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The Canadian Engineer

A Weekly Paper for Civil Engineers and Contractors

Point St. Charles Filtration Works, Montreal

Results of First Year's Operation—Output from Start Slightly Over Full Rated Capacity—Efficiencies During Last Nine Months from 96.2% to 99.1% Without Chlorination, and from 98.1% to 99.8% With Chlorination

DURING the twelve months ended June 30th, 1919, constituting the first year's operation, the Point St. Charles filtration works, Montreal, averaged 50.3 million gallons daily of filtered water. This is slightly more than the full rated capacity, the plant having been designed for a nominal daily output of 50 million gallons.

Montreal's requirements have grown to such an extent that the output of this municipally-owned plant was insufficient, despite the fact that thousands of consumers are supplied by another plant (owned by the Montreal Water & Power Co.); therefore an average of 12.8 million gallons of raw river water was added daily to the 50.3 million gallons of filtered water, and the mixture was effectively chlorinated.

The accompanying table gives the results of the daily chemical analyses, averaged for each month. July, 1918, was the first month after operation commenced for which complete data of all laboratory tests are available, the months of April, May and June, 1918, having been required for regulating the plant and correcting intake troubles due to frazil. In this first month of actually complete operation, with a raw water count of 530, the pre-filters showed 87.9% bacterial efficiency, and the final filters, 95.3%. The filtered water was mixed with 16.1 million gallons of raw water, and the mixture was chlorinated, the final bacteria count of the water as delivered to the mains showing 93.7% removal.

The bacteria-removal figures vary considerably until the end of September, 1918, at which time the plant appears to have been "tuned up" to an average condition or efficiency.

From October, 1918, to June, 1919, both months inclusive, the final filter bacterial efficiency ranged from a minimum of 96.2% in June, 1919, to a maximum of 99.1% in May, 1919. The bacteria-removal of the combined raw and filtered water (after chlorination) ranged, in the same period, from a minimum of 98.1% in October, 1918, to a maximum of 99.8% in April, 1919.

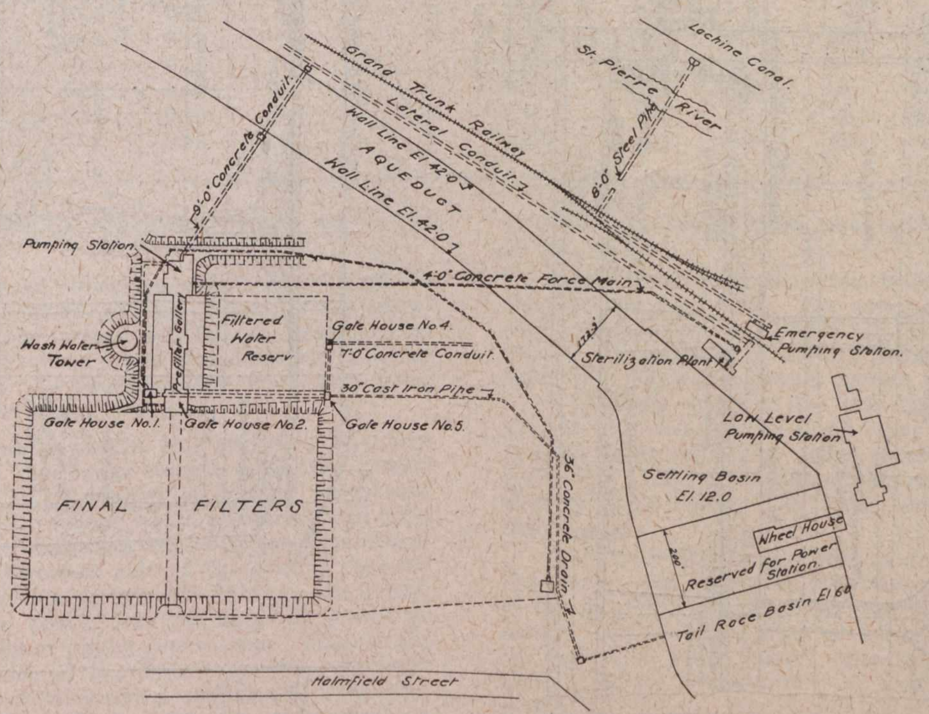

Fig. No. 1—General Plan of Filtration Works

The plant has both a shore intake and a mid-stream intake situated about two miles above the Lachine Rapids of the St. Lawrence River. From an entrance gate chamber which receives the supply from both intakes, a concrete conduit, 8.5 ft. in diameter, formerly conveyed the water to the low level pumping station, from which it was pumped through the distributing mains to the city's reservoirs.

For many years the excessive number of cases of and deaths from typhoid fever had demonstrated to Montreal's citizens the necessity of improving the quality of the water used for domestic purposes. The increasing pollution of the water supply, due to the discharge of sewage and other impurities from towns within the drainage area above the intakes, is indicated by Fig. No. 8, which shows graphically the total number of deaths, and the death rate per 100,000 population, from typhoid fever for a long period of years.

During the late fall and winter of 1909-1910, a severe epidemic of typhoid fever prevailed in Montreal and its suburbs, and occasioned 203 deaths between October 1st, 1909, and March 1st, 1910. The necessity for prompt action was recognized by the city officials, and the chlorination of the municipal water supply was started February 8th, 1910, and has been regularly continued to the present time.

Hering & Fuller, consulting engineers, New York City, were instructed April 4th, 1910, to report on the best means of securing an improved water supply. These engineers submitted their report July 2nd, 1910, and recommended filtration of the St. Lawrence River water. Their recommendation was adopted and they were engaged to co-operate with the late Major Georges Janin, then city engineer, in preparing plans and specifications and in supervising the construction of the works.

A 9 ft. concrete conduit, connected to the 8.5 ft. main supply conduit previously mentioned as having supplied the low level station, brings the untreated St. Lawrence River water to the filtration pumping station. The purpose

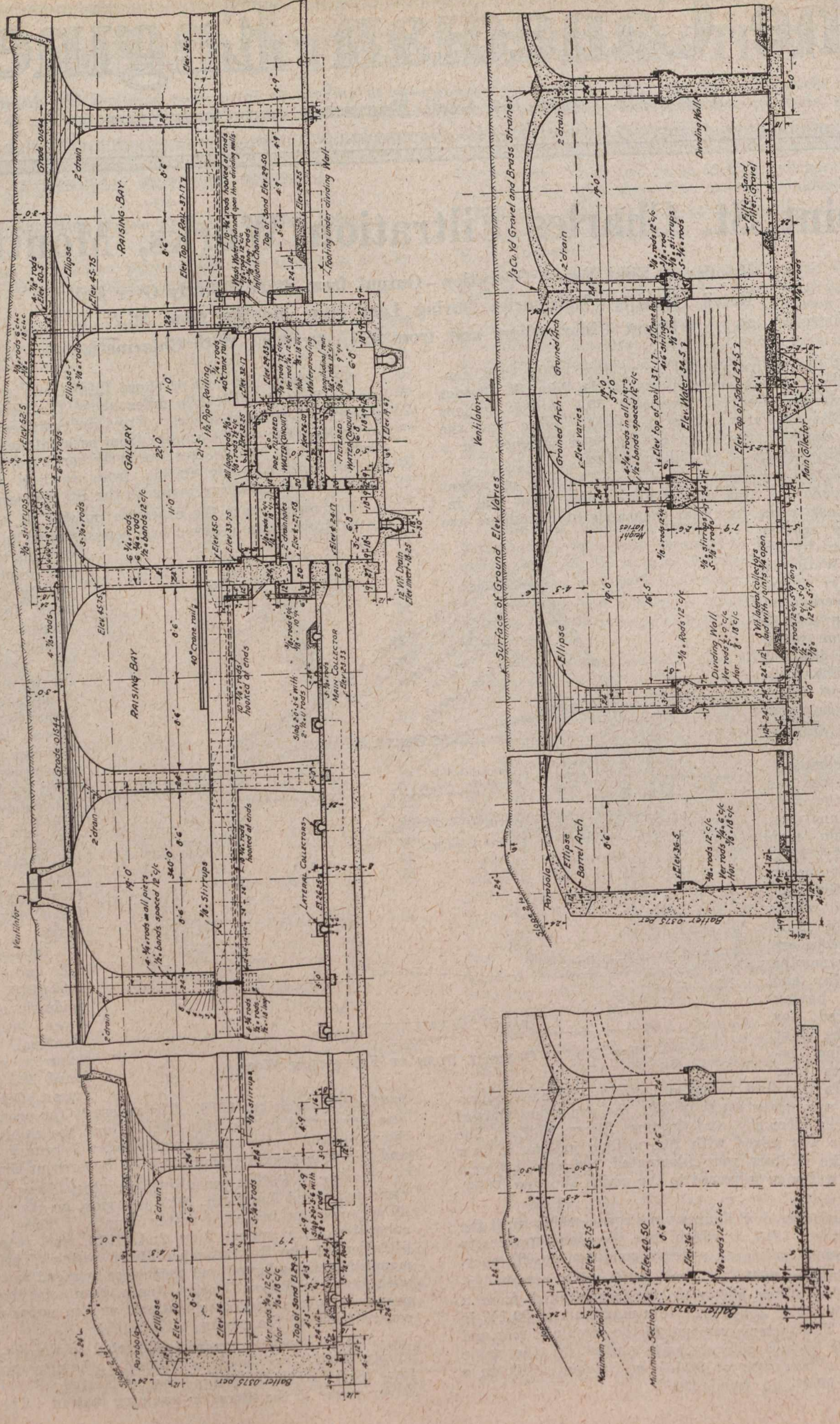

FIG. NO. 2—SECTIONS THROUGH FINAL FILTERS, POINT ST. CHARLES FILTRATION WORKS, MONTREAL of this pumping station is to lift the water to the prefilters, a height of approximately 18 ft., and to furnish water at a higher pressure for washing the prefilters at times of cleaning.

From the prefilters, or rapid filters, which form the first step in the purification process, the water flows by gravity to the final filters, which are quite similar in construction to slow sand filters. Passing through the final filters, the water flows into the filtered water reservoir, and is subsequently chlorinated.

From the filtered water reservoir, the water flows to the filtration pumping station, from which it is pumped to the low level pumping station, where it is forced by high pressure pumps through the distributing mains and to the city's reservoirs.

Should the proposed aqueduct enlargement work be completed, the filtered water will not return to the filtration pumping station but instead will flow by gravity from the filtered water reservoir to a new hydro-electric pumping station at the end of the aqueduct, and from that point will be delivered to the mains.

The filtration pumping station is a two-story structure about 80 ft. by 60 ft. The lower story is below the ground level and is traversed by the raw-water suction conduit and the raw-water discharge conduit, which are placed one upon the other. The direct-connected, motor-driven centrifugal pumps are arranged on either side of the central conduits in such manner as to obtain their supply from the lower, or suction conduit, and deliver into the upper or discharge conduit with a minimum of piping connections. Four of the pumps on the north side of the station are also similarly connected to a filtered-water suction conduit and a filtered-water discharge conduit, and provided with suitable check and controlling valves, equipped with standard hydraulic cylinders. This permits of one or all of these pumps on the north side of the station to be used for delivering filtered water to the low level pumping station. Should a new hydro-electric pumping station be completed, and the filtered water flow to it by gravity, all raw water pumps in the filtration pumping station will be available for supplying the filters.

The pumping station includes the following units:—

4 Raw water pumps	17,500 Imp. gals. per min.
2 Raw water pumps	11,600 Imp. gals. per min.
2 Raw water pumps	5,800 Imp. gals. per min.
2 Wash water pumps	1,300 Imp. gals. per min.
1 Sump water pump	330 Imp. gals. per min.
1 Sump water pump	150 Imp. gals. per min.
1 Three-inch hydraulic pressure pump	90 lbs. pressure.
1 Rotary blower	5,000 cu. ft. air per min.

All of these pumps, with the exception of the 3-in. hydraulic pressure unit, were installed under the original contracts. The 3-in. pump was installed for emergencies, to keep the pressure in the new hydraulic system uniformly 90 lbs.

The blower and the wash water pumps are used in cleaning the pre-filters. The sump pumps remove seepage and drainage water. The six largest pumps and the blower are operated by motors using 2,200-volt alternating current. The other pumps operate under 550-volt current.

The upper story of the pumping station is above the ground level and, similar to all other buildings of the plant, has red brick walls and cinder concrete roofs covered with green tile. The north side of this upper story contains the chemical laboratory. The south side contains rooms for storage, etc.

The pre-filters, located east of and adjoining the pumping station, and supported by groined arches above the roof of the filtered water reservoir, are sixteen in number, each having a net filtering area of 1,200 sq. ft., arranged eight on each side of a central operating gallery. Each prefilter is divided longitudinally by a central gutter into which empty the sixteen lateral reinforced concrete wash water gutters. The strainer and air system is made up of cast iron headers and 2-in. cast iron laterals, with brass strainers spaced at 6-in. centres. The filtering material consists of 15 ins. of gravel, graded into four sizes and placed in corresponding layers, and 30 ins. of filter sand. The details of a pre-filter unit is shown in Fig. No. 4.

Longitudinally through the centre of the operating gallery are two concrete conduits, placed one upon the other.

TABLE SHOWING PERFORMANCE DURING PAST YEAR OF POINT ST. CHARLES FILTRATION WORKS, MONTREAL

	Average Daily Consumption				Turbidity			Bacteria Count				Bacterial Efficiency—Per cent.		
1918	Filtered Water	Raw Water	Total Water	Chlorine Used P.P.M.	Raw Water	Pre-filtered Water	Finally Filtered Water	Raw Water	Prefiltered Water	Finally Filtered Water	Raw and Filtered Water Mixed—After Chlorination	Pre-filters	Prefilters and Final Filters	Filtration and Chlorination of Mixed Water
July	...49.3	16.1	65.4	0.22	10	5	2	530	64	25	33	87.9	95.3	93.7
Aug.	...50.1	16.4	66.5	0.22	10	4	2	375	46	31	17	87.7	91.8	95.4
Sept.	..50.8	14.4	65.2	0.14	10	4	2	450	49	32	9	89.1	92.9	98.0
Oct.	...50.8	11.8	62.6	0.18	12	5	2	951	231	26	18	75.7	97.3	98.1
Nov.	..50.7	11.1	61.8	0.23	20	7	2	1,936	618	34	18	68.1	98.2	99.0
Dec.	..50.7	10.6	61.3	0.24	16	6	2	3,050	1,360	57	15	55.4	98.1	99.4
1919														
Jan.	...50.5	12.9	63.4	0.22	8	4	2	2,950	940	31	6	68.1	99.0	99.7
Feb.	...51.2	10.7	61.9	0.12	7	3	2	2,380	700	30	15	70.6	98.8	99.3
Mar.	...50.6	11.1	61.7	0.19	10	4	2	8,690	2,650	226	57	69.5	97.4	99.3
Apr.	...46.9	12.9	59.8	0.60	28	6	3	9,520	1,836	117	20	80.7	98.8	99.8
May	...50.5	9.6	60.1	0.60	18	7	3	5,500	440	50	20	92.0	99.1	99.7
June	..51.0	16.2	67.2	0.53	15	6	2	1,477	132	55	22	92.4	96.2	98.5

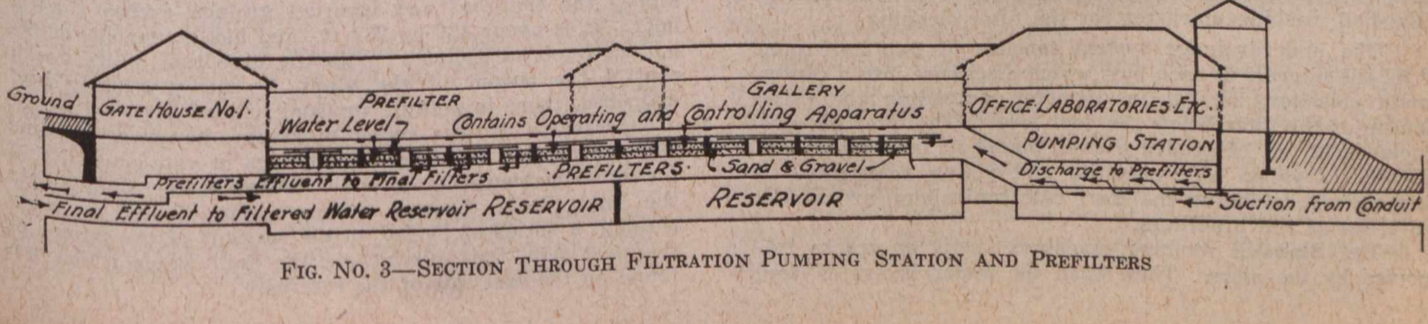

FIG. NO. 3—SECTION THROUGH FILTRATION PUMPING STATION AND PREFILTERS

The upper one is the raw water supply conduit from the filtration pumping station and the lower is the pre-filter effluent conduit leading to the final filters. These two conduits are connected to the pre-filters by cast-iron piping with hydraulic controlling valves. All these valves and also the valves for wash water, air and drainage are controlled from sixteen operating tables on the gallery floor, each table being located in front of its corresponding filter.

