The W P I.

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THE W P I

Vol. X. WORCESTER, MARCH 9, 1895. No. 17.

The W P I is published by the students of the Worcester Polytechnic Institute on alternate Saturdays during the Institute year.

Items of interest are requested from students and alumni of the Institute. All matter must be written in ink and accompanied by the author's name, not necessarily for publication, but as a guarantee of good faith on the part of the writer.

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Once more it becomes absolutely necessary for us to call attention to our condition financially. During the past two months, the Business Manager has sent a bill, together with a letter requesting payment, to every subscriber among the Alumni. The return has been alarmingly small. In fact, only a small portion of the subscribers have remitted their arrears thus far. Now, as it was stated some time since, we are in rather straitened circumstances, and we need every subscription in order to make ends meet.

We do not understand why it should be necessary to emphasize the payment of subscriptions to such a body of gentlemen as constitute the subscribers of the W P I. It is well known that our Alumni occupy prominent and lucrative positions. There is not a subscriber of ours but could immediately pay his subscription without any perceptible inconvenience. Why, then, this delay, and, indeed, sometimes failure?

Our Alma Mater is growing in importance every day. Surely its representative paper ought not to require to have its claims pushed forward in this manner. It is true we have a large number of subscribers who always pay their subscriptions cheerfully and promptly, We are not addressing these gentlemen, but only those who apparently ignore the notification sent them by the Business Manager.

Owing to the previous business mismanagement of this paper, there have been a number of subscriptions collected before they became due, and no record made of the fact on our books. The present Business Manager can simply take the records as he finds them, and thus there have been cases where bills have been sent to subscribers who have already paid. If these subscribers will inform the Business Manager when such is the case, he will gladly make the necessary corrections. It is disappointing to find that we are not to receive the money we expected; but, nevertheless, it is much more satisfactory than to have our notification ignored entirely.

We believe that if our subscribers remembered how materially the publication of this paper increases our work at the Institute, they would be more willing to assist us by prompt remittance when requested. We trust it will not be necessary to mention this matter again. If your bill is still unpaid kindly look it up and attend to it at once.

That our Faculty is interested in our well-being, physically as well as mentally, is shown by the fact that they have arranged to shoulder, in conjunction with the Instructors and resident Alumni, the purchasing of the prizes for next Thursday. Let us prove that we are worthy their kindness.

Next Thurday's Games promise to be a greater success than its most ardent supporters dared hope. Numbers of entries are promised from outside colleges, and many cracks will be here.

The effect on our own athletic outlook is marked, and the Athletic Committee of the Faculty, which has fostered the project from the start, deserves very great credit. They made a bold move, but the result shows their foresight. Captain Allen now has fifty men training daily at the rink. There are several promising men in this number, and it is safe to say that the majority were brought out by the opportunities offered at the Indoor Meet.

With this view in mind the Meet cannot be a failure, no matter what the financial result. We may say, however, that the finances need cause no worry, and there is small doubt but that the Rink will be filled, and the Treasurer of the Association return home rejoicing after the Games.

Is it possible that our athletic fervor has caused us to forget the Burlesque? If so, let this serve as a reminder that the date for the production is but seven weeks distant.

Two things are now lacking, which, if soon provided, will ensure the success of the work; namely, enthusiasm and constant attendance at rehearsals.

Both the ballet and chorus need constant practice to bring them to proper form; inspiration will not do it. The practice at first may be slightly tiresome, but it is sure to grow more interesting as the workers become more skilful, and what satisfaction each one may feel at the part he had in making the Burlesque a triumph in college theatricals.

Let us urge that more men turn out for both ballet and chorus, and that they attend rehearsals faithfully, for the ten per cent. rule doesn't hold in this matter.

It is with great pleasure that we announce the final organization of the Current Topics Club. The idea is an excellent one and should receive encouragement from students and instructors alike. No one who attended the last meeting of the Society could but feel that he had obtained information on an important subject, in a short time and in a pleasant manner.

The tendency of all societies in our College is toward special lines of thought and work, so, when a club is formed whose object is general and wide reaching, it must be of benefit to a great number. It obviates the danger, which is imminent in a college like our own, of the men, engrossed in scientific labor, becoming narrow.

The student in this Institute lacks opportunity for general reading. His studies take up most of his time; and, if not occupied in his college work, he seldom feels like indulging in outside literary work.

This, we may say, is the rule, but we are confident there are many exceptions. But since it is the rule we must deal fairly with it and see how it may be overthrown.

What better way, what pleasanter way, than by attending the meetings of the Current Topics Club? At these meetings remarks are made by men, whose duty it has been to inquire into, and form opinions on, the matter under discussion; men who have carefully collected facts and figures for our enlightenment. All this may become our own at a trifling expenditure of time. This time will be taken but once in two weeks, notice of the meeting being posted in advance so that all may arrange to attend.

All this good, however, can only be accomplished by the awakened interest of the students. Shall it fail? We hope every one connected with the Institute will answer, No. If such an answer is conscientiously made, the Club cannot but be a success.

The responsibility rests with you, Students of the Institute. See to it that you do your duty.

We suggest that a larger attendance might be secured by changing the hour of meeting so that it will not conflict with Burlesque rehearsals.

LABORATORY MEASUREMENTS AND HOW TO TREAT THEM.

An Abstract of Mr. A. D. Risteen's Paper.

