of 5,000,000 gallons capacity was erected, and is still the main dependence of the works.

In 1827 a reservoir was built at Market and Tenth streets, 99 ft. above the creek, with two basins of a combined capacity of one million gallons, afterward enlarged to contain 2.5 million gallons.

These reservoirs were abandoned on June 19, 1879, and removed.

In 1864 a high-service reservoir of 1.5 million gallons capacity was built at Eighth and Rodney streets, 210 ft. above the creek. It is in excavation and embankment, the inside slopes lined with clay puddle and paved with brick laid in cement.

The construction of another reservoir, called the Cool Spring reservoir, was begun, by days' work, in 1874. An estimate of the cost, made in October, 1874, for a basin 18 ft. deep and holding 28 million gallons, amounted to $86,000. Up to November, 1876, there had been expended $129,282.50, and it was estimated that $90,000 was required to finish it. The work was then not satisfactory to the chief engineer. A drain intended to carry off water from springs had become stopped ana the water passed through the bank into the reservoir. The bottom had been underlaid with iron pipe of 2, 3 and 4-in. diameter, intended to drain underlying springs. Some of these pipes were laid with lead joints and some with open joints. The inlet and outlet pipes were laid through the banks without proper precautions against water passing along them. In 1877 a special water commission was created by the Legislature to complete the reservoir. The adjoining land was filled up to divert surface water from the banks. The bottom and slopes were puddled with 2 ft. of clay, and the slopes lined with two courses of brick, on edge, in cement. The bottom puddle was covered with gravel rolled in, and then paved with bricks laid flat in sand. Collars of masonry were placed around the pipes. One basin, holding 11 million gallons, was finished in this manner, and the water introduced in December, 1877. The other basin was finished in October, 1878. Water is pumped from the Brandywine into the north basin, passes over the division wall into the south basin, and thence to the distribution pipes. In November, just after the reservoir had been filled, an increase in the flow of the under drains was noted, and a small hole was discovered in the bottom of the north basin. It was stopped up and no further trouble occurred until March, 1880, when the slope pavement on the east side of the south basin slid down partially, for about 100 ft. in length. It was repaired by building at the foot of the slope a wall 33 in. wide at the top and 39 in. at the base, made with brick taken out in blocks from the damaged brick lining. The puddle under the damaged brickwork was taken out and repuddled, and the paving relaid. The north and west walls of the north basin were strengthened at the base in a similar manner. The total repairs cost $2,365.

In 1878 the flow from the spring west of, and the drainage under the reservoir, was 43,185 gallons per day.

The Cool Spring reservoir is 140 ft. above the creek and the Rodney street reservoir 106 ft. higher, now supplied from a pumping station on Tenth street, near the Cool Spring reservoir.

Distribution is by cast-iron pipe, of which 51.65 miles were laid in December, 1880, with 470 hydrants and 4,344 taps.

The population in 1880 was 42.499, and the daily consumption 3,564,856 gallons. The cost of the works has been about $450,000.

The consumption, expenses and revenue for five years past have been as follows :

	Consumption million gallons.	Expenses.	Revenue.
1876	1.82	$76,302.75	$53,240.34
1877	2.64	40,899.86	55,052.08
1878	3.11	32,694.38	57,173.07
1879	3.58	29,137.00	60,029.13
1880	3.56	42.719.99	68,404.23

The maintenance alone costs about $18,000 per year.

The works are managed by the water committee of the City Council. C. H. Gallagher was the chief engineer for some years before 1877. Henry B. McIntire has held that position since 1878.

LXXXIX.—LYNCHBURG.

Lynchburg, Virginia, is in lat. 37° 22′ N., long. 79° 4′ W., on the south bank of the James River, 90 miles from Richmond. The city is built on a steep acclivity, rising from the river bank and breaking into numerous hills. The town was laid out 1786.

