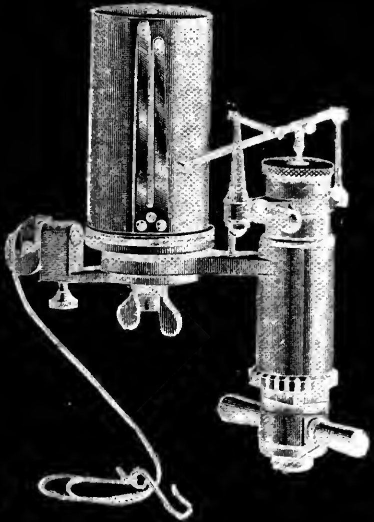

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Feb/95

TWENTY YEARS

WITH THE

INDICATOR.

BEING A

PRACTICAL TEXT-BOOK FOR THE ENGINEER OR THE STUDENT,

WITH NO COMPLEX FORMULÆ.

With many illustrations and rules as to the best way to run any Steam Engine to get the most economical results. How to adjust Valves and Valve Motions correctly. Full directions for working out Horse Power, the amount of Steam or Water per Horse Power, Economy of Fuel. The author's original and correct application of the Theoretical Curve, to show exactly where the steam valve closed, and whether valves leak or not; extended directions for attaching the Indicator, what motions to use and those not to use. Full directions for computation of Power by Planimeter and other methods. with many tables and hints.

NEWLY ARRANGED AND COMPLETE IN ONE VOLUME.

TWELFTH THOUSAND.

BY THOMAS PRAY, JR.,
CONSULTING AND CONSTRUCTING AND CIVIL AND MECHANICAL ENGINEER,
MEMBER OF VARIOUS SOCIETIES, ETC.

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DEDICATION OF VOL. I.

THIS work is respectfully dedicated, with the highest feelings of regard, to my friend, J. M. ALLEN, of the Hartford Steam Boiler Insurance and Inspection Company, for his high value of personal integrity, and for the good he has done, and is doing, to protect the lives of stationary steam engineers and the property in their and his charge,

BY THE AUTHOR.

DEDICATION OF VOL. II.

THIS volume is dedicated, with every sense of respect and the highest regard, to that class of men who are everywhere working to better inform themselves, to better their condition by knowledge and fidelity, and to secure greater safety in the steam power in their control, and consequently better results to their employers, and greater safety to human life everywhere—THE WORKING ENGINEERS—Marine, Locomotive or Stationary—wherever they are, in the humble hope that it may contribute to their benefit, from an extended experience of one who is practically one of them.

THE AUTHOR.

JANUARY 1st, 1885.

PREFACE TO VOL. I.

WHEN the author commenced a series of articles on the Indicator in the BOSTON JOURNAL OF COMMERCE, it was only with an idea of writing a few articles in number, for the purpose of showing up some of the most generally found defects of the builders of steam engines, — defects in practice, — and to explain, in as simple a way as possible, how to adjust, or at least how to overcome these defects, so far as the defects of building would allow, and make a more economical use of steam. The subject, however, grew on the author's hands, and, rather to his disappointment, a great deal of inquiry was elicited. The articles were continued far beyond his own ideas, originally, and, as the paper was growing rapidly in circulation, hundreds of subscribers were added who could not procure the first of the series. Within the first four or five months inquiries began to come in asking us if we would not print the articles in book form. It was a year or more after the appearance of the first article of the series before time could be given to their revision for the purpose of republication in book form. Meantime the name of the paper had been changed to COTTON, WOOL AND IRON, and the subscription list was increasing faster than ever. All this required new quarters, and we were obliged to move in the very midst of the preparation of this book; and the book was still further delayed some two or three months on account of having to add to our plant for printing the paper. This, in brief, is how this book came to be printed. It is offered to the public with the full knowledge that there are many little inaccuracies, arising from the fact that the author has been doing the work of two or three men. Aside from having the full management and editorial charge of the paper, (which is no easy job,) his daily consultations have been large, being obliged at times to travel several hundred miles per week, which, together with the charge as consulting engineer of a number of large steam plants and cotton mills, has made it next to impossible for him to sit down for more than an hour without interruption or being obliged to drop the work entirely for days together.

The subject-matter of the book has been gathered from probably the broadest experience ever enjoyed or earned by any man in this country. It was commenced at a time when but very few people knew anything of the Indicator, and the instrument was in a crude state, — when it was far from perfect. The hobbies and vagaries of engine builders, the ignorance, prejudice, and love of the dollar on the part of the steam users, and the bigotry and prejudice of the working engineer, made it at times almost impossible, even when we were investigating for our own benefit, to obtain access to an engine.

But gradually questions arose which compelled some arbitration ; we were fortunate enough to be appointed by the Supreme Court of several States to carry on investigations, which opened up such questions that the steam user and the engine builders were obliged to make a limited use of the Indicator. Meantime the change in engineering has called for a broader use of the Indicator, has called for more knowledge, and that this knowledge shall be based upon fact. The makers of the instrument have kept pace with the requirements of the engineering profession, and, without doubt, the American Indicators of to-day surpass everything made in the world before, for their accuracy, and their durability under all the range of requirements from the slow moving low pressure engine, to the high speed and high pressure locomotive, and electric light engine.

The lessons in this book are drawn from actual practice ; with very few exceptions the diagrams were all taken by our own hands. What this labor has cost, no one but ourself can properly understand. At times working all night, and not in the pleasantest quarters—sometimes without anything beyond the crudest tools—in attempting adjustment where the builder of the engine had absolutely precluded any adjustment ; working against all the different degrees of prejudice and ignorance, frequently going without food for many hours together, being compelled in a certain time to accomplish all that could be done ; making long railroad rides at night ; working all day and night —all this has not been pleasant, but it has brought about, to a great extent, a revolution in the practice of the Indicator, and an amount of information of easier access to the reader.

These pages are offered with a full knowledge of their faults, but it has been the author's intention to convey knowledge to the greatest extent possible, and in such a way that the working engineer, and the men who use engines,shall understand them and be able to work out their own adjustment, if they will but give a little time and patience to it. The second volume will contain more extended information with reference to the theory of working steam, and the application of general rules as to the measurement of steam and water, with some curious illustrations from actual practice, of the vaious ways of connecting the Indicator to the cylinder, errors in motions, and a variety of matter which is not yet fully laid out. Inquiry has at this time taken a turn toward adding something in reference to combustion and various boiler settings, and, if we follow the subject, it will probably run into the third volume. The second volume will be issued sometime within a year, and, as to the third volume, much will depend upon our personal arrangements, how much can be done, and how much time we can give to it.

The diagrams in this work are, in in every case, full size, so they can be measured and worked from accurately, or a tracing can be made for that purpose. In every case our aim has been to give the facts, and wherever the name of the builder has been mentioned, it is not with any intention of either recommending or disparaging his or their work. The names are used only as the types, and in many cases where bad adjustment has been shown, it has not been any fault of the builder. In other cases this cannot be said. The book is from a practical experience, with all the ins and outs that are liable to occur in a large practice. We only regret that other duties absolutely forbid our giving practical attention and time to the calls which are now made upon us, otherwise we might soon issue a second volume, which, while not containing so much in breadth or in fact, could be made more elaborate, and perhaps more practical and interesting.

THOMAS PRAY, JR.

Boston, January 3, 1883.

Since the publication of Vol. I. [first edition] all interest in the publication and the copyright have been legally transferred to me.

P. O. Box 2,728, Boston, Mass. THOMAS PRAY, JR.

July, 1887.

PREFACE TO VOL. II.

As announced in Vol. I, this book, Vol. II, is launched, not as a literary effort or a scientific essay, but rather as a practical hand-book or text-book for the working engineer, the steam user or any who may be learning something as to the construction of engines and what constitutes the economy of an engine, what use is made of the steam after being produced by the boiler, and whether this use is good, bad or indifferent. The book has not a single mathematical formula, algebra and the higher mathematics having been entirely left out; not because the engineers could not understand them, for many of them are capable of understanding the higher mathematics, as we know, and very many make regular use of formulæ in their calculations for the sake of brevity. We have ourselves had no difficulty in expressing anything in few words without resort to formulæ; and as so many of our engineers have graduated from the fire room, and then taken positions in the engine room, or in charge of both, who have had no chance at even common-school education, we have preferred to put everything in the plainest wording, so that all might thoroughly comprehend and avoid any confusion or misunderstanding. So much for the general character of the work.

This work has been compiled from one of the most extensive practices any man was ever engaged in, at a time, too, when the author has been not only busy but a very busy man. Much of the work has been done "atween times," or when, for his own comfort, he might have been resting, and all the time during the progress of the work, which has been slow, and interrupted twice for several months, he has been busy with a large consultation practice, with the cares of a paper, and other matters, so that Vol. II has been delayed many months longer than was expected.

The subject matter of Vol. II is very largely new, only a few articles having been reproduced from the columns of the *Manufacturers' Gazette*, and in every case these reproductions have been made use of from radical points either of misuse, misconstruction, or some other peculiarities which, while all too frequent, we are not always able to lay our hands upon for ready reference. The various uses of steam cover a broad ground, from the last new ocean steamship to the 15 horse-power high-speed motor for electricity. All through the work the author has endeavored to avoid any personal reference, or to revive any criticisms other than so far as principles of mechanism, or a wasteful use of steam were concerned. Trials of engines have been for the information of the reader; trials of indicators have been to obtain absolute information for our own use, and in these cases all have been judged by the inflexible standard of right, without regard to the assertions of the several builders, patentees, improvers or venders, meaning to place on record only those facts which were of importance in the use of this much-abused, much-misunderstood, and yet so simple and accurate an instrument as the steam-engine indicator. A large majority of the diagrams in this volume have been taken by the author's instruments and hands. It has been the aim to avoid repetition and to introduce, as much as was possible, all the conditions of adjustment, whether right or wrong, of construction or of fancy that might possibly arise upon any engines, anywhere, in any kind of service, so that the book might become more valuable to those who were far away from the builders of engines, and to make it all the more valuable to them as affording a way out of any trouble into which they might be thrown.

The extremely extended use of the steam-engine indicator within the last four or five years, has called for some book from a practical man, which should not in any case toady to the indicator builders, except to apply their instrument when it was reliable, and would record in such a manner that the diagrams were of some practical value to the men who are not thoroughly up in a wide practice. It has also been the aim of the author to be all the more guarded in offering instruction which should be of benefit to the only men for whom we are writing in general, viz., the party who owns the engine and the working engineer in charge of it, so that these two men should be entirely free from the assumption so frequently imposed upon them by ignorant and impractical men who assume the rôle of experts, never having run an engine a day in their lives.

Every diagram which is presented is engraved as nearly as it is possible with all the variations which the original contained, in other words, our aim has been not to discriminate in favor of or against any engine builder's work, but to produce actual fac-similes in size, in good or bad points, precisely as the originals were when taken from the engine. The full intention expressed with reference to the second volume has not been realized. The only point, however, is that treating upon the errors of different motions, which is in itself an exceedingly wide range of subjects, and requires a great deal of preparation as well as careful experiment. The results of incorrect motions are shown in several instances, and how to obtain correct diagrams is also in several instances carefully explained.

As referred to in the first volume, it is not improbable that the third volume will follow the second, during the latter part of 1885, in which a careful analysis of motions, the result of errors in motion, and any new features with reference to indicators, or possibly with reference to errors in the different indicators will also be fully illustrated. Much of this work has now been done. Careful study of these motions has been made, experiments are completed, but Vol. II has grown so rapidly, by including in it some of the largest marine powers, that before we would have wished it, our printer has said that we have already exceeded the limit, and the book is, therefore, somewhat larger than at first promised.

The aim in Vol. II has been to meet the latest practice in such a way that the working engineer should receive from it practical instruction, and if that end is answered, then the real object of the book is consummated.

Vol. III will undoubtedly follow before the New Year, 1886, and will illustrate different reducing motions, and methods of giving motion to the Indicator.

The labor embodied in a volume of this kind, and especially of Vol. II, cannot be estimated by any one, except its author. It has cost thousands of miles of travel, any amount of personal or physical inconvenience, in order to obtain the information which is set forth, and the book, as presented, shows the latest practice in American high-pressure, high-pressure condensing and compound of the latest steamers launched for ocean service, as well as the steam-jacketed high-pressure engines.

The tables in the book have been so arranged for reference as to embody some new principles, and the table of areas in Vol. I having been found faulty, that in Vol. II has been largely computed, and any errors which were found were corrected before its being issued.

With the wish that the book may answer the purpose of a ready and reliable reference to the steam-power owner, or others interested, especially those men in charge, we send it on its way, realizing fully that it contains some faults, and without doubt many omissions, but we hope also that it contains much which is valuable, and that the favor with which Vol. I was received may be extended to Vol. II, and it is a curious fact, up to the time of this writing, that many employers have ordered Vol. II for their engineers, while in the case of Vol. I, the engineers ordered it for themselves. Evidently the employers have found that the efforts of the engineer towards self-education and a promotion, were for their interest, and we welcome this as a sign of encouragement, especially to the stationary engineers, to continue to improve themselves, which, we know they are doing, in many instances when they can ill-afford the expense. "Knowledge is power," and a stationary engineer can control his power with knowledge, to his own benefit, far better than by lack of knowledge, as so many have already found. The author will be thankful to any of the readers of this work, who will point out any error or who will suggest important points of practical use to be covered in Vol. III.

THOMAS PRAY, Jr.

New York, January 1, 1885.

The author has now located in Room 193, Times Building, New York City, his headquarters, to which all inquiries and correspondence may be addressed, and where all professional calls, personal or otherwise, will receive prompt attention.

THOMAS PRAY, Jr.

New York, March 13th, 1891.

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TWENTY YEARS WITH THE INDICATOR.

VOLUME II.

INTRODUCTION.

The steam engine indicator has been an appendage to the steam engine that has been entirely too little understood by the majority of men who follow the profession of steam engineering. Indeed, it has not been many years since the indicator was considered as an especial profession, belonging to a class of men who had styled themselves experts. In many cases our personal contact with these men has persuaded us that they were not only entirely devoid of any cultivation with reference to the application of the indicator, but that they were decidedly deficient in their actual knowledge of steam; while on the other hand we have occasionally come in contact with men who were in every way qualified to give honest judgment as to what they found, what they saw, and to indicate, correct, adjust and advise without any sort of reference to their pocket interest, either direct or remote. Many of these men persuaded themselves that the working engineer was only a man to shovel coal or put on the grease, oil or slush, as the case might be, and that the expert should be called in whenever anything existed that was not entirely right or up to the mark. Without wishing to criticize any, we may premise that our own efforts, dating back to 1866, have been in the direction of instructing the working engineer to the greatest possible extent and without any reserve. The attempts of some of these men to ape the experts have been amusing, but the very large majority of them have accepted the indicator as an attachment to the engine, without any of the mystery, the secrecy, or other generally supposed requirements of its adoption.

The first steam engine indicator of our own acquaintance gave a diagram which was crude in outline, only an approximation in its indications, and nothing from which we could adjust the valves or tell accurately what their condition or relation was to the stroke of the piston; and it was only when the Richards indicator (invented and perfected by our old friend, Mr. Charles B. Richards, for many years connected with Colt's Armory at Hartford, Conn.; later with the Southwark Foundry, builders of the Porter-Allen engine, in Philadelphia, and now occupying a position to which he will do credit and for which he is particularly fitted—Professor of Dynamics at Yale

College, New Haven) came into our hands, that we commenced, in the latter part of 1865, to adjust the valves of steam engines by the use of the indicator. If we had only been as careful then in keeping our memoranda as we are to-day, we could produce some facts with reference to some of the best steam engine builders in the country that would open the eyes of our readers wide with astonishment. In fact, it is a matter that is known to some people still living that we had a long, almost hand-to-hand fight. The indicator was denounced, and the man who had the presumption to attempt to get away from the old prick-punch marks and cold chisel dents on main shaft, eccentrics, straps, valves and connections, was denounced as strongly as the English language was capable of. In fact, invectives were freely used; but all that has passed away and much credit is due to Mr. Charles B. Richards for his having studied the defects of the old indicator, and by the use of the Richards indicator eliminated many of these defects of the steam engine builders, until finally the very men, who in 1865 were extremely vindictive, because their old ways of working had been declared incorrect, are now the men who make free use of the indicator and who advocate it and advise it.

This change has been brought about within the twenty years covered by our own practice, terminating with the issue of this Volume II. But the indicator is now of use for more purposes than one. In 1880 we commenced a series of articles in a paper then edited by us, which shortly after grew into a large circulation, and which has done much to awaken working engineers to the fact that by extending their knowledge they could make themselves more valuable and could produce higher economy for their employers. These men, many of them, have not been slow to avail themselves of this knowledge, and in very many cases they have been personally benefited by being promoted to better positions, and there are, no doubt, many others who will be rewarded in the same way; but it is a work of time. Employers, on the other hand, have been slow, in some cases, to recognize the value of the indicator and its application, and particularly the fact that the engineer who was familiar with it, was worth more money to him or them than one who was ignorant of it. Like all other innovations on ancient practice, the working engineer must be patient and must produce the results, and then no man or class of men are quicker than employers to find the benefit of the change accruing from the proper application of the indicator; then the men who can handle it with best purpose can certainly receive all that belongs to them. But during the years past employers have a great many times been seriously misled by men who adopted the word "expert" as a prefix or suffix, and who are really incompetent, and they have paid dearly for this experience, so that really the indicator and its advocates must be prepared to outlive this reputation, which is no fault of the indicator, but rather of a class of men who live upon the credence of others. But taking it all in all, the use of the indicator has vastly extended within the last four or five years.

Following up the improvements which have been made in the steam engine indicator since the author's first connection with it (and during which time he has owned almost every indicator which has been manufactured, to any extent at least, and some which never should have been manufactured and are not now), and finally found the instrument which for all purposes has given the most reliable results, including all that is expected of an indicator, and that is, the Thompson Improved Indicator, which is the only one illustrated in this volume, and which the author uses exclusively in his own practice on trials for power, on tests for the position of the valves, for the correctness of working steam and for all purposes wherever he is professionally called to attend to adjustment, correction, economy, or power tests; and in connection with this indicator he has used everything which has been found in the market, ancient and modern, up to the issuing of this book, making trials of different speeds, under different conditions, with different pressures, and with different positions of valves, and the trial has in every case re-asserted the correctness of his adoption of the Thompson Improved, and in some cases where very serious errors were found in either one or the other essential requirement or relation of valve, valve action, working of steam, or large variation in the amount of power, under identically the same circumstances. The author desires to state here that he has no connection with any indicator attachment, engine or steam appliance, no interest financially, direct or remote; and wherever comparisons are used they are used as matters of fact for the information of the reader and with the intention that such information shall be reliable, our sole interest being to make this book more valuable than any that has preceded it.

The various defects which are found in the old indicators have gradually been removed; some of them have been faults of mechanism, others of mechanical construction, while others have led to a change in mechanism and construction, and in some cases in the proportion of parts and to a decided change in the mechanism adopted to produce the required result. The lessons which follow this are very largely from our own practice. Some curious examples are shown, and in every case diagrams are engraved precisely as they were taken, full size, and can form the basis of comparison or can be figured from, without any reduction of proportion or percentages. It is proposed to introduce everything up to the most recent practice, particularly that of some steamships, the diagrams of which have never been printed before. Many of the matters introduced are original, particularly that of demonstrating the cut-off from the actual pressure of steam from some point on the expansion line. Some of the methods of working out diagrams we have never seen in print before, and some of the oldest engineers and best scientific men in the country have carefully gone through the demonstrations and pronounced them mathematically correct. All these demonstrations are put in plain language, without mathematical or algebraic formula, so that everyone can fully understand and work from them without reference to any of the works upon higher mathematics. Volume II. is intended to cover the whole ground, and there is no reference from Volume II. to its predecessor, and no need of reference from one to the other for any purpose of computation. Volume II. will be found to contain a far broader scope than Volume I., and it is intended to be a companion to the working engineer, to answer his questions at all times, and to answer them in such a way that whatever may be the situation or position, he can at once adapt himself and his indicator to the case, with a certainty of correct results.

THE THOMPSON INDICATOR.—HOW TO ATTACH IT, AND WHAT TO USE.

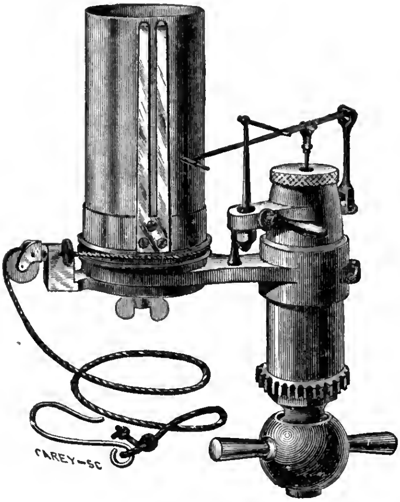


FIG. A.

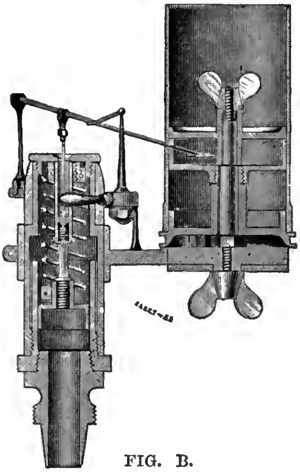


FIG. B.

Figs. A and B represent respectively, A an outside view and B a section. In Fig. A the parallel motion is shown, which is now made of drop-forged, compressed steel. The paper barrel is very light, and when taking off the paper barrel, there will be found inside a milled-head, above which is a thumb-screw, shown in Fig. B. The spring of the Improved Thompson is coiled, in Fig. B, into the section upon which the end of the pencil lever touches; a sleeve runs down over the spindle, upon which is a hook, and that hook engages with the inner coil of the spring. By loosening the thumb-screw shown in the sectional view B, and grasping firmly the milled-head cover, after the paper barrel has been removed, we can get any amount of tension required, changing the tension according to the speed of the engine we propose to indicate. In section B, the spring is shown, the inside of the piston barrel, with an universal joint which engages with the lever at the top and below the piston of the instrument, the coils of the spring and connection with the steam cylinder—all precisely as they are found in the instrument. If we refer again to Fig. A, there are one or two things that need to be noticed. The first is, that the parallel motion of this instrument, while sufficiently strong to withstand all necessary force as employed, must be treated with care; sometimes the springing of either one of these parts will make radical errors in the diagrams, and they must always be carefully lubricated. When applying the pencil to the paper, we do not use the little bone handle shown in both A and B, as connected with the shank which holds the stand of the parallel motion, which brings up against the stop shown between the cylinder of the indicator and the paper barrel in both Figures. A little care right here will save a great deal of trouble, inaccuracy and uncertainty. The end of the pencil lever is split, forming a shank which springs down upon the lead; after the lead (leads are furnished already made) is pushed into this spring shank and through it a little distance, having been carefully sharpened, then adjust this bone handle by means of the screw and the stop, so that the end of the pencil shall not strike against the paper; but when we wish to take a diagram, having put the paper on the paper cylinder, turn on steam, then with the thumb and forefinger grasp this bone handle firmly, hold it against the stop, screw it until you feel the action of the pencil on the paper, screw it up again so that the pencil leaves the paper, and if you do it delicately, you will get the finest possible diagram without any danger of injuring or cramping the instrument. Another thing which should always be done: get the diagram as nearly as possible in the center of the paper and lead off the cord from the pulleys shown, as nearly level and at right angles as possible. Don't turn them around. A great deal of distortion comes from not paying attention to the hints embodied in the previous clause; sometimes parties who cannot afford to be delicate in their manipulation of the indicator, bend the lever by jamming the lead against the paper and springing it perhaps an eighth of an inch or more. That is sure to distort some of the lines and if the pencil lever or the radial bar is sprung, then the instrument must go back for careful overhauling and repair. The radial bar and lever, although made of drop-forged steel, are very small, and while they are strong, they will not do with rough usage, and yet they will withstand an amount of abuse that one might wonder at, after having examined them.

HOW AND WHERE TO ATTACH THE INDICATOR.

There is always a clearance in any engine we have ever yet seen. This is a space between the piston, when it is at the extreme range of stroke, and the cylinder head; this is variously estimated and in different engines varies materially in proportion of percentage to the whole volume of the cylinder. Wherever the indicator is attached there must be a clear way into the clearance, so that the piston shall not shut it off, even partially, when at the extent of its stroke. The usual connection is a half-inch gas pipe or steam pipe, and if this is carried out, it is quite large enough; whenever the engine is indicated, make sure, among other things, at the very outset by "turning her over" that no part of the piston travels over the connection into the clearance; if so, one of two things must be done, either drill another hole—and this is not always practicable—or take a chisel with point so that you can break off the inside, and give fully the area of a half-inch pipe without any possibility of obstruction or reduction. Always endeavor when tapping an engine to tap it so as to use the pantograph, remembering that the pantograph can be used vertically, so as to make your connections on the top of the cylinder sometimes, or horizontally so as to make them on the side. It is best to make these connections between the ports rather than opposite them, but sometimes there is no choice. Whenever these openings are made, take particular care that the inside end is clear, either with the chisel or rimmer, else you have a factor of uncertainty. It is a frequent practice with many builders of the very late years, to furnish what is called a side-pipe and three-way cock with each engine. The whole thing is to be condemned, unless an approximation is wanted for the load, for the position of the valves, etc., and if our readers will turn to Lessons LVI, and LVII, Figs. 116 and 117, they will have a chance to see the position of the valves as shown by the three-way cock and side-pipe in one case, and the short connections in the other case, nothing having been moved, so far as the valves, eccentrics, etc., were concerned. On marine engines it is very fashionable (for we know no other reason for it) to take an inch and a quarter, or inch and a half pipe, lead it from the clearance at either end to the most convenient part of the cylinder, back of the side-pipes, and there put in the three-way cock. We have seen and used this upon condensing engines with 12 and 14 feet stroke, and in one case where the steam line figured 3⅜ inches of the length, by the proportion of stroke on the diagram, the engineer had the curiosity as well as good sense to strip his side-pipe; two days afterwards we applied the indicator with short connections showing that the valves were open at the very commencement of the stroke and the steam line did not vary one-half of one inch when the short or proper connection was made, yet in traveling several feet it showed late, for the paper barrel started when the piston started, but the steam traveled from the clearance through the various angles and ports of the cock into the indicator with whatever little condensation took place on the way, so that the motion was distorted 3⅜ inches from the truth; this makes a difference in the pressure of steam as well, so that it may be laid down as a rule, to avoid three-way connections if the real position of the valves is of any consequence, or if the actual condition of the valves is to be learned from the diagrams. Several instances of side-pipes are shown in this volume, some of these would be very dangerous if the valves were adjusted to bring the steam lines up at right angles to the atmospheric line and still use the side-pipe. It would be apt to result in something quite similar in effect to that shown in Lesson LXIX, Fig. 135.

It is sometimes impossible to use the short connection, but wherever it can be done, it is decidedly better to do it, if accuracy is any sort of a condition towards which you are aiming for results. Avoid elbows and valves in feed-pipes and exhaust-pipes as much as possible, always remembering one of the fundamental laws of all engineering, viz.: that the shortest possible distance from any given point to another is a straight line, so remember that in handling steam the utmost economy attainable wherever steam is conveyed through pipes, is invariably accomplished by taking the steam as direct as possible and avoiding every impediment or obstruction, such as is offered by globe valves, reducing valves, throttle-valves, elbows, crosses, T's, or other angles, through which steam must pass in order to reach the piston head. Anything which interrupts the flow of steam causes friction, loss of pressure; and in every case where the pressure of steam is reduced, its volume is increased and it takes the first step towards the conversion from steam into water again.

A POINT AS TO HOW TO MAKE THE LEAD DO GOOD WORK.

It is much better to sharpen the lead before being put into the spring shank in the end of the lever, by means either of a scythe-stone or dry oilstone, or if nothing better is at hand take a fine file. A point which is rubbed up in this way, and made smooth and clean, will last much longer, make a cleaner mark and be much better than one which is whittled or coarsely done. The best way is always the easiest, the surest and the cheapest, all things taken into account. There is no necessity for running over a large number of times. This much for the manipulation of the instrument.

Having attached the indicator to the side pipes, which must in all cases be blown out thoroughly and completely before applying the indicator, be careful not to employ joints with red lead or white lead or any other material which can possibly interfere with the action of the piston; then adjust the indicator to the top of the cocks, screw down the variable screw, having first put the indicator as nearly in line with the motion as is possible, make sure that all is fast and then let the steam on to the instrument gently, warm it up, allow all the water to get out so far as possible. While the instrument is working put a drop or two of porpoise oil on to the top of the piston as it comes through the cover of the case; repeat this occasionally. Now, try the motion with the pantograph, pendulum or whatever else may be used, and carefully adjust it for the stop. The paper cylinder must not, on any account, touch either end of the travel against the stop, even so slightly as not to be noticeable, for it will distort some line of the diagram as sure as it does. Having balanced the instrument, as we term it, you are now ready to go ahead. In taking a diagram, don't work with dirty hands; you are sure to dirty the instrument, and the diagrams look as though they had been in the hands of a careless man. Putting the paper about the cylinder is a little knack in itself. The paper should go down square, fit as close as a glove, and be just as clean as though it had never been touched; a little practice is required. Having accomplished all this, let the steam in; don't take the diagram until after the instrument is heated. Take the diagram first as per previous directions, shut off the steam, being careful not to allow any steam to blow through the three-way cock, and the moment this is closed tightly then take the atmospheric line while all parts of the instrument are warm. If the atmospheric line is taken before the instrument is thoroughly warmed up, it will be incorrect; if it is taken after contraction has taken place by cooling off, even some time after the diagram, it will then be incorrect. Take the diagram first, the atmospheric line afterwards; then, having noted the steam pressure, knowing the dimensions of the engine in diameter and stroke, and number of strokes or revolutions, put all this data carefully upon the proper place in the card; be sure and add to it the scale and any memoranda which are necessary, and you will have progressed systematically; and if you have followed the directions given for handling the pencil, you will have produced a beautifully-drawn diagram, which will give you the correct working of the steam, the position of everything and its relation to the economical, or otherwise, handling of the steam.

THE STEAM WHICH A SPRING WILL TAKE.

The American Steam Gauge Company give their rule as: Multiply the scale of the spring by $2\frac{1}{2}$ and subtract 15; the result will be pounds of steam pressure from the vacuum line that the spring will take accurately; as, for instance, $30 \times 2\frac{1}{2} = 75 - 15 = 60$. We think this might be changed with benefit, for it is not always necessary to provide for the 15 pounds vacuum, and it is desirable always to make the indicator diagram as large as can be. For this purpose we adopted some years since the practice of having a set of washers made, which would slip on to the sleeve under the cover on top of the indicator piston cylinder, or upon the shank of the piston itself at the bottom, and these washers vary in thickness from $\frac{1}{32}$ of an inch to $\frac{1}{8}$ of an inch. By these means we can take 75 pounds of steam with a 30 spring by first blocking down the pencil lever; instead of standing, as shown in Fig. A, it will stand nearer the bottom of the paper cylinder when at rest. There are two things to be guarded against: never under any circumstances undertake to indicate a pressure of steam which shall be beyond the capacity of the spring; for in the one case you will bring up solid, and in the other case, at the top, you will throw the pencil lever out of a parallel line by passing beyond its capacity, and get something which may appear to you like Fig. 135 in this volume. It will distort the lines and not do the instrument any good.

The best oil that we can obtain is pure porpoise jaw oil; ordinary mineral, animal or vegetable oils are affected more or less, and the porpoise oil, which is worth a good many dollars a quart, only requires a very small amount if you use it carefully; this should be used on all parts of the indicator.

Before we leave the subject of springs, it may be proper to state that the softest spring which can be used, and keep within the limits of its capacity, is the spring in every instance that you should use. The practice is becoming quite common among parties in this country of using 50 and 60 springs, and in other places of using a small diagram, the smaller the better. In every case keep clear of this kind of practice. The larger the diagram, the more the faults of the instrument are shown, if there are any, and the more the faults of the engine builder, if he has been careless in his construction. The only case where we advocate the small diagram is with engines running above 300 or 350 revolutions. This will be referred to later. The smaller the diagram, the less real reliance is to be placed upon it, and the cause of this will be found in some of the lessons on high speed, where different diagrams are referred to, and the real reason why the larger scales should be always used will be found with a little reasoning.

CHANGING THE SPRING.

It is frequently necessary while working upon an engine, for some reason or other to change the spring with varying pressure, speed, or some other requirement. There is no reason why this cannot be done in about one minute, providing you have the spring where it is wanted, and understand your work and are careful about it, and there is no instrument we have ever seen that begins to compare with the Thompson for accessibility. Having decided, you must change the spring, commence with the connection of the top of the piston with the pencil lever, taking out the little milled-head screw, then release the pencil bar from the piston, taking notice that the ears on the piston connection have a screw-thread in one and a clear hole in the other side; having separated these, then unscrew the cover to the piston casing, lift the whole thing off, piston, spring, cover, pencil lever, etc. Be careful never to drop the piston upon a gritty floor, rather take it in your handkerchief o some other clean cloth; now unscrew the piston from the under side of the cover, the spring from the lower end of the piston, put on the other spring, screw it on to the shank on the upper side of the piston, put it through the casing, screw the shank of the cover into the top of the spring; now put the top of the connecting rod so that the pencil lever will easily drop between the two ears, adjust the screw which passes through one ear, then through the pencil bar, and screw into the other ear on the top of the connection rod; screw the cover into the casing, after having put a drop of oil on the piston, and see that it works easily back into the casing, and that the piston drops easily into the cylinder and the cover goes down into the casing all easy together, and that the pencil lever, parallel bar and radial lever are all easy and none of them are sprung, having previously taken care that the connections are all blown out, so that no dirt can be blown into the indicator from any of the connections. This can all be done in less time than it has been written in. You are now ready to go ahead.

GENERAL HINTS.

Sometimes, in taking the indicator off from the steam connection, it may receive a jar in such a way that the stand which connects the piston barrel and the paper barrel together may be sprung. We have sometimes found this to be done. There is no necessity for it; it should never occur. If it occurs, and you are out of reach of help, you may take the thing in your own hands; but never take a diagram unless your pencil bar describes an absolute right angle line to the atmospheric, and then it is a good plan when this occurs to send it back to the shop to be put into the jig and examined. It may have a crosswise spring, and except a diagram is accurate it is valueless.

The Thompson Improved Indicator succeeds the Richards' Indicator, which has worked a revolution in engine building. When speed and other matters of importance came up, Mr. J. W. Thompson patented the parallel motion, not shown, for it has now practically been discarded, and has been displaced by the Improved Thompson, shown in Fig. A. This instrument is manufactured solely in the United States by the American Steam Gauge Company, Boston.

We call the attention of the reader to Fig. C, which is not all that we wish it were. It is the Thompson Improved Indicator, with the detent motion attached, by which the paper cylinder may be caught and held while the paper is changed without unhooking the cord. This is extremely simple; it does not interfere with any other part of the instrument. It is perfectly satisfactory in its working, and for people who are not accustomed to high speeds or to close quarters, it is a very great advantage. For our own individual use we would not have it, for we prefer to feel of the attachment to the motion every time we hook and unhook, and do not care what the speed is as long as it is below 700; but there are so many men who only take diagrams occasionally, and are not up in the little knacks of an extensive practice, that this detent motion will be a very great accommodation to them, and without doubt will make their indicators work better and last longer. It is so arranged as to be completely under the control of the operator, and it can be instantly disconnected if desired. The change is accomplished by simply sliding out or in the little knob seen on the back of the steam chest (shown in Fig. C), which engages with a tooth in the paper cylinder barrel wheel seen at the right.

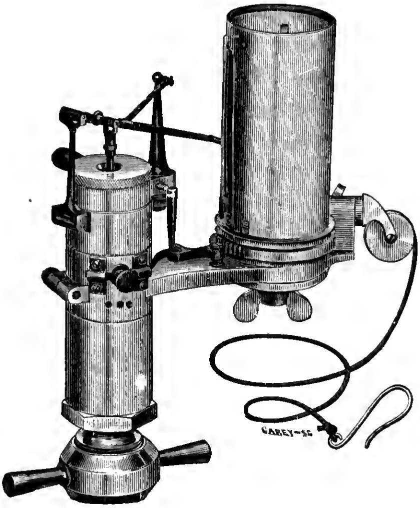


FIG. C.

GIVING THE MOTION.

Leaving Figs. A and C, a peculiar device is seen, for the lack of which there has been much trouble in times past. Fig. D shows an improved method of taking the motion off the paper barrel. A represents the wheel, which is also shown in dotted lines in a different position; B represents a stand holding the wheel over which the cord passes; and the end of the stand is a sleeve running into the solid stand shown, the whole thing being bored through; and the flat

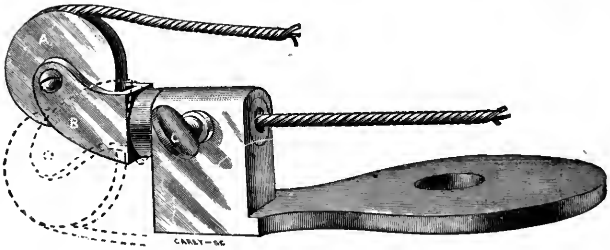


FIG. D.

part shown at the right is secured against the bottom of the stand by means of a thumb-nut at the lower end of A, B, C. The sleeve which extends into this stand has in its center a groove into which the flat-headed thumb-screw, C, enters, holding it in any position, to the right or the left, up or down, giving it the full swing of the whole circle, and in this way the motion can be taken from any point, at almost any angle that it is possible in the whole 360°, either horizontally or vertically. It is one of the improvements made by the Steam Gauge Company within the last two years, and is the subject of separate patents. Wherever the old plan of wheels is in use on the old Thompson or the Improved Thompson, this can be substituted if required. All instruments now made are made with the device shown in Fig. D, and this device, as simple as it is, makes it possible to use the instrument in many places where special motions had to be arranged by the old method.

We now come to the

METHOD OF ATTACHING THE INDICATOR, OR OF MAKING UP THE REDUCING MOTION.

There is probably no one device which has been used so much as the old pendulum, and there is no device which is so generally incorrect or so much misapplied. These pendulums have various faults, and the usurs of them have many vagaries. We recently saw in a large engine-room a pendulum attached to a piece of iron, leading from one girder to another in a fire-proof arched floor, and it is no exaggeration to say that the top of the pendulum chattered from an eighth to a quarter of an inch sidewise, while the strap which passed from one girder to the other jumped up and down as much more, making a most peculiar motion. The string was then taken off at an angle of 10° or 15°, brushing by the side of the steam-pipe, and was deflected from the straight line between the carrier pulley above and the indicator pulley below more than one inch. It was perfectly useless to attempt to show the party using it that he had errors multiplied by each other into an outrageous accumulation, and that his diagram was worse than worthless for any purpose whatever. The pendulum can be used. It must be firmly fixed at the top, it must be strong enough in its cross section not to spring either edge-wise or flat-wise; the bottom of the pendulum must in every case start from the actual center of motion, it must travel precisely as far one side of this center of motion as the other and not an iota farther one side than the other; in other words, it must be exact. If these simple precautions are heeded, then the pendulum becomes endurable, but in taking off the cord it must not be taken from a point near the top at an angle anywhere from 1° to 120°, down to the indicator direct on the cylinder. It must be taken at right angles to the central line of the pendulum when at rest, to a point over the indicator, and if only one instrument is to be used, the carrier pulley may be placed on a line plumb over the center of the cylinder, so that the cord leaving the pendulum shall leave it at right angles absolutely when it hangs plumb, and passing over the pulley, there is no necessity then for continuing this exactness.

for a little to the right or left of plumb in that case does not distort the motion; but if the first portion is not at right angles, then we get distortion of the worst kind. The pendulum may be inverted by the same precautions, as it is sometimes impossible to get a pantograph between the cross-head and the side of the wall; or we have, in some cases where we could not use either on account of too much distance at one end and too little at the other, laid a pendulum on its side; most men would not take pains with this and we do not therefore advise it.

Instead of the old means of attaching, Fig. E shows what is known as Bacon's Improvement, being a combination patented by our old friend F. W. Bacon, made by the American Steam Gauge Company, consisting of five pieces; the jointed links at the right are intended that the longer parts should be put under the check-nut of the oil cup to which it may be attached on the cross-head; the shorter parts turn over each other according as the longer parts may be farther apart or nearer together, until the holes match, through which the screw-thread shank, shown at the top with a hole through it, may be used for the pantograph, or the screw-thread at the bottom may pass through this hole and be used in the pendulum, as is shown in Fig. F. There are a great many ways of attaching this to different engines which will be followed up. Fig. E shows the parts in detail, Fig. F shows them attached to a pendulum, Fig. G shows the top of a post, pantograph, and the Bacon attachment connected to a vertical cross-head, although the cross-head is not shown, it simply shows the method of attachment. Fig. H shows the pantograph attached to a vertical cross-head and the pieces are attached to the shoe at the bottom by simply raising up the nut which holds the slide in, and then gripping them by screwing down upon them again. In both of these methods of attaching the pantograph, bear in mind the rule with reference to the pantograph. The post on the outside must be set at exactly right angles to the center of motion when at rest; in other words the pantograph must travel precisely as far one side as the other of the center of motion, and not as we have sometimes seen it, forming the hypothenuse of a right angled triangle, working all the distance one way. Fig. I shows another method of connection to the Corliss cross-head, to which all the same rules apply. Fig. J shows the pantograph and the Bacon attachment connected to a horizontal cross-head.

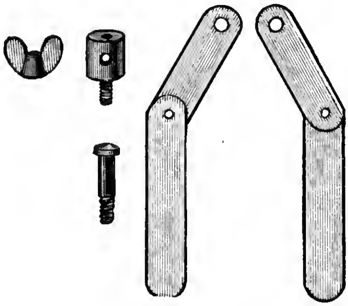


FIG. E.


FIG. F.

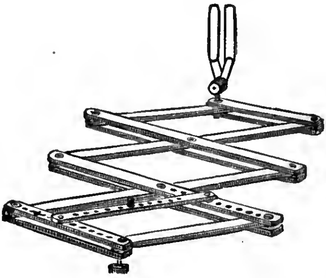


FIG. G.

RULE FOR THE PANTOGRAPH.

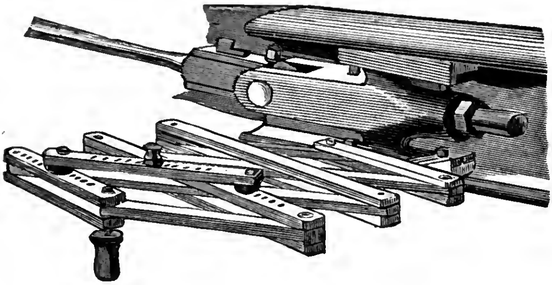


FIG. H.

In all these attachments of the pantograph, whether horizontal or vertical (and the pantograph can be used as well vertically as horizontally, if a little care be used in attaching it, being the simplest and the most correct of all the motions known), let the pantograph be attached as shown in Fig. J, whether it be the center of the cross-head or one end of the cross-head is entirely immaterial, but let that point at which it is attached be invariably the exact center of motion. Set the out-post square with the center of motion, and in no other place or position. Now, as the stroke of the engine varies it is necessary to get more or less motion, which can be done by moving the peg-post or peg arm out or in on this line, which has been drawn squarely across with the center of motion. Let the line from the peg-post to the indicator be at a right angle to the center of motion, or in other words, let the line which connects the peg-post of the pantograph with the paper drum of the instrument, be as nearly parallel with the piston rod as it is possible to get it. If these two simple rules are observed, any engineer can obtain a diagram which is mechanically, geometrically, and mathematically as correct as any other man on earth can do it. We have frequently said before different audiences, written it over and over again: the indicator diagram, the valve motion, the pantograph or the pendulum, are only and simply a combination of right angles. If everything is done exactly on the square, everything else will be exactly right, whether you are working for the position of valves, use of steam or anything else; the indicator diagram in this case with these two simple rules observed, will be a positive quantity, perfectly reliable, and if these two rules are not observed, it is as perfectly and as completely worthless as it is possible to be.

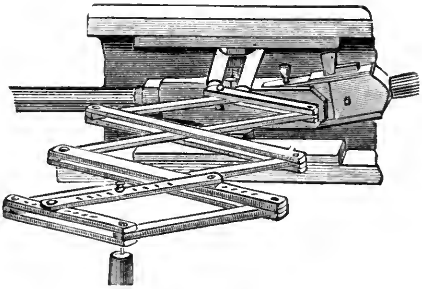


FIG. I.

Fig. K represents the pantograph more in detail, with letters of reference. This simple arrangement, like so many other things, we are indebted to George H. Corliss for. It has a great variety of names; it has been called "lazy tongs," "long legs," "pantograph;" it was originally called and we believe Mr. Corliss himself terms it his "drum motion." It consists of nothing more or less than a system of levers; these levers must be absolutely of the same length, those shown at A being double and those at B being single. These are pivoted by means of hollow pivots and washers which are bushed. The hitch strip is shown at G and the stud-pin or hitch-pole F. When the pantograph is properly arranged the stud-pin F is in the line between C and D, which are the two ends of the pantograph, one being the dead end D, which is fastened to the post, while C is the live end or attached to the cross-head of the engine. The point C attaches, where Fig. E is used, to the two links connected together, so that the pin at the end, C, readily drops through them. If the links have to be used so that they stand vertically, then the little screw-head, shown in Fig. E, is attached by means of the thumb- nut and the taper end at C drops into this screw-head, turning a vertical into a horizontal bearing, the least variation in the location of the pivot-holes in the "lazy tongs" or pantograph will be met by an absolute refusal to work at all, and we have no doubt that some of our engineers or mechanics who have attempted to make a pair of "lazy tongs," have had lots of fun out of it, and nobody else been any the wiser; whether they enjoyed the fun or not, we do not know. Correctly made, the pantograph is complete, but with the slightest variation from correct, it is like the diagram from a distorted motion, absolutely incorrect and worthless.

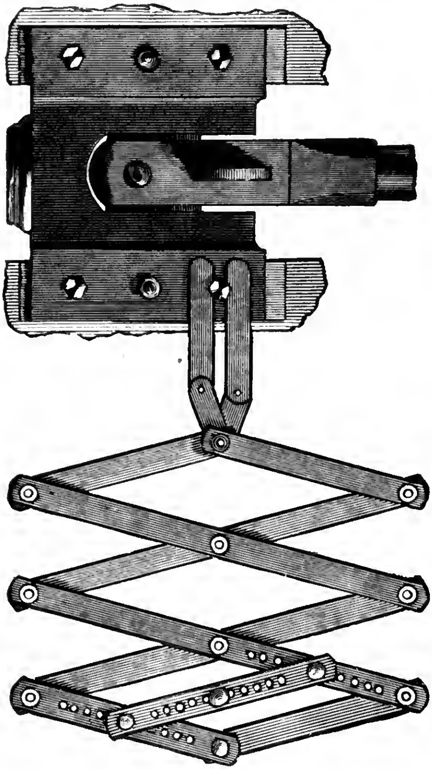


FIG. J.

In applying the pantograph, let the end C drop into any point on the cross-head to which you can attach, or any one of many ways which will readily suggest themselves to the mechanical engineer. The end D may drop into the top of the post, or we frequently build ourselves a little stand of inch boards, four inches wide, braced, and then get two or three hundred pounds of old iron or anything else which is heavy, and when

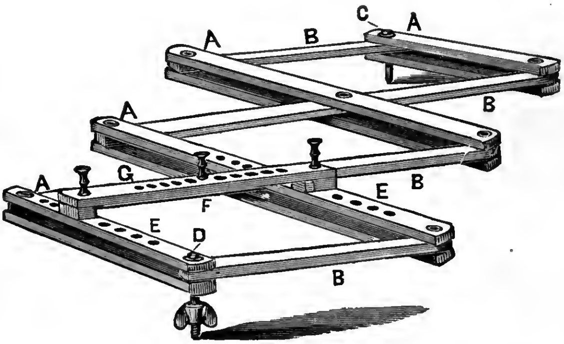


FIG. K.

we get it in line, weight it down, square it, have the points C and D exactly level so there will be no weave or strain, or cross motion which will vitiate the correctness of your diagram. The line from C to D must invariably be at right angles to the line of motion of the cross-head, and absolutely in the center of motion; then shove your post at D out or in to get more or less motion; put the stake-pin F wherever you want it, and set this peg F so that the line from that to the indicator shall be parallel to the piston or parallel to the line of motion of the cross-head. If you cannot do this, or if from any cause it is necessary to have the peg-pin, hitch-pin or stake-pin, F, further away from the cylinder than the indicator connections are, immediately set up a second little stand, and take the cord from the peg F parallel to the motion of the piston and around the guide pulley to the indicator. Whenever the pantograph is properly put up, every point on a line from C to D is a positively true motion, parallel with the guides, varying from nothing at D to length of the stroke at C. Wherever engineers wish to use one motion for several engines there is nothing better than a piece of gas-pipe, ground off, with an attachment which may be fastened with a set-screw to slide up or down to fit different engines; to this attachment may be fastened a socket to catch the D end of the pantograph while the other catches into the cross-head. By means of a T on the top of the piece of pipe, which has a flange at the bottom for screwing to the floor, are connected two side pipes standing at a right angle to act as braces; this can be attached to any engine or flange, screwed down, the braces squared and screwed down, the piece that slides up or down put at the proper level, the pantograph hooked on and you are all ready to go ahead.

SLIDING LOOP.

There are all sorts of hooks, slips, knots, and other matters used for connection; until within the last few months we have invariably used the old-fashioned, flat, sliding loop, which is about as nearly worthless as anything can be. While doing some work for one of the lines of steamers, our attention was called to a crude idea by the chief-engineer of one of the ships which we have put into shape, and is shown at Fig. L. This is so clearly shown that no description is necessary; it is a piece of brass tube, spun over at the end, finished, holes bored through it and finished, and it is the only thing in the way of a sliding loop we have ever seen yet that was worth talking about or using. The American Steam Gauge Company make them, there is no patent on them, and any one has the right to make them. We prefer always to use a plain hook on the end of the indicator cord, which is attached to the paper barrels, having means of adjusting by use of this sliding loop from large to small or long to short, using as little cord as possible, more especially on a high-speed engine. We prefer this adjustment to anything we have ever seen, for where we are working with water steam,

FIG. L.

more or less heat, oil, or any of the other accompaniments, no cord will retain its position for any great length of time by any device we have ever used, until we adopted Fig. L, and some method of ready adjustment is necessary. We have previously referred to the adjustment of the paper barrel by means of the cord, and now having proceeded to obtain the diagram, if the directions have been followed, we are ready to commence the computation of the diagrams.

THE DIFFERENT METHODS OF COMPUTING THE INDICATOR DIAGRAM.

The indicator Diagram, having been taken, should bear on it memoranda taken with each and every diagram when it comes from the indicator, wherever the work may be performed; this data should bear upon each diagram, or each pair, the diameter of the cylinder, the length of stroke, the revolutions per minute and the scale of spring with which it is taken, for these are the most important elements and without them the diagram cannot be correctly worked. Wherever it is possible to ascertain the percentage, the clearance should also be noticed. Many engineers of late have accustomed themselves to ascertaining the clearance of their engine so as to know precisely what the amount is. It is also a good plan to carefully note the pressure of steam in the boiler by the gauge, and also to notice whether this gauge shall be located above or below the line of the cylinder, and whether there is hanging on the gauge a column of water in the siphon several feet in length, or in the vacuum gauge, how or where it is connected, for we frequently find very radical differences between the pressure in the cylinder and the pressure as shown by the gauge. All these items of data are particularly necessary, for if they are clearly expressed, we may then judge pretty well of various peculiar points which so frequently occur on the diagram, and having the data at hand, we can in every case base our judgment upon fact, and know how a certain falling off or back pressure or any peculiarities of steam or exhaust will be explained by comparison of the data with the fact.

WORKING UP THE DIAGRAM.

If the motion has been properly attached to reduce the stroke of the engine, we shall have an accurate card, and without it is accurate, it is not only valueless but a waste of time. Endeavor by all means to keep the card clean and to avoid the possibility of any mistakes. The general unit called for is the horse-power of a diagram; the unit of horse-power is 33,000 pounds lifted one foot high in one minute. For this reason we use the length of the stroke, the revolutions per minute and the mean pressure of the diagram, and then by computation, obtain the horse-power. Having our diagram before us we proceed to work it up, and the working up simply obtains the mean pressure from an irregular form. There are several ways of working up an indicator diagram; the one most generally in use, up to five years ago, was dividing the diagram into ten ordinates or lines at right angles with the atmospheric line, and at equal distances from each other, and then measuring by the same scale with which the diagram was taken, the pounds of pressure upon each one of these ordinates, which was exerted on the piston, then dividing the aggregate by the number of amounts, giving the average or mean pressure. But this was crude, it did not take into account little differences which exist, and while not very far from correct, it was far enough to make a very considerable difference as between the correct computation and the one practiced; hence, this has been discarded for general use.

Another way, which is virtually the same thing, was to take a narrow strip of paper, perhaps one-eighth or one-quarter of an inch wide, and marking the steam pressure on the first ordinate from the end of the paper laid on the atmospheric line or line of back pressure, then put the first mark on the atmospheric line or line of back pressure of the second ordinate, and mark the top of the second ordinate by another short mark of the lead pencil; in this way we are simply adding them together. When all the ordinates have been measured (measure them in inches), multiply by the scale of the spring as 20, 30, 40, and divide by the total number of ordinates measured, and you have the mean pressure. But this has virtually the same inaccuracies as the first method of measuring.

There is still another way by which many diagrams have been measured, and that is a sort of general average; taking a piece of glass with a straight edge, it is placed below the steam line and above the lower part of the expansion line, until the two quantities apparently balance each other and a line drawn across the length of the diagram; its height found, multiply by the scale, this gives the mean pressure. But this, too, has been discarded and for the last few years the planimeter has been used, and is the only correct way to work up any diagram; the fact that it is named planimeter is another way of expressing the fact that it is for measuring plane surfaces without regard to how irregular their form may be.

Fig. M shows a modification of the Amsler Polar Planimeter, as made by the American Steam Gauge Company, Boston. Other forms of the instrument may be bought if desired. The proper use of the planimeter will reduce any irregular surface to a parallelogram or square by observing its reading carefully, measuring by means of the pointer, and then reading from the index wheel and vernier and obtaining the value as indicated by simply adding or subtracting. The point at the left is a needle point, which should simply be set into the paper on which it is used, and it is better to use a medium, rough, brown paper or blotting paper, something which is not calender finished on the surface, than to use a smoother paper. Having fastened the card, as shown in the cut, by a couple of pins or tacks, commence at any point you choose, simply making a mark with the point of a pencil; traverse the point, shown at the right, over the line of the diagram in the direction of the hands of a watch, or from right to left on the line which is

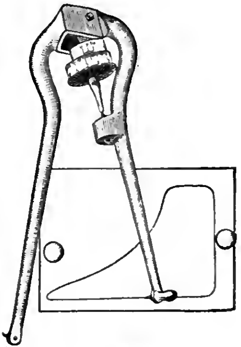


FIG. M.

shown. Having pinned the diagram down on the paper (which, by the way, should be upon a smooth board or surface), next adjust the planimeter so that the index wheel, which is graduated about its entire circumference, shall not meet with any obstacle in its course, or anything to interfere with a perfectly free motion. Now obtain the reading. There are a series of figures about the circumference of the index wheel, from one to zero, making ten lines; each one of these divisions has ten subdivisions, while the vernier, shown at the left of the index wheel, has eleven divisions in exactly the same distance that the large wheel has ten, so that wherever the index wheel stops one division on the vernier will be bound to correspond with a division on the index wheel. We will suppose we start our reading and that the figure 3 is past the zero on the vernier; we then count that 6 above 3 is a trifle below zero on the vernier. We now cross over on to the vernier and find that 3 on the vernier exactly coincides with a division on the wheel. This makes our reading 363. We now travel the index point at the right, around the diagram, until we stop at the same point from which we started. We now find that 5 has passed below zero on the vernier, and that the third line above 5 has also passed; then running up the vernier, we find that 8 stands exactly coincident with a line on the index wheel. We have our reading then 538; subtract the first reading from this, the result is 175. Now repeat the operation two or three times until you get three readings, which may be 175, 176, 174; they will vary exceedingly little if you pay careful attention to following the lines. The average of these three readings is 175, which is correct. There is no necessity, although it sometimes saves trouble with a beginner, or doubter, to place the zero on the wheel against the zero of the vernier in starting. If this precaution is considered necessary, a few trials, without commencing every time at zero, will convince any one that it is entirely unnecessary. We first read from the index wheel the figure which has passed the zero on the vernier; this we will call hundreds. Then count the lines up until you find which one has passed zero between that and the next figure; this is tens. Then follow the vernier until a line is found which precisely coincides with a line on the wheel; this is units. The instrument is exceedingly simple, and there can be no mistake whatever if care is given, for the reading is just like that of a clock or watch—may be taken at any point through the day without figuring from twelve o'clock or six o'clock. This gives you the area of the figure in square inches or in fractions of a square inch. In case you read so that zero on the wheel completes the circuit and passes zero on the vernier, you must then prefix 1 to the hightest number previously read. If in the case we have just cited we are working on hundreds, your first reading should be 175, the second 350, and so on until zero passes; you would then prefix 1, which would make it thousands instead of hundreds, and if it passes again it becomes two thousands instead of one. A little practice with the instrument will familiarize any one, and a little pains taken to familiarize yourself with the reading will shortly put you in possession of the key to it, all which is so plain that no mistake need occur. The instrument will work precisely as well backward, but unless care is taken, and you should obtain a diagram which had a compression loop at the top and an expansion loop at the bottom, you might get a negative result which would be incorrect. So, until you are familiar with it, always work it like the hands of a watch or as shown in the cut, from right to left, following the diagram around in the same direction; there will then be no possibility of trouble. The planimeter does not make any allowance, but if the work is correctly done you have at once a correct result from the outline, and by the use of the planimeter the different areas of the diagram may be separately measured with perfect exactness, so as to ascertain the value of the vacuum apart from the steam, or the high pressure and low pressure cylinders of the compound can be very accurately measured, without any regard as to whether they are all taken on the same scale or not.

Another point which is frequently one of great interest, is to measure the difference between the power in the condenser, taking the vacuum gauge, and the result as given by the indicator in the condenser. The line can be drawn to show what would be the result in case the pressure—as shown by the vacuum gauge—was realized in the cylinder; so you may get the actual as compared with the gauge result, and in this way make comparisons showing the absolute value of any factor which is contained in the diagram.

TO ASCERTAIN THE POWER FROM THE PLANIMETER READING.

Many of the diagrams illustrated in this work have lines at the steam end, and release end, which are erected at right angles to the atmospheric line and line of vacuum. The length of the diagram, without any regard to its form, whether there be a heavy compression loop on the steam end, or an expansion loop on the other, or any imperfection in release or exhaust,—the length of the diagram is the extreme distance from the very ends, and if a little attention is paid to the way these lines are erected, there will be no necessity for any difficulty in getting at the exact area; for, wherever a compression or expansion loop is contained in the diagram, start at any certain point and follow the diagram line as the indicator made it, and the loops, which are resistance, will be taken out of the area by the instrument without any further care on the part of the manipulator.

Having accomplished the measurement of the area, we now desire to compute the power. In order to save a great many figures it is better to compute a constant for each pound of mean pressure (even if at different speeds) instead of having to do this with every diagram which is worked up. This is produced as follows: Take the area of the piston in square inches, multiply this by the number of feet traveled each minute, and divide this result by 33,000; the result will be the constant which shows how many horse-powers, or what fraction of a horse-power, is yielded by every pound of mean pressure on the diagram. Having the area of the diagram in square inches or fractions of an inch, divide the area by the length in inches or fractions of an inch (farther on in this work will be found a table of fractions of an inch, decimally expressed, for convenient reference),—the area divided by the length of the diagram gives a result which may be a decimal or otherwise. This is to be multiplied by the scale of the spring for the mean pressure; then the mean pressure multiplied by the constant (directions for which are given above) gives us at once the horse-power, and in the simplest possible way.

If we have, for instance, a diagram measuring 450, which is equal to 4.50 square inches, and which is $2\frac{7}{16}$ inches in length, see the table and find that $\frac{7}{16}$ equals .4375 inch. Now, the area 4.50, divided by 2.4375, equals 1.846, which means that a parallelogram 1.846 inch in height would be exactly equal to the irregular figure which has been described by the indicator. If we have been working with a 30 scale we have only to multiply this 1.846 inch by the scale 30, which equals 55.380 pounds of mean pressure; multiply this by the constant or number of horse-powers which every pound of mean pressure gives, and you have then the horse-power of the diagram.

It is frequently a matter of satisfaction to the beginner, in the use of the planimeter, to have something with which to test. This can be very easily arranged by drawing a circle with a pair of pen dividers, one inch in diameter, or any other sized circle that may be desired (we mention the circle because it is more easily drawn correctly, as a general thing). Having this, measure it by the planimeter and then see if its reading agrees with the table of areas. This will always give you a test gauge.

DIFFERENT FACTORS IN THE DIAGRAM.

It is frequently necessary to ascertain the amount of back pressure in horse-power, which can be done if the atmospheric line is perfectly taken and the diagram is also correct. The amount of vacuum in comparison with the amount of steam worked, or the loss in vacuum—all of these are interesting features; while if the reader will familiarize himself with the theoretical curve, as applied to any diagram shown in the lessons further on in the work, he can then see what amount of steam, properly handled, would have done the same or more work, perhaps, than is shown by the diagram from which he is working. The planimeter is invaluable for all this. To get the percentage of the condenser work, as approximating the theoretical, erect the absolute vacuum line, and then measure the exact amount of vacuum as shown by the indicator, and it is very easy to immediately convert the actual into a percentage of the theoretical, taking the theoretical vacuum at 14.7 pounds. Comparison of realized pressure with boiler pressure is frequently an interesting matter. Erect the line of boiler pressure, from which you can carry all computation, so as to get at the actual and the theoretical. The planimeter measures these irregular forms with absolute correctness, if the operator works with care in tracing the lines, and in a fraction of the time that would be necessary by any other method.

NECESSITY OF RELIABLE DATA.

There is frequently a great deal of ambiguity about information obtained from people in charge of different engines. Wherever a man is sent to work with an indicator, there is only one correct way: Pull off the cylinder head, measure the cylinders and the volume of clearance, and make everything as near correct as possible, for very slight differences are frequently fatal to the report on the case, and carelessness is entirely inexcusable, guess-work or assumption very much more so, and we have seen old and intelligent engineers thrown out of court very abruptly, because of some radical error, even though trifling in extent, shown in their report, where they had, to save themselves a few hours' hard work, assumed that because one part was one size, the other was the other, or some other equally trifling matter which was more than vital to the case. While some more careful man had shown in details that such difference existed, and by that means had thrown doubt on the whole of the work of the careless man. Correctness in every possible way is an element of value, and a lack of care or thoroughness makes an indicator diagram absolutely worthless.

LESSON I.

BACON'S METHOD OF LAYING OUT THE THEORETICAL CURVE BY ORDINATES.

Fig. 6 was drawn by Mr. Bacon to illustrate a simple and correct method of delineating the theoretical curve of expansion, which we shall take, as it is properly lettered, upon which to commence our lessons in the general uses of the different lines, and this will be frequently referred to; it will therefore be well for the beginner to familiarize himself with reference to this particular figure. For the time being we shall confine ourselves to the outlines bounded by the letters A, B, C, D, E. The line A E represents the true vacuum line; the line A B the admission line; B C the steam line; C D the line of expansion; D E A the exhaust line, and as this engraving is made, it represents exhaust and vacuum lines, while the line between D and E running the whole length of the figure and seen above A, between A and B, is the atmospheric line of the instrument or of a high pressure engine These, in brief, are the various lines of any high or low pressure engine. No matter what form the diagram may take, whether it be a finely proportioned one or one that may be full of errors, these lines, in some relative proportion, all exist in every Indicator diagram. The admission line in this case is very nearly perfect,— in fact, too nearly perfect,—and it would not be advisable in changing the

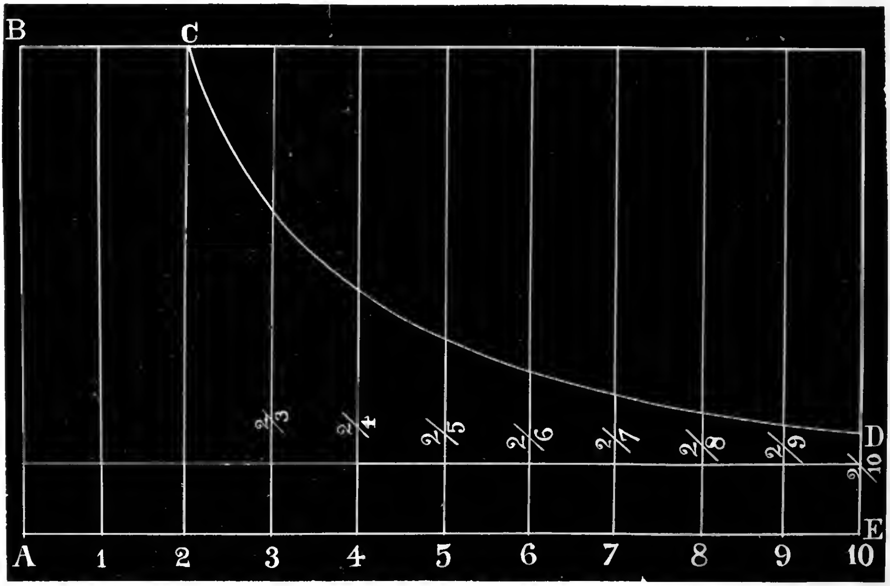


Fig. 6.

valves of an engine to ever produce an absolute right angle for an admission line, except in a very slow moving and low pressure engine; for in a high pressure, fast moving engine, there would be a certain shock by the production of a line of this sort on the Indicator, and it is much better to confine a small amount of steam by shutting the exhaust valve so as to put in compression or cushioning. This would be done by shutting the exhaust valve between the figure 1 and A on the vacuum line, so that the line, instead of starting from A to go to B, would start from a point between A and the figure 1 and gradually rise one-quarter or one-third of the distance from A to B. The line of which we are speaking is not represented in the engraving, but would be represented in about the manner we have described. This is very much more advisable in fast moving engines, from the fact that the steam thus confined costs nothing, and it is much better to assist the piston in coming to a stop without having a tendency to go any further, if it were possible. It prevents a strain upon the connections and really assists the whole thing to come to a stand-still while the crank passes the absolute center.

As we progress in this study of lines, a very considerable change will be observed in the steam line as well as in the admission line. Upon this point of admission line a great many good engineers run away with the theory that they can tell as well by the lead of the valve, as by the Indicator, what the steam line of an engine is. It is just as well to disabuse yourself of any preconceived ideas, for they are simply and only guesses, and no living man can tell anything about the lines made by the action of the steam in the cylinder, by any marks, figures, or computations, and only until he applies the Indicator, does he *know* anything about what is going on. He can theorize and suppose, but it is simply and purely theory and supposition. There is nothing actual or absolute about it.

We now come to the steam line, B C. The diagram here represented is one which is like what would be taken from an automatic cut-off engine in which the point of cut-off is controlled by the action of the governor, either by changes in the pressure of steam or by changes in the load. This class of diagrams is different from those of other engines. This may be described as admitting the full pressure of steam for a limited amount of stroke, — the steam is then cut off and expansion finishes the stroke. The other classes, or groups, are described by a valve having an invariable motion, but with more or less lap, which closes the valve for a portion of the stroke, always cutting it off at a certain fixed point, the pressure being changed by the throttle-valve of the regulator.

There is still another class, which is virtually a subdivision of the one we have last mentioned, in which the motion of the valve may be changed by hand, either by link motion or an independent cut-off gear. Both of these classes use a regulator in the pipe which governs the pressure of steam admitted through a portion of the stroke; that portion of the stroke remains constant — it is always the same. This is the case in the Huntoon, Judson, Waters, and many other governors of that class, which regulate by means of a valve in the steam-pipe, governing the amount of steam required by a fixed motion of the valve, instead of, as in the previous case, the automatic cut-off, like the Corliss, Lawrence, Porter-Allen, and others, in which the full boiler pressure is admitted for a length of the stroke, which is controlled by the governor.

There is only one other class of engines, and that is the old style plain slide valve engine, having an invariable motion without lap of any amount, so that the steam follows the piston for nearly the whole length of the stroke. In some cases, the mean pressure in the cylinder is adjusted by changing the point of cut-off, as in an independent cut-off gear; but these engines are only applicable to work in which there is very little or no variation in the load, and they are not at all applicable to the modern system of working, where accuracy in the speed is one of the important requirements.

In the consideration of these various classes of engines, we shall first look after the automatic cut-off, because it is the most effective, the most economical, and by far the most used. Its lines are always defined. They may or may not be correct, but in some of the classes to which we have referred, it is extremely difficult to ascertain where one of the lines commences or another one leaves off.

The steam line, B C, is one of the important lines of the diagram. It is very frequently the case that the line, B C, drops away from C, sometimes more, and sometimes less. The engine that comes nearest to good practice will maintain its steam line as nearly as possible to a straight line; and wherever any considerable variation is found, it may result from one of several causes — principally two causes; the first may be an insufficient supply from the boilers to the chest of the engine — that is, the steam pipe is not large enough, or the valve may not be as large as the pipe; and, in the other case, to a very late and incorrect opening of the steam valve. In either case, the lack of a good steam line is a lack of economy. The opening of a valve, or an insufficient area in the ports, may also combine to produce an imperfect, throttled, or wire-drawn steam line upon the Indicator diagram. The steam line should therefore approach closer to boiler pressure, and should be as nearly as possible at right angles from the line, A B, until the cut-off valve closes. The piston, in traveling from B to C, is influenced by the total boiler pressure. When the piston, in its track, reaches the point, C, the steam valve is closed. Now commences the line of expansion. The perfection of this line depends upon various and important causes. The cut-off valve should close instantaneously; the valve, in its action, should work quick, or else we shall have an exaggerated expansion line; because, if the valve works slowly or imperfectly, it will commence to reduce the pressure, and will still be admitting steam, so that the line of expansion may be plus at one point and minus at another, when proved by the theoretical curve. Only the Indicator can tell us whether the engine is constructed properly, or with a capability of doing this properly and correctly,—and when the valve closes it must be tight. If any steam leaks, or is drawn under the valve after it is closed, it is a waste of steam, and is certainly not an improvement upon the working of the engine. But these points must be treated upon as individual cases rather than as collective ones.

We now come to the consideration of the line, C D,—which is the curve formed by the expansion of the steam from a higher pressure to a lower one, by increasing the room in the cylinder, by the motion of the piston, from one end to the other. This is usually known as Mariotte's law: that the pressure of steam diminishes in proportion to its volume; in other words, that steam, at 100 pounds, expanded into double the room, would give a pressure of 50 pounds; and into four times the room, 25 pounds. The use of the theoretic curve is a very considerable and valuable one; but only as a means of comparison, no man has yet shown that steam *does* expand as Mariotte laid down the law as given. By its proper application we erect a theoretically correct diagram,—in other words, a perfect diagram. Now, the line of the perfect diagram, if properly done, with the proper data, shows what the engine should have done with the amount of steam and the ratio of expansion, as applied to that individual circumstance. In this way we get a theoretical diagram erected from the data of the actual diagram, and we can then ascertain whether the actual diagram is a large or small percentage of the theoretical. The curve erected from C to D, illustrates Mr. Bacon's method of easily ascertaining just what the theoretical curve should be. The ordinates are here erected, making ten spaces, or divisions; he cuts off the steam at the second ordinate. If the pressure be sixty pounds from A to B, and be maintained from B to C, it is cut off at two ordinates. The pressure at which the next ordinate should measure is two-thirds its former; and then, as will be seen by his method, two-fourths, two-fifths, two-sixths, two-sevenths, two-eighths, two-ninths, two-tenths. Theoretically, this is correct. If the curve given by the instrument should be above the theoretical curve, we conclude that the steam valve leaks. But if we find the curve made by the Indicator falling below the theoretical line, we are certain that either the piston or the exhaust valve leaks, or that we have discovered something new,—which is not likely, however, to be the case. This line varies greatly in different engines.

To apply the theoretic curve to any diagram, add the clearance between the piston and cover, or head of the cylinder, to which add the area of the ports and passage ways clear to the face of the valves; reduce this clearance to cubic inches, then ascertain the actual number of cubic inches in the stroke of the cylinder, and get the percentage or proportion of clearance to the volume of cylinder. If the stroke of the cylinder has two thousand inches, and the clearance is fifty inches, the percentage will be one-fortieth, or two and one-half per cent.; now add one-fortieth to the length of your diagram, then draw the line of perfect vacuum, from which all the calculations must be made. Whether the engine is high or low pressure makes no difference. Having added the clearance line, and the line of perfect vacuum, then divide the length of the diagram into ten parts, or spaces. If the steam is expanded, four times the terminal pressure will be one-fifth of the initial. This will be above the atmospheric line of the instrument—not above the true vacuum line.

LESSON II.

In this lesson two diagrams are shown, which are as radically different as is possible, in the action of the valves and the steam, so far as principle is concerned. In reading these diagrams, it is necessary to remember one point, to which we have previously referred; that is, that the Indicator, when properly applied, records absolutely the performance that is going on inside the cylinder. We must educate ourselves to read these lines properly and correctly. The Indicator is simply a mechanical appliance. It does not, in any event, do anything more than record the processes which are taking place inside the cylinder. We must properly apply and manipulate it, and then draw our deductions from its lines, from knowledge gathered from experience and contact with it.

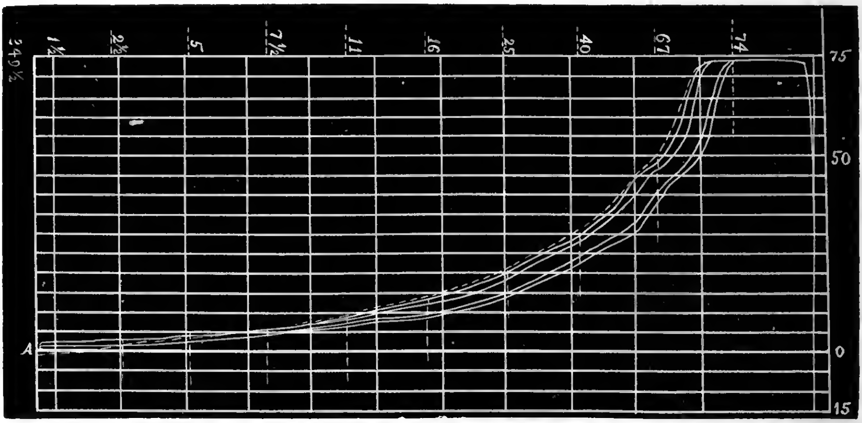


Fig. 7.

Fig. 7 is a diagram taken from a Corliss engine. The real vacuum line has been drawn, while the atmospheric line extends from O, on the right, to A, on the left. Two lines are erected, one of which is the right angle from which to measure the length of the diagram; and the line at the extreme right is the clearance of the engine, added for the purpose of putting in the expansion or theoretical curve, which is shown by the dotted line. This diagram, in itself, is quite a study. Theoretically, it is almost absolutely perfect. Four motions of the piston are recorded by the pencil mark of the Indicator, and if careful attention is given to the dotted line, it will be seen that the valves of the engine were almost absolutely tight; that very little condensation took place, and that the termination of the correct expansion curve at A, is as nearly correct as it is possible in actual practice to obtain one. This diagram is divided in two directions — the lines from right to left being at five pounds, with the scale used, so that the pressure at any point upon the diagram can be shown without using the scale. The ordinarily used ordinates, and the clearance line erected, complete the lines of the figure. If we study the lines near the upper right hand corner, the line drawn by the pencil of the Indicator is at a little distance from the inner line of ordinates. A little space will be seen between the inner line and the steam line near the figure 75. Whatever proportion this distance shall bear to the whole length of the diagram, just that proportion of the stroke the piston had moved on its outward travel before the valve opened sufficiently to admit the steam to the pressure denoted by the line. In other words, steam was admitted somewhat late. This is a very common observation where engines have been running any length of time. The steam-line of this engine, as we have before stated, is almost perfection. It does not diminish in pressure, but follows along very squarely, and wherever the valve closes, or cuts off, the pressure instantly drops, the corners are very little rounded, and in the expansion line it will be seen that very little expansion occurs. The serrations in the line at the second ordinate, between the figures 40 and 67, may be made by either one of several causes; it may be due to a trifling oscillation in the instrument, to the presence of water, or to a very insignificant leak; we are supposing the instrument is in perfect order and condition. As the ratio of expansion increases, the line more closely follows the theoretical line, and it will be noticed that the four lines are all merged into and apparently cross one another at almost the same precise spot. Had the steam valve been leaking, or had there been much water in the steam, the line under the figure 7½ would have risen considerably above the theoretical line, — and this is very commonly found, — but in this particular case the valves were tight, and the line continues down to its complete expansion, or termination, almost absolutely.

Fig. 8 is a very different diagram, and was taken from a steamship engine; and this may properly be termed one of the vicious forms, or at least a vicious diagram; and even now, we find some men so antiquated as to advocate this method of working steam. It must be read, not from its comparison with the other, so far as the Indicator goes, but as an absolute result given by the Indicator of what was being done in that engine at that time, and we can then compare it with Fig. 7, each diagram being the positive production of a different engine, given by the same Indicator, perhaps, just the same as a pair of scales would weigh a pound of sugar or a pound of nails. The work done by the scales is simply a mechanical result, while the matter, which passes the hands of the operator of the scales, may be as entirely dissimilar as sugar and nails. This diagram has in it some very peculiar points.

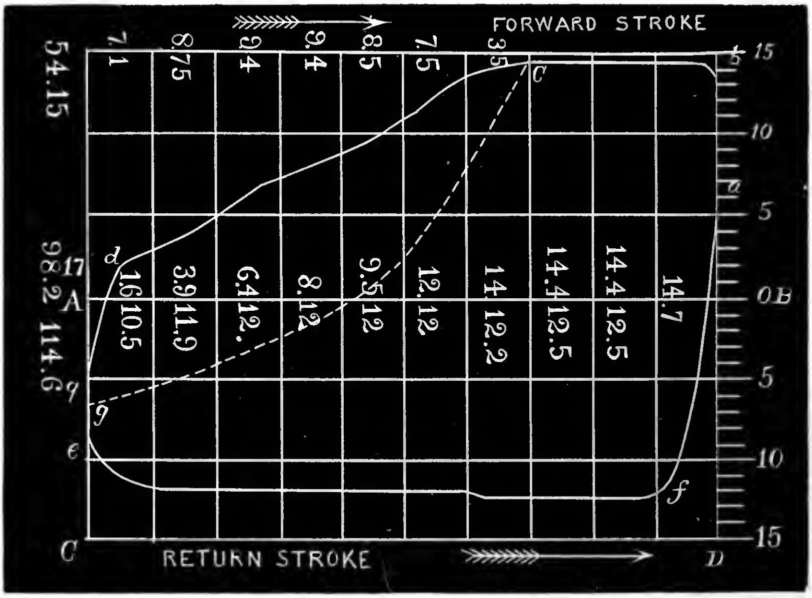


FIG. 8.

Fig. 8 is taken upon a scale of twelve pounds to the inch. The line, A O B, is the atmospheric line, while the line, C D, is the line of perfect vacuum. We have previously spoken of compression. It is illustrated in this diagram, and we shall commence at *f*, in the right hand corner, where the piston, on its return stroke, in passing *f*, commences to compress the steam which the closing of the exhaust valve has confined. The operation in this case would seem to reach about five pounds above the atmospheric line; at *a*, the steam-valve has opened, and the steam is admitted, carrying the pressure up to *b*. Then the piston starts upon its forward stroke. The continued opening of the valve maintains the pressure at almost the initial point. When the piston has traveled forward to *c*, the steam-valve commences to close, and continues to close, but the actual point of closing cannot be ascertained from the diagram without geometrical delineation; but had the valve been properly closed at *c*,—as it should have done with an automatic engine,—then the dotted line, *c g*, would have been approximated very nearly by the steam-line, the lines, *c g*, being the theoretical expansion curve from the point, *c*, and the line, *c d*, the real expansion curve of the engine. At *d* the exhaust valve commences to open and the condenser to do its work in producing a vacuum. The vacuum in this case is about twelve pounds. The notch in the line, between *e* and *f*, is caused by the fact that the air was expelled, or that the condenser had then produced its maximum effect. The line here, *e f*, will be seen to drop from 9 below to 12+. When the condenser takes hold at *d*, the steam has expanded to only two pounds above the atmospheric line, the piston has not reached the full length of its travel, and the condenser seems not to have the capacity to take and produce a prompt vacuum. When the engine reaches its center, on the outward stroke, it will be seen at *q* that the line of the instrument drops vertically. At *e*, the piston has commenced its return stroke. Only nine pounds vacuum has yet been attained. As the piston travels on its return stroke, the condenser commenced moving again, and the vacuum is steadily reduced from 9 to 12 in about one-seventh of the return stroke.

We are now to return to the expansion curve, real and theoretical. The area bounded by the line, *c d g*, and *c g*, is really just the same as so much steam thrown away; for, had the valve closed at *c*, the line, *c g*, would have been produced; but as the valve was so slow in its closing, the quantity of steam admitted led the real line of expansion unusually far above the theoretical; and while a certain amount of power was produced, it was at an enormous expense compared with the rest of the area of this diagram, — really at no positive advantage.

In comparing the two diagrams, Fig. 7 shows the perfection of the working of steam, and Fig. 8, we might with propriety say, the perfection of waste of steam. Although the one is called a high, and the other a low pressure diagram, had a condenser been attached to the engine from which Fig. 7 was taken, there would not have been the least difficulty in producing a better vacuum than that of Fig. 8, and the waste between the two engines would be enormous if they were both adapted to the same work.

We shall, in another lesson, show a diagram from a modern steamship engine, which is as radically different from Fig. 8, as Fig. 8 is different from Fig. 7. The figures upon these diagrams are the old method of working up, and it will be good practice to work these over and corroborate the figures, or to make a nice tracing of these diagrams, lay out the curves, and find the percentages of economy and waste.

There are high pressure engines, now running, which are fully as wasteful as Fig. 8, some of which we shall illustrate; but it must be borne in mind that this diagram was taken a number of years since, when it was supposed a great improvement had been made in working steam expansively upon marine engines. Many marine engines have most elegantly-contrived expansion valves, or arrangements, which we shall treat upon more fully. Fifteen years ago it was supposed that some of the steamships crossing the Atlantic had reached the highest point in the economy of fuel; but, within the last eighteen months, vessels, with more tonnage than those with which the comparison was made, have crossed, from New York to Liverpool, upon a little less than one-fourth the amount of fuel per day than the engines are using which were supposed to be so economical; while, in other departments of working steam, results have been obtained, by the application of steam pumping of water, which far surpass the performance of any steamship engine that has been built up to this date. This has been done, partially, by studying carefully the force, and its application to raising water; but if the steam mechanism had not been as nearly perfect as it is possible to make it, it would not have shown such immensely economic results. The perfection of application of the power produced has wrought out this result—to which we shall again refer.

The study of this diagram, by those who are not entirely familiar with the Indicator, will be of great value. No man should be intrusted with the running of large engines, especially in cotton or woolen mills, where perfection of speed is required, and where the best results that are possible are not only desirable but, from an economic point of view, are a most imperative necessity. Many of our larger corporations now require that an engineer shall have a practical knowledge of the Indicator before they will put him in charge of their engines and boilers. The time for setting the valves of an engine by the eye, or by scratches or punch marks, has ceased to exist in the eyes of intelligent and competent engineers; and the engineer of the future is probably a man who is capable of a careful manipulation of the Indicator, and of producing the highest economic results from following the lines drawn therefrom, without regard to the whims of the builder, owner, or others, after he has qualified himself to read these lines, and make them by the proper manipulation of his instrument.

LESSON III.

In this lesson we present two diagrams from different classes of valve motions, and the two figures represent as radical a difference as is possible, from the two practices, in the way of working steam, but by this time the reader should be quite able to read the lines. In Fig. 9 we have a diagram of rather peculiar appearance, and yet it is not many years ago that a great many engines were working under circumstances no more favorable than is shown by this card. It is a low pressure condensing engine. The steam is carried half the stroke, the pressure being regulated by the throttle valve in the pipe, but the admission line is a little late. The steam line is very well maintained, but at what an expense! While the expansion line is somewhat irregular, and is much higher at the termination than it should be, from the fact that the valve which is used in this case did not close promptly enough. The condensing is almost a farce. It will be seen that the valve opened very slowly, or that the condenser took hold very imperfectly; and the piston had returned nearly half its stroke before the condenser had attained the maximum vacuum, while the distance between the return line of the steam and the line of absolute vacuum is about equally divided. In other words, the vacuum is just about half what it should be; the atmospheric line of the instrument running through the Indicator lines, and the absolute vacuum below,—without measurement we should say it was about one-half,—and yet there are engines running today in just this kind of practice. This engine uses double the steam in amount, at half the pressure, and the engine only affords about half the vacuum. It is therefore utilizing something less than one-third of the fuel that is burned in the furnace.

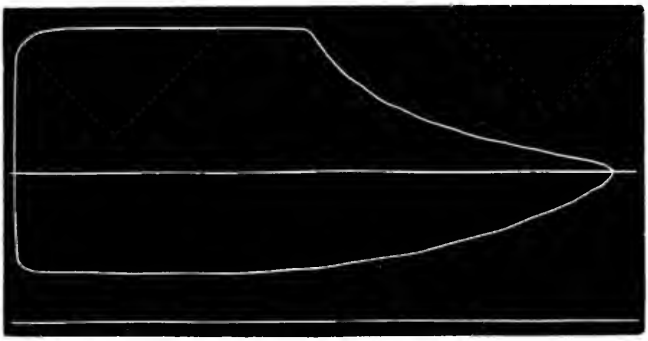


Fig. 9.

Fig. 10 we have chosen for an especial purpose. It is a fine outline; the compression is an elegant line; the steam valve opens at just about the right point, and the admission line is correct. The expansion line looks well to the eye, but the style of engine is one that makes a fine diagram, and most essentially misleads the unpracticed eye in its reading. The diagram in question is made from a non-condensing engine, at a slow rate of speed, from what is known as the Sickels valve-gear, using single or double poppet valves.

The clearance of this engine, by reason of the valves used, is enormous, but they have a chronic way of leaking, so that the expansion line in this engine, except the whole clearance be known, is of no use whatever in erecting upon it a theoretical curve in order to measure its efficiency. And while the outline is agreeable, with the exception of the undulations in the expansion curve, it bounds a waste of fuel that would not be tolerated today by any sane man who had to pay for fuel himself, and could not be used by any concern who paid for their fuel or meant to pay their bills. When the valves and seats are new and tight, it works with much more economy than when any little trouble has arisen from the wear of the valve. But the clearance is so very large that economy is absolutely out of the question. The question has several times been asked us: Is it possible for an engine that is not economical to make a handsome Indicator card? This is an example and an answer to that question.

The Indicator card, in itself, is of very little value, except all the circumstances that surround it are made known from the positive standpoint of absolute measurement. In this case, if the actual clearance was known, the termination of the line of expansion would, without doubt, be above the proper termination of the theoretical curve; for the clearance is very large, and whatever amount of clearance is found in an engine is a constant quantity that must measure out an amount of steam, which does no good beyond filling a certain amount of dead room at every revolution of the engine.

