

was changed in 1640 and in 1832 it was incorporated as a city.

In 1843, the population being 11,000, Charles Stearns built a reservoir on the site of the present Lombard reservoir, and laid 8 miles of wooden logs, bored to 7, 6 and 4-in. diameter.

In 1845 the works were enlarged and the Springfield Aqueduct Company organized; they built the "Lombard," "Heywood," "Chapin" and "Worthington" reservoirs.

The number of takers at this time was 700, and the annual water rents amounted to \$2,700. The company enlarged its works from time to time, but the supply was always inadequate. In 1867 the wood pipes were replaced by wrought-iron and cement, the east Van Horn reservoir was constructed, which was estimated to contain 45,000,000 gallons, and the Lombard reservoir was subsequently enlarged, and the west Van Horn reservoir built.

The first action taken by the city was in 1860, when a well 20 ft. deep and 10 ft. diameter was sunk, the flow of which was estimated to be 50 gallons per minute.

In 1860 a private company known as the City Aqueduct Company was incorporated, which, in this year, laid 1,950 ft. of 7-in. pipe and a brick drain or gathering gallery, along the base of the hill. The flow was about 40 gallons per minute. This awakened much opposition from residents on the hill, whose wells it drained, and whose trees suffered from want of moisture. The following year it was purchased by the city for \$2,921.12 and abandoned.

In 1873, works were constructed by the city after the plans of Phineas Ball, C. E., taking water from Broad and Higher brooks, whose drainage area is about 6.7 square miles, and impounding it in the Cherry Valley reservoir of 445 acres water surface at 402 ft. above the city datum plane.

The reservoir is formed by two earth dams. The Cherry Valley dam is at the outlet of a tributary of Broad Brook, and the Ludlow dam in the ravine on the divide between the drainage areas of Higher and Broad brooks.

The foundation of Cherry Valley dam begins on compact bluish hard pan. The bank was built of this material in 18 and 24-in. layers, each layer being flooded with a thin film of water, on which the next layer was dumped and driven over by teams. A heart wall of rubble masonry, 18 in. thick and 1,297 ft. long, comes to within 2 ft. of the surface of the bank, and is protected from frost near the surface by a dry rubble wall on each side of it, 2 ft. in depth from the top and 18 in. thick.

The dam is 25 ft. wide on top with slopes of 2 to 1, 39 ft. high above the natural surface and 47.6 ft. high above the lowest point of excavation, 2,352 ft. long, 1,521 ft. of which ranges from 3 to 5 ft. in height. The waste pipe is 20 in. in diameter laid, in stone masonry, and has a gate at each end. The inside slope is covered with rubble paving, 12 to 29 in. in thickness, the interstices filled with blue clay. The over-fall masonry rests on ledge rock and is 34 ft. long.

The Ludlow dam is 496 ft. long with a heart wall of rubble masonry 3.33 ft. wide with 6-in. concrete core. It is 35 ft. wide on top, 18 ft. high above the natural surface and 22 ft. high above the foundation.

A masonry gate-house is built in the dam from which a 30-in. cast-iron pipe is laid. A short distance above the Ludlow dam a dry rubble wall was built for holding in place a quantity of sand and an open space 100 ft. in length for filter screens. The space between the dam and the filter is four acres in extent, and was covered with clean sand. The filtering materials are placed in a duplicate set of vertical movable boxes made of oak plank.

The filtering material is wood "Excelsior," and acts only as a mechanical filter. The thickness of material is 28 in. or 14 in. in each box. A derrick on a bridge over the filter raises and lowers these boxes into place. This filtering apparatus appears to have been used in 1875, but no mention of it is made in later reports.

The reservoir is centrally situated between the Higher and Broad Brook water sheds, and the water from these streams is conducted to it by canals. The canal to Higher Brook is 5,278 ft. long and has a grade of 3.7 ft. to the mile. The Broad Brook canal is 11,960 ft. long and has a fall of 1 ft. in this distance. It is 8 ft. wide at bottom and 6 ft. deep, with slopes of 1½ to 1.

