PIPE and The Public Welfare

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and

The Public Welfare

BY

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NEW YORK
THE STIRLING PRESS
1917

Introduction

To the men who are responsible for the installation of conduits that are to be used not only for the present, but for future generations, the data herein is presented in the hope that it may serve to point the way to the selection of that material which will be most durable and economical.

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HISTORICAL

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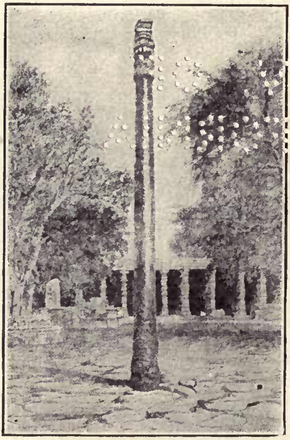
AMONG the many questions which City and Consulting Engineers, members of Water Boards or Street and Lighting Committees of our growing municipalities are called upon to consider, none is of more vital importance than the life of pipe used for water and gas mains.

The history of pipe is the history of civilization—upon no other single product have the great cities of the world depended in such large measure for their health and comfort.

Beginning with the crude clay pipe of early Babylonian days, 4000 years B.C., there has been a constant effort to reach the ideal—a pipe that would endure under ground.

Iron was known to man in prehistoric ages, and there are many evidences of its use in early history, most notable of which is the iron column of Delhi, in India, a Hindu monument about sixteen inches diameter and fifty feet long, believed to have been erected about 1000 B.C. However, iron does not seem to have played an important part in the world's activities, aside from its use in the art of war, until the fourteenth or fifteenth century of our present era.



Courtesy "The Valve World"

The Pillar at Delhi, India

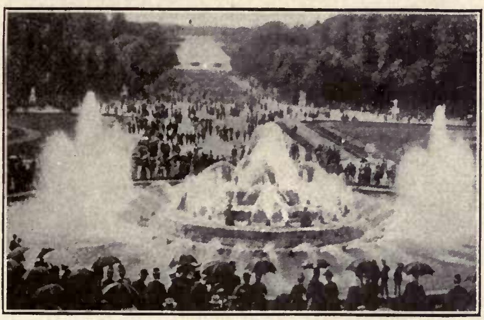
(From Thurston's "Materials of Construction," Vol. I)

Indeed, in the absence of definite knowledge as to when and where the first iron pipe was made, it may well be assumed that it followed closely upon the development of, or was produced coincidently with, that greatest of all engines of war, the cannon, the earliest mention of which is found in the year book of the city of Ghent, dated 1313.

The fact that no record is found of the production or use of iron pipe during the three hundred and fifty years following this date, however, leads to the conclusion that if made at all it was in very limited quantities, and up to the seventeenth century the pipe most commonly used throughout England and France was of cast lead or bored logs.

Water Pipe

The earliest authentic records of the installation of cast iron pipe for underground water conduits relate to several lines of various diameters laid, by order of Louis XIV, near Paris, from the reservoirs of Picardie to those of Montbauron, together with the spring water conduit, the whole supplying the town and parks of Versailles. The important details of these installations are given in a paper on "The Life of Cast Iron Pipe," by C. Cavallier, in the Journal of the New England Water Works Association, June 1904, page 218, as follows:



Fountains in the Park at Versailles, France

"According to the Ministry of Public Instruction and Art, the conduits which supply the water to the great fountains in the park at Versailles are of cast iron, and date from the same period as the park itself. The most important are as follows:

"Three pipes, 500 millimeters (20 inches) in diameter, 3,000 meters (10,000 feet) long, which bring the water from the Park of the Trappists to the reservoirs of Montbauron.

"Two pipes, 500 millimeters in diameter and 2,250 meters (7,500 feet) long, and three pipes, 325 millimeters (13 inches) in diameter and 1,500 meters (5,000 feet) long, which conveys the water from the reservoir of Montbauron to the principal gate house.

"Two pipes, 500 millimeters in diameter and 3,000 meters (10,000 feet) long, and one pipe, 325 millimeters in diameter and 1,500 meters (5,000 feet) long, which bring water from the reservoirs of Gobert to the reservoirs of l'Aile.

"All of these pipes were laid in 1685, or 219 years ago. The conduit of Chevreloup, from the reservoir of l'Aile to the Trianon, 325 millimeters in diameter and 3,500 meters (11,500 feet) long, was laid in 1687, or 217 years ago.

"Several old pipes of various diameters for conveying water from the reservoirs of Picardie to those of Montbauron, for distribution within the parks and in the town, and the spring water conduit, having in all a length of about 8,000 meters (26,000 feet), were laid between 1664 and 1688, or from 216 to 240 years ago.

"All of these pipe lines consist of pipes one meter in length, joined by means of bolted flanges. They are of considerable weight and still serve their purpose satisfactorily.

"The few repairs which have been required have generally been necessitated by the bad condition of the flange bolts, which have rusted out."

Mr. Cavallier also gives the following details in regard to early installations of pipe in several other French towns:

"According to Mr. Lamandiere, engineer and superintendent of the Rheims Water Works, the water supply of that town was established in 1748 by Mr. Godinet, canon of the cathedral. This system was in more or less regular service until 1840. At this time a new system, much better constructed, was built and is still in operation, although with considerable modifications and enlargements.

"The distribution pipes in Canon Godinet's system were of lead. In building the pumping works some cast iron pipes of the system built in 1748 were found. These were about 20 centimeters (8 inches) in diameter and 1.20 meters (4 feet) long, with square flanges. These pipes were in good condition when found.

"Mr. Delechamps, Engineer and Superintendent of Public Works of Claremont-

Ferrand, furnishes the following notes relating to the old cast iron water pipes of that town:

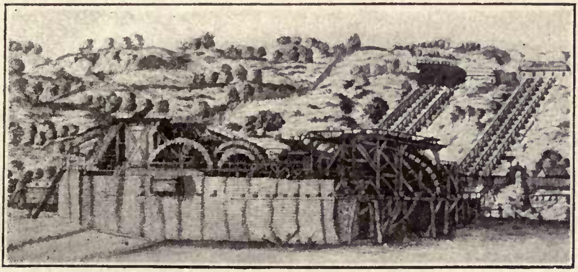
" 'On December 5, 1730, a meeting of the town council noted that the conduit was considerably damaged. Sixteen years later, on September 14, 1746, the commissioners of fountains made an agreement with the Sieur Marchais, iron merchant of Paris, for furnishing pipes of cast iron for the fountains. The works were constructed about 1748–49. The conduit, for a length of 1,570 meters (5,150 feet), consists of 1,555 tubes, 5 or 6 inches in diameter and 3 feet long. On the plain where the pressure is greatest the pipes are nine lines (0.8 inch) in thickness, elsewhere they are six lines (0.5 inch) thick.

" 'In 1867 the old conduit was paralleled by cast iron pipes with lead joints, which was to supplement the old system. This (referring to the old system) is now out of service at several points.

" 'The pipes were cast horizontally. The flange joints were made with a thick lead gasket, sometimes as much as 23 millimeters (⅞ inch) in thickness. The system is under a considerable pressure.'

"According to Mr. Andrieu, Engineer and Superintendent of Public Works of Saint-Etienne, there are in that city some cast iron pipes which have been in service since 1782, or for 122 years."

The city of London laid cast lead pipe as early as 1235 to 1285 A. D., and also experimented with "Red earth, baked," and with pipes of stone. The first extensive water works in London were built by Sir Hugh Middleton, between 1609 and 1613, and following the construction of a boarded aqueduct,



Ancient Pumping Plant at Marley
(From an old wood cut)

called the "New River," over 400 miles of wooden mains were installed.

The great fire of 1666 destroyed much of both the lead and wooden pipe and except for house services the use of lead was largely discontinued. It was also found necessary to take up and replace each year an average of 20 miles of the wooden pipe which had been injured or proven defective, so that a complete renewal was made every 20 years.

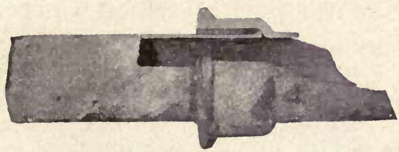
As early as 1746 the Chelsea Water Co., of London, laid a 12 inch flanged cast iron pipe which was relaid in 1791 on account of the joints "being perished." It was the engineer of that water company, Mr. Thomas Simpson, who designed the first bell and spigot pipe. This was about 1785, at which time an experimental section of pipe was laid with lead joints, which proved so successful that the entire systems of all the London companies were gradually relaid with cast iron pipe, the uninterrupted service record of which now covers 100 to 125 years.

Old Bored Logs in Philadelphia

In the United States, following the European practice, bored logs were laid toward the close of the eighteenth century in certain of the larger cities. Specimens of log pipes 18 inches in outside diameter, with a 6 inch bore, laid in 1799, may be seen in the Franklin Institute in Philadelphia, together with the following note:

"Prior to the year 1817 all water mains were of wood, and considerable trouble was experienced on account of insufficient strength. The Watering Committee decided to import from England a small quantity of cast iron pipe to be laid as an experiment. The results were so satisfactory that from time to time iron pipes were gradually substituted for wood."

These pipes were of bell and spigot type, in 9 foot lengths, and further details are contained in a paper read before the American Society of Civil Engineers, October 7, 1914, by Marshall R. Pugh, C. E., a prominent member of that Society, who quotes as his authority the Philadelphia Bureau of Water, as follows:



Cast Iron Pipe Laid in Philadelphia, 1831
Removed 1915, in practically perfect condition

"A curious feature about them was that each length had three or four ribs, or rings, about it, approximately 1½ inches wide, which were presumably to afford places with heavier walls in which to tap the pipe. These pipes are of particular interest, owing to the fact that they are still in use after 95 years, with every evidence of continuing to give a good account of themselves. Though forming only an infinitesimal portion of the present distribution system, they, nevertheless, constitute quite a considerable mileage.

"A few of these pipes are noted in order to give an idea of their character: A $4\frac{1}{2}$ inch cast iron pipe on Chestnut Street, from Broad to 15th Street, laid in 1817, was removed only recently. A 22 inch cast iron main leads from Fairmount Basin to Green Street, to Pennsylvania Avenue, to Callowhill Street. It then reduces to two 20 inch mains leading to Broad Street and thence to Chestnut Street. This pipe was laid in 1819, and, with the exception of a portion which was removed in 1897 on account of the construction of the Pennsylvania Avenue Subway, is still in use.

"Mains on Market Street, from Juniper to Broad Streets, laid about 1820, from 11th Street to Juniper Street, laid in 1823, and from Water Street to 11th Street, laid in 1822, were in good condition when removed in 1907 to make way for the Market Street Subway. Mains 6 and 10 inches in diameter, on Second Street, between Greenwich Street and Lehigh Avenue, were laid between 1823 and 1852; 8 inch mains on Front Street, between Wharton Street and Laurel Street, were laid at various dates between 1822 and 1834; one 10 inch main on Chestnut Street, from Front Street to Broad Street, was laid in 1821 and 1823; and a 20 inch main on 15th Street, from Callowhill Street to Chestnut Street, was laid in 1829. All these mains are still in use.

"This list might be extended to several pages, but it serves to show that a century's use has not rendered these pipes unfit for service. Virtually the whole of the old distribution system laid at that time has given an equally good account of itself."

In New York bored logs were used in all the early water distributing systems, including that of the Manhattan Company, organized in 1799 by Aaron Burr, the following very interesting history of which is contained in a handsome brochure issued in 1914 by the Bank of the Manhattan Company, now one of the strongest financial institutions in the City:


Old Bored Logs from Early New York Water Supply System

"At the beginning of the nineteenth century New York was by no means so healthy a place as it is today, for it was frequently swept during the hot season by epidemics of yellow fever. One of the most severe of these, which occurred in 1798, and was attributed to the inadequate and inferior water supply, led a number of public-spirited gentlemen, among whom were John B. Church and Daniel Ludlow, wealthy merchants, to apply to the legislature for a charter for a company that would supply New York with pure water.

"Two of the most active spirits in the movement were Aaron Burr and Alexander Hamilton, who at this time were not by any means the bitter rivals they were three years later. And the two, together, on February 25th, 1799, called upon the mayor in advocacy of the movement, and were directed by the Common Council to put in writing their request for the granting of the charter to the Manhattan Company. It does not appear what further interest Alexander Hamilton had in the movement, but the company was formed with a capital of two millions, and it was given the name of the Manhattan Company.

"A clause was inserted in the charter permitting the company 'to employ all surplus capital in the purchase of public or other stock or in any other moneyed transactions or operations not inconsistent with the Constitution and laws of New York or of the United States.'

"There was some opposition to the provisions of this charter which granted the company banking privileges, as the Bank of New York, organized by Alexander Hamilton in 1784, had received a charter in 1792. The Bank of New York and the New York Branch of the First Bank of the United States were then the only banks doing business in the City of New York. As this monopoly of banking facilities was of great value to the Federal Party which, under the leadership of Hamilton was then in control, much jealousy arose among the leaders of the opposition, under Aaron Burr. So that, however willing Hamilton may have been to grant the charter to the water company, there was much opposition to the granting of a charter which would open the doors to a banking business.

"The need of a proper water supply was, however, too strong to be denied, particularly as it could be carried through by a responsible company with large capital. And it passed the legislature on April 2, 1799, and soon received the governor's signature.

"The books were opened for public subscription to the $2,000,000 capital stock of the Manhattan Company, the par value of which was $50. Among the subscribers to the stock Daniel Ludlow, John Watts, John B. Church, Brockholst Livingston, William Laight, Pascal N. Smith, Samuel Osgood, John Stevens, John B. Coles, John Broome and Aaron Burr, many of the best-known merchants of the time.

"The entire amount was subscribed to by May 15th, New York City taking 2,000 of the shares, and the charter provided that the Recorder of the city should be *ex officio* a director of the company—a provision which was in effect for one hundred and eight years, until the abolition of the office in 1907.

"The first meeting of the board of directors was held at the house of Edward Barden, inn-keeper, April 11, 1799. All the directors, including Richard Harrison, Recorder of the City of New York were present, except William Edgar. Daniel Ludlow was chosen president, and Samuel Osgood, John B. Coles and John Stevens were appointed a committee to report the best means to obtain a water supply.

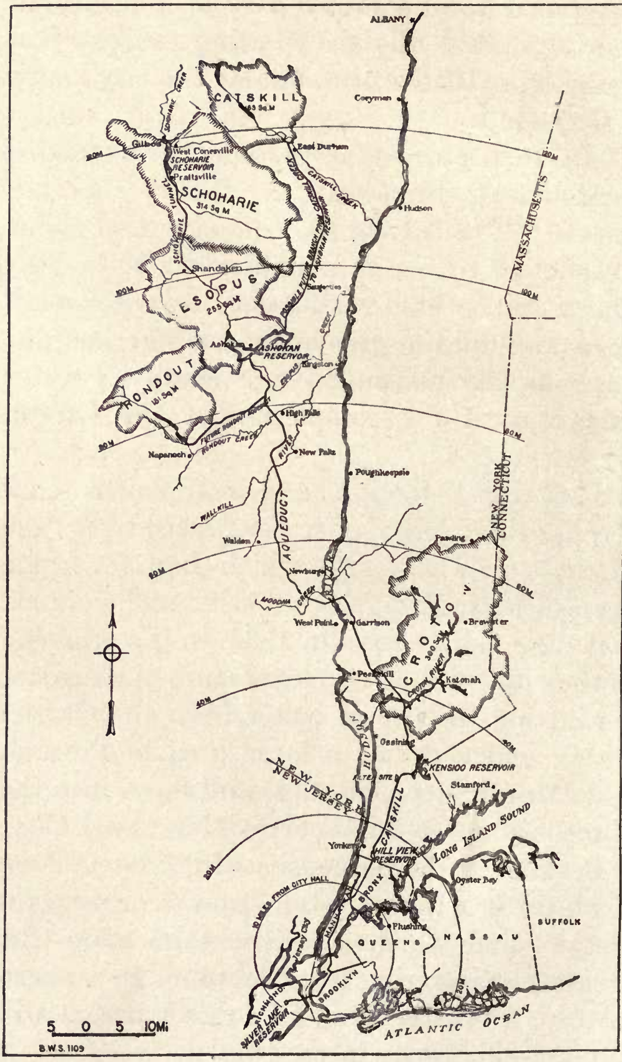
Taking Down Old Cast Iron Tank in 1914—After More Than 100 Years Service

"It was decided to dig a number of wells in various parts of the city, and particularly a large well, thirty-five feet deep, between Reade and Chambers Streets, a few feet from Collect Pond. Over this early well, a tank of iron was erected, which is now enclosed in an old-fashioned building, and is still owned by the Bank of the Manhattan Company. The water was piped to the lower part of the city in pine logs, and the distributing system was gradually extended throughout the city south of City Hall.

"In 1836 the water system was extended north, along Broadway, as far as Bleecker Street. At that time the company had about 25 miles of mains and supplied 2,000 houses. The water, while wholesome, was not very clear, and did not give entire satisfaction, but the company continued to operate its water service until the completion of the Croton system in 1842."

The dissatisfaction and complaints concerning the quality of water furnished by the Manhattan Company, which had for some years been growing in intensity and volume, had their culmination in 1834, in the granting to the city by the state legislature of a charter permitting the use of water from the Croton River, which drains a large area in Putnam and Westchester Counties, and flows into the Hudson about 32 miles north of New York City.

Because of the immensity of the latest New York water supply system, now nearing completion, and which is, without question, the greatest engineering feat of its kind in modern history, a brief review of its development will undoubtedly prove interesting.