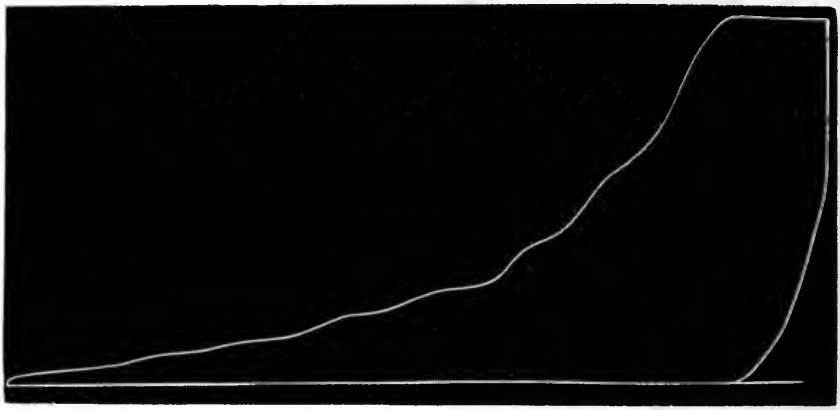


FIG. 10.

As steam is a fluid which is capable of measurement just as much as water or milk, do not allow an engine builder to talk you into the use of a large clearance, by any roundabout method of argument; for if you are using a cut-off engine, the amount of steam wasted in the clearance must be filled with live steam, while the valve is open, and the ratio of expansion has nothing to do with it. The amount of steam which you measure out in this way is for each end of each revolution, and the waste is therefore as many times the excess of clearance as your engine makes strokes per day, month, or year.

In Fig. 10 there is positively no back pressure, and back pressure is no more necessary in a well constructed engine than a leaky piston head; and except some obstacle is offered to the exhaust, an engine should exhaust at no back pressure, without some visible, sensible reason, as in the case of very extended exhaust pipes, exhausting through small pipes to heat rooms, or some such reason as that. An engine making the card, Fig. 10, although high pressure, will do nearly, if not quite, double the work with the same coal as the engine which makes the card, Fig. 9; while if Fig. 10 should be set to work with a proper condensing apparatus, it would do a very large percentage more than the engine upon which Fig. 9 was made, with the same amount of coal.

LESSON IV.

IN this lesson we shall come at once to the practical. Both diagrams shown are from the same engine, and taken upon the same day.

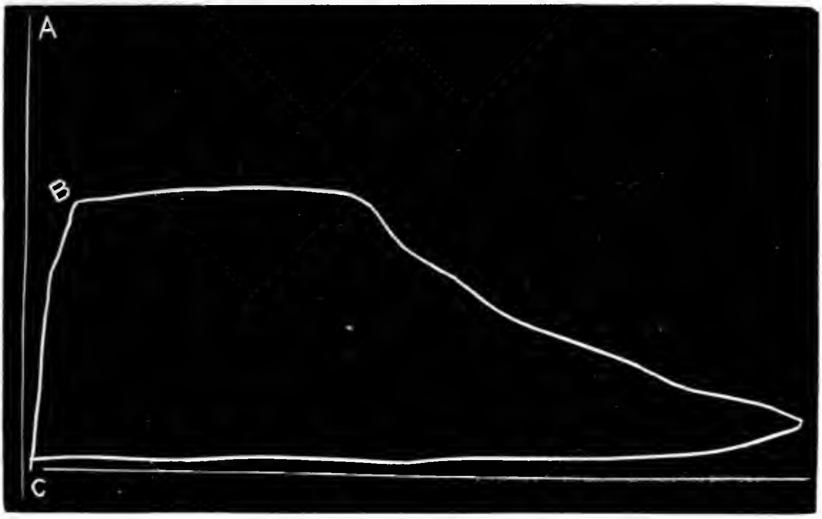


FIG. 11.

Fig. 11 is not an uncommon diagram, although this was from a modern built cut-off engine, by Wheelock. The engineer in this case had become dissatisfied with himself and everybody else, and he was one of those men who do not consider an Indicator of any practical value; consequently he had placed the valves in such a position as he *knew* was correct. The result proves that he was *not* correct. The line at A represents the steam pressure in the boiler, and is the same in both figures, and it is erected at right angles to the atmospheric line of the instrument. Mr. Engineer, in making his changes, made the motion of the valves very late, as will be seen at B. The valve did not commence to open till after the piston had started on its stroke, and the old saying, "a stern chase is a long one," was never better exemplified than in this case. The valve being late in its opening, is late at every portion of the stroke. The steam line in this case rises after the piston starts, for when the valve gets wide open it admits more steam than it did at first. The expansion line is a rather awkward affair, while the exhaust resembles an old-fashioned shoe toe, and it is evident the engine has too much back pressure. At C there is a peculiar little point, caused by the late closing of the exhaust valve; and after the piston stops, the Indicator seems to drop a couple of pounds. From C to B the admission line is very poor.

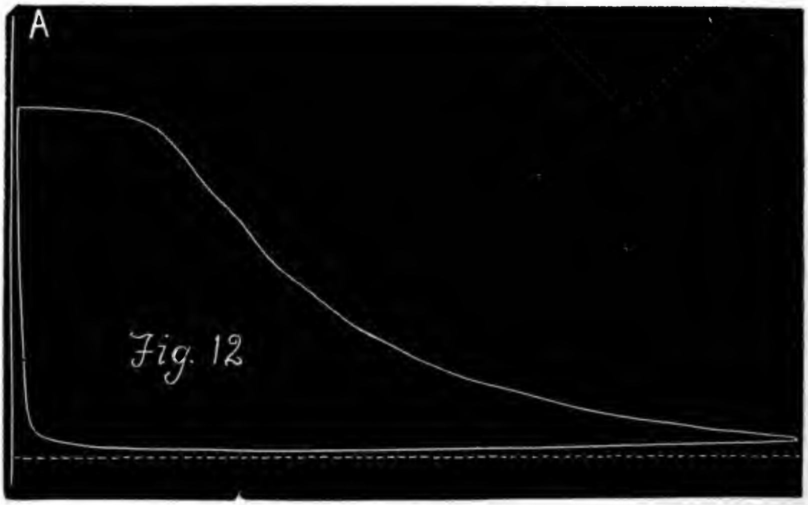


FIG. 12.

Fig. 12 shows the diagram a couple of hours afterward, and which presents a very different appearance indeed. In this case, the admission line does not come fully up to the boiler pressure. The steam line is hardly maintained as it should be, — it is a very great improvement over Fig. 11, — but the improvement is not entirely in the outline.

On these diagrams there is another very serious question. Fig. 11 was not doing any more work than Fig. 12, — in fact, it was running the very same machinery, and did not run it at quite full speed, — while the amount of coal used to produce Fig. 11 was sixteen tons, and that used to produce Fig. 12 was twelve tons in the same time. Now, this evident discrepancy was not from any particular fault in the engine builder, but all lay in the fact that the engineer knew very much better, in his own estimation, than he did as a matter of fact, what should be going on inside the engine cylinder, — and this is a very common mistake.

Fig. 12 shows very much less back pressure and earlier exhaust, and a slight amount of compression, but sufficient to arrest the motion of the piston.

The steam valve commences to open just about early enough, and the steam is carried a little less than one-half as far on the steam line in Fig. 12 as it is in Fig. 11. The consequence is, less steam is admitted to the cylinder to do the same work, less steam is exhausted, and very much less is wasted, and only by the simple and proper placing of the valves.

Sometimes men reason, although very falsely, that they can tell by the motion of the valve, or the exhaust, or something else, how the engine takes steam; but, as a matter of fact, no person can tell anything about it till after the Indicator is applied, — and not then except the application be strictly correct, — and whoever reads it must have had some practice in reading the lines of a diagram. The two figures are as unlike as it is possible to make them, while the serious question is: Why should not any engine make Fig. 12 as well as Fig. 11, while it costs less to make it? And the only answer is that the engine *will* make it if you have an engineer who is willing to steer by the Indicator. There is no trouble whatever in doing this; but the fact is, engineers do not always like to learn, and in many cases parties in charge of manufacturing establishments do not furnish their engineers with the materials with which to work.

This is only a single lesson, but what is very frequently done, and as a rule the men who do it are not the engineers. If the reader will figure both these diagrams from the same data, they will find a very serious difference, and this difference is WASTE to the owner, and is precisely the measure of difference between a good and a poor engineer. There is no material difference in the amount of work done, although, as a matter of fact, the same machinery was run at the same speed, in each case, by the very same engine; and it will be good practice to figure the difference in an engine of 18 × 42, running 65 revolutions, and see how much was wasted.

LESSON V.

In this lesson we have two interesting subjects. One, a high speed engine, 12½ by 16 inch cylinder, running 160 revolutions, diagram with a 50 spring. This diagram (Fig. 13), as a general outline, approximates very closely to locomotive practice. The engine takes steam at A, and the steam is shot into the cylinder, and immediately decreases in pressure to a very great extent, from A to B, — perhaps we have made the line a trifle too long, — about one-third of the stroke. This is very nearly the steam line. The pressure at A is 75 pounds. At B it is 50 pounds. We have no data upon which we can figure or lay out the curves. Hence, we cannot say whether the expansion line of the diagram is correct or not. The exhaust valve opens at A B, nearly one-sixth of the stroke. The exhaust line is very good. There is no back pressure, but the exhaust valve closes again very nearly at C, which is one-half of the stroke. The compression line in this case is well formed, but whether it is an economical one or not can only be judged by data which we are not possessed of. The outline of this diagram is peculiar, to say the least, and we have no doubt it is interesting, if we had the whole facts, from which we could make deductions as to its economy, or otherwise. The steam in this case does not obtain access to the piston as readily as it should. The line, A to B, indicates what the steam line at induction pressure would be, for whatever length of stroke it is carried; and the line from the horizontal to B shows the pressure line from the opening of the valve to the cutting off. The clearance of this engine, although very small, shows a very good expansion curve. But if the clearance exceeds 4 or 5 per cent., the curve would not rank well. We do not mean well as to the ideas of some engineer or builder — we mean well as to the coal pile.

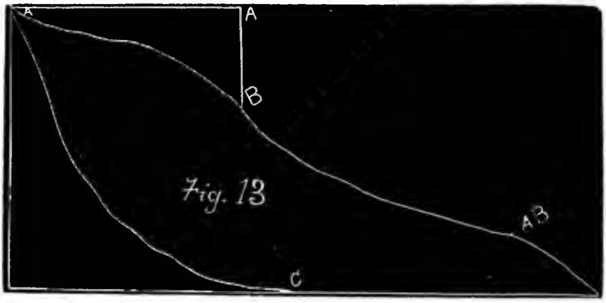


FIG. 13.

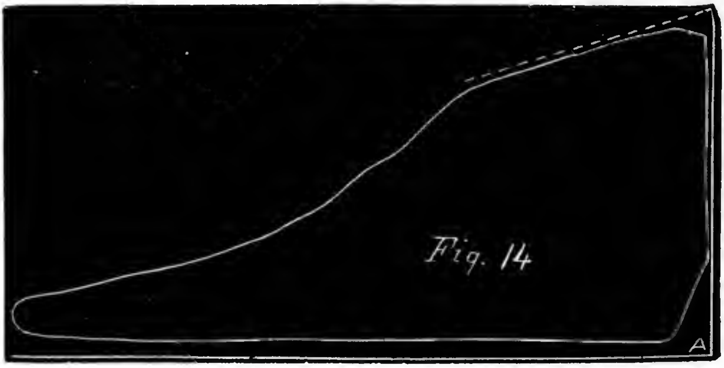


FIG. 14.

Figs. 14 and 15 are from a Corliss engine, and in both these cases the steam valve opens late. The admission line is therefore tardy. The steam line in Fig. 15 is somewhat peculiar, as it carries the induction pressure very squarely for a short distance, when it drops off; and, from the formation of the line, we should infer more steam entered the cylinder. We have not, in this case, the clearance upon which to erect a theoretical expansion curve. Our purpose is not to treat this diagram from a theoretical stand-point, but to draw from it a practical lesson for those who are not too hard-headed to learn. This is another expensive practical lesson, where men overreach themselves in their attempt to do their own engineering. The cylinder of this engine is 23 inches in diameter, 60 inch stroke, 75 revolutions. The diagrams are taken with a 40 spring.

Fig. 14 shows more back pressure than Fig. 15. In either case the amount is very large. From the time the engine takes steam until the valve closes, and the admission of steam to the cylinder is stopped, a considerable decrease of pressure upon the piston is shown. The shape of this line tells the practiced eye plainly that there is some reason for it. The line, for a portion of its distance, is almost a right angled triangle, or two sides of it, when compared with the upright line, A. The formation of the line, therefore, shows that the cylinder is calling for more steam than the port is able to supply. In this case, the reason is a very simple one. The parties who are running this engine bought a 200 horse-power machine; it is indicating 350 to 380 horse-power, or nearly double what it was ever intended to do economically. Investigation into this question, of a very recent date, by a competent engineer, develops the fact that the engine is working at double the load it was ever intended for, and, with all its disadvantages, upon 29 pounds of steam per indicated horse-power, upon a test. These diagrams do not show an economical use of steam, from the fact that the load upon the engine is so large that the ratio of expansion is entirely too small. More steam is required to drive the load than the steam-ports will properly handle, so far as economy goes. That is to say, the amount of steam required at each end of each stroke, is so much, that the capacity of the ports will not admit it all, at the pressure required, or furnished by the boiler; that the amount of steam admitted is

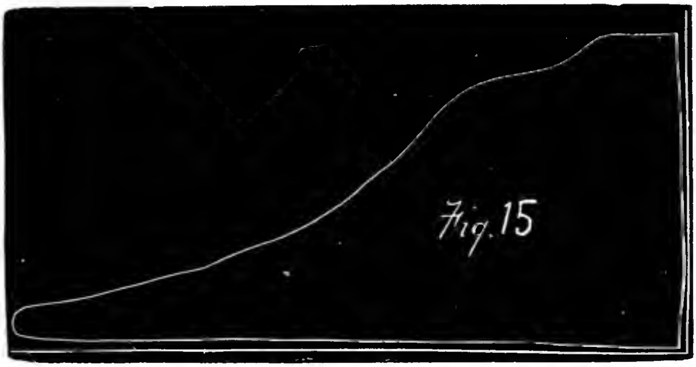


FIG. 15.

more than will be admitted at boiler pressure; and upon the other end of the stroke, the volume of steam, after expansion, is more than the exhaust ports will readily relieve the engine of; so that a loss is made at both ends, — a radical loss of initial pressure, and a loss of resistance by back pressure after the steam has expanded, or done all its work. For all this fault there is only one remedy: less load, or a larger engine. In this case, we presume the engine will be charged with what is really the fault of the owners or managers, and, without much doubt, they will be entirely blind to the fact that they are themselves the cause of a costly steam power. Our next lesson will show a modern built engine, which the reader will do well to contrast with this overloaded Corliss. It is no use to expect to load a 300 horse-power engine to 560 horse-power, and get an economical result in the use of steam. But there are people in the world who are just complacent enough to suppose that one pound of coal will do an immense amount of work — if they only direct the way in which it shall be used.

In these lessons we have nothing to do with the theoretical, beyond the simple comparison, believing that, as facts are facts, and these examples are all from actual use, our readers, who are honest with themselves and can learn from example, cannot fail to profit by them. In too many cases the use of steam is an expensive luxury, and the overloading of an engine is not the least expensive. And aside from the danger incurred, the liability of a complete smash-up or stoppage, it must also be borne in mind that all of these circumstances tend to involve danger to the lives of all those immediately in reach, — and this is a factor which is not always taken into account or consideration.

LESSON VI.

In this lesson we have a rather interesting and instructive subject. The diagrams furnished are both from the same engine, are from actual practice, and were taken for the purpose of ascertaining what economy the engines are working with. The size of the engine is 6 × 14 inches, running 220 strokes, or a trifle more, giving an indication of + 17 horse-power, with an assumed clearance in the construction of the theoretical curve of three per cent. of the volume of the cylinder capacity. Subsequently to the trial the piston was found to be leaking badly. The compression on this, as most other high-speed engines, is a considerable factor, much more than we should like to see. But it is a part of the motion of the valve. If it opens early for the exhaust, it must necessarily close very early, and as there is no limit of changing the throw of the one witnout the other, then the whole matter has to be averaged. The peculiar kink at the upper right-hand corner of each card shows the action of this compression, and the opening of the valve. In one case the steam line, properly speaking, is theoretically correct, with the exception that it does not rise nearly as high as the steam pressure; while, in the other case, the valve does not open as it should, and the steam line falls away rapidly, until the real point of cut-off is lost, and the line becomes very irregular on the expansion curve. The back pressure amounts to but very little, indeed, while the compression line, theoretically or mechanically, is quite too much, and approximates to locomotive practice, where it is very necessary to bring the reciprocating parts of the engine to perfect rest by a free use of steam. The compression occurs here at about one-sixth of the stroke, or rather more than that. The curve in this case includes the clearance, and is seen to be materially above what was expected of it, approaching nearer the expansion line at the point where expansion ceases. Taking the cut-off at the apparent point, including clearance, it is .295 of the stroke. The feed-water consumed during the trial was 40.78 pounds per hour. The power of this engine is small. We have not all the facts in connection with it as to the effectiveness of the boiler. It is only one instance of a pretty card in its general outline, which, when it comes to be surrounded by the facts, makes a very expensive

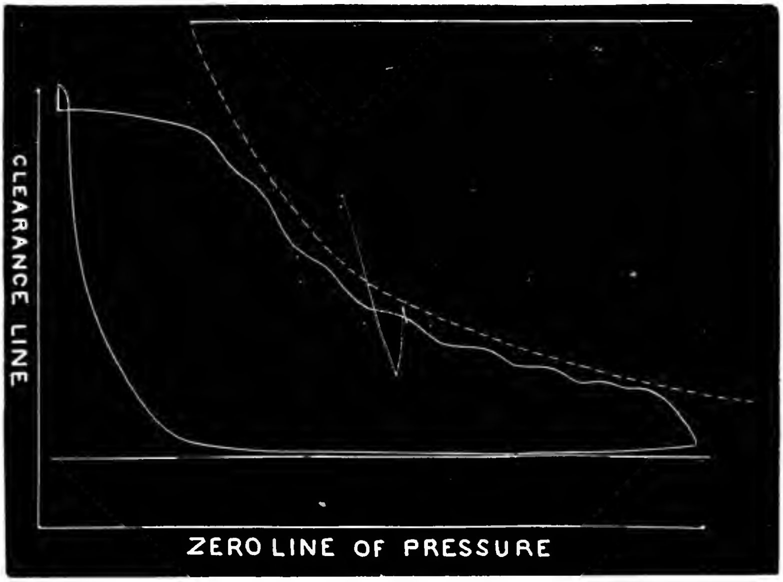


FIG. 16.

power. The action of the valve is such that it requires a large amount of steam, and whatever the amount of leakage may have been, it was probably not enough to radically increase the amount of steam used per hour.

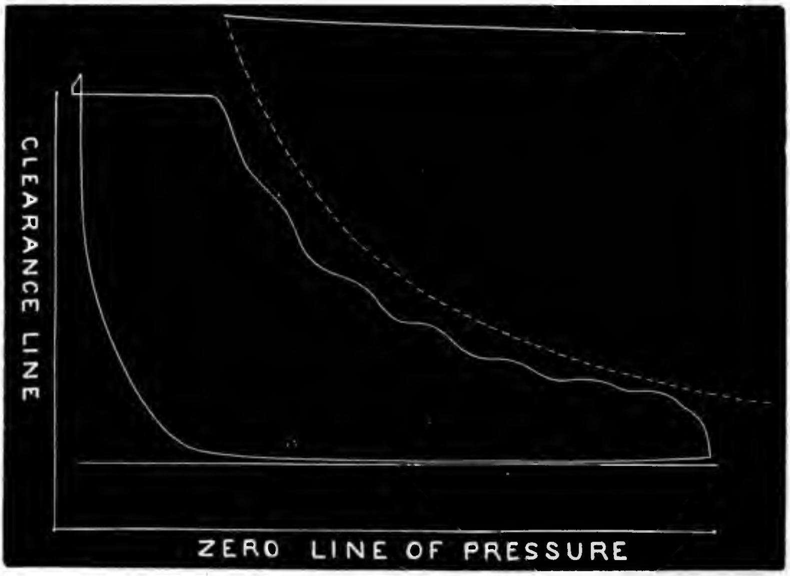


FIG. 17.

LESSON VII.

THE originals from which the engravings were made for this lesson, were sent us by a man, with the statement that he is a practical engineer,—but not an expert,—and that he is trying to learn something by the practical application of the Indicator to different steam engines. He asked several questions, and sent three sets of cards from two different engines. The cards contained in themselves a whole lesson, and we propose to answer his questions from a practical point of view.

The diagrams (18 and 19) are taken from a Harris-Corliss engine, 36 × 14 inches, speed 65 revolutions, 55 pounds boiler pressure, 30 scale. Our correspondent asks: "What are the reasons for the fluctuations shown by the governor? I suppose, in figuring these, it would be proper to take the mean. When the engine is loaded, the trips of the cut-off seem to act all right, but when she is not loaded, the fluctuations are very wide. What is the reason?

In the first place, these diagrams, for practical purposes, such as adjusting the valves of an engine, or ascertaining the actual pressure of each end of the cylinder, are absolutely worthless. They have no value whatever, and for this reason: The diagrams, as shown here, are taken by a connection leading from either end of the cylinder to the center of the cylinder, at which place a three-way cock is probably used, and in the time required to change the three-way cock from one side to the other, the load of this engine may vary from 20 to 30 horse-power. If the diagrams were taken as quickly as possible, they cannot both be taken upon the same stroke; consequently the value of the comparison between the different ends is lost. In the loaded engine and the unloaded, the same readings are apparent. We have drawn the atmospheric lines; and the lines, A B, upon each side of the diagrams, are at exactly right angles to the atmospheric line of the instrument. The admission line upon one of these cards falls away from the upright; consequently the induction valves, or steam valves, are too late in their movements in opening. This is applicable to each one of the four diagrams. It will be noticed that the crank end, upon each set of cards, does not give the same initial pressure as the head end, and if Indicators were used upon each end of the cylinder; — this would undoubtedly be found to be the fact in all the cards. The crank end is much later in taking steam than the head end. As the piston commences to move away from the head of the cylinder before the steam valve opens at all, and the crank valve is much later in opening, with reference to the motion of the piston, than the head end, it never gets open wide enough to admit the full pressure, from the fact that the volume of the cylinder is increased so much faster by the movement of the piston than the capacity of the steam-port will supply. The head end, upon both diagrams, has several

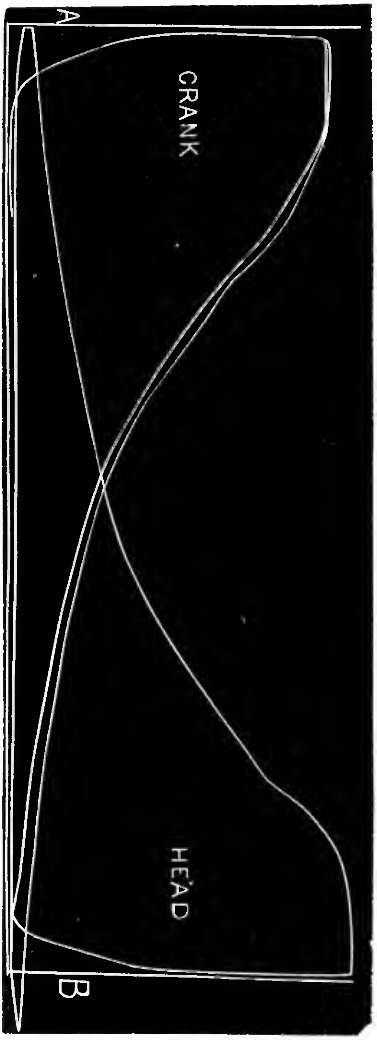


FIG. 18.

pounds more initial pressure than the crank end; and although the head end is late in the motions of the valve, the valve opens relatively sooner than in the crank end.

The way of connecting the Indicator to the middle of the cylinder, although altogether wrong, is the favorite method adopted by almost all the high-speed engine builders, for it shows their line of admission nearer to a right angle to the atmospheric line of the instrument, and it is, therefore, a point of advantage with them. They are obliged to open their valves very quickly, or to use an enormous amount of compression. The little amount of time lost by the steam running the whole length of this pipe, if only 12 inches, makes a certain correction, which is in their favor. On the Corliss engine, as in this case, the admission of steam is shown late upon the diagram, and, no doubt, if the Indicator was connected by the shortest possible connection to either end of the cylinder, this motion would be somewhat diminished, but the essential feature of the valves opening late would be found to be a fact.

FIG. 19.

Our correspondent asks why the regulator fluctuated more upon the crank end than upon the head end. The reason is perfectly plain. When the engine takes steam upon the head end of the piston, it takes a larger amount than it can take upon the crank. The tendency of this is to increase the speed of the engine. While the piston is making the stroke toward the crank end, the speed is somewhat accelerated, the regulator ball slightly raised, and the crank end of the engine, when it takes steam, is tripped just that amount shorter in order to maintain the proper speed which the engine is set to run at. Having taken this amount of steam, the balls drop, and the head end trips longer. In other words, the head end is doing considerable more work than the crank end, and the crank end is endeavoring to adjust all the time; and if the Indicators could be applied to both ends of the engine, and simultaneous diagrams taken, there is hardly any doubt, in our mind, that the fluctuation would be found as wide upon the head as they are shown upon the crank end. This we have proven, over and over again in practice. One end of the engine is doing more than the other, and the other end is trying all the time to strike an average and keep its speed; consequently the regulator changes the point of cut-off at every single stroke of the engine. This is not so apparent in the diagram taken with the whole load on, because the percentage of variation is so very much less in proportion that it does not show in the lines.

It would not be proper to take the mean of either one of these two diagrams as the actual amount of work done. It would show, to be sure, what was being done at the instant the diagrams were taken, but an average of 36 upon one end and 16 upon the other, does not, by any means, give the actual average of 26 horse-power as the work required to overcome the resistance. If our engineer friend will throw away his three-way connection, put it in the scrap-pile, and leave it there forever, make the shortest connection possible with each end of the cylinder, borrow an Indicator, — if he does not own two, — and apply these Indicators to both ends of the engine, he will find, we think, just what we have laid out for him. Then, if he finds the admission line a little late, let him shorten up his connection until the angle of the lines, A, B, and the admission line from the point of compression shall be one line instead of two, get his engine so that it takes steam sharp upon the center, — not a particle before, — then watch his engine for an hour, and whenever he changes the trip-dogs, changing both whenever he changes one, putting one back and the other forward, figure his diagrams, — and upon an engine of this size he should not allow a variation of more than two or three horse-power, — taking care to adjust the engine as nearly as possible from the full load; he will then find, if he cuts the belt off his fly-wheel, that the engine will cut off with the lightest load, both ends at the same stroke, and the variation in the amount of work done should be, and will be, with proper adjustment, very small indeed. He will find that his regulator will assume a very much more settled condition — it will not be reaching with every stroke. He will find that the confusion of lines will disappear, and that this will not be all.

An engine of 150 horse-power was recently indicated by us at the request of a party who was anxious to ascertain if the Indicator had any value. The mean of the first diagrams, taken from simultaneous cards, showed 168 horse-power. The head end was doing fully 15 per cent. more than the crank end. After the engine had been adjusted, the mean of two cards was 154 horse-power, with a variation of less than 4 horse-power as the mean of 12 sets of simultaneous cards. The difference between 154 and 168 was being thrown away; in other words, the engine was requiring steam capable of maintaining 168 horse-power, when, as a matter of fact, the load only required 154 horse-power. The speed of the readjusted engine was much nearer correct than that of the engine, when one end was reaching after the other alternately.

There is a point here that engineers should understand, and that is, that the variations of one end of the cylinder reaching after the other, when it is not properly adjusted, calls for the use of more steam to do the same work, because it does not do its work properly. The amount of coal required on this engine was 26 tons, before adjustment; after the adjustment, the parties reported that in the same length of time 20½ tons did all the work for three successive weeks. The result of the matter has been, the party has ordered a pair of Indicators, and his engineer is to make himself familiar with them, and take diagrams every day. This is entirely a practical lesson, and there are hundreds of engines running worse than this, which are considered to be doing very well.

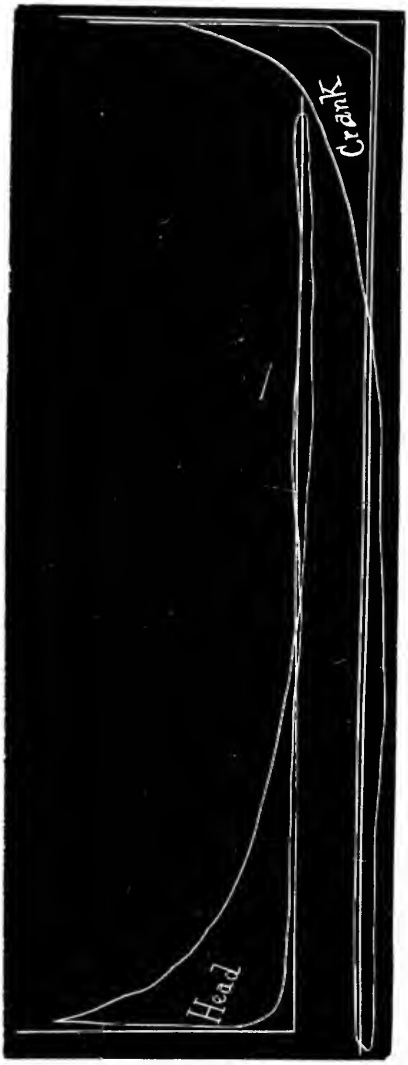


FIG. 20.

The diagrams 20 and 21 are from an 18 × 42 inch automatic cut-off engine, built by Geo. A. Rollins & Co., Nashua, N. H., with valves of the Corliss style, running 72 revolutions per minute. The scale is 30, high pressure, the clearance being 2½ per cent. The smaller diagrams, or the lightest load, show that the head end is doing the most work. The motion of the valves is a little late upon each end, as will be seen by reference to the upright line. The crank end cuts off very sharp, while the head end does more work than the crank end. This is purely a question of the adjustment of the valves. These cards are very clean in the track of the Indicator pencil. The card, with several lines upon it, is from the same engine under varying loads, and the lines of the instrument have been traced as nearly as possible.

In Fig. 21, A is the atmospheric line of the instrument, the back pressure valve being closed. This engine is in the Bay State Sugar Refinery, Boston, and the variation in the lines is caused by the throwing off or on, two or three at a time, of the centrifugal machines used in the works, which take from 25 to 50 horse-power each to start. The engine carries steam the full length of the stroke, in an almost absolutely straight line. This could not be done unless it had sufficient valve-port room, while, in cutting off at nearly three-fourths of the stroke, or at about one-half of the stroke, the lines are very good. The exhaust, in this case, we cannot tell exactly about, as the back-pressure valve is closed. But it is evident, from the general conformation of the three lines, that the exhaust valve has a capacity nearly equal in exhausting to carrying steam almost the full length of the stroke. When the centrifugal machines are thrown on, they are required to be brought to speed as soon as a half minute, which makes a very large change in the load of the engine, or the requirements. In this case, however, the engine seems to be fully able to answer these requirements, and the variation in speed was very slight. But with carrying the steam the whole length, it necessarily reduced the speed of the engine somewhat, — else the cut-off would have acted. If anything, the exhaust valves of this engine should open a little earlier than they do. There is hardly compression enough in it, and the lines of all three diagrams which are traced, show that the exhaust is somewhat retarded at the commencement of the return of the stroke of the piston. The opening of the valves to admit steam is slightly late, — only slightly so, — while the steam lines are most excellently well produced. The outline of B, Fig. 21, shows that the exhaust line is almost as perfect as the steam line of the largest figure. The turning of the instrument shows it slightly rounded, — in other words, that there is a small accumulation of steam in the way of retardation. If the outlines are correctly traced in the figure by the eye of the reader, these will be found to increase as the load increases, by the carrying of steam further on the stroke. In other respects, the lines corroborate the outline, making a working which should be very satisfactory, both as regards speed and economy. As a general rule, engineers do not pay attention enough to what seems to them trifling indications of variation. Every retardation of the exhaust upon the smallest diagram, is multiplied, as the amount of steam is let into the cylinder to overcome an increased resistance; and the little points should be carefully attended to, in order that they shall not become serious ones with the increase of the load. The cushioning, or compression, is quite too little upon this engine, and if the amount of motion at the commencement of the exhaust is put upon the end of the exhaust, or, in other words, if the exhaust is opened earlier, it will close as much earlier as it is opened. You will therefore reduce the back pressure at the commencement of the exhaust, and increase the

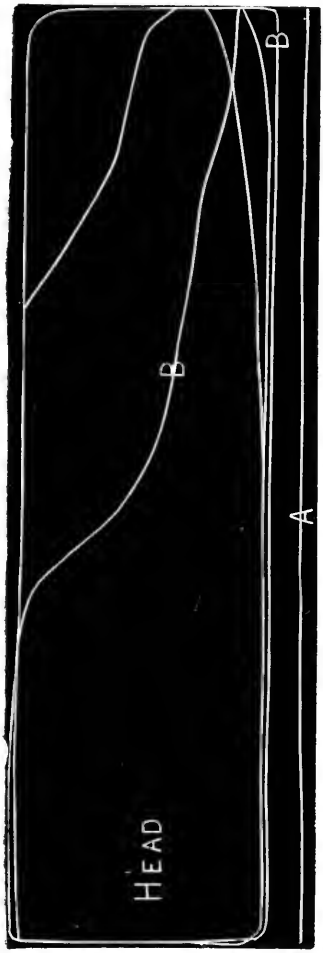


FIG. 21.

amount of compression by the closing of the exhaust, both of which are advantageous in economy, and are certainly advantageous to the good working of the machine. In the smaller cards, or those which indicate the smallest load, the amount of steam used by the head end is more than that used by the crank end. If this were balanced, the engine would work smoother, and there is no difficulty in balancing it if you have Indicators and a little patience. And the nearer right this can be done, the better production will be obtained regularly from the engine. Little matters are the important ones wherever steam power is used, and in no case is it more essentially important than in noticing little variations by the Indicator, when it is applied. The width of a pencil line upon the Indicator diagram does not appear to be much. At the same time, it may be an important feature in determining where the trouble lies, and should be watched very closely, and no changes should be made without carefully considering whether everything is tight and just right; for the value of an Indicator diagram increases precisely in the ratio that you give it care or attention in the manipulation, and valuable in results only as you are accurate and correct in obtaining them.

LESSON VIII.

THE examples in this lesson answer an often repeated question, Are simultaneous diagrams of any especial value over those which are not simultaneous? The diagrams which we represent are not simultaneous diagrams for the whole set. Each pair of diagrams were taken at the same time, but not upon each cylinder of the engine at the same time. There is, therefore, more variation than there would be if they were simultaneous diagrams. But these diagrams represent another important feature. They were taken from a Corliss engine which has been in use nearly or quite seven years, the valves of which have never been bored, turned, or changed. It is, therefore, a very fair expression of the value of the Corliss engine, in reference to the valves remaining tight while doing the constant regular work.

In the next lesson we shall produce diagrams from high-speed engines, taken from both ends of a pair of engines, and from each one of the engines at the same instant of time. A comparison will aptly illustrate the value of simultaneous diagrams, which are very much underestimated by engineers in general, as well as by engine builders, and their men who set up and start engines.

LESSON IX.

THE diagrams, Figs. 22 and 23, are from the Social Mills, Woonsocket, R. I. The cylinders are 30 × 72 inches, 48 revolutions per minute, with a 40 spring, working three-quarters condensing. The figures in each one of the cards represent the area as measured by the planimeter. These figures may, for comparison, be called horse-power; for, if reduced to horse-power, the amounts would represent precisely the same ratio that these figures do. The left-hand engine is doing the most work, as the cards are taken, if they were simultaneous, but the load may have varied between them. The left-hand machine works all condensing. The back end shows 490, the front end, 513; while the right-hand back end condensing is 488, the right-hand front end high pressure is 376. The right-hand engine is working with about the same amount of cut-off, and the front end, high pressure, is doing almost the same amount of work as the back end without the vacuum. This could be very easily adjusted by the use of the Indicator, if it was desired so to do. Let it carry steam a trifle longer and it would do as much as the back end; but all these points are practically those of fancy, with the average engineer, though not in a practical sense fanciful points.

There are some especial features about these cards. The valve gear upon this engine has not, perhaps, the same delicacy of adjustment as the motion Mr. Corliss is now building; therefore the toe of the vacuum is not so abrupt, and the engine is not working with as much perfection as would be desirable if the valve gear could work to an exact adjustment. We say exact adjustment, for if an engine has been working several years, the valves seat themselves; and if the throw or travel of the valves should be changed, the engine would be apt to leak steam until the valve seated itself in its new position. For this reason, the adjustment of the valves of an engine should be made not less than three or four times each year, as in that case the valve never becomes seated so deep but that it will readily accommodate itself to its new position.

The admission line in all these cards is very nearly correct, — we might say, almost exact. The steam lines are a little broken at first, — whether this is in the faulty motion or not, we have no means of telling, — but the admission of steam is ample, although the line is somewhat ragged. The cut-off is well defined in all the cards, although not as sharp as it would be in an engine that had been recently overhauled; but when we come to consider the fact that the engine has been working for seven years, without any tinkering, and that the theoretical curve applied to these diagrams covers 92 per cent., we must admit that the cards are very fine. The amount of power involved is nearly one thousand horses. This is one of the engines reported upon at the New England Cotton Manufacturers' Association, in comparison, in 1880, and it was found producing its work with 2.66 pounds of coal per horse-power per hour, and is now doing much better.

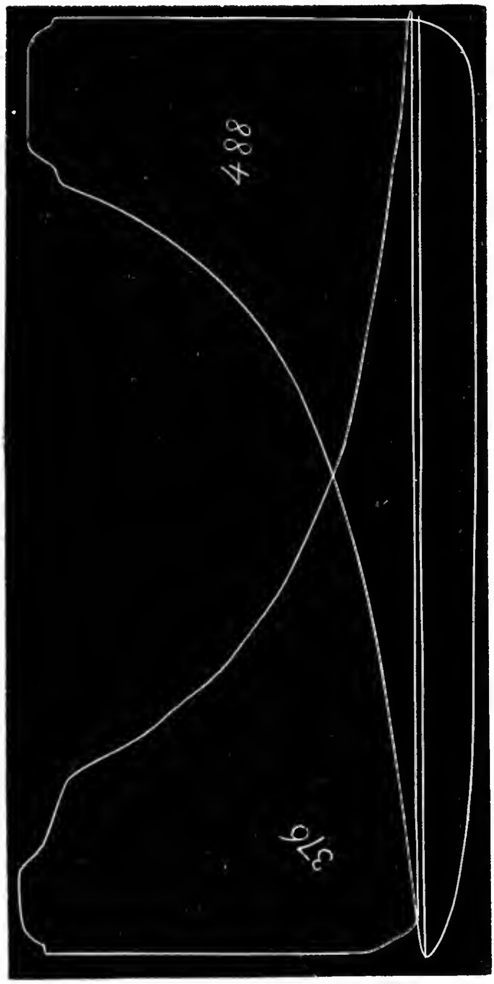


FIG. 22.

The expansion line of all these diagrams is very good indeed. The steam is well handled, and, should the engine be improved a little, with a valve gear such as is now being put upon engines of this size, there is no reason why the amount of fuel consumed will not be made smaller, and the working of the engine more perfect. But taking an engine, which has done duty so long and so regularly, covering 92 per cent. of the theoretical, — with an honest showing, — we must admit, at once, that although the outlines of the cards are not perfect, they are very much nearer perfection than in some newly-built engines, where not quite so much brains have been mixed in their care and management.

It is noticeable that the outlines of the four diagrams are almost exactly identical; a slight leak, perhaps, in one, is almost the only change. The steam lines are very nearly the same, while the expansion lines vary but little. The vacuum is very even, and very nearly alike upon the three-fourths which are used condensing, and it is certainly a credit to the engineer in being able to show such a result after nearly or quite seven years of uninterrupted service. This engine drives the mill by a gear balance wheel. The boiler pressure is from 85 to 90 pounds; the temperature of the hot well, as recorded, is 110, attaining nearly 28 inches of vacuum, even in August.

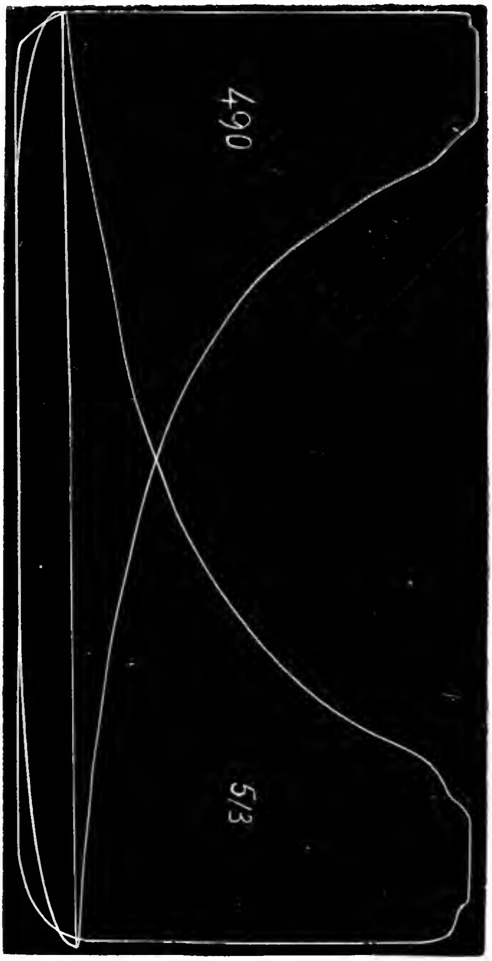


Fig. 23.

One of the most noticeable features is that of 88 pounds of steam, shown by the gauge, at the time the cards were taken, 83 to 85 is shown by the Indicator. This point is often ignored in practice, but it is, nevertheless, one of the most important practical ones. Steam made in the boiler is of no more use, if it cannot be used at full pressure in the cylinder, than money in the bank that cannot be used in the business man's everyday affairs,—with just this difference: the steam costs money to generate,—and there is no use to throttle it down by imperfectly made valves and ports, and no use whatever in attempting to preach economy where the construction of an engine is such as to preclude the realization of boiler pressure in the cylinder. The actual vacuum shown by the Indicator is almost twelve pounds, and varies but slightly upon the three cards. These diagrams will bear careful inspection, and, although not perfect, they are very much beyond the average, and far beyond the general practice in steam engine working. The engineer of this concern believes in the use of the Indicator, and makes a daily report to his agent, of the amount of power, where it is being done, and how; and we believe he must make a pretty good annual return to the concern that employs him, by the use of good judgment and skill in the manipulation of his Indicators and engine.

LESSON X.

In this lesson we have another type of engine, and a different way of working steam, by way of contrast. In this case we have the diagrams (Figs. 24 and 25) from both ends of each cylinder on a pair of horizontal engines, all taken at the same instant of time, four instruments being used. The engine in question is a Buckeye engine, built at Salem, Ohio. It is 22 inches in diameter of cylinder, 44 inches stroke, 90 revolutions per minute, boiler pressure 85 pounds, throttle valve wide open, scale of spring 40. These diagrams were taken for the purpose of ascertaining the condition of the engine, and the amount of power transmitted. The figures show the number of horse-power. The right-hand engine is doing the most work. The outlines of the diagrams are peculiar to this type of engine. The left-hand engine, head-end, has 148¾ horse-power; crank-end, 164 horse-power. The amount of steam pressure shown, when the valve opens, is 66 pounds carried into the cylinder. The dotted lines show the pressure realized as 66, while the fine dotted line above shows the boiler pressure. The mean pressure upon the piston in the diagram doing 164 horse-power, is 21.92 pounds. The engine cuts off at about 8.8 inches, or, say one-fifth of the stroke. The theoretical mean pressure, from an initial pressure of 66 pounds, the ratio of expansion being five, would be 22.01; while, if this engine used the boiler pressure shown by the upper line, only 6.3 inches of the cylinder would be obliged to be filled with steam at each stroke, instead of 8.8 inches at a lower pressure.

Fig. 24.

These diagrams are precisely as they were taken, and they are not by any means the worst we have seen where engines did not approximate to the boiler pressure. It is a very general thing, indeed, not only for this build of engine, but for many others, not to come within 15 to 25 pounds of the boiler pressure; and whoever makes steam, and only uses a proportion of it, throws away a proportion of his coal, which bears a relative value between that which is generated and that which is used. This engine is working under a back pressure, so that we could not obtain precisely the data as to what did exhaust with the pressure valve lifted. The compression upon this engine, as will be seen by the little notch upon two of them, is considerable; so much so that the pressure falls back before the valve is opened. The steam line falls away rapidly after the steam is admitted. The expansion curve is very good, but no doubt the valves were leaking slightly, and perhaps some steam was blown by the piston. These matters are of secondary importance, our object being to instruct our readers, rather than to criticise, except so far that our readers shall learn to read the diagrams as the result of cause.

Upon the right-hand engine, 166 and 171, the compression line will seem to take a different shape, comparatively, from those of the left-hand engine, the admission line commencing nearer the travel of the valve than it does upon the left-hand engine, so that, instead of forming a hook, it forms a point upon one side. This engine, like its fellow, shows a very rapid dropping off of steam pressure after the steam valve commences to open to admit the steam, and the piston to move away. This would raise the question in our mind whether the supply ports were large enough to supply that volume of cylinder with steam; or, as is the case with most slide valves, the travel is so much different from that of the rotary that, in order to be enabled to cut off, the travel is short and the ports usually somewhat smaller than in the case of valves of other forms. The back end of the left-hand engine is doing much less work in proportion than the forward end,—at least ten per cent. difference,—doing nearly twenty per cent. less than the forward end of the right-

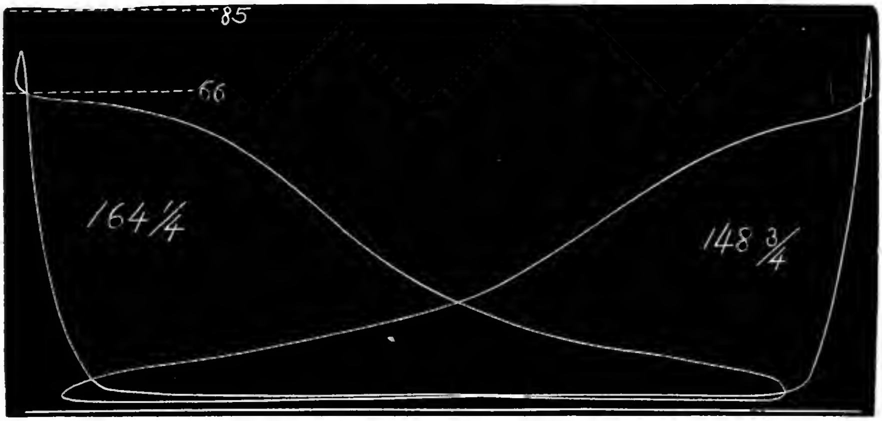


FIG. 25.

hand engine. At the same time the steam is wire drawn worse, or it falls most in pressure after being admitted to the cylinder. Each pair are given as they were taken, those of the right-hand engine, and those of the left. The difference between working 66 pounds 8.8 inches, and 85 pounds 6.3 inches, amounts to 28.2 per cent., very nearly, as the 8.8 inches of the volume of the cylinder, 22 inches in diameter, must be filled with steam, every stroke, to do the amount of work that 6.3 inches in length of the same cylinder would do if boiler pressure were admitted into the cylinder. Aside from this, the card is a very well produced one, — we mean aside from the fact of falling off in boiler pressure, and the loss of effective pressure upon the head of the piston after the steam-valve opens. These diagrams were taken by the writer from the engine, and are a peculiarity of the type or figure produced. We do not know of the economy of the engine, or what is being done by the coal, except that it cannot be economical in comparison.

LESSON XI.

We have, in this lesson (Figs. 26, 27 and 28), not only an interesting, but an instructive subject. These diagrams were taken by the writer, from machinery designed and built by George H. Corliss, to the order of the Committee of Improved Sewerage of the City of Boston. The engine is a double cylinder, having a pair of beams, a cylinder attached to one end of each beam, and the other end of the beam connected with a crank upon the fly-wheel shaft. One of these cylinders carries steam at high pressure, which exhausts into a receiver. The receiver extends from one cylinder to the other, and supplies the low pressure cylinder. The diameter of the high pressure cylinder is 18 inches, that of the low pressure cylinder, 36 inches. Both cylinders

FIG. 26.

have a stroke of 72 inches, and a speed of about 27½ revolutions, or a piston speed of 330 feet. The pump cylinders are connected direct to the walking beam, half-way between the trunnion bearing and the end of the beam, or the point at which the steam cylinder connection is made at one end, and the crank connection at the other, — therefore the speed of the pump plungers per minute is 165 feet of travel. The high pressure diagrams are taken with a 60 spring, by the Thompson Indicator, built by the American Steam Gauge Company; the low pressure, by the same Indicator, with a 20 spring. The vacuum gauge showed 27 inches. The steam gauge showed 119 pounds, of which 112 pounds is exerted on the piston. The high pressure cylinder exhausts under a pressure of 12 to 14 pounds, 11 to 12 pounds of which is utilized in the low pressure cylinder. The instruments were attached to the engine about two o'clock in the afternoon. The engine was neither stopped nor adjusted for taking diagrams. The diagrams were taken in the middle of the day's work, without any notice or preparation, and were not out of our hands from the time we took them from the instruments until they went to the engraver.

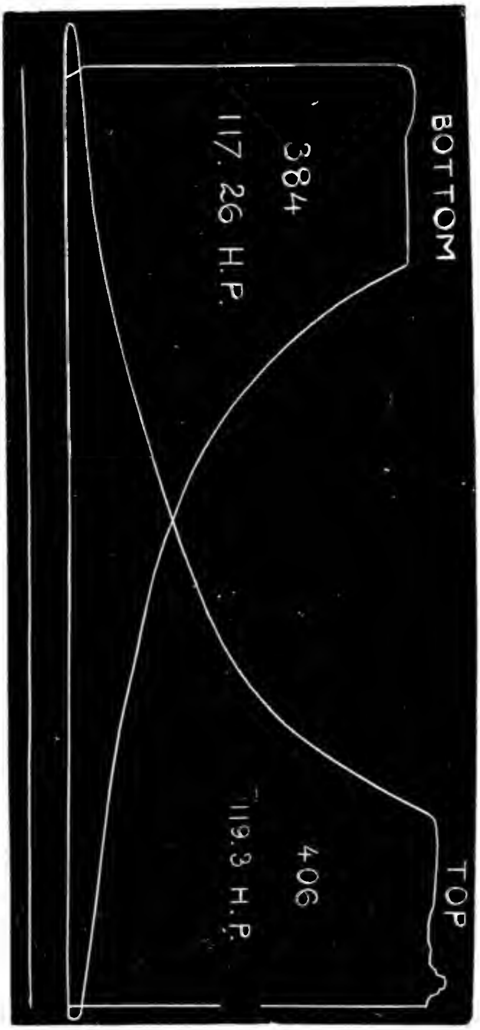


Fig. 27.

This engine has an essentially new arrangement for working the valves. It has no compression whatever upon either cylinder; the exhaust shows precisely what is going on; the high pressure cylinder has a slightly ragged steam line; but the point of cut off is very sharply defined, and the line of expansion is almost theoretically perfect. Another point is particularly noticeable. The low pressure diagrams do not vary one ten-thousandth of one inch in the area of the two diagrams, the planimeter reading of which is given upon each diagram. The high pressure end varies but very slightly when we come to consider the high pressure of the steam, being only two horse-power. The bottom of the high pressure cylinder, and both ends of the low pressure cylinder, vary less than one-fourth of one horse-power.

These diagrams were taken at the same instant of time, and during the same strokes of the engine. The outlines of the cards, aside from the serrations in the steam line, are very perfect indeed. This engine is jacketed, and has produced the wonderful result of 1.37 pounds of coal per indicated and developed horse-power per hour, using poor Cumberland coal at that. The actual power of the four diagrams averaged is 235.73 horse-power. The load in this case is very nearly constant, and consisted in lifting water to a height of 47.3 feet.

The reading of the planimeter and the horse-power are both given upon each of the diagrams, and it will be an interesting study for those who are versed in the use of steam, or those who are used to reading the Indicator cards, to give these some attention. Ninety-eight per cent. of the boiler pressure is utilized in the high pressure cylinder, and from 95 to 97½ per cent. of the receiver pressure is utilized in the low pressure engine. The vacuum attained is from 12½ to 13 pounds, and the temperature was not below 70° F. when these diagrams were taken. The action of the valves may be noticed particularly by all lovers of a first-rate diagram. The corners are as sharp and well defined as it is possible to make them, and if the Indicator had not been an almost completely perfect instrument it would not have shown it as it has. The vacuum line of the low pressure engine is particularly worthy of careful consideration. The condenser takes hold sharply and maintains its hold, making the corner as sharp as can be. This is a truly remarkable production. The lines upon the high pressure engine show as perfect a working of steam as we ever saw from any engine, while the production of this engine in duty has surpassed that of any other engine ever built, and tested at work, so far as we are informed.

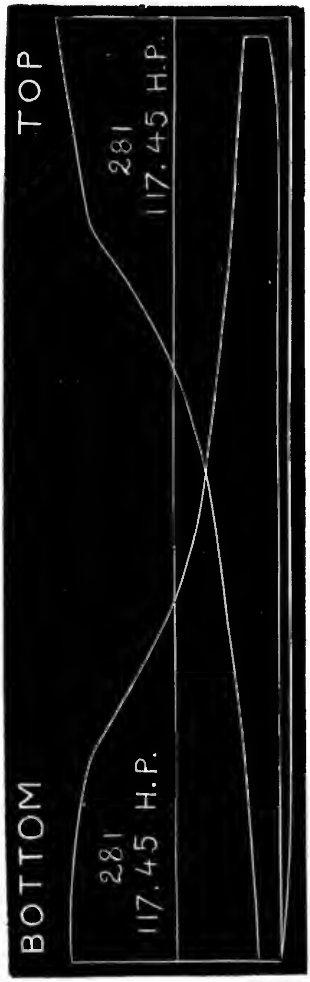


FIG. 28.

Diagram 27 is a pump card, taken directly from the pump, Thompson Indicator, 20 spring. The head under which the instrument was at the time was 47.3 feet. The dimension of the pump and its speed are given above. The pressure upon the Indicator is that due to a head of water of that height.

The lines of the card indicate that the pump is filled and kept full by the action of the piston or plunger. This card will also bear examination and comparison, and it must be further understood that this engine has not received any special elaboration, but was built and running five months and three days from the reception of the order. When the order was received, no drafts or patterns were in existence, and the original working parts of the engine have never been tampered with. The engine was not assembled until it was put together out of doors ready to go to work, in such a position that it could not be lined or leveled, except one part with another. The bearings for the beams to work on are 54 feet above the level of the ground. When standing upon the gallery, there is no jar or shock to the machine in its working at full speed and under its full load, pumping twenty-five million gallons of water 47.3 feet high. The performance of the engine, we believe, has never been equaled in the world, or at least in engineering records.

The engine is at work at the Pettaconsett works of the Providence Water Works, with a set of pumps entirely different from those which it was working at the time of this test. The pumps which were first used were adapted and constructed for pumping sewage, while the pumps which are now in operation are of the same general construction, although different in shape, as those which have done such economical work in the Pawtucket Water Works, and the engine which was guaranteed by Mr. Corliss to develop 100,000,000 duty, has shown +113,000,000 in its test by the city engineer of Providence.

LESSON XII.

THE educated man, — educated, we mean, in practice, — and the practical engineer will see, in examining the diagrams in this lesson (Figs. 29 and 30), two of the most elegantly perfect steam engine diagrams that they have ever laid eyes upon. These diagrams were taken from the Pawtucket (R. I.) Water Works pumping engine, built by George H. Corliss, and which, up to the time of the construction of the Boston sewage pumping engine, by Mr. Corliss, had accomplished the largest duty in the lifting of water that had ever been attained by any engine in actual operation, in a practical way, under the control and daily management of the engineer in charge.

A description of this engine will not be out of place. It is a compound engine of the horizontal pattern. The high pressure cylinder, 15 inches in diameter, 30 inches stroke; the low pressure cylinder, 30 inches diameter, 30 inches stroke. The pumps are in a hollow casting, which serve also for a pillow-block for the fly-wheel, which is mounted between the cylinders. The pump is in the lower part of this pillow-block casting, and is attached directly to the same rod that the piston is. The slides are in the rear of the pillow-block, where it is connected with a peculiar rocker-motion, which is again connected to the crank upon the fly-wheel shaft upon either side of the engine. The diameter of the pump barrel is 15 inches, the diameter of the plunger is 10.52 inches. The diameter of the air-pump is 20 inches, length of stroke 7¼ inches. The suction and discharge pipes are 15 inches in diameter; the fly-wheel is 18 inches in diameter. Three boilers are used, 14 feet high, 4 feet in diameter, 48 tubes three inches in diameter, the fire-chamber being 40 inches high. The grate surface is 19.63 square feet, the fire surface 560 square feet, the average steam space 3¼ to 4 feet, — it is supposed that the steam space means 3¼ feet to 4 feet in height, of the boiler, — the steam pressure, 125 pounds; average water pressure, 110 pounds; the head against the pump is 269.1 feet; displacement at one revolution, 5.6592 square feet. The test of this engine for twelve days, running ten hours, and lying still fourteen hours, gave 104,357,654 foot pounds for every one hundred pounds of coal. This trial was made on August 6th, and the days following, in 1878. The engine was started pumping February 2d, 1878, pumping directly into the pipes until November 6th, 1878. After it was put in charge of the engineer, the duty for the first year was 106,234,300 foot pounds on all fuel consumed in pumping.

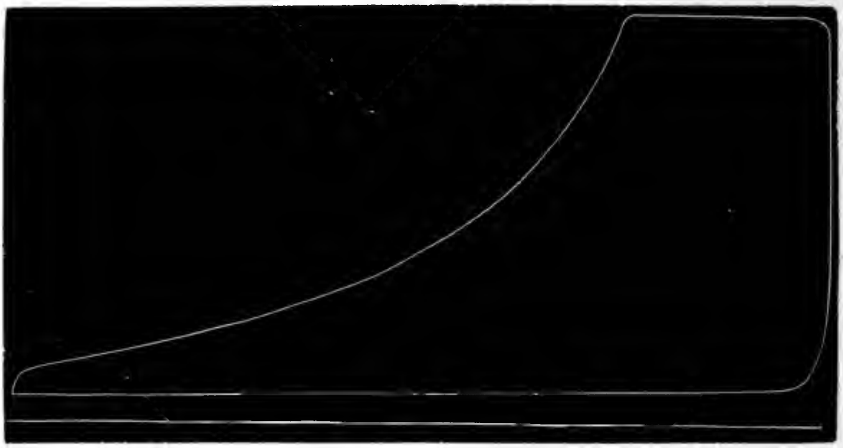


FIG. 29.

One diagram shown is from the high pressure cylinder, 15 inches in diameter, 30 inches stroke, 46 revolutions per minute, steam at 125 pounds, scale 58. There is only one criticism to make upon this diagram. It is absolutely perfect. Taking the clearance of the engine, the expansion curve is so nearly perfect that it is no use to express it in any other way. The steam line, as well as the admission line, are almost geometrical forms. The expansion curve in this card is slightly better than that of the engine built for the Boston Sewage Committee, mentioned in the preceding lesson, and the reason for this may be found in the fact, probably, that the engine makes 46 strokes instead of 27½. The other diagram is from the low pressure cylinder of the same engine, 30 inches diameter, 30 inches stroke. The pressure from the high pressure cylinder is almost entirely utilized in the low pressure. The vacuum is as good as it can be in practice, approaching the theoretical very closely. The condenser takes full hold very early in the stroke, and maintains an elegant vacuum line until the valve closes. The difference between the high pressure cylinder, and that of the imitators of Mr. Corliss is, that they cannot obtain a steam line which amounts to boiler pressure. In this case, nearly the entire boiler pressure is secured by the piston. The steam line falls one pound before it is cut off. These diagrams were taken without any preparation. The coal consumption was 1.8 pounds per horse-power per hour, and there have been no repairs on the engine since it was started. It had done over five years' work, of ten hours per day, at the time the diagrams were taken.

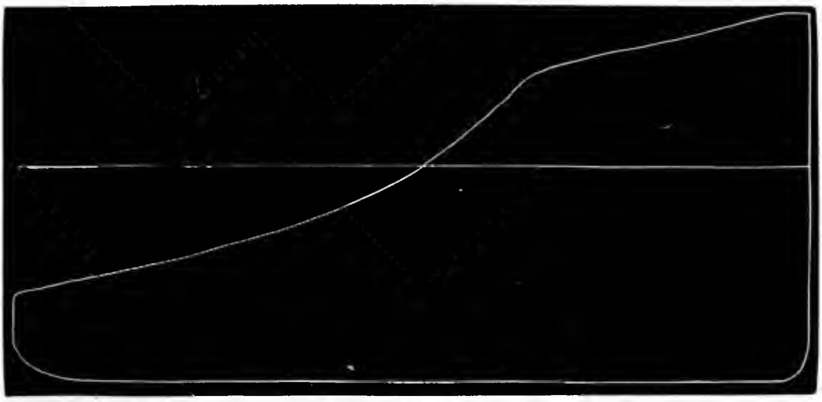


FIG. 30.

We have seen and taken thousands of diagrams in actual practice, and we have yet to see one that approximates these in absolutely answering every requirement of the engineer, and we believe it will be a long time before we see another. The record of the engine has been that of a perfect working machine, furnished within the time it was promised, at the price at which it was engaged, and instead of doing 30 per cent. of the work that it was contracted for, it did over 30 per cent. more work than Mr. Corliss guaranteed it to do.

Diagrams may be taken almost absolutely perfect, and if engineers who study these lessons with an eye to benefit themselves, can produce such diagrams upon their cylinders in actual working, as that of the high pressure cylinder, they will not have to figure very largely upon coal; and when their engine is in condition to make these, they need not fear extensive bills for repairs.

LESSON XIII.

In this lesson we have, for the moment, abandoned actual practice in reading, for the best effect, and show matters which are occasionally found in actual practice. Fig. 31 is a card taken from a Corliss engine, 20⅜ inches diameter, four feet stroke, 60 revolutions, 72 pounds boiler pressure, 30 spring. This engine has received a great deal of attention from a number of parties. There was known to be a fault existing, and yet the fault was not traced, and the trouble was not remedied. The expansion line seems to be good, and the atmospheric and exhaust lines fairly run into each other, so that no trouble could exist in that region. There is no compression, but there is a curious hump at A, which might occur from one of two things, but in this case it was an anomaly. The cylinder head was taken off, and the full pressure of steam on the steam valve showed that the valve did not leak; consequently it was not a leaky steam valve. The question then arose, Where was the trouble?

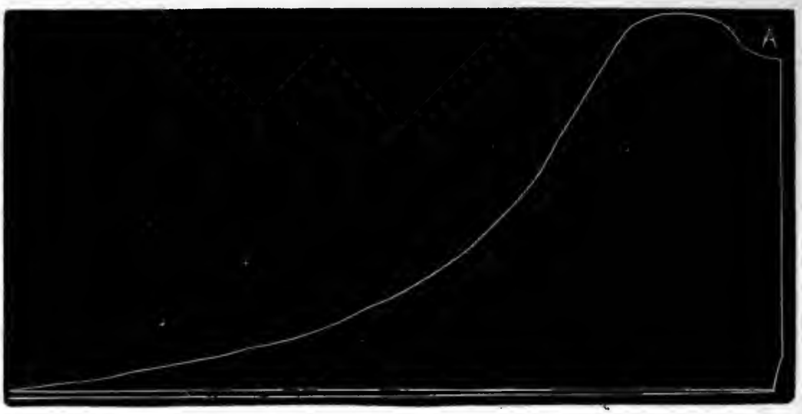


Fig. 31.

The engine was started again and, as we have stated, several engineers gave up the problem, declaring that the engine was not properly constructed. Mr. Mosman (now deceased), with the American Steam Gauge Company, was sent to examine the engine, and it was a considerable problem to him, as well as tedious. He made all the ordinary tests, found the valves tight, and then began to use his judgment. Upon experimenting with the exhaust valve in this end of the machine, it was found, after the engine had moved an inch or two of the stroke, that the exhaust valve had been set so that it opened upon the back side, and allowed the steam, or a portion of it at least, for two or three inches of the stroke, to pass by. This was corrected, and the trouble was at an end. And yet there are two or three engineers who declare that the engine is not right, and cannot be made right, although it makes as handsome a diagram as any Corliss engine that has been in use, and been taken good care of. It was a very serious defect, and it was a puzzle.

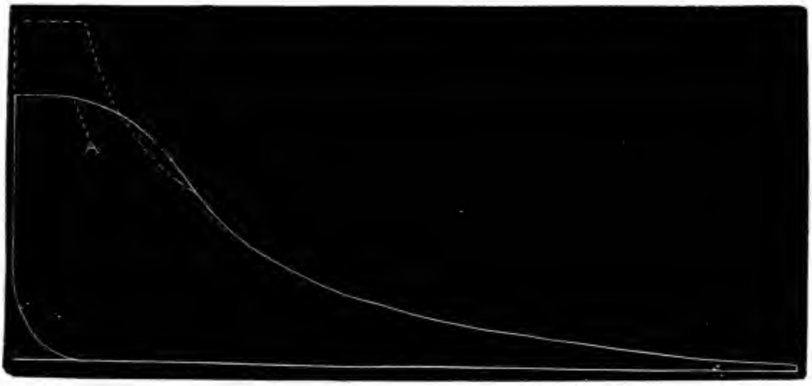


FIG. 32.

Fig. 32 represents a not uncommonly found result. In this case the engine gets blamed for what the Indicator is at fault about. And yet the Indicator, with which this was taken, was in the hands of an expert. The cut off is very near the point, A, and the dotted line, and would extend above the line as shown by the dotted line, but in this case the instrument leaks, the piston and the cylinder both being worn, — we mean the piston and cylinder of the Indicator, — hence, in this case, the Indicator is very unreliable. This can be ascertained fully by actual tests, and whoever reads this diagram, and is posted in his business, would find, upon applying the expansion curve, that the point of cut off was very much shorter than that shown in the card. This case was also handed over to our friend Mosman, and the Indicator was afterwards reorganized.

Fig. 33 is another case of a most peculiar diagram. The admission line is straight, the engine taking steam like a hurricane, but the piston Indicator drops from the point, A, to that of B, in precisely the same way that it comes up on the admission line. This line is not due to the action of the engine, but the piston, or the cylinder, or both, were grooved, the steam being shot into it, the piston moving at a good speed. When the Indicator commences to descend, it goes out of all semblance of real expansion, because the steam shoots through the grooves until it partially seats itself again, when the vibration makes the little notch in the expansion line. All these are matters which can only be learned by practical demonstration, and this is a most peculiar case, yet it is not the only one we have ever seen. An Indicator, to be reliable, must have a considerable amount of attention paid to it. The engineer must know how to apply tests for correctness, and he must know how to read the lines which he gets, and know what is possible to be made by his carelessness, or lack of attention, in applying his motion, as well as in seeing that his instrument is in perfect order.

The effect of either one of the illustrations which we have given, if a man were ignorant at all of the true reading of the lines, would be to go on with

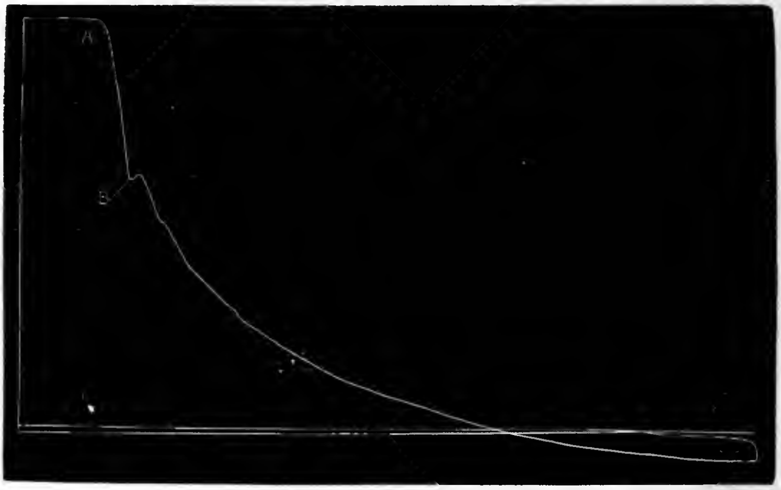


FIG. 33.

poor work, condemning the engine for what, in two of the cases, is clearly the fault of the instrument, and, in Fig. 31, a lack of brains in whoever attempted any such mal-adjustment; but there are certain engineers who run by the rule of thumb, and it proves a very expensive rule to run by for the man who pays for the coal. If a man has no care for the interests of his employers, he is the last man in the world to have the handling of an Indicator or the running of a steam engine.

These three illustrations make one of the most interesting lessons which we have given. They are from positive fact, in actual practice. In every case the information which they embody has been most dearly bought by the parties who were paying for the fuel which was run through the engines in question.

If an engineer will pay attention to these lines, and remember how they can be caused, he will then, whenever a difficult or seemingly uncommon card is presented for him to read, remember, from his own experience, or from his reading, — if he observes and remembers, — that certain matters will cause certain results, and he will be enabled to judge of the probability of these without experimenting at the expense of his employer. A man to be successful with the Indicator must be one who reasons, and applies the somewhat uncommon rule of common sense; and the man who has the most common sense is the man who oftenest succeeds in obtaining excellent results from the proper use of his instrument.

LESSON XIV.

It is frequently stated that the Indicator is of very little use, except for the careful noting of results, or for the following out of doctrines or theories which relate, more particularly, to expert tests. This assertion is as void of truth, and is as far from the fact, as it is possible to put any given number of words into a sentence attempting to mean something, and yet make a signal failure of it.

Fig. 34 is a curious figure to be described by an instrument. This was taken from a 250 horse-power engine, made by Charles S. Brown, of Fitchburg, but Mr. Brown, in his adjustment of the engine, did not make any such card as this. One of those men who know everything but one, and who never use the Indicator, — a man who was able to set the valves of an engine by the marks, or by gauges, or measures, or by guess, or something else, — made his arrangemenents upon this engine, and when he got the machine in such a condition that it would not run with much more than half its usual load, he concluded that the engine was not worth anything; and the owners of the engine concluded that they must find somebody who could tell them whether the engine was good, bad, or indifferent. The diagram in question was one of the first ones taken after the adjustment of the instrument, and it fully illustrates the folly—or foolishness, to use a plainer word—of a man in attempting to tinker with the valves of an engine. In this case the exhaust valve closes at A, while the stroke ends at B. Compression takes place, which carries the piston of the Indicator to C, when it follows the outer line back to D, as the piston starts on its return stroke. At this point, rather late in the day, the steam valve opens; but, as a stern chase is always a long one, the engine gets steam all the way, from D to E, as the motion of the piston is shown by the leaning line from D to E, and the pressure cannot be brought up fully, because the piston is moving, and requires a very large amount of steam, in order to fill the volume of the cylinder from B to D, which could not be filled until after the valve opened at D. From E to F, the steam line is short, where the cut off takes place. The expansion line is good, the exhaust line is first-rate, but the line, E, G, B, D, C, simply represents lost work or steam used after it could be useful, or of any effect. The area of these figures is respectively 194 effective, and 70 absolutely lost or thrown away. Undoubtedly, if the steam had been properly applied, 210 to 220 would have expressed the whole area; but, in this case, one-third of the steam used is absolutely thrown away. This is an interesting study to show what can be done by these men,—and we believe there are less of them than ten years ago,—who can set an engine by their ear, or by marks, and it will be a caution to those among our readers who have the good sense to let alone matters which they cannot be positively sure of. After the engine was properly adjusted, there was no more doubt as to whether Mr. Brown's work was or was not up to his ordinary standard.

Fig. 34.

Fig. 35 represents, truthfully, only the proportion that is being done by the different ends of the engine. The little hooks at A, and the badly formed lines, B, are due to the inferiority of the instrument, which was in very bad order. In this case the instrument leaked. When the compression was made, before the valve opened, the steam came through the instrument to a certain extent, so that the piston, by the action of the spring, dropped, making this hook. There is no point of cut off upon the one. Upon the other, the cut off is squarer, but, at the same time, it falls like a brick. Very little need be said of these diagrams, except to show that an instrument, which is not properly adjusted, or which is not as it should be, may mislead a man very seriously in getting at the effective value of the work being produced.

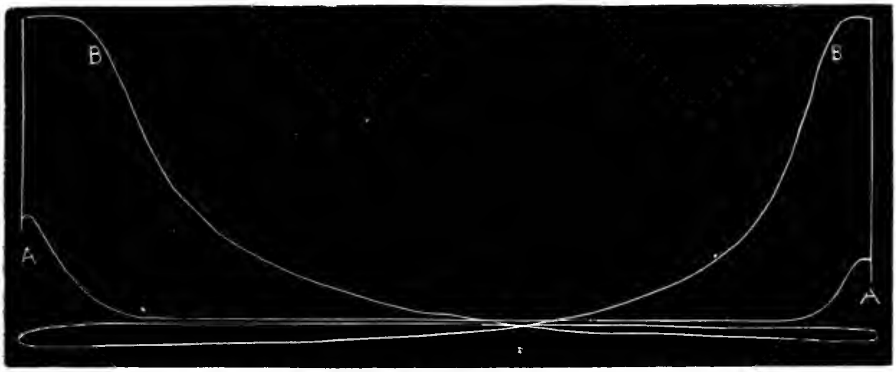


FIG. 35.

LESSON XV.

THE diagrams in the present lesson are of more than passing interest, and were taken from the engine of a man who places no value on the Indicator. It is only necessary to say that the diagrams were only taken when he found that something was the matter, which his engineer could not manage; and this is only one of numerous practical applications of the value of the Indicator, which the expert in its use is continually meeting. The engine in question is a Harris-Corliss, 14 inches diameter of cylinder, 42 inches length of stroke, 60 revolutions per minute, the pressure in the boiler varying from 65 to 75 pounds. The diagrams, Figs. 36 and 37, are from the different ends of the engine, 37 being the crank end, and 36 the head end. Fig. 37 is one of those peculiar looking ones which we frequently meet with in actual practice, more especially from engineers who know exactly how to set their valves by a scratch or prick punch mark; and they can tell exactly how "she takes steam" by watching the cut-off slide. The engineer, in this case, simply had to give it up, and if he had gone a few steps further, his engine would have run the other way. Fig. 36 shows three lines, as they were taken from the instrument, and they are most wretchedly irregular lines too. The steam line is as full of humps as a camel's back, and the notches and irregularities are the exact counterpart of the movements or action of the steam, as it is admitted to the cylinder. The admission line, in itself, is very late. The steam valve commences to open only after the piston has commenced its stroke. It does not open fully until after the piston has traveled several inches. The exhaust will be seen to be very late, upon both diagrams, Figs. 36 and 37. It is comparatively small in its showing upon Fig. 36, from the fact that it shows a very much lighter load than that of Fig. 37. The amount of power,—32.4 horse-power,—given on Fig. 36, is the mean of three lines, the largest amount being plus 50 and the smallest only 22. Fig. 37 has the same general outline as Fig. 36, but in this case Fig. 36 was set to cut off at less distance than Fig. 37, so that Fig. 37 is only a single line, and is doing three-quarters the work of the engine. The line, in the case of Fig. 37, is very bad indeed. The valve does not commence to open until after the piston has started on its return stroke. The cut off is very badly defined, and might lead to the idea that the valves were leaking badly, but no experienced engineer would try to ascertain this question until the valves were in proper position. The toe at the end of the expansion, at the commencement of the exhaust line, is an additional amount of work thrown away.

FIG. 36.

This is only a fair specimen of the way that many engineers get their valves, and they are always found in the hands of those people who do not use the Indicator, and who frequently make the assertion that they do not believe in the Indicator, for it is of no use. All such are perfectly welcome to their belief, and their employers sometimes change their minds when the engine has been properly indicated and adjusted by those who do believe in the Indicator, and who know how to apply it and read properly its results.

C and D (Fig. 38) are from the very same engine, after the Indicator had been properly applied, and the needed corrections made in the motion of the valves. The horse-power is almost identically the same in both, the fractions being very small. The compression is, almost to a unit, the same. The admission line is lost in the proper compression, and the steam line is carried as straight as a line can be. The line of expansion shows very little loss, and the diagram, taken altogether, is a very good production. It is needless to say that a very considerable saving of fuel resulted as the difference between the engineer's setting, Figs. 36 and 37, and the man who applied the Indicator in Fig. 38. These diagrams are from actual practice, and were given us by the late Mr. Mosman, of the American Steam Gauge Company. They were taken with 40 springs, and the engine at its regular work. Probably the question never entered the head of the engineer in charge, as to the result of the use of steam, as in the diagrams, Figs. 36 and 37. The steam in Fig. 36 is admitted, in all sorts of quantity, in the endeavor of the regulator to reach after and equalize the load, which is done in the other end of the cylinder; but

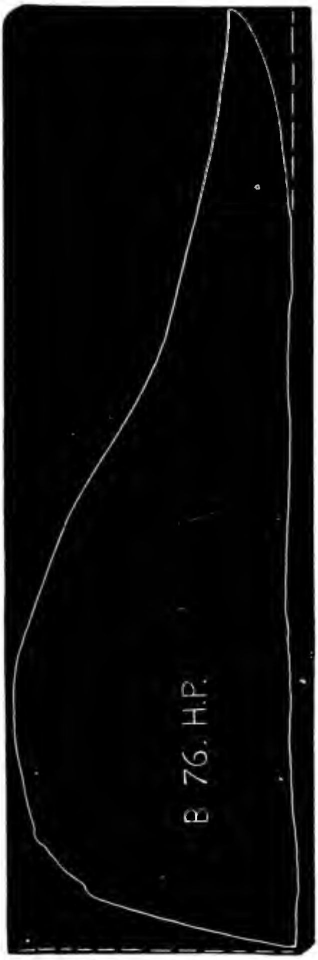


FIG. 37.

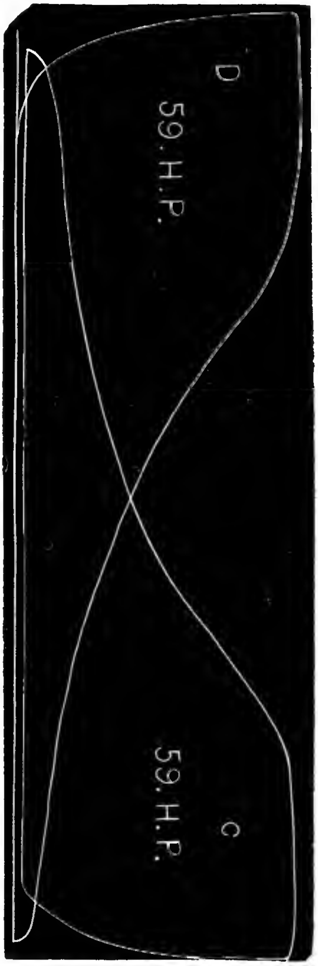


FIG. 38.

as the cut-off slides are set, in Fig. 38, to cut off longer than is necessary, and in Fig. 36 are set shorter than they should be, it is simply impossible for the regulator to adjust the difference between them; for the difference is so great that the regulator cannot measure it by the differential strokes of the cut-off slides, or the motion which is given them through the change of position of the balls on the governor. In this case the crank end of the engine is doing more than double that of the head end, and these motions of the head end are shown in the irregular steam lines by its race after the other end of the engine; and exactly in proportion as these lines differ from each other was the resistance or the strain upon the different parts of the engine, differing at each end of the stroke, making 120 times per minute. In other words, the engine jumps 120 times a minute after its load, and the regulator is simply unable to adjust the difference; or, in other words, is attempting to accomplish an impossibility. The engine in this case is using something like forty per cent. or more steam than would be necessary, when properly adjusted, as is seen in Figs. 37 and 38. This is only another important lesson that people can learn if they will, but usually only learn when they are obliged to. It is all the more to the credit of the Indicator that it is able to show up, in the hands of an experienced manipulator, these points where pocket value is the result attained; and in a case like this, the amount of coal burned, before and after adjustment, is a factor that can always be measured in dollars and cents. This is the standard of too many steam users in quite an opposite direction.

LESSON XVI.

In this lesson we have a decided difference in engineering practice, and upon one of the points which we have dwelt in previous lessons, and which will be distinctly exemplified by the comparison between the cards. It refers to the realization of the boiler pressure of the cylinder. The diagrams, A, B (Fig. 39), were sent us by a correspondent, with the following data: Buckeye engine, 14 × 28, 40 scale, 70 pounds steam, 112 revolutions. Diagrams taken with one instrument standing in the middle of the cylinder,—which, we suppose, means taken with a three-way cock. A is the crank end of the engine; B is the head end. The figures 102 and 116 represent respectively the area of the diagram, as measured by the planimeter. C, C, represents, by the little white line above the letter, the 70 pounds boiler pressure. D represents the atmospheric line of the instrument. Our correspondent writes: "My vacuum gauge reads 25 inches, while the vacuum on the instrument only shows four pounds, or eight inches." He further writes: "Will you please give me some information in regard to setting the valves?"

We cannot give any information regarding the setting of the valves from the diagrams given. The engine appears to be working free, and really it is the best pair of Buckeye diagrams we ever saw taken from actual practice,—we mean the outline and apparent action of the valve. In taking diagrams with the three-way cock, where there is any variation in the load, it is absolutely impossible to balance, as we term it, each end of the cylinder, and have one do the same amount of work as the other on its return stroke. If both of these diagrams had been taken upon the same stroke of the engine, with two instruments, one upon either end, we should say, by all odds, to set the valve so that the crank would not be cut off quite so soon. The particular feature about these cards is one which we generally find on this kind of an engine—it fails to utilize the full amount of the boiler pressure. In another set of cards, sent by the same party, from the same engine, and doing much more load, the head end measures 227, and the crank end 194 on the planimeter. In this case, quite a considerable difference is therefore indicated in horse-power, the head end, as is generally the case, doing the most work. Taking the pressure of the steam and the point of cut off, this diagram approaches the theoretical curve in a very practical degree.

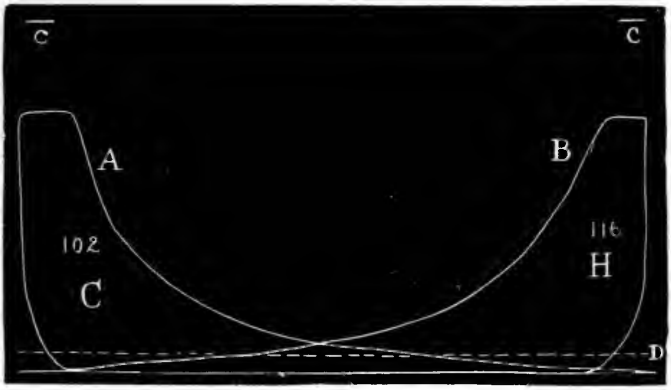


FIG. 39.

The diagrams, C, D (Fig. 40), were taken from a Harris-Corliss engine, 36 × 14 inches, in the Massachusetts Charitable Mechanic Association building, at the exhibition of 1881; 75 revolutions, 40 spring, boiler pressure 85 pounds,—the steam was carried some distance,—gauge on the pipe 82 pounds. The Thompson Indicator was applied by Mr. Mosman for the American Steam

Gauge Company. The initial pressure, as the Indicator records it, is 78.5 pounds. These diagrams were taken by a three-way cock, but under radically different circumstances from those which are shown by the diagram in Fig. 40. The engine had no connection with any machinery in the building, except the dynamo machines for the electric lights. The engine regulated in the very best possible manner, the variation in speed was almost nothing, being run, therefore, with as constant a load as it was possible to attach to it, diagrams being taken by turning the cock. Probably one was taken upon one stroke of the engine, and the other not missing more than one or two strokes, while the load, at the same time, is shown by twelve pairs of diagrams, which we have, and which varied much less than one horse-power in twelve sets. One end reads 420 on the planimeter, and the other 417. This is a result that is very seldom obtained in practice, and in this case it was undoubtedly effected by good judgment and careful adjustment by the parties in charge of the engine.

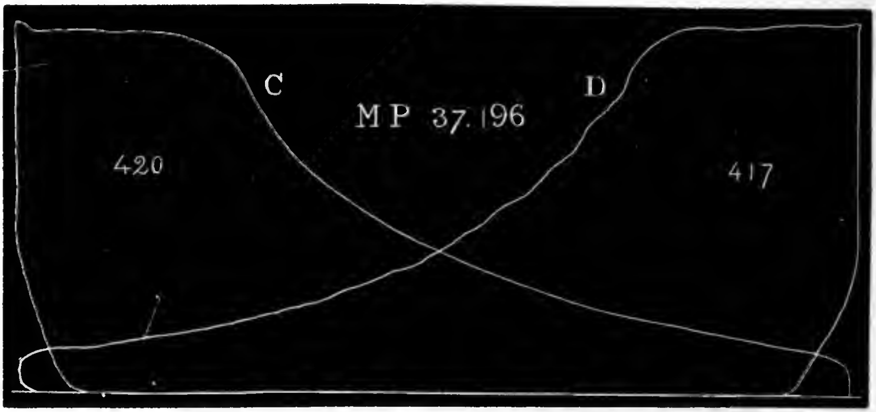


Fig. 40.

In this case it will be seen that almost ninety-six per cent. of the steam pipe pressure is actually shown by the piston of the Indicator and its pencil attachment. Two cases could hardly show more completely the difference in the practice of two engine builders. The Harris-Corliss engine was making 450 feet piston speed per minute. This result shows that the Indicator is reliable, when in practical hands, to a nicety that was hardly credited to it a few years since, even by men of experience and who should have had confidence in their own opinions. And yet there are men who call themselves engineers, who attempt to belittle the results of the Indicator's reading, or practical application. But one thing is certain — engine builders are coming to place more and more reliance upon the application of the Indicator in practical hands; and a man who has any breadth of practice with the Indicator can demonstrate to the absolute satisfaction of any party who knows enough to know the difference between twelve tons of coal a day and fifteen tons of coal a day, that the man who sets by marks or spots, prick punches, or the end of his thumb, may work a week upon an engine in setting the valves, and the practical application of the Indicator will demonstrate that in this way the valves of any good engine could not be set within a row of apple trees of right, and apple trees are usually not nearer than twenty feet apart.

LESSON XVII.

THE cards in this lesson are from actual practice, by an engineer who seems to know something about the Indicator, and that it is something more than a curiosity or a plaything. They were sent us by a correspondent, who asked several questions. Fig. 41 is a diagram from a modern built engine, with so-called Greene cut-off. The party running this engine supposed he had arrived at the limit of its power. After the valves had been adjusted, twenty pounds less boiler pressure were used, with a very great saving in fuel. The size of this engine is 12 inches diameter, 36 inches stroke, 50 revolutions per minute, boiler pressure 55 pounds, scale 40. Our correspondent stated that the valves were left, by the man who put them in, so that they produced this diagram. This is rather a curious looking figure, yet, by no means, an uncommon one. B shows the boiler pressure, and what would have been the admission line, if the valves had been in order. The valves do not fully open, so as to admit any approximation to the boiler pressure, until after the piston has traveled more than one-fifth of its stroke. We should judge from its length, after it gets a steam line, that the engine was heavily loaded for its capacity, although little can be told as to the load which the engine is really doing from such an outrageous outline as this. The steam is carried for a large proportion of the stroke, the expansion line is irregular, the exhaust valve only partially opens at C, while, if it opened as it should, it would commence at D, and make the line, D, E. In this case the exhaust valve really opens at C, and the piston returns some distance before the steam is freely exhausted. For some reason—we cannot see why—there seems to be a small amount of compressed steam at E. When the piston starts upon its return stroke, the piston of the Indicator drops, and the under portion of the loop is formed. After the piston has returned upon its stroke, and the lines cross each other, the steam valve seems to open but slightly, and the admission line commences at F. The engine works under a small amount of back pressure, and makes a very poor use of the steam which is fed to it from the boiler; and if our correspondent had sent us a card showing the engine correctly working with approximately the same load and the same amount of steam, it would have been an easy matter to have told him what the loss was in this card, which cannot now be told. It is only an illustration of how badly an engine will work when it is not properly taken care of.

