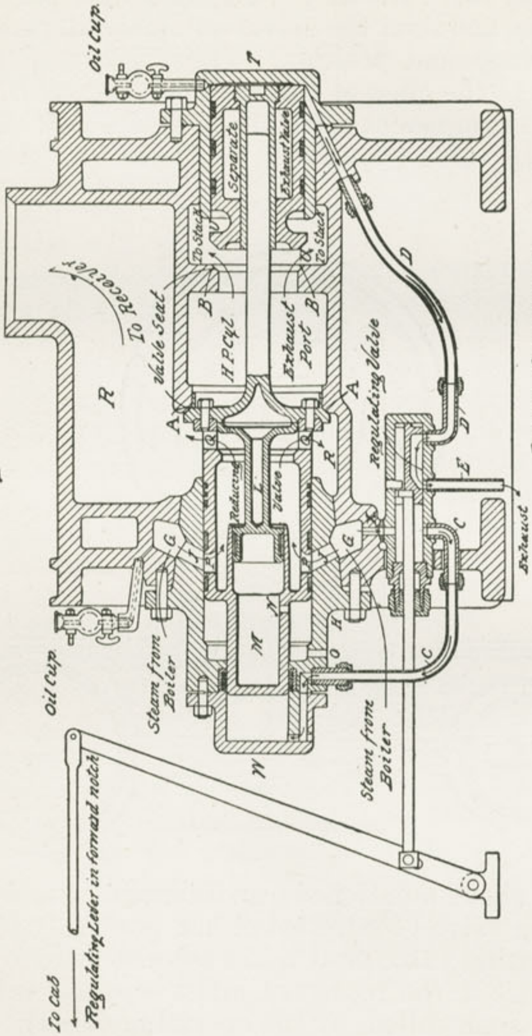


Fig. 162.

Rogers Compound
Position of Intercepting Valve when running simple

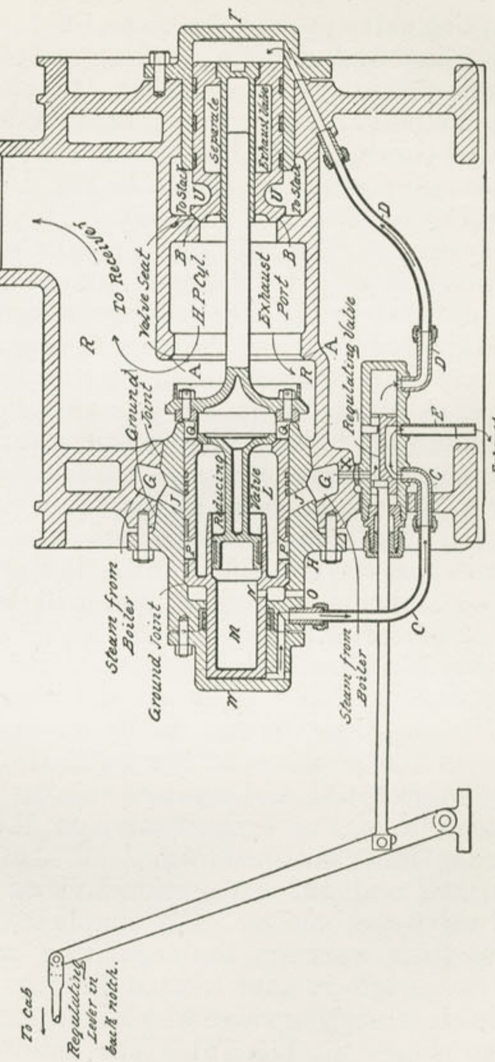


Fig. 163.

Rogers Compound
Position of Intercepting Valve when running compound

intercepting valve has two positions, one for working compound and one for working simple. In the former position, as shown in Fig. 163, the high-pressure cylinder exhaust is connected to the receiver and thence to the low-pressure side, while in the simple position, as shown in Fig. 162, this communication is closed and the high-pressure exhaust directed through the separate exhaust valve to the stack, live steam at the same time being admitted to the low-pressure steam chest through the reducing and the intercepting valves.

To somewhat reduce the high compression that takes place in the large low-pressure cylinder when running at high speeds without steam—as, for instance, down grades—a by-pass arrangement similar in some respects to "La Chatalier" brake is employed. This consists of an automatic device for connecting the two sides of the low-pressure piston when steam is shut off, and will be fully described hereafter.

Fig. 161 is a view from the front, showing the high-pressure cylinder to be on the right-hand side of the engine. In the saddle on that side are shown the positions of the regulating valve and the intercepting and separate exhaust valves. The location of the by-pass valve on the low-pressure cylinder is also shown.

Figs. 162 and 163 are sectional views of the special valve mechanism. For simplicity in explaining their working, the regulating valve is shown as though it were located directly underneath the intercepting valve which is not its actual position shown in Fig. 161. The intercepting

valve is composed of two parts bolted together and is shown cross-sectioned more heavily than its casing while the reducing valve *L* within it is distinguishable by its still darker appearance. Its principal port openings to the receiver and from the high-pressure cylinder exhaust are lettered and the direction of flow through them is indicated by arrows, that an understanding may be the more easily arrived at. Port *G* is an annular chamber around the intercepting valve cylinder *H* and is connected with the high-pressure steam pipe in the saddle and therefore has live steam pressure when the engine throttle is open. Between *G* and the intercepting valve is a series of holes marked *J*. The intercepting valve is hollow and has two series of holes through its shell at *P* and *Q*, the latter being to the right of the reducing valve seat.

Fig. 162 shows the intercepting valve closed (to the right) on its seat *A*, and the reducing valve off its seat (open), as it is when working simple except that the reducing valve *L* is then brought near enough to its seat to the left, to prevent more than about one-half the boiler pressure from passing through it. As usual, the reducing is accomplished by the two ends of the reducing valve *L* being of different diameters, the smaller end having its outer left-hand side always connected to the atmosphere through small ports marked *N* and *O*, while the outside of the larger right-hand end is exposed to the receiver pressure when in operation, as in Fig. 162. The left-hand smaller end *M* of the intercepting valve works in a cylinder *W*, while the right-hand larger area of the intercepting valve is exposed either to the receiver or the high-pressure exhaust cavity, according to the position of the valve. The separate exhaust valve is located in a chamber *U* directly connected to the main exhaust pipe *Z*. (See Figs. 161 and 163.) The right-hand end of the separate exhaust valve is in the form of a piston and works in a cylinder *T*. The outer ends of these two cylinders, *W* and *T*, are connected by small pipes *C* and *D* with the regulating valve, as shown in Figs. 162 and 163. The stem of the intercepting valve extends over into separate exhaust valve and forms a guide to keep both valves central, and also serves as a dash-pot, but allows each valve to act independently of the other. All pistons are fitted with packing rings, as shown, and the valve seats and ground joints are so indicated.

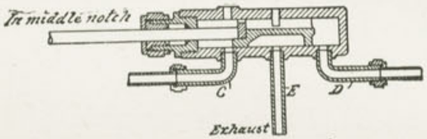
The regulating valve receives steam from *G* through a small port *X* and therefore has live steam whenever the engine throttle is open. The regulating valve consists of a slide valve of the well-known "*D*" type and moves on a seat having two steam ports and one exhaust opening, as usual with a slide valve. Steam admitted through the right steam port and pipes *DD* to chamber *T* would bear against the separate exhaust valve and close it, as in Fig. 163. Steam through the left port and pipes *CC* to chamber *W* would force the intercepting closed, as in Fig. 162. If the engineer places the regulating valve lever in the forward notch, as in Fig. 162, live steam entering the regulating valve chamber from ports *G* and *X*

finds the left hand port uncovered and passes through the small pipe *CC* to the cylinder *W* (as indicated by arrows), moving the intercepting valve to the right against its seat *A* and thereby closing communication between the high-pressure cylinder exhaust port and the receiver *R*. In this position live steam pressure from *G* passes through ports *JJ* and *PP* to the interior of the intercepting valve, automatically opening the reducing valve and flowing through ports *QQ*, enters the receiver *R*, the other end of which is connected to the low-pressure steam chest, as shown in Fig. 161. Thus the low-pressure cylinder has received live steam at a reduced pressure and can work independently of the high-pressure cylinder, as its exhaust is as always to the stack. The intercepting valve now being closed, the exhaust from the high-pressure cylinder (its communication to the receiver being thereby shut off) forces the separate exhaust valve off its seat, as in Fig. 162, and escapes to the stack and the engine works simple, or with a live steam admission and an exhaust to the atmosphere on both sides. The separate exhaust valve remains open, as shown in Fig. 162, because chamber *T* is connected to the atmosphere through pipe *DD*, the under side of the regulating slide valve, and pipe *E*—as indicated by arrows.

If the regulating lever in the cab be moved to the back notch, the regulating valve takes the position shown in Fig. 163 and will then admit steam through the right-hand pipe *DD*, into chamber *T*, pushing and holding the separate exhaust valve against its seat *B*, and at the same time chamber *W* will be in exhaust through pipes *CC* and *E*, as indicated by arrows. The separate exhaust valve being now closed, a slight pressure in the cavity marked "high-pressure cylinder exhaust" will open the intercepting valve, that is, move it off its seat *A* into the position shown in Fig. 163. Then the high-pressure cylinder exhausts through the intercepting valve into the receiver and thence to the low-pressure steam

Fig. 164

Rogers Compound



Regulating Valve
Position for starting.

chest, and the engine works compound. No live steam from ports *GG* can get to the receiver in this position as the ports *PP* are not in register with those at *JJ*.

It will be noticed that there is an extended flange on the face of the intercepting valve, that enters the seat of the latter enough before closing and leaves it sufficiently late in opening, to prevent live steam from flowing through ports *PP*, *QQ*, and *R* to the high-pressure cylinder exhaust port when

the intercepting valve is opening or closing. If the engine is standing and the regulating valve is moved to its central position, as shown in Fig. 164, when the throttle is opened steam will pass through both pipes *CC* and *DD* to the outer ends of the intercepting and the separate exhaust valves respectively, and they will both be instantly closed against their respective seats *A* and *B*, Figs. 162 and 163. The receiver would then be filled with steam through the hollow intercepting valve and the reducing valve, as indicated by the arrows in Fig. 162; but as soon as the pressure at the high-pressure exhaust port became about twenty per cent. of the pressure in the dry pipe at the time, the intercepting valve would be opened and thereafter held open by the receiver pressure acting toward the left on the large right-hand end of the intercepting valve; thus a slight pressure on the large area of this valve overbalances the higher pressure on the smaller left-hand end *M* in chamber *W*, and the engine automatically changes to compound after two or three strokes, the main ports being opened as in Fig. 163.