ALBANY
Coeymans
CATSKILL
East Durham
Gilboa
West Conesville
SCHOHARIE RESERVOIR
Prattsville
SCHOHARIE
314 Sq M
CATSKILL CREEK
Hudson
MASSACHUSETTS
Shandaken
ESOPUS
255 Sq M
Saugerties
Ashokan
ASHOKAN RESERVOIR
Kingston
RONDOUT
131 Sq M
High Falls
RONDOUT CREEK
Napanoch
New Paltz
Poughkeepsie
WALLKILL
Walden
AQUEDUCT
NEW YORK
CONNECTICUT
Newburgh
West Point
Garrison
Brewster
CROTON
CROTON RIVER
Katonah
Peekskill
Ossining
KENSICO RESERVOIR
Stamford
NEW YORK
NEW JERSEY
HUDSON
CATSKILL
Yonkers
HILL VIEW RESERVOIR
LONG ISLAND SOUND
10 MILES FROM CITY HALL
BRONX
Oyster Bay
Flushing
QUEENS
NASSAU
SUFFOLK
BROOKLYN
RICHMOND
SILVER LAKE RESERVOIR
ATLANTIC OCEAN
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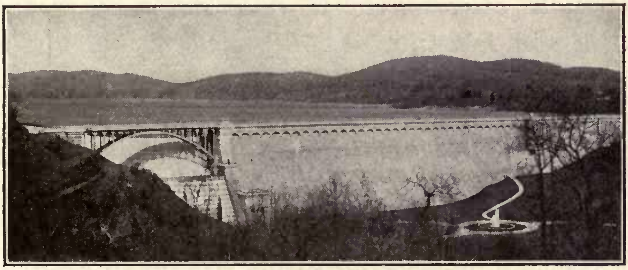
Beginning in 1834 a fifty foot dam was built on the Croton River some forty miles above the city and the water from this river, known familiarly to New Yorkers since that time as "Croton water," was brought down by gravity through an aqueduct largely of the "cut and cover" type, crossing the Harlem River through cast iron pipe carried by the picturesque stone-arched "High Bridge," thence



New Croton Dam—New York Water Supply

connection was made with the city distributing mains. This system, now known as the "Old Croton Aqueduct," which was planned to supply 36,000,000 gallons daily, was put into service in 1842; but by 1880 the rapid growth of the city had placed a burden of 95,000,000 gallons per day on it, and an increased supply became imperative. There was secured between 1880 and 1884 an additional 23,000,000 gallons from the Bronx and Byram Rivers two smaller streams nearer the city, and in

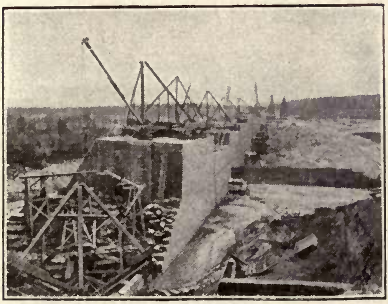
1884 was begun the second Croton aqueduct, completed in 1891.

The New Croton Dam, located about three miles below the first one, was, for some years after its completion, the largest and highest reservoir dam in the world, impounding some 36 billion gallons of water. The aqueduct from this dam is thirty-three miles long, constructed almost wholly through deep rock tunnels, crossing the Harlem River by means of a siphon tunnel 1,300 feet long and about 300 feet below tide level, and has a delivery capacity of 300,000,000 gallons per day. From the termination of this aqueduct at the 135th Street Gate House, cast iron pipe lines distribute the water to and throughout the city, one set comprising 8 lines of 48 inch laid in one trench.

Several years after this system was put into operation the total storage capacity of the district was increased to 105 billion gallons by connection of the chain of small lakes in the Croton Watershed, to retain the excess water of the flood periods, and feed the river in times of drought.

Scarcely ten years had passed, however, until the daily water consumption of Manhattan and the Bronx exceeded the 300,000,000 mark, and again the city faced the problem of securing a new and much greater supply.

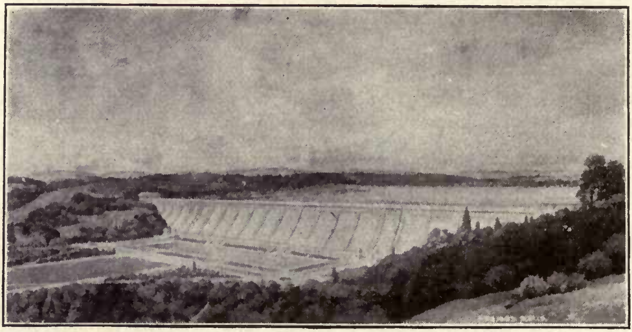
Permission was obtained from the state in 1905 for the construction of the Catskill Aqueduct, to utilize the water from Esopus Creek, in Ulster County, and work was at once begun on the immense and now famous "AshokanDam" which, together with two earthen and rubble dikes, has an estimated and impounding capacity of 130 billion gallons—"enough to submerge Manhattan Island to a depth of 28 feet."



Ashokan Dam in Course of Construction

This water will be conveyed from Esopus Creek at the rate of 500,000,000 gallons daily through a reinforced concrete aqueduct about 92 miles in length, over a rough and rather mountainous country, crossing several valleys by means of pressure tunnel siphons, and passing under the Hudson River at "Storm King" Mountain, through an inverted siphon cut for a distance of 3,000 feet through solid rock, at a depth of about 1,000 feet below the river bed, to the Kensico Reservoir, the largest of its type in the world, at Valhalla, about 12 miles north of the city line, thence to an equalizing reservoir at Hill View, on the northern border of the city.

From here it is distributed to the various boroughs of Greater New York by deep pressure tunnels, reaching Staten Island through a

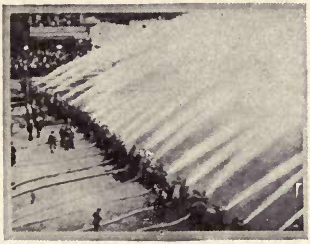


Kensico Dam As It Will Appear When Completed

line of 36-inch cast iron flexible joint pipe laid under water at the "Narrows," the entrance to New York Harbor.

The Boroughs of Brooklyn and Queens have already a daily supply of about 185,000,000 gallons, developed from wells and surface streams which, added to the Croton and Catskill supplies, the latter of which is expected to be available in 1916, will give the Greater City a total of over a billion gallons daily, with a storage capacity of nearly 300 billion gallons.

It may be stated in passing that nothing but cast iron pipe is used for the distribution of this water throughout the entire city, both for domestic and fire service, with pressures varying from 25 to 300 pounds, the total length of such pipe aggregating, in 1915, some 3,015 miles.

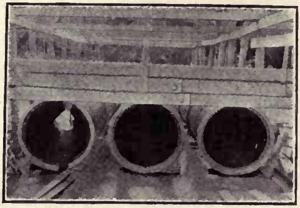


Test of High Pressure System in New York

While practically all of the large cities in the United States are supplied with water through cast iron pipe conduits, a system worthy of further particular mention is that of the Metropolitan Water and Sewerage Board of Massachusetts, which includes the well known Wachusett Reservoir covering 4177 acres, and which with Lake Cochituate and eight other reservoirs on the Sudbury River, is capable of supplying 173 million gallons per day, to the City of Boston and environs.

Distribution from the aqueducts to the several municipalities comprising the Metropolitan District is effected by means of about

116 miles of cast iron pipe, a large portion of which is 48″ and 60″ in diameter. In the distribution systems of the various cities there are in addition about 1779 miles of cast iron pipe in sizes ranging from 4″ to 48″.



Three Lines 60-Inch Cast Iron Pipe Being Laid Under Charles River, Boston

As has already been mentioned, cast iron pipe early became an important factor in the development of the water supply of Philadelphia. In the present system the water from Torresdale Filter Beds to the Lardner's Point Pumping Station is conveyed by means of a masonry conduit or tunnel; from this station 60″ cast iron bell and spigot pipe form the force mains to Frankford Creek, where the water is delivered to the distribution system working against the 48″ relief line to the Oak Lane Reservoir.

A subsequent report by a board of expert engineers suggests that the use of 60″ cast iron pipe instead of masonry conduit would have been cheaper and preferable. Four lines of 60″ cast iron pipe lead from Lardner's Point Station, and were laid after two cast iron lines 48″ and 30″ diameters had been moved to one side while under water pressure—a severe test of the bell and spigot joint both as to flexibility and tightness.

Altogether the total mileage of cast iron water mains in Philadelphia at the close of 1915 was about 1800 miles, in sizes ranging from 3″ to 60″ diameter.

Gas Pipe

The development of the illuminating gas industry in this country was practically coincident with that of municipal water supply systems, and the earliest record of the use of cast iron pipe for gas distributing mains indicates that they were installed probably first in Baltimore between 1820 and 1835. Some of this pipe has recently been taken up and examined and found to be in practically perfect condition. An article in the March 8, 1916, issue of "The Gas Record" contains the following interesting comment on this pipe:

"Historical Section of Cast Iron Pipe"

"A section of cast iron pipe unearthed just outside the David St. building during recent alterations was found to be in excellent condition and is shown herewith. Concerning

Cast Iron Gas Pipe 83 Years in Service in Baltimore, Md.

this pipe, George Beadenkopf, chief engineer of the Baltimore Consolidated Gas, Electric Light and Power Company, says:

"'The pipe, when taken up, was in first class condition. There were absolutely no signs of deterioration, inside or outside. The inside of the pipe had a hard, smooth, thin coating of tar, which was likely deposited in the pipe at the time the plant was in operation, some sixty years ago.

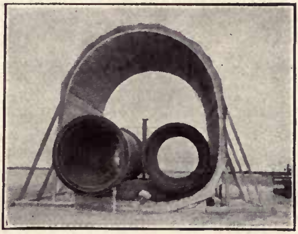
"'The fracture of the iron shows it to be good metal. My belief is that the pipe has been in the ground eighty years or more, and I think it is a fine example of the lasting qualities of cast iron pipe. I am unable to say who made the pipe, but believe from what I have heard from older men who were connected with the gas industry in Baltimore, that the pipe was imported from England as were also other parts of the gas plants first erected in Baltimore.'"

The cities of New York and Philadelphia began the use of cast iron pipe for gas mains as early as 1840. Much, if not all, of this pipe is still in service.

The high development of the manufactured gas industry in New York is indicated by the following interesting account of the opening of the Astoria Light, Heat & Power Company's plant on Long Island, as given by the *New York Times* of October 28, 1915:

"Astoria Gas Tubes World's Greatest"

"Twenty-two million cubic feet of gas is now being drawn every day beneath the East River through the largest cast iron pipe at present in use in the world. It is expected that by the end of this week its mate, which lies alongside it in the Astoria Gas Tunnel, will be ready.



Model of Astoria Gas Tunnel

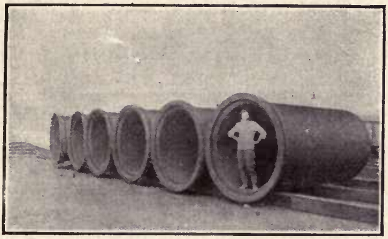
"These gigantic tubes are six feet in diameter and they extend for 4,700 feet from Astoria to 132d Street, the Bronx. Part of the gas goes to mains in the Bronx and part may be diverted to pipes in Manhattan.

"These mains represent a notable feat of gas engineering. Many years ago it was recognized that gas plants could not always be operated in Manhattan and several new ones were built on Long Island. The first mains laid on the river bottom were 10 and 12 inches in diameter. The building of the million-dollar plant of the Astoria Light, Heat

& Power Company on Long Island with its great holder necessitated the boring of the tunnel under the river to carry the gas to consumers in the city. To accommodate the big pipes it was necessary to have a tunnel of an average diameter of eighteen feet, and twenty-six feet in the clear at the western end. The Astoria shaft was sunk in 1910 and the Bronx shaft at Port Morris, at the foot of 132d Street, was put down a year later.

"The digging of this tunnel under the supervision of William H. Bradley, Chief Engineer of The Consolidated Gas Company, of which the Astoria plant is a subsidiary, was accompanied by many difficulties. There was much decomposed rock, and through fissures considerable quantities of water were admitted into the tunnel. There were at one place three large water flows at various times. One of them had an average flow of one thousand gallons a minute. The ingenious use of cement in a grouting process stopped the flow, and the entire tunnel was lined with segments of steel. The mains were then carried through the tunnel side by side and were surrounded by decking. Over them is a runway which may be used for any further utilities.

"The Engineer-in-Chief said yesterday that



Cast Iron Pipe—72-Inches Diameter

the iron pipes were unquestionably the largest ever made. They are 72 inches in the clear and their metal walls are 2 ¼ inches thick. They have hub and spigot joints and were cast in standard twelve-foot lengths. The weight of each length is thirteen tons and the displacement of water for each is 24,800 pounds, from which it is seen that even if the tunnel should fill with water the pipes would retain their position secure. Each twelve-foot section is supported by two concrete blocks. The laying of the mains, the caulking of the joints and many other processes required special devices owing to the great size of the sections. The mains are now connected with a net-work of pipes under the city streets. Owing to their size the gas is drawn through them with pumps."

W. R. Addicks, Vice-President, Consolidated Gas Company, New York City, in a paper read before the New York Section Illuminating Engineering Society, Nov. 9, 1916, on "Some Notes on Gas Standards," says:

"There have appeared from time to time epoch making influences in the history of the gas industry since 1792, when Murdock introduced gas for lighting. Some have been apparent at the time while others are appreciated only after a lapse of years during which their influence has been at work.

"The introduction of cast iron pipe about 1808 for distribution purposes greatly aided in making the gas industry permanently successful. Cast iron mains seldom require renewal except because of obsolescence due to existing mains being too small for the demands of modern industry."

At the close of 1915 there was in use in the five Boroughs of Greater New York over 3600 miles of cast iron gas mains which, together with the water mains already mentioned, made a total of 6,646 miles.

The City of Boston has nearly 1100 miles of gas mains, Philadelphia has over 1500 miles, making considerably over 3000 miles of cast iron pipe in use in each of these cities.

CHAPTER II

MATERIALS AND METHODS OF MAKING METAL PIPE

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IRON, in its crude form (ore), is widely and abundantly distributed throughout the world, but its availability for manufacturing purposes depends largely on the proximity of good and cheap fuel. Not the least of the value of iron is its cheapness—even with the primitive smelting apparatus the cost of a pound of iron was probably not more than a fifth of the cost of a pound of the earlier used bronze.

Courtesy "The Valve World"
Primitive Furnace for Smelting Iron (From "Iron and Steel" Magazine, Vol. 10)

It was formerly thought that, aside from meteoric iron, it did not occur native—that is, in the same form as produced by smelting, —but it has lately been found in large quantities in the basaltic lava of Greenland. This, however, is not chemically pure, nor is any iron manufactured from the ore in the large way free from impurities; and the substances thus present such as graphite, or carbon, silicon, sulphur, phosphorous and manganese, are of great importance in reference to the character of the metal produced.

More than any other metal, iron (and its modified form known as steel), affords the combination of qualities needed in the development and application of energy, and in recent years it has come to occupy a position of cardinal importance in the construction of vessels for the purpose of retaining and transporting substances, especially liquids.

Iron is at once hard, rigid, flexible and tough and has these characteristics through a considerable range of variations, which may readily be induced by manipulation either chemically or mechanically.

There are three forms in which iron is put upon the market, which differ essentially in their properties:

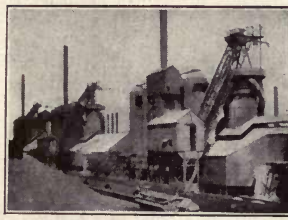
First —*Cast Iron,* which is hard, comparatively brittle, readily fusible, and cannot be forged or welded.

Second—*Wrought Iron,* which is comparatively soft, malleable (capable of being shaped or extended by beating or rolling), ductile, weldable and fusible at a very high temperature.

Third —*Steel,* which is also malleable and weldable, but fusible, and—what is of great importance—capable of being tempered to a very high degree of hardness, so that it cuts cast iron and wrought iron with ease.

Each of these forms will be treated separately and in the order given, so far as they are used in the manufacture of pipe.

Cast Iron

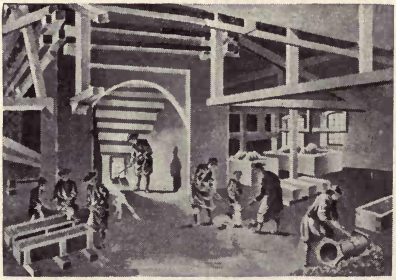


A Modern Blast Furnace

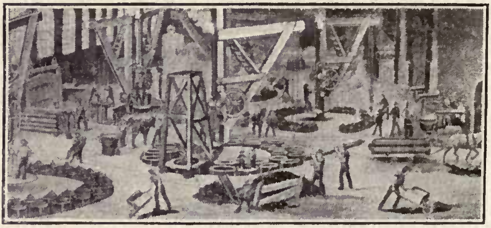
The product of the blast furnace, out of which all forms of iron and steel are now made, is called pig-iron, and the name cast-iron is ordinarily given to pig-iron which has been re-melted in an air furnace, or cupola, and cast into any desired shape, by which process its qualities are not sensibly changed.

When cast into properly shaped moulds, the result is cast iron pipe, but much more is involved in this process than is indicated by this simple statement.

So far as is known the first cast iron pipe was moulded in wooden frames, or flasks, packed with sand sufficiently moist to retain its shape, and the pipe was cast in a horizontal position or "on the side." Indeed, this method still obtains for casting short lengths of pipe, but as the standard of length increased from about 3 ft. to 6 ft., then to 9 ft. and later to 12 ft., the position of casting the moulds changed from horizontal to a slope, and finally to the present vertical position. These changes were made in order to secure a more uniform thickness of wall and better distribution of metal, as well as to insure cleaner and stronger castings by bringing all dirt, or scoria (which rises and floats on the heavier metal) to the top of the mould, into a large runner which is broken or cut off.

