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PAPERS AND DISCUSSIONS

OF GENERAL INTEREST

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PORTLAND CEMENT

BY THADDEUS MERRIMAN*

(Presented at a joint meeting of the Boston Society of Civil Engineers and the Designers Section held on October 19th, 1938)

ONE of the most perplexing of the problems which often confront the engineer is the behavior of concrete made with Portland Cement. A large proportion of all concrete is sound and durable and gives complete satisfaction but a disturbingly large fraction begins to disintegrate at early ages and fails to render the service for which it was intended. This disintegration, moreover, is often progressive and, once begun, continues until replacement becomes necessary.

For every such failure an alibi is usually presented. The sand was "bad", the stone was "dirty" or "unsound". Too much water was used in the mix or the forms were pulled "too soon". Curing was not "properly" done. The weather was "too cold" or the sun "too hot". These and other obvious causes undoubtedly leave their imprint on all concrete but the major, and, in many cases, the far more probable cause is to be found in the cement itself.

Because of custom and tradition all Portland Cement is sacrosanct. Every bag as it comes from the mill contains 94 pounds of a dark grey to yellowish powder which is perfect in all respects. It

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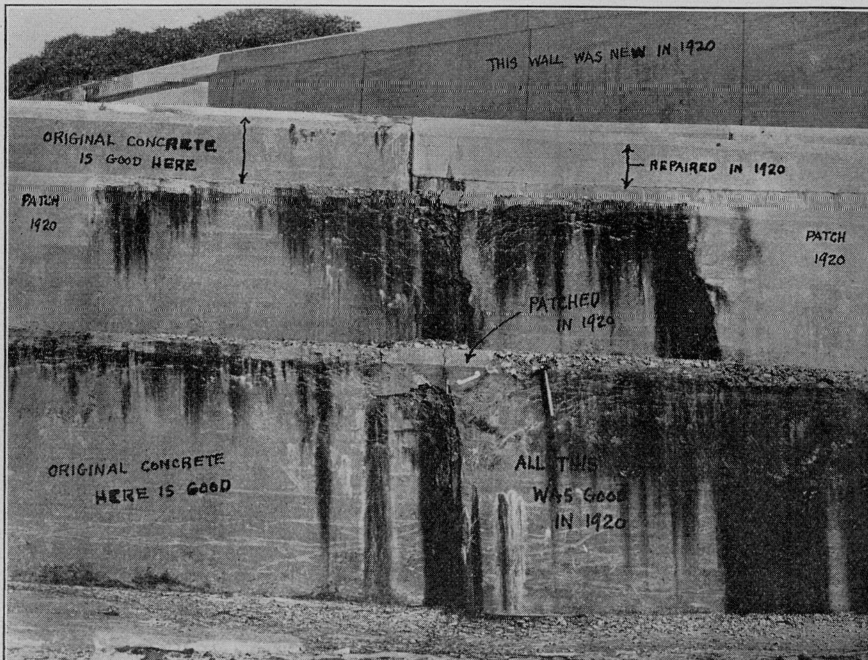

FIG. 1.— THIS SPILLWAY WAS BUILT IN 1913. ALMOST IMMEDIATELY THE CONCRETE BEGAN TO DISINTEGRATE. MAJOR REPAIRS WERE MADE IN 1920. THIS VIEW, TAKEN IN 1925, SHOWS HOW THE DISINTEGRATION CONTINUED. IT HAS BEEN CONTINUOUS SINCE THEN AND FURTHER REPAIRS ARE NOW URGENTLY NEEDED. MANY SECTIONS OF THIS STRUCTURE ARE IN GOOD CONDITION. THE CAUSE OF THE DISINTEGRATION WAS THE EXTREME VARIABILITY OF THE CEMENT BOTH AS REGARDS COMPOSITION AND MANUFACTURE.

is "Standard Portland Cement" and its quality is above reproach no matter what its origin, how it was made, or what its composition. This naïve view has been so long fostered that the engineer and the consumer alike have come to believe it as a fundamental truth. How many engineers who write specifications for Portland Cement have ever visited a cement mill or studied the manufacturing process which, collectively, result in the finished product? How many have sought to determine the effect of these processes on the cement as it finally goes to the user? Few indeed, because had they done so the causes for much poor concrete would now be well known. Great effort and much study has been given to the study of cement *per se*. Some work has been done in attempting to determine the quality of the products which are developed as the cement sets and binds the aggregates together but practically no effort has been made to determine what the qualities of a cement must be if it is to produce hard, strong, sound and durable hydration products in concrete. The primary interest of the consumer is in the finished concrete. He cares little as to how the cement is made or what it contains if only it will make strong and durable concrete. On the other hand the major interest of the producer is that of making a product which will at least "meet the specifications".

Between these two viewpoints there is a wide gap. On one side of the picture is "cement" while on the other is "sound concrete". The equation is incomplete. No one has yet put the sign of equality between these two quantities. After twenty-five years of study and research in the laboratory of the Board of Water Supply of the City of New York a small beginning has at last been made on this important problem.

The quality of a cement as related to the quality of the concrete it is capable of producing depends on several factors. Among them the most important are:—

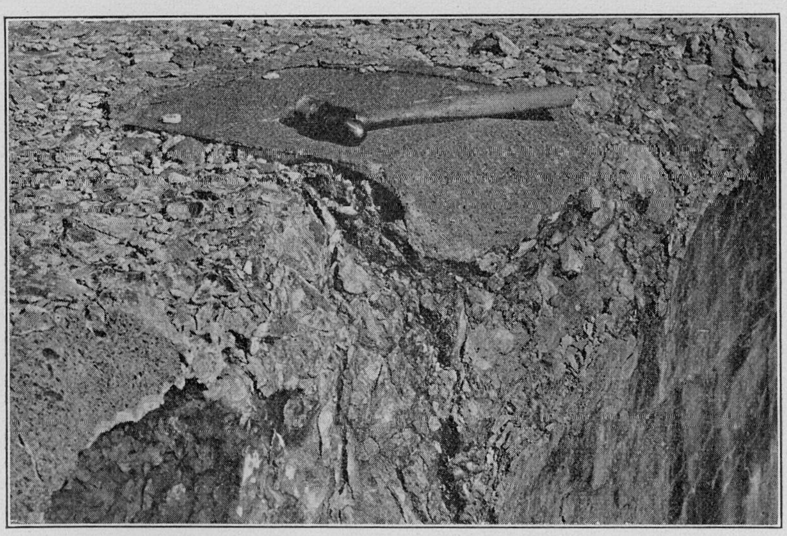

Fig. 2.—Another Place on the Spillway of Fig. 1. This Picture Taken in 1925 Shows a Patch Placed in 1914 Where Disintegration Had Then Already Begun. Note How it Progressed from 1914 to 1925 Leaving the Patch in Its Original Condition.

Its composition.
The methods and care employed in its manufacture.
The care with which it is handled after manufacture.

It is obvious, of course, that two cements of different compositions will display different behaviors and characteristics while even the uninitiated find no difficulty in appreciating that the methods of manufacture must also have their effect on the quality. The care after manufacture comes within the realm of every-day experience in that a caked and lumpy cement is always viewed with suspicion.

Manufacture of Portland Cement

Within the limits of this paper it will be possible to touch but briefly on the fundamentals of the manufacture of cement. In general, the first step is that of assembling, blending and grinding the raw materials and it needs no argument to convince anyone that the more thoroughly the blending is done and the more finely the raw mix is ground the better opportunity will the subsequent process of cal-

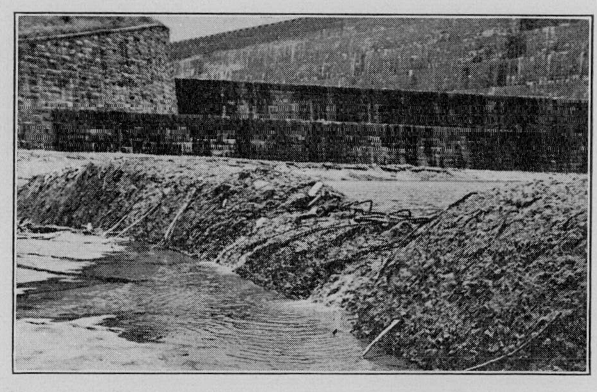

Fig. 3.—The Concrete in This Small Overfall Dam Was Placed in 1926. When This Picture Was Taken in 1938 About Half the Volume of the Structure Had Disappeared. The Dam in the Background is of Concrete Faced with Stone. The Concrete Behind the Stone is Disintegrating and by Volume Increase is Gradually Destroying the Facing. The Cement Used on This Work Had a High Sugar Solubility and, While Passing the "Standard Specification," Was Much Underburned and of Poor Quality Generally.

cining or "burning" have to complete the combinations between the several constituents. The more thoroughly and more uniformly these combinations are effected the better will be the resulting product.

Portland Cement is universally calcined in the rotary kiln which is a large hollow cylinder ranging in different mills from 100 to over 300 feet in length and from 6 to 12 feet in diameter. This cylinder is lined with fire resistant material and is mounted on a slight slope so that when the raw cement mixture is introduced at the upper end it will tumble progressively toward the lower end as the entire cylinder is slowly rotated. Into the lower end is blown the fuel consisting of powdered coal, oil, or gas and here also enters the air necessary to support the combustion. An intense flame is thus produced with the result that, as the kiln is rotated, and the raw material progresses downward from its point of entry it moves along an ascending temperature gradient until it enters the "hot zone" at from 15 to 30 feet from the end of the burner pipe through which the fuel is introduced.

As the raw material moves downward through the kiln it is heated so that at first the contained moisture is driven off. Then the carbonates are disintegrated and CO_2 is expelled. Next the clays are decomposed and finally, in the "hot zone" the lime, the silica, the alumina and the ferric oxide are welded together to form the compounds which confer on Portland Cement the properties which make it one of the most important of the materials used in engineering construction.

These compounds, whatever they are, and there is no need to here discuss the many theories relating to them, having been formed in the kiln the product is now known as "clinker" and should, in physical form, consist of an aggregation of rounded lumps ranging in size from two inches in diameter to pea size and smaller. See Fig. 4.

On cooling, the clinker is then in shape to go either to storage or to the final grinders. Just before this grinding it is usual to add the gypsum or calcium sulphate which furnishes the SO_3 necessary to control the "set" of the cement.

In the several processes briefly outlined above there is room for very wide variations all of which have their effect on the quality of the finished product and thus on the subsequent behavior in concrete. Let us consider some of the more important of these:

Effects of Cement Composition

The principal compounds in the clinker are those between the silica and the lime which, in their pure states, enter into combination

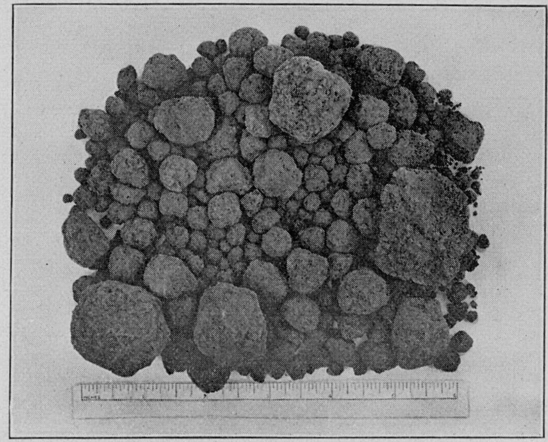

Fig. 4.—Portland Cement Clinker Burned to Meet the Requirements of the Board of Water Supply Specifications. It is Strong, Hard, Dense and of Uniform Internal Structure. None of the Pieces Have Soft Brown Centers; All Are Black Throughout.

only under high temperatures and carefully controlled conditions. Fortunately, however, in the presence of alumina (Al_2O_3) and iron (Fe_2O_3) the lime-silica compounds form more readily and the alumina and the iron are said to act as "fluxes". While this is an important circumstance it, nevertheless, has its limitations. Too much flux makes the mix so "easy" to burn that the important lime-silica compounds are only partially completed while too little flux renders the mix so "hard" to burn that these compounds are also incompletely formed.

It is a further fact that the greater the proportion of silica with respect to the lime the more difficult is it to complete their combinations, while if there is too little silica there will be no place where the lime can go. These several conditions present a four-fold dilemma which can be met at any particular plant by holding the composition of the raw mix as constant as possible so that a constant temperature in the kiln will then be able to produce a clinker of constant quality. To realize this optimum combinations of conditions is practically impossible but the more nearly it is approximated the better will be the cement.

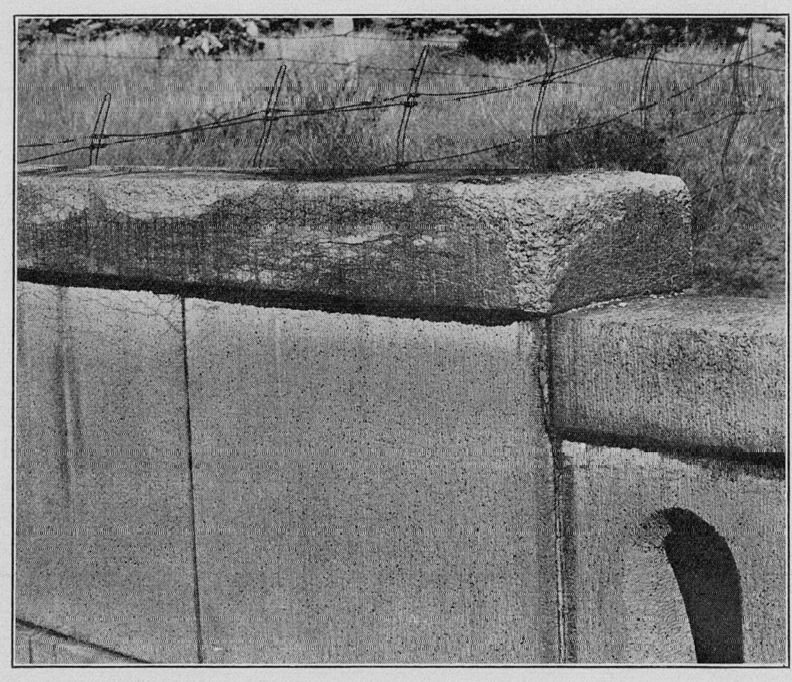

FIG. 5.—A BRIDGE BALUSTRADE OF SAND CAST CONCRETE BLOCKS COMPLETED IN 1914. THIS PICTURE WAS TAKEN IN 1925. BY 1936 THE TOP BLOCK CARRYING ONLY ITS OWN WEIGHT HAD COMPLETELY CRUMBLED INTO DUST.

Another closely related and complicating factor at this stage of the process is the relation between the quantities of the alumina and the iron. Each of these acts as a flux and each is probably capable of combining with lime to form a separate compound. The compound of lime + alumina is known by experience to be detrimental in concrete under certain types of exposure while that of lime + iron is generally not recognized because it is probable that most of the iron goes to form a compound of lime + alumina + iron. It is important, therefore, that the composition of the raw mix should be kept uniform with respect to its four principal oxides and that the quantitative relations between the lime and the silica, as well as between the alumina and the iron, should be closely maintained. Other oxides present in the mix tend to further complicate the picture but aside from mentioning their names their effects will not be discussed here: magnesia, manganese oxide, phosphorous pentoxide, titanium oxide, sodium oxide, potassium oxide and "free lime".

By reason of the foregoing considerations each particular mix needs to be burned at a particular temperature and for a particular time interval during which the cement compounds may be formed. In the actual kiln the time during which the mix is in the "hot zone" depends upon the rate at which the kiln is rotated. This time varies from 7 to 15 minutes and, at best, is all too short. The "hot zone" is the very heart of the entire process! The cement compounds are formed only in this zone. The temperature in this zone must be right as also must be the interval during which the cement material is in it.

Now if the temperature in the "hot zone" is not right, even if the mix be perfect and uniform, the resulting clinker cannot be right. This is one of the important causes of variation in cement quality. Most mills are not equipped to continuously measure and to record the temperature in the "hot zone", their principal reliance being placed on the judgment of the "burner" who operates the kiln and who, by viewing the hot zone through his "blue glasses" and by visual inspection of cooled samples of the clinker, pronounces on the completeness of the burning process. Each burner, of course, has his own "personal equation" and no one of them is a completely free agent because each is under the natural pressure of "keeping the output up".

Many causes operate to cause variations in the burning temperature. Some of these are practically unavoidable while at some plants much greater variations occur than at others. Space is not available to discuss this matter in detail and it must suffice to say that range in temperature from kiln to kiln is often, and for varying periods, outside the probable allowable limits. Whenever the temperature falls below the allowable limit the clinker is underburned. Seldom if ever is a clinker burned too much or "too hard".

In general it may be said that the quality of the product of the average rotary kiln varies between rather wide limits and from "good" to "bad" with "intermediate" predominating. As the clinker passes into storage these distinct qualities are blended so that the final cement is a mixture in which they occur in varying proportions. The same is also true where several kilns are operating in parallel but in this case their joint output is more thoroughly mixed and blended.

