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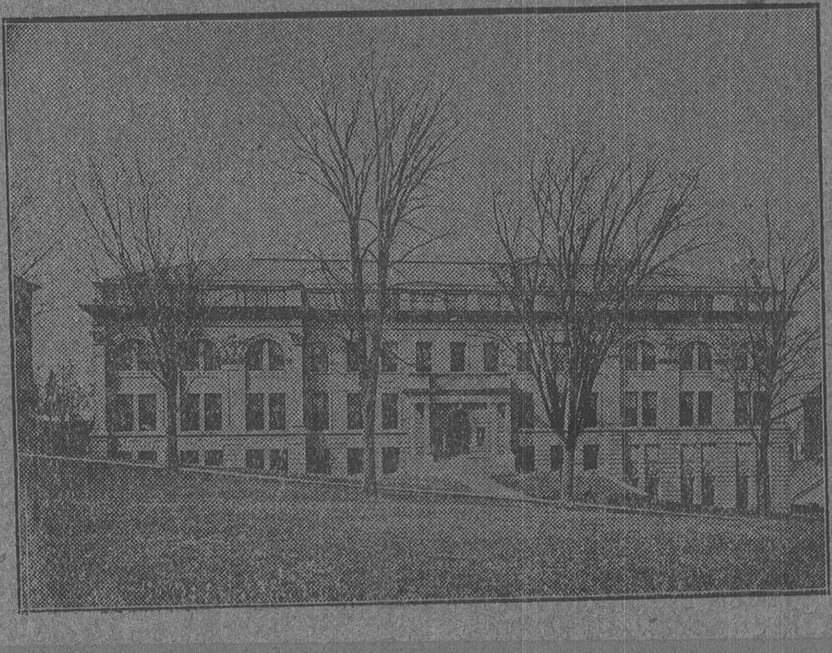
THE WISCONSIN ENGINEER

Vol. 7 MAY, 1903 No. 3



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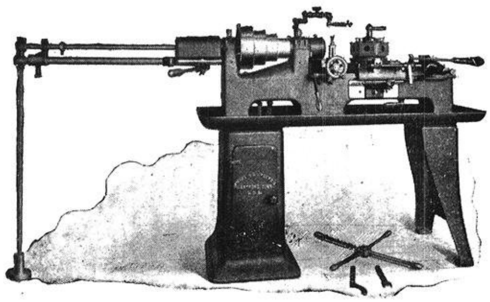

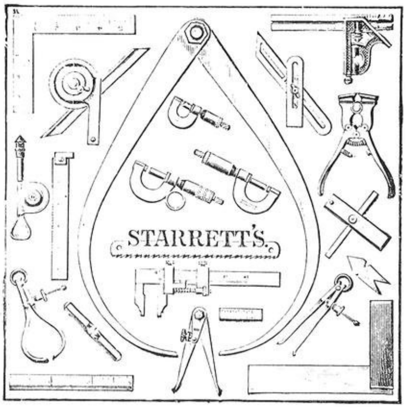
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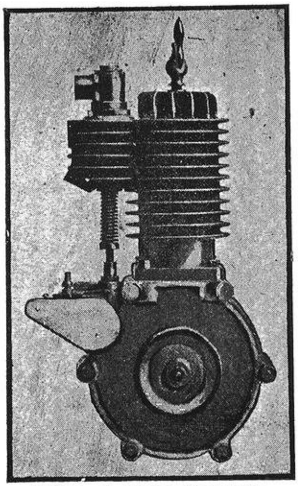

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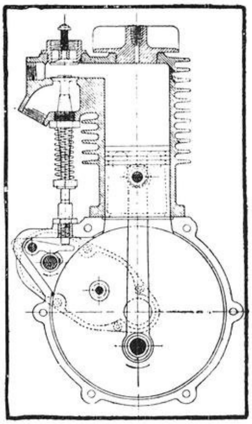

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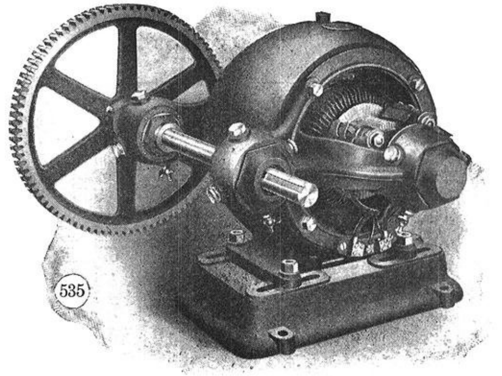

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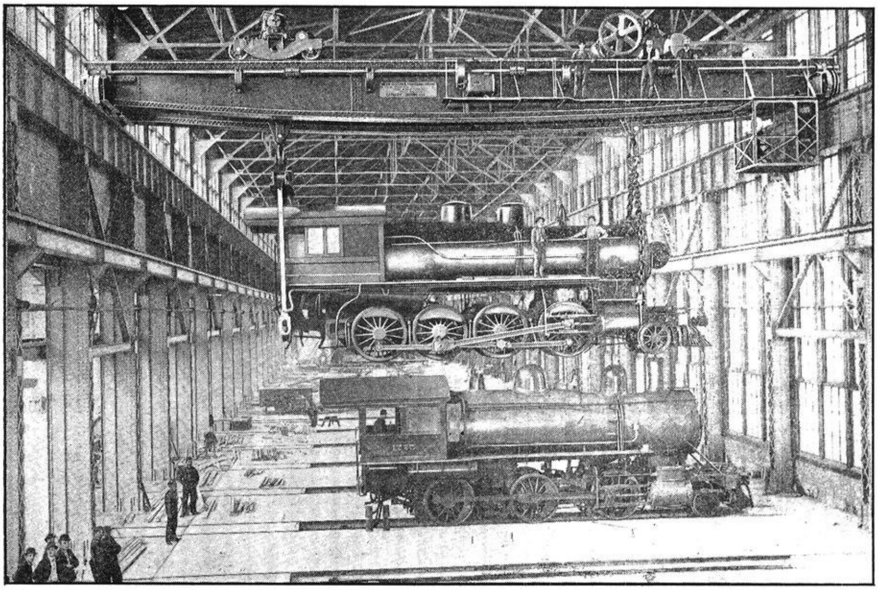

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THE WISCONSIN ENGINEER

VOL. 7. MAY, 1903. NO. 3.

THE POTENCY OF ENGINEERING SCHOOLS AND THEIR IMPERFECTIONS.*

DUGALD C. JACKSON.

It is natural at a time like this to revert in thought to the teaching of engineering in the technological schools of the country, and to ponder on the influence which this teaching produces upon their pupils and upon the economic welfare of the land. I have assumed that some consideration of this question will interest my audience today. A discussion of the potency in the body politic of engineering education is particularly appropriate before the school of applied science located under the inspiring heights of your majestic mountains, which afford an unrivaled richness to him who attacks their depths with efforts properly directed by science. Applied science gives you the power of reaching your ore, hoisting, treating and finally smelting it—applied science, which has been taught here and elsewhere to the chemists and engineers of your rugged state.

I am the more ready to discuss this theme here, in the inspiring presence of your mountains and their bracing atmosphere, because you have laid the foundation for, and have the opportunity to build up, a school of applied science (an engineering school) that may stand unexcelled amongst its eastern brethren. True, you are far from the centers of dense population; but the hum of industry is about, and great works are yet to be accomplished before the wealth of your

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* Address delivered before the School of Applied Science of the University of Colorado on November 14, 1902, on the occasion of the celebration of the quarter centennial anniversary of the University.

state reaches its highest development; and the engineering school numbering 500 students may be as great as the school that numbers 1,500.

In the building up of your school of applied science, in this, your university, your people must remember that men and money are required. Men who are practiced, and, if possible, great, in two professions—the professions of engineering and of teaching. Money is requisite to pay for the services of these men, and much money for the equipment of laboratories in which they may adequately teach their students—the sons of your state and of its neighbors. In following my remarks, please remember that I bear no mission of instruction to this university; but I make a plea and explanation to those not technically informed friends of the university who may not fully understand, and who desire to know, whence spring the peculiar advantages of technological education and those requirements which demand particularly large expenditures in its adequate support.

During the course of two decades, we as a people have rapidly advanced toward an appreciation of the proper relations of the engineer to his surroundings. The true conception of engineering may be accepted as comprised within the good old definition, "Engineering is directing the sources of power" (and wealth) "in nature to the use and convenience of man." The man who with fullest success follows the profession defined by this keenly conceived sentence must be a man of science, a man of the world, a man of business, and a man who is well acquainted with the trend of human civilization and human aspirations. To make such a man requires the highest thought and effort of the best teaching influences. Michael Faraday (one of the magnificent men whose lives have been dedicated to the commands of pure science) said that it requires twenty years to make a man in physical science, the intervening period being one of infancy. How much more effort must be carefully expended to make a man not only in physical science, but also a man in business and a man in sociology, all in one! Such men are all of the great engineers, measured according to their times; and to them ought to be accorded in their youth the most careful training.

Our engineering college men at their graduation should properly be looked upon as apprentices in the engineering profession. The student must be inspired in college and taught to work for himself in the manner adopted by George Stephenson, when instructing his assistants and pupils. "Learn for yourselves," said he, "think for yourselves, make yourselves masters of principles, persevere, be industrious, and there is then no fear of your success." The students should become *thinkers* in college, capable of usefully applying their scientific knowledge therein obtained; and they should be expected to become thorough engineers through experience in applying this knowledge in a manner which may only be gained in an apprenticeship in the industries, similar to the office and hospital apprenticeships of rising young lawyers and doctors.

The methods used at West Point and Annapolis in training officers for the army and navy, and the course of the graduates after leaving those academies, fairly illustrate my point. It is there held that "a man, to know how to teach another man how to pull a stroke oar, must get on the stroke oar himself; to be safe as a quarter-deck officer, to give orders for reefing a topsail in a gale of wind, he must himself have reefed a topsail in a wind. To know how to tell a man to ease a weather sheet or to work the gear of any part of a ship, he must have had his practical experience on that same gear. He cannot instruct his men properly, he cannot command them safely and efficiently, unless he has been through three or four years of hard practical experience, hand in hand with the men in the forecastle. The same thing is true of engineering. No man is fitted to be superintendent (or manager) of a road or works, no man is capable of carrying on large engineering operations until he has had the practical experience which fits him to pass judgment upon what will be the result of the directions which he may give to others."

Four years is but a small part of Faraday's period required "to make a man" in the physical sciences, and in so short a period (which is the duration of the engineering college course) only the foundation of the engineer (the *man* in science, business and sociology) can be laid. "There is a great difference between reading and study; or between the indolent reception of knowledge without labor, and that effort of mind which is always necessary in order to secure an important truth and make it fully our own," says Joseph Henry; and the engineering college course should be bent toward such a complete and true presentation of thorough science and truth that the student is incited permanently to secure it for himself and make it fully his own—and he may then put it to valuable use in future practice. "It is not enough to join learning and knowledge to the mind; it should be incorporated into it."

The engineering college graduate should be a fertile and an exact thinker, and a man of value upon his graduation; but he can not come to his highest fruition until years thereafter. The speaker would gladly be judged by the success attained by his students after years of practice in their profession, but let no judgment be passed (as is so often done in some colleges) upon the basis of wages received during the year after graduation. Our engineering college teaching may be properly condemned if it does not plant those methods of thought which will grow more valuable with the years, and, indeed, become most valuable only after the mature development of the individual.

The engineering course should not be too formal or limited to the expository methods used of old in instruction in classics. Professor Tait speaks the views of the scientists when he says: "It is better to have a rough climb (even cutting one's steps here and there) than to ascend the dreary monotony of a marble staircase or a well-made ladder. Royal roads to knowledge reach only the particular locality aimed at, and there are no views by the way. *It is not on them that pioneers are trained for the exploration of unknown regions.*" The truth of this proposition has been discovered of late years by even the most ardent classicists, and those of us who are called upon to teach men in every one of whom must be developed a certain spirit and power 'for the exploration of unknown regions'— we who meet this unique problem, untrammeled by traditions and strongly aided by the influence and examples of the old engineers, should most fully appreciate and adopt this precept of a great mathematician and philosopher.

To the engineering student in college the laboratory is of inestimable value. In it he can learn the true relations between science pure and science applied. He can learn to reason true, from cause to effect. His mind may be developed less trammeled than in the class-room, and the inspiration to independent thought may be more readily given deep root. 'Every branch of engineering is becoming more firmly rooted to the scientific bed rock upon which it rests,' and the engineer must be a man of scientific methods, besides being a man of business. He must have learned with the scientist that the price of success is constant, concentrated effort. All this can be taught better in the laboratory than in the class-room. A spirit of indifferenee which may be readily bred in the class-room, and which is ruinous to success and happiness in life, can not exist in the laboratory that is properly administered. "Genius is nine parts character. The prize is to him who dares, not merely to him who can." *In the laboratory the student may be inspired to dare.*

It must not be thought that I do not give adequate place to the class-room lecture and the text-book recitation. The laboratory work should be carried on in unison with and fortify the work of the class-room. A power may be had through it which can not be gained in the more formal meetings, and I would have at least one-half of the time allotted by students to the study of applied science spent in properly supervised laboratories.

The subjects taught are not of so much importance as the effect to be gained in the students' powers, but certain branches lend themselves particularly to the desired end, and admirable laboratory equipments in those branches are essential to every fully successful school of engineering. Here the budget of the university is affected. It requires large sums of money to equip, maintain and administer such teaching laboratories, and only few (very few) of the greater engineering schools have yet approached a satisfactory point therein. In this state of great mineral wealth, that has been, and is still more largely being developed through the knowledge of the engineer, it is reasonable to hope that some public-spirited citizen of ample means will adequately endow the engineering laboratories of this, the university of his own state, so that they may take and hold due rank with the best.