"It has long been known," the speaker began, "that *poets* cannot be made, but must be born. To a certain extent this is true of observers also; but just as one may learn to write creditable verse, even in the absence of the 'divine frenzy' that is necessary to make one a poet, so, also, one may learn to be a very fair observer, even though he has no especial natural aptitude for observing. I am not here to tell you how to observe, but rather to discuss the treatment of the observations after they have been made; and yet I should like to say a few words about observing, by way of introduction. In the first place, you should study your instrument, and investigate the errors to which it is liable; and you should then endeavor to plan your experiments so that the effects of these errors will be as small as possible. For example, let us consider the common tangent galvanometer. (1) In the first place we have to consider the possibility of *parallax* errors; for if the needle is not in the same plane with the scale we shall obtain an erroneous reading, unless the eye is situated directly over the needle. Parallax errors are easily avoided, as you know, by placing a piece of mirror-glass below the needle, and taking care that the image of the pupil of the eye is bisected by the needle as we look down to take a reading. (2) We have also to consider the possibility of the needle-pivot being slightly eccentric with respect to the graduated circle. Any instrumental imperfection of this kind will cause the reading to be too great at one end of the needle and too small at the other end; and its effects may be eliminated by observing the needle at both ends, and taking the mean of the two readings so obtained. (3) The zero of the graduated circle may deviate a little from strict magnetic north, or the plane of the coil may not be accurately square to the line joining the needle-pivot and the zero-point of the instrument. In either of these cases the observed deflection will be too large or too small; but the effects of such errors in adjustment may be eliminated by making *two* observations, one with the current traversing the coil clockwise, and the other with the current passing counter-clockwise. One of the readings so obtained will be too large and the other too small; and if the instrument is only *slightly* out of adjustment the mean of the two readings will be unaffected by the errors we are considering. Of course there are still many other errors to which galvanometers are liable, but I have said enough to illustrate the point I wanted to make, which is, that in order to get good results we have to study our instruments carefully, and plan our work so that the various instrumental errors may be eliminated, as far as possible.

You must always remember that *you* are a part of the mechanism by which the observation is made—you are really a part of the instrument. You must, therefore, take care, not only of the inanimate part of the combination, but also of *yourself;* and you must know something about the errors to which you are liable. Above all, do not try to do too much at once. Do what you do carefully and well; but if you find that the work cannot be completed to your entire satisfaction to-day, remember that there is another day coming, and wait for it. The human body never works perfectly, and it is found that the very best observers have a constant habit of error in making certain kinds of observations. This habitual error, or 'personal error,' as it is called, has been studied most in connection with the estimation of *time*. In observing the passage of a star across the meridian, for example, some observers will be late in their estimate, and will not be satisfied that the transit has occurred until a fraction of a second *after* the true passage. Others, on the other hand, will be anxious to be 'on time,' and will conclude that the event has occurred, when it still *wants* a fraction of a second of the true time. A novice will observe transits sometimes too soon, and at other times too late; but the experienced observer settles down to a constant habit, so that his estimates are all too early, or all too late, by an amount which is fairly constant. A *constant* personal error is of small importance, because the ultimate object of time-measures is usually the determination of an *interval* of some sort; and if the errors committed at the beginning of the interval and at the end of it, are identical, both in magnitude and in sign, the interval itself will be unaffected by them. It may interest you to know how 'personal error' was first discovered, so I will read you the account of it given in the *American Cyclopædia:* 'The first recorded case of personal equation [*i. e.* personal error] occurs in the *observations*, for the year 1796, of Maskelyne, the astronomer-royal of England. He says that in August, 1795, his assistant, Mr. Kinnebrook, began to record his observations half a second later than he should, and in 1796 about eight-tenths of a second too late, and that it appeared to be impossible for him to overcome the habit. Maskelyne assumed that his *own* observations were correct, and discharged his assistant, although he says he was "diligent and useful." This was a case of personal equation, and at the present day astronomers place as much reliance upon the observations of Kinnebrook as upon those of Maskelyne.'

As I have said, you cannot avoid having a personal error; and hence you should take measures to ensure that that error shall be *constant*, or as nearly so as possible. You should never allow yourself to feel in the least degree anxious about your work, you should always do your observing in a comfortable position, and you should take care of your general health. As a single illustration of the attention that good observers pay to small points, I may say that the best of them, in recording times by means of the electric chronograph, take care that their arm and hand shall always be in about the same position, so that the muscles may have the same leverage every time they press the key, and the fingers respond with uniform quickness to the impulse sent to them by the brain.

In recording observations and in making computations, always be methodical. It is best to have ruled note-books in which to record measurements, but in the work that you will be likely to do this will seldom be feasible, on account of the *expense* involved. However, you can easily prepare some sheets of paper by ruling them with a pen, and writing in the headings of the various columns. I would advise you, wherever possible, to use *ink*, both in recording and computing. Above all things, do not record your measures on miscellaneous slips of paper, relying on your memory to tell you what the various entries mean. These bits of advice may seem beneath your notice; but I assure you that they are worthy of the most careful consideration. If you relax your vigilance in the smallest respect, you may be sure that errors will creep into your work—somewhere and somehow.

There is one point that I should like to discuss very fully, but which I shall have to dismiss with a few words. I refer to the *rejection* of observations. You may as well make up your mind, at the very outset, that you are going to make some discordant measures, because then you will be more resigned to them when they come. Professor C. S. Peirce, formerly of the U. S. Coast and Geodetic Survey, once had a couple of young men at work for him (I wasn't one of them!), and for a considerable time their measures came out very smoothly. They were quite elated, and called the Professor's attention to the quality of the work they were doing; but he, instead of being properly impressed, merely nodded his head, and said, sympathizingly, 'Boys, don't be discouraged! Keep right on, and you'll *get* some bad ones.' The temptation to reject an apparently bad observation is often too great to be resisted by the novice; but you will find that competent, honest, and experienced observers do not throw out such work, but write it right down in his books, possibly marking such suspected measures with an (?), so that they can afterwards remember which they were. The best rule that I can give you in a few words is, *Never* reject a measure, unless you have *positive knowledge* that it is wrong. If your instrument falls over on the floor, or if you *know* you disturbed an adjusting-screw, there may be reason in rejection; but otherwise my counsel would be, to *keep everything*. Several important discoveries have been brought to light by observations that were apparently discordant, and I have seen repeated instances in which suspected observations were afterwards proved to be the best of the lot. You will often see published observations in which the results are remarkably accordant; and when you compare these with your own, you may possibly be discouraged and feel that your work is extraordinarily poor. You must not allow yourself to do so! Rest assured that those smooth, published results conceal a story that would be of extreme interest, if we could only read between the lines. I do not mean to imply that they have been dishonestly 'prepared,' but that they are very likely the final outcome of a great amount of relatively poor work, which does not appear on the surface. Many hours of patient, unrecorded toil were required before the conditions of success were understood, and the instruments and methods of observing perfected sufficiently to make accordant results possible."