In 1877 a waste channel of masonry fitted with iron gates was built through the Cherry Valley dam at the south end, through the over-fall and the bottom of the inner slope of the dam was covered with additional embankment.

The inner slope of the Ludlow dam was covered with loam, with the object of silting up all crevices in the gravel and preventing a leakage which had appeared below the dam and caused some uneasiness. Three overflows were constructed in the Broad Brook canal.

The main conduit to the city is 24 in. in diameter, 56,410.5 ft. long, 3,736 ft. of which, from Ludlow dam to Higher Brook, is of cast iron. The Chicopee River is crossed at Indian Leap by a bridge of 168-ft. span, the upper chords of which are two tubes 26 in. in diameter, 12 ft. apart which form the aqueduct. They are made of ¾ in. boiler plate, riveted, and were lined with cement after erection. This bridge was designed and built by John R. Smith, C. E.

The rest of the conduit pipe is of wrought iron, lined and covered with cement laid on by hand after the pipe was in the trench. On being first filled many leaks occurred in a section of this pipe about 2,000 ft. long, where the ground was very firm and of good gravel. They were attributed to the fact that this part of the pipe was laid in very hot weather, and the cement at the joints set too quickly.

The section of cast-iron pipe gave great trouble from its having been laid in quicksand and settling. It was raised and laid on timbered foundation without interrupting the flow of water. This work of repairing was continued for four years.

There are two distinct services. The high service is supplied directly from the Cherry Valley reservoir, and the low service is supplied from the high by a regulator valve, and also through the Van Horn and Lombard reservoirs. The upper Van Horn reservoir has an area of 9.5 acres, a depth of 24 ft. and a capacity of 28 million gallons. The lower Van Horn reservoir has an area of 18.5 acres, is 30 ft. deep and contains 73.6 million gallons. The Lombard street reservoir has an area of 3 acres, is 23 ft. deep and contains 9 million gallons. All have their water surface at 198.5 ft. above the city datum.

The distribution pipes are partly of cast iron and partly of wrought iron and cement; 63.93 miles are in use, from 2 to 24 in. in diameter, 19 miles of which are of less than 6 in.

In December, 1880, there were in use 381 fire hydrants, 25 fire reservoirs, 3,290 taps and 44 meters. The use of meters began in 1878.

The population in 1870 was 26,703, in 1880 it was 33,340.

The daily consumption is not given in the reports. The cost to December 1, 1880, was \$1,216,847.53. In 1880 the cost of maintenance, exclusive of interest and construction, was \$10,008.31, and the revenue \$79,280.92.

The works are under the control of a Board of three Water Commissioners. Phineas Ball C. E. designed the works, and they were carried out under

his superintendence and that of Geo. A. Ellis, C. E., City Engineer, who is engineer and registrar of the works at the present time. J. C. Hancock is the superintendent.

XLIV.—SALEM.

Salem, Massachusetts, in lat. 42° 34' N, long. 70° 54' W, is chiefly on a low tongue of land, formed by two small inlets of the sea. Settled in 1626, its population in 1796 was about 8,000, when Daniel Frye dug a well on Gallows Hill and supplied water from it to several consumers through wooden pipes.

In 1807 an association of five members, styled "The Proprietors of the Frye Aqueduct," was formed, taking water from this well. In 1809 there were 12 takers, and in 1852 the company expired.

A second company was organized in December, 1796, which was the beginning of the "Salem Aqueduct." Their first works consisted of a fish hogshead sunk in a spring on Gallows Hill, and wooden pipe of 3-in. bore. In 1798 they built a reservoir on Gallows Hill 10 ft. deep and 24 ft. square.

The works were extended from time to time, but each extension was followed by complaints of scarcity of water. In 1834 a line of 6-in. iron pipe was laid down.

In 1850 16,165 ft. of 12-in. iron pipe were laid to "Spring Pond" and a reservoir built of 652,000 gallons capacity. The company after this replaced their wooden pipe with iron. In 1859 they had laid 40 miles of pipe. In 1865 a connection was made with Brown's Pond.