Fig. 41.

Fig. 42 is a diagram from the same correspondent, from a full stroke engine, doing from 12 to 18 horse-power, and using coal enough to run forty horse-power with any kind of decent usage. The cylinder was 18 inches in diameter, stroke 12 inches, 100 revolutions per minute, boiler pressure 60 pounds, scale 40, vertical engine. While this is an old-fashioned engine, and we may expect old-fashioned practice, it has some peculiarities of its own not at all in its favor. A represents the line of boiler pressure; B, the admission line; C, the steam line; D, the line of curiosity; E, getting ready to exhaust; F, the exhaust valve opens; G, the atmospheric line of the instrument. The line of curiosity, as we have expressed it, is really the pressure in the cylinder increased after the expansion has taken place. This very seldom occurs in well constructed engines. When, in all probability, all the steam had been given which was required, — the engine was a double port one, — and after the valve had made its travel, the ports were temporarily opened during the last of the stroke of the piston; therefore the piston of the Indicator was raised by the admission of more steam, or the governor opened the valve from a changed speed. Not knowing the real construction of the engine, this is only a guess, but it is one of the things sometimes found in actual practice. In any event, the exhaust of this engine is about as poor as it can be. The valve opens very slightly at E, commences to open thoroughly between E and F, and gets open so as to reduce the pressure in the cylinder just before it closes for the admission line, B. We do not wonder that our correspondent felt curious, for he has really struck the old curiosity shop in Indicator diagrams; but, stranger than his personal adventure, is the fact that men are still found who do and will use engines making just these same botch-work diagrams. There can hardly be two instances where steam is worse misused than in the two diagrams shown. Fig. 41 is entirely the fault of the operator; Fig. 42 is really without any remedy, except to put the engine into the old scrap pile, where it ought to have been put years ago, if fuel is of any account.

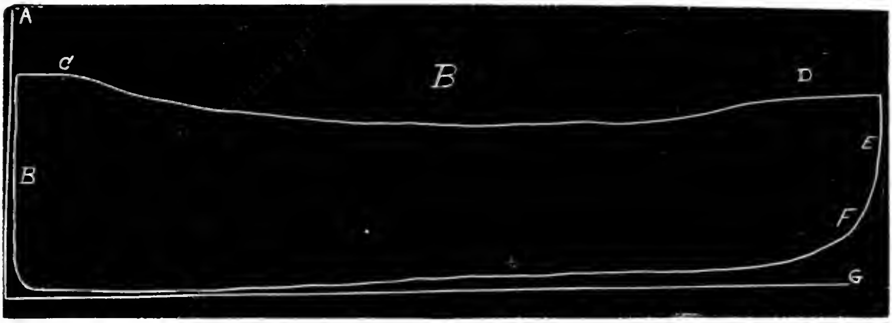


FIG. 42.

LESSON XVIII.

IN this lesson we have some peculiar looking diagrams, and they are also peculiar in another sense — peculiarly wasteful. They seem to be lacking in every respect where economy has any claim, and yet the engines from which these diagrams were taken are in use, and undoubtedly the men who are using them consider that they have a pretty good arrangement for a steam engine. The diagram (Fig. 43) really required considerable study on our part to ascertain which end up it was; and we only found, after corresponding, that the party who sent it to us was not joking; he only sent it as a curiosity, — something which he picked up in actual practice, no longer ago than June, 1881. The data, which comes with it, is as follows: Diameter of cylinder, 12 inches; length of stroke, 24 inches; revolutions per minute, 85; boiler pressure, 75 pounds; scale, 20. As this has a throttle regulator, there is, of course, no approximation to the boiler pressure; the actual realized pressure on impact is from 35 to 36 pounds. The engine would seem to take its steam early enough, but its carrying line, or steam line proper, has a variety of contortions in it which have no significance, no economy, do not approximate to good practice, and are all as nearly bad as need be. The commencement of the exhaust, at C, is the commencement of a struggle. The engine, as we have mentioned before, takes steam at about 35 pounds; when the exhaust valve commences to open at C, the engine commences to exhaust under precisely 30 pounds back pressure. After one-half of the cylinder has been exhausted, we still find 14 pounds of back pressure on the line, D, and at the termination of the back pressure, or when the valve closes, we still find 8½ pounds at E, the area of the figure, by the Indicator, showing that the power exerted is 295, while the area of the figure between the diagram proper and the line of rest of the instrument, or the real atmospheric line, has an area of 229. In other words, if this engine were doing 295 horse-power by the steam which is used, it would be working under a back pressure of 229 horse-power; and if the back pressure were only a little larger, it might be a question whether the engine would run at all, or if it would not start and run the other way. We believe that there are not many such engines as this in use—at least, we should hope not. But it is only a question. No doubt the man who constructed this engine had in his mind a good working one, and that he made the ports and the travel of the valves, and the lap and the lead, and all those things, just as nearly right as he could. Probably the introduction of the Indicator would somewhat, at first, surprise the man running the engine; but if he could not read the lines to see what was doing inside the cylinder, he could evidently understand, if fuel was of any value at all, after having these lines explained to him, that one-half the fuel which he burned was a little worse than thrown away,—in fact, he was burning two pounds and twenty-nine hundredths to put a brake on to the two and ninety-five hundredths which did the work,—whereas, had this engine been making use of its steam at the same pressure, so that the valves would have exhausted properly, instead

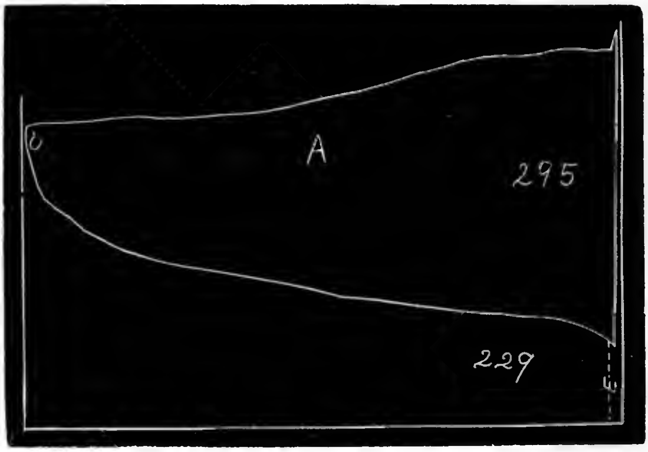


FIG. 43.

of having 295 horse-power of work, and 229 horse-power of back pressure, the outline of a figure, constructed to properly take charge of the steam, would yield 426 horse-power; hence, here is a waste almost equal to one-half of the fuel, and, at the same time, only a trifle more than one-half of the proper load which the engine should do, is being yielded. Twice two being four, the engine is using four times the amount of fuel it should do to develop the load which the Indicator shows is being done. Aside from the fact that some men still exist who do not think the Indicator has fulfilled its mission, or that a man can set the valves of his engine by his eye or ear, jack-knife or rule, this diagram would not be worth the space it occupies.

In Fig. 44, we have another style of engine, a different style of diagram, a radically different result, — but the same principles are embodied, — and although not to quite so great an extent in percentage, the result of loss is much larger than in the small engine. This diagram was taken in a saw-mill, in the northern part of Michigan. We have frequently read that a saw-mill was a rough place, but we did not suppose they would work steam on exactly this kind of a scale. The data, which comes with this diagram, is as follows: Cylinder, 28 × 28 inches; 100 revolutions per minute; boiler pressure, 105 pounds; scale, 40; the ports, 2 inches by 18, for steam; exhaust ports, 3⅜ by 18 inches; lap on each end of the valve, $\frac{13}{16}$. This is rather a peculiar shaped diagram. The dotted line, A, is the initial pressure, 80 pounds; the regulator, therefore, stifles the engine from 25 pounds of working pressure. The steam ports of this engine seem to be, for their size and stroke, nearer the correct area than the exhaust ports, — the difference in pressure in the length of the stroke, at the point B, is only 12 pounds, — the engine, therefore, loses but 12 pounds in carrying steam seven-eighths of the stroke from the initial pressure, — the initial pressure being 80, and the pressure, at the moment the steam valve closes, 68 pounds. This engine, in common with many others of

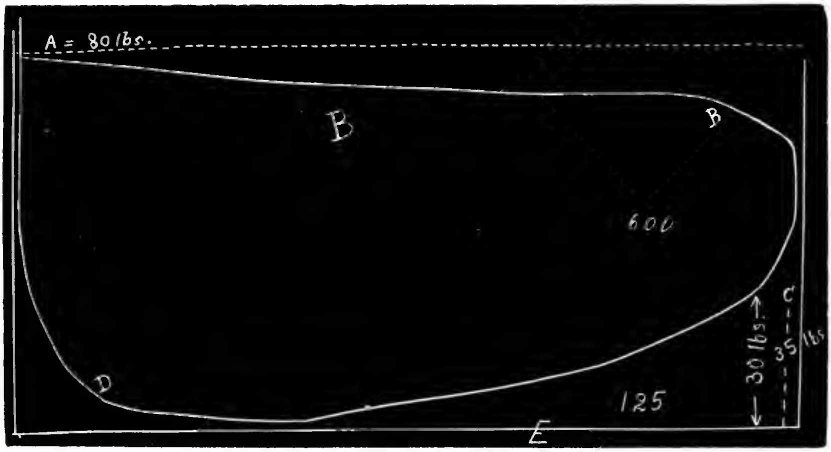


FIG. 44.

the slide valve type, is late in the motions of its exhaust. The exhaust valve opens, or commences to open, rather, just above the letter C, and here we have 35 pounds back pressure as the piston starts on its return stroke. The exhaust is never allowed to touch the atmospheric line of the instrument, E. At D, the back pressure will be seen to have increased, the smallest amount of back pressure being three pounds, about what we might expect in a well regulated engine of the family from which this one came. At D, the pressure increased to nearly nine pounds, and the exhaust valve seems to have closed. At a point above D, not very well defined, the steam valve seems to have opened, but the pressure is not sufficient to carry the piston of the Indicator up so but that the line leans away from the vertical line, showing that the steam line opens a trifle late. This is a general analysis of this diagram.

The planimeter says that the area of Fig. 44, as described by the Indicator, is 600; it also says that the area of the figure which bounds the back pressure is 125. Here we have 600 units of work and 125 units of worthlessness in back pressure, or about six times that which should be allowed in an engine of this type when in good condition. This engine probably never did exhaust correctly, and without some change, which cannot be determined without further data, it never will. If the exhaust port of this engine is 3⅜ × 18 inches, the party who made the examination should have ascertained whether the same area as the 2 × 18 was not in some way mixed up with this 3⅜ × 18. He also asks the question, What would be the effect of attaching a condenser to this engine?

Briefly, if the exhaust valves of this engine will not open better than they do now, the condenser will not have a chance to make much, if any, of a vacuum. If, by changing your exhaust arrangements, you can make the exhaust valve open at B, on the upper line, without making it close enough quicker at D to lose by enormous compression what you would gain by early release, then your condenser may possibly effect a great deal of help to the engine. If a saw-mill can afford to run an engine under these circumstances, by burning sawdust, slabs, or that sort of trash, they may be able to make lumber; but an engine of that kind, working at that rate of expense for fuel, anywhere in this country where coal had to be used, would ruin any concern with a hundred thousand dollars capital, in less than five years, if all the rest of the branches of their business were well managed.

These diagrams are two of the worst instances of the use of steam that have ever come to the eyes of the writer. They are neither uncommon in their outline, nor in the fact that such diagrams can be produced, almost any day, without going ten miles from Boston. Men are running engines which should have been in the scrap pile years ago, but the fact of it is they have some cut-off arrangement, some safety-stop arrangement, possibly their son has invented something which has been attached to it, or they bought it second-hand, and bought it cheap. It would pay the users of either one of these engines to buy a strictly first-class engine of double the capacity of either one of these, run in debt for it, pay ten per cent. a year interest, and in five years they would have the engine paid for, and more than have saved its cost in fuel and in production. An engine that is overloaded in this condition can never do its work right or regularly, and any little laying on of the last straw will break the camel's back entirely, — that is, reduce the speed so that it does not work up as it should. It is a little curious that so many men pay no attention to this very important element in our manufacturing establishments. A very little difference in a mill of a thousand looms makes a good profit on a mill of three or five hundred looms; if the looms all lose a pick a minute, in a thousand loom mill, on 64 × 64 goods, it makes nine pieces a day, or 2,700 pieces per year; and the fact of the matter is, we have seen mills of this size which varied from 5½ to 7 strokes on the engine in a minute, and so on all through the day, making a difference of several thousand pieces of cloth in a year.

LESSON XIX.

We received an invitation from an engineer friend to visit, with him, a large manufacturing establishment, in which he would show us something good. The time was set, and we gave him an hour's leeway to get ready this exhibition, before appearing on the scene. After waiting for some fifteen or twenty minutes, while his Indicators were attached, he showed us something good; it was something wonderful, at least — not very good, — and we rather imagine he was slightly non-plused himself when he came to show us the original of which Fig. 45 is as near an exact reproduction as we can make it. The data, which goes with this, is as follows: Corliss engine, 30¾ inches diameter, 36 inches stroke, revolutions from 88 to 90, 32 spring; boiler pressure, at the time this particular diagram was taken, 70 pounds; duty, rolling wire; high pressure. A condenser was attached, but was not working at the time this was taken.

Here are two very peculiar outlines, and all the more peculiar because of the complaints which our friend had received that the engine worked hard. We should rather think it did work hard. H and C are respectively head and crank ends. The engine is a trunk lighthouse, cylinder at the top, crank at the bottom, driving a large fly-wheel, from which a 30-inch belt conveyed the power. The lines, E, are at right angles with the atmospheric line of the instrument, and were the basis of the adjustments which followed. These are drawn, in order to show whether the engine is early or late in taking steam. The same letter refers to the same lines upon all the diagrams. After the diagrams in Fig. 45 had been taken, the question then became of consequence what to do with the engine. It will be seen that the admission line upon the head end is late,—in fact, very late indeed; so late that, out of 70 pounds boiler pressure, only 28 pounds are admitted. While on the crank end, the Indicator has attempted to draw a map, and after progressing for about three or four inches of the stroke, 28 pounds boiler pressure are utilized. The crank end is doing nearly, if not quite, double that which the head or upper end is. There is an approximate cushion upon diagrams at B, but it amounts to nothing practically.

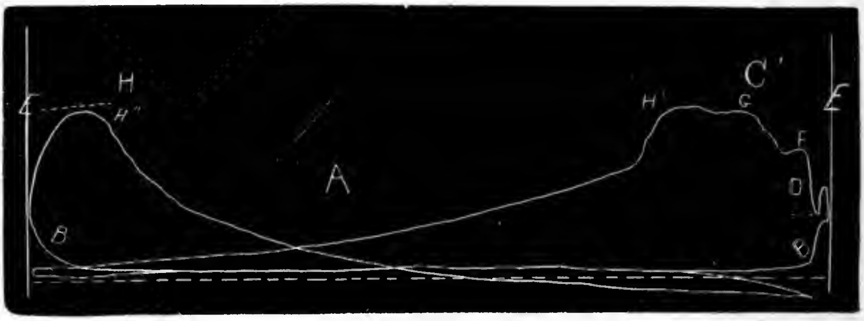


FIG. 45.

In order to get through with the thing at the earliest moment, we suggested some changes, which were promptly made by the gentleman in charge, while our friend took the diagrams. After making two or three changes, the figures shown at B were the result. In this case, however, it will be seen that, while more steam enters the cylinder, the motion of the valves was still very far behind. Having adjusted the cut-off so that the two ends were approximately correct, or balanced one with the other, and, having used all the leeway upon the rod stems, or connections, which we dared to, the load remaining the same all the way through, we then had recourse to the eccentric, sliding it over on the shaft an inch or more. From this we obtained diagrhms C, Fig. 47, which are vastly different looking from those of diagrams A, Fig. 45. All this was done within an hour, starting and stopping not less than four or five times. We do not know precisely the estimation in which the gentleman in charge of this engine holds the Indicator, but these three plates, which form the subject of our lesson, show the difference between an engine which does its work very hard, and the same engine given a fair chance to do its work easy. In Fig. 45 we have 28 pounds of the boiler pressure admitted into the cylinder. In

Fig. 46 we have 40 pounds admitted into the cylinder. In Fig. 47 we have 52 pounds; therefore, by simply changing the position of the valves, double the steam is admitted into Fig. 47 that was admitted in Fig. 45, and we doubt if there are many cleaner cards found, than those in Fig. 47; whether the engines are in cotton mills or rolling mills is not a matter of any consequence.

The cushion lines, B, in Fig. 47, conform very nearly to our own ideas of the proper amount of cushion for an engine, simply enough to relieve the jar or shock, and it makes little difference what the amount of load is, the cushion does not increase with the load in the Corliss engine, or in any engine built with the Corliss valve. This is a point which slide-valve makers do not exactly appreciate. If there is any use of the Indicator at all, there is no instance in which its value can be any clearer shown than in this particular case. Here is an engine doing regular work, in which we presume the load is varied from 15 to 25 horse-power, sometimes between the very stroke of the piston up and down, and that a hundred horse-power variation can be made in less than one-half of one minute when it is doing its regular work.

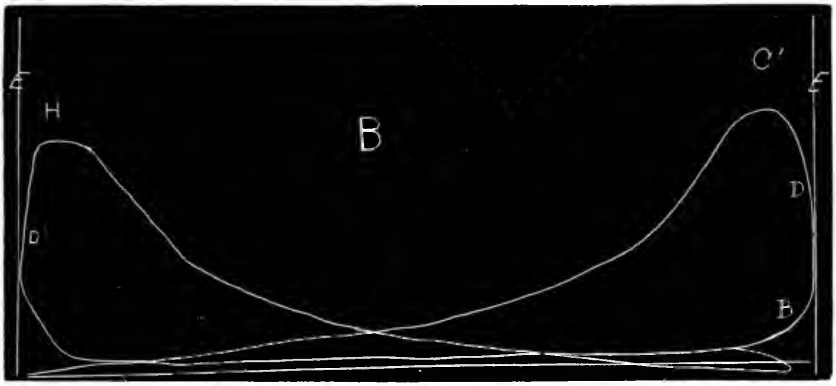


FIG. 46.

If there is anything in the use of steam, the diagrams A, Fig. 45, show an extraordinarily bad working of steam; diagrams B, Fig. 46, show a desirable improvement, and diagrams C, Fig. 47, show a great deal better work than either of the others; and yet this is the very same engine, the same valves, the same load, the same speed, the same steam boilers, and only an hour's difference from the time of taking the diagrams, and no expense beyond that of simply changing the nuts, and running the rods out or in, as was necessary to bring about the adjustment; and yet, if this engine is doing 300 horse-power per day, — and it does do more than that, — using three pounds of fuel per hour, actually costing $4 per ton, the difference between the actual result in using the valves as we found them, in Fig. 45, or using them as we left them in Fig. 47, would be a trifle over $12 per day. Yet there are some men in the world who are so wise that they consider that the Indicator has outlived its days of usefulness, and that, while it is a very pretty toy, "it don't amount to much in practice."

As it may interest some of our readers to ascertain how these changes were made, we shall take Fig. 45 for our first analysis. If you refer to the letters B, in the corners where the line of compression should be, you will find that there is hardly an outline of compression in either one. The amount of steam which is compressed is very slight. Rising above where the compression line strikes the admission line, following upward on the line E, you will find that the admission line gradually leaves the line E, more and more, as it approaches where the steam should be cut off. And the reason for this is very plain. The steam valves are terribly late. The exhaust valve on the head end opens earlier than it really needs to. It does not open as early in Fig. 47 as in Fig. 45, from the fact that it was set back by the connection. Now, the question is simply, What is needed to be done? The straggling line on the crank end, which is marked C′, simply means that the valve opens very slightly; the piston moves along a little, and the valve opens more, which makes the line D; when the piston arrives at F, the valve commences to open still more, and finally it gets wide open after the piston has proceeded so far in its stroke as G, — all these letters referring to diagrams A, Fig. 45. Now, it will be seen that this carries steam clear over to H′ before it is cut off; while on the other end it is simply guess-work to tell where the cut off comes. Now B, upon each of the diagrams A, Fig. 45, requires to close the exhaust valve earlier; D, F, G requires to open the crank valve very much sooner; while H′, as compared with H″, is much longer than H″. Then we must open the crank valve much sooner than before; we must lengthen the cut-off dog so that the crank end will cut off much shorter, and we must shorten the head cut-off dog so that it will not cut off so soon. Now, the exact quantity of movement to

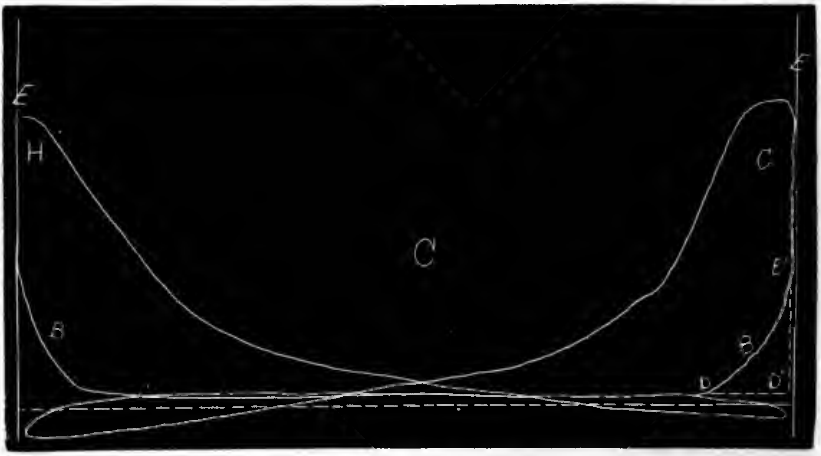


FIG. 47.

be given any one of these several alterations is a matter of judgment, — no man can say a sixteenth of an inch, an eighth of an inch, two turns, or three times round, — but we must always proceed with caution. Diagrams B, Fig. 46, show what resulted from it. It will be seen in C′, that the compression at B has increased; that instead of D, F, G, H, in diagrams A, Fig. 45, we have a very fair admission line at D, and D′, but that both these motions are still late, as compared with the line E. The cut off is much nearer balanced, although the head end does not get quite as much steam as the crank end, C′. We have now approached the limit of safety in running the connecting rods out of the nuts and connections, and it does not do to go too far in this direction. If now we compare the diagrams B, Fig. 46, with those of diagrams A, Fig. 45, we notice, in general, that the motions are much nearer uniform — that is, both ends — than they were before. Now, there is only one question remaining: Having "balanced up," as we term it, the various motions, take the eccentric and roll it forward on the shaft, say an inch, for a guess. This is a quantity which can only be measured by the lines drawn upon the Indicator. Fig. 47 shows what the result of this movement was. In this case, it will be seen that we have very nearly "balanced up," although the head end cuts off a little sharper than the crank end. The expansion lines are approximately well disposed to each other, while the compression at B is just about right for a 200 horse-power engine. Now, there seems to be a question as to the right amount of compression, or cushion, as it is termed. We have therefore drawn in a dotted line to show the square-cornered diagram, which so many people admire. The only difference between the line, B, which is the actual line of the instrument, and the dotted line, is, that in the line, B, the exhaust valve is completely closed at D, and the piston of the Indicator gradually rises to about the point E′, thus making 24 pounds pressure. This pressure does not cost anything, — it simply confines so much steam, which would otherwise be exhausted, — but it does accomplish a very useful effect in allowing the piston-head to cushion upon 24 pounds pressure, and gradually bring itself to rest, while, if the dotted line was followed, the exhaust valve would not close until D′. In this case, there is nothing left for the piston to cushion against, and the whole arrangement would go a half inch further if the connection would let it; consequently there is that peculiar chuckling noise, which is frequently called pounding, — and, in reality, it is a species of pounding, — and sometimes it pounds the keys off in the cross-head, and the cylinder head comes off. In other words, the line, B, by closing the valve at D, produces a compression, and it eases the piston and all the connections back to the crank in coming to the dead center, or line of rest. Then, if the steam valve opens properly, these two lines, compression and admission, merge into one another, so that only an experienced man can tell precisely where the blending occurs; and just so much steam as is used by this proper compression is an absolute saving of money to whoever pays the bill. If fuel is of any value, the parties who are running this engine will have made a simple saving of more than $2,000 a year, in difference between Fig. 45 and Fig. 47, if they will only take as good care of their engine as the diagram C, Fig. 47, will produce by the fuel.

These diagrams are not perfect, for the engine has been in use for a number of years, and they are only given for the purpose of imparting information from actual practice.

LESSON XX.

We frequently receive requests to show the exact difference between a perfect or theoretical use of steam and the actual or accomplished use in diagrams. There are so many ways of constructing a hyperbolic curve, that it is well not to confuse those readers who are so much interested in learning it, and, at the same time, the process and the tools or instruments required, must be confined to something that does not entail expense upon them. For this purpose we have selected and engraved a method which is very nearly accurate, — sufficiently so for all practical purposes. This method was originated by Prof. John Pierce, of Providence, R. I., twenty years ago.

G, A, equals the clearance in the engine, and in this our readers must not make any mistake; the clearance of the engine is not in proportion by measurement between the piston head and the cylinder head — which is given in this engraving — in any well constructed engine; and, in figuring the clearance of the engine, the steam and exhaust ports must be figured from the bore of the cylinder back to the face of the valve, in cubic inches. The amount of these two calculations must be reduced to so many inches of an increase or extension of the bore of the cylinder; for instance, if we have a 26-inch cylinder, and we find that an aggregate of the steam and exhaust ports added to the clearance between the piston when at full stroke, and the piston head, amounts to 265 inches, it is equivalent to one-half inch of an extended bore of the cylinder; so, if it amounts to 530 inches, it is equivalent to one inch added to the bore of the cylinder. This is how we obtain the line, G A.

A B represents that portion of the stroke which steam was carried; B represents the point of cut off proper; A C represents the whole length of the travel of the piston. Now the line, G C, represents the length of travel and the clearance included; A F equals the steam pressure realized in the cylinder; A F = G H = B E = C D. To the line, A F, before we commence to erect the perpendiculars, we add 14.7 pounds for the pressure of the atmosphere, so that we should have said A F represents the boiler pressure and the atmospheric pressure added thereto; so that C D, B E, A F, G H, are all one and the same thing, — the boiler pressure and the atmospheric pressure, making the absolute pressure. Now, develop B C into any number of points that is desired, — preferably making them repetitions of the distance A B, — numbering them 1, 2, 3, 4, join each of these and the point C with H, the joining lines intersect B E in the points A, B, C, D, E; then draw the lines, 1, 2, 3, 4 parallel to B E, and at right angles to B C, to intersect the former series of lines, H 1, H 2, H 3, H 4, H C. Now, from the line, B E, starting at A, draw a line at right angles to B E, and strike the first upright 1; wherever the line A strikes the line 1 at right angles to B E, that is, where the line of the expansion curve, or hyperbolic curve, should pass through that point. We have now the line, A F; draw the line, B G, from B E to 2; then the line, C H, from B E to 3, and the line, D I, from B E to 4, and the line, E K, from B E to C D. The points then given, F, G, H, I, K, are a properly constructed hyperbolic curve, which is approximately correct, for the line of expansion of steam, according to Mariotte's law. Now, all this can be laid out with a pair of steel triangles, taking one having a six-inch leg, and its fellow may be perhaps a four-inch leg for the long legs.

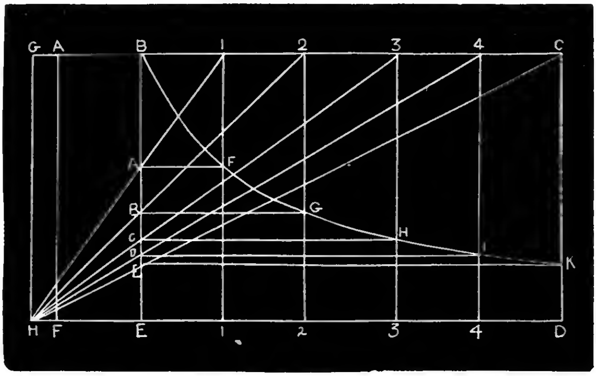


FIG. 48.

This is one method of laying out the hyperbolic curve. We shall, in a future lesson, show how some particular engine builders take, perhaps, a little liberty with mathematics or geometry, or may be with facts, in describing the line of cut off, to satisfy their ideas of working steam expansively. The method we have given is not, by any means, the best for laying out the curve, but it is a simple one, it is approximately correct, and it is one that all our engineers can understand. In our next lesson, we shall show another way, which is really simpler than this, but this embodies the principles so well that it will be well for those following up these lessons to take a few cards, where the point of cut off is well defined, and experiment with them. Now, it frequently occurs that an engineer wishes to test this and not allow other people to know that he has been doing it. In that case, let him take his Indicator diagram, and a piece of tracing paper; then fasten the tracing paper over the diagram and do all his work with a lead pencil upon the tracing paper, having put a small tack, or a drawing tack, through each end, or through two corners, so that he can compare the lines without making the least mark upon his Indicator diagram. He can then, after having completed the demonstration, draw, with a steady hand, the expansion or actual line of the engine in a different colored pencil, or by dotted line, and he will then have the whole thing, so that he can hand over the card to some of his better educated friends, perhaps, and let them try their hands on the same diagram.

LESSON XXI.

In this lesson we give another method of laying out the hyperbolic curve and where the point of cut off is clearly defined. This method is simple and accurate, and can be done upon any Indicator diagram in a few moments' time, with a pair of dividers, a pencil, and a short, straight edge. In Fig. 49, G H = B E, and both lines equal the pressure upon the piston, with 14.7 added for the atmospheric pressure; hence the line, B E, equals the boiler pressure and atmospheric pressure combined. G B is the length which the steam is carried, B being the point of cut off. On the lower line, H E = G B, and 8, 1 = H E, 1, 2 = E 1, etc. Divide the distance from E to 4, or from B to the end of the diagram, into equal distances, which are the repetition of the distances, G B, and H E, and from the point, B, draw a line to figure 2, and the point at which this line intersects the ordinate 1 is the point through which the hyperbolic curve will pass. From B, through the ordinate 2, draw a line to the point 3, and so on, drawing the line B 2, B 3, B 4, B 5, or whatever the number of points may be. The line joins the base line, H 5, one point further from B than the line through which it passes. Whatever the point of cut off may be upon any diagram, leave as many spaces and one more as the length of the diagram covers. Then draw the lines from the point of cut off, B, through each one of the ordinates, to the foot of the next ordinate beyond, whether it be five lines or nine lines; then, by means of a curve, or the dividers, draw the hyperbolic curve through, and you have one of the best arrangements for the delineation of the actual line of expansion that we know of. This method, like the one in the previous lesson, was originated by Prof. Pierce, of Providence, R. I.

Fig. 50 is one of the nearest approximations to a perfect Indicator card that we have ever seen. The data, which comes with this, is as follows: Rollins engine, built by G. A. Rollins & Co., of Nashua, N. H.; Corliss type, 24 inches diameter, 42 inches stroke, speed 75 revolutions per minute, boiler pressure 75 pounds, scale 40; new engine, in the Cleveland Rubber Company's factory, Cleveland, Ohio; 74½ pounds of the boiler pressure realized in the cylinder. The engraving is an exact *fac simile* of the card which came from the Indicator, and was not a tracing. The steam line is perfectly elegant, and is as straight as we ever saw. The expansion line has a little variation, which is no doubt caused by the instrument. The exhaust line is as nearly perfect as the steam line; the slight amount of compression shows a very finely working exhaust valve, while the admission line is just as nearly right as it can be. This is simply an elegant Indicator card from actual practice, and leaves very little to be desired. Those of our engineers who are running Corliss engines, and are practicing with the Indicator, may imitate this card as near as they can, and may rest assured that when they reproduce it they are doing as near the best of anything possible as they will ever do. Every motion of the valve is smooth and clear, and some of our beginners will do well to take this as a model to apply the curve to, by either of the methods given in this or the previous lesson, and figure up the percentage. In this engine, no excess of compression or cushioning is used, steam is given at the right place and at the right time, the corners are perfectly sharp and clear, and

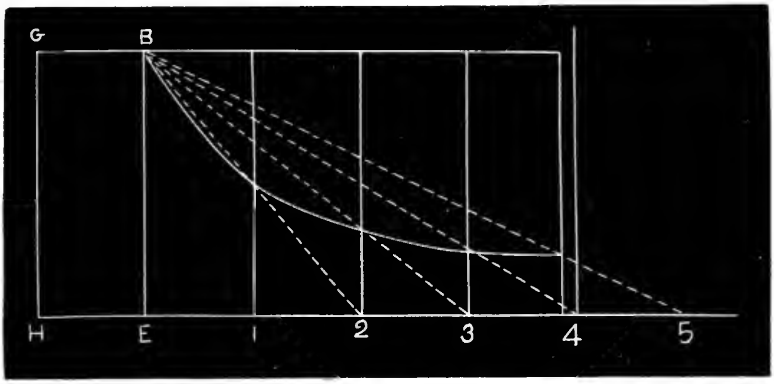


FIG. 49.

very well defined; and, when we say it is one of the handsomest specimens of a card or diagram from actual practice, we merely tell the whole story, and state a fact. Messrs. Rollins & Co. are to be congratulated; and we know that Mr. Rollins himself is a close student of the Indicator, and a man who profits by his experience with it. While we do not know the fact in this relation, we have no doubt that he has profited by the practical application of the Indicator in the perfection which he has attained in the handling of his steam and exhaust valves.

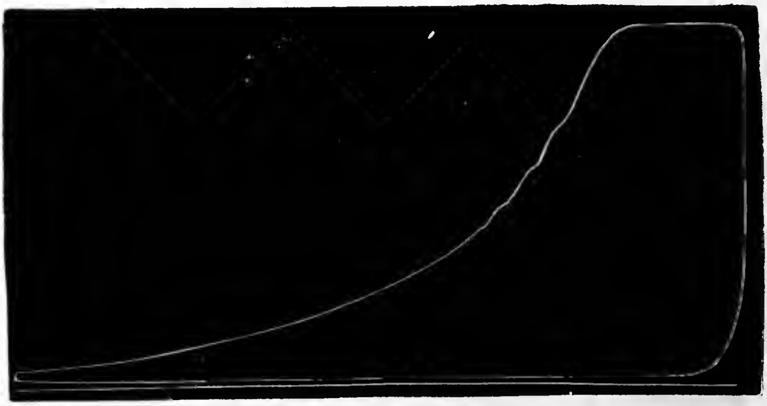


FIG 50.

LESSON XXII.

THIS lesson illustrates another instance of experimenting. The diagrams in question are our own, taken from an engine having a Corliss cylinder 16 inches diameter, 42 inches length of stroke, intended to be run at 55 revolutions, with comparatively little regulation, steam pressure 65 pounds, scale 30.

The diagram, H R, Fig. 51, is from the head end of the cylinder, as we found it working, and presents some peculiar characteristics. The admission line is a peculiarly lazy one, and the serration at A, it will be seen, is repeated four times distinctly before the steam line, B, is really commenced. When the steam line is finally started at B, it will be found to be one-sixth of the whole stroke before the steam valve becomes completely open. The steam line is then maintained very well; but with steam 65 pounds in the boiler, there is only 52 pounds on the piston. This is entirely too much of a difference. If it was two or three pounds, or five pounds even, upon this size of an engine, and at this speed, it would not be so very considerable. If it were a five or six hundred horse-power engine, and the difference was seven or eight pounds, we should not think so much about it on account of the volume of steam, as in this case, where the volume is so small, and the engine is situated so near the boilers. It will be noticed that the admission line leans very much too far away from the upright we have erected.

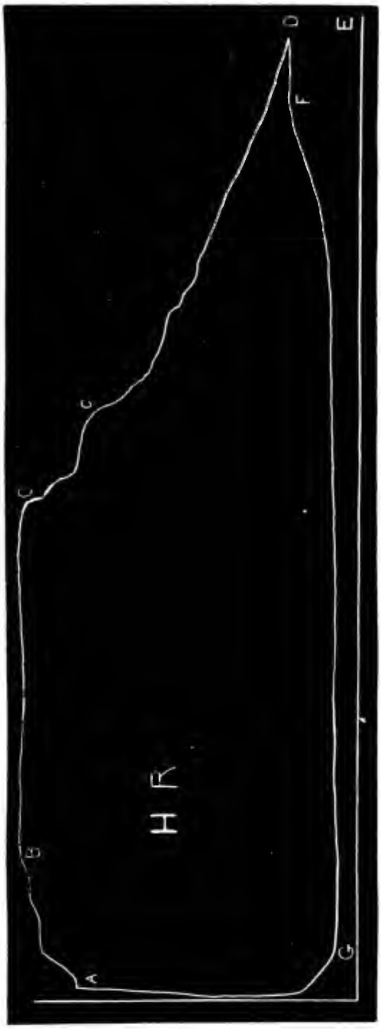


FIG. 51.

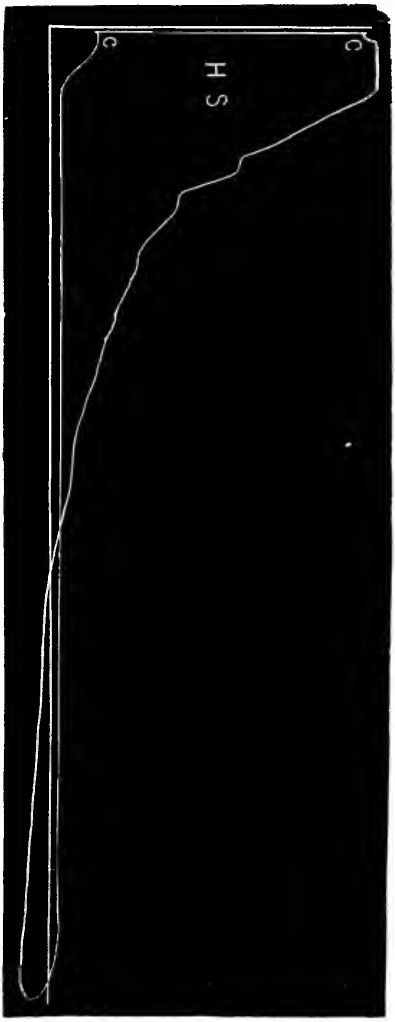


FIG. 52.

Leaving the connection of the steam line with the cut off at C, we have the expansion line, C C D, with some peculiar looking steps in it. Exactly what causes these steps is, to a certain extent, conjecture in any ordinary engine. In this, there is no conjecture about it; the engine is badly regulated, and is jumping about; the load is variable, and we should not be surprised even to find saw teeth all the way down the length of the expansion curve. In fact, the serrations are visible far below the second C. This is caused by the very unequal action of the regulator in giving different impulse to the piston, and by the peculiar action of the ever-varying load.

At D we commence to exhaust. Curiously, the piston of the Indicator is held up for one-twelfth of the stroke, and a pressure, at D E, of 12 pounds, is exerted against the piston. Ordinarily we might ask, Why was this peculiar point? In this case it is easily explained. This engine — the dimensions already given — is expected to exhaust through a five-inch exhaust pipe, while it is fed through a five-inch pipe and a six-inch valve, as though the valve could increase the capacity of receiving steam from the boiler which was throttled in a five-inch pipe. When the exhaust commences at D, there is twelve pounds back pressure between D and E, E representing the termination of the atmospheric line of instrument. After the steam is started to exhaust, all men, who are conversant with it, know that a current of steam will soon aid essentially in relieving the pressure; hence, it requires one-twelfth of the stroke to establish this current in the exhaust pipe. It commences to decrease the pressure at F, and from there to the end of the stroke, or at G, the back pressure is gradually reduced, in no case being less than three pounds. There is a certain way out of this in the proper adjusting of the valves. Its mate, diagram H S, Fig. 56, was taken from the same end of the same engine, and shows what improvement can be made by even a little adjustment; and, for the sake of relieving the exhaust pipe, the load was very materially reduced in this diagram, to ascertain whether the engine would exhaust freely with a lighter load or not.

This is a very practical illustration of what may be accomplished in an hour's time by the proper application of the Indicator. It will be seen that the Indicator will not increase the amount of steam drawn through a too small pipe, nor will it make less steam than is actually present. The diagram, H S, Fig. 52, shows how the steam can be admitted properly, so far as the capacity of the valve motion and valves will admit. C C, in the diagram H S, shows us conclusively that there is a little lost motion — probably in the valve in the stem.

Time was not allowed for a full bringing up to the standard of this engine, as the question was between the builder and purchaser as to whether it was in good condition; and, until further changes are made in the work, it is impossible to bring it up to standard. The lesson, however, is instructive to those who are watching these points, and if any of our readers desire to apply the hyperbolic curve, erect the upright in the same scale precisely to the extent of 65 pounds; take the same point of cut off, carry their expansion line out, and see what the actual percentage of the work done by this engine is, with the steam that should be in the cylinder if the pipes had been properly connected, and the valves had done their work. If any of them try this, they will be astonished, and it will be an interesting and instructive example.

LESSON XXIII.

We have something in this lesson of more than ordinary interest, and from which we can learn something in reference to real economy. The card, W C, Fig. 53, came from a reliable party, and was taken from an engine built some years since to do 350 horse-power. The dimensions and data are as follows: Cylinder 28 inches diameter, 5 feet stroke, 50 revolutions, steam-pipe 6 inches diameter, exhaust-pipe 7 inches diameter, steam ports 24⅜ inches area, exhaust ports 24.5 inches area, balanced poppet valve and automatic cut-off, scale 30; steam pressure 50 pounds, which is one of the most peculiar features of the whole diagram. The line, E, in the diagram, W C, Fig. 53, is

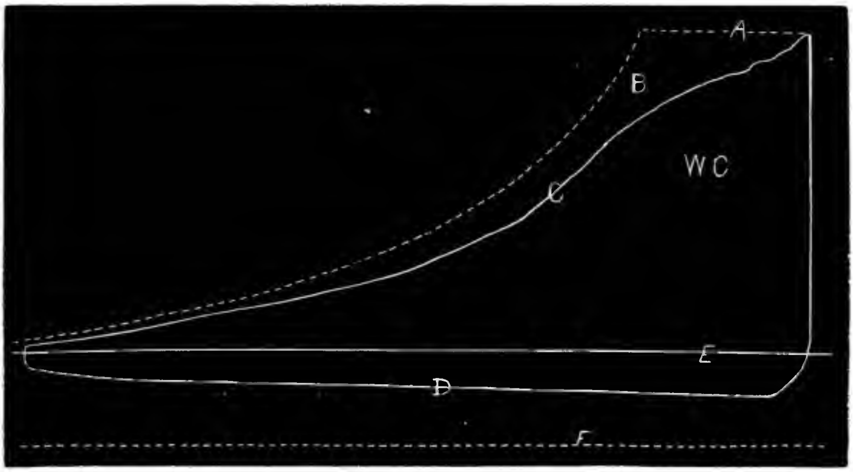


Fig. 53.

the line of rest of the instrument, or the atmospheric line of rest; the dotted line, A, is the line of steam pressure. We have assumed, in our calculation, that the engine should have carried steam on the dotted line, A, instead of which, when it cuts off at B, it has fallen 15 pounds from boiler pressure. The dotted line shows the expansion curve had the engine cut off at boiler pressure. It will be seen that the steam line is quick rather than late in its movement, and that, when the valve is open, the steam pressure is maintained for so brief a period of time that it makes simply a point. The steam, therefore, commences instantly to fall away from the boiler pressure, and, as the piston commences to travel away, its motion is slightly increased, and the boiler pressure falls correspondingly. On being cut off, at B, the real line of the engine is found at C, and without going into the niceties, its approximation to the real theoretical curve below would lead us to infer, and with very good reason, that the valves, after closing, were not tight, or that some re-evaporation took place. When the exhaust valve does open, and the vacuum line, D, is made, the condenser, when it gets hold, only gives us two pounds, or four inches; after traveling one foot we have four pounds, in the middle of the stroke we have five pounds, and at the heel of the exhaust we have six pounds, or twelve inches, as the largest amount of vacuum obtained. The line, F, is the line of absolute vacuum, or 14.7 pounds; it will be seen that we do not, in the largest measure accomplished, quite reach one-half of the vacuum, which we should have done. There are two points about this diagram which absolutely corroborate what we shall find if we turn to the area of the steam ports and exhaust ports, and that is, that they are both insufficient to do the amount required with that size cylinder and that size engine. The steam ports are shown, conclusively, to be very lame in their dimensions, by the instantaneous falling off of the boiler pressure, the moment the valve is opened and the cylinder begins to travel; cutting off, at about one-quarter the stroke, we lose 15 pounds boiler pressure, and when the exhaust valve opens, for the condenser to operate, we get 2, 4, 6 pounds vacuum, instead of 8, 10, 12. These two things show conclusively, therefore, that this engine never was fit to run with economy at that speed; it might have done very well at one-half the speed, or perhaps 30 to 35 revolutions. The party who sent it wrote as follows: "The engine was unable to perform the 350 horse-power with any sort of economy, and came near ruining the parties by reason of their very large coal bills and irregular speed."

In another engine of the same general type, we have the diagrams C C, Fig. 54, from a Wright engine, thirteen years in use, with 22 inch cylinder, 42 inch stroke, 63½ revolutions, scale of 40 pounds, boiler pressure 78 pounds, non-condensing. The diagram, which we reproduce, is one of a pair upon the same card, and shows 52½ pounds of steam at the moment of impact, or at A. The dotted line, B, represents the realized pressure. This engine carries its pressure to the point of cut off with a loss of only three pounds. The expansion line is very good; the exhaust valve opens and closes well, and the difference between the exhaust line and the atmospheric line, of 2½ pounds, is partially caused by using steam for heating. If we were running this engine, we should open the exhaust valve quicker, so as to avoid the initial back pressure on the dotted line, C, and to try and open it more in the line of D. This would probably give us a little more compression, which would be all the more favorable, as shown at E, and would relieve the engine, so far as it can be relieved from its peculiarities of make. Evidently, this engine has been in the hands of parties who have taken good care of it, else it would never have made thirteen years' time, showing such good lines as it does. The most serious fault about it is, its lack of realizing the boiler pressure; whether it is caused by pipes we cannot say, not having that data given, and there is not in this diagram anything to show that the steam passages and exhaust passages are stifled, as in its fellow, Fig. 53.

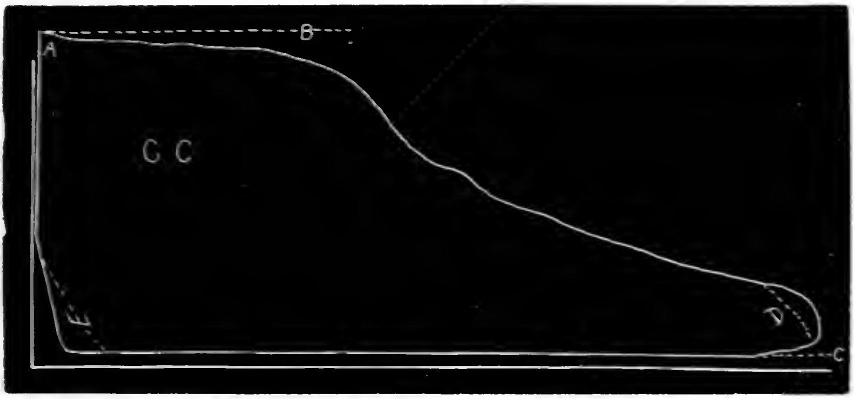
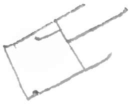


FIG. 54.

The difference between these two engines is, simply and purely, that C C, Fig. 54, will do much more work with the same fuel than W C, Fig. 53. Whether C C, Fig. 54, could be improved by increasing the size of the steam pipe and exhaust pipe, we do not know. These diagrams are from actual practice, and are all the more interesting because they are so; both are from the same type of engine generally, although some differences exist, and the point is conclusively shown that, if one is faulty, there is no reason that the other need be, or for any real cause on account of the system adopted.



LESSON XXIV.

In this lesson we have diagrams taken from condensing engines from two different builders. The differences in practice, in the condensing engines, are quite as radical as in the high pressure or non-condensing engines, both as to valve gear movements, and control of the valves, regulation, and the vacuum; and, as the vacuum is the important part of the condensing engine, we have chosen engines which are not fitted with any of the patent condensers, or the portable or attachable condensers, whatever they may be called, both having the air-pump condenser, or, as it is generally termed, the old-fashioned condenser.

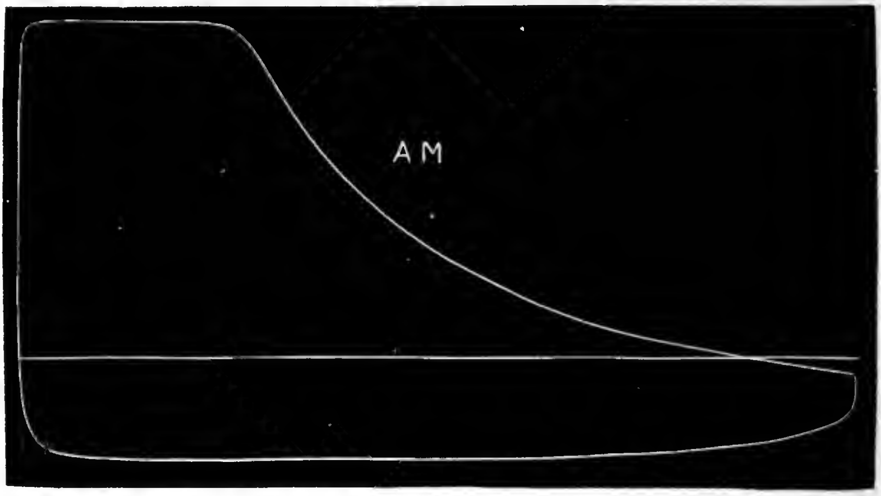


FIG. 55.

A M, Fig. 55, is a Corliss engine, which has been running nearly thirty years, and was one of the first ones built where it was to be run for economy over some other one. The diagram is from a 32-inch cylinder, 7 feet stroke, running 36 revolutions, 40 pounds of steam, vacuum gauge 27¾, scale 20. Thirty-four pounds of steam are put into the cylinder; the steam line is almost absolutely straight — does not vary half a pound; the expansion line is very good; if anything, we would open the exhaust valve sooner, allowing the condenser to get hold earlier in the stroke, and yet the vacuum, at one-third stroke, measures 20 inches, and further along 22 inches, bearing in mind that this 22 inches is in the cylinder. Aside from the alteration of the exhaust valve, hardly anything is desired in this diagram. If the exhaust valve should open earlier, so as to allow the condenser access to the steam quicker, the value of the vacuum would, without doubt, be increased from three to five per cent., and might be more than that.

This engine has been noted for its economy, and has produced very gratifying results to its owners. The steam valves, which are now working in this engine, have been in use for many years, without change, but there is just this difference: the engine has been well taken care of,—although it has been idle for some time,—and the diagram shows plainly enough that one of the objections that many people urge against the Corliss engine has no real foundation in fact, when the engine has received the same care, or really less care than some others, where parties make such an outcry about semi-rotary valves. In this place we must judge the engine by what it absolutely produces, not by any man's preferences or prejudices, and although this is an old machine, it certainly makes a card that speaks well for its maker and for its users.

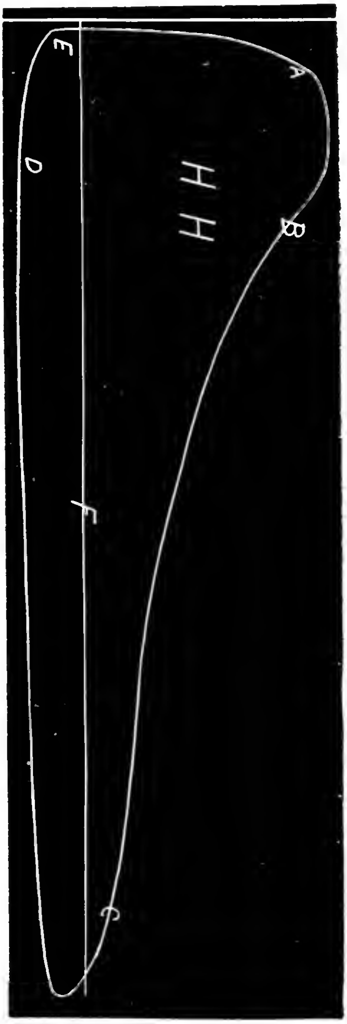


Fig. 56.

In contrast to this, we present a diagram from an engine built by Hicks & Hargrave, in England, some years since, now in operation in a New England cotton mill. The data is as follows: Horizontal, 20-inch cylinder, 42-inch stroke, 62 revolutions per minute, spring 40, boiler pressure 70, vacuum 28, hot well 110. This engine (diagram H H, Fig. 56) has four grades of cut-off, which can be varied by hand, while the engine is running,—double-balanced poppet steam valves, 5½ inches, and the same style of exhaust valves 6½ inches in diameter, with a double-balanced throttle valve and ball regulator.

We have erected the line at right angles to F, which is the atmospheric line of the instrument, to show that the motions of the valves are very late in opening, as the steam valve only opens after the piston has traveled from the upright line to A. The cut off takes place slightly before B; the expansion line is excellent from B to C; at C the exhaust valve opens,—and this is one of the best forms of exhaust in any engine, either condensing or non-condensing, — and exhausts early enough to allow a sharp falling-off of pressure a little before the piston finished its stroke. The vacuum is 24 inches almost at the start, and 26 inches at the center of the stroke. The valve commences to close at B, and is quite closed at E, while the steam valve commences to open. This diagram, it must be remembered, is by a regulator which throttles the steam in the main pipe. And, in contrast to the dimensions of pipes given in our last lesson, this engine, with a 20-inch cylinder, has a six-inch steam pipe, instead of, as in one of the diagrams in the same lesson, having a 28-inch cylinder and a six-inch pipe. This, therefore, accounts for the loss between boiler and realized pressure in the cylinder, the boiler pressure being 70, and the realized pressure, between A and B, only 52 pounds. This engine has been running economically for some twelve years, although, perhaps, the position of the valves might be improved somewhat, so as to increase their economy. These are very considerably different in design and practice, both being intended, practically, to accomplish the same economical result. We have not the figures, nor is that the purpose of the article, which is only to show the actual difference in practice between the makers; and this may be still a very good card for an engine regulating at a fixed cut off by a double pressure. The pressure is governed by the regulator.

LESSON XXV.

THE diagrams illustrated in this lesson are again the result of actual practice and a search after information. The data is as follows: Engine 10 inches by 24 inches, 72 revolutions, 67 and 68 pounds boiler pressure, 40 spring. Diagrams F F A, Fig. 57, is the engine as it was found; the line at the left is the boiler pressure; the distance from this line to the dotted line, F, is the distance the piston traveled before the valve was fully opened. It will be seen that the valve made a series or succession of efforts to open, represented by the letters A, B, C, D. These will need no explanation to the man who thinks, — that the first movement of the piston is slow as it moves away from the center, and that, as the motion is accelerated, each one of these steps moves farther away from the perpendicular line representing the boiler pressure; and at each one of these steps, or stages, it will be seen that the pressure increases until, finally, the steam line, E, is reached. The cut off is reasonably sharp, but it is terribly late. The line, F, is dotted through the steam line, E, to show, that of 68 pounds boiler pressure, 37 pounds only are realized upon the piston head, with this very late opening; while, if we refer to the other end of the diagram, we shall find that 47 pounds are realized; and, if we look at H, we find the departure from the perpendicular line is about one-fifth of what it is at the other end of the engine. In other words, the valves upon the left card open after the piston has moved away three inches, while upon the right the valve commences to open after the piston has moved three-eighths of an inch, and is quite open at one inch. The opening, after the piston has receded one inch, reduces the realized pressure from 68 to 47, whereas, in the other end of the engine, we have only 37 pounds of realized pressure out of the 68; this shows, therefore, that the rule is well founded that when the valves do not open promptly, the loss of pressure increases in proportion as the valves are late in their movements. It will not be necessary

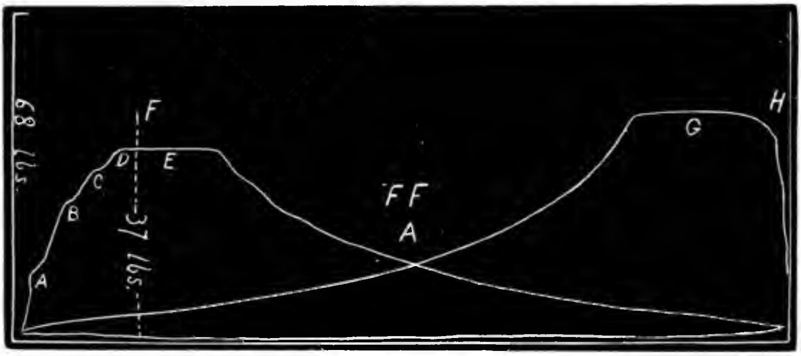


FIG. 57.

for us to give any rule for this, for our readers must endeavor always to avoid rather than to approximate; for that reason we omit it. It is a self-evident fact that this engine is doing badly enough, and yet it is not the worst, by any means, of those which we have.

Turning to diagrams F F B, Fig. 58, we have the same engine, same dimensions, same speed, and approximately the same boiler pressure, but the valves have been readjusted in their opening, and already show a very radical improvement. In this case, we have sixty-seven pounds boiler pressure, instead of sixty-eight, as in the other set of diagrams; *d* represents the boiler pressure; the left hand diagram opens the valve a little quicker than we should advise; the right hand diagram a trifle later, but very nearly right. At A the admission should come nearer the perpendicular line. It will be seen that the admission touches the perpendicular line at the top, or, as the boiler pressure was nearer realized while on the other card, at B, the Indicator line leans slightly away from the perpendicular line; therefore, the motion at A is a little too quick, and at B is a little too slow, and there is also rather too much cushion at A. The steam line, in this case, is peculiar to poppet valve engines that run at high speed. The left hand card falls away from the steam line ten pounds at the cut off, *c*, and it is very nearly or quite the same upon the other card at the approximate cut off, or the same point. In this case, the boiler pressure is not realized within five or six pounds; at the same time the diagrams are immensely superior to those of F F A.

While we know nothing of the result of this change, as regards the fuel, we are safe in saying that diagrams F F A will probably do one-half the power of diagrams F F B; and that it would cost from fifty to one hundred per cent. more coal to do it, to say nothing of the better regulation of the engine, with the diagrams F F B. This adjustment is something which can be done by any good steam engineer who has the Indicators, and who will give a little time and attention to them. If our mill owners and power users would resort to the Indicator more, there would be less growling about incompetence, and much more satisfactory results in the combustion of fuel, more power would be realized from the same coal, better work and less repairs, and generally a very much better tone in and about engine rooms and among power users.

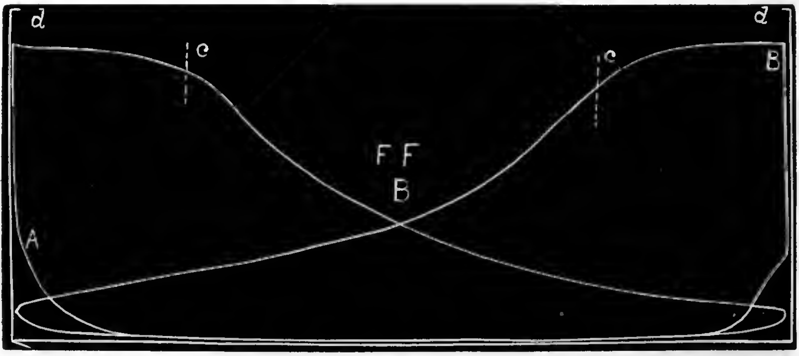


FIG. 58.

LESSON XXVI.

IN this lesson, we shall illustrate the Planimeter, as applied to the practical measurement and computation of the Indicator diagrams, giving plain directions how to use it, and what not to do. The Planimeter was invented in 1827, by a Swiss engineer named Oppenkofer. In 1849, another Swiss engineer, named Welty, made considerable improvements over Oppenkofer, but these instruments were heavy, bulky, and not adapted to general use. In 1854, M. J. Amsler, a mathematical professor at Schaffhausen, succeeded in making the Polar Planimeter, and again this has been simplified materially. Our illustration, Fig. 59, shows the Amsler Planimeter, as manufactured by the American Steam Gauge Company, of Boston. The Planimeter is a surface measurer, or, we might say, a plane measurer, for measuring the area of any irregular form that may exist upon paper, to reduce it to the exact area contained in that form upon any scale which may be applied to it. In other words, the Planimeter computes the area of any form which may be submitted to it, when properly handled, doing it by a mechanical process rather than a mental one. As shown, it is but little larger than a pair of dividers, and is enclosed in a nicely lined and leather covered case, which can be readily carried in the pocket, is always ready for use, and, with a little care, will last for years. Substantially this has been explained and the Planimeter illustrated on a previous page, but we have also added to this explanation the general features of the computation of the Planimeter, as applied to "working out" the Indicator diagram.

We have taken a high-pressure, or non-condensing card, G M, Fig. 59, and, for the sake of computation, we shall put the following data with it: Diameter of cylinder 24 inches, length of stroke 60 inches, 60 revolutions per minute, 30 spring. When using the Planimeter, we take a piece of thick pasteboard, and get the bookbinder to paste a sheet of good blotting paper upon it, pressing it over night, or until thoroughly dried. We never use a finished or sized paper, or one that has a polish on it like glass. The surface of this paper should be kept free from bunches, projections, grit, paste, or dirt. A piece of blotting paper can be pasted upon a pine board, well seasoned, and the board hung up out of the way, when not in use, in the engine room or office. A piece of drawing paper can be pasted upon a board, or, for immediate use, any piece of brown paper which is even on its surface, not having bunches or projections, can be drawn out on a smooth board, and the Planimeter set up at once.

Referring to Fig. 59, the point, A, must be outside of the diagram, or outside of the area to be measured. The index roller, C, must travel smoothly over the paper, and anything which interferes with its travel interferes with the correctness of the computation to be made. Grit, dust, oil, or any foreign matter, makes your computation at once worthless. The tracing point, B, is what you will take between the thumb and fore-finger, running it around the figure in the same direction that the hands of a watch travel. The point, A, is the stationary one, and, having placed your diagram, you can change the point, A, into any position you like that will not allow the roller, C, to come in contact with the edge of the Indicator diagram, but will reach the most remote point of the line traced by the Indicator, without touching the paper on which the diagram is traced. Let it roll freely upon the paper which forms your table. In starting with the point, B, we usually do so in the corner of the card, or any convenient point, taking care that a little pencil dot is made so that you may start from the same point, and stop at that point so as to read closely. The roller, C, after having adjusted the diagram and the Planimeter to the point from which you are to start, may be lifted by raising the joint of the instrument slightly from the paper, so that the 0 on the wheel, and the 0 on the vernier, or little scale attached to the joint of the instrument, shall coincide with each other precisely. Then take the tracing point, B, run it around the diagram, being careful to follow the line exactly, stopping at the same point from which you started. Now, to get at the result, you must make a correct reading. In our case, we started at 0. When we stopped, the 3 on the wheel, and nine of the divisions between 3 and 4, have passed the 0 on the vernier; hence, we read 3–,9–, then from the cipher on the vernier we count back until the mark of the vernier coincides with a mark on the wheel, — which is 3, — hence, we have 3.93, and that is the result of this computation. We now take the point, B, and travel around the diagram, G M, once more; this time we get 7 as having passed the 0; the eighth line has also passed the 0; then we count up the marks on the vernier, and find that the eighth mark on the vernier coincides with the mark on the wheel. Previously we had 3.93, so we subtract 3.93 from 7.88. This time we have 3.95. Surely, we have done one or the other carelessly, so we repeat it. The next time we are more careful, and we get 3.93. This is also repeated, until we are satisfied that 3.93 is right. In reading, we sometimes come across curious mistakes. If we start at A, the corner of

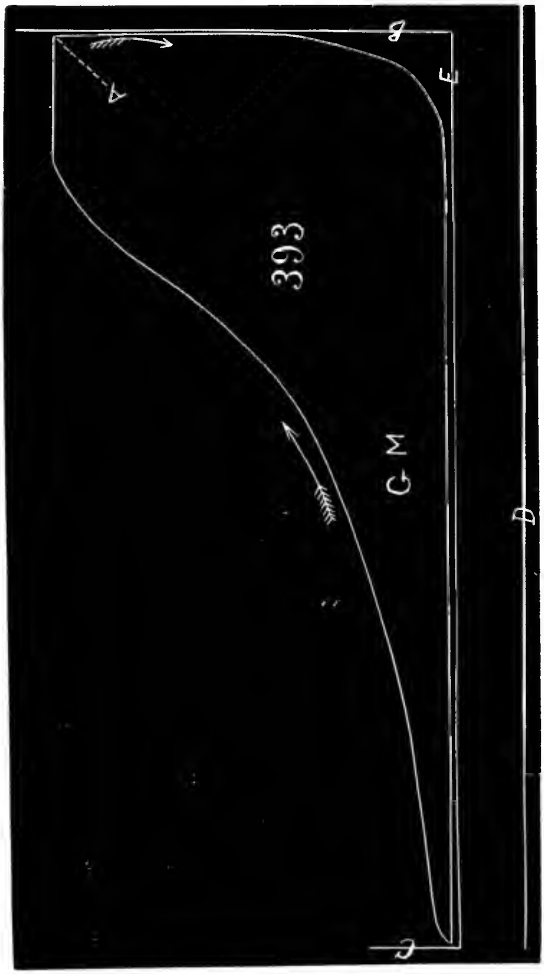


Fig. 59.

the diagram, G M, taking hold of the point above B, at that end of the lever, with the point, A, at our left hand, and the point, B, coming directly toward us, the diagram being slanting, the right hand toward us and the left hand from us, taking the lever A in the diagram as a straight surface parallel to our face; then we bring the point, B, in the direction of the arrow in the diagram, backward from where the Indicator made the marks when attached to the engine. We come down the admission line, work to the left on the exhaust line, go up on the expansion line in the direction of the arrow, and come back to A again. Now, the top of the index wheel must be read to the left of the 0 in the vernier; that is to say, in our last reading we have the figure 7 on the wheel, which has passed the 0 on the vernier to the left; the seventh line has also passed the first line on the vernier, and then we must count upon the vernier to the ninth line, or until we find a line upon the vernier which exactly corresponds with a line upon the wheel. The line upon the vernier is the last one that is read. Remember, the readings on the vernier are last, and that the numbers on the wheel must be read to the left of the 0, when the instrument is properly operated. In this way you will not become confused, and your results will not negative each other, making confusion. It is not necessary to set the roller to the cipher on the vernier; you can commence anywhere, having perfected yourself with reading the instrument, just as you can a clock when you look at it. It is better to use a small pocket lens in reading this. The marks on the vernier are tenths of the marks on the wheel. The marks on the wheel are hundredths, so that the marks on the vernier are thousandths. Anything can be figured or computed by the Planimeter as well as an Indicator diagram, and, if you wish to test it carefully, take a piece of zinc, and, with a pair of dividers, make a circle exactly one inch in diameter; then, with the Planimeter, measure this carefully, and you will have the area of a one-inch circle, if you have drawn the line right.

Having ascertained that the area of G M is 3.93, we have now to measure its length, and here is where beginners frequently make an error. The length of the Indicator diagram can only be properly measured by erecting the vertical lines, B, C, and to do this we use the steel triangles, placing one at the base, and with the other drawing the lines, B, C, just as closely as we can to the pencil mark actually made by the Indicator; and we must measure the extreme range of travel of the instrument, else our computation is incorrect and unreliable. It does not matter what the shape or form of the lines drawn by the Indicator, follow the lines made by the Indicator, and this gives the power transmitted. Sometimes, in figuring for other purposes, we have to take in an area not defined by the Indicator. In measuring the diagram of a condensing engine, it can be measured in either one of two ways. That portion which is above the atmospheric line, or the high pressure, can be measured separately, to see what is being done; and that which is below the atmospheric line can be measured to see what the condenser is doing; or, if you simply wish to ascertain the amount of power exerted by the engine, then include the whole figure above and below for obtaining the area of this figure, and we think the process has been carefully described.

The next point is to reduce it to something which shall represent power or work. In this case we have 3.93 on the Planimeter, the length of the diagram is $4\frac{25}{32}$ inches, the decimal for $\frac{25}{32}$ is .7812. We will, therefore, divide 3.93 by 4.7812 inches, and this will give us the height of an ordinate which will make a rectangular form that will represent precisely the area of the diagram, G M. Dividing 3.93 by 4.7812 gives us .821. This is a decimal of an inch. As the spring with which we are working is number thirty, or thirty pounds to the inch, we multiply the height of the ordinate by thirty, which gives us the number of pounds mean pressure exerted, which is 24.63. This process is the same for any size engine, or any number that may be had on the Planimeter, and to simplify matters in our own practice, whenever we are figuring an engine, we do it as follows: The diameter of the cylinder, reduced to square inches (see table on properties of steam), multiplied by the number of feet per minute, divided by 33,000, gives us what we term the constant, which represents the number of horse-power exerted by each pound of mean pressure upon that piston at the speed which is given. In this case, therefore, the following formula is applied: The diameter of the piston being 24 inches, area 452.39 square inches; five feet stroke, 60 revolutions, make 600 feet per minute; 33,000 pounds one foot high in one minute is one horse-power; hence, 452.39 × 600 ÷ 33,000 =8.22, which represents 8.22 horse-power for every pound of mean pressure which the

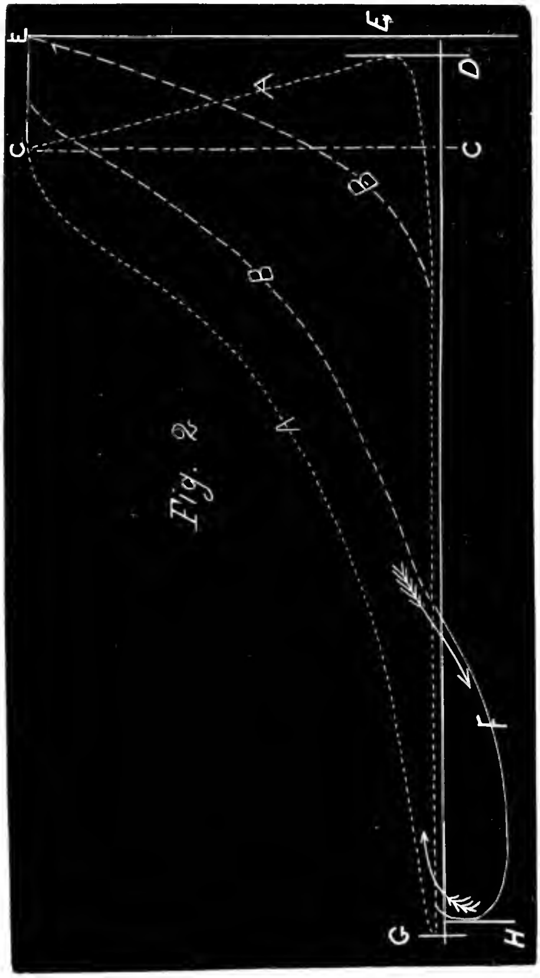


FIG. 60.

Planimeter gives for any diagram upon this particular engine at the speed we have given. Now, as we have 24.63 pounds mean pressure, multiply 24.63 by 8.22 and it gives 202.4586 horse-power.

The rule for reducing the figure of the Indicator is as follows: Get the reading of your instrument accurately; where but slight differences exist, take three or four readings and average the result; divide this by the length of the card, taking care to include the extreme length of any variation. When this result has been attained, multiply by the scale of the spring which you are using; this gives you the pounds of mean pressure. Multiply the pounds of mean pressure by the co-efficient, which represents the number of horse-power of each pound of mean pressure, from the rule given above, and you will very materially simplify the process of working up these diagrams. If you are used to logarithms you can do them with about one-fifth the figures.

The question is frequently asked as to "what shall I measure in other respects." The following illustrations will answer, as examples, but the rules which we have given above will apply to each and every one, changing the figures according to the facts as they exist, observing always to take good care of the decimals and whole numbers. In Fig. 60 we have drawn the outline of two different Indicator diagrams, embodying radically different principles, in order to show what may and must be done with the Planimeter whenever using it. The diagram, A A, which is purely a fanciful one, based on the same steam pressure as B, is drawn for the purpose of showing that any measurement made is taken by starting the perpendicular line at the extreme point, D, and measuring from G D. Should we drop the horizontal line from C to C, we should not include the actual length of the figure over which the Indicator traveled. In the diagram, B B, it will be seen that the end of the expansion line falls below the atmospheric line, making the loop, F. In running the Planimeter over the outline of this figure, follow the lines precisely as the steam Indicator left them upon the paper, in the direction of the arrows. Now the space, F, really acted upon the piston of the engine by holding it back. The Planimeter deducts this space from that above the line in such a way that actual pressure upon the piston only is given. In this case, we must draw the vertical line from E to E, and the length of the card, B B, is from H to E. In brief, the rule for the action of the Planimeter, in computing areas, is to follow the outline of the card as the instrument leaves it, without any reference to ideas. It is sometimes a question, in the case of an engine with a large amount of back pressure, how to figure it. Take the area of the figure bounded by the instrument which gives the transmitted power, and, if you are figuring for fuel, or desire to know what the whole power exerted by the steam is, take in all the back pressure, as in the diagram, G M. The line, D, in this card, is an imaginary one, and represents what might be an enormous back pressure. Now, if this engine is exhausting under this pressure, E being the real atmospheric line of the instrument, and D the supposed line of back pressure, then we must measure the area between E and D for fuel, for, as a matter of fact, the boilers furnish the steam to do this work with, but the work is not figured in because it is spent to no purpose. The power is consumed in the engine itself, and is not, therefore, transmitted to the machinery beyond.

The use of the Planimeter does not require a particle more skill than does the use of any other good tool about the mill; it works to ten-thousandths of a square inch; it is a delicate little instrument, and must not be thrown around like a pair of gas-pipe tongs or a blacksmith's hammer. A very little puts it out of order, and then it must go into the hands of some man who can put it into order again. We have one of the large ones, which we have carried probably 25,000 miles, within the last five years. It never has been out of order for a moment; it is as perfect as the day we bought it, eleven years ago, and, if it is not abused, will be good twenty years hence. An Indicator may be properly classed in exactly the same category; it is expected to detect little differences or discrepancies, and it requires to be handled very carefully. Either instrument is as serviceable as a good watch, and requires just about the same care in the handling, and, if they are well used, will give accurate results every time.

LESSON XXVII.

THE diagrams, here shown, are very interesting comparisons. Diagram B S N, Fig. 61, is from a Corliss engine, built by George H. Corliss, in 1865, with his old style valve-tripping, tripped direct by the governor, closed by springs, 20¼ inches diameter, 42 inches stroke, 84 revolutions per minute, 100 pounds of steam in the boiler, throttle-valve wide open. The parties who own this valve, write as follows: "Enclosed is diagram from our engine, as it was running on the 11th of March. We call it a good card." In response to an inquiry, they wrote as follows: "Our engine has very variable work. At times it will be doing more than 300 horse-power, and instantly drop to 150, or below, and the governor regulates so promptly that it will not vary a turn when the changes are so sudden and extreme. We have bored out the valve seats twice, and put in one set of new valves since it was started. It had poor management in early life, and from 1865 to 1870 the expenses for repairs, cut-off attachments, oil pumps, and eccentric arrangements, were large, but the trouble arose from the incompetency of the mechanic in charge. Since the new valves were put in — four years ago — we have not spent one hundred dollars in all repairs on the engine, incident to her regular work. We run ten hours a day, and from 305 to 306 days in each year."

Here is an engine that was, for the first five years of its life, badly abused, in charge of an incompetent man, — the bill of expenses for repairs was large, — but since the new order of things all this has been radically changed. We frequently hear it said, — mostly by parties who are interested in some other style of engine, — that the Corliss engine requires reboring, refitting, and a new set of valves every few months, or weeks, even, but we seldom find people who are using them, where they have anything except a numskull in charge of the engine, who corroborate any such kind of a statement or story. We have drawn vertical lines, and find that this engine is taking its steam very nearly right; in fact, the admission line and the vertical line are so near together, that we would not advise any alteration at all. The steam line of the engine is very good indeed, considering its high speed, and the amount of work it is doing. With one hundred pounds in the boiler, we get 92 pounds at A B. The steam line on the head end is hardly as good as on the crank end, and it falls, before cutting off, ten pounds, from the initial pressure realized in the cylinder. The expansion lines are very good; the only change we would suggest, would be the opening of the exhaust valve at C, D, making the dotted line down to the atmospheric line of the instrument, so as to save the little back pressure

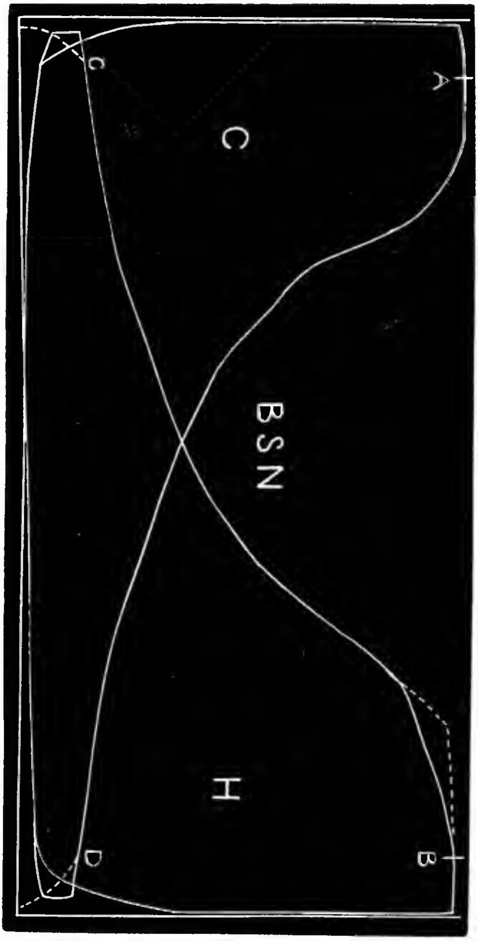


FIG. 61.

upon the return of the piston. This would, undoubtedly, make a little more compression, and would make the engine run fully as quietly as now. Practically, the diagrams are first-rate, better than the average, which only goes to prove that the Richards Indicator, with which they were taken, with a 40 spring, is reliable, when kept in good order; and we believe, with proper care, it will take a steam engine up nicely to a speed of one hundred revolutions. The diagrams in question were taken with a three-way cock, and are of no value in the adjustment of one end with the other.

In contrast with diagram B S N, we publish diagram H E W, from an engine which has been running 30 years, old fashioned slide valves, cutting off at half stroke. The cylinder has never been rebored. It is 20 inches in diameter, 4 feet stroke, 55 strokes per minute; boiler pressure 75 pounds; mill heated by exhaust, as also the wash room and dye room of the concern from which this was taken. The scale of the diagram was 44 pounds per inch. Fifty-five pounds of the boiler pressure is put upon the head of the piston, cutting off at about one-third stroke. Six pounds is lost at the cut off from the pressure realized at the commencement of the stroke. The expansion line is somewhat wavy, and the back pressure is not excessive, when it is considered what an amount of work the engine is doing. While this engine is not among the most economical motors of the day, it is an example of old style engineering, which is capable of doing lengthy service with reasonable economy. We are not informed as to the amount of fuel used for the power. It will not, however, compare with the economy of diagram B S N. At the same time, diagram H E W is a vast improvement over engines built in its day, some of which are now running. We have hardly the data at hand for comparing the relative efficiency. We would not advise the purchase of an engine of this class, from an economical stand-point, and yet, some of them are doing fully as good work, for the pounds of coal consumed, as modern engines not built upon the right principles.

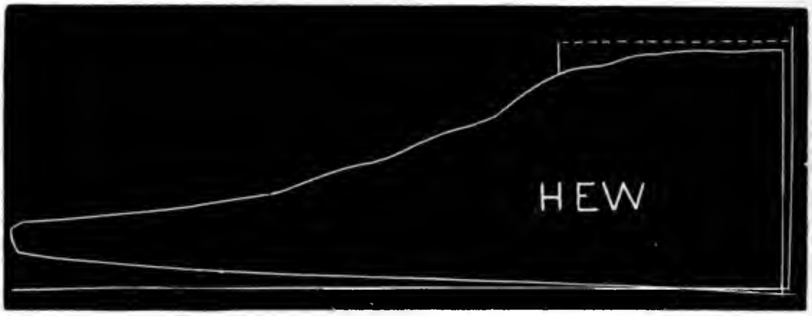


FIG. 62.

LESSON XXVIII.

THE object of the diagrams in this lesson is to illustrate, as the acquaintance with the Indicator extends, some little occasionals that will persist in cropping up, and not always to the pleasure or profit of the party who is operating the instrument. These diagrams are, for the sake of convenience, traced upon the same block. As they are both from actual occurrences, which are liable to occur at any time, we have made them the subject of this lesson. The Indicator is a delicate instrument, and requires care; it also requires, what good printers have to mix with their ink to get nice work — a little brains and practice in the use of it. The card, A, Fig. 63, is taken from a Richards instrument on a Corliss engine. The engineer discovered, all at once, that the Richards Indicator was not reliable, and he made this discovery by the help of a gentleman who was very strongly prejudiced in favor of another Indicator; and this gentleman, who was educating the engineer, forgot entirely to tell him that possibly his Indicator might be out of adjustment, even if he knew it himself; so the engineer was writing for advice regarding whose instrument he should buy, and the diagrams came to us through the mail. Now, if our readers will pay attention, some of them may know immediately what is the trouble when they see this thing repeated. Starting at A, or at the termination of the exhaust and commencement of compression, we notice that the line is heavy; it gradually comes to be dots, and the dots are further apart, — there is no steam line, — and, after the expansion has begun, it starts in again with dots, and finally, after some time, makes a heavy line again, and at A, on the expansion curve, comes down to about the right sized line again. Now this instrument was a Richards, made several years since. We wrote the engineer to please send us his instrument, and thought we could tell him where the trouble was. Upon our applying the instrument, it did not take over twenty seconds to find the whole trouble. The piston barrel is surrounded by a casing, and the paper cylinder is held in place by a short bar. The stand which surrounds the piston casing of the instrument had been thumped, and the bar had been sprung so that the top of the paper barrel was further away from the top of the piston than the bottom of it. Consequently, when we fastened the pencil to the bar, it made a heavy mark at the bottom, and made no mark at all at the top. In other words, the paper cylinder was out of parallel with the piston rod of the instrument. Sometimes the cylinder gets sprung exactly the other way, so that there will be a heavy mark at the top and none at the bottom. A little readjustment and correcting of the springs, — which had been used a number of years, — and after loosening the nuts in the heads of the springs, we put the instrument back again upon the engine, and it made elegant diagrams, so much so, that on its return the engineer decided that he did not know all there was about an Indicator, although he had been using it a number of years; and, instead of buying a new instrument, concluded that a reliable instrument would answer just as well. This is a thing that not infrequently happens. We have seen parties lay an instrument down upon a bench, or hit it carelessly against a weight, shaft, or something, and then, for the next three months, grumble about their Indicators having given out, or got out of order, when, as a matter of fact, a little carelessness put the instrument out of shape, and lack of patience, or pains in ascertaining just where the trouble was, kept them from realizing their folly or ignorance.

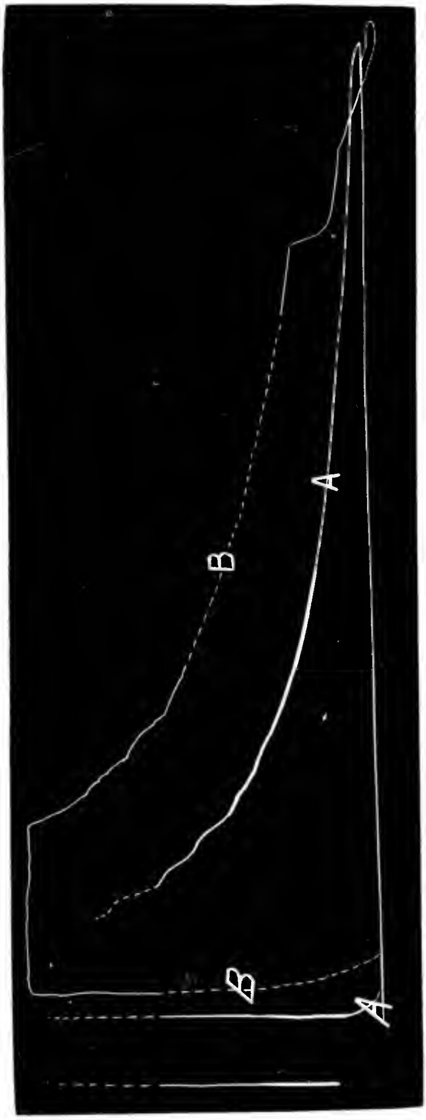


Fig. 63.

In card B, Fig. 63, we have quite another case, yet not a particle less interesting or less profitable. In this case, the compression line will be found to be dotted; the steam line is very good, but the expansion line — the upper portion of it — is anything but good, and it finally drops away into dots; and down on the expansion line, B, there is a sudden falling off, and a very erratic continuation of the expansion line. This is a peculiar, but by no means impossible diagram, and, if our readers will draw a line parallel with the atmospheric line of the instrument on the diagram, they will find that the dots commence at about the same height from the parallel line at both ends of the card; in other words, that the dots on the compression or admission line, and on the expansion lines, commence at just about the same height from the atmospheric line in both cases. This can hardly occur from any action of the steam in the cylinder. The party who sent this diagram took it from the Thompson instrument, and he declared his belief that the Thompson instrument was not over half made. We requested him to send it to us, which was promptly done. Somebody, who had been trying to handle it, had bent the piston head on the end of the rod in one direction, and had sprung the piston exactly in the other direction. When the bend in the piston rod, or shell which surrounds the connection with the parallel motion above, came through the bearing in the top, it necessarily bound, although but slightly, and the pencil jumped. The steam line is straight, or nearly so, for the best of reasons: the piston of the instrument was at that moment standing still, the pressure being so nearly uniform. When it starts to descend, it makes a very fine cut off, but after it descends an eighth of an inch, then the trouble commences by the piston beginning to stick, and sticking worse until it makes dots. Beyond the letter B, on the expansion line, where the jog is marked, it drops off instantly, and, if the curve is applied, the expansion line at this point will be found too high. Up to this time, the pressure in the cylinder was nearly enough to help the bend in the piston-rod, but, when the steam became thoroughly expanded, then the piston went down with a jump, and the line beyond it shows exactly how it worked. Upon a careful examination of this Indicator, the bend was found to be very small, but was just as essential as though it had been bent double. The piston was sent back and reorganized, a new piston put into the instrument, and some of the most elegant cards taken at the first trial. Upon returning the Indicator to our inquirer, he wrote briefly, saying, "I believe that the Thompson Indicator is well made, and that I am a good deal nearer a blockhead than anything else. Please don't give this away, and the next time I am stuck I shall know where to send."

Now these cases are possible. It does not do to put your Indicator in a vise in order to get at any unscrewing of the parts; it must not be run by tallow or cylinder oil blown into the piston, for the piston was not made to work in that kind of material any more than in a sand bank; it requires, at times, a little patience, and makes a good deal of annoyance, as we have often found, at the expense of burnt fingers and abraded knuckles; but impatience, and getting out of sorts, don't make the Indicator work better, and it does frequently get a man into a complete tangle. It makes no difference how much pains the maker of the instrument takes in its adjustment, the machine must be used as a machine, and as a very intelligent one.

LESSON XXIX.