In 1799 "The Lynchburg Fire Company" obtained leave from the trustees of the village, "to sink wells and erect pumps on Main street for the convenience and safety of the citizens." This privilege was exercised to a very limited extent. In 1811 the council granted to John Lynch the privilege of conveying water in wooden pipes through the streets from the springs at the head of Horse ford Branch, reserving to the town the right to use the water for extinguishing fires free of cost. In 1813 the town authorities built a reservoir 12 ft. square near the market-house, and established four fire-plugs. The water was conveyed about 4,000 ft. under 40 ft. head, from the springs to the reservoir, and distributed about 2,500 ft. on Main street. The pipes were 10-in. logs, with 3-in. bore and 10 ft. long, jointed like pump logs and banded at the joints with iron. A log house was built over the reservoir. This was removed in 1830. John Lynch sold his rights to James Wade in 1817. The wooden pipes were all taken up in 1828, except two sections, which were discovered in 1869 in making a sewer excavation, and were in a good state of preservation. They were secured by Mr. Forsberg, the city engineer, but were stolen from him by negroes for fuel.

In 1828, the population being about 5,000, water-works were built by the town, after the plans of Albert Stein, C. E., taking the supply from the James River. A dam at the lower end of Daniel's Island and a series of dams above, connecting Jones & Woodroof's Island with the opposite shore were built, and water conducted by a race to the pump house, where a breast wheel 19-ft. in diameter and 9.5-ft. wide operated a pump of 10-in. diameter and 48-in stroke, which forced the water 22,000 ft. through a 7-in. cast-iron pipe into a reservoir built in excavation, its bottom paved with brick laid in cement, and its slopes paved with cobble stones, and containing 500,000 gallons, with a depth of 10 ft. at 255 ft. above the river. The bottom of this reservoir leaked for many years. The pipe for draining it was placed 1 ft. above the bottom, which increased the labor of cleaning out the sediment from the river water, which is deposited at the rate of 4 in. per year.

This reservoir is now reported as in a dangerous condition.

In 1835 the James River & Kanawha Canal Co. contracted to keep the dams, canals and races belonging to the city perpetually in repair, and to supply water to an amount not exceeding 600,000 gallons per day for consumption and enough water to furnish power to lift that quantity into the reservoir. A freshet in 1870 so injured the canal that the supply of water to the city was cut off, and the company was unable to repair its works except by procuring a loan from the city of $35,000 and assigning to the city all leases for water drawn from the canal. In 1877 another flood caused damage which was repaired by a second loan of $15,000, secured by second-mortgage bonds on the canal property. These bonds have been compromised by the payment of $3,305.83 by the Richmond & Allegheny Railroad Company, the successors of the canal company. On Aug. 5, 1881, by a contract with the railroad company, the city is guaranteed one-fifth of the entire flow of the James River, the minimum flow of which is estimated at 1,000 cubic feet per second.

In 1868 a 60-in. Reynolds turbine was put in, operating a pump of 12-in. cylinder and 60-in. stroke, designed by A. Forsberg, C. E.

In 1879 R. D. Wood & Co. began the construction of two vertical plunger and bucket pumps, operated by a Jonval turbine, and so arranged that during freshets in the river the power can be supplied from a horizontal steam engine of 20-in. diameter by 30-in. stroke, with two tubular boilers of 50 horse-power each. The capacity of these pumps is one and a half million gallons in 24 hours, with 330-ft. lift to the high-service reservoir, located 4,400 ft. from the works.

In June, 1881, the old pump and breast-wheel, constructed in 1828, were removed to give room for a forebay to the new works, and a Knowles steam pump of 18-in. steam and 12-in. water cylinder, 18-in. stroke, was erected, pumping 500 gallons per minute to the low-service through the old 7-in. main.

The piston pump, constructed in 1868, is now being renovated and supplied with a new turbine. The council has also authorized the erection of a duplex, double plunger pump of 2,000,000 gallons capacity. The plunger pattern has been adopted on account of the gritty water and trouble encountered by the piston packing. When this pump is completed there will be a total pumping capacity of 5,000,000 gallons. Steam-power, however, will only be used in case of high water in the river.