The speaker then passed to the consideration of graphical methods of treating observations. He touched first upon the simple plotting of the results, giving as an example the calibration errors of a thermometer, and illustrating the process of interpolation by finding, from the diagram, the calibration—correction to be applied to a given reading of thermometer. Regnault, he said, plotted his observations on a smooth copper plate, by means of a dividing engine, making the interpolations in the same way. The usefulness of the graphical method in enabling us to draw conclusions concerning points that cannot be directly investigated by experiment, was illustrated by quoting Rankine's method of obtaining the position of the absolute zero of temperature.

Rankine argued that such bodies as air and carbonic acid will depart more and more from the condition of a perfect gas, the greater their density becomes; and he considered that the coefficient of expansion of a perfect gas might be obtained by determining the limit towards which the coefficients of actual gases approach, as their densities are indefinitely reduced. By using the results obtained for air and CO_2, the speaker deduced, graphically, the limiting value of the coefficients of expansion; and the reciprocal of this gives the position of the absolute zero, which was found to be about 274.3° C. below the freezing point. The chief objection to the graphical method is its crudeness, and the speaker showed how this could be overcome by the use of "residual curves," such as are described in Pickering's *Physical Manipulation.* Several examples of these curves were given, the principal ones being Mr. Schott's investigation of the magnetic declination at Paris during the past 350 years, and an illustration of the determination of wave-lengths by means of scale-readings on a single-prism spectroscope.

"The graphical method is also useful," he continued, "when we wish to determine empirical equations between observed quantities; for a plot often enables one to make a shrewed guess at the form of equation that will fit the given observation curve. I remember a very good illustration of this point that was once given by Professor Sinclair. 'If you glance out of the window and see something in the yard that looks like a cat,' he said, 'that does not prove that it *is* a cat, but yet it lends some color to the supposition; and it is then easy to find out whether you are right or not. In the same way, if you see a curve that *looks* like a parabola, you have not proved anything, but you have a suggestion, which you can then proceed to investigate.' I have thought of that illustration a great many times, and there is a good deal in it. I have often been asked how to find the equation of a given curve. The only answer to this question that can be given is 'If you know some general property of the curve you can find its equation; but otherwise the problem is impossible.' The equation of a curve really contains an *infinite* amount of information, inasmuch as it gives the relations between the coördinates of an infinite number of points. In order to derive the equation we have to know something about *all* of these points. A general property of the curve supplies such information; but when nothing is given but the coördinates of a few of the points, we are really required to deduce an infinite amount of information from a finite quantity of data. I think the mere statement of the problem, in this light, is sufficient to show the impossibility of solving it. But although we cannot find an exact equation to a curve from such meagre data, we can always find some curve that shall agree with the given curve so closely that the distance between the two shall nowhere exceed a certain proposed limit."

When the curvature is not very great, it is usually possible to approximate the curve satisfactorily by means of an equation of the form

$$y = a + bx + c x^2 + \cdot \cdot \cdot \qquad (1)$$

keeping as many terms as experience may show to be necessary. When no satisfactory equation of this form can be found, it is often useful to try a series of descending powers, such as

$$y = a + \frac{b}{x} + \frac{c}{x^2} + \cdot \cdot \cdot \qquad (2)$$

When neither of these forms will give a satisfactory result by itself, some combination of the two may be found serviceable; for example, something like this:

$$y = a + b x + \frac{c}{x^2} \cdot \cdot \cdot \text{"}$$

Methods of finding the coefficients of (1) and (2) readily were given, but space will not allow us to describe them.

At the conclusion of Mr. Risteen's address Dr. Mendenhall spoke briefly of a few points that occurred to him in connection with the subject under discussion. He agreed with the speaker, he said, in his advice to keep all observations that do not involve manifest blunders. Professor Benjamin Peirce had devised a mathematical criterion for the rejection of observations, but it is not generally in use among observers at the present day, and some doubts have been expressed with regard to its validity. It is important to note all the little irregularities of an observation curve—the "big humps" have all been seen before, and have been pretty thoroughly investigated. Only a short time ago Mr. Schott, of the U. S. Coast and Geodetic Survey, had discovered a most minute variation in the magnetic declination, a variation so slight that it had entirely escaped the attention of others. The period of this variation has been found to coincide with the moon's period of revolution about the earth, and there is little doubt about the irregularity in the motion of the magnetic needle being due to an actual tidal motion of the solid earth, under the influence of the moon's attraction. Here is a case in which important conclusions are drawn from irregularities in the observations so slight as to be barely perceptible, even when we are told that they are there. Another instance of the importance of "bad" measures is afforded by the results of Crookes' researches on high-vacuum tubes. In determining the atomic weight of thallium Professor Crookes found that his weighings were subject to slight errors that he could not account for. By patient investigation he discovered the cause of the discrepancies, and they opened up before him a new and unexplored realm in the physics of gases. Some of the properties of gases that were discovered in this way were shown in the beautiful high-vacuum tubes exhibited by Mr. Risteen last year.