The Quality of Cement

For all practical purposes a very satisfactory means of considering the quality of a Portland Cement is to picture it as consisting of a

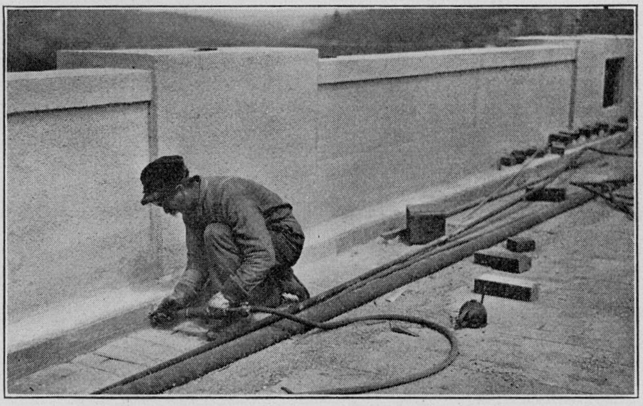

Fig. 6.—The Balustrade of a Bridge Built in 1912. The Concrete Was Perfect. When Removed in 1937 to Increase the Roadway Capacity It Showed No Trace of Disintegration. Why Should This Have Been so Good While That of Fig. 5 Was so Poor? The Answer is that There Was Much Amorphous Constituent in This Balustrade and Very Little in That of Fig. 5.

mixture of several compounds each having its own characteristics and qualities. Thus, if four compounds be assumed, they appear as follows:

Compound Characteristics and Qualities

Form 1. Intimate combination of constituents; makes durable and resistant concrete of high strength.

Form 2. Indifferent combination of constituents; makes strong concrete which tends to disintegrate.

Form 3. Loose combination of constituents; makes concrete of good strength which disintegrates easily.

Form 4. Poor combination of constituents; develops little strength in concrete and acts as an adulterant which readily disintegrates.

Every cement probably contains some of each of these four forms but the proportion in which they occur in different cements varies with the character and the fineness of the raw mix, with its overall chemical composition, with the relation between its content of silica and lime, with the quantity of the fluxes, with the ratio between them, as well as with the temperature of the burning and with the time that the mix is exposed to the combining temperature in the kiln. One cement may thus consist largely of Forms 1 and 2 with a little of Forms 3 and 4; it is an excellent cement. Another may consist of a little of Forms 1 and 4 with much of Forms 2 and 3; it is a medium cement which tends to disintegrate on exposure. Still a third may consist of Forms 2, 3 and 4 only, with Form 3 predominating; it is a cement which will show a good strength but will quickly disintegrate. All of these combinations and many others are acceptable under the usual specifications for Portland Cement if only they comply with the minimum strength requirements. So are they branded as equals and stand side by side in the markets of the world. Obviously, they are not all of the same value and the problem before the engineer is that of differentiating between these varieties in such manner as to select those which are best adapted for his particular work. Just as there are differing grades of steel, so should there be differing grades of cement.

Variations in Quality of Cement

The foregoing has given but a passing glimpse of the variations that may and do occur to varying degrees and often from hour to hour and day to day in the quality of cement up to the point where it has passed through the kiln and become clinker. Nothing which can be done from this point onward will make the clinker better though its quality is undoubtedly affected by the manner in which it is cooled after emerging from the kiln. As to the effects of the cooling process there is little known with the exception that it is clear beyond peradventure that any excess of water used for cooling is detrimental. As the clinker comes from the kiln it has all the "hydraulic" properties of the cement and the addition of water can only operate to reduce its quality by hydrating some of it and thus detracting from its cementing value. At some plants much more cooling water is used than at others and some of the clinker is, on occasion, wetted much more than others. The cooling of the clinker with water is thus another and variable cause which operates to bring about variations in the quality of the finished cement. At some cement mills under most recent practice, the clinker is air cooled and no water is used.

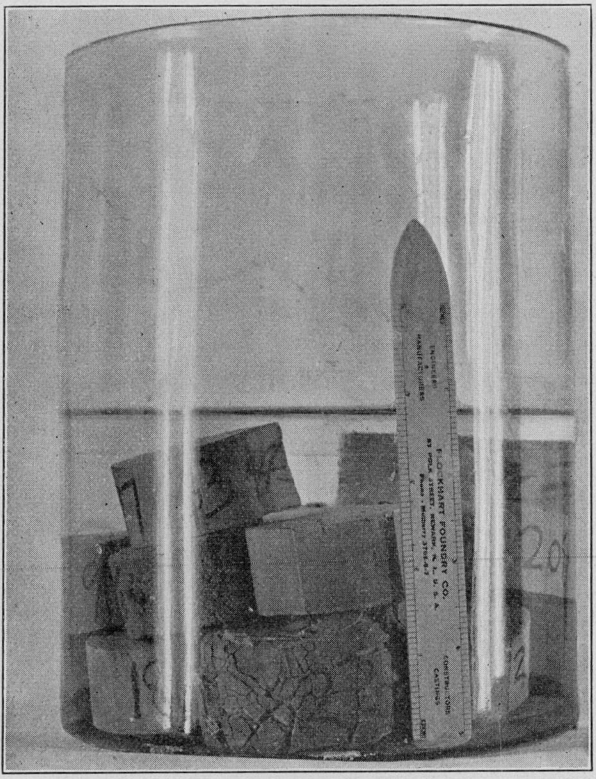

FIG. 7.—THE SODIUM SULPHATE TEST DISCLOSES GREAT DIFFERENCES OF BEHAVIOR AMONG "STANDARD" CEMENTS. NOTE HOW LITTLE THE BRIQUETTE IN THE CENTER HAS BEEN AFFECTED BY THE SOLUTION AND HOW GREATLY THE ONE BELOW IT HAS INCREASED IN VOLUME. THE CHANGES SHOWN OCCURRED IN 60 DAYS.

Still another cause of variation is in the manner and the length of time during which the clinker is stored before being ground into the finished cement. At some plants the clinker is stored under cover. This represents the best practice. At others it is stored outdoors for weeks or months and, in extreme cases, for years. Clinker so stored is subjected to repeated wettings by rain and progressively deteriorates from its original quality. This deterioration is often tacitly admitted by the manufacturer by the practice of mixing fresh clinker from the kiln with clinker from the outdoor storage piles.

As the clinker finally goes to the grinding mills which convert it into cement it may be dry or damp or wet depending on the several factors above referred to. Whatever moisture is contained in the clinker, including that in the gypsum, added at this stage in the process, is converted into steam by the heat generated in the grinding process and acts to hydrate the cement by breaking down the compounds formed in the kiln. The practice of outdoor storage and wetting of the clinker is thus responsible for still another variable but, of even greater importance is the procedure followed at some plants of introducing water into the final grinding stage for the purpose of making the grinding "easier". The engineer, not knowing of this practice can do no less than express his wonderment at this astonishing procedure which, however, is sanctioned by the words of the Standard Specification which he makes part of the contract under which his cement is supplied. The words of this specification are

> "Portland Cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of calcarceous and argellaceous materials with no additions subsequent to calcination *excepting water* and calcined or uncalcined gypsum." (Italics ours.) C 9-30.

On these two italicized words hangs much of the law and many of the prophets. Even the specification of 1938 similarly permits the use of water!

While the specification allows the use of water it is strangely silent as to when, or how, or how much of it may be added! The clinker "subsequent to calcination" may therefore be stored out in one or any number of rain storms while before pulverizing it may be either dry, or moist, or wet. Within the rules, moreover, water may then be also added directly into the final grinding mills.

These permissible practices naturally result in many variations in quality and these in combination with the variations due to composition, to the degree of burning, to the time in the "hot zone" and to the conditions of cooling result in a wide range of variations in the finished product. Many of these factors are susceptible of easy control and the more they are controlled the better and more uniform will be the completed cement.

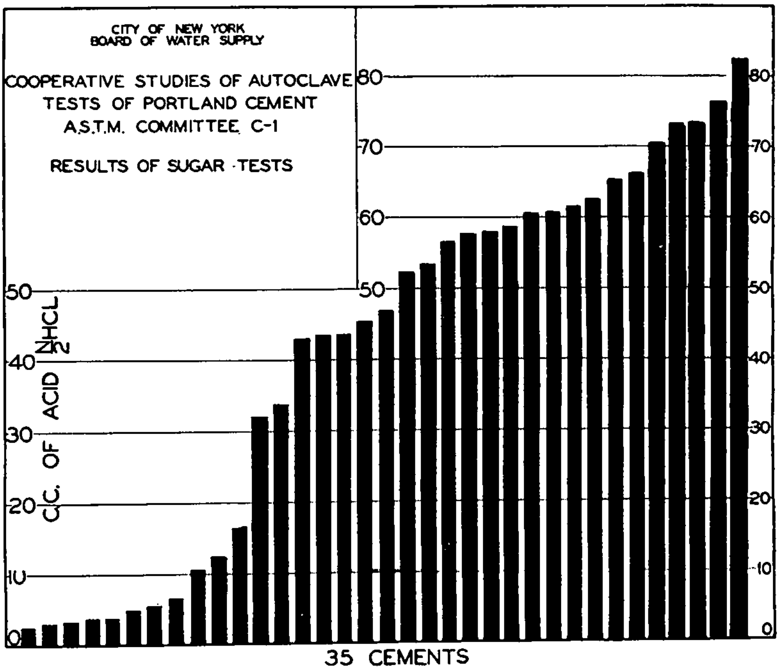

FIG. 8. — THE SUGAR SOLUBILITY TEST WHEN APPLIED TO THESE 35 "STANDARD" CEMENTS FROM 35 DIFFERENT MILLS FROM ALL PARTS OF THE UNITED STATES DISCLOSED THE GREAT DIFFERENCES SHOWN ON THIS DIAGRAM. THE CEMENTS ARE ARRANGED IN THE ORDER OF THEIR "CLEAR POINT" SUGAR SOLUBILITIES. (SEE TEXT; ALSO SECT. 10 OF THE FOLLOWING APPENDIX.) WHY SHOULD A STANDARD PRODUCT SHOW SUCH GREAT VARIATIONS IN THE SAME TEST? DIFFERENCES IN BURNING AND IN CARE OF THE CLINKER ARE THE PRINCIPAL REASON.

is great and, most important of all, it develops large proportions of the amorphous constituent of which more will be said hereinafter.

The principal parts of this specification are attached to this paper as an appendix and the essential items are here summarized:

(1) The alumina (Al_2O_3) content shall not exceed 5.60 per cent.
(2) The silica (SiO_2) content shall not be less than 21.50 per cent.
(2) The magnesia (MgO) content shall not exceed 4.00 per cent.
(3) The sulphuric anhydride (SO_3) content shall not exceed 1.75 per cent.
(4) The loss of ignition shall not exceed 0.90 per cent.
(5) The ratio alumina/iron shall lie between 1.2 and 1.6.
(5) The ratio lime/silica shall not exceed 2.90.

The Board of Water Supply Specification

It was because of frequent and unpredictable failures of concrete on the work of the Board of Water Supply that the matters hereinabove outlined were studied. So clear were the inferences which naturally followed that it was decided in 1936 to write a specification which would place certain limitations on the more important of the manufacturing processes. For this we have been mildly criticized. Some manufacturers have said that we have invaded their territory while a number of engineers maintain that it is none of our concern how a cement is made and that we ought to "specify tests for what we want." In order to be sure, we have done both things and the reason for this procedure lies in the very simple fact that if the history and the origin of a cement is unknown the significance of any test is meaningless. During the past 25 years an enormous amount of work has been done in the way of testing cements. In various extensive cooperative tests samples of many cements have been sent to many laboratories and "tested" from every conceivable angle but the histories of these cements were always unknown and even the names of the plants from which they came were kept hidden. As a natural and inevitable consequence the results of these tests never disclosed anything while each new series merely added to the confusion of thought and the uncertainty of viewpoint. See Fig. 8. Had the variations in the quality of these cements, due to the manufacturing processes and practices, been considered and evaluated we would long since have made great advances in our knowledge of Portland Cement. Even today the illogical idea of a universal and "standard cement" still stands in the middle of the road where it blocks and retards true progress.

Under the specification of the Board of Water Supply, above referred to, there have been made to this date over 260,000 barrels of cement while more than 3,400,000 other barrels are under contract and an additional 3,300,000 barrels will be included in contracts soon to be let. All of this cement, used to date, and manufactured at six different plants has been of remarkably uniform quality and has made the best concrete we have ever had. It produces no "laitance" even when the concrete is cast in lifts of 20 feet. It shows no signs of crazing, checking, or cracking and is hard and strong. Its early strength is ample to permit prompt removal of forms, its final strength

(6) The cement shall pass the sodium sulphate test.
(7) The cement shall pass the sugar solubility test.
(8) The "alkalinity" of the cement shall not be greater than 3.8.
(9) The "free alkali" shall not be greater than 3.5.
(10) Not less than 90 per cent but not more than 98 per cent shall pass the No. 200 sieve.
(11) Requirements for tensile strength in both "neat" and 1-3 sand mixes are also included.

The above requirements are directed toward securing uniformity of composition, of fineness and of physical behavior while in order to secure uniformity of quality in the clinker and the manufacturing operations generally, the specification carries the following:

(a) The clinker shall be burned at about 2700°F. and a continuous record of the temperature and rate of kiln rotation shall be kept.
(b) Only a minimum of water may be used for cooling the clinker and then only while the clinker is hotter than dull red.
(c) All clinker must be stored under cover and for not longer than six weeks.
(d) No undeclared matter may be added at any stage of the manufacturing process.
(e) The "flue dust" from whatever source may not be returned to the kiln unless the "alkalinity" and the "free alkali" are within the limits specified under (8) and (9) above.

Discussion of the Specification

The first part of this paper has made clear the reasons for most of the several limitations and requirements above enumerated. The "sodium sulphate test" referred to under paragraph 6 above is described in full in the appendix. The "alkalinity" requirement of paragraph 8 is similarly described and has for its purpose the limiting of the alkali content to such point as will protect the men who work in the concrete from the hazards of "cement burns." The requirement for the "free alkali", paragraph 9, places a limit on the alkali content both to keep down the "efflorescence" of the completed concrete and to insure that in the setting process while the hydration products are being formed the environment will be such that a maximum of the amorphous constituent will be formed. When too much alkali is present there is a strong tendency toward the formation of the crystalline calcium hydrate which lacks durability and is rather readily soluble in water. Too much alkali prevents the formation of the dense and durable amorphous constituent which is the most desirable of the hydration products. While cement is generally bought for the purpose of making concrete it should be bought for its ability to make durable hydration products because on them depend both the quality of the concrete and its life. Durable hydration products make durable concrete and conversely.

The Sugar Solubility Test

Of the several tests mentioned by this specification, that under paragraph 7 above as the "sugar solubility test" is the most important. It is a very simple test and has been developed during more than 15 years of study and experimentation. While it was long ago believed that this test served the purpose of indicating whether or not the compounds in a cement had been reasonably completed during the burning process this could not be proved or demonstrated until it became possible to obtain cement which had been made under controlled conditions and the history of which at every stage of its manufacture was known. This condition has been met by all of the cement furnished under our specification and all of it has passed the "sugar test." We, therefore, feel confident that this test which, by the way, has been of great help to the manufacturers in keeping abreast of their operations, does, in fact, serve to measure the completeness with which a cement has been processed. It will easily detect a clinker which has been underburned and it will also detect whether a well made clinker has been spoiled by the addition of water or by storage conditions after the clinker was made.

The sugar test thus fills a long felt need. Its application to cements within the range of composition laid down by this specification is unquestioned. In all probability it will also be found to apply to cements outside this range if and when they are burned and processed to meet the requirements of their respective compositions. This is a task beyond our facilities. It must be taken up and solved by the manufacturers who have plants and kilns with which the requisite work and experimentation can be done. We have merely succeeded in pointing the way within a rather narrow range while the story of how it came about is too long for this paper.

