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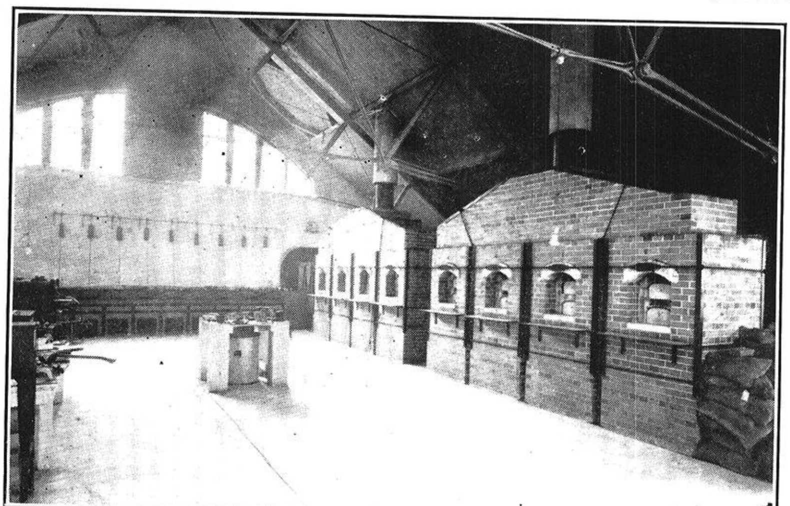
The Wisconsin Engineer



INTERIOR MINING LABORATORY.

MAY, 1911

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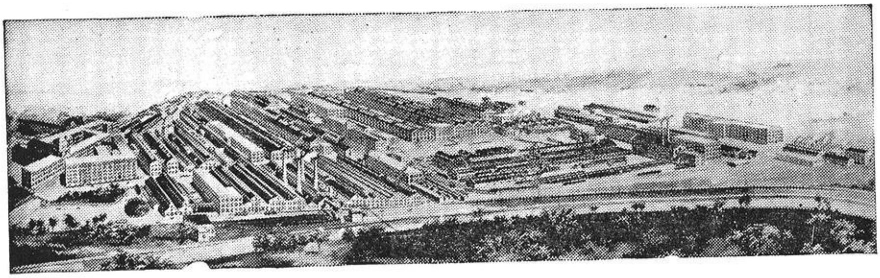

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The Wisconsin Engineer

VOL. XV MAY, 1911 NO 8

FIELD WORK IN CONCRETE CONSTRUCTION AT THE UNIVERSITY OF WISCONSIN.

ARTHUR PEABODY.
Supervising Architect, University of Wisconsin.

Concrete floors in masonry buildings offer many advantages as compared to the best timber construction, aside from resistance to fire.

Steel and tile floors commonly used in the so-called standard fire proof construction are too expensive for ordinary work such as dwellings and other small buildings. The comparative merits of each as a fire resistant has not been given the thorough tests that time will afford, but it may be they are about equal. For buildings not more than five stories in height brick walls and concrete floors appear to be the most economical and to unite the advantages of the old and the most modern systems of construction. Such buildings can be erected with the same thickness of walls as good construction demands and the sole difference in cost as between ordinary and fire proof construction is the excess cost of concrete floors and fire proof partitions over those of timber.

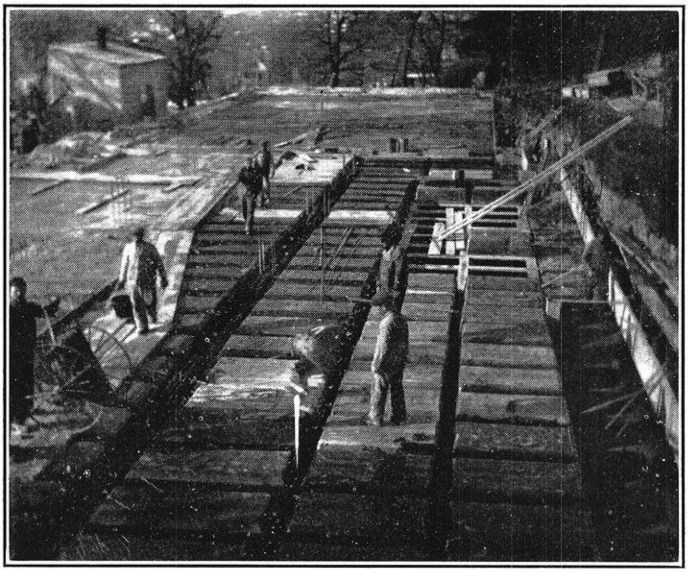
One of the chief expenses in reinforced concrete work is the false framing upon which the concrete is poured. About fifty per cent of the lumber used in making false work is usually destroyed on taking down. Any system by which the major part of this can be saved results naturally in a decrease in the total cost of the building. In applying concrete construction to small work the scale of parts involves expensive and intricate preparation of false work so that the cost of this part sometimes exceeds the value of the concrete poured upon it.

Small buildings, meaning those not over five stories high, have been built since civilization began and their elements have been so especialized particularly in modern times as to meet in an excellent way all the various requirements of strength, convenience and good appearance. Provision for modern improvements have been practically standardized and become a habit with the carpenter, the plumber and other workmen. If these buildings were not subject to the danger of fire there would be no good reason for making radical changes in building methods.

The invention of steel and tile construction introduced quite different members into floors and brought a good number of difficulties, some of which have not yet been satisfactorily met. Among these are the fastening of wood floors, the placing of pipes in accessible places and the like. With the advent of concrete the faults of steel and tile construction were mainly conserved and others added. All of this was done with apparent unconsciousness and probably without knowledge. The problem of construction was taken over by the engineers, who from training and practice are better acquainted with questions of strains than details of convenience and architectural appearance.

The first concrete buildings were designed as economy of strength and expense would suggest. The wide spacing of beams, together with their large size, produced a result at once simple and scientific. The application of accessories such as plumbing, heating, lighting, finish and decoration to these buildings was attended with some credit but not entire success. It was very soon discovered that the loss of continuous spaces in the structure of the floor and the recurrence of impervious beams at intervals having no relation to the divisions of rooms was no small inconvenience.

Very soon systems of construction securing flat ceilings were developed and the fact was emphasized by the designers while advertising other merits. The practice of imbedding pipes and wires in the concrete seems to meet the approval, however, of every one but the owners of the buildings. Experience with this practice shows its disadvantage. In concrete construction there cannot be permitted the usual "tearing up" of floors to repair electrical and plumbing work, etc., as in wooden floors. It is no easy matter to cut out concrete that has hardened for some time, and beside, as reinforced beams are designed, it is extremely hazardous to break into them at random. Whatever, therefore, is cast into the work is there "for all time," and there is a serious embarrassment whenever the owner wishes to remodel his building.

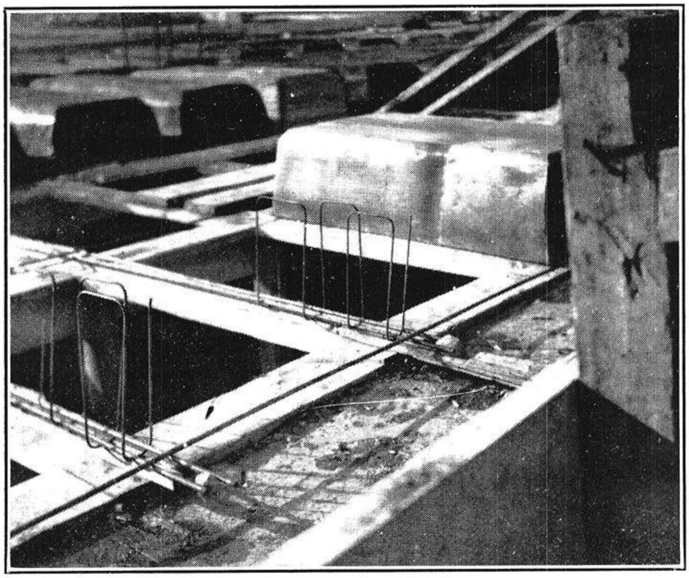


Pouring a concrete floor on the movable forms. At the left the joists and girders are completed, ready for the floor sheet. In the center the steel shows in the girder. At the right a space is still to be covered with the forms.

There is room for trouble also in constructions where a certain beam supports a considerable area. Such a beam is usually calculated to do the work intended, with a good margin of safety, but suppose the casting of the beam proves to be faulty, or in some manner the beam suffers slight damage. At once the entire area is threatened. This suggests the arrangement of many beams of small size, each supporting a small floor space. To this there arises the objection of increased cost. Beams of long span and narrow width suggest cross bracing, and again the comparison with wood construction suffers as regards expense. The good elements of wood construction are however precisely those of advantage in concrete. Wood beams are of long span, slight dimensions, and are set closely together. Each beam is braced to its neighbor by cross bridging. Under the beams all sorts of pipings are extended, and a flat ceiling is placed beneath. Upon the beams the floor is laid. What could be more reasonable and convenient? Should a pipe fail it requires only the removal of the ceiling for its repair. Should it be necessary to change the dimensions of rooms the necessary readjustments are readily made. Should a beam be slightly defective, or suffer injury, the beams adjacent will support the load, or if necessary, a section can be replaced without removing a large area of the floor. None of these advantages are to be had in the "mill type" of floor construction.

To retain the advantages of the ordinary form of construction and at the same time to effect a decrease in the cost of concrete work would seem to be worth while. In order to bring this about a decided improvement in the false work must be made and the false work must be preserved for future use. At the same time methods of placing steel must be simplified and standardized so that it can be safely done without the assistance of a skilled engineer. The steel must be made secure while the concrete is poured upon it. Field methods must take the place of laboratory methods, without serious loss of quality in results. The system employed at the University of Wisconsin has been found prctical, conomical and effective, and for buildings intended for ordinary use more satisfactory than the "mill type" of construction. In competition it has been found less expensive where the requirements of the specification for the steel and other elements forming a necessary part of good construction have been conserved. This has been put to proof by obtaining alternate propositions on the same work, imposing only the requirement that the steel shall be strained not to exceed a certain amount, that spaces shall be provided for pipes, etc., and that the ceilings shall be flat.

Other systems approach the practical values of this one in some degree, as for instance that one where hollow tiles are used in place of the wood cells. Where but one building is to be constructed the cost of the cells might excel the cost of the tile. Where the building is of several stories, or in buildings of large enough area so that one part can be constructed before another, thus permitting the repeated use of a reasonable number of cells, the cost of the tile would probably exceed the proportionate cost of wood cells. The tiles serve no useful purpose except



Detail of construction. Planks extending in both directions, supporting the cells. The steel and stirrups are set in place for demonstration only. Note the stirrups enclosing the rods, and standing without supports.

as forms between which the beams are cast, and their weight adds to the dead load of the floor construction. In either case a floor sheet must be placed on top, and the ceiling must be furred to receive piping and other accessories. Of course, such pipes may be buried in the floor sheet, but there is serious objection to this. It is done in most fire proof buildings, but the expense of repairing damage in case of leakage of water, gas or electrical current is made very heavy on account of it. Changes also are very expensive and difficult, and it is safe to say that every building will be changed over a number of times before it becomes obsolete.