But some of you may say, "What is the benefit to the body politic of the expensive laboratories in our midst? We admit the benefit to the students who personally enjoy their advantages, but is their effect more far reaching?" Most assuredly their effect *is* more far reaching—it reaches to the uttermost limits of the industrial progress and prosperity of the land. In this nation the industrial pursuits are engineering pursuits, and each betterment of clear perception amongst the engineers goes to strengthen the roots of our whole national life. He who truly ponders the question of modern civilization can not but admit that its best and kindest features rest immediately upon the foundations of scientific discovery and invention, and that the engineers and their works constitute the most mighty human force now moving society. Let us think of a few of the engineering feats of the century gone by:

George Stephenson, in 1829, after painfully developing the locomotive, won the Rainhill contest, and the preeminence of steam locomotion over draft animals was established before the world. Here was the christening of that civilization which rests upon the ready communication between the people.

Joseph Henry, engineer by nature and education, scientist of renown, perfected the electromagnet, adapted it for signalling purposes, and taught the world how to operate it at a distance. The fruits of this single application of electromagnetism, brought to commercial perfection through the efforts of the then derided Morse and the brilliant Graham Bell, have twice revolutionized the commerce of the world and incalculably advanced its civilization.

Through the brilliant and daring Ericsson, one of those mighty acts of Providence that sometimes occur in the guise of miracles was wrought in Hampton Roads for the preservation of independence and liberty amongst the race.

These examples from the last century are sufficient to serve my purpose of illustration. The progress of the new century bids fair to magnificently exceed the past.

The engineers of the world may be thought of in connection with three classes:

The scientific followers after principles and inventions.

The plodding constructors and originators of structures.

The engineering plungers and promoters.

The first are to-day by far the greatest, and their preeminence grows with each application of new discoveries to the use and convenience of man. But we must not fail to give proper honor to the faithful workers of the second class, who founded the profession and are yet its mainstay; or to lend due admiration to the brilliancy and daring of the third class.

In the first class are found such names as Rankine, Lord Kelvin, Werner Siemens, John Hopkinson and Joseph Henry, to whom I have referred. In the second class stand Telford, Stephenson, Gramme, Corliss and many others of renown; while James Watt stands as a link between them and the first. The third class lists such men as the admiration-compelling Ericsson, Bessemer, Holly and Morse.

These men, who have so largely contributed their part of blood to the living strength of of the industries, whom I have selected to represent the past in engineering, are giants in beneficent influence upon the growth of civilization and the development of the wealth of the world. Their lives will be felt until the name of the nineteenth century is blotted from the memory of man. Each has played his part. The industry-promoting Bessemers more immediately increase the wealth of the world; the steady Telfords and Stephensons contribute much to its permanent comfort and convenience; but the scientific discoverers of principles and engineering inventions appear to lend the most far-reaching influence to the world and its civilization. Let us see what foundation of knowledge now exists upon which such men may base their work.

With all the effort of the centuries since the days of Gilbert and of Bacon, when the validity of experimentally proving natural laws was firmly established, we have really advanced but little towards the heart of nature's secrets. The material progress of the world depends largely upon improvements in our methods of utilizing what we now think of as three factors:

1. The properties of material matter.
2. The characteristics of energy.
3. The characteristics of intellect as found in organic life.

We are yet profoundly ignorant of the ultimate character of either matter, energy or life. Experiments seem to indicate that we may find the clue to the mystery of the first two, but it is yet impossible to assert whether, in our present state, we may reach an entire understanding of their true character. Experimental investigations often become increasingly difficult as we approach the goal of ultimate truth, and the final attempt to press into the citadel of a cardinal truth may cost more effort than all of the approach through the outer works.

However, we have gained a store of knowledge about materials, energy and organic life, and have organized it in such a way that it seems to point to a few great, generalized facts. We apparently have learned that nature is never idle, but that she is a persistent worker with a steady, cumulative activity in which there is ever a unity and no discontinuity; that there is an ever-present "dovetailedness," as Dickens, I think, put it. Nature's activities are not isolated and independent of each other, but are apparently all in intimate relation, and governed by the same all-pervading fundamental laws. This is the foundation on which the engineers of the present century have to work. Meager as it is, it is far in advance of that occupied by their predecessors one century ago.

Of fundamental laws we seem to have proved two—the law of the conservation of energy, as it is called, and the law of organic evolution, which controls the development of life through the "survival of the fittest." I spoke of these as proved, and so they have been as far as they relate to the problems of our daily life; but they have been rather deduced by inference, as far as the universe at large is concerned, than established by demonstrations. The law of evolution has been so widely discussed in type and speech, that I may assume on the part of each of you some knowledge of its doctrine, and I will at once pass on.

The law of conservation of energy asserts that energy cannot be created nor destroyed. We may transform energy in any manner within the compass of our intellect, but we finish with the same amount of energy as we started with. We may transform the chemical energy of coal, by combustion in a boiler furnace, into heat energy, and this may be utilized to "raise steam." The energy in the steam may be transformed into mechanical energy by means of a steam-engine, and this into electrical energy by a dynamo. The electrical energy will be less than the original chemical energy because some of the heat has gone to contribute warmth to the surrounding air and solid bodies, but the available electrical energy added to all of this heat (which has not been destroyed, mind you, but continues to exist as heat) *makes a sum which exactly equals the original chemical energy in the coal.*

Another fundamental law has been ordinarily accepted as governing; this relates to matter. You all know that matter is apparently indestructible. Transform it as we may; change, by combination, the matter which we call hydrogen and that which we call oxygen into that which we call water; again, combine this with metallic sodium to form caustic soda;

again, form other combinations or compounds—through them all we have apparently transformed matter without gain or loss, and hold the same mass at the end of our transformations as we had at the beginning. The chemists have been making a very thorough study of this idea for years past, and they do not seem convinced that it represents a universally applicable law; but for all present purposes of the engineer it may be safely accepted.

In accordance with these laws relating to matter, energy and life, and their myriad corollaries, the professional engineer must carry on his work through the discovery of scientific principles and their useful combinations. Invention is no longer a mere question of designing a working machine. That may now be safely left to the skilled mechanic; while the engineering inventor must discover new combinations of scientific principles and give them applications that are useful to man, in order that they may more perfectly contribute to the support of the race. Men must be educated for this purpose in our schools of applied science. This education can not be efficiently gained without the help of the schools.

Again, new principles must be discovered and great laws deduced, and contributions must be levied from them for the support and advancement of the race. It has long and justly been regarded a signal achievement to discover an important phenomenon or principle in science, and the discoverer has been stamped a learned and great man. It is still a signal achievement to discover, but the discoverer may add luster to his fame in our time by directing the application of his discovery to the service of mankind, so that no undue delay may be suffered to occur before it too contributes to the welfare of civilization. These men also may be most effectively educated in our schools of applied science.

The motive force of progress and civilization at the opening of the twentieth century is infinitely greater than at the opening of the nineteenth; largely due to discoveries and the world's slight education in science; and the possibilities following great discoveries are equally increased. Carrying this education of the people in applied science to its farthest limit must accentuate the progress, bringing with it those trains of good that follow in the wake of broader intelligence and wider opportunities. Every industry, every line of transportation or system of intercommunication, every branch of useful endeavor, has profited by the growth of scientific teaching and the work of the engineering schools; and civilization, which spreads, fattens and grows great through transportation and intercommunication between peoples, has been the gainer. Manifestly the influence of the schools of applied science is vastly greater than the effect directly produced on their individual students.

Consider the growth of our own people! The nineteenth century opened while the meridian crossing the center of our population bathed half its length in the Atlantic Ocean. Now it approaches its baptism in the Mississippi. The opening of our fertile domains, of which this tells the tale, is a story of transportation and intercommunication — the steam railroad and the electromagnetic telegraph, applied science allied with vigilant energy.

Much was formerly preached of a discord between theory and practice in engineering, and the old specter has not yet been laid for some. But no such discord ever existed except in the minds of the unlearned who failed to see that it was the finger of truth which washed away their rule of thumb; and with even them it existed only as the suspicion arising, as Bacon says, 'of little knowledge.' Even this phantom was laid in 1855; through an admirable address by the learned engineer, Professor Rankine, whose discoveries added much to engineering practice, and whose early death was so deeply mourned. After tracing the development of meager scientific knowledge and mechanical practice amongst the ancients, Professor Rankine makes the following observations:

"As a systematically avowed doctrine, there can be no doubt that the fallacy of a discrepancy between rational and practical mechanics came long ago to an end; and that every well-informed and sane man, expressing a deliberate opinion upon the mutual relations of those two branches of science, would at once admit that they agree in their principles, and assist each other's progress, and that such distinction as exists between them arises from the difference of the *purposes* to which the same body of principles is applied."

"If this doctrine had as strong influence," continues Rankins, "over the actions of men as it now has over their reasonings, it would have been unnecessary for me to describe so fully as I have done the great scientific fallacy of the ancients, I might, in fact, have passed it over in silence, as dead and forgotten; but, unfortunately, that discrepancy between theory and practice, which in sound physical and mechanical science is a delusion, has a real existence in the minds of men; and that fallacy, though rejected by their judgments, continues to exert an influence over their acts. Therefore it is that I have endeavored to trace the prejudice and practice, especially in mechanics, to its origin; *and to show that it is the ghost of a defunct fallacy of the ancient Greeks and of the mediæval schoolmen.*"

Enough has been said to illustrate my point. The influence of schools of applied science is vast and far-reaching, and every dollar spent in the establishment and maintenance of well-considered schools not only returns abundantly to the states in which the schools are centered, but their usefulness may extend to the nation and the world at large. Patriotism now needs no better object than the founding of such schools.

We may now justly turn to enquire into the character of the education for the individual that may be derived from such schools. Herbert Spencer names in a sentence the true criterion by which to judge of the adequacy of an educational process, and I can not refrain from a quotation: "To prepare us for complete living," says he, "is the function which education has to discharge; and the only rational mode of judging of any educational course is to judge in what degree it discharges such function."

Here arises the query, What is complete living? Spencer answers this, but we may each likewise answer for himself out of his personal consciousness and experience: An education for complete living includes training the faculties of self-preservation, the faculties of self-support, the faculties of proper parentage, the faculties of proper citizenship, including the betterment of our political and social relations, the faculties of properly enjoying one's leisure and lending enjoyment to others. Education, to use the words of Huxley, "ought to be directed to the making of men," and must include "things and their forces, but (also) men and their ways." We can not, we must not, cultivate one to the exclusion of the other.

The study of science and its applications, in the atmosphere of our better engineering schools, certainly lends largely to each of the faculties and powers which are required for complete living. It has been asserted that it lends more immediately to the earlier and less disinterested ones; but this assertion I must deny. The profession of the engineer demands a creative imagination cultivated to the sober, clear sight which sees things as they are; and a quick appreciation of the effect of sentences and their combinations; which make him akin to the creators of art and literature, and give him in large degree the more disinterested faculties named. I am willing to yield to no one in an appreciation of art, literature and music as an element of the highest importance in the education which goes to relieve the strain of an overarduous professional existence and to smooth the relations between fellow men; and I can not but regret that these liberal branches must be omitted from the curricula of the engineering schools. But I also can not fail to remember that an education in applied science brings keenness of perception, and recognition of truth and beauty, to its average followers, from which springs an appreciation of art and literature and music which rivals that produced in the most gifted product of the literary colleges. "With wisdom and uprightness a nation can make its way worthily, and beauty will follow in the footsteps of the two, even if she be not specially invited."

Of all the intellectual faculties which we cultivate through education, the most useful is the faculty of sound and mature judgment; and of all, this is the one most often deficient. Here the laboratories of applied science are strong in their influence for good. That man who follows the laboratory courses in one of our well-administered engineering colleges and goes forth without improvement in his faculty of judgment and a quickening of his executive powers is an unworthy son of man. The force of straight thinking can not be over-estimated. "Victory is for the people who see things as they are without illusion, who do not take phrases for facts," and straight thinking is one of the gifts derived from the engineering laboratories. The engineer's duties require that he shall possess this most important of mental attributes; and fortunate it is for the profession, for it makes of every great engineer a man of greatness. Do you question this statement? If you but enquire of the past you will find it proved. Amongst no class of men is found a broader sympathy with humanity and a more liberal view of the progress of the race than is exampled in the lives and works of the great engineers, and none have been better or nobler citizens.

Yet, withal, it must be a matter of concern in the technological schools lest the lines be drawn too close, and the students become absorbed in an ungenerous, overearnest pursuit of details. Breadth of view may be sacrificed unless our teachers be men of ripeness and power, and the students learn through them that each element in the life of the "complete liver" has of itself an intrinsic merit. This fear of a belittled outlook for some of our students, whose ambitions or mental aspirations may have never been stirred in their precollege days, would be dissipated could the personality of each teacher in the schools of applied science include that rare combination of mellow scholarship, clear scientific perceptions and engineering common sense which we occasionally meet and which a few colleges rejoice to retain in their midst.

The teaching force of an engineering school should ideally be made up of engineers—men who have seen some years of successful practice (and preferably continue to hold some practice), who are held in esteem for such by their brethren in practice; but who have a joy in the quiet life of the scholar which is traditionally associated with the colleges, and who may thus be contented when outside of the immediate tide of engineering production. Yet the teaching of engineering is a question of pedagogy rather than of the engineering profession, and it must be dealt with with this clearly in view. Here is one source of many profound imperfections in our existing schools. I venture to say that it is the exception rather than the rule when a teacher in a school of applied science has given any consideration to the tenets of psychology and pedagogy, upon the due application of which depends much of his success in properly impressing his students. These teachers are doubtless no greater offenders than their brethren in the so-called colleges of liberal arts, but in this is found no palliation for the offense. Fortunately, a goodly proportion of the older ones amongst the devoted men who are contributing their blood and brains to the welfare of the engineering schools are often endowed with a natural sense of fitness in the processess of education, and the younger gain due appreciation of methods from association with them. Yet I must regret to say that proposals relating to the curricula of the technological schools are frequently offered, which unpardonably violate every tenet of good teaching.