In a few words the principle underlying the sugar test is this. It has long been known that solutions of cane sugar have the property of dissolving large quantities of lime. On the basis of this fact it then appeared possible that a cement made from a completely and thoroughly burned clinker would yield to a water-sugar solution

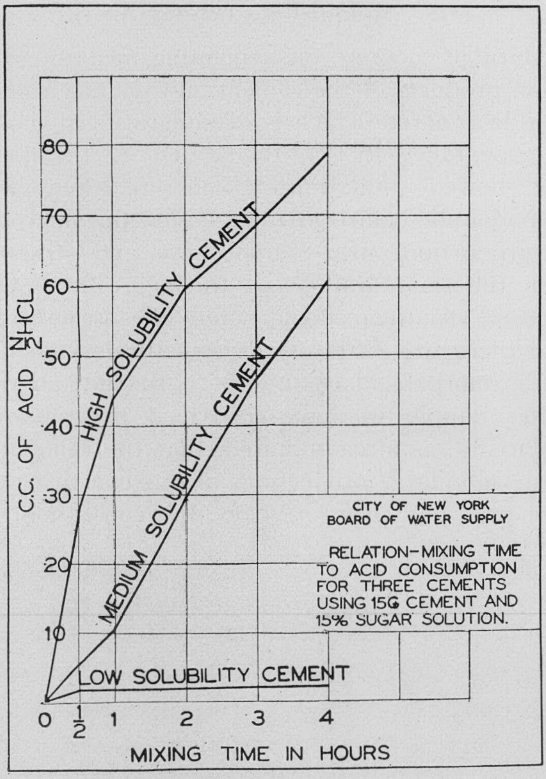

FIG. 9.— THIS DIAGRAM SHOWS HOW SMALL AN EFFECT THE TIME OF MIXING HAS ON THE SUGAR SOLUBILITY OF A THOROUGHLY BURNED CEMENT (THE BOTTOM CURVE). IT ALSO SHOWS HOW GREATLY THIS VALUE IS AFFECTED IN THE CASE OF A POORLY BURNED CEMENT (THE TOP CURVE). THE MIDDLE CURVE REPRESENTS AN INTERMEDIATE CASE.

less lime than one made from a soft underburned clinker. This, on trial, was soon proven to be the case in isolated instances but not until we knew the history of many barrels of cement and had run on them hundreds of tests was the possibility proven. Even then the case was not entirely clear because it was still necessary to wait and see what kind of concrete the cement indicated to be good by this test would make. That has now been done and it is possible to definitely say that cement which passes the sugar test will, if reasonably handled, always make durable concrete.

The Amorphous Constituent

In good, durable concrete the cementing medium, which consists of the hydration products of the cement, always has a dense rock-like structure, while in concrete which is disintegrating, it is soft, whitish, and anemic in appearance. In 1914 the late Dr. R. J. Colony of Columbia University showed* that durable concrete when viewed in thin sections and in doubly polarized light under the microscope always showed large proportions of a dark, dense and structureless compound between the sand grains and the aggregate. On the other hand, in poor and disintegrating concrete the structure was largely crystalline and there was little of the structureless compound which he named the "amorphous constituent." In the laboratory of the Board of Water Supply we have confirmed these findings and, in addition, have found, as already stated, that the cements which pass the sugar test develop large proportions of this constituent in concrete.

These cements, moreover, develop this constituent even in the

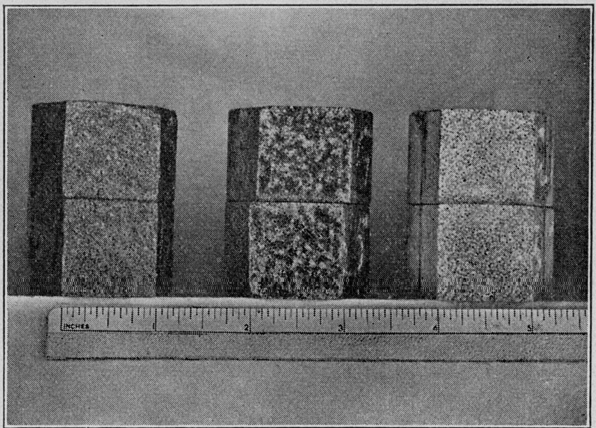

Fig. 10. — The Broken Surfaces of the Middle Briquette in This Picture, by Their Mottled Appearance, Clearly Show the Amorphous Constituent. The Briquettes on the Sides Show the Appearance of the Average "Standard" Cement. These Briquettes Were 28 Days Old When Broken. This Difference in Appearance is a Good Index of Quality.

* Petrographic Study of Portland Cement, The School of Mines Quarterly, Columbia University, Vol. XXXVI, No. 1, November, 1914.

unfavorable environment of the 7 day standard mortar tension briquettes. See Fig. 10. In these, on the broken surfaces, this constituent is easily recognizable by the eye in the form of dark areas producing a mottled appearance. This condition has never been noticed except in the case of cements made under the controlled conditions of our specification and it appears in all of them.

With a little practice it is possible for the eye alone to distinguish between those concretes which contain the amorphous constituent and those which do not. In case of doubt the difference may readily be resolved by a thin section under the microscope.

Conclusion

It has been suggested by some that the cost of the inspection necessary to secure cement under our specification is excessive. That is not the case. The cost, of course, is greater than it formerly was but it is the most worthwhile of all the inspections we know. Even on the average job inspectors are stationed on the sand and on the stone, on the mixer and at the form. The steel is inspected at the mill and in the machine shop but because of tradition, Portland cement is taken practically on faith and is declared to be acceptable on the basis of a few casual and routine tests. It has been our experience that inspection at the cement mill pays greater dividends than any other form of inspection of which we are aware. So it is that we look hopefully forward to the time when the concrete we are now making will completely demonstrate that we have learned to overcome the mistakes of the past. At very least we are certain that this concrete will be much more dependable than any within our past experience. Our belief in this respect is founded on the simple fact that only good concrete contains large proportions of the amorphous constituent while poor concrete contains but little. In all of the concrete made with cement produced under our specification there is, even at early ages, much of this constituent. We believe that concrete which is good at early ages will remain good during the years.

The research described in this paper was begun in 1912 under the direction of the then Chief Engineer of the Board of Water Supply, the late J. Waldo Smith, a former member of the Boston Society. It has been carried on under the general direction of the author with the able assistance of Assistant Engineers L. B. Stebbins and N. T. Stadtfeld and of the late Richard H. Gaines, Chemist. Chemists

Nathan Goodman and Martin Schoen also rendered able assistance. The petrographic work on thin sections was carried on by the late Dr. R. J. Colony until 1918 and more recently by Paul H. Bird, Geologist.

All of the operations of the Board of Water Supply are under the direction of Walter E. Spear, Chief Engineer, a long-time member of the Boston Society of Civil Engineers. Charles M. Clark is Deputy Chief Engineer and Assistant Engineer N. T. Stadtfeld is now in charge of the laboratory.

APPENDIX

Board of Water Supply

City of New York

Specification for Portland Cement

Sect. 1. Under this item the Contractor shall furnish, deliver and place in the work Portland cement that has been manufactured at established American plants of such recognized capacity and quality of output as to insure a product at least equal to that hereinafter specified. Unless otherwise permitted, cement from not more than three plants shall be used and, in general, only the product of one plant shall be used at the same time in any section of the work. Within 15 days following the notice to begin work the Contractor shall submit for the approval of the Engineer the names of the plant or plants from which he proposes to furnish the cement and no cement shall be furnished from any plant until it has been approved. At the same time, he shall also furnish to the Engineer an estimated schedule of the monthly deliveries he will require from each of the said plants during the ensuing 4 months. This schedule shall be revised by the Contractor every 60 days thereafter.

Sect. 2. The cement and the clinker from which it is made will be subjected to thorough inspection, to tests, and to frequent analyses as provided in the following sections. The cement when delivered and used on the work shall be dry and free from lumps and caking.

Sect. 3. The raw materials from which the cement clinker is made shall be thoroughly blended and finely and uniformly ground; either the dry or the wet process may be used. The flue dust from the kilns shall not be returned to the raw mix, but shall be rejected unless the nature of the raw materials and of the flue dust is such that the alkalinity of the finished cement is less than 3.8 and its content of free alkali is less than 3.5 (See Section 8 for test procedures). The kilns shall operate at about 2,700 degrees Fahrenheit and a continuous record of the temperature shall be kept. A regular record shall also be kept of the rates of kiln rotation; these records shall be available to the Engineer and are called for in order to insure the greatest possible uniformity of kiln output. The speed of kiln rotation and the kiln temperature shall be controlled and co-ordinated so as to produce a hard and completely burned clinker in which the combinations between the several oxides it contains have been substantially completed. Only a minimum of water may be used as an aid for cooling the clinker while it is hotter than dull red; at all other stages, it shall be kept dry and protected from the weather. In general, the clinker shall be ground immediately after it has been made; occasionally, it may be stored, but not for a period longer than six weeks. Grinding aids shall not be employed unless they have been declared to and approved by the Engineer. No water or steam shall be permitted to come into contact with the cement or applied to it at any stage of its manufacture. The gypsum or other source of SO_3 shall be reasonably dry when mixed with the clinker before grinding. No material or admixture shall be added to the raw material, to the clinker, or to the cement at any stage of the manufacturing process without the approval of the Engineer, except that gypsum, anhydrite or plaster may be added in quantities sufficient to secure the necessary percentage of sulphuric anhydrite. Water may be added to the clinker only as above provided.

SECT. 4. The cement shall be ground so that at least 90 per cent., but not more than 98 per cent., by weight, will pass the standard No. 200 sieve. These limits shall not be exceeded. Pats of neat cement, in the steam test for soundness, shall remain firm and hard and shall not distort, check, crack or disintegrate. Similar pats kept in the moist closet for 7 days shall remain firm and hard and unchanged. The cement shall not develop its initial set under the Vicat needle in less than 45 minutes, or in less than 60 minutes when the Gilmore needle is used. The final set shall be attained in not more than 8 hours.

SECT. 5. The average tensile strength of not less than three standard briquettes made of neat cement and mixed to normal consistency shall not be less than the limits stated in the following table:

Age at Test in Days	Storage of Briquettes	Tensile Strength, Pounds per Square Inch
1	1 day in moist closet	350
7	1 day in moist closet, 6 days in water	600

The average tensile strength of not less than three standard mortar briquettes made of one part of cement and three parts of standard Ottawa sand, measured by weight, shall not be less than the limits stated below:

Age at Test in Days	Storage of Briquettes	Tensile Strength, Pounds per Square Inch
7	1 day in moist closet, 6 days in water	275
28	1 day in moist closet, 27 days in water	375

The average tensile strength of the mortar briquettes at 28 days shall be at least 15 per cent. greater than the average tensile strength at 7 days.

SECT. 6. The composition of the cement shall be such that the chemical analyses will show it to meet the limits stated below:

The percentage of silica (SiO_2) shall not be less than 21.50;
The percentage of alumina (Al_2O_3) shall not be greater than 5.60;
The percentage of magnesia (MgO) shall not be greater than 4.00;
The percentage of sulphuric anhydride (SO_3) shall not be greater than 1.75;
The percentage of loss on ignition shall not be greater than 0.90;
The percentage of insoluble residue shall not be greater than 0.30;
The ratio between the percentage of alumina (Al_2O_3) and the percentage of ferric oxide (Fe_2O_3) shall not be greater than 1.60 nor less than 1.20;
The ratio between the percentage of lime (CaO) and the percentage of silica (SiO_2) shall not be greater than 2.90;
The molecular ratio (Colony's ratio) shall not be greater than 2.60 unless approved by the Engineer. This ratio is obtained by dividing the molecular ratio of the calcium oxide by the sum of the molecular ratios of the silica, the alumina and the ferric oxide.

SECT. 7. All chemical analyses and physical tests specified in the preceding sections shall conform to the following procedures: Chemical analyses shall be made by the methods prescribed in the United States Bureau of Reclamation Specification 566 for cement for the Boulder Dam, while the physical tests shall follow the methods and procedures of Sections 13 to 45 of Specifications C77-32 of the American Society for Testing Materials, entitled "Standard Methods of Sampling and Testing Portland Cement". All limits prescribed in these specifications include all so-called "tolerances". At least 14 days shall be allowed for the completion of the 7-day tests, and the 28-day tests shall be completed within 32 days.

SECT. 8. The alkalinity of the cement shall not be greater than 3.8 and its content of free alkali shall not exceed 3.5. These characteristics shall be determined as follows: Weigh out 800 grams of cement and put into an enameled saucepan with 500 c.c. of distilled water. Stir frequently for two hours, then filter through large folded filter paper for 10 minutes. If filtrate is not clear, refilter. Titrate 25 c.c. of the filtrate with N/2 HCl, using methyl orange as the indicator. The number of c.c. of acid required to neutralize the filtrate to the methyl orange end point is the measure of the alkalinity.

The free alkali content of the cement shall be determined as follows: Measure out 100 c.c. of the filtrate obtained in the alkalinity test of the preceding paragraph into a small beaker and add 30 to 35 c.c. of a saturated filtered solution of $Ba(OH)_2$. Let stand, filter and wash with H_2O. Pass CO_2 into the filtrate for five minutes. Let stand, filter and wash the precipitate with H_2O. Heat to boiling and, if a precipitate forms, filter it out. Then boil the total filtrate plus wash water down to about 50 c.c., filter it and make it up to 100 c.c. with distilled water. Now take 25 c.c. of the solution and titrate it with N/2 HCl in the presence of methyl orange. The number of c.c. of the acid required to neutralize the 25 c.c. to the end point of the methyl orange is the measure of the free alkali content. Both of these tests are to be made at room temperature.

SECT. 9. The cement will be subjected to the sodium sulphate test. In this test the slabs shall, at the end of 28 days, remain firm, hard and strong and shall show no signs of disintegration of softening. Slight warping or small surface cracks on the edges and corners will not be ground for rejection. The test procedure is as follows: One hundred and fifty grams of the cement are mixed with 43 per cent, by weight of water and stirred for one minute by a rotary stirrer in an earthenware jar about 3 inches in diameter and 4 inches high. Near the bottom of this jar is a ⅜-inch diameter hole closed with a cork. When the stirring is complete the mixture is rapidly poured, by withdrawing the cork, onto a sheet of moistened paper as made by the Paterson Parchment Paper Company, of Bristol, Pa., 30-pound 400 Parchment, white, 24 inches by 36 inches, 34.0 pounds per 500 sheets, or equal, cut to 8 inches by 10 inches, the paper being supported on a clean glass plate 8 inches by 10 inches in size. On this paper at convenient positions are placed six $\frac{3}{16}$-inch steel balls held in position by paraffin shavings. The poured slab assumes an oval shape about 4 inches by 8 inches in size. A second glass plate, also having a moistened parchment paper on its face, is then gently lowered into position on the steel balls so as to exclude all air bubbles. A light weight (two soundness pats are sufficient) is then placed on top of the upper glass plate and the assembly carefully put into the moist closet. Twenty-four hours thereafter the assembly is put into the water storage tank (circulating water). After another twenty-four hours the glass plates and papers are removed and the slab carefully sawn to size, 2 inches by 4 inches, with a hack-saw and templet, it being kept under water except during the sawing process. At this time a small hole is also drilled through the slab at ½ inch from one end and on its center line. This hole serves to suspend the slab in the test solution. The slab then goes back into the water storage tank for 24 hours, when it is removed and hung on a copper hanger in a 2-quart Mason jar containing 1,500 c.c. of a 10-per-cent., by weight, solution of anhydrous sodium sulphate (Na_2SO_4). The slab is suspended so that its top is one inch below the surface of the solution. About ten drops of an alcohol solution of phenolphthalein are added to the sulphate solution and, after the slab has been placed therein, it is titrated every 24 hours to the phenolphthalein end point with 6N sulphuric acid. During the test the jars are covered with glass tops without washers, except when the titration is being done. During that process the slab is removed and hung in an empty jar close at hand. A daily record of the quantity of acid added is kept. A sudden increase in the quantity of acid consumed is an indication of failure of the slab before cracks visible to the eye appear. This test is to be made at room temperature.

SECT. 10. The sugar solubility of the cement shall not be greater than 8.0 to the phenolphthalein end point, nor greater than 10.0 to the final clear point. These values shall be determined as follows: A sample of about 100 grams of the cement is passed through the 200-mesh screen and put into a glass bottle closed with a rubber stopper. From this bottle 15 grams are then weighed out and placed into a Nessler tube containing 100 c.c. of a 15-per-cent. solution of cane sugar in distilled water (commercial granulated sugar such as "Jack Frost"); this solution shall not be more than three days old. The tube and its contents are then quickly shaken by hand and placed on a wheel revolving about 60 times per minute. At the end of about 1 hour and 50 minutes the mixture is poured into a filter paper and funnel and allowed to filter for 10 minutes when the beaker containing the filtrate is removed. (In case the filtration time of 10 minutes is too short to produce a volume of filtrate of 30 c.c., it may be lengthened by shortening the time of shaking, but the total time from the putting of the sample into the solution to the end of the filtration must be exactly 2 hours.) Twenty-five c.c. of the filtrate is now titrated with N/2 HCl in the presence of phenolphthalein and the number of c.c. of acid to the end point is the first measure of the sugar solubility. At this stage of the test, in the case of a thoroughly burned cement which has been kept dry, the solution will be practically clear and only traces of ferric oxide and alumina will be in suspension. In the case of an under-burned cement, or one which has been exposed to moisture, the solution will be heavily clouded and the end point must be approached slowly and with caution. When so performed, the phenolphthalein end point can be definitely determined, as the color changes from light pink to yellow. The titration is then continued until the solution is crystal clear and nothing remains in suspension. The total number of c.c. of acid from the beginning of the titration to this final clear point is the second measure of the sugar solubility. This test shall be made at room temperature. In addition to disclosing the quality of the cement as above stated, this test further indicates the character of the hydration products which will be realized in the completed concrete.