For controlling the rate of filtration, rate controllers of the "Earl" type are provided. These are so connected to a master controller that the discharge from the pre-filters is automatically adjusted to the discharge from the final filters, which in turn is similarly controlled automatically by leaving the sand bed clean and uniform, and pump away to the drains all dirt and other foreign matters which may have accumulated since the previous washing. All this is accomplished at one operation and by one operator. Among the advantages of this method of cleaning the filters, says Fred E. Field, assistant superintendent of water works of city of Montreal, are that the length of time the filter is out of service is a minimum, being from 6 to 8 hours only; the removal of the dirt from the sand is more complete than can be done by hand cleaning, as the cleaning process extends to any desired depth below the surface of the sand; the sand bed is left more uniform and without the compacting which accompanies walking over the sand by work-

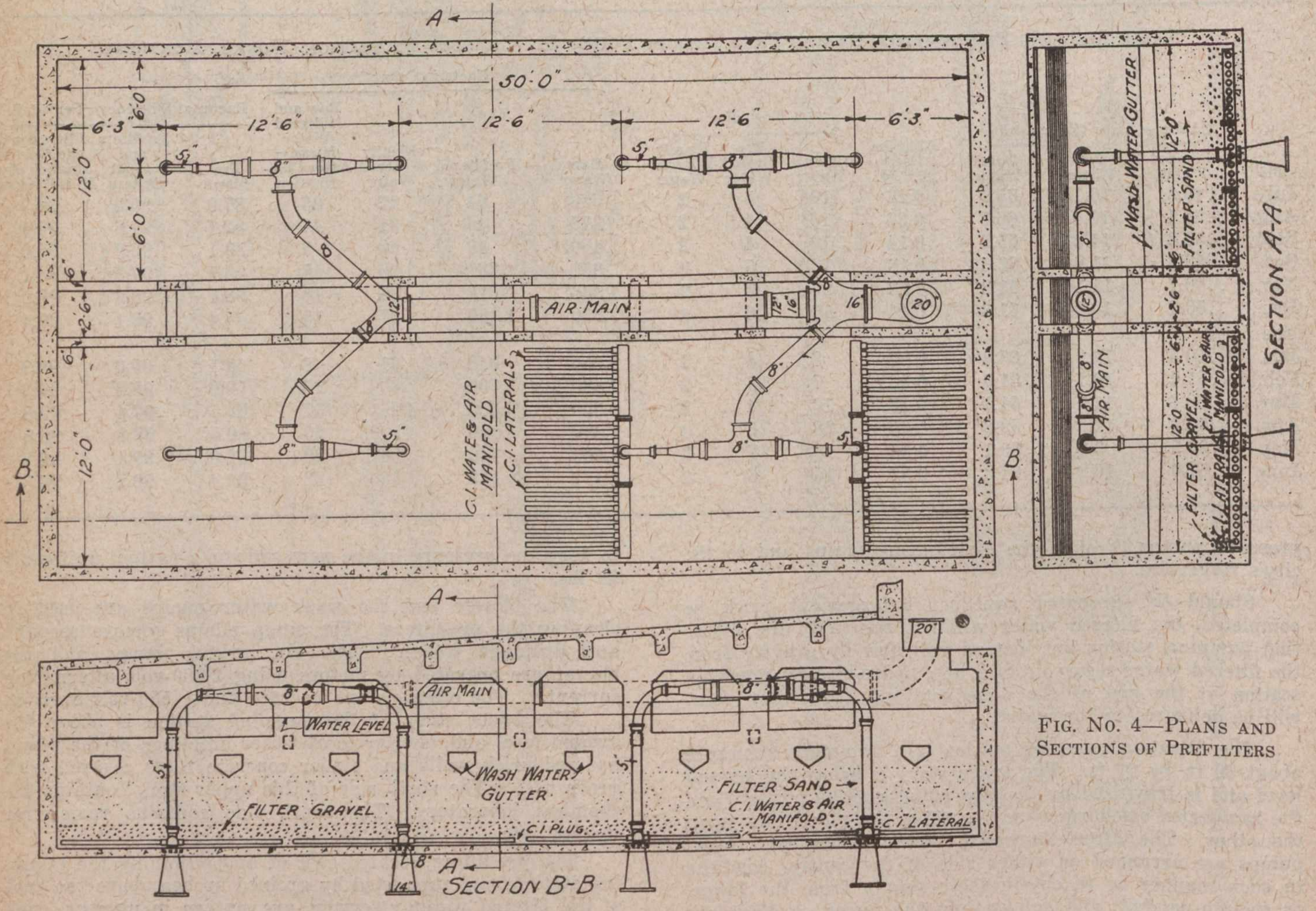

Fig. No. 4—Plans and Sections of Prefilters

the amount of water being drawn from the filtered water reservoir. In other words, the plant as a whole delivers filtered water at the same rate as it is used in the city, without manual operation of the many controlling valves.

The final filters are sixteen in number and, similarly to the pre-filters, are arranged eight on each side of the operating gallery. The filters are covered by groined arches supported by piers spaced at 19 ft. centres. The pier load is carried on foundation blocks independently of the rest of the floor, which is flat and but 5 ins. thick. The filters are each 55 by 340 ft., inside measurements, with the short dimension adjoining the gallery to accommodate the use of Blaisdell washing machines for the filter cleaning.

The underdrainage system consists of two half-round 8 in. tile laterals in each bay, which discharge into a central main collector, 2½ ft. in diameter, extending the entire length of the filter below the floor level. The filter material includes 12 ins. of graded gravel, placed in four layers, and 27 ins. of sand. The conduits and piping connections in the gallery, including the Earl rate controllers, are similar to those of the pre-filters.

The Blaisdell washing machines travel on tracks supported by the piers. They wash the upper layers of sand, men; there is no break in the routine of the work during the winter and no decrease in the effective filtering area.

A heating and ventilating system is provided to prevent skim ice forming during the winter months and interfering with the free movement of the washing machines, and also to make the plant more healthful and comfortable for the workmen. This system consists of a fan and air ducts so arranged that heated air can be blown uniformly over the entire area of the filters. It was not found necessary, however, to use this system during the past winter.

The filtered water reservoir is of concrete, with groined arches for the roof and inverted groined arches for the floor. It is about 430 by 232 ft., and has a capacity of 6¼ million Imperial gallons. With the exception of its use to control the output of the plant, as has previously been described, there is nothing unusual in its design or method of operation. It was found necessary, however, in June, 1918, to place a bulkhead of stop-logs in gate-house No. 3, for its entire depth, to force the filtered water coming from the final filters through the east side of the reservoir, through a series of baffles, to the suctions of the pumps on the west side, thus eliminating the dead water which was found on the east side of the reservoir.

A butterfly valve was also placed on the filter effluent to prevent overflow of the filtered water reservoir into the pumping station. This valve can be closed rapidly but, in so doing, the final filters are disturbed. The usual practise, on occasion of power failure, if of more than five minutes' duration, is to close the sixteen filters by releasing each automatic valve. This, while not so rapid as the action of the butterfly valve, preserves the filter formations intact.

The filtration works uses electric current for power, heating and lighting. The city obtains current from the Montreal Light, Heat & Power Co., which has a 10,000-volt transmission line near the works. Branch connections from this transmission line bring 10,000-volt alternating current to the filtration transformer building, where it is reduced to 2,200 volts and then transmitted through an underground conduit system to the filtration buildings. Here it is used at 2,200 volts for the motors operating the main pumps or reduced by transformers to 550 and 220 volts for other machinery and for lighting and heating.

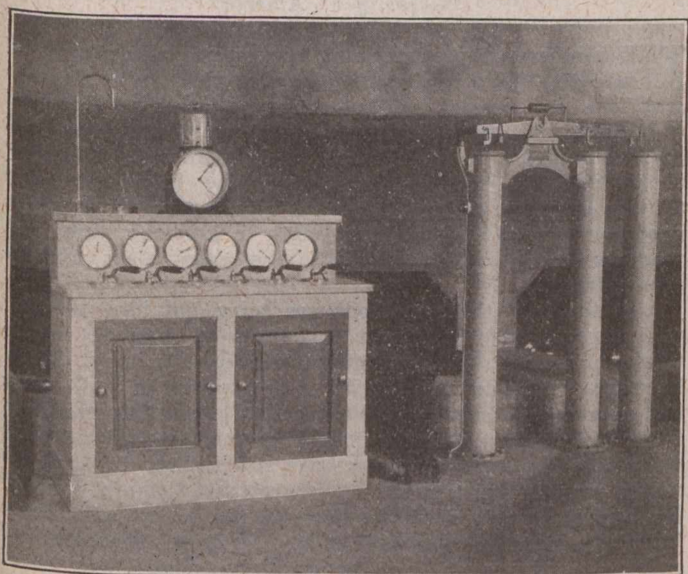

FIG. NO. 5—PREFILTER OPERATING TABLE AND AUTOMATIC CONTROLS

Heating throughout the entire works is accomplished by means of electric radiators.

The Blaisdell machines require direct current. Consequently a motor-generator set is provided to supply this current to the machine motors through the three miles of double trolley lines by which the machines are operated in the final filters.

The cost of the plant is given in the following table:—

FILTRATION CONTRACTS

	Cost
Pumping machinery, blower and cranes, British Electric Plant Co.	$ 40,250.00
Final filters and appurtenances, F. H. McGuigan, transferred to Norman M. McLeod	674,436.20
Prefilters and filtered water reservoir, F. H. McGuigan, transferred to Norman M. McLeod	498,782.30
Pumping station, wash-water tower and buildings, F. J. Jago Co.	160,076.00
Interior painting, Charles Larin	1,815.42
Exterior electrical conduit system, G. M. Gest.	6,069.80
Underground electrical cables and appurtenances, Northern Electric Co., Ltd.	12,627.04
Transformer building, city of Montreal	6,000.00
Total cost	$1,400,056.76

The operating tables, gauges, the strainer system and other filter equipment were supplied by the Roberts Filter Mfg. Co., of Darby, Philadelphia, Pa. The rate controllers were supplied by the Pittsburgh Filter & Engineering Co., of Pittsburgh and Oil City, Pa.

After practically all of the above contracts were completed, the operation of the plant was prevented by the lack of proper filter sand. The earlier contractors endeavored to obtain filter sand and gravel from numerous locations around Montreal Island, but they were all found

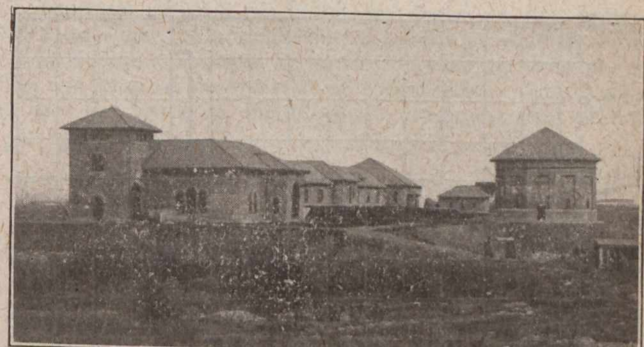

FIG. NO. 6—EXTERIOR VIEW, POINT ST. CHARLES FILTRATION WORKS, MONTREAL

to be unsuitable. A plant was finally erected under the design of W. B. Fuller, formerly of New York, and was located at Pierreville, near Lake St. Francis.

A suction dredge was used and the material was washed in tanks and then graded by passing through suitable revolving screens. The gravel was treated in similar manner. It was found that the available sand properly graded for the pre-filters ran about 50% of the quantity handled to obtain same. The sand for the final filters was found in different pockets, under water, practically graded to conform to specifications. This sand ran close to 100% of the quantity pumped.

The total quantity of sand required for the pre-filters, ranging from 0.40 to 0.50 mm. in diameter, was 2,000 cu.

FIG. NO. 7—PREFILTER GALLERY

yds.; that for the final filters, ranging from 0.25 to 0.35 mm. effective size, was 27,000 cu. yds. The total quantity of gravel for the pre-filters was 800 cu. yds.; the final filters required 8,000 cu. yds.

When the design of the Point St. Charles filtration works was started, the amount of water supplied by the municipality was about 37 million Imperial gallons daily. The filtration works were designed for a nominal capacity of 1⅓ times the requirements at that time. It was realized that extensions to the filters would be required in a few years, and the design allows for extensions with but little difficulty and without serious disturbance of the regular operation of the plant.

Annexations of adjoining municipalities, and the large extension of the city's water distribution system, have been more rapid than was expected. The new plant was required to work to full capacity from the day it was put into service and is now inadequate. The need for immediate action to provide for a much greater daily capacity of filtered water is so apparent that the city will undoubtedly

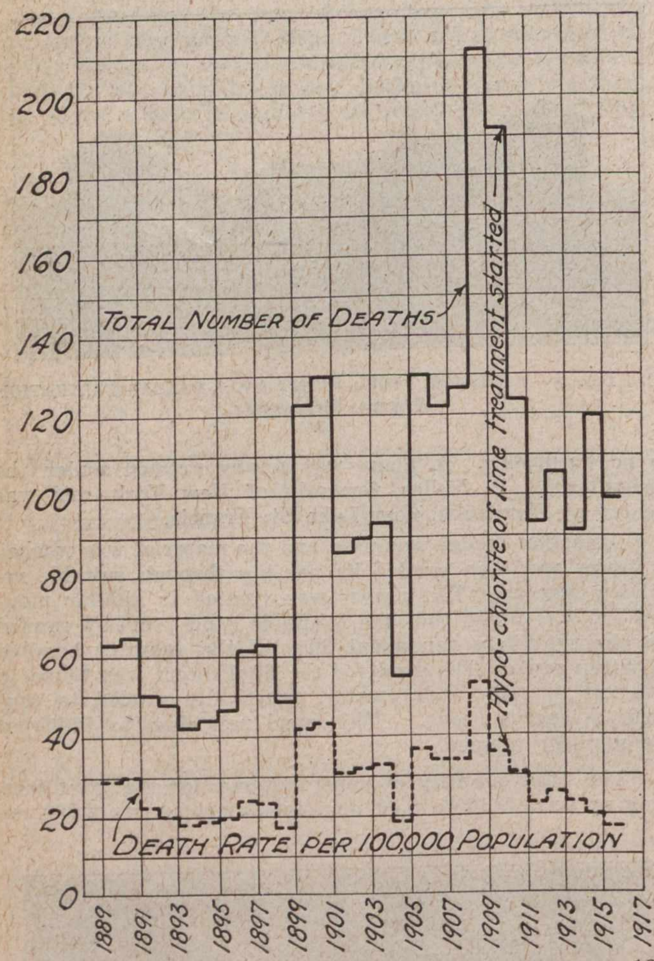

FIG. NO. 8—GRAPH SHOWING DEATHS FROM TYPHOID, 1889 TO 1917, CITY OF MONTREAL

in the near future let contracts for extension of the present works.

The original design contemplated the ultimate enlargement of the plant, it is said, along the following lines:—

Conversion of the final filters into slow sand beds,—capacity	30,000,000 gals.
Conversion of the pre-filters into mechanical filters,—capacity	40,000,000 gals.
Construction of two additional batteries of mechanical filters,—capacity	80,000,000 gals.
Total daily capacity	150,000,000 gals.

To carry out this scheme of extensions, it would be necessary to construct a new basin for coagulation, using alum as the coagulant, and also a new filtered water reservoir at a higher elevation than the present one, so that water could be delivered under greater head to the proposed new pumping station. The scheme contemplates the use of the existing reservoir as at present, but only to store filtered water from the proposed slow sand beds.

It is claimed that the proposed new pumping station could be built to advantage to the southeast of the site of the proposed power station, between Halmfield Street and the aqueduct excavation. This location would eliminate further congestion at the present low level pumping station and would allow for future extensions, it is said, to greater advantage than the present site.