The complaints against this company were frequent. At times the water was entirely shut off from the manufactories. The stock always paid large dividends, but little money was expended from the earnings for improvements.

In 1865-69 works were built by the city after the plans of James Slade, C. E. Water is taken from Wenham Lake, which has a watershed of 2.7 square miles, an area of 320 acres and an extreme depth of 53 feet. It is fed by springs from the bottom and has no entering streams. The bottom is free from mud and vegetation and is of clean quartzose sand. It is surrounded by a smooth, gravelly margin. The supply is taken from the south end, where the shore is bold and the water deep.

A 36-in. cast-iron pipe, with a bell mouth turned up and grated, beginning 32 ft. from the shore, conducts the water 175 ft. to a masonry gate chamber 10x8 ft., from which a brick conduit 10x7 ft. and 26 ft. long, leads to the pump well, which is 31.75x10 ft. inside, built of stone masonry, lined with 12 in. of brick, and resting on a timber and plank platform covered with 2 ft. of concrete. Quicksand was encountered in the excavation. A Worthington compound engine of 5 million gallons capacity lifts the water 114 ft., through 5,600 ft. of 30-in. cast-iron pipe, to the reservoir on Chipman's Hill, which is built in excavation and embankment, is 400 ft. square and 20 ft. deep, and contains 20 million gallons, with its surface 142 ft. above mean tide. A puddle wall is built in the centre of the bank, stepped down the slopes and carried 2 ft. thick over the bottom, where it is covered with 1 ft. of gravel and a stone paving. The inner slopes are covered with 12 in. of gravel, on which is a dry stone wall 15 in. thick.

At the centre of the westerly bank is the influent, and in each of the southerly corners is an effluent pipe 20 in. in diameter and 2 ft. above the bottom. They are surrounded with screen cribs containing screens 8 ft. high. The tops of the cribs are solid and have a trap door for access to the pipe. The pipes pass through the bank turning downward and then following the clay puddle. Each pipe is supported on a brick pier. Two walls of masonry 2 ft. thick are laid across the be-

gining of each pipe to prevent the water from following it. Under each is a drain pipe of 10-in. diameter.

The force main is connected with the supply mains, and at their junction is a 30-in. wrought-iron stand-pipe 55 ft. high, extending 25 ft. above the water surface of the reservoir.

The supply main is a 20-in. cast-iron pipe, and is carried across Bass River, the arm of the sea between Beverly and Salem, in a wooden box on piles, passing under the channel by an inverted siphon of 30-in. pipe, boxed with heavy timbers and filled around with concrete.

Water is supplied to the town of Beverly by special contract.

The distribution is by wrought-iron and cement pipe, of which 85 miles were in use in 1879. In that year there were in use 343 hydrants and 117 meters. The number of taps is not given. The consumption in 1879 was 1,940,000 gallons per day.

The population of Salem in 1880 was 27,598.

The total cost of construction to November, 1879 was \$1,338,155.48.

In 1879 the revenue was \$50,629.74.

The works were built by a board of Water Commissioners, and have been managed by the Wenham Water Board.

James Slade was chief engineer until 1868. James P. Kirkwood was consulting engineer during construction, after February, 1868, and Charles H. Swan the chief engineer. James W. Lyon is the Superintendent.

XLV.—NEWPORT.

Newport, Kentucky, is on the south side of the Ohio River, opposite Cincinnati, and separated from Covington by the Licking River on the west.

The site of the town was first occupied in 1791. The population in 1871 was 16,000, when water-works were built by the city, after the plans and under the superintendence of Theodore R. Scowden, C. E., taking water from the Ohio River, 4 miles above the city.

The engine-house is on limestone rock at the river's edge. Through an arched opening in the wall the water is admitted to the pump-well, the floor of which is 3 ft. below extreme low-water mark.

The water is lifted 350 ft. through a 20-in. cast-iron main, 1,445 ft. long, by a direct-acting non-condensing pumping engine, with vertical steam cylinder of 26 in. diameter and 48 in. stroke, 57 ft. above a double acting plunger pump of 13½ in. bore. The connection between the pump and the main is by an 8-in. pipe.