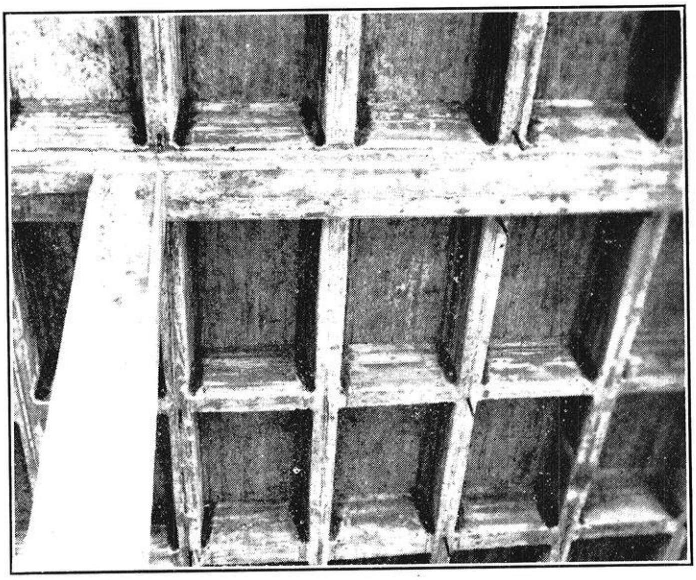
The system or design of the floor construction in use at the University of Wisconsin consists of an arrangement of narrow beams spaced at about three feet centres and braced by cross beams at six and one-half feet centres. The beams are formed by employing a series of wooden boxes, with slightly flaring sides and ends, laid face down upon a system of supporting planks upheld by shores. The intervals between the boxes or cells being filled with concrete constitute the beams and cross braces of the floor. The concrete is reinforced with steel after calculations made by the Dean of the Engineering Department of the University.

Upon the beams a floor sheet is poured, reinforced with steel wire fabric and finished with a wearing surface of cement and granite "fine stuff."

The reinforcing steel consists of round rods enclosed in loose stirrups. In the girders the rods are bent according to the the best practice. Straight rods are used in the joists with counter flexure rods over the girders. In the cross braces small single rods are placed. The stirrups are of the U form, but to secure correct spacing and holding, several stirrups are bent from a single rod forming a unit series. These have been found very convenient on account of stability and resistance to drifting, falling and other annoying peculiarities of single stirrups. Mild steel has been employed in all work. High tensions have been prohibited, as well as calculated tension in concrete. This may be conservatism, but is no doubt wise. The effort of the Architect has been to simplify and reduce the cost of work and to retain the good elements of old fashioned constructive systems; to provide reasonable means of access to parts for repair and changes and to bring back the forms of surfaces on the interior of buildings which long custom has found most suitable and agreeable.

In detail of work it has been found that two rods in each beam are more convenient than one, although theoretically very narrow beams closely spaced and containing each a single rod would be ideal.

The rough way in which concrete is now mixed and cast, the danger of imperfect castings and the liability of damage to concrete in stripping forbid the use of very slender parts at present. For private house work the concrete floors of today are probably excessive in strength. Refinement in the false work and casting will come in time, however, and it is to be expected



Ceiling of shop and storehouse building showing concrete joists and cross-bracing, and one main girder. The bolts extending out of the joists are for attaching line shafts.

that future constructions will be very much lighter and less expensive.

By the system described spans from twelve to twenty-six feet have been successfully cast at the University during the past two years. It is proposed to cast beams of twenty-eight feet span this year. These will require joists eight inches wide on the bottom, fourteen inches deep, and ten inches wide on top. With a spacing of 3′–4″ from center to center of joists the amount of concrete employed does not seem excessive. The cross braces in the floor, due to the intervals between the lengths of cells, have not been considered in the estimated strength of the floor. Their value in holding the joists against lateral strain is unquestionable and they serve also to distribute the load upon the floor. The increased width of the beams at the top, due to the flaring sides of the moulds gives increased resistance to crushing, while the narrower bottom, enclosing the steel, is sufficient and economical.

The calculated strength of the floor is entirely in the beams. That is to say, the floor sheet is not expected to increase the compressive strength of the joists as in the T beam. The floor, reinforced with a woven wire fabric simply applies the load to the beams.

In casting this work the supporting columns are poured first and are left over night to shrink. The girders and beams follow, being also allowed to shrink, after which the floor sheet, almost a separate item, is cast and finished with cement and granite.

This method of working has been followed upon finding that heavy members need time in order to avoid cracking at the junction with the thin floor sheet. It has been found that the floor sheet may be cast at any convenient time, care being taken to clean the upper surfaces of the beams to secure good contact with the floor. In fact with a sufficient number of boxes or cells an entire building may be constructed, casting the posts, girders and joists, but leaving the floor sheet to be placed after the building has been enclosed. Where mosaic floors are required it may prove economical to lay them at once on the wire fabric without going to the expense of the preliminary floor sheet. This, however, has not been verified. For attaching the ordinary ceilings to this construction small strips of wood are cast into the bottom of each joist and secured by bent nails, thus affording a ready means of applying the furring strips for the ceiling. These in turn give the needed spaces for pipes, etc. Upon the furring strips wire lath or plaster board is nailed and the plastering is applied.

The false work for posts and girders is composed of dressed planks put together in the ordinary way. These parts suffer the least injury in removal and may be set up a good number of times. The cells rest upon the girder boxing where adjacent, forming the false work for the upper part of the girders. In other locations they are supported by the plank scaffolds above described or upon the inside edge of the walls. In all places they are carefully levelled so that the concrete cannot penetrate between the scaffold planks and the cells. A few nails from below hold the cells securely to the plank.

The spaces between ends of cells may vary somewhat, where convenient. Nice adjustments do not give great results where labor is expensive. Making the joists narrower on one side of a girder than on the other, on account of a slightly shorter span does not bring final economy at times. It is simpler to make the "lay out" regular and strong enough for the longer span.

Posts and girders are incidental to all floor construction of large areas. Concrete posts are the least desirable element of concrete work because of the necessarily large size as compared to their length. Their elimination by increasing the spans of the floor seems to be the present solution of this problem.

With the completion of the false work the floor is ready for placing steel and casting concrete. The supporting columns are poured first and while the concrete is settling the steel is placed in the girder and joist channels. The "unit stirrups" are set in the ends of the girders and joists, being held up from the bottom of the forms by the small wooden strips to which the ceiling furrings are to be nailed later. The stirrups confine the tension rods of the beams. The steel is laid in the girders and joists of the entire floor before any part is covered with concrete. It may be inspected all together, corrections made, and the pouring is then begun. As fast as the joists are filled with concrete the counter flexure rods of the joists are floated in the concrete, extending over the girders and the work is ready for the floor sheet. At the end of the day's work the concrete of the joists and girders is dammed off at the center of the spans and the work is resumed the next day.

The second day's work usually begins with pouring the floor sheet on the area completed the day before. The woven steel fabric is unrolled over the surface and the concrete poured upon it. When sufficiently hard the surface finish is applied and the floor is completed. The pouring of the remaining joists follows the part of the sheet, using a half day on the sheet and the other half day on the joists and girders so that no part of the unfinished floor is more than one day old.

Practice has shown that the floor sheet is not separable from the joists even when poured after the joists have been set for several days. The finishing of the surface of the floor must be done of course soon after the sheet is poured. The entire work is allowed to set for three or four days before the mason work of the walls is allowed to proceed, but no stripping is done until after fourteen days. The girders and posts are then stripped and the cells are drawn out from underneath. For this work a chain about the interior framing of the cell is looped over a stout lever and one end of the box is started, whereupon it falls out, ready to be used over again. Small shores are then placed under the joists and left for a short time.

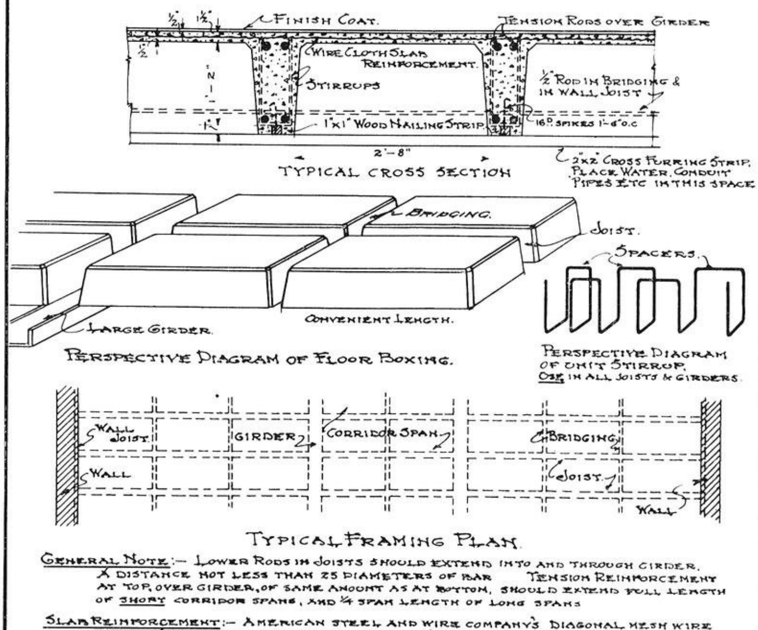
The cells first made at the University were built of pine sheathed with yellow pine flooring quite smooth and carefully put together. These cells were successfully drawn and were used fifteen times without a great percentage of loss. Their cost was approximately two dollars and fifty cents each. Each cell presented twenty-eight square feet of surface, making a first cost of eight and nine-tenths cents per square foot. After fifteen casts the cost per square foot remained at about nine-fifteenths cents per square foot, assuming that the cells were then worthless. The contractor then covered them with sheet iron, at a cost of one dollar and forty cents each and expects to use them probably fifteen times more. This iron covering is well greased before using.

At this time a good number of new cells were constructed, also covered with iron. These were well built but without the same care in smoothing the surface on account of the iron covering. These cells slip out of the concrete so easily as to show a great advantage in the use of a metal covering which presents a smooth unbroken surface to the concrete. It obviates also the swelling of the wood covering, from dampness which made the drawing of the first cells rather hard at times and destructive to the cell. The life of a cell depends of course on the treatment it receives. Some were wrecked the first time they were used.

Many of them were in apparent good order except as to the lower edges after fifteen casts. Their weight occasioned some damage, especially if allowed to fall to the ground on being drawn.

DETAILS & TABLE
OF
STANDARD JOIST CONSTRUCTION
UNIVERSITY OF WISCONSIN ARTHUR PEABODY ARCHITECT.
LIVE LOAD - 60# PER SQUARE FOOT.