SECT. 11. Cement shall be delivered in strong, well-made, 4-ply paper packages, each plainly marked with the manufacturer's brand. The weight of all packages shall be uniform. Packages received in broken or damaged condition shall be rejected, or accepted only as fractional packages. If so required, each package of cement shall be sealed or stamped at the expense of the Contractor, under the supervision of, and with a seal or stamp furnished by, the Engineer. With the approval of the Engineer, cement may be delivered in bulk if the Contractor provides approved storage, weighing devices, and all other necessary facilities to insure keeping the cement in good condition and affording a correct measure of the cement used in each batch, as well as in total quantity. Bulk shipments shall be made only in clean cars or containers. Any such in which lime has been shipped shall not be used unless especially cleaned.

SECT. 12. The Contractor, at all times, shall have at the sites of the work a sufficient supply of accepted cement, and shall guard against possible shortage from every cause.

SECT. 13. The Engineer shall be notified by the Contractor when the cement is to be manufactured, and the Engineer shall have the liberty at all times to inspect the materials, the processes of manufacture and the laboratory records of analyses and tests made at the cement works, and to supervise the packing. Samples will be taken at the place of manufacture by the Engineer and sent to the Board's laboratory, where the tests and analyses herein specified will be made. Samples shall be stored and shipped in moisture-proof, air-tight containers which will be furnished by the Board. These containers shall be crated, ready for shipment, by the Contractor and shall be delivered by him to the express company. Express charges will be paid by the Board.

SECT. 14. The Contractor shall notify the Engineer when orders for cement are placed and shipments are to be made in ample time (at least 48 hours) to enable him to have his representative present to observe the burning of the clinker, the manufacture of the cement, its loading for shipment and to obtain the necessary samples. In case additional tests become necessary, the Contractor shall re-handle the cement in the storehouse before the purpose of obtaining samples as directed.

In general, the cement shall be sampled from the conveyor belt at the mill by a continuous sampler, one sample being taken for every 200 barrels or more as determined by the Engineer. Each sample shall weigh 5 pounds. If sampled from the bin proper, tubes shall be used. If a bin is full, it shall be sampled from the discharge openings. The methods of sampling must at all times be approved by the Engineer. All cement stored at the mill shall be kept in sealed silos or other approved bins.

Cement kept in store at the mill for more than six months may be re-tested. Cement failing to pass such tests shall be rejected. If any cement proves unsatisfactory and portions of it have been used in the masonry, such masonry shall be ordered removed and replaced with masonry built of acceptable cement at the Contractor's expense. Test-cylinders from concrete or mortar being used in the work shall be made by the Contractor at any time for purposes of test, if so directed.

SECT. 15. Cement may be rejected at the discretion of the Engineer if it fails to meet any of the requirements of these specifications. Cement may be accepted without awaiting the results of the 28-day tests when, in the judgment of the Engineer, the 7-day tests are met and there is definite justification, based on experience and actual plant performance, that the 28-day tests will be satisfactory.

SEWAGE DISPOSAL SYSTEM AT KEENE, N. H.

By George A. Sampson, Member* and E. B. Cobb, Member†

(Presented at a meeting of the Sanitary Section of the Boston Society of Civil Engineers held on December 7, 1938.)

The City of Keene is located in southwestern New Hampshire on the Ashuelot River about 22 miles above its confluence with the Connecticut River at Hinsdale. The population of the City in 1930, by the United States Census, was 13,794 persons and it is estimated that the population will increase to 18,650 by 1960.

Ashuelot River

The Ashuelot River is the natural outlet for a sewage disposal system. The watershed of the river above Keene is steep, rather impervious, and without any considerable ground water storage to augment dry weather runoffs. There are also several lakes and ponds on the watershed that, by surface storage and evaporation, reduce the ordinary minimum flows.

The Ashuelot is joined by a sizeable but extremely variable tributary known as The Branch, near the southerly City limits. The combined drainage area of the two streams at their junction is about 220 square miles. The average flow just below The Branch is approximately 1.08 Mgd. per square mile, of 237.6 million gallons per day. The ordinary low water flow is about 15 Mgd. although the minimum for a single day, due to regulation of storage, may be considerably less than this figure.

Historical

The Keene sewerage system is of historical interest in that it is the first separate system of sewers constructed in New Hampshire.

In the tenth annual report of the New Hampshire State Board of Health for the year ending October 31, 1891, is a report written by George E. Waring, Jr., C.E., of Newport, R. I., describing the sewerage system of Keene, in general, as follows:

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*Partner, Weston & Sampson, Consulting Engineers, 14 Beacon St., Boston, Mass.
†Engineer, Weston & Sampson.

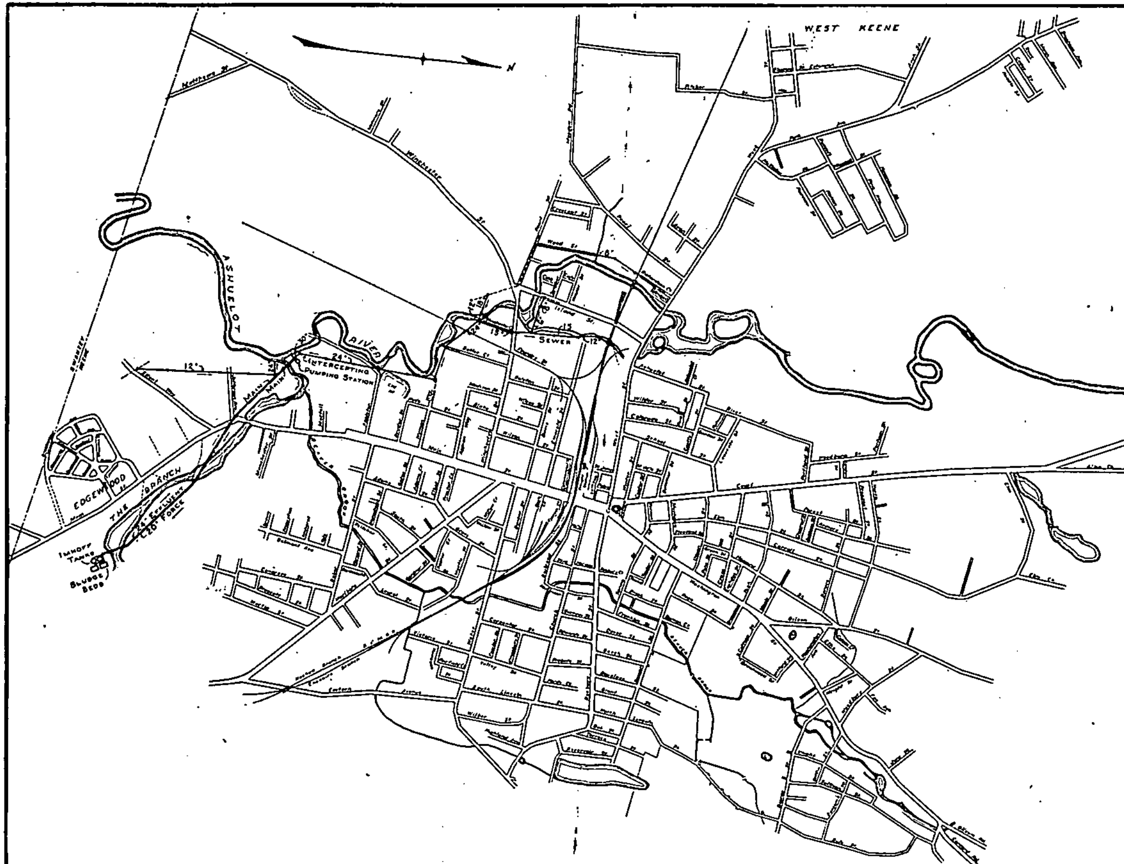

Fig. 1. — General Plan of Sewage Disposal System for City of Keene, N. H.

There was a movement for a sewerage system in Keene about 1876. It was proposed to construct a combined system of sewers and storm drains varying in size from tile pipes 12 inches in diameter to brick sewers 40x60 inches. However, the estimated cost was so high that nothing was accomplished.

In 1880, following the successful installation of sewers at Memphis, Tenn., the project took on new life. A system of the separate type was proposed and in 1882 construction was started. In 1883, construction was substantially completed, the total length of sewer being a little more than 11½ miles, all of pipes ranging from 6 inches to 15 inches in diameter, of which 6-inch pipe constituted 73% of the whole. The system also included 44 automatic flush tanks and 51 manholes. The contract price was about $84,000 or, roughly, $7,300 per mile.

By 1890 the system had been enlarged to about 13½ miles of sewers, 52 flush tanks, 51 manholes and 3 outlets into the Ashuelot River. The premises of about 800 families were connected with the sewer. The two principal outlets at this time were the Beaver Brook and the Butler Court sewers, both of which were 15 inches in diameter. According to the report, no offense or difficulty had been encountered with these outlets.

The report continues—

"The Ashuelot River is subject to high floods. The Butler Court outlet is sometimes submerged to a depth of 6 or 8 feet and much of the flat area through which the Beaver Brook main runs is under water, in some cases over the tops of the manholes. These conditions indicated that it would probably be necessary to make use of jet pumps near these outlets during high stages of the river. It was found that during the spring flood of 1884, which was unusually high, the natural flow of the sewers maintained a constant current through the whole system. No inconvenience was caused by any failure of the house drains, even in the lower portions of the town, to discharge freely, and it was thought unnecessary to carry out this part of the plan at present. The indications now (1891) are that such an aid may be required at the Butler Court outlet."

Maintenance in 1891 amounted to $828 including $400 for superintendent's salary and the compensation of the plumbing inspector.

In the fifty-fourth annual report of the Sewer Department of the City of Keene for the year ending November 30, 1937, the sewerage system, exclusive of sewers constructed for the disposal system, is described as consisting of about 43.5 miles of sewers, varying from 6 inches to 18 inches in size, 417 manholes, 927 standpipes and 2751 service connections. The flush tanks had all been abandoned and removed.

On October 4, 1933, Weston & Sampson, Consulting Engineers of Boston, presented a report to the City recommending a sewage disposal system consisting of the following essential elements,—

Intercepting sewer,
Sewage pumping station,
Force main to disposal plant,
Sewage disposal plant,
Effluent main from disposal plant to Ashuelot River.

With assistance proffered by the P.W.A., construction was commenced on September 28, 1934, and on May 20, 1936, the system was placed in operation.

The Problem

The sewerage system of the City had been installed from time to time to serve various drainage areas without any consideration of sewage treatment. There were ten separate gravity sewers from the railroad bridge near West Street to the Edgewood outfall in a distance of 1⅞ miles. One of these outlets entered the canal, otherwise known as Mill Creek, near the railroad bridge, and the remaining nine sewers discharged directly into the Ashuelot River.

The average flow of the river provides sufficient dilution for the disposal of the sewage from the City without any great nuisance. The low water flows, however, which may extend over several weeks during the summer months are entirely inadequate to properly dilute the sewage. In addition, the slope of the river along the sewer outlets is slight and the sewage solids readily settle in the bottom of the channel and along the banks.

The sewer outlets were visible at ordinary stages of the river but were backflooded at high water. The diameters, elevations and distances from the sewage pumping station of the various outlets are given in the following table:

Sewer	Size (in.)	Elevation* of Invert	Distance from Pumping Station (ft.)
Ashuelot Street	10	467.8	5454
Richardson Court	6	472.0	6906
Island Street	8	465.0	4799
Winchester Court	6	465.7	3339
West Keene Sewer	18	466.3	3734
Butler Court	15	465.3	2715
Madison Court	6	467.8	2168
Appleton Street	8	466.3	1326
Beaver Brook Sewer	15	465.6	100
Edgewood	12	465.0	2428

*Datum is 5.25 ft. below Mean Sea Level

Solution of Problem

The first essential step in relieving the Ashuelot River from sewage pollution was to construct a trunk sewer along the river of sufficient size and at the proper grade to intercept all existing and future sewer outlets. Because the present sewers discharged into the river at near low water level, and several at about the same elevation, an intercepting sewer at its lower end, in order to provide a self-cleaning velocity, must necessarily be several feet below the river level. It was also apparent that sewage must be pumped to the treatment plant.

The logical location of the pumping station was near the outlet of the Beaver Brook sewer which is also near the junction of The Branch with the Ashuelot River.

Because it was only necessary to remove enough of the polluting material in the sewage to permit its sufficient dilution during the periods of low flows in the river, it was felt that treatment in Imhoff tanks would be acceptable. Owing to the considerable depth of these tanks it was advisable that they be located above or near ground water level to facilitate their construction. There were no locations immediately along the river where the ground is at a sufficient elevation for a treatment plant. Probably the best site from an economical standpoint was at the westerly end of the plateau in Edgewood just above the meadow and approaching the Swanzey line. This would have been an ideal location in all respects some years ago before the development of this area into a residential district. At the present time, however, on account of the proximity of dwellings and cemetery property, especially with the prevailing northwest wind, such a location was deemed inadvisable.

The only other location that lent itself to a low construction cost for the treatment plant and was sufficiently removed from residences was in the easterly part of Edgewood near the easterly end of the City's gravel pit, just south of The Branch. There was also sufficient area available at this site for the installation of trickling filters should an increased degree of sewage purification later prove desirable.

Because the flow in The Branch is so erratic it was not felt advisable to discharge the effluent of the treatment plant into this stream. It was therefore decided to install an effluent main parallel to the force main discharging into the Ashuelot River immediately below the junction with The Branch.

Intercepting Sewer

The intercepting sewer as it enters the pumping station is a 30″ reinforced concrete pipe with a slope of 0.7 foot in 1000 and the invert is at elevation 461.25. At station 1+00, or at the connection with the Beaver Brook sewer, the interceptor is reduced to a 24″ concrete pipe with a slope of 1.0 foot in 1000. Continuing upstream, the Appleton St., Madison Court, Butler Court, Winchester Court, and the West Keene sewers enter the 24″ interceptor. At station 33+39, or at the junction with the West Keene and Winchester Court sewers, the interceptor is reduced to a 15″ concrete pipe laid with a slope of 1.5 ft. in 1000. A 6″ connecting sewer from the Island St. sewer enters the interceptor at station 42+12. At station 48+91, the interceptor is reduced to a 12″ cast iron bell and spigot pipe laid with a slope of 1.74 feet in 1000. Instead of being in a trench as is the rest of the interceptor, the cast iron sewer is supported on reinforced concrete piers along the bank of Mill Creek. The interceptor terminates at station 54+54 at which point it con-

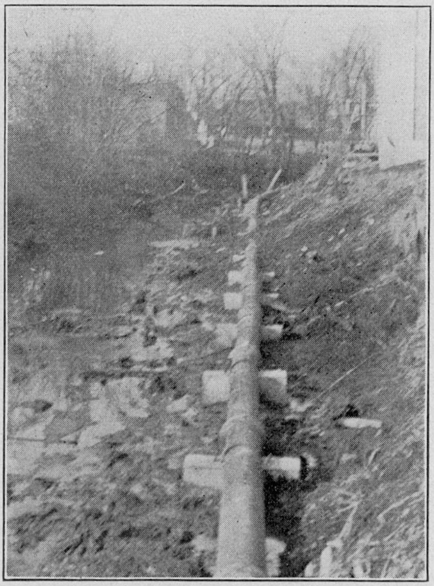

Fig. 2.— 12-inch Cast Iron Intercepting Sewer Along Mill Creek

nects with the Ashuelot Street sewer. Where the interceptor crosses the railroad and also under the concrete pavement of Winchester Street, the pipe is laid in tunnel.

The West Keene sewer is connected to the interceptor by means of an inverted siphon under the Ashuelot River constructed of 12″ Universal cast iron pipe. The Island street sewer is connected in a similar manner with a 6″ Universal pipe.

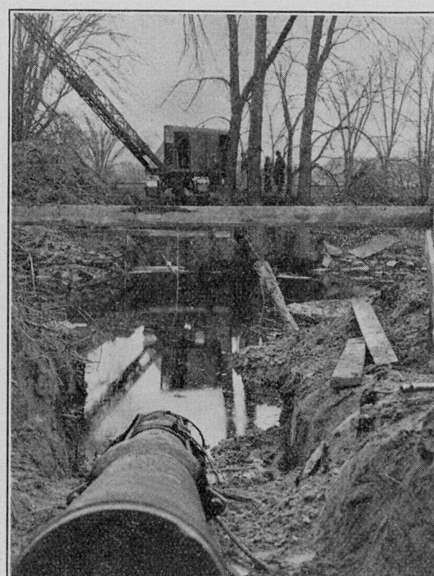

Fig. 3.—River Crossing on West Keene Connecting Sewer

The Richardson Court sewer was extended as an 8″ tile pipe with a slope of 1.09 feet in 1000 under the railroad, across a field, and through Wood St., a distance of 1972 feet, discharging into the present 15″ West Keene sewer at the junction of Wood and Pearl Streets. This sewer is laid at a very flat grade because no greater slope was available for gravity discharge.

The Edgewood sewer is intercepted at a manhole near Silent Way by a 12-inch tile pipe laid with a slope of 2.8 feet in 1000 extending across fields and underneath The Branch to a manhole on the 30″ concrete interceptor just outside the sewage pumping station, a distance of 2428 feet.