At the crest of the bluff, the force main discharges into a cast-iron main of 24 in. diameter for 275 ft., and of 20 in. diameter for 4,318 ft., in which distance it falls 56 ft., discharging into the reservoir formed by an embankment across the junction of the two ravines, and divided into two basins by a transverse embankment. The main dam is 85 ft. high, built of earth, with stone paving on the slope. The water surface is 8 acres and the capacity 41 million gallons. The surface drainage from the surrounding country is carried under the reservoir in 24-in. iron pipes, meeting in a 36-in. pipe, which passes under the dam, with stone collars 8 ft. square and 2 ft. thick every 12 ft.

Two 30-in. effluent pipes, laid through the dam, conduct the water to the 20-in. supply main in the city.

On June 17, 1875, one of the 24-in. drain pipes broke, the north basin was rapidly emptied and the slopes slid in. On examination, it was found that half the drain pipes were broken. They were stopped up, surface drains made, and the banks reconstructed. The slopes of the south basin showed a tendency to slip in 1878, and not more than 12 ft. of water could be safely put in it, and in 1879 one foot less was stored. In 1880 there were indica-

tions of saturation of the earth past the centre of the main bank.

The distribution is by cast-iron pipe. In Dec., 1880, there were 20.45 miles in use, nearly half of which is of 4-in. diameter. There were 110 fire hydrants, 1,577 taps and 16 meters in use at that date. The consumption is not given, but the engine is reported as working to its full capacity nearly all the time. The population in 1880 was 20,438.

The cost of construction, including repairs to 1881, had been \$780,781.11, and the revenue from water rents \$91,356.61. The bonded indebtedness is \$700,000. The total receipts for the year 1880 were \$21,861.99, and the expenditures \$13,288.39.

The works are controlled by a board of three trustees, who report to the Common Council. George Hornung was the Engineer and Superintendent from 1873 to 1877. From 1878 to 1881 B. R. Morton has been City Engineer and Superintendent of the Water-works.

XLVI.—NORWICH.

Norwich, Connecticut, in lat. 41° 32' N., long. 72° 5' 28" W., is 15 miles from Long Island Sound, at the confluence of three small streams which form the Thames River, and which, having a rapid descent, afford a valuable water power.

The population, which in 1810 was 3,528, had increased to about 15,000 in 1868, when water-works were constructed by the city, after the plans and under the superintendence of John T. Fanning, C. E.

The supply is by gravity from two small streams N. E. of the city, 252 ft. above tide level and 225 ft. above the main street of the city. The impounding reservoir is formed by an earth dam 25 ft. high and 468 ft. long, 25 ft. wide on top, with rubble masonry heart wall through its centre, and its inner slope paved with stone.

The overflow waste-way is in a depression a mile from the dam, leading to another valley. The shores of the reservoir are cut down vertically to 4.5 ft. below the flow line, and protected by a vertical dry stone wall, 2.5 miles long. The area of the reservoir is 66 acres, and its tributary watershed 0.75 sq. mile. Two filtering dams have been made at the inlets of tributary streams.

From a masonry gate-house on the inner slope of the dam a 16-in. copper pipe, designed by Mr. Alba F. Smith, with a flexible joint which permits the end of the pipe to be adjusted to take the water from the pond at any depth, conducts the supply to the gate chamber.

The first pipe collapsed in 1873, and was replaced by one of heavier copper.

The distribution pipes are of wrought iron and cement. They are mostly of 6-in. and 4-in. diameter. More than 9 miles are less than 6-in.

On Oct. 13, 1869, and July 27, 1873, the distribution pipes were struck by lightning. In the first case 2,000 ft. of pipe were injured and in the second 94 ft. The joints appeared to have been "struck with a ball 2 in. in diameter, leaving a dent in the form of a spoon and with the appearance of burnished silver." In March, 1880, there were in use 30 miles of pipe and 245 hydrants.