The filtration works were constructed under the general supervision of Paul E. Mercier, engineer of public works, and T. W. Lesage, engineer-superintendent of water works. Frederick E. Field is the assistant superintendent of water works; A. B. Reid, electrical and mechanical engineer; Allan Kilpatrick, chief filter operator; and J. H. Harrington, chief chemist. To Messrs. Field, Kilpatrick, Reid and Harrington, *The Canadian Engineer* is indebted for all of the above information, drawings and photographs.

PREPARATION OF SPECIFICATIONS FOR CONCRETE

Practical and Advantageous to Specify Concrete According to Strength or Any Other Quality Desired—Some Specifications Result in Unknown Factors of Safety

BY I. F. MORRISON

Assistant Professor of Structural Engineering, University of Alberta

THE problem of proportioning concrete is the subject of extensive investigations in many laboratories at the present time, and several well-known investigators have arrived at reliable results which have quite well determined the sound principles to be followed in the making and mixing of concrete. In fact, sufficient data and information are already available to enable almost any contractor to make good concrete of a required strength in a certain time, and more is being rapidly added to the great mass already accumulated.

In the field these methods are being put into practice with success, resulting in a uniformity of product, a certainty of results, and consequent economy. In most offices, however, where designs are being carried out in both plain and reinforced concrete, this is not the case. The reason is this: Specifications for the quality of concrete are not kept up-to-date and many designers are still calling for 1:2½:5 mixes for 500 lbs. per sq. in. concrete; 1:2:4 mix for 650 lbs. per sq. in.; 1:1½:3 for 750 lbs. per sq. in., etc., these being the allowable stresses at, say, 28 days. The factor of safety is relied upon to cover the deficiencies.

Now a 1:2:4 mix may or may not make a concrete good for the usually assumed 2,000 lbs. per sq. in. at 28 days. That depends upon several factors, including the quality of cement, quality and grading of fine and coarse aggregates, quantity of water and methods of mixing and handling; and, to any engineer who may read this, upon several of his own pet ideas on the subject, even upon the effect of the change in declination of Polaris.

Nevertheless, the above-mentioned factors are the most important, and most contractors realize their importance. The control of the work on any large job now-a-days is such that attention is given to all of these matters.

The designer in the office, however, is still plodding along, calling for a 1:2:4 mix—which is so antiquated as to be almost meaningless—when he uses a stress of 650 lbs. per sq. in. in his design. The result is that one job, or a part of it, has a factor of safety of, say, about 2, and the next, or a part of the same one, has a factor of safety of about 6 or 7. This is certainly not economy; furthermore, if additions or extensions are to be made in the future, how is one to tell whether the original factor of safety was 2 or 7?

This article is essentially addressed to the designer and the one who writes specifications in the office. If they are to make use of the methods and valuable information already acquired for mixing good concrete which is suited to the purpose, they must co-operate with the engineer and contractor in the field. After plans and specifications leave the office, it is too late to change materially the entire design; the damage is already done. It may be possible for the field engineer to produce 2,000 lbs. per sq. in. concrete, but it may not be economical. On the other hand, a contractor would certainly be living up to the specifications if he put in 1:2:4 concrete, as called for, whether it gave 1,000 or 3,000 lbs. per sq. in. at 28 days.

Now for the constructive part of this criticism:—

Specifications should call for concrete of a certain strength. The strength called for should be varied to suit the various purposes to which the material will be put, and an appropriate factor of safety should be used in the design. Available materials in the locality of the proposed work should be sampled and tested by a competent engineer, and, in order to make use of the information, the designer should be informed, as early as possible, as to the strength available from these materials.

In almost any locality tests on 6 by 12-in. cylinders can easily be carried out. There usually is not time to do this after the contract is let, but some weeks are usually spent in preparing the layouts preliminary to the actual design of the work, and it is during this time that the proposed testing should be carried out.

Even if it be too late to carry out such tests, a contractor can succeed in making a concrete of any reasonable desired strength if the matter be left entirely in his hands. There is considerable information always available to enable him to accomplish the working out of the proper proportions, and he should be required to present his proposed proportions to the inspector sufficiently early to permit a careful checking of them.

Several years ago such a method as is herein suggested would have been open to several objections. These objections to-day are not well founded. The method of specifying concrete according to the strength, or any other quality desired, has not only become extremely practical, but is more advantageous from the standpoint of economy to all concerned.

PUBLICATIONS RECEIVED

Sand and Gravel in Ontario.—By A. Ledoux. Report to the Ontario Bureau of Mines, published by the King's Printer of Ontario, 138 pages and paper cover, 6½ by 9½ ins., illustrated. The report reviews the characteristic properties of sand and gravel and methods of testing, and deals with the origin and occurrence of fragmental rocks, and the distribution of sand and gravel in Ontario. The several counties have been arranged alphabetically and the location of every described deposit has been indicated by township, concession and lot. Deposits in more than forty different counties were visited during four months of field work. The author states that this report should be considered as only preliminary, as it is desirable to make a large number of tests of mortars and concretes made from the materials sampled, and also to secure further chemical analyses.

A new power project in Manitoba, known as the Winnipeg River Power Co., has been organized, and the $7,000,000 plant proposed will require three years for completion. The site of the development will be Bonnet Falls, 75 miles northeast of Winnipeg. This plant will have an ultimate capacity of 168,000 h.p., in six units of 28,000 h.p. each. This will exceed the combined output at present of the municipal plant at Point du Bois and that of the railway company at Pinawa Channel.

The Dominion Bureau of Statistics, Ottawa, has just issued a directory of the chemical industries in Canada, listing the names, addresses and products of nearly 500 Canadian firms manufacturing chemicals or other products in which the processes used are essentially dependent upon the agency of chemical change.

The Dominion Iron & Steel Co., Ltd., Sydney, N.S., have accepted an amendment to their government contract for steel plate. The original contract was for 50,000 tons per year for a period of 5 years, at $4.15 per hundred pounds. This has been modified by mutual agreement to $3.65 per hundred pounds. This means a saving of approximately $2,500,000 to the government. The company will now complete the erection of the new mill at an approximate cost of $5,000,000.

THE COST OF A MILE OF ROAD*

By George A. Duren
State Highway Engineer of Texas

The three diagrams herewith present the elemental facts pertaining to the cost of a mile of road. Fig. 1 shows transportation costs for motor vehicles for various grades and surfaces. Fig. 2 is based on facts as set forth in Fig. 1, to show the annual cost of a mile of road, including cost of maintenance, cost of traffic for varying costs per ton mile, and interest on the cost of construction. Fig 3 shows the cost per ton mile, including the transportation cost per

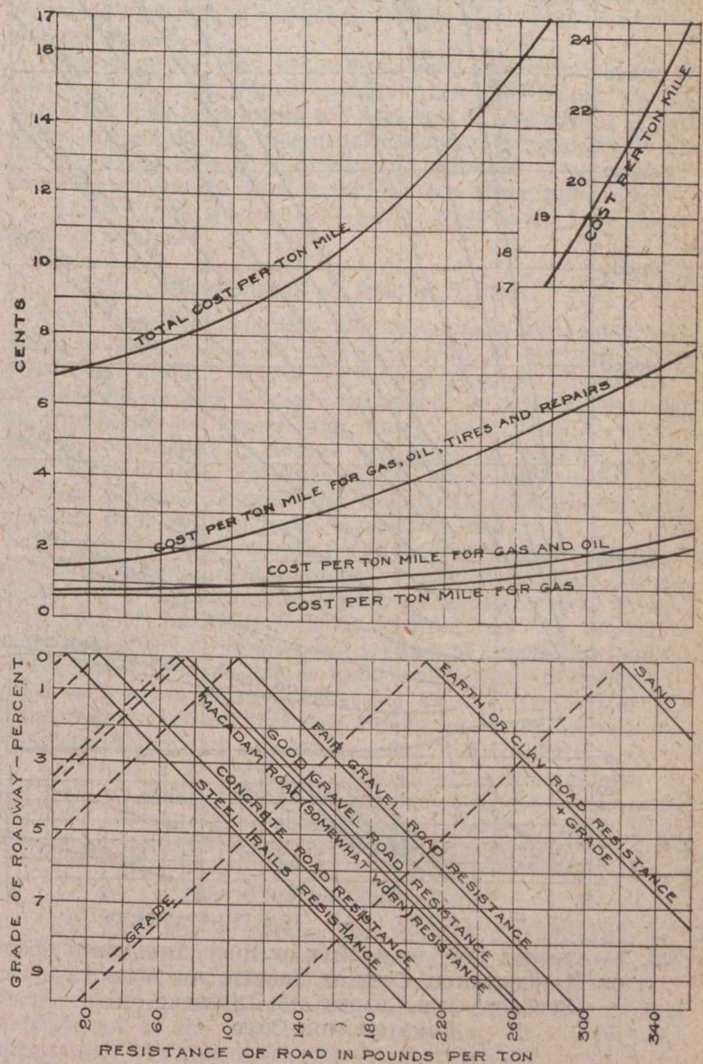

Fig. 1—Transportation Costs for Motor Vehicles for Various Grades and Surfaces

ton mile paid by the user of the highway and the cost per ton mile of the highway itself, which is paid by the taxpayer in highway construction and maintenance.

All the highway authorities have been dealing with highway construction and maintenance almost solely in an effort to deal with this subject at the least possible cost on the part of the taxpayer, with little or no consideration for the cost of transportation.

The authorities agree that a 9-ft. gravel road is a satisfactory and economical highway for traffic not to exceed 200 vehicles per day, and that a 16-ft. gravel road is a satisfactory and enonomical highway for use of vehicles not to exceed 500 per day. Authorities differ concerning the automobile highway for traffic of from 500 to 1,000 vehicles per day, but the general opinion is that for this traffic some form of

*From a paper presented at an Engineering and Road Builders' Congress at Mineral Wells.

bituminous surface is most satisfactory. It is suggested that for traffic exceeding 500 vehicles per day and not exceeding 750 vehicles per day, a macadam road with bituminous surface treatment should be used; and for traffic exceeding 750 vehicles per day and not exceeding 1,000 vehicles per day, a substantially built asphalt macadam construction should be used. Traffic exceeding 1,000 vehicles per day

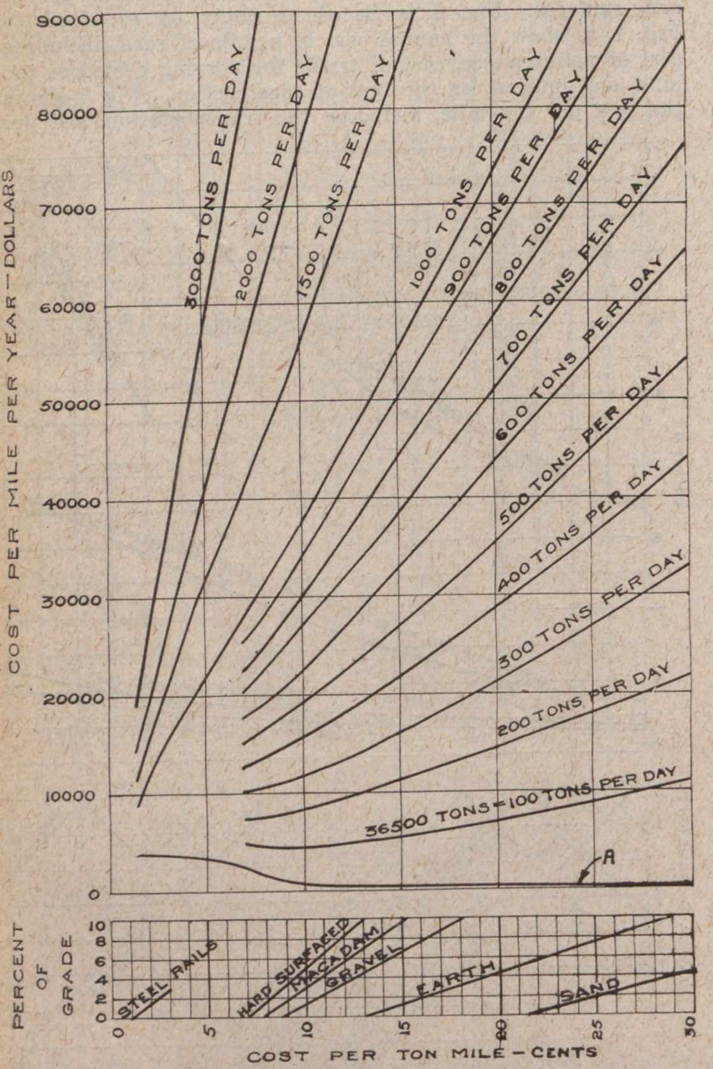

FIG. 2—ANNUAL COST OF A MILE OF ROAD, INCLUDING COST OF MAINTENANCE, COST OF TRAFFIC FOR VARIOUS SURFACES AND GRADES AND INTEREST ON CONSTRUCTION COST

Assuming interest at 5% per annum. Assuming initial cost per mile of concrete at $40,000; macadam, $20,000; gravel, $15,000; earth, $3,000; sand, $0. Assuming annual maintenance per mile of concrete at $400; macadam, $300; gravel, $300; earth, $200; sand, $0. Bottom curve (A) represents costs per annum of mile of roadway, including maintenance and interest on investment.

should be served with a concrete paving not less than 16 ft. wide. For traffic amounting to as much as 2,000 vehicles per day, a concrete pavement 20 ft. wide should be used, and for traffic exceeding 1,500 vehicles per day a brick pavement is desirable. Traffic exceeding 2,000 vehicles per day should be served with a pavement not less than 20 ft. wide and constructed with concrete foundation not less than 5 ins. thick, with brick, wood block, rock asphalt, sheet asphalt, granite block, or some form of asphaltic concrete not less than 2 ins. thick, should be used. These conclusions are probably in keeping with economy when viewed only by the cost of building and maintaining the highway under the varying intensities of traffic for units formerly used. All of these types of construction are such as will enable traffic such as formerly was found on the highways to continue 365 days a year. Traffic amounting to less than 50 vehicles per day has been provided for by earth roads, occasionally graded and dragged. Traffic amounting to 1, 5 or 10 vehicles per day has been accustomed to getting along the best it could over the natural surface of the ground.

The approximate costs of transportation are as follows: Upon an unimproved road, 30 cts. per ton mile; on an improved earth or sand-clay road, 25 cts. per ton mile; on a hard gravel road, 20 cts. per ton mile; on a bituminous surfaced gravel road, 15 cts. per ton mile; on a concrete or brick road, 10 cts. per ton mile.

Fig. 3 is based on more conservative assumptions, as follows:—

Cost per ton mile on 9 ft. gravel road, 22 cts.
Cost per ton mile on 16 ft. gravel road, 21 cts.
Cost per ton mile on 16 ft. bituminous road, 20 cts.
Cost per ton mile on 16 ft. asphalt macadam road, 19 cts.
Cost per ton mile on 9 ft. concrete road, 18 cts.
Cost per ton mile on 16 ft. concrete road, 17 cts.
Cost per ton mile on 16 ft. brick road, 16 cts.