If the engine had been working simple, with the valves as in Fig. 162, and the operating valve lever were placed in either the center or back notch, the working would automatically be changed to compound; if in the center notch, it would take a slight accumulation of pressure at the high-pressure exhaust port, as just explained; if in the back notch the intercepting valve opens with almost no pressure from the high-pressure exhaust port as then chamber *W* is in exhaust through pipe *CC* and the regulating valve. Subsequently to working simple, it is best to move the regulating lever to its middle position (Fig. 164) for a few seconds without closing the engine throttle; after that it can be moved to its back notch, as in Fig. 163, and left there until it is desired to again start simple or go from compound to single-ex-

Fig 165.

Rogers Compound

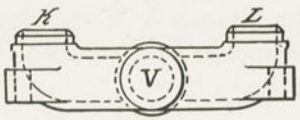
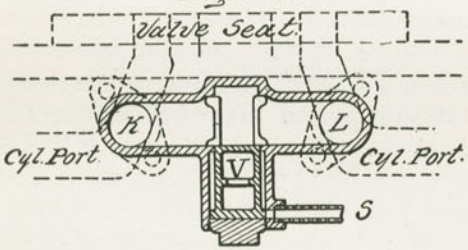


Fig. 166.



pansion in order to prevent stalling on a heavy grade.

Figs. 165 and 166 show two views of the by-pass arrangement which is placed on the low-pressure cylinder in the position shown in Fig. 161. It consists of a valve V which automatically opens

and closes the port in a hollow casting bolted to the cylinder and connected below the valve seat at K and L with the steam ports of the low-pressure cylinder, as illustrated in Figs. 165 and 166. The hole through this by-pass casting is two inches in diameter. In Fig. 166 the valve V is shown dropped down in its chamber, thus leaving a two-inch open communication between the steam ports and hence the two sides of the low-pressure piston. A small pipe from the live steam port in the saddle of the high-pressure cylinder leads through the pipe S to the under side of this cylindrical valve V, as shown, so that when the engine throttle is opened the valve V raises to the top of its chamber and shuts off all communication between the ports K and L, remaining there as long as the high-pressure cylinder is receiving steam; but when the throttle is closed, it falls again by gravity and is thus an automatic valve.

Accidents to Rogers' Compounds.—In case of break-down on one side of this engine, can it be run in with the other side? Yes. The reducing valve would furnish a live steam supply for the low-pressure cylinder, or the separate exhaust valve would give an exhaust opening for the use of the high-pressure cylinder, according to which side was to be used; hence, in either case, general instructions would be to place the regulating valve in its extreme forward position, as for working simple, Fig. 162.

Under such circumstances would the engine be as powerful as a simple engine on one side? Yes, considerably more so at low speed, but the smaller port openings than usual would not permit of as great speed.

As there are three notches in the cab for the regulating valve lever, how should this be handled when it is desired to change from simple to compound, or the reverse? It is not advisable to throw it from forward to back notch, or the opposite, without pausing a second or two in the middle notch and thereby producing a more gradual movement and causing a cushioning of the intercepting and separate exhaust valves.

Under ordinary circumstances, in what position is it best to keep the regulating valve? In the back notch, or compound position.

How should a light train be started? With the regulating valve lever in the center notch. The engine starts thus as an automatic compound.

If the engine actually works compound in the center position, why is that not advisable? Because in that position the opening and closing of the throttle while running and the wide variations of pressure in the steam pipe and receiver when running, would cause more or less unnecessary movements of the intercepting valve.

When running the engine with one side, in what position will the "by-pass" valves (Figs. 165 and 166) be found? No matter which side is in use, live steam from the high-pressure steam pipe acts to keep them closed.

What kind of oil should be used in the oil cups shown in Fig. 162? Nothing but valve oil and that regularly but not too often, as it has a

tendency to gum the valves where there is not a constant flow of steam.

If the high-pressure side were on the center, why would not the engine move with the operating lever in compound position (back notch)? Because then the valves would be as in Fig. 163 and no live steam could be admitted to the low-

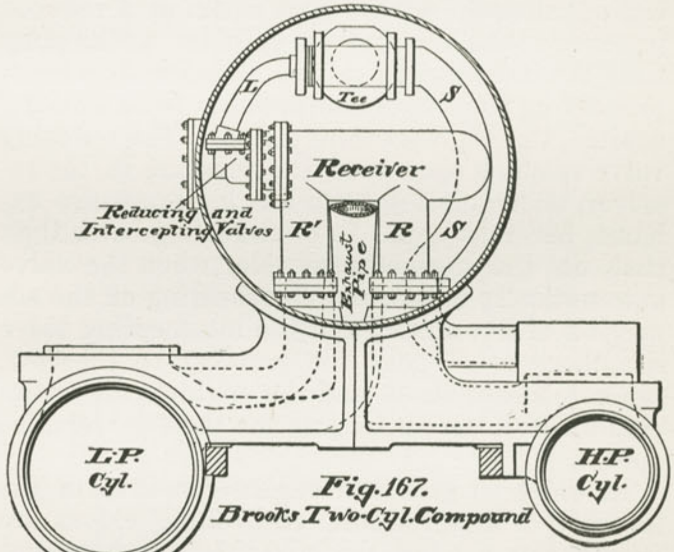


Fig. 167.
Brooks Two-Cyl. Compound

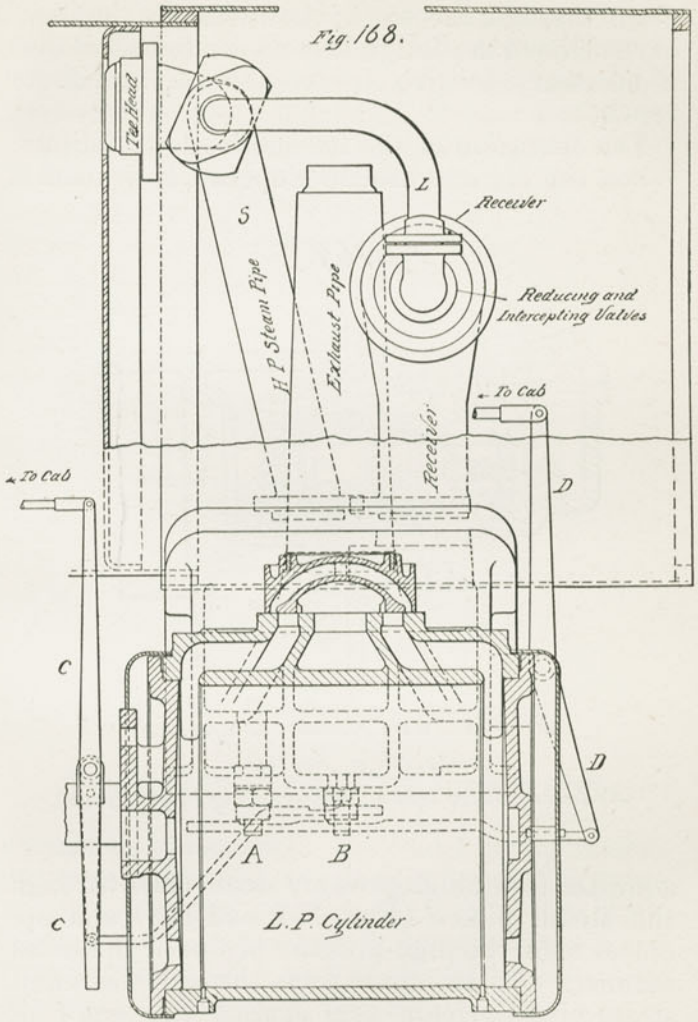
pressure cylinder. This would not be the case in starting with the regulating lever in either of the other two notches.

BROOKS TWO-CYLINDER COMPOUND.

This design is of the two-cylinder or cross-compound type, built under the Player patents, having the high-pressure cylinder on the left side and a receiver in the smoke-box between the two cylinders, as shown in Fig. 167.

There is a combined admission, pressure-regulating and intercepting valve located either on the receiver in the smoke-box as shown, or in the cylinder saddle, which valve upon opening the engine throttle admits live steam at a reduced pressure to the low-pressure cylinder; at the same time the intercepting valve automatically closes, preventing the live-steam pressure from working against the high-pressure piston. The reducing valve remains open until the pressure in the receiver, accumulating from the high-pressure exhaust, becomes equal to or slightly greater than that on the low-pressure side, when the valve automatically closes, thereby shutting off the admission of live steam, and the intercepting valve simultaneously opens the receiver to the low-pressure steam chest, and the engine works compound thereafter as long as the throttle remains open.

In order to give the engineer control of the locomotive at all times, controlling valves are provided on the low pressure side. In the illustration (Fig. 168) these valves, *A* and *B*, are shown located in the bottom of the receiver and are connected to the cab by suitable levers *C* and *D*. They are sometimes made larger, connected higher up with the exhaust pipe, and arranged as to work automatically in combination with the intercepting valve, so that the engine can be run simple as long as desired and the exhaust take

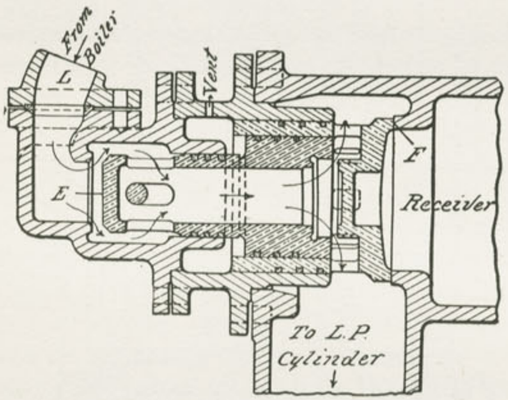


BROOKS TWO-CYLINDER COMPOUND.

place through the stack; however, its builders have claimed the design here shown to be "all that is necessary to give the engine its maximum power."

The operation of the locomotive is as follows: When the engine throttle is opened, live steam is

Fig. 169.

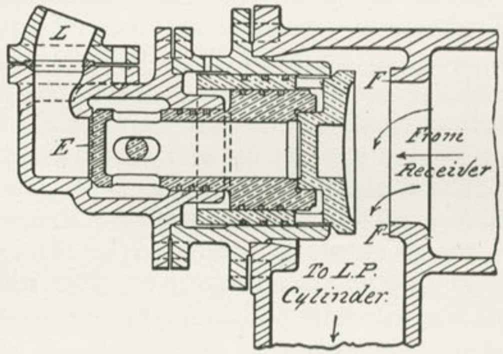


Brooks Two-Cylinder Compound
Starting Position
Reducing Valve Open, Intercepting Valve Closed.

admitted to the high-pressure steam chest through the steam pipe *S* (Figs. 167 and 168) and operates upon the high-pressure piston in the usual manner. At the same time, through the small steam pipe *L*, steam acts against the seat *E* of the reducing valve, then closed as in Fig. 170,

causing this valve to open, passing through the hollow portion of the valve, automatically closing the intercepting valve against its seat *F* on the receiver, as in Fig. 169. Steam then flows through the passages in the intercepting valve and down to the low-pressure steam chest, as in-

Fig. 170.