This condition ought not to exist, and it can not continue after the truth has seized hold: that these schools are facing a teacher's problem, which must, indeed, be met by engineers with all of the directness and power of the engineer's best efforts—but that the problem can not be solved as one solely relating to the engineering profession.

It is sometimes thought that men who can not make a success in business life are just right for teaching. This is entirely wrong, and the idea should not be admitted for a moment in any modern technological school. The discontented man who has made a failure in business life will certainly make a failure in teaching engineering. Engineering colleges should avoid "men who are fools in working," even though they are "philosophers in speaking." Enthusiastic men are wanted; they may be young men, if needs be, but they must be paid well enough so that they may take places as self-respecting members of the engineering profession, and they must be properly chosen with respect to their qualifications. These men must be good professional engineers; they must possess power and satisfaction gained from engineering research, and from attainments in other lines than those of purely professional acquirement; but sound teaching is their work of first importance. It is very difficult to teach well, but that is no excuse for admitting poor teaching into the engineering schools.

The problem in the engineering colleges is rendered more complex by the character of the curricula, which require that the students shall follow for a period what may be denominated preparatory science instruction before they enter upon the truly professional work. In the latter, at least, the teaching should be largely by inspiration and suggestion.

The process of gathering, organizing and assimilating knowledge by each student should, as Spencer suggests, be as far as possible a process of self-evolution. If a professional student will not follow his work with zest and satisfaction, it is a thankless and doubtful task to force him to it. The best method for the teacher in professional subjects (but the method of all methods difficult to follow without abuse) is indicated in Kipling's verse:

> "For they taught us common sense,—
> Tried to teach us common sense—
> Truth, and God's Own Common Sense
> Which is more than knowledge.
>
> * * * * * *
>
> "This we learned from famous men
> Knowing not we learned."

The engineering colleges are at fault in not more fully developing the initiative, the enterprise, and the executive powers of their students, though this is a difficult part of the task of "making a man." But that thing must be done in order to make successful industrial engineers. It can be done largely by influence, by the character of the treatment of the students, and by the sort of ambitions that are put into them. It can be done in some degree by the selection of the work assigned to the curriculum, but the subjects studied are of less importance than that the students learn,

"Truth, and God's Own Common Sense."

The teacher must remember when he tries to teach by inspiration, even though his time and method be wisely chosen, that he may expect to receive in the class-room some hard blows to his self-regard and his esteem for his teaching. He may pour stimulatlng thoughts over his students day after day for weeks, and finally find that few have taken root. He may even be brought to that state of desperate depression that is illustrated in one of Turgeniev's novels when its hero, Dmitri Rudin, failed to succeed in his post at the university. The engineering teacher—provided he is sure of his time and method—may take heart by remembering this: that if every stimulating thought presented to his students, whether relating to professional applications of theoretical principles or directly to the development of initiative, self-reliance and executive powers—if every stimulating thought took root in every students mind, those minds would become over-burdened cyclone centers of thought; and if one real thought takes root from time to time to each student's mind the teacher may be truly satisfied.

I have already suggested that the question of professional instruction in the engineering schools is entangled with the problem of leading the students through a course of preparatory science looking towards the professional studies. The medical schools may and largely do escape this responsibility by requiring their students to pursue a liberal college course before embracing the professional courses. The existing plan of the medical schools is ill-advised when viewed from the engineer's standpoint, but we hope that some inviting plan may yet result from the proposals made by several great university presidents in respect to co-ordinating the liberal and professional college courses. We would gladly welcome the old-time college course and the old-time preparatory course, especially as far as they made men of vigorous thought who could spell and cipher; and we now gladly receive and encourage all students who have been willing and able to complete an academic college course before entering upon their technological studies.

Broadly, however, until there arises such an advantageous plan of coordination which may be adopted with advantage to our students and to the profession, the engineering schools will continue as heretofore, to instruct their students for four years immediately following the high-school course—the first two years being largely filled with mathematics, chemistry, modern languages, drawing and other subjects leading to the professional studies of the engineer. These students come freely to the college at an age between seventeen and twenty, equally immature in mind and body—and one part must not be trained at the sacrifice of the other. "It is not sufficient to make his mind strong; his muscles must also be strengthened; the mind is over-borne if it be not seconded."

Montaigne puts it very gracefully: "It is not a mind, it is not a body which we erect, but it is a man, and we must not make two parts of him." A prime requisite to success in life "is to be a good animal," and the engineering schools must look after the bodily and social welfare of these entering students in a way that is not required of the medical school with its course largely recruited from the liberal college. These students should be encouraged to enter into the various interests of the life around them, especially of the college life, including its social affairs and its athletics and gymnastics. The extra responsibility which thus rests upon the teacher in the engineering schools equally increases the effect of the influence with which his personality affects his students. The latter is a recompense that every lover of teaching will willingly make sacrifices to obtain.

My discussion of my subject has been brief, though perhaps, as long as your desire. I have tried to show you that the wide influence of the engineering schools is of two branches: First, a direct effect exerted through the graduates extending the useful applications of science to the advantage of man (which is the effort of every true engineer); second, an indirect (but equally important) effect resulting from the admirable education disseminated amongst the people. And I have pointed out not only elements of great educational strength, but also some sources of weakness in the schools. It has been my particular wish to bring to your mind some image of the potent influence for good which has been in the past, and still more may be in the future, borne on the body politic by these schools, and to impress you with the desirability of bringing to their support the same bountiful endowments that are now justly flowing to the support of the medical schools. I trust that I may have interested you and that I may have reached, in some degree at least, my object.

In the course of my remarks I have had frequent occasion to use the phrase 'applied science.' You must not mistake me. Applied science is not something set off by itself and differing from 'pure science,' so-called. Far from it. It is pure science, if you wish, pursued in the stimulating, nutrient atmosphere bred of the belief that all scientific knowledge returns to its possessor great good in proportion to the advantages which he, through it, brings to mankind. Such an atmosphere is to be found in many of our medical schools and, I hope, equally in our engineering schools.

THE RENEWAL OF WORN STEEL RAILS.

N. L. HURD, '02.

Ever since steel first came to be used for rails, one of the most important problems with which the maintenance of way engineer has had to deal has been that of advantageously disposing of rails which have become too badly worn for main lines and heavy traffic. Since the modern steel cars and hundred ton locomotives have come into general use, the quantity of rail to be replaced each year by new and heavier material has become greater than ever before, and each year a greater quantity of steel is being put on the market as scrap at a comparatively small part of its original cost.

Many schemes have been tried, with more or less success, for lengthening the useful life of the rail. On nearly all roads it is customary, when a rail has become badly worn down by the flanges of the wheels, to place it on the other side of the track so that a fresh surface is brought to the place where the wear is greatest. Of course this allows the rail to be used longer than would otherwise be the case, but the track that results can hardly be said to be perfect. It is probable that more rail is taken out of the track on account of bad joints, or battered ends, than for any other one cause. Rails so badly battered at the ends as to be unfit for use are no uncommon sight, though they may not be very badly worn in the main body of the rail. On some roads it is customary to take the rails out of the track as fast as the ends become battered, saw off the battered ends, drill new holes for the splice bars and put the rail, worn as it is, back in service again; altogether, rather an expensive process in view of the results attained.

But of late years another method of treating worn rails has been developed, renewal by rerolling. More economical than selling the old rails and buying new, far better than all attempts to make the old rail do a little more work by sawing off the battered ends or by turning it, the new process makes the old rail into a new one, fit for the service for which it was originally intended, and equal to it, in some cases better than it in every respect.

This process was originated by Mr. E. W. McKenna, a thorough railroad man, as a result of long experience with the problems confronting the maintenance of way department of a great railway system, and in 1895 the first actual renewing was done. The old North Chicago rolling mill of the Illinois Steel Co. was leased for the purpose of experiment, and thirty-five hundred tons of rails were rerolled for a number of leading roads of the country. After two years of service in the track the condition of these experimental rails was so satisfactory that a rolling mill was built in Joliet, Illinois, to be used exclusively for rerolling rails, and the following year a second mill was built in Kansas City, to be followed by a third and larger one at Tremley Point, New Jersey, in 1901.

The last named mill is driven by motor with the exception of the main rolls. In most instances the motors are direct geared, and they greatly increase the ease of operation of the mill. In the near future it is probable that the main rolls will be driven by 500 H P. motors geared to the rolls.

In this process, the great object is to renew the rail with as little reduction of area as is consistent with a perfect section. In practice, the renewed rail is but very slightly reduced in web and flange. The web is usually of the same height as in the old rail, in order to accommodate the splice bars used for the original section. The head has received the most work and is somewhat lower than the original head, though not as low as the lowest side of the worn rail. Frequently metal is forced from one side of the head to the other instead of reducing the height to that of the point of greatest wear. This has always, heretofore, been pronounced impossible by expert rollers, but it is accomplished without difficulty. Often a railroad company desires its old rails, of an obsolete section, made into a new rail of some one of the standard sections, differing from the old rail in shape as well as size. In doing this the height of the rail has sometimes been actually increased, but, of course, at the expense of width.

Considerable variation is found in the requirements of different railroads. As a rule, the heaviest possible rail is desired. Some roads prefer to get as long a rail as possible, at the sacrifice of weight per yard. Sometimes the renewed rail must fit the old fish plate, and sometimes the fishing of the rail must be changed to conform to a later pattern of joint. Fashions change, in rails as in everything else, and it has sometimes happened that several kinds of rails, of old sections, have been rerolled to the same section, of a more modern form; usually one of the American Society of Civil Engineers standards. All these requirements can be, and often have been, successfully fulfilled.

The first step in the renewal of a consignment of worn rails is the development of the section to which they are to be rolled. Templets of the worn rail are made, often while the rail is still in service, showing as accurately as possible the worn section, and then the new section is laid out with regard to the amount of metal and the shape it is in. In this no hard and fast rules can be applied, and everything depends on the judgment and experience of the designer. The rails are first taken to the grinding machines where the fins on the side of head are removed by cup wheels. These fins are so hard, from the cold rolling they have received from the car wheels, that great difficulty was experienced in devising a means of getting rid of them. They would not roll in with the rest of the rail and so had to be removed, and one of the first methods tried was planing, but they were so hard that even Mushet steel fused with the metal and that scheme had to be abandoned. Soon, however, a very satisfactory grinder was developed, and no further difficulty was encountered. The present grinder has two cup-shaped wheels, past which the rail is fed slowly by feed rollers, and the depth of cut of the wheels is regulated by moving the wheels themselves, in a direction parallel to their axes. One pass is sufficient to smooth up one side of the rail, which is usually all that requires grinding. After the fins and slivers are removed the rails are taken to the charging machines and pushed into the furnaces. The charging machine is essentially a movable table that takes twenty-one rails, enough to fill a furnace, and pushes them into the end of the furnace in lots of seven. The furnace itself is of a special type, and is the result of a great deal of experiment and study. The difficulty of heating 30-foot rails, twenty at a time, and getting all parts of all rails at a practically uniform temperature, can readily be imagined, but it is now done without great trouble. The furnace is of the direct fired reverberatory type having two fire chambers, and using the waste heat for steam purposes by means of vertical water tube boilers. After the rails have been heated, which takes about thirty-five minutes they are taken from the furnace by means of a hook which is inserted in one of the old bolt holes. As soon as the end is fairly out of the furnace it is seized by the drawing out rolls and rolled out into the transfer table, its height being brought down to a certain standard in the process. From the transfer table it passes through two sets of rolls, the roughing and finishing passes, two passes being all that is required for renewing, and then goes to the hot saws and is cut to the standard length; then through the cambering machine and on to the cooling bed. From this point the treatment of the rail is exactly similar to any rail mill, the operations of straighthening and drilling completing the process, and the old rail has become new and better than before.

In renewing rails much of the ordinary rolling mill practice has been changed, and as a result the quality of the metal is improved. While the chemical nature of the steel is unchanged, the physical properties are much improved by the heat treatment and additional working of the metal, and the fact that the finishing of the rails is done at a much lower temperature in renewing than is customary in new rolling is a very important factor in improving the wearing powers of the rail. In fact the benefits of rerolling are being recognized to such an extent that new rails are being sent to be treated by the McKenna process before ever being put into service.

In the work of the American McKenna Process Company, many difficulties have been encountered. A great deal of the machinery had to be invented for the work, though much of it is the same as, or adapted from, ordinary rolling mill machinery. The furnaces had to be developed. New forms of rolls and new methods of rolling had to be devised, and that the difficulties have been overcome is due largely to the ingenuity and untiring energy of Mr. D. H. Lentz, the present general superintendent of the company.

It has been impossible in this article to go into the countless minor details which of course are what make any enterprise interesting. It has been impossible, without the working drawings and plans of the mills, to describe clearly the special machinery and methods used, but both from the standpoint of economy and that of efficiency, the subject of rail renewal is well worth the attention of the railway powers to be; at present peacefully laying out imaginary lines under the direction of Prof. Taylor.

* THE MANUFACTURE OF BEET SUGAR.

BY MAGNUS SWENSON, B. S. Met. E. '80.

About three years ago I had the pleasure of addressing you on the subject of chemical engineering. At that time I referred to an industry in this line which, in view of the fact that it was particularly adapted to Wisconsin, seemed to me to be of special importance. I refer to the beet sugar industry, which will be the subject of my address today.

Before going into a general description of the manufacture of sugar from beets, I want to review briefly the development of the industry during the last few years.