The recent discovery of "argon," the new constituent of the air, was due to a similar methodical investigation of what seemed to be bad observations. A slight difference was observed between the density of nitrogen as obtained from the air, and that of the same gas as obtained from its chemical compounds. Instead of rejecting discrepant measures and "smoothing things," Lord Rayleigh and Professor Ramsey examined all the results systematically, and after a great deal of hard, blind work, they succeeded in isolating the substance "argon," which is now thought to be a new element. This discovery is undoubtedly one of the most important that have been made for many years, and we cannot yet foresee its consequences. At the present moment the new substance seems to be entirely anomalous, and if subsequent research confirms its elementary nature, we shall undoubtedly have to modify many of our present chemical theories to make room for it.

The design for the new arrangement of the chapel was by W. H. Morse, Jr., '95. He will receive the prize offered for the best design.

THE STEAM ENGINE.

Lecture to Seniors by A. K. Mansfield.

Gentlemen:

I have selected for the subject of my remarks, "Present Tendencies in Engine Construction," and design, if possible, to bring out some points of interest to you relating to changes now going on, and to be anticipated in this branch of mechanics.

I labor under the disadvantage of not knowing to what extent you are acquainted with the science of steam engineering, therefore to make my conclusions more intelligible, will begin with a brief historical review.

The science of steam engineering, as you are all doubtless aware, may properly be said to have begun with the investigations and discoveries of James Watt. The intelligence of this wonderful man, by some called the Shakespere of steam engineering, was so remarkable that he was able, in a few years, to solve the principal problems connected with the economical use of steam, as we understand it, so completely as to leave comparatively little for his ambitious followers to accomplish.

Before Watt, condensation was accomplished by spraying water directly into the steam cylinder. He separated the condenser from the engine, thus enabling the cylinder to be held at a more nearly uniform temperature, and enabling him to double the useful effect of the steam.

He invented the steam jacket, and explained its philosophy in a masterful manner. He first applied the centrifugal governor, that beautiful machine which may safely be said to be the most truly classical of all mechanical devices. He also invented the steam engine indicator,—in a crude form, of course, but refined enough, as it was sure to be from his hands, to fully suit the requirements of his day.

Some political economists have told us that the steam engine has done more to civilize the world, during the last century, than all other influences. If this be so, and it may not lightly be denied, then James Watt may well be placed at the head, as the greatest individual benefactor of the human race. I believe that in mechanics we are too prone to separate the man from his work, rather glorifying the work while half forgetting the worker. If this be an error, as I believe, I shall try to avoid it this morning.

As I propose to consider stationary engines alone, I only casually refer to Stephenson, the father of the locomotive.

He is known principally through his two great inventions—artificial draft produced by the escaping exhaust, and his wonderful link motion—the latter another of those classical combinations in mechanism which immortalizes its inventor.

In stationary work, the next great inventor to leave a well-defined footprint in the path of Watt, was our George H. Corliss. In considering his work we must bear in mind that, dating from Watt, the science of which we are treating is but little more than a century old. That the first half of that century saw but few engines produced compared with the vast number made in the latter half. Corliss' work began in about 1849. He seems to have invented the rocking or Corliss valve, and originated the application of the centrifugal governor to the so-called releasing valve gear.

His work, however, seems to me to have been more in the line of a constructing engineer and a pushing business man than in that of an inventor. He applied such admirable skill and boldness to the details of design and proportions of parts, that in spite of what must have been viewed in the first place as extreme complexity of mechanism, the admirable results in point of economy which he obtained, justified the means; and the civilized world by copying his work, has glorified him as the originator of a new and successful type.

Last among the names of those whose work I wish you to consider with me to-day, is that of Mr. J. W. Thompson. This name may not be familiar to you, but the name of the "Buckeye" engine doubtless is. In this case the name of the inventor has been obscured by that of the company which adopted his invention. It is known to you that I am engaged in that company's service. Being, therefore, fairly familiar with their product, I shall occupy a little time in explaining some of its features to you. Before doing so, let me call your attention to the interesting fact that the founders of this company's business began to manufacture steam engines more than half a century ago. Their experience, therefore, extends over nearly half the time since Watt first gave *his* attention to the subject. They began before Corliss entered the field, and the number of important improvements in engine construction which have been made at their works in this time, is worthy of your careful consideration.

I speak of these matters merely as an onlooker, and in a desire to do justice; even to glorify the notably successful workers in steam engineering.

Previous to the invention of the now well-known Buckeye engine the founders of this business had built a large number of highly successful high-speed saw-mill engines, which coupled directly on to the saw mandrels, thus making them, in this country, at least, the pioneer builders of high-speed engines. The modern Buckeye engine, however, was first brought out shortly prior to the Philadelphia Exposition. It was invented and designed by Mr. Thompson, and at once attracted the attention of the engineering world. I consider this invention to be entitled to the distinction of being classed as a new and important type, and shall ask you to consider with me some of its novelties.

I have here a model of a valve-movement, showing the construction and operation of the ordinary slide-valve. It is not a Buckeye valve, but if you understand this well you will understand the *Buckeye* better. I take it that you are already so familiar with this that it would be useless for me to occupy much of your time with it, but will, nevertheless, to refresh your memory, point out its leading features.

The valve, as I said before, is the *ordinary* slide-valve. It dates from Watt's time, and is still in very extensive use. Nearly all the locomotives of the world have it.

In stationary practice it is principally used in connection with throttling governors.

This is the kind of engine which Corliss displaced, being able to guarantee about forty per cent. better efficiency by the use of his automatic cut-off system with condenser than could be obtained by throttling performance without condenser; about half of this being due to the condenser.

I will now call your attention to the Buckeye hollow-valve. This valve is made hollow to obviate the necessity of the "D" cavity of the ordinary slide-valve.