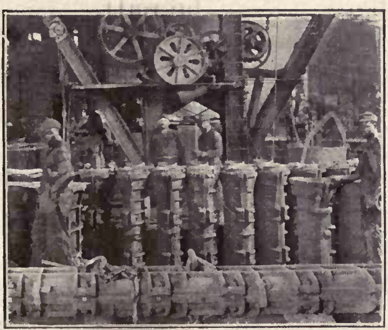


17th Century Pipe Foundry in France

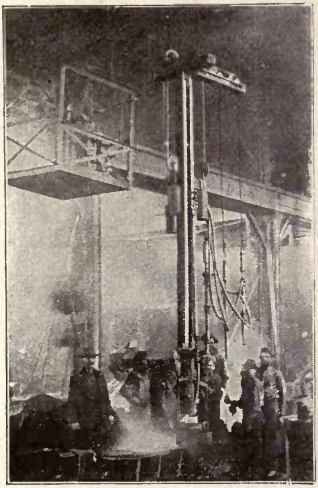


Early 19th Century Pipe Foundry

The most important feature of the modern pipe foundry consists of one or more large pits, either circular or rectangular in shape, and about 12 feet deep, filled with iron flasks accurately machined and fitted for the various sizes of pipe. These flasks are made in two pieces, loosely hinged together on one side and with flanges for clamping the halves together when closed. The inside diameter of the iron flasks is several inches larger than the outside of the pipe pattern, which is also of iron, accurately turned and polished. This pattern has a tapered bottom end, which rests in a correspondingly tapered seat in the center of the "ramming stool" on which the flask is placed for moulding. And being thus centered, the space between the pattern and the flask is filled with sand and thoroughly "rammed."



Modern Pipe Foundry

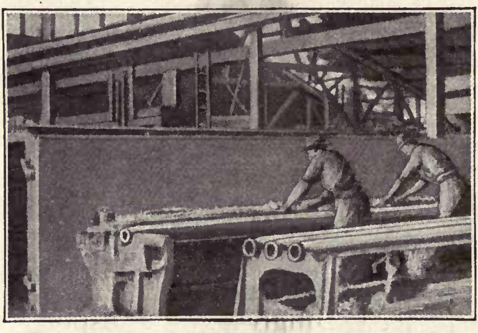


Ramming Moulds

This ramming is done in various ways,

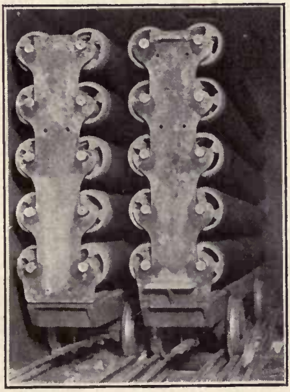
either with blunt end rods, hand or mechanically operated, or by compression by means of a specially shaped pattern, or by jarring the flask after it has been filled with sand.

When the sand has been thoroughly rammed in the flask, the pattern is withdrawn and the mould washed on the inside with a liquid "facing" preparation which prevents the sand from burning and adhering to the pipe when cast. The mould is then placed over an oven, heated with either coke or gas, where it is dried, or baked, and from whence it takes the name of "dry sand mould."



Making Cores

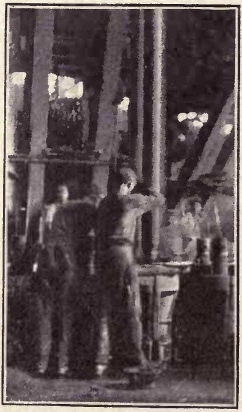
While the moulds are being rammed and dried other workmen are preparing the cores necessary for making the bore of the pipe. This core is made on a hollow mandrel, or "bar," perforated throughout its entire length (about 13 ft.), the holes being ⅛ to ¼ inch diameter. The bar has accurately turned spindles in each end, which rest in horizontal bearings in which the bar is placed parallel with a metal-edged board, or "strike," the edge of this strike fixing the diameter of the core.



Cores in Drying Oven

While being revolved in the bearings at moderate speed a covering of combustible material is first placed on the bar, either in the form of rope made of hay or excelsior, or of paper in the form of pulp, and this is followed by roughing coat of loam of the consistency of a stiff mortar, gauged as to thickness by the metal edged strike. These cores are placed on metal cars and run into large ovens where this first coat is thoroughly dried, then they are covered by a finishing coat of loam and finally by a coating of liquid facing, and again placed in the drying ovens.

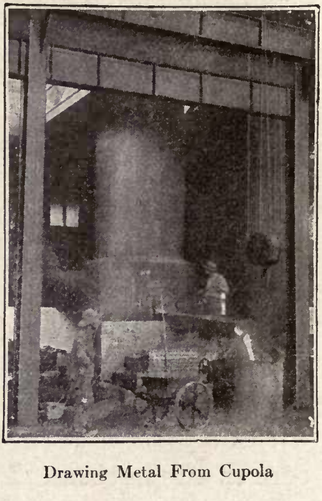
When both moulds and cores are dry, the cores, having tapered bottom ends, are set in the moulds resting on "casting stools" with a corresponding taper which centers the core at the bottom. The head core, or runner



Setting Cores

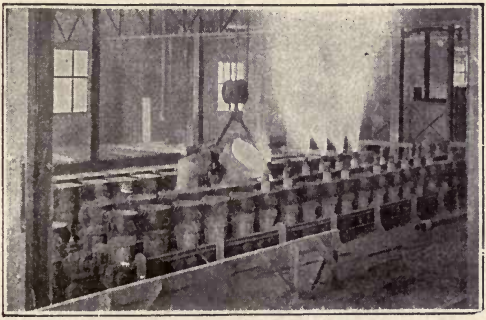
core, with holes, or "gates," for the metal, which is made separately from the main core, is then placed in the top of the mould, thus centering the main, or body, core at the top. A deep runner, or reservoir, is made on top of the mould, which is then ready for casting.

In the casting of pipe care is taken to fill the runner or reservoir, at the first tilt of the ladle and keep it full until the mould is entirely filled, thus providing a large body of metal at the top of the mould in which all foreign matter, of lighter weight than the metal itself, will remain, thus minimizing the danger of defects in the casting.



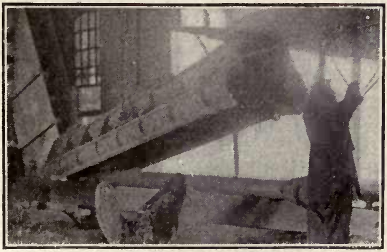
Drawing Metal From Cupola

Within a few seconds after the metal begins to enter a pipe mould, the gases generated by contact with the sand shoot out from the small holes in the flask in the form of a blue flame, and this is quickly followed by a dense smoke from the



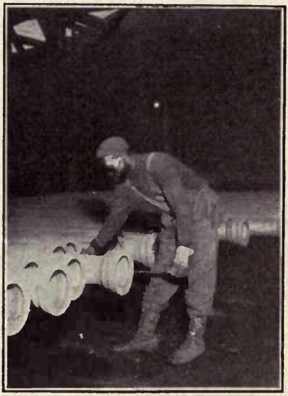
Pouring Pipe

top of the core bar, conducted into its center by the perforations in the bar which, on being touched off with a torch, burns with a heavy flame until the combustible material on the bar is entirely consumed. By this time the metal in the pipe is "set" and the bar can be drawn out and used again for the next cast.



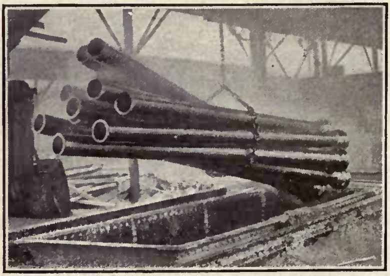
Shaking Out Pipe

The pipe is allowed to remain in the mould until sufficiently cool not to show the color of heat, when the flask is lifted out of the pit and opened on the "shake-out skids," the hot sand dropping into a "tempering pit" beneath, and the pipe starting on its journey through the cleaning shed.



Cleaning Pipe

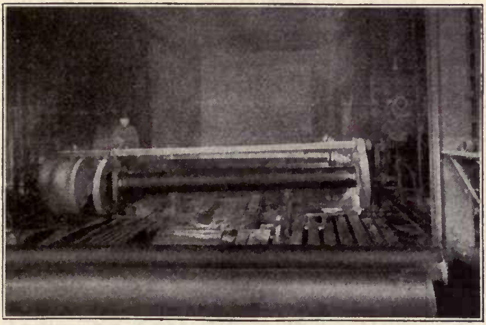
In the cleaning of cast iron pipe, which is done almost entirely by hand, an inspector keeps a watchful eye on every operation, and such defective pipes as are found are almost invariably discovered and marked for rejection before they reach the testing press. When cleaned of all loose sand both inside and out, the baked loam material of the core left on the inside of the pipe by the withdrawal of the bar having to be cut and scraped out with special tools made for that purpose, the pipe intended for water service, which is always coated, is rolled into an oven



Dipping or Coating Pipe

where it is heated to about 300 degrees Fahrenheit and is at that temperature dipped into a bath of coal tar.

After being drained of all surplus tar each pipe is tested to 300 lbs. hydrostatic pressure and carefully hammered under pressure to disclose any hidden defects. Pipes for special high pressure purposes are tested as high as 750 lbs. From the testing press the pipe goes to the scales where the weight of each length is plainly marked on it in white paint and it is then taken to the stock yard and piled according to its weight classification.



Testing Pipe

Even from this brief description of the manufacture of cast iron pipe one must necessarily be impressed by the amount of labor, and the importance of the "personal equation" involved in its production—which is probably unequalled in any other large industry in these days of modern mechanical and labor-saving devices.

In this connection the following statement by a superintendent of the Water Dept. of a large steel company, in the course of a discussion of cast iron pipe standards during one of the sessions of the American Water Works Association Convention at Cincinnati, Ohio, in May, 1915, is of interest:

"I am not a pipe manufacturer. . . . I believe we will save more money by letting the pipe manufacturers work that (a suggested change in standard) out for us than we would by attempting to dictate an arbitrary standard.

Laboratory Test of Pig Iron Mixture

"The pipe people keep a large laboratory and they study their manufactured product day in and day out. . . . They live with the pipe, they know it, they are making the pipe and they know how to make it. They pile up all of their pig-iron in different piles and each pile is numbered. A detailed analysis of each pile is carried and they can tell you, if you give them the number cast on a pipe in the large size, what mine that ore came out of, the day it reached their yard, how they made up that mixture and the test both for tensile and cross-breaking strain.

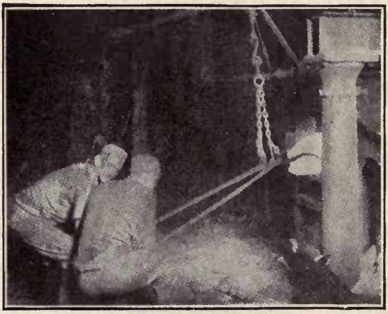
"They are anxious for any man who buys a foot of pipe to give them the history of any failure there is, and I have known of instances where they spent hundreds of dollars following up a small break simply because there was something in there that to the minds of these pipe manufacturers indicated that something had got by them in the manufacture of that pipe. . . . It is wonderful how they make this pipe, the care, thought and endeavor that they put into its manufacture."

Transverse Test for Strength of Metal

Wrought Iron

The term wrought-iron, in its broad definition, viz.: "Iron that is or may be wrought into form by forging or rolling, and that is capable of being welded," is often used in referring to articles made of steel, and as the *method* of making pipe from both materials is identical, and experience has shown that there is little, if any, difference in their durability, only a brief explanation of the preparation of the two materials and of their physical and chemical differences will be given.

The process of transforming pig-iron into wrought-iron is called "puddling," by which process the carbon and other foreign matter is removed, or reduced to the lowest possible limit. This is done by placing the pig-iron on the hearth of a specially-constructed furnace, called a "reverberatory furnace," in which the hot gases are deflected toward the hearth, fusing, or melting all the foreign substances (except the carbon), which melt at a lower temperature than the iron itself, and as the mass is slowly stirred the fusible matter is gradually worked out, settling in a molten state in the bottom of the hearth, the carbon being taken up and carried off with the gases.

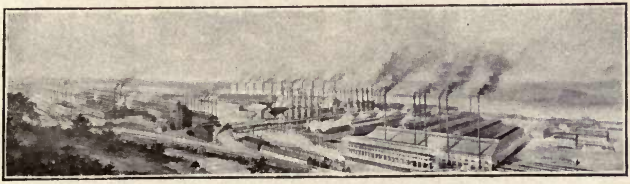


Puddling Furnace

When the metal has been freed, to an extent, of this foreign matter it is formed into pasty balls of convenient size for handling, and these balls are hammered or squeezed, while in a plastic state, to still further eliminate impurities, and passed through rolls forming "muck bar," which is sheared, piled, and reheated and then rolled into "skelp," from which form it is ready to take the shape of pipe, by a process to be described later.

Steel

Steel is a form of iron in which the amount of carbon is intermediate between that in



A Modern Steel Mill

wrought-iron and cast-iron, and in which the carbon does not exist in the form of graphite, but is either combined with or dissolved into the steel. It is also distinguished from wrought-iron by its homogeneity, or freedom from intermingled slag or cinder.

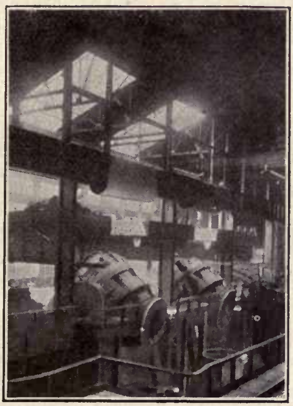
The earliest method of making steel was by the "cementation" process, by which hammered-out bars of wrought iron were given a hard steel crust by heating to a red heat in charcoal or bone dust. Crucible steel, the forerunner of the modern steels, was first made by Huntsman, in England, about the middle of the eighteenth century, but it was not until the invention of Henry Bessemer in 1855, known as the "Bessemer Process," followed in 1861 by the Seimens-Marten, or "Open Hearth Process," both of which provided methods for making steel on an immense scale, that this valuable material was made available for general purposes.

The following description of steel-making, which is given by one of the largest producers of steel and wrought iron pipe in the United States, explains in a very clear and interesting manner the processes involved:

"From the blast furnace ladles having a capacity of 40 tons each convey the melted pig-iron to a building known as the mixer house. The mixer house contains large brick-lined vessels of about 300 tons capacity each, their duty being to keep the pig-iron molten and thoroughly mixed. Samples are taken from these mixers at regular intervals for analysis.

"As required, the hot metal is poured from the mixer into a specially designed ladle which delivers it to the Bessemer Steel Plant. Here the iron is poured again, this time into a large cylindrical vessel tapering toward and open at the top, mounted on trunnions, and operated by hydraulic power. When ready, the vessel is turned from a horizontal to a vertical position, air being blown through the contents.

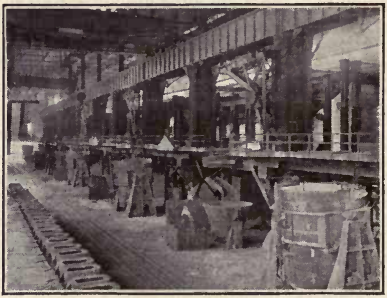
"Pig-iron contains between 94% and 95% of metallic iron; the remaining percentage consists of silicon, manganese, carbon, sulphur and phosphorous. The air blast mentioned above oxidizes the silicon and manganese rapidly, they being the first impurities to be attacked, at the same time raising the heat of the molten mass. As the heat and flame increase the carbon oxidizes. At the beginning of the process the flame is red and as the impurities are burned out the flame changes to a brilliant white, and soon the operation is completed.



Bessemer Converters

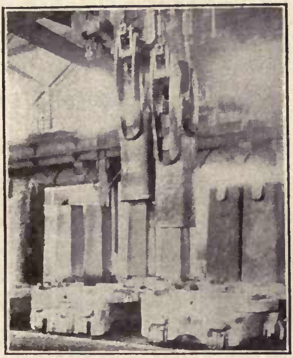
"The vessel is now turned to a horizontal position and the contents poured into a service ladle from the bottom of which the hot metal is run into iron moulds forming Bessemer Steel ingots. Test ingots are taken from the beginning and end of each of these melts as they are being poured into the moulds, these test specimens being carefully analyzed and results obtained on them before the ingots are rolled.

"In the manufacture of Open Hearth steel large rectangular regenerative furnaces erected in batteries and heated by gas are used. Molten iron is charged directly into the furnaces. The other necessary material is loaded in charging boxes in the adjoining stock house, where every charge is carefully weighed. These boxes are then conveyed to the open hearth furnaces and are emptied by means of a charging device of special design directly into the furnaces. The mixture in the furnaces is heated until it reaches the molten state and then is slowly boiled. This melting or boiling process lasts about ten hours, sometimes twelve or fourteen hours, during which time the impurities—the carbon, silicon, manganese, sulphur and phosphorous—have been reduced to within the required content. Laboratory tests as well as the observation of



Open Hearth Furnace

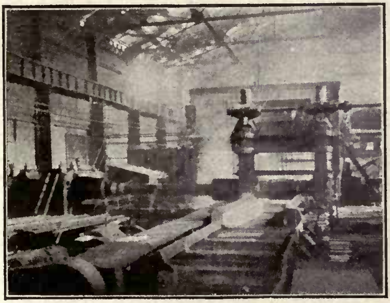
expert men indicate the completion of the process, at which time the furnace is tapped and the contents run into ladles, which in turn are poured into molds forming open hearth steel ingots, from which further tests are taken for analysis.



Stripping Ingots

"After the ingots of either the Bessemer or Open Hearth steel have properly cooled, the moulds are lifted or stripped from the ingots by means of a crane—consisting of a clutch for lifting the mould, and a ram, for pushing out the ingot.

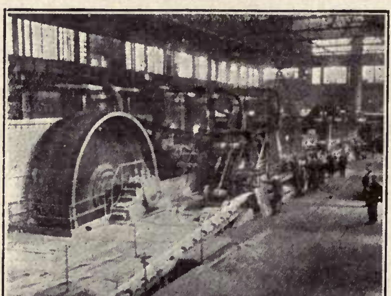
"Having been stripped of their moulds, it is necessary to reheat the ingots in order to have a uniform temperature throughout for the subsequent rolling required to reduce the ingots in size. This reheating is done in pit furnaces, or



Rolling Ingots

soaking pits, equipped with recording instruments which keep a close check on the temperature of the furnace while the ingots are being reheated. Each ingot must be heated so that it is homogeneous throughout as it can be readily seen that an ingot having a surface much hotter than the inside, or vice versa, cannot be properly rolled.