Due to soft clay being encountered in the excavation over a considerable portion of the intercepting sewer and connecting sewers, together with a considerable flow of ground water, it was found necessary to excavate below the grade of the pipe from 6″ to 24″ and refill with screened stone. In addition, single or double 6″ tile under drains were generally required to keep the ground water below the invert of the sewers during construction.

Brick manholes with concrete floors were provided at all sewer connections and also at frequent intermediate points to facilitate inspection and cleaning. The joints of the concrete and tile sewers were made with asphaltic jointing compound and of the 12″ bell and spigot cast iron pipe with "Leadite". The bells and spigots of the concrete pipes were coated with a bitumastic primer to secure a proper bond for the jointing compound.

The specifications limited the leakage to an average of 5 gallons per 24 hours per lineal foot of sewer. The results of leakage tests on the combined sewers showed an average infiltration of 4.8 gallons.

The manhole at the connection of the Beaver Brook sewer and the interceptor was constructed as an overflow manhole and the abandoned portion of the Beaver Brook was utilized as the overflow outlet. This makes it possible to divert the sewage from the pumping station.

Sewage Pumping Station

The sewage pumping station consists of a heavily reinforced concrete substructure, 51′-4″ x 36′-4″ in plan, and 27′-3″ deep to the lowest point, surmounted by a brick superstructure 34′-4″ square. The substructure is divided transversely into two compartments, one being a sump for storing incoming sewage and the other a pump room. Included in the sewage sump is a smaller compartment containing a grit chamber and screens. Immediately above the grit chamber and over a portion of the sewage sump is the screen room where screenings and grit are handled. Over the pump room is a balcony on which the office, switchboard and meter register are located.

The sewage enters the station through a 30″ sluice gate into the grit chamber in which the velocity of the sewage is reduced to about 1 foot per second to remove sand and heavy mineral solids. The grit chamber is in two sections, one or both of which may be used depending on the volume of sewage. After leaving the grit chamber, the sewage passes through two screen cages with 1¾″ square openings in order to remove rags, sticks and other sewage solids that would clog the pumps. The screen room is equipped with an electric hoist traveling on an I-beam for raising and lowering the screen cages for cleaning. From the screens the sewage passes through a trapped opening into the sewage sump. The trap is provided to prevent gases and odors in the sump from entering the screen room. The sewage sump has a storage capacity of about 20 minutes with one pump in operation. Odors from the screen room are prevented from entering the adjacent control room by tight fitting double doors and a ventilator.

The superstructure of the building is constructed of dark red waterstruck brick. The inside of the screen room and control room is faced with buff-colored brick.

The roof is of steel truss construction with "gyp-steel" plank covered with slate.

The contractor for the sewage pumping station commenced work on October 10, 1934, and the building of this structure proved to be a very difficult undertaking. The contractor first attempted to lower the ground water level by means of a system of wellpoints. One hundred sixtenn (116) 1½" well points were driven and the usual system of suction mains and pumping unit installed. The attempt was a failure because soft clay was encountered at and near the grade of the pumping station floor, which, being practically impervious, prevented the water from reaching the well points. After repeated attempts to lower the water level by this method which extended over a period of six weeks, the contractor decided to abandon well points and resort to sheeting and pumping.

Excavation was carried on by a derrick equipped with a clam shell bucket and was nearing completion when, aided by high water in the river, the tremendous pressure of the clay caused the sheeting to collapse, allowing the surrounding material to partially fill the excavation. Larger sheeting and heavier bracing were obtained in February, 1935, and the sheeting was again driven and the excavation started anew. During this period, there were two or three high water stages of the river which flooded the excavation and greatly interfered with the work. In addition, the weather during the winter of 1934-5 was extremely cold with excessive snowfall. When the excavation was nearly finished, one of the bottom rangers twisted and buckled as a result of which the sheeting again collapsed.

On May 15, 1935, after the spring high water, the work of

Fig. 4. — Effects of Flood on Excavation for Pumping Station

Fig. 5. — Result of Collapse of Bracing in Excavation for Pumping Station

excavating for the pumping station was resumed. Progress was interrupted in July due to the unusual summer flood which filled the area with water. The excavation was finally completed on August 20, 1935, and tests were made to determine the bearing value of the clay bottom. These tests showed that the soil was very soft and not capable of supporting the weight of the pumping station. Ninety-two wooden piles were driven to solid ledge, ranging in length from 18 feet to 31 feet. The total length of piles driven was 2222 feet at a cost of $2452.29 or $1.10 per lineal foot. Also 12″ to 18″ of clay was excavated below the grade of the floor and refilled with screened gravel. The sheeting on the river side of the station was left in place to prevent settlement of the sewers and force main.

Work progressed slowly during the fall and winter until the pumping station was substantially completed at the end of February, 1936. On March 13, 1936, high water occurred in the river which by March 19 reached elevation 479.8 which was at least 5 feet above any previously recorded flood level, and as a result the station was completely filled with water. After the flood, the water was removed from the station and the damage repaired by the contractors. Work was finally completed on August 1, 1936.

FIG. 6. — COMPLETED PUMPING STATION

PUMPING EQUIPMENT

The pumping equipment consists of two duplicate Morris horizontal non-clog sewage pumps direct-connected to 50 horsepower, 1150 R.P.M., 220 volt, 3 phase, 60 cycle, alternating current "Ideal" motors. Each pump has a designed capacity of 2500 gallons per minute against a total dynamic pumping head of 59 feet. The impellers are capable of passing sewage solids 4″ in diameter. The suctions of the pumps extend through the pump room wall into the sewage sump turning downward into bellmouths. Each pump discharges through an individual horizontal check valve and gate valve to a common discharge header and thence through a Venturi meter tube and finally to the force main. Each suction is provided with a gate valve and a cleanout hand-hole.

The switchboard consists of two panels and was furnished by the Sundh Electric Co. A transfer switch allows either pumping unit to be the leading pump, and the starting of the pumps is controlled by

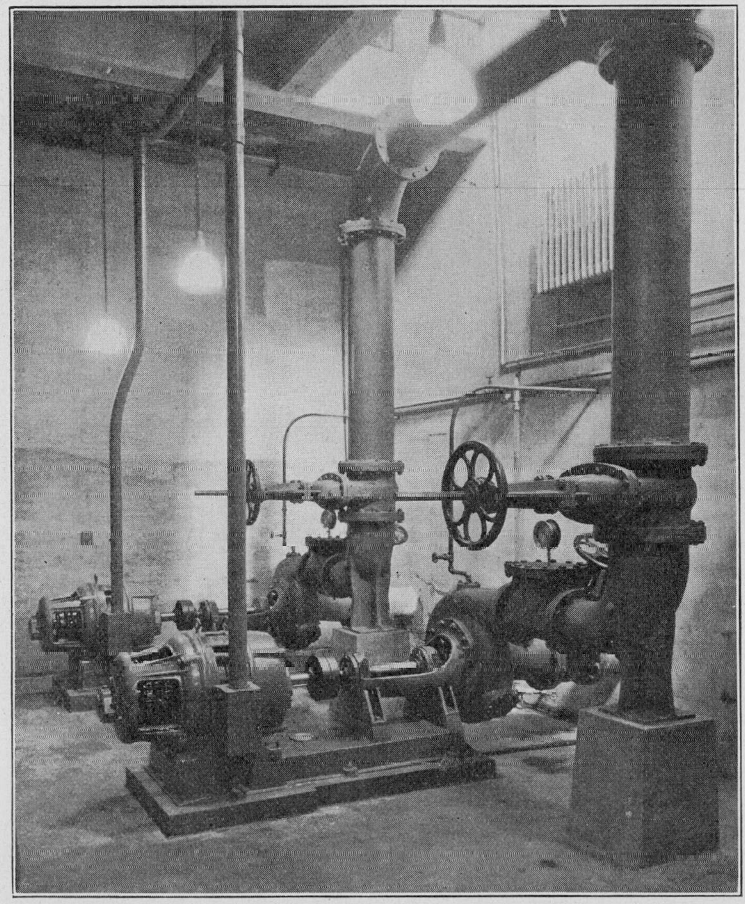

FIG. 7.—SEWAGE PUMPS

float switches operated by floats in the sewage sump. The leading pump starts when the sewage in the sump reaches elevation 460.25 or a depth of 6.75 feet. Should the leading unit fail to start, or if the volume of sewage exceeded its capacity, the other pump would be put in operation automatically as soon as the sewage level reached 6 inches above the fixed level.

Acceptance tests of the pumping units were made on May 20, 1936. Pump No. 1 was found to have a wire to water efficiency of 73.75% and pump No. 2 of 75.0%, as compared with a guaranteed efficiency of 72.9%.

The capacity of both pumps operating simultaneously was 4500 gallons per minute with a total pumping head of 67 feet.

Force Main

The force main running from the pumping station to the treatment plant is constructed of 20″ Universal cast iron pipe with bolted joints. The line is 4153 feet in length and generally follows the course of The Branch which it crosses three times and occupies the same trench as the effluent main. Near the pumping station there is a 12″ drain leading to the Ashuelot River through which the force main may be drained or the pumps discharged directly into the river. Underdrains and gravel foundation were required over most of the length of the force main.

Sewage Disposal Plant

Imhoff Tanks

The treatment plant consists of two duplicate Imhoff tanks and twelve sludge drying beds with interconnecting piping. The Imhoff tanks are 50 feet in diameter with a depth of sewage of 32 feet. The sewage enters the settling compartment in a 16″-90° elbow discharging upward. The settled sewage flows over a weir set in the end of a similar 16″-90° elbow on the opposite side of the tank, into the outlet pipe leading to the effluent main. By shifting the weir and manipulating the valves, the direction of the sewage flow may be reversed and thus accomplish a more even distribution of the sludge in the tanks.

The settling compartment is circular in plan and provides for a detention period of about four hours at a rate of 1.5 million gallons

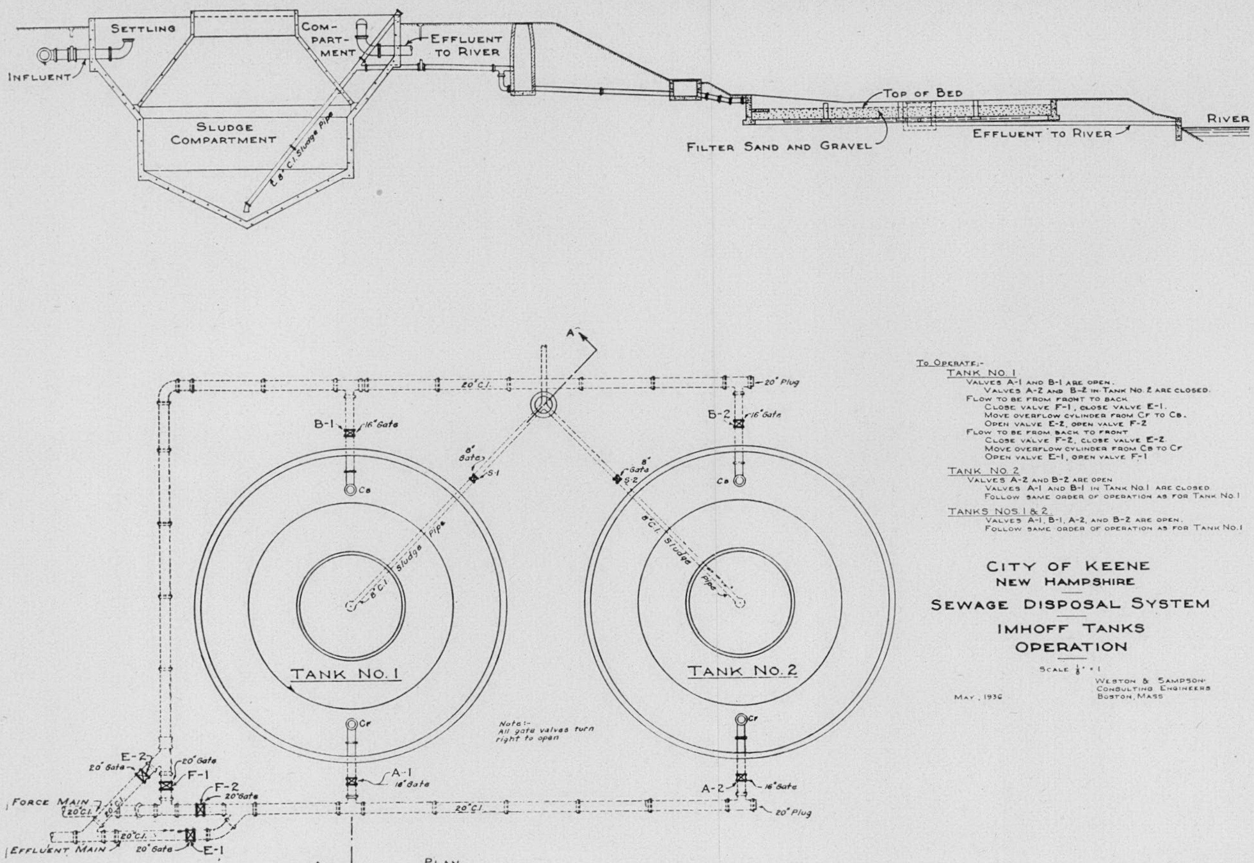

Fig. 8. — Piping Plan of Imhoff Tanks, Also a Profile of the Imhoff Tanks and Sludge Beds

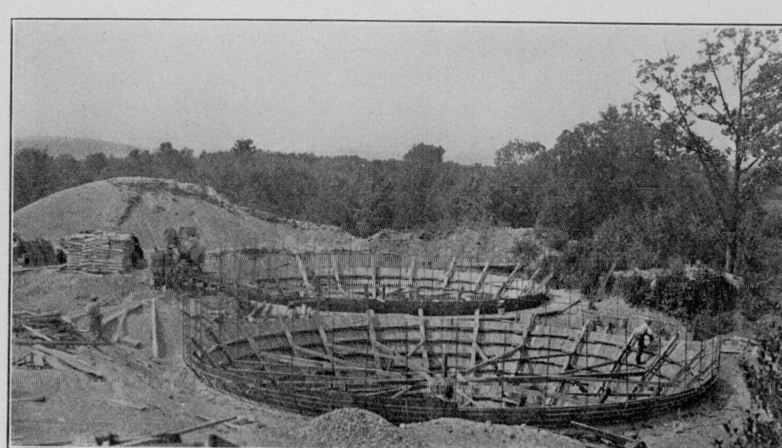

Fig. 9. — Forms for Bottoms of Imhoff Tanks

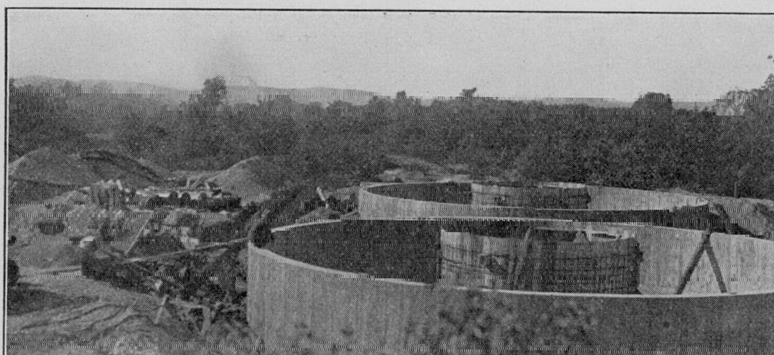

Fig. 10. — Imhoff Tanks Under Construction

per 24 hours. The sludge chamber is separated from the settling compartment by means of an annular baffle wall which also prevents the sewage gases from interfering with the settling.

The sludge compartment was designed for eight months' storage between sludge removals, it being estimated that the sludge would collect at the rate of about 12 inches per month. The sludge is removed through an 8″ cast iron pipe extending to near the bottom of the sludge compartment and connecting with the sludge beds. The flow of sludge is accomplished by gravity.

Sludge Beds

The twelve sludge drying beds are each 20 feet x 50 feet in area. The inlet to each bed is through a 10″ shear gate discharging upon a semi-circular concrete platform. The beds are underdrained with open-joint tile pipe surrounded with gravel. The filter bed is 21″ in depth, consisting of 13″ of supporting materials and 8″ of filtering sand. Each bed has a capacity of about one month's sludge which allows an ample drying period before the sludge is removed.

Fig. 11. — Placing Gravel in Sludge Beds

Effluent Main

The effluent main which conveys the sewage after treatment in the Imhoff tanks back to the Ashuelot River consists of a 24″ reinforced concrete pipe with asphaltic compound joints. At the two crossings of The Branch 24″ Universal cast iron pipe with bolted joints was substituted. The total length of the effluent main is about 3950 feet and, as mentioned before, was laid in the same trench as the 20″ force main. The discharge is into the river just below its junction with The Branch.

Cost

The total cost of the project was as follows:

Intercepting and connecting sewers, force main and effluent main $114,518.21

Pumping station, Imhoff tanks and sludge beds	67,324.06
Pumping equipment	5,300.00
Venturi meter and register	821.73
Rights-of-way	3,566.65
Legal	813.06
Preliminary	357.80
Engineering	22,250.00
Total cost	$214,951.51
Grant from Federal Government (P.W.A. project)	56,000.00
Cost to City of Keene	$158,951.51

The contractors were:

J. H. Ferguson Co.—Sewers, force main and effluent main.

Central Engineering and Construction Co.—Pumping station and disposal plant.