To explain how it is held to its seat and balanced: Suppose a hollow box filled with steam at boiler pressure, thus (referred to figure on blackboard) the pressure of the steam is counter-balanced within the valve, and there is no tendency of the valve to leave its resting place. Suppose an opening or port cut through. A steam pressure due to the area of this port now tends to lift the valve from its seat. Suppose this port to be so placed relative to the cylinder port that steam is admitted to the cylinder; there is now a lifting pressure due to the areas of both ports. Now suppose one or more round rings, resting on the top of the valve and fitted to a steam chest, steam tight, above the valve; the steam chest also contains steam at boiler pressure. Clearly the valve is forced to its seat by a pressure due to the total area of the circle or circles whose diameter is the outside diameter of the ring or rings. This is true so long as the ring rests on the top of the valve with the usual steam-tight joint.

Now if we cut through the valve inside the ring at D to admit steam to the valve, the conditions of balance are not changed, for the steam without acts against the steam of equal pressure within, quite the same whether a wall is interposed or not. Thus far the *method* of balance; now as to the amount, or the size of the rings. I have said that in the position shown, which is the position in which the valve has its maximum lift, the areas of both ports are a measure of the lifting force. This needs to be modified. The lifting force may be and usually is greater than this. A certain amount of steam gets between the valve and its seat and adds to the lifting force.

To cut off as far as possible the extent to which this steam can act, a groove is cut in the valve. This groove communicates with the exterior.

The eccentric operating the cut-off valves is in turn operated on by the shaft governor. This device, now so universally in use, was first successfully applied through the ingenuity of Mr. Thompson.

In considering the tendencies of steam engine construction, compound or multiple cylinder engines are very soon forced upon our attention. The reason for the superior economy of compound engines is usually said to be owing to the reduction in cylinder condensation attained thereby. You are doubtless acquainted with the theory of this matter, and I will not take the time required to go over it, but will rather call your attention to some facts less commonly considered.

Let a vertical line, A, represent the origin of volume, and a horizontal line, B, the origin of pressures in a steam engine cylinder. Suppose the length, AO, to represent the maximum volume obtained in them.

(Here followed blackboard explanations to show the impracticability of high rates of expansion in a single cylinder, aside from any consideration of cylinder condensation.)

Now, if it is true, as is often asserted, that the best economy is obtained by compressing to the initial pressure, then in the case shown we would have to compress along the expansion line, therefore no steam would be admitted and no work done. Such a use of steam is clearly not practical, yet to expand to eight pounds above zero is thoroughly practical in compound practice, and six per cent. or more clearance is very usual. Even if a less compression than to initial pressure is best, yet the method of distribution with the assumed initial and terminal pressures is not good. I merely cite this elementary case to show that cylinder condensation is not alone the reason for compounding engines.

There are a variety of reasons why compound engines are more favorable to economical performance beside the fact of reduced condensation. Another, is the increased facility of lubrication, as we shall see further on.

Perhaps the most marked tendency of the present time is that of increase of boiler pressure.

Watt is recorded as being inclined to favor low pressures, being satisfied with about seven pounds above the atmosphere.

Shortly after Watt, with the advent of so-called high pressure or non-condensing engines eighty pounds boiler pressure was employed, and for many years eighty to ninety pounds was almost universal practice in stationary work in this country.

In locomotive practice higher pressures prevailed. When eighty to ninety pounds was stationary practice one hundred and ten to one hundred and twenty was in common use on locomotives. During the last few years higher pressures have come into rather frequent use, and at the present time we are called upon to provide engines to work under one hundred and twenty-five to one hundred and fifty, and even one hundred and sixty pounds boiler pressure, while locomotives are using from one hundred and sixty to two hundred pounds.

I suppose it is easy to understand that engine builders would prefer not to have to meet such important changes in practice as this. Given an engine well adapted to work under a boiler pressure of eighty to ninety pounds, it may be very ill-adapted to use steam at a pressure of one hundred and twenty-five to one hundred and fifty pounds; therefore, a company which is well equipped for building engines to meet the first conditions named, may require to extensively change its methods to meet the higher pressures.

This is what has occurred, and is occurring with most engine builders—a gradual change in methods, and in proportions and strength of parts to meet the modern demands.

This change is brought about not only from the increase in pressures used, but also because of the modern method of running engines continuously, which is coming more and more in vogue.

It is common practice in electric lighting and railroad stations to run engines under heavy pressure and load twenty-four hours per day, for all the seven days of the week. Similar practice is often followed in rolling mills, flouring mills, etc. Add to this the fact of the continued shifting from no load to maximum, which occurs in some lines of business, such as electric street railways and modern rolling mill practice, it will be appreciated that to produce engines for some of the demands of modern service is quite a different matter from what it was to build engines for the more moderate demands of a few years ago.

(Here a letter from a manufacturing firm was read stating that a Buckeye engine in their works had just completed a continuous run of thirteen months and thirteen days, without a moment's stop.)

I am able to point out to you some of the difficulties attending the changes to which I have referred. First, referring back to the ordinary slide-valve it will be seen that the extent of surface subjected to friction is a function of the width and length of the port. (The valve travel is a function of the width of the port). I would go into this matter with you with the aid of the Zeuner diagram, but you either are already familiar with that branch of the subject or will soon become so.

Now it is a somewhat curious fact, that although the extent of wearing surface in the ordinary slide-valve, as well as in the Buckeye, and other valves, is a function of the dimensions of the port; yet so long as ordinary pressure of steam was used, this surface was great enough so that its pressure, or the pressure on it, per square inch was not enough to interfere with easy lubrication. But as the use of the more modern heavy pressures came about, this wearing surface was not adequate. To be sure steam at a higher pressure is a more dense substance, and larger ports are required to permit its easy passage to the cylinder, and, as before indicated, the wearing surface became greater with the larger ports, but not to the required extent to overcome the trouble. Here is indicated a possible source of grief in the construction of steam machinery which I would warn you to avoid. The method of lubricating the valves and piston of an engine is at best crude. Heavy oil is admitted by suitable means to the rapidly passing steam. Of course, but a very small portion of this steam, and therefore of the oil, reaches the surface to be lubricated. Yet the method serves well where these surfaces are not subjected to an over pressure, and when the oil is of suitable quality. Moreover, two surfaces reciprocating on each other, through a short distance, are often specially hard to lubricate. Take the case of a Rocker arm vibrating on its shaft. (Explained from model.) An annoying case has come to my attention within a few days.