"The first reduction in the size of the ingots is done in a mill known as a blooming mill of the two-high type, which consists of two parallel grooved rolls through which the ingots are passed and repassed until they are formed into blooms or slabs, which terms are used to indicate the relative size and shape of the semi-finished material. From the blooming mill the slabs are conveyed to hydraulic shears which cut off the ends, leaving them clean and square.



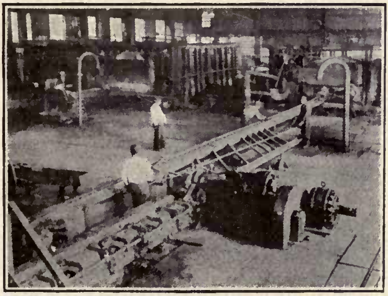
Skelp Mill

"The slab is now conveyed to the universal plate mill, consisting of vertical edging rolls in addition to the horizontal rolls, where the slabs are rolled into plates of uniform width and thickness, known as skelp, and used in the manufacture of pipe.

"In making the narrower widths of skelp the blooms are rolled into billets or bars which are run through a series of rolls known as a continuous mill, and the skelp so produced is used for the manufacture of the smaller sizes of pipe."

The actual processes of making wrought-iron and steel pipe which, beginning with the skelp, are identical, are described by this manufacturer thus:

"Small pipe is made by the butt-weld process. This consists of heating the skelp in a furnace to a welding heat, and when the proper temperature is reached the skelp is drawn with tongs through a bell or circular die, the inside diameter of which is approximately the same as the outside diameter of the pipe when finished.

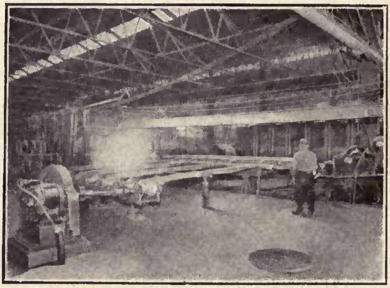


Butt Weld Tube Mill

"The welded pipe, still red hot, is now run through sizing and straightening rolls and thence to cooling tables or skids.

"The temperature of the pipe is greatly reduced while on these cooling beds, and it is usually here that the uneven, or crop, ends are cut off, so that we now have the finished pipe ready for threading and testing.

"The larger sizes of pipe are made by the lap-weld process. The skelp is first heated a cherry red and then bent into the shape of a pipe with edges slightly overlapping. This operation forms the pipe but does not weld it. It is now charged into a furnace and reheated to a welding heat, and is then forced between welding rolls and over a mandrel of approximately the same size diameter as the internal diameter of the pipe. The pressure of the rolls with the mandrel inside the pipe causes the overlapping edges to become welded.



Lap Weld Furnace

"The welded pipe now passes through a series of rolls known as sizing rolls, which produce an equal pressure on the whole diameter, and thence through the cross rolls which finish the surface and further straighten the pipe — after which the pipe is cooled and conveyed to the cold-straightening press, where it is given a final straightening.

"The pipe is now ready to be finished as plain end pipe, or to be fitted with threads or couplings."

As the development of the steel industry is of comparatively recent date, the first rolled metal pipe was of wrought iron and its production in this country dates from about 1830, the first pipe mill being located in Philadelphia.

According to the best information obtainable, rolled steel pipe was first produced in this country in 1887 by Frank Hearn, Manager of the Riverside Iron Works, Benwood, near Wheeling, W. Va.

Because of the high tensile strength and extreme ductility of rolled wrought iron and steel pipe, and the fact that it can be produced economically in sizes smaller than it is practicable to mold cast iron pipe, the growth of the industry in the United States in the past quarter century has been truly phenomenal.

Careful consideration and comparison of the methods of making metal pipe, however, as described in this chapter, will show that with cast iron pipe the greater amount of labor is in the preparation of the molds and cores (nearly all hand work) and the material is used in its practically unchanged form, whereas in the making of wrought iron and steel pipe the greater amount of labor is in the preparation of the material, changing it from its natural to an artificial form to meet certain requirements of tensile strength, which can only be met by the sacrifice of durability.

CHAPTER III

SOME TECHNICAL AND HISTORICAL DATA ON METAL PIPE DETERIORATION

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ONE of the most fascinating studies for the student of metallurgical chemistry in the past twenty or twenty-five years has been the *cause* of rust—the acknowledged arch-enemy of all iron products. Some five or six different theories have been evolved, each of which has its adherents, but since it is not so much the *cause* of rust with which the user of pipe is concerned as the *effect*, the following paper presented at the Convention of the American Foundrymen's Association, held in Atlantic City, N. J., Sept. 30–Oct. 2, 1915, on "The Structural or Mechanical Theory of the Effect of Rust on Cast Iron and Wrought Iron and Steel," by the author, in collaboration with Mr. Harry Y. Carson, may prove of value:

"Paper by R. C. McWane"

"From out of the maze of chemical controversy of recent years as to the cause, or causes, of rust, stands the fact that cast iron resists the action, or actions, that prove so quickly and so completely destructive to *wrought iron or steel, and with this fact chemists have never yet been able to reconcile their theories.

"In all the chemical, or electro-chemical theories so far advanced, cast iron has been shown to be most susceptible to rust, because of the larger percentage it contains of foreign matter, such as graphite, silicon, manganese, sulphur and phosphorous, yet the facts of history prove that while cast iron will become quickly coated with rust, it will remain practically unimpaired in weight and strength for hundreds of years under conditions that prove absolutely fatal to wrought iron or steel in 10 to 20 years.

"These facts indicate, therefore, that we must look to other than chemical causes for a satisfactory explanation of the phenomenon of rust damage, and the theory which seems to be most nearly in harmony with the facts, but which has received scant attention in the discussion of this subject heretofore, is that of the marked difference in *structure* between cast iron and wrought iron and steel.

"This difference is graphically shown in

*Only "rolled" wrought iron and steel is referred to in this paper.

Figs. 1 and 2, these illustrations being reproductions of actual photomicrographs.

"Whatever may be the accepted theory of the actual process of rust, whether the

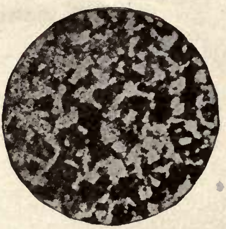


Fig. 1
Cast Iron

Fig. 2
Wrought Iron

hydrogen-peroxide, the carbonic acid or the electrolytic, the three most generally accepted theories at present, it is unanimously agreed that the process is a form of slow combustion, with the presence of oxygen as an all-important factor, and that if the material can be fully and permanently protected, to exclude oxygen, rusting will not take place.

"By reference to Fig. 1, it will be noted that cast iron has a distinct granular or crystalline structure, a form common to all metals having undergone the simple process of smelting and cooling, which was one of the processes of nature in the formation of the ore, and it is this distinctive structure, in combination with the chemical, or electro-chemical, action taking place on the surface of the metal, which serves to stop that action, after it has proceeded to a certain depth, and hold the result (ferrous oxide) as a permanent, oxygen-excluding protective coating. This stoppage of rust action results from the fact that the crystals, or granules, in cast iron are bound together at one or more points by a metallic bond, or bonds, and after a rust coating has been formed of the loose crystals on and near the surface of the metal, and the oxide penetrates between the crystals more strongly bound together, the force exerted by the absorption of moisture is not sufficient to separate the crystals, and the oxide remains as a permanent coating.

"The undisputed fact that from the moment we begin to manipulate cast iron by puddling and rolling, we lay down the barriers for the invasion of rust, and the further well-known fact that the thinner a sheet of wrought iron or steel is rolled the more rapidly it will succumb to the action of rust, leads inevitably to the conclusion that the change in structure brought about by such manipulation has a most important, if not altogether final, bearing on this much discussed question.

"Passing over the intermediate processes, from cast iron to the extreme of thinly rolled sheet steel, we find the structure of the metal to have changed from crystalline to fibrous and finally to distinct laminations, or leaves and in each process of heating and rolling the natural bond found in the crystalline structure of cast iron has been further disturbed, until in the steel sheet we find the leaves bound together largely, if not altogether, by the force of compression, yet distinctly differentiated

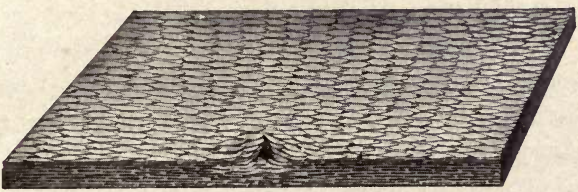


Fig. 3

one from the other by the very small percentage of silicon always present but uncombined with the steel.

"The rusting of steel is evidenced by a form of pitting and exfoliation, or flaking-off of minute particles of metal, exposing a new surface for attack, from time to time, until the entire section is affected. This can be clearly understood by reference to Fig. 3, which is from a drawing made to represent a piece of sheet steel, very much enlarged, showing a surface and sectional structure, and a typical *pit*, which is likely to occur at various points in sheets apparently well-protected with paint or other coating. Uncoated sheets will scale off much more uniformly, and despite the claims of various manufacturers in the past few years of having produced a coating that will successfully and permanently adhere to the smooth surface of rolled steel, rust damage to such steel goes on apace, especially in locations where it cannot be watched and the coating frequently renewed.

"An important factor in the scaling-off or breaking up of the surface of rolled steel, and one which has never been considered heretofore, would seem to be the forces of expansion and contraction as offering a reasonable and satisfactory explanation of the rapid deterioration of such steel when exposed to sudden and violent changes in temperature. These changes, taking place on the surface of the metal before the interior portions are affected, tend to buckle, or stretch, the surface metal and to tear the laminations apart or open them up so that rust action is accelerated.

"The change in structure from a crystal of appreciable size, bound to its fellows by a metallic bond, to an infinitesimally thin leaf, with no bond strong enough to resist the efforts of the rust coating to tear it away from its fellows, is a thoroughly understandable and logical explanation of the effect of rust on the two materials, and is not in any way weakened by the well-founded claim that 'old-fashioned wrought iron' resists rust to a remarkable degree.

"The early and crude methods of making wrought iron, while producing metal of greater tensile strength than cast iron, accomplished the desired end by increasing the density of the structure through hammering or forging, making little change in the shape of the crystals and, above all, *not destroying the natural metallic bonds* between the granules of iron. Structures such as link chain bridges, erected more than 100 years ago, have been referred to as instances of the power of wrought iron to resist rust, yet links taken from these bridges, showing no sign of deterioration from rust, have been heated and rolled by modern processes and found to rust as rapidly as ordinary steel plates. On the other hand, rolled steel plates may be cut up, remelted and made into steel castings, thus restoring the natural bonds in the crystalline structure, and it is found that they resist rust almost as well as cast iron.

"No more striking illustration of the lasting, or rust-resisting qualities of cast iron is afforded than the pieces of cast iron pipe shown in Fig. 4, the photographs having been taken in Paris, France, in 1909.

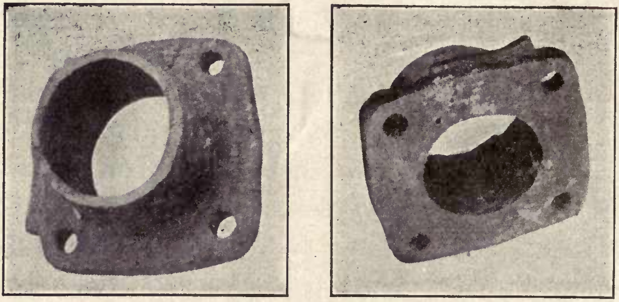


Fig. 4—Pieces of Cast Iron Pipe from an Underground Line Installed Prior to 1685

"These pieces of pipe are from an underground line installed prior to 1685 for the purpose of conveying water to the famous fountains in the Versailles Park, and official report says that when taken up this pipe was 'in apparently as good condition as when installed.'

Fig. 5—Effect of Rust on Cast Iron

"Figs. 5 and 6 illustrate the relative effect of rust on cast iron and wrought iron. The cast iron shown here was used in the same service with the wrought iron and for the same length of time, and shows no sign of deterioration, while the wrought iron is completely destroyed."

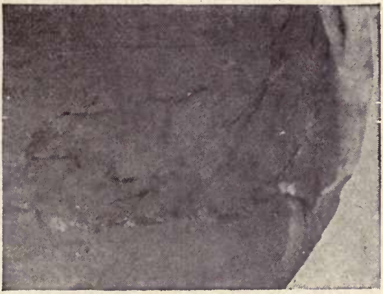


Fig. 6—Effect of Rust on Wrought Iron

"PAPER BY HARRY Y. CARSON"

"Perhaps no field affords a better means of studying iron pipe corrosion at first hand than pipe contained in the plumbing of buildings. First, this is due to the fact that both wrought iron and cast iron pipe have been installed and used in the waste lines of buildings during the past 20 years; second, old buildings are continually being torn down or remodelled, so that it is possible to obtain specimens of cast iron pipe which have been in the same service with wrought iron and steel pipe; and third, when such a pipe line fails the sewer gases escape from it and render poisonous the atmosphere of the building.

"Corrosion in waste and vent pipes is attributable to the moist condition of the air within the piping system, together with the hydrogen sulphide (H_2S) and carbon dioxide (Co_2), etc., products of bacterial decomposition of sewage, which may be considered as dilute acid reagents attacking the internal surface of the pipe.

"Such are the normal conditions analagous perhaps to the damp air of cellars where it is so common to note the corroding of iron taking

Fig. 7—Wrought Iron and Cast Iron Pipe Coupled Together for Service to Compare Durability

place at a fairly high rate. In many drains and vents the corrosive action is found to be even more severe than this. Where hot water or steam is discharged into the waste pipes, or where strong acids, disinfectants or other strongly corrosive substances are discharged along with the waste water into the lines, the corrosion of wrought iron or steel becomes far more rapid and the lines break down in 5 to 10 years after being first put into use. To explain the wide difference that exists between the life of cast iron pipe and wrought pipe, none of the commonly discussed theories can be made to fit the facts of actual service. Indeed, they are in direct opposition to the facts.

"Typical is the comparison offered by the installation illustrated in Figs 7, 8 and 9,

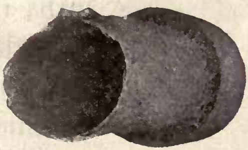


Fig. 8—The Wrought Iron Pipe, Showing Effects of Corrosion

Fig. 9—The Cast Iron Pipe, Still serviceable

which gives an actual comparison of the durability of cast iron and wrought iron soil pipe joined together and used in the same 5-inch drainage stack for 18 years.

"The wrought iron pipe in all cases indicates a continuous peeling off of rust scales, until the whole section is destroyed, while cast iron pipe is unimpaired by the same corroding action which destroys wrought pipe. The cast iron pipe shows when removed, a closely adhering rust coating on the surface, which undoubtedly prevents the destruction of the pipe. The loss in weight and original thickness of cast iron pipe by 18 years of service was something less than 1 per cent, while that of the wrought iron pipe was more than 72 per cent. It is not unlikely that the greater part of the 1 per cent loss in cast iron pipe actually took place during the first year the pipe was put into use, since this pipe is not tar-coated, and it is well-known that the surface of uncoated cast iron pipe corrodes very quickly. It is probable that uncoated cast iron pipe will show a higher initial loss by corrosion during the first few months of service than would be shown in the wrought iron or steel pipe subjected to the same corrosive action during the same period of time.

"Observing the manner in which all rolling mill products corrode, we must necessarily attach a great deal of importance to the microscopic structure of the iron. The same typical flaking-off of rust scales may be observed on rolled steel beams, round or square bars, or any other of the many products which are turned out of the modern rolling mill. In every known case the material showing this typical flaking-off has a rolled, laminated structure, in which the natural bonds between the existing, but deformed, granules of iron are completely destroyed or weakened beyond the point at which they can successfully resist the action or actions of rust.

"Ancient wrought iron or steel, and even that made 100 years ago, is known to have resisted corrosion much better than the modern wrought iron or modern rolled steel. This can be explained by the fact that old iron does not have the same physical structure as the modern milled product, because ancient iron was smelted from the ore by crude methods into small-size pieces of metal and then hammered—not rolled—into its finished shape. Had the ancient iron been manipulated like the modern rolled steel, it could not have lasted more than a few years.

"These facts lead to the obvious conclusion, namely, that iron which has a granular or crystalline structure in which the natural bond has not been disturbed by mechanical manipulation, is more resistant to corrosion, regardless of its chemical content than iron or steel in which an attempt has been made after rolling, to restore the crystalline structure by annealing or other processes."

In addition to the more rapid corrosion of the metals themselves, it must be considered that the section of pipe made of rolled wrought iron or steel sheets, is much thinner than that of cast iron pipe, the relative thickness of some of the larger sizes being as follows:

Size	Cast Iron—Class B	Wrought Iron or Steel
24″	7/8	1/4 to 5/16
30″	1	1/4 to 5/16
36″	1 1/8	1/4 to 5/16
42″	1 1/4	1/4 to 3/8
48″	1 7/16	1/4 to 3/8

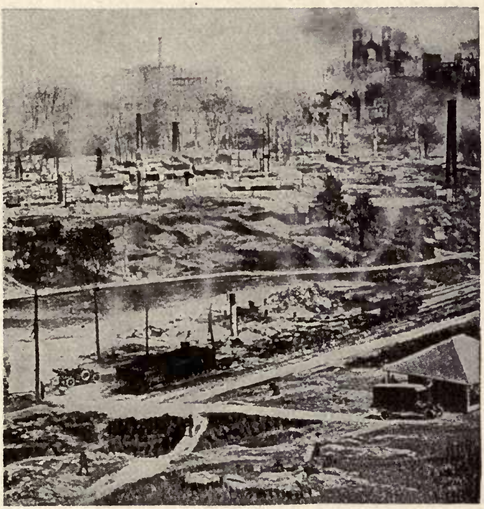
From this it will be seen that even if the rate of corrosion were the same for the two metals the steel would be perforated while the cast iron would still have about three fourths of its thickness unaffected. Exhaustive tests have proven that cast iron loses through corrosion approximately one per cent. of its original thickness and strength in the first ten years under ground. Should the same ratio of loss continue, the pipe would be entirely consumed in a thousand years. But further tests have proven that, under normal conditions, corrosion of cast iron pipe ceases after the first ten years, so that its life may be said to be even longer.