In 1869 Samuel Miller bequeathed to the city $20,000 on condition of its use in 10 years toward payment of the cost of "furnishing a supply of water to persons residing on the hill west of the city not now supplied with the James River water," and in 1877 and 1878 a high-service reservoir was built on College Hill, 75 ft. higher than the old reservoir. It is circular in plan, with 232 ft. diameter at the top, and inside slopes of 2 to 1 lined with two courses of stone flagging laid in cement. It is 16 ft. deep, holds 4,000,000 gallons, and cost, including land, $23,480.55. The excavation for the reservoir was through a bed 10 ft. thick of dark tenacious clay, in which sandstone boulders were thickly imbedded. This bed was overlaid with a foot of red clay and underlaid with porous gravel. The same pumps supply both reservoirs at present.

The low-service reservoir is now to be enlarged to the same size as the high-service, which will give a total storage capacity of eight million gallons.

A new 18-in. pumping main will also be laid as soon as practicable.

The distribution is by cast-iron pipes of from 3 to 18 in. diameter, of which nearly 13 miles are in use, about one-third being of less than 6 in. diameter. There are 136 gates, 131 fire-hydrants and 750 taps. Meters are not used. The first pipes laid were unprotected from corrosion, and the river water, which is very soft, caused the formation of tubercles to such an extent as to interfere seriously with the distribution. A 3-in. pipe in Main street was found in 1858 to have its diameter reduced nearly one-half, and a new one was laid, the old one being still retained, but so weakened by corrosion that a tap could not be made without strengthening the pipe by wrought-iron bands or cast-iron sleeves. A section of a 4-in. pipe, which had been in use for 48 years and was badly corroded, was contributed by Mr. Forsberg for exhibition by the American Society of Civil Engineers at the Centennial Exhibition in 1876.

These original pipes were manufactured in Philadelphia. They were of exceedingly hard metal, were in 9-ft. lengths, with 4-in hubs. The 3-in. pipe were $\frac{9}{16}$ in. thick and the 4-in. were $\frac{5}{8}$ in. thick. They were evidently cast horizontally, and many of them were so irregularly cast as to be scant ⅜ in. thick on one side, and full ¼ in. on the other. They are supposed to have been made by Wood & Co., whose foundry at that time was supplied with metal from their furnace making charcoal iron, chiefly out of Delaware and New Jersey bog ores.

Since 1868 all pipes have been coated with Dr. Angus Smith's preparation, with the result of entirely preventing corrosion.

The population in 1880 was 15,959 and the daily consumption 1¼ million gallons. The original cost of the works in 1828 was $50,000. The total cost for construction has been $171,102.88, and for maintenance, repairs and salaries, $51,378.18. The expenditures for 1880 were $6,841.37 and the receipts $12,337.05.

The works are managed by a committee of the Common Council. The city engineer, August Forsberg, C. E., has had since 1866 the charge of construction and general control of the works. James Allen has been the superintendent since 1874.

CORRECTIONS.—Sept. 10, p. 364. *Syracuse*—1st, 3d and 5th paragraphs, for *Oliver Tease*, read *Oliver Teall*. 1st paragraph, for *Aaron Borst*, read *Aaron Burt*. 3d paragraph, for *Stolf's Spring*, read *Stolp's Spring*.

Sept. 10, p. 364. *Danbury*—Second line, for *Paliquioque*, read *Pahquioque*. *5th paragraph*, insert: The dam is 330 ft. long, 30 ft. high and 22 ft. wide at bottom, built of dry stone, except a lining wall, which is made water tight by being laid in cement mortar. *Ninth line from bottom:* There are 2,000 taps. *Sixth line from bottom:* The daily consumption is not known. The supply is all that the consumers need. Some meters were set soon after the introduction of water, but caused so much trouble by freezing up that their use was discontinued. Service pipe are generally of galvanized iron. *Last two lines*, insert: The annual cost of maintenance is about $1,000. The bonded indebtedness is $148,000. This includes the cost of the proposed extensions. The water commissioners pay interest on bonds out of the receipts, and if there is any surplus the borough directs how it shall be used. The engineer of the works is David G. Penfield, C. E.