Four years ago this industry was just beginning to foreshadow the importance to which it is destined and its growth since then has been phenomenal, particularly in our neighboring state, Michigan. The reason for getting such a start in Michigan was probably the bounty law, by which the state offered to pay a bounty of two cents per pound for all the beet sugar produced within its borders. As this meant anywhere from $150,000 to $200,000 a season to a single factory of ordinary capacity, it could not but attract those who were thinking of embarking in this industry. As a result two or three large plants were built in Michigan and large bounties earned the first year. But before the money was paid over, the bounty law was declared unconstitutional and no bounties were paid. The result of the campaign, however, was so favorable and it was so clearly proved that the business was profitable without the bounty, that Michigan at once took the lead as a sugar producing state. A large number of new factories were therefore built, and during the past campaign sixteen large factories were in operation and ten more are in course of construction. These will have an aggregate capacity

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* Address delivered before the College of Engineering, University of Wisconsin.

of about 15,000 tons of beets a day, producing therefrom not less than 3,000,000 pounds of white granulated sugar, and the total output of sugar for 1903 for the state of Michigan will be probably not far from 300,000,000 pounds. The total capital invested in the factories alone will be about $12,000,000 and the value of the sugar produced will be about the same. When it is considered that all of this money is produced directly from the soil of Michigan, that no raw material has to be imported into the state (with the possible exception of fuel), the enormous commercial importance of this industry and its possibilities can easily be appreciated.

Wisconsin also has a beet sugar factory at Menomonee Falls, which has had two successful seasons. Colorado, Nebraska, California, Utah and some of the other states also are producing considerable quantities of beet sugar. The question of over-production may occur to you; but this does not enter into the problem at the present time, as we produce only a small fraction of the sugar that is consumed in this country, while the value of the imported sugar is in the neighborhood of $100,000,000 a year; and, owing to the low prices and also largely to the growing population, the consumption is steadily increasing.

With this preliminary statement of the present status of the industry, I will now take up what will prove probably more interesting to you, namely, the processes required in the manufacture of beet sugar.

When beets were first used for the manufacture of sugar they contained only from four to five per cent. of sugar and the gradual improvement of the beet root is one of the most striking and interesting chapters in the whole history of scientific agriculture. By careful selection, using the seed only from such beets as showed the highest content of sugar, entire crops of beets, containing from fifteen to seventeen per cent. of sugar, have been produced, and individual lots often go much higher. The purity of the beet is also of the greatest importance, as soluble substances other than sucrose in the beets interfere seriously with the crystallization of the sugar and form with the sugar that they keep from crystallizing the residual molasses, which is of little or no value.

The raising of high grade beet seed is an entirely separate industry and involves a tremendous amount of analytical work, as every beet used for seed is selected not only for its size and shape, but also for its high content of sugar, and each one must be subjected separately to chemical analysis.

When the beets are ripe they are delivered into the beet storage houses at the factory, which are so constructed that the beets can be discharged into them either from railroad cars or from wagons with a minimum of handling. From the storage house the beets are usually floated into the factory through a flume running down the centers of the beet storage houses. The beets on their arrival have more or less of the soil and sand attached to them and quite a good many small stones entangled in their roots, and the first operation is to free the beets as far as possible from these substances, as they are very objectionable on account of their action on the knives in the slicers. The beet washer is a large trough with a perforated bottom. In the center of this trough is a shaft carrying arms or flights which, aside from agitating the beets violently, carry them slowly from one end of the trough to the other and the sand and stones settle and go through the perforations into the double bottom of the machine where the sediment is gradually drawn off. The beets are elevated from the flume into the beet washer by the beet wheel. This wheel is usually sixteen feet in diameter, containing buckets which lift the beets out of the flume into the washer in the same way as does an ordinary bucket elevator.

After the beets have been thorougly washed, they are carried by a bucket elevator into the top of the building, where they pass into a weighing machine, which automatically weighs and records the number of tons of beets which are received by it.

From there the beets pass into the slicer, which consists of a horizontal disk carrying a large number of knives, and the beets, being contained in a hopper over the disk, which revolves rapidly, are sliced in precisely the same manner that shavings are made by an ordinary carpenter's plane; but the knives are shaped so as to produce a chip that is about one-eighth of an inch square in section: The knives are fastened to frames made in such a way that they can be easily and quickly removed and new ones containing sharp knives inserted.

From the slicers the chips pass into the diffusion battery. The function of the diffusion battery, as its name implies, is to extract the sugar from the beets by the process of diffusion. This is based upon the fact that crystallizable substances like sugar will pass through a cell wall into the surrounding water until the liquid in the cell and the water surrounding them have become equally saturated. The beets, in addition to the sugar, contain certain soluble, uncrystallizable impurities which do not pass through the cell walls as readily as sugar and it is important to have them remain as far as possible in the chips, and, for this reason, the chips should be clean cut so as not to rupture the cell walls any more than is absolutely necessary.

The ideal diffusion apparatus would be a long cylinder, with the beet chips entering at one end and passing through continuously and uniformly to the other end, where water would enter and pass in the opposite direction, gradually growing stronger and stronger in sugar until it would run off in a steady stream at one end of the cylinder, while the chips would pass out of the other, exhausted of their sugar. Many attempts have been made to build such an apparatus; but so far mechanical difficulties have stood in the way of its success. The chief difficulty has been the imperfect extraction of the sugar from the beets owing to the impossibility of maintaining the proper degree of heat throughout the contents of the cylinder and also because the water would flow through the cylinder unevenly, forming channels and thus leaving portions of the beet chips unexhausted. It is of the greatest importance that the circulation of the water through the chips should take place uniformly and also that the temperature should be under absolute control. It must be sufficiently high to prevent fermentation and not high enough to break down the structure of the beet. If heated too high the beet chips become soft and pulpy and not only make circulation difficult, but make an impure juice owing to the breaking down of the cell walls.

In order to meet these requirements, the diffusion battery usually consists of fourteen cylinders or cells, placed alongside of each other, either in a circle or in straight line, each cell being a duplicute of the other. At the top it has an opening for the reception of the beet chips while the bottom consists of a large door through which the exhausted chips can be discharged. The lower part of the cell for a space of about two feet and also the large door are covered with perforated steel screens, so as to retain the beet chips, but at the same time give free circulation to the water. These cells are connected by pipes in such a way that the water in circulating down through the cell containing the sliced beets is forced through openings at the bottom of each cell and through pipes into the top of the next cell. Each of the cells has an independent heater, through which the juice circulates, whereby the proper temperature can be maintained. In actual practice a cell has to be emptied every five or six minutes, so that it is very important that the exhausted chips may be quickly emptied. This is accomplished by having at the bottom of each cell a large door, which is opened and closed by the use of a hydraulic cylinder. A tight joint between this door and the body of the cell is made by a rubber tube, similar to a bicycle tire, which is inserted in a groove in the bottom of the cell and protrudes therefrom about half an inch. This tube is connected with a water tank a little higher than the tank which gives the pressure in the battery cells, so that the pressure in this tube is always a little greater than in the cell itself, thus giving under all circumstances a perfectly tight joint. The juice as it comes from the battery contains, in addition to the sugar, considerable albumen and other organic matter, which must be eliminated as far as possible before it is concentrated.

The carbonatation process is now used exclusively for the purification of the juice. The process is conducted in large tanks provided at the bottom with a perforated pipe for the injection of carbon dioxide and with steam coils for keeping the juice up nearly to the boiling point. About three per cent of lime is added to the juice, making it strongly alkaline and causing many of the impurities to coagulate. It is important, however, to remove the lime which dissolves in the juice and this is done by injecting carbon dioxide into it until nearly all the lime has been precipitated as insoluble carbonate of calcium. If this process is carried too far, so that the liquid becomes neutral or slightly acid by an excess of carbon dioxide, the coagulated impurities will become redissolved. Hence, it is important that the process of carbonatation is stopped while the liquid has still a slightly alkaline reaction. During this process the liquid foams very badly and the tanks in which the work is done must be made very tall in order to avoid losses. Sometimes jets of steam are blown over the surface in order to break the foam, and for the same purpose fat or oil is sometimes applied to badly foaming juices. During the carbonatation the liquid is also heated to near the boiling point; this causes the precipitated carbonate of calcium to be more granular and easy of filtration.

The next step is to filter this juice in order to remove the suspended carbonate of calcium and the coagulated impurities. This is done in the ordinary filter press, which consists simply of a series of frames over which the filter cloths are stretched, the whole being clamped together and the cloths making tight joints between the frames. It is constructed so that when the juice is forced through these cloths the solids remain on one side and accumulate in the chambers until they become full and the contents are removed in the shape of filter press cake. The juice after this first carbonatation is much lighter in color and perfectly clear and limpid; but it still contains some lime in solution and also some of the organic impurities which have become redissolved owing to the slight acidity of the juice where the carbon dioxide enters during the last stages of the carbonatation process. In order to remove these as far as possible a much smaller quantity of lime is added to the juice and the carbonic acid is again injected, this time to a point more nearly approaching neutrality. The juice is again filtered and treated with sulphur dioxide, generally by burning sulphur and injecting the gas until the juice is slightly acid. This not only precipitates some other impurities, but it also bleaches the juice until it becomes very light in color. It is again filtered through what are called mechanical filters, the principle being the same as in the filter presses, except that less pressure is used. There are not sufficient impurities present to form a hard cake. In most factories it is the practice not to sulphur the thin juice, owing to the danger of changing the sucrose into invert or uncrystallizable sugar, and this process is applied later to the semi-syrup.

The juice now is as pure as it is practicable to make it, and the next operation is to remove the large amount of water contained in the juice. When the purified beet juice enters the evaporators, it contains about eighty-seven per cent water and thirteen per cent solid matter. In a factory of ordinary size, working five hundred (500) tons of beets per 24 hours, about twenty-five tons of water per hour or very nearly half a ton a minute must be evaporated. The evaporation takes place either in a triple or a quadruple effect and owing to the large amount of water to be removed, it is of the greatest importance to have this apparatus economical in the use of steam and so constructed that the sugar solution shall not be subjected to any action that will discolor or have any other deleterious effect on the product. For the purpose of evaporation all the exhaust steam from the engines and pumps is used, and in order to make steam of such low pressure effective, a vacuum is maintained in the evaporating chambers. The product from the multiple effect is called "semi-syrup" and consists of about fifty per cent water and fifty per cent solids in solution, and it is again treated with sulphur dioxide and filtered. The next operation is that of boiling to grain or crystallizing the sugar. This is accomplished in what is called a vacuum pan. This vacuum pan is a large, round, kettle-shaped apparatus, usually from ten to twelve feet in diameter. On the inside it contains a series of copper coils, one arranged above the other, into which steam can be admitted. These coils have an outlet at the lower end from which the water of condensation can be drawn. First, enough semi-syrup is drawn into this vacuum pan to cover one or two of the lower cells. The amount of semi-syrup used depends on the purity of the syrup and the kind of sugar that is to be produced. If a coarse grain is desired, a comparatively small amount of syrup is drawn into the pan at the start. The steam is turned on to the lower coils and it is evaporated rapidly. From time to time small samples are drawn from the pan by an apparatus called the "proof stick," by which this can be done without breaking the vacuum. By holding a sample up to the light on a piece of glass, the formation of crystals of sugar can be readily seen.

The operator at the proper time draws in some more semi-syrup. The quantity has to be carefully gauged so as not to draw in enough to dissolve the crystals that are already formed, but still draw enough so that the continued evaporation will not produce a second crop of crystals; the object being to add just enough of the semi-syrup from time to time to cause the original crystals to grow, until by the time the pan is full these crystals will have grown to the desired size. If at any time during the progress of this boiling, through carelessness, a crop of false grain has been formed, there will be two sizes of sugar crystals, and the only remedy is to add enough semi-syrup to dissolve the false or smaller grain without dissolving the larger original crystals. This, however, always results in dissolving the sharp corners of the large crystals and affects the brilliancy and the appearance of the resulting sugar. After the "strike,"—as it is technically called—has been finished, it consists of a mass of sugar crystals intermingled with the syrup. This is discharged directly into a large receiver, containing a stirrer to keep the sugar from hardening and settling, from which it is drawn into centrifugal machines, where the crystals are purged from the adhering molasses, the last traces being washed away with a little pure water. The resulting sugar, if well made, is pure white and brilliant and requires only to pass through a dryer to become the ordinary granulated sugar of commerce. If it has a yellow tinge, it is given a wash of water containing bluing which neutralizes the yellow and makes the sugar appear much whiter than it is. The resulting syrup or molasses is now of a much darker color and much less pure owing to the extraction of the large proportion of sugar. This sugar is technically called "firsts." The second crop of sugar, called "seconds," and usually of a brown color, is afterwards crystallized from the resulting molasses in a way somewhat similar to that just described and separated from the resulting molasses in the same way. The molasses from the "seconds" is again evaporated to a heavy consistency and placed in large, revolving cylinders, or else in stationary cylinders having arms inside of them which revolve in order to keep the molasses in constant motion. Formerly—and it is still practiced in many of the older sugar houses—molasses from the "seconds" was evaporated to a heavy consistency, called "string proof," and placed in either large tanks or cars, where it was allowed to stand and crystallize for a period of several months. But it was discovered that if the crystals could be kept in motion so that they would constantly come in contact with fresh syrup, they would grow much more quickly, and by the application of this principle the process of several months' duration was shortened to three or four days. The sugar called "thirds" resulting from this crystallization is of a still darker color than the "seconds," and usually this process is carried on still farther, depending largely on the purity of the original beet. All the dark colored sugars obtained in this way are redissolved in the fresh juice, so that nothing but white granulated sugar is ultimately produced in the modern beet sugar factory. After all the sugar that can practically be crystallized has been separated, the residual molasses still contains considerable quantities of sugar, which is prevented from crystallizing by the presence of the original impurities which have been concentrated in this molasses. A farther quantity of sugar is extracted from this molasses by diluting it until it contains about eighty per cent of water and passing it through what are called "osmose" filters, consisting of frames over which parchment is stretched. The same process takes place in the osmose filter as in the diffusion battery, namely, the crystallizable portions of the dilute molasses pass through the membrane or parchment, leaving the gummy portions on the other side. By concentrating that portion into which the sugar has passed, nearly all of this sugar can be recovered by crystallization.