Before steel came into use many cities used genuine WROUGHT IRON for water mains. The early pipe made of this material resisted corrosion to a much greater degree than modern steel pipe, but the metal is not suitable for large diameter pipe. The experience with wrought iron pipe (cited in the following instances) would have been much worse had steel been used.

Report for 1880, Salem, Mass. Page 13

"There has been some trouble with the wrought iron pipe the past year, principally from rust and letting the water on the hydrants at fires. In all cases of breaks, the pipe has been found badly rusted, and there are doubtless many small leaks that have not shown on the surface as yet but will if they get larger."

This was a significant forerunner of the



Salem Ruins

report of Franklin H. Wentworth, Secretary of the National Fire Prevention Association on the disastrous fire in Salem, Massachusetts, June, 25, 1914, which caused a loss of more than $15,000,000, and from whose report the following is quoted:

"The wrought iron water mains did not

burst until after the fire had spent its force, but the constant fear of their known weakness paralyzed all efforts to use water except by the steamers supplying their own pressure. The abundant water supplies of Peabody, Danvers and Beverly were gingerly tied into the Salem system in fear that the pressure they had to contribute would shatter Salem's obsolete old mains and end the water-throwing for good. With water enough to raft Salem out to sea her citizens on the borders of the fire zone threw away their garden hose and extinguished the sparks on their shingle roofs with tree-spraying outfits."

Wrought Iron Gas Pipe in Use Five Years, Leavenworth, Kan.

Report for 1880, Lowell, Mass. —Page 54

"This wrought pipe has been in use about 13 years and on uncovering it many places were found badly corroded. There was one leak of considerable size and several other places where the water oozed out slowly. Doubtless before another season the pipe would have burst in several places."

Report for 1890, Worcester, Mass.—Page 9

"I would respectfully suggest that larger pipe be laid as recommended in former reports, and that cast iron pipe be laid in place of wrought in streets where leaks have been frequent the last year." (96 leaks were discovered that year.)

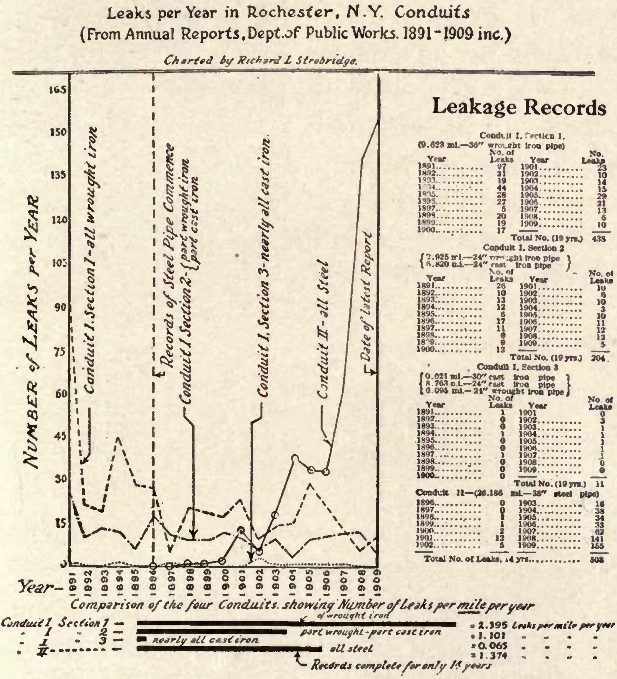
Report of T. J. Bell, Asst. Supt., Cincinnati, Ohio, Water Works

"With but few exceptions all cities having adopted in the original construction wrought pipe, are now using cast iron pipes. It is yet to be proven that wrought iron pipe, whether coated with asphaltum, enameled, galvanized or cemented can be relied on beyond ten years. In our practice five years is the limit of its durability, for corrosion is constantly weakening its structure and it is only a question of time, depending on the nature of the soil in which it lies, the pressure it has to withstand and its original thickness and the material with which it is protected, when it will give out."

Probable Life of Steel Pipe

Owing, perhaps, to the fact that many engineers and superintendents of water works, where steel lines are in use, are still in office, and would naturally be disinclined to reverse their judgment in having installed such material, it has not been possible to obtain figures regarding deterioration and maintenance in all cases where such figures are desired.

The two conduits which furnish the most reliable data are those at Rochester, N. Y. and Coolgardie, Australia. At Rochester, 26 miles of 38 inch steel pipe was laid in 1893 and 1894. In a paper read at a convention of the New England Water Works Association held in Rochester in 1910, Mr. Emil Kuichling, Consulting Engineer in the construction of this main, stated that the best of metallurgical skill was embodied in the manufacture of the pipe and in the work of construction and over-seeing, the specifications were closely adhered to. Within four years after being placed in service defects began to develop, and increased markedly up to the present time when the line is in dangerous condition. In discussing Mr. Kuichling's paper, Mr. Fisher, City Engineer of Rochester stated that the annual expense of maintenance was about $10,000.00. Repairs consisted of uncovering the pipe, driving into the rust holes a wooden plug which was cut off flush with the exterior of the pipe, scraping out all the rust possible, placing a lead patch over the hole, over this a steel patch held in place by wrought iron bands drawn tight around the



Leakage Records

Conduit 1, Section 1.
(9.623 mi.—36″ wrought iron pipe)

Year	No. of Leaks	Year	No. Leaks
1891	97	1901	23
1892	21	1902	10
1893	19	1903	14
1894	44	1904	15
1895	28	1905	29
1896	27	1906	21
1897	5	1907	13
1898	20	1908	6
1899	19	1909	10
1900	17	Total No. (19 yrs.)	438

Conduit 1, Section 2
{2.925 mi.—24″ wrought iron pipe / 6.820 mi.—24″ cast iron pipe}

Year	No. of Leaks	Year	No. of Leaks
1891	26	1901	10
1892	10	1902	6
1893	13	1903	10
1894	12	1904	3
1895	6	1905	10
1896	17	1906	11
1897	11	1907	12
1898	9	1908	12
1899	9	1909	5
1900	12	Total No. (19 yrs.)	204

Conduit 1, Section 3
{0.021 mi.—30″ cast iron pipe / 8.763 mi.—24″ cast iron pipe / 0.095 mi.—21″ wrought iron pipe}

Year	No. of Leaks	Year	No. of Leaks
1891	1	1901	0
1892	0	1902	3
1893	0	1903	1
1894	1	1904	1
1895	0	1905	1
1896	0	1906	1
1897	1	1907	1
1898	0	1908	0
1899	0	1909	0
1900	0	Total No. (19 yrs.)	11

Conduit II—(26.186 mi.—38″ steel pipe)

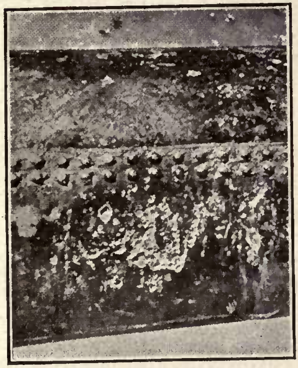
1896	0	1903	16
1897	0	1904	38
1898	1	1905	34
1899	1	1906	33
1900	2	1907	62
1901	13	1908	141
1902	5	1909	155
Total No. of Leaks, 14 yrs.			503

pipe by malleable iron shoes with threads and nuts, the steel patch caulked and the whole protected by two coats of special paint. Only a portion of the pipe was uncovered each year, and of the portion uncovered, the accompanying chart shows the number of leaks discovered and repaired up to the time of their last pipe report in 1909.

These pittings were discovered on the outside of the pipe; the inside would probably show, if examined, a still worse condition. As the pipe has nearly reached the limit of its useful life, the results since 1907 can reasonably be supposed to show an increased rate of deterioration. Their annual reports show the following cost of maintenance *per mile per year* calculated as applying *on the whole* line:

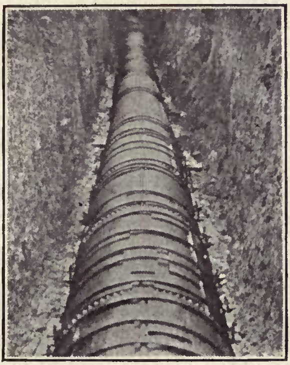
1900	$122.08
1901	92.60
1902	154.44
1903	133.90
1904	256.93
1905	280.63
1906–7	255.45

These expenses for seven years are during the comparatively early life of the pipe. Mr. Fisher's statement in 1910 that about $10,000.00 were then expended annually on the line shows an expense of maintenance of about $385.00 per year for the whole line. Mr. John F. Skinner, Special Assistant Engineer, appointed to make an examination of this line, reported in 1901 (7 years after its installation) that prior to 1900 no holes in the plates were discovered but that since that time fifteen had been found in seven different excavations. During the investigation eight more developed, and a large number of pits were found, some so deep that it was found advisable to patch them. In one case three leaks were found in a single sheet of the steel. The experience of Rochester has indeed been unfortunate. The result shows that they have at the present time:



Steel Pipe at Rochester, N. Y., Showing Pitting and Formation of Tubercles

An unsafe water carrier that may at any time give out and deprive the city of water through that conduit. A large expense for repairs.



Method of Repairing Steel Pipe at Rochester—Plates Held in Position By Steel Bands

No physical value of material, as the value of the steel in its present condition would not pay for its removal.

A prospect of a large expenditure for replacement with a durable material.

The inconvenience to the city while such replacement is being installed.

If cast iron pipe had been installed originally, they would now have:

A line giving them good service, for no cast iron lines are known which have failed in the time this steel line has. Security in water supply; little or nothing expended for maintenance.

In addition, at the end of the life of a cast iron main, there is left nearly the original number of tons of re-meltable iron, which disregarding market fluctuations, is worth about one-half the original cost of the pipe.

Coolgardie, Australia.—About 350 miles of 30-inch steel main was laid from an impounding reservoir to a service reservoir at Coolgardie to supply the gold fields which are located in an arid region with only about five inches of rainfall annually. The work was completed in 1903. In 1909 the Western Australian government found it necessary to institute an investigation to determine the best methods for checking the corrosion which was taking place. It was found that both internal and external corrosion were in progress. The committee consisted of the late

Dr. George F. Deacon, Sir William Ramsay and Mr. Otto Hehner. *They found that corrosion was working beneath the coating which appeared to be in good condition.* An analysis of the water showed that it contained a considerable proportion of sodium chloride and magnesium chloride, while carbonates were present in minute quantity only. Generally speaking, the report shows the pipe to be in very bad condition. Mr. De Bernales, Managing Director, writes (August 20th):

Steel Pipe Line in Oregon Abandoned After Less than 15 Years' Service

"There is no doubt but that the Government made a serious mistake in putting in steel pipe instead of cast iron and, furthermore, the whole of the piping will have to be replaced very shortly. The Government, I believe, recognize that a cast iron piping is what is necessary, but are stopped from replacing the present line with a cast iron line owing to the enormous expense such an enormous undertaking would mean, as also the reflection it would make on their administration for having originally put in steel pipe."

The average expense of making necessary repairs for the total length of the line during the three years, 1907, 1908 and 1909, was $197,58 per mile per year, not counting general expense, nor cost of extra plumbing due to the leaks, and other items of loss.

Other steel conduits that have proved defective in foreign countries in a short time may be briefly mentioned as follows:

Nancy,	France	Madrid,	Spain	Wittmund,	Germany
Reims,	"	Santiago,	Cuba	Gottingen,	"
Aniens,	"	Havana,	"	Metz,	"
St. Etienno,	"	Cienfuegos,	"	Berlin,	"
Orleans,	"	Belocks,	Germany	Ladysmith,	So. Africa
Paris,	"	Nordenham,	"	Pretoria,	" "
Rome,	Italy	Zwicken,	"		

Port Elizabeth, So. Africa —defective in 5 years
Warwick, Canada — " " 2 "
Tay Bridge, Great Britain — " " 9 "
This line was protected by a wooden box.
Bombay, India, replaced with cast iron pipe in 4½ years.

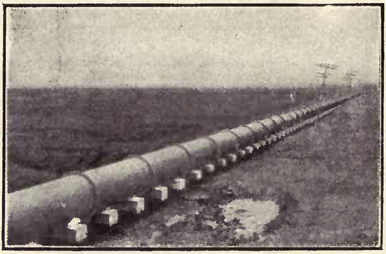
Troy, N. Y.—A line of steel pipe laid in 1902 was in 1912 so nearly at the end of its life that it leaked 800,000 gallons per day, as shown by tests, and contract was let in January 1914, for over 6,000 tons of 30-inch cast iron pipe for its replacement. This steel pipe was made and laid under very severe specifications. Mr. J. M. Divin, Superintendent of the Bureau of Water Supply, of the City of Troy, writes (June 22d, 1912):

"The section that has given trouble promises more, though it should have gone from 14 to 20 years. I am at work now figuring on a 36-inch or 42-inch cast iron line paralleling this steel line, or may possibly conclude to put in two 30-inch, which would give us a double supply when the steel line was entirely gone."

Another View of Abandoned Steel Pipe Line in Oregon

It will be noticed that this line failed to live to its expected term of 20 years.

Atlantic City, N. J.—This line of steel pipe laid across the salt meadows in 1901 was made under stringent specifications which were fully lived up to (see their report for 1900–1901). In addition to the usual coating this pipe was protected by strips of burlap laid on the outside "while the coating was still hot and sticky, by a gang of paper hangers, in the same way wall paper is brushed on to a wall." In spite of all this protection the line has rusted beyond repair, has been abandoned, and replaced during 1914 with a line of 48-inch *cast iron* pipe. As the action of salt water is very trying to any metal structure, this can hardly with fairness be cited as an instance of what might be expected under usual conditions, and is mentioned only for comparison, for which purpose it can be stated that a cast iron main, paralleling the steel main, *laid ten years earlier*, is still giving good service. The steel main was patrolled daily its entire length, and the cost of repairs was considerable.



Cast Iron Pipe Line That Replaced Steel Pipe at Atlantic City, N. J.

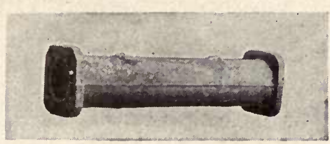
Conditions of soil, water and manufacture affect steel pipe to such a degree that as these conditions vary, the life of the pipe is correspondingly affected. Thus, in some instances, where soil and water are favorable, we find steel pipe in *apparently* good condition, while in some instances it is deteriorating rapidly after from five to ten years' service. An average of its useful life would probably be somewhere between ten and twenty years, while under the most favorable conditions it might last thirty years.

Probable Life of Cast Iron Pipe

The ultimate length of service of a properly constructed cast iron pipe conduit is unknown, as in some instances the earliest pipe cast is still in use. In Versailles a line of cast iron pipe is in use to-day which was installed 249 years ago. The City of Glasgow, in common with many other cities in Great Britain, has cast iron mains laid 165 years ago. This was uncovered and examined in 1905 and found to be in perfect condition.

Following are some official reports as to the experience had with cast iron pipe in different European cities, as given in a book published by the "Deutsch Verbund:"

Clermont-Ferrand.—The first Cast Iron conduits dated of 1748–1749. The greatest part of them are still in service today (1910). (160 161 years old then.)



Cast Iron Pipe 160 Years Old—From Line Laid in Clermont-Ferrand, France. Still in Regular Service

Rheims, 1748.—Those pipes were removed to be replaced by modern ones, but they were still in very good state. (162 years old.)

Saint-Etienne, 1782.—Conduits still in service to-day.

Brussels.—The laying out of the conduits dates of 1856–57. Some had to be replaced in different sections due to the increase in the population, but in general most of them used now date of 1856–57.

Liege.—The first water conduits laid in 1867 are still in use to-day.

Antwerp.—Some of the pipes were laid in 1874–75 by Dick & Quick. The greatest part of them were placed in 1879–81, and the service began in June, 1881. A second main conduit was placed in 1899. All are in good state. (January, 1911.)

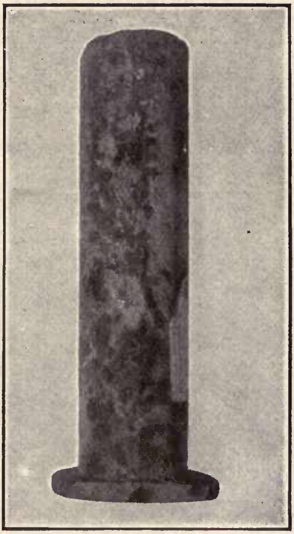
Vienna.—Conduits of high service and line of 813 kilometres (542 miles), of pipes of 55 (2.16″) and 950 m/m. (37.4″) diameter laid in 1803; still in service.

Conduits (called Duke of Albert) of Cast Iron pipes 105 m/m. (4.13″) in diameter laid in 1805, are still in good working service for a length of several kilometres.

London.—From the Chief Engineer of the Water Works: "As Chief Engineer for a good many years for the new East Company of London, I had many occasions of seeing some of the old conduits dating of some 90 years, which when removed were found in perfect order."

Aix-La-Chapelle, 1840–1841.—These pipes

were removed in 1904 and replaced again in another section of the city.



Cast Iron Pipe From a Line 120 Years Old in Stolpen, Germany

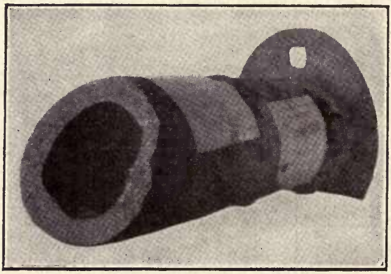
Berlin. — The municipal service of the Water and Gas of Berlin laid their first Cast Iron pipes in about 1845–46. The canalization was put to service January 1, 1847. Although the length of time since put in regular service cannot be exactly determined, but is estimated as from 35 to 40 years. The older conduits placed at the centre of the town have been replaced at times by larger ones, but used again after standing same tests as new pipes. These old pipes were many times laid down again just because of their sound appearance.

Bochum, 1870.—We never had any repairs done on our water conduits.