THE different classes of engines in use show, to the investigator, peculiar vagaries and radical departures from either the theoretical or practical, so far as economy is concerned. At the same time, men have peculiar ideas, and frequently indulge themselves in experiments which, sooner or later, develop into such peculiar looking objects as we have for the subject of this lesson. We have had much to say and do with the rotary valve, and now we have a fixed slide valve, or, as it is usually spoken of, a plain slide valve, in which case there is no cut off beyond that limited by the carrying of the steam. The four sets of cards shown represent four different engines; we might, with perfect propriety, say four abortions in the use of steam. A little explanation will show that each one of these was an attempt to work out somebody's ideas in the use of steam.

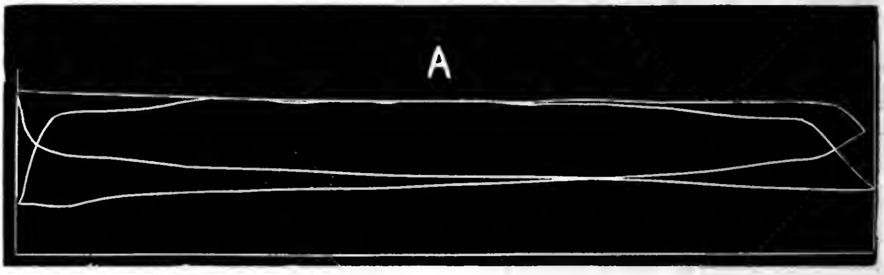


FIG. 64.

Diagrams A, Fig. 64, is what is termed a rotary-plug valve, scale 40, and it might, perhaps, puzzle some of our readers to ascertain which was the steam end, and which the exhaust end of the diagram. Both diagrams are given, but the subject is hardly worth more space than we have now given it. The scale is 40, and the base line, or lower line in the card, is the line of rest, or the atmospheric line of the instrument. The man who arranged this did not believe in clap-trap valve-gears, and he succeeded in making his own valve gear work. To use a little quotation, "No need of such nonsense; we can make a simple, cheap engine that will work just as economically as any of them." Strange as it may seem, this man really had the good sense to make use of the Indicator, and he was very soon converted to a clap-trap valve gear. We don't wonder that he was.

Diagrams B, Fig. 65, show what may occur to the plain slide-valve engine when the eccentric slips from one-quarter to one-third of its way on the main shaft. The steam and exhaust are very late, and this engine would make first-rate junk, and would be cheaper in the junk pile than in the engine room if it had to work in this way.

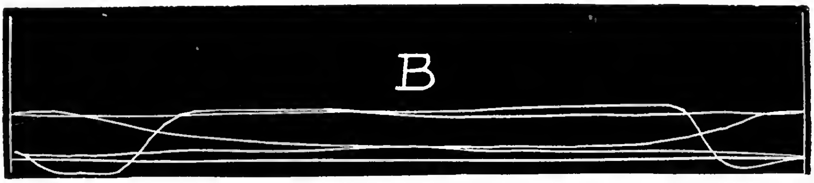


Fig. 65.

Diagrams C, Fig. 66, are a curiosity in the literature of engineering. The engine was moderately well constructed, the steam line, as shown, is very fair, the exhaust commences to open at about the right place, but it never gets open enough to get rid of the back pressure. But the trouble in this case is not in the engine, it was, rather, in the vague ideas of a man who did not believe in heating his mill by direct steam. He was going to economize his exhaust. His train of argument was something like this: "If my exhaust steam can be carried through a long pipe, I can extract all the heat from it, and save what would otherwise be thrown away." Not satisfied with this, he had another exceedingly happy thought: having used a considerably long circuit, he kept reducing the size of the pipes for fear that one or two extra degrees of heat might escape his grasp, until, finally, what little heat there was left in the steam, was made to escape through a three-quarter inch pipe, and a tank of water. The diagram shows that he made a brilliant success in one respect, and a brilliant failure in the other. He probably succeeded in extracting all the heat, but at a slight expense in fuel. The figures show the reading of the Planimeter. It will be seen that the effective work yielded was 238 out of 773. In other words, it required 773 horse-power, if you choose, to develop 238 horse-power, transmitted to the

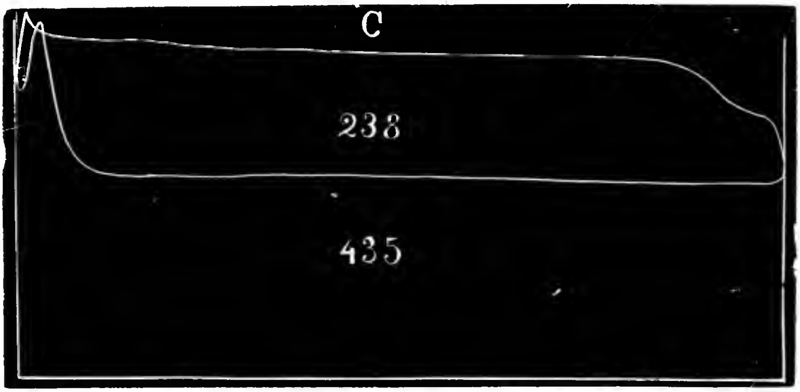


Fig. 66.

machinery, 238 horse-power being yielded by the belting, and 435 horse-power being consumed in pushing the steam out of the cylinder, through several miles or less of pipe, into a tank of water. While the amount of power in this case is largely exaggerated, the actual proportions are precisely as stated. He did heat the rooms, and he did squeeze the last item of heat out of the steam; which, in turn, revenged itself upon him in his fuel bill, as any sensible man would long before have discovered. At the commencement of this operation he congratulated himself. We can imagine him rubbing his hands with glee, but when the fuel bills began to come in, his face grew as long as a broomstick; he wondered somewhat, after a little time wavered, then doubted his own success, and, as a last resort, called in the doctor; and we will let him down easy, by saying that he now uses direct steam for heating his mill, runs his exhaust steam through a heater, and takes very great pains that his heater has an extravagantly good amount of exhaust room, that the steam is not choked anywhere, and looks out for sharp turns in every direction; and he is not only a converted man, in the strictest sense of the word, but is richer, both by experience and in his pocket. Heating by exhaust steam is a great hobby with some people, and others who have tried it have found that it is, unless properly managed, very expensive; in fact, so much so, that many concerns have abandoned it, preferring to heat their feed water, and then, having economized in a sensible way, they can well afford to make more steam, and send it around by direct circulation. It hardly pays to heat by exhaust steam when it troubles the power of the engine, and this party referred to above was, no doubt, an unbeliever in the utility of the Indicator, until he was converted by main force. In other words, it required him to bring his skull in contact with a stone in order to set him thinking.

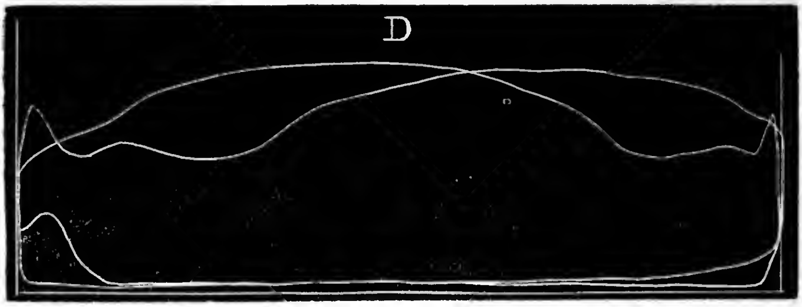


Fig. 67.

Diagrams D, Fig. 67, represent an experiment upon an elaborate scale, by an engine builder, and a man of some considerable experience, who really made a pretence of building a good engine. This man also had a hobby. It was, that the impact of the steam upon the piston head was tremendous, and that, instead of doing the work as it should, by attempting it in that way, continually tore the engine to pieces, or set it to thumping and pounding—

so he had a brilliant idea. As the impact of the entering steam was altogether wrong, and could not do any work, for the crank was on the centre, he concluded that the time for the action of full pressure was in the middle of the stroke, as he believed in putting the steam where it would do the most good. He constructed his ports and valves to work as these diagrams show. He believed he had the philosopher's stone and the true theory of steam distribution, and either his engine, or one of the high speed engines, must fall. His conversion was, perhaps, as forcible as the engine. He admitted steam gradually at first. (The diagrams are taken with a 40 spring.) It will be seen that the steam raised in the middle, struck to the highest pressure, takes a back lash before it gets ready to exhaust, and really bears a very fair analogy to the shape of a sperm whale's head. The figure is a literal representation of the obtuseness of this man, who afterward found that there was a good deal of difference between tweedle-dee and tweedle-dum.

There is nothing good to be said of any of these diagrams, yet they are not, by any means, the worst that could be produced. Taken as a class, A and B are fair representations of what is being done regularly, while C and D are monstrosities, and are of no more practical use, or real practical value, than a wooden man would be as engineer. We have given them, not because they conveyed valuable instruction to our engineers, but for the reason that this lesson is intended more for steam users and for some of those parties who belong either to the chronic or constitutional grumblers. We know, personally, where there are engines running worse than either of the four cards, and not five miles from where we are now writing.

LESSON XXX.

THE diagrams for this lesson are both from men who are running engines. Diagrams A, Fig. 68, are from an engine manufactured by the Hartford Engineering Company, of Hartford, now in operation in a New England cotton mill. The data which comes to us is not complete. Steam 72, scale 30, revolutions 124 per minute. The steam line is very good indeed. The cut off of this engine is closely defined; the expansion line would seem to be very good, but, as the clearance is not given, we cannot state definitely what its approximation is to the so-called theoretical curve. The exhaust valve upon either end opens early at A, and the back pressure is very small. We have no means of knowing whether the steam is being exhausted into the open air, or is being used for heating. At any rate, the back pressure is less than two pounds. The compression lines made by the valves of this machine require less length of stroke, and approximate to steam pressure nearer than that of the generally constructed high-speed engines. In other words, there is less compression in volume as regards the proportion of compression to the whole length of the stroke, and the compression is made effective by what appear to be close working valves. The engine falls about ten pounds short of boiler pressure; but, unlike most high-speed engines, the steam line does not drop off ten pounds from the pressure first realized on the piston. The falling off of the steam line from the first impact is not appreciable, in fact, cannot be measured by the scale used. It is rather a matter of regret that more data did not accompany the card. The valves would seem not to be leaking; their action is proportionately the same; the expansion line, we have little doubt, will approximate very nearly the curve; and yet, much of this depends on the condition of the steam, and the distance of the engine from the boilers; but, taking it precisely as it reaches our hand, it is a very good diagram. This engine must not be confused with what is known as the Buckeye engine, built in the West. This is peculiarly an Eastern machine, and is very far superior to any cards we have ever seen taken from the Ohio machine.

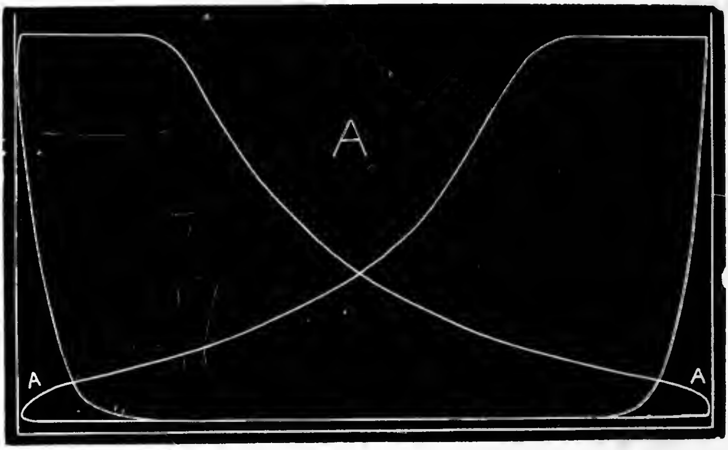


FIG. 68.

Diagrams C F, Fig. 69, come to us all the way from St. Louis, and is from the Reynolds-Corliss engine, built by Allis & Co., of Milwaukee, Wis. The data, which comes with this diagram, is: Diameter of cylinder 28 inches, length of stroke 5 feet, revolutions 63, spring 40, boiler pressure 75. The peculiar feature of this engine is its beautiful compression lines and the close expansion line. The steam pressure is very nearly the same, falling nearly ten pounds from boiler pressure. The dotted lines over the steam line would lead us to suppose, not having the facts in our possession, that the steam was either drawn some ways from the boiler, or else through a pipe that was hardly large enough to supply the demand made by the opening of the steam valves. It will be noticed that the head end falls off more radically than the crank from the steam line or induction pressure, and this fact would give us the rounding over of the corner from the fact of the steam valves closing on a deficient supply of steam, so that the steam is, to a certain extent, wire drawn through the valve after it commences to close, and this, in fact, is the only poor feature of this diagram. Judging from the appearance of the cards, we should say that the engineer in charge had some pride in his engine, and was endeavoring to see how well he could do with it, rather than how much he could get out of it. Both these cards were taken by the engineers themselves.

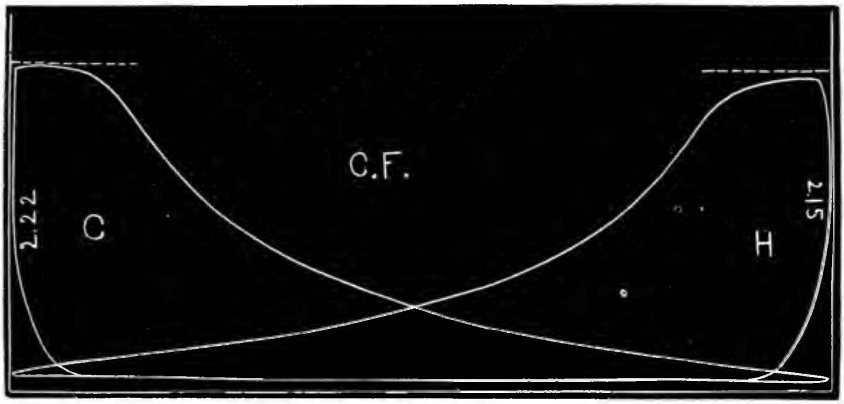


FIG. 69.

LESSON XXXI.

A PRACTICAL illustration of the value of the Indicator could not be more forcibly made to the mind of any man, who is capable of reasoning, or one who is not prejudiced, than the one which is here presented. We frequently receive inquiries as to peculiar points of working, some of which cannot be explained satisfactorily without a careful investigation, and others which can never be remedied until after the faults which are left by the builder in the machine are all removed.

In order to save space, and, at the same time, to make the lesson all the more forcible, we have drawn two sets of diagrams upon the same block. The disproportion in the outlines which follow each other can be studied by any one who is interested. Briefly stated, the case is as follows: Some time ago, the writer of this was called to look at an engine just outside the City of Boston. The engineer did not believe in Indicators, and considered that any man who attempted to meddle with the engine, after he had placed it where it should run, had taken in a "pretty fat job," to use exactly his own words. However, the engines were adjusted, although but one of a pair was generally used. After he saw how easy it was to control the movement of the engine, and to bring everything into working order, he became very much interested in the Indicator, and the agent of the concern ordered a set, with which the engineer is now very greatly interested, and is keeping close track of his engine. The engines were carefully adjusted, and, as some changes were going on at the time of our visit, we advised the changing of the main steam pipe leading to the engine. As some especial piece of casting had to be procured, it was not done at the moment. So we were somewhat surprised, a short time afterward, to receive a pair of diagrams, one taken at either end of the cylinder, on the same stroke, of which A A are almost absolutely exact reproductions, together with a note from the agent, saying that there was some trouble with the engine, but, as nothing had been changed that they were aware of, he could not explain, nor could the engineer, why they should make such cards; would we telegraph him, the instant we received his letter, what to do? Here was a puzzle. The crank end is the same for each diagram, in general, at least, but the disproportion between the head and crank dotted line is rather too far out for general use. The other engine was disabled. He

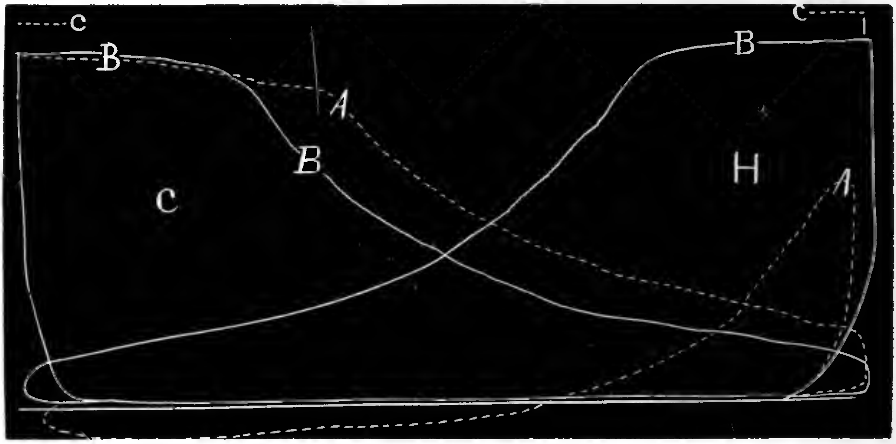


FIG. 70.

had worked all day Monday in trying to get at the matter, so that our letter was received Tuesday morning. We telegraphed him at once to take off the head end of the cylinder and see if there was anything jammed into the port, or if the valve was free in its working. After two or three hours, back came his answer: "Port all clear; will be ready to run in half an hour. What shall we do next if the card don't improve?" Away went our answer: "If the same difficulty still exists, pull off the new valve and see if there is anything in the steam-way so that the valve don't get steam; if this don't cure it, I will be there at five o'clock." This left our office about eleven o'clock. At four four o'clock, P. M., came another: "No improvement on taking off the cylinder head; we followed directions, and dug out a blacksmith's shop; just connected up, and everything is lovely and on the top shelf." Next morning's mail brought us along a laughable letter, enclosing diagrams B B, showing the boiler pressure at C C, scale 40, engine 60 × 23, running 56 revolutions. The end of this letter was about as follows: "If there is a man in this country, today, that swears by the Indicator, it is your old friend, our engineer, but he thinks that a little Indicator, some telegraph, and some common sense, work in pretty well together." Herewith follows an explanation. The joke of the matter was, that he threatened to send us the whole batch of stuff taken out of the steam passage between the main valve and the steam valves.

"When the new steam pipe and valve arrived, our master mechanic, who usually has charge of these things, joked the engineer about his not loving that 'feller' who came out with the Indicator. They had some good-natured chaff, and when it came stopping-time at night, the master mechanic, thinking to make some of his tools all safe, put a large lump of copper, a short stub wrench, an S wrench, and a piece of lead, which he had been using, into the steam chest of the engine. The next morning the master mechanic was called to another part of the yard, and, before leaving, sent one of the men to the engine room, expecting to join him in a few moments. Being bothered, himself, by something which demanded his attention, the engineer and his assistant, being in a hurry to get that mill started, helped machinist number two to lift the big valve in its place, and then they had a hunt after the wrenches,—not, however, finding them. Others were procured, the valve was put on, the gaskets placed, and everything screwed up for 'keeps.' Steam was then put on, and the engine started slowly to see that everything was all right. The result you have in the cards. The joke of the whole thing is that, by changing the men, one had forgotten about his tools, and the other knew nothing of it, so that we were all day digging out our machine shop. The lesson has not been without good results, and if our master mechanic is easily nettled now by reference to his new tool chest, you can imagine why he appreciates the joke. The engineer in turn laughs at the mechanic, who had previously chaffed him (the engineer) about the Indicator affair, by threatening to take out a patent for his new tool chest."

Our readers have here a stubborn fact, and an expensive one, but, at the same time, a very instructive one. The diagram, A, head, shows conclusively that the steam is shut away from the piston by some reason or other. Sometimes tools have been clogged in the port, but we do not know that the passage was ever before, in our own experience, blocked up back of the port. A lump of copper, five and one-half or six inches long and more than two inches in diameter, and a piece of lead as big as two ordinary fists, cover a large proportion of the length of the steam port. Come to mix these up with a stub wrench, made from inch and a half iron, and some other little matters, which, fortunately for the valve, were so placed by the blast of steam that they did not pass over the valve and catch between the valve and the port, or they would have made music, and an expensive bill of repairs, and effectually shut the steam away from the head valve of the engine. One of the beauties of the automatic adjustment is seen in A, crank. The steam pressure steadily diminishes from the time of impact, and the steam line drops nearly ten pounds; but, compared with B, it carries steam very much longer, endeavoring to make up for what the head end, A, lacks. The race, however, was a stern chase, and it was impossible. But after the machine shop was removed from the steam chest, B B shows that the engine was in excellent adjustment, one valve, if anything, being a trifle off time, but the steam lines are so nearly good that it is not necessary to criticise them.

There is also another lesson to be drawn from this, viz.: It don't pay to joke too hard, or to play tricks, one workman with another, in a job like this, where one man may forget what he has done, or another one forget exactly where he left off. It was a very fortunate occurrence that a smash-up did not occur, and had some of these tools passed the steam passage to the front of the steam valve, there might have been a smash with serious consequences. The Indicator only tells the truth, and, if the steam is shut away from the piston, it may not write upon the Indicator card that practical joking is expensive, or a machine shop out of place has choked the steam off, but it does tell distinctly that the steam don't get to the piston, and sensible men, like those who use the Indicator, usually commence an investigation without waiting for a smash. There was never a better illustration of the real value of the Indicator than this; and, although it is absurd in one point of view, we consider the instructive as predominant, hence, give it a place among our many lessons.

LESSON XXXII.

THE point in the following needs a little preface, in order to be thoroughly digested by our readers; we mean, of course, the practical ones. Yet it is only one case where a consulting engineer has to trample down both ignorance and prejudice, and can only let daylight shine, where prejudice and ignorance has sway, by the use of a sledge hammer. The point in question is one which reaches directly the pocket of the victim; and for this, steam users are not so much to blame as those men who sign themselves "experts." Briefly, the case is as follows: A manufacturing company had a large engine and boilers, and a first-class, sensible, clean, and intelligent engineer. The engineer had satisfied himself that he was using more coal than he should; precisely the reason he did not know, for he had no Indicator. After a good deal of persuasion, he induced the manager to make a call upon us for advice. We suggested the application of the Indicator; but he did not understand the thing, could "not see why his engineer could not set the valves," and repeated the whole train of arguments which are so often rehearsed to the man who is a consulting engineer, and has any practice. He finally inquired our terms. "Fifty dollars a day," we answered him, "and not more than one day at a time; we must consult our other work and appointments." He thought that was pretty hard; in fact, he "would not pay any man fifty dollars a day, — it was more than he was worth." We mildly suggested to him that there were other men who could apply the Indicator, and we were perfectly willing for them to have every chance. But in his case it was not sufficient to have the Indicator applied; but, as the darkey said to the surgeon, he wanted also to apply the "know how," which we have been trying to learn for the past twenty years. We bade him good-bye, and good-naturedly advised him to call again and give us his results. A few weeks after, he called, bringing some Indicator cards, and frankly confessed that while the engine had been improved somewhat, he was thoroughly terrified at the amount of coal it was running through. He presented us with the card X A 1, Fig. 71, and any one who knows anything about working steam would not dream that this was made by a Harris-Corliss machine. If it had been made on one of the old-fashioned, grid-iron cut-offs, sliding on the back of the main valve, built thirty years ago, we would have called it a pretty fair production of that style of engine; but, as to its comparison with any modern idea, it is radically deficient, and one of the worst abortions we ever saw from this kind of an engine. The old question then arose. We told him frankly we had quite enough to do without the job; at the same time, we liked just such a job, for it furnished food for reflection for other people who are using steam power. But the old gentleman thought the price was abominable, and went to consult his treasurer. A few days after, he and his treasurer walked in with the same diagrams. A half hour was spent in chatting and chaffing, and no result was reached.

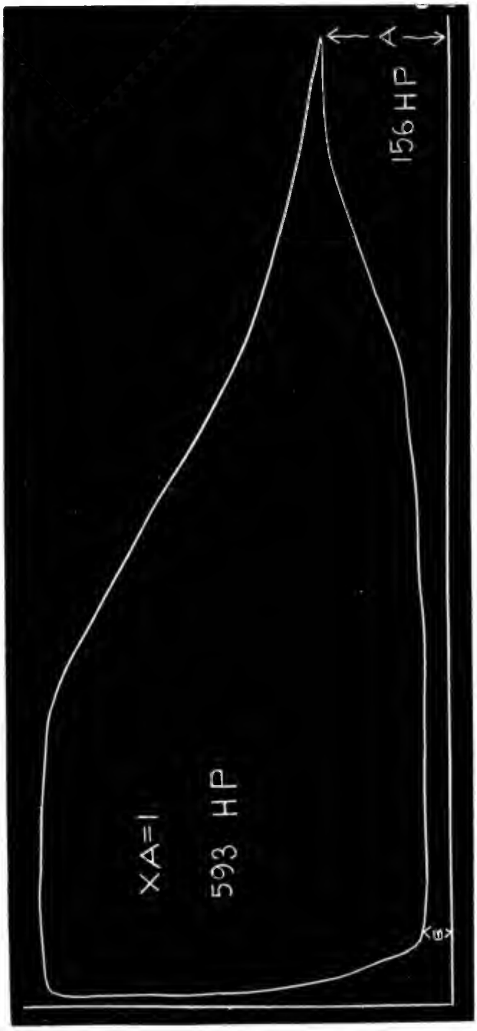


Fig. 71.

In about a week, the son of the agent came in, bringing the cards which our expert friend had taken, showing the state in which the engine was left. The son was one of those intelligent fellows, who not only wants to know what is going on, but also some good reason why. We asked him if he had any objection to our running our Planimeter over the card. "Certainly not; he wanted information." In running the Planimeter over the card, X A 1, we told him that he was losing about 25 per cent. of his power by back pressure; in other words, that the back pressure was abominable; that the engine was largely overloaded, and that the draft of steam did not allow him to realize his boiler pressure; but that, if he could afford to burn five tons of coal to do what four tons ought to do much better, it was not our business, but his. We finally made him a proposition, that we would indicate the engine, adjust the valves to suit ourselves, and be responsible for results, if he would agree that the engine should be let alone, and we would take one-half of what we could save in fuel for thirty days' running time; to take his last four or six months' account, and average the time, and take our thirty days' run, actual weight, and let himself, his father, and his engineer, make their own figures. He went away. A day or two after, he accepted our proposition. We named a day, and obtained a half dozen reproductions of X A 1, with little variations, according to the load. The engine is 23 × 60 inches, 57½ revolutions, 90 pounds of steam, scale 40. Measuring from the atmospheric line, or line of rest on the instrument, we get 85 pounds into the cylinder. It is hard work to tell where the cut off is, or where the expansion line commences. There is evidently no difficulty in telling where it ends, or that there is a slight amount of back pressure in the cylinder. At the commencement of the exhaust, with a nine-inch exhaust pipe wide open into the air, and not more than 40 feet long at that, at A, we get 25½ pounds back pressure; at the centre of the stroke, we get 7½ pounds, and at B, we have 5 pounds left. The engine was burning twelve and a half tons of coal a day, of eleven hours, developing 750 horse-power, of which 595 horse-power was transmitted, less 156 horse-power back pressure. If our readers will figure this a little, they will find that the engine was running with three pounds of Lehigh furnace coal, or what may be better known, perhaps, as "broken," in pieces about the size of a man's fist. Slightly over 25 per cent. of the load was thrown away. After four hours' work, a part of which was spent in making explanations, and several stoppages, we produced X A 2, which represents 470 horse-power, nearly, and yet was driving the same machinery as X A 1.

It will be seen that X A 2 has exactly 90 pounds of steam in the cylinder at the impact; that the point of cut off is very sharply defined; that the steam pressure, to the extent of five pounds, is lost; so that we start with 90 pounds, and cut off very sharply with 85 pounds. The expansion line, without applying the theoretical curve, to the practiced eye, is a beauty. It must be remembered that every pound of the mean pressure on the piston of this engine gives 7.239 horse-power; hence, 37½ per cent. of the load by X A 1 is exactly thrown away. Yet no heating was being done; the engine was exhausting in both cases into the open air. X A 2 shows 1½ pounds of back pressure on

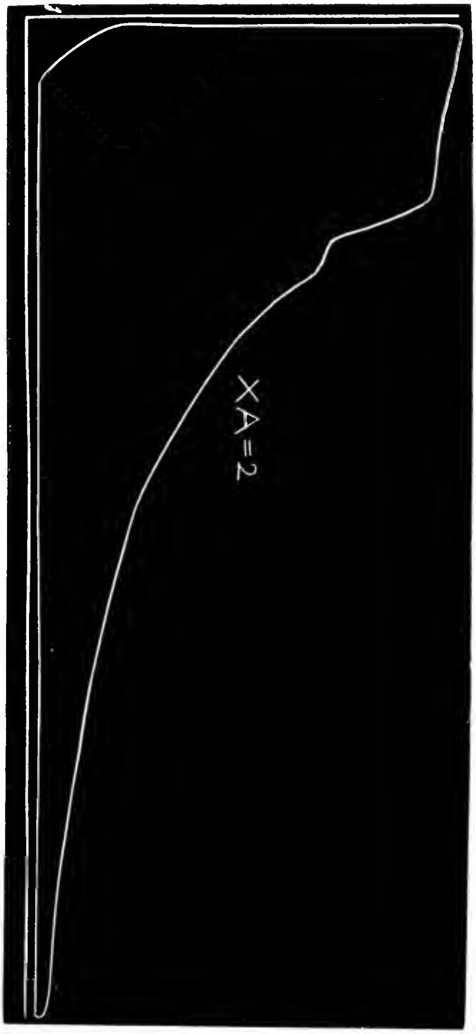


FIG. 72.

an average, commencing slightly in excess of that, and terminating the exhaust by a very handsome compression, and almost absolutely correct admission.

This is a most interesting case, because it is based on absolute facts. At the end of three weeks from the adjustment of the valves, the old gentleman called to see what our charge was to be. We referred him to the engagement made in his son's letter. A day or two afterward, the treasurer called with the same question. We simply referred to our agreement, which was in writing. The day before the termination of the thirty working days, the son called, asking us if we expected a saving which would amount to 30 tons of coal. We told him we expected a saving of over 70 tons of coal, as the total amount saved, and he told us they were going to exceed that amount, he thought. Here the matter was left until the thirty days terminated. The account rendered, is as follows: For four months' working days, 24,783 pounds of fuel were used, including banking fires at night, and on Sunday, under boilers sufficient to run their big fire pump. For the thirty days after the readjustment, 5,140 pounds of coal were saved each day, the fuel account being charged with banking the fires, and maintaining a steam pressure not less than 50 pounds on four boilers every Sunday for the big fire pump. The coal in the coal-house cost $6.40 per ton, making a clean saving of $16 per day, saying nothing of the few pounds of coal over 2½ tons. They figured, therefore, the saving, by the simple readjustment of the valves, to be $480 for five weeks' running time, 66 hours per week, making thirty working days. The letter received from the old gentleman a few days after, enclosing his check, stated simply as follows: "Six weeks ago I would not have believed that you or any other man could have shown how ignorant a man can be in the use of fuel. The only thing I regret is that I had not long ago employed you. If this should ever be given in the columns of your paper, do not give any clew to the mill or the manager, if you have any respect for yours truly."

And yet this is not as bad as some mills are actually doing today. The way out is simple, and some of our corporations, that consider an engineer is getting above his business when he attempts to learn something, may perhaps get down to their business through their legitimate representatives, if they themselves were to learn more of the Indicator, of the absolute facts which it records, and of the saving which the proper reading of the simple pencil lines of the instrument upon a piece of paper will allow a man practiced in it to effect. Dollars and cents are the measure of most men's success, and they are quite as ignorant why a man should spend years in this practice, and then ask them but a very nominal sum indeed for the use of his experience, as the old darkey was why the surgeon should charge $25 for fifteen minutes' work, which might save a man's life, not taking into account the years he had devoted to study in acquiring an intimate knowledge of human anatomy. But there are people who can only learn from experience, and the case which we give here is peculiarly one of these applications.

LESSON XXXIII.

THE diagrams, Fig. 73, which are the subject of this lesson, came from a Reynolds-Corliss, 24 inches in diameter, 48 inches stroke, rated at 330 horsepower, making 76 revolutions per minute, 40 scale (boiler pressure not given), driving a cotton mill in Mississippi. This inquiry comes with them: "What do you think of them, and what improvements would you suggest which will work for our advantage?"

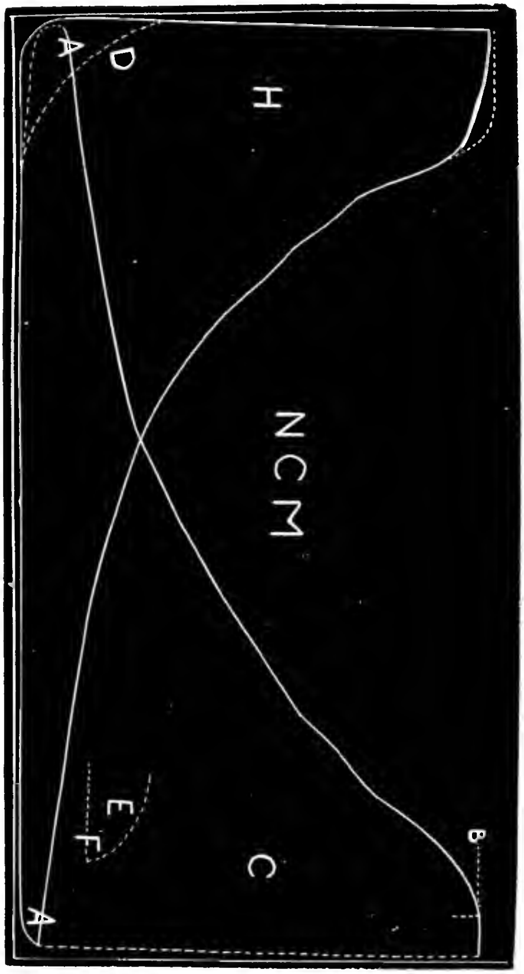


FIG. 73.

Apparently there would appear to be little difference, and yet the crank end, while seeming to cut off the shortest, is doing more work than the head end. The cut off is cleanest on the head end; but, after the valve is closed on the crank, the steam seems to come through under the valve, and the expansion line is higher than it should be. Remedying this would be an improvement which would save money to the concern. The head end, if attention is given to the vertical line, will be found late in taking steam. We would quicken that valve slightly, by opening it a trifle sooner. This would have a tendency to somewhat increase the pressure, which would probably go nearer to the dotted line on that end. On the diagram marked C, the steam line proper is very short, while the cut off is apparently at B. This valve, seemingly, opens quicker than the other, and, if the instrument is correct, the line leans the wrong way, as it leans to the vertical line rather than from it. If the valve was opened slightly quicker, and the cut-off then adjusted to do the same amount of work upon each end, there is little doubt but there would be less loss in pressure than is shown by the diagram. Taken all in all, the diagrams are very good, yet the engine could be made to do its work with a perceptibly less amount of fuel by the changes we have indicated, and, if they are made, we should be glad to see other diagrams after the alteration.

At A, on each of the diagrams, it will be seen that the commencement of the exhaust is abrupt, and the toe of the diagrams is square on the wrong side. If the movement of the exhaust valves was slightly quickened, the dotted line, D, would be produced upon that end, while E would be produced on the termination of the expansion line, and the commencement of the exhaust at F. Both these outlines will be produced by shortening the jim-cranks slightly, if it is the ordinary Reynolds-Corliss engine. The boiler pressure in this case is not given; had it been, we might have told whether further improvements could have been made. It is evidently plus one hundred pounds, as nearly one hundred pounds is realized in the cylinder. On the whole, it is better work than the average, and speaks well both for the builder of the engine and those who have it in charge.

LESSON XXXIV.

In this lesson we have a veritable study, not exactly in natural history, but in the misuse of steam. These diagrams, Fig. 74, were taken from a Greene engine, and a machine capable of doing much better work than this. The man in charge of this engine had an Indicator, but whether he did not know how to use it, or did not want to, we cannot tell. The diagrams are about as bad as anything can well be. C D represents vertical lines, showing the boiler pressure, 55 pounds, 40 scale. If we take A, and start on the admission line, we find the admission line leaning away from the vertical, and this tells us conclusively that the motion of the valves is late. The steam rises to 1, where a sharp off-set is made, as the piston begins to move at that point. The pressure then rises to 2, where another off-set is made, and very much more rapid than the other. This is owing to the accelerated motion of the piston. The motion of the piston is increasing in speed all this time; the motion of the valve is also late in its opening, and so does not keep up with that of the piston. The motion of the piston from 1 to 2 is much slower than from 2 to 3, hence the admission line varies less from the perpendicular from 1 to 2 than from 2 to 3. At 3, fifty pounds pressure is utilized, and from 3 to 4 we may call it a steam line. At 4 the valve is closed. The expansion line continues to 5, where the exhaust valve partially opens. The expansion line then commences, and returns on the exhaust line, until we meet a very queer character near 6. What makes this peculiar notch at that end of the diagram, and in that way, we confess we are unable to explain satisfactorily. If the engines had grid-iron valves for exhaust, the valves might have closed and traveled past the opening again, so as to compress the steam to a point and then reduce it again by admitting it into the exhaust until the valve traveled to another grid.

B is, in a general way, worse than A. The exhaust valve closes at 7, making a very peculiar kink. Compression taking place, the pencil of the Indicator travels past 8, drops down when the piston of the engine begins to move, and begins to travel backward, passing at 8, running up to 9, at which point the piston starts on its journey, the valve opening very late; at 10 it is still later, and at 11 very late. The round outline of A shows that the valve does not supply steam in any quantity sufficient for the area exposed. From 11 to 12 we may call it a steam line. From 12 on, the expansion line takes place, making one of the most outrageous cards found in practice. We do not know of any explanation for this appearance unless, perhaps, the engineer never knew the use of the Indicator, possibly did not care to know, or else that, in attempting to change the valves by the Indicator, he had got lost, and this is probably the nearest to a plausible explanation we can suggest.

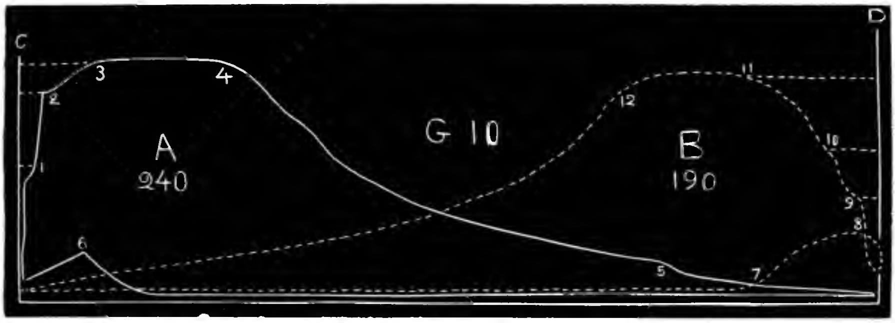


FIG. 74.

If we were to study this card for economy, we find that A figures 240, B 190, or in that proportion. Little more than half the steam, will do the work of A, and considerable less than one-half the steam used at B, if properly applied. Here, then, we have an engine doing its work nearly thirty per cent. more at one end than at the other, and using fully double the steam that it should to accomplish the work.

Some parties sometimes ask questions in reference to compression. They do not understand how the lines 7, 8, 9, 10 are made. Remember that the pencil of the Indicator travels up and down while the motion of the paper cylinder is at right angles with the pencil, or, we might say, is backward and forward, just like the piston of the engine. At figure 7 the exhaust valve closes over the exhaust port; the piston has not reached the end of its stroke proportionately, as the distance from 7 to the vertical line is to the whole length, C D. Whatever steam is in the cylinder at the time is closed in. Now, as the piston approaches the line, D, the steam in the cylinder is compressed to a greater density. This compression raises the pencil of the instrument slowly, making the rounded outline in this case instead of an angular one. When the piston gets as far back as 8, for some reason, perhaps leaky rings or valves, or condensation of steam, the pressure gradually diminishes, and, instead of holding the Indicator piston up as high as 8, the change which takes place in the steam reduces the pressure, and the piston of the Indicator falls downward; it reaches the lowest point, as will be seen, at the very extreme end of the travel of the piston. The steam valve now commences to open, and steam is let slowly into the cylinder. The piston commences to go back on its outward stroke, and the steam increases in pressure, making the line up to the figure 9. During the time this line is being made the speed of the piston is very slow indeed, and it is just passing off the dead center. As the piston starts away it gradually grows faster and faster every inch that it travels, so that when the Indicator piston reaches 9, the piston of the engine has started to travel much faster, and the line falls back from the vertical line, D, much more between 9 and 10 than between 8 and 9, and the same applies to 10 and 11 as greater than 9 and 10. If the motion of the steam valve is late at the commencement it does not open any faster, for it has no connection with the piston, and the volume of the cylinder increases very rapidly. Steam should be admitted to the cylinder by opening the valves when the piston is on its dead center, or actual point of rest, if possible. This can be done without giving any shock to the engine, or without any danger. Evidently whoever had been working with this engine was either ignorant or careless. It would require an hour, perhaps, to put it in first-rate order, and, with an engine not having large areas of port and valve—and the Greene engine is noted for this—the results would have been far less economical, if, indeed, there is any economy in the diagrams at all.

The first thing to do in a job of this kind, in adjusting, would be to throw the eccentric ahead two or three inches on the shaft, quickening all the motions. Then it is a question of give and take; perhaps one motion would have to be slowed, and another one quickened a little. In a future volume in this series, we purpose to take up this subject of making the alterations in an engine, and give the whole series of diagrams, in order to show just what is done by making a little change. We would not advise our readers, however, to imitate the diagrams given in this lesson, upon any account, for they are worse than bad, if it is possible to have them so. A good engineer would not make such a diagram if he had an Indicator, and knew what it was for. If this engine was doing 200 horse-power, and coal was worth $4 a ton, the proper arrangement of the valves by the Indicator would save just about half the coal, to say nothing of more regular speed and less keying up of the engine.

LESSON XXXV.

THE diagrams in this lesson were taken from the report of Henry Hiller, the Chief Engineer of the National Boiler Insurance Company, of Manchester, England, for 1881. It is not an uncommon occurrence, and, at the same time, it is very peculiar. The cylinder is 16 inches in diameter; stroke 36 inches; revolutions per minute 65; scale No. 1, 22 per inch; boiler pressure 57 pounds. No. 2, same diameter, stroke, and revolutions as the previous one; scale 12. These diagrams were taken, No. 1 from one cylinder, and No. 2 from the other cylinder of a pair working together.

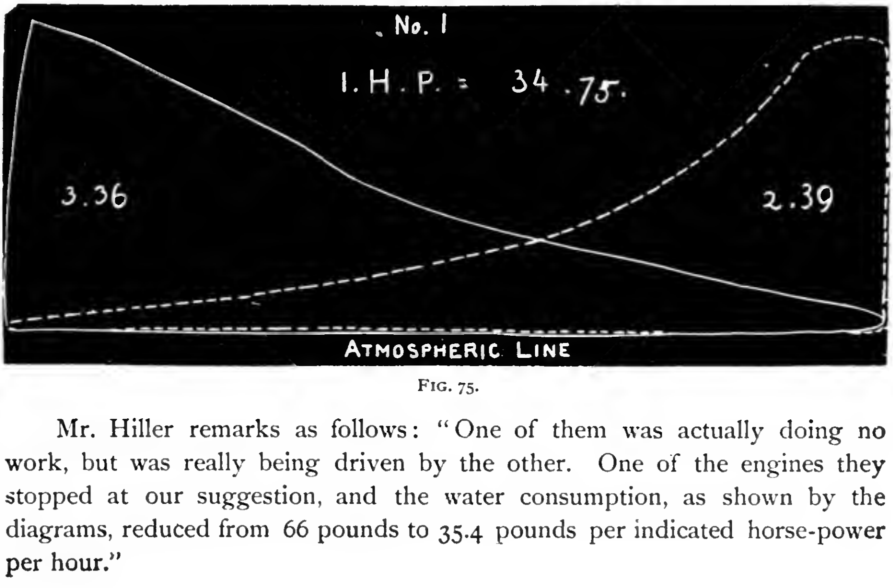


FIG. 75.

Mr. Hiller remarks as follows: "One of them was actually doing no work, but was really being driven by the other. One of the engines they stopped at our suggestion, and the water consumption, as shown by the diagrams, reduced from 66 pounds to 35.4 pounds per indicated horse-power per hour."

These diagrams are peculiar in more respects than one. No. 1 is very late in taking steam at both ends, more so at one end than the other. Whatever the pattern of the engine may be, no description being given, the steam would seem to be badly wire-drawn. The expansion line is a wicked one, and the effective pressure differs radically between the two ends. Sixty-six pounds of water per hour is an outrageous quantity. Twenty-five or six is accomplished on old-fashioned slide valve engines, and as low as thirteen to sixteen by the Corliss condensing.

Diagram No. 2 is more than peculiar. The steam is admitted, cut off sharply, and expanded across the atmospheric line at about one-fifth stroke. That part of the diagram which is below the atmospheric line, in which the steam is long drawn out beyond its usefulness, has an area larger than that of the pressure on the piston above the atmospheric line, and it is the same at both ends, although a little more difference exists in one than in the other. No doubt some of our readers will get bothered in measuring this with the Planimeter. They are reproduced full size, so that they may be measured. The boiler pressure, in this case, is 57 pounds, while the realized steam pressure is only 24 or 24½ pounds. The indicated horse-power of this pair of cards is less than nothing; in other words, the horse-power is minus 2½, or, to put it into still another shape, 2½ horse-power is being developed against the other engine. This is caused by the expansion of the steam, which is drawn out past its useful or efficient force, so that it really retards, or would retard, the action of the engine, were it not that the other side is driving so much more power, and this is doing very wastefully what it is doing at all,

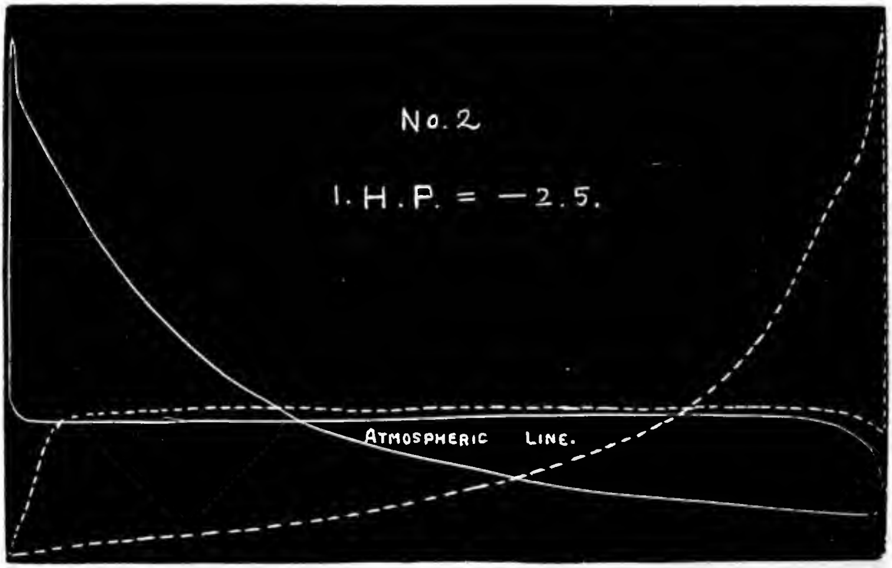


FIG. 76.

from the fact of the steam being admitted at a much lower pressure than in the boiler, and then being expanded at such a ratio that it practically ceases to be of any use. We do not wonder that, when this engine, as Mr. Hiller advised, was stopped, the other engine did all the work with less fuel. The measurement of the spaces, below the atmospheric line, is always taken from the measurement of that space above the atmospheric line, by the action of the Planimeter; but in this case the space below the line is of the most account, consequently the Planimeter gives us a negative result at the end of its travel. This will be an excellent exercise for learners to practice upon, and it will give them useful information in regard to taking the areas of surfaces which are somewhat mixed.

If we take No. 1, in this illustration, we have the fact of 38 pounds of steam, out of 57 boiler pressure, being shot through the ports on to the piston head, after it has been on its way some time, so that it never catches up. We then have a low ratio of expansion, from the fact of wire-drawing and throttling, and the steam is reduced in pressure to that extent which makes it a most exorbitant consumer of water.

In No. 2, the same thing is carried out. The steam is put into the cylinder of the engine to do less than any work at all, and, aside from wasting the amount of steam which is put into the cylinder, the parties were also wasting power which had to be made up by the other cylinder of the machine. This is a most unique example. It is different from anything which we have before had, and does not show very good economy in the use of steam. We have introduced it in this place more for the purpose of giving our readers practice with their Planimeters and computations, than because of anything which is radically instructive. In No. 2, the dotted line produces eight pounds of vacuum, or pull-back, while the other end only produces five pounds at the starting point. The space of the stroke traveled by drawing the steam, below the atmospheric line, is double, or more than the space traveled by the piston before the expansion line crosses the atmospheric line; but where the space is laid out different, the Planimeter gives us a reading that both sides are negative results. The valves of engine No. 2 must have been in elegant order, for they make first-class air-pumps, or would, if they had water with which to condense the steam, and from which to extract the air. Taken all in all, these cards are a very interesting study, and only show what can be done, if parties would only try; but we should much rather that they would try on some other man's coal pile than our own. Perhaps some of our readers will gather ideas from this that will set them to thinking more closely, and if they will attempt to erect the theoretical curve upon either one of the diagrams they will find that all new rules will give them a great deal of variance.

LESSON XXXVI.

FIG. 77.

THE diagrams shown in this lesson are from a Wheelock engine, 14⅛ × 42 inches, 76 revolutions, boiler pressure 72 pounds, scale 30. The diagrams are simultaneous, or taken at the same instant of time; A the crank, B the head end. The boiler pressure, in this case, is 72 pounds; the Indicator accounts for only 60 pounds upon the head of the piston, or one-sixth the boiler pressure does not enter the cylinder. We know nothing of the reason. The crank card, in this case, has rather a neat outline, but there are radical faults in it. We find the line from A to C, instead of becoming concave, or expanding, as steam should do, becomes convex. The dotted line shows about what should occur. The cut off of this diagram is clearly marked at A; there need be no guessing at it. The clearance of the engine is not given, hence we have nothing in particular to assume. If we take the steam as it probably cut off at A, the pressure should immediately drop to the dotted line, and follow it, or very near it, instead of which we find that steam actually enters after the valve is closed at A, or is maintained somewhere between the cut-off valve and the piston head. This steam either leaks in, or has been fed in, we cannot say which, and the dotted line gives the appearance of the first part of the hyperbolic curve, which is concave, while the actual line of the instrument is convex. The line, as erected, should be much better.

Diagram B is one of those peculiar features that we sometimes come across, and is correctly stated as being a minus quantity; in other words, B does less than nothing, but rather holds back on A somewhat, and A not only has to do all the work the engine is doing, but has to help do what B holds back. These diagrams are both of full size, and exact reproductions from the original cards; therefore, our readers can measure them, or run their Planimeters over them. It would be interesting for them, especially upon B, to see exactly where the difference lies. The diagram, B, shows some of the same features that A does, and, while it is a negative quantity, shows plainly the feeding of the steam into the cylinder after the valve had closed. The precise reason for this we cannot say — probably a leak. The expansion lines on these cards are not perfect, and, not having the clearance, we cannot lay out exactly what it should be. It is a self-evident fact that an adjustment of the valves would be very advantageous to parties running the engine. We cannot guess at dimensions or conditions under which an engine is working, and no man who is honest with himself can apply exact measurements or give the precise data that shall lead to a computation of the efficient work of such an engine. The diagrams are peculiar; they are not uncommon, — not especially as regards this engine, — but diagrams even worse than this are much nearer general practice. If the cut off on the head end is lengthened and the crank end shortened, to even up the load, the head end will be doing something, and the crank end will not have to do all the load and a little more. These diagrams will bear study, analysis, and computation.

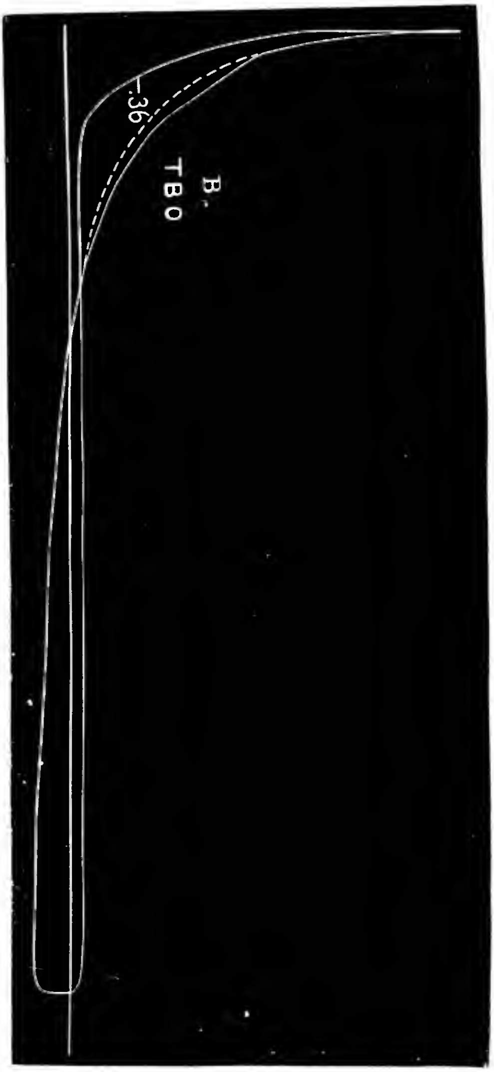


Fig. 78.

LESSON XXXVII.

THE diagram in this lesson will be full of interest to many of our readers who have been following the lessons closely, and have familiarized themselves somewhat with the arguments usually advanced. It is from the so-called high-speed engine, 18 × 36 inches, running 92 revolutions with 90 pounds of steam, and was sent to us by the owner of the engine, asking if we would tell him what were the defects, and what the percentages of useful effect. The defects are of the class usually found in engines where people build them without taking advantage of knowledge gained by experience and practice. The line, A B, is the vacuum line; A C, the line of boiler pressure, as well as the boundary of the clearance; C D is the boiler pressure; E F is the realized pressure in the cylinder; F G the line of cylinder pressure; H I is the theoretical curve erected from the point of actual cut off, or the time the valve really closes in its stroke. The distance between the lines, A C and E F, designated by the letter M, is the clearance of the engine from actual computation, and is enormous. We have here a rather curious specimen of diagram. The compression is very large, as it commences before the piston on its return stroke reaches K. After the compression is finished, the motion of the steam valve is somewhat late, and the jog, or notch, near the letter F, shows that steam is not promptly admitted

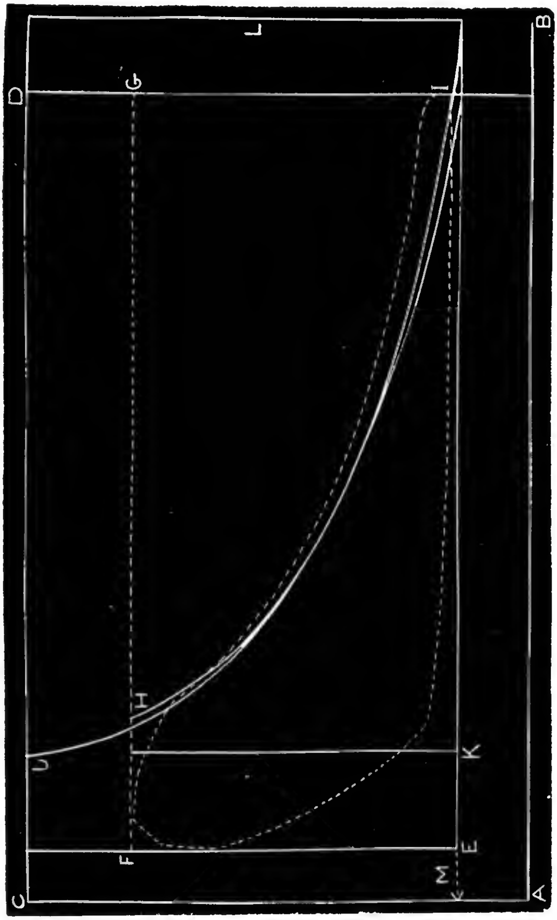


FIG. 79.

in full volume. It almost immediately falls off again, and the difference between the perceptible closing of the valve, and the real closing of the valve, amounts to more than two inches, and the maximum amount of steam admitted into the cylinder is 69 pounds. But this is not the worst feature. After the cut-off valve closes there would seem to be, between the valve and the piston, a large amount of steam, or else the valve is leaking badly. This will be found by the expansion line which, at I, is 6 pounds above the line of theoretical expansion. This engine does not approximate good practice anywhere, and even in the exhaust, which is through only 40 feet of pipe into the open air, it will be found that there are 3½ to 6 pounds of back pressure. Among other inquiries was, "What is the percentage of useful effect?" In erecting the theoretical curve, we have given the engine all the benefit of the doubt, and have placed the point of cut off at H, on the line, F G, which is as nearly as possible to the absolute point of cut off. We have here 69 pounds of steam cut off at $\frac{27}{157}$ of the stroke. The Indicator lines give us, by the Planimeter, 2.48, while the theoretical curve, with the direct point of cut off, gives us 2.22, giving us ten per cent. leakage of the valve, and ten per cent. of the total amount of steam used is sifted through the valve after it is closed. Now we use 69 pounds of steam in the cylinder, by the Indicator. We had 90 pounds in the boiler and 89 pounds in the steam chest. Giving the engine the benefit of good practice, and calling for only 95 per cent. of the boiler pressure in the cylinder, we should have 85½ pounds by the Indicator, instead of 69; therefore, the effective value of the engine is 80 per cent. of boiler pressure. The engine cuts off at $\frac{27}{157}$ of the stroke. If the full boiler pressure was used, or, say 95 per cent. of it, as is the case with all good engines, instead of cutting off at $\frac{27}{157}$ it would cut off at $\frac{20}{157}$ of the stroke. This is further proved by the fact that the track of the Indicator, on the diagram gives, by the Planimeter, 2.48, the theoretical curve 2.22, and cutting off at $\frac{20}{157}$, 2.38, with the Planimeter, allowing the same fault of compression and back pressure which now exists. Hence, if we could get the full boiler pressure, 85½ pounds, into the cylinders, we should save $27\frac{1}{10}$ per cent. of the steam at each end of each stroke, or over one-quarter of all the steam used, by this simple saving alone. This grade of expansion would, no doubt, yield higher than $27\frac{1}{10}$ per cent., from the fact of there being more loss by wire-drawing of the steam to 69 pounds than there would be by doing the same load by the full boiler pressure, 85½ pounds. Therefore, to answer the question which is asked us, "What is the effective value of this engine?"—it is lessened 20 per cent. in boiler pressure, 12 per cent. by leakage of the valve, and 27 per cent. in the amount of steam used, if it could do the work at 95 per cent. of the boiler pressure; and the actual value of the engine, as an actual transmitter of power or consumer of steam, is less than 50 per cent. that of a first-class, modern-built engine, working upon principles which are every day practiced in New England by the best builders. In all this computation we take the steam in the boiler at one hundred per cent. This is no doubt a general arrangement, and those parties who have little or no faith in the Indicator can submit this to any engine builder who has any reputation for first-class work, and they will find it precisely as we state. The line, K, shows the volume of the steam which would be used at boiler pressure, while F H is the amount used at the reduced pressure. The line, L, is simply an extension in order to carry out the curve a little further and see precisely where it would strike.

LESSON XXXVIII.

It is really refreshing to turn from bad engineering, such as we have illustrated in some of our previous lessons, to an approximatively good practice, where preferences and prejudices have been laid aside and ignorance is ignored. We have just this kind of a case in this lesson. The diagram which is shown is from an engine 24 inches by 48, running 58½ revolutions, 55 pounds boiler pressure, taken in actual work, and not for the purpose of exhibition. This engine was built by C. H. Brown & Co., of Fitchburg, Mass., and it may properly be said that Mr. Brown is one of the few engine builders in this country who has adopted the Indicator as his standard to work from and to work toward. In other words, if his Indicator tells him his ports are too small, and the throw of his valves is not right, he has had the good sense to adopt that as his standard, and endeavor to attain all that the Indicator suggests. This diagram (Fig. 80) shows the result of his approaches.

The compression in this engine is easy, and gives a graceful line; the steam valve opens as the compression ends, and fills the cylinder without there being any hitch in the line. When the piston starts on its stroke, steam is carried for a little period of time at full boiler pressure, then it commences to fall off a trifle, as at B; from B to C it falls nearly two pounds. The reason of this is found in the fact that when the piston starts from the dead center on the crank, or from the very commencement of its stroke, its motion is very slow; after it has proceeded a very short distance, the speed is decidedly accelerated, and the pressure is slightly reduced, — a little, indeed, — but in practical working it is of no possible consequence, either as to perfection or economy. When the valve closes the line is distinctly formed, and we know just where to figure in attempting to work for the quantity of steam consumed or to lay out the theoretical curve. The corner of this is not rounded off like the circle made by a coach-and-four in making a turn. We can put our finger definitely upon the very point where the valve commenced to close, and where it did close, — there is no guess-work or assumption, — and we do not have to begin backward or at the end of the expansion curve and guess that the valve did not leak, or suppose that the steam did not do something else.

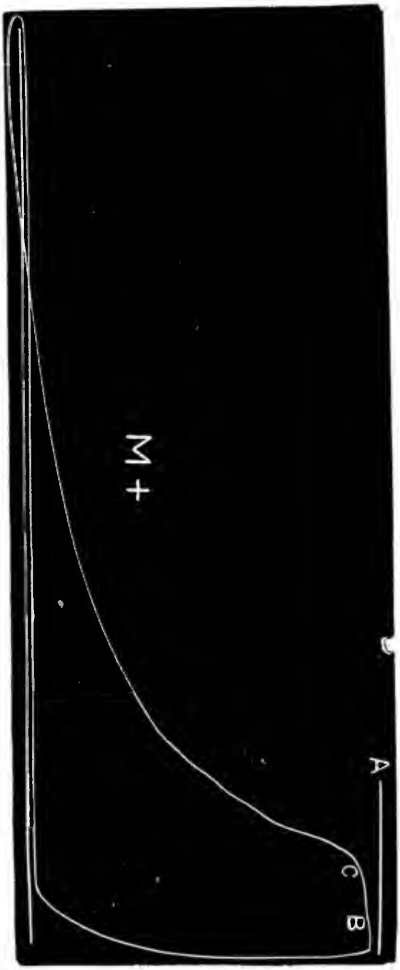


FIG. 80.

The line, A, is drawn slightly above boiler pressure, in order that it may not merge into the steam line proper; and when we say that 98½ per cent. of the boiler pressure is admitted into the cylinder, we only state a simple fact, and one which our readers, who have been working with 60, 70, or 80 per cent. of the boiler pressure, will not be slow to put its proper value on. The expansion line of this card is very fine; its exhaust is as near perfect as we need to expect, and, taken all in all, it is certainly a model card. We do not know the clearance of the engine, or we would have elaborated it somewhat. When dealing with this subject, however, we prefer to have the absolute fact of the clearance either from measurement or the builder's plan, and sometimes we take pains to corroborate the builder's estimate from the measurement. This card was taken from one of a pair of engines while it was at work in the middle of the day, with no preparation or readjustment of valves, for the purpose of ascertaining, more than anything else, how near it approached to boiler pressure. The experiment was afterward conducted by making vertical lines with the Indicator, and then taking a diagram across these lines to ascertain whether the Indicator, the steam gauge, and the cylinder pressure agreed. The pressure in the cylinder with this experiment covered the top of the vertical lines by the steam line at a slightly lower pressure than the one shown, so perfectly as to make complete union by the steam lines crossing the very end of the vertical line while the Indicator cylinder was at rest. This engine has been running some two years, and it is under the care of an engineer who takes good care to adjust the valves of his engine with his own Indicator, and he believes that the nearer to perfection he can bring it, the nearer he is doing his duty by his employer, and parties visiting his engine room will find things as nice and clean as though he was in a library rather than an engine room. Oil and gurry are not found burnt on to his engine, the brass and nickel work are as bright as a new looking-glass, and the owner of the engine finds that it costs less to employ a first-class man, when all things are taken into account, than it does to employ what are frequently spoken of as tramps. There is economy in this card, as well as perfection, and if those of our readers who are interested will figure it carefully, they will find that the figures run up into the nineties all round.

LESSON XXXIX.

We are frequently shown cards from the Indicator which develop most astounding approximations to the theoretical value of steam, but the best way to get at this practically is to take cards or diagrams from the every-day working of the machine, and then ascertain whether the machine, in its every-day work, can and will do what these expert or scientific builders frequently assert they can do. Having this thing in mind, we have taken the card, which is the subject of this sketch, out of a complete set, which were not taken for adjustment of valves, or for any other especial purpose beyond that of ascertaining the precise condition of the engine. It is from one of a pair of large Corliss engines, now working in Fall River. The size is 28 × 60, 54 revolutions, 40 scale, boiler pressure 87 pounds by the gauge. The line, A, is the atmospheric line of the instrument; B, actual vacuum; C, boiler pressure, including actual vacuum; D, boiler pressure; E, end of the stroke, or what should be the admission line; F, the long dotted line, the theoretical curve from the actual point of cut off, as seen on the card; G, fine dotted line, the actual line of the instrument. The admission line plainly shows that the valve does not open early enough, and, as a matter of fact, nearly two inches, after the piston has begun on its stroke, is accomplished before the valve is wide open. The steam line, therefore, falls away from the actual boiler pressure 3½ pounds. We have no data to say how far the steam travels from the boilers. The cut off is very sharp, and the expansion line is very good. It will be noticed that our cut off point, as taken from the instrument, should have been carried a little farther on the stroke. We have assumed it a trifle longer than it really is, but taking this for data, in all the computations which follow, is a little against the engine rather than in its favor, taking absolute facts, from which our computations are made.

The exhaust valve of this engine does not open as early as it should, by fully two inches of the stroke of the engine; it does not open early enough, and the condenser, therefore, does not obtain the amount of vacuum it should and will do if they will open it early enough. At the other end of the stroke there is very little compression indeed, in fact, none of any amount, and opening the exhaust valve earlier, allowing the condenser to do its work more efficiently, would make compression at the end of the stroke, which would be favoring the engine, and compression can be obtained on a condensing engine, notwithstanding statements to the contrary by men who style themselves experts or engine builders.

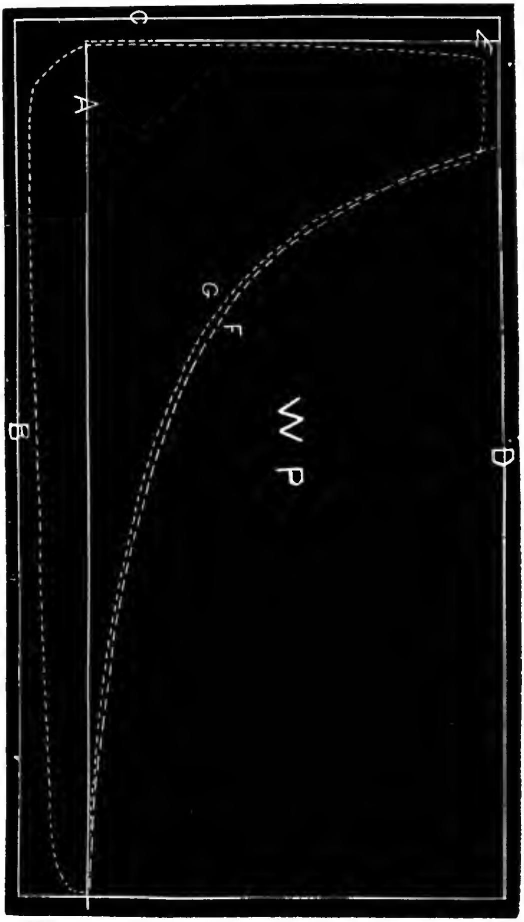


FIG. 81.

The distance between the lines, C and E, is the actual measure of the clearance of that end of the cylinder from which this card was taken; the volume of space, including both valve ports, amounts to 1.71 inches; in our figures we have included the clearance of the engine. The clearance, and the distance which steam is carried, amounts to $\frac{26}{174}$ of the whole stroke. The Planimeter gives us, including the boiler pressure, the full space of the theoretical curve, an absolutely perfect vacuum, and a compression of one-tenth the stroke, not including the clearance, 444. The actual line defined by the Indicator, gives us 388, or 87.4 per cent. of the theoretical, including all the outs or bad features of the diagram. If the engine took its steam properly, and exhausted properly, there is no difficulty whatever in making this engine do 92 to 94 per cent. of the theoretical, and doing it from the coal-pile, and not from any one's ideas. If the engine took steam quicker, we should save the area between the lines, E, and the admission line or fine dotted line, and this would shorten the space which steam is carried, so that, instead of being $\frac{26}{174}$, it would probably run down to 22 or 23, and the very fact of opening this valve earlier would allow more steam to enter this cylinder, and would give us nearer actual boiler pressure; hence the displacement of the steam valve of the engine is working decidedly against its economy. If the exhaust valve opened earlier, the condenser could do its work better, because it would take the bulk of the steam quicker, and would make a more effective vacuum or a nearer approach to complete vacuum. Therefore, when we say the engine is doing 87.4 per cent. of the theoretical, we do not say that the engine is doing all that it will or all that it can; but, taking the card precisely as it came from the Indicator, and just as the engineer was running the engine, in the face of very apparent disadvantages, which could and ought to be remedied by the proper application of the Indicator, it is then doing almost 90 per cent. of the theoretical. In doing this, the displacement of the steam valve loses 3½ pounds boiler pressure, the condenser gives us 108 or 110, while in the theoretical we figure 150 to 155, the condenser only doing 75 per cent. of the theoretical — this in the total figures against the engine. If we take the high pressure part of the diagram, and suppose the engine would exhaust as these engines usually do, we should have 88½ per cent. actually developed by Planimeter measurement. The steam valve of the engine should be quickened considerably, and the exhaust valve quickened also; this means moving the eccentric ahead on the shaft from an inch to an inch and a quarter; then perhaps the jim-cranks may have to be lengthened or shortened, as the case may be, in order to bring the other valves up to time. There is a point where half a turn on the jim-crank, or a quarter of an inch on the eccentric forward or back, makes a radical difference. Eighty-two pounds in the cylinder, with 87 in the boiler, and the steam valve opening two inches behind the piston, is a better showing than a great many engines make.

The man running this engine should open his steam valve so that it would touch the line, E, where the dotted portion is at the bottom, quite up until the steam line is commenced. These changes are simple, and, with the Indicator can be readily made. Where the point of cut off is so thoroughly defined, as in this case, there is no difficulty whatever in following the lines from the point of cut off, not from the termination of the expansion line.

This, as are all our diagrams, is exactly full size, and can be measured and worked from by any of our readers who are so disposed. This will be interesting for them; it is good practice; it deals only in facts, and it will show them how to apply the rules, which any one can do, and how to ascertain whether the engine does what the builder represents, especially where they are loud in decrying well-established precedents by other builders. Facts are not always agreeable, but they are the best things in the world from which to obtain information, and they sometimes take the conceit out of people, even if at considerable cost, and are to sensible men invaluable.

LESSON XL.

As a fitting close to the practical lessons embodied in this volume, we introduce one of the most radical departures in steam engineering, and one of the most successful of the almost numberless candidates working in the direction of high speed. This engine is, to a certain extent, an anomaly, and in Volume II., which will complete this work, we hope to embody the valves and valve motion, and the regulator with its full line of action, so that our readers, who do not become discouraged in this volume, can gather from them what has been attained by a careful keeping in view of the theoretical value of steam after it is made, and the practical working out of the largest percentage of that theoretical value, which has, as yet, we believe, been attained by any high speed engine.

Figs. 82, 83, and 84, were all taken from the Armington & Sims engine, on the same day, under varying conditions. The size of the engine was 9½ inches diameter of piston, 12 inches stroke, 300 revolutions per minute, boiler pressure varying from 85 to 82 pounds, scale 60.

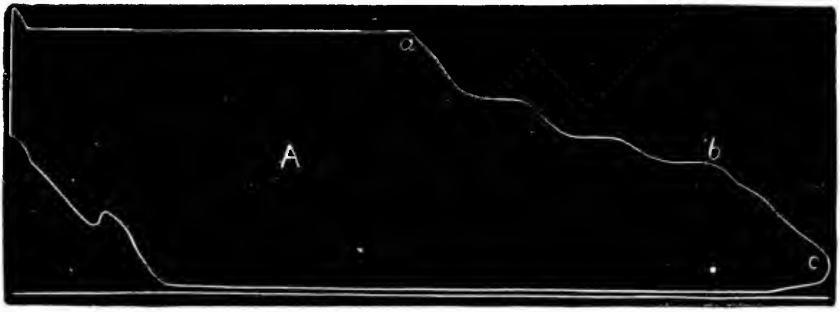


FIG. 82.

Diagram A represents the engine as working at 80 horse-power indicated, with an average pressure of 56.51 pounds. The admission line is almost absolutely perfect. There is a trifling variation, probably caused by the piston of the Indicator. The steam line is simply perfect, cutting off at *a*. The expansion line, under such a speed, is slightly waved; and this, without doubt, is somewhat owing to the intensity in the action of steam and the impulse of the momentum of the Indicator. The variations are, however, very slight, when the speed is considered, and the mechanical perfection required both in the valves of the engine and in the piston of the Indicator. The release, at *b*, approximates closely to locomotive practice; the commencement of the exhaust, at *c*, shows a back pressure of between one and two pounds at the commencement, and about one pound at the termination. The cushion, or compression, on this engine, owing to its very high speed, is not precisely of the same character as in the slower moving engine, the line being somewhat irregular. The peculiar points of this diagram will be noticeable by every steam engineer when he considers that it was completed in one-tenth of one second while running at regular speed. This diagram, taken all in all, is one which embodies a very high economy with an almost perfect regulation.

Diagram B is the same engine precisely, developing 52.08 horse-power, with an average pressure of 36.83 pounds. In this case we have not lost any of the beauty of the steam or admission lines. As in diagram A, the expansion line has a somewhat more wavy appearance, the release commences almost at the same point,—if anything, a trifle earlier,—and the compression being comparatively earlier, coinciding with the release. Diagram A has 85 pounds boiler pressure, and 81 pounds by the Indicator in the cylinder. Diagram B has 85 pounds boiler pressure, and 82 pounds in the cylinder, while diagram C has 80 pounds in the cylinder, with an indicated horse-power of 11.78, and a mean pressure of 8.33 pounds.

FIG. 83.

Parties who will study these three diagrams will see that the release and compression vary materially, and on these points it is well to say that this is the first engine we have ever noticed which worked steam according to the theory of expansion and compression, as approaching most nearly the production of the largest amount of utilized units of heat from the steam; in other words, the regulator and valve motion of this engine are so arranged that the valve has an absolutely constant motion, with reference to giving the engine steam, but every other position of the valve is variable according to the load, and in the case of release and compression, these two important and often overlooked points are, by the inventors and builders of this engine, made to vary *inversely* as to the load.

Diagram C gives us the nearest approximation to what our old friend, Prof. Thurston, of the Stevens Institute of Technology, has long argued was the correct way of working steam; that is, that steam at a certain pressure and temperature should be expanded that number of times which would make it most efficient, and which, without any exhaust, could be compressed on the return stroke, making another line lower in utilic effect than the first, and needing only a small amount of steam to make it do the second and each successive stroke. Armington & Sims, in this case, have so arranged the motions of their valves that the load upon the engine varies the amount of steam admitted, and the amount of the load governs the release and exhaust inversely; that is, in opposition to the regular proportion, the greater the load the later release and compression; the lighter the load, the earlier release and compression; hence, we have, in diagram C, a release somewhere about plus one-half the stroke, and a compression of slightly minus one-half the stroke. By this mode of compression one of the greatest antagonisms to the success of high speed, in practice, has been overcome; that is, the loss of steam and the expense of maintaining a large clearance.

Diagram C, it will be seen, compresses 56 pounds; the steam valve then opens and the admission and steam lines are almost at absolutely right angles to each other. The larger the load the later the release and compression, but the engine exhausts freely up to that load, which is the maximum; and when the engine is running almost without load, the release and compression are so arranged that no thumping or jar occurs to the machine. This is the highest attainment toward working steam expansively. It is done by a single piston valve controlled by a variable regulator, the engine furnishing the power, the regulator changing its movements according to the increase or decrease of the load, varying from ten to eighty horse-power on perhaps three strokes of the engine without making a change of more than three or four revolutions, or affecting the speed for more than one-half to three-quarters of a second. These diagrams will bear a great amount of study, and practical engineers cannot fail to admire them.

FIG. 84.

LESSON XLI.

DEMONSTRATING THE ACTUAL POINT OF CUT-OFF FROM THE STEAM USED, WITHOUT REGARD TO TERMINAL PRESSURE OR LACK OF DISTINCTNESS IN THE CUT-OFF LINE.

In our own experience, we have frequently been unable to determine the point of cut-off with sufficient accuracy or reliability, wherever the line of the diagram was not clearly defined, and this oftentimes becomes necessary in making computations, or in comparing one engine with another for efficiency. It was, therefore, after considerable investigation, that we adopted the method first published by the writer, September 15th, 1883, as a method of demonstrating the positive point at which steam is cut off, or a point on the line of initial pressure equal to cutting off steam at a particular point, even where a leak had occurred, or where steam had drifted past the steam valve after it was supposed to be closed. At that time we used the following expression: "We have, therefore, stolen a march on volume two of Twenty Years with the Indicator, by showing the mathematically correct way of demonstrating the positive point at which the steam is cut off, or a point which is equal to the cutting off of the steam at some especial or particular point whenever steam leaks or drifts in."

Since this statement was made, this method has been examined by some of the best mathematicians, and has been pronounced correct. It will be referred to in the following lessons in this volume as *the* demonstration or our demonstration. We reproduce the original diagrams, now in our possession, which were published with this first demonstration.

It has been customary in years past for builders of engines, engineers and experts to erect their comparison from the "axis of the hyperbola," or from the terminal pressure. "The axis of the hyperbola" is an indefinite, uncertain quantity, and the terminal pressure is as apt to be wrong as right, and we wish to impress upon the reader of this, that in this case we divide the problem into two different and distinct demonstrations; first, we locate the exact point of cut-off on the line of initial or realized pressure in the cylinder, from a point a little past or at the center of the expansion line of the diagram. The reason why we do this is that at or a little past the center of the expansion line, the steam has become more settled in its action, is less liable to irregular pressure, the speed of the piston is nearer constant, and the load affects least either the piston or the crank in overcoming the resistance, on the same principle that a train of cars, after in motion, gives a better idea of the actual load than when starting or stopping them. This point, wherever located, is termed the base line of the demonstration. This method is founded upon the principle that if the pressure at a given point is known, and if steam does expand somewhere near Mariotte's law, then it becomes a mathematical problem, and, if we know the pressure at a certain point, we can lay out, by the means to be explained, the precise point at which a known initial pressure of steam should be cut off to realize the pressure denoted by the base line wherever it is located. This is the whole theory and it has been reduced to practice in so many different forms of diagrams, at so many different points of cut-off, under so many different pressures, and with such a variety of types of engines, that the best authorities in several of our institutions of learning have adopted it, and have pronounced it mathematically correct. We do not mean to go into mathematics to any extent, and shall, therefore, refer our readers to the various diagrams illustrated in this volume, which are founded upon this demonstration, and which embrace a large range of different types of engines at all sorts of speed, under all differences of pressure, and that the comparisons made are actual rather than visionary.

Very frequently, as in one of the first examples given in this lesson, we have found the apparent or visible cut-off, on the diagram as made by the instrument, to vary materially from the demonstrated line. To explain this briefly, it frequently occurs that the valve does not seat itself, or that some disturbance occurs in its action, so that after it is apparently closed and the expansion line has been commenced, that a quantity of steam drifts into the cylinder, so that the indicator does not make a true expansion line from the quantity of steam shown by the visible point of cut-off, and this method shows us precisely the amount of steam wasted as between visible and demonstrated points of cut-off. We have never yet found an engine with this demonstration where the actual line of the indicator overran in amount of work yielded, the theoretical line drawn from the point of cut-off from the demonstration.

Another point for the reader which may be asked, we will anticipate. It is frequently necessary (in his mind only, however,) to know precisely the amount of clearance to an engine, in order to know exactly the use of the steam. With this method of demonstration the clearance becomes unnecessary so far as the demonstration goes; it is very important, however, if we are figuring the diagram for economy in water, to know the clearance, but so far as the action of steam goes, and the reliability of the demonstration based on that action, the clearance is an unnecessary quantity. We are dealing with the steam after the expansion takes place, it shows us what the valves do and shows it correctly, but if we are to get at the actual amount of steam used, in every instance, we must then learn the clearance of the engine and add a proportionate length to the amount of steam used; but these two elements are not of necessity identified with each other so that the clearance need to be taken into account in the demonstration.

Fig. 96 is taken from a Corliss engine, which has been running many years. To explain our demonstration, we first of all draw the line of initial pressure C, then the line of absolute vacuum D, the vertical line B, which in this case represents the clearance of the engine. We have now actually known factors. Now, at some point in the expansion line, in this case at the crossing of the expansion line with the line of rest of the instrument, we draw the vertical line A; this is also a known quantity; it is the actual pressure in the cylinder above the vacuum line, it is, therefore, a known quantity. There is no especial reason why we locate it at this particular point in the stroke, only at that point the line is entirely settled in its work.

Now, from the intersection of A, D, we draw the angular line E, which connects the base of A with the intersection of B, C, at the point representing the clearance of the engine added to the diagram and the initial pressure. This line is for the purpose of demonstration; now we wish to obtain a parallel line to the one just erected; measure the distance from A to the line just erected on the atmospheric line, as in this case the top of the line A intersects with the atmospheric line; lay off this distance A, E, on C which gives the distance F, I; lay off the same distance on the line D, which gives us D, K, or from the base line A to the new line K, F. F is, therefore, the

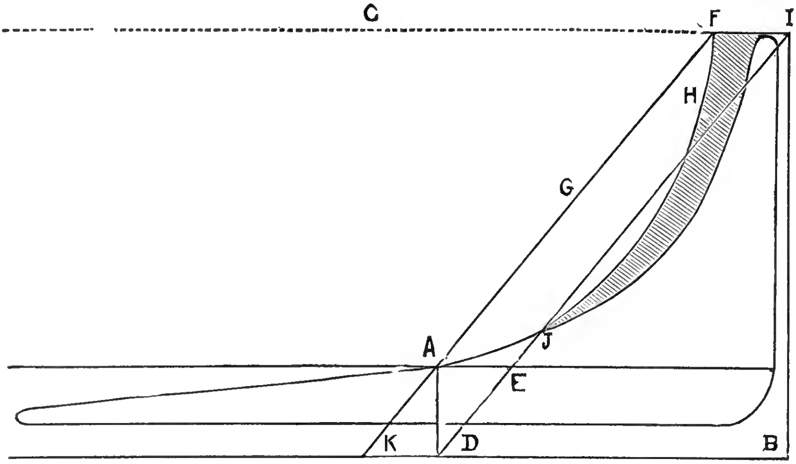


Fig. 96.

point at which the initial pressure of steam should have been cut off to have given the pressure A at that point in the expansion line. It will be seen that the fact and the demonstration do not agree apparently. This is the end of the demonstration practically. Now, if we compare results, we find that the lines of the indicator diagrams, as left by the instrument, show a very much shorter cut-off than the line F. But, at the point J, the theoretical curve dropped from the line F, joins with the actual line of the instrument, and from the point J the theoretical and the actual run on together. After the valve in the engine closes, an amount of steam passed through under it and was carried into the cylinder, and the amount of steam increased after the cut-off was shown by the indicator to equal the amount shown by the shaded portion of the diagram, between the actual line of the instrument and the theoretical line dropped from F, continuing H, J, or about twenty per cent. The point F represents the point of cut-off equaling the actual amount of steam put into the cylinder, taking the whole diagram into account as demonstrated. The steam drifted into the cylinder from the time the cut-off valve was apparently closed, as shown by the indicator, up to that point in the stroke represented by J, where the leakage stopped, the valve then had become positively closed and no more steam was admitted.

It may be remarked that, after this demonstration had been published, the agent of the mill from whose engine this diagram was taken was written to, asking him if he would examine his engine to see whether the valve on the head end was leaking or not. His answer was:

"Yours of——————received: contents noted. I removed the cylinder head last night, and found a bad leak in the steam valve."

In contrast to this, we introduce Fig. 97, taken from the Pullman engine at the Pullman Car Works, near Chicago; the same engine which was exhibited at the Philadelphia Exhibition in 1876, by Geo. H. Corliss.

In this case we erect first the line of initial pressure, then the vacuum line. In this case the clearance is not known, and in contrast with Fig. 96 we make our base line, A, below the atmospheric line. The demonstration is then made precisely as in the former case, with the result that the motion of the valve in this case is a trifle slow as compared to the stroke, and the visible and actual points of cut-off vary slightly, but come together at the point J, which in this case is much nearer the commencement of the stroke. The actual and theoretical then run along almost identically. It will be noticed that there is nothing assumed in this case, and if the demonstration is carefully made, which anyone can do with a pair of triangles, you will get positive results. F, I, in this case represent the amount of steam introduced into the cylinder. The expansion line runs considerably below the atmospheric line, and the vacuum line is almost a perfect line, there being no compression. The admission line is parallel to the vertical by its side, but the opening valve is a very trifle late; or, we might say properly, is a trifle slow in its motion, so that a very slight diminution of pressure is observed. The convexity at H in this diagram is caused by a slight leak in the valve when it seats. It must be borne in mind at this time that the expansion is

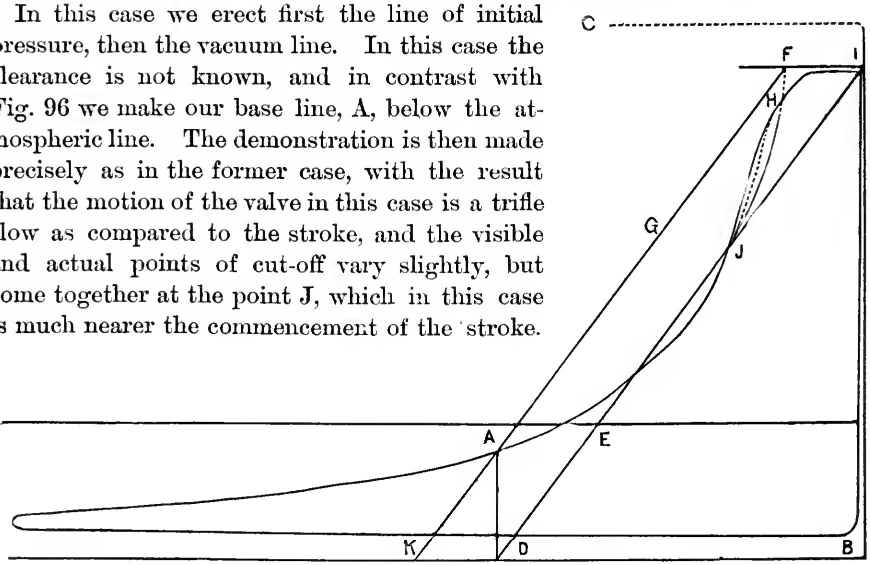


Fig. 97.

in a very rapid ratio, and when J, the expansion line, has been reached, the valve is seated and not another particle of steam obtains access into the cylinder. During the time of this leak, which is insignificant, the engine makes but trifling progress in its stroke. From the point J to the termination of the expansion line, there is a variation of less than one-fifth of one per cent. from the theoretical, taking into account the realized boiler pressure there is a loss of 1.7 per cent. This engine is, therefore, realizing 98.3 per cent. of the theoretical, taking realized steam pressure as the unity.