Brooks Two-Cylinder Compound
Compound Position
Reducing Valve Closed, Intercepting Valve open.

dicated by the arrows. To render them readily distinguishable, the reducing or regulating valve is cross-sectioned very heavily, while the intercepting valve is less dark in appearance.

From Figs. 169 and 170, it will be seen that the right-hand end of the reducing valve is of larger area than that acted upon by live steam at its seat on the left-hand end *E*. It is this difference that causes the partial closing of the valve, thereby throttling the steam passing through it to a reduced pressure. These areas being about two to one, the reducing valve, in order to equalize the work of the two cylinders in starting, prevents more than about one-half the pressure in the dry pipe from passing to the low-pressure cylinder.

As soon as the high-pressure cylinder has exhausted sufficient steam into the receiver to overbalance the reduced live steam pressure holding the intercepting valve closed, this valve opens automatically, at the same time locking the regulating valve against its seat as shown in Fig. 170. Exhaust steam from the high-pressure cylinder then flows through the receiver to the low-pressure steam chest, as indicated by the arrows and the engine works compound. The receiver pressure can become considerably reduced and still, through the action of the combined valves, keep the pressure regulating valve closed.

Accidents to Brooks Two-Cylinder Compounds.—What should be done in case of an accident necessitating the removal of the main rod on the low-pressure side? Disconnect that side, block the crosshead and clamp the valve in center, as with a simple engine. Open wide the controlling valves underneath the saddle and run in with one side. The exhaust will take place through these valves. To obtain a larger exhaust opening than the controlling valves furnish and thus permit of more speed and better steaming qualities,

attempt should be made to place the slide valve on the disabled side so as to uncover the exhaust port and thus give an exhaust through the stack.

What should be done for a similar accident to the high-pressure side? Just the same as for a simple engine. There being then no exhaust into the receiver, the intercepting and reducing valve would admit live steam to the low-pressure cylinder upon opening the engine throttle.

What mode of procedure should be followed in case of a broken valve stem or rocker arm? Proceed as above, according to which side was broken.

What should be done if the intercepting valve became broken so as to leave an opening between both ends of the receiver? The proper method would be to disconnect the small steam pipe *L* (Figs. 167 and 168) and insert a blind gasket. The engine could then be started and worked only as a "strictly plain" compound and should not be stopped with the high-pressure side on center, as no live steam could be given the low-pressure cylinder for starting. Without disconnecting the steam pipe the engine could be run in with part of a train by reducing the boiler pressure or by using a slightly open throttle, in which case live steam from the reducing valve would pass through the receiver and work against the high-pressure piston in starting, and hence the engine should not then be stopped with the low-pressure side on center.

What should be done for a broken reducing valve? The same as for a broken intercepting valve.

Should the controlling valves fail to open, where would you look for the cause of the trouble? They operate very similarly to cylinder cocks and their levers becoming disconnected or bent may cause them to either fail to open, or remain continually open, as the case may be. The remedy is obvious.

BROOKS FOUR-CYLINDER TANDEM COMPOUND.

The Brooks (Player System) of four-cylinder compound is of the tandem type, that is, two cylinders on each side, one ahead of the other, as shown in Fig. 109. With this system the two low-pressure cylinders and their saddles are placed similarly to ordinary single-expansion cylinders, with which they can always be made interchangeable. They are of course larger, have a different style of steam chest and, bolted preferably to their forward ends, as shown in Figs. 109 and 171, are the two high-pressure cylinders which have steam chests communicating with the steam chests of the low-pressure cylinders with an enlargement between, all together forming a receiver. There are no devices in the smoke-box except those usual to single-expansion locomotives.

The steam is supplied to the high-pressure valve chest through suitable pipes connecting with the usual steam pipes in the smoke-box, and the exhaust from the low-pressure cylinder is through the usual cavity in the saddle.

As shown in Fig. 171, the low-pressure cylinders are fitted with the usual balanced slide

valves, while the valves for the high-pressure cylinders are of the piston type and hollow, having internal admission and external exhaust edges. The low-pressure valve is controlled by the usual eccentric and rocker arms, as ordinary with simple engines. It is rendered advisable to have an internal admission with the high-pressure valve in order to lessen the cooling of the steam from the boiler as well as for constructive reasons.

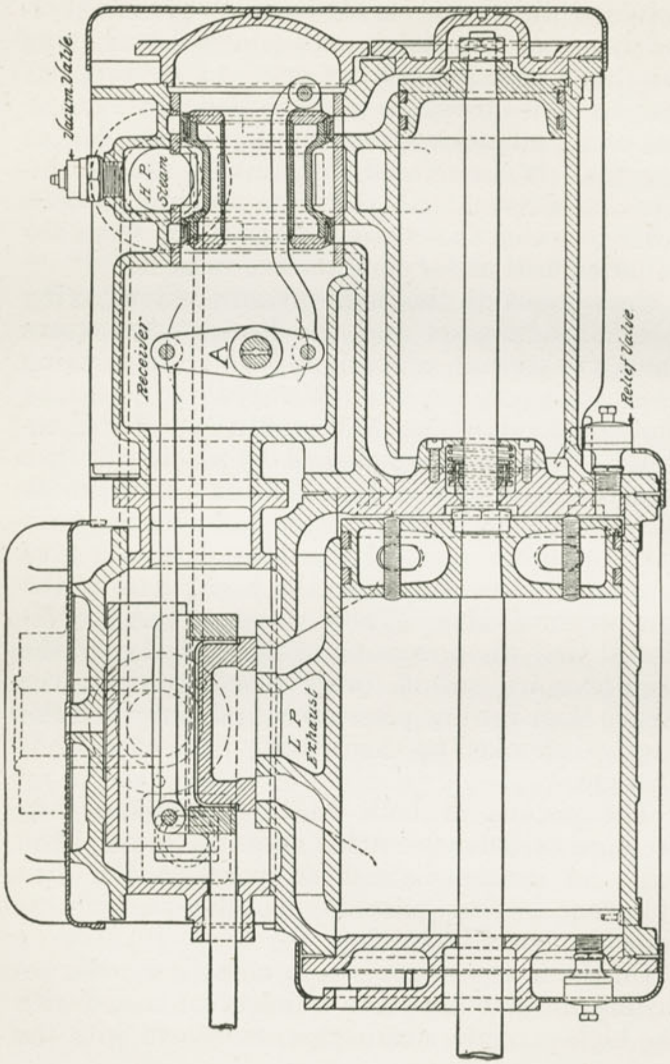
On account of the high-pressure valve having internal admission and the low-pressure valve having external admission (the latter being usual with ordinary slide valves) it is necessary that these valves should travel in opposite directions. This is accomplished by placing in the receiver (as shown in Fig. 171) an intermediate rocker arm *A* which is connected by rods to both valves and has arms of the desired ratio to give a relatively less travel to the high than to the low-pressure valve. These valves are so proportioned that when running in nearly full gear, the high-pressure cut-off takes place later in the stroke than the low-pressure cut-off, but when the engine is hooked up the relative time of cut-offs changes.

The pistons of both the high and the low-pressure cylinder are fitted upon the same piston rod, the intermediate head between the two cylinders having suitable metallic packing, as shown in the illustration.

On the low-pressure steam chest is fitted a reducing and starting valve which is connected with the high-pressure steam pipe, as shown with the

Fig 171.

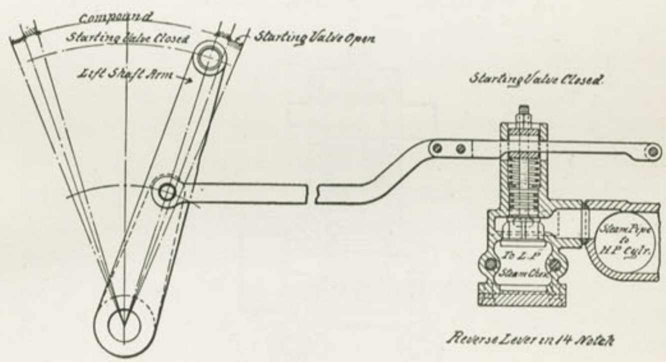
Fig 171.



Brooks Tandem Four-Cylinder Compound.

reducing valve in closed position by Fig. 172. By the connection of a rod with the arm of the lift shaft, this reducing valve is automatically opened whenever the reverse lever is placed either in full forward or full back gear. In the intermediate positions of the reverse lever, this reducing valve is locked to its seat by a suitable spring, so that it is rendered inoperative and the engine must necessarily work compound at all

Fig. 172



Brooks Tandem Compound

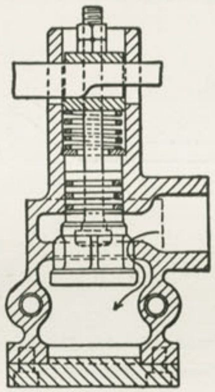
Operation of Starting Valve

times and under all conditions of steam pressure when the reverse lever is in any other position than full gear. Fig. 172 shows the range of the lift shaft arm for the starting valve to be either open or closed. This combined starting and reducing valve, when open, permits live steam to enter the low-pressure cylinder at a pressure equivalent to the maximum pressure obtained in this cylinder when the engine is working compound. As soon as the engine has made one complete revolution, the receiver becomes charged sufficiently by the exhaust from the high-pressure cylinder to close the reducing valve against its spring, thus automatically rendering the starting

Fig. 173.

Brooks Tandem Compound.

Starting Valve Open.



Reverse Lever in full Gear, 17 Notch.

valve inoperative and thereby necessitates the compound working of the engine. The reducing valve on a larger scale is shown in open or starting position by Fig. 173.

The engine operates in the following manner: Steam is admitted to the high-pressure steam

chest through suitable pipes, into the annular steam admission cavity surrounding the high-pressure piston valve, thence to the high-pressure cylinder, and exhausts into the receiver—the exhaust from the forward end of the cylinder passing through the inside of the hollow piston valve. The low-pressure steam chest, being also of large size, somewhat increases the receiver capacity, so that practically uniform pressure is maintained therein, steam from the receiver being admitted to and exhausted from the low-pressure cylinder by an ordinary slide valve which gives a distribution in that cylinder in the same manner as for simple engines.

This style of compound has been in operation for several years and, the builders state, shows an excellent economy in fuel, water, and repairs.

Accidents to Brooks Four-Cylinder Tandem Compound.—What would you do if it became necessary to disconnect one side of the engine? The same as with a simple engine of similar design in other respects.

In case the front head of the high-pressure cylinder became broken, how would you proceed in order to run the engine in with a full train? Remove the front steam chest head, place the reverse lever so as to throw the high-pressure valve clear ahead, disconnect the high-pressure valve and its intermediate rocker-arm rod (Fig. 171) and block this valve securely in the center so as to cover all ports; then block the starting valve open on that side, thereby allowing live steam at a reduced pressure to enter the low-pressure cylinder. This will enable the engineer to slowly handle a full train, but should not be so run for any distance or the high-pressure cylinder will be badly cut. In the lighter service of passenger trains, the engine would be capable of greater speed by disconnecting the broken side, blocking the valves in the center of their seats, and running with one side, as would be done with a simple engine.