Starkweather Engineering Co., Inc.—Pumping equipment.

Simplex Valve & Meter Co.—Venturi meter.

Weston & Sampson were the engineers for the project.

Results of Operation

At the height of the hurricane of September 21st this year, a flood of the Ashuelot River inundated the pumping station and as a result most of the records of operation were lost. However, a few figures gleaned mostly from the annual reports are available.

During the period from June 11 to December 1, 1936, a total of 186,290,000 gallons of sewage was pumped, or an average of 1,076,820 gallons per day. The screens were cleaned daily, 7471 gallons of screenings being removed and buried. The grit chamber was cleaned three times, 1800 gallons of grit being removed and buried. Power consumed amounted to 59600 KWH at an average cost of $0.0193 per KWH, or a total cost of $1,158.44, equivalent to $6.20 per million gallons.

During the period from December 1, 1936 to December 1, 1937, a total of 498,970,000 gallons of sewage was pumped, or an average of 1,367,000 gallons per day. For the same period, the water department reported an average daily water consumption of 1,192,000 gallons per day or 175,000 gallons per day less than the sewage flow.

The screens were cleaned 347 times, a total of 16,685 gallons of screenings being removed. Sludge was drawn off from the Imhoff tanks five times equaling a depth of 4.0 feet over all the sludge drying beds, or 48,000 cubic feet of wet sludge. Power consumed for pumping was 158,800 KWH at an average cost of $0.0187 per KWH or a total cost of $2,974.07, or $5.95 per million gallons.

Costs of operation, maintenance and fixed charges for the same period were as follows:

Labor	$ 3,452.43
Supplies and expenses	795.89
Light and power	2,974.07
Heat	164.06
Water	25.55
Garage	91.90
Bonds and interest	13,120.00
	$20,623.90

This is equivalent to a total cost of $41.33 per million gallons or $15.00 by omitting fixed charges.

Sometime prior to July 1937, digestion in the Imhoff tanks became upset causing the sludge to rise in the circular gas vents. This condition was allowed to continue until a layer of sludge and scum nearly twelve feet in thickness clogged the vents and the slots in the settling compartments. The foaming and resultant odors were so bad that the local residents petitioned to have the plant closed down. The State Sanitary Engineer was called in and his investigation disclosed that the pH of the sludge was down to 6.0. Upon his advice 600 pounds of lime per day was added to each tank. This amount has been gradually reduced until at present about 50 pounds per day per tank is added.

The City health officer has made daily tests for the pH of the sludge since the lime treatment and at present it averages about 7.0. The objectionable odors have ceased and foaming is no longer apparent.

Sedimentation tests made recently in Imhoff cones indicated 92.4% removal of the settleable solids.

Some Legal Difficulties

Following the completion of the sewers, the contractor for this part of the project brought suit against the City for about $7500 for losses sustained by him on account of a delay in completing his contract because the pumping station sub-structure, constructed under another contract, was not completed on time. The case was tried before a jury and a verdict of about $2,500 was found for the contractor.

The City appealed to the New Hampshire Supreme Court and the verdict was reversed. The following points are of interest regarding the final judgment of the court.

The contractor for the sewers was required under his contract to connect the sewer pipes with the pumping station and in order for this to be done it was necessary for the pumping station to be completed up to the ground level. On June 28, 1935, the contractor for the sewers was required to suspend work because the operations of the contractor for the pumping station had not, at that time, reached the required level. On that date all but 300 feet of sewers and the connecting of the intercepting sewer with the pumping station had been completed.

The contract for the sewers provided that the work should be performed "according to the requirements of the Engineer" and that the contractor should accept the contract price "as full payment for the work including all loss or damage arising out of the nature of the work or from the action of the elements or from any unforeseen obstruction or difficulties which may be encountered in the prosecution of the work, and for all losses or expenses incurred by or in consequence of the suspension or discontinuance of said work".

The engineer was constituted an adjudicator. He was to decide all questions that might arise "relative to the intent and fulfillment of the contract," and his estimates and decisions were to be final and conclusive. The contract contained the express provision, "Construction work may be suspended at any time on account of the weather or for any other reason, if deemed necessary or advisable by the Engineer or the City, without additional compensation to the Contractor".

The contract between the City and the contractor for the pumping station provided that the engineer might require the contractor to hire additional labor to prevent the job from being delayed or in event of unnecessary or unreasonable delay take the work from the contractor and complete it otherwise.

The contractor for the sewers was an unsuccessful bidder on the contract for the pumping station with a bid of $80,000 as compared with $63,000 by the successful bidder. The court held that the contractor for the sewers was, therefore, thoroughly familiar with the task confronting the contractor for the pumping station and from a knowledge of the local topography must have realized that the place was likely to be flooded. Having all this knowledge, he agreed to stand the loss occasioned by any interruption in the prosecution of his work and to suspend work whenever the engineer or the city deemed it necessary or advisable.

The plaintiff, according to his own evidence, had confidence in the engineer, and the inference is inescapable that they trusted to his ability and integrity to see that the pumping station was constructed with as little interruption to their own operations as possible.

If the engineer arrived at his conclusion under a clear mistake as to material facts, relief seems proper; but where his knowledge of the facts of the case is adequate, though his judgment may be unreasonable, it is a total change of the terms of the contract for the court to permit the judgment of a jury to be substituted for that of the engineer for which the contract provided.

The testimony of the engineer, appearing as a witness for the City, supporting his judgment was that the conditions encountered were extremely difficult for excavating and the floods were unusual compared with any other similar jobs under his supervision. As to the advisability of permitting the contractor for the pumping station to continue his contract, he stated that he thought it was better they should go on, that they surely had had plenty of experience in that particular place and to take the work away from them would, in his opinion, delay the work longer than it would to have them continue.

Because there was no evidence that the engineer acted arbitrarily or capriciously or in bad faith and his decision was based upon the material facts, which he fully understood and no grounds for impeachment of that decision had been shown, the court held that the judgment should be for the City.

WELDING APPLICATIONS IN THE NEW MASSACHUSETTS GENERAL HOSPITAL BUILDING, BOSTON, MASS.

By J. Theodore Whitney*

(Presented at a Joint Meeting of the Boston Society of Civil Engineers and of the Boston Section of the American Welding Society held on December 21, 1938.)

The George Robert White Memorial Building is in the center of the group of buildings known as the Massachusetts General Hospital. In the buildings which surround this building there are over one thousand patients, many of whom require absolute quiet for recovery.

The noise that results from riveting or reaming for turned bolts was considered by the hospital authorities to be a serious matter and as a result they requested that the structure be field welded. The application for the permit was made and the Architects of the building, Messrs. Coolidge, Shepley, Bulfinch and Abbott, requested approval of field welding of the structural steel.

Due to the fact that Boston is still operating under the old obsolete law which does not cover welding, and, inasmuch as the new law passed at the recent legislative session had not been signed by the Mayor and Council, and therefore could not be followed, it was necessary to go to the Board of Appeal for permission to weld. This permission was granted with the proviso that J. Theodore Whitney should assume entire charge of the welding in all its aspects, that he file an affidavit to cover the welding and make a final affidavit when the work was completed. Also, that he should have a qualified inspector at the building when welding was in progress and that only welders approved by the Department should be employed.

The New England Structural Company of Everett, Massachusetts, made the welding details which were subject to approval of the Welding Engineer, and also fabricated the steel framing. The Scott Welding Company of Brooklyn, New York, was the welding contractor. Mr. Anthony S. Coombs, a member of The Whitney

*President, The Whitney Engineering Company, 100 Arlington Street, Boston, Mass.

Engineering Company, (of which Mr. Whitney, the Welding Engineer, is President) was also identified with the welding of the Boston Edison Building on Tremont Street and the Pediatric Building of the Boston City Hospital, and he served as Inspector for welding at this building. The Sawyer Construction Company of Boston was the General Contractor.

The welders were all steel workers and each was required to pass a test to show proficiency in welding unless a recent test had been made and the man had recently been engaged in welding. These tests were made in a flat, vertical and overhead position with the requirements for qualifications of a tensile strength of not less than 100,000 lbs. on the 6″ of a ⅜″ weld on a test specimen, that regardless of the strength of the test the weld should show no porosity, lack of penetration or slag inclusion. Many of these tests broke between 120,000 and 130,200 lbs. These tests were made at the laboratories of the Massachusetts Institute of Technology.

Eight Hobart machines of 300 amperes capacity were used for the work and Una Wire No. 3100, sizes 5/32ds inch, and 3/16ths inch diameter were selected by the Welding Contractor for the electrode.

The building is of the tower type and covers about 28,000 square feet on the ground, gradually changing in plan to a T shape at the 5th floor level. The building then assumes a cruciform plan for six stories and then changes into a tower for the remainder of the building. The basement floor which is the first framed level is at elevation 13.08″, Boston base and the roof of the tower, the eighteenth framed level, is at elevation 219.00, a distance of 206 feet from basement floor to roof. The tonnage of steel used in the structural frame amounted to 2,274 tons. Except for fifteen inches of welding which was done by a gasoline driven generator, all welding was done by electric driven generators. The foreman representing the welding company laid out the lengths and designated the sizes of all welds in accordance with the welding details and the inspector checked these lengths and sizes as well as the actual condition of the welding. The number of welders engaged totaled twelve, not including the foreman who did some welding when opportunity permitted. Eight welders were used for a considerable period, but in general five constituted the average number.

The welding followed closely the erection and there were several instances where the welders had to lay off until steel could be erected. The inspector submitted daily reports on the welding that had been completed, describing this work in detail, recording the floor level, number of the beam, length and size of weld deposited and number of the welding sheet detail covering the specific joint. The Welding Engineer carefully checked this report to make sure that all joints had sufficient carrying capacity for both shear loads and wind stresses. Every joint, as it was reported, was checked off on the erection plans both by the inspector in the field and in the Welding Engineer's office.

The contractor elected to remove the erection bolts which is not usually done.

The welding on this particular building again confirmed previous observations regarding welding, namely—speedier erection, stiffer frame, less scaffolding needed than for riveting, reduced fire hazard because there are no hot rivets to drop, decreased accident hazard, because there are no hot rivets to pass, noise practically eliminated, and greater ease in rectifying shop errors or in making changes required after the steel is erected.

Scepticism regarding welding is due primarily to lack of familiarity with the process. No new set of mathematics is necessary for the computations of loads, stresses or strains. Welding is simply another means of fastening steel together and it seems highly desirable that all facilities and processes should be made available for use under controlled procedure. The term "controlled procedure" should be emphasized. No reputable engineer should assume responsibility for reinforced concrete work that he designs unless he has the power of control through supervision, and the same applies to welding. Where the procedure of welding is under control, it is just as safe as the procedure of concreting when under control and at the present time there is no hesitation in using concrete if the procedure is controlled. Furthermore, in these days when economy in construction is needed to make possible more building in order that more taxable property may be developed in the community, any new process, tool or material when proven safe and adequate, should be allowed under such regulations as will secure adequate and proper results.

A careful analysis of the reports and other data collected on this building give the following interesting data:

MASSACHUSETTS GENERAL HOSPITAL

WELDING STARTED: August 16, 1938   WELDING FINISHED: November 23, 1938.

1.	Height Basement floor to roof (18 levels)	206 feet
2.	Total tonnage in building	2274 tons
3.	Number of inches of welding (all sizes)	115,238 inches
4.	Equivalent 5/16ths weld	129,516 "
5.	Equivalent 3/8ths weld	89,925 "
6.	Number of inches of weld (all sizes) per ton	50.68 "
7.	Number of inches of 5/16ths equivalent per ton	56.95 "
8.	Number of inches of 3/8ths equivalent per ton	39.54 "
9.	Number of inches of weld (all sizes) done by foreman	3074 "
10.	Number of inches (all sizes) done by welders	112,164 "
11.	Number of hours of welders' time	2,060 hours
12.	Inches per hour of welders' time	54.4 inches
13.	Feet per day welders' time	36.26 feet
14.	Total helpers' time	580 hours
15.	Number of inches per hour of helpers' time	198.7 inches
16.	Number of hours hoisting engineer's time (Union requirement for machine attendants)	842 hours
17.	Number of inches of weld per hour of hoisting engineer's time	136.86 inches
18.	Number of hours of foreman	592 hours
19.	Number of inches (all sizes entire job) per hour of foreman's time	194.7 inches
20.	Electrode used 5/32" Una Wire 500 lbs. 3/16" Una Wire 4900 lbs. Total	5,400 lbs.
21.	Weld, per lb. of electrode wire bought	21.34 inches
22.	Inches of weld per lb. of electrode melted	30.49 "
23.	Amount of electrode melted (Assume waste as 30%: 1,620 lbs.)	3,780 lbs.
	Pounds of electrode melted per ton of steel	1-2/3ds
24.	Number of K.W.H. electricity used	13,754
25.	Number of K.W.H. used per ton of steel	6.05
26.	Number of K.W.H. used per lb. of electrode melted	3.63
27.	Number of lbs. of electrode melted by 1 K.W.H.	0.274 lb.

A DISCUSSION OF MOMENT CONNECTIONS IN TIER BUILDINGS

By Theodore Higgins*

(Presented at a meeting of the Designers' Section of the Boston Society of Civil Engineers held on December 14, 1938.)

THE design of connections in tier buildings to resist wind stresses is a problem which has already received considerable study. My remarks do not contribute much theory that is new. The objective of this paper is rather to emphasize certain phases of the problem which in general practice do not receive the attention they deserve and, if possible, to clear up some of the confusion regarding the function of rigid type connections.

Wind moments are usually distributed between the several joints in the frame by empirical methods. The more mathematically precise solutions are tedious and therefore are not much in favor. Furthermore, studies have shown that the results from the empirical methods are reasonably in agreement with those obtained by the precise methods. The location of the various masonry walls probably cause discrepancies between the figured and actual distribution at least as great as the discrepancies observed between the precise and empirical methods.

So much for the accuracy of the wind stresses used in the design of the connections.

Professor Rathburn in his studies of the data taken on the Empire State building, published in the September, 1938, *Proceedings of the American Society of Civil Engineers,* points out that the stiffening effect of the masonry in this building produces a rigidity equal to 350% of what could have been expected of the frame acting alone. The proportions of this building are such that the masonry is probably of less assistance than is the masonry on any building here in Boston, or any which is likely to be built here. This being the case, it may safely be said that, insofar as stresses resulting from wind loading are concerned, our practice in the design of connections for wind stresses is to say the least conservative.

*Chief Engineer, New England Structural Co., 310 Second St., Everett, Mass.

It is the stresses in these same connections resulting from the application of gravity loads that deserve more attention. And it is in this respect that the action of the connection becomes confused.

Not infrequently it is argued that, because of some inherent flexibility in the connections, restraints to the gravity loads are dissipated at the joints thereby eliminating or greatly reducing secondary stresses in the frame. On this hypothesis the common practice is to proportion beams for the gravity moments on simple spans; the moment of restraint is not considered in the column design; and rigid-type wind connections are proportioned to resist the wind moment only, although this moment may be only a fraction of the gravity moment if the connections do in fact restrain the members; i.e. if they are not flexible.

As far as this discussion is concerned, the effect of secondary stresses on the members of the frame is of no interest. But the question of their existence is of importance to design of the wind connections.

Since their existence hinges upon the flexibility of the connection it is important to consider this condition in detail. As used here flexibility may be defined as the ability of the connection to permit angular movement of the beam with respect to the column at the point where the two are joined. A connection would be completely flexible if this angular rotation could equal the angular change in slope of the beam at the connection when supported on a knife edge with no end restraint. And conversely the connection would be entirely flexible if no angular change takes place.

In the common type of wind connection made up of T-stubs attached to the top and bottom flanges of the beam, whatever flexibility may exist would have to be developed either by a slippage in the rivets through the beam flanges or a distortion in the fitting material. This distortion would be the sum of the elongation due to tension and shortening due to compression in the free length of the T-stub stems between the rivets through the beam flanges and the face of the column, and the deflection due to bending in the tension T-stub flange between the rivets attaching the T-stub to the column.

Assume a T-stub 8″ wide with rivets attaching it to the column located 3″ either side of the stem. Also, assume that the width of the stem is narrowed down so that the load required to produce a bending stress in the T-stub flange approaching the yield point in the metal—say 30,000#/s.i."—will produce the same stress on the net area of the stem. The gross area would be larger by the area of two rivet holes. If the thickness of the flange is 1" and of the stem ½" and the rivets are ¾" in diameter, the net area will be about 68% of the gross area, and the unit stress in the gross area about 20,000#/s.i.". Assuming that this unit stress is applied along a distance of 6" on the top and bottom fittings a total horizontal movement of about .008" may be expected. At the same time the deflection of the flange between rivets on the tension stub might produce an additional horizontal movement of .003" making a total movement of a point on the top of the beam at the connection with respect to a point below on the bottom flange of .011".