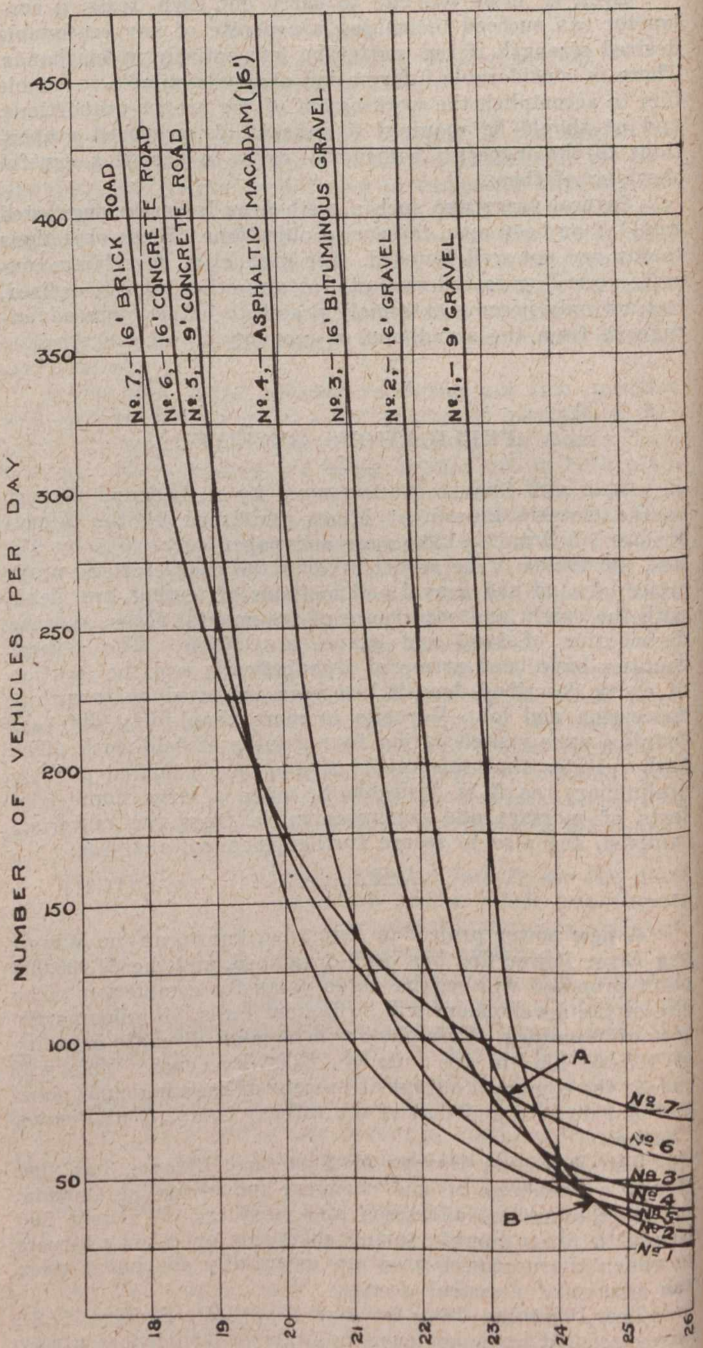

FIG. 3—TOTAL COST OF TRAFFIC PER TON MILE, INCLUDING TRANSPORTATION COSTS FOR VARIOUS TYPES OF SURFACES —SEE TABLE 1 FOR ASSUMPTIONS USED IN CALCULATING ABOVE CURVES

At point A, No. 2 equals No. 6, at 82¼ vehicles a day. At point B, No. 1 equals No. 5, at 43¼ vehicles a day.

The tonnage of traffic is assumed at one-half the number of vehicles, and the annual cost of the road assumed also is conservative and most favorable to the cheaper type of construction.

The cost of a road is essentially an annual cost. Man has not yet constructed any permanent structure and no highway has yet been constructed which, if it is used, does not require annual expenditure for maintenance. This rule applies to the Appian Way and every other road. We have not lost the art of road building, but we have lost the willingness to spend a sufficient amount of money on the road.

A permanent road is a road that is permanently maintained. The cost of a mile of road is the cost per mile of road per year. Too much attention is given to the original cost of construction and too little interest and attention is given to the cost of permanent service. A rational study of the cost of a mile of road must be arrived at by adding the interest on the original investment to the cost of annual maintenance necessary to retain the original structure. This seems all that must be considered as a part of the cost of the road; however, the most important matter to be considered is the cost to the traffic using the highway as affected by the condition of the highway.

TABLE 1—ASSUMPTIONS USED IN CALCULATING THE CURVES IN FIG. 3

Curve	Kind of Road	Cost of Surface only in Thousands of Dollars	Annual Maintenance*	Total Cost per Ton Mile (Dollars)
1....	9′ Gravel	3	$y	(150+y)/182.5y+0.22
2....	16′ Gravel	5	0.8y	(250+0.8y)/182.5y+0.21
3....	16′ Bit. Gravel	8	0.6y	(400+0.6y)/182.5y+0.20
4....	16′ Asph. Mac.	9	0.4y	(450+0.4y)/182.5y+0.19
5....	9′ Concrete	10	0.2y	(500+0.2y)/182.5y+0.18
6....	16′ Concrete	18	0.15y	(900+0.15y)/182.5y+0.17
7....	16′ Brick	25	0.1y	(1,250+0.1y)/182.5y+0.16

*y = number of vehicles a day (assumed to be ½ ton per vehicle).

The use of the road occasions a cost to traffic amounting to a certain rate per ton mile. The improvement of the road is an economic waste unless a saving is effected by its expenditure as an investment in reducing the cost of the traffic using the road. The cost per mile of road per year should never exceed the reduction in the cost of transportation using said mile of road, made possible by the improvement.

E. H. Harriman is remembered as being a railway wizard as well as a financial genius. He took over unprofitable railways and bankrupt railways and spent millions of dollars on these losing ventures to improve the roadway, reducing the grades and laying heavier rail and building better track. He did not reduce the cost per mile per year of maintaining the track thereby, but he did reduce the cost per ton mile of all traffic using the road, thus transporting the tonnage at an enormous saving, which went into dividends. Yet he was able to accomplish only the small saving of approximately one-half of 1% per ton mile.

The seventeenth annual convention of the American Road Builders' Association will be held at Louisville, Ky., Feb. 9th to 13th, 1920. Both the sessions of the convention and the exhibition will be accommodated in the First Regiment Armory. About 53,000 sq. ft. of floor space will be available.

The United States Navy Department has just increased the pay of its technical employees. The force had been working for over seven months to obtain a greatly needed readjustment in compensation. Their case was handled through special wage boards at the navy yards and a department board.

Dr. C. J. Hastings, medical officer of health for the city of Toronto, favors the construction of another water works intake at that city, declaring that the supply should not be entirely dependent on one intake, as a serious situation might be created in case of certain accidents to the present system.

WATER WASTE CONTROL BY HOUSE INSPECTIONS WITH DISTRICT METERING*

By E. D. Case

Vice-President, The Pitometer Co., New York City

HOW to control waste of water in city distribution systems is a problem that is becoming of greater importance each year. The old idea that water should be as "free as air" is now obsolete. The increase in cost of extensions which are necessary if waste is not curtailed, due to high price of pipe, building material, labor, etc., has made it imperative that every water works manager who desires maximum efficiency in his plant, take steps not only to reduce waste to a minimum, but to make such a reduction permanent.

Water waste may be said to come under two general heads: (1)—Underground leakage; and (2)—House waste. While the first item exists to a greater or less extent in all water works systems, it is usually smaller by comparison to the second, especially in unmetered plants. The item of house waste may be further divided into three sub-heads:—(1)—Wilful waste; (2)—Leaking services; and (3)—Leaking fixtures.

Development of Deacon System

The most obvious and effective means of controlling waste of this kind is to place meters on all services. The owner will not run water for cooling purposes in summer, or allow his faucets to run continuously to prevent freezing in winter, if he knows that every cubic foot of water wasted will appear in dollars and cents on his next water bill. Furthermore, when paying for water on such a basis, he loses no time in repairing leaks in his fixtures or services as soon as they make themselves evident.

Unfortunately, however, local conditions make universal metering impossible in a great number of places. Either sentiment is against this method of selling water, or the first cost of installation is prohibitive and the manager must look about for some other method of controlling waste. Fortunately, there is one at hand which when properly applied will prove quite as effective as universal metering. This system may be described briefly as house-to-house inspections under the supervision of a district meter. It is by no means a new idea, as it is simply a development of the "Deacon Meter System," originated by George F. Deacon, engineer of the Liverpool (England) water works. The scheme in general at that time was as follows:—

New Portable Flow Meter

The distribution system was divided into districts by valve operation, and a meter especially designed for the purpose, called a "Deacon Meter," was placed in a vault on the main supplying each district with water. By cutting a block out of the district, or by shutting off the service, the amount of water used or wasted in this block, or through this service, was recorded by the meter. Inspectors were then sent into blocks where flows were abnormally high, and the cause of the high flow located and the leaks repaired.

This system was almost universally adopted throughout Great Britain, with the result that the per capita consumption in British cities at the present time is remarkably low. The accompanying table shows the per capita in some of the larger cities in Great Britain.

The "Deacon Meter System" was adopted by the city of Boston in 1881, with considerable success, but its use did not become very popular in the United States owing to the large cost involved in installing the district meters, also due to the fact that they deteriorated very rapidly and repairs and replacements were constantly needed, which made the cost of maintaining them very high. These drawbacks were overcome about 1900 by the development of a portable flow meter, called the "Pitometer," an application of the principle of the Pitot tube. Practically the same methods were used, but instead of permanently setting a

*From a paper read at a recent convention of the Southwestern Water Works Association.

large meter on the supply line to each district, all that was necessary with the portable instrument was to tap each supply line with a standard 1-in. corporation cock, and the flow meter was moved from one gauging point to another as the occasion demanded.

This system was first used in Terre Haute, Ind., in 1897, and later in Columbus, Ohio, in 1902. Since that time over 200 cities of the United States have adopted this method of controlling water waste, and from year to year the system has become more complete until at the present time its efficiency is unquestioned.

Probably the most successful results of recent years have been obtained in Trenton, N.J., and Buffalo, N.Y. In Trenton, the daily consumption had gradually increased from 9,000,000 gals. in 1902 to 21,000,000 gals. in 1913. This was partly due to increase in population and industrial use, but in most part was due to the fact that waste conditions were becoming greater as no steps were taken to curtail them. In 1914, when the population supplied was approximately 125,000, the "Pitometer system" of controlling water waste was installed, with the result that in a year's time the consumption had been reduced to 15,000,000 gals. a day. If nothing had been done to stop the waste, the consumption would have been about 27,000,000 gals. per day, based on the average rate of increase for the ten preceeding years. This means that by installing the system of waste control, a saving of $4.40 a day was made in coal alone. In addition, the need of a new reservoir and a new pump was put off indefinitely, together with the resulting necessity for larger mains. These extensions would have cost approximately $1,000,000. By repeating the district house-to-house inspections under the supervision of the "Pitometer," this reduction in waste has been made permanent up to the present time.

City.	Population.	Average per capita consumption, gallons daily.
Aberdeen	155,000	54.0
Ashton	140,000	24.0
Belfast	360,000	39.6
Birkenhead*	104,920	40.8
Birmingham*	775,502	33.6
Blackburn*	130,000	30.0
Bolton*	237,159	32.4
Bournemouth*	85,920	27.6
Bradford*	450,000	54.0
Bristol*	353,374	26.4
Cardiff*	190,000	30.0
Darlington	46,000	25.2
Derby*	129,500	26.4
Dublin*	333,300	43.2
Dundee*	202,000	60.0
Edinburgh*	435,500	49.6
Glasgow*	1,075,735	67.2
Halifax*	224,933	18.0
Leeds*	430,000	42.6
Liverpool*	850,000	37.7
London	6,304,653	40.8
Manchester*	1,082,000	34.8
Newcastle*	485,000	45.5
Northampton*	120,000	18.8
Nottingham*	301,000	24.0
Oldham*	223,000	27.0
Paisley*	101,000	83.2
Plymouth*	132.326	55.2
Portsmouth*	200,000	48.7
Rochdale	100,000	22.8
Sheffield*	429,552	32.4
S. Essex*	146,000	24.0
Stockport*	135,000	27.0
Stockton*	230,000	62.4
Swansea*	110,000	34.8
Wakefield*	138,000	21.6
Wolverhampton*	136,000	26.4
Grand average,		37.6

*Adjacent communities also supplied.

The results obtained by the city of Buffalo have been perhaps even more remarkable, inasmuch as it was necessary to carry on the work on a much larger scale than in Trenton. For a great many years Buffalo had the distinction of having the highest per capita consumption of any city in the United States. In 1917, just prior to the start of the water waste survey, about 180,000,000 gals. a day were being pumped into the mains, or a per capita of approximately 360 gals. In June, 1917, the "Pitometer system" of waste control was installed, and the daily consumption has now been reduced to about 120,000,000 gals. a day, or a per capita of 240 gals., although the first inspections have not been extended over the entire city. Of this amount, 100 gals. daily per capita are sold to the industrial consumers, leaving a domestic per capita of about 140 gals. This is still far in excess of the actual need of domestic consumers, but is being reduced day by day, and within the next year will undoubtedly reach a reasonable figure. What these results will mean to the city of Buffalo may be seen from the following facts:—

One Pumping Station Eliminated

The water is pumped from two pumping stations, each containing five 30,000,000-gal. pumps, with an approximate capacity of 150,000,000 gals. a day. The present daily pumpage is within the capacity of one station, and for the past six months only one pump has been in operation in the second station. When the margin of safety becomes a little greater, this station will be put into reserve and the entire load carried by one station. An enormous saving will result in operating costs.

For the purpose of the survey, the city was divided into ten sections and each section subdivided into a number of districts. The flow was then measured into each district by the "Pitometer," and further investigations made by subdividing each district at night, so that the rate of flow between each pair of valves was determined. Wherever this seemed excessively high, inspectors were sent into the blocks to locate and stop leaks. Each inspector was equipped with a blank form, which enables him to report the number, location and cause of all leaks discovered on the services or on the premises of consumers. Notices were left with the property owner, and a duplicate filed in the water works office, which required that the leaks be stopped within a designated number of days, with a penalty of shutting off the service in case repairs were not made. After re-inspections had been made to determine that all waste had been stopped, a remeasurement was made of the entire district and the results recorded. These results demonstrated the efficiency of this system.

Periodical Remeasurements

In order to discover the permanancy of the reduction in the various sections of the city, re-measurements were made of the flow in typical districts after periods of six, twelve and eighteen months had elapsed. In this way it was determined that in some sections of the city the waste had not returned in a sufficient amount to warrant reinspections until a period of eighteen months had elapsed. In other sections the investigations proved that in order to control waste, yearly inspections should be made; while in still other sections, notably those containing the poorer class of consumers, with exposed plumbing and anti-freezing toilets, inspections every six months, or even oftener, were necessary in order to control the waste.

In some cities it has been found practical to combine a system of selective metering with house-to-house inspections, which has been productive of even more satisfactory and permanent results. This system permits the metering of all wasteful commercial users of water, such as garages, livery stables, laundries, bakeries, saloons, etc., as well as metering the domestic consumer in cases where the officials are convinced, by repeated inspections, that this is the only way of compelling the owner to keep his plumbing in repair.

Probably a great many water works managers or superintendents will say that they have tried to reduce waste by house-to-house inspections, but that either no reduction in the daily consumption has resulted, or what reduction has occurred has not been sufficient to be of any practical value. This was the situation in nearly all of the unmetered cities where the "Pitometer system" has been introduced in the past twenty years. It is a matter of interest to note that inspections had been carried on for a number of years previous to the installation of this system in Buffalo, but in spite of that fact, the consumption was gradually increasing each year. The same force which had been employed in carrying on this work was used in making the systematic inspections under the supervision of the "Pitometer," and the increase in the efficiency of the inspections is well demonstrated by the results obtained. The reason is easily explained:—

Efficiency of Work Increased

When the inspections are made under the supervision of the "Pitometer," the inspector knows the amount of waste in each block before he starts his inspections. He also knows that there will be a remeasurement after repairs have been made, and if the flow has not been reduced to a satisfactory amount, further inspections will have to be made. This arouses his personal interest and enthusiasm, and the efficiency and thoroughness of his work increases correspondingly.

All Must Curtail Waste

Every city of Canada and the United States where the consumption figures show the existence of water waste, must some day take steps to curtail this waste. The leaks will not stop of themselves, and it is not only uneconomical and impractical to continue to install new pumps, build new reservoirs and lay new mains, but in many cases it is impossible on account of insufficient supply.

The fact that a city or town has an inexhaustible water supply, as is the case of those situated on lakes or rivers, is no reason for allowing waste to exist. No matter what the conditions are, it can only be brought to the consumer at considerable expense, and it is inexcusable to permit the waste of water on this account when such waste can be eliminated and controlled at a nominal expense.

Hopeless if Too Late

The fact cannot be emphasized too strongly that when the city is actually facing a water shortage, it is usually too late to save the situation by reducing the waste. It is then almost invariably necessary to install the new pump, to build the new reservoir or to lay the new main, thereby burdening the city with a much greater expenditure. The far-seeing water works manager or superintendent will never allow conditions in his plant to reach this point, when they may be avoided by comparatively small expense and effort on his part.

A very curious situation was brought to light some years ago in a large office building, where an apparently excessive consumption caused the water officials to attach a meter to the service pipe for the purpose of arriving at a suitable charge. It was hardly to be believed, but the registration by the meter showed that more water was being consumed at night, when the building was empty save for the janitor and family, than during the day, with all the suites occupied and water being freely used by all. A careful investigation was made, and it was found that all the toilets were fitted with a very poorly-constructed ball-cock fixture, which became disarranged every night by the increased pressure in the mains. This allowed a steady flow from the tanks, down the waste pipes, that lasted throughout the entire night all over the building until the day usage again reduced the pressure. Naturally, the owners of the building had a heavy water bill, but, needless to say, the wasteful fixtures were speedily replaced by others of a better kind and this ususual and costly source of waste was closed.