The resulting molasses is very dark in color and of rank and salty taste and is practically a waste product and even worse, for it pollutes the srteams and lands about the factory and its disposition is a matter of serious concern to many factories. Here is an inviting field and problem that must sooner or later find solution. If a process cannot be found by which the sugar can be extracted from it profitably, some direct use must be found for it. In Europe it is used almost exclusively for making alcohol, but in this country the high government tax makes this unprofitable.

There is one important process that I have not yet touched upon, namely, that of the production of lime and carbon dioxide for use in the carbonatation process. Every beet sugar factory has a lime kiln into the top of which is charged alternately coke and lime stone. A draught is produced through the kiln through a suction pipe near its top connectied with a large pump, which draws the gas from this kiln first through a washer where the gas is cooled and freed from dust as well as from any sulphur dioxide that may he mixed with it. This gas as well as the lime from the kiln is used for the purification of the juices in the carbonatation process.

Another by-product of little value is the exhausted beet pulp which is used to some extent for cattle feed. In order to get it in condition to handle so it can be kept or shipped, it is now being dried and used for feed.

One of the difficulties in the way of the rapid development of the beet sugar industry is the great expense involved in the construction of factories. A plant having a capacity of 500 tons a day cannot be erected for much less than $400,000, and, owing to the short season—not exceeding one hundred days in the year—the factory must run continuously night and day in order to make the work profitable, and any stoppage or break-down is exceedingly expensive. For this reason the machinery must be made as perfect as possible, and every part of it must do its full share of work continuously throughout the season, so that cheap machinery and poor construction would be a very unprofitable investment. There is also a great lack of competent men to operate the plants, and the chemical engineer will here find a field well worthy of his best efforts.

THE BALLISTICS OF HEAVY GUNS.

SIDNEY GRAVES KOON.

(*From the Sibley Journal of Mechanical Engineering.*)

Much has recently been written about the trials of the mammoth 16-inch gun which has just been completed for the United States army, and which appears to be destined to form a part of the ultimate coast defense of our metropolis. One of the technical papers made a comparison between this gun and two of the most powerful abroad, mounted, the one on two of the ships of the English navy, the other in the German coast defense system. To this list the writer has added the famous 17-inch gun of the Italian navy and the most powerful gun in the French navy, together with our new navy 12-inch rifle, making a total of six as shown in Table I. The journal above mentioned alluded to the fact that the remarkably high "figure of merit" possessed by the Krupp gun (which, by the way, is the longest gun ever built), by virtue of the abnormal velocity developed, would not hold at any considerable range, in comparison with the English and American 16-inch pieces; this lack of carrying power being due to the relatively light weight of the projectile which it uses. It is for the purpose of demonstrating this fact, and the great advantages accruing from the use of heavy projectiles when ranges are great, that the present paper is written.

TABLE I.

Gun.	Bore Inches.	Weight Tons.	Projectile Pounds.	Initial Velocity Ft. per sec.	Muzzle Energy Foot tons.	Fig. of Merit.
Armstrong...	16.25	110.5	1800	2087	54415	492
U. S. Army..	16	130.	2400	2306	88580	681
Krupp.......	12	57.6	771.6	3330	59336	1031
Italian.......	17	105.	2000	1988	54862	522
French......	13.4	51.2	926	2625	44287	865
U. S. Navy...	12	52.	850	2854	48095	924

The theory determining the loss ef velocity in a projectile depends upon a number of considerations, and, owing to the impossibllity of regulating certain atmospheric conditions, absolute accuracy cannot be obtained in the determination of any such quantity. A very reasonable begree of approximation can, however, be reached. Among the most important features effecting the fall in velocity are the ratio of the weight of the projectile to the square of its diameter (which is nothing but inertia divided by the area meeting resistance), the initial velocity with which it enters the range in question, the length of that range, the density of the atmosphere and its humidity. The formulas connecting these quantities are transcendental, and of a very complicated character, so much so, in fact, that they have been collected for convenience into the form of tables and so published by the United States navy department in a little book entitled, "Ballistic Tables." These tables are founded on Mayevski's laws of the resistance of the air, as deduced from Krupp's experiment at Meppen, Germany, published in 1883, and have been reduced to a standard atmospheric condition with the barometer at 30 inches and the thermometer at 62° Fahrenheit. The value of g, or the acceleration due to gravitation, is placed at 32.16 feet.

It was found that the resistance or retardation of the atmosphere below a velocity of 790 feet per second varies as the square of the velocity; between 790 and 970 feet per second it varies as the cube of the velocity; between 970 and 1230 feet per second it varies as the fifth power of the velocity; between 1230 and 1370 feet per second, it varies again as the cube of the velocity while between 1370 and 2300 feet per second, it again varies as the square of the velocity. This represents the limit of the experiments in question. It has been assumed for want of experimental data that above 2300 feet per second, the resistance of the air varies as the square of the velocity. The tables cover all velocities between 500 and 3600 feet per second.

On the basis of these tables, the remaining velocity, and hence the energy of any projectile may be found, at any range, if we know the characteristics of the projectile, the velocity with which it entered the range, and the length of the latter. In this manner Table II has been computed, showing the velocities, in feet per second, remaining in the projectiles from the guns under consideration, at a series of ranges varying from 1760 yards (one mile) to 17,600 yards (ten miles). The maximum range of firing at sea will probably never exceed 8,800 yards (five miles), on account of the extreme unlikelihood of scoring a hit at such a range; the figures beyond this have been added merely to show how rapidly the relative change in energy and velocity takes place when the performance of a heavy shell is compared with that of a light one.

TABLE II.

REMAINING VELOCITY IN FEET PER SECOND.

Range, Yards.	Armstrong.	U. S. Army.	Krupp.	Italian.	French.	U. S. Navy.
1760................	1885	2141	2925	1798	2295	2537
3000................	1754	2032	2670	1675	2087	2335
5000................	1562	1868	2304	1495	1791	2043
7000................	1391	1717	1988	1334	1537	1787
8800................	1259	1592	1741	1214	1340	1584
13200...............	1048	1324	1264	1027	1039	1194
17600...............	930	1131	1013	917	894	996

Based on the figures in Table II, Table III has been computed, showing the energy remaining in each several projectile at the same ranges as those illustrated in Table II.

TABLE III.

REMAINING ENERGY IN FOOT TONS.

Range, Yards.	Armstrong.	U. S. Army.	Krupp.	Italian.	French.	U. S. Navy
1760................	44382	76379	45778	44881	33840	37975
3000................	38440	68801	38158	38960	27997	32166
5000................	30494	58135	28422	31009	20621	24615
7000................	24187	49125	21167	24707	15189	18842
8800................	19784	42214	16237	20442	12212	14808
13200...............	13724	29188	8552	14650	6944	8452
17600...............	10687	21316	5493	11684	5138	5850

Dividing the result in Table III by the weight of the gun in tons (of 2240 pounds each), we have the "figures of merit" above mentioned; values of this figure are given in Table IV.

TABLE IV.

ENERGY PER TON OF GUN.

Range, Yards.	Armstrong.	U. S. Army.	Krupp.	Italian.	French.	U. S. Navy.
1760	402	588	795	427	661	730
3000	345	529	662	371	547	619
5000	276	447	494	295	403	473
7000	219	378	367	235	297	362
88000	179	325	282	195	239	285
13200	124	224	148	140	136	163
17600	97	164	95	111	100	112.5

In the velocity table the first thing to notice is the great rapidity with which the Krupp shell loses its high velocity. Its tremendous initial velocity enables it to keep ahead of all the others in this respect up to a range of ten miles, with the sole exception of the 16-inch gun first mentioned, but the United States 12-inch navy gun is close behind it, and would pass it at about the eleven mile range. It would naturally be supposed that the French shell, being nearly 10 per cent. heavier than the American 12-inch shell, would maintain its velocity better than the latter. That it does not is due to the fact that its much greater diameter and sectional area set up such an augmentation of resistance as to overcome whatever advantage it may have on the score of weight.

The steady march of our 16-inch gun from fourth position in relative velocity to first, which place it reaches just before the seven-mile mark is passed, is very gratifying. Its marked lead over all competitors so far as the energy of its shell is concerned, speaks volumes for the destruction it could compass, once a hostile ship came into contact with one of its shells. Its muzzle energy is sufficient, could it be properly applied, to lift the Oregon bodily $8\frac{1}{2}$ feet.

The closeness with which the English (Armstrong) gun and the Italian gun approximate to the same velocity is noteworthy; still more so is the much greater degree of closeness exhibited in the energies of these guns. Although the Krupp gun starts out second in the matter of energy, it soon falls to fourth place, and near the nine mile mark the United States navy 12-inch gun passes it, leaving only the French gun with a smaller amount of energy.

As to the figures of merit, the Krupp gun, due to its abnormal length, starts out far ahead of all others, and holds its primacy up to about four miles, when the United States army 16-inch gun passes ahead of it, and the United States navy 12-inch gun is very close behind. At five miles, the latter gun has taken second place, forcing the Krupp into third. Somewhere about the eight-mile mark the Italian gun passes it; the French gun does the same at about nine miles; while just before reaching the ten-mile limit, the English gun does likewise. This places the Krupp gun at the ten-mile range, last of the six, in point of energy per ton of gun. The United States army gun has a large and rapidly increasing lead at all ranges above four miles. The United States navy gun stands second after five miles, but the Italian gun follows closely and would pass it before a range of eleven miles was reached.

The guns at present being supplied to the ships of the United States navy are of the model of 1899, their main characteristics, as designed, being shown in Table V.

TABLE V.

Gun.	Weight Tons.	Projectile Pounds.	Inital Velocity Feet per sec.	Muzzle Energy Foot Tons.	Figure of Merit.
3-inch	0.87	13	2800	709	815
4-inch	2.56	32	2900	1870	730
5-inch	4.48	60	2900	3503	782
6-inch	8.2	100	2900	5838	712
7-inch	13.33	165	2900	9646	724
8-inch	18.	250	2800	13602	756
10-inch	33.4	500	2800	27204	814
12-inch	52.	850	2800	46246	889

As before, the remaining velocities, energies and figures of merit at various ranges are collected into tabular form, and exhibited in table VI.

TABLE VI.

REMAINING VELOCITY IN FEET PER SECOND.

Gun.	RANGE IN YARDS.						
	1760	3000	5000	7000	8800	13200	17600
3-inch........	1731	1240	910	742	623	*	*
4-inch........	2049	1604	1118	917	800	587	*
5-inch........	2171	1770	1278	1016	893	685	530
6-inch........	2258	1893	1425	1113	970	761	610
7-inch........	2359	2040	1614	1280	1087	859	712
8-inch........	2344	2068	1689	1380	1170	922	778
10-inch.......	2437	2209	1887	1611	1398	1058	901
12-inch.......	2490	2291	2004	1753	1557	1178	988

* Beyond the scope of the tables; *i. e.* under 500 feet per second.

TABLE VII.

REMAINING VELOCITY IN FOOT TONS.

Gun.	RANGE IN YARDS.						
	1760	3000	5000	7000	8800	13200	17600
3-inch........	270	139	75	50	35	*	*
4-inch........	932	576	278	187	142	77	*
5-inch........	1963	1307	680	429	332	196	117
6-inch........	3540	2485	1411	860	653	402	258
7-inch........	6375	4770	2980	1876	1352	844	581
8-inch........	9531	7421	4955	3309	2375	1476	1051
10-inch.......	20606	16970	12388	9036	6779	3882	2819
12-inch.......	36573	31095	23700	18175	14297	8187	5778

* See Table VI.

TABLE VIII.

ENERGY PER TON OF GUN.

Gun.	RANGE IN YARDS.						
	1760	3000	5000	7000	8800	13200	17600
3-inch.....	311	159	86	57	40	*	*
4-inch.....	364	225	109	73	55.5	30	*
5-inch.....	438	292	152	96	74	44	26
6-inch.....	432	303	172	105	80	49	31.5
7-inch.....	478	358	224	141	101	63	43.5
8-inch.....	529.5	412	275	184	132	82	58.5
10-inch.....	617	508	371	271	203	116	84
12-inch.....	703	598	456	349	275	157	111

* See Table VI.

These tables require no further comment than is necessary to point out the great difference between the light and heavy guns, so far as the ability to maintain velocity and energy is concerned.

Some little time ago the writer made a calculation similar to the above, in which all of the projectiles considered had weights varying as the cubes of their diameters, the 6-inch shell of 100 pounds being adopted as the standard. This relationship between the different sizes of shells, for some reason or other, is only approximately followed in the United States navy; all of the guns other than the 6-inch having shells which weigh more than the value given for them under the above assumption. These shells were all assumed to have an initial velocity of 2500 feet per second. From the data thus at hand, the remaining velocities were calculated at 2000, 4000, 6000, 8000, 10000, and 12000 feet. The figures are given in Table IX.

TABLE IX.

REMAINING VELOCITY IN FEET PER SECOND.