In these two diagrams we have avoided any confusion of lines in laying out the theoretical curve. That method will be explained in the following diagrams, and if the readers of this will follow the different examples, showing the adaptation of this demonstration, they cannot fail, we believe, to become as proficient and as careful in the application of the demonstration and the theoretical curve, as anyone need to be for all practical purposes. By this method of demonstration we show, in the case of Fig. 97, 98 per cent. plus, while in Fig. 96 we show a little less than 80 per cent. of the theoretical. Either of these diagrams, without any demonstration upon them, make a fine-looking curve; it shows, therefore, that the application of some system of demonstration with a basis of fact, will give us what we are studying the indicator for—actual information with regard to some thorough and reliable test, to ascertain whether the diagrams, after taken, if good-looking, shall give us practical results, showing an economy in the use of steam as well as a pleasing appearance by comparison.

To embody the whole matter for reference, we give the following

DIRECTIONS FOR MAKING THE DEMONSTRATION.

Take any indicator diagram, lay out upon it the absolute vacuum line with the scale that the diagram was taken with. Then lay out the initial or realized pressure in the cylinders; these two lines will, of course, be parallel. Then connect these two lines at the admission end of the diagram by a vertical line at right angles to the two horizontals already laid down. If the clearance is known, this line may include it, otherwise erect it simply the width of a line away from any portion of the admission line; but this may be varied somewhat; if the engine takes steam too early or too late, let the vertical line barely be outside of the extreme point covered by the line of the indicator. Now, from some point on the expansion line near the center, if anything, a little beyond, erect the base line from the actual line of the indicator to the absolute vacuum line, and be careful to have it at right angles to the vacuum line. From the intersection of this line with the vacuum line, draw a diagonal to the intersection of the steam pressure and vertical line. Now, by means of a triangle lay off a right-angled line from the top of the base line, or its intersection with the expansion line of the diagram, until it intersects with the diagonal line just drawn. The purpose of this line is to measure carefully, with a pair of dividers or otherwise, the distance from the top of the base line to the diagonal, so that this distance may be transferred both to the vacuum line and the steam pressure line, as the exact points from which to draw the parallel diagonal, and this parallel diagonal line must in every instance, and will if properly done, pass by the exact top of the base line at the point of its intersection with the expansion line of the instrument. Wherever this line, the last diagonal, touches the line of steam pressure, from that point drop a perpendicular to the vacuum line. You have now the precise point of cut-off from the pressure at the base line, or first line erected.

These instructions apply to the low pressure, condensing, compound locomotive, marine or any other indicator diagram, whether taken from steam, water, air, gas, so far as we have ever been able to prove it. This rule has been given to familiarize the reader, and without any letters of reference, so that the principles may be thoroughly understood. The mathematical demonstration is not necessary, we think, from the explanation which has preceded it.

LESSON XLII.

DEMONSTRATION OF THE POINT OF CUT-OFF, AND HOW TO LAY OUT THE THEORETICAL CURVE.

Fig. 98 is an interesting diagram in many respects, and only shows what the general tendency is among steam users by overloading their engines. The data with this diagram is 17 inches diameter, 36 inches stroke, 57 revolutions per minute, boiler pressure 70, scale 30. A is the absolute vacuum; B, highest realized pressure in the cylinder; C, vertical line being nominally to represent the end of the stroke, clearance not included in this case.

Having surrounded the diagram by a parallelogram, we commence by drawing the line D, which represents the pressure of steam above absolute vacuum at that point of 63½ pounds. From the intersection of A D, E is drawn to the intersection of C B. Now, from the top of the line D, draw at right angles the dotted line J, connecting D E; the distance from one end to the other of J is the distance to be laid off on the line B, as well as A for the parallel line, F. From the intersection of F B we drop G, and the length of the line, B, from C to G, is the volume of the cylinder filled with steam at the initial pressure, which should be cut off at the point G on B to produce the pressure, D, on the expansion line. This finishes the demonstration of the point of cut-off.

We wish now to erect from this data already obtained the theoretical curve, in order to ascertain whether the expansion line of the engine approximates closely or otherwise to the theoretical line. We repeat here the method given in Volume I, and shall endeavor to explain it so fully that no reference to Volume I will be required. We commence at the intersection of A C, drawing the radial lines, and to prevent confusion, we have used numerals rather than letters in this figure. These lines are drawn from the point K on the intersection of A C. In erecting the theoretical curve, the base of our computation must always be absolute vacuum. While this differs somewhat in barometrical range, it is exceedingly small, and for the moment we assume it at 14.7. We draw the lines, 1 from K to G, and the line 2 from K to the end of the line B, covering the very end of the diagram. Now, between these two lines, 1, 2, on B, we drop the ordinates at right angles to B, a little below the expansion line, at any distance apart we choose. In this case we drop 3, 4, close together; then 5, 6, 7, at a distance double that between 3 and 4. There is no special reason for making any difference in this. We sometimes drop the ordinates closer together in the first part of the expansion curve, where the greatest variation takes place in expansion, but they can be put as near together or as far apart as the demonstrator may choose.

Now, from the intersection of the ordinates, 3, 4, 5, 6, 7, and the line B, draw the radial lines from the point K to each separate point of intersection. Now, wherever the radial lines cross the line G, is the point of our next computation. From the points of the radial lines crossing the ordinate G, we next draw lines at right angles to G until they cross the ordinates 3, 4, 5, 6, 7. We have here then following out this process with each one of the lines to their crossing with G, the lines, 8, 9, 10, 11, 12, 13. Now wherever these two lines 8-3, 9-4, 10-5, 11-6, 12-7 intersect, through the points described by their intersection lies the hyperbolic curve from the demonstration.

In this case it will be noted, to return to the diagram for a moment, that we start off with an initial pressure of 70 pounds. The steam pressure is gradually reduced or, as engineers term it, wire-drawn, throttled so that it is constantly reduced in pressure on the diagram. At the point where the ordinate G is erected, we have 13 pounds less than we started with, or 57 pounds realized at that point; dropping off still further, so that at the point where D intersects the hyperbolic curve we have only 49 pounds. Now with the ordinary demonstration which has been so frequently printed, and upon which so many arguments have been based, in this diagram we should have no possible data with any sort of certainty, for ascertaining precisely where the steam was cut off. In this case, the result proved the correctness of the assumption, and the assumption is based on the fact that the demonstration is correct. The theoretical curve in this case starts from the point B, G, and strikes the actual line of the instrument at the point I, or directly over the line D, and the two lines, which are very clearly drawn (the actual line of the indicator in long dots and the theoretical curve very fine dots), pass over each other for such a proportion of the distance that the two lines are inseparable until almost the commencement of exhaust. At the last ordinate the line of the instrument is very slightly above the theoretical line. The line D may be placed anywhere on the expansion line between the visible point of cut-off and the visible point of release; and in the case of some diagrams, which will be shown further on, it will be seen that where difficulty exists, in every one of these points the demonstration proves what the action would have been if there is any accuracy at all to the action of the valves, and a cut off was intended. In this case the action of the engine was fettered somewhat by a late release, we might say, but, as a matter of fact, while the exhaust valve could have been opened a trifle earlier, the amount of steam in the cylinder was enormous, and the exhaust is partially clogged for that reason. It will be interesting when we state that the theoretical use of steam on this diagram, Fig. 98, measuring the full boiler pressure up to the point of cut-off, then following the theoretical line, making a perfect exhaust, is 792, while the actual useful effect measured by the planimeter is 715, giving us a percentage of a trifle over 90 per cent., and yet this is by no means good practice; it speaks well for the design of the engine, but not for the management of its owner.

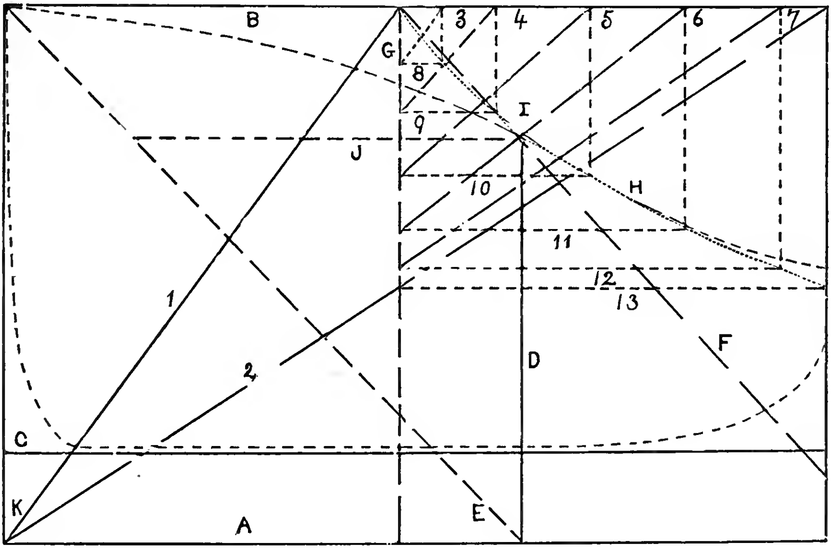


FIG. 98.

Referring to the demonstration of the point of cut-off, Fig, 98, as compared with Figs. 96, 97, shows almost the other extreme of the efficiency of the application of this demonstration to the every-day work of the working engineer. Any engineer with a steady hand can do all that we have been describing. A pair of steel triangles, we prefer, made by Brown & Sharpe, although rubber or wood will do, if they are taken care of, a sharp pencil, and for laying out the theoretical curve a series of curves of different radius, which can be bought at any draughtsmen's supply place, and only two or three will be required for a very large range of work—this is all the apparatus—and a board a foot square, covered with blotting paper or coarse rope paper not sized or glazy finished, completes the whole apparatus.

LESSON XLIII.

THE DEMONSTRATION OF THE POINT OF CUT-OFF AND THE LAYING OUT OF THE THEORETICAL CURVE WITHOUT REFERENCE LETTERS.

If the two previous lessons have been carefully studied, the reader will have a pretty good idea of how to do, and what is being attempted. Fig. 99 is taken from the steamer City of Worcester, Norwich Line of New York and New England Steamers, between Boston and New York. The diagram illustrated was taken while her engines were being adjusted and before they were fairly complete. We have chosen this diagram for the especial purpose of making the demonstration upon it, not having taken the most perfect one for that purpose. This diagram was taken while she was at full speed, her cylinders being 90 inches in diameter, 12 feet stroke, 35 pounds pressure by gauge, 22 inches of vacuum per gauge, throttle wide open, running 18+ revolutions per minute, 24 scale.

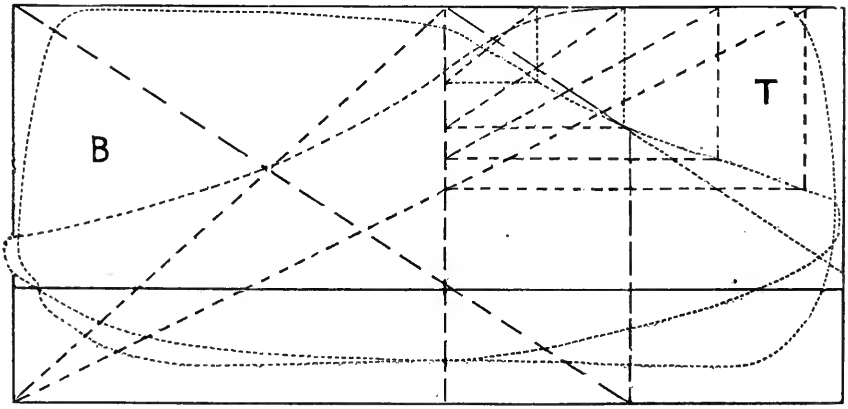


FIG. 99.

The bottom diagram in this case carries steam the greatest distance, as is usual in marine engines. We have been compelled to draw our line representing the initial pressure a very trifle above the actual, in order to allow the lines of the diagram to show, for the bottom end of the cylinder, although it takes steam late on the opening of the valve. In this case it realizes full boiler pressure after having traveled several inches, and at the point of cut-off by demonstration loses only three pounds from the initial; while the top end realizes full boiler pressure to the very point of cut-off visibly. The release as shown in these diagrams is rather late, later diagrams improved it very much; so the vacuum in this case was improved after.

The base line in this case is erected at about half-way on the expansion line. The parallels are drawn and the point of cut-off located very closely to what we would have termed the visible point. Radial lines and ordinates are erected as before stated, and where the ordinate and the line from the point of cut-off cross, it will be found to almost touch in each of the four cases, the line of the indicator as it left the diagram, so nearly at least, that we have not thought it worth while to attempt to draw in the theoretical line, from the fact that the two lines are so very close together that it would lead to a confusion in the mind of the reader. The top end of the cylinder is a little late in taking steam but not as late as the bottom; the result of this is shown in the slightly increased pressure and in the fact that the steam line in itself is much straighter than in the other end.

We desire it understood that this diagram was not selected to show the performance of the steamer; it was selected rather as a diagram, somewhat distorted, for the sole purpose of showing that the demonstration of the point of cut-off was equally as applicable to a diagram in which the lines were not clearly established, and that the result could be depended upon for practical application aside from any or all theoretical questions.

LESSON XLIV.

MODERN STEAMSHIP ENGINES EXAMINED BOTH WITH REFERENCE TO ECONOMY AND THE APPLICATION OF THE DETERMINATION OF THE POINT OF CUT-OFF, AS WELL AS A COMPARISON OF THE ACCURACY OF TWO DIFFERENT INDICATORS ON THE SAME SHIP.

Figs. 100 and 101 are from a modern steamship running between New York and——————. The diagrams 100 and 101 were taken with an English instrument furnished by the builders of the vessel. There are several very noticeable features about this diagram 100. The bottom end of the cylinder gives us more than boiler pressure; this cannot possibly be, the boiler pressure as given at the moment was 78 pounds, scale 32; we have fully 80 pounds as per indicator card. The steam lines are very irregular and the expansion line, it will be noticed, is very much higher than it should be about the point of cut-off, showing first, that the steam is throttled in the passage-ways, and next, that the valve closes slowly and continues to admit steam. The stroke of the engine is 54 inches. We have located the point of cut-off from the usual demonstration and it will be noticed that the curve from the release, following up the expansion line, denotes where the steam to have been cut off, would have given the theoretical line following the expansion the majority of the way.

The release of the engine appears to be very good, and it is at 38 pounds above the atmospheric line, but there is something very curious about the exhausting of the engine from either end, with reference to the positively straight line A, B, while as a matter of fact such a line as this, where the receiver is used as between the high and low pressure cylinder, cannot be made, if we are to have any faith in modern engineering. It shows, therefore, that there must be something wrong with this indicator, and if we come to analyze it a little further we shall probably find it. By the indicator, the steam valve closes at $29\frac{3}{8}$ inches of the stroke on the bottom; this gives us an indicated horse-power of $1255\frac{1}{2}$. The exhaust valve closes on a receiver pressure of 19 pounds at four inches before the end of the stroke, while on the top end the exhaust valve closes at $5\frac{56}{100}$ inches, the top giving 1129 horse power.

If we compare this with the low pressure, Fig. 101, the line B represents the pressure of steam in the receiver, while the line A represents the realized pressure on the piston, which is 11 pounds, while the receiver pressure is 19 pounds. We have made the demonstration upon the top end showing the cutting off at $26\frac{1}{4}$ inches of the stroke, giving 1293.72 horse-power, while the bottom end gives 1341.93 horse-power. Only about half the receiver pressure is realized, that is carried one-half stroke and shows a very fair performance. The vacuum only 18 inches is realized as the extreme, giving 9 pounds.

For the sake of comparison, Figs. 102 and 103 are given, taken from the Improved Thompson indicator, the American Steam Gauge Company's build, from the same ship, arrangements previously being made; these followed 100 and 101 as soon as the instruments could be changed, the ship running under the same pressure of steam, same number of revolutions, smooth water. Here we have a decided contrast. Fig. 102 shows the high pressure cylinder, and we have here erected three different curves. A, Fig. 102 is the theoretical curve from the arrow-head in the line D, which shows that that cylinder actually used steam sufficient to cut off at $25\frac{7}{10}$ inches, giving an effective horse-power of 988.2. B is from the initial pressure 78 pounds, scale 40, and shows what was expected of the engine, while C is the theoretical curve from the terminal pressure showing quite another result. The line B shows what was expected, viz.: to cut off at one-third and to realize boiler pressure. We find, however, the terminal pressure of the diagram is 27 pounds above the atmosphere, while the terminal pressure of the curve from the supposed point was 20 pounds above the atmosphere. The line C shows the engine to have cut off at $21\frac{45}{100}$ inches of the stroke, if the terminal pressure was right. It will be seen that the diagram upon which the two curves are erected, only realizes 70 pounds of steam, and that at one-third stroke 12 pounds less than that is realized on the piston head. The line A, as drawn from the data given, shows about the actual performance of the engine cutting-off realized pressure at 25.7 inches, developing 1075.73 horse-power. The dotted line E, if continued, would barely touch the end of each diagram, and shows the rise in pressure in the receiver, between the commencement and middle of the exhaust, amounting in this case to about 7½ or 8 pounds. The minimum amount of pressure in the receiver in this case is 9 pounds, the greatest amount 14½ to 15½.

Another point engineers often require has been carefully figured on the right-hand diagram where B and C are shown, the exhaust valve of the high pressure engine closes at 5.2+ inches before the end of the stroke, while on the left hand diagram the exhaust valve closes at 7.8+ inches.

Fig. 103, scale 10, realizes a trifle over ten pounds of the receiver pressure. In this case, we have applied the demonstration from the average of the expansion line, as nearly as we can judge. The action of the valves, in this case, shows plainly the change in pressure in the receiver from the commencement to the middle of the exhaust. The steam line is a very peculiar one, and the demonstration shows that the valve was closed at 21.7 inches of the stroke, giving a horse-power of 1042.4, while the other end gives 1143.48 horse-power. There are one or two points with reference to this diagram worthy of notice. On the left-hand diagram the exhaust valve closes at 11.85+ inches of the stroke, at a lower pressure than the right-hand end, which closes at 10.53 inches of the stroke. The cushion or compression, in this case, plainly shows that the higher pressure and shorter closure produced the highest compression. The vacuum shows a trifle over ten pounds at the highest, the lowest being eight.

Diagrams 100 and 101 show the total amount of power required to drive the ship as 2510.09 horse-power, while 102 and 103, taken within a very few moments of the others and as near as possible under the same circumstances, show the probably correct action of the valves, and the correct amount of power as 2124.94 horse-power. 102 shows plainly the rise in the receiver or exhaust line, and 103 plainly shows this action in the steam and expansion line of the right-hand diagram. Experiments are now being conducted on that ship with a view to adjustment and finding where the engines will do the best work. We would not attribute any motive, but it is somewhat curious that the indicator furnished should make a difference of a few hundred horse-power in the power required to drive a ship, and, therefore, presumably make the amount of fuel per horse-power less than if the actual amount of power was known to be much less than it was supposed, and the amount of fuel much more than it had been considered. These diagrams are well worthy of a careful study for they will interest stationary engineers as much as marine. We should have grave doubts as to the economy of these engines as compared with some of the examples from other engines which will follow.

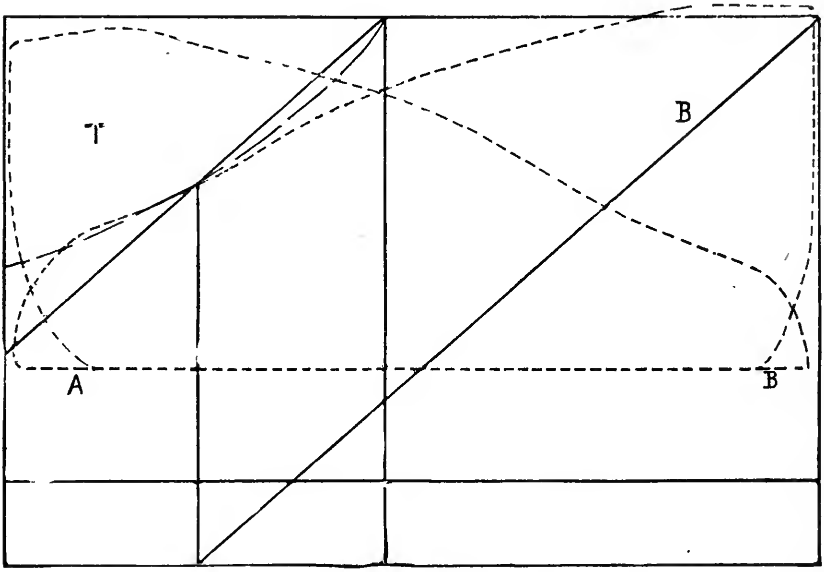


FIG. 100.

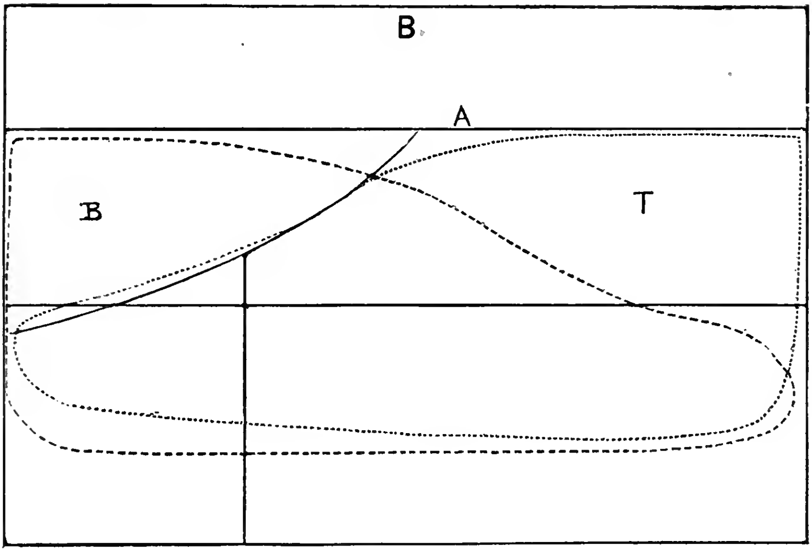


FIG. 101.

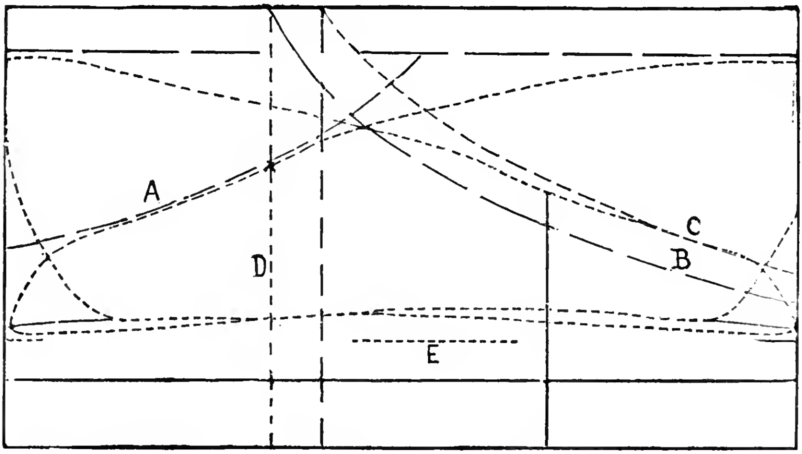


FIG. 102.

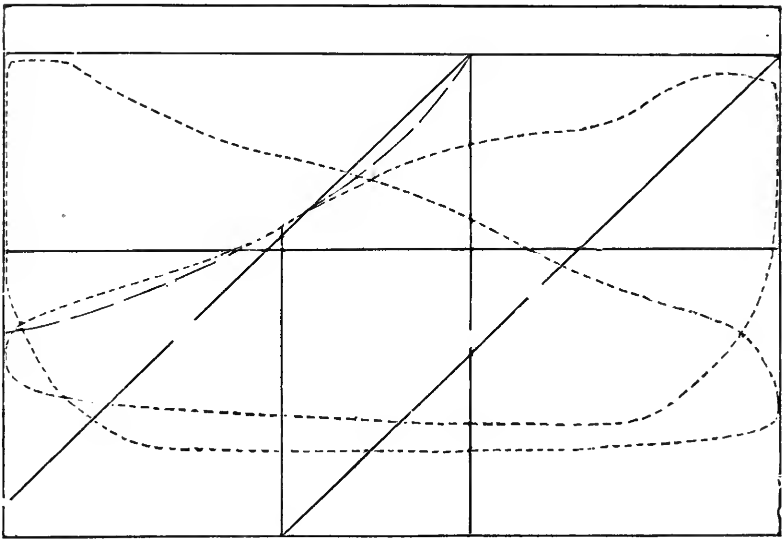


FIG. 103.

LESSON XLV.

BADLY THROTTLED ENGINE, LOSS IN INITIAL PRESSURE, AND LOSS IN VALVES.

The diagram Fig. 104 is from an engine sixteen inches cylinder, thirty-six inches stroke, running sixty revolutions, boiler pressure eighty pounds,

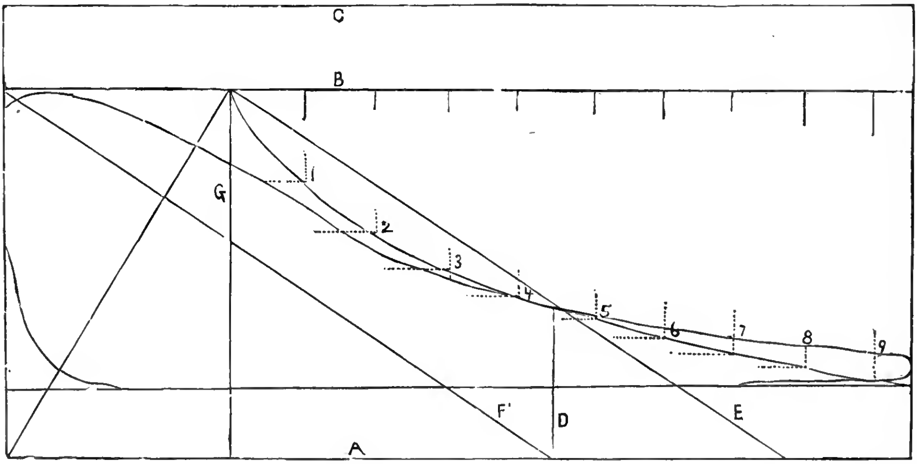


FIG. 104.

scale forty, with a three-inch feed pipe and a five-inch exhaust pipe. There are points of interest about this diagram well worth examination.

A represents the line of absolute vacuum, B the line of realized pressure, C boiler pressure. It will be noted there is a wide difference between the lines B C; for with eighty pounds boiler pressure, there is only 62½ pounds initial pressure, the steam valve opens slowly, and we doubt if it ever gets wide open, judging from the steam line. From the diagram there is nothing positive to tell where the point of cut-off is, so we must resort to the demonstration to gain information. In this case we erect the line, D, rather past the center of the expansion line. We then draw the first parallel, F, from the intersection of D A to the intersection of F B. The line E is then drawn parallel with F from A to B. Wherever the line E touches B, from that point drop an ordinate G, which represents virtually the volume of steam admitted to the cylinder to do the work, and this line measures the amount of steam, from the commencement of the stroke to its cutting off, that was used to produce the known pressure at D, supposing the steam had been properly put into the cylinder and that valves and piston were tight so that it was correctly handled after it was once put there; but, unfortunately, the steam did not get in on the piston as it should have done. Now, had the proper amount of steam been correctly applied between the introduction and the line G, it would have followed out the line B to the point B G, and then would have followed the theoretical line or the dotted line. But in the first place we see that it falls away short of the theoretical line until it reaches the fourth ordinate; at that point it seems to go above the theoretical line, we find at the ninth ordinate it commences to exhaust at the very point where it should have expanded to.

To refer again to the demonstration and its purpose, this application is not at all to raise questions to confuse the engineers, but rather to show them different points which arise in our own practice and that of others, where so many of these things are constantly coming up which vex the operator and the builder. In this case it is perfectly fair to presume that the stream drifted in after the valves commenced to shut, gradually ran down on the line G, until the expansion is five pounds at the first ordinate below the theoretical line. This theoretical line is based on the actual pressure of steam at the line D, or the base line, so that the pressure at the first ordinate should have been five pounds more than it is; at the second ordinate plus three pounds more than it is; at the third ordinate two pounds; at the fourth ordinate the lines virtually run together; at the fifth ordinate the theoretical line runs below the line of the instrument; at the sixth ordinate still more below; seventh, eighth, and ninth increase until we stop at the ninth ordinate five pounds above the line, as we were five pounds below at the first, while the distance from the base line D to the ninth ordinate is about the same as that of the ordinate G.

Now, what is the cause of this almost exact balancing of the figure? Why has it been below in one point and above in the other? There are two reasons that could make it so, and the indicator cannot tell us which of the two it was.

In the first place the pressure actually was below what it should have been; in the last, it was above. Now, this pressure may have been caused by a leaking-by of the piston or valves, and in the one case it would account for the terminal pressure at the ninth ordinate, probably to be more like a leak in the valves; or, if the steam was wet, there might be a certain amount of re-evaporation which would tend to keep the pressure a little above its theoretical value or its real value. This shows how unfair it is to base any absolute demonstration on the terminal pressure, as showing the real action of the engine. If the piston had been leaking-by during expansion to any such extent, the leak would have shown on the exhaust of the other side, and as it did not, we know that the opening of the valve was insufficient from the dropping of pressure below B on G at point of cut-off, and also that the pressure at B, cut-off at G, gives us the volume of steam to give the pressure, D, at that particular point in the expansion line, and that the valve was slow in closing, or, when closed allowed steam to pass through, or, leaked sufficient steam to raise the terminal pressure as shown, wasting the 62½ lbs. of steam realized in the cylinder by valves insufficient in area and probably insufficient in their relative motion to give steam for the speed of the piston at the regular speed of the engine.

LESSON XLVI.

HIGH-SPEED ENGINE DIAGRAM.

The diagram Fig. 105, in this lesson was taken from an Armington & Sims engine, 8½ inches diameter, ten inches stroke, running at 320 revolutions per minute, boiler pressure seventy, Thompson improved indicator, forty scale. The load in this case was given by a lever bearing upon the under side of the balance wheel, and in several instances the load varied by intention from the mere friction of the engine to 25 or 28 horse-power, within a quarter of a minute. At the particular instant when this diagram was taken, the load was constant for the sake of ascertaining the accuracy of the indicator, and this was only one of several diagrams in the series, and this particular diagram is chosen in order to show the largest range of variation recorded; in other words, the worst diagram of the set.

The admission line at A will be seen to vary a little from the vertical line, whereas at B the impact given by the admission raises the pressure somewhat, and at the same time is a trifle late as compared with the movement of the piston. The oscillations, it will be seen, are confined, and the steam line, when fully drawn, stands at sixty pounds, maintaining fifty-seven to the point of cut-off at C. It is a curious fact that some makers of indicators are recently claiming that the expansion line must be *without* oscillations, similar to those shown in this diagram, in other words, their instruments draw in the hyperbolic curve perfectly. In this case we wish to call the attention of our readers to the fact that a number of elements are at work between the points C and D, in order to prepare them to reason out in their own minds as to whether our own ideas upon the subject will bear the application of reasoning from the stand-point of fact.

This engine is traveling very fast; at the point C the valve is closed or very nearly so; every thousandth of an inch that the piston moves forward on its stroke increases the volume of the cylinder; no more steam is being admitted; an increase of volume means a decrease of pressure; a decrease of pressure means a decrease of temperature, and a decrease of temperature means, when applied to steam, an increase of water present in the cylinder. Now the ratio of the volume of the cylinder is increasing all the while after the valve closes; the volume increases, the pressure decreases, the water increases, etc. Now, is it possible for steam—supposing it was a perfectly dry steam at this point, which it is not—is it possible to make any instrument that will make any portion of a hyperbolic curve when these several elements are each one working negatively upon the other? Even after the release commences, which is at D, it will be found then that the variation of volume, temperature, etc., make a still further fluctuation in the line at E, by which time the exhaust port is fully open. We shall show, in a subsequent lesson, that it is not precisely the correct theory, if men are to make truthful indicators.

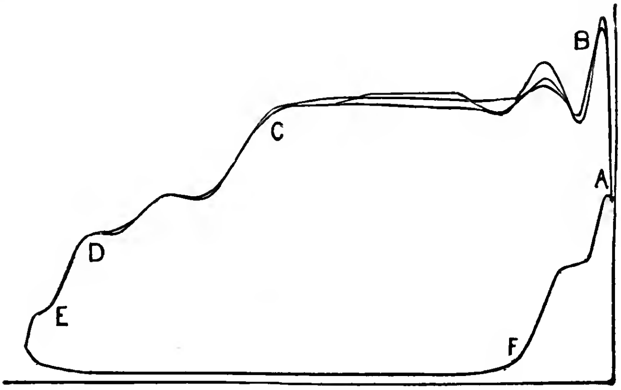


FIG. 105.

Now, added to the elements that we have cited, there is another very important one, the expansion and contraction of the metal, the weight of the piston, change in the spring, the friction of the moving parts, which is but extremely little, yet it is something. Perhaps some one can tell us how it is possible to make an indicator tell an untruth, or in other words, make some portion of the hyperbolic curve from C to D, instead of the undulating line, which is without doubt caused by the various elements to which we have referred, and it is somewhat curious that when the exhaust valve closes near F, in the compression of the steam, the increase of density or pressure by shutting the steam up and compressing it brings back certain units of heat, and that the compression line has certainly, in the same ratio, given us the undulations in an inverse way, (showing compression) to what the expansion line from C to D is. Compare the lines F A and C D, and tell us why these changes should take place, one proving the other. It will be noticed that the undulations in the line are reversed in F A to what they are in C D, showing that the expansion with the indicator piston upon the steam is very correctly noted, while on the other side in compression the steam is driven up against the piston, showing the same effect precisely, but that the directions of the lines are reversed.

The diagram shows a very good use of steam; possibly the action of the steam valve should be quickened a trifle in its relation to the piston of the engine, that would make a somewhat sharper corner at the termination of release and commencement of exhaust, and would also carry the compression a trifle higher and avoid the little hook at A, or in other words, would run the compression line into the steam line and would bring the point B nearer the vertical line shown. Taken all in all, it is a beautiful specimen of the high-speed engine diagram as well as of the indicator's work. The three lines, as shown in the original, are carefully reproduced in all their variation, and the subject of the maintenance of pressure, quick expansion, almost locomotive release, as well as locomotive compression are well executed and illustrated, but with the full effect of boiler pressure to the point of cut-off, or a close approximation to it, and a fine exhaust, both showing that boiler pressure and free exhaust can be realized in this type of engine, and are accomplished in every-day work.

LESSON XLVII.

MEDIUM HIGH SPEED ENGINE.

Fig. 106 is from a different type of engine, one of medium high speed, which has not been running many months. The diagram is from the Buckeye engine, twenty-four inches diameter, thirty-six inches stroke, 100 revolutions per minute, condensing, one of a pair, front end of the left hand. Boiler pressure seventy-two, scale thirty, Thompson improved indicator.

Some pains have been taken to make the demonstration as plain as possible in this case, for those not familiar with the new method of laying out the point of cut-off, and then applying the theoretical curve for efficiency, or to detect leakages or other troubles.

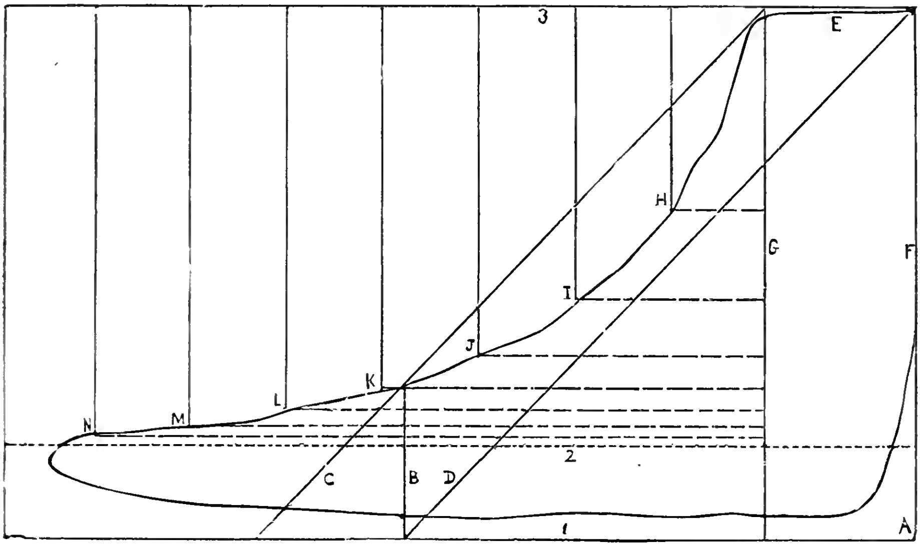


FIG. 106.

On this diagram, 1 represents the absolute vacuum, 2 the atmospheric line of the instrument, 3 the line of realized pressure in the cylinder, which is sixty-eight pounds plus, or a little less than four pounds below that of boiler pressure at the instant of taking. B is our base line from which the whole demonstration is made with reference to the point of cut-off; B is drawn from a point a little to the left of the center of the line of expansion, from that to the line of absolute vacuum. From the intersection of the lines B, 1, the line D is drawn to the intersection of 3, F, representing respectively the realized pressure in the cylinder, the line 3, and F, the admission line. In this case we do not know what the clearance is, so we have assumed nothing, but that the indicator made exactly the lines showing the work done, so that no clearance is included. We show the steam used, and as we do not know what the clearance is, we prefer to call it an unknown quantity.

C is drawn parallel to D exactly, starting from 1 and crossing the end of B at its intersection of the expansion line. Wherever this line C strikes on 3, that is the mechanical point of cut-off, assuming only that geometry is correct in its application, wherever the intersection of C, 3, comes, there is the point of cut-off, which in this case is perceptibly a trifle longer by the instrument than by the demonstration; we do not believe in the system of ordinates or logarithms where pressure and temperature are combined, but we believe if a mechanical demonstration is capable in any one direction, that a mechanical demonstration is far better for us to locate our point of cut-off, and not be guessing, supposing, assuming, etc., etc.; hence we make the whole of our demonstration mechanical rather than by assumption.

We have, therefore, the intersection G, our first ordinate with the line 3, is the actual point of cut-off from that part of the expansion line where we have located the line B, from the point A all these lines radiate. (See Lesson XLII in both demonstrations.)

We locate the point of cut-off mechanically, and then demonstrate the theoretical curve mechanically, so that we notice here a variation of far less than the width of the line, it shows us clearly that the valves of this engine must have been working very nearly tight. Practically they are tight, and wherever any broad variation from the actual line of the theoretical curve from the point of cut-off with this demonstration occurs, you may commence at once to look for leaky valves, piston rings or something of that sort, in this case it means nothing; we are without the clearance line, and this diagram, as it stands, is simply and purely an actual exponent of the work being done at the time, but it does not show the whole bulk of the steam used, only as we know precisely what the clearance of that end of the engine was, but for all practical purposes we would not give a farthing to know, and it may be well to say here that the clearance, *if known*, would add its volume to steam used, but would in no way affect the cut off, or expansion. We have a diagram here which shows a very fine working of steam, so far as taking, carrying, cut-off, expansion and release go. The vacuum might, perhaps, be improved in amount, but as it is an independent condenser and no part of the engine, we do not criticise it. It starts with only four pounds, runs down to nine, ten, eleven, then commences to go the other way, making a fine compression, though possibly a trifling steam lead.

One point must be taken care of in locating this basis for the demonstration, and that is, that the ordinate B should never be drawn too early in the expansion line, for steam, like any other body where work is being done, as a steamship or a train of cars, takes a little time for the engine to get to pulling, and so it takes a little time for the steam to settle down to its expansive work, and that place which is fair for it, all things considered, is a trifle beyond the center or when the speed of the piston is very slightly diminished by getting up on the crank; in other words, where the speed of the piston is very slightly slower and the pressure of steam has very considerably diminished; sometimes sudden fluctuations will be found in expansion line by rings leaky, in such a case get two or three points and demonstrate from each, and so find where the leakage occurs.

LESSON XLVIII.

EXPENSIVE USE OF STEAM. COMPARISON BETWEEN EXHIBITED FACT AND POSSIBILITY.

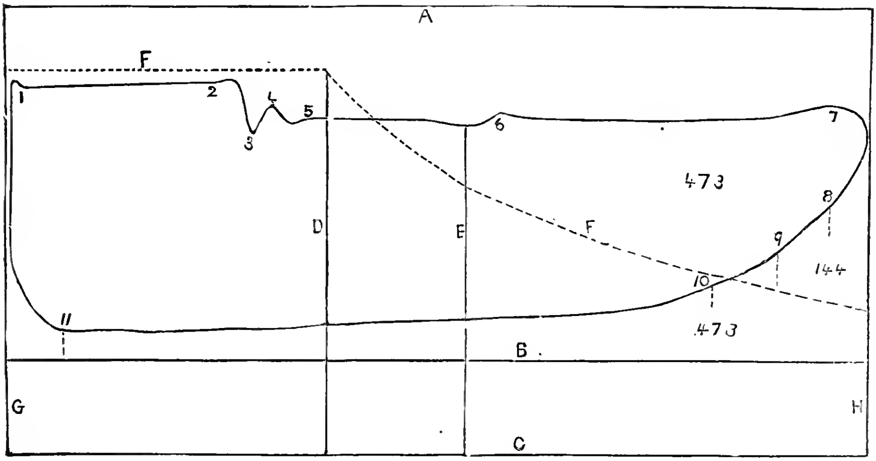


Fig. 107.

In Fig. 107 we have something not only to think of, but something which we can compare as between the application of geometry to fact and mathematical rendering of the geometrical delineation, by so simple a process that every reader who has a planimeter can, in fifteen minutes, tell whether our statements are correct or not. We have chosen about as awkward a diagram as we could conveniently, for two reasons: almost anybody who has been reading our indicator articles for the past few years, can make a demonstration on a finely-outlined indicator card; and we have chosen this curiosity more for the sake of the application of our own method of finding out, first, where the steam was cut off, and then finding out what ought to have been done. A represents the line of boiler pressure, which is far above the realized pressure in the cylinder; B represents the atmospheric line of the instrument; C represents absolute vacuum from which all computations are made both for geometrical demonstration of the point of cut-off, and quite another demonstration having nothing to do with the first, which gives us the theoretical curve, supposing steam does expand either according to Mariotte's law or Rankine's formulas; but the two demonstrations are not in any way connected, beyond that the line D shows the amount of steam used in the cylinder, the volume from C to D being filled, if cut off and properly expanded, and the intersection of line D with the line F shows point of cut-off on the line F. The engine from which this was taken was running eighty-two revolutions per minute, scale thirty, governed by one of the throttle governors and was supposed to be doing good work. The card made by the indicator starts off with forty-five pounds initial pressure, makes a nice little jog at 1, runs along at forty-five pounds, and commences a peculiar gyration at 2, dropping off suddenly from this point to 3, rising again to 4, and making a peculiar short curve, commencing at 5 again to run in a straight line, and at 6 another peculiar vibration. The terminal pressure at 7 is forty-one pounds. We have thus a very peculiar expansion line, and almost any one with any knowledge of steam enginery would pronounce it not by any means a model card, but we have less to do with this than with the next factor in this most interesting case. A little beyond 7 the exhaust valve commences to open and opens slowly, so that at 8 we have twenty-four pounds back pressure, at 9 we have seventeen pounds and at 10 ten pounds. The back pressure gradually becomes less until the exhaust valve closes at 11, where it has been reduced to five pounds; we have all the space bounded between the exhaust line of the instrument and the atmospheric line of the instrument B, making a large area, the exhaust being, perhaps, a little less ragged than the upper line 1 to 7. The closing of the exhaust valve at 11 is very nearly correct, but the opening from and after 7 shows distinctly that the motion of the valve is incorrect, for it is entirely too slow, if large enough, in its proportion to the stroke, and all the area when open is not sufficient; hence we do not realize the theoretical line of exhaust, nor indeed the usual exhaust of a half pound of back pressure. The planimeter reading of the indicator card precisely as it comes from the instrument is 473; the planimeter reading of the area covered in by the back pressure is 144; then we have an area of 473+144=617. Now there are parties in the world who claim (we will call this horse-power) that in this case the 473 horse-power is transmitted to the machinery, and that the 144 amounts to nothing. Perhaps this is so. All engineers know that the boiler capacity is invariably measured from the atmospheric line, and in this case the boiler would receive credit for and would actually be doing 617 horse-power. It is claimed also that the back pressure upon one end equalizes the back pressure on the other; perhaps this is so; possibly not. Now, while the piston moves from 1 to 7, the steam is escaping from the other side of the piston, and from 7 to 11 is going on, on the other side of the piston. Now, if we have 473 on one side of the piston, 144 added to it, if it were working as it should, but, in this case, working against it, does it require anything on the other side of the piston to push that 144 out of one side of the piston and out of one end of the cylinder, while the steam is making the card upon the side of the piston in the direction of from 1 to 7? Now, if this statement is a fallacy will somebody show us where? In other words we have drawn the line E from the expansion line or steam line, whatever it may be, to the line C; from the base of E we have drawn a line to the intersection of F G, namely, realized pressure. and the boundary line of the card, giving the steam and vacuum lines, parallels to this line, which is omitted in the engraving. We have drawn from a point on C to the line F, which crosses the line F at the intersection of D F; from this point we drop the line D. Now, the space bounded by the line C G F D represents the volume of the cylinder at which steam should have been cut off in order to produce its equivalent at E. Then by the same plan given in Lesson XLII, we draw in a theoretical line F. Now, we assume here simply that had the engine been handled as an engine should have been, it had a pound or so above the actual initial pressure, that it would have been cut off at D on the line F, and then if the valves were tight it would have expanded according to the curve F, and if it had exhausted as it should have done, it would have returned upon the line B. There is something curious about all this. The dotted steam and expansion line with the correct exhaust gives us precisely the same planimeter reading as in the diagram above 473 without the 144 back pressure. This may be the correct way of working engines, we mean the actual diagram, but in our own demonstration we have only shown what the engine should have done, providing the steam were worked correctly and at the real boiler pressure instead of that which was realized. It is a little curious that this result comes out precisely as it does, without any calculation other than that all the simple demonstration and the addition of about one-third of an inch in length for clearance. The comparison shows a most expensive mis-application of steam.

LESSON XLIX.

A HIGH SPEED ENGINE, RUN AT A LARGELY INCREASED SPEED TO TRY AN EXPERIMENT WITH THE THOMPSON IMPROVED INDICATOR.

The author was among the very first of the engineers who had actual experience with the high-speed type of engines, beginning with Mr. Porter's engine in 1869, and has had much to do with and has advocated the high speed for certain purposes, and it would seem, perhaps, better if we were to give some few illustrations which have not been previously given. In Fig. 108 we give something which we believe never before done, and in this case was done for an experiment, but we presume will soon be adopted as practice. It is a well known fact that in electric lighting long-stroke engines have in some cases proved to be (even with the best regulation) very undesirable, from the fact that on the incandescent light the strokes of the engine can be counted with the utmost precision, if any one will give careful attention to it. On the other hand, with some high-speed engines the short stroke has been a disadvantage, by means of not thoroughly overcoming what was expected in the matter of measurement of time as between the long and short stroke, and the high-speed engine requires a great increase of accuracy, if such a thing is possible, over the slow speed, in proportion as the stroke is shorter, than the slow-speed engine. The same factor of an increase of speed from the commencement to the middle of the stroke, and the decrease of speed from the middle to the end of the stroke, is present in the short-stroke engine, but it becomes beautifully less in percentage as the stroke is shortened and made more frequent. In other words, the visible effect on a high-speed engine, if run at regular speed, is exceedingly little. Regular speed does not mean a great variation, but a close approximation to a certain line, and any variation from this is very noticeable indeed, and is not only noticeable, but has a very pernicious effect upon the film of the incandescent lamps.

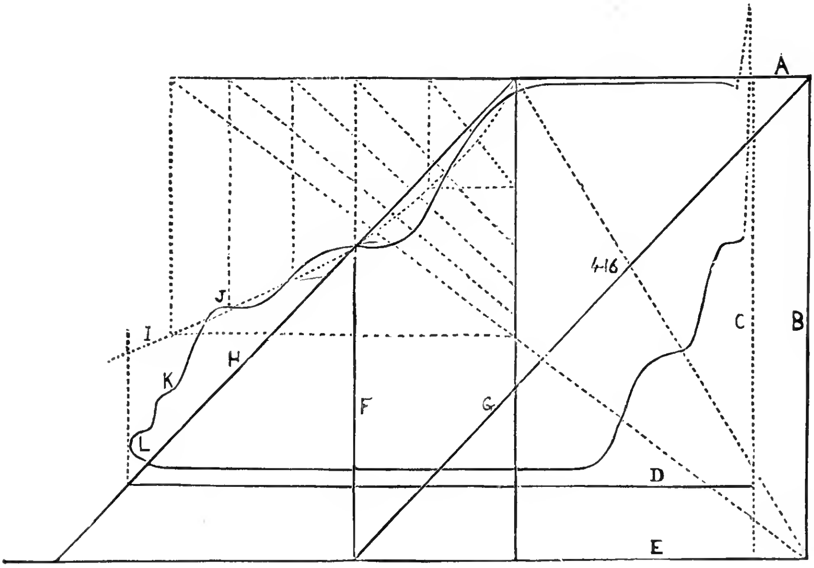


Fig. 103.

The author was called upon to make a test with some indicators. He had desired very much to obtain an indicator that would give a reliable card from an engine running 500 revolutions. We had no engine running 500, nor could we get access to one, but through the courtesy of the owner of an engine we were allowed access to his engine during the noon hour, with the privilege of running it into the afternoon if we would agree to stay by and take care of it. The regular speed of the engine was a little above 300 per minute.

We set the regulator arm-springs down as much as we dared to, adjusted our indicators as nearly as possible, and opened the throttle valve. We had intended to run at about 400, but were simply guessing at the tension of the springs. The speed was simply terrific; counting was entirely out of order, and the engine ran as smoothly as at 320. Finally the gentleman who had invented the 500-revolution-per-minute engine decided that he would experiment somewhere in the neighborhood of the speed we were using. A counter was then procured, and we found that our speed ran in fifteen seconds 109, thirty seconds 217, one minute 435, and two minutes gave us 866.872 and 870. The steam was then let into one of our new Thompson improved indicators. Fig. 108 is one of the diagrams taken from the head end of an Armington & Sims engine, 8½x 10, 435 revolutions, boiler pressure 90, scale 40. A represents the line of boiler pressure 88 or initial pressure, C the vertical line at right angles to D, which is the atmospheric line of the instrument, and E the line of absolute vacuum. In this case the line of the diagram above C, where the compression closes and the steam valve opens, shows that the steam valve is slightly in advance; in other words, that there is a little actual lead. The opening of this valve is instant, and the steam in this particular case shows an impact rising of between thirteen and fourteen pounds, but it as instantly descends to about four pounds below realized pressure. The steam line is then carried off very handsomely, and the visible point of cut-off is, we think, for such a speed, very plainly shown.

Here comes up the old question of what makes a wavy line of expansion, and we do not think we have far to seek in this for the reason. In this diagram there is no assumption, for we have all the facts, and the expansion line, as is shown in the first dropping after the cut-off valve has closed, descends something below the theoretical, then rises slightly above, again falls slightly below, and just before the exhaust valve opens at J, the theoretic and the practical line in its oscillations cross each other absolutely. The sudden outlet from J to K shows us that the steam will expand in anything but a section of a hyperbolic curve, when allowed free egress. At K we have another little oscillation, another sharp curve approximating much nearer to a right angle with the theoretic curve, and at L we have still another oscillation. The cause of this we have frequently been asked for, and lately in a case where the same factor appeared. Our reasoning of this is: From J to K, when the exhaust valve opens, there is a sudden exit of a considerable volume of steam under a pressure of thirty-three pounds above the atmosphere. The exhaust pipe in this case is of quite a length and when the steam from the cylinder, released by the exhaust valve, impinges upon the steam already moving in the exhaust pipe, a little reaction is caused by this very elastic medium, which makes a crook in the line at K. The steam then moves along again, that which is being released from the cylinder striking or pushing the other, all of which is very elastic, and at L the pressure is reduced so materially that no further vibration in the movement of the body of steam can be recorded by the indicator; and this may be further proved, perhaps, by the dropping off of the line as it turns from the termination of the exhaust just below the letter L, dropping down nearly two pounds before the exhaust line starts on its continuation. The line then, it will be noticed, drops a little as the exhaust is completed and before the exhaust valve closes again, a little to the left of D. Here we have precisely these same vibrations or oscillations or changes as the compression increases, showing plainly that the exhaust valve closes and the compression ceases in amount of pounds, making a nearly straight line on the upper step before the steam valve opens.

Proceeding with our usual demonstration, first to find the point of cut-off and the actual amount of steam used, we have erected here the line F, and, if the reader will notice, we have erected it not at the point of lowest pressure, but at about the highest point after the expansion really gets settled. From F we carry the parallels G H, and in this case we have included the actual measure of clearance of the engine, embracing the inside of the valve, the passage from the valve into the cylinder and the actual space between the piston and cylinder head, from data obtained from the engine when still and the clearance filled with water. We have therefore drawn G from the intersection of F E to the intersection of A, line of boiler pressure, B representing between C and B the actual amount of clearance as compared with the total cubic contents of the cylinder through which the piston moves. In this case it will be noticed we charge the engine with the absolute boiler pressure; we also charge it with every particle of clearance at that end of the cylinder.

Having thus defined the point of cut-off, we draw the first ordinate from A to angle formed by E B, see lesson XLII, starting from the intersection of the lines B E, and we have made the whole demonstration except the point from which the lines radiate, and these are omitted purposely in order to show clearly just what the effect of the action is; from the joining of the second ordinate with a line at right angles to the first ordinate at the crossing, and the process being repeated by the third, fourth, fifth and sixth ordinates through these points from the first ordinate the theoretical curve is dotted. It will be noticed that the second ordinate of the theoretical curve crosses a trifle above the actual line of the instrument, and at about the center of the stroke or when the speed is at its very highest. The third ordinate crossing is a trifle above the line of the instrument, the fourth is a trifle below, the fifth is absolutely on the line.

At J the exhaust valve opens and the curve is carried forward, passing I, in order to show where it would have come had the pressure been maintained by keeping the exhaust valve closed. We have not figured this for absolute effective percentage, though the percentage is very high, but present it as an example from actual practice, showing that we may charge the engine with its whole clearance, about nine per cent., remembering that the cylinder is 8½ inches in diameter, and that while the clearance may be large in proportion, the handling of the steam, charging everything to the engine that we may properly or justly do, is most excellent, even at this tremendous speed. It is impossible at such a speed as this to take a card quite so neatly as we like to do from one running 80 to 125 per minute, for if you touch the paper at all you must necessarily make several records. In this case the lines did not vary the width of one another apart at any point of the diagram, so that we have engraved a single line.

The question of the recording of the lines of expansion of steam under pressure and the oscillations is, to our own mind, always an evidence of extreme sensitiveness and reliability in the indicator, and we believe that, sooner or later, the real doctrine of the expansion of steam will be settled upon a basis that will not be filled with vagaries.

LESSON L.

CARRYING STEAM FULL STROKE AND EXHAUSTING UNDER EXCESSIVE BACK PRESSURE.

In Fig. 109 we have a comparison of high pressure steam, throttled down and then carried full stroke, and, to make the matter all the worse, the exhaust is nearly equal in resistance to the whole amount of work transmitted. We have made some comparisons on this diagram, both from the boiler pressure and the realized pressure, and to show how the effective use of the steam is entirely done away with and no economy attained. Boiler pressure, 100 lbs.; revolutions, 114 per minute; scale, 60.

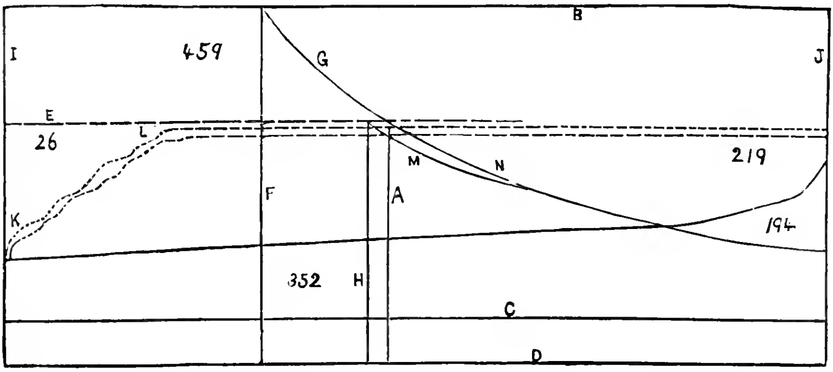


Fig. 109.

The line A in this case is the base of the first combination, B the line of boiler pressure, C the atmospheric line of the instrument, D the absolute vacuum. From the intersection of A D, we draw a line (according to our method of delineation) to the intersection of I B, then on D we lay off towards J the same distance that exists between the intersection of A and the steam line of the indicator card and the line D I. From this point on the line D we find the point through the top of the line A which intersects B, from which we drop F, showing the amount of steam used in the cylinder to make the theoretical expansion curve G, showing the amount of steam at 100 pounds cut-off to make very nearly the same amount of work as that shown by the indicator diagram and the back pressure; the planimeter reading of the indicator diagram outline is 219, the back pressure 194, the sum of the two being 413, while if we take 100 pounds of steam, cutting it off so that A shall equal the pressure at that portion of the stroke, we obtain 459. Now there is a point here to be considered; if we were to make the outline bounded by cutting off the hundred pounds at B F, taking in the theoretical curve G, we have 459 on the planimeter. Now, if we should make the same misuse of steam by the valve in the larger feature, or by cutting steam off in admitting steam, that the indicator card itself makes from K to L, the sum total of our areas should be exact. In the case of cutting off the 100 pounds of steam, we have simply assumed that the cylinder is to be filled at the commencement of the stroke; so that while with 100 pounds of steam, cut-off B F making G, returning on C and admitting again on the line I, we have almost a perfectly theoretical diagram; but in the actual misuse and abuse of steam bounded by the dotted line, which is the indicator card, we have 219, the back pressure which should have been useful effect, and the little triangle bounded by the dotted line which is the induction pressure, or realized pressure after the steam valve gets open, the vertical line I and the irregular hypothenuse K L, we have an area of 26 on the planimeter, hence we have 219+194+26=439 as against 459 developed by the proper use of steam.

But there is another factor in the case: Using A in the third computation as our base line, triangulating with the dotted line E, which is the line of realized pressure in the cylinder, we obtain the line H as the volume of steam admitted at that pressure, and the expansion line should follow the lower line M, which strikes the theoretical curve G at N, and then follows so near that it is almost impossible to show the two lines on the card; this is supposed to exhaust freely, or what the engine should have done had the steam been entered at the pressure E, at the very commencement of the stroke, cut off at H, expanded on M G to the terminal pressure and exhausted freely. In this case we have 352.

By this time our readers may wish to know what all these letters, figures and lines mean, or where the working engineer is going to learn anything from such a mass of references. Let us see; in the first place we had a hundred pounds of steam, for the scale is 60, the engine was running 114 revolutions per minute, it made the dotted line diagram which figures 219; suppose we call it 219 horse-power, working against the back pressure 194. In other words, the boiler was yielding 413 horse-power to do 219. Steam was carried the whole length of the stroke after it was first admitted. If the steam had been admitted at the pressure represented by the line E, which is about sixty-three pounds, and been cut off at H E, expanded as shown by M

G, it would have produced 352 horse-power with an expense of a little less than half the steam, provided the valve had admitted the steam at the outset and the exhaust had not been checked. On the other hand, had this engine admitted the boiler pressure of one hundred pounds, cutting it off at F on B, properly expanded and exhausted, the steam which was in the boiler and was not used on account of defects in the construction of the engine, *a still less quantity of steam* would have given 459 horse-power as against 219 horse-power by this wretched misuse of the steam.

The valves in the engine from which this diagram was taken are very wrong in their construction, and have a fault common to many of the new engines of '83 and '84. They do not travel far or fast enough to give either induction free from the throttling, or eduction free from back pressure; steam cannot be used profitably or economically without free passage—into and out of the engine.

LESSON LI.

HARRIS-CORLISS ENGINE—DISTORTION OF DIAGRAM BY THE INDICATOR MOTION.

The approximate value of the correct reading of an indicator diagram is something which can be gained by careful attention to facts, and we believe only in that way. Fig. 110 is a rather peculiar case, from a Corliss engine 23×48, running sixty-six revolutions, seventy-nine pounds of steam at the moment of taking, nearly eight pounds of back pressure, and was the cause of considerable argument and investigation.

The line A is absolute vacuum, B atmospheric line of the instrument, C exhaust line of the indicator, D expansion line of the instrument, E realized boiler pressure in the cylinder, F boiler pressure. It will be seen that the engine takes steam very squarely, carries it for a short distance, and immediately commences to drop off. We have located the base line, G, a little beyond the center, in order to allow the steam time for settling down to its work. From the intersection A G we have drawn I E, and parallel to it H; the intersection of H E by this demonstration gives us the point at which steam was cut off, to give the pressure at G in the stroke. The demonstration is made for ascertaining whether the steam expanded correctly or not from the point E I; and the line J, which is dotted differently than the line D, is the hyperbolic curve from E I, or the amount of steam used. Curiously enough this line

J crosses the expansion line D at the point G, or very near it, and it falls nearly as much below the expansion line of the instrument on finishing the stroke, as it rises above it between H I and G H.

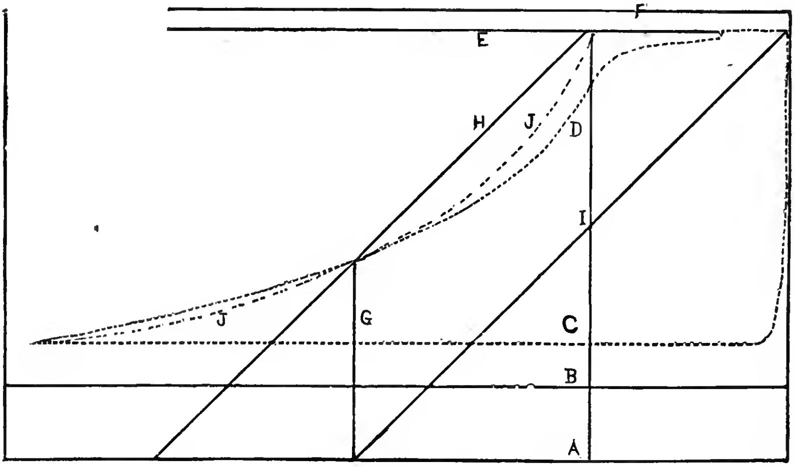


Fig. 110.

There is something rather curious about the peculiar formation of this line, as also in the cutting off, and after the question was submitted we wrote the engineer that his engine was either leaking or that his attachment was wrong, which gave motion to the indicator—a careful draft of all the connections settled the point that the motion was not square with the engine, and that the motion of the paper barrel of the indicator was so arranged that it ran too fast and too slow from distortion of the motion, and showed a "leaky valve" if the motion had been correct—but the trouble was remedied by throwing away a bad motion, and using the pantograph properly attached, and the distortion ceased.

LESSON LII.

A CURIOSITY—IN DIAGRAMS.

In Fig. 111 we have a rather knotty subject, more for the sake of the information it contains, but also to show the difference in indicator's performance. The diagram illustrated was taken from a Porter-Allen engine, one of a pair-right-hand engine, back end, boiler pressure eighty-two, fifty scale, revolutions 355 per minute, Tabor indicator.

The admission line A gets on very well until the piston of the engine commences to move, when an oscillation takes place, making a very attenuated-looking figure 8. Curiously enough, the first loop seems to be against the motion of the piston and the next one with it, as the steam is introduced, and the movement of the piston so sudden, carries the second slant of the pencil lever up above boiler pressure some twenty pounds; coming down again as the motion of the piston increases, crossing under B, making a most peculiar curve, dropping into the saw-tooth, and then upward by a reversed curve or a concave, instead of convex movement, turning over again, coming down in the direction of D; and, if you turn this wrong side up, you have a handsome Roman nose, rather sharp at the point, or a good-looking saw-tooth for a hand saw. The peculiarity of this, again, is a convex instead of a concave movement, dropping away considerably from the theoretical expansion line, which is dotted in. The vibrations, then, which take place in the expansion line, become less and less. but continue until the very end of expansion and commencement of release.· The engine is working with a condenser, and the line F is that of the vacuum. We have erected, as nearly as possible, the theoretic point of cut-off from our own system of demonstration, charging a moderate amount of clearance; whether correct or not, we do not know. It will be seen that the demonstration gives us a close approximation to what would ordinarily be termed the visible point of cut-off, or where the expansion line really commences. The second notch comes closely up to the theoretical, the third the same, while the fourth, fifth and sixth are slightly above. Whether this is caused by any possible leak (which must be very trifling), or whether larger clearance would have made it still below, we cannot say, for in this case we have assumed the clearance, and, to our mind, it only shows that there is a certain analogy in the demonstration, and the actual effect wherever an approximation is made, and it also shows that the indicator, at high speed, may possibly become, in a measure, entirely unreliable in its

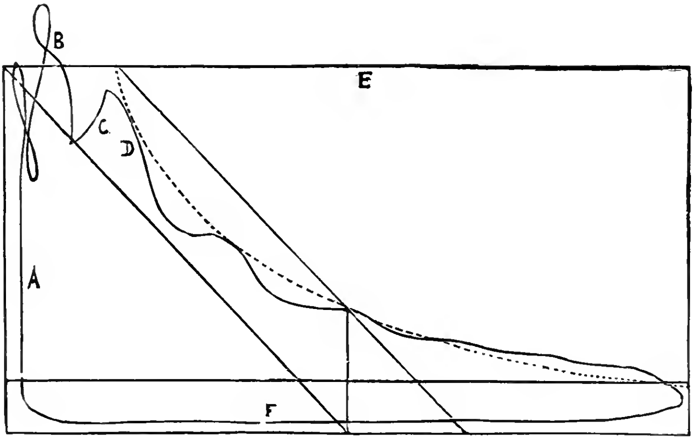


Fig. 111.

readings of the position of the valves—for in a case of this kind there is not the remotest approximation to any position from which we could work to adjust the valves. The impact of the steam entering the cylinder at the pressure and speed given, is something fearful—and the indicator may not have had a steady motion, and any irregularity, or instability, in the reducing motion would have given the distorted lines shown. The engine from which this was taken does not make any such diagram, and this is introduced as one of the curiosities of practice.

The question at issue really is: What made these funny-looking crooks and curves in this diagram? It certainly was not the engine. Was it the motion, or was it some defect in the instrument, or something between the instrument and the cylinder? Who can teli? This will be something for the engineers to work over, and it will well repay them for any trouble they may take. There are some curious features about it. This diagram was taken nearly two years ago, but it is just as well worth studying now as ever before, and, without further information, we cannot attribute all the fault to the indicator, or to the engine—but an insufficient spring in the indicator, or a tampering with the barrel-spring or a pendulum too weak for the speed and tension, either one will accomplish practically the same result—to a certain extent, but not to so radical a change.

LESSON LIII.

ADJUSTING CORLISS ENGINE VALVES.

This time we have an interesting illustration, and we hope our readers will not get confused with the several lines upon it. The diagram (Fig. 112) in this case represents an engine built by one of the best makers, and which had been abused most effectually. A shows the diagram in fine, dotted lines, after the adjustment was complete; B, a solid line, shows the second stage, or during valve adjustment; and C, a wavy line, shows where we found it. This is one of a series of diagrams taken to find out what power parties were using, with a view to ordering a larger engine. Commencing with the diagram C, and ninety-five pounds of steam, we obtain sixty-five pounds realized on the piston in the cylinder—a very bad beginning for a Corliss engine, but the engine was not to blame. Notice the two lines forming an angle at D; this is about where the line of admission would have come out if it had gone on at the same ratio, with the pressure at that point; but if the pressure had reached that point, it would have gone forward of D decidedly, owing to the quickening motion of the piston. Now, let us see. The steam valve does not open; the steam line looks like an old-fashioned poppet valve engine, which began to cut off the moment it was open. It is hard work telling where expansion begins or ends.

Having looked this matter over, and finding both ends were alike, we moved the eccentric a little more than half an inch ahead on the shaft, so as to quicken the *time* of movement. B was the result; the valve opens considerably quicker, and it will be noticed with this change we have eighty-eight pounds of steam. But by this time our crank valve is working nicely, but the head valve is pushed back by the jimcrank shaft, or, in other words, the claw pushes the valve back on its seat, so as to get a good hold and start again; but this wont do, so we must move the eccentric forward again, which is done, and we secure A, which is just about as well as we can do. We have now ninety-five pounds out of ninety-seven; take steam about at the right spot. Our crank valve at this time is a little too fast, so we must change that on the jimcrank by slowing.

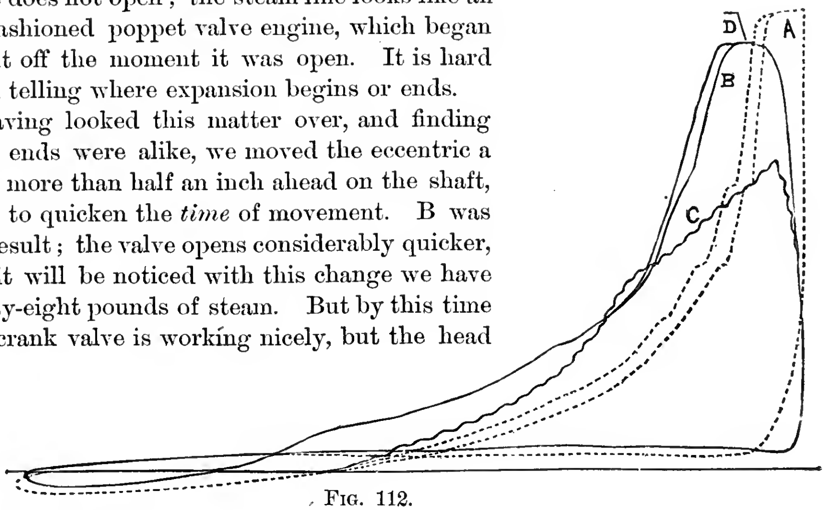


Fig. 112.

We have not space here to make all the illustrations that would be necessary, especially as regards the release and compression. It will be seen, however, in the fine dotted line, that the compression and the opening valve merge into one line beautifully. The expansion line looks very nicely, but for the sake of avoiding any confusion we have omitted any demonstration, the object of this being to impress upon our readers the fact that the proper way to open the valve gives the best possible use of steam; and the reader who may be informing himself with the use of the indicator can see here a most notable case, where the exact opening of the valve gave a prompt cut-off, a beautiful expansion line to all appearances, exhausted slightly under the atmospheric line and compressed so as to make as fine a line as we need to work for. It is a simple lesson, but there is a good deal in it.

The whole thing was done in less than half an hour, and the engineer and the parties who were looking on, when they came to load the machine, never saw it do so well before. If an engine runs right with a light load, it will run well all the way through, and we have no doubt that this engine would have cleared itself creditably if it had been running and carrying steam as far as it could have done; but under these circumstances there would have been a good deal of loss, for the steam pipes were insufficient to carry any great part of the length of the stroke.

LESSON LIV.

EXPENSIVE "CUT-OFF" BY CHEAP ATTACHMENTS.

The diagram, Fig. 113, was sent us by an engineer with the request that we lay out for him the expansion curve from the apparent point of cut-off, and as nearly as possible from the cut-off made by the quantity of steam really in the cylinder, according to our method previously illustrated, the data of the size of the engine was not given and is immaterial for the purpose for which he asks information. The data which accompanies it is twenty-four spring, fifty-five pounds of steam in the boiler, head end of engine, seventy revolutions.

The diagram is a peculiar one, in fact a most wasteful one, and for that reason alone it is given space.

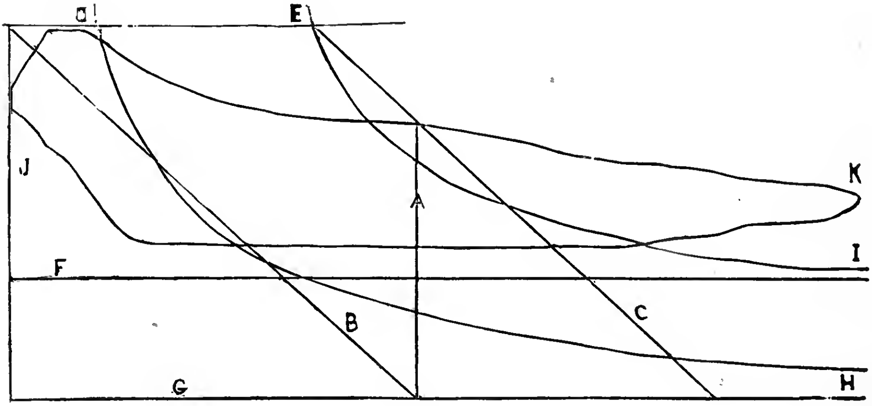


FIG. 113.

The line A is the basis of our computation of quantity of steam accounted for in the center of the expansion line. [The engine is supposed to be working with a cut-off]. B C parallel lines, B extending from the intersection of the vertical line and the line of initial pressure D E, E is the point of cut-off established according to this method of ordinate A, parallels B C, all of which are explained, in Lesson XLII, as the method of locating the exact point of cut-off, taking the expansion of steam somewhere nearest the center or the point of least variation. F is the atmospheric line of the instrument, G the line of absolute vacuum.

In answer to our inquirers we have taken the visible point of cut-off, D, slightly beyond the sharp corner, and, from the intersection of the line of absolute vacuum and the vertical line or admission line proper, have laid out the theoretical curve according to the method referred to above. This line terminates at H and shows a decided change between the visible point of cut-off and the actual terminal lines, the point K in the actual diagram being twenty-seven pounds above the vacuum line and the point H being four pounds above vacuum line, and the point H is where the terminal pressure should be *if* D is the point of cut-off as it appears, and *if* the valves close tightly.

Taking the line A as the basis of our calculations, we find the point E to be designated as the cut-off by demonstration, a termination of the expansion line proper at I, being 1½ pounds above the atmospheric line of the instrument, 16½ pounds above absolute vacuum, while the real line of the instrument is, as before, twenty-seven pounds above absolute vacuum. There are some other peculiar features to this diagram; in the boiler we have fifty-five pounds steam pressure, only thirty-two of which at the outset is realized in the cylinder. If we follow the line of the instrument we find that after the valve commences to close, somewhere near D, there is a gradual sifting in of steam until it passes the intersection of the line A with the expansion line of the instrument; in other words, the engine takes steam a long way after the cut-off valve appears to be closed, and if there is any economy in the engine, it must be economy in running a cheap engine at an enormous expense for fuel. If the reader will figure the water consumption of this engine, for comparison with any size and speed engine he chooses, he will find it is enormous.

The exhaust of the engine is anything but good; starting with nine pounds of back pressure, averaging five, but perhaps this is not all in the engine, our informant does not give us this fact. Whatever may be in the engine it is not a good exhaust. The compression line is fair but the steam admission seems to be late, peculiarly so on the upper part of the line; the steam-carrying line, or the steam line proper, is very short, and while the visible point of cut-off is sharp to a certain extent, the practiced eye soon discerns that there is no expansion line to the diagram. It shows what is termed sifting in of steam, until considerably past the half stroke.

In outline the diagram has every appearance to us of a peculiar arrangement known as a regulating cut-off, where some sort of a cam is applied to the throttle-valve regulator, which lifts the throttle valve at the commencement of every stroke and drops it again. That probably accounts in the action of the regulator for the peculiar line from between the commencement of the admission line and the steam line. It is a sort of combination which is both unsatisfactory and expensive. The visible point of cut-off, as our writer terms it, at D, equals almost exactly one-ninth of the stroke; while the point of cut-off, supposing the valves were tight, or according to the quantity of steam used in the center of the expansion line, is shown at E, is 16-45 of the stroke or plus one-third; in other words the engine is actually using more than three times as much steam as is shown by the indicator diagram at a casual glance and without the application of some test to determine it. This is readily shown by the very great height of the termination of the expansion line above absolute vacuum. The cutting off of thirty-two pounds of steam, where we should have fifty-five pounds, with a terminal pressure of twelve pounds above the atmospheric line, is eleven pounds too much at the termination of the expansion, and is just about in that ratio to the economical use of steam, as is shown in this case.

LESSON LV.

THE CORLISS OR MODERN COMPOUND HIGH DUTY PUMPING ENGINE.

Figs. 114 and 115 are from the Corliss Pumping Engine at Pawtucket, R. I. It has been running several years in charge of one of the most intelligent and painstaking of engineers, Mr. John H. Walker.

Fig. 114 is from the high-pressure cylinder, 15 inches in diameter, 30 inches stroke, making 47 revolutions per minute, scale 60, steam pressure 132 pounds, Corliss upright boilers being used, 130 pounds are realized on the piston and the steam line is carried as straight as is possible to the point of cut-off. The expansion line is a marvel of beauty and correctness; the release is early and the exhaust into the receiver shows a commencement of ten pounds receiver pressure and a terminal of eight pounds, there is very little rise in the pressure in this case. The admission could hardly be better. The demonstration in this case precludes the possibility of drawing the theoretical line a portion of the way, as the lines would pass one over the other. Very little compression is used; that, for some reason unknown to us, is one of Mr. Corliss' ideas, to work with little or no compression. There is a very slight difference between the apparent cut-off and the theoretical, but it is so exceedingly slight as to be almost unworthy of notice from a critical standpoint.

115 is from the low-pressure cylinder of the same engine, the cylinder being 30 inches in diameter, 30 inches stroke, running 47 revolutions per minute, scale 12. 114 is from the front end of the high-pressure cylinder, and 115 from the back end of the low-pressure cylinder. From the ten pounds in the receiver, we have nine pounds initial pressure, gradually falling off to seven pounds before the close of the valve, expanding to seven and one-half pounds below the atmospheric line. The condenser takes hold at twelve and one-half pounds, the maximum vacuum being about thirteen and one-half pounds, or very nearly approximating to the theoretical. The demonstration

in this case shows a very close approximation of the actual to the theoretical, taking into account the lowest pressure from the initial and the point of cut-off.

This engine has been running some eight years, and these diagrams were selected from the regular indication of each day. Comparing the two diagrams one with the other, the high-pressure gives about the highest possible effect of steam, and the low-pressure gives almost the maximum efficiency of the receiver pressure for the distance which it is carried. We have, therefore, a very fine result economically, and through the courtesy of the engineer we are furnished with the following facts from his regular log-book, which has been carefully kept every day since the engine was delivered to the Water Board. This engine was originally built to supply the town of Pawtucket; since that time they have added a very large mileage of pipe and a large amount of water to the supply, so that the pumping engine is now furnishing double what it was originally intended to do, and this over a very scattered area of territory. The engine is now running, November, 1884, twenty-four hours per day, the actual amount of coal consumed is 216 pounds per hour; Wilkesbarre egg coal is used, which costs $4.35 per ton of 2,000 pounds, screened; the amount of ashes is nearly twelve per cent. and when we say 216 pounds of coal per hour, this is the actual amount of coal fed into the furnace, no allowance being made for anything. The pumps of this engine are now working under a head of 272 feet. The high-pressure diagram figures 72.658 horse-power, the condensing cylinder figures 65.398 horse-power, making 138.056; the variation between the two ends is very trifling. Taking the coal which is actually consumed we have 1.57 pounds per horse-power per hour; taking the combustible we have 1.39+ pounds per hour, per horse-power. Taking the cost of the power in dollars and cents, calling all coal, we have 3.4 mills per horse-power per hour, while if we figure the combustible, we have the cost of one horse-power, per hour as 3.02 mills.

The duty under the Board of Experts' test, was 133,522,060 foot-pounds for one hundred pounds of coal. Mr. Corliss took exception to this, and denominated it the "humbug" test from the fact that allowances were made. An absolute test made afterwards by the same Board on Mr. Corliss' basis gave it a duty of 104,357,654 foot-pounds per hundred pounds of coal, and this duty has been somewhat exceeded in its regular every-day work, while in charge of its efficient chief. The duty from the time of its start, January 31st, 1878, to the 6th of November, 1878, was on fuel consumed to pump, 106,234,300 foot-pounds. In June 1882, the engine was stopped for inspection and the piston rod in the low-pressure cylinder, where it passes through the plunger in the pump, was found to be so corroded by the action of water, that it was necessary to have a new piston-rod. This was the first repair made upon the engine. The duty of the engine for the twelve months ending January 1st, 1883, was 113,439,331 pounds of water raised one foot high with a hundred pounds of coal, counting all coal used with no deduction for ash or cinders.

It has been a most gratifying success, both in economy, durability, lack of repair bills; and the diagrams show if not the highest, certainly a very high, economy considered from any point, taking advantage of no technicalities, allowances or possibilities. These diagrams may be studied critically, in comparison with those in some of the preceding lessons, where compound engines of foreign builders are compared, and with favor to Mr. Corliss, upon grounds of absolute fact, with no assumed allowances of any kind.

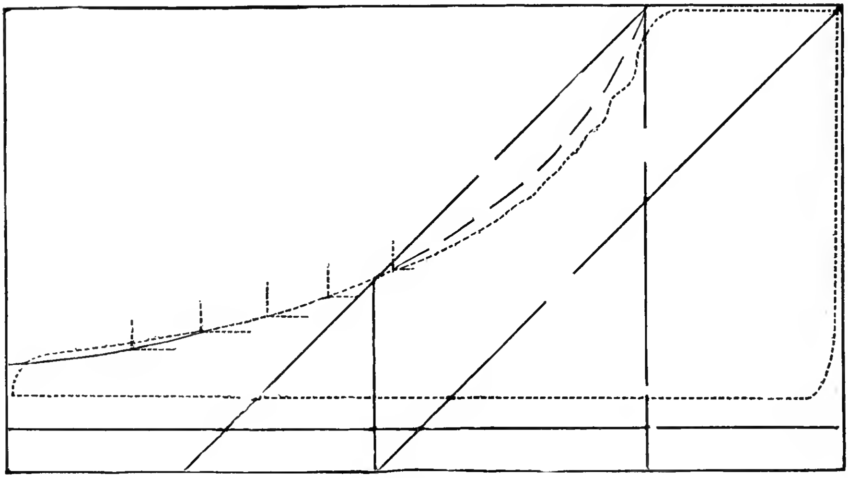


Fig. 114.

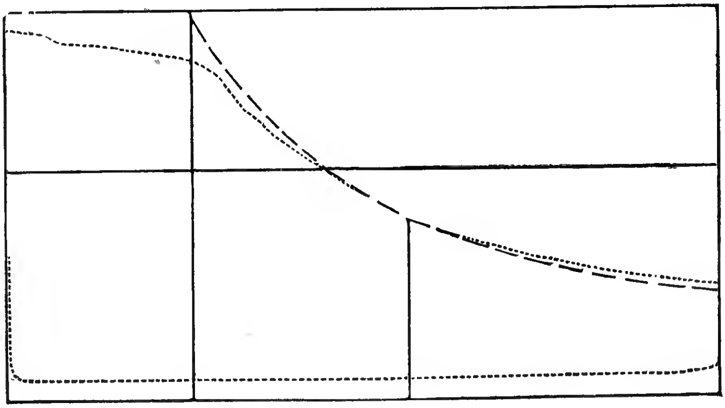


Fig. 115.

LESSON LVI.

SHORT CONNECTIONS TO THE ENGINE, WITH NO CHANGE OF POSITION FROM THE THREE-WAY COCK ATTACHMENT IN FIG. 117.

Diagram Fig. 116 is one which is somewhat peculiar in respect to an excessive cushion. It is taken from one of the new Buckeye engines, running 222 revolutions per minute, with a steam pressure at the moment of 92 pounds, scale 50, Thompson improved indicator.

In justice to the engine we will say, the party in charge was partial to the three-way cock for indicating, and Fig. 116 was taken from the same engine, with not the least change of valves from Fig. 117. Let the reader compare the two outlines.

In this case, A equals the vacuum line, B the atmospheric line, C boiler pressure at the moment of taking, D highest pressure by compression, E point at which the exhaust valve closed on the return stroke. In this case, the exhaust valve closed at about 3½ inches before the end of the travel, and although the engine was exhausting very freely, in fact, without any perceptible back pressure on the indicator, it will be seen that at the point F, a little more than a quarter inch from the end of the stroke, the compression amounted to 113 pounds. From F, the rest of the stroke, there appears to have been a slight leak, a portion of which was undoubtedly in the indicator, and some of it may have been in the piston or valves of the engine, so that from the point F the pressure falls away to the angle indicated by the dotted

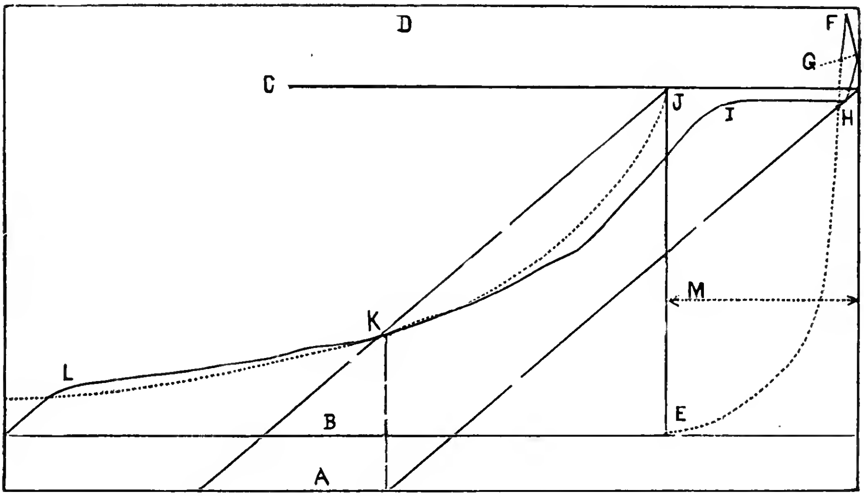


FIG. 116.

line G. From this angle it will be noticed that the pressure continues to fall, while the engine had passed the center and the indicator had commenced to move again in the direction of the outward stroke; G indicates the point at which the crank passed the exact center of the return stroke, and commenced its outward stroke; meanwhile the steam pressure slightly drops until H is reached, which give us between 87 and 88 pounds initial; from H to I the steam is carried, and at I the steam valve commences to close.

The peculiar angle formed by the line dropping from its highest point, F, is caused by a fall of pressure while the engine completes the last portion of the stroke, the angle in the line F, H, shows the precise point where the motion of the engine changes, and after the motion has changed the pressure still continues to fall, showing that the valves of the engine were in a splendid condition and were tight. At H we have the first real evidence of the steam valves opening, and the steam line crosses the compression line, making the steam line H I. Here we have another most interesting example of the efficiency of the indicator when correctly applied, and its lines correctly read from the diagram. In many cases such a compression line would be at once called an early admission line or "taking steam too quick"—but such is not the case.

Now, to analyze the diagram for efficiency, we will commence our demonstrations by the line K, the actual pressure at K gives us an absolute cutting off of the pressure of steam realized at C, J, so that while the valve commences to close at I, apparently it becomes closed at J, or very nearly so; from J to K the theoretical curve runs slightly above or outside of the actual curve of the instrument; from K to L, the point of commencement of release, the theoretical line runs slightly under the actual line of the instrument. The release is most excellent, and it commenced under about twelve pounds pressure, making a very clear exhaust and commencing to compress or cushion too early and making the loop. The particular feature of this loop is a very considerable shock to the engine; in fact, there is quite too much compression, and if the engineer will reduce this compression by one-half, his engine will sail over the center much easier, and without so much wear and tear on the connections, brasses, etc, The boiler pressure in this case is very handsomely realized, showing that the makers of the engine have made considerable improvement in proportion and motion of their valves.