SPAN IN FEET.	WIDTH OF JOIST AT BOTTOM IN INS	REQ STEEL AREA IN SQUARE INS.	NUMBER & SIZE OF RODS.	NUMBER & SIZE OF STIRRUP
14.	4.0	.375.	2 - ½"	4 - ¼" AT EACH END.
16.	4.0	.490.	2 - ⅝"	4 - ¼" "
18.	4.0	.620.	2 - ¾"	4 - ¼" "
20	4.5	.760.	2 - ¾"	6 - ¼" "
22.	5.0	.920	2 - ¾"	6 - ¼" "
24.	6.0	1.100	2 - ⅞"	8 - ¼" "
26.	7.0	1.280	2 - 1"	8 - ¼" "
28.	8.0	1.500	2 - 1"	8 - ¼" "



TYPICAL FRAMING PLAN.

GENERAL NOTE:— LOWER RODS IN JOISTS SHOULD EXTEND INTO AND THROUGH GIRDER. A DISTANCE NOT LESS THAN 25 DIAMETERS OF BAR TENSION REINFORCEMENT AT TOP, OVER GIRDER, OF SAME AMOUNT AS AT BOTTOM, SHOULD EXTEND FULL LENGTH OF SHORT CORRIDOR SPANS, AND ¼ SPAN LENGTH OF LONG SPANS

SLAB REINFORCEMENT:— AMERICAN STEEL AND WIRE COMPANY'S DIAGONAL MESH WIRE CLOTH. STYLE NO 28 OR EXPANDED METAL; Nº 9 METAL. 6" MESH; OR Nº 10 METAL 4" MESH (BIRMINGHAM GAGE).

Diagram Showing Joist Construction.

The most convenient size of cells appears to be two feet, eight inches wide by six and one-half feet long. Beyond this size they cannot be so easily handled. Some cells were made seven feet long and a few five feet. At times it is necessary to build special cells to finish out a span.

Variation in strength of floors was made in spacing the cells farther apart, making the concrete joists wider for the heavier floor. The percentage of steel was then increased according to rule. The joists were sometimes left exposed, over laboratories, and made a very presentable appearance. This gave opportunity for the convenient support of shafts, etc. Electric conduits were there left exposed, following the direction of the joists and cross bridgings. In other buildings plastered ceilings were attached in the ordinary manner. Steam coils were suspended from hangers secured by drilling the joists at the neutral axis. For line shafts bolts were cast in the concrete at regular intervals, to which timbers carrying the shaft hangers were bolted.

The floor sheet, two and one-half inches thick including the sand finish, seems fragile. In walking over the floors the resonance of the parts between joists suggests the same thought. Experience, however, shows that, except for the mechanical difficulty of casting the floor could be thinner. Floors have been broken during construction, but by blows which would break other floors considered amply strong. On one instance a scaffold plank fell about sixteen feet, striking on end. At another time a piece of sand stone three feet long, weighing about four hundred and fifty pounds, fell the same distance upon the floor. Each of these accidents made a break about a foot square, leaving the steel fabric but little damaged, and the repair of the floor very easy. Drilling through the floor for extending steam risers or setting anchor bolts shows the strength to be ample if not excessive.

All floors thus far constructed have been covered with a finishing coat of cement and granite, following the usual method in sidewalk work. This coat must be put on to the sheet at the time of pouring, and is a source of trouble and anxiety, especially in winter. The mixture is probably too rich, resulting in some contraction and cracking. The recent practice of tamping the rough concrete and floating smooth may be a decided improvement. There is no great need for a granite finish in floors. The surface must be covered anyway with some material less hard and unyielding than stone. Linoleum and cork carpet have proved very successful and are pleasant under foot.

Where concrete floors are exposed the surface wears off a disagreeable dust that is untidy in appearance and injurious to everything. This may be ground off and the hard concrete exposed, or the floor may be coated with special paint which resists wear and closes the pores of the concrete, preventing the absorption of water.

An example of the use of the system, with resulting costs is shown in a floor constructed in the Mining Laboratory of the University of Wisconsin. The floor area was approximately 4,500 square feet. The superimposed load was taken at 200 pounds per square foot. This work being done by the University forces gave an opportunity to know exact costs, as follows:

			Per square foot.
Crushed limestone, sand and Porland cement,..	$474.00	or	10.54 cents
Lumber for girder and post forms, etc.	252.00	or	6.60 cents
Cost of placing false work and cells............	250.00	or	5.55 cents
Cost of steel reinforcement.....................	354.00	or	7.86 cents
Labor of placing steel and pouring concrete.....	200.00	or	4.44 cents
Labor of removing false work..................	50.00	or	1.11 cents
Use of 200 cells at 1/15 original cost...........	33.00	or	.73 cents
Total cost	$1,613.00	or	35.83 cents

The cost of lumber for girder and post forms is of course too high, no allowance being made for the value of the material after removal. This lumber was not greatly damaged, but the exact value is hard to set down, as no subsequent floors of good area have been constructed by the University where it could be used. If the material could be taken to be as durable as the cells the proportionate lumber cost would be brought down to $16.70 instead of $252.00 and the total cost to $1,387.70 or 30.84 cents per square foot.

In applying this system it is to be noted that except in the items of concrete and steel a light floor will cost as much as a heavy one. It can be cast with the same cells, planks, shores, etc., and with approximately the same amount of labor. The increase on the heavy floor would of course be in the labor of pouring the larger amount of concrete. In the use of this laboratory the floor calculated to carry 200 pounds per square foot has been greatly overloaded, with no bad results however, which indicates that the actual strength of concrete construction is probably far in excess of that calculated.

This suggests lower factors of safety or diminished sections, but chiefly, in building work, longer spans. The economies in materials are not great, as between a strong and a weak floor. The elimination of posts is of much greater interest. If spans up to forty feet could be safely employed the interiors of many buildings might be quite clear and the parts arranged in the most convenient way, unhampered by lines of supporting columns. With the present depth of fourteen inches for the cells there is of course an economical limit to spans. Deeper cells would bring a new set of calculated values, however, so that there may be no reason why long spans should not be made use of.

Along with the description of constructive systems the real values of concrete floors are no less proper to consider. Aside from the first quality of resistance to fire, the elimination of unseasoned lumber with the consequent shrinking and sagging is of itself an important item. Concrete floors are practically immovable and not at all responsive to foot falls. For this reason they are more nearly noiseless than wooden floors. When covered with a soft material they very quite indeed. Another excellence is the intimate and continuous contract between the floors and walls which cuts off the passage of air, fumes, odors, etc. and the easy access from story to story of insects and vermin, the common nuisances incident to timber construction.

The use of tile partitions is possible in connection with concrete floors of the usual strength. This completes the exclusion of wood from the structure of the building. Whatever may be the resisting qualities of concrete the omission of wood from constructive parts both in floors and partitions removes such a large quantity of fuel that the possibility of serious fires is materially reduced.

These qualities have been met with only in ''regular'' fire proof buildings and in the ancient vaulted floors of European buildings, until the advent of concrete construction. Concrete buildings are warmer in winter and cooler in summer than those of ordinary construction. They are quiet. The ordinary sounds from over-head or underneath do not penetrate through the stories. An exception to this must probably be made as to musical sounds. A "resonance" travels some distance in certain cases. The claim that concrete floors are cold is probably wrong. In buildings heated by steam the entire building is warm. Concrete being a good conductor takes the same temperature as the room and should not fell cold to the foot. The probability is that wooden floors are really colder than concrete, on account of the draughts of air admitted into the spaces between the joists. Their quality as nonconductors may not carry the temperature so readily to the person, but all things considered concrete floors are probably warmer than wooden floors.

The less agreeable qualities of concrete are not so quickly discovered, but are none the less present. One of the first of them to be noticed is resonance. An uncovered floor in a large room produces a surprising echo or ringing which can be overcome only by applying a fibrous or sound absorbing cover to the floor. This has been met at the University by linoleum, and cork carpet. Both of these substances have given good results. Both, however, have the tendancy to wrinkle in summer and shrink in winter, that obtains in all such materials. Some use has been made of very hard asphalted felt, and the results have been rather gratifying.

SOME RECENT IMPROVEMENTS IN PAVEMENT CONSTRUCTION.

LEONARD S. SMITH.
Associate Professor of Civil Engineering.

The Improved Rattler Test for Paving Brick. The present general movement toward the standardization of both materials and methods of road and pavement construction marks one of the most significant forward steps ever taken by municipal engineers. The fact that the American Society of Civil Engineers gave up over half of the program at their recent annual meeting for a discussion of the road question alone emphasizes the importance of this movement from the standpoint of the engineer.

The success of this movement toward standardization is indebted in no small degree to the helpful co-operation of the manufacturers of paving materials. A decade ago manufacturers commonly concealed their trade secrets in a belief that this was necessary to their individual success. Indeed, even engineers were formerly slow to disclose to their brother engineers valuable information derived from their experience. This has now been replaced by a spirit of co-operation. An excellent example of the improvements which come from such co-operation is seen in the valuable and extensive experiments recently conducted under the auspices of the National Paving Brick Manufacturers' Association.

In the case of paving brick, all are agreed as to the need of some standard to determine the uniformity of structure, toughness, and the ability to withstand abrasion and impact. The history of the efforts to determine the best manner of making such tests, while very instructive, is quite beyond the limits of this paper.* The point I wish to make is that, due to a lack of care in standardizing brick tests, the results were frequently most misleading. The same brick, when tested by different labora-

* For a brief summary see "Municipal Engineering," Feb., 1911. P. 91.

tories, might be reported as excellent by one laboratory and condemned as unfit by another. The reason for this lack of agreement has been made clear within a few months by the extensive experiments alluded to above. These experiments were carried on in duplicate at Columbus, Ohio, under the charge of Professor Orton, and at Indianapolis under Mr. M. W. Blair.

This duplication of work proved a most valuable feature because the disagreement of results under apparently the same conditions of test finally lead to the discovery of the real sources of disagreement and lack of uniformity. In a word, the prime cause was due to variable conditions in the construction and use of the rattler, conditions until recently only partly suspected or understood. The variable conditions included:

(a). The size and materials of the rattler.

(b). The state of repair of the rattler.

(c). The amount and condition of the charge.

(d). The quality of the iron used in the charge with respect to hardness, and

(e). The number of brick included in a single test.

This utter lack of uniformity has for a long time concealed the fact that the results of the rattler test were affected to a large extent by the kind and manner of use of the rattler itself.

The approval of poor and the rejection of good paving brick has resulted in the construction of many poor brick pavements and in needlessly increasing the price of all brick pavements.

It is indeed fortunate that so important a matter has been in charge of experienced engineers. Few engineers will refuse to accept their conclusion reached as a result of so extensive and painstaking experiments.