Gun.	RANGE IN FEET.						
	Shell ℔.	2000	4000	6000	8000	10000	12000
3-inch.....	12.5	2068	1711	1416	1187	1047	956
4-inch.....	29.6	2168	1881	1631	1416	1234	1107
5-inch.....	58	2232	1993	1779	1588	1416	1270
6-inch.....	100	2274	2068	1881	1711	1557	1416
7-inch.....	159	2305	2126	1960	1808	1667	1537
8-inch.....	237	2329	2168	2020	1881	1752	1631
10-inch. ...	463	2362	2232	2108	1993	1881	1779
12-inch. ...	800	2384	2274	2168	2068	1973	1881

From these figures, and the curves drawn from them (Figure 1), the following deductions were made:

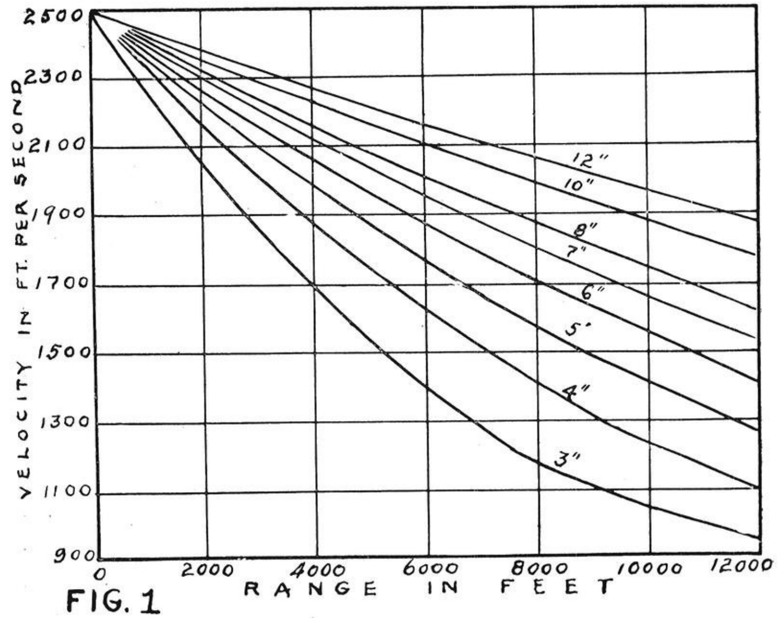


FIG. 1

1. That with constant initial velocity, the range covered during the progress of a given fall in velocity varies directly with the caliber of the gun.

2. (Corollary to 1.) That the range required to produce a given fall in velocity varies with the cube root of the weight of the projectile.

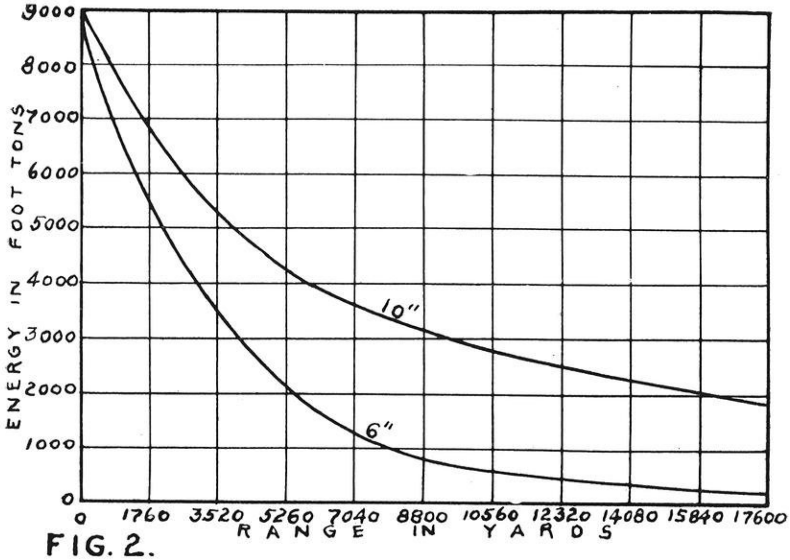


FIG. 2.

Thus, it is seen that the remaining velocity of the 3 inch shell at 2000 feet is the same as that of the 6-inch shell at 4000 feet and of the 12-inch at 8000 feet. The same may be said of the 4-inch at 4000 feet, the 6-inch at 6000 feet, the 8-inch at 8000 feet, the 10-inch at 10,000 feet, and the 12-inch at 12,000 feet. A considerable number of such instances might be traced from the table, and a great variety of them may be observed from the curves.

As a final example, two guns will be chosen, of decidedly different characteristics, but having the same muzzle energy. This latter will be produced by a high velocity and light projectile in the one case, and by a low velocity and heavy projectile in the other. The resultant kinetic energies of the projectile will then be compared by means of the curves of Figure 2. For this purpose, the smaller gun will be the 6-inch heavy gun, as now under experiment, for a muzzle velocity of 3600 feet per second, with a 100-pound shell.

The larger gun will be the navy 10-inch rifle, firing a 500-pound shell at an initial velocity V_{10} to be so determined that.

$$E_{10}=\frac{M_{10}\,.}{2}V_{10}^2=\frac{M_6\,.}{2}V_6^2=E_6 \qquad (1)$$

Solving this equation for the V_{10} we have:

$$\begin{aligned}V_{10}&=V_6\sqrt{\frac{M_6}{M_{10}}}\\&=3600\sqrt{\frac{100}{500}} \qquad (2)\\&=1612 \text{ feet per second.}\end{aligned}$$

In each case the muzzle energy is 8,995 foot-tons. The resultant velocities and energies are portrayed in Table X, and graphically in Fig. 2.

TABLE X.

Range in Yards.	Velocity in feet per Second.		Energy in Foot-tons.		Energy per Ton of Gun.		Ratio.
	6-in. gun.	10-in. gun.	6-in. gun.	10-in. gun.	6-in. gun.	10-in. gun.	
0	3600	1612	8995	8995	1097	269	.245
1760	2803	1403	5454	6829	665	204	.307
3000	2350	1276	3834	5648	468	169	.362
5000	1769	1122	2255	4370	275	131	.486
7000	1332	1022	1231	3628	150	109	.729
8800	1085	957	817	3177	100	95	.95
13200	823	832	470	2403	57	72	1.26
17600	658	734	301	1872	37	56	1.53

It is a remarkable fact that whereas the energy per ton in the case of the 10-inch gun in this example is less than one-fourth that of the 6-inch gun, at the muzzle, yet at a range of a little over five miles the two are the same, and at greater ranges the 10-inch gun passes rapidly ahead of the other. It may also be remarked that the heavier shell, which had less than one-half of the velocity of the lighter shell, when leaving the gun, passes ahead of the latter at a range of seven and one-half miles, and from that point maintains a rapidly increasing lead.

RATES AND METHODS OF CHARGING.

BY J. W. SHUSTER.

[Read before the Northwestern Electrical Association.]

It will be conceded that a correct business policy is the first requisite for progress in any business undertaking.

The success of any company in the electric lighting business, and the confidence placed in it by its consumers, are dependent to a very large extent upon the adoption of a fair and equitable method of charging.

That station managers are coming to recognize this fact is shown by the varied, interesting and instructive discussions which have recently taken place in the different Lighting Associations, and particularly in the National Electric Light Association.

Most questions of great importance have numerous theories proposed as their correct solution. In this respect the question of charges is no exception.

I will endeavor to present a few of the more promising methods of charging which are being adopted in this country.

In the outline which follows, the several systems are scheduled with the particular point of service which they are designed to cover.

Methods.	1. Flat Rate.	Contract price on 16 c. p. lamp per mo.	
	2. Meter Rate.	a. Charge per K. W. hr.	
		b. Discount or sliding scale depending on total power consumed.	
	3. Wright Miximum Demand.	a. Charge on Maximum Demand of capacity for first two hours per day.	
		b. Charge on basis of cost of generating per K. W. hr. for power used subsequently.	
	4. Doherty Rate.	a. Fixed Charge	Office expenses, reading meters, etc.
		b. Stand by Charge	Interest, depreciation, taxes and insurance.
		c. Power Charge	Cost of generating per K. W. hr.
	5. Fore-See System.	a. Stand by charge on sliding scale.	
		b. Power Charge.	
	6. Double Rate Meter.	Different rate per K. W. hr. depending on the time of day.	

Taking the systems in the order named, I will endeavor to bring out the distinguishing feature of each. The only apology for mentioning the Flat Rate in this paper is the fact of its existence. It came into use as the first method of charging before meters were developed and before the station man had gone into details as to methods of charging. One feature of this method which makes it popular with consumers is that the charges are a fixed amount per month, and the customer knows just what he will be called upon to pay. The fact that the station has no check on the length of time the lamps are in use, or the power delivered, makes it obvious that the rate is unjust and entirely void of business principle. Therefore, the rate should be refused entirely, or what is equivalent, it should be made so high that all consumers will prefer some meter rate.

The progress in the question of rates is the ordinary development from the crude to the more refined. The natural step from the Flat Rate was the introduction of a meter which would record the power used by a consumer; and then make a charge per unit of power consumed. This condition was approximated when the ampere hour meter was introduced and a charge made per ampere hour. This instrument did not take into account the variation in line voltage, and was soon replaced by the recording watt meter, which is now almost universally adopted for measuring the power delivered. The charge was then made on the K. W. hr. basis.

On the face, this seems a very adequate method of charging, for in the majority of business undertakings if the seller is paid for the commodity delivered, the transaction is satisfactory. While in dealing with most commodities a charge for the product delivered is an equitable one; the supplying of electric power involves conditions which are seldom or never met with in other lines of business. These conditions require the working out of special systems of charging which are more equitable to station management and consumer, and which are reasonably applicable to all cases.

The *most important* of these *special conditions* is the fact that no adequate method of storing electrical energy economically is in existence. This necessitates the keeping in readiness at all times the apparatus of the station, such as dynamos, engines, boilers, transformers, etc., which are loaded to their full capacity for only a short interval each day during the busy part of the year, and are never fully loaded during the season of light loads. To keep in readiness this large installation, requires a corresponding investment on which a reasonable return for interest, depreciation, tax and insurance must be obtained before any profit can accrue. Now if a consumer uses his power for only a short period of time each day, and that at the time of heaviest load, or during the peak, it means that the station management must purchase and maintain all the apparatus necessary to supply this consumer and depend on him for returns on the same. If it does not do this, it must serve him at a loss and over-charge the long hour consumer to make up the deficit.

On the straight meter rate with the present limitations, it is practically impossible to charge the short hour consumer a sufficiently high rate per K. W. hr. to cover the expense to which he puts the company.

To devise a system by which each consumer pays his proportionate part of the stand by charges, has been the purpose of a number of leading station men in this and other countries. Mr. Arthur Wright, of Brighton, England, was one of the first to attack the problem of capacity charge in a systematic manner. He introduced what is known as the Wright Maximum Demand system, in Brighton, in 1893.

Mr. Wright determined from his station costs that the stand by charge was the main item of expense. He devised an instrument by which he could determine accurately the maximum capacity of the station used by any customer. He also determined the cost of generating per K. W. hr. after all stand by charges were paid. From these stand by expenses and the cost of generating power he determined the income which he must have from each K. W. of plant installed if used for two hours per day throughout the year. Then for power used in excess of two hours per day he charged at a rate per K. W. hr. determined from the cost of generating. The ratio between these two rates he found to be 4.4, then if the first rate was 20 cents per K. W. hr., the power subsequently used would be furnished at 4.5 cents.

Mr. Wright invented a very serviceable instrument known as the Wright Maximum Demand Meter. This meter records the maximum current used by a consumer during the interval between two readings. This meter is read at the same time as the recording watt meter, and from its indication the amount of station capacity used by this consumer, and the amount of power to be charged at the high rate is determined. All power in excess of this is charged at the lower rate. For example, if the demand meter reads 10 ampheres on a 100 volt circuit, and the recording watt meter registers 90 K. W. hrs., and the maximum charge is made on two hours per day, the first charge will be on $10 \times 100 \times 2 \times 30 \div 1000 = 60$ K. W. hrs. Taking the rates at 20 cents and $4\frac{1}{2}$ cents respectively, the bill will be $(60 \times \$.20) + 30 \times \$.045 = \$13.35$.

This system gets at the correct basis of charging, but has a weakness in that the very short hour consumer will not use power enough to pay for the demand or stand by charge even at the higher rate. Taking the case above; if the watt meter reading is 30 K. W. hrs., the total bill will be $30 \times \$0.20 = \$6.00$, or only half the amount determined on as the stand by power charge; so that the system fails to reach the very class at which it is aiming. This defect in the system is obviated in some cases by making the high rate charge a fixed charge and collecting it whether the power is consumed or not. Beside this, the management in many cities is limited by franchise so that eight or ten cents per K. W. hr. is the maximum charge which can be made. Obviously the Wright Demand system would be of little benefit in such cases.

The leaders in the rate reform in the United States have attacked the problem of determining equitable rates in much the same way as it was taken up by Mr. Wright. However, instead of making the capacity charge payable on a K. W.

hr. rate on the first two hours use of the installation per day, it is made a fixed charge per lamp and the total amount of this fixed charge is determined by the number of lamps which the customer demands at any one time. His service is then limited by an interrupter or similar device which winks the lights when the predetermined demand is exceeded. While an interruption of the circuit in this way may be objectionable in some cases, it has the advantage that it can be checked by the consumer, and there can be no suspicion on his part that the meter reader is beating him.

When a consumer has settled his demand and paid or fixed his demand charge, he is charged for the power consumed on the basis of generating costs which obviously gives him a low K. W. hr. rate and he will for this reason use his lights more freely and thus broaden the peak of the load and greatly improve the load factor. One station which has used this system for a little more than a year reports an increase of 50 per cent. in the output of the station for the year, with an increase in the cost of coal of 20 per cent.

This method of charging has been advocated quite thoroughly before the National Electric Light Association, particularly by Mr. H. L. Doherty, in 1900, and in a modified form, called the Fore-See System, by Mr. Wallace in 1901.

The apparent equity of the capacity charge system and the hearty discussion and approval which it has received from leading central station men point to its general adoption, and a study of the methods of determining this charge is of considerable interest. Differences of opinion are encountered as to what should be included in the stand by or capacity charge. Mr. Doherty takes the general office expenses and makes this a fixed charge per customer, while Mr. Wallace includes this in the stand by charge. The first is the more logical, since the capacity charge is on stand by losses and is calculated as a definite per cent. on the cost of the station per K. W. on the assumption that it is not being used. Evidently the office expense is not a factor in this case. It has the disadvantage, however, of making the divisions of the charge too numerous to suit the consumer who does not understand the method by which they are determined.