We have recently installed three compound engines in a street railway plant, in which all of the rocker arms have shortly become cut on their shafts. The extent of surface was exceptionally great and the strains on the surfaces were light, but, owing to the short extent of vibration and to some lack of judgment in arranging grooves to carry the oil to every part of the surface, a small part of the surface "ran dry." If the rocker had vibrated through a large arc, or revolved about the shaft, probably no trouble would have been experienced.

To return to the valve surface. Various methods have been used to reduce the friction due to high pressure. In locomotives, balancing plates have been applied to the back of the valve in such a way as to partially balance the pressure due to the "D," notably the Richardson method. In stationary service partially balanced valves, such as the Buckeye and others, are employed; also gridiron valves of large extent of surface and small travel. The only completely balanced valve, however, is the round or piston valve. This form of valve is coming into great favor in marine service, being usually applied on all the cylinders of triple expansion engines, except the final or low pressure cylinder, which is fitted with a flat valve. This construction I have introduced on Buckeye Compound Engines of the larger sizes, and even on smaller engines when applied to severe service. It is a well-known fact that for tightness of action the flat value has no rival, while for ease of handling and lubricating, the round valve is pre-eminent, although it is difficult, if not impossible, to prevent slight leakage past the valve at some points of its movement. Both qualities can not be attained in the highest degree in either valve alone.

The application of the round valve to the high pressure cylinder, and of the flat valve to the low pressure, seems to be a good combination; for although a small amount of leak may occur past the first valve, the effect of this steam is not entirely lost, for it does some work in the low pressure cylinder. This argument, however, should not be taken as an apology for using the round valve. The round valve has such points of superiority, especially when used double—

that is, one round valve within another with constant travel of each—that it is a highly desirable device for use in *simple* engines using high pressures.

This form of valve, *i. e.* the single round valve, has been applied to locomotives by the Baldwin Locomotive Works in recent years, and I look to see its use in this service become much more extended.

Triple expansion is used to some extent in stationary work, and good results have been obtained in point of economy; but *I believe* that one of the former students of this Institute has correctly pointed out that the method of carrying the expansion through three cylinders has been applied where, in some cases, as good economy would have been obtained by the judicious use of two cylinders only. The "Rockwood System," so called, may not supplant triple expansion, but Mr. Rockwood has already, in his persistent advocacy of his views, made an undoubted impression, influencing the tendency of the times. This means that two-cylinder engines are sometimes found to be ample for economy where three cylinders have before been thought essential to produce that economy. In marine service, where high rates of clearance space seem to be essential, this is probably less true. I was recently on a small ocean steamer in which, as I was told by the builders, the lowest clearance, *i. e.* the clearance of the cylinder which had the least amount, was 23 per cent. This seems enormous to a builder of stationary engines, who, fortunately, usually has more room to work in.

Compounding without the use of the condenser, or non-condensing compounding, is coming into use slowly, but with *some* gain in economy. In Ohio there is a large manufactory of portable farm engines, which last year began to build these engines with compound cylinders. While this is economical of fuel, I believe that the plan was adopted principally to lessen the amount of water necessary to be carried on the machine.

There seems to be a reaction away from the short-stroke engines of high rotative speed, recently so much advocated.

The belief that short, quick strokes would reduce cylinder condensation to such an extent as to improve economy, has not been realized. The notable examples of economical engines have been slow running—*i. e.*, as to revolutions.

The lowest record in compound engines is one designed by Mr. E. D. Leavitt. The engine is a pumping engine, having a uniform load, and a stroke of ten feet. Not many of us may hope to construct an engine of as great stroke as this.

The difficulties attending the running of engines seem to increase with the number of revolutions per unit of time. We know that the inertia of reciprocating parts increases with the square of the revolutions, while decreasing only directly with the stroke; and this inertia becomes a somewhat serious matter to take care of in engines of high speed. Centrifugal force of revolving parts increases with the square of the revolutions; for instance, that of the balance weight in the crank, which produces friction on the journal. The work of friction increases with the revolutions, increasing liability to heat at rubbing surfaces. What I want to make clear is that among engines, those of high rotative speed are most troublesome. Yet there is a plain tendency to increase the speed of medium and long-stroke engines. This is found to be entirely practicable, for the rotative speed is still kept much less than in the short-stroke engines to which I have referred. Whereas 600 feet piston speed is as much as should be commonly used in short-stroke engines, we find that 800 to 900 feet is being recently applied in the longer-stroke engines with success.

As I have said before, engines for certain kinds of work are being built of much heavier construction than heretofore. Electric street railway service has been the greatest influence to bring this change about. This kind of service, while it is perhaps no more severe than rolling mill work, yet it occupies a larger field and therefore exerts a wider influence.

There can be no doubt that most of us learn wisdom from unpleasant experiences, and in this line of service the experiences which have led up to the massive high-duty engine of the present moment (so to speak) have been unpleasant to a good many builders. Among these experiences may be mentioned the considerable number of disasters to heavy fly wheels which have occurred, say in the few years while you have been following your studies in this Institute. I can call to mind a dozen or more of these accidents which have, in the aggregate, caused the destruction of a good deal of property and some loss of life. These experiences, which may be added to in kind any day, should lead users of large wheels not recently designed, to have them examined expertly, and replaced if of doubtful strength, and have led engineers and theorists to give the matter of wheel construction very close attention recently. A twenty to thirty foot wheel, whose rim may weigh from twenty to forty tons, flying through the air at the rate of a mile or more per minute, may have a centrifugal force of twenty to thirty pounds per pound of rim weight—a bursting strain of a good deal of importance, and a mechanical element whose design is now known to require the utmost skill. We have insurance companies which insure against the accidental bursting of boilers. It has been suggested that it is not impracticable to exercise the same supervision over the construction and operation of wheels.