The number of taps on March 31, 1873, was 1,503. Service pipes are of wrought iron and cement.

The population in 1880 was 21,141. The consumption is not stated in the reports.

The cost of the works to March 1880 had been \$411,870.94, the receipts for the previous year \$24,169.24, and the cost of maintenance, \$6,262.62.

The works are managed by a Board of Water Commissioners.

The superintendent is H. B. Winship.

XLVII.—WILLIAMSPORT.

Williamsport, Pennsylvania, is in lat. 41° 14' N., long. 76° 2' W., on a plain between the north bank of the West Branch of the Susquehanna River and a range of hills. The town was founded

about 1795, and incorporated as a city in 1861.

Lycoming Creek flows through the city from the north, and parallel to it is Loyalsock Creek, two miles east of the city limits. Two private companies supply the city with water. The Williamsport Water Company, incorporated in 1853, when the population was 2,500, procures its water from Hagerman's Run, and the Citizen's Water & Gas Company, incorporated in 1865 as the Lycoming Gas & Water Company, procures water from Mosquito Creek. Both of these are mountain streams, south of the river, each draining about 25 sq. miles, and dammed about a mile and a half from the city at 140 ft. above the river. Neither company has more than a small basin, less than a hundred feet square, for settling purposes.

The water is conveyed to the city in two 16-in. cast-iron pipes, which pass under the river for 1,000 ft. The distribution pipes are of cast iron. The two companies supply 2,500 consumers and 150 fire hydrants, for which the city pays \$10 each per annum. The population in 1880 was 18,934. Meters are not used. The amount of water used, and the details of cost and revenue are not furnished. J. H. McMinn is superintendent of the Citizen's Water & Gas Company.

XLVIII.—DAYTON.

Dayton, Ohio, is on a level plain at the confluence of the Mad and Great Miami rivers. Settled in 1796, it made little progress until 1829 on the opening of the Miami Canal. It was incorporated as a city in 1841.

Water-works were built by the city in 1869-70, taking the supply from wells and from the Mad River.

The first well was sunk 300 ft. south of the Mad River and ¼ of a mile above its junction with the Miami. The well is about 20 ft. in diameter, and is sunk below the bed of Mad River. A conduit connects it with a trench 100 ft. distant, which is 108 ft. long, 18 ft. deep and 15 ft. wide. The well and trench are both roofed. The capacity of this source was about 500,000 gallons per day. In 1873, the supply falling short, connection was made directly with the Mad River by three lines of 20-in. cast-iron pipe, laid out into the river, the end supported in a revetment wall of masonry 15 ft. high and 50 ft. long. Against the wall boulders were piled to act as a strainer. Inside the levee the pipes are also supported by a masonry wall. The water from this had a brownish color and a strong odor and taste.

A second well was dug in 1875-6 30 ft. deep and 18 ft. diameter. This supplied about 500,000 gallons per day.

The supply being inadequate, and resort being constantly had to the Mad River, which is very impure and takes the drainage of a thickly populated valley, the construction of a second filter gallery was begun. In 1880, 106 ft. of it had been finished. It is a rectangular chamber, 4 ft. wide and 8 ft. high, with dry stone side walls, flat stone cover and plank flooring, 26 ft. below the surface of the ground.

The first pumping engines consisted of two Holly elliptical rotary pumps of 2,000,000 gallons capacity and a set of gang pumps of 3,000,000 gallons capacity in 24 hours. In 1880 these pumps were removed and four piston pumps on an inclined frame, geared to the old engine, 3 to 1, were substituted.

The second pumping engine erected in 1873-4 is a Holly Compound Engine, with four steam cylinders, of 18-in. diameter and 30-in. stroke. The pump cylinders are 12 in. in diameter and 30-in. stroke. The capacity of this engine is 4,000,000 gallons in 24 hours. The engines pump directly into the mains under 50 lbs. ordinary pressure and 100 lbs. fire pressure.

The distribution is by cast-iron pipe, of which in 1880 32.5 miles were laid, most of which is of 4