Bonn.—Gas in 1878–79. Water in 1873–74. These pipes are still in excellent condition.

Breslau.—Water service 1850–55. Some of these pipes have been changed after 35 years, but have in all cases been laid down again as new.

Darmstadt.—One of the old conduits laid in the 18th Century is still in good working order to-day. The gas canalization dates of 1854. It has for a great length of it been replaced by larger mains, but the old pipes have been used again.



Another View of 120 Year Old Pipe From Stolpen, Germany

Ehrenbreitstein.—Old Canalization dating of 1750 still in service.

Homburg Von Der Hohe, 1790.—The conduits are still in service and they do not show a slight attack of rust.

Bains de Krouznach, 1872.—These conduits are very well preserved, the Cast Iron having excessively well stood the saline influences of the soil.

Leipsig, 1837.—The pipes when removed were found to be in excellent condition.

Mannheim.—Canalizations dating of 1850 are still like new.

Weilburg is using mains installed 210 years ago. At Bombay the Vehar mains, after 55 years' service have been taken up and relaid within the city boundary. Mr. Midgley Taylor in his report on the Bombay cast iron pipe says: "In May, 1912, an inspection made of a piece of cast iron main, 48 inches, laid in 1893, showed that there was absolutely no corrosion on the main, that the coating which had been *originally* placed on the pipe, was in good order, and that, in consequence, the co-efficient of roughness would remain the same from the time that the main was laid in 1893 to the present day."

Cast iron pipe has of course been in use in this country a shorter time, but no cast iron mains are now known here that have worn out, or rusted out.

We thus see that the structure itself is practically everlasting. Reasons of expediency, necessity of increasing the supply (due to growth of population) by installing larger mains, and other unforeseen contingencies may cause the obsolescence of cast iron pipe before its physical deterioration. On account of these factors, which in most cases are remote, it is customary in calculating to assign a useful life of 100 years to cast iron pipe.

Faults that are common to both steel and cast iron pipe are:

Tuberculation. Electrolysis.

TUBERCULATION is a growth (due to properties in some waters) on the interior surface of the pipe, which reduces its area, and consequently, its carrying capacity. This growth is equal, under the same conditions for both steel and cast iron pipe. Under modern methods it is possible easily and cheaply to remove tuberculation from cast iron mains by scraping, thus restoring nearly its original carrying capacity, while this is not practicable with steel pipe, as the scraping would remove the coating, which even without tampering will not adhere, and thus destroy the life of the pipe.

ELECTROLYSIS is the deterioration of the structure of the metal itself due to the electrolytic action of stray electric currents from trolley systems. This can be prevented by the proper return to the power station of the current. Steel is a better conductor than cast iron and for this reason stray currents enter and leave a line of steel pipe at more frequent intervals than the same current would enter and leave a cast iron line.

In this connection it is important to emphasize the wide difference between electrolysis from stray electric currents of appreciable voltage and galvanic electrolysis, it being the accepted theory that the latter is always present when corrosion takes place from any cause whatever.

When galvanic electrolysis takes place in steel pipe it is accelerated by the rust scales which may already be present on the surface of the metal or those which may be formed later thus making progressive the destruction of the entire wall thickness of the pipe.

Coating for Protection

As has already been stated, both steel and cast iron pipes are coated with a protective preparation to keep the corrosive elements of the water from attacking the metal. This coating is applied hot to the heated metal. As cast iron is of crystalline structure, the heating expands the molecules of the metal so that the hot coating becomes incorporated with the metal itself, to an appreciable distance from the surface, while with steel (a smooth, fibrous material) the coating is little more than a paint which will not adhere under the conditions required by actual service.

Burlap and Tar Coated Steel Pipe. Coating Melted by the Sun and Running Off in Sheets.

Fresh claims are made almost yearly by manufacturers that a coating has at last been developed that will adhere to steel pipe, but such claims have not as yet been substantiated. A coating may appear to be in good condition, but in reality be defective, and the steel beneath it undergoing progressive corrosion. The report by eminent engineers employed by the Australian Govern-

Mannesmann (Steel) Pipe, Burlap Covered, Replaced After 11 Months' Service. Close Alongside is a Line of Cast Iron Pipe in Service 13 Years Without Apparent Defect.

ment to examine the Coolgardie Line of Steel Pipe states:

"It has been found that the coating which appears perfectly satisfactory to the naked eye contains, when examined with a magnifying glass, small holes due to minute bubbles, which penetrate to the metal beneath.

"Examination revealed the fact that the metal has decayed below the coating, having been attacked by the penetration of water through one of these minute holes in the coating to the metal surface."

That coating in the case of cast iron pipe is less necessary to its life than in the case of

Another View of Burlap-Covered Mannesmann (Steel) Pipe Badly Damaged by Rust

steel pipe is evidenced by the fact that cast iron pipe is used for gas without any coating and such pipe has been in use for many years with no appreciable evidence of deterioration. Thus it can be seen that the user of steel pipe pays rather for a coating (and not a durable one at that) than for the metal itself. This coating is absolutely essential to steel, but not to cast iron.

Engineer's Estimate of Relative Value

Some engineers are accustomed to assign that additional value to cast iron that is measured by an amount, placed at compound interest, that will reconstruct the steel line at the end of its assumed life of, say, 30 years. That such computation is fallacious can be seen at a glance when it is pointed out that the cost of the second and even the third replacement, that would be necessary before the end of the useful life of the cast iron main, is not taken into consideration, nor the factors of high cost of maintenance and repairs to steel pipe and the salvage value of cast iron.

At Portland, Maine, about 14 miles of 42-inch cast iron main was laid in 1910 at a cost of about $90,000.00 in excess of the proposals offered for 48-inch lock bar steel. The relative value of the two types of pipe was carefully considered by eminent engineers and cast iron pipe adopted after painstaking investigation. The larger diameter of steel pipe was considered by reason of the obstruction of flow by the joints and the resistance offered by the longitudinal bar to the corkscrew motion of the water in the pipe. Portland has had no cause to regret its decision.

It is commonly believed that Public Service Corporations conduct their affairs with an eye single to profit and good business procedure. This is evidenced by the fact that neither of the two largest private water companies in Connecticut, those of New Haven and Bridgeport, have any steel mains in their systems, and at Bridgeport there has recently been installed a 48-inch CAST IRON MAIN ten miles long.

Comments by Eminent Authorities

Professor J. Lawrence Smith, celebrated both in this country and in Europe as a scholar on many subjects, said in 1875:—"My opinion is asked in relation to the distribution of water in the service of a large city, as connected with the employment of cast iron and wrought iron mains. This is a subject to which I have paid a great deal of close critical attention having had occasion to do so in responding to the demands of companies engaged in the distribution of water and gas. I have examined almost every variety of pipe used for these purposes. I would not use *wrought iron pipes*, however low the cost, when as an engineer I was expected to construct permanent water works. Even with 20 per cent difference of price in favor of these pipes over cast iron, the extent of which they are used is comparatively limited. In conclusion, I would say that in my opinion, when water is to be distributed in a large city, and fifty or one hundred years or more was considered but a small part of the life of that city, nothing but cast iron mains should be laid for water.

A. W. Craven, *Consulting Engineer*, for many years Chief Engineer of the Croton

Aqueduct Department, New York, thus expresses his opinion:—"In cast iron you are dealing with a certainty. Pipe which has been in constant use for 100 years, and unprotected by any coating, either of its interior or exterior surfaces, has been examined and to no appreciable extent was there any diminution in its weight or strength. I do not consider it true economy to use any known substitute in any portion of the distribution of a town."

R. Rawlinson, in the *London Sanitary Engineer* stated, in answer to a question as to his opinion of the durability of cast iron pipe:—"My answer in brief is that I do not know, although I have an experience of 30 years. The pipe used by me are as sound now as the day when they were first laid down."

H. V. Ketcherside, *Engineer of Water Works, Long Beach, Cal.*, says:—"I have laid hundreds of thousands of feet of riveted steel pipe of all kinds, but am now paying from 50 to 100 per cent more for cast iron and consider it *cheaper*."

Mr. Starke, *Engineer of Water Works at San Bernardino, Cal.*, after an unfortunate experience with steel mains at the place, says:—"Our Board of Water Commissioners have passed an order that all future replacements and extensions be laid of cast iron. In 1904 the City of San Bernardino completed extension of water system of sheet steel pipe, with a bond issue of $231,000.00. The pipe was furnished and specified of best material and dipped in the best manner possible. This pipe began to pit in 1908 and shows leaks and is continuing to deteriorate so rapidly that portions of the pipe have been taken out in 1910 and relaid with cast iron pipe. Money spent for sheet steel water mains is money thrown away."

JOHN W. HILL, *Consulting Engineer of Cincinnati, Ohio,* formerly Engineer of the Filtration System of Philadelphia, says:—"The chief objection to steel pipe is the lack of durability of the materials when laid in earth filled trenches, subject to the salts in the water and moisture and acids in the soil. The durability of cast iron pipes is so thoroughly proven, and so well known to Engineers and Capitalists, that no limit is placed on its life, and for convenience of calculation in the appraisement of the value of a water system, is usually taken at 100 years; although, with such pipe now in the ground (at Philadelphia and elsewhere) and serviceable after 100 years, it is clear that a life of 100 years is not the correct limit."

PROFESSORS NACHTEH AND ARNDT, *at Neckeroda:*—"We have had bad experience with protected steel pipes. In the third year, even repairs have had to be made, which increased from year to year, whilst on the other hand the cast iron pipes have up to the present developed no faults whatever. The municipality intends to take up the steel pipes in that part of the main where the pressure is highest, and intends to replace these by cast iron pipes."

PROFESSOR G. MEISNER, *Paris:*—"The advantages of cast iron water pipes are so varied that they must be preferred to all others. Cast iron mains cost rather more than those of sheet steel, but their life is incomparably longer."

C. A. DE FAUVAGE, *Civil Engineer, Haarlem:*—"It would seem to me that, following on the experience gained, cast iron pipes must absolutely be preferred over any other system, and that even in the case when the first cost of steel pipe is much lower than that of cast iron."

M. DUBOIS, *Havana:*—"In this town, all the steel pipe with asphaltum coating has had to be taken up. The bad state of these mains necessitated repairs almost every week."

N. S. TANTE, *Antwerp:*—"The City of

Antwerp about the year 1892 made use of steel pipe tarred and covered with tape, for the high pressure (hydraulic) piping to supply the Armstrong Machines for use on the quays. In March, 1908, quite a number of cellars were constantly flooded. The Water Company tested its cast iron mains half a dozen times in that district, being threatened with legal proceedings. The end of it was that it was found to be the steel piping used by the town for the hydraulic machinery of the port, which was in a pitiable condition."

BOARD OF ALDERMEN, *Buffalo, N. Y.*
(Minutes No. 22, Page 1353.)
No. 35. Buffalo, May 24, 1915.

"The undersigned desire to call the attention of your Honorable Board to that section of the fire pipe line system in Washington Street from Perry to Exchange Streets, which is of *wrought iron construction and was laid in the year 1897. The condition of this section by corrosion is such that it not only requires constant repairs, but a serious break is likely to occur at any time, which if it did so, under the present arrangement of the system would place the entire line out of commission.

* The "wrought iron" line referred to was really of steel.

"The importance of providing against such an accident is most apparent for the reason that the efficiency of this pipe line system in arresting great conflagrations in the business and mercantile sections of the city has been demonstrated time and time again and we therefore respectfully urge the laying of a section of cast iron pipe, 12 inches in diameter, in Main Street from the connection at Perry and Main Streets, to Exchange Street, and to connect with the present line at that point. If this is done it will not only assure two ways of delivering water to any point along the entire length of the system, but may be the means of saving many thousands of dollars worth of property, within the radius of the fire lines.

Respectfully submitted,

SIMON SIEBERT,
E. C. BURGARD,
WM. PERSON,
Fire Commissioners."

Referred to the Committee on Fire.

(NOTE:—The Committee on Fire made a report recommending the replacement of the above section of pipe with cast iron pipe.)

J. H. BROWN, *Manager Eastern Gas Appliance Co., New York,* (Formerly Water

Works Construction Engineer in the Middle West), says:—"The specifications for East Chicago Water Works and also for the city of Hammond, Ind., called for steel and *kalamein pipe. I tried in every way to convince the City Councils and to have them change the specifications to cast iron pipe, but was unsuccessful. However, before the steel pipe had been in the ground one year their troubles commenced, and they put questions to me asking what should be done. The third year the city of East Chicago gave me a contract for $40,000.00 to replace the steel pipe, which I did, and also for the city of Hammond a little later.

"The trouble in these cases was the great amount of alkali in the soil of that section, and I had the same trouble in Newton, Kansas, where I put in steel pipe and the city had to replace all of it inside of three years. This city was short of money and tried to economize by using steel pipe, but it turned out to be very dear in the end, as it will for any one who uses steel pipe instead of cast iron. Before the second year was ended they were obliged to keep men working all the time on nothing else but repairing leaks and broken pipe.

* Kalamein is an alloy coated steel pipe.

"From the many years experience I have had in building water plants I would certainly not use steel or kalamein pipe were it to be delivered on the ground free of charge, and anyone who uses such pipe is burying trouble that will have to be dug up in a comparatively few years."

JOHN J. HAYES, *Superintendent Water Works and Sewers, Rapid City, South Dakota*, says:—"Our distribution system was mostly Kalamein laid from fifteen to twenty-five years. Practically all of the old pipe has been replaced with cast iron, Class C, and as fast as funds are available I am taking it out and laying cast iron.

"As long as the coating is perfect it is all right but as soon as coating or paint is gone it rusts through in a short time. I place the extreme usefulness of it at twenty years, while cast iron pipe lasts in our soil an indefinite period. Cast iron pipe laid 23 years ago is as good to-day as when laid.

"It is false economy to install anything but cast iron pipe in a water main system."

J. H. RADFORD, *Chairman Water Commission, Galt, Ontario*, says:—"We have had installed about one mile of steel main which is very unsatisfactory and we would not recommend putting down steel pipe any place, particularly where you intend to tap, as from our experience we find that it is an impossibility to tap successfully even with a saddle and prevent leaking at a very early date.

"Steel main might be used as a conduit or conductor pipe if properly laid and thoroughly calked but under any circumstances we consider it inferior to iron pipe."

J. W. TURNER, *Superintendent Water Works Department, Edmonton, Alberta, Canada,* says: —"During 1913 this Department installed some twenty-three (23) miles of 6″, 8″, and 10″ steel mains. The result of the past two years' experience with these steel mains and connecting house services thereto, has convinced me that it is desirable to confine the use of steel to the larger size mains, and for the smaller mains from which house connections are made, to use cast iron. During 1914 we installed a considerable amount of steel pipe ranging from 14 to 30-inch diameter, as feed mains. Where the wrapping and the coating of the steel pipe is kept intact, and recoated at any points where damaged before laying of pipe, I feel confident that this class of pipe will give satisfactory service. On the other hand, with regard to the sizes under 12-inch, into which house connections are tapped, it becomes necessary to fit special saddles or clamps and to cut the wrapping for every service connection that is made. As the shell of the smaller sizes of steel pipe is so extremely thin a main-cock cannot with safety be tapped direct into the pipe.

Another important point in connection with these steel mains is that the money for water-main construction is usually raised by municipal debentures for periods of thirty or forty years, and while I am satisfied that cast iron pipe will last for that period, the question of the lifetime of steel mains is still an open one."

William W. Brush. *Assistant Engineer Bureau of Water Supply, Gas and Electricity, New York* (Transactions Am. Soc., C. E., Vol. LXXVIII, p. 865, 1915):—"An examination, made about a year ago, of a length of 48-inch pipe which was laid in 1867 in Central Park, near the large reservoir, in ground that was low-lying and wet a good part of the year, showed the outside coating to be practically perfect. The general condition of the entire pipe system of New York City is such that the outside of the pipe generally shows no corrosion that would affect its life.

"The interior of the pipe shows very materially the difference in effect of waters supplied to the different boroughs of New York City. Croton water has such slight corrosive effect on cast-iron pipe that sections of mains laid shortly after this water supply was introduced, in the early Forties, or in use some sixty years, show practically no corrosion. Therefore, there has been no necessity for cleaning these mains; whereas in Brooklyn, where the

Section of Cast Iron Water Pipe in Philadelphia 98 Years Old

water has a comparatively high chlorine content, varying during the past fifty years from a maximum of about twenty-five parts per million to a minimum of about eight parts, with an average for the past twenty years of possibly fifteen parts per million, there is a corrosive or tuberculating effect, especially on pipe laid uncoated. The pipe laid in 1858 was mainly Scotch pipe, in 9-feet lengths, and was uncoated. There was also some pipe cast in the United States at about that time and laid uncoated. Such pipe required cleaning, as the tubercles in a 6-inch pipe were of such size that a 2-inch rod could not be passed through the pipe without breaking off some of them. That pipe, when cleaned, was good, apparently, for another fifty years, as far as the strength of the wall limited the life."

MESSRS. MONTEATH BROS., *of Subiaco*, in a letter to *The Western Australia Mining, Building and Engineering Journal*, of December 15, 1915, after reciting a number of failures of wrought iron and steel pipe, say:

"As against these steel and wrought iron failures, there is not a single known case of a failure in cast iron, except in one or two isolated cases, where the ground was such that possibly no material would have a long life. The life of cast iron mains is known to be over one hundred years, as the following cases will show:—(1) Versailles, 249 years; (2) Weilburg, 210 years; (3) Claremont-Ferrand, 165 years; (4) Glasgow, over 100 years; and the Vehar mains, in Bombay, after 55 years' service, are now being lifted and relaid within the city.

"The foregoing remarks require no comment as to which material should be adopted by corporate bodies and others if they will take the trouble to study the question carefully on facts and have the interests of the community at heart."

In this same letter is also quoted the following extract from *Indian Engineering* of August 23, 1913:

"Cast Iron *versus* Steel Pipes."