Each laboratory received brick in lots of 1,050, the whole 2,100 being taken from one kiln, an equal number being selected from the upper, middle and lower levels. These brick were carefully marked so as to identify them, and very careful records were kept of the results of both the absorption and rattler tests.

The rattler was charged in the following three ways: a—using cube shot with ten brick, b—using spherical shot with ten brick, c—using fifteen brick but no shot. Of the 350 brick taken from each zone of each kiln, 100 brick were used for the usual absorption test. Of such 100 brick, the 20 which showed the highest or lowest in the absorption test were kept separate for tests 9 and 10, while the remaining 80 brick were used in tests 1 to 8 inclusive, care being taken to have the mean of the absorption records as near as possible the same in each charge. From the 250 brick which were not given the absorption test, 10 charges of 10 each were so arranged as to apportion the irregular and defective bricks equally among the charges, and from the 150 remaining brick, 5 charges of 15 brick each were selected in the same way. The remaining 75 bricks were reserved for any duplicates or extra tests.

Two series of tests were first made with the old form of charge, viz., cubical shot composed of 75 lbs. large (7.4 lbs. each) and 300 lbs. of small (7/8 lb. each). Later similar series of tests were made with spherical shot. A comparison of results disclosed the fact that while the spheres used by Orton had given average results higher than those reached by Blair, the use of the cubes resulted in exactly the reverse. An examination of the composition of the abrasive material showed that it varied greatly, and that the abrasive action found in the rattler tests increased in severity with the amount of combined carbon contained in the shot. Further tests proved the impossibility of obtaining like results unless the abrasive material used was closely the same, a most important discovery.

In other experiments on the effect of the condition of the rattler staves, it was found that the severity of the machine increased with the distortion of the staves, in some cases being very marked. In order to learn the best form of stave, experiments were made with steel plates of various thicknesses, with cast iron, manganese steel, and structural channel with the face protected by a wearing plate. The last was found to be the most satisfactory.

In presenting a progress report of these valuable experiments, the engineers state: "While we believe that we have eliminated considerable variation from this machine, it must still be recognized that there remains a hazard in the machine itself which is unavoidable."

The following are the specifications of the new rattler:*

NEW RATTLER SPECIFICATIONS.

The machine shall be of good mechanical construction, self-contained, and shall conform to the following details and dimensions, and shall consist of barrel, frame and driving mechanism as herein described.

The Barrel. The barrel of the machine shall be made up of the heads, head-liners and staves.

The heads shall be cast with trunnions in one piece. The trunnion bearing shall not be less than 2½ inches in diameter nor less than 6 inches in length.

The heads shall not be less than ¾ of an inch thick nor more than ⅞ of an inch. In outline they shall be a regular 14-sided polygon inscribed in a circle 28⅜ inches in diameter. The heads shall be provided with flanges not less than ¾ of an inch thick and extending 2½ inches from inside face of head, to afford a means of fastening the staves. The flanges shall be slotted on the outer edge, so as to provide for two ¾-inch bolts at each end of each stave, said slot to be 13/16 of an inch wide and 2¾ inches center to center. Under each section of the flanges, there shall be a brace ⅜ of an inch thick and extending down the outside of the head not less than 2 inches. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. There shall be for each head a cast iron head-liner 1 inch in thickness and conforming to the outline of the head, but inscribed in a circle 28⅛ inches in diameter. This liner or wear plate shall be fastened to the head by seven ⅝-inch cap screws, through the head from the outside. These wear plates, whenever they become worn down one-half inch below their initial surface level, at any point of their surface, must be replaced with new. The metal of which these wear plates are to be composed shall be what is known as hard machinery iron, and must contain not less than 1 per cent. of combined carbon. The faces of the polygon must be smooth and give uniform bearing

* This machine can be obtained of Hetherington and Bernes, Indianapolis, Ind., for $150 each.

for the staves. To secure the desired uniform bearing, the faces of the head may be ground or machined.

The Staves. The staves shall be made of 6-inch medium steel structural channels 27¼ inches long and weighing 15.5 pounds per lineal foot.

The channels shall be drilled with holes 13/16 of an inch in diameter, two in each end, for bolts to fasten same to the heads, the center line of the holes being 1 inch from either end and 1⅜ inches away from the longitudinal center line.

The space between the staves will be determined by the accuracy of the heads, but must not exceed 5/16 of an inch. The interior or flat side of the channel must be protected by a lining or wear plate ⅜ of an inch thick by 5½ inches wide and 19¾ inches long. This wear plate shall consist of medium steel plate, and shall be riveted to the channel by 3½-inch rivets, one of which shall be upon the center line both ways and the other two upon the longitudinal line and spaced 7 inches from the center each way. The rivet holes shall be counter sunk on the face of the wear plate and the rivets shall be driven hot and chipped off flush with the surface of the wear plate. These wear plates shall be inspected from time to time, and if found loose shall be at once re-riveted, but no wear plate shall be replaced by a new one, except as the whole set is changed. No set of wear plates shall be used for more than 150 tests under any circumstances. The record must show date when each set of wear plates goes into service, and the number of tests made upon each set.

The staves when bolted to the heads shall form a barrel 20 inches long, inside measurement, between wear plates. The wear plates of the staves must be so placed as to drop between the wear plates of the heads. These staves shall be bolted tightly to the heads by ¾-inch bolts, and each bolt shall be provided with lock nuts, and shall be inspected, at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection, showing in what condition the bolts were found.

The Frame and Driving Mechanism. Investigation into the effects of variations in the construction of the frame, and in the mode of driving the barrel, has not yet been undertaken and hence no established accuracy is offered at all comparable to that which has been reached in the construction of the barrel and uses of shot herein set forth. Without insisting, therefore, upon absolute uniformity in the frame or driving mechanism, the following principles of constructions are recommended, pending the completion of further studies upon the points involved.

The barrel should be mounted on a cast-iron frame of sufficient strength and rigidity to support same without undue vibration. It should rest on a rigid foundation and be fastened to same by bolts at not less than four points.

It should be driven by gearing whose ratio of driver to driven should not be less than one to four. The counter shaft on which the driving pinion is mounted should be belt-driven and the pulley should not be less than 18 inches in diameter and 6½ inches in face. A belt of 6-inch double-strength leather, properly adjusted so as to avoid unnecessary slipping, should be used.

The National Paving Brick Manufacturers' Association will furnish without cost to all proper applicants, the complete drawings of a machine which will meet the above specifications and requirements.

The Abrasive Charge. (*a*) The abrasive charge shall consist of two sizes of cast-iron spheres. The larger size shall be 3.75 inches in diameter when new and shall weigh when new approximately 7.5 pounds (3.40 kilos) each. Ten shall be used.

These shall be weighed separately after each ten tests, and when the weight of any large shot falls to 7 pounds (3.175 kilos) is shall be discarded and a new one substituted, provided, however, that all the large shot shall not be discarded and substituted by new ones at any single time, and that so far as possible the large shot shall compose a graduated series in various stages of wear.

The smaller size spheres shall be, when new, 1.875 inches in diameter and shall weigh not to exceed 0.95 lbs. (0.43 kilos) each. Of these spheres so many shall be used as will bring the collective weight of the large and small spheres most nearly to 300 lbs., provided, that no small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 inches in diameter, drilled in a cast-iron plate ¼ inch in thickness, or weigh less than 0.75 lbs. Further, the small spheres shall be tested by passing them over such an iron plate, drilled with such holes, or shall be weighed after every ten tests, and any which pass through or fall below specified weight, shall be replaced by new spheres, and provided further that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective, it shall be at once replaced.

(*b*) The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon	Not less than 2.50 per cent
Graphite carbon	Not more than 0.10 per cent
Silicon	Not more than 1.00 per cent
Manganese	Not more than 0.50 per cent
Phosphorus	Not more than 0.25 per cent
Sulphur	Not more than 0.08 per cent

For each new batch of spheres used, the chemical analysis must be furnished by the maker, or be obtained by the user, before introduction into the charge, and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

The Test. The rattler shall be rotated at a rate of not less than 29½, nor more than 30½, revolutions per minute, and 1,800 revolutions shall constitute the standard test.

A margin of not to exceed ten revolutions will be allowed for stopping. In case a charge is allowed to run several minutes beyond its proper termination, and the loss incurred is still within the prescribed limits, then the test shall not be discarded, but the fact shall be entered upon the record.

Stopping and Starting. Only one stop and start per test is regular and acceptable. If from accidental causes a test is stopped and started twice extra, and the loss exeeds the maximum permissible, the test shall be disqualified and another made.

A counting machine shall be attached to the rattler for counting the revolutions.

The Results. The loss shall be calculated in percentage of the original weight of the dried brick composing the charge. In weighing the rattled brick any piece weighing less than one pound shall be rejected.

The tests on this machine show that it is much more severe than the old type of rattler, giving an abrasion of about 25 instead of 18 per cent.

Brick Pavements. The past year has witnessed the practical acceptance by the committee of city officials and by engineers in general of the specifications for brick pavements prepared by the National Paving Brick Manufacturers' Association. These specifications, known as No. 1, have been printed and widely distributed. Perhaps the most peculiar and most interesting feature of these specifications is the added care taken to insure a proper grout filler and its thorough incorporation in the interstices of the brick. During the month of November, 1910, the writer inspected about a hundred miles of pavements in Cleveland, O., laid under these or similar specifications. He was very much impressed with the fine condition in which he found such pavements. On the other hand, the condition of brick pavements noted, built by the use of soft fillers, was generally found in striking contrast. At the meeting of the Wis. Society of Engineers two years ago the writer showed samples of some brick that had been used on heavy traffic streets in Ohio cities, which showed very little wear after nineteen years of use. Many similar pavements were to be found at the time of the inspection referred to. At the American Society of Civil Engineers' meeting in January, 1911, the State Highway Engineer of Ohio, Mr. Wonders, reported the construction of country highways with brick on a 4-inch concrete base at a cost, including engineering services, of less than $9,000 a mile. This cost is less than many miles of macadam road that have been built in New York and some of the other eastern states. At this meeting Mr. Wonders ventured the opinion that these country highways would be in good condition 25 years hence, suggesting that on main trunk highways between cities it was possible that the use of a brick pavement might offer the best solution of the present difficult problem of macadam road construction and maintenance.

Granite Block Pavement. Most of us have become so accustomed to the rough and ugly stone block pavements usually found in the heavy traffic portion of our American cities that we find it difficult to form any other concept of such pavements. During the past year, however, the City Engineer of Newark, N. J., has been able to construct stone block pavements under amended specifications requiring a block with smaller variations in dimensions than previously allowed, and laying same with 3/8-inch joints, put together with grout filler in a manner to insure a remarkably smooth pavement, one, indeed, which is not very much different in appearance and traction from an ordinary brick pavement. The extra cost of such a pavement over the ordinary form has not exceeded 25 cents per square yard. It is believed that the life of such a pavement will be sufficiently prolonged and the ease of traction sufficiently improved to more than justify this small addition in the initial expense. New York City has also recently adopted a modified form of this granite block pavement. The writer inspected some of this form of pavement in New York a few weeks ago and was impressed with the marked improvements over the usual form of construction. A rather complete description of the Newark granite block pavement will be found in "Engineering-Contracting" for Nov. 16, 1910.