Taken all in all, the admission and expansion, release and exhaust lines of the diagram are excellent, the compression is no fault of the design or mechanical part of the engine, if the compression is reduced to less than one-half the amount shown here. The engine will do more work with the same steam, and will regulate better without any doubt. It is not policy to compress twenty pounds above the initial pressure you are working with; it does not make the valves last any longer, or work any easier; it causes entirely too much strain on the brasses and connections, and is bad policy every way. The dotted line M, from the line J to the vertical line at the end of the diagram, gives the volume of the cylinder filled with steam, simply for the purpose of computation.

This lesson is a most complete demonstration of the lack of reliability of the three-way cock attachment, when used to *adjust* the valves. Fig. 116 was taken, close connection, on each end of the cylinder, only one end shown.

LESSON LVII.

THREE-WAY CONNECTIONS FROM SAME ENGINE AS LESSON LVI.

The old way of side pipe and three-way cock still exists. It is entirely useless for adjustment of valves or for any other than approximation to power, position of valves, or realized pressure.

The reader will find food for thought in carefully comparing diagrams, Figs. 116 and 117, with each other—both were taken from the same engine, with no sort of change except the side pipe and three-way cock were used in Fig. 117 and taken off in 116, the spring of indicator being changed to suit the increased boiler pressure in 116.

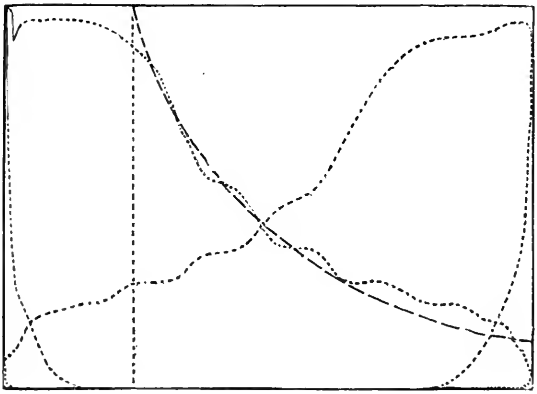


Fig. 117.

Figure 117 was taken from a Buckeye engine, made by the Buckeye Engine Company of Salem, Ohio, nine inches diameter of cylinder, fourteen inches stroke, 225 revolutions by the counter, eighty-five pounds of steam in the boiler, throttle valve wide open, scale of spring, forty, Thompson improved indicator. This engine was on exhibition at the American Institute Fair, New York, and is one of the Buckeye Improved. The makers have for the past year been making changes, with a view of improving the economy, the regulation and the action of their engine.

The engine was running electric lights, and this will plainly tell of any trouble in regulation. The diagram 117 was taken upon one of our own indicators, but it has just this defect, it was taken by a three-way cock in the center of the cylinder, a thing which we disapprove of, from the fact that it introduces inaccuracies. The steam had entirely too much water in it, but that should not be taken into account against the engine.

The application of the theoretical curve to the diagram shows a very good action indeed of the valve, and we have taken the highest pressure realized at the moment of impact, and it will be noticed that the theoretical curve follows down past the center of the stroke, almost on the actual line of the instrument. Below the center or half-stroke, as the motion is changed from fast to slow, the actual line of the instrument rises somewhat above the theoretical. This may be caused by the change in the pressure and the amount of water present; it probably is not any fault of the valves. The action of the valves on this engine is certainly very good. It is one of the best Buckeye engine diagrams we ever saw, and if the improvements are up to this quality of work, the engine will do better work than ever before, and give the best results.

We have only made the theoretical curve upon one of the cards. There are several points in it to study, particularly the action of the steam valve in taking steam, the difference in compression as between the two ends. This short diagram was made use of because we refused to take a diagram from another instrument of greater length, which does not show the oscillations in the expansion line, and makes quite a difference as between the compression shown by the Thompson. We would call especial attention to the serrations or fluctuations in the expansion line, which show the most delicate action of the indicator—and the variations caused by rapid expansion and changes of temperature, pressure, etc.

These diagrams bear close examination, and are a very close approximation to the theoretical expansion, bearing in mind that the position of the valves and their action as to motion are erroneously shown by that attachment, which should be prohibited everywhere—a three-way cock and long side pipe. [See lesson LVI in connection with LVII.]

LESSON LVIII.

HIGH COST—LOW ECONOMY STEAM YACHT COMPOUNDS.

Fig. 118, H. P., 119, L. P., are a pair of diagrams from one of the rich men's fancy yachts, more expensive than fast. 118 is the high-pressure diagram which came to us without any atmospheric line; 119 is the low-pressure diagram; the scale of the high-pressure being fifty to the inch. We have assumed the dotted line as atmospheric line in Fig. 118, at slightly an excess of the realized pressure on the low-pressure diagram, which is sixteen per inch. We have

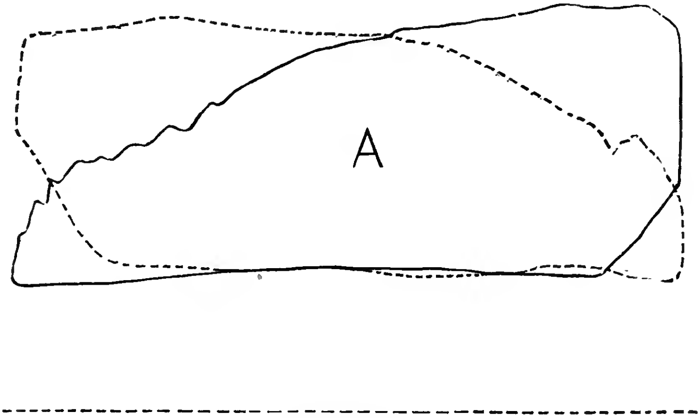


FIG. 118.

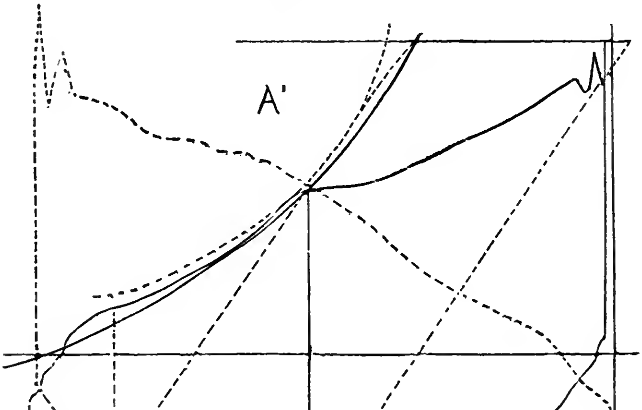


FIG. 119.

twenty-six pounds realized pressure on the low-pressure cylinders; on the high-pressure cylinders we have made no demonstration, from the very fact that we are not certain of our data, and at the best they are as wretched diagrams as were ever taken from anything in the shape of a steam engine. Those who are interested will understand that a link motion is used, but it must be a sorry link which makes such a use of steam as is shown in the steam line of the solid-drawn diagram. In Fig. 118 the admission line commenced very well, but when the steam line begins it is a curious line; really there is no cut-off to it, the expansion line is a fearful one, and not economical or correct, and is convex instead of concave, and when it comes down toward the release, the line instead of being an expansion is turned into saw-teeth. Like most compound engines, the exhaust line is considerably higher in the center than at the commencement. This is all natural enough, but when we turn to the dotted line on Fig. 118, we have, if anything, a worse line than the solid line in the diagram; a peculiar jump about the commencement of release we are unable to account for satisfactorily to ourselves, but which is probably caused by low-pressure cylinder valves.

If the party who took the diagrams had been careful to draw in his atmospheric line, we should have been pleased to make a demonstration. We have drawn in the atmospheric line at about what we supposed it should be drawn, and this gives us full initial pressure 105 pounds, as the throttle valve is wide open, and the link full, scale fifty. On the low-pressure card we have something more to work by, for in this case the atmospheric line is properly drawn in by the instrument, scale sixteen, link up full, speed in both cases 126, wide open. Here we have an impact initial pressure of twenty-six pounds, a vacuum of about nine pounds. The cut-off is very well defined in the solid line and less so in the dotted. We have made two demonstrations here, one with the dotted line and the other with the solid line. The dotted line is to ascertain whether the steam expands under the generally conceded theoretical law after expansion apparently commences. The solid line shows what ought to have been done at the actual pressure at the point of cut-off which is visible. We start with a pressure of twenty-three pounds; at a little past half stroke it runs down to $13\frac{1}{2}$, and the diagram line of the indicator shows that the valve closes. The dotted line shows that the valves were practically tight, for the pressure falls away triflingly, if we take the commencement of release, or just prior to that point, as the basis of that computation. But if we take the actual pressure before the valve becomes positively closed on the line, we find that the general ratio of expansion is closely on the theoretical, understanding always that there will be more variation in the link motion than in the positive eccentric and lever or rock or wiper motion. Now, if we use our sixteen scale as a rule, we find the solid line from which our demonstration is made to be twenty-five inches (call it) from the commencement of the stroke. At this point $13\frac{1}{2}$ pounds of steam were cut off, having been reduced in pressure from twenty-three, and carried, we will say, twenty-five inches. Now if the pressure had been realized it would have required only eighteen inches, cut off at twenty-three pounds, or, in other words, it would have required

18-25, or two-thirds, practically, the amount of steam it did require. The high-pressure diagram is abominable, and the use of steam is without any sort of economy, the pressure drops rapidly both on high and low-pressure cylinders after the valve gets open. In the low-pressure cylinder there may be some excuse from lack of volume, or pressure varying in receiver, but in the high-pressure cylinder it is choked or wiredrawn by insufficient ports or pipes.

These engines were built in 1883. It is, perhaps, needless to say that this is not the fastest yacht in the world by any means, and whoever the builder may be, he need not consider himself particularly flattered with this kind of result, if economy is to be considered at all.

LESSON LIX.

ANOTHER OCEAN S. S. COMPOUND ENGINE.

We hear so much of the economy of some of the new ocean steamships that it will do us much good, perhaps, to examine some of the results of the work of the engines, and for that reason diagrams, Figs. 120 and 121, from the high and low-pressure cylinders of a compound engine are introduced; the high-pressure cylinders of which are seventy-two inches diameter, sixty-six inches stroke, fifty-four revolutions, seventy pounds boiler pressure, scale thirty-two. The same letters apply to the same lines on each for comparison. On the high-pressure diagram steam is cut off at about 18-49 of the stroke. Starting with a boiler pressure of seventy pounds, E, and do not get within seven pounds of it on the piston. There is very little approach to an expansion line, and no one can tell where the valve closes from the appearance of the line. In fact, there is no marked feature of it to show where any expansion takes place.

The steamer in question has been built several years, and is not by any means the fastest or the most economical now afloat; she was built to accomplish a certain purpose and has done it, but she has never been economical with fuel to the extent that some of the more modern compound engines have been except by remote approach.

Making *a* the base of our computation, give us B, E, point of cut-off and volume, reference letters the same in both diagrams. From B, the pressure given at *a*, the line F shows us what power should have been exerted and where the steam should, under ordinary conditions, have been cut off and expanded to. It will be seen that the boiler pressure is not realized, cut-off is entirely lacking in definiteness, and the end of the expansion is considerably above that point which the actual pressure at *a* gives from the cut-off B, E, showing clearly that there is either a very radical error in the indicator motion, which is hardly probable, or if we look at the low-pressure cylinder, or that the valve is slow in closing, or that the valve leaks, which is the most probable reason of all, for we are certain that the valve closes slowly—from the course of the line. The high-pressure cylinder exhausts under a pressure of about eleven pounds to start, at the center it is fifteen, and at the commencement of compression it is almost fourteen. The admission line is a little late in the opening of the valve, and the rounding over at the corner is not of necessity due to the link motion which was used, but rather to some little give or play, or what is usually termed lost motion. We cannot consider this as a very economical diagram, there is too much loss in realizing the boiler pressure, and a wire-drawing of the steam, (if tight valves) and the exhaust of high-pressure cylinder into receiver is fully as high as it should be, and much higher than the low-pressure utilizes. The expansion line is not nearly as good on the high as the low-pressure cylinder.

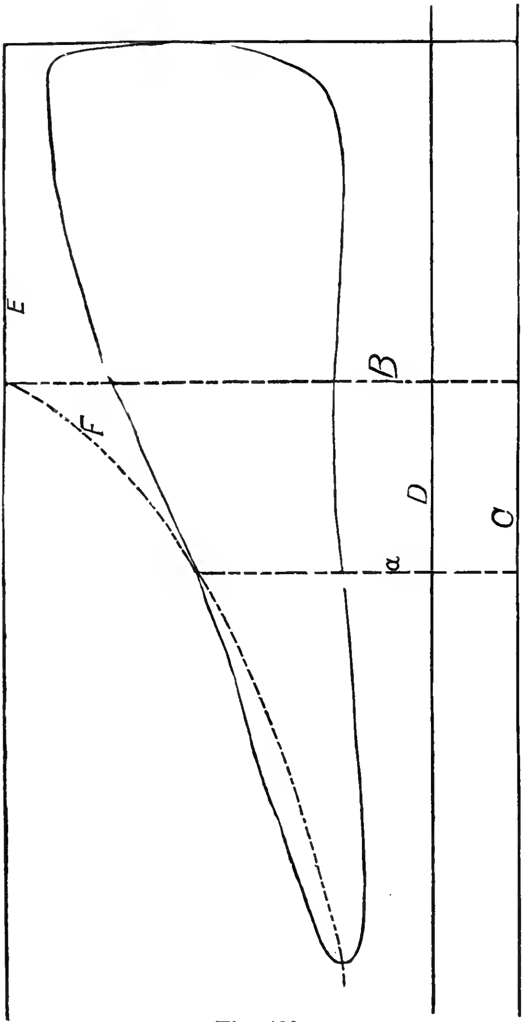


Fig. 120.

Taking the low-pressure card made at the same time, E representing the initial pressure from the high-pressure cylinder or receiver, *a* the base line, gives us B as the volume of cylinder at which the valve should have closed to have made the pressure at *a*, and in this case we have a tighter valve and a very much better condition of circumstances, showing but exceedingly trifling variation as between the theoretical and actual, taking the pressure at *a* from which to make our demonstration. In this case the pressure is a variable quantity, changing from one to the other cylinder in exhausting and the acceleration of speed of the piston, as well as in condensation, which may take place in the passage or in the receiver, so that we lose somewhat in the low-pressure cylinder from what should be the initial pressure if we had received the whole eleven pounds from the exhaust of the high-pressure cylinder, passing through the ports and into the low-pressure cylinder. We, therefore, get only nine pounds realized, and lose again before cutting off about four pounds more, expanding below the atmospheric line; in this case we have ten pounds vacuum in the condenser to start with, and this is held very well until more than two-thirds of the stroke has been made.

Here is an answer to those people "who do not believe any cushion can be obtained in the low-pressure cylinder;" if not, then what makes the compression in this diagram? It commences to compress at about 7–45 of the stroke, say one-sixth. The admission line is very square, and the admission and carrying of steam in the lower-pressure cylinder is better than it is into the high-pressure. The expansion line and the theoretical line very nearly coincide through the major part of the distance from pressure at base line *a*, showing conclusively that the valves in this case do not leak and that the difference in the high-pressure diagram (probably taken by the same motion) cannot be in the motion but is in the valve. A decided falling off from pressure that under the circumstances should hardly be allowable, and about two-thirds the vacuum that should be realized is obtained.

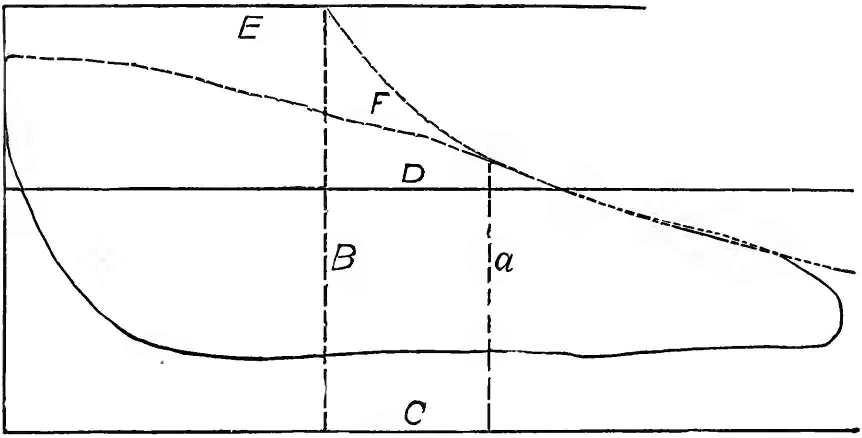


FIG. 121.

We do not know the precise percentage of coal this steamer is now burning, but it was very largely in excess of some of the later steamers at the last time we knew of it. The lower-pressure cylinder is 120 inches in diameter, sixty-six inches stroke, fifty-four revolutions per minute, scale twelve, pressure variable. It may interest some of our readers to figure the power in these diagrams from the data given. The low-pressure cylinder cuts off at about 17–45 of the stroke, starting with an initial pressure of nine pounds, cutting off at a pressure of a trifle over 4½ pounds; the commencement of release is four pounds under the atmospheric line, which shows a very good grade of expansion. But we must not expect perfection in these large engines, although we might probably attain higher results of duty than these particular diagrams show. The principles of adoption are the same—economy, speed, etc.,—as with the stationary engines. There is plenty of data here to figure from, and it would be interesting, for those who care to take the trouble, to solve the points of ratio of expansion, the amount of water, power, etc.

LESSON LX.

AN EXPERIMENT BY AN ENGINE BUILDER.

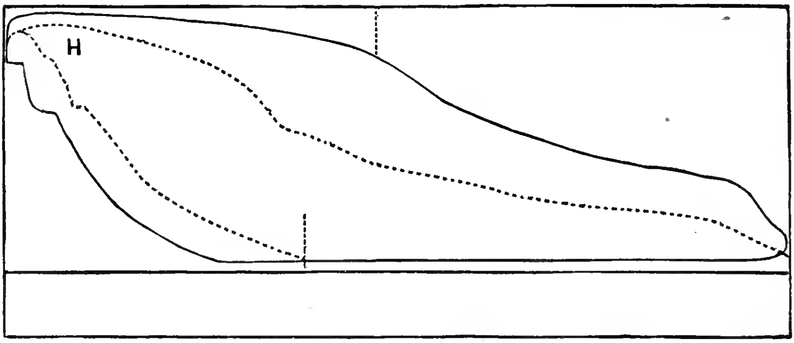


Fig. 122.

Fig. 122 is from the first engine of a new builder for the especial purpose of electric lighting. The data is: Boiler pressure 70, spring 40, diameter 10⅝, stroke 12 inches, revolutions 115.

To attempt to demonstrate all the faults in this engine would be to do work which should have been done by its designer and builder; for this we have neither the space nor the disposition. This is evidently a very bad imitation of a well-known engine. Taking initial pressure, seventy pounds boiler pressure; to economize room we have traced the dotted line card, showing the same engine under a little different load. We have fifty-six pounds initial pressure out of seventy. This in itself will condemn the engine, providing the connections are free. The engine starts off with a round instead of a square corner between the admission line and the steam line. With an initial pressure of fifty-one pounds, gradually rising to almost fifty-five, and at about the point where the cut-off appears to take place, we find between forty-five and forty-six pounds of pressure, having fallen off ten pounds in carrying steam four-tenths of the stroke. The engine commences to release with a pressure of seventeen pounds on the piston, releases very well, but does not get down in the exhaust to the atmospheric line; compression starts at rather more than half the distance that the steam is carried. The compression line here may have been shaken up by a poor foundation, but more probably by a constant changing of pressure in the compression in the solid line card, but in the dotted line the compression line is a very queer one, and the little hook at the extreme end, with the peculiar formation of the steam line, in starting on to take steam for the stroke, shows that the valve does not open as wide with a light load as with a heavy one. Notice that the steam is cut off at a very much lower pressure in the light load, proportionately, than the full load, on the larger diagram of the two. Whatever makes the funny jog in the dotted line on the expansion line after cut-off, or whether the steam is carried to that point of the indentation and then the cut-off actually takes place, we are a little at a loss to tell from the appearance, and the card has no value in an economical way.

The diagram is very uneven, and contains so many faults that we have not cared to give the time to a demonstration on the expansion curve. This engine would be most decidedly lacking in economy; whatever its regulation may be we do not know, but it was evidently built by some man who has not progressed into the new style of valve motion, for the valves do not travel correctly nor far enough. Whatever their proportions of ports may be we do not know; one thing is sure, it is too small, either by insufficient opening of the valve by the action of the regulator, or by insufficient ports and passages. Such a diagram may do fairly at 115 revolutions per minute; what would it do at 250 or 275, the usual speed of the engine of which this motion is evidently a copy?

LESSON LXI.

EFFECT OF SPEED ON REALIZED PRESSURE IN THE CYLINDER—A LESSON ON FEED PIPES.

In Figs. 123, 124, we have valuable information in reference to one of the most important, least-attended to details of steam engineering. Both these diagrams are taken from the same engine, under the same conditions, except with reference to speed. Fig. 123 is from the engine in its regular work. Cylinder diameter 34 inches, stroke 60 inches, revolutions 50 per minute, boiler pressure 69, scale 40, condensing. We find 62 pounds of initial pressure realized. By the demonstration, with A as the base line, we find the cut-off at D, C. The theoretical curve, it will be seen, follows the expansion line exactly, covering it from a short distance beyond the line D, which is quite sufficient for the purpose of demonstration, showing that the 62 pounds steam pressure cut-off at D, would make precisely the expansion line, making a most effective working of the steam; and for determination of the one point of particular interest in this lesson, viz., that the feed pipe in this case was amply sufficient to supply that engine at that speed, doing that amount of work. In our own practice we would prefer to have had the exhaust valve open sooner, as at F, in order to allow the condenser to sooner realize the vacuum. In this case, on the opening of the valve, about four pounds is realized, while, were the valve opened slightly earlier, ten pounds ought to have been. If the exhaust valve opened sooner, it would necessarily close sooner, and we should have an approximation of the compression line to that of G.

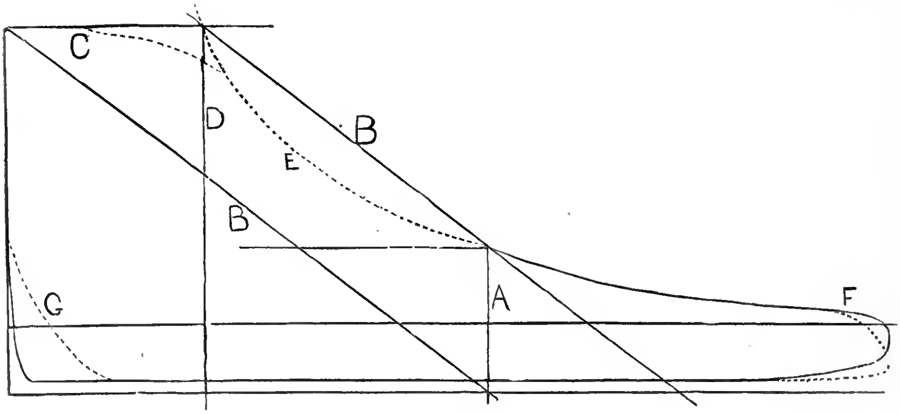


Fig. 123.

In Fig. 124 we have the same engine running 68 revolutions per minute for some especial work required; at the time of taking the diagram, we have 73 pounds of boiler pressure. In this diagram, 124, it will be noticed that the admission line is a trifle late, the initial pressure realized is 72 on the very commencement of the stroke, or before the piston gets into motion; directly the motion of the piston commences to increase, the pressure falls away very rapidly, so that at the point of cut-off we have only 58 pounds. The demonstration in this case shows that the pressure falls very rapidly indeed, from the commencement of the movement of the piston until at the point where the theoretical curve and the actual line of the indicator touch, just above the letter D; there was 20 pounds less realized pressure than at the commencement of the stroke, leaving 52 pounds effective pressure on the piston only.

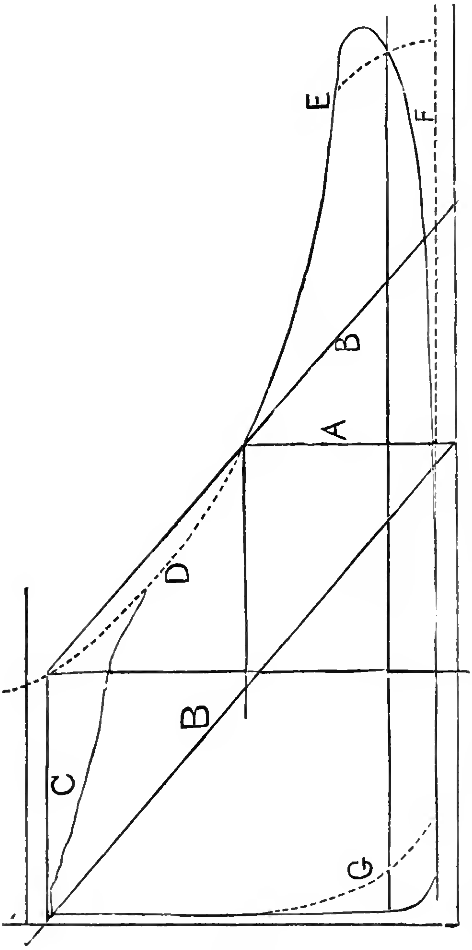


FIG. 124.

The demonstration in this case, made from the point A, gives the cut-off on the line C, from which the theoretical curve is dropped, exactly following the line of expansion from the intersection of the two lines to the point which is the base of the demonstration. Upon continuing this line, the terminal pressure will be found slightly above, showing that a volume of steam, equivalent to the full pressure, on the line C up to the line between B, D, was used to effect this. In the case of this movement, we find that the supply pipe for this engine, which was sufficient for 50 revolutions, is entirely insufficient for 68 revolutions; and we also find another feature at the terminal of the expansion line, viz., that a very much less vacuum is obtained, and none at all until after the piston has returned several inches on its stroke. The maximum vacuum is ten pounds; the first quarter of the stroke eight pounds only is realized; the second quarter nine, the third quarter ten, and the cushion commences on ten pounds. Had the exhaust valve been timed earlier, as recommended for 123, we should have obtained the dotted line E or some approximation to it, and the dotted line F, as a realized vacuum, which would have added materially to the power of the engine and also in the saving of steam. Allowing the alteration to have been made in the time of the exhaust valve, we should also have obtained the compression line G and have compressed to 35 pounds, saving exactly this amount of live steam in opening our steam valve upon 35 pounds instead of nothing. This shows the necessity of a proper supply, and that the supply pipe must be proportioned to the speed at which the engine will travel, and that unless this is done some such change in matters will occur as that shown. Should 123 call for a much larger load, the supply pipe in that case would be insufficient, for it must be understood that after the piston goes a proportion of the stroke in its travel, it calls for steam very much faster than when it first starts. In this case, 123, the pressure is somewhat reduced, and if the engine were required to carry three or four inches further we should probably find, in a less degree, the same features attending the steam line as in 124.

LESSON LXII.

ANOTHER LESSON ON SUPPLY PIPES.

Changing the circumstances as much as possible to make the application more forcible, we have taken Fig. 125 of the high-speed class of engines and running under fully as much load as the builders recommend. This is taken from an Armington & Sims, 14½ inches diameter of cylinder, 13 inches stroke, running 245 revolutions per minute, boiler pressure 92 pounds, scale 60, indicating about 125 horse-power, fed with a six-inch steam pipe. The realized pressure is 83 pounds, the steam is carried 150 feet from the boilers through several elbows.

The demonstration in this case by the line A, parallels B B, gives the point of cut-off at B C (for clearness the ordinate is not drawn), C represents the steam line, its cut-off is very sharp. The oscillations in this diagram are referred to in previous lessons, and the point of cut-off and the following of the theoretical curve is through the intersecting points of the lines *d d* which are drawn at six different places in the expansion line. It will be seen in this case, that the variations in the line of expansion of the instrument vary but very slightly from the actual passage of the theoretical line, and this approximation is so close that the drawing of the theoretical curve would simply confuse. The commencement of release at the point E compares well with the compression F, but if anything the compression is slightly larger in proportion to the stroke than the release, and in a high speed engine this is somewhat a necessity. The exhaust line varies only in the least possible degree from the atmospheric line of the instrument until the exhaust valve closes at F. The compression line has the same wavy appearance that the expansion line has, but exactly reversed in effect. We have a compression here amounting to 60 pounds when the steam valve opens and the admission line is formed.

The amount of power yielded by this engine is large, when we take the volume of the cylinder into consideration, but is not its maximum power when we take its speed into consideration. The admission and steam lines are very square; the cut-off is very clearly marked and all the lines of the diagram give a high efficiency, which has since been proved by trial of the engine, and in comparison with Figs. 123 and 124, it will be seen that a very large pipe for the volume of the cylinder is required as the speed is increased. The efficiency of Fig. 125 is above 90 per cent. and shows good sense in connections, as the outline, in itself, shows very satisfactory work with the steam so far as valves and engine are concerned. It is probably in three cases out of five that we find too small feed pipe, and in entirely too many cases too small exhaust pipes as well. Both of these points work against the efficiency of the engine and whenever efficiency is involved then economy is certainly less than it should be. The comparison between the three diagrams 123, 124, 125 will be interesting on this point of feed pipes, realized or lack of realized pressure.

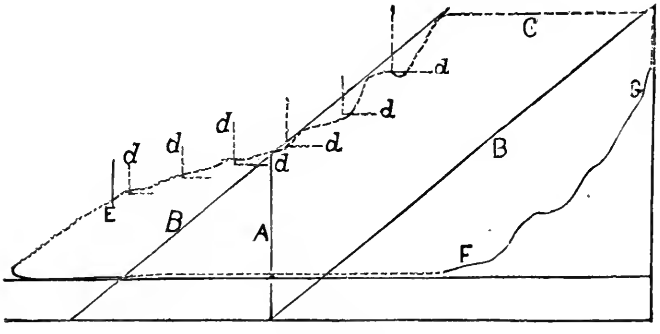


Fig. 125.

LESSON LXIII.

LARGE CYLINDER, LOW-PRESSURE ENGINE ON A SOUND STEAMER.

Fig. 126 was taken from the steamer Providence, one of the Old Colony Steamboat Company's Sound steamers, running between New York, Newport and Fall River. The cylinder is 110 inches in diameter, 12 feet stroke, and, when running full, makes 17 revolutions per minute, scale 16, steam at the moment of taking, 23 pounds.

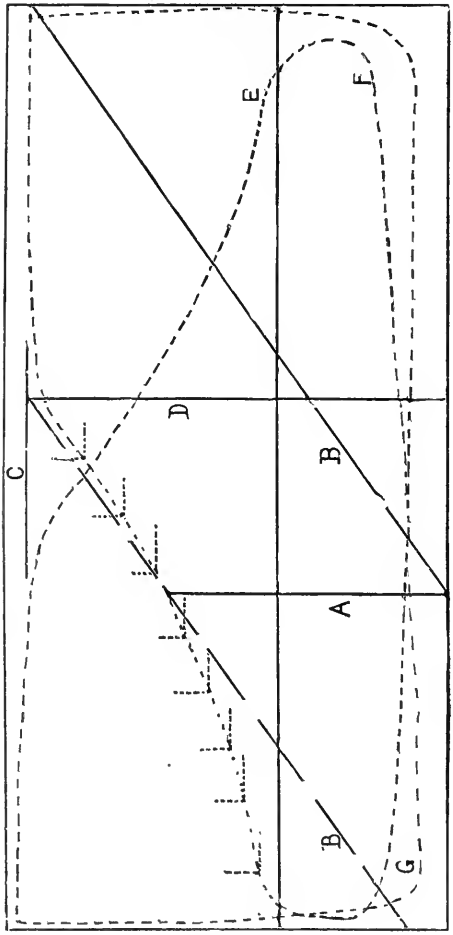


Fig. 126.

The demonstration has been made only upon one diagram. The admission line is a little late upon the right hand, the steam line is perfectly satisfactory, carrying 21 pounds almost to the point of cut-off, and cutting off at barely 20 pounds pressure. In this case the demonstration has been made inside the center of expansion for the purpose of putting the engine to a disadvantage, if it was not handling steam correctly. The valve closes at D, on C; the line C has been broken to prevent a confusion with the steam line of the diagram. A few inches to the right of D the valve commences to close. From the time the valve commences to close until it does close, the piston only travels 5¾ inches. The expansion line is very nearly a perfect one; the difference is so exceedingly small that there is nothing in practice to find fault with. The release might be improved by opening a trifle earlier. The condenser takes hold with seven pounds and runs down to eleven before reaching half-stroke and to almost twelve on the last part of the stroke. If the engine released a trifle earlier, a little more compression would be the result, and if the compression were increased slightly we believe it would make the engine run steadier, but this matter of release, vacuum and compression, is so entirely a part of the engineer's fancy, that so long as the engine runs quiet, they do not mind it, and so few of them are furnished with indicators that they really have to run the engine by their eye and ear, which is not exactly to the credit of the owners, nor in all cases to the owner's profit. For some unexplained reason there is a difference between the right and left-hand diagrams. It may have been caused by a little variation in the steam pressure between the times of taking from the different end of the cylinder, or what is much more likely to be the case, the bottom or left-hand very likely opens the valve wider, and it certainly opens it a trifle sooner than the top end or right-hand diagram. The upper line represents boiler pressure; the approximation is very close indeed on the bottom, and the amount of pressure realized on the top end is maintained very nicely, and for that reason we suppose it must be that the valve opens a trifle late and does not open fully. Practically the diagrams are very fine.

Few people have any real idea of the amount of power involved in such diagrams. Every pound of mean pressure on this engine at the speed it was running at the time these diagrams were taken, gives 117½ horse-power, the piston traveling 408 feet per minute; figuring these diagrams, we find the top end yields 2771.143 horse-power, while the bottom end gives 2747.209 horse-power; a little difference in the ends makes a very large difference in horse-power, and also makes a very considerable difference in the economy of the run. We have no data to give us the exact coal consumption of this ship. The release on the bottom at E is hardly as good as upon the other end of the cylinder, the realized vacuum at F being eight pounds only. The engines of the Providence are fitted with the Sickles cut-off, and show a very decided contrast in closing with those using the rounded wiper cam, and decidedly to the advantage of the engine.

LESSON LXIV.

LARGE LOW-PRESSURE ENGINE. ANOTHER SOUND STEAMER.

Fig. 127 was taken from the new steamer Pilgrim of the Old Colony Steamboat Company's New York and Fall River Line, after she had been running a few months. The dimensions of her engine are, cylinder 110 inches in diameter, length of stroke 14 feet, speed at regular duty 17 revolutions per minute, or 476 feet of piston travel per minute; the area of the piston is

9503.34 inches, giving as a result 137.078 horse-power for each pound of mean pressure. The diagram is taken with a 24 spring.

The line C represents boiler pressure at the moment of taking, which is 43 pounds. The demonstration in this case is made on the bottom end, from the base line A, using the parallels B B, showing the point of cut-off on C, at the intersection of C D. The expansion line, it will be noticed, runs down very closely to the actual line of the instrument after the valve gets entirely closed. That there may be no misunderstanding with reference to the line D, it may be explained that the intersection of D with C shows where the realized pressure should have been cut off to produce the amount of power from the pressure at the point A. As a matter of fact the steam valve did not close at the line D, for the pressure, it will be seen, drops away six pounds between the line C which is realized pressure, and the dotted line of the indicator, showing the difference between the indicated pressure and the boiler pressure at that point of six pounds. After the piston passes this point, the diagram plainly shows that more steam entered the cylinder, so that the volume which entered was sufficient, had the pressure been realized, to have equaled the effect of the full pressure of 43 pounds, cut off at the intersection of C D.

We think the valves of this engine might be improved with profit to its owners. To get an idea of the distances represented by these indicator lines, the release opens on the bottom end, expansion line, eight inches before the piston gets to the end of the stroke, and if it opened still sooner it would be better, for after the piston passes the center, we only realize about four pounds of vacuum, and this is increased until ten pounds is realized. When a pound of mean pressure means almost 150 horse-power, every pound of the vacuum has a value in dollars and cents worth looking after. If the release of this engine could be made slightly quicker, say ten or twelve inches, so as to be wide open by the time the cylinder reaches the center or extreme limit of the stroke, then the condenser would sooner get hold, and gave a greater effect for vacuum. The exhaust valve commences to close so that compression begins 25 inches before the piston reaches the bottom of the cylinder. In taking steam, notice the rounded corner where the admission runs into the steam line; but this very slight difference on this engine means 3$\frac{3}{8}$ inches that the piston moves before the steam reaches the highest point in the cylinder. We have now 42 pounds of initial realized, while at the point of cut-off from the demonstration we have only 36, terminal pressure at the commencement of release is ten pounds above atmospheric. This valve is slow in its opening and most decidedly too slow in its closing, with regard, at least, for the engine or the economical handling of the steam.

The top diagram we have made no demonstration from, leaving it without any confusion of lines for a close study, and it has some points of superiority over that of the bottom. Its admission and steam lines are decidedly better; the release is not quite as quick, and the compression is not quite as much. Excepting the steam valve on the top end, all the valves of this engine could be quickened with benefit to it and its work. To get a proper idea of the advantage of handling these valves correctly, we have only to refer to the amount of power shown by the diagram in Fig. 127. The bottom end shows 4935.679 indicated horse-power, while the top end taken with an intermission of one minute or two, shows 4443.479 horse-power. When we come to handle 5,000 horse-power of steam in a single cylinder and with a single steam and exhaust valve, it becomes very necessary to be careful in the adjustment, not only for the economy of steam, but as well for the wear and tear of the engine. Compare Fig. 127 with Fig. 126; the steamer Providence makes the best use of steam, being fitted with the Sickles cut-off and the Pilgrim with the Stevens. These cylinders are very large and the more perfect the adjustment of the valves, the finer work and consequently higher grade of economy will be produced. All these engines are fitted with the old-fashioned side-pipe, indicator cock in the middle, and we hope some day steam engineers will progress out of this absurd, incorrect and misleading notion. The day has gone by, when the width of a man's thumb will do in adjusting steam machinery, and the interval of time on an engine making only 17 revolutions per minute, or 476 feet of piston speed in that minute, which is required for the steam to pass through into the indicator, is quite misleading as to the actual position of the valves. Compare Figs. 116 and 117, on a small, quick-running engine, notice the difference in position between the three-way cock and the direct attachment, and multiply that difference by the difference between the 14-inch cylinder and the 14-feet cylinder, running 17 revolutions instead of about 225. In all these steamship diagrams, it has been absolutely impossible to get a short connection with the end of the cylinder, so as to show the actual position of the valves.

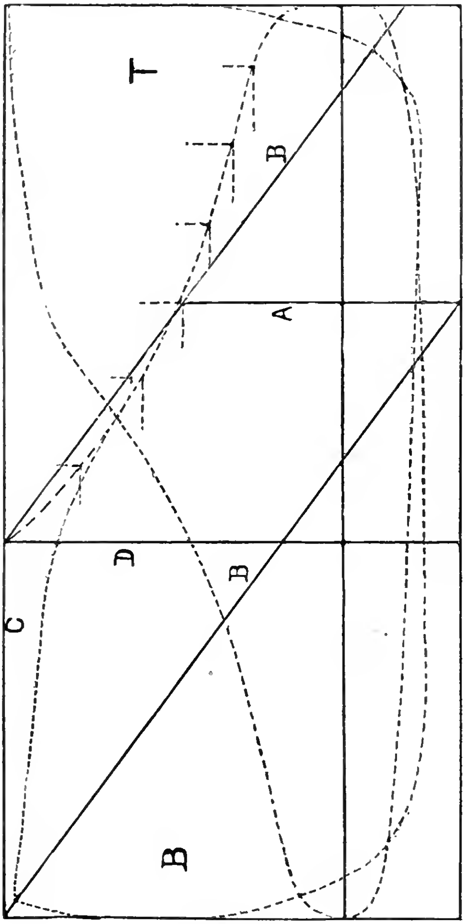


Fig. 127.

LESSON LXV.

AN OVERLOADED ENGINE.

Fig. 128 was taken from a Buckeye engine in the wire mills of a large steel works. Diameter of cylinder is 16 inches, stroke 32 inches, 95 revolutions per minute, 100 pounds boiler pressure, scale 60, indicating 240+ horse-power.

There are only two objects to be attained by showing such a diagram as Fig. 128; the first is to show the excellent handling of the steam by the valves on an engine indicating 90 per cent. more than it was ever intended by the builders, taking the rating of the engine at 125 horse-power and adding 90 per cent. to it; the other reason is to show how extremely inconsistent the owners of steam engines are in asking a load equivalent to almost double its rated power. Out of a hundred pounds boiler pressure, the engine has an initial realized pressure of 96 pounds, cutting off between 95 and 96 pounds pressure at the actual point of cut-off from the demonstration. The theoretical curve in this case follows the expansion line almost exactly, and it is a wonder how the engine relieves itself in exhausting from a terminal pressure of 46 pounds above the atmosphere, and yet the engine exhausts with a back pressure of about two pounds. The terminal pressure is almost exactly identical on both ends; there is an extremely small variation by the planimeter in the area of the two ends, and taken all in all, it may be considered as a first-class accomplishment in doing such a large amount of power. It is a credit to the builders, but no credit whatever to the owners of the machine who will abuse a good engine like this.

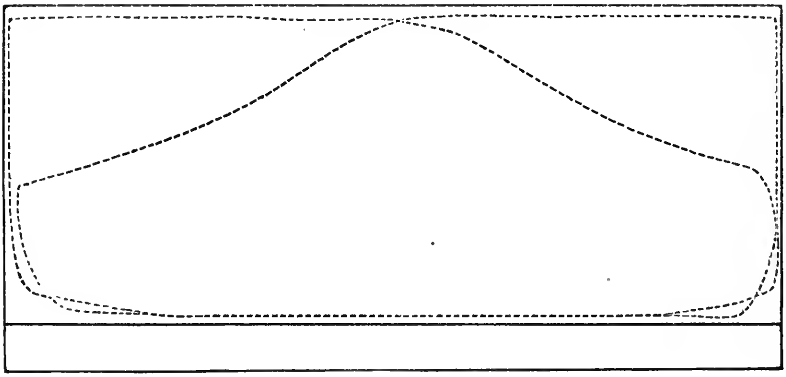


Fig. 128.

The practice of overloading is becoming too common. A number of very bad accidents have occurred within the past few months, and steam engine users may by-and-by become accustomed to the rational use of an engine and the proper care of it as well.

LESSON LXVI.

HARRIS-CORLISS ENGINE, OVERLOADED—FINE CARD.

Fig. 129 is taken from one of a pair of Harris-Corliss engines, running in the Exposition Cotton Mills, in Atlanta, Ga. Some repairs had to be made upon one side, and the other side in producing this diagram, drove the following amount of machinery: 4 pickers, 99 cards, 288 slubber spindles, 1,320 fine speeder spindles, 11,400 spinning frame spindles, 306 looms, six spoolers, four warpers, with brusher, folder and press. The size of the engine is 24×48, speed 77 revolutions per minute, scale 40, boiler pressure 83.

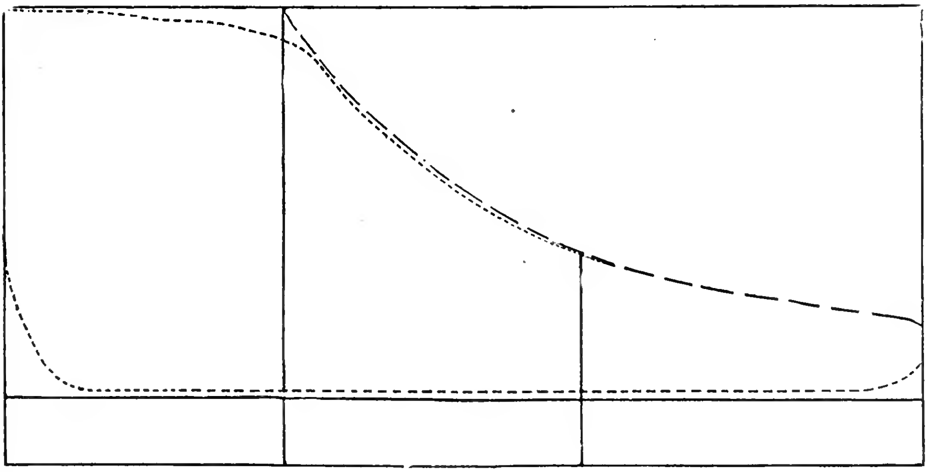


FIG. 129.

The production of this diagram is a credit to the engineer in charge, as well as to its builder. The engines had been in operation for nearly three years at the time this card was taken. It will be seen that the steam pressure realized is fully up to boiler pressure; the credit of this is due to the fact that new steam pipes have been put on by the present agent, and the engines are not at all throttled. The engine in this case is doing about two-thirds of the work of the mill with one side, and is starting with 83 pounds of realized pressure, the cut-off closes on 77 pounds, showing that the extraordinary demand for steam is much better met than in the average supply pipe, or that the capacity of the feed pipe is fully up to a large increase of load over the regular power of the engine, when both sides and its regular load are running. The expansion line by the demonstration shows but an exceedingly trifling variation at that point, and the terminal pressure is almost absolutely correct. A little earlier release would, perhaps, avoid the small amount of back pressure shown. The compression is sufficient to keep the engine working smoothly and the steam line is practically correct.

This is as fine a diagram as we may expect from practice, and in this particular case the engineer of the mills has given a great deal of attention to the adjustment of valves by the indicator, which has been backed up by a good mechanical knowledge and ability, as well as good common sense. The horse-power is 390.2509. This is another case of overloading by reason of necessity, but it is not in excess of the ability of the engine to do it very economically, and correctly as well. The ends of the engine vary less than one horse-power in total amount of load.

LESSON LXVII.

THE LATEST TRIPLE COMPOUND STEAM ENGINE.

The diagrams in this lesson are from one of the latest specimens of marine, triple compound engines, having a high-pressure cylinder in the center with a compound fore and aft. The high-pressure cylinder is 71 inches diameter, six feet stroke, running 70 revolutions per minute, boiler pressure 110, scale 40. Fig. 130 is from the high-pressure cylinder, in which J, I, represent respectively the base line of our demonstration for the top and bottom diagrams respectively. The line C is that of initial or realized pressure, D is the line of boiler pressure, A, B are respectively the points of cut-off, A for the top cylinder, B for the bottom, their intersection with the line C, marking the point at which realized pressure was cut off practically, to occomplish the pressure at J, I, respectively, at that point in the stroke. The top diagram of this engine is somewhat peculiar, and the line A, which is, properly speaking, the volume of steam from H to A, which was used in the bottom of the cylinder, is in this case used to show where the valve was supposed to cut off from the staff of the engine ; it is found by the demonstration to be entirely misleading, as the terminal pressure is 12 pounds below the real theoretical line, or below the actual point of cut-off from the steam consumed. The line A then becomes the volume of the cylinder from H to A, which was actually used at the initial pressure C to accomplish the result which is given by the actual line of the instrument, the steam and expansion lines of which are shown by dotted lines. The motion of the valve is a little late in admission on both ends, the bottom carries steam farthest and accomplishes the most work, the top end cylinder's pressure falls off more than in the case of the bottom, and the actual line of expansion from B, C shows a near approximation to the line of the instrument on its expansion from the time when the two lines run on nearly together ; on the bottom end the line approximates reasonably close. But what shall we say to the loss of pressure, which is 13 pounds between the initial and the boiler pressure, and 10 pounds between initial and the line of the indicator at the point of cut-off, or 23 pounds below the boiler pressure at the point of cut-off on the top ; on the bottom end 30 pounds is lost from boiler pressure and 17 from initial pressure at the point of cut-off. The average pressure in the receiver from the high-pressure cylinder is from 22 to 24 pounds above the atmosphere. The power developed by the bottom is 5449.5 horse-power, by the top 5054.61

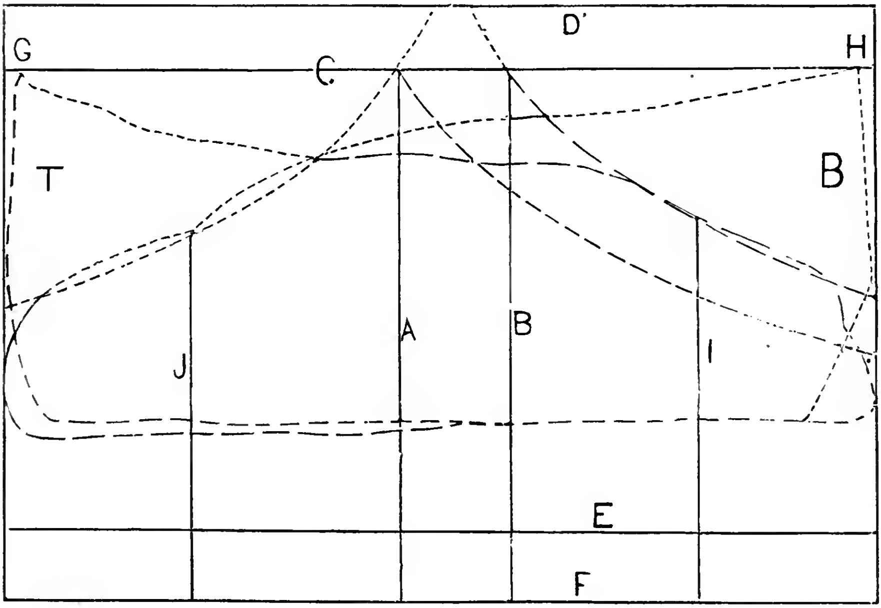


FIG. 130.

horse-power, taking the actual line of the indicator. If this cylinder had cut off boiler pressure at the intersection of the two lines with D, it would have added to the bottom, all other being the same, 1184.675 horse-power, with the same expenditure of steam, and to the top would have added 1693.64 horse-power. This gives then an idea of the efficiency of the engine. The release is excellent, and we have some doubts as to the exact accuracy of these diagrams from several minor points, and we believe the conditions under which the engine is working would be more reliably shown by an improved indicator; these are the same features shown in a previous lesson, where a contrast is shown as between the old-fashioned instrument and the new Thompson.

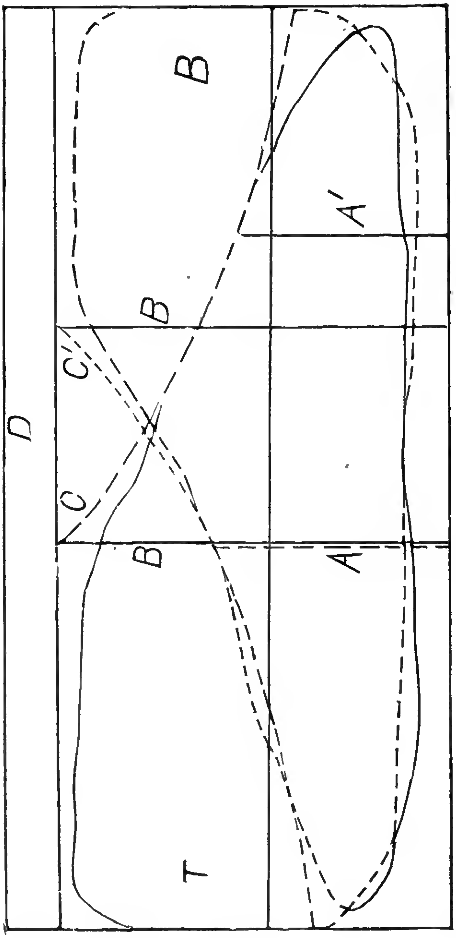


Fig. 131.

Fig. 131 is taken from the forward low-pressure cylinder 105 inches in diameter, six feet stroke, 70 revolutions, spring 16. In this case, D represents the receiver pressure from the atmospheric line 23 pounds; the top end of this cylinder realizes $17\frac{1}{2}$ pounds, which falls off at the point of cut-off to 15, while the bottom end only realizes 16 pounds, falling off at the point of cut-off to 15. Both ends of this cylinder realize much better than the average low-pressure on the compound; owing to this the vacuum falls to ten pounds at one-fifth stroke and to 12 pounds at the end of the stroke, or before the exhaust valve is closed. A, A′ are the base lines. B is the point of cut-off on line of realized pressure for the top, B′ for the bottom end of the cylinder. The bottom end shows 4102.98 horse-power, the top end shows 4401.92 horse-power, with a very considerable loss between the realized pressure and the pressure in the receiver as shown by the high-pressure diagram.

Fig. 132 is from the aft low-pressure of compound, cylinder same size as the forward cylinder, same scale. This cylinder for some reason shows a very considerable increase of power and a much better realization of receiver-pressure on the top end than on the bottom, as the top end, when the valve is fully open, realizes $22\frac{1}{2}$ pounds, the bottom end only $19\frac{1}{2}$. The steam valve for the bottom end of this cylinder is considerably later than the steam valve for the top end. The point at which steam was cut off is a little longer on the bottom than on the top, but the top end of the cylinder makes the best use of the steam. The release in this case is early, so that a good vacuum is obtained at the very commencement of the stroke, which is held all the way through. A very considerable loss is made as between the realized and theoretical from the pressure at A, A′, which would amount to some hundreds of horse-power. The diagram from the top of this cylinder gives 4675.25 horse-power, from the bottom 4528.68.

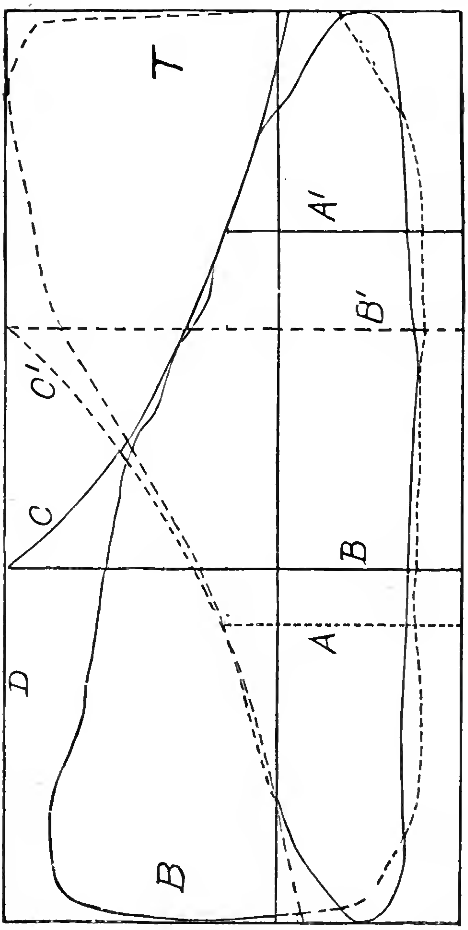


Fig. 132.

There is one point with reference to the compound cylinders that must be noticed: the practice is becoming very common of running the low-pressure with the highest vacuum that can be obtained. In this case the temperature runs from 236° to about 120°, and it is fair to suppose that a certain amount of condensation is effected every time the cylinder is filled with steam after having exhausted through the condenser. There may be serious questions as to the real efficiency of the compound engine carried to an extreme; and undoubtedly there is a serious lack of economy in working steam as these three diagrams show, as compared with the expense of maintenance, and we doubt somewhat whether this style of engine will very long continue. The power given out by the boilers in the high-pressure cylinder, including the loss in handling the steam and the resistance in the receiver, is almost 9,000-horse on each end. That which is used in the compound cylinders makes up a large volume, and the condenser increases the amount realized, but whether this cannot be done by some other combination is a question which we believe engineers shall soon study, and that the key for successfully running a large ship which requires from 12,000 to 14,000 horse-power, as does this one, lies in changing the proportion of the compound engine materially as between the different cylinders, and realizing more heat units with less refrigeration.

There must be a way of using steam much more economically than is shown by these figures, which are from one of the very latest of marine engines that have not yet made their full record for economy or speed, but which have shown a very large power; we have not been able to ascertain the relative efficiency or the actual economy when measured by pounds of coal.

LESSON LXVIII.

GERMAN BUILT CORLISS COMPOUND ENGINE.

Figs. 133 and 134 were taken from a Corliss compound engine built by the Augsburg Engine Company, Augsburg, Germany, at work in a spinning mill in that neighborhood. The information is from a series of experiments made by Prof. Schroter of Munich, but the diagrams which we illustrate we obtained direct from the director of the company which built the engine; no tracings were made use of, but original diagrams. The engine has horizontal cranks at right angles, fitted with a Sulzer valve gear, having a horizontal intermediate receiver placed below the cylinders and at right angles to them. The high-pressure cylinder is jacketed with live steam from the boiler to the admission valves. The low-pressure cylinder jacket is supplied by a branch pipe from the main steam-pipe, the high-pressure cylinder cannot be shut off but the low-pressure can. The expansion in the small or high-pressure cylinder is regulated by the governor, while the point of cut-off in the low-pressure cylinder is adjusted to any varying point by hand. The air-pump is a horizontal, driven by bell-crank below the engine-room floor. The diameter of the small cylinder reduced to inches, is 14.57; large cylinder 24.07; proportion of cylinders 1:2¾; clearance of the high-pressure cylinder 4.3 per cent.; clearance of the low-pressure cylinder 3.1 per cent.; volume of receiver exclusive of clearance 11.548 cubic feet; volume of the receiver to the volume of the low-pressure cylinder 1:1.19; revolutions per minute 71.29; mean piston velocity 444.5 feet; stroke 37.4 inches. Reducing motions were used, made of pulleys, fixed at either end of the guide opening in the frame, on the hub of which a small drum was placed to give the indicator barrel proper motion.

The professor in charge of the test remarks that when the valve gear of steam engines are so arranged as to prevent a loss of pressure, he finds an increased economy of twelve per cent. in the result, and this was taken from two pairs of engines indicating about 300 horse-power, and his basis is made from an actual test instead of any theoretical comparison. The deduction is also brought out that when the change of volume between the receiver and the low-pressure cylinder ranges from 0.2 to 1.2 times the volume of the large cylinder, that a mean volume of receiver equal to that of the low-pressure cylinder is the most advantageous. In the original, the metric system is used in all dimensions giving us fractions of inches.

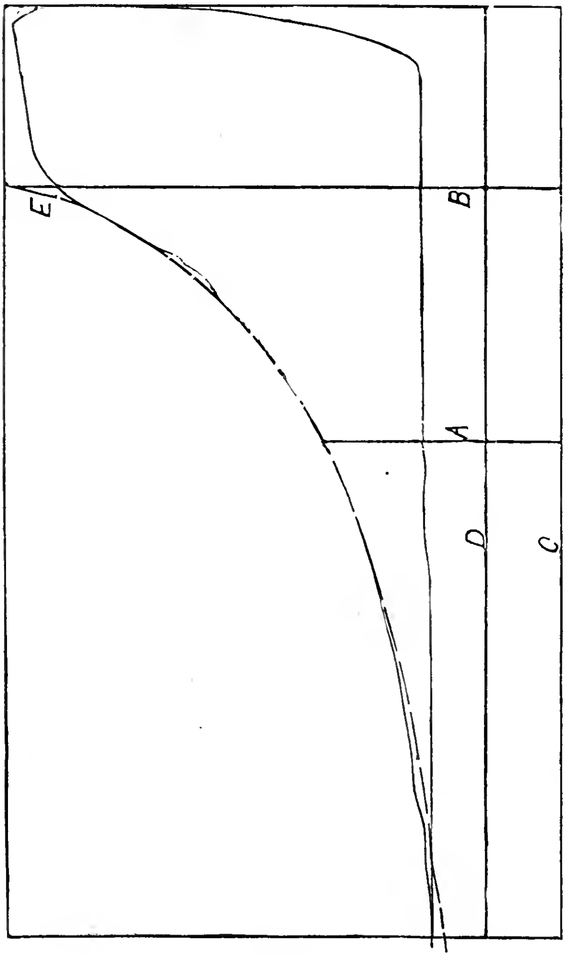


Fig. 133.

Diagram 133 on, as nearly as practicable, a 32 scale, shows a rather handsome compression, good admission, a peculiar little jog in the commencement of the steam line, but the realized pressure starts off at eighty pounds, closes on the line B with 70 pounds. The expansion line, based upon the pressure at the line A, follows very closely indeed until past the middle of the stroke, when the indicated pressure expansion line slightly exceeds the theoretical or broken line. The terminal pressure is about the limit of expansion, and the receiver gives a pressure of 9 pounds to the square inch in the exhaust at the commencement of the stroke, which increases to about 11 pounds at the middle of the stroke, and this pressure is very nearly continued to the commencement of compression. Taking the low pressure cylinder on Fig. 134, its tarts off with a realized pressure of 10 pounds: basing our demonstration on the pressure at the line A, we find the cut-off to be at the intersection of E B, at which point the pressure has fallen about three pounds. The theoretical and the actual lines run on very nearly together, showing remarkable efficiency of the expansion, but a considerable loss is realized from the receiver of the pressure given out by the receiver. The vacuum realized is 11 pounds at almost the commencement, and nearly 12 pounds at the commencement of compression.

We may judge from these diagrams that the efficiency of the live steam jacket is very considerable, and yet the same argument as in the case of the large compounds comes up in this question, the outside of the cylinder is heated with live steam and the inside is changed a hundred degrees or more by the difference between the realized steam pressure and the vacuum obtained at each stroke. There is a somewhat curious theory advanced in the lengthy report originally made upon this engine, which is embodied in the following, referring to the exact proportion as indicated by two different diagrams: "a phenomenon which goes far to disprove the necessity for employing complicated steam-distribution apparatus to attain nice lines in diagrams; and that the day is not far distant when a good distribution, by means of slide valves, will be preferred to any of the modern forms of releasing gears."

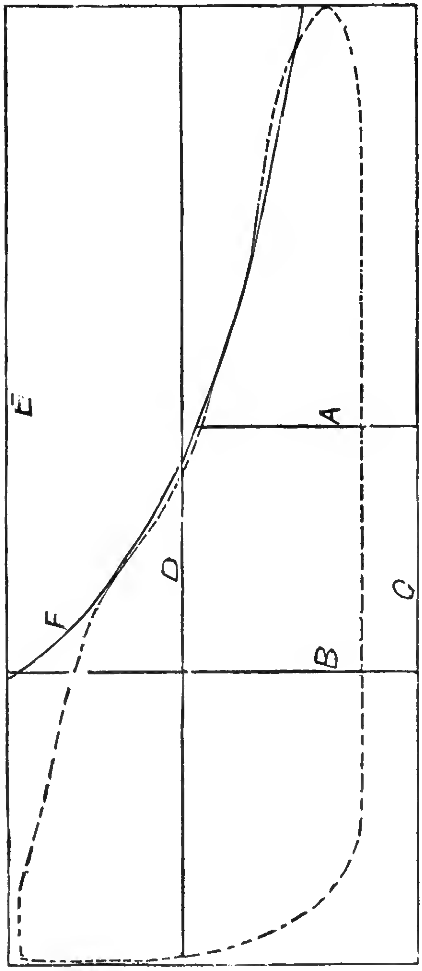


Fig. 134.

The illustrations Figs. 133, 134, show us distinctly that there is not that perfection attained in this so-called Corliss engine with some other kind of a valve gear, as will be found by the simple Harris-Corliss in Fig. 129, or the Corliss modern compound in Figs. 114, 115. The fact will not have passed from the engineering fraternity who are familiar with steam engines, that slide-valve gears, which have given the utmost perfection attainable in the nice indicator diagram lines, lately existed in the United States, but that these engines never showed an economy to compare with the Corliss, when economy of fuel, the minimum of repairs and the maximum of durability were all three items considered, and in this combination the Corliss valve gear, up to a reasonably high speed and even in marine service, when properly cared for, has outstripped every system of valves that has so far been applied, while the slide-valve gear referred to has passed out of use commercially. The feed water per hour as given in this report, with a steam jacket in use, is **14.704** pounds of feed water per hour, per indicated horse-power, but many facts embodied in American tests are not reported. Some changes were made in the volume in the receiver which are unimportant here. Taken all in all the diagrams show very good working of steam, but nothing which would induce us to abandon the Corliss valves, or prefer the suggestion in the report upon them, of the adoption of the slide-valve in preference to the liberating valve gear.

LESSON LXIX.

MISTAKE IN THE MOTION—RESULT.

Fig. 135 shows a result not to be desired. This was taken from an Armington & Sims engine, where the parties had trouble, and the trouble was in getting more pressure in the cylinder than they had in the boiler, a consequent reaction which was not particularly desirable. A is the base line of the demonstration, B the volume of cylinder filled, E boiler pressure, 80 pounds, scale 40, C atmospheric line, D absolute vacuum, theoretical line J. The release in the diagram takes place a little before letter J, and directly under J the expansion line crosses or falls under that of the return of the exhaust which is slightly above atmospheric pressure. The valve apparently begins to close at about half stroke on the exhaust, carrying the compression up very rapidly, and at the point F the compression crosses the line of boiler pressure passing up to G which is 15 pounds above boiler pressure. Here the amount of pressure does not increase any further, but the piston continues its travel to H, at H at the end of the travel of the piston, the pressure falls to I, where the steam valve evidently commences to open, and allows the pressure to pass out, or to equalize itself in such a way that the steam line is not shown as it ordinarily is made by this engine.

It will be seen at the very outset, the point of cut-off, B E, by the demonstration, is practically inside of the real line of the instrument, but only for a very little way. The theoretical line K passes through the line of the instrument at a trifling advance beyond the line B, falling below it, while before we reach the demonstration line A, the theoretical line is above the actual line of the indicator. It then passes below it before the release, after release it barely touches the expansion line on its return.

This is a very curious diagram, for the readings are, to a certain extent, negative in every direction. What was the reason? At the left of the diagram we have drawn the whole cause of the trouble. These makers use a pendulum with an arc of a circle from which the cord is led direct to the indicator. In this case, we found the arc of the circle reversed, or the upper dotted line instead of the lower shaded line, the point L being in either case the pulley which received the cord from the motion. There is not a single correct line on the diagram; the motion is distorted precisely in proportion to the reversing the arc of a circle, as shown, M being the center, the cord being led in the angle of the dotted line instead of, as it should have been, from below M or the shaded portion.

Upon adjusting the motion the diagram assumed its normal appearance, and entirely different from that which is shown. The question may arise in figuring such a diagram as this by the planimeter, what to measure, from the fact that there are negative quantities at each end of the diagram. We have

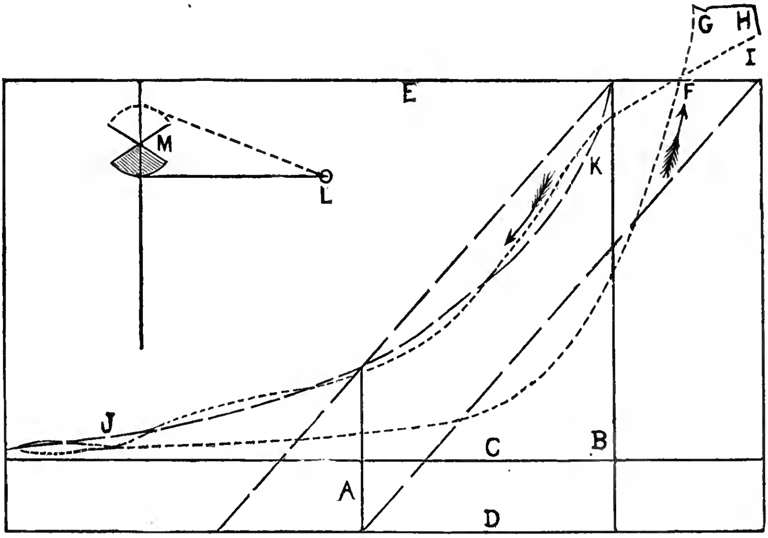


Fig. 135.

therefore drawn two arrows, one on the expansion and one on the compression line, to show the direction which should be taken. Locate the planimeter properly, start at the intersection of the line at F, follow the line in the same direction that the pencil of the indicator followed it; starting at F follow the steam line down the expansion line in the direction of the arrow, at J cross the expansion line, come up, again recross the expansion line under J, follow the exhaust and compression line in the direction of the arrow, cross F up to G, to the right to H, down to I, then down to F. This will give you the area less the negative quantities or resistance. Now as the negative quantities increase the length of the diagram, the total length from the extreme at I to the other end at the left of J, must be taken into the account, so as to get the correct ordinate which, reduced to the scale, is the mean pressure.

LESSON LXX.

DEFECTS WHICH ARE SHOWN BY THE INDICATOR. COMPARISONS.

The various adaptations to which the indicator can be put, the certainty of the readings, if properly interpreted, the different defects which may be pointed out with absolute certainty, are very frequently lost sight of, more especially when, as has been stated in this volume previously, this particular part or adjustment, or indications for defects, has been kept in the hands of men who have not understood it any too well themselves, and have not been fully conversant with the details of the machinery which they have attempted to criticise.

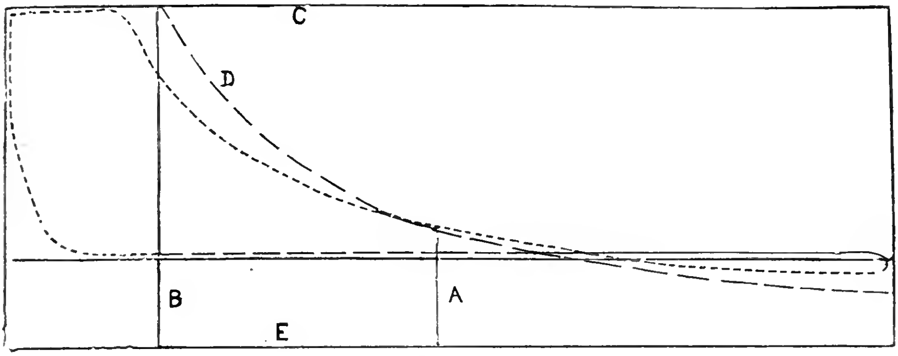


Fig. 136.

Take Fig, 136, and taking away the theoretical dotted line D, almost any engineer or engine builder would pronounce it a very fine-looking card, but the purpose of this volume is to give information. We must, therefore, resort to our demonstration, and, if we take the base line A, the scale of the diagram being 30, we find we have above absolute vacuum, a pressure of 19 pounds plus. Upon making the demonstration, we are rather surprised to find that the point of cut-off is located at the intersection of B, C, the distance from the left-hand vertical line to B, representing the volume of the cylinder in comparison to the whole length of the stroke, which was filled with steam at the initial pressure of 40 pounds, or absolute pressure of 54 plus.

Taking B as our starting point, and our readers must not forget that these are two different problems in geometry, the first problem closes with the erection of the point B, C, we then adopt the second problem, which is to lay out the hyperbolic curve, by the means already described; this gives us the long-dotted line D, which it will be seen starts 10 pounds above the actual line of the indicator as it crosses the line B, gradually nearing the actual line of the indicator at A, and shortly after crossing below the actual line of the instrument. We find that the end of the expansion line, which is under the atmospheric line is three pounds, actual, above the theoretical, or 13 pounds above the absolute vacuum, instead of 10 as it should be. There are several theoretical questions which enter into this, that it is not our purpose to discuss, for they have little bearing upon the practicability of the application of the indicator or its readings. Our demonstration is based upon the fact that the expansion line in the cylinder is entirely settled at the point A, or about half-stroke on the expansion; or, in other words, that it is less liable to be disturbed here. Now, the point A is a positive fact, and if steam expands, according to Marriotte's law, or Regnault's demonstration, or Joule's experiments (and these are acknowledged as approximate to the fact) then the actual pressure at A gives the point B C, as where the initial pressure of 40 pounds should be cut off and expanded, according to these different authorities, to produce the pressure at A. In this case the point A is higher on the expansion line than it should be if the steam had been properly cut off previous to B, showing that something must have occurred while the piston traveled from B to A, which admitted steam into the cylinder after the cut-off valve closed, as is shown by the indicator line. Now, this may be admitted in so small an amount as to apparently be imperceptible, and the demonstration is the only way of ascertaining what does occur. In this case, the steam was admitted after the cut-off valve apparently closes, but in such a small amount that at A it is sufficiently high above what it should be, to throw the point B forward on the line C, and the other end of the expansion line quite corroborates this, the sequel proves the correctness of the application. When the engineer who submitted the diagrams to us, was allowed an opportunity to take down his engine, he found a bad leak under the steam valve, so much so that he had to draw-file the end bearing of the valve, or shoulders of the valve, to let down upon its seat, and to stop the leak, which was visible when the cylinder head was removed.

The old-fashioned way of taking the terminal pressure and working back, would be a very wrong practice in connection with this diagram, and there need not be any confusion in the minds of any of the readers of this work, who correctly apply the demonstration to any diagram, if the few simple directions are followed which are so plainly given. It will at once settle the fact, that something is wrong, without stopping to experiment.

If, now, we take up the case of another series of complications, defects and conditions not desirable, we will refer to Fig. 137, the scale of which is 40, steam pressure at the time of taking, 82 pounds. This was a new engine built to run 83 revolutions, and was sent to us from several hundred miles away. The actual diagram is reproduced; A representing the base line of our computation, B the point of cut-off at which the initial pressure C of 50 pounds was equal to cutting off in the amount of steam used to produce the pressure at A. Had the theoretical line F been run to the boiler pressure line D, it would have shown that the use of about one-third the amount of steam, properly cut off, would have performed much more work, if it had not been for other defects, of which we shall shortly speak. The diagram, in this case, shows on its cut-off and expansion line, an exceedingly close approximation to the side of an old-fashioned iron wedge. It is extremely difficult to locate the point of cut-off, or to find out where the expansion line begins, and the approximation to anything which is valuable or economic is so entirely remote that we will not waste further time upon that portion of the diagram. The theoretical line F shows a close approximation of the terminal pressure as between the theoretical and actual, demonstrating that an amount of steam bounded by the line B, cut off on C, was about equivalent to the amount of steam used, taking the assumed line F with the actual line of the instrument.

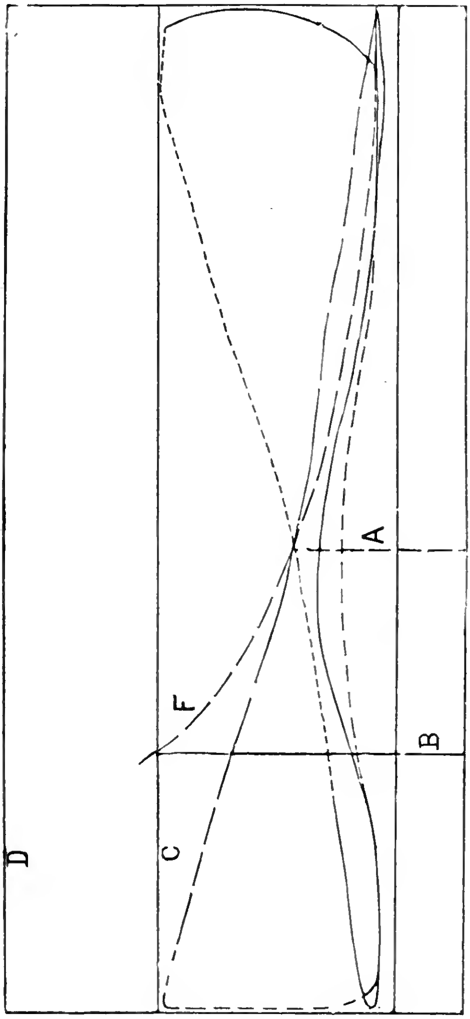


FIG. 137.

In this case, we find the extreme terminal about in unison with the theoretical, but back of that where we suppose the exhaust valve commences to open (for the lines are indistinct and indefinite) it is several points higher. But the main feature now is, the trouble in getting rid of the exhaust steam, one line is dotted and the other is solid; they have both a peculiar hump, showing either that the exhaust passage is clogged by insufficient ports, or what is more apt to be the case, and what we at once decided when submitted to us, that the steam from one end of the valve passed into the exhaust about the center of the stroke, for a brief space of time, increasing the back pressure. A variety of theories were advanced, one of which was that the valves were not tight, but would in time wear down to a seat. Whenever an engineer finds this kind of a diagram, the shortest way out is to abandon the whole thing, or condemn the engine and get it into the scrap-pile as soon as possible. It is so exceedingly extravagant in its use of steam for the small amount of power, and considering the fact that it was intended as an automatic cut-off engine, that it is unworthy further attention, its only purpose of introduction being that it is an incident in practice which may be valuable to some one in trouble.

As the best way to judge between bad and good practice is by comparison, we introduce into this lesson another diagram, which was not taken by the Thompson indicator, partially to show the expansion line, about which more or less argument has been made among indicator makers for the last few years, and also to contrast it, with the circumstances all stated, with Figs. 136 and 137 in this lesson, and the four succeeding figures in the next lesson following.

Diagram Fig. 138 is an exact reproduction, taken from one of George H. Corliss' steam-jacketed new pattern engines, boiler pressure 75, 30 inches diameter of piston, 72 inches stroke, 54 revolutions, 40 scale. This engine is driving a flour mill in the City of New York, has been running 3½ years, about 140 hours per week, and from six o'clock Monday morning until six o'clock or midnight Saturday night, the throttle valve is never closed. The engine is grinding about 1400 barrels of flour every 24 hours and its weekly run amounts to 143 hours each week. The indicated horse-power is about 575 H. P. We have 66 pounds initial pressure out of a boiler pressure of 75; the line A is the base line of the demonstration which gives B D as the point of cut-off on D, or the volume of the cylinder represented by the dotted line C D in proportion to the whole length of stroke, as that portion of the cylinder which was filled with steam at initial pressure to accomplish the work. Making the demonstration from A B, by means already described, we have the points *a*, *a*, *a*, etc., showing the exact line of the theoretical in comparison with the actual. The line D is drawn triflingly above the actual line of the instrument, or nearly two pounds above, in order to show the actual record of the indicator; for that reason, a slight difference is made in the position of

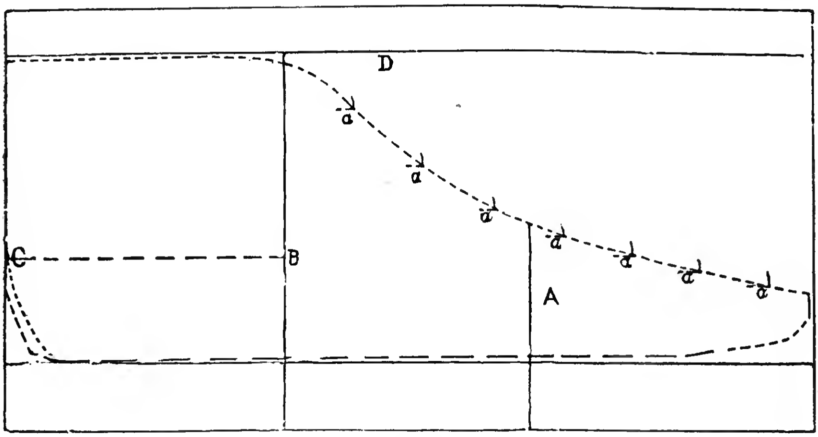


FIG. 138.

the lines, showing the points through which the theoretical curve runs, but whatever that difference may be, it is so near to the width of a line as to be a feature of no possible account in variation, and would be hardly recognizable had the line D been drawn directly through the steam line of the diagram.

There is no mistake about the work which this engine is doing, provided the indicator is correct, and it is hardly probable that any great difference exists with the action of the indicator; but there is a point in connection with this expansion line which is treated of in the next lesson, to which our readers will do well to pay careful attention, and that is in relation to the change of pressure, volume, temperature, etc., and whether the expansion line in this diagram is an absolute reproduction of fact; this will be illustrated in the immediately succeeding lesson.

With regard to adjustment of this engine, little can be said other than if we were ourselves adjusting the valves, we should give it a slightly earlier release, so as to let the exhaust line down where it belongs, and this in turn would give us the fine dotted line for compression, which we should much prefer to see. This diagram was not taken with any preparation, change or otherwise, but was taken while the engine was at its regular work, and speaks not only for its builder, but as well for the care which has been given it by the chief engineer. This shows an exceedingly close approximation as between practical and theoretical, where everything is in working order, well taken care of, doing severe work and running for practically twenty-four hours per day, six days each week. No new valves and no lost time are yet charged to this engine.

LESSON LXXI.

AN EXPERIMENT WITH INDICATORS ON THE SAME END OF THE SAME CYLINDER, AT THE SAME TIME, WITH THE SAME SPRINGS IN EACH.

Fig. 139 was taken from a $9\frac{1}{2} \times 12$ Armington & Sims engine, running 276 revolutions per minute, 80 pounds of steam, 40 spring. The pattern of indicator with which this was taken, is what is now known as the old Thompson, with what was practically the Richards parallel motion, or a very much heavier motion than that which is used on the Improved Thompson of to-day. Some of the indicator makers have put out some very curious literature in the way of circulars, showing the defects of each other's indicator, according to the figures which accompany the circulars or pamphlets which have been spread broadcast. The experiment which we are to record here, was made for the purpose of ascertaining what the indicators will do, in actual practice; and we desire at this point to call the attention of our readers to what we have very radically differed from many of the engineers, with reference to the expansion line of the instrument, and the record which is made by the action of the indicator on particular points, and we are glad, therefore, to show Fig. 139. At A we have a realized pressure of 76 pounds, at B 35 pounds, at C 16 pounds, at D 9 pounds, and at E the expansion line crosses the atmospheric line, and when the exhaust valve opens at the termination of the stroke, the pressure rises gradually until about one pound above, when it returns across the expansion line at E, passing along, gradually increasing to F as the valve is closing, until at F it is closed, when the pressure rises rapidly. This diagram is one of many, and is taken without any particular selection.

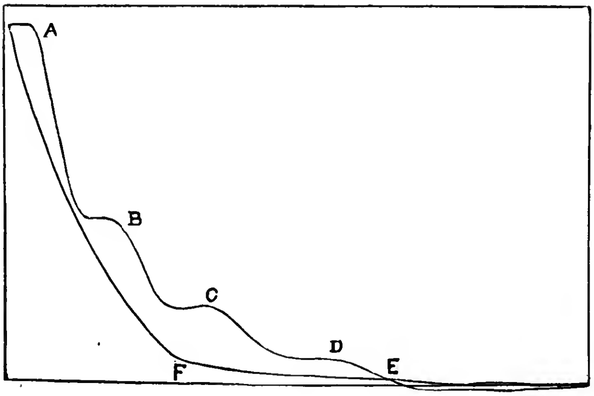


Fig. 139.

We will now refer to Fig. 140, which was taken by another indicator, with the same spring as stated above. The two diagrams, 139 and 140, were taken on the same stroke of the engine, with the same steam pressure, each indicator run by a separate cord, and a slight difference in the length of the cards is shown. The peculiarity of the two cards is perfectly perceptible to any one. In Fig. 140, we start off at A with a pressure of 65 pounds initial. At B we have 51 plus, at C 48, at E 27, at F 15, at G 8. A, however, is the height of the compression line which falls off to D, rebounds to B, comes down to C, during the time that the valve is opening, and then starts off to the left, making the first curve in the steam line. The rebound of pressure, by the sudden expansion, increase of volume, and the struggle between the elements and the speed carry the expansion line below the compression line on the card, and when the next fluctuation in pressure occurs, at E, in the forward movement of the engine, and the rapid expansion and falling of pressure, the expansion line crosses the compression line, making the second wave at D; dropping to F, it covers, but does not cross, and then advances again, the oscillations becoming less and less perceptible, until they barely cross the atmospheric line at the end of expansion, and come back upon the atmospheric line alone until the compression line is made. There is such a radical difference as between the two diagrams that one must be nearer right than the other, and one must be exceedingly far from correct. We have settled in our own mind that 139 shows the position of the valves, and the action of the steam.

But there are other elements to be brought into this lesson. It has been upon one part of the indicator-using fraternity, their earnest endeavor to reconcile all differences of position, all fluctuations of working, to the idea of making a smooth card, for which see 140, 142. We have frequently had cause to say editorially, and before different audiences, that we had been unable to reconcile all these differences which do take place in the steam cylinder of an engine, to the theory that a steam engine indicator must of necessity produce the true hyperbolic curve, or the nearest approximation to it, with a correctly working indicator. Inferentially we have condemned this as all wrong, and believe that the various elements entering into the expansion line of high speed diagrams, if correctly delineated by the indicator, will very much more approximate 139 and 141 than they will 140 and 142, both as to the position of the valves, and actual record of the working of the steam in the cylinder. If we take 139, we find from A to B a change of 41 pounds pressure, in 140 we find from C to E a change of 21 pounds pressure. If we take the temperature of the steam at A on 139, we find it 308.4°, at B it is 259.3°, while at C it is only 216.3°. Let us now see what the volume in each case is. At A the volume is 377, at B 764, at C 1572. If this were the only element it would be quite enough to produce the radical changes shown in 139. If, now, we refer to the dotted lines, showing the friction load, in Fig. 142, we find there a diagram taken with a stiffer spring, which almost absolutely ignores any fluctuations in temperature, pressure or volume. Referring to the solid line in 141, which represents the friction card, with the Thompson indicator, with

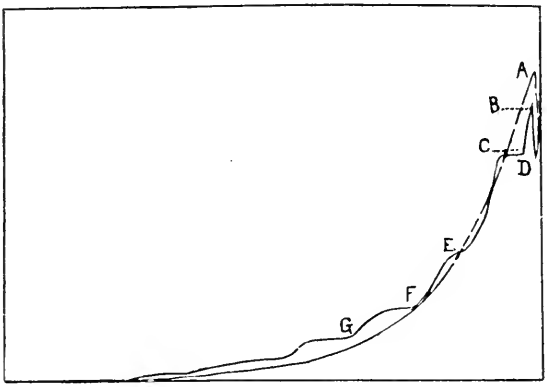


Fig. 140.

the same spring as 142, we find these differences very elegantly shown in the load, and plainly perceptible in the friction card, which is enclosed within the other. Both these diagrams in 141 and 142 were taken by preparing for it beforehand, so as to throw a break upon a pulley, properly connected, raising the load from the friction to the amount shown, in the shortest space of time consistent with safety to those employed. Now, if nothing except the volume and the temperature were to be considered, we have then elements of immense disturbance, as shown by the figures quoted. In Fig. 139 the volume increases in the fraction of a second from 377 to 20,890 at E; while in Fig. 140 the volume increases from 434 to 20,890, and the temperature diminishes in the fraction of a second from 308.4° to 102°. But if we refer to Mr. Charles T. Porter's book, entitled the "Richards Steam Engine Indicator," which has been in our possession for fifteen years at this writing, we find the most reliable and best tabulated data that we have ever yet had access to, with reference to the speed of the crank at different degrees in the steam engine, as well as to the speed of the crank as compared with that of the piston. We find the following statement with reference to the rotative force exerted upon the crank, being the same for equal divisions of the diagram:

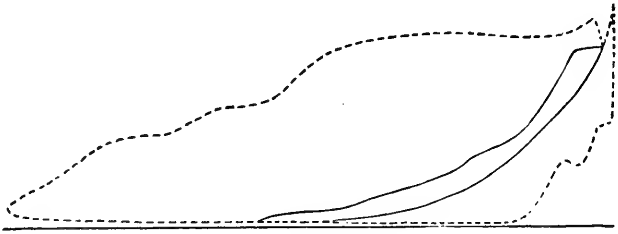


FIG. 141.

"If the reciprocating parts of engines were without weight, so that the pressure of the steam was always exerted upon the crank precisely as it is on the piston, then the rotative force on the crank of the steam pressure would be equal for equal divisions of the diagram measured at any part of the stroke. This is often denied, and still more often doubted. Being a fact, it ought to be placed beyond either denial or doubt. The motion of the crank is supposed to be uniform, passing through equal arcs in equal times, the motion of the piston, on the contrary, is, first, scarcely two-thirds that of the crank, being to the latter in proportion of 1:1.5708, and, second, it changes at every point of the stroke. At the instant that the crank is on the dead center the piston has no motion. Then its motion, at first infinitely slow, becomes gradually accelerated, until the velocities of the piston and the crank are equal, when it begins to be retarded, the ratio of retardation increasing until on the opposite center its motion has ceased. But whether the revolution of the crank is uniform or not,—as in fact it can never be absolutely, since then the fly-wheel would cease to act as a regulator, and might be dispensed with,—the motion of the piston has a fixed relation to it, being equal (if we disregard for the present the effect of the angular vibration of the connecting rod) to the versed sine of the angle which the crank makes with the center line. The study of the table of versed sines will explain all about it. We will employ the two extremes for illustration. The versed sine of 1° is .0001523; the difference between the versed sine 89° and that of 90° is .0174524. Therefore, the length of the crank, or of the half stroke of the piston, being 1, while the crank is traversing the first degree the piston moves the distance .0001523, and while the crank is traversing the ninetieth degree the piston moves the distance .0174524, which is nearly 115 times greater than the former. The rotative effect of a force varies also as the versed sine of the angle at which it is applied. Therefore, the effect of the rotative pressure of the steam on the crank while it is traversing the ninetieth degree is 115 times as great as while it is traversing the first degree, but also the piston moves in the former case 115 times as far as in the latter. It follows, therefore, that equal movements of the piston, or equal portions in the length of the diagram, at any part of the stroke, represent equal rotative effects upon the crank."