"At the present time some water, gas and sewerage works *engineers* are being tempted to put down steel pipes instead of cast iron, owing to the saving in capital expenditure, without thoroughly looking into and comparing the risks attached to steel, and the ultimate cost of same. It is most important that members of corporate bodies who have the settling of these matters should have before them all the facts obtainable before arriving at a decision as to which material to adopt.

"Owing to the thinness of the steel pipes, and the liability of corrosion, the life of a steel main is entirely dependent upon its protective covering, and as corrosion takes place most rapidly where the steel main rests upon the ground, and where it is practically impossible to re-coat the pipe, it is perfectly plain to anyone that if corrosion once commenced nothing can stop it. Engineers who have had experience with steel mains are mostly agreed that its use is limited to:

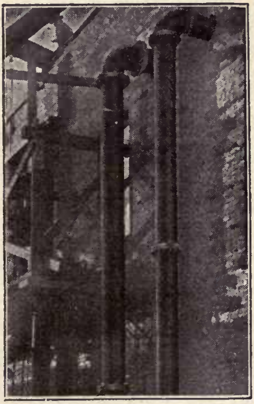
1. Very high pressure;
2. Temporary purposes;

3. Physical impossibility to put down cast iron;
4. Inability to raise sufficient money to pay initial cost of cast iron."

"*Le Tuyau en Acier Compare en Fonte:*" A French article under date of July 10th, 1911, is quoted in part as follows:

"The underground conduits for water and for gas are generally made of cast iron, and the use of that metal is justified principally because of their long life and good preservation, some conduits having been placed under ground since the 17th Century are still in good condition. In the meanwhile frequent attempts have been made by different inventors to replace cast iron by some other metal, and steel in particular has been, under different forms, the principal rival of cast iron pipe.

"At first sight, its lightness may mislead, especially in case of shipping to distant countries without means of up-to-date transportation facilities. But the resulting danger by the use of steel or wrought iron underground piping is the great facility with which these metals are attacked by rust; therefore, both manufacturers and inventors had to find some protecting devices to protect the metal from oxidation to permit steel to rival cast iron from the standpoint of conservation. It is thus one saw in 1860 steel pipes coated with a thick asphalt covering put on hot. This was the pipe ("Chameroy"). More recently the asphalt has been replaced by a jute coating. But, does not the need of investigation and the use of a protecting covering show better than anything else the lack of confidence steel pipe promoters have regarding the value of the metal for underground conduits use?



Replacing Wrought Iron Pipe with Cast Iron Flanged Pipe

"Conclusions. — By what we have seen above, the cast iron pipes have to their credit a very long record, which has made to-day their quality universally recognized.

"The wrought iron and steel pipes, on the contrary, cannot produce an example of any long duration. Several installations can be cited where steel and wrought iron pipes had, due to deterioration and rust, to be replaced by cast iron ones. No example can be cited regarding cast iron mains failing, due to this same cause.

"In all instances where cast iron pipes in service for several years had to be withdrawn due to modifications or abandoning of the mains, they have been used again at other places.

"The prospect of having of necessity to replace a conduit in a shorter or longer time, varying with the condition of the soil, does not give any choice as to the kind of pipe to be used to obtain the longest service with least up-keep expenses. All practical men will choose the cast iron pipe.

"The municipal administrations, who in a majority of cases cannot afford the laying down of new mains for their water and gas service every ten years, will do well to select cast iron pipes, well known and tried, of which no one up to this day has been able to fix the exact limit of durability. They will thus fulfill their duties imposed upon them by the taxpayers."

The American Gas Light Journal in an article in a recent issue, under the head of "External Corrosion of Cast Iron Pipes," gives some conclusions that have been arrived at after a comprehensive study of the subject —They are:

"(1) Under ordinary conditions of soil, cast iron pipe has a probable life of from one to three centuries, so far as external corrosion is concerned. (2) Under certain soil conditions, such as salt marshes or saline soils, cast iron pipe may be rendered useless in from seven to twenty years. (3) At times cinder and slag fills may exert a strongly deleterious influence. Acid mine waters are also destructive. (4) Substituting wrought iron or steel pipe for cast iron is ineffectual. Cast iron will outlast the others. Remedies fall under four heads:

(a) Increasing the skin resistance of cast iron.

(b) Utilizing the protective influence of alkalies by surrounding the pipe with lime or cement where practicable.

(c) Exclusion of acids, salt or air.

(d) Galvanizing the cast iron pipe, thus protecting it at the expense of the zinc.

"So much has been written upon this subject of the corrosion of pipes, most of all of the comparative corrodibility of cast iron, wrought iron and steel, that the ordinary mind has been thrown into some confusion on the subject. We think it is time, therefore, we had something authoritative from a committee of metallurgists that might guide us to use the right metal in the right place, quite apart from a discussion of cures for corrosion."

C. M. Saville, *Chief Engineer of Board of Water Commissioners, Hartford, Conn.*, several years ago made a report on "The Use of Cast Iron Pipe for Nepang Conduit, which is so comprehensive and exhaustive that it is quoted in full as follows:

Hartford, Conn.
April 23rd, 1913.
Files 86 and 87.

To the Honorable Board of Water Commissioners, City Hall.

Gentlemen:—In the matter of the construction of the proposed pipe line for conveying the water from the Nepang Reservoir to the present source of supply at West Hartford, two kinds of material may be given final consideration—Steel Plate and Cast Iron. Both kinds of pipe are used on work similar to that proposed here and the following facts are presented for your information relating to carrying capacity, durability, leakage, strength and reliability, first cost and cost of maintenance.

Carrying Capacity:

The fundamental formula for the flow of water in long pipes is expressed by the equation V-CV-RS in which:

V = the velocity in feet per second.

R = the hydraulic mean radius of the pipe—diameter in the case of circular pipes running full or half round.

S = the sine of the angle of slope.

C = a co-efficient varying with the different conditions under which flow takes place.

The difference in carrying capacity is due principally to the presence of obstructions on the interior wall, such as faulty joints, rivetheads, etc., which project into the waterway. Cast iron pipes are particularly free from obstructions of this kind,—the interior of the separate pipes is smooth and if well laid the joints offer little or no resistance to flow. In lock-bar pipes there is the lapping of the plates and rows of rivet heads each 30 feet at the circumferential joints and the obstruction of the lock-bar in two places in the circumference reaching the entire length of the section. In riveted steel pipes there are similar circumferential joints, 7½ feet apart and there is a single longitudinal joint with two rows of rivets along the entire length.

The values of "C" given below are believed to be representative of the best practice among hydraulic engineers and to conform to the results obtained from scientific investigation of the phenomena relating to the flow of water in pipes.

Co-efficient "C:"—Percentage of discharge same size pipe. Comparison in each case being made with cast iron pipe:

	New	30 Years	New	30 Years
Cast Iron	140	95	100	100
Lock-Bar	130	92	93	97
Riveted Steel	108	82	77	86

The 30-year period seems of particular interest as that appears to be near the critical time in durability of steel pipes. Under the conditions indicated in the table of co-efficients above, it appears that equal capacities may be expected from 42-inch cast iron, 43-inch lock-bar and 44-inch riveted steel pipe. Based on these figures, it appears also that lock-bar pipe and riveted steel, when compared under similar conditions with cast iron, will have respectively 7% and 23% less carrying capacity on the Nepang Pipe Line, with comparatively straight stretch of pipe and without the obstruction of sharp bends, valves and other impediments, it seems certain that for the same diameters cast iron pipe will prove of the greatest capacity, both when new and after a lapse of years.

Durability:—The comparative life of steel and cast iron pipe is taken by various authorities as 30 to 35 years for the former and from 70 to 90 years for the latter material. The use of cast iron for water pipe is well known and its practical indestructibility is without question. Only recently the writer examined a piece of 6-inch cast iron pipe dug in Front Street and found it perfect as far as the metal was concerned. I am told that this pipe was part of the old system laid in 1871 and that this was in service up to within a few years ago.

Three Lines of 60-Inch Cast Iron Pipe

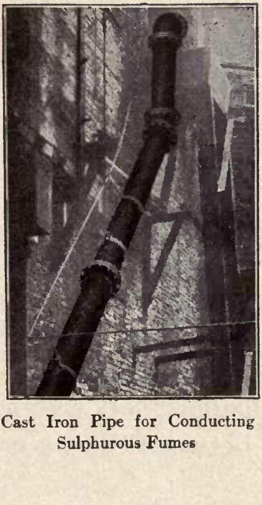
It is unnecessary to make detailed statements regarding this metal further than to state that the writer has personal knowledge of 20 and 30-inch cast iron pipes removed in Boston which were laid in 1850 and when taken up in 1900 the pipe was in good condition. It is of record that there are at least several instances of cast iron pipe being in good condition after over 100 years of service. Steel pipes are of comparatively recent origin. The use of soft iron (wrot.) for the manufacture of boilers was generally employed for this purpose for some time previous to the use of steel, and there are many pipes in use to-day made of this material. On account of its composition, wrought iron is much more resistant to corrosion than steel. Its use is, however, limited on account of the difficulty in obtaining this material at the present time. Within the past 20 years, long lines of steel pipes have been installed in many places among which may be mentioned:

	Year	Diameter	Thickness	In Feet	Kind
East Jersey Water Co.	1891	48″	$\frac{1}{4}$ to $\frac{3}{8}$″	115,000	Riveted
Rochester, N. Y.	1893	38″	$\frac{1}{4}$ to $\frac{3}{8}$″	140,000	"
Cambridge, Mass.	1895	40″	$\frac{1}{4}$ to $\frac{5}{16}$″	24,000	"
New Bedford, Mass. . .	1896	48″	$\frac{5}{16}$″	42,000	"
East Jersey Water Co.	1896	42″	. . . .	89,700	"
Adelaide, Australia. . . .	1903	15–26″	$\frac{1}{4}$″	63,472	Lock-Bar
Coolgardie, "	1903	30″	$\frac{1}{4}$ to $\frac{5}{16}$″	848,000	"
Newark, N. J.	1903	60″	. . . .	39,300	Riveted
Springfield, Mass.	1909	42″	$\frac{1}{4}$ to $\frac{7}{16}$″	71,000	Lock-Bar

At present lock-bar steel pipe lines of large size are being placed at Akron, Ohio, and at Winnipeg, Man., and recently pipes of large diameter of this material have been constructed for the New York additional supply and at Johnstown, Pa. Cast iron is much less susceptible than steel to electrolytic action or to corrosion from acids in clay and peaty solids. The following abstracts regarding durability of steel pipe are taken from various reports:

Rochester, N. Y., Pipe Laid in 1893.—"The second conduit consists of 38-inch steel riveted pipe varying in thickness from one-half to three-eighths inch. This was laid 16 years ago and we have had considerable trouble with pitting on this conduit. For the past 8 years we have each summer uncovered varying lengths and carefully scraped the old coating off and repainted the pipe with coats of mineral rubber and two coats of graphite paint. On the sections thus recoated we have had no further leaks, and the pitting has not advanced appreciably. The probability is that the entire length of this steel pipe will eventually have to be thus treated."

Cambridge, Mass., Pipe Laid in 1895.—"During the month of March last, a leak occurred in this line near Appleton Street and upon digging down we found a hole about five-eighths inch in diameter through the pipe and pittings around the hole seemed to indicate electrolysis. A further examination showed that the pipe was in such condition that a thorough examination was desirable and consequently about 400 feet were uncovered; in



Cast Iron Pipe for Conducting Sulphurous Fumes this length more than 400 pittings were found. In addition to the section near Appleton Street another section between Fayerweather Street and Lake View Avenue developed these leaks, and examination showed it to be in bad condition; in some respects worse, if possible, than the portion near Appleton Street (Annual Report of Cambridge Water Board, 1904, P. 51.)

Newark, N. J., Pipe Laid in 1890 and 1891.—"Upon investigation it was found that the 48-inch steel pipe conduit No. 1 was badly corroded at a point on the outside.—Investigation was carried still further to ascertain what condition the two lines were in. Nos. 1 and 2 were uncovered for a distance of 700 and 400 feet respectively south of said streets, and line No. 1 was found to be affected by corrosion on the outside in many places, in most cases from one-half to three-fourths of its full thickness." (Report, Street and Water Commissioners, Newark, N. J., 1909, P. 68.)

Port Elizabeth, South Africa.—"A long debate on the water works took place to-day at the meeting of the Port Elizabeth Town Council, when it was stated that seven million gallons of water were being lost monthly between the water works and the town, owing to a leakage in pipes. When the new water works were constructed some seven years ago, the town saved many thousand pounds in the cost of transport by laying down steel mains instead of cast iron. Washouts about a year ago revealed that this pipe was not wearing at all well; in fact, at several points was discovered to be completely rusted through. The defective pipes were replaced, but now it transpires that practically the whole main, over 25 miles long, is affected and will have to be replaced. The council decided to delay action pending a detailed inspection of the main by the Board of Works." (*Engineering News*, April 3rd, 1913, P. 651.)

Coolgardie, Australia, Steel Line.—"Pipe installed in 1903; 30-inch diameter, one-fourth to five-sixteenths inch plate, lock-bar steel 350 miles long; care taken to remove mill scale, using steel wire brush; tested 400 pounds pressure; coated with a mixture of coal-tar and Trinidad Asphaltum. External corrosion noted 2½ years after laying, the worse places being in low wet clayey places. Internal corrosion—pitting under tubercles—appears to be a critical depth of one-eighth inch. The corrosion is fairly conclusive that ultimate failure, if corrosion be not stopped, will result from internal not external corrosion. External corrosion is localized and can be repaired without stopping of flow." (Abstracted from *Engineering News,* August 24th, 1911, P. 22.)

New Bedford, Mass., 48-Inch Steel Pipe Line Laid in 1896, 5-16-inch Thick.—"In the section under consideration they (the tubercles) range from 3 to 70 per square foot with very few sheets showing the largest numbers—beneath the tubercles are pittings many of which range from 75 to 90 thousandths (0.075 to 0.090) of an inch in depth. The thickness of the steel sheets is about five-sixteenths of an inch, or 312 thousandths, so it will be seen that some of these pittings approach one-third the thickness of the steel." (Report of the New Bedford Water Commissioners, 1903, P. 26.)

"The tubercles appear to have somewhat increased in number. Found one pitting 0.117 inch in depth and perhaps four others ranging between that depth and 0.100. Several others were found ranging from 0.085 to 0.095 inch." (Report of the New Bedford Water Commissioners, 1909, P. 33.)

The Water District of Portland, Maine, after an exhaustive investigation decided to adopt 42-inch cast iron pipe instead of 48-

inch steel pipe for their conduit in spite of an increased cost of 15 per cent and the much smaller capacity of the cast iron pipe. Summarizing the deteriorations of steel pipe in several cities in the United States, Rochester, N. Y., does not specially state the cause, but from the description it may be inferred that the pittings were perhaps due to "mill scale" or other local happenings. In the case of Cambridge, Mass., and Newark, N. J., electrolysis seems to be held to be the cause. In these cities there is no statement as to the condition of the inside of the pipes, the external damage only being noted. In the case of New Bedford, Mass., the interior only was examined and the pittings due to tubercle were in many cases one-third the thickness of the pipe, in twelve years. The outside of the pipe was not examined.

Cast Iron Pipe 100 Years Old, From Godesberg, Germany

There is no reason why these two causes of deterioration, electrolysis on the outside and tubercles on the inside, may not act simultaneously. On account of its greater conductivity, electrolysis action is much more rapid on steel than on cast iron pipes. For steel and cast iron pipes laid under similar conditions of pressure, the cast iron walls would be from three to four times thicker than those of steel and so in addition to composition afford a much longer period of resistance to serious danger from corrosion.

Leakage.—It is probable that at first the leakage for steel pipe would be less than for cast iron pipes as the joints are double caulked inside and outside and the caulking is not affected by settlement. The field joints of the lock-bar type are less advantageous than those of riveted steel pipe, because of the crimp required around four bars instead of two thin plates. As time goes on, however, it is probable that the leakage in the cast iron pipe, due to silting up, may grow less, while that in steel pipe owing to the pittings, may increase. So far as leakage is concerned there seems to be little advantage in either pipe as regards amount of water which may be lost. As for repairs, the cast iron pipe is much more easily and quickly cared for because all that is necessary is to caulk up the joints while with the steel pipe, if due to corrosion, it is rather an expensive matter to uncover a section and put on rubber patches held down by steel bands passing around the pipe.

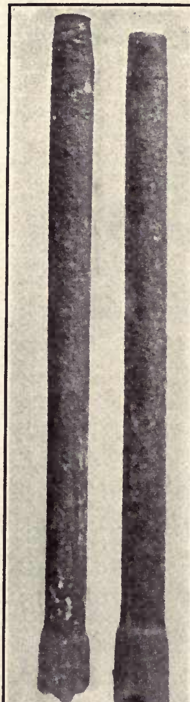
Strength and Reliability.—Steel is stronger than cast iron, and on account of its being malleable, a steel pipe is thought of by some people to possess greater reliability because it can more readily adapt itself to settlement of trenches and in length due to temperature. Experience, however, is a good teacher, and that which has been had with cast iron pipes, even of large diameters if of proper thickness and well laid has been very satisfactory. In the large cities cast iron pipe, of 36-inch diameter and over, has been in use in the Water Works System for over 50 years. The Metropolitan Water Works of Massachusetts from 1895 to 1912 had constructed or acquired nearly 102 miles of cast iron pipe, about 42 miles of which is 42 inches in diameter or larger. There have been comparatively few breaks on this system, and the experience of the City of Hartford with about six miles of 30-inch main in which only one serious break has occurred in one year must certainly be considered convincing.

On the other hand a break in a cast iron pipe may result in a section of the pipe being blown out and a large hole made from which a considerable amount of water may escape in a short time. With steel pipe the breaks when they occur usually result in comparatively small openings, although several cases are on record where the hole torn in the steel pipe was of large size.