PROPORTIONING OF PIT-RUN GRAVEL FOR CONCRETE*

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THE factors upon which the strength of concrete must depend are (1) the density of the concrete, and (2) the extent to which the particles are cemented together. The latter factor depends upon the amount of cement in a given volume, and upon the total surface area of the particles.

Table I.—Ratio of Cement to Aggregate Constant

Per cent of "Sand" in Aggregate, by Weight.	Proportions (1:5).	Density.	Water, per cent of dry materials.	Compressive Strength, lb. per sq. in.
42	1:2:3	0.789	9.33	1600
55	$1:2\frac{3}{4}:2\frac{1}{4}$	0.770	10.65	1200
75	$1:3\frac{3}{4}:1\frac{1}{4}$	0.737	12.65	920
95	$1:4\frac{3}{4}:\frac{1}{4}$	0.673	15.30	480

Inasmuch as numerous authorities are agreed that the density of the mixture is partly and the surface area wholly dependent upon the grading of the aggregate, and that the density also depends upon the consistency, or amount of water in the mixture, the writer has formulated for his own use the following rule for proportioning concrete mixtures:—

Use the best graded aggregate available, enough cement to make concrete of the class desired, and mix with the least amount of water which will yield a workable mixture for the conditions under which the concrete is to be placed.

Table II.—Physical Characteristics of Aggregates Used

Sand No.	Pebbles No.	Percentage of Voids, Loose.	Loose Weight, lb. per cu. ft.	Percentage of Silt.	Specific Gravity.	Sieve Analysis: Per cent Passing Sieve No.								
						......	......	......	4	8	14	28	48	100
						Size of Opening, in.								
						1.5	0.75	0.371	0.185	0.093	0.046	0.023	0.0116	0.0058
1	...	39.8	99.9	4.0	......	......	......	......	......	100.0	67.5	25.5	6.5	1.5
2	...	39.3	100.7	2.0	......	......	......	......	......	100.0	83.5	57.0	18.5	4.5
3	....	42.2	95.9	9.0	......	......	......	......	......	100.0	72.5	37.0	12.0	7.0
4	....	37.9	103.0	2.0	......	......	......	......	......	100.0	82.0	49.5	10.0	3.8
5	....	40.5	98.4	4.0	......	......	......	......	100.0	82.0	58.0	23.6	5.8	1.5
6	....	......	......	1.3	......	......	......	......	100.0	87.0	69.5	45.2	16.0	2.0
7	....	45.0	91.3	7.5	......	......	......	......	100.0	79.8	55.3	28.2	10.0	3.8
8	....	39.7	99.8	0.8	......	......	......	......	100.0	85.2	66.5	39.4	6.2	0.3
11	....	41.2	98.8	2.0	2.68	......	......	......	......	100.0	87.6	43.2	11.1	1.3
12	...	41.3	101 1	1.8	2.75	......	......	......	100.0	96.4	60.1	32.9	18.2	3.8
13	....	42.0	99.1	1.8	2.73	......	......	......	......	100.0	76.6	39.3	9.7	1.8
15	....	41.2	98.7	2.0	2.69	......	......	......	100.0	85.2	59.7	31.6	8.6	1.2
16	....	39.3	104.4	1.6	2.75	......	......	100.0	92.8	61.5	35.2	17.9	9.7	2.1
17	....	42.3	98.5	1.5	2.72	......	......	100.0	98.0	83.9	61.3	30.6	7.4	1.6
20	....	40.0	100.0	2.0	2.68	......	......	100.0	99.1	87.7	63.7	33.7	9.1	2.1
21	....	37.7	103.6	......	2.66	......	......	100.0	99.4	87.3	59.8	31.5	10.2	2.1
....	9	37.5	103.7	0.0	......	100.0	89.7	52.8	29.6	1.9	......	......	......	......
....	10	41.6	98.1	0.0	......	100.0	84.5	24.2	3.7	0.8	......	......	......	......
....	18	42.4	102.3	0.0	2.81	100.0	86.9	49.2	27.9	8.4	......	......	......	......
....	19	42.4	100.0	0.0	2.82	100.0	74.8	31.7	10.3	......	......	......	......	......
....	22	42.2	101.0	1.5	2.80	......	100.0	82.5	31.5	1.6	......	......	......	......
....	23	37.4	103.5	1.0	2.65	100.0	64.9	52.5	12.7	1.1	......	......	......	......

The material to be considered in this paper is pit-run gravel, to be used without change as it comes from the pit. The problem is to establish some relation between grading and the amount of cement such that, for mixtures of the

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*Paper read at the annual meeting of the American Society for Testing Materials, June 24th to 27th, 1919.

same plastic consistency, concretes of equivalent strength could be designed.

To establish such a workable relation, it is necessary to express the grading of the gravel by numerical functions. Other experimenters, notably Abrams and Edwards, have done so, and their work could be used as a basis for proportioning pit-run materials. However, both Abrams' "Fineness Modulus" and Edwards' "Surface Area" method require the making of a complete sieve analysis of the material. The method herein described requires the separation of a sample into only two sizes and a simple determination of the weight per cubic foot of the loose gravel.

TABLE III.—VARIATION IN COMPRESSIVE STRENGTH OF CONCRETE WITH THE PERCENTAGE OF SAND IN THE GRAVEL, WHEN THE RATIO OF CEMENT TO THE SAND PORTION OF THE GRAVEL IS KEPT CONSTANT

CEMENT TO SAND = 1:2 BY WEIGHT.

CLASS I—SAND PASSING SIEVE NO. 4—PEBBLES RETAINED ON SIEVE NO. 4 AND PASSING 1½ IN. SIEVE.

Series No.	Sand No.	Proportions: Weight: Cement to Aggregate.	Proportions: Weight: Sand to Pebbles.	Proportions: Loose Volume: Cement to Aggregate.	Proportions: Loose Volume: Sand to Pebbles.	Proportions: Loose Volume: Computed for Equivalent Strength.	Proportions: Absolute Volume: As Used.	Proportions: Absolute Volume: Computed for Equivalent Strength.	Weight, lb. per cu. ft: Aggregate.	Weight, lb. per cu. ft: Green Concrete.	Absolute Volume: Parts of Unit Volume in Green Concrete: Cement (c).	Sand (s).	Pebbles (p).	$c+s+p=$ Density.	Water in Percentage Mix, by Weight.	Compressive Strength, lb. per sq. in.: Age, 7 Days.	Age, 28 Days.
5	5	1:4.75	42:58	1:3.9	48:66	1:4.05	1:5.5	1:5.5	112.0	147.6	0.121	0.284	0.379	0.784	10.9	1235	1854
		1:3.66	55:45	1:3.2	62:51	1:4.1	1:4 3	1:5.5	110.2	149 0	0.148	0.346	0.292	0.786	11.2	1438	2275
		1:2.66	75:25	1:2.3	82:27	1:3.35	1:3.1	1:4.35	107 1	147.2	0.182	0.426	0.142	0.750	13.9	1637	2826
		1:2.10	95:5	1:2	97:5.1	1:3.2	1:2 5	1:3 9	100 1	146 1	0 209	0.493	0.030	0.732	14 8	2244	3532
6	6	1:4.75	42:58	1:3.8	48:68	1:3.9	1:5 4	1:5 4	114.8	146.1	0.122	0.279	0.383	0.784	9.8	1872	3360
		1:3.66	55:45	1:3.1	62:52	1:3.7	1:4 4	1:5.1	112.35	146.1	0 144	0.340	0.291	0.775	10.4	1792	3296
		1:2.66	75:25	1:2.3	80:27	1:2.7	1:3.1	1:3.6	107.1	141:2	0.175	0.408	0.137	0.720	13.2	2120	3452
		1:2.10	95:5	1:2	96:5.2	1:2.7	1:2.5	1:3 35	101 1	141 8	0.206	0.482	0.024	0.712	14.5	2360	3864
7	7	1:4.75	42:58	1:3.9	51:66	1:4.15	1:5.6	1:5.6	111.3	146.1	0.116	0.272	0.382	0.770	11.85	1150	2340
		1:3.66	55:45	1:3.2	65:49	1:4.05	1:4.25	1:5.3	107.8	145.6	0.145	0.339	0.276	0.760	12.1	1423	2872
		1:2.66	75:25	1:2.4	84:26	1:3.3	1:3.1	1:4.1	102.3	143.0	0.175	0.410	0.136	0.721	15.0	1550	3245
		1:2.10	95:5	1:2.1	98:4.6	1:3.35	1:2.5	1:3.8	94.0	142.0	0.204	0.480	0 024	0.708	15.3	2045	3680

The principal conclusion resulting from the investigation carried out is that the grading of pit-run gravel may be measured by the ratio of fine aggregate to total aggregate (that is, percentage of fine aggregate in total) and by the weight per cubic foot of the material, measured loose. For purposes of commercial convenience the dividing line between fine and coarse aggregate is taken on the common No. 4 sieve. In the following discussion, fine aggregate as defined above will be called "sand," and coarse aggregate "pebbles."

Two assumptions have often been made by users in proportioning the cement to pit-run gravels:—

1. That the ratio of cement to total aggregate should be a constant.

2. That the ratio of cement to the sand portion of the aggregate should be a constant.

The former is wrong and on the unsafe side. The latter is also wrong but is on the side of safety.

Cement to Aggregate Constant

Table I. is typical of the strength of concretes made under the assumption that the ratio of cement to total aggregate should be kept constant. Further demonstration of the fallacy of this assumption is not necessary.

Cement to Sand Constant

The assumption that the ratio of cement to percentage of sand in the gravel should be a constant was investigated in twenty-four series of tests. Materials from several localities and two classes of concrete were used. Table II. gives physical characteristics of the aggregates used in the investigations described herein.

Each series comprised tests of gravels containing respectively 42, 55, 75 and 95 per cent. by weight, of sand. The mixtures were made arbitrarily by combining sand and pebbles in the right amounts. The same sand and pebbles were used in each mixture in a series. Each series included tests of forty specimens. Five specimens were broken for each test of a mixture. Specimens from all series were tested at 28 days old; specimens from some series were tested at 7 days and from others at 6 months. Specimens were 8 by 16-in. or 6 by 12-in. cylinders stored in water.

In some of the series the No. 8 sieve was taken as the dividing line between sand and pebbles. The general result was very similar to that obtained with the No. 4 sieve.

In Table III. are given typical results of these tests for three series, showing the variation in strength of concrete with the percentage of sand in the gravel, when the ratio of cement to sand is kept constant. The strength increases with the percentage of sand in every mixture in the table, save one, and the results are typical of all series.

Obviously, neither the ratio of cement to total aggregate, nor the ratio of cement to the sand portion, should be a constant, but for equivalent mixtures the ratio of cement to total aggregate should increase in some relation to the percentage of sand in the gravel. That this is a straight line relation is demonstrated as follows:—

The "Sand" Method

The "sand" method of making concretes of equivalent strength, using gravels of varying sand content, depends upon the assumption that there is a direct relation between the strength of concrete and the ratio

$$c/[1-(c+s+p)] = c/(1-d),$$

in which c = absolute volume of cement, s = absolute volume of sand particles, and p = absolute volume of pebbles in a unit volume of freshly made concrete; d = coefficient of density = absolute volume of solid material in a unit volume of freshly made concrete = $c+s+p$; and $1-d$ = volume of air and water voids.

DATA CONCERNING PROPORTIONS FROM TYPICAL SERIES

Per cent of Sand in Aggregate, by Weight.	c	s	p	d	$\frac{c}{1-d}$
33	0.096	0.227	0.440	0.763	......
42	0.105	0.286	0.378	0.769	0.455
55	0.122	0.361	0.282	0.765	....
75	0.132	0.456	0.145	0.733	....
95	0.167	0.525	0.026	0.718	.....

By absolute volume of a granular material is meant the actual sum of the volumes of all the particles; it is expressed as the fractional part of the total space occupied by the material.

The quantities are computed as shown in Taylor and Thompson's "Treatise on Concrete."

Fig. 1 demonstrates the truth of the assumption that, other things being equal, the strength varies with $c/(1-d)$.

The tests grouped on this diagram are comparable by reason of being made from the same cement, similar materials, and subjected to the same conditions as to making, molding and curing. Each point is derived from the average tests of five specimens. Diagrams of other groups of tests comparable among themselves give similar results. A similar diagram published in the last (1918) edition of Johnson's "Materials of Construction," computed from data published in U.S. Bureau of Standards Technologic Paper No. 58, corroborates this assumption.

In order to compute proportions for equivalent strength, it is necessary to assume for each class of concrete that some mixture is satisfactory. For the three classes of concrete considered in this paper, the following mixtures were taken as the basis:—

Class I.—Proportion 1: 4½, gravel containing 42 per cent. sand.

Class II.—Proportion 1: 5½, gravel containing 42 per cent. sand.

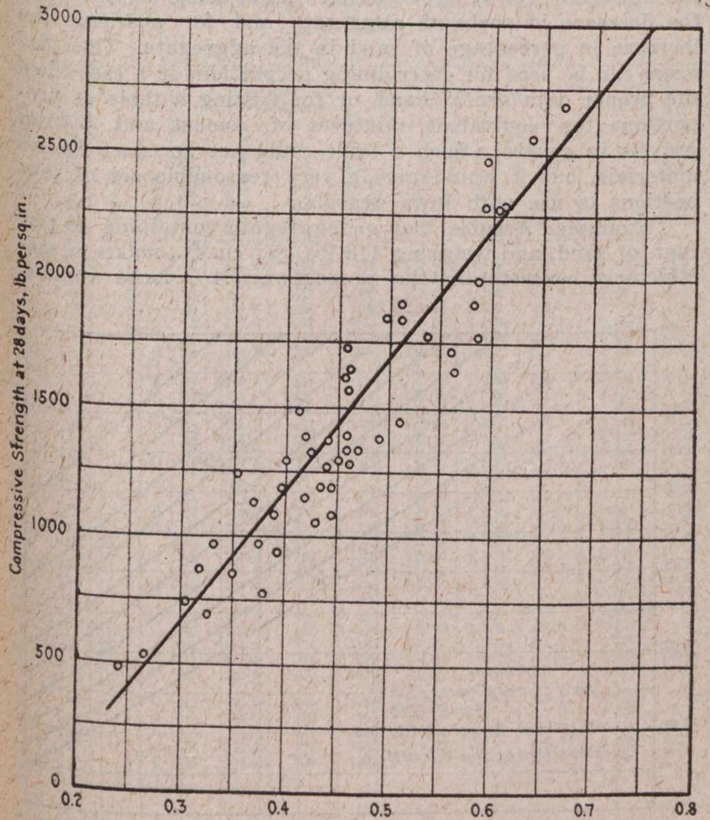

FIG. 1.—RELATION BETWEEN COMPRESSIVE STRENGTH OF CONCRETE AND THE RATIO $c/(1-d)$

c = Absolute Volume of Cement and (1—d) = Volume of Air and Water Voids in a Unit Volume.

Class III.—Proportion 1: 7, gravel containing 42 per cent. sand.