Wood Block Pavement. As a result of the new standard specifications adopted by the organization of city officials, a heated controversy has recently arisen regarding the amount and character of the creosote oil suited for the treatment of wood block. Briefly stated, the specifications have increased the amount from 16 pounds per cubic foot to 20 or even, in extreme cases, to 24 pounds. The specific gravity now required in the new specifications has been increased from 105% to 110% or above. This has been accomplished by the mixing of coal tar pitch with the creosote oil. It would appear from the limited literature on the subject that this new form of creosote oil cannot be purchased in the open market from the ordinary dealers in such supplies, at least in commercial quantities. It is charged, indeed, that one firm has practically a monopoly on the supply of this oil. As a result, there have been many remonstrances to the adoption of such specifications. In Cincinnati the Citizens' Bureau of Research has thoroughly investigated the merits of such a heavy oil, and has published several bulletins descriptive of their findings. The experts in charge of the investigation claim that no improvement in the block comparable with the high increase in the cost of the oil and the resulting high cost of the block is discernible. One of the objections which has been urged to the use of such a heavy oil is the resulting increased slipperiness. It is to be hoped that engineers using these amended specifications will report to the engineering societies the results of their experiences. In view of the fact that in most cases the wood block is *worn* out by traffic long before it has a chance to decay it would seem to the writer that undue importance has been attached to the kind and amount of preservative used.

Bituminous Concrete Pavement. One of the most significant developments of the past ten years has been the remarkable increase in the use of bituminous concrete pavement, especially the patented form known as the Warrens Bithulithic pavement. Ten years ago there were but sixteen thousand yards of such pavement, while during ten months of 1910 over four million yards of this pavement were laid, giving a total of over fourteen million square yards constructed in the past ten years. This is equivalent to a 30-foot roadway for a distance of 832 miles.

Bituminous concrete pavements, the binding material being coal tar, have been in use for over thirty years in many cities in this country, but no patent for such pavements was ever taken out until the Warrens Bithulithic patent in 1901. One of the most important features of this patent is based upon the use of graduated stone, from the finest pulverized limestone to a stone passing a 1½-inch screen, in such quantities as to give a minimum amount of voids, claimed to be about ten per cent.

Several cities have resisted the collection of the royalty demanded on this pavement, 25 cents per yard, but so far it appears that the courts have decided in favor of the Bithulithic patents. As a result, many substitutes, more or less successful, have been proposed for the Bithulithic form. One form called the Sarcolithic laid by Mr. Lynn White, Engineer for the South Park Board Commission, Chicago, has proved a very satisfactory pavement for boulevard and even much heavier traffic. Another form, called the El-Oso, as been constructed both in eastern and southwestern cities. The latter pavement appears to have met with great success wherever it has been used, and because it has been acknowledged by the Warrens patentee not to be an infringement, the formula for its mixture will be of interest, viz.:

Bitumen	7 to 11%
Mineral Aggregate, passing 200-mesh screen	5 to 11%
Mineral Aggregate, passing 40 mesh screen	18 to 36%
Mineral Aggregate, passing 10 mesh screen	25 to 55%
Mineral Aggregate, passing ¼-mesh screen	8 to 22%
Mineral Aggregate, passing ½-mesh screen	less than 10%

It will be noted from the above that from 25 to 50 per cent of the total mineral aggregate is composed of stone passing a 10-mesh screen, and that only 10 per cent is as large as ½ inch. This mixture is heated to from 225 to 325° F., and mixed in a manner to thoroughly coat each particle of stone, gravel or sand and produce a uniform mixture. Such asphaltic concrete is then hauled on the street and spread with hot iron rakes and shovels and thoroughly rammed or tamped into position in a manner to produce, when thoroughly compressed by tamping and rolling, a thickness of two or more inches. It should be said, however, that it is laid on the usual 5 or 6-inch Portland cement concrete foundation. Care is taken to have the asphaltic concrete mixture contain enough mortar to fill all the voids and come to the surface of the pavement as free mortar when rammed and rolled, thus producing a solid mass. The final compression is given by a steam roller weighing at least ten tons, the rolling being continued as long as the asphaltic concrete will take any compression. The material can be mixed in the usual asphalt plants, or in even much more simple plants. It is claimed that the surface has all the advantages of the Bithulithic pavement and none of the disadvantages. How far this is true in fact, the writer is not prepared to state, but, like most engineers, he welcomes a form of asphaltic concrete which can be laid at a reasonable cost and which will take the place and do the work of the Bithulithic. It is to be expected that further improvements will be made along this line in the near future.

TEST OF A 4½" COLUMBIA HYDRAULIC RAM.

D. P. DALE, '11.

INTRODUCTION BY GEORGE JACOB DAVIS, JR.
Assistant Professor of Hydraulic Engineering.

The hydraulic ram was invented by John Whitehurst in 1772 and in 1796 Joseph Montgolfier improved it by making its action automatic. Since the latter date no important improvements have been made in its design.

Hydraulic rams have come into extensive use for pumping small amounts of water to isolated dwellings, hotels and other buildings situated near small falls, but it was not thought practicable to build and operate large rams until 1895, when Professor D. W. Mead designed and built a ram for supplying the city of West Dundee, Ill., with water. This ram* had a drive pipe 10 inches in diameter and 2,200 feet long and operated under a supply head of 43 feet. This demonstration of the practicability of large rams has led to their adoption in many places for pumping the water-supplies of small cities and irrigation projects.

On account of its entering into competition with other types of pumping machinery in moderate sized installations, it is becoming important to have more precise knowledge concerning the principles of design and of operation of the ram. During 1907 an investigation of the hydraulic ram was made in the Hydraulic Laboratory of the University of Wisconsin by L. F. Harza.* In his investigation theoretical formulas accounting for the action of the ram were derived and checked by experiment, thus demonstrating the practicability of rationally designing hydraulic rams for any given working conditions.

In the usual installation a ram would not be specially designed

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* D. W. Mead, "A Large Hydraulic Ram," Eng. Rec. 44:174, Aug. 24, 1901.

* L. F. Harza, "An Investigation of the Hydraulic Ram." Bul. Univ. of Wis. No. 205, Engng. Series, Vol. 4, No. 3.

for the conditions under which it is to operate, but one, or a battery of rams, of some commercial make would be selected. In order to make a wise selection it is necessary to know the characteristics of the various types of rams and the proper conditions for their operation. In determining these characteristics there are many practical problems which need to be solved experimentally. A few of them are listed below:

1. What is the effect of variations in the size of the air chamber?
2. What amount of water should be kept in the air chamber?
3. What is the best rate of closure for the waste valve?
4. What should be the range of movement of the waste valve?
5. What is the best type of waste valve?
6. What is the best type of check valve?
7. What is the proper proportion between the check valve area and the diameter of the drive pipe?
8. What diameter of drive pipe is best under various conditions of operation and installation?
9. What is the best length of drive pipe to use under given conditions as to supply and discharge heads?
10. What rate of stroke is best for given conditions of supply and discharge heads and length of drive pipe?

These and other problems in connection with the hydraulic ram are suitable subjects for theses, because the apparatus involved is simple and of small size and can therefore be installed, changes made in the set-up and observations made by one or two men. Some of the problems are too large to be completed in the time available for the preparation of one thesis. For instance, the last two listed above form the subject of the thesis of D. P. Dale, abstracted on the following pages. The experimental work planned was only partially carried out on account of lack of time, but it has been continued by A. B. Brown, with whom Mr. Dale worked, assisted by Messrs. Brue, Burmester and May. It is hoped, when their work is ended, to have a complete solution of the problem, in so far as it relates to the size and type of ram used in the experiments.

I. THEORY OF THE HYDRAULIC RAM.

Parts. (See plate I.) Any hydraulic ram consists essentially of three groups of parts:

(1) A supply tank, drive pipe, and waste valve.

(2) A check valve and air chamber.

(3) A discharge pipe and reservoir.

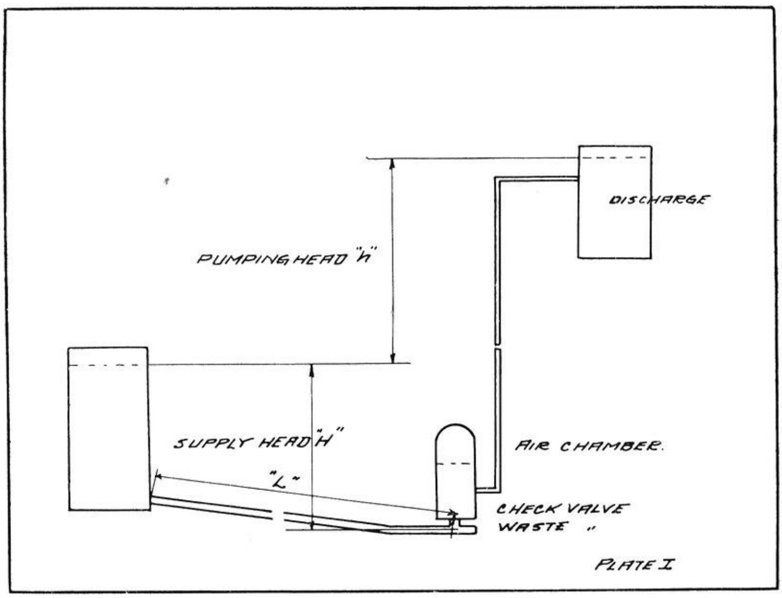

Plate I.

Nomenclature. The following symbols will be used throughout this discussion:

H = head of supply tank on waste valve.

h = head of discharge reservoir on supply tank.

Q = rate of wasting water, pounds per minute.

q = rate of pumping water, pounds per minute.

r = rate of strokes, number per minute.

E = efficiency, per cent.

Manner of Working. Let us assume the waste valve in Figure 1 to be open. Due to gravity, water flows down the drive pipe with an accelerated velocity and makes its exit through the valve. This valve is so constructed that when the velocity of the water reaches a certain point, it will close suddenly. The result is a water hammer; the pressure in the pipe rises, forces open the check valve, and water enters the air chamber. It continues to enter until that pressure is relieved and equilibrium is established. Thereupon the check valve closes, the waste valve closes, and another cycle begins. Water has been forced into the air chamber against a high head; the air has a cushioning effect and produces a nearly uniform pressure in the discharge pipe. As the velocity of water into the air chamber is gradually extinguished, the pressure on the valve falls until it is equal to the pumping head. The water is now in a slightly compressed condition, and the walls of the pipe are distended. Such a condition is obviously unstable. The resulting contraction of the pipe and expansion of the water cause a flow back into the supply tank. The momentum of the resurge sets up a wave of rarefaction which reduces the pressure and opens the waste valve, thus starting another cycle. Were the waste valve to remain closed tightly, waves of compression and rarefaction would occur until friction damped out the accumulated energy.