While it is desirable to make a capacity charge sufficient to insure the plant from a loss on short hour consumers, this charge should be made as small as possible so that the lamps demanded will be a large per cent. of the total lamps connected.

The items which unquestionably come into this charge are interest, taxes and insurance. Depreciation is usually figured in on this charge, but in my opinion only so much of this item as is due to apparatus going out of date should be included. Depreciation due to wear and tear should go to generating expenses.

Numerous other items, such as coal for banking fires, etc., are sometimes included in the capacity charge, but when there is a question as to where a charge should go, I would put it in the generating costs and make the actual output pay expenses just as far as possible, and not impose on the *special privilege* granted on account of *special conditions.*

The distribution of the loads of different consumers as to time, makes the maximum demand on the station much smaller than the sum of the demands of the individual consumers. On the meter basis of charging it has been found that the maximum load on the station is usually from one-third to one-half of the total lamps connected. Under the new method the lamps demanded will be considerably less than the total lamps connected, and experience with the system is required before one can determine with a reasonable degree of accuracy the maximum load which is likely to come on the station. This once determined, the stand by charges per lamp demanded should be equally distributed.

If we take interest at 5 per cent,, depreciation (as above stated), taxes and insurance 7 per cent., we have from the following table the stand by charges per K. W. installed per year on stations which cost from $100 to $400 per K. W., and in columns 5, 6 and 7, the annual charge per lamp figuring that the ratio of station capacity to lamps demanded is 1 to 1, 1 to 2, and 1 to 3, respectively,

1	2	3	4	5	6	7
Total Cost of Station per K. W.	Interest.	Depr'ciation Taxes and Insurance.	Annual Stand by Charge per K. W.	Annual Stand by Charge per Lamp Ratio 1 to 1	Annual Standby Charge per Lamp Ratio 1 to 2	Annual Stand by Charge per Lamp Ratio 1 to 3
$100.00	5%	7%	$12.00	$0.60	$0.30	$0.20
200.00	5%	7%	24.00	1.20	.60	.40
300.00	5%	7%	36.00	1.80	.90	.60
400.00	5%	7%	48.00	2.40	1.20	.80

This charge and the office charge make a definite fixed charge by contract corresponding to the Flat Rate. The power consumed is then charged for by the K. W. hr. at a rate based on the cost of generating.

This method charges the expense of readiness to serve equitably among consumers and relieves the plant from the chance of loss on the short hour consumer.

The low rate per K. W. hr. delivered will have a strong tendency to broaden the peak and increase the output of the station.

The double rate meter developed by the General Electric Company is a recording watt meter with a clock movement by which the driving mechanism is shifted from one dial to another at a pre-determined hour. The object of this system is to give a low rate to customers using power during that part of the day when the station is not loaded. While this method would have a strong tendency to broaden the peak, it would also tend to reduce the maximum which should not be done. Obviously the high rate will come at an hour in the evening, especially in the business district, when light is very essential, and if the rate is doubled or tripled at that time, as it is by companies using this system, it will mean a reduction of lighting of business places or the adoption of a light other than electric, either of which is undesirable from the station standpoint.

While the amount of power used, the time of its use, the ocation of the consumer etc., make an absolutely equitable charge difficult to obtain, the systems which are being adopted approximate this to a reasonable degree, and with the experience of a few years of actual use we may expect the details to be worked out to a refinement which will greatly improve the business conditions of central stations and give the consumer the fairest treatment possible.

CONCRETE CULVERTS.

A. W. CAMPBELL.

[Paper read before the Engineering Society of the Toronto School of Practical Science.]

A great many townships throughout the Province have largely discarded timber as a material for small culverts and sluiceways. Cedar where obtainable has been most commonly used, but all varieties of suitable lumber are becoming scarce, the price is constantly increasing, and the quality now available is far from being equal to that of former years.

Those municipalities which have experimented with vitrified and concrete tile, have, with very few exceptions, been favorably impressed with the new materials. Failure and some dissatisfaction are occassionally reported, but this in every case can be traced to the causes not in any sense condemnatory to the new materials. Where any kind of tile is used there are certain requirements which must be observed. In the first instance the tile must be of good quality. It is just as necessary to use good tile in culverts as in sewers; where "culled" tile are used, failure is almost of necessity the result. These tile must be perfectly sound and straight, not warped or mis-shaped in any way, otherwise good joints cannot be made, water will lie in hollow places, and culverts are apt to wash out.

Excellent culvert pipe of concrete can be manufactured cheaply in any gravel pit under the immediate direction of the road overseer. The pipes are from two to four inches in thickness, according to diameter, which latter may safely and conveniently reach three feet, in lengths of two and one-half feet.

The implements required are of the simplest kind. The most important are two steel spring-cylinders, one to sit inside the other, leaving a space between the two equal to the thickness of the finished concrete pipe. By "spring-cylinder" it may be explained is meant such a cylinder as would be formed by rolling a steel plate into a tube without sealing the joint. With the smaller of these cylinders the edges overlap or coil slightly; but are so manufactured that the edges may be forced back and set into a perfect cylinder. Accompanying these moulds are bottom and top rings, which shape the bell and spigot ends of the pipe.

The two cylinders with joints flush are set on end, the one centrally inside the other and on the bottom ring, which in turn rests on a firm board base. The concrete, made of first-class cement and well-screened gravel in the proportion of one of cement to three of gravel, is then tamped firmly but lightly into the space or mould between the two cylinders. The tamping-iron used to press the concrete into place is so shaped as to fit closely to the cylinders.

The concrete is allowed to stand in the mould for a short time, when the cylinders are removed; the outer and larger cylinder by inserting an iron wedge into the joint and forcing the edges apart; the inner cylinder, by inserting the wedge into the joint and turning the edges, so as to allow them to again overlap, returning to the shape of a coil. The outer cylinder having thus been made larger and the inner one smaller, they can readily be taken away, and the concrete pipe is then left until thoroughly hardened.

Just such a number of pipe as are actually required for the season's work need be manufactured; the implements required are inexpensive, and the pipe may be made by the municipality for actual cost, which, after a little experience, can be reduced to a very small amount.

If cement concrete pipe are employed, they must be of first-class quality. They must be well shaped, as with sewer pipe, and all the rules for making a good concrete must be observed—that is, the material composing the concrete (cement, sand and stone) must be of good quality, and properly mixed. The making of good concrete is not a difficult matter, but it is sometimes difficult to find men who will follow directions. Dirty sand or gravel, too much water, careless and insufficient mixing, neglect to see that the materials are used in the right proportions, are the defects most commonly found. Concrete cannot be mixed like common mortar, and an attempt to do so is far too often made. It is affirmed by cement manufacturers that masons are the greatest offenders in this respect; that it is almost impossible to get them to follow any system other than that to which they have been accustomed in the use of common lime; and that therefore an entirely inexperienced but practical man, who will follow directions, will often make the best concrete.

To meet with success in the use of tile culverts they must be put in place properly. They should be laid with a good fall on a regular grade to a free outlet, in such a way that water will not stand in them. The tile should be laid with the spigot end down grade, and the joints made tight with cement mortar. If the joints are open, water will work its way along the outside of the culvert, and finally make a considerable channel which will allow the culvert to get out of line and finally result in a "cave-in." To prevent the water finding its way along the outside of the pipe, it is advisable to protect the ends with concrete, stone or brick head walls. Care should be taken to excavate a concave bed for the pipe, with depressions for the bell of the pipe to rest in, thus securing an even bearing, without which a heavy load passing over before the culvert has properly settled into place, may burst the tile. Tile cannot be used in very shallow culverts, but must have a sufficient depth of earth over them, to protect them from the direct pressure of heavy loads. The depth of covering necessary increases with the size of the pipe. At least a foot of earth over the top is advisable in every case, but for culverts of two feet in diameter, or over, this should be increased to at least eighteen inches.

The earth should be well packed and rammed around the tile to secure a firm bearing, and light soils should not be used immediately over or around the culvert. A heavy clay, a firm gravel, or a compact sand or gravel will answer, but vegetable mould, water sand, and light loams are subject to wash-outs. At the outlet the culvert should be set nearly flush with the surface of the ground. If set higher than the surface, the fall of water will wash out a depression, and in time will undermine the end of the culvert. A too rapid grade will have the same effect, and it is well to cobble-pave an outlet where this undermining action is liable to occur.

Culverts, in many townships, are very numerous, and necessarily so. Water should be disposed of in small quantities, along natural watercourses, otherwise if gathered in large bodies along the roadside, it gathers force and headway, resulting in extensive wash-outs, and is in every way more costly to handle. Water should be taken away from the roads as quickly as possible, for it is excess water that is the great destroyer of roads.

Culverts, in addition to being a matter of considerable expense to municipalities, are too often in a bad state of repair, sometimes dangerous, and when not level with the roadway, are an annoyance and interruption to traffic. Good road-making is largely a matter of good drainage, and culverts are a detail of drainage upon which municipal councils should bestow a good deal of attention, with a view to a greater permanency, increased efficiency, and a reduction of cost.

The concrete arch culvert is, in a number of municipalities, replacing the old form of timber structure. Greater in first cost, the concrete culvert, if rightly constructed, is a permanent saving in road expenditure. The greater portion of the annual road appropriation is, in many townships, spent in repairing and re-building wooden culverts and sluiceways. The life of timber in this work is very short. Wooden culverts are quickly upheaved by frost, warped by the sun, and decayed by penetration of moisture. Wherever concrete culverts have been fairly tested they give satisfaction, and their general use by a township will mean, in the course of a few years, a marked reduction in this branch of roadwork.

The stone arch is designed on the principle that it will remain in place without the use of mortar. The concrete arch, on the other hand, is a monolith, dependent upon its cohesive strength. That the concrete arch is dependent upon cohesive strength points to the necessity, in construction, of a generous proportion of cement, very great care in mixing the concrete, and a good quality of all materials employed.

A concrete can best be regarded as a mixture of mortar and broken stone, the mortar being formed from a mixture of sand and cement. Given a sample of broken stone in a vessel, the requisite quantity of mortar can be gauged by pouring water into the vessel until the stone is submerged. The quantity of water used will indicate the amount of mortar required to completely fill the voids in the stone. The proportionate amount of cement needed to fill the voids in the sand can be gauged in the same way. The proportions of cement, sand and broken stone obtained in this way would provide, with perfect mixing, a mortar in which the voids in the sand are filled with cement and each particle of sand is coated with cement; it would provide a concrete in which the interstices of the stone are filled with this mortar, and each stone coated with mortar: This would be the case with perfect mixing, and would provide a theoretically perfect concrete. Perfect mixing is not possible, however, and it is necessary to provide an amount of cement in excess of the voids in the sand, and an amount of mortar in excess of the voids in the stone.

With proper mixing and good materials, a satisfactory concrete for bridge abutments can be formed from cement and broken stone, in the proportions of one, three and six. It is recognized that the greatest strength in concrete can be obtained by making the mortar rich in cement, rather than by lessening the quantity of stone, but beyond providing for a strong adhesion of mortar and stone, little is gained by making the mortar materially stronger than the stone. The foregoing applies to crushing strength, however, rather more than to the tensile strength required to some extent in the arch. For the arch proper, it will be well to use a richer concrete, in, say, the proportions of one of cement, two of sand and three of broken stone.

The cost of the abutments may be lessened, where they are of sufficient thickness, by the use of rubble concrete. The casing or curbing must be built up as the laying of the concrete proceeds. Within the casing and firmly tamped against it, there should be placed fine concrete to a thickness of about six inches. This will form a shell for the abutment, inside of which large stones may be placed in rack-and-pinion order, ends up. There should be a space of at least two inches between the stone, filled with fine concrete, and all firmly rammed. The outer shell of fine concrete should always be kept built up six inches or so in advance of the rubble work. The rubble should be placed in layers, each layer well flushed with a layer of fine concrete.

The lumber used in making the curbing or casing should be dressed, tightly fitted and firmly braced, so that the concrete may be well rammed into place. The framework should be closely boarded up against the work as it proceeds. The centering for the arch should be well formed. The ribs should not be further than three feet apart. The lagging should be three inches thick and dressed to the intrados of the arch. All the framework, centering and supports should be substantial and well constructed. This framework is a considerable item of expense in the building of a culvert, but it can be used as often as it may be required for arches of similar span. The exterior of the culvert when finished should have a smooth face, free from holes, and a surface coating, which is of little use, should not be necessary.

There is some difference of opinion as to the relative strengths of gravel and broken stone in concrete. The natural inference is to suppose that a rough, irregular surface will secure greater adhesion than one that is smooth. However that may be, there is little reason to doubt that gravel will make a good concrete, but there is a right and a wrong way of using gravel. It is not uncommon to find cement and gravel just as it is taken from the pit, mixed to form a concrete. Remembering the proper composition of a concrete, and placing beside this the fact that gravel usually contains sand, but not in any definite proportions, and that some pockets of "gravel" may be almost completely sand, while in the layers adjoining there may be little if any sand, and that many gravel beds contain much clay or earthy material, it will be readily understood why it is that, in some cases, concrete mixed in this way may be successful, yet it will always be uncertain and hazardous. The only safe method is to separate the stone and sand composing the gravel by screening, then to mix cement, sand and clean stone uniformly and in their right proportions.

A cause of poor concrete is the excessive amount of water used when mixing. The tendency very often is to bring concrete to the same consistency as common mortar. Concrete when ready to be placed in the work should have the appearance of freshly dug earth. Where an excessive amount of water is used, the hardened concrete will have an open, spongy texture.