Taking each series of tests by itself, the probable proportions to use with the different percentages of sand in the aggregate, to yield concrete equivalent to the one having 42 per cent. of sand in the aggregate were derived as follows:—

To arrange the proportions for equivalent strength it is necessary to so change the relation between the absolute volumes of cement and aggregate that the ratio $c/(1-d)$ will, in each case, become equal to 0.455. The adjustment can be made by increasing or decreasing c and decreasing or increasing $s+p$, so that d will be unchanged, thus:—

Let c', s' and p' be the new values required for c, s and p, respectively. As explained above, these values are the percentages of absolute volumes of the materials in a unit volume of freshly made concrete.

$$c'/(1-d) = c'/[1-(c'+s'+p')] = 0.455$$

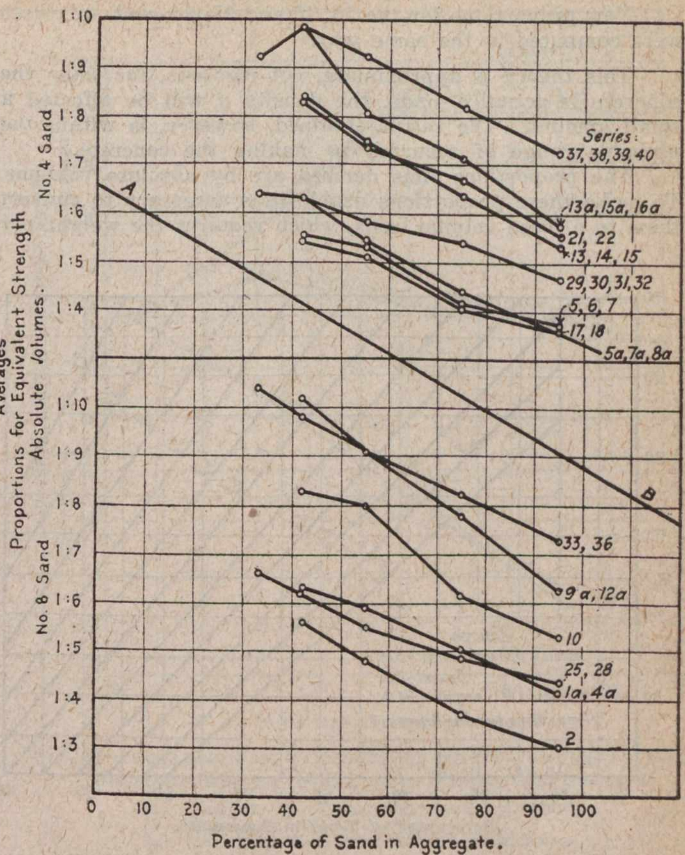

FIG. 2.—RELATION BETWEEN PERCENTAGE OF SAND IN GRAVEL, AND THEORETICAL PROPORTIONS BY ABSOLUTE VOLUME, NECESSARY TO YIELD CONCRETE EQUIVALENT TO A GIVEN BASE MIXTURE

Therefore, to convert the mixture containing 33 per cent. of sand:—

$$c'/(1-0.763) = 0.455$$
$$c' = 0.108$$
$$d = c'+s'+p'$$
$$0.763 = 0.108+(s'+p')$$
$$(s'+p') = 0.655$$

Accordingly the ratio of absolute volume of cement to absolute volume of total aggregate, required to make a proportion using the 33-per-cent. sand mixture equivalent to the 42-per-cent. sand mixture is 108: 655, or 1: 67.

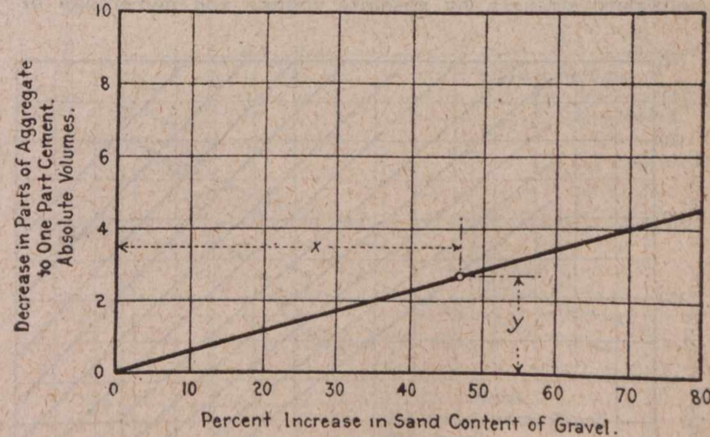

FIG. 3

To determine the amount of cement to use with a given pit-run gravel to yield a concrete equivalent to a given mixture of sand and gravel:

1. Reduce the proportion of the standard mix to the basis of absolute volume.
2. Determine from curve decrease in parts of aggregate corresponding to increase in percentage of sand in aggregate.
3. Change the absolute volume proportions thus found to the loose volume basis.

Formula for computing Item 2.

$$\tan \alpha = 3.6/62 = 0.058 \text{ (See A B, Fig. 2)}$$
$$y = x \tan \alpha = 0.058\ x$$

New proportions for the 55, 75 and 95-per-cent. mixtures were computed in the same way.

This theory is approximate, not rigorous, for when the concrete is actually made, the density *d* will be affected a small amount. The result obtained, however, is within the probable range of accuracy in making the concrete.

The proportions thus derived are by absolute volumes. To make these proportions usable it is necessary to convert them to a loose volume basis, which requires the weight per

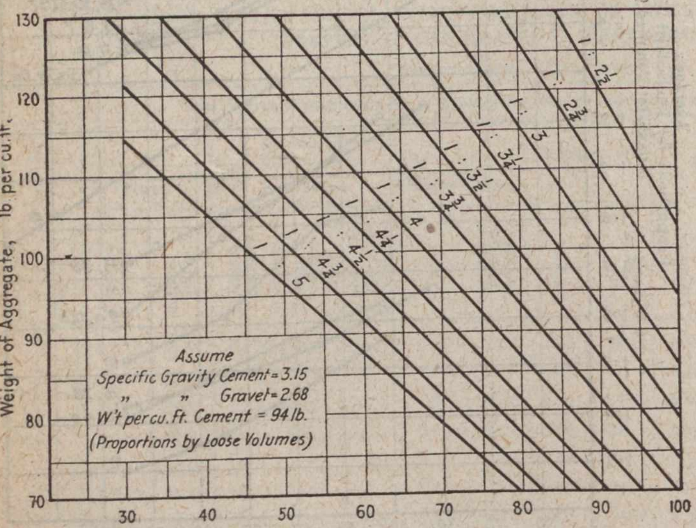

FIG. 4—DIAGRAM FOR USE IN PROPORTIONING PIT-RUN GRAVEL FOR CLASS I. CONCRETE

cubic foot of cement and loose aggregate. Assuming cement to weigh 94 lbs. per cu. ft., its specific gravity = 3.14, and that of the aggregate = 2.68, absolute volume proportion of aggregate (cement = 1) may be changed to loose volume proportion by the following equation: Aggregate (loose) equals aggregate (absolute) multiplied by 80 and divided by the weight per cu. ft. of aggregate (loose).

In this way the absolute proportions and loose volume proportions of materials to yield concrete equivalent in strength to the one in each series whose aggregate contained 42 per cent. of sand, was determined for aggregates containing 33, 55, 75 and 95 per cent. of sand.

In Fig. 2 the relation between the proportions for equivalent strength by absolute volume and percentage of

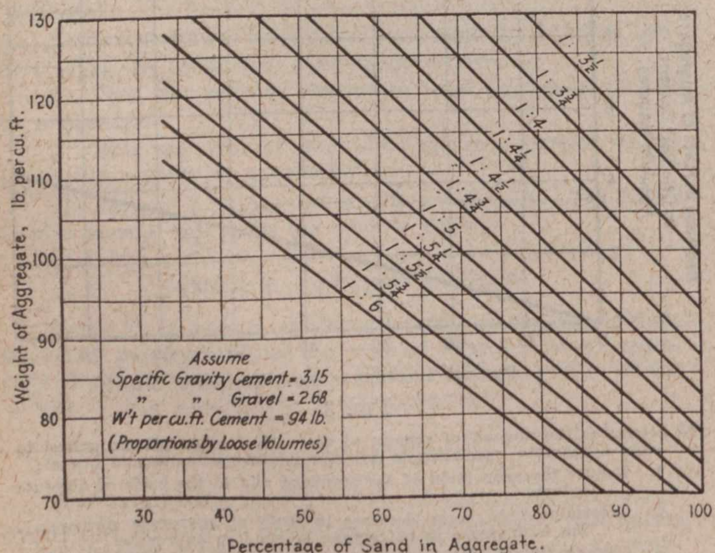

FIG. 5—DIAGRAM FOR USE IN PROPORTIONING PIT-RUN GRAVEL FOR CLASS II. CONCRETE

sand in aggregate is shown for all of the specimens tested. Each line is the average of results from 3 or 4 different sands, and, therefore, represents the conclusion drawn from 3 or 4 series of tests. Each point is the average of from 75 to 100 individual specimens.

The conclusion drawn from a study of this diagram is this: The relation between proportions by absolute volumes to give equivalent strength, and sand content of the aggregate, varies uniformly and at approximately the same rate for all degrees of quality of concrete. The line *AB* in the diagram is established to indicate this rate of variation as an average.

To make use of this diagram to determine the proportions to use with a given material having a certain sand content, it is necessary first to assume an aggregate and proportion known to be satisfactory. Locate the point representing this known condition and draw a line through it parallel to *AB*. Then pick from this line of proportions the proportion corresponding to the given aggregate.

To make a single line diagram of general application, the line *AB* (Fig. 2) is plotted on Fig. 3, using for ordinates the decrease in parts of aggregate, and for abscissas the increase in percentage of sand in the aggregate. This diagram can be used for determining proportions in a case when the proper data are at hand, or for writing a table of proportions for equivalent mixtures of cement and pit-run gravels in general. Such a table could not be exact for all materials, but it would give a very reasonable set of proportions to use with Iowa gravels.

Example: Assume that an aggregate containing 42 per cent. of sand, and weighing 112 lbs. per cu. ft., makes a satisfactory concrete in the proportion 1:4½ loose volume.

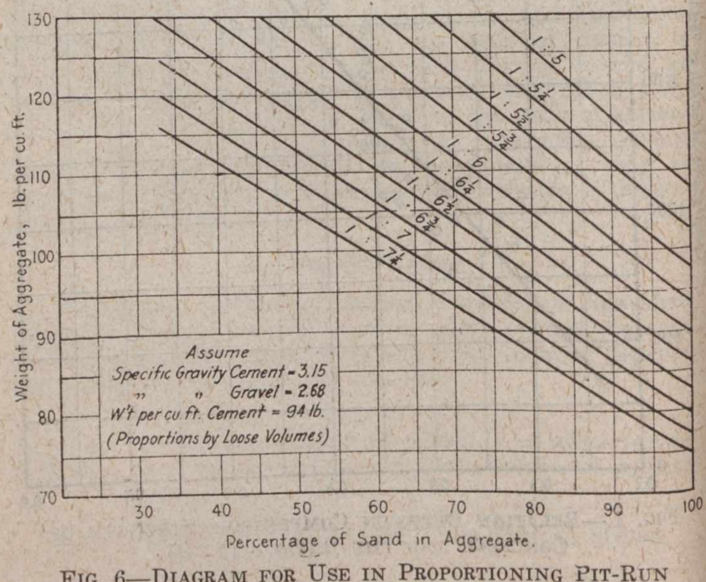

FIG. 6—DIAGRAM FOR USE IN PROPORTIONING PIT-RUN GRAVEL FOR CLASS III. CONCRETE

What proportion should be used with a similar gravel containing 75 per cent. of sand and weighing 107.1 lb. per cu. ft?

Change the proportion 1:4½ to a proportion by absolute volume, thus:—

$4.5 \times 112/80 = 6.3$. Proportion (absolute) = 1: 6.3.

The increase in percentage of sand is 33. From Fig. 3 the corresponding decrease in parts of aggregate is 1.9. $6.3 - 1.9 = 4.4$. Therefore, the proportion for the aggregate containing 75 per cent. sand should be 1: 4.4, absolute volumes, or 1: 3.3 loose volumes.

Fig. 3 is perfectly general and can be used for designing mixtures equivalent to any assumed base.

The diagrams in Figs 4, 5 and 6 have been arranged for convenience in proportioning pit-run gravels for three classes of concrete:—

Class I., suitable for reinforced concrete in general, water-tight concrete, and base course of concrete pavement. It should range in strength from 2,400 to 3,000 lbs. per sq. in.

Class II., suitable for first-class foundations, gravity section piers and abutments for bridges, and base course of non-reinforced floors and walks. It should range in strength from 1,800 to 2,400 lbs. per sq. in.

Class III., suitable for large foundations and heavy mass work in general. It should range in strength from 1,200 to 1,800 lbs. per sq. in.

Verification

Table IV. shows the resulting strengths of laboratory specimens made in accordance with the foregoing principles. It is believed that these results verify the reasonableness of the method of proportioining pit-run gravels described. Series Nos. 48, 49 and 50 were made about one year after Series Nos. 46 and 47 from different materials, and by a different operator. The consistency was approximately the same in both groups.

Fig. 7, compiled from the averages of numerous tests of various materials and classes of concrete, illustrates in general the decrease in strength when the ratio of cement to total aggregate is made a constant, the increase in strength when the ratio of cement to sand portion of aggregate is constant, and the equivalent strength when the mixtures are proportioned according to the foregoing method.

TABLE IV.—PIT-RUN GRAVEL CONCRETE PROPORTIONED BY THE SAND METHOD

Concrete Class	Series No.	Material	Characteristics, Mixed Aggregate. Percentage of Sand.	Weight, lb. per cu. ft.	Fineness Modulus.	Surface Area, sq. ft. per 100 lb.	Proportions. By Weight.	By Absolute Volume.	By Loose Volume.	$\frac{c}{1-d}$	Percentage of Water in Mix, by Weight.	Compressive Strength at 28 days, lb. per sq. in.
I	48	Sand, No. 21; Pebbles, No. 23.	33	113.9	533	819	1:6.06	1:6.6	1:5	0.374	10.0	1479
			42	114.7	501	978	1:5.49	1:5.92	1:4.5	0.414	10.0	1945
			55	117.5	458	1220	1:4.97	1:5.87	1:4.0	0.403	10.6	2425
			65	115.7	424	1398	1:4.61	1:5.0	1:3.75	0.426	10.3	2465
			75	113.6	392	1575	1:4.23	1:4.60	1:3.5	0.428	10.9	2565
			85	109.3	360	1753	1:3.78	1.4:10	1:3.25	0.433	11.3	2580
			95	106.9	327	1931	1:3.41	1:3.7	1.3	0.434	12.3	2160
II	49		33	113.9	533	819	1:7.27	1:7.90	1:6	0.308	10.1	1343
			42	114.7	501	978	1:6.71	1:7.28	1:5.5	0.340	9.6	1920
			55	117.5	458	1220	1:6.25	1:6.79	1:5.0	0.343	10.2	1800
			65	115.7	424	1398	1:5.54	1:6.01	1:4.5	0.363	10.3	1955
			75	113.6	392	1575	1:5.14	1:5.58	1:4.25	0.367	10.6	2135
			85	109.3	360	1753	1:4.65	1:5.06	1:4	0.356	11.7	2005
			95	106.9	327	1931	1:4.26	1:4.63	1:3.75	0.373	12.4	1860
III	50		33	113.9	533	819	1:8.78	1:9.52	1:7.25	0.269	9.4	1113
			42	114.7	501	978	1:8.54	1:9.26	1:7.0	0.284	9.5	1318
			55	117.5	458	1220	1:8.13	1:8.82	1:6.5	0.270	9.9	1415
			65	115.7	424	1398	1:7.38	1:8.14	1:6	0.287	10.1	1416
			75	113.6	392	1575	1:6.95	1:7.54	1:5.75	0.263	11.2	1225
			85	109.3	360	1753	1:6.40	1:6.93	1:5.5	0.263	12.3	1059
			95	106.9	327	1931	1:5.87	1:6.38	1:5.0	0.260	13.7	1031
I	46	Sand, No. 20; Pebbles, No. 22.	33	115.6	494	756	1:6.15	1:6.8	1:5	0.447	8.8	3120
			42	115.0	468	915	1:5.50	1:6.3	1:4.5	0.490	8.6	3290
			55	114.4	431	1142	1:4.87	1:5.53	1:4.0	0.536	8.8	3260
			75	112.5	374	1495	1:4.16	1:4.73	1:3.5	0.602	9.3	2970
			96	102.5	320	1839	1:3.27	1:3.8	1:3	0.604	10.8	3090
III	47		33	115.6	494	756	1:9.22	1:10.3	1:7.5	0.231	7.7	2000
			42	115.0	468	915	1:8.56	1:9.7	1:7.0	0.293	9.1	1810
			55	114.4	431	1142	1:7.91	1:9.0	1:6.5	0.316	9.25	1950
			75	112.5	374	1495	1:6.88	1:8.0	1:5.75	0.334	10.6	1580
			95	102.5	320	1839	1:5.45	1:6.3	1:5.0	0.371	11.0	1760

The writer expects further to verify the method by making and testing field samples from a large number of jobs on which such material is used.

Application

The mere fact that pit-run gravel is ordinarily not a well-graded material, is not an insuperable obstacle to its use. All that is required is its use with the right amounts of cement and water. The principal difficulty is the fact that the product of a pit is often extremely variable as regards grading. Nevertheless, large amounts of this material are being used, and since in many cases great economy results from its use, it would seem that engineers should be prepared to lay down rules for the proper handling of this material.

This investigation was undertaken by the Engineering Experiment Station of the Iowa State College, at the request of the Iowa State Highway Commission, and their present specifications for the use of pit-run gravel are based upon this work.