If the intermediate rocker arm or the valve rod should break what should be done? Broken at some certain points, the engine might be treated as for broken high-pressure cylinder head; but the preferable procedure, all things considered, would be to disconnect on that side and be sure to block both valves over ports, to do which it may be necessary to remove front steam chest head and block the high-pressure valve inside.

In disconnecting one side of these engines, should it be imperative to securely block the crosshead? It should, because of the difficulty of securely holding the high-pressure valve in its central position.

How could it be determined if the metallic piston-rod packing between the two cylinders were blowing badly? Place the engine with one side on the upper quarter and the reverse lever in the center, block open the starting valves, and open the cylinder cocks and the throttle. If no steam escapes from either the high or low-pressure cylinder cocks, it has been determined that the valves are not leaking. Now close the throttle and remove blocks from reducing valve,

put the reverse lever in about half forward gear and allow all steam previously admitted to the pipes to escape from the open cylinder cocks. Again open the throttle and, as steam will then be admitted behind the high-pressure piston only, a blow through the forward low-pressure cylinder cock would indicate that this packing was blowing. The same operation should be repeated for testing the other side.

Should the engine fail to develop its proper starting power in full gear, what might be wrong? Open the cylinder cocks, with the throttle open and the engine standing, and if steam at no considerable pressure escapes from the low-pressure cylinder, examine the attachments connecting the reverse lever with the starting valves; they operate similarly to the ordinary cylinder cock arrangement and may likewise become defective and thus fail to open the reducing valve.

COOKE COMPOUND.

The compound arrangement for two-cylinder locomotives built by the Cooke Locomotive Works is such that, by means of a small steam

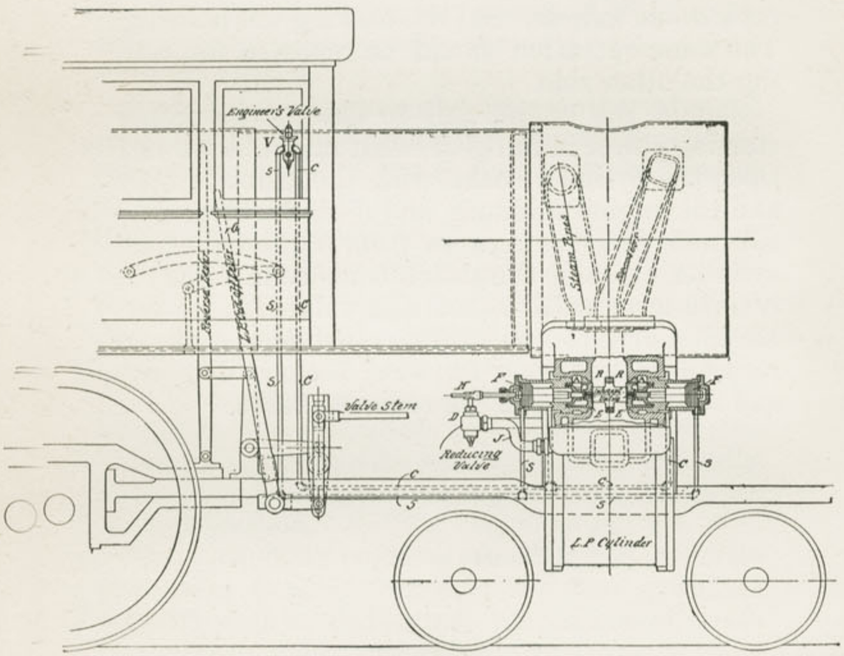
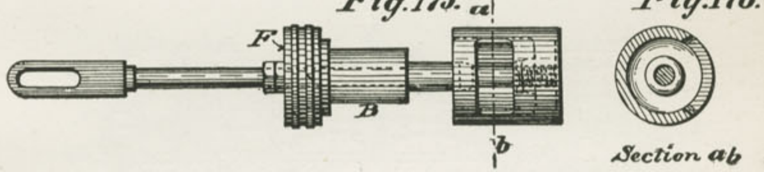


FIG. 174. COOKE COMPOUND.

operating valve in the cab, the engine can be run either simple or compound as the engineer may desire, and is, therefore, a convertible compound. This operating valve admits steam to suitable pistons which open and close the inter-

cepting valve and operate the reducing valve by a suitable lever connection. The intercepting valve is placed on the right-hand side of the engine within the saddle of the low-pressure cylinder and in the passages *RE*, leading from the receiver to the low-pressure cylinder, as shown in Fig. 174; it also has two connecting ports *AA*, leading into the main exhaust to the stack. By the movement of this valve, steam from the high-pressure cylinder, coming through the receiver, can be thrown out to the atmosphere instead of being allowed to pass to the low-pressure cyl-

Fig. 175. Fig. 176.



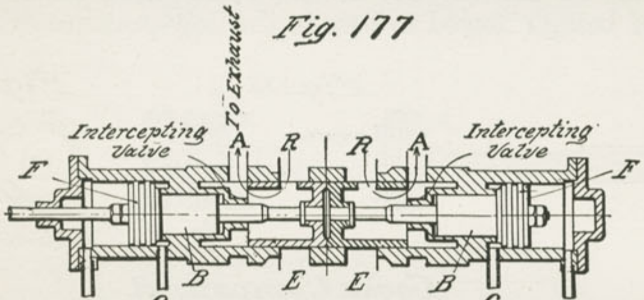
Cooke Compound

—Back Half of Intercepting Valve—

inder for compound expansion. This movement makes an independent engine of the high-pressure side and at the same time opens a reducing valve *D*, Fig. 174, which supplies, at a reduced pressure, live steam from the boiler to the low-pressure steam chest. The high-pressure cylinder always exhausts into the receiver, and the exhaust from the low-pressure cylinder is direct to the stack with either simple or compound working.

The reader will notice a novelty in the shape of an additional low-pressure cut-off lever *G*, located in the cab, as shown in Fig. 174. This lever is sometimes applied to Cooke engines of this class and is used to increase or decrease the travel of the slide valve on the low-pressure side independently of the valve on the high-pressure side, in order to equalize the power developed on opposite sides of the engine under variable conditions of steam pressure and different positions of the reverse lever.

Fig. 177



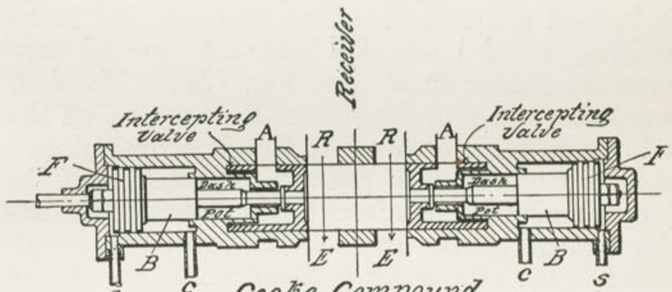
Cooke Compound
When Engine is running simple.

The intercepting valve is composed of two pistons in duplicate, as shown in Figs. 174, 177 and 178, each part being moved by a piston *F* in a separate chamber. Figs. 175 and 176 show one-half of the valve removed from its chamber. It will readily be seen from Fig. 174, that live steam from the engineer's valve *V* in the cab can be supplied through two small pipes *S* and *C* to either the outer or the inner sides, respectively, of these two pistons *FF*. Ports *RR* are passages

from the receiver and ports *EE* lead to the low-pressure steam chest.

To start the engine with single expansion or to run it thus at any time, the engineer pulls the handle of his engineer's valve *V* in the cab to the back notch. This admits live steam through the small pipe *S* (Fig. 174) to outside ends of the two pistons *FF*, thereby moving them and their attached intercepting valve pistons until the two latter come together, the position in which they

Fig. 178



Cooke Compound
When Engine is running Compound

are shown on a larger scale in Fig. 177. In this position the intercepting valve has closed the ports *EE* to the low-pressure cylinder, and the high-pressure exhaust into the receiver can pass out from ports *RR*, through the hollow intercepting valves and escape to the atmosphere by exhaust ports *AA* leading to the main exhaust, as indicated by arrows. The extended and slotted stem of the left-hand intercepting valve piston *F* (shown in Figs. 174 and 175) in moving to the right has pulled with it the crank lever *K* (Fig. 174) and opened the reducing valve *D* which, by a connecting pipe tapped into the main steam passage of the high-pressure side, admits live steam to the low-pressure steam chest through pipe *J*.

When the engineer desires to work compound, he pushes the handle of the engineer's valve *V* in the cab to the forward notch, thereby admitting steam through pipe *C* (Fig. 174) to the inner sides of the two intercepting valve pistons *FF* and forcing them and their valves outward, as shown in Fig. 178. In this position the passage is opened from the receiver through the intercepting valve ports *RR* and *EE* to the low-pressure steam chest (See Fig. 174). The outward movement of the pistons *FF* has shut off the admission of live steam to the low-pressure cylinder by closing the reducing valve *D*, and the steam must now pass from the high-pressure cylinder through the receiver and the low-pressure cylinder to the exhaust or, in other words, the engine works compound.

Each stem between the operating pistons *FF* and the intercepting valve pistons has an enlargement *B* (Figs. 175, 177 and 178) which fits loosely into a chamber of the intercepting valve bushing and thus forms an air dash-pot, thereby preventing the slamming of the valves when their positions are changed.

The stem of the piston *F* which extends back to operate the reducing valve *D* is slotted out, as shown in Fig. 175, so as not to engage the valve crank *K* (Fig. 174) until after the intercepting valve has closed the ports *EE*. Thus the live steam used in the low-pressure cylinder in starting cannot reach the high-pressure side through the receiver and produce a back pressure on the high-pressure piston.

The builders state that in case of accident to either side of the engine, the opposite side may be run for any length of time as a simple engine by disconnecting and blocking the injured side in the same manner as for single-expansion locomotives.

DICKSON COMPOUND.

The Dickson Locomotive Works' compound is built under the Dean patents which cover special valves both for automatic and for convertible compounds, but, inasmuch as the practical information is based on the mechanism for the former class only, the detailed description will be confined to the automatic compound.

The starting and intercepting valves are placed on top of the high-pressure steam chest on the right side of the engine. Upon opening the throttle for starting, live steam is admitted to both cylinders, but, after a stroke or two, the intercepting valve automatically opens and the engine works compound thereafter.

The high-pressure exhaust port *Q* (Fig. 179) is in the balance shield of a Richardson balanced valve *P*, having its top removed, and thus the exhaust steam from the high-pressure cylinder passes up through it and the intercepting valve *G* to the receiver and low-pressure cylinder, when the intercepting valve *G* is open. Beneath the seat *R*, intercepting valve *G*, is a port E^1 leading to the chamber *E*.