The concrete should be mixed at a point convenient to the work in a box which is sometimes specified as water-tight, but the concrete will quickly make it so. It should be mixed in just such quantity as is required, and a constant stream kept passing to the work. It should be laid in layers, each layer thoroughly rammed until moisture appears on the surface.

It is very necessary to see that the sand and stone used in making concrete are clean, that it is free from clay, loam, vegetable or other matter which will act as an adulterant, and result in a weak and friable concrete. If such matter is intermixed with the stone it is well to flush it away with a good stream of water. Large stone used in rubble concrete should be also treated in this way. It is well, particularly in hot weather, to dampen the stone before mixing it with the mortar. The heat of the stone in hot weather causes the moisture of the mortar to evaporate, causes it to set too quickly, and at all times there is more or less absorption from the mortar in immediate contact with the stone, unless the stone, as intimated, has been dampened.

When the work ceases for the day, or is for other reasons interrupted, the surface of the concrete should be kept damp until work is resumed. When work is in progress in hot weather, any exposed surfaces should be kept damp and protected from the rays of the sun, otherwise the surface will, in setting too rapidly, be interlaced with hair-like cracks which, filling with water in winter, and freezing, will cause the surface to scale off. The same scaling sometimes results from laying concrete in frosty weather.

Arch culverts of masonry or concrete fail frequently from settlement caused by an insecure foundation. The foundation should always be of at least sufficient depth to be free from any danger of undermining by the action of the water, and of sufficient further depth to be safe from settlement.

HIGHER DEGREES.

Those of us who have been connected with the College of Engineering for some time have all been struck by the fact that so very few of our graduates fulfill the requirements exacted by the Faculty for getting the second and professional degree. This state of things has been deplored by everybody, both because of the graduates themselves and because of the University. It certainly cannot be denied that the professional degree, even if it has not the value of an M. D., has yet a certain value, which I am afraid especially the young graduates of the College of Engineering do not appreciate. The consequence is that these young men do not think of acquiring this degree during the years when they would have ample time to do the work required. If the time comes when they suddenly find that it would be an advantage to them to have the professional degree, they perhaps discover at the same time that either the time is lacking or else that it would be very inconvenient for them to work up a subject on which to write a thesis. They probably imagine that it will be very much easier for them to do so in a year or two, and in this wise postpone the realization of an object which some years previous would have been very easy to accomplish, and which they now fully realize would be a decided gain for them in many directions.

The University of Wisconsin confers on its graduates from the College of Engineering, the degree of Bachelor of Science, the special course, which the student has taken, being added to the degree.

As is well known several technical schools of this country confer the professional degrees upon their students when they graduate, among these institutions being Cornell. Necessarily this difference in the kind of degree granted upon graduation has been discussed both among teachers in technical colleges and by the graduates themselves, and it is not surprising that one should find graduates from the College of Engineering of the University of Wisconsin who criticize the authorities here because they have not been giving the professional degrees to the graduates from ourUniversity. Because of this feeling which, the writer knows exists, it will perhaps not be out of place briefly to state some of the reasons which have led to the adoption of the degree of Bachelor of Science for the graduates of the large majority of our technical colleges. The principal reason is perhaps that a graduate from these colleges, and here Cornell University and the other institutions which give the professional degree are included, is not an engineer when he graduates. It is true that he is supposed to have considerable engineering knowledge but it is only practice which can make him an engineer and which will determine whether he can ever become a civil, mechanical or electrical engineer. To give the degree of Civil Engineer for instance to a graduate, of our College of Engineering in the civil engineering course would therefore inevitably cheapen and degrade the degree, which certainly ought not to be the desire of those of our gradates who after graduation really become, for instance, civil engineers. In addition it ought also to be mentioned that some of our graduates, and the same holds true for all other similar institutions, never enter the professional engineering field. Some of our graduates have become lawyers, some bankers, some merchants, and it certainly would seem out of place that such men, who perhaps never have spent an hour since graduation in the work of our profession, should have the right to affix the professional degree to their name. The second degree, which, for instance Cornell University offers, Master of Mechanical Engineering, does not, in the opinion of nearly all professional men, mean very much and is only being used to a very limited extent, and as it is very desirable that the technical branches of our universities should be able to offer a second degree, another reason for the granting of the Bachelor of Science degree upon graduation has been explained.

The requirements for the granting of the professional degrees at the University of Wisconsin are in the main similar to those of most of the institutions with which we can be compared. They are as follows:

The degrees of Civil Engineer, Mechanical Engineer, and Electrical Engineer are conferred as second degrees upon Bachelors of Science in the civil, mechanical, and electrical engineering courses respectively, (1) who pursue advanced professional study at the university for one year, and present a satisfactory project or thesis; or (2) who present suitable evidence of three years of professional work, of which one must be in a position of responsibility, and a satisfactory thesis.

It will therefore be seen that a reasonably successful graduate from the College of Engineering should find no difficulty in fulfilling the requirenent. It is only after practising the profession for three years that the graduate can become a candidate for the professional degree and the condition is certainly only reasonable, especially in view of the second condition that the candidate must have spent one of the years in a position of responsibility. It ought to be taken for granted that no graduate can even hope to attain a position of such character till at least two years have lapsed since he left the university. My experience as a teacher in Engineering for almost 24 years has fully convinced me of this. And because a professional degree only ought to be given to the person who actually practices the profession and who has shown that he is capable of becoming something else than a mere mechanic, the requirements as to time and experience must appear to everybody as only fair. The additional requirement of the presentation of a thesis on some engineering subject, to be approved by the proper department at the university is one which if viewed in the right light will be seen to be to the benefit of both the candidate and the Alma Mater. With respect to the latter it seems evident that this thesis will perhaps show, better than anything else, that the candidate has attained that degree of professional experience which should entitle him to the professional degree, and in addition, the thesis very frequently provokes material of such a character that it will be useful to the teachers and students for instructional purposes, which reason, although perhaps a selfish one, nevertheless should count with graduates in relation with their Alma Maters. Looking at the question from the standpoint of the candidates, the requirement of a thesis does not, in the opinion of the writer, seem less desirable. When an engineering student graduates he usually will have to be contented with the taking of a position in which the merest routine work fills the time from morning to night. Under such circumstances he is apt to forget that there is something else in the profession, that original investigation, thoroughgoing study of problems and selfreliance are some of the necessary requirements which the world demands of a good and competent practicing engineer. If by means of the thesis the engineering graduate can be reminded of this fact, it certainly is an advantage, and, besides, the very work done may help the individaul directly by furnishing the necessary opportunity for showing his capability to his superiors, which again should lead to a promotion in the branch of his profession which he has chosen.

The conclusion therefore, is that, from what ever point the requirements for the professional degree are viewed, they seem to be not only fair but desirable both to the candidates and to the Alma Maters.

However there is still another reason why it seems very desirable that a large number of the graduates from the College of Engineering should avail themselves of the opportunity of getting their second professional degree, and that is because of the necessary correspondence with respect to the thesis and other requirements. The hearts of our graduates will necessarily be kept at higher temperature in their relation with their Alma Mater than if the work for the professional degree is not being prosecuted. The writer can imagine that some of our recent graduates will try to deny this statement; but "time will tell," and if some one who doubts, that the working for a professional degree, has something to do with the very desirable intimate relation of the alumni with their Alma Mater, will ask a few of those of our graduates who date farther back in the past, he will find that the writer is not far from the truth, at least. The writer has been connected with the College of Engineering, or rather with the teaching force for engineering students, for so long a time, and he is acquainted with so many of our engineering graduates that he feels justified in making an appeal to these men, both in the behalf of their Alma Mater—but also for their own sakes, to make some tangible exertions for the purpose of increasing the number of professional engineering degrees which are granted each commencement. The writer can assure those in whom the appeal shall find a response that the gratitude and well wishes of their former teachers will always follow them. STORM BULL.

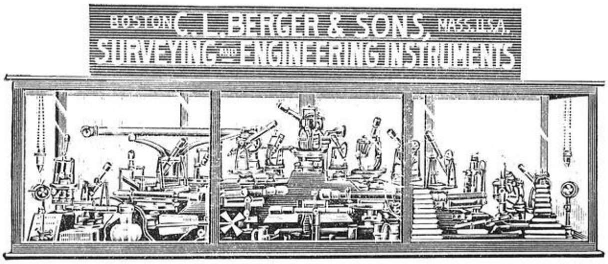
ANNOUNCEMENTS.

The constantly increasing demand for Christensen Air Brakes and "Ceco" Electrical Machinery has made a change of our organization necessary. To accomplish this result, the owners of the stock of this company have organized the National Electric Company, and the assets, good will, etc., of this company have this day been transferred to the National Electric Company; the purposes, ownership, management and control of the new company are identical with those of the old.

We desire and solicit a continuance under our new name of the satisfactory relations which have heretofore existed between us and the trade.

Yours very truly,
CHRISTENSEN ENGINEERING CO.

The Niles, Bement–Pond Co., of New York, N. Y., have issued two handsome catalogues of their "Multiple Drills" and "Horizontal Boring, Drilling and Milling Machines." The "Horizontal" machines are designed for boring, drilling and milling work which is too large to be conveniently handled on other types of machines. Each pamphlet contains about fifty pages 9 x 12 inches in size.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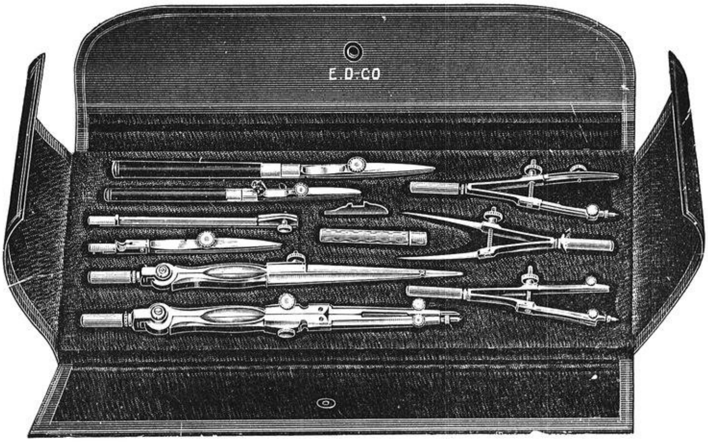
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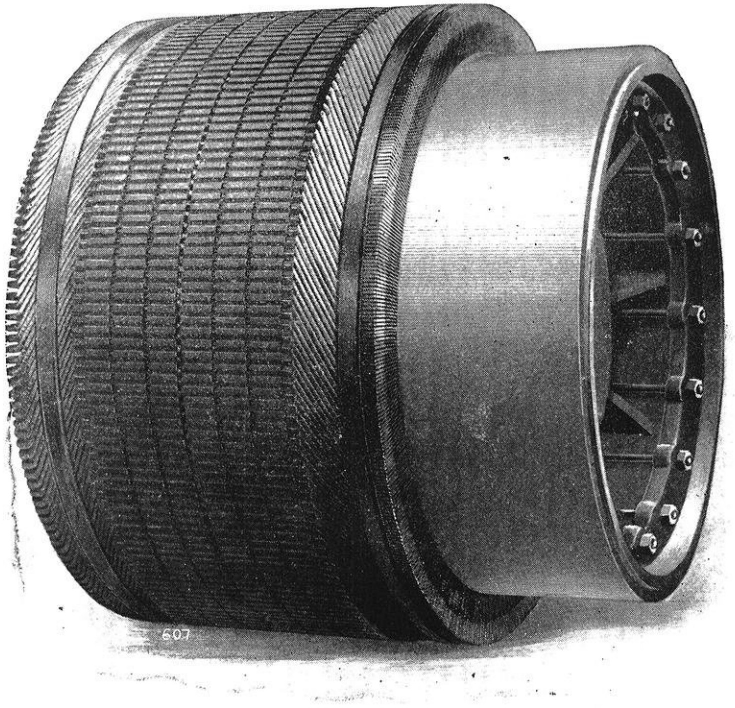
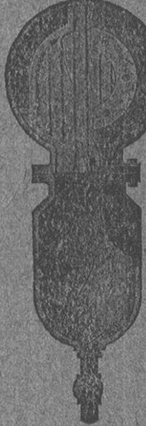
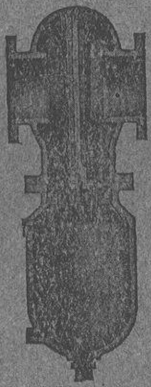


ARMATURE FOR ENGINE TYPE GENERATOR



Cochrane Separator
Part Section facing Baffle

Cochrane Separator
Section through Baffle



Cochrane Separator
Section through Pipes

Water is Heavier than Steam

What's the use of stirring or mixing up the water you want to take out of steam? Water is heavier than steam. Then why not give it a chance to fall out of the current of steam? Let gravity have full play, and don't skimp on the passage ways, or old Mr. Friction will have a bill to present.

Suppose you and I get down to designing a separator for taking water or oil out of steam. Of course we will have the separator strong and compact and use first-class fittings, bolts and gaskets. Then we will give the water an opportunity to drop out of the steam into the well of the separator, from which it cannot again be picked up.

To stop the water when the steam is driving it past our well, and to hold back the flying particles, there's nothing so good as a solid plate—a baffle, if you please—and we will rib that vertically to prevent the separated particles from following around the baffle to and through the side ports. The natural—and therefore the best—place for these ports or passageways for the steam is just above the bottom line of the pipe, so that all space below will be storage space for either steam or water.

Why after all's said and done, the

COCHRANE SEPARATORS

cover the very points you and I have in mind, and there's the **Catalogue 44—S** of the Cochrane Separators full of interesting information about separators, their design, construction, dimensions, styles, how to install and drain them, etc. Yours on request.

HARRISON SAFETY BOILER WORKS,
3176 N. 17th St., Philadelphia, Pa.
Manufacturers of COCHRANE FEED-WATER HEATERS