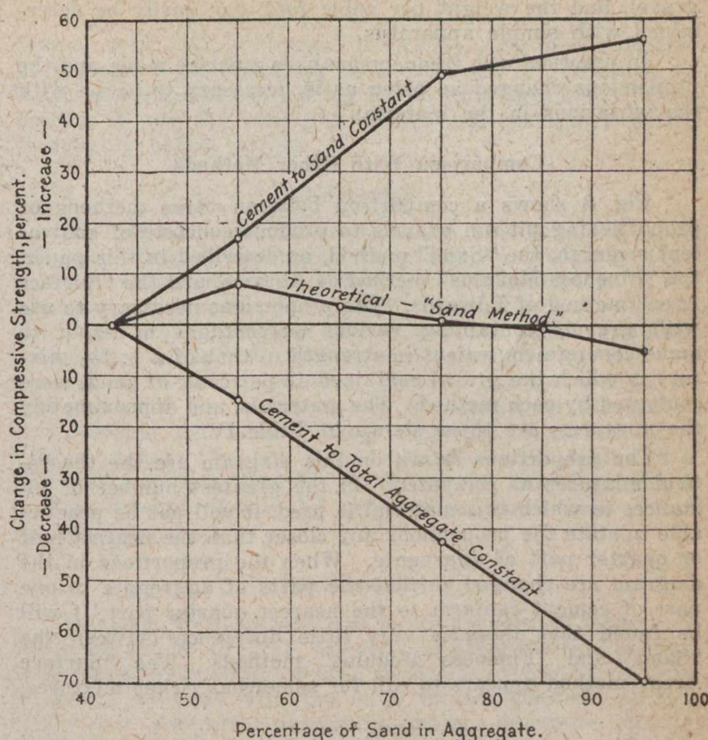

FIG. 7.—VARIATION IN STRENGTH OF GRAVEL CONCRETE, WHEN PROPORTIONED BY FOLLOWING THREE METHODS:—
(a) Cement to Total Aggregate Constant,
(b) Cement to Sand Constant,
(c) The Sand Method for Equivalent Mixtures.

An important advantage of the method of proportioning described in this paper is the simplicity of the field tests required. The percentage of fine aggregate (or sand) in the

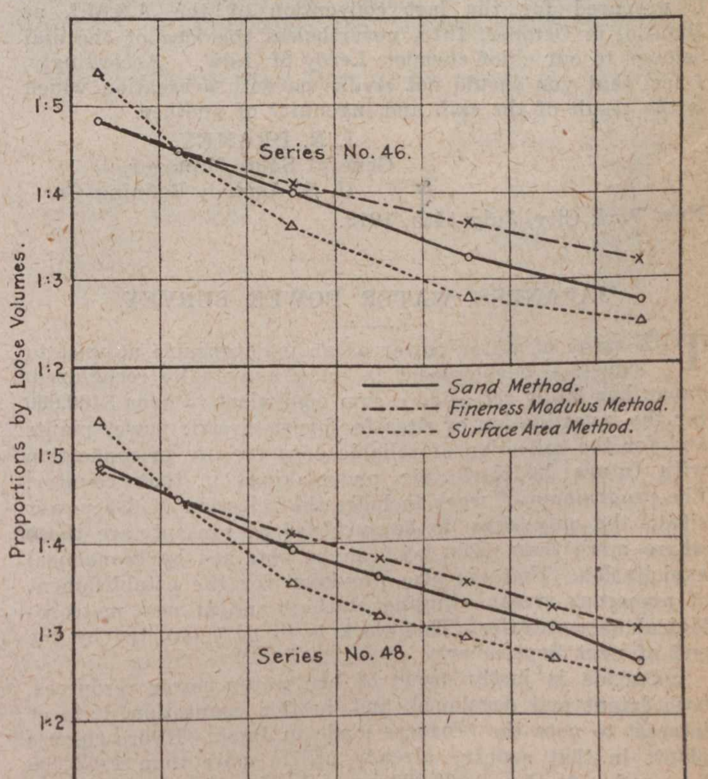

FIG. 8—RELATION BETWEEN THREE METHODS FOR DERIVING PROPORTIONS TO YIELD CONCRETE OF EQUIVALENT STRENGTH, "FINENESS MODULUS," "SURFACE AREA," AND THE "SAND" METHODS

gravel, and the weight per cubic foot, can easily be determined with simple apparatus.

In practical use, frequent analysis must be made and the proportions changed as often as is necessary to agree with the variations in the material.

Comparison With Other Methods

Fig. 8 shows a comparison between three methods of proportioning pit-run gravels to produce concrete of equivalent strength, the "Sand" method, as described in this paper, the "Fineness Modulus" method of Abrams, and the "Surface Area" method of Edwards. The proportions necessary to use with gravels containing various percentages of sand, to make concrete equivalent in strength to that of a 1: 4½ mixture in which the gravel contained 42 per cent. of sand, were computed by each method. The materials, and approximately the mixtures, are those shown in Table IV.

The proportions shown on this diagram are the theoretical mixtures as computed. In the greatest number of instances in which this material is used, it will not be practicable to state the proportions any closer than the nearest half or quarter part of aggregate. When the proportions in the diagram are changed so that the parts of aggregate to one part of cement conform to the nearest quarter part, it will be found that there is very little difference between the "Sand" and "Fineness Modulus" methods. The "Surface Area" method appears to call for somewhat richer mixtures.

LETTER TO THE EDITOR—CORRECTION

Sir,—We are very pleased with the notice given our penetration dial in your issue of July 10th, but wish to call your attention to an error in connection therewith. While it is true that the idea of advocating concordant action in specifying the penetration of asphalt for the various types of pavement made with that material, where traffic conditions and climate are the same, was indicated by the paper I prepared for the last convention of the A.S.M.I. at Buffalo, in October, 1918, nevertheless the idea of the dial belongs to our chief chemist, Leroy M. Law. Accordingly, I feel that you should not credit me with a creation which is the result of the skill and ingenuity of another.

J. R. DRANEY,
General Sales Manager,
U. S. Asphalt Refining Co.

New York City, July 14th, 1919.

JAPANESE WATER POWER SURVEY

THE value of water power as an indispensable adjunct to industrial development is being universally recognized. Japan has lately set aside a sum equivalent to over $400,000 for the investigation of sites for hydro-electric power plants and for the collection of reliable data for use in connection with future hydro-electric undertakings in that country. The programme of work includes the selection of 635 power sites; the only sites to be surveyed at present are those where more than 1,000 h.p. can be obtained by economical exploitation. There is also provision for the establishment of numerous stream-gauging stations and of new meteorological observatories. This work is to be completed by the end of next September.

Canada is justly proud of her water power resources, both latent and developed, and, in this connection, it is of interest to note the progress made in Japan. Hydro-electric plants in that country already utilize more than 1,000,000 h.p., and a further 2,000,000 h.p. is under lease for development. Construction work for about one-half of the latter quantity is now being proceeded with, and it is estimated that some 5,000,000 h.p. is capable of development on commercial lines. In Canada, the total hydro-electric power developed is over 1,800,000 h.p.—By L. G. Denis, writing in "Conservation," an official journal published by the Commission of Conservation, Ottawa.

TNT AS A BLASTING EXPLOSIVE

By Charles E. Munroe and Spencer P. Howell
Bureau of Mines, Washington, D.C.

TRINITROTOLUENE is an explosive which is obtained by acting upon toluene with nitric acid in the presence of sulphuric acid. Toluene is a liquid substance which is produced from soft coal in the process of making coke, coal gas and coal tar, and it is recovered for use from both the gas and the tar. It is also made in other ways. The name TNT is an abbreviation of trinitrotoluene, which is the name given by chemists to the explosive in order to state its composition while designating it, and to thus distinguish it from many other nitrotoluenes known to them.

History

TNT has been known to chemists since 1863, and it was adopted as a military service explosive by 1902, but it did not become widely known until the Great War, when it came to be extensively used as bursting charges for high explosive shells, depth bombs, mines, torpedoes and other devices, and in demolitions where very violent detonation effects were sought to be produced with the largest measure of safety from these effects to the users. It was also used in admixture with other substances to produce other military explosives, such as amatol and sodatol.

Safety

Because of the devastating effects produced by the explosion of these devices charged with TNT, and because of the many most disastrous accidents which have occurred during the manufacture and transportation of large quantities of TNT under the hurried conditions necessitated by war conditions, many have been led to conclude that TNT is an especially dangerous explosive, but it really possesses characteristics which render it less dangerous than many explosives generally used in our industries. Thus it has been found more difficult to explode it with certainty than nitroglycerine, dynamite or gun cotton. In fact it was considered so safe that in 1910 the British government, on advice of its explosives experts, issued an order-in-council exempting it from being deemed an explosive, and subject therefore to the explosives regulations, during manufacture and storage unconditionally, and when conveyed and imported, provided it was perfectly packed. But this order has since been rescinded, and it may be proper to say in this connection that all substances possessing explosive properties should be treated with special care and surrounded by safeguards.

Industrial Use

With the cessation of hostilities this continent found itself with very large supplies of TNT on hand. So large, indeed, that it was deemed unwise to keep all of it in storage awaiting future military use, and it was proposed to devote many million pounds of it to industrial use. Now, although nitrotoluenes in admixture with other substances have been used as industrial explosives to a certain extent for more than a decade, TNT, as such, for several reasons, and especially because when its special value as a military explosive was recognized stocks of it were accumulated for war purposes, has not been used in industrial blasting except tentatively. It is not surprising, therefore, that objections should have been made to its suggested use as an industrial blasting agent, and doubts expressed as to its operativeness. It is the purpose of this paper to show how TNT may be safely and efficiently used in industrial blasting operations by those skilled in blasting and to correct many erroneous or misleading statements which have been circulated as to the properties of TNT by giving the results of careful experiments and observations, many of which have recently been made at the United States Bureau of Mines Experiment Station.

General Characteristics

When chemically pure TNT is a pale yellow, crystalline substance which acquires a deep yellow to brown color on exposure to light. It melts at about 80.5°C. (177.9°F.), and when in the molten state it is cast into shells or run into cold water where it is granulated, by chilling, in the form of pebbles or pellets. TNT may, therefore, appear in granulated crystalline form, in pebbled or pelleted form, or in blocks or other cast forms. As offered by the Department of the Interior for use in blasting it is in the granulated crystalline form. Naturally, as produced on a large scale, TNT is not chemically pure, though the admixed substances are principally other nitrotoluenes which do not materially affect the explosive quality of the product though they do change its appearance and other physical characteristics. Thus the War Department secured and has alloted to the Department of the Interior for industrial use three grades of TNT as follows: Grade 1 having a setting point (S.P.) of 80°C. (176°F.); Grade 2, (S.P.) 79.5°C. (175.1°F.); and Grade 3, (S.P.) 76°C. (168.8°F.), the setting point of the molten TNT being employed by the Ordnance Corps, U.S.A., as the criterion of purity, because it is more readily observed with accuracy than the melting point of the solid. This Grade 1 appears as a dry granular crystalline powder, having a slight yellow color, and so fine that it will pass through a 30-mesh sieve. Because of its dryness it readily gives off dust; Grade 2 is a granular crystalline powder resembling light brown sugar, with a reddish tinge in color, and so fine that it will pass through a 12-mesh sieve. It is less dry and, therefore, less free-running and dusty than No. 1, and Grade 3 as a dry crystalline granular powder having a pale sulphur-yellow color, and so fine that it will pass through a 12-mesh sieve. It is not dusty, has the consistency of brown sugar, looks as if it were slightly moist, or greasy, and shows a tendency to cake, and is less free-running than No. 2.

Solubility and Hygroscopicity

TNT is almost insoluble in water. According to Marshall, water at 15°C. (59°F.) dissolves 0.021 per cent. of it, and at 100°C. (212°F.) 0.164 per cent. That is, 100,000 parts of water at 15°C. dissolve 21 parts of TNT, and at 100°C., 164 parts. The solubility of the different grades mentioned above is of the same order as this. In fact, the lower grades, and especially Grade 3, have a greasy feel and appearance and are, to a degree, water repellant. The proved solubility of TNT shows that it cannot be deliquescent ,or more than slightly, if at all, hygroscopic. Investigation at the Bureau of Mines Experiment Station has shown that it absorbs moisture when exposed to the atmosphere to about the same extent as powdered glass. This is for all practical purposes an entirely negligible quantity.

Packages

Military TNT, as offered for use in industrial operations, is packed in the granular crystalline form, in boxes made of white pine, ⅝-inches thick. The boxes are lock-cornered construction, and lined with paraffined paper. Most of the boxes of TNT received at the Explosive Experiment Station of the bureau were 22⅝ by 15¼ by 13 inches outside dimensions, and occupy a volume of 4,436 cubic inches (2.57 cubic feet). The boxes contained 100 pounds of TNT, and their gross weight averaged 113 pounds. It is possible that the boxes supplied by other manufacturers differ in dimensions and weight from these. The tops and bottoms are fastened on with nails. In opening the boxes, if force is necessary, the covers should be pryed off with wooden wedges. Grades 2 and 3 tend to cake during storage, and the lumps must be broken up to render the explosive "free running," so that it may be made into cartridges or loaded directly into bore holes. They may be so broken by pressing them with a wooden paddle or striking them light blows with a wooden mallet on a wooden surface.

Poisoning

TNT has a faint smell and a bitter taste. It produces brown stains on the skin which are difficult of removal. It is toxic and may produce poisoning by being inhaled as dust, or taken into the mouth, or by absorption through the skin but, unlike nitroglycerine, which produces severe headaches if but even a minute quantity touches the skin, rather long contact with TNT is required before its toxic effects become of moment. Nevertheless, those engaged in handling it, crushing the lumps and loading it into cartridges should avoid getting it into the nose and mouth, and clean their hands thoroughly before eating.

Detonation

TNT is more difficult to detonate with certainty than nitro-glycerine, dynamite, or the explosives ordinarily used in engineering operations, in mining and in quarrying. TNT charges require a No. 8 detonator (blasting cap) or electric detonator, while dynamite and the other high explosives ordinarily used in industrial operations require but a No. 6 detonator. Objection has been raised to the use of TNT on the ground of the increased cost consequent on the use of this stronger detonator. From inspection of current price lists it appears that No. 8 detonators cost nine-tenths of a cent more apiece than No. 6 detonators, and that No. 8 electric detonators cost 1.7 cents more apiece than No. 6 electric detonators.

Sensitiveness

As shown by tests with the pendulum friction device, all the three grades of TNT are less sensitive to friction than 40% straight dynamite, gelatin dynamite or picric acid, and as shown by tests with the large impact machine, all are sensitive to percussion than 40% straight dynamite, amonia dynamite and nitrostarch powders. It may be set on fire, when it will burn, but this burning may change to a detonation. Hence TNT must be protected from fire and causes of fire, such as sparks, flame, heated bodies, friction, percussion and the like, as all explosives should be at all times.

Gaseous Products of Detonation

In tests made at the Pittsburg Experiment Station by detonating TNT, Grade 1, and collecting the gases, it was found that 454 grams (one pound) of the explosive gave 506.5 liters of gases having the following compositions:—

TABLE I.—GASES FROM DETONATION OF GRADE 1, TNT.

	Per cent. by volume.	Volume in liters.
Carbon dioxide	4.9	24.8
Oxygen	2.5	12.7
Carbon monoxide	46.6	236.0
Hydrogen	24.6	124.6
Methane	2.6	13.2
Nitrogen	18.8	95.2
	100.0	506.5

from which it appears that there was produced 46.6%, or 236 liters of a poisonous gas (CO), and 73.8%, or 373.8 liters of combustible gases (CO, H and CH_4). The tests of other grades of TNT gave similar, though not identical results, but all indicate it to be unsafe to use TNT in close places, such as underground workings and particularly coal mines. These results emphasize the importance of remaining away from the face of the blast after the explosion, until assured that the gases produced have been blown or have diffused away from the interstices of the debris. The safe waiting time will, of course, vary with the quantity of explosive fired, the location, such as a pocket, or valley, or plain, and the atmospheric conditions, particularly that of the force and direction of the wind. These precautions are such as should be taken with all explosives.

Relative Efficiency

In determining the relative efficiencies of explosives in use, the Bureau of Mines has long employed the "unit deflective charge," and the "rate of detonation" as criteria. The unit deflective charge is ascertained by exploding a known weight of the explosive in the ballistic pendulum and this term "unit deflective charge" is defined as "that weight of an explosive which will swing the ballistic pendulum the same distance as one-half pound of 40% straight nitro-glycerin dynamite." It appears that the less the unit deflective charge, the greater the propulsive capacity of the explosive; hence, this is considered a measure of the ability of an explosive to dislodge and bring down material in which it is exploded.