The common practice has not been to design T-stub for as much flexibility as would exist in this example. Tension rivets are crowded as close to the T-stub stem as clearances will permit, and the stems are not narrowed down except as may be required for fire-proofing. The example has been chosen to provide the maximum flexibility that can be developed even under ideal conditions.

The horizontal movement of a point at the free end of a simply supported beam may be obtained by multiplying the area of ½ of the moment diagram by the depth of the beam and dividing by EI.

For a uniformly loaded beam this distance—e—would be $\frac{MdL}{3EI}$. If there is substituted for M, the resisting value of the beam in bending, fs or $\frac{2fI}{d}$, there results $e = \frac{2fL}{3E}$, from which it is apparent that e, for any given working stress, varies as the span and manner of loading without regard to the depth of the beam.

For a beam uniformly loaded on a 26′ span so as to develop a bending stress of 18,000#/s.i.", e would be ⅛".

Referring to the distortion in the connection just investigated it is found that, unless the stresses are permitted to go beyond the yield point, the flexibility of this joint on the 26′ span would be something in the order if 9% of the connection is welded and possibly twice as great if riveted, assuming a rivet slip .01".

Admittedly these figures are at best approximate. Other factors would operate to modify them somewhat. But they are sufficiently accurate so that it may be assumed that there is comparatively little flexibility in this type of fitting.

Therefore, secondary static stresses do exist in the main members having joints designed to resist wind stresses, and consideration must be given to these static stresses in the design of the joints.

The precise determination of gravity moments in a particular joint due to restraint is only possible through an analysis of the whole frame. Such an analysis for several conditions of gravity loading, any one of which may produce the maximum joint stress, is even more of a task than similar analyses for wind stresses would be.

Where these computations have been made in connection with the design of the frame, the Engineer can furnish the fabricator with all the data required to design the connections. But in the absence of this data some other approach must be used.

A method of "safe limits" offers such an approach. By that is meant the proportioning of the several joints for the maximum restraining moment that the gravity loads are likely to impose.

The most obvious limit is the strength of the beam itself, for if the connection can without failure resist a moment which will stress the beam beyond its elastic limit, an adjustment will take place in the elastic curve tending to limit the moment to this amount.

Another obvious limit has to do with the ability of the joint as a whole to resist the moment of restraint that may be developed in any one member. If the connection of a comparatively large beam is adequate to carry a moment equal to the combined strength in bending of all the other members entering the joint, it is adequate for any duty it will be required to perform. This condition applies particularly at exterior columns with beams framing in on one side only. The column below and column above must be considered as separate members entering the joint.

Both of these limits however, if adopted without any further modifications, would impose a burden on the cost of fabrication out of proportion to benefits to be gained.

While it cannot be denied that some of the connections will, in fact, be over-stressed if the limit is lowered to two-thirds of the value of the gravity moment which the beam is required to accommodate on a simple span, there is in my opinion sufficient justification for reducing the limit to that extent.

Assume that the gravity loads are such that the bending stresses in the restrained end of the beam exceed the elastic limit. As I have already pointed out an adjustment will take place in the elastic line tending to limit the moment in the connection to the value the beam was carrying at the time of the adjustment. If the connection was designed for 2/3 of the beam moment and no distortion of the connection material occurred the maximum stress in the connection would be 50% greater than the maximum stress in the beam—a value still within the ultimate strength of the connection. But as the stress in the connection increased beyond the yield point, distortion in the connection would become more rapid causing a greater angular rotation and thereby still further reducing the moment to be carried. When stress and strain arrived at an equilibrium, the relation of connection stress to beam stress would be much less than 150%.

This is the same action that must take place when the connection is designed for a wind moment of much lower magnitude than the gravity moment except that in this case the distortion in the connection must be carried much further to arrive at an equilibrium. The final stress in the latter connection may possibly not be much higher than in the former, but the distortion may have been sufficient to injure the fitting material.

A limit for the connection design moment of 2/3 the gravity moment developed on a simple span is also suggested by the relationship that exists between the simple span moment for a beam uniformly loaded $\left(\frac{WL}{8}\right)$ and the moment at the ends of the same beam with the same load when fully restrained $\left(\frac{WL}{12}\right)$. In this case the term "fully restrained" has the same meaning as used in the tables of moment formulae for various static loading conditions published in the handbooks.

The corresponding relationship for beams designed to carry a concentrated load at mid-span $\left(\text{i.e. } \frac{PL}{4} \text{ and } \frac{PL}{8}\right)$ would suggest that the connection for beams so loaded be designed for only ½ the simple span moment. In the case of isolated heavy beams this reduction would be justified, but for ordinary framing the saving as between 2/3 and ½ would have little or no effect on the cost of the connection.

Exterior columns with beams framing on one side only are seldom fully restrained. To apply the 2/3 rule in the design of these connections would be unnecessary and wasteful in most cases. Here, however, the maximum moment of restraint can be determined approximately. The elimination of a member on one side of the column greatly reduces the number of factors that influence the rotation of the joint.

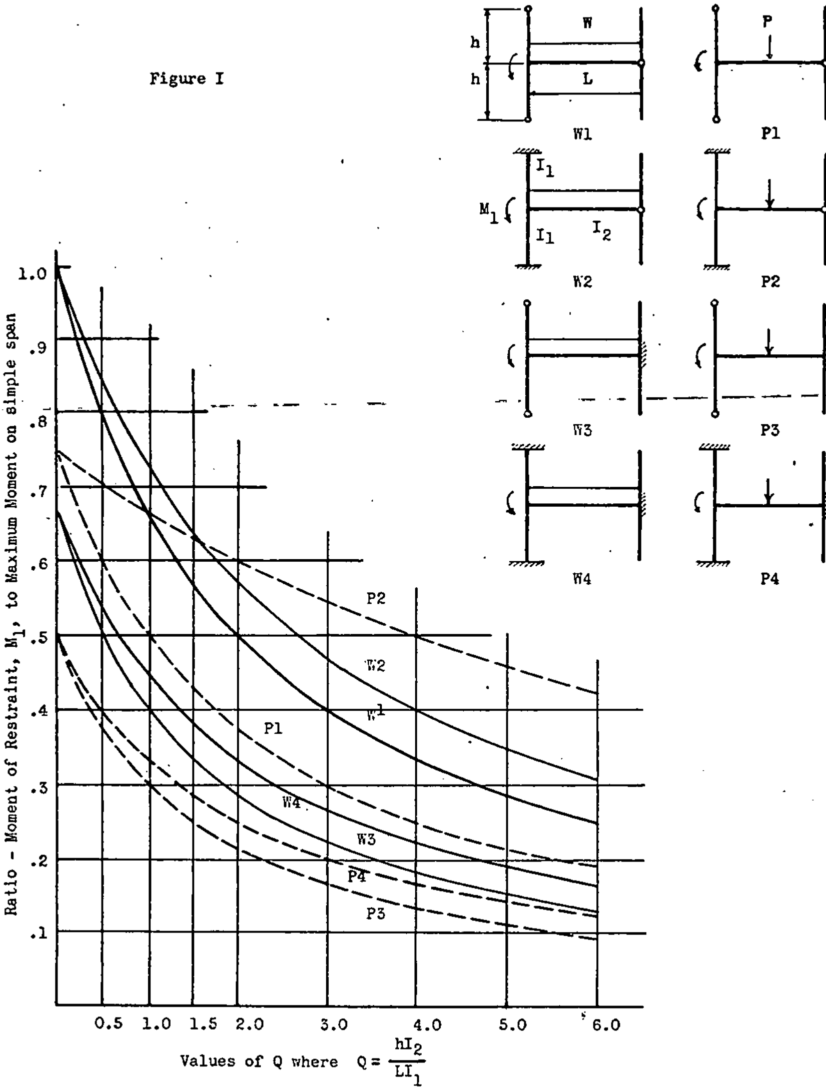

FIG. 1

The moment at the column may be approximated in terms of the gravity moment at the center of a simple span by reference to the curves in Figure 1. For these curves the abscissa, Q, expresses relative stiffness of the members entering the joint. The curves are given for various conditions of fixity at the outer ends of the members forming the joint. If Q equals or is greater than 1 the moment of restraint is less than the 2/3 limit for all conditions except where the outer end of the beam is pinned—not a common condition in wind bents. Note that as Q increases, the moments rapidly diminish.

In the design of the wind connections for the George Robert White Memorial Building, formulae were developed which discounted the reduction in restraint resulting from the elongation of the top flange T-stub under gravity loading.

The fabrication was on a shop riveted-field welded basis and, in the interest of down-hand welding and also because rivets in tension

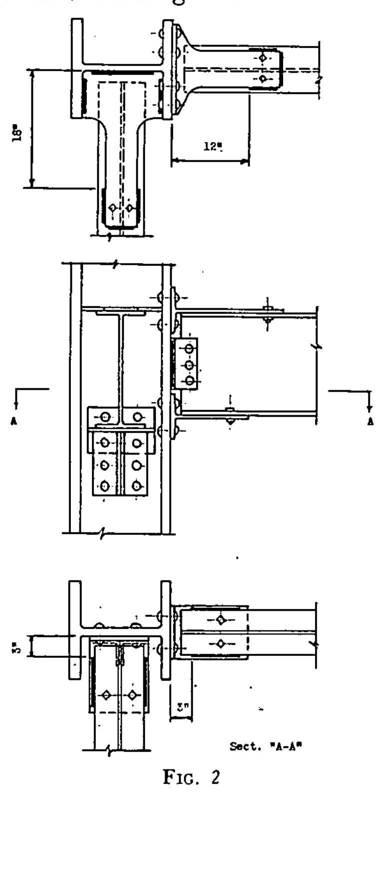

FIG. 2

were more economical than welds serving the same function, the T-stubs were riveted on the columns in the shop leaving the field welding to be employed in attaching the stubs to the beam flanges.

Figure 2 shows the typical connections that were used. The top hitch for beams framing to column webs consisted of a plate inserted after the beams were landed and then welded to both the columns and the beams.

A fixed distance of 12″ was maintained from the face of the column to the start of the field welding, and the elongation in this distance at the allowable working stress was expressed in angular rotation of the end of the beam. This rotation was subtracted from the total rotation of the ends of the beam assumed loaded on a simple span. The result multiplied by EI represented the algebraic sum of the negative and positive moment areas for ½ the span. Knowing the area for a simple span it was an easy matter to then obtain the end moment.

The practical application of this principle required a formula which would give the required area of the stem of the T-stub in tension at the allowable working stress when resisting the restraining moment that would exist after the elongation at that stress had taken place. This formula developed to be:

$$A = \frac{S}{Ld}\left(.638\ \frac{S_1 L}{S} - 1\right)$$

Where L is the span in feet
d is the beam depth in inches
S is the section modulus of the beam
and S_1 is the section modulus required on a simple span.

This area was compared with the area required for the wind moment alone and the larger area was used.

By calling for sufficient field welding to insure a strength of weld greater than the strength of the computed tension area of T-stub stem and taking precautions to insure that this area was actually used, we had positive knowledge that unexpected stress concentrations beyond the capacity of the welds would not develop. This would not have been the case, first, if the connections had been proportioned for the wind alone without thought to the possible static moments and secondly, if the ratio of weld to area of tension metal had not been carefully controlled.

In closing there is one thought I should like to leave, particularly pertinent where field welding is to be used. Other things permitting, it is highly desirable that deep girders carrying heavy loads be framed over the top of the supporting column even if it means interrupting the column and beginning it again on top of the girder. Not only is the saving in welding that would otherwise be required to carry the reaction a substantial one but, by making use of the load on the column to assist in caring for the wind moment, the connections to adjacent beams can be made sufficiently flexible to avoid restraint of the gravity moments. Such restraints on deep girders can present serious problems.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

OCTOBER 19, 1938.—A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, Karl R. Kennison, at 7:00 P.M.

This meeting was the annual joint meeting with the Student Chapters of the American Society of Civil Engineers at Harvard University, Massachusetts Institute of Technology, Tufts, Rhode Island State College, New Hampshire University, Worcester Polytechnic Institute and the Northeastern University Section of the Boston Society of Civil Engineers. The meeting was also a joint meeting with the Designers Section, Boston Society of Civil Engineers. About 225 members and guests attended, and 187 persons attended the buffet supper.

The President extended a welcome to the students and expressed appreciation of the cooperation of the officers of the student organizations and of the faculty members who had cooperated in obtaining so large an attendance.

The Secretary reported the election of the following members on this date:

Grade of Member: Irving R. Travers*.

Grade of Students: John L. Bean, Anthony R. Benedetto, Ralph S. Carr, Jr., Alfred C. Carosi, Joseph J. Cegelski, Ralph F. Crowther, Jr., Dean Freeman, Winfield B. Knight, Saul Landman, Frank J. Lariviere, Louis G. Reiniger, Henry G. Seeley, Louis H. Sinofsky, Walter E. Stone, Richard D. Sutliff, L. Gerard Wahl.

The President then introduced the speaker of the evening, Dr. Thaddeus Merriman, Consulting Engineer and former Chief Engineer, New York Board of Water Supply, Consulting Engineer, Metropolitan District of Southern California, and of the Metropolitan District Water Supply Commission, Boston, who gave an extremely interesting talk on "Portland Cement". The talk was illustrated with lantern slides.

The meeting adjourned at 10 P.M.

EVERETT N. HUTCHINS, *Secretary.*

NOVEMBER 16, 1938.—A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers Club. The meeting was called to order by the President, Karl R. Kennison. Forty members and guests attended. Thirty-two persons attended the supper preceding the meeting.

The Secretary announced the election of the following members on November 16, 1938:

Grade of Member: Michael A. Avellino, Constantine J. D'Amato, William C. Paxton, Jr., Charles M. Anderson,* Paul A. Beigbeder,* Gerald T. Pillsbury,* William A. Redfield,* Frank Venti.*

Grade of Junior: Charles A. deLuccia, Henry Campbell,† Chester F. Garland,† Robert H. Lewis,† Frederick P. Moran,† Darel O. Packard,† John S. Ross†.

The President read a letter from Theodore R. Kendall, who represented the Society at the Installation of Mr. Edwin Sharp Burdell as Director, at

*Transfer from Grade of Junior.

†Transfer from Grade of Student.

Cooper Union, New York, held on November 3, 1938.

Mr. Frank B. Walker outlined the plans for the next meeting which will be a joint meeting with the Welding Society and an excursion to the General Electric Plant at Lynn.

The President then introduced the speaker of the evening, Mr. Thomas Worcester, member of the firm of J. R. Worcester Co., Consulting Engineers, Boston, who gave a very interesting talk on the "Construction of the MacGregor Bridge at Manchester, N. H."

The MacGregor Bridge, which was opened to traffic on January 1, 1938, is a Highway Viaduct and Bridge, 1500 feet in length, crossing the Merrimack River and connecting the east and west sides of the City of Manchester. It replaces at a high level an old roadway on the surface and a three-span iron bridge over the river which was destroyed by the flood in March, 1936.

The project also includes the elimination of the grade crossing with the main line of the Boston & Maine Railroad and several switch tracks. The construction consisted of a single span steel arch over the Merrimack River with concrete arch construction at both approaches and a rigid steel frame over the railroad.

The paper was supplemented by lantern slides showing pictures taken during construction.

A question period followed the paper.

The meeting adjourned at 8:30 P.M.

EVERETT N. HUTCHINS, *Secretary.*

DECEMBER 21, 1938.—A regular meeting of the Boston Society of Civil Engineers was held this evening at the Auditorium, General Electric Company, River Works Plant, Lynn, and was called to order by Vice-President, Frank B. Walker, at 7:10 P.M.

Vice-President Walker reported upon a recommendation of the Board of Government relative to the use of the current income of the Permanent Fund.

Voted: That the Board of Government be authorized to use as much as necessary of the current income of the Permanent Fund for current expenses.

Final action on this matter will be taken at the January 25, 1939, meeting of the Society.

This meeting was a Joint Meeting with the Boston Section of the American Welding Society. Mr. Walker therefore turned the meeting over to Mr. Patrick J. Horgan, Chairman, Boston Section, American Welding Society. Mr. John Hull, Assistant to Manager of Engineering of the General Electric Company, extended a welcome to the members and guests of both Societies.

Papers were presented as follows:

"Welding Applications in the New Massachusetts General Hospital Building, Boston," by J. Theodore Whitney, President, Whitney Engineering Co., Boston.

"Welding Applications to New Gear Building, River Works," by C. T. Anderson, General Electric Co.

"Heating and Ventilating New Gear Building," by John Milo, General Electric Co.

"1500-lb. Steam Distribution System," by A. T. Comstock, General Electric Co.

During the afternoon, prior to the supper, there was a shop visitation to various sections of the General Electric Plant where welding demonstrations and work were inspected. Also, the miniature model demonstrations of street lighting was well attended, both in the afternoon and later in the evening.

The members of the Boston Society passed a vote of appreciation to the General Electric Company for its hospitality and courtesy in providing for the shop visitation, and for the opportunity to have the supper at the company cafeteria.