The receiver, as usual with cross-compounds, is located in the smoke-box, but its shape is out of the ordinary. It is made very large and, between its connections with the high and the low-pressure saddles, branches into two forks, each of which is oval and has metal ribs lengthwise with the pipes. Fig. 180 shows a section through this

double portion of the receiver. The object of the designer has been to obtain a very large heating surface, so as to re-evaporate some of the water

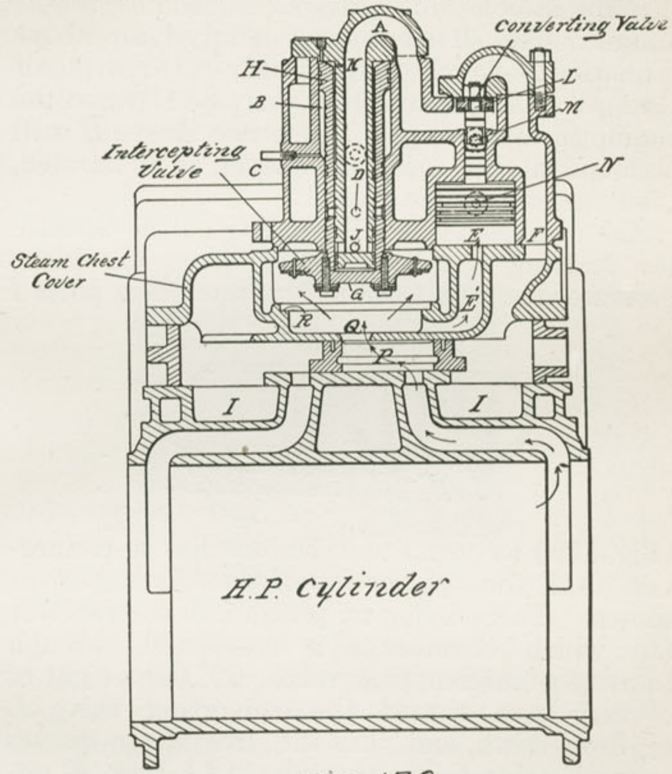


Fig. 179.

Dickson Compound.

condensed in the high-pressure cylinder as it passes with the exhaust steam through the receiver to the low-pressure side. From the reported economy of these engines, it would seem that the object has been largely attained.

Referring to Figs. 179 and 181, it will be seen that the intercepting valve *G* is fastened to the annular stem *H* having an enlarged top above the space *B* which is constantly filled with air pressure or live steam from the pipe *C* when the engine throttle is open, and hence sleeve *H* will be found at the top of its travel, as illustrated, after the engine has started.

The operation is as follows: Open the throttle for starting and live steam enters the high-pressure steam chest from the induction ports *I*

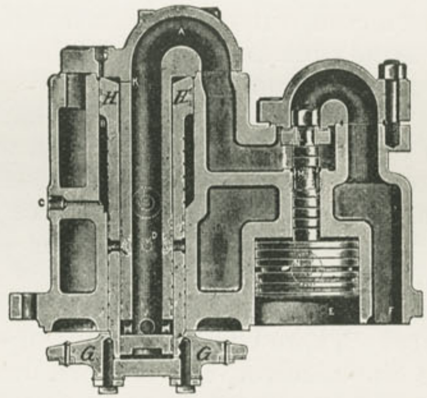
Fig. 180.

—Dickson Compd.—
—Cross Section through Receiver—

(Fig. 179) as usual and besides has a connection to *F* through the top of the steam chest, as shown. There being no pressure in the receiver (to which chamber *E* is connected through the open intercepting valve *G*), the weight of *N* will have caused the converting valve *L* to drop down, and thus the live steam passes through valve *L* into the tube *AJ*. Port *K* admits steam to the enlarged top of the annular stem *H*, forcing the intercepting valve *G* down on its seat *R* and bringing the ports *D* in the stem *H* opposite the ports *J* of the central steam tube *A*, thus admitting live steam through them to the

receiver and low-pressure steam chest. With the intercepting valve *G* closed (down), the first high-pressure exhaust, acting in chamber *E* through the port E^1, causes piston *N* to lift and close the converting valve *L* (as shown in Figs. 179 and 181), thereby shutting off the supply of steam from *F* to the central tube *AJ*. What

Fig. 181.



Dickson Compound
Starting Valve in position, working Compound

steam remains in this tube escapes through the relief port *M* and allows the intercepting valve *G* to move up (open) by live steam pressure from the pipe *C* acting in the annular cavity *B*, as hereinbefore described, assisted by the high-pressure exhaust below *G*. The engine then works compound, as live steam is shut off from the low-pressure cylinder and the exhaust from the high-pressure cylinder takes its place.

The engine above described is an automatic compound, that is, starts with live steam in both cylinders but after the first stroke changes automatically to compound.

The inventor of this system, in a design not shown, introduces a reducing valve in the central tube *A* and adds a separate exhaust valve operated by live steam from a three-way cock in the cab, thus making a compound of the convertible class, but at the same time he does not advise convertible construction in compounds.

Accidents to Dickson Compounds.—What should be done in order to run the engine in with the low-pressure side only? Nothing different from a simple engine, but the boiler pressure carried should be reduced about one-half or else the engine throttle opened very slightly.

How could the engine run with the high-pressure side only? There being no means of exhaust except into the receiver, the low-pressure valve would have to be placed so as to uncover the exhaust port or, if that were found to be impossible, the valve entirely removed.

RHODE ISLAND COMPOUND.

The type of compound locomotive built by the Rhode Island Locomotive Works is sometimes known as the "Batchellor" system, that being the name of the inventor of the device.

In the saddle of the low-pressure cylinder on the left side of the locomotive is located an intercepting and a reducing valve and in the smokebox a separate high-pressure exhaust valve. When the throttle is opened, the engine starts with live steam in both cylinders. With the separate exhaust valve closed the engine automatically changes to compound in the course of a complete revolution; with it open, the engine continues to work as a simple engine as long as desired. This separate exhaust valve is operated at the will of the engineer by means of a three-way cock in the cab; and thus the engine belongs to the class of convertible compounds.

Fig. 182 shows a vertical section lengthwise through the intercepting valve, with the latter in the position when the engine is either starting or being run as a single-expansion locomotive. Fig. 183 shows the same section with the intercepting valve in compound position. *R* is the receiver port; *S* is a connection from the main steam pipe; *L* is a port leading to the low-pressure steam chest, and *B* is a reducing valve. The intercepting valve is composed of the four pistons, *1*, *2*, *3* and *4*, of which the last works in an oil dash-pot *C*.

If the engine had stopped after running compound with the valve, as in Fig. 183, and the engine throttle were then opened, live steam from the pipe *S* would force the intercepting valve into simple position as shown in Fig. 182, because piston *2* is larger than piston *1*. In this latter position small port *D* is open and steam from *S* passes through it and the reducing valve *B* to the low-pressure side. Piston *3* has now closed the communication with the receiver *R* in which one

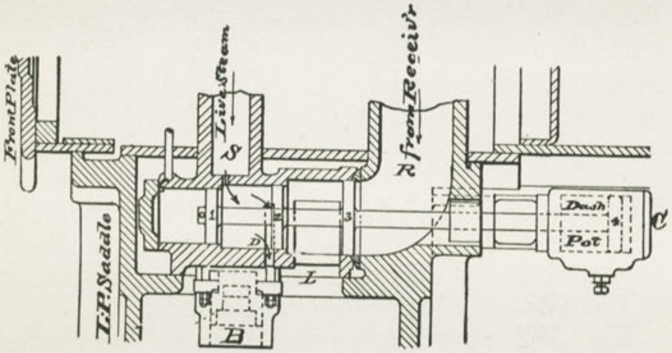


Fig. 182.
Rhode Island Compound
Engine Working Simple.

or two exhausts from the high-pressure cylinder soon produces sufficient pressure to react on this piston *3*, bearing the intercepting valve to the left against the differential pressures on pistons *1* and *2* acting in the opposite direction, and the valve is shifted to compound position, as in Fig. 183, in which position no more live steam can pass through port *D* to the low-pressure side, and

the receiver *R* is connected through port *L* with the low-pressure steam chest, for which it forms the supply thereafter, as indicated by the arrows.

The port leading from the live steam supply *S* into the intercepting valve, is larger than it appears from the illustrations, as it extends partly around the circumference of the valve.

The separate exhaust valve shown in Figs. 184 and 185 is placed on the receiver in the smoke-

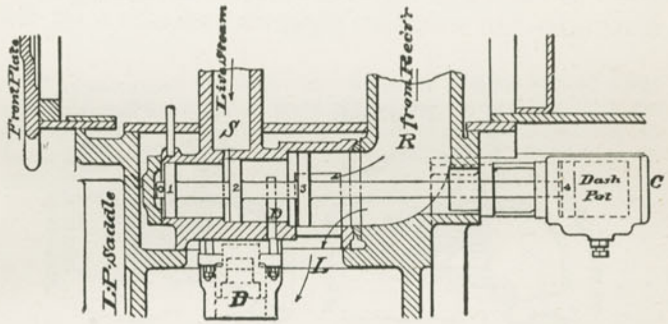
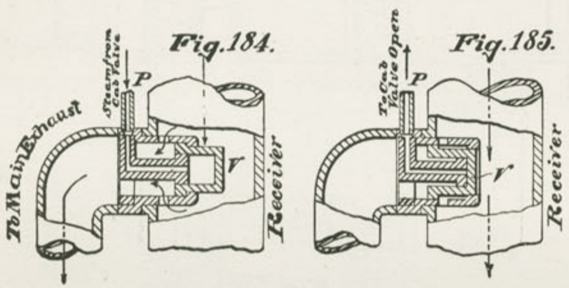


Fig. 183.
Rhode Island Compound
- Engine Working Compound -

box and, when opened by pressure through pipe *P* leading from a three-way cock located in the cab and under the control of the engineer, connects the receiver with the main exhaust pipe. The opening of this valve will thus permit the high-pressure exhaust to escape and there will be no accumulation of pressure in the receiver. Hence, from the previous explanation, it will be seen that the intercepting valve remains in simple position (Fig. 182) until such time as the engineer closes the separate exhaust valve, when a stroke of the engine automatically changes the mechanism to compound position, as before described when starting.

The operation of the separate exhaust valve, shown in Figs. 184 and 185, is very simple. Pressure admitted from the cab through pipe *P*, moves the valve *V* from its closed position (Fig. 185) to the right and vents the receiver pressure direct to the exhaust pipe, as indicated by the



Open-Engine Working Simple. Closed-Engine Compound.

Rhode Island-Separate Exhaust Valve

arrows, Fig. 184. Withdrawing the pressure from the pipe *P*, allows the receiver pressure to automatically move and hold closed the valve *V*, as in Fig. 185.

Accidents to Rhode Island Compound.—If it became necessary to disconnect either side, how should the engine be run? Disconnect properly, observing the same precautions advised for simple engines, then open the separate exhaust

valve so that no pressure can accumulate in the receiver.*

What would you do with a broken intercepting or reducing valve? Open the separate exhaust valve and run with very light throttle, or, preferably, carry a reduced boiler pressure.