ACKNOWLEDGMENTS.—Received from A. C. Sekell, City Surveyor and Supt. W. W., Report of Board of Public Works of Grand Rapids, Mich., for April 30, 1881. From A. Forsberg, City Engineer, Lynchburg, Va., Reports of city officers of Lynchburg for 1878 and 1880, and notes on water-works. From T. C. Keefer, C. E., Reports on Proposed Extension of Hamilton, Canada, Water-works, by T. C. Keefer and John Kennedy, 1879, and Historical Sketch of Hamilton Water-works. From Edgar H. Brown, Treas., Sec. and Supt. W. W. Co., Historical Sketch of Water-Works of Syracuse, N. Y. From E. H. Keating, City Engineer, description of water-works of Halifax, N. S. From F. B. Rhoads, Supt. Water Dept., Annual Report of Phœnixville, Pa., Water Dept., and sketch of works. From John W. Bacon, C. E., sketch of water-works of Danbury, Conn. From H. B. McIntire, Chief Engineer Water Department, Annual Reports of the Water Department of Wilmington, Del., 1876, '7, '8, '9, 1880.

CORRESPONDENCE.

BEST BOOKS ON SEWERAGE.

QUEBEC, Sept. 10, 1881.

EDITOR ENGINEERING NEWS:

Can you inform me what is the best work on sewerage for towns and villages, one which embodies the vat system, as well as other methods of disposing of sewerage material.

Respectfully, E. MOORE.

[By "vat system" we suppose our correspondent means the treatment of sewage by precipitation. The best work which embodies the sewerage for towns and villages, as well as the methods of disposal, is Bailey Denton's "Sanitary Engineering." The most complete and scientific treatise on sewerage alone is Latham's "Sanitary Engineering." The best books on sewage precipitation are: Robinson and Mellin's "Purification of Water-carried Sewage." London. 1877. Robinson, "Sewage Disposal." London. 1880. Another good little book on sewage utilization alone is Burke's "Sewage Utilization." London. 1873.]

GORDON'S FORMULA AND PHŒNIX COLUMNS.

PHŒNIXVILLE, Pa., Sept. 12, 1881.

EDITOR ENGINEERING NEWS:

DEAR SIR: Various technical periodicals of recent date extract from a paper presented to the American Society of Civil Engineers, a "record of tests" made on Phœnix colums at the Watertown testing machine. This extract is supplemented in each case by the remark that the results thus obtained *show the inapplicability of Gordon's formula to these columns.*

No well-informed engineer interested in this question can let such a statement pass uncriticised. In reality the discordant results are due not to Gordon's formula, but to the persistence of engineers to use that formula in a manner altogether unwarrantable.

It is well known that Gordon deduced the various constants from Hodgkinson's experiments, and that they therefore represent *English iron.* But the constants: 36,000 $(=f)$ and $\frac{1}{3000}$ $(=a)$ are to be used *for solid rectangular sections only*, and this is plainly stated by the various authorities (Rankine App. Mech., p. 362) (Rankine Civ. Eng., pp. 237 and 522), hence the utter absurdity of applying these constants to columns of *American manufacture and of any cross-section*, and then announcing that the results by Gordon's formula do not agree with experimental inquiry.

That engineers generally fail to recognize this fact, is shown plainly enough by various published records of similar experiments, for while they note many details; just such data as would enable one to make necessary calculations are omitted—I refer to data allowing the calculation of the radius of gyration.

In order to substantiate the above, and to show that a right application of Gordon's formula will give results agreeing quite closely with experiment. I have calculted "f" (ultimate strength in pounds per square inch) by that formula and compared the same with the record referred to above. The following tabulated statement admits an easy comparison:

I.—No. of experiments.	II.—Length of columns.	III.—Area of cross section.	IV.—$\frac{l}{d}$	V.—r^2.	VI.—"f" in lbs. per sq. in. (by experiment).	VII.—"f" in lbs. per sq. in. (by formula).	VIII.—Differences of cols. VI. and VII.
	Feet.	Inch.					
1	28	12.062	42	9	35,150	33,576	1,574
2	28	12.181	42	9	34,150	33,576	574
3	25	12.233	37.5	9	35,270	35,000	270
4	25	12.100	37.5	9	35,040	35,000	40
5	22	12.371	33	9	35,570	36,367	797
6	22	12.311	33	9	34,360	36,367	2,007
7	19	12.023	28.5	9	35,365	37,650	2,285
8	19	12.087	28.5	9	36,900	37,650	750
9	16	12.000	24	9	36,580	38,820	2,240
10	16	12.000	24	9	36,580	38,820	2,240
11	13	12.185	19.5	9	36,857	39,845	2,988
12	13	12.069	19.5	9	37,200	39,845	2,645
21	25 ft. 2.65 in.	18.30	25.6	20	36,010	38,475	2,465
22	8 ft. 9.50 in.	18.30	9	20	42,180	41,537	643

Columns 1, 2, 3 and 6 are obtained from published accounts, 4 and 5 by approximate calculations, 7 by calculation by formula, and 8 by subtracting results of columns 6 and 7. The radius of gyration was assumed to be the same for all 4 segment columns. No graphical representation will be needed, the last column showing plainly enough the character of the results. The form of Gordon's formula employed in the above calculations is:

$$p = \frac{42,000}{1 + \frac{1}{50,000} \times \frac{l^2}{r^2}} \quad \text{(1.)}$$

and is extracted from a lecture delivered by Prof. Burr before the class in Civil Engineering at the Rens. Poly. Inst., since published in Vol. 2, No. 2, of the papers of the Pi Eta Scientific Society, and reprinted in ENGINEERING NEWS of July 30, 1881. The constants here used are deduced from American experiments, and hence *American iron*, while the term $\frac{l^2}{r^2}$ allows the adaptation to *any form of cross-section.* It will be noticed that some of the experiments have been omitted. They are those in which the ratio of length to diameter becomes small, for then we have no more a "long column," and our formula being deduced for such only does not apply.

It is also seen that for a column 25 ft. long the results of formula and experiment are almost identical. I find that this is exactly the mean length of the Phœnix columns experimented upon by Bouscaren, and from which the formula used was deduced. Hence it would seem that, were the above constant determined from a greater number of reliable experiments, results by the same would be still more accurate, while the addition of a term in the numerator might allow its application to columns of more varied lengths.

GEO. A. JUST.

P. S.—While discussing the above it has been remarked, that with such a change of constants the formula is no longer that of Gordon.

Now this is an entirely erroneous notion. Gordon's formula virtually consists of two distinct parts; the one entirely mathematical, and therefore perfectly general (the proof of which is known to every engineering student), the other empirical, and hence adapted to material of one manufacture only. Names (instances can be drawn from almost every branch of engineering) are affixed to the analytical formulæ, hence it is wrong to hinge the name in this case on the constants. Gordon's formula always will remain Gordon's formula, no matter what changes may take place in the constants.

Again, it has been urged that American manufacturers are frequently called upon to proportion columns according to Gordon's formula, and that tests as the foregoing were intended to illustrate both the unfairness of the requirement and the superiority of American iron. This may seem to offer an excuse for employing old constants, but it does not touch upon the matter of cross-section; and surely no engineer would dare endanger his reputation by forcing the application of a formula to circular columns (or what is still worse, to "built columns"), which was deduced for solid rectangular cross-sections only.

Gordon's formula, used as it should be, is as good to-day as when originated, and will, when applied with a knowledge of its derivation, give results accurate enough for the purposes of the engineer.

G. A. J.

WIND PRESSURE.

PITTSBURGH, Sept. 12, 1881.

EDITOR ENGINEERING NEWS:

In your number of Aug. 20, I notice an article of Mr. E. J. Ward, C. E., which refers prominently to a remark I made at the conclusion of my discussion of a paper read before the American Society of Civil Engineers by Mr. C. Shaler Smith, on Wind-Strains.

Judging from Mr. Ward's remarks, it seems I was not as clear as I intended to be, and would,