About one hundred and forty persons attended the evening meeting.

The meeting adjourned at 9:00 P.M.

EVERETT N. HUTCHINS, *Secretary.*

Sanitary Section

OCTOBER 5, 1938.—The regular October meeting of the Sanitary Section was held this evening at the Society Rooms, 715 Tremont Temple. Preceding the meeting, nine members and guests gathered at Patten's Restaurant, Court Street for dinner. The meeting was called to order by the Chairman, Samuel M. Ellsworth, at 7:20 P.M., with fourteen present.

Letters of resignation from the Executive Committee were read from Samuel T. Drew and Gail P. Edwards. The resignations were accepted and it was voted that the Chairman appoint a nominating committee to submit names to be voted on to fill these positions at the next regular meeting.

Prof. Curtis M. Hilliard, Head of the Department of Biology and Public Health at Simmons College, was introduced and gave a very instructive talk entitled "Public Health on the Move". Prof. Hilliard gave a brief history of Public Health work and discussed recent developments in Bacteriology, Sanitation, Housing, Pneumonia Control and Public Health Administration. After an interesting discussion, a rising vote of thanks was given to Prof. Hilliard and the meeting was adjourned at 8:50 P.M.

RALPH M. SOULE, *Clerk.*

DECEMBER 7, 1938.—A regular meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening at the Society Rooms, 715 Tremont Temple. Preceding the meeting, a group of twenty-one members and guests dined at Patten's Restaurant on Court Street. The meeting was called to order by the Chairman, Samuel M. Ellsworth, with forty-five present.

The report of the nominating committee for filling the vacancies on the Executive Committee was read by Mr. Francis H. Kingsbury. It was recommended that the clerk be promoted to the position of vice-chairman of the Section but that he retain the duties of clerk until after the annual meeting and that Mr. John W. Greenleaf be elected to serve on the Executive Committee. There were no further nominations and it was voted that the report be accepted and placed on file and that the clerk cast one ballot for the election as recommended by the nominating committee. This was done in due form.

Mr. George A. Sampson of the firm of Weston and Sampson, Consulting Engineers, presented a paper on the Sewage Disposal Plant at Keene, N. H. Mr. Sampson discussed various problems encountered during the construction and early operation of the plant and illustrated his talk with slides.

Mr. George F. Brousseau, Superintendent of Sewers in Braintree, Mass., presented a paper on the Construction and Maintenance of Sewers in Braintree, in which he illustrated by slides various breakdowns and unit costs on sewerage construction in Braintree.

Considerable interest was shown in both papers by the discussion which followed. A rising vote of thanks was given to both speakers and the meeting adjourned at 8:50 P.M.

RALPH M. SOULE, *Clerk.*

Designer's Section

OCTOBER 19, 1938.—Due to the fact that the regular meeting for October would come on October 12th, a holiday, the section accepted the hospitality of the main society, and joined its Student Night, held October 19, 1938, at Chipman Hall, Tremont Temple, at 7:00 P.M.

The speaker was Mr. Thaddeus Merriman, Consulting Engineer, whose subject was "Portland Cement." Mr. Merriman prefaced his technical talk with remarks particularly for the benefit of the student members.

This section wishes to express its

thanks to the main society for the opportunity to participate in that meeting.

ANTHONY S. COOMBS,
Chairman and Clerk pro tem.

DECEMBER 14, 1938.—A regular meeting of the Designers' Section was held at the Society Rooms this evening and was called to order at 6:30 P.M. The speaker was Mr. Theodore Higgins, Chief Engineer of the New England Structural Company, whose topic was "Girder Connections for Wind Moment."

Mr. Higgins outlined the development of types of girder-to-column connections, the purpose of which is to be sufficiently flexible to allow for end restraint in the girders and at the same time be rigid enough to resist wind moments. The talk was supplemented with charts and diagrams with the reflectoscope. A discussion period followed. The attendance at the meeting was 40.

Respectfully submitted,

ANTHONY S. COOMBS,
Chairman and Clerk pro-tem.

Highway Section

NOVEMBER 30, 1938.—A regular meeting of the Highway Section of the Boston Society of Civil Engineers was held in the Society's room, 715 Tremont Temple, this evening. The meeting was called to order at 7:10 P.M. by the Chairman, Mr. Thomas C. Coleman.

The minutes of the previous meeting were read and accepted.

The Chairman appointed the following members to be the Nominating Committee for officers for the coming year:

Professor H. B. Alvord
Professor A. J. Bone
Mr. G. A. Graves

The Chairman then introduced the speaker of the evening, Mr. Earl F. Bennett, Soils Engineer for the Maine State Highway Commission and Instructor in Civil Engineering at the University of Maine who spoke on the subject "Soil Mechanics Applied to Highway Engineering".

Mr. Bennett told of his pioneer work in the development of soils survey and soils tests in connection with work of the Maine State Highway and Bridge work, and finally the establishment of his laboratory at the University of Maine in Orono.

He spoke of the benefit derived from his surveys in locating available sources of supply of gravel and borrow material for use on highway projects, both to the contractors in estimating jobs and to the Commission in obtaining competitive prices.

His description of his work in exploring sub-surface conditions for structures by test pits, soundings, soil augers and wash borings proved interesting. Finally we were treated to a showing of several reels of moving pictures taken by the speaker showing his work in supervising the settlement of fill over swamps by the use of explosives. The slow motion parts showing the raising of the mass of fill and then its action in pushing out the muck when it dropped proved very enlightening.

The audience showed how interested it was in the talk by a rising vote of thanks.

The meeting adjourned at 9:00 P.M. with an attendance of 42 members and guests.

ARTHUR E. HARDING, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[January 20, 1939]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

BLISS, E. HAYWARD, Wakefield, Mass. (b. May 21, 1911, North Providence, R. I.) Graduated from Wakefield High School, June 20, 1929; attended Northeastern University, 2 years of civil engineering curriculum on co-operative plan September, 1930 to June, 1932, and was with Metropolitan District Water Supply Commission on co-operative work from October, 1931 to June, 1932. May 17, 1932 until present time as rodman, instrumentman, inspector, draftsman, computator, and chief of party with Metropolitan District Water Supply Commission in Enfield, Boston and Natick. Refers to E. S. Averell, J. F. Brittain, K. R. Kennison, C. C. McCully, F. E. Winsor.

COLETTI, ALFRED, Newton, Mass. (Age 31, b. Newton, Mass.) Educated in the Newton Public Schools and Newton High School, class of 1925; Lowell Institute, building course, class of 1930; Franklin Union, surveying course, class of 1934. From 1926-1929, as apprentice foreman and 1929 to 1932 as foreman with P. J. O'Malley. 1932 to 1936 with Newton Engineering Department as transitman for a field party. and from 1936 to present time with Newton Engineering Department as senior engineering draftsman. Refers to S. L. Conner, J. N. DeSerio, W. P. Morse, A. Q. Robinson, P. R. Vandersloot.

HYLAND, GEORGE G., Boston, Mass. (Age 32, b. Boston, Mass.) Graduate of Mechanic Arts High School, 1923. Took evening courses at Northeastern University, Franklin Union and State University Extension, majoring in Civil Engineering; 1923 to 1925, with Stone & Webster, Boston, Mass., as messenger and tracer; 1925 to 1929, with City of Boston, Transit Department, as rodman and transitman in charge of line and grade survey party; 1929 to 1930, assistant superintendent Peerless Construction Co., constructing six mile road job, Braintree; 1930 to 1934, engineer in charge of lines, grades and estimates in the construction of the Boylston Street Subway extension at Kenmore Square and in charge of line and grade work for street widenings on Boston side of Summer Vehicular Tunnel; 1934 to 1938, resident engineer in charge of laying 15,000 ft. of 48" steel pipe in Jamaica Plain for Water Department, Public Works Department, City of Boston. Since June 21, 1938, Commissioner of Public Works, City of Boston, Mass. Refers to G. F. Haskell, W. T. Morrissey, T. H. Sexton, A. D. Weston.

SMALLCOMB, JOSEPH HENRY, South Boston, Mass. (Age 37, b. South Boston, Mass.) Graduated from Frederic W. Lincoln School, South Boston, 1915; Mechanic Arts High School, 1915-17; Chicago Technical College, 1928-29; Franklin Union, 1930; Lowell Institute, 1930-31. Experience: 1917-18, U. S. Quartermaster Department; 1919-21, draftsman, Keefe Construction Company, Quincy, Mass.; 1921-25, rodman, transitman, Love and Touhey, San Diego, California; 1925-27, draftsman, L. A. J. Rose Construction Co., Reno, Nevada; 1927-31, draftsman, estimator, Cundari Engineering Company, Boston, Mass.; 1931-35, in business for myself as a licensed builder in Boston, Mass.;

1935-37, E.R.A.-W.P.A., Boston, Mass., as an engineering draftsman and senior civil engineer in Bridge and Ferry Division, City of Boston; senior civil engineer on Project Planning Board; senior civil engineer Boston Park Department; supervisor of construction, Sewer Department, City of Boston; supervisor of highway construction, Massachusetts Department of Public Works; 1937, special investigator, building operations, Massachusetts Department of Labor and Industry; 1937 to present time, engineering draftsman, Massachusetts Department of Public Works. Refers to T. C. Coleman, T. G. Giblin, G. A. Graves, R. W. Johnson.

For Transfer from Grade of Junior

JENNESS, GEORGE WILTON, Hanover, Mass. (b. April 9, 1909, Pembroke, Mass.) Graduated from Sylvester High School, Hanover, Mass., June, 1927; attended Tufts College, September, 1927 to February 1928; Thayer Academy, Braintree, 1928-1929. Was graduated from Northeastern University June, 1934, with degree of B.S. in Civil Engineering. During co-operative periods at Northeastern University, in highway division of Massachusetts Department of Public Works, October 22, to November 16, 1930 and May 22, to June 1, 1931. Was graduated from Northeastern University June, 1934. March 19 to 29, 1935, with Lewis W. Perkins, Plymouth County Surveyor, North Scituate, Mass.; with W. G. Ford, Marshfield, Mass., private surveyor, several weeks since and during summer of 1935; November 22, 1935, to April 8, 1937, engineer on P.W.A.—historic American landscape architecture, plotting and drawing contours. Fall of 1937 and summer of 1938 made out project slips and drew up plans and acted as supervising engineer on grading at Norwell High School, Norwell, Mass.; May 3 to 24, 1937, transitman with W. W. Churchill, Milton, and May 25 to July 22, 1937, transitman with E. M. Brooks, Newtonville, Mass. Since June, 1934, have made private surveys in Norwell, Hanover, Hansen, Pembroke, Marshfield and Hatfield, Massachusetts. At present with George A. Griffin, C.E. Woods Hole, Mass., as chief of party. Refers to H. B. Alvord, F. L. Flood, R. N. Mayall, W. C. Whiting.

KOMICH, JOHN B., South Boston, Mass. (b. February 2, 1911.) Graduated from Northeastern University, degree of B. in Civil Engineering, in 1932 and degree of B.S. in Civil Engineering in 1933. During co-operative periods at Northeastern University with Aspinwall & Lincoln, Civil Engineers, Boston, Mass. Experience: August 1932 to May, 1934, instrumentman and chief of party on highway construction, Public Works Department, Highway Division, City of Boston; June to July, 1934, with E. M. Brooks, Civil Engineer, Newtonville, Mass., as calculator and draftsman computing traverses and making final tracings for Mass. Land Court Surveys; July 1934, to June 15, 1935, with Steadfast Rubber Company, Mattapan, Mass., as foreman and inspector curing concrete pavements to meet highway specifications of states of Pennsylvania and Illinois. June 15, to September 5, with U. S. Engineer Office, Boston, Mass., as surveyman operating instruments on harbor and river surveys; October, 1935, to April, 1936, with U. S. Engineer Office, Eastport, Maine, as surveyman and chief of party on general building construction; April, 1936, to present time with U. S. Engineer Office, Boston, Mass., chief of party on river and harbor surveys throughout New England. Refers to H. B. Alvord, C. O. Baird, Jr., L. A. Chase, J. A. C. Komich.

For Transfer from Grade of Student

CARUSO, JOSEPH JOHN, Roslindale, Mass. (Age 23, b. Mattapan, Mass.) Graduated from Boston English High

School, 1933, and Northeastern University, 1938, with degree B.S., in civil engineering. September, 1936 to November, 1937, as a co-operative student with Henry F. Bryant & Son, Brookline, Mass., as transitman, rodman and inspector; November, 1937, to January, 1938, part time transitman with Holyhood Cemetery Association, West Roxbury, Mass.; June, 1938, to November, 1938, supervisor of maintenance, Northeastern University, Boston, Mass. November, 1938 to date, junior engineering aide, Metropolitan District Water Supply Commission, Marlborough, Mass. Refers to H. B. Alvord, C. O. Baird, Jr., A. E. Everett, Jr., E. A. Gramstorff.

DALLAS, JAMES LORNIE, Beverly, Mass. (Age 25, b. Beverly, Mass.) Graduated from Northeastern University, 1937, with degree of B.S.C.E. and Harvard Graduate School of Engineering, 1937, with degree M.S.S.E. May to July, 1935, with Whitman and Howard, transitman on construction of Suffolk Downs; August - September, 1935, with M. McDonough Company, as transitman on construction of Agawam Race Track; May, 1936, with Aspinwall and Lincoln, as transitman on Old Harbor Housing Project; May - August, 1936, with Massachusetts Department of Public Works, as a junior engineering aide on highway construction; August - September, 1936, with Engineering Department, City of Beverly, Mass. With Massachusetts Department of Public Health, Division of Sanitary Engineering, from July, 1937 to June. 1938, as senior sanitary engineering aide; June, 1938 to present time, as junior sanitary engineer. Refers to H. B. Alvord, G. M. Fair, F. H. Kingsbury, J. E. Lawrence, A. D. Weston.

ADDITIONS

Members

CHARLES M. ANDERSON, 8 Oxford St., Somerville, Mass.

MICHAEL A. AVELLINO, 706 Hyde Park Avenue, Roslindale, Mass.

HAROLD G. HERSEY, Hampton, N. H.

WILLIAM C. PAXTON, JR., 22 Forest St., Lexington, Mass.

WILLIAM A. REDFIELD, 77-44 Austin Street, Forest Hills, N. Y.

FRANK VENTI, 50 Neptune Road, East Boston, Mass.

Juniors

RICHARD G. BERGSTROM, 150 Jenness Street, Lynn, Mass.

HENRY CAMPBELL, 12 Pearl Street, Stoneham, Mass.

ROBERT H. LEWIS, 53 Pequissette Road, Belmont, Mass.

FREDERICK P. MORAN, 102 Bridge St., Newton, Mass.

JOHN S. ROSS, 305 Corey Street, West Roxbury, Mass.

JOHN N. SQUAREBRIGS, 55 Vernon St., Brookline, Mass.

Student

FENTON G. KEYES, 83 Central Avenue, Newtonville, Mass.

DEATH

HARRY E. SAWTELL . . Jan. 3, 1939

BOOK REVIEWS

*"Sundials, how to know, use and make them," by R. Newton Mayall and Margaret L. Mayall. 197 pp. Illustrated. Boston. Hale, Cushman and Flint, $2.00**

Mr. and Mrs. R. Newton Mayall, the former a member of our Society, have pursued astronomy as a hobby to such an extent that they have collected a great deal of information about sundials, the devices used for reckoning time by light from the sun.

Their book not only is replete with historical data concerning the develop-

*By Albert Haertlein, Associate Professor of Civil Engineering, Graduate School of Engineering, Harvard University, Cambridge, Mass.

ment of all sorts of sundials, but also, and this should be of particular interest to civil engineers, gives detailed accounts of how to build many different types, classifying them as spherical, conical, plane and portable. The merits of making one's own rather than purchasing a ready-made product are emphasized. He who has observed only the common garden variety, the horizontal plane type, will be amazed to learn about the skill and ingenuity which has been put into these devices. The heliochronometer, the peer of all sundials, is as carefully made as a fine watch or clock and gives standard time to within a few seconds. The authors tell us that such was the standard to which railroad watches in France were set as late as 1900.

Many examples are illustrated and described in considerable detail. The world's largest is at the Jaipur, India, occupying nearly an acre of ground. It was built in 1724. In contrast is illustrated a small portable instrument, 7" long, 2½" wide and 1" high, made in Japan. It contains in addition to the small brass hemisphere, an inkwell, compass, abacus, brush for writing, pair of scissors, two ivory-handled drills or needles and a knife. This and other similar dials are in the Ernst Collection, on display at the Harvard College Observatory in Cambridge—said to be the best collection of portable sundials to be found anywhere. The authors acquaint us with other types of sundials which can be seen nearby. The armillary on the campus at Phillips Academy in Andover, Massachusetts, is one of the finest in this country; the limestone dial at Boston College in Newton is another artistic prize.

The authors are to be commended for their selection of photographs of interesting objects as well as for presenting detailed and explicit directions to amateurs as well as to skilled craftsmen for the building of all sorts of sundials.

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