A somewhat curious coincidence is that a mile per minute seems to be about the safe limit of speed for wheel rims, belts and locomotives.

We recognize a tendency toward the use of larger engines. Modern practice seems to be in the direction of concentrating power, where it may be done without detriment, increasing boiler pressure, compounding and condensing. Until recently condensing has only been performed where plenty of condensing water was easily available, but now a new device, which may be called a water cooler, is coming into vogue. By means of this apparatus the same water is repeatedly used for condensing the exhaust steam. This water is kept cool enough for its purpose by being sprayed, or finely divided, by certain mechanical means, and allowed to fall like a shower past rapidly ascending air, driven past the water by means of a large revolving fan. The results obtained from this apparatus seem to make it probable that condensing steam plants will soon become the rule rather than, as heretofore, the exception.

It can hardly be expected that I would miss so good an opportunity as the present to inflict some little advice on you.

It is now about twenty-two years since I completed my studies, such as you are occupied with. I remember that one of the things I thought I had learned, which seemed to me to be of the greatest importance, was that the science of engineering was the science of economy. That engineering meant the application of economic principles; how to produce the required result with the least material, etc., etc. In the best sense, this is no doubt true. But I warn you to begin early to learn to apply it in the best sense. You are taught about factors of safety. Let me ask you to be generous with them. After a long course of study in applied mechanics, and the manipulation of figures to determine how small an amount of material may be employed in a shaft or a bolt or a wheel, or any mechanical element to do the required work, or withstand the imposed strain safely, a tremendous temptation has been—I might almost say—forced upon you, to try to gain credit by accomplishing the result sought with as little material as possible. I warn you earnestly to steer clear of this rock. I have seen innumerable failures from parts being made too weak, but do not remember any where the part which failed was too strong. Be bold and err knowingly, if it is possible, on the safe side, and you will earn the proud distinction of being safe engineers.

I presume you have not been taught the bone theory. It is an excellent guide. Some twenty to twenty-five years ago I had the good fortune to gain some experience under the direction of an able engineer, who had practically no technical education in the sense in which we generally understand the expression.

He was, in the work with which he was familiar, a safe man. His work stood. It did not break down, nor easily wear out. He fixed dimensions without calculation. I once asked him why he made a certain shaft that size. He replied, "I feel it in my bones that that is right." I have found that to be a comfortable feeling to have. With that feeling a man sleeps nights; but when you feel doubtful, and lie awake with a feeling of distrust in your bones, go over it and increase your factor of safety.

I know of an eminent engineer who, in designing a large and important cotton mill here in Massachusetts, calculated with great care the dimensions of the beams and columns which were to support the lower floor, and from that all the floors above. These beams and columns were of cast iron and were shaped with the utmost regard to the most economical distribution of metal, according to the knowledge of the day when they were designed. After the mill was erected and the machinery in it set in operation, the deflection of the beams became great enough to be a matter of serious apprehension to the designer, so much so that he quickly had duplicate columns and beams placed beside the originals, thus doubling the strength of the whole. Such a course, after the refined calculations of the first design, seems wasteful of material, but the mill stands, and has stood for some twenty-five or thirty years.

How shall we determine our factors of safety? In the first place, let me urge you to avoid reliance upon your own individual judgment when it is possible to refer to precedents, and, in matters of importance, let those precedents be such as have stood the test of long service. It is a singular fact that parts of heavy machinery such as engines, which may do good service for a year or two, or more, may not be suitable for a good deal longer period. Some have accounted for this by a subtle influence named by them, "fatigue of metals." I do not know to what extent metals get tired of the duties sometimes imposed upon them, but to eliminate the necessity of factors of fatigue, choose the cases from which you derive the constants for your formulæ, as before said, from those which have endured the test of time.

I do not take kindly to the term "factor of safety," although it probably has a more or less legitimate use. To convey the idea which I have in mind, the use of a factor, which might be called "factor of rigidity," would have more appropriateness. Many parts of machines or mechanical structures may possess vastly more strength than is actually necessary to perform their functions, and yet may deflect, vibrate or tremble under their strains to such an extent as to seem to the eye to be weak. This must be overcome by making them stronger yet.

As a case in point, I remember a large, high-speed engine, having an overhung cylinder. The outer end of the cylinder, as is often the case in such engines, had a slight sidewise or lateral vibration. By measurement, I found the amount of this vibration to be about two-hundredths of an inch, yet it seemed so great an amount to the eye of the purchaser of the engine that he complained of it with bitterness. A structure ought, when it may, to have the *appearance* of sufficient strength as well as the actuality. Rigidity is essential to this.

Let me call your attention to the increasing tendency toward the use of steel in places where wrought or cast iron has been used. This is a matter of great interest and importance. I spoke of cast iron beams and columns which were used some twenty-five or thirty years ago in the construction of a certain mill. In modern practice these parts would be made of steel. This tendency is quite the same in engine construction as in other branches of engineering, although, perhaps, not so marked. Certain shapes are much better produced by the moulders' art than otherwise, but in these shapes steel castings are, to some extent, supplanting cast iron. I look to see this tendency increase rapidly, for a great deal of capital has recently been applied to the establishment of foundries for the production of steel castings. This should be a matter of congratulation to you, the coming engineers, for cast iron is a treacherous material, when its qualities are compared with those of the modern material called steel.

POLO.

Harvard vs. Tech.

The game of polo Saturday, Feb. 23, at Cambridge, resulted in the first defeat for the Tech team this year. The score was 2 to 0.

The boys took their defeat gracefully, acknowledging that they got into a little too fast company.