II. APPARATUS AND METHOD.

Purpose and Range of Experiments. The experiments were designed primarily for the purpose of ascertaining the effect of length of drive pipe on the efficiency and capacity of the ram. The method outlined was to vary one factor while all the others are kept constant, and to vary in turn r, h, H, and L. It was believed that some of the runs could be omitted when the laws of variation were established. It was proposed to cover L at 20′ 40′ and 60′; H at 4′, 6′, 8′, and 10′; and h and r throughout the range of which the machine was capable.

Apparatus. The apparatus consists of Columbia Hydraulic Ram No. 195, cylindrical steel tanks for supply, discharge and waste, and a Crosby water gauge for registering h. The ram is 44″ high and weighs 600 lbs. The tanks are those regularly used in the hydraulic laboratory, and are fitted with calibrated glass gauges. The drive pipe is 62.4′ long, is 4½″ inside diameter, and has a bellmouth fitted on the end to reduce entrance loss of head.

Method of Varying the Conditions. Supply head is fixed by the length of the wire joining the float in the supply tank to the arm of the float valve. Valves in the supply mains are set to give approximately the desired flow; the float valve takes care

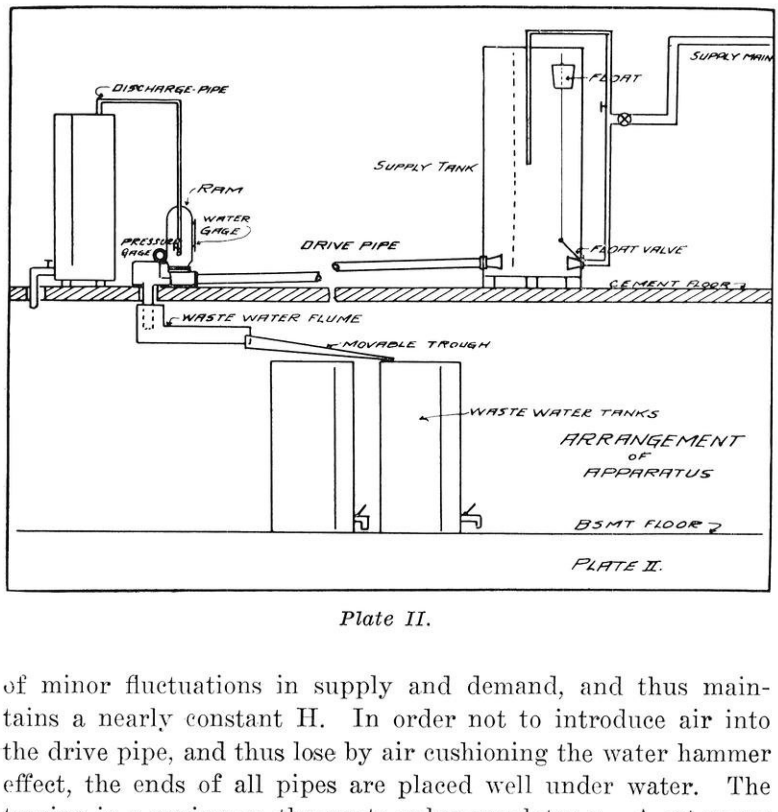

Plate II.

of minor fluctuations in supply and demand, and thus maintains a nearly constant H. In order not to introduce air into the drive pipe, and thus lose by air cushioning the water hammer effect, the ends of all pipes are placed well under water. The tension in a spring on the waste valve regulates r. A set screw device is used to fix this tension and thereby to govern r, the factor most often changed.

Method of Calculation. Two formulas for efficiency are in use:

Rankine, $E = qh \div QH$.

D'Aubisson, $E = q(H + h) \div (Q + q)H$.

Rankine's formula is used in these experiments.

Sample Calculation, Run No. 195. See original data sheet below.

q	14	11	5
	8.32	7.90	6.20
	2.38	3.22	4.06
	5.94	4.68	2.14

5.94 9:53 to 10:07 = 14 minutes.
4.68 9:55 to 10:06 = 11 minutes.
2.14 9:57 to 10:02 = 5 minutes.

30) 12.76 cubic feet = 30 minutes.

.425 cubic feet per minute.
.425 × 10 = 4.25 = discharge in cubic feet.
4.25 × 62.2 = 264 = discharge in pounds = q.

H 2.61′ average reading on supply tank gauge
4.63′ height of zero of said gauge above waste valve

7.24′ supply head = H.

h 106′ average registered pumping head
.6 height of center of gauge above waste valve

106.6 head of discharge reservoir on waste valve
7.2 supply head

99.4 head of discharge reservoir on supply tank = h.

Q 3220 first tank
3290 second tank = 3320 — 30

11) 6511 waste for 11 minutes

592 waste per minute
592 × 10 = 5920 waste for 10 minutes = 10Q.

$$E \quad \frac{264 \times 99.4}{5920 \times 7.24} = \frac{26240}{42860} = 61.2 \text{ per cent.}$$

$$\frac{h}{H} = \frac{99.4}{7.24} = 13.70 \quad \frac{q}{Q} = \frac{26.4}{592} = .0446$$

Check on Efficiency, 13.70 × .0446 = 61.1

By the above method of computing q, all the readings, not merely the first and last, are used. In most cases, however, where the rates were uniform, only the first and last readings were used. When deemed necessary the more careful method was used to compute Q. All the efficiencies were calculated by solving for qh ÷ QH by multiplying out and using slide rule to divide. They were checked by slide rule, and were rechecked by multiplying h ÷ H by q ÷ Q on the slide rule. All cases differing by .3 of 1% or more were recomputed.

III. DATA.

SAMPLE SHEET OF ORIGINAL DATA. DATE, AUGUST 10, 1910.
NOTE: PARENTHESIS IN Q COLUMN REFERS TO TIME.

Run No. 195.

Time	r	Discharge Cu. Ft.	10 q	h	10 Q	H	E	$\frac{h}{H}$	$\frac{q}{Q}$	Lbs. per min.
9:53	43	2.38		106	0 (54)	2.60				
55	44	3.22		106	1190 (56)	2.61				
57	44.5	4.06		106	2380 (58)					
					2970 (59)	2.61				
10:02	44	6.20		106	3220		26242			
					30		—			
							42861			
06	45	7.90			2130 (03)					
				106	2780 (04)					
07		8.32			3030 (04.5)					
					3230 (05)					
										26.4
10	44	4.25	264	99.04	5920		61.2	13.70	.0446	592

Sample of Summarized Data.

Run No.	Time Min.	r	h	H	q	Q	$\frac{h}{H}$	$\frac{q}{Q}$	E
195	10	44	99.4	7.24	26.4	592	13.70	.0446	61.2
196	10	51	99.4	7.20	22.1	521	13.80	.0245	58.6
197	10	35	99.4	7.18	30.5	714	13.85	.0427	59.2
198	10	35	111.4	7.23	27.7	705	15.40	.0393	60.5
199	10	39	111.4	7.22	26.1	650	15.44	.0400	62.0
200	10	28.5	111.4	7.20	37.4	1020	15.47	.0367	56.9

IV. DISCUSSION OF RESULTS.

The Curves. The results of the experiments are shown in 140 curves, some typical ones of which are here given. The following outline shows the factors involved:

Factors Involved in Curves.

Set of Curves	Variables	Constants	Remarks.
1..........................	E, r	L, H, h	h=63′
2..........................	E, r	L, H, h	h=126′
3..........................	E, h	L, H	For Maximum Efficiency.
4..........................	r, h	L, H	" " "
5..........................	E, r, h	L, H	H=9.2′
6..........................	E, r, h	L, H	H=7.2′
7..........................	r, q and r, Q	L, H, h	h=63′
8..........................	r, q and r, Q	L, H, h	h=126′
9..........................	Q, h	L, H, r	
10..........................	q, h	L, H, r	
11..........................	q, Q	L, H, r	H=9.2′
12..........................	q, Q	L, H, r	H=7.2′

Set 1 shows the variation in efficiency with rate of strokes, H and h constant. E increases with r for a period and then falls off. Twelve such E—r curves were plotted with H=9.2′, h varying from 24′ to 186′. Of these, the full line curves of sets 1 and 2 are examples, viz., when h = 63.3′ and when h = 126.4′. The dashed curves are the corresponding ones for H = 7.2′. It may be observed that efficiencies are lower with the lower supply head. The curves for all pumping heads are similar, and resemble parabolas.

Under the higher heads the range of rate of strokes is smaller, and the range of efficiencies is larger. This variation gives a more sharply defined maximum point to the curves for higher heads. It can be noted that the maximum point in the E — r curves as h changes from 24′ to 186′, rises for a time, and then gradually decreases. This rise and fall in maximum efficiency as h increases can be seen to better advantage in curve 3. It may also be noted that the maximum point moves simultaneously to the right, and then returns. This rise and fall in the rate of strokes for maximum efficiency can be seen in curve 4.

Curve 5 shows the simultaneous values of three variables:

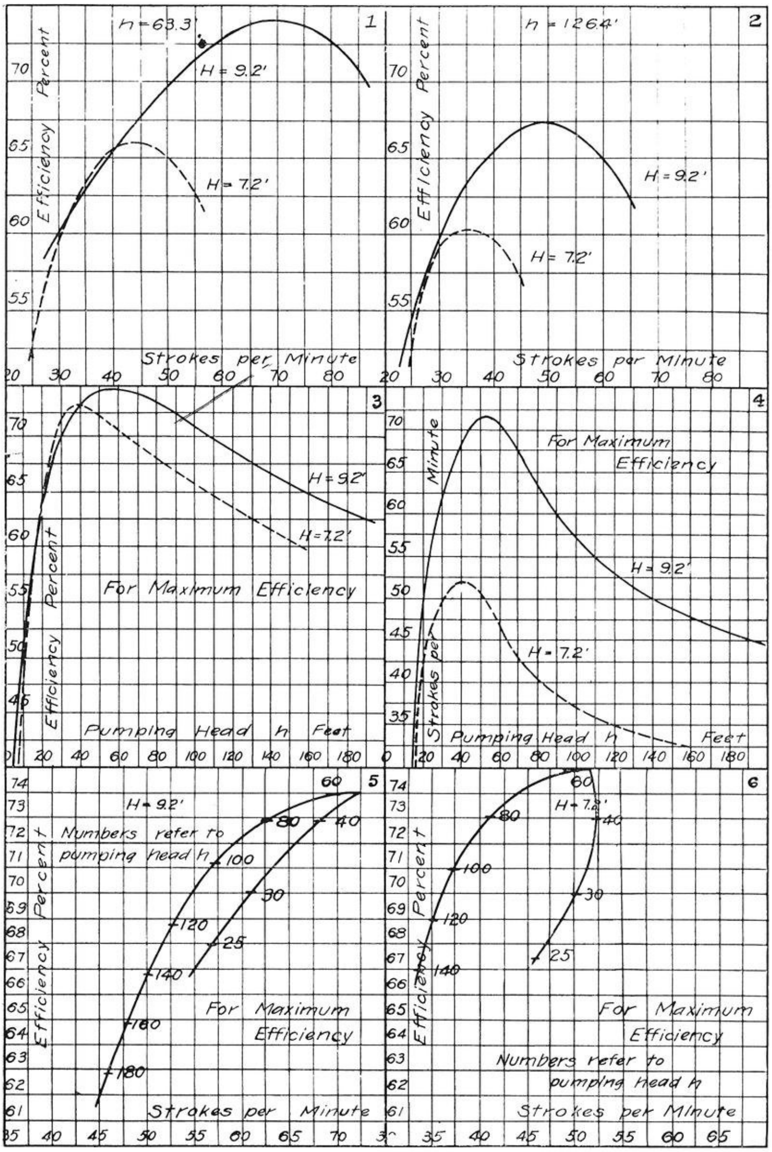
1
h = 63.3'
H = 9.2'
H = 7.2'
Efficiency Percent
Strokes per Minute
2
h = 126.4'
H = 9.2'
H = 7.2'
Efficiency Percent
Strokes per Minute
3
H = 9.2'
H = 7.2'
For Maximum Efficiency
Efficiency Percent
Pumping Head h Feet
4
For Maximum Efficiency
H = 9.2'
H = 7.2'
Strokes per Minute
Pumping Head h Feet
5
H = 9.2'
Numbers refer to pumping head h
For Maximum Efficiency
Efficiency Percent
Strokes per Minute
6
H = 7.2'
For Maximum Efficiency
Numbers refer to pumping head h
Efficiency Percent
Strokes per Minute

Plate III.

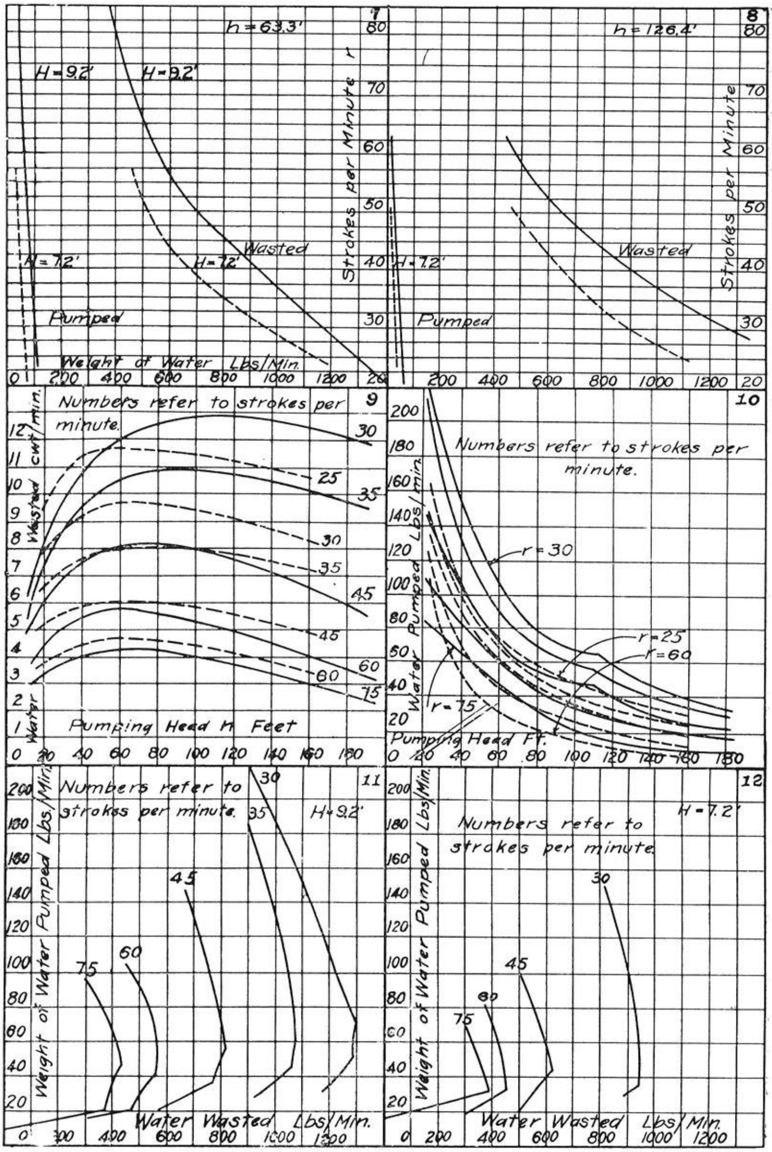
7
h = 63.3'
H = 9.2'
H = 9.2'
H = 7.2'
H = 7.2'
Wasted
Pumped
Weight of Water Lbs/Min.
Strokes per Minute
8
h = 126.4'
H = 7.2'
Pumped
Wasted
Strokes per Minute
9
Numbers refer to strokes per minute.
Water Wasted cwt/min.
Pumping Head h Feet
10
Numbers refer to strokes per minute.
Water Pumped Lbs/Min.
r = 30
r = 25
r = 60
r = 75
Pumping Head Ft.
11
Numbers refer to strokes per minute.
H = 9.2'
Weight of Water Pumped Lbs/Min.
Water Wasted Lbs/Min.
12
H = 7.2'
Numbers refer to strokes per minute.
Weight of Water Pumped Lbs/Min.
Water Wasted Lbs/Min.

Plate IV.

rate of strokes, pumping head, and maximum efficiency for that pumping head. It combines (3) and (4) by eliminating h. Suppose we have a fall of 9.2′, and wish to pump water to a height of 100′. Curve 5 shows that the maximum efficiency of 73% will be secured by setting the machine to run at 63 strokes per minute. Curve 6 shows the relations existing under the condition H = 7.2′. When the series of experiments of which these are a start are finished, a number of curves similar to (5) may be plotted on one sheet, and will show for any combination of values of H and h within the range of the machine, the maximum efficiency that can be secured, and also what rate of strokes to use to secure the same.

The curves for Q (6, 7,) show that Q and r vary inversely. More water is wasted when the strokes are longer although there are fewer of them because the rapid increase in velocity acquired in the longer strokes more than offsets the effect of fewer strokes.

By curve nine it may be seen that with r constant, as h increases, Q increases up to a certain point, and then decreases. By curve 10 it appears that q decreases always as h increases.

This constant decrease of q, and rise and fall of Q, as h increases, is shown in curves 11 and 12 for the different values of r.

Subsequent Investigations. Later experiments by A. E. May and H. N. Brue show the following results when L=42′ as compared to those obtained when L=62′:

The range of r′ (where r′ = rate of strokes for maximum efficiency as in set 4) is about twice as great. The range of efficiencies is also nearly twice as great. In order therefore to get good efficiencies with the short drive pipe, more care must be used in the adjustment of r for h. Efficiencies generally are lower with the short pipe; the curves cross.

Q is considerably greater, and q is slightly greater. This result agrees with the attendant circumstance that efficiencies are lower.

General Conclusion. When high efficiency is desired, operate according to curves 5 and 6. Maximum efficiency is usually secured by running at a fairly high rate of strokes. When maximum capacity is wanted, and efficiency is of secondary importance, run at the lowest possible rate of strokes.

POWER PLANT EFFICIENCY AS DETERMINED BY THE TECHNICAL EDUCATION OF EMPLOYEES.

C. M. JANSKY,

Associate Professor of Electrical Engineering.

The idea that profits are determined by the ignorance of employees is still the principle of action of some prominent managers of public utilities. To learn if there is even an element of truth in the assumed principle that ignorance on the part of the employees increases profits, I made a brief and incomplete investigation with reference to some of the smaller central electric stations of the state.

Many investigations have been made concerning the relative incomes of technically trained or college men and so-called practical men, men who have never attended a technical school. The results of these investigations show that the income of the technically trained man, for the first few years of his employment after graduation, is less than the average of the practical man. Curves have been drawn showing that between the ages of 25 and 30 the technical man's income becomes higher. The practical man's income curve reaches a maximum value above which it does not rise, while the income curve of the technically trained man does not have a maximum value, but increases during the active life of the man.

These facts supply some of the favorite arguments of engineering college authorities in regard to the value of technical education. While arguments based on these facts are valid and legitimate, they nevertheless do not tell the whole story. In the main, the work performed by the college graduate is different from that performed by the man who has not had the advantages of a college education. The purpose of the present investigation was to look at the other side of the question, to find out, if possible, if the employers' income and profit increases in proportion to the number of technically trained men or in proportion to the quality of the training. That is, does the employment of technically trained men in fields usually occupied by untrained and unskilled labor increase the efficiency of the plant?

The writer is well aware of many defects in such an investigation, and knows that many objections can be urged against any conclusions that may be drawn from data obtained from plants that operate under different conditions, have different machinery, different load factors, and many other differences that might be mentioned. Not knowing what the data would be, but believing that some interesting, if not valuable, information might be obtained, 100 information blanks were sent out to as many superintendents and managers of lighting plants in different parts of the state. The information asked for had reference to the number of men employed in various positions, the character of their education, and the number of years practical experience. Replies were received from about fifty plants. The fifty reports were classified in accordance with the population of the town as follows:

Group.	Population of towns	Number of reports	Total Employees	Remarks
A.	1500 to 2000	10	27	
B.	2000 to 2500	9	26	
C.	2500 to 3000	3	11	
D.	3000 to 3500	6	29	
E.	3500 to 4000	2	10	
F.	4500 to 5000	3	7	Reports incomplete; 2 plants 7 men report.
G.	5000 to 5500	4	18	
H.	5500 to 6000	2		One waterpower; other incomplete.
I.	6000 to 7000	2	7	One waterpower; one steam.
J.	12000 to 20000	5	27	1 waterpower; 3 steam; 1 incomplete.
K.	24000 to 37000	4	36	3 steam; 1 waterpower.
	....	50	198	

Summarizing the reports as to the educational qualifications we get the following:

One superintendent or manager in each of the groups A, I and K is reported to be a graduate of the literary department of some college or university. One plant in each of the groups B, D, E, and G is managed by a technical college graduate. This makes seven superintendents in all, who have had college training, four of whom are graduates of engineering schools.

None of the stationary engineers has had the advantages of a college training, either literary or technical. The boiler room of one plant is presided over by a man who has had two years' college training. This is in group B. In group G we find one technical graduate as station electrician.

The meters of three stations, one in each group A, D, and E, respectively, are kept in good running order by college trained men. Out of a total of four men, one plant in group E reports two with college training, a superintendent and meterman.