Unit Deflective Charge

The unit deflective charge, in grams, of 40% dynamite and of Grades 1, 2 and 3 of TNT, with their corresponding percentage figures, using 40% dynamite as the basis of 100%, are given in the following tabulation:—

TABLE II.—UNIT DEFLECTIVE CHARGE OF FOUR EXPLOSIVES

Explosive.	Dynamite 40%.	TNT 1.	2.	3.
Unit deflective charge (grams) ..	227	201	199	209
Unit deflective charge (%)	100	113	114	109

From the above, it will be seen that each and every grade of TNT is stronger when so measured than 40% straight nitro-glycerin dynamite.

Rate of Detonation

The method of determining the rate of detonation is to charge the explosive in a file 1¼ inches in diameter and 42 inches long at normal density (that is, no unusual effort is made to get the explosive to a high density), and to fire the charge with a No. 8 electric detonator.

The "rate of detonation" is considered a measure of the ability of an explosive to disrupt and shatter material in which it is exploded.

The results of such tests are given in the following tabulation:—

TABLE III.—RATE OF DETONATION OF FOUR EXPLOSIVES

Explosive.	Dynamite 40%.	TNT 1.	2.	3.
Apparent specific gravity	1.24	0.91	0.88	0.86
Rate of detonation (meters per sec.)	4,772	4,747	4,852	4,482
Rate of detonation (%) .	100	99	102	94

Packing in Cartridges

It should be carefully noted that the comparisons made in the unit deflective charge table are by weight and in the rate of detonation table by volume. When either of the three grades of TNT are packed in cartridge cases, or in bore holes under ordinary tamping pressures, the apparent specific gravity of the charges vary from 0.81 to 0.95, while when 40% straight dynamite is so packed, the apparent specific gravity of its charges are from 1.15 to 1.34. It is evident, therefore, that for equal weights the TNT cartridges will be more bulky than the dynamite cartridges. As a consequence of this, larger bore holes must be used for TNT charges than for dynamite charges of equal weight. This presents an advantage for the dynamite over the TNT, but on the other hand, it has been observed that as the apparent specific gravity of the TNT approaches the lower limit given above, its resistance to wetting, when the cartridges are immersed in water, increases. Hence, it is recommended that except in assuredly dry holes, or in big blasts, where full boxes of the explosive may be fired in chambers, the TNT be packed for use in cartridges and that, as the No. 3 grade is the most water resistant of them all, it be packed at a low pressure and reserved for use in the especially wet work. To particularly distinguish the cartridges of grade 3, the wrappers may be of a specially chosen color or, better yet, they may be packed in paraffin coated wrappers and after the charge has been packed in these wrappers and the ends folded in, the ends should be redipped in the molten paraffin to completely seal them. For emergency use, newspaper may be employed for wrappers, being made up into cylinders of the desired dimensions by rolling about a pick handle or other convenient tool, but where considerable quantities are to be packed, it will be better to make a regular job of the operation, and to pack the explosive in the standard manilla wrappers, made by means of a cartridge machine.

It is only in large scale operations of crushing and repacking TNT into cartridges that there is much likelihood of any one becoming poisoned, for, as a rule, it requires continued contact with it through some period of time to produce this result. In handling TNT the following rules should be observed:—

Precautions in Packing

1. Only persons in good health should be employed.
2. Special clothing should be provided to be used only during working hours. Gauntleted gloves may be worn, but this is not necessary.
3. The hands and face should be washed before meals and before leaving the factory.
4. Care should be taken that none of the TNT comes in contact with the mucous membrane, such as that of the mouth, nose, eyes, etc. Workers should, therefore, be cautioned against touching these parts with their hands, or taking a chew of tobacco.

Cases of TNT poisoning which have occurred in considerable numbers in the factories operated under war conditions, appear to have resulted from neglecting to observe all the foregoing rules.

This poisoning is usually first evidenced by the appearance of a rash on the hands, neck or face. When this occurs, the case should receive prompt medical attention, and it would be desirable to transfer the person to other work. In this way, a worker who is easily susceptible to TNT poisoning will not be exposed to further danger. In factories where the opportunities for TNT poisoning are great, the effects are not usually evidenced until after five weeks of work.

Charging Bore Holes

TNT should be charged into bore holes, primed, tamped and stemmed in the manner customarily followed in the use of high explosives in blasting, special care being taken in charging wet holes not to tear or break the cartridge case or wrapper while loading it into the hole and tamping it. It may be used in chambering holes for subsequent charging with black blasting powder, just as dynamite is used. When TNT shots are fired, if the detonation is complete, there will be produced large volumes of dense, black smoke.

Practical Field Demonstrations

The practical value of TNT, grade 3, for general blasting purposes has been demonstrated by a number of field tests, such as adobe shots on boulders and concrete piers, blasting out oak stumps, splitting oak logs and shooting under water. In all the tests described herein the TNT was loaded in extemporized wrappers, made from newspapers, and detonated by a No. 8 electric detonator. A brief description of these tests, made at the Explosives Experiment Station by A. B. Coates, J. E. Tiffany and W. J. Montgomery, are as follows:—

Test No. 1—Adobe.—A 1½-pound charge of Grade 3 TNT was mudcapped with wet clay and fired on a sandstone boulder, 6 ft. long, 3 ft. wide and 1½ ft. thick. The largest piece obtained was 2 ft. by 2 ft. by 1 ft. Forty per cent. of the boulder was broken into fragments 2 ins. or less.

Test No. 2—Adobe.—In removing two concrete piers, 10 ft. long, 7 ft. high, 1½ ft. thick at top and 3½ ft. thick at bottom, an opportunity was given to compare TNT directly with 40% straight nitro-glycerin dynamite. All shots fired were adobe shots mudcapped with moistened clay. In six blasts, using a total weight of 10.7 pounds of TNT, 159.5 cubic feet of concrete were removed, or 14.9 cubic feet per pound of TNT, while in five blasts, using a total weight of 9.6 pounds of 40% straight nitro-glycerin dynamite, 135 cubic feet were removed, or 14.1 cubic feet per pound of 40% dynamite.

Test No. 3—Stump Blasting.—A solid oak stump 3 ft. in diameter, rooted in clay, was removed by the use of six 1½-pound charges of TNT, one charge being inserted under

(Concluded on page 174)

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PRINCIPAL CONTENTS

ROAD TAX ON GASOLINE

RAISING money for roads has always been the hardest part of their construction. Various means have been suggested from time to time for financing roads more readily than by the present methods of taxation. Several months ago, C. A. Mullen, director of the paving department of the Milton Hersey Co., Ltd., Montreal, contributed an article to *The Canadian Engineer*, suggesting a wheel tax. Mr. Mullen now writes that his attention has been drawn to the possibility of raising funds by taxing the gasoline used by motor vehicles.

While this is not a new suggestion, having been discussed many years ago by Clifford Richardson, of the Barber Asphalt Paving Co., it is one which has not yet received the thorough consideration and discussion which it very evidently merits.

A tax on gasoline would in many ways be a very equitable method of raising funds for road construction. There is an analogy between the wheel tax and the gasoline tax, as both try to secure money from the actual users of the road in proportion to the service they receive. But the wheel tax does not take into consideration the extent to which the vehicle is used, while a tax on the gasoline is in direct relationship to the actual use. The more a vehicle is operated, naturally the more gasoline it requires; also, the heavier the vehicle, the greater the amount of gasoline it consumes per mile. Therefore a tax on gasoline would approximately be a tax per ton-mile.

As Mr. Mullen points out, there would be certain difficulties to be solved, such as finding a means for taxing vehicles not using gasoline, and devising simple ways of rebating the tax on gasoline used for purposes other than to generate power for transportation over highways. More discussion of this plan of taxation might lead to a solution of some difficulties.

CANADA'S FUEL PROBLEM

THERE is no necessity for Canada, with her vast resources of fuel and water-power, to go cold or to have her industries throttled by shortage of power, but Canada may have a sore trial in both these respects unless every possible effort is made to deal with the fuel and power situation in a comprehensive manner, writes Arthur V. White, consulting engineer of the Commission of Conservation, in the last issue of the "General Electric Review," published by the General Electric Co., of Schenectady, N.Y. Mr. White's article, "Canada's Fuel Problem—Some National and International Aspects," was reprinted in full in last week's issue of *The Canadian Engineer*, on account of the vital interest to Canada of his subject, and the broad and statesmanlike manner in which he deals with it.

The fuel problem of Canada must be solved by the engineers of Canada. It cannot be left entirely to politicians or financiers. Their help is needed, but the way must be and is being pointed out by Arthur V. White, R. A. Ross, C. A. Magrath, B. F. Haanel, James White, J. B. Challies, H. G. Acres, John Murphy, Arthur A. Cole, and a score of other prominent engineers who have specially studied the problem and who realize, better than any other group of men in Canada, the steps needed for its solution.

Mr. White's article was the twenty-eighth in a series on the more efficient utilization of America's fuel resources that is appearing, one article each month, in the interesting and well-edited "house-organ" of the General Electric Co. This series of articles forms a very important contribution to the existing literature upon the subject, and no doubt has been followed with interest by many of those engineers who have recognized the importance of the problems discussed.

Letter to the Editor

PRESENT SYSTEM IS CONVENIENT

Sir,—In connection with the present attempt to introduce the metric system into North America, attention is called to an apparently unobserved connection between length, volume and weight contained in our system.

The American railway usage of a 100 ft. chain, with the foot divided into tenths, hundredths and thousandths, is the only decimal system applicable to office, shop and field. The meter (almost 3.3 ft.) is too long for the office, and its next division, the decimeter (4 ins.), is too short for office use. A 20-meter chain (almost 66 ft.) is, like the Gunter chain, too short for railway work, and in levelling it is difficult to catch which meter is being read on the rod when close up.

The foot furnishes a remarkable relationship between volume and weight through the fact that a cubic foot contains 1,000 cubic tenths and a cubic foot of water weighs 1,000 ounces (62.5 lbs.). Thus a cubic tenth holds a fluid ounce of standard water, which weighs an ounce.

To apply this, imagine a box 1.5 tenths (0.15 ft.) by 1.5 tenths (0.15 ft.) by 2.7 tenths (0.27 ft.) long. It contains 6.075 cubic tenths (0.006075 cu. ft.) and will hold 6.075 fluid ounces of standard water, weighing 6.075 ounces av.

It would be possible to obtain a much better international measure by dividing a meter into three parts, calling each a metric foot (almost 1.1 ft.). This metric foot could be divided in tenths and the cubic tenth would weigh a metric ounce and hold a fluid metric ounce. One cubic metric foot, weighing 81.749 lbs. av., could be taken to contain ten metric gallons and to weigh 100 metric lbs. Each metric pound would contain 10 metric ounces. The "Canadian Magazine" published an article on this subject by the writer about 1895.

C. R. COUTLEE.

Ottawa, Ont., July 22nd, 1919.

PERSONALS

Major Alan Mair Jackson, who was recently appointed engineer of Brant County, Ont., was born in 1879, in New Zealand. He was educated at Dunedin High School and Otaga University, and served as an apprentice for six years in a foundry and machine shop, much of this time being spent in the erection of machinery. Major Jackson then became assistant engineer on drainage and sewerage in the city of Dunedin. Afterwards he served for six months as supernumerary engineer on a cargo tramp steamer, but left same upon its arrival at England. In 1905 he was sent to British Guiana to erect a gold dredge and to run a survey of a large gold dredging concession in the jungle. Subsequently he joined the Barima Gold Mining Co., in Demerara, on the border of Venezuela, where he erected all the company's machinery and built several miles of light railway. After four years in Demerara, Major Jackson returned to England in 1909, and early the following year came to Canada, where he spent a year in the mechanical department of the Canada Foundry Co., and then started a small engineering practice in Dunville, Ont. In 1912 he passed the O.L.S. examinations and became engineer for Haldimand County. The following year he moved to Brantford, Ont., and purchased the surveying and consulting practice of Howard Fairchild. In March, 1916, he enlisted as a captain in the 215th Battalion, but was soon promoted to the rank of major. He reverted to a captaincy upon his transfer to the 257th Railway Construction Battalion, with which unit he went to France. This battalion later became the 7th Battalion of Canadian Railway Troops. In France he was again promoted to the rank of major, and was in command of a company of the 7th Battalion for twenty-two months. In April, 1919, he returned to Brantford, and was appointed county engineer when construction work under the Ontario Highway Act was commenced by Brant County.

G. A. Kent, of Vancouver, gave an illustrated lecture recently before the Vancouver Board of Trade on a proposed extension of the Pacific Highway via Vancouver, Squamish and Lillooet, describing the scienic advantages of the route and the water power, timber and other natural resources that would be made available.

Sir Donald Mann, who is visiting British Columbia, has given an interview to the press in which he states that he is through with railroad construction. This is Sir Donald's first trip to the Pacific coast over the Grand Trunk Pacific Railway. He is very enthusiastic about the prospects of the interior of British Columbia.

Frank S. Easton, hydro-electric engineer with the British Columbia Electric Railway Co., Vancouver, has resigned to enter the employ of the Mexican Light & Power Co., with headquarters in Mexico City. Mr. Easton will have charge of cèrtain hydraulic and electrical work for the company, under the direction of G. R. G. Conway, managing-director, who was formerly chief engineer of the British Columbia Electric Railway Co.

TNT AS A BLASTING EXPLOSIVE

(Continued from page 172)

each lateral root and one under the top root. The stump was broken into two about equal sized pieces which were thrown 35 and 65 ft. respectively from their original position. A crater 12 ft. in diameter and 4 ft. deep was formed. This shot was evidently overloaded.

Test No. 4—Stump Blasting.—An oak stump 3 ft. in diameter rooted in clay and sandstone fragments was removed by the use of eight ¾-pound charges, six being placed under the lateral roots and two under the centre. The stump was broken into four pieces, two large and two small. The large pieces were overturned at the edge of the crater, one small piece remained loose in the ground and the other was thrown about 75 ft.

In connection with this test, it is important to call attention to the fact that the charges were loaded in wet holes for a period of 1½ hours.

Test No. 5—Stump Blasting.—An oak stump 18 inches in diameter, rooted in clay was removed by a single 2-pound charge of grade 3 TNT placed under the centre of the stump. The stump was broken into two pieces and overturned at the edge of the crater.

Test No. 6—Stump Blasting.—A solid oak stump 3 ft. in diameter, rooted in clay was removed by four 1¾-pound charges placed under the lateral roots. The stump was split into three large pieces which were lifted about 10 ft. in the air and fell back into the crater.

Test No. 7—Log Splitting.—A solid oak log 6 ft. long, and 39 ins. diameter, was split into two separate pieces of practically the same size by 4 ounces of grade 3 TNT, loaded in a 2-inch hole located midway between the ends and about 2 inches beyond the centre of the log.

Test No. 8—Log Splitting.—A solid oak log, 6 ft. long, 44 ins. diameter at one end and 40 inches at the other, was split into two separate pieces of practically the same size by 5 ounces of grade 3 TNT, loaded as in Test 7.

Test No. 9—Wet Boreholes.—As the ability to use an explosive under water in very wet boreholes is of great importance, the following test was carried out: A borehole 1½ inches in diameter and 42 inches in depth was drilled vertically in the floor of a coal mine, through coal, limestone and fireclay. The top of the borehole was 4 ins. under water. As the maximum effect was sought, the borehole was overloaded with 2 pounds of grade 3 TNT, the explosive being pressed in sufficiently hard to break up the cartridges. No tamping was used. After a wait of 15 minutes, the charge was fired. A crater 4 ft. in diameter and 42 ins. deep was formed and considerable other material about the crater was so loosened as to be easily removed by a pick.

Conclusions

1. Grade 3 TNT can be successfully used for adobe shots of boulders, for removing stumps and for splitting logs.
2. Grade 3 TNT has shown itself to give results the equal of 40% straight nitro-glycerin dynamite.
3. Grade 3 TNT detonates completely with a No. 8 electric detonator.
4. The evidences of black smoke is not to be taken as an incomplete detonation.
5. Grade 3 TNT detonates completely under water.
6. Grade 3 TNT detonates completely after moderate immersion in wet holes.

ORDER YOUR BOOKS NOW

Owing to the great advance in the prices of paper, printing and binding, John Wiley & Sons, Inc., the well-known publishers, have found themselves compelled to increase the retail prices of a number of their publications, the advance to take effect August 20th. The prices of twenty-three of their leading books are being advanced by from 25c. to $1.00 per volume.