The best feature of the game was the playing of Goodridge, the Harvard rusher. His work was of the highest order and he received much applause.

The Tech team's best playing was done by Sibley and Harris. In fact, if it had not been for their star work, the defeat would have been much more severe.

The line up was as follows:

W. P. I.		HARVARD.
Warren, Knowles	Rushers	Clarkson, Goodridge
Philpot	Centre	Sharpless
Sibley	Half-back	Elliot
Harris	Goal	Brown

Rushes won by Knowles	Goal by Goodridge
" " Warren	
" " Goodridge	" " Goodridge
" " Warren	

Stops in Goal { Harris 10, Brown 5 }

Referee, Mr. Jewell.

W. P. I. A. A. INDOOR MEET.

The Arrangements for March 14th.

Arrangements for the Athletic Meet are fast being completed. The list of events, as it now stands, is slightly altered from that first given out a few weeks ago. The open handicap events are four in number, consisting of a 40-yards dash, 600-yards run, 1-mile walk and pole-vault. The Academy and High School have entered large teams, and a team of 12 men from Harvard is entered.

At present there are only three events for Tech men exclusively. These are high jump, 600-yards run, and 1000-yards run. There is some probability, however, that a 40-yards dash will be added to these.

The team race between the classes will be the last event, in order to give the men opportunity to participate in the other events while at their best.

A team race between the St. Paul's of this city and the St. Mary's of Boston, had been arranged, but has been withdrawn on account of illness of the team from Boston.

After Tech's inability to secure a team race with M. I. T., an attempt to secure a team from Brown was made, but Capt. Allen received word the first of the week that they would not run against our team. Both Amherst and Trinity were immediately communicated with, and it is hoped a race may be arranged with one or the other of these colleges. In case this project fails, the Tech 'Varsity team will run a team of W. P. I. graduates. The graduate team will probably consist of Messrs. Dadmun, Gallagher, Whipple and Allen.

Reserved seat tickets are now on sale at Speirs' athletic store. The south side of the rink will be reserved for ladies and their escorts. The members of the Faculty and the Alumni will occupy the south gallery.

The prizes are on exhibition at Corbett's jewelry store. In the open events the prizes are: Princess lamps for firsts and statuettes for those winning second place. In the closed events the first and second men will receive silver loving cups.

The officials of the evening will be: Referee, H. A. Adams; Judges at Finish, Prof. G. B. Viles, Dr. J. R. Fitzpatrick and A. O. Knight; Field Judges, E. W. Kinsley, W. A. C.; H. J. Fuller, W. P. I., and N. C. Keyes, W. C. I.; Timers, P. H. Hurley, W. A. C.; I. E. Bigelow, W. A. C., and F. Coulson, W. A. C.; Starter, W. F. Donovan, W. A. S.; Clerk of Course, W. A. Beaudette, W. A. C.; Assistant Clerk of Course, F. E. Knowles, W. P. I.; Announcer, H. D. Temple, W. P. I.; Inspectors, Dr. L. L. Conant, Dr. L. P. Kinnicutt, E. G. Penniman, W. P. I.; A. G. Mason, W. H. S., and R. E. Barker, W. A. The ushers will be Messrs. Davis, Warren, Clement, Sanford, '95.; Mayo, Gibbs, Crawshaw, '96; Elliott, '97; Murless and Synyer, '98.

CURRENT TOPICS CLUB.

Report of First Meeting.

The Current Topics Club has been organized with the following officers: President, A. W. Clement, '95; Vice-President, C. C. Chalfant, '97; Secretary and Treasurer, H. H. Morse, '97. These three officers, with Prof. Cutler and Dr. Haynes, form the Executive Committee.

The object of this society is to discuss current topics of wide general interest. It is one of the duties of the Executive Committee to assign to several members different topics for discussion. The number of assignments for each meeting is not great, and the object of this measure is to provide facts for the general discussion of each meeting. A question draw is also encouraged, and it is the wish of the Executive Committee that the questions for discussion be handed to the Secretary at least three days previous to any regular meeting. The meetings will be held fortnightly, and all members of the Institute can become members, if they so desire, by paying a trifling initiation fee and an annual assessment.

The first regular meeting for discussion of some topic was held in Boynton Hall, Friday evening, March 1st. At 7:45 President Clement called the meeting to order, and stated that the topic to be discussed was "The War Between China and Japan." Mr. Riley, '96, opened the discussion by remarks on the causes which led to the struggle. The next speaker was Mr. Throop, '97, who spoke on the progress of the war. His words were easily followed by the assistance of a sketch of Corea and China, which he had drawn on the blackboard. Mr. Clement then spoke on the relative conditions of the two countries, and was followed by J. W. Chalfant, Jr., '96, on the causes which have lead to the numerous victories won by Japan. The formal discussion was closed by Mr. Brigham, '96, who predicted some of the effects of the war on the world.

The meeting adjourned at nine thirty P. M.

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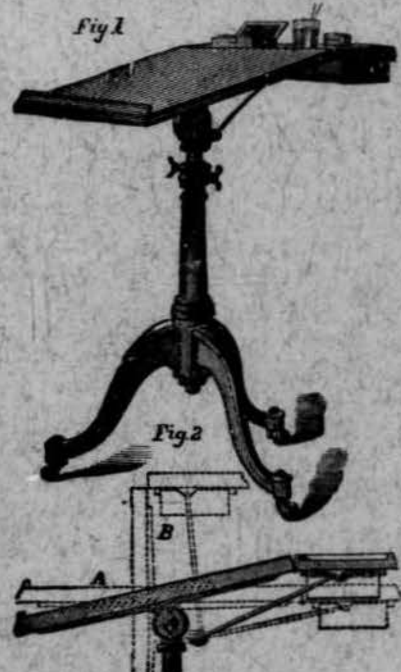

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