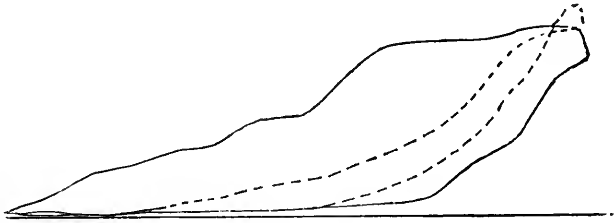


Fig. 142.

We have made this lengthy quotation, first, because Mr. Porter has so well said, and has substantiated his assertion by indisputable fact, and, second, while we are not dealing in this lesson with the rotative force on the crank we *are* dealing with the speed of the piston, and will now drop our digression and return to the subject in hand. Added to the extreme range in temperature, as well as the tremendous increase in volume, we have now another factor which shows us that the difference between the travel of the piston through the first degree of the stroke and the last degree of the stroke is 115 times; we have then precisely what we require to substantiate our own assertion, that if the indicator is to be the exponent, or is to truly record what is actually done in the cylinder, then it must also record these extreme ranges of fluctuation in pressure, volume, temperature, all of which are governed by the varying speed of the piston. We have, therefore, just these elements; referring to diagrams 139 and 141, from A to D, in 139, the speed of the piston is constantly increasing, the pressure of the steam, as shown by the indicator diagram, falls very rapidly, the temperature decreases very fast indeed, while the volume increases at a tremendous rate; the speed of the engine, being 276 revolutions, reduces the time in which this diagram is made to about one-tenth of one second, or that portion of it which lies between C and D is reduced to $\frac{1}{20}$ of a second $\frac{1}{1200}$ of a minute approximately, more correctly being $\frac{1}{1104}$; and when we add to this the fact that the speed of the piston is an ever-varying amount—anything but constant—we do not hesitate to state that while our assertion may have been doubted or denied, it is susceptible of proof, and that proof we believe is offered in these elements beyond dispute, if the facts are considered.

Figs. 141 and 142 were taken with a 60 spring to ascertain what difference, if any, would be shown as between two instruments on the same engine, at the same speed, with the same steam and spring, and at the same instant of time; 141 was taken with the Thompson instrument, with the new or Improved Thompson, with the light parallel motion. In 141, we have dotted the outside or total load and drawn the friction of the engine, so far as we could do, in a solid line. In Fig. 142, we have been obliged to reverse this operation, owing to the fact that the friction crosses the initial. The two diagrams may be treated from any standpoint, and only require a careful observation to convince any person, who is disinterested, where the actual position of the valves and the working of the steam is shown. To our own idea 141 shows every element of accuracy, while 142 shows quite a different result for power and position of the valves; and we may in this connection, perhaps, with perfect propriety, quote again from Mr. Porter's book, as follows:

"VIBRATIONS OF THE SPRING.

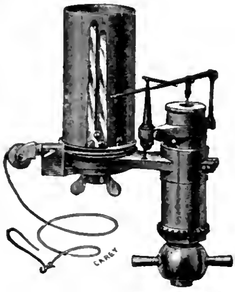
"Sometimes at very high speeds, or with very sudden action of the steam, the spring of the indicator is put into vibration. If the line produced by these vibrations is a waving line, quite free from angles, this is an evidence that the action of the instrument is frictionless, and the mean of the vibration gives a true line." Almost on the same page Mr. Porter makes this statement: "There are no vibrations or pulsations of steam in the cylinder; all appearances of this kind, on the expansion curve, are caused by the spring of the indicator being put into vibration by the sudden action of the steam."

If the vibrations do not occur while the engine is under motion, or if the pulsations are not caused by the conflict in the molecules of steam, or steam and water, as well as the different mechanical forces, then we confess that our steam engine indicator had better be laid upon the shelf instantly, there to remain until we can prove that different mechanical forces, acting as we have cited above, are capable of producing a true hyperbola by means of a spiral spring. Whatever may be the fact with regard to pulsations, we call particular attention to the difference in the outline which shows the position of the valve, as between 141 and 142, while the differences between 139 and 140 are quite sufficient for anyone, however unsophisticated he may be in the uses or abuses of the indicator. In our own experience in taking diagrams with different indicators upon the same end of the engine, at the same speed, and under the same conditions, we have found that diagrams showing wavy lines, figure somewhat less power, and give generally a more accurate idea of the working of steam in the cylinder, and that the same indicator also sooner responds to any actual alteration made in the valve motion, by showing it upon the diagram, showing that its accuracy extends into this important realm of the functions of the indicator, viz.: position of valves, while the stiff-working indicators do not show it as soon nor as delicately.

LESSON LXXII.

EXTREME HIGH SPEED, DIFFERENCE IN INDICATORS.

The tendency to high speed has led to some very curious developments, and one of the principal claims of engine builders, as well as indicator makers, to-day, is, that their engine, or their indicator, is the most, if not the only, reliable one at high speed. High speed, it has been proved to our own satisfaction, has a limit where efficiency ends and extravagance begins, and while we have no purpose in this article to criticise, we must express our opinion so that we may not be placed on record as advocating the speed (at which the diagrams illustrated in this lesson were taken) for practical purposes.


Thompson, No. 2.

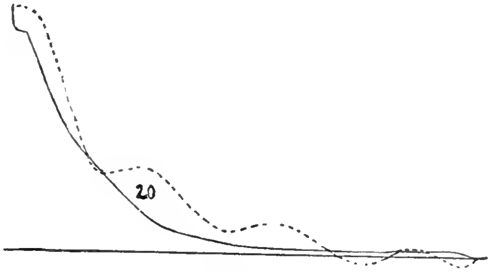


Fig. 143.

These diagrams were taken in the shop of Armington & Sims, Providence, R. I., where they had prepared an engine by increasing the strength of some of the parts of the regulator, and our intention was to have carried the experiment to 700 or more revolutions per minute. Diagram 143 was taken with a Thompson Improved Indicator, No. 2, on small paper barrel, an illustration of which is given with this, which differs from the larger indicator only in the size of paper barrel, and some minor changes with reference to the stand, the spring and motion being the same as that in the larger instrument. This instrument is made with or without the detent motion, generally with the detent motion; this is a matter which is invaluable to those who are unused to high speeds, or are not familiar with the practice of

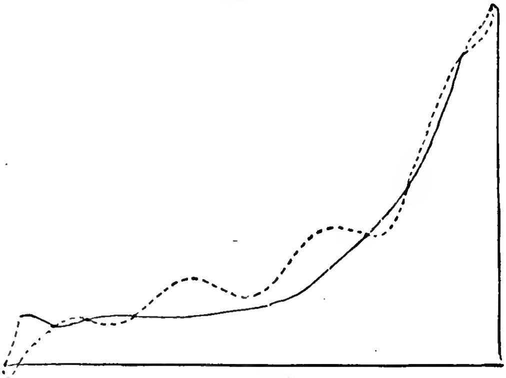


FIG. 144.

taking indicator diagrams, and it is especially valuable to those who are taking diagrams from the locomotive. Fig. 143 was taken with this instrument in April, 1884, at a speed of 536 revolutions per minute, actual count, the regulator being graduated and adjusted for that point. The reader will necessarily have to compare several diagrams, one with another; for this purpose, with the exception of Fig. 149, we have in this article, dotted the steam line and drawn the expansion line solid in all the figures.

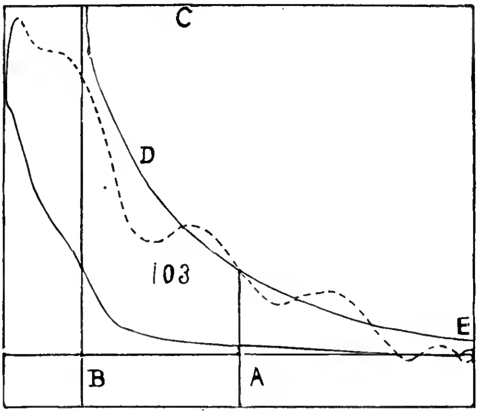


FIG. 148.

In Fig. 143, it will be seen that the expansion crosses the atmospheric in the vibrations, and returns again, making a very handsome atmospheric line, and that the compression line crosses the first or largest vibration, but that the steam line is very handsomely shown. Fig. 144 was taken by an instrument from another maker; it will be seen in this case that there is a very great difference between the atmospheric line and compression line.

Fig. 143 was taken with a 50 spring, 144 with a 40 spring. Fig. 145 was taken with the same instrument as 144, at a speed of 536 revolutions; there being such a difference between 143 and 144 as to position, that 146 was taken with the little Thompson, the spring being changed to 40, the speed being increased to 562. It will be noticed here that a change takes place in the admission and steam line, which continues through the other diagrams, the motion of the valve being shown as a trifle late, the expansion line having its peculiarities, but the record being very clear. The steam pressure in 146 was 75 pounds. To ascertain what could be done, we again changed the spring to 50, the steam meantime having been raised to 95 pounds, and obtained from this change Fig. 147, with the Thompson No. 2, revolutions 562.

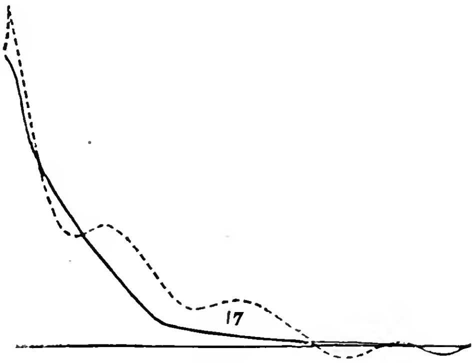


FIG. 146.

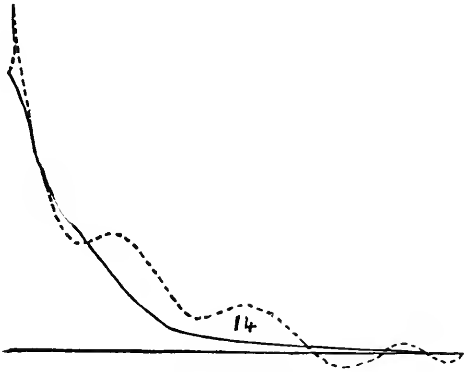


FIG. 147.

For the sake of experiment, arrangements were then made to add a load to the engine, and Fig. 148 was taken with the Thompson Improved No. 2, steam pressure 92 pounds. The peculiarities in 146, 147 continue with reference to the valve motion, showing it a trifle late; the compression and expansion lines are very nearly identical, except that the load is increased. Upon 148 we have erected the demonstration from exactly half stroke, the line A being the base line, showing the cut-off to be at B, on C, and for the terrific speed at which it is running, there is a very good showing for the valves as well as the indicator. Having so far determined that the action of the indicator was at least capable of showing changes, an effort was made to increase the speed of the engine from 562 to 700, the regulator was changed as much as it was deemed safe and a start was made, producing Fig. 149 with the new Thompson No. 2, at a speed of 642 revolutions per minute. Two other cards were produced, and while changing for the fourth one, a piece of the regulator which had been made of steel, straightened out by the strain upon it, and we were treated to an example of solid bodies going off at a tangent, and the engine was stopped for repairs. The ordinary speed of this engine is 320 or 330 revolutions; the action of the regulator shows plainly on 149, with 95 pounds boiler pressure, and an initial of 90:92, the load was made constant, but it is absolutely impossible to engrave the variations which took place, only at the curves in the expansion line. The intention at the outset of this experiment was to try the three indicators which are in the market; one of them stopped inside of 400, one ceased its

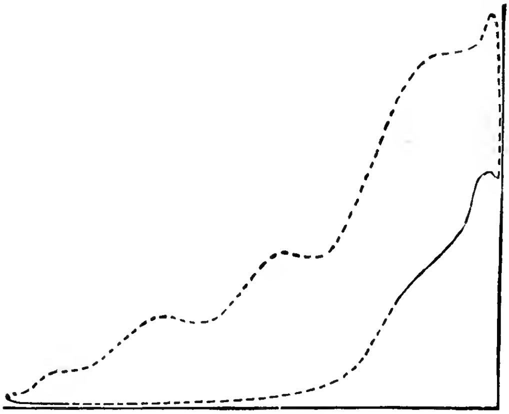


FIG. 145.

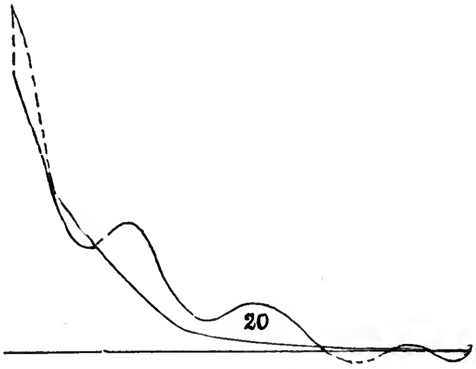


FIG. 149.

accuracy practically at 536, or probably below, while the third one made the diagrams which we have shown, leaving the little Thompson master of the situation in this experiment.

We have, since that time, been allowed to test an engine more for speed than anything else, and have succeeded in getting very fair diagrams at above 720, but the action of the steam shows plainly that the engine will not become a merchantable or commercial affair, and there is no use in devoting space to that which is not practical; we do not consider this lesson as one of any particular importance for the student of the indicator, and it is introduced more as a curiosity to show the results of a single experiment, upon which we do not place any particular stress, and would not advise any person to buy the Thompson indicator solely upon what is shown in this lesson, or not to buy either one of the other two because of their ill success at this experiment. One of the makers of the engine was present and saw all the experiment. The intention was fully pursued of giving to each instrument every benefit and every advantage, and the results shown are, as nearly as possible, the actual result of the work of the instruments. We do not, however, advise our readers to adopt any such speed, nor do we consider the actual indicator diagram at this speed as an unquestioned performance. The claim has been made that diagrams have been taken at above 1000; while we have no reason to doubt the assertions, we consider them simply experimental, or in the light of a curiosity, and having no possibility of practical value, unless it be to gratify a whim, which cannot result in any economy to the general steam user, at least with present engines, indicators or mechanism.

LESSON LXXIII.

AMERICAN BUILT COMPOUND STEAM ENGINE FOR A RIVER STEAMER.

The question of simple condensing engines, or of compound engines, for our river steamers has been one upon which a great diversity of opinion has been expressed, and in which the extremes of practice have been worked out within the last few years. Wishing to get data regarding this, we asked and obtained permission to indicate a river steamer's compound engine working a screw, and this steamer is doing the work with about one-half the fuel that a condensing beam engine did it, and is one of the fastest steamers for her class running out of New York.

Fig. 150 is the high-pressure diagram, taken with a 50 spring, the cylinder being 30 inches in diameter, 36 inches stroke, making 88 revolutions per minute, with 85 pounds of steam.

Fig. 151 is from the low-pressure cylinder of the same engine; 56 inches in diameter, 36 inches stroke, making 88 revolutions, scale of spring 10. The diagrams were taken at the same instant of time, two indicators being used, so that they represent what was done on the same stroke at the same instant of time.

In Fig. 150, A is the base line of the demonstration, which touches through the theoretical curve G, the realized steam pressure line F, at B. B represents the volume of steam actually used to do the amount of work at the realized pressure, which is 9 pounds less than the boiler pressure E. The valve in opening, as will be seen, allows the pressure to drop slowly from the line F after the piston has passed but a few inches of its stroke, so that at the point B, on F, the realized pressure by the indicator is 10 pounds less than the realized pressure at the commencement of the stroke. We then find, after having passed pretty well toward the end of the expansion line, that the expansion rises above the theoretical to a certain extent. The exhaust valve is somewhat slow in its opening, and the pressure in the receiver at the very highest amounts to between 11 and 12 pounds. The same general features will apply to the valves, both high and low-pressure cylinders, viz., that the opening of the valve seems to be either slow or insufficient, and the pressure gradually drops from and after the time when the valve opens, and owing to this feature it is also slow in closing, and the amount of steam accounted for is considerably in excess of that which is generally considered shown by the indicator. If we refer to 151, taken with a 10 scale, we charge against that cylinder 12 pounds initial pressure, which is the extreme amount shown in the high-pressure cylinder as back-pressure or between the high-pressure and low-pressure cylinder. The lines I and I′ represent respectively the steam admission from the receiver to the low-pressure cylinder. If we refer to the line I we see that after the steam is first introduced the pressure is kept at

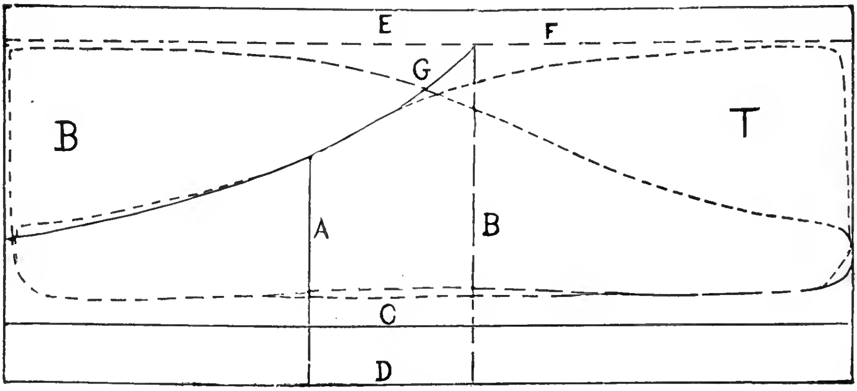


FIG. 150.

11 pounds above the atmospheric line C for a very small portion of the stroke; that as quick as the speed of the piston begins to increase, then the pressure of the steam commences to drop away, until at the line B there is only 4 pounds above the atmosphere, and at the point of visible cut-off, or where the valve finally closes, there is only two pounds above the atmosphere. I′, while not making so good a start, has a pressure of almost three pounds at the visible point of cut-off, which is considerably beyond the line B′. Now, what happens? When the valves of this engine commence to open, the steam is not admitted in proper amount, owing to its low tension, to fill the cylinder at the pressure which exists in the receiver. The moment the piston starts to move away from the end of the cylinder—and the motion of a piston with a short connecting rod, not more than two cranks, accelerates very rapidly—then the amount of steam which is admitted grows less and less or is more and more wire-drawn. The steam is cut off at the line B′ of the other diagram, as we express it, visibly; or, that is, the point, almost two-thirds of the stroke, where the steam valve closes and the expansion on the low-pressure cylinder begins. If we go a step further to the line A′, which is the base of our computation, we find at that point, only a trifling distance beyond the point of cut-off, the pressure above absolute vacuum is about 14.3 pounds. Now, had we here cut off the pressure of steam at B to make the theoretical line G′, we should have used the same amount of steam, practically, and have expanded down the line G′ without the outlay of a single pound of coal more than we are now using, while on the other side the dotted theoretical line G would have cut off at B′ and have gone down the dotted line, utilizing the space bounded by H, I, G as efficient pressure on the piston, instead of following the steam lines I and I′. This is serious,

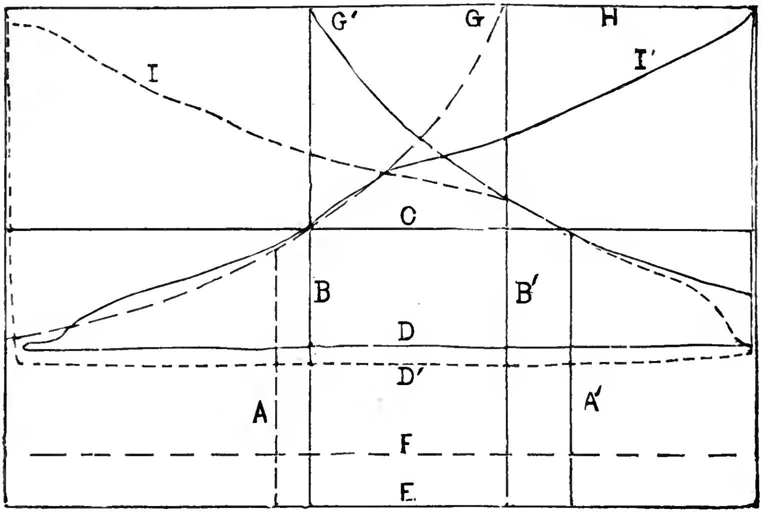


Fig. 151.

but we will shortly show by the figures what would be produced with a proper arrangement of the valves. The line D is the vacuum line on one diagram, and D′ the vacuum line on the other. It will be noticed there is a peculiarity with reference to the vacuum of this engine. We have only 6.2 pounds on one end and 7 pounds on the other, or practically 12¼ inches and 14 inches; the coarse dotted line, F, shows what we should have realized in obtaining a vacuum of 12 pounds or 24 inches. These diagrams were taken on the night of December 18, 1884, when the water was certainly cold enough to have produced a good vacuum, but the proportion of the machinery would not allow it. Here, then, we have the difference between D′ and F, which should have given us 5 pounds more of mean pressure effectually, or of mean effectual vacuum more than we did receive.

These are the general features and facts with reference to the diagram. The engine is well built, well proportioned, seemingly, and the boat is very fast and economical. Now, suppose we could improve it in design or in execution, what would be the effect? In the high-pressure cylinder we have in the respective ends 520.25 horse-power on the bottom, and 508.7 horse-power on the top; in the low-pressure cylinder, the actual diagram by the indicator figures 389.24 horse-power on the bottom, and 332.55 horse-power on the top. If the valves had worked, so that we could have obtained our theoretical diagram by opening the valves sufficiently to feed the cylinder with the pressure, cutting it off sharply so as to make the theoretical lines or close approximation to them, and only have obtained the same vacuum which is shown by the instrument, we would then have attained relatively 499.46 horse-power on the bottom and 402.72 horse-power on the top, making a very radical gain. But if we could make this engine still more perfect in its working, so as to admit the steam, cut it off and then produce the vacuum of 12 pounds, we should have had a very different result indeed; it would then have been 683.15 horse-power on the bottom and 616.29 horse-power on the top, or to condense it, the actual diagrams combined show now 852 horse-power on the top and 897 horse-power on the bottom. With proper increase, it would give 1136 horse-power on the top and 1191 horse-power on the bottom, or would make a still further difference of a very large amount in proportion to the coal which the steamer burned, if these results were realized. The receiver pressure is well taken care of by the low-pressure cylinder, but the whole amount of steam is not accounted for as between the high and low-pressure above the atmospheric line, and the account below the atmospheric line on the low-pressure cylinder should by some means be very radically improved. It is quite possible that the ports and passages, and probably the throw of the valves in this engine, are all based upon the olden-time practice and would, upon careful investigation, be found to be too small in area or too short in valve travel, and yet, as compared with previous practice, this steamer has a splendid record. The only question now is, how much higher the record can be made by proper adjustments of the engine.

LESSON LXXIV.

A COMPOUND NON-CONDENSING ENGINE.

Very frequently diagrams are put before an engineer to ask his general opinion, and while there is no information of a positive sort to be gained from this lesson, it is entirely within the province of the work to show some things with which working engineers are frequently annoyed or expected to do work with or against natural obstacles, in their way, which preclude economy, regulation of speed, or any other practical result. Referring to Fig. 152, we have the high-pressure side of a compound non-condensing engine, scale 30. This is supposed to be governed by a throttle governor in the pipe, which jumps up and down like a jack-in-the-box; the different lines here are precisely as the indicator left them. It will be seen that the initial pressure of steam entering the cylinder in the highest instance is 38+; it then varies to 27, and from that down to 18. Notice, that in two of the lines an attempt is made to cut off, and in the other two lines, strange as it may seem, initial pressure is below the maximum pressure by several pounds. The back pressure amounts to between three and four pounds at the commencement, and runs down to one and one-half pounds at the moment of compression.

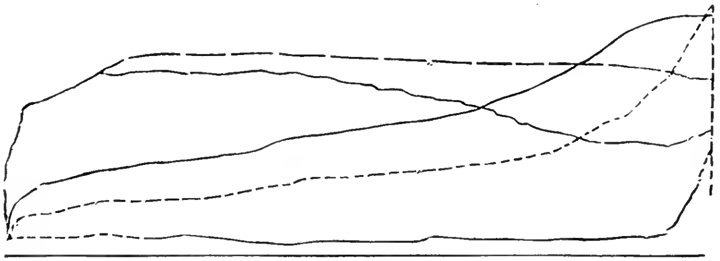


Fig. 152.

Fig. 153 represents the low-pressure side, running as high-pressure in connection with 152. This arrangement was brought about by shifting a valve between the cylinders, so as to allow direct steam to enter into both ends and sides. The scale of 153 is ten. We have here 13 pounds initial, but with an exceedingly great variation in the action of the steam, commencing with a back pressure of two pounds, running up to four, and dropping back to three, showing that there is some peculiar action in the cylinder. Fig. 153 was taken after 154.

Figs. A, B, 154 are from both ends of the compound cylinder, and were taken at the same instant as 152, scale ten. We have an initial pressure in the A end of 7 pounds, which falls down to 1½ pound by a most peculiar line. It then runs along and gradually increases to 2 pounds, and a little later to 3¼. Whether this obstruction is caused by the peculiar passing of the steam through the double-ported slide valve between the cylinders, or whether it is caused by the motion of the exhaust valve, we have not determined, not being enabled to examine the inside or working parts of the engine. The expansion in either case is most peculiar, and the terminal of this double expansion line seems to be slightly below the atmospheric, but we have the same general formation of the return or exhaust line which passes above the line of direct pressure more than half a pound, falling back again slightly and compressing above the induction pressure. The diagram, taken altogether, is peculiar. It shows but an exceedingly small amount of power exerted upon the piston as the back pressure nearly neutralizes the forward pressure. Turning to the B end of the cylinder, we have, if anything, a worse diagram than the A. The features, it will be noticed, are very similar indeed in general, but there is a little difference of outline. The extreme amount of initial pressure is only about five pounds; that barely continues for an inch of the stroke, when what we suppose to be the expansion line, falls away similarly to that of the A end, resting on the atmospheric line for an instant of time and dodging away again to a pressure of nearly three pounds at the maximum on the second introduction of steam. In the exhaust, for a very brief interval, the line returns on the atmospheric pressure line, then rises very materially above the direct steam line continuing two pounds above the atmospheric line with only five pounds of initial pressure. It is usually supposed in compounding that some gain is to be derived. In this case there is no economy, and what the gain can possibly be by compounding a high-pressure engine with another high-pressure cylinder, one side doing eight and one-half times as much power as the other, we cannot imagine. The high-pressure side of this engine is doing from seven to eight and one-half times the amount of power that the compound is doing. We think the idea of high-pressure compounding is entirely a mistake, unless some very different way of working it out shall be adopted from that shown in this lesson. The movement of the governor was most erratic, and we have no doubt, if the different parts of the engine were compared with a correctly moving valve motion, that all the ports and steam passages would be found

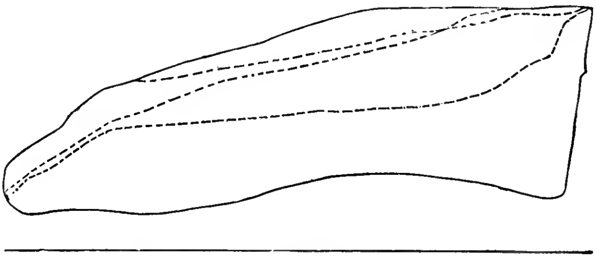


FIG. 153.

radically differing from good practice, and that the travel of the valves was very ill-proportioned to the travel of the piston. They simply take their place as curiosities, and for information to the working engineer, which, we hope, very few of them will ever encounter, especially if they are compelled to take charge of them. This engine is burning more than eight pounds of fuel per horse-power per hour, if the data given of the amount of coal burned is correct. The diagrams were taken to ascertain certain facts, by the writer's hands and indicator.

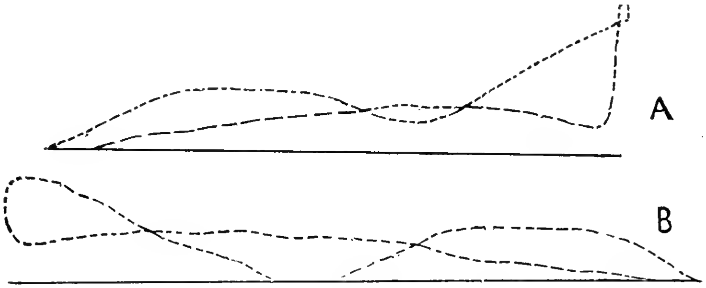


Fig. 154.

LESSON LXXV.

FISHKILL-LANDING CORLISS.

Fig. 155 was taken from a Corliss engine, built by the Fishkill Landing Machine Company, 18×42 inches, running 63 revolutions, steam pressure 68 pounds, spring 30, heating a portion of the mill by exhaust steam. This diagram was taken from an engine in its every-day work, without making any changes, as the attachments were made at noon-time. The point was to get at the average work of the engine, as well as the load upon it. Very little need be said of it, other than that the valves of the engine seem to be in admirable condition for working, although, for best results, we would quicken the action of the steam valve slightly so as to avoid the rounding corner between admission and steam lines, as well as to obtain nearer approximation to boiler pressure, if possible. The demonstration on this diagram shows a very close approximation to first-class practice. We would prefer a trifle earlier release so as to obtain a little more compression, but, taken all in all, the diagram gives a very excellent handling of the steam, and shows plainly that the valves are tight, and that the vibrations in pressure are taken account of by the indicator. The approximation to boiler pressure is but in small measure due to the late opening of the steam valve, (61 out of 68 pounds are realized) but rather to the crooked steam pipe which has in it more or less valves, and through which steam is drawn for dyeing as well.

If the reader should be at all skeptical as to the absolute necessity of expressing the clearance on a diagram to obtain the result for which we make the demonstration, let him add two per cent. to the length of the diagram and then make the demonstration. Some engineers and others who have had but little experience with the matter frequently attempt to show that no demonstration is correct upon a diagram without adding the volume of clearance, and whether it is guessed at or otherwise, it is necessary. The volume of clearance added to this particular diagram will not vary the expansion line more than the width of it, and for the purposes for which we make this demonstration will not allow the planimeter to discover any difference, but if we are figuring for the amount of water per horse-power, or steam per horse-power, the clearance is necessary in order to insure the correctness, but if we are looking to show what a certain pressure at a certain point will require cut-off at a certain point, to accomplish that base line the clearance is no more necessary in a computation of this kind than is the reading of a thermometer out-doors.

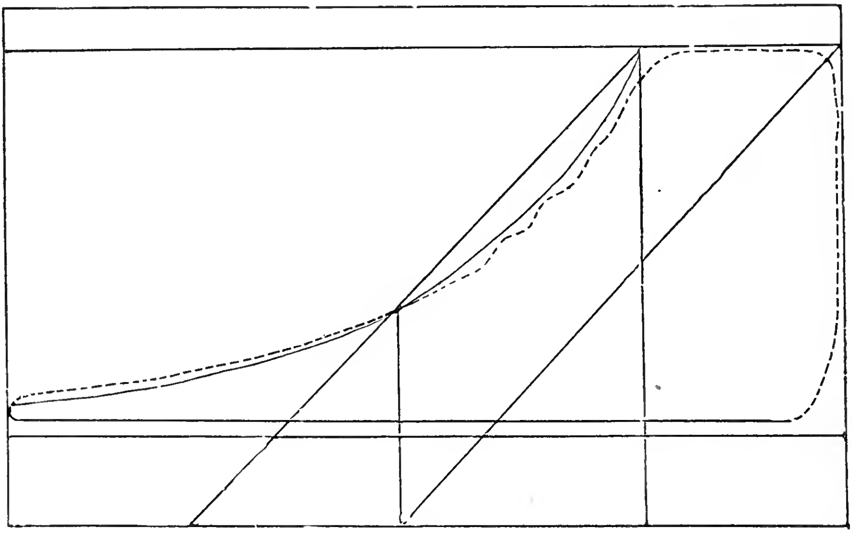


FIG. 155.

LESSON LXXVI.

AN OCEAN STEAMSHIP COMPOUND ENGINE FITTED WITH CORLISS VALVES.

Figs. 156 and 157 are from an ocean steamship, fitted with English engines and English-built Corliss valves. If we refer first to 156, the solid line diagram is precisely as the instrument left it. It is not a diagram that is pleasing to the eye from its general appearance or proportion, nor indeed is its mate when divested of the test of its efficiency. These were pronounced by several chief engineers to be very rough-looking diagrams, and so the general reader might term them; but as we are dealing not in proportions, but for information, we will apply the test and see. In the dotted diagram we have taken the absolute pressure at A from the absolute vacuum line D, which we find to be 54 pounds. Upon working the demonstration, as duly explained in previous lessons, we find that the realized pressure cut off at the point C E, gives the actual pressure at A upon the proper expansion of the steam. The theoretical line E, which is drawn dotted, shows plainly that the same approximation exists in the correct working of steam, as is shown from the time the steam valve gets open at the commencement of the diagram up to the point where the amount of steam equals the cutting-off at the point C E. The theoretical line in this case follows the actual expansion line for quite a distance so closely as to avoid any cause for criticism. The departure of the line of the instrument from the theoretical line shows plainly where the valve commenced to open to allow the steam to exhaust. The release is very good. We now come to a point in which there is a radical difference between the valves and those of some engines which are shown in this volume.

We find a receiver pressure at the commencement of exhaust of five pounds, the maximum pressure is between seven and eight pounds, barely reaching eight, while the terminal or commencement of compression is about seven. There is a greater difference in the action of this engine with reference to the receiver and the high-pressure cylinder in their relations to one another, than in that of almost any other large marine engine diagram shown in this volume. This steam line falls away but slightly, and we have an initial pressure of plus 70 pounds, which falls to 68 at about one-fifth stroke, and at the point of cut-off we have 62 pounds out of 70, showing that the capacity of this valve to furnish steam at the maximum pressure or initial pressure, is almost equal to fully one-half of the volume of the cylinder in its steam supply, while in the slide-valve engines, as a rule, we find a diminution of pressure varying all the way from 7 to 25 pounds from the initial, and in some cases exceeding even that. This might lead us to consider whether the perfection of valve motions is increasing or decreasing, so far as actual results go, upon the other marine engines of new construction. It is a self-evident fact from the diagrams, that while the compounds may have accomplished certain results with a less expenditure of fuel than that which has previously been accomplished, that there is still room for a vast improvement in the marine service, over that of the old-fashioned beam, or high and low-pressure engines, and whether this cannot be carried very much further so as to compare with the best stationary practice, in spite of the difficulties which beset the marine service, is not a question upon which much discussion can be had if the economic factor is a predominant one. This diagram, 156, so far shows the highest economic efficiency of any marine diagram we have yet obtained.

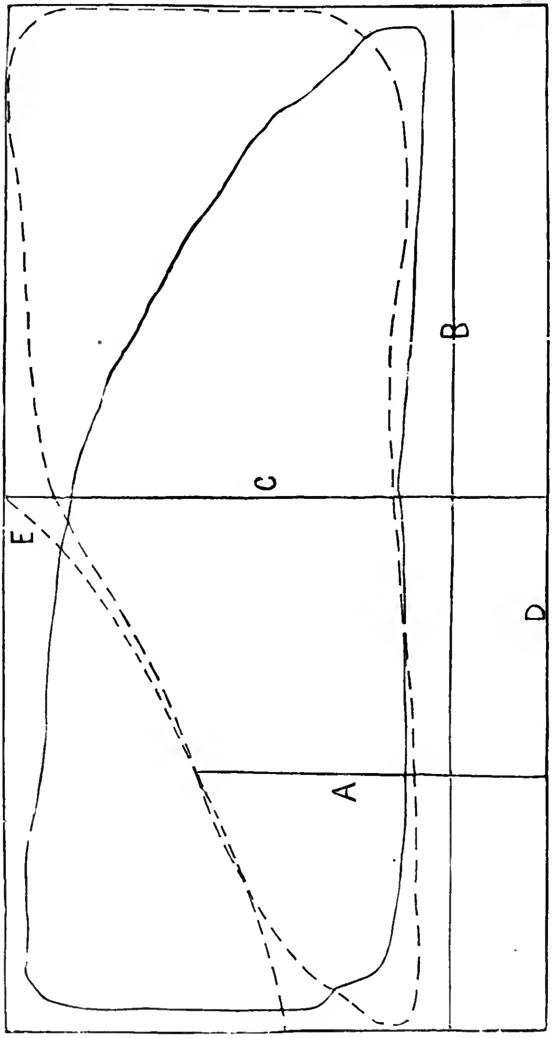


Fig. 156.

If we now turn to Fig. 157, which is from the compound cylinder, we have charged against this cylinder the maximum pressure in the receiver from the high-pressure cylinder diagram. It will be noticed that there is quite a falling off, and it is not the proper way, but in this case it has been deemed preferable, so as to see what loss was incurred from a possible one, taking the initial pressure as the maximum pressure of the high-pressure cylinder. If we take the realized pressure in the compound cylinder, it, if anything, is carried rather better as an approximation to a straight line than that in the high-pressure cylinder, the reason for which is undoubtedly a larger valve area. The demonstration in this diagram, taking A as the actual pressure from the absolute vacuum, gives us 13¼ pounds, and, taking the initial pressure as stated, gives the cut-off at the point C and the theoretical line E. In this case the approximation is exceedingly close, and the terminal theoretical pressure varies slightly above the terminal of the expansion line, as it will do whenever this basis is taken. If we are using a steam of lower tension than we really charge in our computation, its terminal pressure must be expected to be somewhat above the terminal of the theoretical line, for volume and tension must both be taken into account. The release in this case is not equal to that in the high-pressure cylinder. The expansion according to the theoretical is 4¾ pounds below the atmospheric line, while the actual line is precisely 4 pounds below. The commencement of the vacuum is between eight and nine pounds, gradually running down to between ten and eleven on one end and eleven and twelve on the other. The question may readily occur as to this effect in the economy of the engine; in our own minds a vacuum of twenty-four inches, or twelve pounds, is preferable to one of twenty-seven or twenty-eight; the question has been often asked but never answered, why should we use fifteen or twenty men at the mouth of the furnace in throwing in coal, and a donkey engine at the other end of the engine doing its level best, to produce a temperature of from freezing down towards zero on the alternate ends of the low-pressure cylinder, calling for its equivalent in heat at every filling of the cylinder with steam? The probability is, the engineer who has charge of this ship has found that he can run his feed-water a good many degrees hotter with a twenty-four inch vacuum than with one which goes lower, and, we have no doubt, that in that respect he is entirely correct.

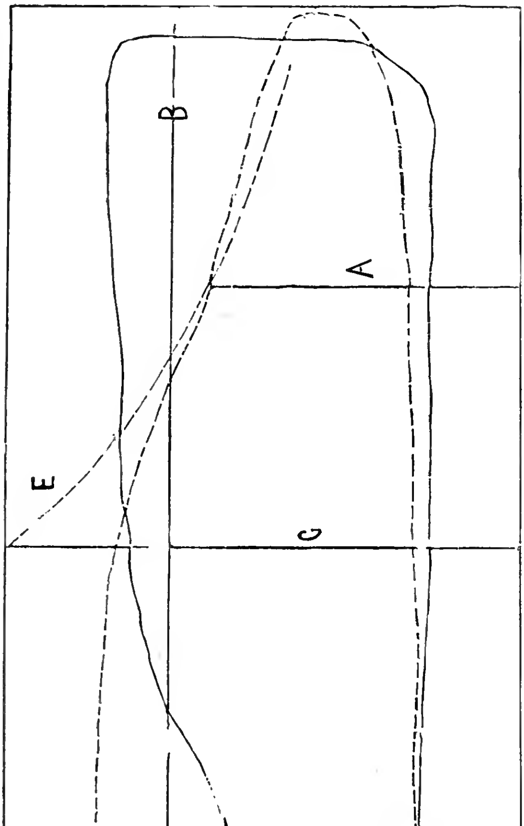


FIG. 157.

There is another thing which may be said of steam engine diagrams as taken from marine engine cylinders. We have been allowed to examine a great many steamships, and we have never yet seen proper or fully correct appliances for taking of diagrams. Usually the side-pipes are connected at the bottom of the cylinder, a round turn made and then connected on the side near the top. A three-way cock is arranged above the grating and the motion is taken from any convenient point. The clearance between the indicator and the bottom of the cylinder we have measured where it has had three times the distance to pass upon the bottom of the cylinder than on the top, for the steam to pass from the engine into the piston of the indicator, and for that reason we usually find the bottom of most marine engine diagrams latest, the corner most rounded, and it is not impossible that such is the case with 156 and 157. While the diagrams show practically the amount of power used, they show only an approximation to the actual in the valves, and the further removed the indicator is from the piston, the less is the accurate working condition of the valves shown or known. These two diagrams in 156 and 157 have a great many points of study for the practical engineer, and they show at once an entire difference in the handling of the available pressure, from that of most of the marine diagrams which are illustrated. The full dimensions of the engine and the boiler pressure are not given; scale of the high-pressure diagram is 30, that of the low-pressure, 8.

LESSON LXXVII.

ANOTHER OCEAN STEAMSHIP COMPOUND ENGINE.

Quite a contrast in practice from the preceding lesson, and yet one of the best engine results, will be found by a reference to Figs. 158 and 159, which are from one of the recently built steamships with high and compound cylinders, the high-pressure being 52 inches, compound cylinder 93 inches in diameter, length of stroke five feet six inches, revolutions 62½ per minute, pressure in boiler 90 pounds, scale high-pressure forty, compound twelve, vacuum gauge 25, hot well temperature 114°. The high-pressure cylinder has piston valves, the compound has slide valves.

Taking 158, our base line A shows that the cut-off occurred at the intersection of C D, D being the realized pressure, and C representing the volume of the cylinder in its proportion to the length of stroke that the line D is to the whole distance between the two extreme vertical lines. The theoretical curve E shows that the loss from initial pressure to the point of cut-off is 13 pounds, total loss from boiler pressure at the point of cut-off 19 pounds plus. The theoretical curve follows more closely than we would suppose after it strikes the line, running but very slightly below it. This would probably be accounted for by the fact that the steam is slightly superheated. The action of the valves in this case was very nearly perfect, so far as being tight go; the release is early, and the counterpressure in the receiver commences at eleven pounds, increases to plus thirteen, and at the point of commencement of compression is between fourteen and fifteen pounds. The point at which compression ceases and the steam valve commences to open, shows an almost exactness of 43 pounds upon either end of the cylinder; this is a point of very material economy in a quick-acting engine like this, which is quick-acting for so large an engine. The steam lines are carried very well, and the opening of the valves is very nearly right in both cases. This is a desirable improvement over that of some of the steamships which still maintain the old-fashioned slide valve, or even the old-fashioned piston valve with slow speed in its whole length of travel. In this case, we have no doubt the valves of the engine are not based upon the old-fashioned idea of valve travel, and yet there could be a radical improvement if they were speeded still higher in their proportion of travel to that of the piston of the engine. Possibly a little increase of travel would aid it.

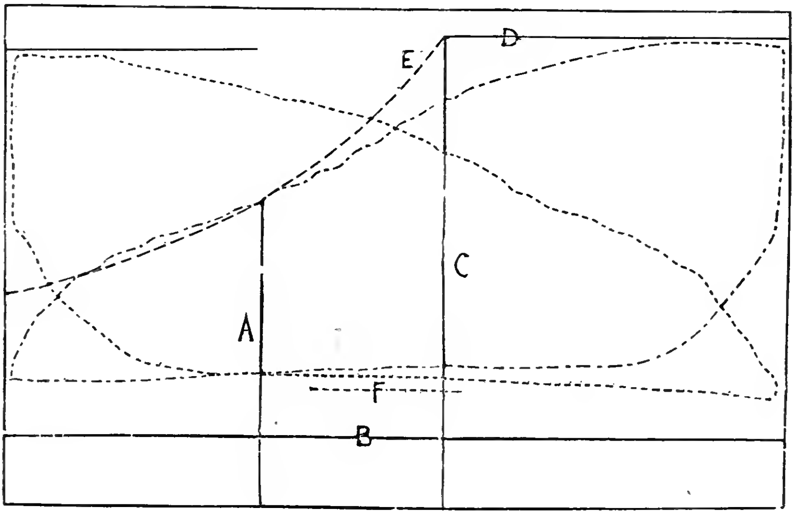


Fig. 158.

In diagram 159, we have again charged the engine with the full amount of the maximum pressure in the receiver. One end has 13 pounds plus for its initial, while the other end only gets 11 pounds, and it will be noticed that the end upon which we have erected the demonstration, the main valve is considerably later than on the other end. This, without any doubt, accounts for a portion of this change, and the contrast, as between the admission and carrying of steam in the two diagrams, shows the most radical difference between that of 158, the fact being 158 is piston and 159 slide valves. The opening and closure of valves in 159 show plainly that they are very slow in both motions, whether the passage ways are sufficient or not can only be told by actual demonstration from measurement, but it is a self-evident fact from the indicator, that the admission of steam on the left-hand diagram of 159 is exceedingly slow. The valve is also slow in its motion, and the pressure drops away much faster than on the other end of the same cylinder. This is sometimes accomplished by having the valves so balanced for opening that the real travel of the valve never reaches wide open on that end, while upon the other end of the cylinder the valve, having been cast solid and finished, had a travel which may be slightly earlier in its opening, and, owing to the angularity of the rod, quicker in its movement. In this case the theoretical curve follows closely, after the actual line of the instrument and the theoretical curve meet. In this case, our demonstration base A shows an actual pressure at the very point of crossing the atmospheric line of 14.7 plus above absolute vacuum. The line D represents the maximum receiver pressure, and the working out of the two problems on the base line A gives the point C on D, from which the quantity of steam at the pressure of D should have been cut off to furnish the pressure at A; and in the computation for power or fuel consumption, the amount of steam used between the valve's opening and closing, was equivalent to the pressure cut off at C on D, so that while the valve was not closed at C, its closing was equivalent to an increased pressure, and a diminished volume of the cylinder filled at that pressure to accomplish what was done at A. The release on both diagrams is very good, generally considered, but the right-hand end diagram seems to have some kind of a struggle going on which makes a curiously-shaped expansion line, or in the

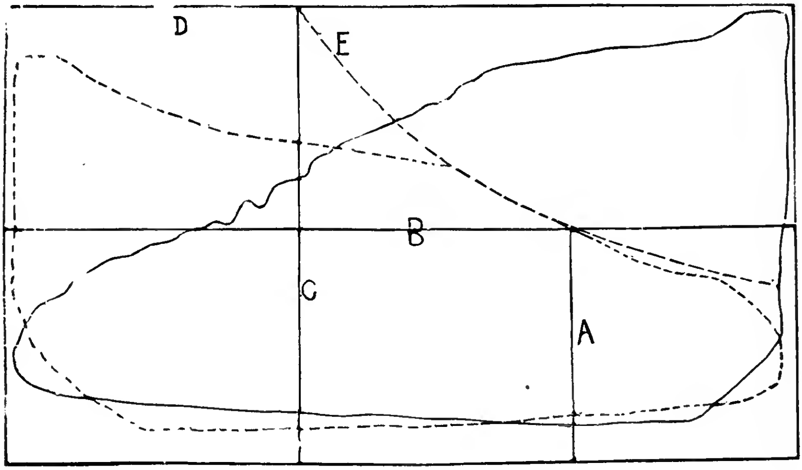


FIG. 159.

closure of the valve evidently causes some vibration in the pressure which is not fully accounted for. The solid-lined diagram commences with 9 pounds of vacuum, runs down to plus 11 pounds, compresses on about 12 pounds, and takes steam about the crossing of the atmospheric line. The other end of the cylinder commences its vacuum at about 10 pounds, running down to plus 12, as it could readily do from the less amount of steam used upon that end of the cylinder.

The two diagrams, 158 and 159, were taken by a Thompson indicator in order to ascertain the exact power, and as nearly as possible the position of the valves. It would be very interesting if short connections, and a positively correct motion could be arranged for this pair of engines. to get at the facts with reference to the actual position of the valves from a close connection to the cylinder, and the closest approximation to a positive and correct motion for the instrument.

LESSON LXXVIII.

CONDENSING CARRIED BEYOND ITS ECONOMICAL APPLICATION.

In Fig. 160 we have an old Corliss engine, which has been running night and day for a number of years, twenty-two inches diameter, forty-eight inch stroke, running 500 feet per minute piston speed, independent condenser, twenty-four spring. In this case the amount of steam actually used by the engine is represented by the line A, one end of which touches the admission line, and the other the dotted line, which is the boundary of the proportion of the cylinder filled with steam. The demonstration is made from the line of

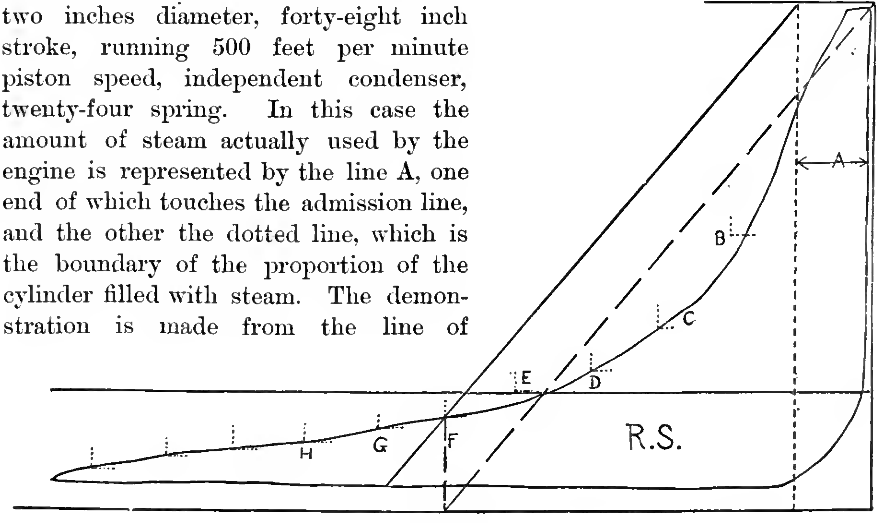


Fig. 160.

pressure F. Apparently the engine cuts off very much shorter than where the dotted line is drawn, but upon the demonstration we follow down the dotted corners of where the ordinates cross the lines, forming the boundary of the theoretical curve. At B we find that the line of the indicator or actual is below the theoretical, at C the actual line is but very triflingly below. Now what happens between A and B, or B and C? Nothing more or less than that the valve does not close tight, or else that it leaks after having closed and before it is firmly seated. From C to D the steam continues to come in; at E the expansion line is below the theoretical and it shows to the eye, comparatively, that the line drops. It is undoubtedly caused by the much more rapid expansion of the steam. At F the lines are together, and so on, getting a trifle above before the end of the stroke. There are several points about this worthy of notice, the first, that the expansion line is somewhat irregular, and the second is that the drifting which occurs from one point to the other is fully proved by the location of the theoretical and the actual lines. The vacuum, in this case, reaches nearly twelve pounds, or twenty-four inches; very many of our oldest engineers, who run condensing or compound, claim that at this point it is by far the most economical, as the temperature of the water at this particular point is much more advantageous for re-use or for feeding than as though more vacuum was obtained. The high range of change of temperature between even the terminal pressure of 3 or 5 pounds *pressure* and 12 to 14 pounds of *vacuum* makes a tremendous waste of live steam by condensation, and a moderate vacuum and hot feed water use less coal to produce the same amount of indicated horse-power, other things being equal. We believe this position is tenable; however, it is a point for argument, and engineers who wish to do so may find food for figures drawn from actual experience, in case they take it up, putting any experience they may have in connection with the facts.

There is another point about this diagram which we have not elaborated on, that is, the reference of the area between the high-pressure and condensing, the relation of one to the other. The question is, does this engine do as well as though it carried steam a little further at a less pressure or not? There is not the least doubt that in many cases engines are underloaded, and, "to save coal," the condenser is added, and more coal used with a condenser than without it; the reason is not far to seek. A small quantity of steam raises the heat but little, and it is easier to maintain 14 pounds vacuum on a small amount of steam, and the cylinders are refrigerators to a greater extent than the point of economy.

LESSON LXXIX.

AN OLD CORLISS ENGINE, ACTUAL COST OF A HORSE-POWER PER HOUR.

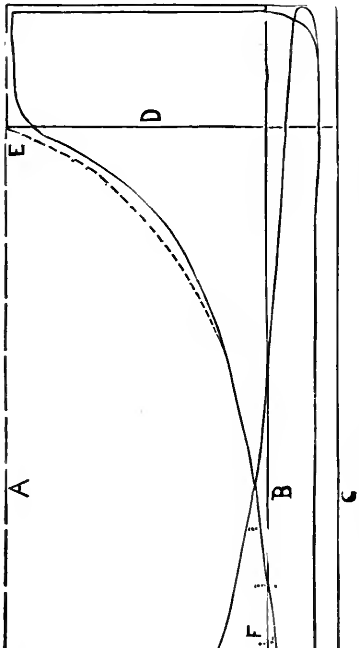


Fig. 161.

In Fig. 161 we have a Corliss engine which has been running a number of years, twenty inches diameter, 60-inch stroke, sixty-three revolutions per minute, fifty-five pounds boiler pressure, throttle valve wide open, forty spring, Thompson improved indicator, not quite the whole amount of work on. Both ends are shown. We have made a demonstration only upon one end for the purpose of finding out how the engine was running. These diagrams were taken with a three-way cock, or by changing from one end to the other. In either case, we have demonstrated from the diagram coming nearest the boiler pressure, and it shows a beautiful working of steam, A line of boiler pressure, B atmospheric line, C vacuum, D volume of cylinder filled with steam at boiler pressure to do the work, cutting off at E, or at the intersection of the lines A, D. The theoretical line is dotted down to the point where it runs into the actual line of the instrument, which is considerable of a distance above the point assumed for the base line. It then follows so closely that we have used our old method again of dotting the intersection of the lines in the demonstration. There may be a slight difference in the terminal of this diagram, for the original was very faintly drawn and was traced over by hand. The steam line is extremely good on the right-hand diagram; the one on the left falls off considerably, and the pressure would seem to have changed between the time of taking the two ends. The vacuum in this case realizes about ten pounds. The diagram was taken August 4, and we could hardly expect much more than ten pounds, or twenty inches, at that time of year.

Taken all in all, it is an excellent diagram. There is in this case no leakage anywhere that we can find. The admission line, steam line, expansion, are all good. If we were to change anything it would be an earlier release and a trifle more compression, and it is possible we might obtain a little more vacuum by so doing. At the time of taking, a portion of the machinery of this mill was stopped. There are some figures accompanying this which will interest steam users. The power of the engine, four times per day, six days per week, averages 151-horse. The fuel used is three-fourths anthracite coal dust from city coal yards, and one-fourth Clearfield coal. The cost of this fuel is as follows: Clearfield $3.30, and anthracite dust $1.80 per ton of 2000 pounds, in the coal house; sixty-six hours' use, 17,110 pounds of dust, 5,622 pounds of Clearfield, making 22,732 pounds, costing $25.80 ; average power, 151-horse. The diagrams were taken twice in the forenoon, twice in the afternoon, and the average of twenty-four cards in the week taken for the amount of power. Pounds of coal per hour, 344; pounds of coal per horse-power per hour, 2.28 ; cost of 151 horse-power per hour, 00.39; cost of one horse-power one hour, .00259. Three horizontal, tubular boilers are in use, 6×16 feet.

Two boilers are used in the summer, three in the winter. The fireman is not allowed to use a slice bar any time during the day, but when the fires are banked at night they are cleaned. The inside of the chimney is equal to the full area of all the tubes in the three boilers, and 106 feet high, and the flue from the boiler to the chimney is a little larger than the full area of the tubes in the boiler. Ash-pit doors are never closed when the boilers are running. The mills started nearly two years ago, and the grates are as straight as when they were put into the furnace. The agent is a close student of the indicator, has profited by his experience, and bought a new Thompson Improved for his engineer, and, on condition that we will not refer parties to him, has given us permission to state the facts in connection, and also that his engineers and firemen are well paid, and take just as much interest in the economic handling of the engine and boilers as he does himself. We might, perhaps, say that this engine was wanted in a hurry, and was second-hand before it went into this mill, having been replaced by a very much larger one. It was overhauled, and this is its record.

NOTE.—The cost of an I. H. P., in anything but fractions of a cent per hour, should not be allowed; pounds of coal per I. H. P. per hour is a meaningless and indefinite term.

LESSON LXXX.

WHAT AN OVERLOADED CORLISS ENGINE CAN DO—SOME OF THE GENERAL DEFECTS OF ARRANGEMENT.

The diagrams with this are from a Watts, Campbell & Co. Corliss engine, and we have laid aside anything that is theoretical or supposed, taking only visible facts. And this shows one of the instances which are constantly coming to the notice of the engineer who has any indicating to do, of the necessity of simultaneous diagrams for adjustment of valves, or for reliable data with reference to power exerted.

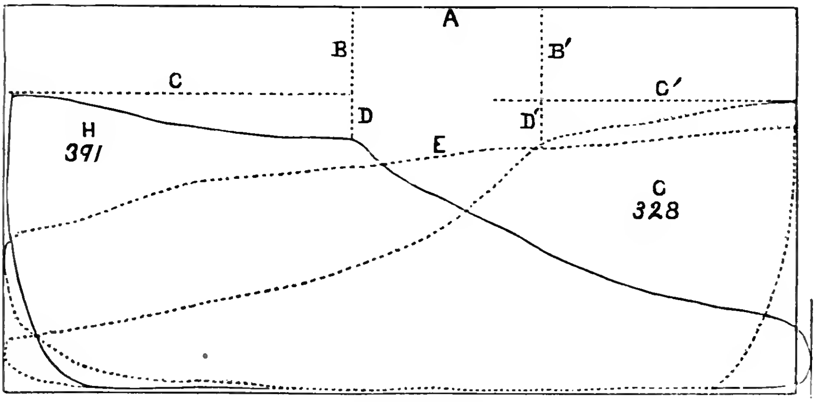


FIG. 162.

The diagrams in this case were taken on each end of the cylinder; A is the line of boiler pressure at the instant the diagram was taken, the scale being forty. B, B′ represent the visible point of cut-off, simply for comparison. C, C′ are the respective lines of initial pressure above the atmospheric line, or the instrument at rest. D, D′ show the lowest pressure from initial realized, and E shows what went on occasionally while one end was trying to catch up with or do as much as the other. These lines, simple in themselves, are full of meaning and will bear a little investigation.

The engine at this time was in the course of adjustment for the position of the valves to obtain the best possible results. The diagrams H and C were taken on the very same strokes of the engine, but we have not drawn in all the fluctuations caused by the reaching of the governor, first to increase for one end and then to diminish the cut-off cams' action for the other. We have here a boiler pressure of eighty-two pounds, a realized pressure of sixty-four pounds, a supply pipe of 2½ or 3 inches diameter for a cylinder of 14 × 32 inches running 80 to 88 revolutions. The H end diagram in this case measures 391 on the planimeter, the C end measures 328. The line E occurred on every single diagram that was taken until after the two ends were balanced. In this case 391 equals 79.5 horse-power, 328 equals 67.6 horse-power, so that on a load of 80 horse-power we have a variation of about twelve horse-power between the H and C ends on the same stroke, or almost sixteen per cent. It will be noticed that the terminal pressure of the head end is seventeen pounds, the terminal pressure of the crank end is thirteen pounds, while the terminal pressure of the crank end when it makes a jump, as in the case of the diagram E, is 33½ pounds. The loss in the first place eighteen pounds between boiler pressure and the highest realized pressure on the head end. A loss is also made from the moment the valves open until they cut-off of ten pounds more on the head end, between realized initial and the pressure at cutting off, making twenty-eight pounds below boiler pressure, or a little over one-third of the steam pressure to start with on the expansion line. On the crank end a loss of twenty pounds between boiler and highest initial and eight pounds between highest initial and at point of cut-off. By a curious coincidence both ends cut off at about the same loss of pressure although at different lengths. The crank end carries steam equivalent to about 13½, as compared with the head end carrying 18, call it inches only for comparison. Most of these diagrams show the racing of the governor up and down with every stroke of the engine, endeavoring in every instance after the valve had been set for the head to get around quick enough to set the valve for the crank; in this case very wide variations were the consequence, and, in the particular diagram which we have engraved, only three lines were made in order to catch carrying steam at three-quarters stroke. Wherever more than four or five strokes of the engine were made upon the indicator card we find this carrying nearly full stroke on every one, so that about one line in four, or five, the regulator jumped to catch the crank end with the head end. Good engineers will understand this at once. The changing of the governor is continual and about once in so many strokes it will set a little further than is necessary and skip tripping the valve. All engineers will also see that this is an exceedingly dangerous practice; there is a great deal of force exerted as between 60 and 100 horse-power, when it is only for a single stroke of the engine, and something has to withstand that power or else the engine would smash.

There is another peculiarity in this case; it will be noticed that the crank valve is very nearly in position so far as the admission line is concerned, while the head valve shows plainly where the cushion terminates and the admission line commences; also that the admission line leans away to the right from the vertical line. This engine had only one screw in the jim-crank of the main steam valves, and the thread which connected the crab-claw with the iron stem was so coarse that a whole turn was too much, and nothing less than a whole turn could be given in adjustment, which is not the case with larger size engines. The eccentric having been put right for three valves, and the same difficulty existing on the crank valve, we were compelled to leave it a little late on the admission line; for had we changed it again on the main rod, it would have thrown the crank valve just as much forward or backward, leaving us with only a whole turn to adjust with. This practice of having right and left threads on both ends of the exhaust and steam valve connections, to give nicety of adjustment should be insisted on by engineers in new engines.

If the readers will figure the pounds exerted between 79.5 horse-power on one end and 67.6 on the other, they will find that there is a very great change of force exerted between the different strokes and as many strokes as are made in each minute, which is not at all to the benefit of the engine. There are very many other points connected with these simultaneous diagrams, but leaving all but the practical, we find enough to encounter to draw our attention to the fact that it is very necessary to use both indicators, if we are getting either the power correctly, the variations in power or the position of the valves. It is an interesting study and more interesting in the practice. It will be noticed on the crank end that the exhaust is a little late on the small diagram, and that the same feature is very evident in the larger one. The small amount of power exhausts under a start of about five pounds, while the jump to nearly whole stroke exhausts under twenty-two or twenty-three pounds back pressure at the beginning of the return stroke. There are several interesting features which will be borne out if a little examination is given, and will prove all the more interesting.

This is one of the troublesome things to engineers, running from 50 to 100 H. P. regularly on a 60 H. P. machine. Some of the full load diagrams on this engine show 102 H. P., the builders did not apply the small feed-pipe, or arrange the engine to carry full stroke.

LESSON LXXXI.

AN OCEAN COMPOUND.

Figs. 163 and 164 were taken nearly three years since, from a then new ocean steamer; 163 is scale 32 per inch; 164, 12 per inch. The difference which is shown between the different ends of the cylinder show a trifle less than 300 horse-power difference between the left and the right-hand card. Taking A and A′ as the base lines, we find the point of cut-off at B, B′, from each of which points the theoretical line is drawn, taking the cylinder as realizing boiler pressure. The expansion line upon one end is somewhat peculiar, but closely follows the theoretical with a little difference, which will be accounted for, as between realized and boiler pressure. Upon the other end we have a different account; the steam enters the cylinder and immediately falls away in pressure, so that at B′ ten pounds of pressure is lost between the initial and the point of cut-off, allowing six pounds for lost boiler pressure equivalent to equal to the other end. There is a reason for this. The left-hand card is from the top of the cylinder where the distance from the steam way to the indicator cock is less than one foot, while the other end is taken from the bottom of the cylinder through a steam pipe more than five feet long. It is probable that the left-hand diagram is much nearer the fact than the right-hand one, and that quite a difference in the horse-power would be developed if both these connections were made short, and two indicators, instead of one, were used. The release of this engine is very good. We find the commencement of exhaust on one end with 7 pounds receiver pressure, and only a trifle more than 7 on the other; the maximum pressure is 12 pounds. Quite a variation occurs in compression, and if the difference exists in proportion to the length of pipe connection that is shown in the compression on the two diagrams, then the left-hand diagram has a square steam corner, and the right-hand one comes honestly by the little hump at the commencement of the steam line. All these diagrams for that matter are only approximately correct, on account of this very crude way of establishing the indicator connections between the top and bottom.

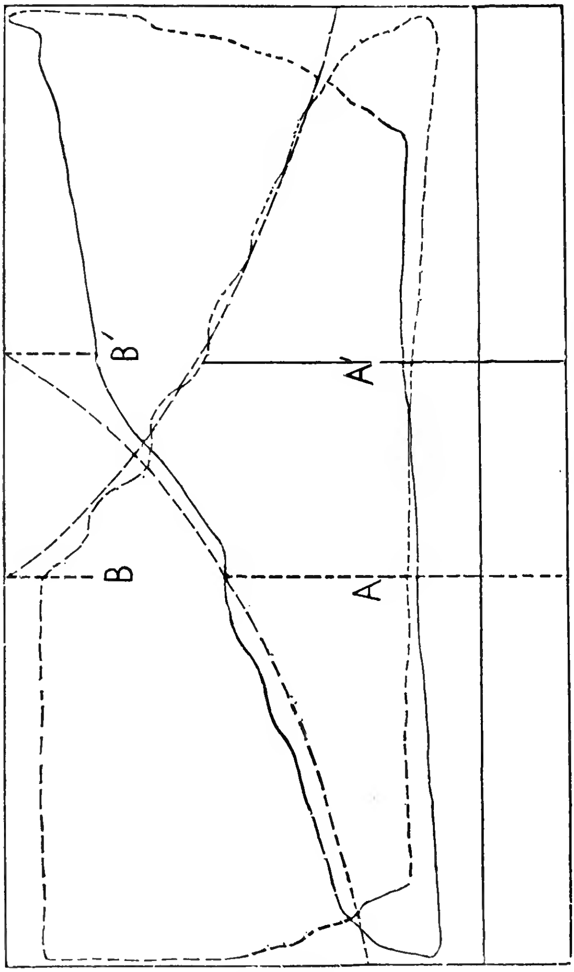


Fig. 163.

Turning to Fig. 164, we have a most peculiar train of circumstances. These diagrams were taken with a 12 scale. We have only drawn the theoretical curve upon one end, as that answers every purpose for comparison of the diagram. We first charge the engine with the full amount of receiver pressure, viz., 12 pounds; it will be seen that the opening of the valve is such that a little kick occurs in the opening action of the indicator. The steam line then falls off from receiver pressure almost 8 pounds. We have drawn the line D where the two steam lines of the diagram cross each other, and we find there a loss of plus 7 on one and about 8 pounds on the other end. But, to give the engine credit, we have drawn the line B on one side and B′ on the other as about the average of the realized pressure initial, and what the engine should have done if either end of the compound cylinder had have worked as well as the left-hand of the high-pressure. The line F is the line of the instrument, B is the line of initial pressure, C equals the volume of the cylinder filled or the point of cut-off, E the theoretical line drawn from the base line A. The steam in the cylinder if it had followed the line B up to the point C, and then the theoretical line would have yielded almost 200 horse-power more than it does do; the actual amount of the card shown is 1474.8 horse-power, while had it have realized the pressure B to the point C and the expansion line, with the same vacuum, it would have yielded 1662.9 horse-power. We find that neither end of the compound cylinder accomplished as much work as the high-pressure, and that there is a more radical difference in the actually developed power in the high-pressure cylinder, than in the low. The results in this case may be of interest to our readers. The steamship, from whose engines these diagrams were taken, made three round trips, the engines were very largely altered and very much improved, as they would need to be from the apparent action shown, from the very great differences which exist

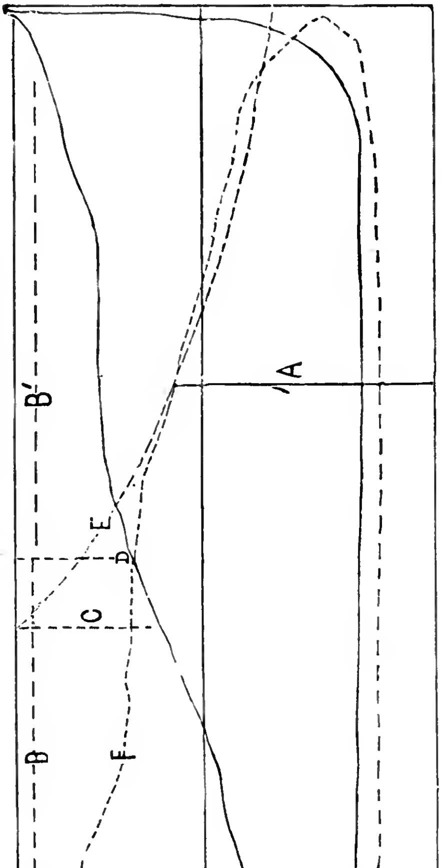


Fig. 164.

in both high and low-pressure cylinder, from first-class practices. These things are not visionary, theoretical, or supposable; it is only a matter of fact that they do exist as they do, and that it is so expensive a matter when such results as these are carefully figured out, to make a change in an engine, or abolish them entirely.

LESSON LXXXII.

DEFECTIVE CONSTRUCTION, AND AN INCIDENT IN THE USE OF THE PANTOGRAPH.

This lesson, with the exception of the Harris-Corliss diagram, shows radical defects in construction, in usage and in the application of the indicator, and it is quite as necessary that the readers of this volume should know where to look for difficulties and how to avoid them, as it is to know the theory of doing a thing right without having the practical results before them.

Figs. 165 and 166 were both taken from the same engine. The engine was of peculiar construction, and had been subject to several examinations and alterations, the warranty being, as is frequently the case, that it should equal the Corliss engine in economy, development and regulation. As the readers of this volume will have plenty of Corliss material with which to compare, they must form their own inferences or deductions, we have only to narrate the facts. The engine in question was built for a speed of 80 revolutions per minute; it was well located, well connected, but for some reason it had not given satisfaction to its owners.

Fig. 165 is an actual diagram with the simple addition of absolute vacuum, the base line and the theoretical curve, with a portion of the initial or realized pressure line added, in order to show that after the valve commenced to open, the pressure in the cylinder considerably increased, and instantly commenced to decrease perceptibly before the point of cut-off, which we have termed visible, occurred. The expansion line would seem to show a very fair action both of the indicator and steam, and without the theoretical curve, (with the exception of the joining of the admission and steam lines, and the little irregularities in that line as well as in the compression) it would seem to be a pretty good diagram. But when we apply the base line, to learn from it the point of cut-off and that one point of the theoretical curve quite corroborates the other with regard to the amount of steam used, it becomes less pleasant than on its first impression.

Fig. 165 was taken at a speed of 80 revolutions; the peculiarities of the diagram will be explained later. Fig. 166 was taken from the same engine during the same trial or observation, and at a moment when the speed of the engine had reached 124 revolutions per minute. The peculiarities in this are that the same general features which occurred in 165 are present, both in the compression and steam lines, and that the serrations or irregularity of the steam line is increased very much more by the high speed than it is by the usual speed of the engine. It will be seen also that the point of cut-off is quite different from that of the previous diagram, or 165, but that there still remains this extreme leak, and that both points on the theoretical line, initial and terminal pressure, corroborate the previous reading. Fig. 165 figures by the planimeter 10.1 horse-power; Fig. 166 figures 10.2 horse-power., at the different speeds at which they were running, at the moment of taking. It will be noticed that the steam line in both these diagrams shows almost a parallel line with the vertical at that end. This engine had been carefully examined by an old engineer, who had indicated it and reported upon it; the report was very favorable indeed. The facts in the case are as follows: The two diagrams, 165 and 166, show a variation of revolutions, 44, per minute; during the time of the trial, the engine ran from 68 to 124, and there was connected with it an attachment for showing the variation in speed, which during the time ran completely off the paper band, without making the least mark; so much for the facts with reference to the regulation. During the time of trial, which extended over some thirteen hours, we applied the theoretical curve, and were somewhat surprised. When the finish of the test was made, the manager was called upon to make some examinations (which had been quietly made the night before, but without any proof). His attention was called to the fact that the piston traveled over the indicator plug holes at both ends of the cylinder, so that, as a matter of fact, the diagrams were perfectly worthless in regard to their steam lines and admission lines; the expansion line is, however, fully corroborated by admitting steam to the chest while the valves were unhooked from the eccentric, and such a jet of steam as came through the indicator plug holes has only been seen by those who have found valves which leak badly. In the case of 165, the steam line

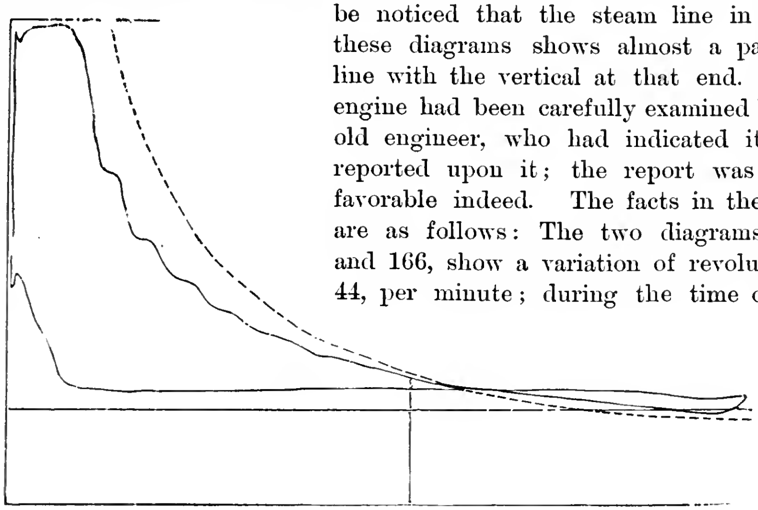


Fig. 165.

approximates closely to a parallel line, but when the piston moves back so that the indicator hole is uncovered, the steam is admitted more and more into the indicator, giving a triflingly higher pressure just as the movement for the cut-off begins to take effect. The compression plainly shows that something goes on beyond it, and whatever amount of space may lie beyond that covered by the indicator hole we know nothing of, for no changes could be made, or we would promptly have made a clearance with a cold chisel or drill.

Fig. 166 shows the admission while the engine was racing, and simply magnifies what is plainly seen in 165 in a smaller degree. The expansion line in both cases, without the theoretical, would give an idea of a good line.

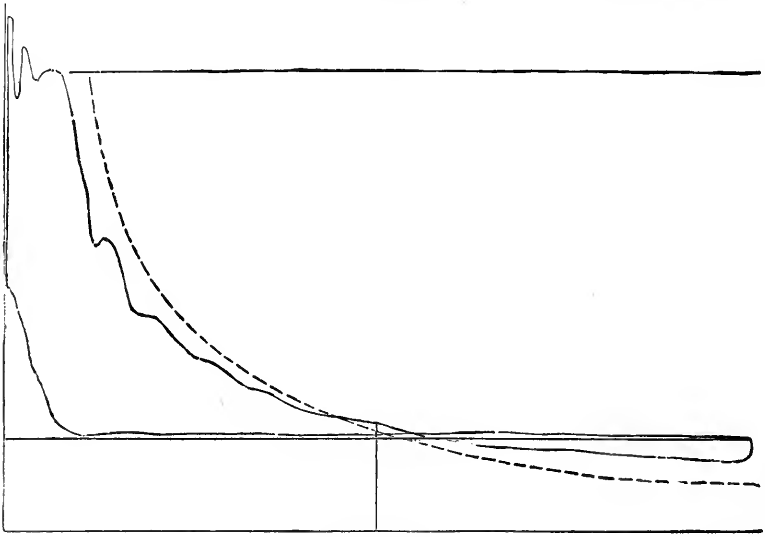


FIG. 166.

But, taking the actual pressure at the base line of the demonstration, we find there is entirely too much pressure for the steam and volume cut-off as by the visible point of cut-off on the diagram. We also find a corroboration of this in the fact that the theoretical line runs below the actual line, and the terminal pressure is as much too high in proportion as the absolute pressure is at the point of the base line. We were told some months after that the price of this engine had more than been paid by the damage it had done to the place it was working in, which would seem to corroborate the indicator's work to the extent of wasting the steam, and also the fact that the regulation was exceedingly far from that of the average-built Corliss steam engine. These two diagrams, 165 and 166, are well worthy the careful study of every engineer who desires to know something further as to the reliability of the indicator. Both diagrams were taken with a 30 scale.

AN INCIDENT.

Fig. 167 is from a Harris-Corliss engine slightly throttled, scale 40, and the only remarkable feature about this is the peculiar twist in the expansion line, something which very rarely occurs. This occurred a number of times while the author was busy in changing the valves, eccentrics, cranks, etc., and was really quite a puzzle until particular attention was given to what made it. The result of an examination proved that the cord which led from the indicator to the pantograph motion, which was being used, struck upon the top of the slotted screw next to the post to which our strings were attached, in such a way that a snap was given to the cord both ways, suddenly changing the speed of the paper barrel first above and then below, until this slot-headed screw, in the forward and backward movements of the cross-head, passed out of reach or control of the line of string. The pantograph was dropped a quarter of an inch on the post, and as much in the cross-head, and a long attempt was then made to repeat it, but it was no use. Both indicators were taken off and carefully examined. Nothing was found out. The pantograph was again raised to its original position, and the matter was repeated, with variations, to satisfy us that this kind of an expansion line can be produced by snapping the indicator string by the movement of a nail, peg, or any other obstruction, across the line of the string. This same matter comes up wherever the pendulum is applied to any engine for the purpose of taking an indicator diagram. In this particular case the speed of the paper barrel was generally changed, first fast and then slow. The same thing occurs, although it is seen in a different way, and will be treated of hereafter, whenever the pendulum motion is being used, unless the sliding bar is used to communicate the motion to the indicator barrel. Whenever the pendulum is so attached that the motion is coincident with that of the piston, and is also exactly equal both sides of the center, very little variation will appear; but whenever the swing of the peg, or even an arc of a circle is used to communicate motion, the distance traveled is unequal distances on a straight line, while the speed of the motion may be uniform; the travel being upon an arc of a circle, it will give an unequal distance when applied to the travel upon the slides by the cross-head, and this varies the speed of the indicator barrel; and while it may be small in amount, it is suf-

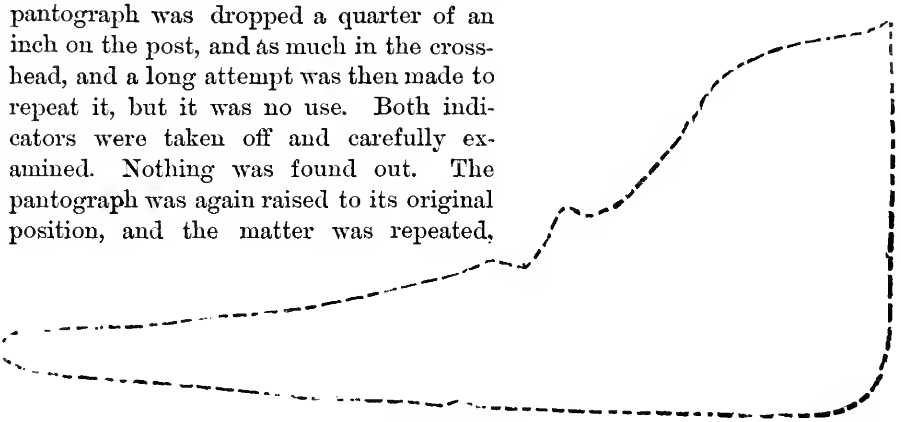


Fig. 167.

ficient to make the expansion line entirely unreliable. This same point can be accomplished by boring a hole and putting a little peg, which has been slightly slotted on the top, with partly rounded sides, into the peg arm of the pantograph ; but if the experiment is tried, be careful that this peg no more than strikes about one-third or one-half the diameter of the indicator cord, or a paper barrel spring completely smashed may be the result. This is an extremely insignificant point in some respects, it is the key to any motion that varies, or attempts to make straight travel by passing through an arc of a circle.

A CURIOSITY.

Fig. 168 is another experiment in steam engine building, scale 30. This was an engine used in grinding rubber. The cylinder was built with Corliss valves, while a different style regulator had been attached to an old bed, or the girder part of the bed. The several diagrams are only a small portion of the erratic movements caused by the changes in the regulator. The changes in the load were considerable, and the regulator would sometimes change from its highest to its lowest point on the very same stroke. Very little more can be said about this figure than that it shows a regulator utterly unfit to be used where any change of load should occur, and shows also that there is an exceedingly good opportunity for the engine to smash itself, in case of a sudden change from one load to the other, that was from the heaviest load to the lightest. On the other hand, if it was suddenly from light to heavy the engine would be exceedingly apt to stop. A, A, indicate the extreme ends of the atmospheric line of the instrument, and, in order to show the differences between the exhaust lines of the different diagrams, the atmospheric line is omitted. B, C and D show variations, the card intending to cover ten strokes of the engine, speed 80 per minute. It shows also that the engine is entirely insufficient in its port ways to exhaust under carrying steam two-thirds of the stroke. It shows in

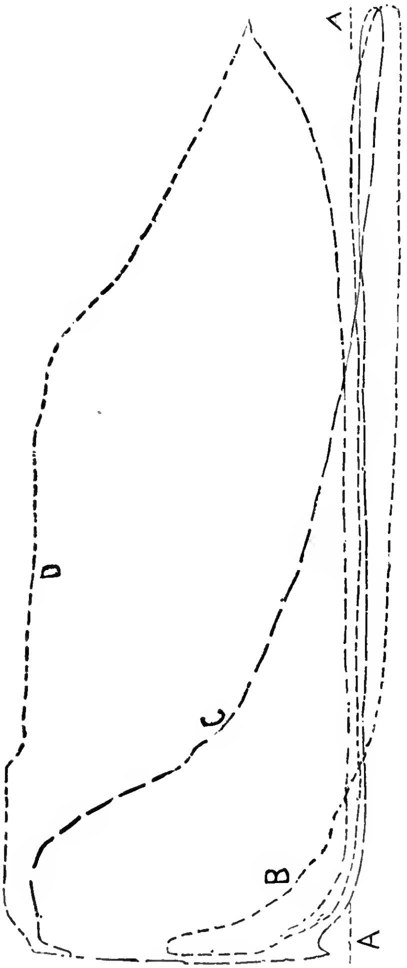


Fig. 168.

every case that the valves are a trifle late in their action, and the steam lines do not approximate very closely to a Corliss engine built by any of the builders who understand their business. In this case we have a pretty good cylinder with a very poor regulator, and an exceedingly poor showing of a Corliss engine for regulation, but it is a Corliss engine only in name, like many others, the improvements upon it make it practically worthless, or a departure from the real Corliss engine principles makes a departure from good practice and also from good results. These four diagrams cover an amount of information which will only be measured by the patience that the persevering reader shall give to them, and the benefits which he will derive will only be measured by his acuteness and careful attention, and if these are given many engineers will be saved trouble or being humbugged by any attempt by parties who are interested in the sale or attempted misrepresentation of the actual working of machines. Excepting 167, these should all find their way to the scrap-pile, and cease to be an annoyance to the engineer in charge, as well as to the men who supply steam and fuel for their running.

LESSON LXXXIII.

FOR THE BEGINNERS.

During the four years which have elapsed since the first systematic course of articles upon the indicator first appeared, the author has found very frequent inquiries for the elements, as men were continually taking up the indicator to learn something of it, who had not seen the first series of articles, and consequently had omitted many little points which are essential to men who have never held or handled the indicator; to such ones this lesson is especially adapted, while it will not do the older ones any harm to occasionally run over it in order to obtain other or more information and frequent reference to something about which they may have doubts. The indicator is intended not only to measure correctly the proper power exerted, but it also gives us, if correctly applied, the manner in which the valves handle the steam; it tells us of the position of the valves with regard to the stroke, whether the motion of the valves is sufficient or not. It also tells us whether the ports, passages, throttle valves, steam pipes, exhaust pipes and ways are all sufficient, or, if insufficient. It is not able to tell the particular point at which the trouble is, but it will give the trouble, and then we must find its exact location. It frequently shows us that feed-water heaters are an element of trouble by the insufficiency of the area of the steam passage allowed for the exhaust steam. Sometimes it will tell us of a leak in valves, or of many little points which are not necessarily to be particularized here, so that to cut the enumeration of all these things short, the indicator will tell us at any time, if honestly applied, when the engine is working correctly or incorrectly; if incorrectly, it will show whether there is back pressure, too late release, too tardy admission, throttling between admission and expansion, whether the engine is overloaded, or any of these numerous happenings which can be found in item and detail by the previous lessons in this book. Directions have already been given for computing; any one can do this, who chooses to give a little time to it.