The total number of men employed according to the reports is about 200, while the total number of those who have had a college education, either technical or literary is 13. Six of these have specially prepared for the work in which they are now employed.

A further analysis of the reports discloses the fact that although only six men have made special college preparation for their work, others appreciate the necessity of such preparation. This is especially true of the superintendents and managers, for sixteen of them have pursued technical courses by correspondence. They also report five engineers, one boiler room employee, and nine electricians as also having made some preparation by correspondence instruction. Since the extent of this training is not disclosed by the reports, no conclusions can be drawn therefrom. The remaining 154 employees are reported as having had no technical training, their educational advantages ranging from that furnished by a good high school to "pick ups," as one superintendent expressed it.

Although other interesting information was disclosed by the reports, such as the attitude of the superintendent or manager towards his men and towards the subject in general, no further analysis was attempted for reasons presently disclosed.

In beginning the investigation the writer hoped to get from the statistical department of the Railroad Commission data concerning the efficiencies of the various plants, and by combining the two sets of data he thought that perhaps some relation between the technical training of the employees and efficiency of plant might be disclosed. It was soon found, however, that a mistake had been made in the title of this paper, the word employees should be employers.

Even a cursory examination of some twenty reports shows that some of the smaller plants of the state are run neither in accordance with technical nor good business principles. The facts disclosed by the reports examined are such that no definite conclusions can be made concerning the relation between the technical training of the employers and efficiency of the plant. The characteristics of some of these reports are as follows:

One plant reports that the superintendent was "fired" last July and that he left no records. A statement of estimated receipts and expenditures is given which shows that the plant is losing $1,800 annually. This being a municipal plant, no account is taken of the cost of operating the street lights.

A privately owned plant does not see the necessity of keeping an account of its fuel bill, and reports an annual coal consumption of *about* 604,000 pounds. Of course, the use of the word *about* could be overlooked if the rest of the report showed that any record was kept of the output and other necessary items.

Another municipal plant has no record of the total energy output, but reports as sold 1,036,200 K. W. H. of energy. This output is the product of one 162 K. W. generator. If these figures are accurate the plant must be operated under a load factor exceeded by only one other plant in the state, which reports an output of 5,326,923 K. W. H. from one 250 K. W. generator.

Still another municipal plant, after repeated requests, sends in a report which is not even disfigured by inaccurate data. The superintendent of this plant reported that his engineers were mere "dubs", and that he acquired his education mainly by "pick ups". Judging from the statistical report, one is inclined to say that the "pickings" must have been poor.

A private plant that does an annual business of $55,200 had to be vigorously stimulated before any report could be obtained. The report as finally sent in shows no record of the output.

The manager of another private plant, whose report was corrected by the statistician after several unavailing attempts on the part of the manager, thanks the statistician for his patience and expresses the sincere hope that he may receive his reward in the future world if not in this.

Out of a total of 21 records examined, 13 may be considered as poor and incomplete, one may be called fair, five good, and two excellent. These reports are from plants differing greatly in size, so it would be unfair to compare their efficiences. It may, however, be of interest to compare the data of two plants operating in towns of nearly the same size, one in group D and the other in group E.

Plant D has an annual operating revenue of $22,800 (in round numbers) and operating expenses of $21,600, leaving a net operating revenue of $1,200. The total output of the plant is given as 240,807 K. W. H. and a total coal consumption of 3,377,098 pounds, or 13.9 pounds of coal for every switchboard K. W. H.

The report of plant E is more accurate and more complete. It reports an operating revenue of $10,500, total operating expenses $8,500, leaving a net operating revenue of $2,000. The total output of the plant is 112,123 K. W. H., with a fuel consumption of 923,000 pounds, or one switchboard K. W. H. for 8.25 pounds of coal.

Plant D pays $3.50 per ton and plant E $3.66 for the coal used.

Although the towns in which the plants operate are practically the same in size, there are undoubtedly local conditions favorable to the one and unfavorable to the other. Yet, it does not seem possible that purely local conditions could be responsible for a difference of 5.65 pounds of coal per K. W. H. output in favor of the plant doing the smaller business. The conclusion seems inevitable that the technical training of the operators may have something to do with this great discrepancy. Plant D reports no employee with any technical training, while plant E reports two college men in its employ. The superintendent of plant E is a technical man, having received his training at one of the best technical schools in the country. The meterman is also a college graduate, but the report does not state whether his training has been technical or literary.

If doubt is cast on the validity of this conclusion the only reply that can be made is, that more weighty conclusions are daily being made from weaker premises.

If the above conclusion is correct, plant D would be justified in paying a good technical man some $2,000 a year, and thereby reduce its operating expenses. The amount saved in the coal bill alone would pay this and have a balance in favor of the company. What other savings might be made, a thorough examination of the plant alone would disclose.

The lesson of all this is that the time has gone by when any business or industrial organization can be run by "rule of thumb", and that the purely practical man instead of speaking disparagingly of the theories of the technical man will have to seek the technical man's advice more and more.

The popular question of the day is the subject of "Conservation of Natural Resources". The place to begin to conserve resources is where they are needlessly wasted. The waste in the small plants is in the aggregate a very important item.

To be efficient, that is, to be practical, in the management of any industrial establishment, the superintendent must be qualified by training and experience to conduct the work in conformity with engineering principles. Unless he knows, and takes advantage of, the fundamental scientific principles that apply in that industry, he must of necessity waste energy, time and money.

In the operation of nearly all industrial works it is necessary to meet intelligent competition, and if competition is absent, economic and efficient production must be the aim. This means that the superintendent or manager must be constantly on the lookout for improved and more economical methods of production. How can this be done if he concerns himself only with the result as to the product, and keeps no record of the work step by step; or worse yet, if he keeps no records at all and estimates the cost? This leads to the subject of accounting which, however, is not the subject of discussion. The important point is that any method of accounting is valueless or worse than valueless in so far as efficient production is concerned unless the manager and employes have had sufficient technical training to understand the relation and interdependence of the various physical quantities involved. It is one thing to deal with figures alone, and, when there is a deficit, lower the wages of the employees until there is a proper showing in the ledger; it is entirely another thing to know all the physical principles and their relations to one another so that the cause of inefficient production can be scientifically remedied. At first it is not a money leak that confronts the manager, but an improper adjustment of physical quantities. No amount of bookkeeping or accounting will disclose to him the excessive losses in his transmission line, the low efficiency of his engines, the inaccuracies of his meters, the proper relation of pounds of coal to switch-board Kilowatt-hour, or any of the physical relations that go toward an economical production and distribution of the energy, unless he possesses a sufficient amount of scientific knowledge properly to interpret the facts. When the superintendent lacks this fundamental knowledge of scientific principles, the figures in his books disclose to him little more than a book of logarithms does to a man who does not understand their use.

The conclusion seems inevitable that to have effective conservation of our natural energy resources, the technical training of many managers and employers in power plants will have to be more thorough and accurate than it is at present.

The Wisconsin Engineer

EDITORIAL.

With this issue THE WISCONSIN ENGINEER completes volume fifteen. During the academic year 1910-1911, we have presented to our subscribers eight numbers in place of the four previously issued during the same time. The field covered has been more broad than special, the articles of general rather than of purely scientific interest. It may be that we have been too catholic in our selection of matter. Yet we cannot but feel that in a college of engineering, it is our duty to present to the students and to the alumni something from every department of engineering. Many civil engineering students will ultimately engage in mining, many men trained in mechanical, may finally elect chemical or electrical engineer's work. As a rule the articles have not been so highly technical that any junior or senior student may not find interest, and realize benefit, in reading them. We dare not advocate too high specializing among undergraduate engineering students in this continent and in this age. We may not for the same reason make our journal too technical or too purely scientific.

* * *

We have received more support than we had expected from the students and alumni in the form of contributions. We were not quite as successful in obtaining an increase in number of subscriptions. We hope that the next year will correct this. We appeal to the outgoing seniors to help us in both ways. The bread thrown thus upon the waters will return to them. The subscribers may rest assured that the standard of the paper will be maintained, that the usefulness of the material will be increased. The contributor will find that the practice of writing technical articles will aid him in securing confidence, in gradually developing his personality in expression and in desription, and may win for him "Kudos" in the technical press of the country which has already emphasized the quality of the articles of volume fifteen. We have then little hesitation in asking the support of our alumni, and in particular of our present seniors, who all too soon will become our graduates.

* * *

To our Seniors we may say a few words while shaking their hands and wishing them adieux. We are loath to see them go from our threshold. The faculty feel they would like to know them better before they leave the house. The younger members of the college household, the juniors and sophomores, have, as yet, scarcely sufficient faith in themselves to replace all which they honored in their seniors. It is possible that the alumnus, looking on quietly, thinks that the faculty and the seniors have acted one to the other as rightly as guardian and host may to ward and to guest. He compares his own day and age possibly unfavorably. Yet that last Senior-Faculty smoker makes us reflective, possibly makes the faculty sensitive and self-analytical. Should they and the Seniors not have developed closer ties of friendship? Let the Seniors believe that the faculty do ask themselves these questions. Let the coming seniors help them to solve the question and further, by all means in their power, the good work initiated by the class of 1911.

* * *

Do not be too sensitive. Do not be too sure. Do be absolutely honest. Do have faith in yourself, and in your capacity to fulfill whatever reasonable trust is placed in your hands. These words to our graduating seniors at the close of this year. You have not yet realized the selfishness of the commercial life. Do not condemn it in the first heat of your disgust with the ethics of practical life. Your competitor is anxious to get ahead of you, to beat you, because he wishes to prove his merit to the world. Or because he wishes to increase his funds in the bank, not for the sake of the bank account, but because of responsibilities he carries to his family, to his wife, to his guardian. Many men are selfish, are grasping, are even possibly unscrupulous because of their unselfishness, of their jealousy of some trust and responsibility devolved on them.

Again, do not attempt too soon to carry more than your capacity, as registered at Lloyd's, may hold. Make up your minds to rise above the mediocre in due time. But in rising learn all that each position offers to you, and you may be certain of ultimate and continued success, when finally the position of high trust and responsibility is given you. As for honesty, there are some things of course that no fellow should do, and you are that fellow.

TAU BETA PI ELECTIONS.

At the semi-annual initiation of Tau Beta Pi, held at the Woman's Building, on the thirty-first of March, the following were initiated:

L. E. Dequine and W. A. Hatch, of the class of 1911; E. H. Carus, F. T. Coup, E. R. Hoffman, S. A. Krell, R. R. Parks, A. C. Shape, G. W. Trayer, and H. L. Woolhiser, of the class of 1912.

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Prof. J. G. D. Mack has kindly loaned us a complete set of the WISCONSIN ENGINEER, dating from June, 1896, when the first number was issued. This set is one of the few complete sets of the magazine now in existence. It is to remain permanently in the office of the WISCONSIN ENGINEER.