Would the working of the engine be affected if the separate exhaust valve *V* were broken? Probably not; but, if it left an opening between the receiver and the exhaust, the engine would run as a simple locomotive only.

*As remarked elsewhere in relation to designs having a separate exhaust valve, if it were the high-pressure side that was disconnected, it would not be necessary to open the separate exhaust valve unless there was some leakage of steam into the receiver.

APPENDIXES.

APPENDIX A.

AIR BRAKE TESTS.

The following tests made by the general manager of a large railroad in the south, clearly demonstrate that the air brake used alone is better than the brakes with the reverse lever, or than the reverse lever alone.

The table of these tests here produced is taken from the published reports of the *Air Brakemen's Association Proceedings for 1895*:

Conditions of the test were as follows:

Driving brake power, seventy per cent; tender, one hundred per cent; N. C. & St. L. coaches, ninety per cent; Pullman Sleeper, forty to one hundred and one per cent.

Boyer speed recorder was used and tests were made: first, brakes applied; second, engine reversed; third, sand lever opened. Track was level, in best possible condition, and all circumstances favorable.

From the record of tests the following valuable information was derived:

First. Best stops are made with braking power not quite strong enough to skid wheels.

Second. Length of stop is the same in reversing the engine whether cylinder cocks are opened or closed.

TABLE.

No.	Brakes Used.	Condition of Train.	Speed.	Sand.	Total No. of Stops Made.	Maximum Length of Stops.	Minimum Length of Stops.	Average Stop in Feet.	Time in Secs.	Wheels Slid.	Flat Spots.
1	Driver and tender brakes.......	Engine and tender..............	30	No.	9	280	240	254	11	No.	No.
2	Driver brake alone.......	" "	30	"	2	438	387	412	18	"	"
3	Tender " "	" "	30	"	7	604	458	538	23	"	"
4	No brakes, engine reversed.. ...	" "	30	"	3	464	426	450	20	Locked and revolved backwards.	"
5	Driver and tender brakes and engine reversed.......... ..	" "	30	"	4	290	245	276	12	Yes.	$2\frac{1}{8}$ in.
6	No brakes and engine "plugged"	" "	30	"	2	540	505	522	25	Locked and revolved backwards.	No.
7	Driver and tender brakes........	" "	30	Abundance	1	260	200	260	11	No.	"
8	No brakes and engine reversed..	" "	30	"	1	280	280	280	12	"	"
9	" " " " "plugged."	" "	30	"	1	265	265	265	11	"	"
10	Driver and tender brakes and engine reversed.....	" "	30	No fresh sand.	4	177	140	158	9	"	"
11	Driver and tender brakes, with engine "plugged."	" "	30	"	1	177	177	177	9	"	"
12	Driver and tender brakes ...	" "	20	No.	1	111	111	111	8	"	"
13	No brakes and engine reversed..	" "	20	"	1	161	161	161	9	"	"
14	Driver and tender brakes..	" "	20	Yes.	1	90	90	90	6	"	"
15	" " " "	" "	40	No.	1	532	532	532	25	"	"
16	No brakes, engine reversed.. ...	" "	40	"	2	861	820	840	32	Locked and revolved backwards.	"

TABLE—Continued.

No.	Brakes Used.	Condition of Train.	Speed.	Sand.	Total No. of Stops Made.	Maximum Length of Stops.	Minimum Length of Stops.	Average Stop in Feet.	Time in Secs.	Wheels Slid.	Flat Spots.
17	Driver and tender brakes...	Engine and tender....	40	Yes.	1	475	475	475	20	No.	No.
18	All brakes cut in....	Engine, tender and 5 N. C. & St. Louis coaches	30	No.	8	271	260	258	11	"	"
19	" " " "	Engine, tender and 5 N. C. & St. Louis coaches	30	Yes.	1	250	250	250	11	"	"
20	" " " " engine reversed	Engine, tender and 5 N. C. & St. Louis coaches	30	"	7	335	199	265	11	Yes.	3 in.
21	" " " "	Engine, tender and 5 N. C. & St. Louis coaches......	40	No.	4	500	400	474	19	No.	No.
22	" " " "	Engine, tender and 5 N. C. & St Louis coaches.............. ...	40	Abundance	1	475	475	475	19	"	"
23	" " " " engine reversed.	Engine, tender and 5 N. C & St. Louis coaches	40	Yes.	1	542	542	542	23	Yes.	4 in.
24	" " " "	Engine, tender, 5 N. C. & St. L. coaches and 4 Pullmans..	30	No.	1	327	327	327	14	No.	No.
25	" " " "	Engine, tender, 5 N. C & St. L. coaches and 4 Pullmans.. ...	35	"	1	465	465	465	19	"	"
26	" " " "	Engine, tender, 5 N. C. & St. L. coaches and 4 Pullmans.....	40	"	2	575	575	575	25	"	"
27	" " " "	Engine, tender & 4 Pullman sleepers	30	"	1	367	367	367	14	"	"
28	" " " "	" " " " "	40	"	1	702	702	702	26	"	"
29	* " " " " engine reversed	Engine, tender and 5 N. C. coaches	30	Yes.	9	375	218	350	13	Yes.	$2\frac{3}{4}$ in.
30	† " " " " " "	Engine, tender and 5 N. C. coaches:...	30	"	1	325	325	325	13	No.	No.
31	* " " " " " "	Engine, tender and 5 N. C coaches.................	30	"	1	375	375	375	14	Yes	3 in.
32	Pullman sleeper "kicked."		30	No.	1	416	416	416	18	No	No.
33	N C and St. L coach "kicked"		30	"	1	202	202	202	10	"	"

* Unexpected Emergencies.   † Expected Emergency.

Third. The wheels did not lock rigidly when the engine would reverse without the brakes being used.

Fourth. The tests demonstrated that the brakes used alone are better than with the engine being reversed. The stop is quicker, and there are no flat spots obtained.

Fifth. Enough sand is much better than too much.

Sixth. Sand should be used before wheels start skidding, as its use will not start the wheels revolving when once skidding; it will simply increase the flat spots.

Seventh. Sand being used on a straight track, the drivers did not lock when the engine was reversed, but on a curve they would. On a curve the engine rocks, and sand is not so likely to strike the rail.

Eighth. In expected emergencies, the drivers did not lock when sand was used before brakes were applied and engine reversed, but it took so long to get the sand running first, that, in the end, the stop was not made as quickly as with unexpected emergencies where the engine was not reversed.

Ninth. The unexpected emergencies are the ones that bear the most weight, as expected emergencies are practically unheard of.

WESTINGHOUSE QUICK-ACTION AUTOMATIC BRAKE.

SUMMARY OF RESULTS OF TESTS, WITH 50 CAR TRAIN, IN OCTOBER, NOVEMBER AND DECEMBER, 1887.

Place of Test.	Down Grades. Feet per Mile.	First. Miles speed.	First. Feet distance.	First. Sec'ds time.	Second. Miles speed.	Second. Feet distance.	Second. Sec'ds time.	Fourth. Miles speed.	Fourth. Feet distance.	Fourth. Seconds time.	Sixth. Miles speed.	Sixth. Feet distance.	Sixth. Sec'ds time.	Seventh. Miles speed.	Seventh. Ft. distance apart.	Eighth. Miles speed.	Eighth. Ft. distance.	Eighth. Sec'ds time.	Ninth. Miles speed.	Ninth. Ft distance.	Ninth. Sec'ds time.	Tenth. Miles speed.	Tenth. Feet distance.	Tenth. Seconds time.
St. Paul . . .	13.6	19	172	7	36	490	15	20 37	200 583	. . . .	. .	. . . .	. .	25	100	20	109	. .	37	327	. .	. .	. . . . .	. .
Chicago . . .	Level, head wind.	22	184	10	37	480	15	20 34	162 470	11 15	19	1,200	62	20	59	20	120	6	33	272	11	. .	. . . . .	. .
St. Louis . .	52.8	20	176	11	36	507	18	35	502	17	21	2,115	128	23	61	20	109	6	38	377	11	. .	. . . . .	. .
Cincinnati .	50.0	25	284	12	35	542	17	37	573	17	21	1,925	75	22	32	20	102	6	41	425	12	. .	. . . . .	. .
Cleveland . .	40.0	26	265	12	43	718	20	38	636	17	23	1,686	65	25	45	20	96	6	40	375	11	43	767	22*
Buffalo . . .	32.20	21	214	12	40	679	19	39	648	19	20	1,000	48	. .	59	20	93	6	40	414	13	. .	. . . . .	. .
Albany . . .	35.0	20	158	10	36	560	18	37	580	19	20	1,342	60	. .	180	19	78	5	40	358	12	. .	. . . . .	. .
Boston . . .	40.0	19	123	10	32	406	16	34	483	17	21	1,035	54	22	62	20	111	8	. .	. .	. .	38	319 547	12 17
New York .	53.0	23	203	12	41	674	20	41	672	20	21	2,137	85	. .	43	22	91	6	. .	. .	. .	45	495 1,204	13 27
Philadelphia	44.0	23	264	14	36	593	19	36	579	18	18	1,889	75	22	35	20	87	6	. .	. .	. .	49	647 932	19 23
Washington	52.0	19	159	10	42	694	21	42	718	21	20	1,643	67	23	58	21	81	6	40	359	11	. .	. . . . .	. .
Pittsburgh	47.0	20	194	11	40	649	21	40	673	20	20	1,720	72	. .	. .	20	95	6	. .	. .	. .	45	494 890	14

* Passenger train only. Compare with freight train in Test No. 9.

THIRD TEST.—In all cases the brakes went fully on within two seconds.

FIFTH TEST.—The brakes were released in all cases in four seconds.

DESCRIPTION OF TESTS.

1. Emergency stops, train running at *twenty miles per hour.

2. Emergency stops, train running at *forty miles per hour.

3. Applying brakes, while train was standing still to show rapidity of application.

4. Emergency stops, train running at *forty miles an hour.

5. Service stops, and time of release. Exhibition of smoothness of ordinary stop and time of release.

6. Hand brake stops at *twenty miles per hour with five brakemen at their posts. At Buffalo there were seven brakemen.

7. Breaking train in two.

8. Emergency at *twenty miles per hour, the brake leverage having been increased to give the quickest stop possible. In the seven previous tests the usual safe-braking power was used.

9. Emergency stop at *forty miles per hour, same leverage was test 8.

10. A train of twenty freight cars and a train of twelve ordinary passenger coaches, run along beside each other on parallel tracks, each being about the same weight and length of trains, and the brakes applied at the same time. This shows the relative stopping power of the old and the new brakes.

*Speed attempted; actual speeds attained are given in statement and as read from speed gauge on engine. Fractions of miles and sections are omitted. Two engines were used in making tests at St. Paul, and one in other tests.

APPENDIX B.

PRINCIPLE OF THE AIR PUMP.