Now the standard in all cases is the ideal or perfect diagram. The perfect steam engine (which has not yet been built) is expected to economize by the use of full boiler pressure, to cut it off sharply, expand it theoretically, release it early, exhaust, if non-condensing, at the atmospheric line, and if a condensing engine, we are expected to accomplish about 14 pounds of vacuum (theoretically 14.7 at the level of the sea) to compress slightly according to the fancy of the builder or the engineer, and in this way to realize all the heat units and the effective pressure upon the piston, and in that way make the coal consumption reduced to the minimum. The steam engine cannot, however, go back to the steam boiler and rearrange inefficient furnaces, too large or too small steam space, or any of the thousand things which may go towards making an incomplete, insufficient, or badly arranged boiler plant. The engine is expected to take the steam pressure in the pipe and use it in the most economical way; for that reason, we have constructed in Fig. 169 the generally-accepted theoretical diagram. It is made upon a

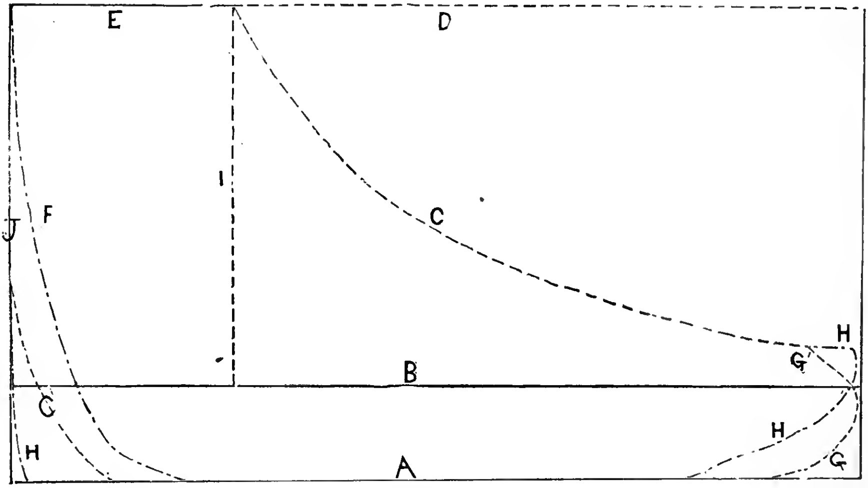


Fig. 169.

scale of 30 to the inch, having 60 pounds steam pressure and 14.7 pounds or absolute vacuum. The various lines to which frequent references have been made in this book, are as follows: A is the absolute vacuum, which differs with the barometric reading, and we have laid out the vacuum for the level of the sea; B is the atmospheric line of the instrument or *the* line at which the pencil point of the indicator rests after having been thoroughly heated, after allowing the steam to come in contact with the piston and working parts of the instrument, and then shut off all steam connections. And here it is well to take notice of a little point which may have been omitted; when the indicator has been attached, the motion arranged and the cord or wire connected, turn the steam gently upon the spring, heat the instrument thoroughly, and not until this has been done, should the atmospheric line be taken; having done this, now be extremely careful never to allow a particle of steam to escape from the three-way cock while taking the atmospheric line, for if you do, you will distort the line, making it too high or too low; D represents the boiler pressure, and is dotted from the point of cut-off E, I, the rest of the length of the diagram; E represents what is usually spoken of as the steam line, or that portion of the diagram made between the time the valve is opened and that portion of the piston travel that the valve is held open; the dotted ordinate, I, dropped from E shows the point at which the cut-off valve is supposed to have positively closed, and C represents the expansion line from the point of cut-off E I to the point of release G′. We will digress for a moment. Such a steam line as we have drawn in Fig. 169, E, will not be found one time in thousands, the reason for it is assignable to a great variety of causes, which may be changed materially by either of the following; by inattention to the correctness of the reducing motion, and insufficient steam ports, steam passages or steam pipes, or too small a throttle valve, to an ill-proportioned travel of the valve with reference to the piston; wherever any of these reasons operate, this line will be modified in any of a great many ways which are shown in the preceding lessons, as well as in Figs. 170, 171. The expansion line C partakes of a great many variations. It is exceedingly rare that we find one that approximates very closely, and for this there are a great many different reasons; the distortion of the motion, any error in the travel or capacity of the valves, any leak in the valves, which may be very trifling, will make a difference in this line. Leaking by the piston, the presence of water, to which is added the variable speed of the piston, or expansion, diminution of pressure, increase in volume, a change in the physical properties of the steam, and if the indicator itself be not in perfect working order, the expansion line is likely to be an erratic one. The theory upon which the expansion line is based is that of Mariotte's law, that increasing the volume diminishes the pressure in a certain known ratio. This from the very nature of the thing, has never been definitely proved, but the general foundation of the law is that as the volume doubles the pressure decreases one-half, and so in proportion. At G′ the continuation of the dotted, like the expansion line C, has been drawn at an angle rather sharper, perhaps, than the general construction of engines will admit of in release, by the actual lines of the indicator, but we have drawn it thus distinct, for the working engineer has frequently an idea that he should not release until he had obtained everything that was possible out of the steam. Here is a point of practice about which some engineers now differ, but those with the largest machinery and the broadest practice, have no doubt and no difference, viz., if we commence our release at G′, following the line which shows a rounding into the condenser at the extreme end of the stroke by a full open valve, we shall then continue the line G below the atmospheric line, so that it reaches the full extent of the vacuum at about one-tenth of the stroke; and if the exhaust valve of an engine—taking the Corliss as standard, or any other well-constructed engine—opens a little before the end of the stroke in order to release the expanded steam as soon as possible, and allow the condenser to have full swing at it, we shall close that valve as much before the end of the stroke on its exhaust as we open it before the end of the stroke, provided the builder of the engine has properly proportioned the travel of the valve. As we are working on an ideal card, we shall suppose we are dealing with a first-class builder so that the distance from G′ to the end of the stroke, will give the condenser a wide open valve at the very commencement of the return stroke, and will immediately reduce the steam to full vacuum at the intersection of the lines G A from the terminal pressure end of the diagram, and will make the dotted compression line G, touching the vertical line J at about 17 pounds above atmospheric pressure. There is a great difference of opinion among engineers, some claiming that it is impossible to compress upon a condensing engine. This is a mistaken idea, and, while many prefer to run their engines without any compression, they will find, if the engine is properly constructed, that compression within a reasonable limit is invariably an advantage, because, if we take the line G as an instance, we have 17 pounds above the atmospheric line of pressure at the very end of the stroke; if, now, the steam valve is properly set, so that it commences to open and continues the dotted line G, from its intersection with J, following up the line J, by what is known as the admission line, we shall then have 17 pounds pressure in that end of the cylinder upon which we put enough

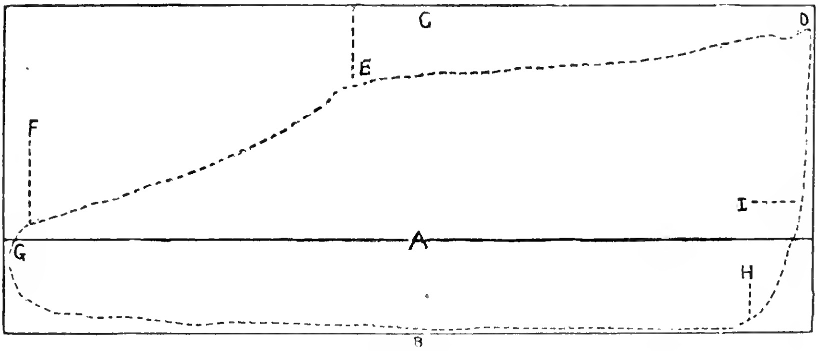


Fig. 170.

to bring it up to 60 pounds, while, if we do not have any compression, we have to put 60 pounds instead of 43. We have now completed the circuit of the diagram; upon the same diagram, 169, notice the irregularly dotted line H (which is the most usual line of compression) in which the steam is carried beyond the point G′, by means of the dotted line H, which is differently dotted from G′, and where the steam pressure is confined until almost the extreme range of travel of the piston, barely commencing to open at the very end of the stroke, in which case the irregular line H is continued and shows the effect of a later opening, so that the absolute vacuum is not obtained until the piston has traveled twice as far on its return stroke, or about one-fifth of the whole stroke, as it did with the earlier release at G′. As the motion of the valve here is later, so it will be later in closing. The line H is supposed then, from the point of its intersection with A, to travel from the line A until it reaches H, where it will be found to extend but little above the atmospheric line, making only a pressure of eight pounds. The general practice on condensing engines is that wherever the late opening and late closure are practiced, that it is much more frequently followed with 7, 8, 9, or 10 pounds of vacuum instead of 14.7. The earlier the release consistent with proper compression, the larger amount of vacuum is obtained from the same amount of steam. The later the release, the later the compression, and the less amount of vacuum is generally obtained, but as all classes have their ideas, and we take diagrams from all descriptions of adjustments, we have thought best to introduce here for the beginner's benefit, the long dash and dotted line F, which shows a very general idea of excessive steam lead, joined to a considerable compression. This line may be made either by excessive compression or by a steam lead; and by steam lead we mean just this, that the compression took place from the absolute vacuum line A, and the steam valve opened considerably before the piston arrived at the end of its stroke or the dead center. This line will be frequently found upon modern constructed engines where an attempt at high speed has been made, but it is not desirable. The difference between excessive compression or steam lead, and correct compression is simply this, if the valve is shut before the exhaust is complete, or slightly before the piston arrives at the end of the stroke, a small amount of low tension steam is compressed gradually to a higher pressure, and consequently to a higher temperature, and it offers mechanically a "cushion" upon which the piston gradually strikes, and it comes to a more gentle stop than as if nothing were there, when there would be a certain amount of strain upon the gibs, keys and connections, if the cushion were not present; and with the cushion an amount of steam is saved, and the wear and tear on the connections of the piston rod, cross-head, connecting-rod, crank-pin is reduced.

For any variation from the ideal diagram there is always some reason, and the beginner or the man who has had practice, should aim to obtain the most perfect results that are possible, and, in every instance, to investigate every departure from the theoretical, unless, as in some of the instances given, the simple outline of a card shows an exceedingly faulty construction;

and it is sometimes well for a person who has not had much experience to study these very faulty cards for his own benefit and future reference.

With a view to some contrast we have introduced Fig. 170, which is from a Corliss engine, overloaded and throttled, or choked in the steam supply. Referring to this figure (170), A represents the atmospheric line of the instrument, B absolute vacuum, C steam-boiler pressure, D highest initial pressure realized, which is only 33 pounds out of 38. The steam line from D to E, supposing E to be the point of cut-off, shows 8 pounds less steam pressure at the point of cut-off than at initial. This is caused by the feed pipe being too small, and contrasts strangely with the ideal line E in Fig, 169. The point of cut-off at E, 170, will be seen to have been rounded over, which is caused by the slow closing of the valve, and the expansion line in this case may proceed closely on the theoretical line, if he can find the exact point of cut-off. F is the point of release or evident opening of the exhaust valve, and

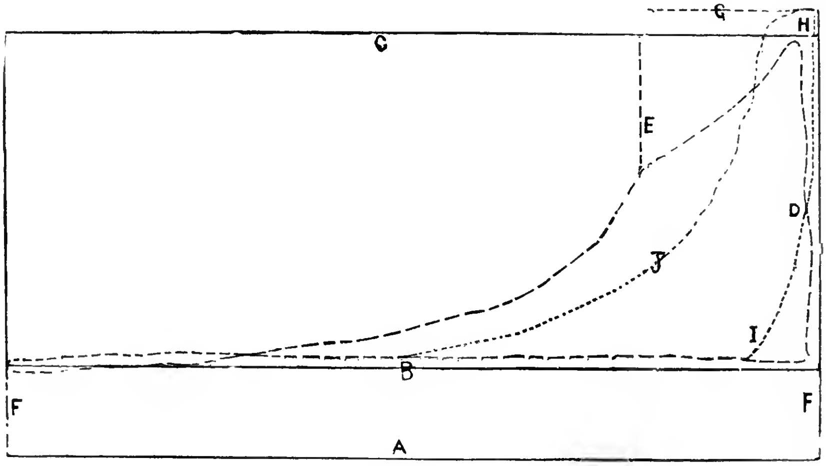


Fig. 171.

G is the commencement of the vacuum, and it will contrast very strongly with the ideal line in Fig. 169, as shown, and in this case (170) the engine runs back to nearly one-third stroke before the maximum amount of vacuum is obtained. At H the compression commences and closes at I above the atmospheric line; while the steam line from I to D, Fig. 170, shows that the valve commences to open very slightly before the piston arrives at the extreme end of its stroke.

In Fig. 171 we have another type of very frequently-found trouble which is more marked in this case from the fact that it is from a Corliss engine. Many engineers have an idea that they must invariably get an engine under motion with a partly closed throttle valve. A Corliss engine that will not start with a throttle valve half open or more, is decidedly out of adjustment. In this case we will not, however, discuss anything except those points which the learner most frequently desires to have thoroughly fixed in his mind. The coarsely dotted diagram, if we start at the point D, shows that the steam valve opens too late; at the top of the line, directly under the letter H, it will be seen that the steam line leans to the left, or away from the vertical line F. The peculiar shape of the steam line, from H down to E, is caused by the throttle valve being so nearly closed that steam enough is not furnished to keep the pressure up to the line of realized pressure C; consequently the cut-off valve is held open for a greater proportion of the stroke than would be were the throttle valve wide open, in which case the pressure C would only be realized. At E we find the visible point of cut-off, or near enough for practical purposes, is 21½ pounds below the pressure at H, while the expansion line runs below the atmospheric, making a loop. This loop is, in all cases, resistance, and should be so figured in computing the diagram for power. If we follow the exhaust line on the return stroke of the piston, we find a square corner at the terminal of the exhaust, and the steam line commences, leaving the vertical line F more and more, which shows that the opening of the valve is entirely too late. The fine dotted line shows the eccentric rolled forward on the shaft to bring the steam line from the point D up to the vertical line F, or so that the valve commences to open and admit the steam as soon as the engine gets upon the dead center. It is a fact, that whenever the valve is late in its opening, the pressure of steam is invariably reduced, and the later the valve is in its opening, the greater the reduction of realized pressure. In this case, after the eccentric has been thrown forward to bring the steam line proper up to the vertical line F, which is at right angles to the vacuum A, and atmospheric B, as well as the realized pressure in the first case, C, it will be seen that the realized pressure on the piston increased nearly five pounds, or to the line G. In this case the throttle valve is wide open; notice the beauty of the expansion line J, which we have only drawn until it reaches the exhaust line at about the point B. This would make decidedly more of a loop than the coarser dotted diagram, but in moving the eccentric forward we have also accomplished another very important and economical point, which is the compression. Notice the fine dotted line I, which compresses the steam 23 pounds to the point D, at which point the steam valve commences to open and fills the cylinder with steam the balance of the 56 pounds. Both these objects, viz., opening the steam valve at the proper time and closing the exhaust valve quicker, are accomplished in this case by moving the eccentric about three-quarters of an inch of the circumference of the shaft forward. Sometimes when this is done we may throw one valve exactly up to the right point and the other one may be too quick, or to give too early a steam line, and it may affect the exhaust valve or compression and release in the same way. Get the steam valves right by means of the jim-crank connection, and on the Buckeye engine, get them right by the compensation arrangement on the valve rod, by which you can divide the travel of the valve, or any difference in the travel to the hundredth of an inch. In the Armington & Sims engine this is usually done at the shop, but in case of tinkering or changes, take off the valve chest cover, and move the check-nuts on either end of the valve until you have it exactly where you want it, and whenever any changes on the engine are made in this way, pay no attention to prick-punch marks, cold-chisel slashes, or anything of that sort, work by the lines of the indicator, taking care that they are perfectly correct in their motion, corresponding to an absolute reduction from the travel of the piston. In this way no difficulty will be found in adjusting the valves of a Corliss engine to an exactness that will give a small fraction of a horse-power difference on a large engine between the ends.

On some of the slide-valve engines, it is exceedingly difficult to balance, for we frequently find the travel of the valve not correctly calculated, in which case we must work for the best good of most of the factors in the combination. Sometimes we have to sacrifice a little on the steam line for the sake of being sure of a good release, and at other times we get a release without compression for the sake of admitting the greatest amount of pressure.

But there are other methods of attaching the indicator which are very valuable. Fig. 172 shows two different diagrams taken at different times,

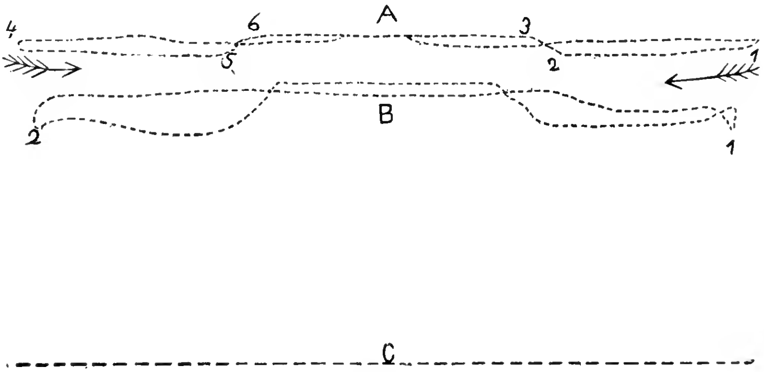


Fig. 172.

but both for the same purpose. These are what are termed steam-chest or steam-pipe diagrams; they are taken by attaching the steam engine indicator to the steam chest where possible, or to the steam pipe below the throttle valve, and connecting the indicator with the same motion by a separate cord (taking pains that no angles except right-angles are made) with which the indicators at the end of the cylinder are driven. Care should be taken to make the steam pipe diagram of the same length, as nearly as possible, with the diagram from each end of the cylinder. In that case the proportions between them are precise, while in the case of a longer or shorter one it requires figuring to learn their proportions.

Fig. A, 172, was taken in 1868 from a Harris-Corliss engine, scale 30, to ascertain what proportion of boiler pressure was realized, and a little study of the diagram will satisfy any engineer that these steam-pipe or steam-chest diagrams are quite as valuable as those taken from the end of the steam cylinder, and frequently they give us a clue to what occurs before the steam reaches the steam chest, so that we may not pull the engine down but rather pull down the pipe and go back to find the trouble. If we start at figure 1 and follow the line in the direction of the arrow to 2, we find that the pressure in the steam chest is slowly diminished, while the valve at that end of the cylinder is held open, and this distance from 1 to 2 shows the exact distance that the valve was held open, or until it completely closes, in feeding the cylinder with the amount of steam allowed by the position of the regulator cams at that instant of time. The valve commenced to close at 2 and the pressure gradually increased up to 3; the valve was at that time fully closed and the pressure ran along to just beyond A, where the pressure dropped slightly by the draft of steam in the pipe. At 4 the other end of the valve opened and steam was carried from 4 to 5, at which point the valve commenced to close and made a more abrupt closing from 5 to 6 than from 2 to 3.

This diagram in itself is one of the finest we have ever taken, and if carefully taken, they tell the action of the steam in the pipe, precisely how far steam is carried on the cylinder, when the valve opens and when it closes, and every fluctuation of pressure which occurs in the pipe from beginning to end. Fig. B, 172, is from a Buckeye engine, at the American Institute Fair in New York, taken in November, 1884, scale 50. This engine was running from 222 to 225 revolutions, and it presents a contrast to the other diagram, from the fact that a large amount of compression was shown upon the right-hand end and a moderate amount upon the other. At figure 1 the pressure falls with the opening of the valve in the steam pipe, is immediately raised by too much compression, and this occurs while there is but a very slight movement on the part of the piston toward the completion of its stroke. The steam pressure is then led off by the opening of the valve, toward B, falling off very little indeed. It will be noticed that the curve on the Buckeye engine, formed by the closure of the valve, is somewhat longer than that on the Harris-Corliss engine from 2 to 3. The Buckeye uses the slide valve, the motion is slightly slower, although it is very fast. We then reach the highest limit of pressure. On the other end of the engine, at the commencement of the stroke, or opening, the pressure slightly diminishes, holds steady for the first half of admission and then the pressure slightly falls away, until the time of the closing of the valve. Both diagrams are very fine and show the difference in practice between the valves; C in both cases represents the atmospheric line. When these steam-pipe or steam-chest diagrams are of exactly the same length as the cylinder diagram, they are exceedingly useful, and they should be taken from every engine that has indicator connections or attachments.

Another good place for the indicator to be attached is to the exhaust pipe between the engine and the heater, or between the engine and condenser. Care must be taken, however, in the case of a condensing engine whenever the indicator is to be applied, never to turn the three-way cock so as to break the connection between the condenser and steam engine cylinder. In the case of a condensing engine, we can frequently find where a part of the difference between the vacuum gauge and realized vacuum is accounted for; in the case of a high-pressure engine we frequently obtain from this a back pressure of from one-half to two or three pounds, and in cases where the steam is returned or changed in its direction through the feed-water heater, we sometimes find that the heaters have not the same area in their tubes as the exhaust pipe has. All of these things the indicator is perfectly applicable to, and with proper connections will be found of great value, or quite as much so as in the case of the cylinder itself.

It is also interesting to indicate steam pumps or water pumps, as we sometimes get a very curious record of the operations which go on inside a cylinder, to show us that the pump throws well one way and not well the other; and it is often to our advantage to examine these things, for we may find the valves on one end of the pump seriously out of order, and in that way avoid trouble in case of fire, or when the pump is called upon suddenly to do its utmost work. In some cases of steam-pipe throttling, it is well to have diagrams taken from different parts of the pipe (the motion can be readily transferred to almost any distance by using carrier pulleys) and in this way we frequently locate troubles, where nothing but taking down a large steam drum or main steam pipe would allow the object to be accomplished otherwise.

It is well for the beginner to also practice somewhat with different motions, to ascertain which are correct and which are incorrect. Get the length of your travel on the diagram on the paper cylinder, then divide this into four equal parts, or into as few or as many parts as you choose, turn the engine over carefully, and, if you are using the pendulum, you will soon find that you cannot make a peg, traveling the arc of a circle, conform to the exact divisions of the travel of the cross-head on the paper cylinder.

Another point, which frequently makes trouble for beginners, is the deducting the piston-rod area from the effective area of the cylinder. The crank end of the engine has the size of the piston rod to be deducted from the area of the piston; beginners sometimes are troubled by not knowing whether this should be taken from both ends, or from one end. It can only be taken from the end that it exists on. If we have a piston 30 inches in diameter, and a piston rod 3 inches in diameter, we take the area of the 3-inch piston rod from the area of the 20-inch piston; the difference is insignificant, but the beginner may as well figure it for a few times and ascertain that it is an almost unimportant factor, unless in the case of steamship engines, where we sometimes have a piston 120 inches in diameter, with a trunk varying from 36 to 50 inches; it then becomes an element of very great importance. A great many hints as they occurred in practice, will be found in the various lessons preceding this, and they can only be properly studied by carefully studying each lesson by itself, for they are best remembered when the circumstances under which they occurred, are recorded.

LESSON LXXXIV.

WATER PER HORSE-POWER FROM THE DIAGRAM, OR STEAM CONSUMED.

It is very frequently necessary to make a computation either upon the amount of steam per horse-power, or the amount of water per horse-power accounted for by the diagram. These matters are to a certain extent complex; not, however, from necessity or reality, but because they have frequently been made to appear complex by the amount of figures incorporated into them. All computations, as we have stated, must be from the absolute vacuum, for on that line is founded the temperature, volume, weight and other properties of steam. The reader of this volume will by this time have become familiar with the reasons why this base line is assumed in every case as the only basis of actual comparison. If we wish to ascertain the amount of steam consumed from the diagram, or, as it is frequently termed, steam accounted for by the indicator, we take the absolute vacuum at 14.7 below the atmospheric line of the diagram. For real correctness the clearance of the engine must be known, and this amount, the clearance, should be added to the diagram on a scale equal to the scale of the diagram. If the diagram is four inches long and represents a stroke of four feet, five feet, ten feet, or twelve feet, it is easy to ascertain precisely what any fraction of the four inches represents proportionately. Add to the diagram of the indicator the clearance, if you can, and this clearance must include the cubic inches between the piston and the cylinder head at full stroke; also, the exhaust port to the face of the valve, and the steam port to the face of the valve as well. It is usual to figure the amount of steam consumed, or accounted for, from the point of release. This is not necessary, and sometimes it is absolutely impossible, to tell precisely where release commences. Take any point on the line, either at the point of cut-off, or on any point of the expansion line before the exhaust valve opened. Now take the length of the stroke, including the clearance, up to the point where the pressure is measured, and from which point the computation is to be made. Multiply the length of the stroke to that point by the area in square inches of the cylinder; this will give you the volume of the cylinder to that point, and to this amount must be added the number of square inches of clearance up to the point of the computation, this gives the volume of the cylinder; multiply by the pressure to the point of computation; divide this product by 14.7; this quotient gives the number of cubic inches of steam at the pressure of the atmosphere discharged from the cylinder at a single stroke, or to that point of the stroke where the pressure is taken. If there is no leak in the valves, and the steam is not saturated with water, the cubical contents of the cylinder multiplied by the pressure at the point of cut-off should exactly coincide with the cubic contents multiplied by the pressure at the actual point of release. If both cut-off and release are well defined, it is a good plan always to make both these computations, and it will frequently be found that the point of release gives the greatest amount. This at once shows a leak. In a compound engine the cubic contents of both cylinders should agree with each other, if the computation is made in this way from the points of release in both cases. Having reached the cubic inches of steam at the pressure of the atmosphere, multiply this by the number of strokes in an hour, and don't get confused, you are working upon one side of the piston only; take care that revolutions are not considered, for in the one case you will get double, and in the other half the actual result. Having multiplied by the number of strokes in an hour, or the number of times that end of the cylinder is filled with steam in an hour and exhausted, divide this product by 1728, the number of cubic inches in a foot, in order to reduce cubic inches to cubic feet. We have now the number of cubic feet of steam used per hour, divide this by the indicated horse-power of the diagram and you have the cubic feet of steam per horse-power per hour. If the amount of water used or accounted for is required, divide the number of cubic feet of steam per hour by 1700, this gives the cubic feet of water used per hour. If pounds of water are wanted, multiply the last result by 62½; or, if gallons are wanted, divide the product by 8.33 pounds for wine gallon. Care must be taken in making these computations to get at the average or actual power required. It is hardly possible for the indicator to account for all the steam consumed or all the water used, for as a matter of fact any excess of leakage, or any change of circumstances, such as blowing-off, will require a larger amount of water in the boiler than the indicator can account for; the indicator simply accounts for what is used at and in the engine, and the indicator cannot account for leakage from any cause.

Or, to repeat the formula in a different way, without the explanations, obtain the volume of the cylinder to any point which is perfectly plain, between the point of cut-off and the point of release; this is in cubic inches, and must be multiplied by the pressure at the above point from the vacuum; then divide by 14.7, the pressure of steam at the atmospheric pressure, this gives in cubic inches the amount of steam discharged at each stroke. This quotient is multiplied by the number of strokes or times that the cylinder is filled at one end per hour; this gives the total number of cubic inches of steam accounted for by the number of strokes which are made in one hour; this is reduced to cubic feet by dividing by 1728, which gives cubic feet of steam. Divided the cubic feet of steam by 1700, the volume of steam at atmospheric pressure, and the result gives us cubic feet of water; multiply this last result by 62½ and we have pounds of water; this divided by the horse-power gives us pounds of water per horse-power for one hour.

ANOTHER METHOD OF COMPUTING THE WATER PER HORSE-POWER PER HOUR.

The volume of the cylinder multiplied by the number of strokes per minute, multiplied by 60, or the minutes per hour, divided by 1728, gives cubic feet. Multiply the last result by the weight of a cubic foot of steam at the pressure at the point of cut-off—or the point from which the computation is made, using the pressure above absolute vacuum—and divide this last by the horse-power, and the final result will be pounds of water per horse-power per hour. (See table of "Properties of Saturated Steam" for weight of one cubic foot in decimals of a pound.)

VACUUM.

TEMPERATURE AT DIFFERENT "POUNDS PER SQUARE INCH" AND "INCHES OF MERCURY."

The very peculiar position in which we are placed in using one or the other of the thermometer scales, now generally in use or cited by scientific men in experiments, or in contrast or comparison of results, makes an enormous amount of trouble and bungling by comparing all others with the Fahrenheit scale which commences on an assumption over 300° from correct and ends in a guess, or, as Mr. Porter has so aptly said, "begins in a blunder and ends nowhere."

Fahrenheit assumes 32° as freezing, and 212° as boiling. Centigrade gives 0° as corresponding to freezing on the F. scale, and 100° on his thermometer to boiling, or 212° on the F. The general adoption of the Centigrade scale for scientific purposes, at home and abroad, should be much more general, as the F. does not commence with fact or continue with accuracy.

TOTAL HEAT.

There is no term used which is more of a misnomer. Absolute cold has been determined with all reasonable certainty as 459° to 461° below the arbitrary point as assumed by Fahrenheit, so that in the tables of all scientific works "total heat" is a false application of a term, notably in some of the literature which has emanated from the United States Bureau of Steam Engineering, and total heat expresses only from Fahrenheit's assumed zero.

INCHES OF MERCURY.

Usage has confirmed the use of a scale as rude as the tally stick of ball players in our younger days, when notches were cut in a stick with no graduation or calculation, simply guessed at. The English government have adopted at the Royal Arsenal at Woolwich, mercurial gauges based on equal divisions from the "standard of usage," that 15 pounds to the square inch equals 30 inches of mercury, and the curious feature of these "standard" gauges to us, on examination, was the fact that each pound pressure coincided with *even inches.*

The expansion of mercury for each increase in its temperature of one degree F. equals .000100854 inch.

The starting point is, mercury at 32° F. equals a volume of 1, and as the changes in temperature occur—if mercury is to measure the changes—then we must correct the column of mercury for the degrees. Hence it follows that inches of mercury do not follow any assumed or empirical scale of equal inches, and when so combined neither element shows a correct reading.

One pound pressure in inches of mercury equals 2.03601 inches.

The specific gravity of mercury is 13.595+.

Water is at its greatest density at 39.2° F. or 4° C., and M. Regnault has brought out some curious facts in his elaborate experiments on air, water and steam; and these are so extensive and so valuable that all persons who study steam should have them at hand.

He has determined that saturated steam cannot be investigated separately on account of "the expansion and contraction of its volume consequent on changes of pressure, and those consequent on temperature, because at the same time its volume is being contracted under increasing pressure, its expansion takes place with increasing temperature," so that the density of saturated steam is an unsolved problem, and Mariotte gives us data approaching exactness from formulae of air, which, under a constant pressure doubles its volume on an increase of temperature of 272.8° C., or 491° F., and in temperature of steam a confusion exists at the same pressure by different authorities, and frequently some unexplained feature exists which may be the point from which they start out, and we have to ascertain this point and add or subtract 32°, or some other number, frequently, in order to reconcile the data given.

The Density of Steam is 1, divided by the volume at any given pressure, and at the atmospheric pressure the volume is 1702, so that the density becomes the fraction $\frac{1}{1702}$ that of water at same pressure.

TEMPERATURE OF VACUUM.

The following table is from M. Regnault by transposition, and shows the pounds per square inch. The temperature and the inches of mercury corrected for temperature. The temperature is given by each 4° F., and the fractions are closely as possible expressed in three places in the first column, and four places in the third column.

The unit of heat being the heat required to raise the temperature of one pound of water 1° F., if we require to compute from any point; the heat contained in the water from the starting point, 32° F., must be subtracted from the heat given, and we can then convert into steam from and to any pressure, from any of the tables in this work:

Pounds per square inch.	Temperature.	Inches of Mercury.	Pounds per square inch.	Temperature.	Inches of Mercury.
1.127	208°	2.3028	13.182	116°	26.8608
2.186	204	4.4538	13.345	112	27.1908
3.172	200	6.4638	13.493	108	27.4908
4.095	196	8.3428	13.624	104	27.7588
4.954	192	10.0948	13.743	100	28.0038
5.755	188	11.7258	13.852	96	28.2238
6.497	184	13.2418	13.948	92	28.4218
7.190	180	14.6508	14.035	88	28.5988
7.833	176	15.9588	14.114	84	28.7588
8.427	172	17.1718	14.183	80	28.8988
8.978	168	18.2948	14.245	76	29.0249
9.489	164	19.3338	14.300	72	29.1374
9.959	160	20.2928	14.350	68	29.2372
10.393	156	21.1768	14.393	64	29.3256
10.792	152	21.9928	14.431	60	29.4038
11.162	148	22.7428	14.465	56	29.4726
11.499	144	23.4318	14.495	52	29.5335
11.811	140	24.0638	14.521	48	29.5867
12.093	136	24.6418	14.543	44	29.6334
12.352	132	25.1718	14.563	40	29.6742
12.591	128	25.6548	14.581	36	29.7097
12.807	124	26.0958	14.596	32	29.7407
13.004	120	26.4968			

As 32° F. is the freezing point we stop at that point, as there would be no economy in going to that point, even if it were a possibility. The point of greatest economy by marine engineers is now considered to be about 124° F., at which point the changes of temperature are not so radical as with more vacuum, and a greater degree of cold in its action on the surfaces of piston and cylinder.

We believe in a less vacuum as a means of greater economy; and that some of the examples of compounding, as shown in this work, are but an approach to the highest economy in the application of steam to motive power.

AN IMPROVED DRAUGHT GAUGE FOR CHIMNEYS.

[The following article is from *The Locomotive.* It contains so much that is valuable that it is put upon record in permanent form for the engineer, who can compute closely the questions most nearly connected with chimney draft, height, area, etc. :]

The influence of the chimney upon the working and economy of a steam-power plant is a factor of the greatest importance, and is one which, in too many cases, does not receive, in its design, location and execution, the consideration which should be given to it.

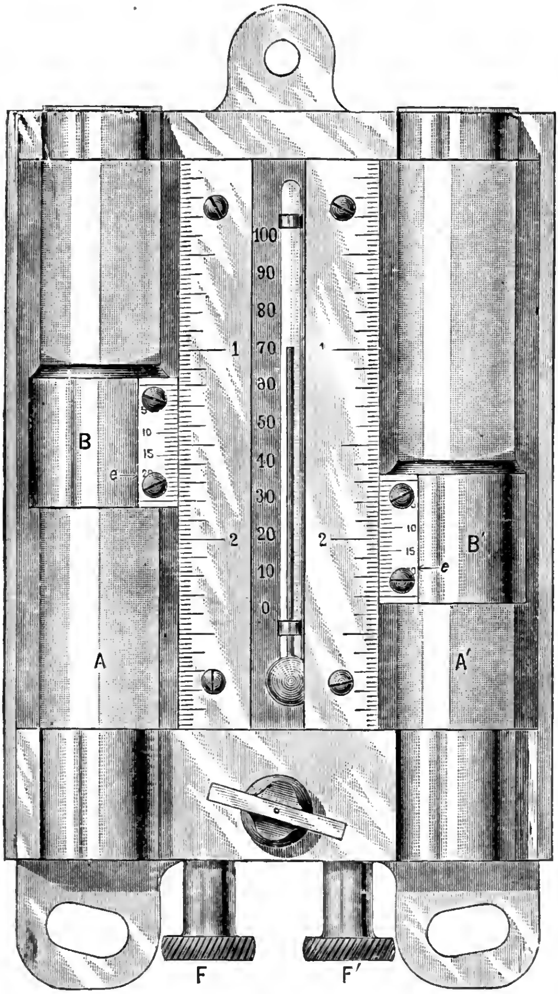
The function of a chimney is, primarily, to furnish sufficient draught to properly burn the fuel; secondly, to carry off the products of combustion. If the chimney is so constructed that the first of the above-named conditions is properly fulfilled, the second will, in general, follow as a natural consequence.

In designing a chimney for any given boiler plant, due regard should be paid to its location with regard to the surrounding buildings or adjacent hills, if there are any, the general direction of the prevailing winds, etc., as all these conditions have a direct and often a very great influence upon the proper working of the chimney. The chimney should be well constructed, the foundation should be firm enough to prevent any unequal settling which would be liable to crack the walls, the bricks should be carefully laid, care should be exercised that no air holes exist in the shaft of the chimney or the flue leading to it. The chimney, if of considerable size, should be built with double walls; the inner stack or core should be entirely independent of the outer one. This construction serves two important purposes: it prevents undue loss of heat by radiation, and prevents the excessive, unequal expansion and contraction of the outer stack, which might occur if it were a single shaft exposed on the inside to the heat of the escaping gases, and on the outside to the atmospheric temperature, the difference of which in some cases is as great as 600° F. This adds greatly to the very important element of the strength and durability of the outer shell of the chimney.

The cause of the draught power of a chimney may best be illustrated by assuming a particular case and following its working. Let us suppose we have a chimney 100 feet high from the top of the grate bars, the point from which the height of a chimney should always be reckoned. Suppose the temperature of the external air is 60° F., the temperature at the bottom of the chimney 400° F., which is about right in a well-arranged plant, and the barometer stands at 29.92 inches.

Then it is evident that we shall have in the chimney a column of the hot gases, the temperature of which is 400° F., and the height 100 feet.

The density or weight per cubic foot of these gases, when twenty-four pounds of air are supplied to each pound of coal burned, will be about .0482 pounds, while the density of the external air will be about .0764 pounds per cubic foot. Now it is plain that in this case the pressure of a column of the atmospheric air 100 feet high will be 7.64 pounds per square foot, while the pressure of a similar column of the chimney gases would be but 4.82 pounds. Now as the pressure of that portion of the atmosphere above the chimney-top is evidently the same on the top of the column of hot gases as it is on the surrounding air at the same height, it may be neglected, and we need consider only the gases for the given height of chimney and the same height of the external air. Now in the case we are considering, the difference in the weights of the column of atmospheric air at 60° and the chimney gases at



400° is for a height of 100 feet 7.64–4.82=2.82 pounds per square foot, and it is this excess of pressure of the external air over that in the chimney which causes it to flow into the chimney through every opening into it. In properly-arranged boiler furnaces the only available opening is, of course, through the layer of incandescent fuel on the grate; in its passage through the fuel all the incoming air is heated and forced upward in its turn, and thus the process goes on continuously.

Now it is evident that if we can measure this unbalanced pressure in the chimney, we have a means of determining whether the chimney is "drawing" as well as its height should indicate, and if it is not, it may aid us in discovering where the fault lies, and so remedy it. This, the instrument shown on the preceding page, enables us to do with very great accuracy.

It has been designed and made by this company, who felt the need of something for their own use which would give more accurate and reliable results than the crude siphon gauges heretofore used. We are not aware that anything at all approaching it, in accuracy or completeness, has ever been made or used for this purpose.

The cut shows the instrument full size. A and A′ are glass tubes suitably mounted, as shown, and communicating with each other by means of a passage through the base, which passage may be closed by means of the stop cock shown. Surrounding the glass tubes are the two brass rings B and B′. These rings are attached to blocks which slide in dovetailed grooves in the body of the instrument, back of the 3-inch scales, and may be easily moved up and down by screws, the milled heads of which are shown at F, F′. The 3-inch scales are divided into fortieths of an inch, and read to thousandths of an inch by the verniers *e* and *e*′, which are attached to the sliding rings B, B′. This arrangement of scale and vernier is exactly the same as that of the ordinary Brown & Sharpe vernier caliper, with which every machinist is familiar, and is so adjusted that when the instrument is perpendicular, and the tops of the brass rings B and B′ are at exactly the same height, the reading of each is precisely the same. This being the case, it is evident that if the two short rings are set at different heights, as shown in the figure, the difference in their readings will give the difference of level between them. The thermometer shown in the center of the instrument is for the purpose of noting the temperature of the external air at the time of making observations, without the trouble of taking along an extra thermometer. The method of using the instrument is as follows:

At any convenient point, as near the base of the chimney as possible, a hole is made large enough to insert a thermometer to ascertain the temperature of the chimney. (This is something that it is extremely important to know, for other reasons than those connected with the use of the above instrument, and facilities for so doing should always be provided when a chimney is built.) The most available place is generally in the main flue leading from the boiler to chimney, and about twelve inches from the side of the chimney. The height from this opening to the top of chimney, and also to top of grates, should be noted for reference.

The chimney gauge is then attached to some convenient wall by means of small screws, the holes for which are shown in the cut. The tubes are then filled about half full of water, when the verniers afford an easy means of setting it exactly perpendicular. One end of a flexible rubber tube is then inserted into the upper end of one of the glass tubes (which are both open at the upper end) and the other end of the tube is inserted in the chimney flue. Then it is evident that the surface of the water in one of the tubes is open to the atmosphere, and that in the opposite tube is in communication with the somewhat lesser pressure of the hot gases in the chimney, and consequently the water in the tube communicating with the chimney will rise to an amount dependent upon the difference of pressure inside and outside of the chimney. The tubes B, B′ are then adjusted by means of the screws F, F′, until their upper ends are just tangent to the surface of the water in the two tubes. As the surface assumes a curved form in consequence of the capillary action of the sides of the tubes, this may be done with very great accuracy. The reading of the two scales is then taken, and their difference gives the height to which the water has risen. At the same time the temperature of the flue is noted, as well as that of the external atmosphere. Comparison may then be made with the following table, which has been computed by us for use in connection with investigations of chimney draught. The calculations have been made for a chimney 100 feet high, with various temperatures outside and inside of the flue, and on the supposition that the temperature of the chimney is uniform from top to bottom. This is the basis on which all calculations respecting the draught-power of chimneys have been made by Rankine and all other writers, so far as we know, but it is very far from the truth in most cases. The difference will be quickly shown by comparing the reading of the above described gauge with the table given. For other heights than 100 feet, the theoretical height is very easily found by simple proportion, thus: suppose the external temperature is 60°, the temperature of flue 386°, height of chimney 137 feet, then under 60° at the top of the table and opposite to 386° in the left hand margin, we find .52″.

Then 100 : 137 :: .52″ : .71″ which is the required height for a 137-foot chimney, and similarly for any other height.

Some interesting facts relative to the cooling of the gases in chimneys have been developed by us, of which we shall give an account in a month or two. For instance, in one chimney, 122 feet in height, we noted the following: Temperature at the base, 320° ; temperature at the top, 230°, and the amount by which the height of water column in the gauge fell short of the theoretical, as given above for uniform temperature, was accounted for to less than the thousandth of an inch.

HEIGHT OF WATER COLUMN DUE TO UNBALANCED PRESSURE IN CHIMNEY ONE HUNDRED FEET HIGH.

Temperature in the Chimney.	*Temperature of the External Air—Barometer,* 14.7.										
	0°	**10°**	**20°**	**30°**	**40°**	**50°**	**60°**	**70°**	**80°**	**90°**	**100°**
200	.453″	.419	.384	.353	.321	.292	.263	.234	.209	.182	.157
210	.470	.436	.401	.371	.338	.309	.280	.251	.227	.200	.175
220	.488	.453	.419	.388	.355	.326	.298	.269	.244	.217	.192
230	.505	.470	.436	.405	.372	.344	.315	.286	.261	.234	.209
240	.520	.488	.451	.421	.388	.359	.330	.301	.276	.250	.225
250	.537	.503	.468	.438	.405	.376	.347	.319	.294	.267	.242
260	.555	.528	.484	.453	.420	.392	.363	.334	.309	.282	.257
270	.568	.534	.499	.468	.436	.407	.378	.349	.324	.298	.273
280	.584	.549	.515	.482	.451	.422	.394	.365	.340	.313	.288
290	.597	.563	.528	.497	.465	.436	.407	.379	.353	.326	.301
300	.611	.576	.541	.511	.478	.449	.420	.392	.367	.340	.315
310	.624	.589	.555	.524	.492	.463	.434	.405	.380	.353	.328
320	.637	.603	.568	.538	.505	.476	.447	.419	.394	.367	.342
330	.651	.616	.582	.551	.518	.489	.461	.432	.407	.380	.355
340	.662	.638	.593	.563	.530	.501	.472	.443	.419	.392	.367
350	.676	.641	.607	.576	.543	.514	.486	.457	.432	.405	.380
360	.687	.653	.618	.588	.555	.526	.497	.468	.444	.417	.392
370	.699	.664	.630	.599	.565	.538	.509	.480	.455	.428	.403
380	.710	.676	.641	.611	.578	.549	.520	.492	.467	.440	.415
390	.722	.687	.652	.622	.589	.561	.532	.503	.478	.451	.426
400	.732	.697	.662	.632	.598	.570	.541	.513	.488	.461	.436
410	.743	.708	.674	.643	.610	.583	.553	.524	.499	.472	.447
420	.753	.718	.684	.653	.620	.591	.563	.534	.509	.482	.457
430	.764	.730	.695	.664	.632	.602	.574	.545	.520	.493	.468
440	.774	.739	.705	.674	.641	.612	.584	.555	.530	.503	.478
450	.783	.749	.714	.684	.651	.622	.593	.564	.540	.513	.488
460	.793	.758	.724	.694	.660	.632	.603	.574	.549	.522	.497
470	.802	.768	.733	.703	.670	.641	.612	.584	.559	.532	.507
480	.810	.776	.741	.710	.678	.649	.620	.591	.566	.540	.515
490	.820	.785	.751	.720	.687	.659	.630	.601	.576	.549	.524
500	.829	.791	.760	.730	.697	.669	.639	.610	.586	.559	.534

HOW TO TEST FEED WATER FOR BOILERS.

Feed-water heaters are a matter of great importance; they are not always put in as they should be, nor are they given credit for all that they do, or even all that they are capable of, and in a great many cases they are not used, as they might be, for the profit or benefit of the owner. Testing the temperature of feed water for a boiler, is not an agreeable or desirable undertaking at all times, but it is a matter which can be done every hour in the day, if the engineer in charge will only think so. It is a matter not generally understood, that the feed water varies a great deal whether it is tested under pressure or in the open air. Water cannot and will not show any temperature greater than 212°, if, indeed, it does that, unless it is under pressure. It is remarkable that engineers will insist in drawing water out of a boiler under 60 or 80 pounds pressure, and dip a thermometer in the current of water which is running away from the boiler into the open air, and then wonder why the feed water does not show the same result! If the reader will refer to Fig. 1, in which A represents a side of the feed-water heater, B the feed pipe to the boiler from the upper portion of the heater, C, D, E, F, are all for the testing of feed water, and will be explained further on. Fig. 3 is a crude, but simple and reliable, method of testing any thermometer, and it is a very desirable proceeding to test thermometers, for we have found them varying 15° to 20° from the standard which we have, and always refer to in any test of pressure, or steam, or for temperature of feed water, whenever we are working around boilers or in any steam work. Take a tin can or pail, anything which will hold water three inches deep or over that, and put it upon a fire, or anywhere else, to boil; when it is boiling, then enter the thermometer bulb into the water an inch or more in depth, and notice whether it records 212° or 220°, or any other point, and also notice that the water is kept boiling until the observation is complete; whatever the variation is between 212° and the record of the test, remember that and make the allowance in all future observations taken with that thermometer. It is very seldom that we find a thermometer which shows less than 212° at boiling.

If we refer to Fig. 1 again, there is a cross put in the feed pipe from the heater to the boiler, from which the feed pipe proper leads off at B, the pipe which is continued down to C, branches off again at D, having an outlet, say one-quarter of an inch in diameter upon one side and one and one-half inches upon the other. We have found these arrangements sometimes put upon the heater of one maker by another who was desirous of making a test of his opponent's feed-water heater, and it is somewhat curious that the most of these tests are made by means of thermometers exposed to the open air.

while, as a matter of fact, the heater is used in its every-day work "under pressure;" the temperature of the water drawn from the boiler itself, will not be over 212°, if tested at the point D or E, no matter if the boiler was ten feet distant, and the pressure 80 pounds.

We will now refer to Fig. 2, in which A represents the glass tube of the thermometer correctly graduated, and used only after it has been thoroughly tested, D is a cast-iron plug which fits into the top of the cross, immediately over the boiler feed pipe B, Fig. 1; into the top of D is drilled the hole for a half-inch gas-pipe plug B, which has been cupped out, and under it a piece of rubber packing, C, fitted. The holes in B and D are slightly larger than the thermometer tube, and the rubber is punched so as to fit close; when the tube has been put into place, the rubber slipped down upon it, and the plug, B, screwed up, so that the bulb will be held below the crossing of the other pipe, we are ready to put the plug into the top of the cross and commence operations. As a safeguard the cord E is led from a small peg in each side of the plug through the ring in the top of the thermometer, so as to prevent its moving up by the pressure. In this disposition of the thermometer the boiling point should always be left above the top of the plug.

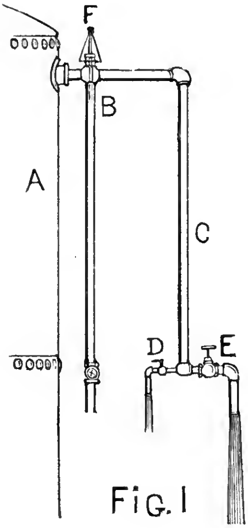


FiG. I

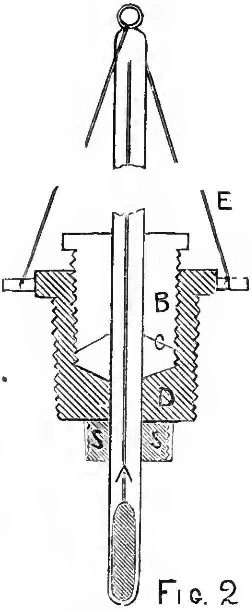


FiG. 2

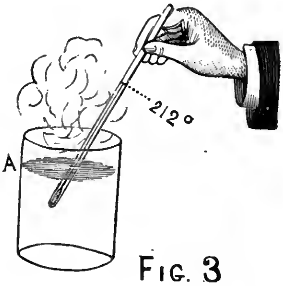


FiG. 3

With this arrangement, which any engineer can readily fix up for himself, it is perfectly easy to test correctly and completely what the temperature of feed water is, which is passing into the boiler, and it can be done for fifty cents beyond the price of the thermometer, and these, from a reliable maker, will cost from $1.30 to $1.50 each. If there is an angle valve in the feed near the boilers, it is a first-rate place in which to put the thermometer so as to know at what temperature the water enters the boilers, but whenever the apparatus is put in, let the bulb of the thermometer *always remain in the current of water which is under pressure.* Water boils at the level of the sea at 212°, and for each 500 feet above the level of the sea, it boils at one degree less than 212° ; never test steam or water under pressure unless you put the thermometer into the current of moving water or steam.

LUSTERLESS FINISH ON TEMPERING STEEL.

A fine lusterless surface on tempered steel can be procured by either of the following operations : After the steel article has been tempered, it should be rubbed on a smooth iron surface with some pulverized oil-stone until it is perfectly smooth and even, then laid upon a sheet of white paper and rubbed back and forth until it acquires a fine dead finish. Any screw holes or depressions in the steel must be cleaned beforehand with a piece of wood and oil-stone. This delicate, lusterless surface is quite sensitive, and should be rinsed with pure, soft water only, when the article will be found to have a fine, lusterless finish.

PATTERN VARNISH.

A varnish has been patented in Germany for foundry purposes and machinery, which it is claimed dries as soon as put on, gives the patterns a smooth surface, and is a good filler. This varnish is prepared in the following manner : Thirty pounds of shellac, ten pounds of Manilla copal and ten pounds of Zanzibar copal are placed in a vessel, which is heated externally by steam, and stirred from four to six hours, after which 150 parts of the finest potato spirit are added, and the whole heated during four hours to 87° C. This liquid is dyed by the addition of orange color, and can then be used for painting the patterns. When used for painting and glazing machinery, it consists of thirty-five pounds of shellac, five pounds of Manilla copal, ten pounds of Zanzibar copal and 150 pounds of spirit.

THE CALORIMETER TEST.

RULE FOR MAKING IT.

We give the following old but simple rule for a Calorimeter test: Take steam from main pipe near boiler with $\frac{1}{2}$-inch pipe—the pipe must be thoroughly protected by covering with hair felt; the lower end of pipe should be closed, and $\frac{1}{8}$-inch holes drilled so as to form a rose; the holes should be close to bottom of cap, so as not to trap water; the valve should be within easy reach; a can (bright tin is preferable) holding twelve to fifteen pounds of water should be provided, with sufficient opening in top to insert steam pipe and take temperature; this also should be well protected with hair felt; a small scale, steelyard, or spring balance, can be used for weighing; put exactly ten pounds water in the can, note its temperature, move the scale weight out one pound, so as to have just eleven pounds water when test is complete; blow steam through pipe to free it of any water of condensation, insert pipe in can, and when just one pound of steam has been condensed (eleven pounds water in can) shut off steam and note temperature of water. The difference is the caloric.

This formula is based, as all are, on the total heat of steam latent and sensible, less the temperature of water above zero, and can be calculated thus: Latent heat 966, sensible 212=1178, less the temperature of 10 pounds water, which leaves 1178—80=1098. Now we turn one pound steam into 10 pounds water, and find the temperature has risen from 80° to 176°, a gain of 96°. This we multiply by 11 pounds water, 11×96=1056, nearly equal to our 1098 total available heat; 100° rise of temperature, if no heat had been absorbed by the can containing the water, would be dry steam. It has been found by experiment that 96° under the above rule is dry steam. Had the rise of temperature been but 80°, the amount of water in the steam would have been 20 per cent. The tables approximate closely to the actual amount of water carried over in the steam:

RISE OF TEMPERATURE OBSERVED ABOVE THE 96° SUPERHEATED STEAM.	PERCENTAGE OF WATER IN STEAM.
96 degrees dry steam.	
92 " "	5 per cent. water.
88 " "	10 " "
80 " "	20 " "
71 " "	30 " "
63 " "	40 " "
54 " "	50 " "
46 " "	60 " "
37 " "	70 " "
28.5 " "	80 " "
20 " "	90 " "
15 " "	95 " "
11.5 " "	100 all water.

IRON PAINT.

Iron paint, as it is termed—a paint composed of pulverized iron and linseed oil varnish—is a recent German invention, and is intended for covering damp walls, outer walls, and, in short, any place or vessel exposed to the action of the open air and to the weather. Should the article to be painted be exposed to frequent changes of temperature, linseed oil varnish and amber varnish are mixed with the paint intended for the first two coats, without the addition of any artificial drying medium. The first coat is applied rather thin, the second a little thicker and the last in a rather fluid state. The paint is equally adapted as weather-proof coating for wood, stone and iron; nor is it necessary to previously free the latter from rust, grease, etc., a superficial cleaning being sufficient.

JOULE'S EQUIVALENT.

The conversion of heat into work is the main purpose of the steam engine. In other words, we could not use coal in the steam cylinder, and water is therefore made the medium to convey the products of combustion, transferred from coal to water, through the steam boiler, and the steam in the fluid state, under various pressures, passes through all the pipes, valves, ports, is controlled by the valves so that it is more or less economically used according to their action, and the only way we have of establishing this action for economical comparisons for the purpose of ascertaining the power, is by means of the indicator. We must, therefore, have some standard, and for that purpose frequent reference is made to the unit or equivalent. Mr. Joule, at Cambridge, England, in 1845 or '46 first exhibited the apparatus, and at that time he considered that it required 781.5 pounds to equal the raising of one pound of water 1° Fahrenheit, while in another case it was slightly increased, but was subsequently settled that the precise equivalent of the unit of heat was 772 pounds raised one foot high, and this is what is termed Joule's equivalent.

Joule's equivalent has been generally substantiated by scientific research and is accepted as true. It may be defined as the work done raising one pound through one foot, and is called either the foot-pound, or the unit of heat; or the heat required to raise the temperature of a pound of water 1° Fahrenheit, and is the equivalent of 772 units of work. When a pound of water at the temperature of boiling, 212° Fahrenheit, or 100° Centigrade, when at the atmospheric pressure, passes into a state of steam of the same temperature, 966.6 units of heat, equivalent to 746,215 units of work, disappear, being converted into internal and external work.

Mr. Joule also has announced what absolute cold was, and this is considered proven by scientific research at 461.2° below zero of the Fahrenheit scale or — 274° on the Centigrade scale. The theory upon which Joule's equivalent is rested is that heat is motion, and that absolute rest would be absolute cold, and that the atoms of which bodies consist, are always in motion, and if they were brought to absolute rest, this would give the result which he first announced, and which has generally been accepted by the best authorities, as 461.2° below zero, Fahrenheit.

COLORING SOFT SOLDER YELLOW.

When brass is soldered with soft solder, the difference in color is so marked as to direct attention to the spot mended. The following method of coloring soft solder is given by the Metallarbeiter: First prepare a saturated solution of sulphate of copper (bluestone) in water, and apply some of this on the end of a stick to the solder. On touching it with a steel or iron wire it becomes coppered, and by repeating the experiment the deposit of copper may be made thicker and darker. To give the solder a yellower color, mix one part of a saturated solution of sulphate of zinc with two of sulphate of copper, apply this to the coppered spot, and rub it with a zinc rod. The color can be still further improved by applying gilt powder and polishing.

On gold jewelry or colored gold, the solder is first coppered as above, then a thin coat of gum or isinglass solution is applied and bronze powder dusted over it, which can be polished after the gum is dry and made very smooth and brilliant; or the article may be electro-plated with gold, and then it will all have the same color.

On silverware the coppered spots of solder are rubbed with silvering powder, or polished with the brush and then carefully scratched with the scratch brush, then finally polished.

RECIPES FOR SOLDERING FLUID.

One dram each of powdered copperas, borax and prussiate of potash; one-half ounce powdered sal ammoniac; $3\frac{1}{2}$ ounces fluid muriatic acid; let the mixture cut all the zinc it will and then dilute with one pint of water. This is something extra for soldering raw edges of tin or galvanized iron. The above quantity of fluid costs fifteen cents.

Add granulated zinc or zinc scraps to two fluid ounces of muriatic acid until hydrogen ceases to be given off; add one teaspoonful of ammonium chloride; shake well and add two fluid ounces of water.

Also a good fluid for soldering bright tin can be made of well-pounded resin and sweet oil. It was used years ago by the tinners of Great Britain for soldering planished ware made in those days, and is excellent for soldering fine work, silver and plated ware; it can be wiped off with a clean rag and leave no stain or scratches.

SAFETY-VALVE PROBLEMS.

1. Do you wish to know the pressure of the ball as it hangs? Ball weighs 90 pounds. Multiply the weight of the ball by the distance in inches the weight hangs from the center of the fulcrum, say 30; divide that by the distance in inches from the center of the valve to the center of the fulcrum, say 5; add the weight of the valve and lever in pounds, say 20; divide this by the square inches in the valve, say 20; and the result will be the pressure in pounds on a square inch of the ball, equal to 28.

$$90\times30\div5+20\div20=28$$

2. If you wish a certain pressure with a ball you have never used, then say the valve is 4 inches in diameter, the area is 12.566. Multiply this by the pressure you want in pounds, say 40; subtract from it the weight of valve and lever, say 16; multiply this by the distance from the center of the valve to the center of the fulcrum, say 4; divide this by the weight of the ball in pounds, say 80; and the distance in inches the ball must be from the center of the fulcrum will be the result, as $24\frac{1}{3}$.

$$12.566\times40-16\times4\div80=24\tfrac{1}{3}.$$

3. If you wish a ball upon the lever for a certain pressure in pounds, multiply the area of the valve 7.068 by the pressure required 50 pounds, take out the weight of the valve and lever; multiply that result by the distance from the center of the valve to the center of the fulcrum, say 3 inches; divide this result by the distance from where you put the ball, 21 inches, to the center of the fulcrum, and this will give you the weight of the ball.

$7.068\times50\times3\div21=50\frac{1}{2}$ pounds, weight of ball.

RULE FOR ASCERTAINING SIZE OF SAFETY-VALVE FOR ANY GIVEN GRATE SURFACE.

The required aggregate area of safety-valve to be placed upon boilers, may be expressed by the formula,

$$A=\frac{22.5\times G}{P+8.62}$$

in which A is area of safety-valve in inches; G is area of grate in square feet; P is pressure of steam in pounds per square inch, to be carried on the boiler above the atmosphere. The following table gives the results of the formula for one square foot of grate as applied to boilers used at different pressures:

PRESSURES PER SQUARE INCH.

10.	20.	30.	40.	50.	60.	70.	80.	90.	100.	110.	120.
1.21	0.79	0.58	0.46	0.38	0.33	0.29	0.25	0.23	0.21	0.19	0.17

(area corresponding to one square foot of grate.)

Example.—Required, area of safety-valve in square inches for boiler running at 80 lbs. pressure and 30 feet grate surface.

For 1 square foot from table at 80 lbs.—0.25
Square feet grate surface — .30

Area of valve in square-inches =7.50

If a forced or artificial draft is used, the estimate is based on a consumption of 16 lbs. of fuel for each square foot of grate surface.

This rule was furnished by the scientific commission which framed the inspection law for the city of Philadelphia.

Tarnished colored gold articles, it is said, may be restored by the following method: Dissolve one ounce of bicarbonate of soda, half an ounce of chloride of lime, and half an ounce of common salt, in about four ounces of boiling water. Take a clean brush, and wash the article with the hot solution for a few seconds, and rinse immediately in two clean waters. Dry in warm sawdust, and finally rub over with tissue paper.

WATER IN THE CYLINDER.

It has now become generally accepted among the best authorities that the indicator diagram will show the water or presence of water in the cylinder when working. It must first be positively settled that there are no leaks about the valves or piston or that there is nothing which shall disturb the true diagram, for unless the engine is in mechanical perfection as nearly as possible, the real reading of a diagram does not give us the facts, and ambiguous quantities enter in. We must, therefore, be sure that the engine is mechanically in first-class condition and proper order; then having arrived at the point of the stroke where steam is cut off, with precision, we can figure for water in the steam. This varies considerably with the conditions under which the valves are working. If a great deal of water is present, it makes a radical difference in the expansion curve. We can readily plot upon an indicator diagram the pressure of steam with regard to its density and volume, by reference to the table of Properties of Saturated Steam, if we wish to do so; but in doing this, we have certain other factors which must be taken into account, which involve many figures, and also points about which the best authorities differ so widely that we have not carried it out in this volume; that rather belongs to the science of the indicator than to its practice, and is a point upon which the best authorities do not by any means agree.

To cut Gauge Glasses to length take a drill rod, sharpen the end and turn it at right angles to rod, like cut, and harden the end without drawing the temper. Be careful in hardening not to get the point too hot, as its being so small it is liable to be burned.

Every engineer will find this a handy tool.

When a glass is to be cut find the length, and with this tool cut a ring around the *inside* of the glass and it will usually break off square at that point at once. If it does not, a little heat applied at that point will hasten, or if laid down a few minutes it will crack off.

A glass cut on the outside, unless cut very deep with a file or stone, is liable to crack anywhere.

BABBITT METAL.

Nearly half a century ago Isaac Babbitt of Taunton, Mass., originated the alloy which has since been known as Babbitt Metal. It is highly valued for its anti-friction qualities as compared with other metals. Isaac Babbitt was a goldsmith by trade and made the first Britannia ware produced in this country. He was honored with a gold medal for his discovery of his anti-friction alloy, and was also presented with $20,000 by the Congress of the United States. Below are several formulas for preparing Babbitt metal for different uses:

WHITE ALLOY, OR BABBITT METAL.

A—Copper	10
Tin	72
Antimony	18
	100

This alloy is recommended for high-speed machinery journal boxes.

B—Copper	1
Tin	48
Antimony	5
Lead	2
	56

This alloy is more economical than the above and has a more greasy touch than the first-named above, but is not so desirable for high speed.

C—Lead	32
Zinc	20
Antimony	48
	100

This alloy will resist a rapid friction. The zinc should be melted first, then add the other metals.

D—Lead	90
Antimony	100

This alloy is suitable for pillow blocks, agricultural or other slow working machinery.

[From Hamilton's Useful Information for Railroad Men.]

USEFUL NUMBERS FOR RAPID APPROXIMATION.

Feet........................× .00019 =miles.
Yards.......................× .0006 =miles.
Links.......................× .22 =yards.
Links.......................× .66 =feet.
Feet........................× 1.5 =links.
Square inches...............× .007 =square feet.
Circular " ....× .00546 = " "
Square feet.................× .111 = " yards.
Acres.......................×4840. = " "
Square yards................× .0002066=acres.
Width in chains.............× 8. = " per mile.
Cubic feet..................× .04 =cubic yards.
Cubic inches................× .00058 = " feet.
U. S. bushels...............× .046 = " yards.
" " ....× 1.244 = " feet.
" " ....×2150.42 = " inches.
Cubic feet..................× .8036 =U. S. bushels.
" inches................× .000466 = " "
U. S. gallons...............× .13368 =cubic feet.
" " ....× 231. = " inches.
Cubic feet..................× 7.48 =U. S. gallons.
Cylindrical feet............× 5.878 = " "
Cubic inches................× .004329 = " "
Cylindrical inches..........× .0034 = " "
Pounds......................× .009 =cwt. (112 lbs.)
Pounds......................× .00045 =tons (2240 lbs.)
Cubic feet water............× 62.5 =lbs. avoirdupois.
" inches " ....× .03617 = " "
Cylindrical foot of water......× 49.1 = " "
Cylindrical inches of water.....× .02842 = " "
U. S. gallons of water.........÷ 13.44 =cwt. (112 lbs.)
U. S. gallons of water.........÷ 268.8 =tons.
Cubic feet water...............÷ 1.8 =cwt. (112 lbs.)
" " " ....÷ 35.88 =tons.
Cylindrical foot of water......× 5.875 =U. S. gallons.
Column of water, 12″ high; 1 inch diameter =34 pounds.
183,346 circular inches........ =1 square foot.
2,200 cylindrical inches........ =1 cubic "
French metres...............× 3.281 =feet.
Kilogrammes.................× 2.205 =avoirdupois lbs.
Grammes.....................× .0022 = " "

To write upon terra-cotta tablets, dip the clay tablet in milk, with a few drops of acid added, and then dry. When this is done you can write upon it as easily as upon paper.

THE PROPERTIES OF SATURATED STEAM.

In the tables which follow, steam is considered from M. Regnault's results, and "total heat" is from the Fahrenheit zero.

The bases of all his results are, that the saturated steam maintains relatively density, temperature, and pressure unchangeably to each other, and it naturally follows that if one of these properties are for any cause changed, that the others also change in some fixed ratio, or that each of the others pass through relative changes in proportion, so that all the factors change proportionately, and the basis remains the same or unchanged.

In specific heat, water exceeds any other substance known, and the specific heat of any body is the amount of heat required to raise its temperature 1°, taking the amount of heat required to raise the temperature of water 1° (an equal weight) as the unit. The specific heat of superheated steam, as stated by M. Regnault, is .48, while saturated steam is .305; and the same authority states, that as saturated steam is always at its dew point, and, if its density is maintained, all the loss of heat encountered must be supplied by its partial condensation, and, while it does not contain water necessarily, its temperature cannot be any higher than that of the water from which it was generated. It has, until recently, been supposed that the specific heat of saturated steam was nothing, as it did not require an additional amount of heat to raise its temperature, and it was also supposed that the latent heat gave the increase of temperature; but M. Regnault has determined differently, and that an addition is required of .304° to its total heat to raise the temperature one degree.—See Tables I, II, III, IV and V.

TABLE 1.

PROPERTIES OF SATURATED STEAM, AT PRESSURES FROM ONE POUND TO TWO HUNDRED POUNDS ON THE SQUARE INCH.

Elastic Force.		Heat, in Degrees Fahrenheit.					Volume, that of an equal weight of water at its greatest density being 1.	Weight of One Cubic Foot, in Decimals of a Pound.	Specific Gravity, the Atmosphere at 32° being 1.
In Pounds on the Square Inch.	In Inches of Mercury at 32°.	Sensible Heat.		Latent Heat.	Total Heat.				
			Difference.			Difference.			
1	2.0375	102.		1043.05	1145.05		20890	.0029	.037
5	10.1875	162.37	9.26	1001.9	1163.46	2.82	4627	.0135	.167
10	20.375	193.29	4.93	979.60	1172.89	1.50	2429	.0257	.318
15	30.5625	213.07	3.47	965.85	1178.92	1.05	1669	.0373	.463
20	40.75	228.	2.8	955.5	1183.5	.8	1280	.0487	.604
25	50.9375	240.2	2.3	947.	1187.2	.7	1042	.0598	.742
30	61.125	250.4	2.	939.9	1190.3	.6	881	.0707	.877
35	71.3125	259.3	1.7	933.7	1193.	.5	764	.0815	1.012
40	81.5	267.3	1.5	928.1	1195.4	.4	670	.0921	1.142
45	91.6875	274.4	1.4	923.2	1197.6	.4	608	.1025	1.272
50	101.875	281.	1.3	918.6	1199.6	.4	552	.1129	1.402
55	112.0625	287.1	1.2	914.4	1201.5	.4	506	.1232	1.529
60	122.25	292.7	1.1	910.5	1203.2	.3	467	.1335	1.654
65	132.4375	298.	1.1	906.8	1204.8	.3	434	.1436	1.779
70	142.625	302.9	1.	903.4	1206.3	.3	406	.1536	1.904
75	152.8125	307.5	.9	900.3	1207.8	.3	381	.1636	2.029
80	163.	312.	.9	897.1	1209.1	.2	359	.1736	2.151
85	173.1875	316.1	.8	894.3	1210.4	.3	340	.1833	2.271
90	183.375	320.2	8	891.4	1211.6	.2	323	.1930	2.391
95	193.5625	324.1	.8	888.7	1212.8	.3	307	.2030	2.511
100	203.75	327.8	.7	886.1	1213.9	.2	293	.2127	2.631
105	213.9375	331.3	.7	883.7	1215.0	.2	281	.2224	2.751
110	224.125	334.6	.6	881.4	1216.0	.2	269	.2319	2.871
115	234 3125	338.	.6	879.	1217.0	.2	259	.2410	2.990
120	244.5	341.1	.6	876.9	1218.0	2	249	.2503	3.105
125	254.6875	344.2	.6	874.7	1218.9	.2	239	.2598	3.227
130	264.875	347.2	.6	872.6	1219.8	.2	231	.2693	3.347
135	275.0625	350.	.5	870.7	1220.7	.1	223	.2788	3.467
140	285.25	352.9	.6	868.6	1221.5	.1	216	.2883	3.582
145	295.4375	355.6	.6	866.8	1222.4	.2	209	.2978	3.697
150	305.625	358.3	.5	864.9	1223.2	.2	203	.3073	3.809
155	315.8125	360.9	.5	863.1	1224.	.2	196	.3168	3.927
160	326.	363.4	.5	861.4	1224.8	.2	191	.3263	4.042
165	336.1875	365.9	.5	859 7	1225.6	.2	186	.3353	4.157
170	346.375	368.2	.4	858.1	1226.3	.2	181	.3443	4.270
175	356.5625	370.6	.5	856 4	1227.	.1	176	.3533	4.383
180	366.75	372.9	.4	854.8	1227.7	.1	172	.3623	4.495
185	376.9375	375.3	.5	853.1	1228.4	1	168	.3713	4.607
190	387.125	377.5	.4	851.6	1229.1	.1	164	.3800	4.720
195	396.3125	379.7	.4	850.1	1229.8	.2	160	.3888	4.832
200	407.5	381.7	.3	848.6	1230.3	.1	157	.3973	4.945

TABLE II.

AREA OF CIRCLES FROM ¼″ DIAMETER UPWARDS.

Inches. Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.	Inches Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.	Inches. Diameter	Area.
0.25	.04908	11.5	103.86	22.75	406.49	34.	907.92	45.25	1608.1	56.5	2507.1	67.75	3605.0	79.	4901.6
0.5	.1963	11.75	108.43	23.	415.47	34.25	921.32	45.5	1625.9	56.75	2529.4	68.	3631.6	79.25	4932.7
0.75	.4417	12.	113.09	23 25	424.55	34.5	934.82	45.75	1643.8	57.	2551.7	68.25	3658.4	79.5	4963.9
1.	.7854	12.25	117.85	23.5	433.73	34.75	948.41	46.	1661.9	57.25	2574.1	68.5	3685.2	79.75	4995.1
1.25	1.227	12.5	122.71	23.75	443.01	35.	962.11	46.25	1680.0	57.5	2596.7	68.75	3712.2	80.	5026.5
1.5	1.767	12.75	127.67	24.	452.39	35.25	975.90	46.5	1698.2	57.75	2619.3	69.	3739.2	80.25	5058.0
1.75	2.405	13.	132.73	24.25	461.86	35.5	989.80	46.75	1716.5	58.	2642.0	69.25	3766.4	80.5	5089.5
2.	3.141	13.25	137.88	24.5	471.43	35.75	1003.7	47.	1734.9	58.25	2664.9	69.5	3793.6	80.75	5121.2
2.25	3.976	13.5	143.13	24.75	481.10	36.	1017.8	47.25	1753.4	58.5	2687.8	69.75	3821.0	81.	5153.0
2.5	4.908	13.75	148.48	25.	490.87	36.25	1032.0	47.5	1772.0	58.75	2710.8	70	3848.4	81.25	5184.8
2.75	5.939	14.	153.93	25.25	500.74	36.5	1046.3	47 75	1790.7	59.	2733.9	70.25	3875.9	81.5	5216.8
3.	7.068	14.25	159.48	25.5	510.70	36.75	1060.7	48.	1809.5	59.25	2757.1	70.5	3903.6	81.75	5248.8
3.25	8.295	14.5	165.13	25.75	520.76	37.	1075.2	48.25	1828.4	59.5	2780.5	70.75	3931.3	82.	5281.0
3.5	9.621	14.75	170.87	26.	530.93	37.25	1089.7	48.5	1847.4	59.75	2803.9	71.	3959.2	82.25	5313.2
3.75	11.044	15.	176.71	26.25	541.18	37.5	1104.4	48.75	1866.5	60.	2827.4	71.25	3987.1	82.5	5345.6
4.	12.566	15.25	182.65	26.5	551.54	37.75	1119.2	49.	1885.7	60.25	2851.0	71.5	4015.1	82.75	5378.0
4.25	14.186	15.5	188.69	26.75	562.00	38.	1134.1	49.25	1905.0	60.5	2874.7	71.75	4043.2	83.	5410.6
4.5	15.904	15.75	194.82	27.	572.55	38.25	1149.0	49.5	1924.4	60.75	2898.5	72.	4071.5	83.25	5443.2
4.75	17.720	16.	201.06	27.25	583.20	38.5	1164.1	49.75	1943.9	61.	2922.4	72.25	4099.8	83.5	5476.0
5.	19.635	16.25	207.39	27.5	593.95	38.75	1179.3	50.	1963.5	61.25	2946.4	72.5	4128.2	83.75	5508.8
5.25	21.647	16.5	213.82	27.75	604.80	39.	1194.5	50 25	1983.1	61.5	2970.5	72.75	4156.7	84.	5541.7
5.5	23.758	16.75	220.35	28.	615.75	39.25	1209.9	50.5	2002.9	61.75	2994.7	73.	4185.3	84.25	5574.8
5.75	25.967	17.	226.98	28.25	626.79	39.5	1225.4	50.75	2022.8	62.	3019.0	73.25	4214.1	84.5	5607.9
6.	28.274	17.25	233.70	28.5	637.94	39.75	1240.9	51.	2042.8	62.25	3043.4	73.5	4242.9	84.75	5641.1
6.25	30.679	17.5	240.52	28.75	649.18	40.	1256.6	51.25	2062.9	62.5	3067.9	73.75	4271.8	85.	5674.5
6.5	33.183	17.75	247.45	29.	660.52	40.25	1272.3	51.5	2083.0	62 75	3092.5	74.	4300.8	85.25	5707.9
6.75	35.784	18.	254.46	29.25	671.95	40.5	1288.2	51.75	2103.3	63.	3117.2	74.25	4329.9	85.5	5741.4
7.	38.484	18.25	261.58	29.5	683.49	40.75	1304.2	52.	2123.7	63.25	3142.0	74.5	4359.1	85.75	5775.0
7.25	41.282	18.5	268.80	29.75	695.12	41.	1320.2	52.25	2144.1	63.5	3166.9	74 75	4388.4	86.	5808.8
7.5	44.178	18.75	276.11	30.	706.86	41.25	1336.4	52 5	2164.7	63.75	3191.9	75.	4417.8	86.25	5842.6
7.75	47.173	19.	283.52	30.25	718.69	41.5	1352.6	52.75	2 85.4	64.	3216.9	75.25	4447.3	86.5	5876.5
8.	50.265	19.25	291.03	30.5	730.61	41.75	1369.0	53.	2206.1	64.25	3242.1	75.5	4476 9	86.75	5910.5
8.25	53.456	19.5	298.64	30.75	742.64	42.	1385.4	53.25	2227.0	64.5	3267.4	75.75	4506.6	87.	5944.6
8.5	56.745	19.75	306.35	31.	754.76	42 25	1401.9	53.5	2248.0	64.75	3292.8	76.	4536.4	87.25	5978.9
8.75	60.132	20.	314.16	31.25	766.99	42.5	1418.6	53.75	2269.0	65.	3318.3	76 25	4566.3	87.5	6013.2
9.	63.617	20.25	322.06	31.5	779.31	42.75	1435.3	54.	2290.2	65.25	3343.8	76.5	4596.3	87.75	6047.6
9.25	67.200	20.5	330.06	31.75	791.73	43.	1452.2	54.25	2311.4	65.5	3369.5	76.75	4626.4	88.	6082.1
9.5	70.882	20.75	338.16	32.	804.24	43.25	1469.1	54.5	2332.8	65.75	3395.3	77.	4656.6	88.25	6116.7
9.75	74.662	21.	346.36	32.25	816.86	43.5	1486.1	54.75	2354.2	66.	3421.2	77.25	4686.9	88.5	6151.4
10.	78.540	21.25	354.65	32.5	829.57	43.75	1503.3	55.	2375.8	66.25	3447.1	77.5	4717.3	88.75	6186.2
10.25	82.516	21.5	363.05	32.75	842.39	44.	1520.5	55.25	2397.4	66.5	3473.2	77.75	4747.7	89.	6221.1
10.5	86.590	21.75	371.54	33.	855.30	44.25	1537.8	55.5	2419.2	66.75	3499.3	78.	4778.3	89.25	6256.1
10.75	90.762	22.	380.13	33.25	868.30	44.5	1555.2	55.75	2441.0	67.	3525.6	78.25	4809.0	89.5	6291.2
11.	95.033	22.25	388.82	33.5	881.41	44.75	1572.8	56.	2163.0	67.25	3552.0	78.5	4839.8	89.75	6326.4
11.25	99.402	22.5	397.60	33.75	894.61	45.	1590.4	56.25	2485.0	67.5	3578.4	78.75	4870.7	90.	6361.7

TABLE III.

HYPERBOLIC LOGARITHMS.

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
1.05	.049	2.4	.875	3.75	1.322	5.15	1.639	6.5	1.872	7.85	2.061
1.1	.095	2.45	.896	3.8	1.335	5.2	1.649	6.55	1.879	7.9	2.067
1.15	.14	2.5	.916	3.85	1.348	5.25	1.658	6.6	1.887	7.95	2.073
1.2	.182	2.55	.936	3.9	1.361	5.3	1.668	6.65	1.895	8.	2.079
1.25	.223	2.6	.956	3.95	1.374	5.33	1.673	6.66	1.896	8.05	2.086
1.3	.262	2.65	.975	4.	1.386	5.35	1.677	6.7	1.902	8.1	2.092
1.33	.285	2.66	.978	4.05	1.399	5.4	1.686	6.75	1.91	8.15	2.098
1.35	.3	2.7	.993	4.1	1.411	5.45	1.696	6.8	1.917	8.2	2.104
1.4	.336	2.75	1.012	4.15	1.423	5.5	1.705	6.85	1.924	8.25	2.11
1.45	.372	2.8	1.03	4.2	1.435	5.55	1.714	6.9	1.931	8.3	2.116
1.5	.405	2.85	1.047	4.25	1.447	5.6	1.723	6.95	1.939	8.33	2.119
1.55	.438	2.9	1.065	4.3	1.459	5.65	1.732	7.	1.946	8.35	2.122
1.6	.47	2.95	1.082	4.33	1.465	5.66	1.733	7.05	1.953	8.4	2.128
1.65	.5	3.	1.099	4.35	1.47	5.7	1.74	7.1	1.96	8.45	2.134
1.66	.506	3.05	1.115	4.4	1.482	5.75	1.749	7.15	1.967	8.5	2.14
1.7	.531	3.1	1.131	4.45	1.493	5.8	1.758	7.2	1.974	8.55	2.146
1.75	.56	3.15	1.147	4.5	1.504	5.85	1.766	7.25	1.981	8.6	2.152
1.8	.588	3.2	1.163	4.55	1.515	5.9	1.775	7.3	1.988	8.65	2.158
1.85	.612	3.25	1.179	4.6	1.526	5.95	1.783	7.33	1.991	8.66	2.159
1.9	.642	3.3	1.194	4.65	1.537	6.	1.792	7.35	1.995	8.7	2.163
1.95	.668	3.33	1.202	4.66	1.54	6.05	1.8	7.4	2.001	8.75	2.169
2.	.693	3.35	1.209	4.7	1.548	6.1	1.808	7.45	2.008	8.8	2.175
2.5	.718	3.4	1.224	4.75	1.558	6.15	1.816	7.5	2.015	8.85	2.18
2.1	.742	3.45	1.238	4.8	1.569	6.2	1.824	7.55	2.022	8.9	2.186
2.15	.765	3.5	1.253	4.85	1.579	6.25	1.833	7.6	2.028	8.95	2.192
2.2	.788	3.55	1.267	4.9	1.589	6.3	1.841	7.65	2.035		
2.25	.811	3.6	1.281	4.95	1.599	6.33	1.845	7.66	2.036		
2.3	.833	3.65	1.295	5.	1.609	6.35	1.848	7.7	2.041		
2.33	.845	3.66	1.297	5.05	1.619	6.4	1.856	7.75	2.048		
2.35	.854	3.7	1.308	5.1	1.629	6.45	1.864	7.8	2.054		

TABLE IV.

EFFECT OF EXPANSION WITH EQUAL VOLUMES OF STEAM.

The theoretical economy of using steam expansion is as follows. A like volume of steam being expended in each case, and expanded to fill the increased spaces.

Point of Cutting Off.	Expansion Number.	Mean Pressure of Steam.	Gain Per Cent. in Power.	Point of Cutting Off.	Expansion Number.	Mean Pressure of Steam.	Gain Per Cent. in Power.
.1	10.	3.302	230.	.5	2.	1.693	69.3
.125	8.	3.079	208.	.6	1.66	1.507	50.7
.166	6.	2.791	179.	.625	1.6	1.47	47.
.2	5.	2.609	161.	.666	1.5	1.405	40.5
.25	4.	2.386	139.	.7	1.42	1.351	35.1
.3	3.33	2.203	120.	.75	1.33	1.285	22.3
.333	3.	2.099	110.	.8	1.25	1.223	20.5
.375	2.66	1.978	97.8	.875	1.143	1.131	13.1
.4	2.5	1.916	91.6	.9	1.11	1.104	10.4

In this illustration no deductions are made for a reduction of the temperature of the steam while expanding or for loss by back pressure.

The same relative advantage follows in expansion as above given, whatever may be the initial pressure of the steam.

TABLE V.

FRACTIONS OF INCH EXPRESSED IN DECIMALS.

		Decimals.
1–64	=	.015625
2–64= 1–32	=	.03125
3–64	=	.046875
4–64= 2–32= 1–16	=	.0625
6–64= 3–32	=	.09375
8–64= 4–32= 2–16=1–8	=	.125
10–64= 5–32	=	.15625
12–64= 6–32= 3–16	=	.1875
14–64= 7–32	=	.21875
16–64= 8–32= 4–16=2–8=1–4	=	.25
18–64= 9–32	=	.28125
20–64=10–32= 5–16	=	.3125
22–64=11–32	=	.34375
24–64=12–32= 6–16=3–8	=	.375
26–64=13–32	=	.40625
28–64=14–32= 7–16	=	.4375
30–64=15–32	=	.46875
32–64=16–32= 8–16=4–8=2–4=1–2	=	.5
34–64=17–32	=	.53125
36–64=18–32= 9–16	=	.5625
38–64=19–32	=	.59375
40–64=20–32=10–16=5–8	=	.625
42–64=21–32	=	.65625
44–64=22–32=11–16	=	.6875
46–64=23–32	=	.71875
48–64=24–32=12–16=6–8=3–4	=	.75
50–64=25–32	=	.78125
52–64=26–32=13–16	=	.8125
54–64=27–32	=	.84375
56–64=28–32=14–16=7–8	=	.875
58–64=29–32	=	.90625
60–64=30–32=15–16	=	.9375
62–64=31–32	=	.96875
64–64=32–32=16–16=8–8=4–4=2–2	=	1.00000

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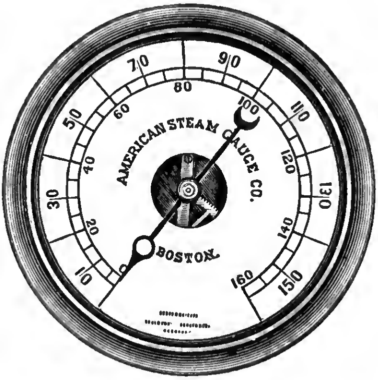
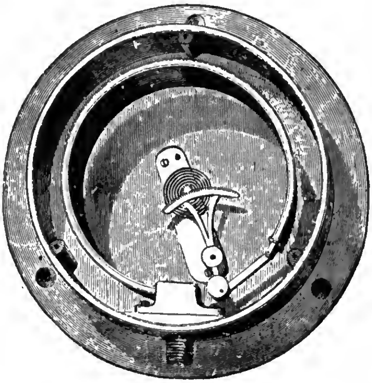
High or Low Pressure or Vacuum Gauges.



(Outside View.)



(Inside View.)

PRICES, INCLUDING COCK.

BRASS CASE.

12 inch Dial	$75.00
10 “ “	40.00
8½ “ “	30.00
6¾ “ “	20.00
6 “ “	16.00
5½ “ “	12.00
5 “ “	11.00
4½ “ “	10.00
3½ “ “	9.00
3 “ “ or smaller	8.00

IRON CASE, JAPANNED.

12 inch Dial	$50.00
10 “ “	32.00
8½ “ “	22.00
6¾ “ “	16.00
6 “ “	13.00
5½ “ “	10.00
5 “ “	8.00
4½ “ “	8.00
3½ “ “	7.00
3 “ “ or smaller	6.00

Discount

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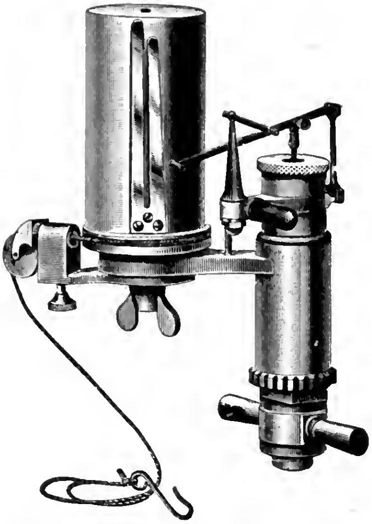

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Gentlemen—I have to say that, after quite an extensive use of the Thompson Indicator, I am persuaded that it is a most excellent instrument, and that my confidence in the same is proven by the orders from time to time sent your company. Yours truly,
E. D. LEAVITT, JR., Consulting Engineer.

SIBLEY COLLEGE, CORNELL UNIVERSITY,
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Gentlemen—It gives me great pleasure to say that the instruments sent us have proved to be of most excellent quality, and, so far as our work has given opportunity to judge, of great accuracy. We have used them on all kinds of work and at speeds of rotation up to 300, and have found them capable of doing admirably. The finish is excellent, and the sizes and fits all that could be asked. They have been very useful, both in class-work and in making engine trials, and eminently satisfactory in all respects. We have had no difficulties with them except such as may have come from their use by inexperienced hands. When used for instruction an occasional accident is to be expected. They have withstood such injuries quite as well as we ought to expect, and have done more work and better work, even in such hands, than I had supposed possible.
Very respectfully yours, R. H. THURSTON, Director.

EDWARD P. ALLIS & CO.,
RELIANCE WORKS,
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Gentlemen—I have used all the prominent makes of Indicators, but very much prefer the Thompson, and believe it has more good points and less faults than any other instrument made. The easy changing of springs, good leading pulley for the cord, general convenience in handling, and last, but certainly not least, its ability to stand abuse, are some of the features that commend it to the practical engineer. Yours truly, IRVING H. REYNOLDS.

F. W. DEAN, MECHANICAL ENGINEER, 53 STATE STREET,
AMERICAN STEAM GAUGE CO., Boston. BOSTON, MASS., March 20, 1891.

Gentlemen—In response to your inquiries with reference to my experience with your high-speed Indicator in quick work, I can say that I have used it on a considerable number of locomotives on various railroads throughout the country, both on slow and fast trains, and have been much pleased with its performance. I have used it with steam pressure as high as 180 lbs. per square inch, and shall soon try it with 200 lbs. The greatest number of revolutions at which I have used it is 376 per minute, and it appeared to respond readily to that speed. Cards can be taken as rapidly as one in one and one-half minutes, with convenience. Very truly yours, F. W. DEAN.

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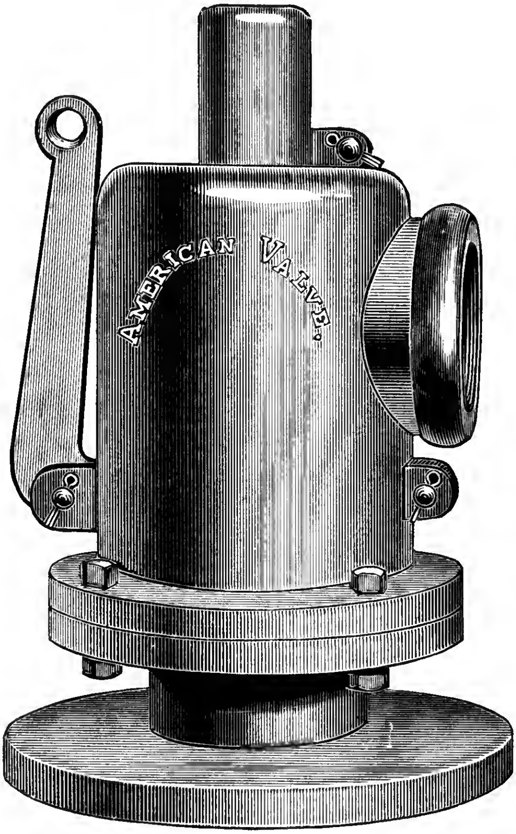
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