NOTE.—In Volume I. *Railway Eqiupment* the air pump is referred to, but not minutely. For that reason it has been thought well to embody a particular description of it here in connection with the *Engineers' and Firemen's Manual*, as it in every case forms a part of their examinations in regard to fitness, or in the absence of such examinations is of value to them as explaining a part of their work. The information is, therefore, embodied here for the purpose of making a more thorough exposition of the subject. M. M. K.

SUPPLEMENTARY REMARKS.

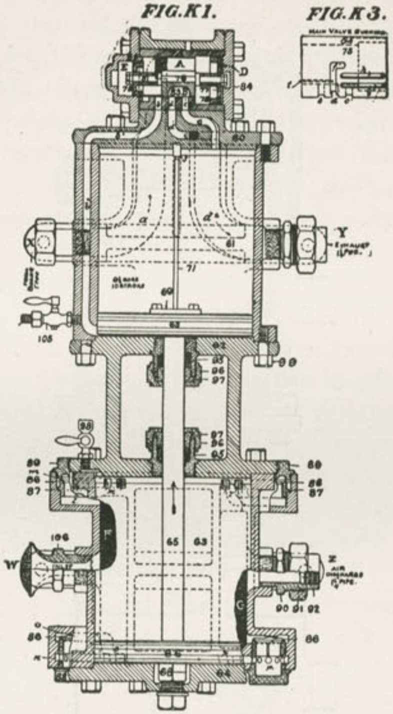
The air pump used in compressing the air for the use of the automatic air brake is placed on the locomotive, usually on the engineer's side of the boiler and immediately in front of the cab, although it is occasionally located similarly on the left-hand side. It is, however, becoming more and more the practice to place a pump on each side of the locomotive, so that there will be one in reserve should the other fail.

When we consider the many efforts made to reduce engine failures and understand that an air pump failure almost invariably results in a delay which is charged up against the locomotive department as an engine failure, it seems as though it would be advisable to place two pumps on all locomotives or employ some such device as the Sweeney Brake, illustrated and described elsewhere.

The air pump is a vertical compressor, consisting of two main cylinders, the upper one being the steam cylinder and the lower one the air cylinder. They are connected by a center casting, through which, in properly designed stuffing boxes, runs the piston rod connecting the main steam piston above with the air piston below. On top of the steam cylinder is the steam head which contains practically all of the valve motion of the nine and one-half inch pump; it will be evident from this last fact alone that this form of pump is superior to the former six-inch and eight-inch pumps not only because of its larger size, but also because these smaller pumps have a portion of their valve mechanism in the main steam cylinder casting of the pump; thus it will be seen that, by the removal of the top head of the nine and one-half inch pump, an entire change of the valve mechanism is effected, and it is this portion of a pump that is most likely to become defective.

These two smaller sizes of pumps (six and eight inches in diameter, respectively,) are being so generally supplanted by the larger (nine and one-half inch size) that it is not considered necessary herein to describe their operation, although it differs but slightly from that of the latter.

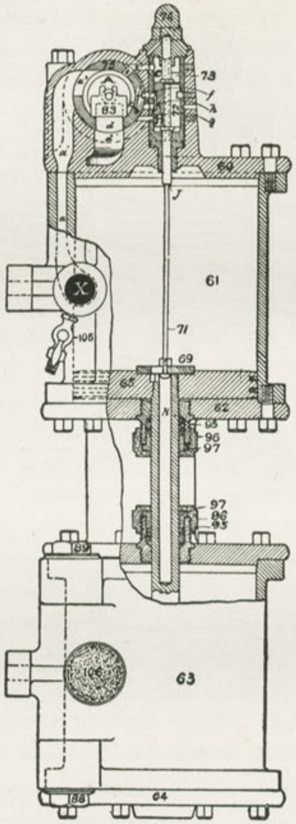
To those not wishing to go into the details of an explanation of the complete cycle of the movement of the nine and one-half inch pump, the following brief exposition of its principle is given:



NINE AND ONE-HALF INCH AIR PUMP.

60.—Top Head, complete.
61.—Steam Cylinder, complete.
62.—Center-piece, complete.
63.—Air Cylinder, complete.
64.—Lower Head.
65.—Steam Piston and Rod.
66.—Air Piston, complete.
68.—Piston Rod Nut.
69.—Reversing Valve Plate.
71.—Reversing Valve Rod.
75.—Main Valve Bushing.
76.—Main Piston Valve, complete.
77.—Main Valve Piston, Large Head.
79.—Main Valve Piston, Small Head.
81.—Main Valve Stem.
83.—Main Slide Valve.
84.—Right Main Valve Cylinder Head.
85.—Left Main Valve Cylinder Head.
86.—Air Valves.
87.—Air Valve Seats.
88.—Air Valve Cages.
89.—Valve Chamber Caps.
95.—Stuffing Boxes.
96.—Stuffing Box Nuts.
97.—Stuffing Box Glands.
98.—Air Cylinder Oil-cup.
105.—Drain Cocks.
106.—Air Strainer.

FIG. K2.



NINE AND ONE-HALF INCH AIR PUMP.

60.—Top Head, complete.
61.—Steam Cylinder, complete.
62.—Center-piece, complete.
63.—Air Cylinder, complete.
64.—Lower Head.
65.—Steam Piston and Rod.
69.—Reversing Valve Plate.
71.—Reversing Valve Rod
72.—Reversing Valve.
73.—Reversing Valve Chamber Bushing.
74.—Reversing Valve Chamber Cap.
75.—Main Valve Bushing.
83.—Main Slide Valve.
88.—Air Valve Cages.
89.—Valve Chamber Caps.
95.—Stuffing Boxes.
96.—Stuffing Box Nuts.
97.—Stuffing Box Glands.
105.—Drain Cocks.
106.—Air Strainer.

Each upward and each downward stroke of the steam piston causes a corresponding movement of the air piston in the lower cylinder. In this air cylinder are two sets of valves that lift whenever the pressure below them is greater than that above; thus both the top and the bottom sides of the air piston have valves to admit air from the atmosphere when the piston is receding, and this valve closes as soon as the piston reverses; the air that is drawn in on the previous stroke is then compressed until the pressure in the air cylinder is greater than the pressure in the main reservoir, when the discharge valve is lifted from its seat and this compressed air discharged to the main reservoir. There is one upper and one lower discharge valve. The pump is double acting, discharging and drawing in air at one or the other side of the air piston on both the up and the down stroke.

To move the air piston the steam must be alternately admitted first to one side and then to the other of the steam piston in the upper cylinder. This admission is regulated by the valve motion of the upper head which consists of a slide valve covering two steam ports leading to either side of the steam piston and an exhaust port leading to the atmosphere. On top of this slide valve is always steam pressure when the pump is working; but this downward pressure of the steam on the slide valve would effect no change of its position without some form of valve motion, so there are two small pistons, one on either side of the slide valve, attached to the ends of a stem having two collars between which this small slide valve is held and thus shifted back and forth in the same manner as an eccentric would reverse the positions of its ordinary "*D*" slide valve on a steam engine. These two pistons that operate the slide valve are of different diameter and consequently when the same pressure per square inch is bearing on their inside surfaces the greater piston is going to overcome the smaller and pull the slide valve in its direction thereby uncovering a port and admitting steam to the under side of the main steam piston and forcing it upward while at the same time, by means of the cavity underneath the slide valve, the upper side of the steam piston is connected with the atmosphere through an exhaust port. When the main piston approaches its upper termination it engages with a stem which moves a very small slide valve in the upper head and allows steam to pass to the outside of the larger main-valve piston. This pressure on the outside of the larger piston just balances the pressure on its inside and leaves the pressure on the smaller piston to effect the movement of the stem and slide valve in its direction, thereby reversing the pump by permitting live steam to enter the steam cylinder above the piston and allowing the exhaust steam from below the piston to escape to the atmosphere through the under side of the slide valve. We have now completed a revolution of the pump and only have to place the valve motion in the position in which they were found when starting the pump (as in Fig. K^1.) This

is done by the engaging of the main piston with the same reversing stem that it struck on approaching its upper limit, only now it is at the approach to its downward termination that it pulls down this stem, thereby drawing its small slide valve with it, which valve permits the steam previously admitted to the outer side of the larger slide-valve piston to escape to the atmosphere through suitable ports. Hence the situation is as at first found—with a larger and a smaller piston acted upon from the inside in opposite directions and no pressure on their outside surfaces; the larger one overcomes the smaller and draws the slide valve to the position as at the outset. (See Fig. K^1.)

As these ports are not large, it is easy to see how small an object it would take to obstruct the passage of steam and consequently cause the pump to stop the same as though some part were broken. That is the reason that the use of nothing but metallic gaskets is advised in the steam connections to the air pump.

THE NINE AND ONE-HALF INCH IMPROVED AIR PUMP.

As will be seen by reference to Figs. K^1 and and K^2 of the accompanying cut, the valve motion of the pump consists of two pistons, 77 and 79, of unequal diameter, mounted on the rod 81, while a slide valve 83, of the "*D*" type, held in position between them provides for the distribution of steam to the upper and lower sides of the main steam piston 65, as required. Steam enters the pump at *X*, where a suitable stud and nut admits of direct attachment to the pump governor, and by means of passages *a* and a^1, and port a^2 is admitted to the slide valve chamber *A* between the two pistons 77 and 79 which (by reason of the greater area of the former) it forces to the right to the position in which the valve is shown in Fig. 1, thus admitting steam through ports *b* and passages b^1 and b^2 to the under side of the main piston 65 and forcing it upward, while the steam previously used on the opposite side in forcing the main piston 65 downward is exhausted to the atmosphere through passage *c*, port c^1, and cavity *B* of the slide valve 83, port *d* and passage d^1 and d^2 at the connection *Y*, from whence it is conveyed by a suitable pipe to the smoke-box of the locomotive.

In Fig. K^3 is shown the outside view of the main valve bushing 75 giving the several ports and steam passages therein, of which port *t* communicates between chamber *E* in the main valve head 85 and the exhaust passage f^1, and hence is in constant communication with the outside atmosphere, relieving the pressure on the surface of the main valve piston 79 exposed to chamber *E*. A reversing valve 72 operates in chamber *C* in the center of the steam cylinder head (Fig. K^2), steam being supplied thereto from slide valve chamber *A* through ports *e* and e^1, and which is given motion through the medium of a rod 71 extending into the space *k* of the hollow main piston rod. The duty of this valve is that of admitting steam to and exhausting it from

space *D* between main valve piston 77 and the head 84, and is shown in Fig. 2 in position to exhaust the steam previously used, from the space *D* through port *h* (Fig. K^3), port h^1 (Fig. K^2), reversing valve cavity *H* and ports *f* and f^1 to the main exhaust ports *d* and d^1 and d^2.

It will at once be apparent, having described how the surfaces of main valve pistons 77 and 79, exposed in chambers *D* and *E*, respectively, are free from pressure other than the atmosphere, that the steam on the insides of these pistons in chamber *A* is exerting a force against both pistons, but the total force to the right is the greater on account of the greater area of the larger piston 77. This effect, however, is reversed when the main piston 65, approaching the upward termination of its stroke, strikes the shoulder, *j*, of the reversing valve rod 71, forcing the rod and its valve 72 upward, causing the admission of steam from chamber *C* to chamber *D* through ports *g* and g^1 (Fig. K^3), thus balancing the pressure on both sides of the main valve piston 77, so that the steam in chamber *A*, acting upon the effective inside area of the main valve piston 79, forces it to the left and live steam is again admitted to the upper side of the main steam piston 65 (while the steam below piston 65 is allowed to exhaust), and thus forcing it downward until at the lower termination of its stroke the button head on the lower end of the reversing valve stem 71 comes in contact with the reversing valve plate 69, again moving reversing valve 72 to the position shown in Fig. K^2, thereby completing the cycle of its movement.

Coincident with the reciprocal movements of the main steam piston 65, the air piston 66 is moved by means of the main piston rod (also lettered 65) and air from the outside atmosphere is drawn alternately into the respective ends of the air cylinder 63 through the screened inlet 106 at *W*, chamber *F*, and receiving valves 86 to the left, Fig. K^1, and from thence discharged under pressure through discharge valves 86 to the right, Fig. K^1 to chamber *G* and the main reservoir to which the pump should be connected by one and one-fourth inch pipe at *Z*. The lift of the receiving and discharge valves 86 should be three thirty-seconds of an inch.

This pump should receive as great care as that recommended for all previously designed pumps. The admonition, however, to use *only a very small amount of oil in the air cylinder* will bear repeating. Ample provision is made for drainage by means of two cocks, Figs. 105, K^1 and K^2, located in the steam passages *a* and b^2, which should be left open in starting the pump and in winter at all times when the pump is not working.

APPENDIX C.

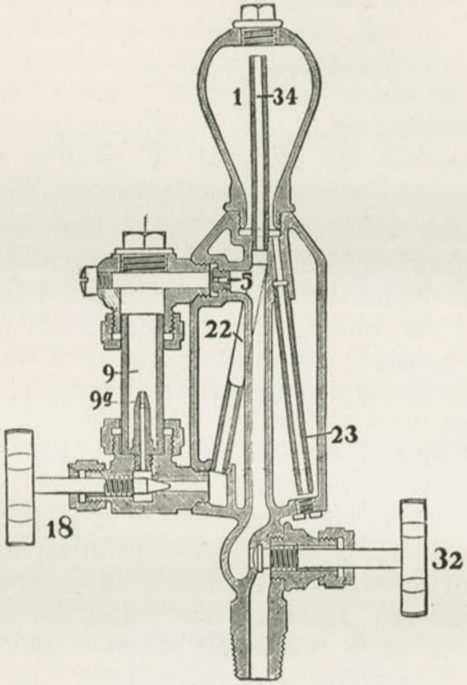
THE LOCOMOTIVE LUBRICATOR.

Although many engines (notably marine engines using distilled feed water) have been run successfully without cylinder lubrication other than that of the steam that is condensed about the walls of the chamber, as higher boiler pressure became used in locomotive practice it was found advisable to employ oil in the lubrication of the cylinders.

The boiler of a locomotive is probably forced more at times and more steam is taken from it in a given time than from that of any other boiler of the same size. This causes priming and more or less of the water is carried with the steam into the cylinders. Hence, if the water has much of any incrustating matter in solution, much of it reaches the valves and valve seats, the pistons and cylinders, and results in cutting these surfaces to a considerable extent, even with the most approved methods of lubrication.

The original method employed for oiling the valves and cylinders was by means of an oil cup located on top of the steam chest through which cup oil could be supplied to the valves and cylinders below whenever steam was shut off.

FIG. 38.



AIR BRAKE LUBRICATOR—SECTIONAL VIEW. (NATHAN.)

1.—Condenser.
5.—Reducing or Choke Plug.
9.—Sight-Feed Glass.
9a.—Sight-Feed Nozzle.
18.—Regulating Valve.
22.—Oil Pipe.
23.—Water Pipe.
32.—Steam Valve.
34.—Condenser Tube.

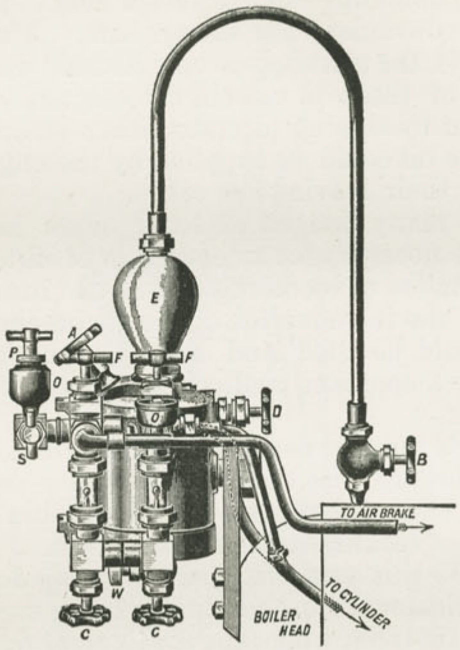
This necessitated the engineer or fireman going to the front end of the engine and pouring oil in these two cups—one or either side. This was neither convenient nor always safe. About the year 1864 the next improvement made was in the placing of these oil cups in the cab and connecting them by sloping pipes to either steam chest. Thus the oil could be supplied by the enginemen without their leaving the cab.

After many designs of hand oilers had been used, the necessity for an even flow of oil to valves and cylinders of locomotives was met in the year 1872 by the introduction of the steam-chest oiler that could be filled and an adjustment made whereby a constant and controllable flow of oil was had.

In 1883 the first *down drop-feed* lubricator made its appearance, one being provided for each cylinder. These lubricators were located in the cab with pipes leading to each steam chest.

In 1885 this was changed to the *up drop-feed*, one lubricator for each cylinder being used, however, until 1886, when the *double sight feed* lubricator was put in use. From the time of the introduction of the air brake and consequent use of the air pump up to 1888, a separate lubricator was used for air pump lubrication. In that year, however, another feed was added to the cylinder lubricator making it a *triple sight feed* lubricator, as at present used.

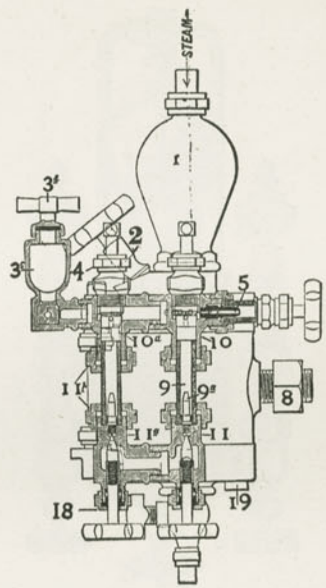
Fig. 39.



Triple Sight-Feed Locomotive Cylinder and Air Brake Lubricator. (Nathan.)

A—Filling Plug.
B—Steam Valve.
C, C, C—Regulating Valves.
D—Water Valve.
E—Condenser.
F, F, F—Safety Valves.
O, O, O—Auxiliary Oilers.
W—Waste Cock.

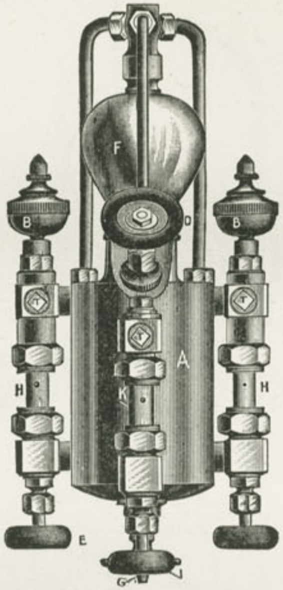
Fig. 40.



Triple Sight-Feed Locomotive Cylinder and Air Brake Lubricator—Sectional View. (Nathan.)

1.—Condenser.
2.—Filling Plug.
3.—Auxiliary Oiler.
4.—Safety Oiler.
5.—Reducing or Choke Plug.
8.—Stud Nut.
9.—Sight-Feed Glass.
9a.—Sight-Feed Nozzle.
10.—Upper Sight Bracket (for cylinder)
10a—Upper Sight Bracket (for air brake)
11.—Lower Sight Bracket (for cylinder.)
11a.—Lower Sight Bracket (for air brake.)
18.—Regulating Valve.
19.—Bottom Plug.

FIG. 41.



TRIPLE SIGHT-FEED LOCOMOTIVE CYLINDER AND AIR BRAKE LUBRICATOR. (DETROIT.)

A—Oil Reservoir.
BB—Auxiliary Oilers.
C—Connection for Boiler Pressure.
D—Water Valve.
EE—Regulating Valves.
F—Condenser.
G—Drain Valve.
HH—Sight-Feed Glasses.
I—Regulating Valve for Air Pump.
K—Sight-Feed Glass for Air Pump.
M—Steam Valve for Boiler Pressure.
O—Filler Plug.
R—Steam Connection to Air Pump.
S—Tallow Pipe Connection to Cylinder.

BOOK III

GENERAL INDEX

TO THE

"SCIENCE OF RAILWAYS."

GENERAL INDEX.

INTRODUCTION.

What follows, while seemingly uninviting, represents long continued labor and, taken in connection with what precedes it, completes the subject of railway carriage. It is at once an Index and, in many respects, an Encyclopedia or key to the door of railway knowledge. By its aid the student may pick out from the woven fabric the particular thread he seeks and follow its devious windings through the different divisions of the railway service with which it is connected and thus obtain a connected view of every subject, no matter how trivial it may seem.

I do not, of course, claim that I have exhausted the subject. If a man could do this, there would never be but one book written on a subject; but, fortunately, what one man writes only serves to stimulate the ambition and broaden the minds of others. I have discovered this in my own experience. Some of my books have been re-written many times. What they represent today is an evolution, not only in railway affairs but in my own life and experience as a writer. In my early experience I called in from the publishers and burned many hundreds of books because I became dissatisfied with them. What seemed at first worthy of being printed, I discovered upon reflection and further investigation to be grossly deficient, hence the books called in and burned, to be re-written and burned again and again. However, they served as a guide until, finally, I have been able to write something that seems to me worthy of being read. I hope that I may not be alone in this belief, but that my readers may feel that after many years of effort I have written something worthy of their perusal.

GENERAL INDEX.

[EXPLANATORY NOTE.—In consulting this general index the reader will note that following each subject are Roman numerals; these refer to the particular volume of the series to which reference is made; the Arabic figures following denote the page. Thus an item as follows;

Accidents....................I, 267; II, 250; V, 570; IX, 127; XI, 67

would mean that the subject of Accidents is referred to in Volume I, at page 267; Volume II, at page 250; Volume V, at page 570; Volume IX, at page 127; Volume XI, at page 67.]

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