First Cost and Cost of Maintenance.—At a diameter of 36 inches the cost of steel and cast iron pipes is about the same; for smaller diameters the cost of cast iron increases much more rapidly than that of steel. Local conditions may largely govern the choice of pipe, but for supply mains it appears generally good practice to use cast iron for pipes of diameter less than 36 inches, and steel for those of larger diameter than 48 inches. For pipes 36 and 42 inches the choice of metal is much more debatable, and more a matter of policy than is the case with pipes for greater or less size. With cast iron pipe, there is, under ordinary conditions a practically indestructible conduit, which, if necessary, can be cleaned of tubercles and restored to its original carrying capacity. With steel pipe, the actual life of the pipe is limited to from 25 to 40 years and it probably would be difficult even during the life of the pipe, to regain its original carrying capacity, by cleaning, on account of the rivet heads, lap of plates and other permanent obstructions. Assuming figures for life that may be considered ultra-conservative so far as cast iron pipe is concerned—35 years for steel pipe and 70 years for cast iron pipe and an interest rate of 4½ per cent compounded semi-annually—the present cost of renewing the pipes at such intervals would be:

Steel............	26.7	cents per dollar of cost of replacement
Cast Iron........	4.6	" " " " " " "

The ratio being $\frac{126.7}{104.6} = 1.21$, that is to say 21 per cent should be added to the price of steel pipe for comparison with those of cast iron. Under the assumptions given above, in 35 years steel pipe will be entirely out of commission and a new pipe will be necessary. The cast iron pipe if cleaned would be restored nearly to its original capacity. If at the end of the period of 35 years assumed as the ultimate life of the steel pipe, the pipe becomes of insufficient capacity, it is probable that at least a 50-inch pipe of similar metal would be required for replacement. If cast iron pipe were laid now this could be cleaned and the additional capacity obtained by laying a second line 36 inches in diameter. Either system would have an initial capacity of 60 million gallons per day, which is about the maximum capacity of the conduit and tunnel. The cast iron system, however, would have a material advantage in furnishing two independent lines, and the retention of a line in continuous service while the additional lines were being constructed. Based on this treatment of the problem, the costs in 1948 would be:



Cast Iron Pipe 100 Years In Service, Homburg v. d. Höhe, Germany

39,500 lin. ft. 50″ Steel Pipe at $9.50,	$375,500.00
39,500 " " 36″ Cast Iron at 7.00	$276,500.00
Present Value:	
Steel......$375,500 at .22......	$82,600.00
Cast Iron.. 276,500 at .22......	60,800.00
Difference............	$21,800.00

which is about 7 per cent of the estimated cost ($216,600.-00) of pipe line proposed from Nepang if steel pipe is decided upon. $16,000 put at interest now for cleaning that would probably be necessary 35 years hence, would then keep the cast iron pipe clean for the remainder of its life.

Resume.—The question of capacity is taken care of by increasing the size of the riveted steel pipe, and allowing equal carrying capacities for the cast iron and lock-bar types. This assumption, however, is very favorable to the lock-bar type which undoubtedly is of somewhat less capacity than cast iron of the same diameter, and so should be given a somewhat larger diameter for equal volume. To have made proper allowance would have necessitated additional detail drawings, the work on which seemed hardly warranted by present conditions. As to the remaining questions which have been stated, there seems to be no doubt that in durability and cost of maintenance steel is *inferior to cast iron*.

For leakage there seems to be little to choose between the two. On the question of strength and reliability for uninterrupted service, it is possible that there may be points in favor of steel pipe. Whatever these may be, however, at present, they are matters of individual opinion rather than proof from data that has accumulated. Granting that steel is the more reliable, at least two reasons can be given why this feature is not of special importance in connection with this particular line, viz.:

First:—The line is laid through a very

sparsely inhabited country, and principally through a wide right-of-way, for all practical purposes, owned by the city. The damage, therefore, from a break in the pipe and consequent wash-out would be comparatively small.

Second:—There will be ample storage in the West Hartford Reservoir to supply the city during any reasonable period the line might be out of order, and for many years to come the amount of water lost from such a break would be a negligible quantity. The country through which the line will run, however, is mostly of a free draining, gravelly or sandy nature and therefore is particularly well adapted for steel pipe. Two railroads are crossed which may be electrified in the future and there is a probability that the trolley car system will be extended into this locality. This section, would, of course subject the pipes to damage from electrolysis to which steel is much more susceptible than cast iron.

As a result of analyzing and summarizing the above statements it seems reasonable, in order that a uniform basis may be used which will take into account the ultimate value of the pipe line to the city, to add 15 per cent to the price that may be bid for all kinds of steel pipe for comparison with the bids for cast iron pipe. Subject to the approval of the Board, therefore, bids will be asked for furnishing and laying both steel and cast iron pipe for the Nepang Pipe Line, Contract No. 4. A statement will be made in the advertisement that 15 per cent will be added to the price bid for steel pipe for comparison with the bids for furnishing and laying cast iron pipe.

I believe that this method of treating the problem will result in much greater advantage to the city in getting reasonable prices for constructing the pipe line if an arbitrary decision were made in favor of either metal.

Respectfully submitted,

(Signed) C. M. SAVILLE.

Chief Engineer.

R. L. HAYCOCK, *Water Works Engineer, City of Ottawa, Canada,* in a "Report on Redistribution System," for that city, under date of October 19, 1915, says:

To the Chairman and Members of the Water Works Committee, City Hall.

GENTLEMEN:—In general this work comprises the addition of distributing mains varying in size from 10 inches to 36 inches to feed our present system throughout the city.

* * *

Messrs. Lea based their estimate for the work on cast iron pipe in 10-inch and 12-inch size, and steel pipe 16-inch to 36-inch, but stated it is desirable to use cast iron pipe in preference to steel for the 16-inch size. I have discussed with Mr. W. S. Lea the advisability of using cast iron pipe throughout for city street mains, and he said, by all means to use cast iron pipe in preference to steel if it is possible to obtain it without too great a difference in cost.

On the 4th of March, 1915, the following table was presented to the Water Works Committee to show the advantage of cast iron over steel pipe:

TABLE No. 1

—16″ Pipe—

Steel Thickness 5/16 Inch	Cast Iron Thickness 3/4 Inch
Corrodes much more rapidly than C. I. Made in U. S. and England. Slow delivery.	Corrosion very slight in comparison to steel. Made in Canada, quick delivery.
More labor to cut for connections.	Easy to cut for connections.
Excessive electrolysis and especially where brass connections are screwed into the thin metal.	Very slight electrolysis and much better joint where connections are threaded into thick pipe.
Has not yet proved by experience its superiority over Cast Iron.	Has proved by experience good for forty to fifty years.
Used extensively in West, where freight charges are ruling factor.	

Though cast iron pipe in the 16-inch size cost at that time about 22 cents per foot more than steel, it was decided to adopt it owing to the records of long life of cast iron as against the short life of steel pipe when used in street main work.

The following circular letter was sent to twenty-two Canadian cities and eighteen American cities, and the replies are tabulated in Table No. 2, as follows:

DEAR SIR:—We are putting down a new distribution system for our water works, and I would appreciate an answer to the following: Kindly state whether you use the following sizes of pipe in steel or cast iron:—16″, 18″, 20″, 24″, 30″ and 36″.

Yours truly,

R. L. HAYCOCK,

Water Works Engineer.

This table shows that cast iron is universally used and that it is the exception to the rule to use steel for street mains. I have found since that New York is using cast iron pipe up to and including 48 inches for city street purposes.

Much information has been obtained on this subject, and the following extracts taken from a great number of examples will show

TABLE No. 2
CANADA

City	C. I. Pipe	Steel Pipe	Remarks
Halifax	All sizes	None	27″ largest size.
St. John	All sizes	None	
Quebec	All sizes	None	Includes 40″ and 44″ mains 8½ miles long.
Montreal	All sizes	None	New England W. W. Ass'n Standard.
Toronto	16″ to 36″		
Hamilton	16″ to 36″		$32 ton delivered at trench
Windsor	All sizes	None	16″ largest at present, future 20″ and 24″.
London	All sizes	None	Have no steel at all
Port Arthur	Up to 12″	12″ and 24″	40,000 ft. 24″ Steel, 6,000 ft. 12″ Steel; balance of pipe used is Cast Iron.
Fort William	All sizes	36″ intake only	
Winnipeg	All sizes	36″ intake	36″ lock-bar Steel from supply to city.
Brandon	All sizes	None	Do not recommend Steel for any size, states not durable.
Regina	All sizes	None	
Edmonton	Up to 10″	Above 10″	Prefer C. I. for long life, but forced to use Steel on account price.
New Westminster	Up to 10″	Above 10″	
Vancouver	18″ under salt water	All sizes	Giving trouble on car line streets, electrolysis.
Victoria	None	All sizes	42″ concrete (reinforced) for flow line.
New York	16″ to 36″		Do not use 18″ size.
Washington	16″ to 36″	24″ and 30″	No 18″ size used.
Philadelphia	16″ to 36″		
Boston	All sizes	None	Cast Iron exclusively.
Portland, Ore	4″ to 30″	Main conduits	Do not favor Steel in mains, especially bad under hard pavements; Cast Iron exclusively.
Albany	All sizes	None	
*Troy	All sizes	None	Prohibit the use of Steel
Buffalo	All sizes	None	
Erie	All sizes	60″ intake only	Do not favor Steel pipe in ground.
	UNITED	STATES	
Cleveland	3″ to 48″	Where mains lead from P.S. and on Hills-sides.	
Detroit	All sizes	None	Do not use 18″ size.
Chicago	16″ to 36″		Do not use 18″ size.
Minneapolis	All up to 48″	48″ and over	
St. Louis	All sizes	None	Are going to try 8″ Steel outside city.
Birmingham, Ala.	All sizes	None	
San Francisco	All sizes	None	
Los Angeles	Up to 30″	36″ and 72″	Used Steel as small as 14″. Exceptional cases where money was scarce.
St. Paul	4″ to 36″		

* Troy laid 33″ best riveted Steel pipe in 1893. After eight to nine years pipe had to be abandoned and duplicated by 30″ Cast Iron at cost of $300,000.

that cast iron pipe is used in preference to steel pipe for many water distribution systems.

* * *

(Mr. Haycock here quotes much of the data contained elsewhere in this book.)

* * *

Recommendations

The following pipe is required for the completion of the redistribution:

5,700	feet	of	18-inch
2,850	"	"	20-inch
2,400	"	"	24-inch
1,550	"	"	30-inch
7,150	"	"	36-inch

The lowest quotation in cast iron pipe for all above listed pipe was $112,719.00. The lowest quotation in lap welded steel pipe for all above listed pipe was $107,074.35.

The relative thickness of cast iron and steel pipes quoted on are as follows:

	18″	20″	24″	30″	36″
Cast Iron	7/8″	15/16″	1 1-25″	1 1-5″	1 3/8″
Steel	1/4″	1/4″	1/4″	5/16″	3/8″

In all steel pipe quotations they state they would give no guarantee as to the life of pipe. Cast iron pipe we know is good for from 50 to 250 years.

Number of letters received from pipe manufacturers	35
Number of quotations received for Cast Iron pipe	9
Number of quotations received for Steel pipe	5
Number of letters received in which no quotations were given	21

After consideration of all the facts laid out in this report, I recommend that cast iron pipe be adopted for the completion of the Redistribution System in the 18″, 20″, 24″, 30″ and 36″ sizes, and that tenders be called for the supply of this pipe, and that orders be placed for winter delivery, as the quotations received show a considerable saving (about 6 per cent) on winter delivery over spring delivery.

I would not take the responsibility of installing steel pipe of the thickness offered when permanency is to be the prime object of an installation of this kind.

Respectfully, submitted,

R. L. HAYCOCK,

Water Works Engineer.

In the valuation of public water and gas utilities the question of depreciation of pipe lines is one on which very little specific data has heretofore been obtainable. Rates have varied from 1% per annum to 50% charged off upon putting the lines into service. That the latter rate is unfair, however, is proven by the following data secured from the Chief Engineer of the Water Departments of a number of the leading cities of the United States and Canada, in response to the questions at the head of the columns:

	What Rate of Depreciation is Adopted?	Is System Based Upon Life of the Pipe?
New York City.....	"Based upon the usual life of the bond, which is 50 years, we use 2% rate."	(See answer to 1st Q.)
Chicago............	"Two and one-half per cent. (2½%) compounded."	"Yes."
Philadelphia........	"No system yet adopted."	"Pipe now in use nearly 100 years old."
Boston.............	"No system yet adopted."	"We usually consider a fair estimate of the life of our pipe to be 60 years."
St. Louis...........	"No system for pipe separate from Water Works in its entirety, and figure would not be fair for pipe only."	"The life of cast iron pipe is generally taken here at 100 years."
New Orleans.......	"Do not carry any depreciation account as yet."	"Always assumed 80 years as life of cast iron pipe."
Baltimore..........	"No system of depreciation."	"Cast iron pipe first laid in 1805 — condition still good."
St. Paul............	"Operating and maintenance charges, repairs and replacements are provided out of the revenues of the department, as well as the interest on its funded debt and a sinking fund for the redemption of its bonds, which are retired at maturity, and which is considered sufficient depreciation—all bonds being issued for a period shorter than the life of the property they cover."	"Condition of pipe always found to be generally good."
Minneapolis........	"Proceedings of the A.S.C.E., Oct., 1908, given by several authorities on Water Works valuation, a range of 50 to 75 years of life of cast iron pipe. This would be equivalent to 2% to 1.33%."	"Our soil is very favorable to long life and when figuring life of water mains as a whole we generally say about 1%"
Edmonton, Can....	"No specific rate."	"Combination—i. e., it is based on the term of the debenture (40 years), but takes into consideration also the estimated life of the asset."

	What Rate of Depreciation is Adopted?	Is System Based Upon Life of the Pipe.?
Montreal, Can......	"None."	"Cast iron pipe in any water works system in a growing community should long outlast its usefulness, that is, the growth of the community would probably make the pipes too small 40 or 50 years after they were laid. That condition we figure, is the greatest cause of depreciation in value of the water mains. Cast iron itself in ordinary soils is well nigh everlasting."
Toronto, Can.......	"None."	"Here we consider the pipe good for 100 years at least."

To sum up: Steel is an experiment, and the unfortunate experience of a number of cities where it has been installed indicates that it is not a very successful one. It deteriorates rapidly, lasts from five to possibly thirty years, entails high cost of maintenance, loss of water through leakage, and insecurity, and has no salvage value at the end of its life.

Cast iron has a history of 250 years or more, is not an experiment, but a certainty; does not depend on its coating for its existence; entails little or no cost of maintenance or superintendence; leakage reduced to a minimum; absolute security, and high salvage value at the end of its life.

CHAPTER IV

WOOD PIPE

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WOOD PIPE

THE occasional discovery in the streets of some of our older cities of pieces of bored logs in a more or less good state of preservation, has furnished an argument for the continued use of wood pipe for water distribution. It should be borne in mind, however, that all of this old wood pipe is of very small diameter, having in most cases an original wall thickness of four to six inches. The modern wood pipe built up of staves, wire wound or banded, is an entirely different article from the bored log of a century ago, and the various processes involved in its manufacture offer numerous points of weakness. It is already generally recognized that the use of wood stave pipe is indicated only when and where the work is to be of a temporary character. The largest market for this pipe has been in western states, generally for reclamation purposes where large volumes of water are carried over long distances through rough and arid sections of the country. In the early development of domestic water supply throughout the Rocky Mountain and Pacific Coast States, large quantities of wood pipe were used, but this has been almost entirely replaced in recent years with cast iron pipe. One of the peculiar conditions of the pipe industry in this country in the past ten or fifteen years has been the shipment to Eastern cities of considerable quantities of wood pipe, which because of its cheapness was used instead of cast iron pipe. At the same time many thousands of tons of cast iron pipe were being shipped from the East and South to the Rocky Mountain and Pacific Coast States for the replacement of wood pipe which had failed in service.

The lack of uniformity in the quality of staves used in the construction of wood pipe and the practical impossibility of securing such uniformity is one of the serious weaknesses of this product. Another, and fully as serious, is the rapid destruction by rust of the steel bands or wire with which the pipe is wound. It can be readily understood that when these bands are broken the usefulness of the pipe is ended. None of the wood pipe installed during the past twenty or twenty-five years has a record of more than six or eight years of uninterrupted satisfactory service.

A "Report on Life of Wood Pipe" by D. C. Henny, Consulting Engineer United States Reclamation Service, Portland, Oregon, published in *Engineering News*, Volume 74, No. 9, is quoted in part as follows:

"The term 'fir' is applied to the most common wood of the Pacific Northwest. Scientifically it is a bastard spruce, first named by Douglas. Locally it is known as fir or Douglas fir, and distinction is sometimes made between yellow and red fir. These come from the same kind of tree, the yellow fir being most common. The large trees yield yellow fir, while the wood from smaller trees is apt to show a reddish tint. Sun exposure also appears to affect the color to some extent. In California the wood is termed Oregon pine. This wood is strong, and can be obtained in long lengths. Mill run of commercial sizes probably average over 20 feet in length. It contains pitch, which forms in seams and pockets, normally occurring even in commercially clear wood within certain limits. The trees usually yield less than 25 per cent of wood free from sap and knots. The expense of eliminating these defects has led to the practice, as regards pipe construction, of permitting some small and sound knots and sap.

"Redwood grows on the Pacific Coast from Santa Cruz north into southern Oregon. By reason of the average large diameter of the trees, the logs are cut shorter than in the case of fir, and the commercial mill run averages about 16 feet in length. The wood is not as strong as fir. About 50 per cent of the wood cuts up clear and free of sap which has led to the custom of demanding freedom from knots and sap in ordinary pipe specifications.

"Continuous-stave pipe consists of staves breaking joint and clamped together with bands, which since 1888 have universally been made up of steel bolts and lugs, the latter being made of cast iron, malleable iron, or pressed steel. The butt joints are made tight by a metal or wooden plate.

"Wire-wound or machine-banded pipe is pipe made up in sections from 10 to 24 feet in length. It consists of staves held together by galvanized wire, spirally wound around the pipe under heavy tension. The wood is usually kiln dried, which is not the case with continuous-stave pipe. The ends of each section are machine turned to an exact diameter, sometimes slightly tapered. Sections are united by some form of sleeve, a sleeve made up of staves and wound around with wire or individual bands being most common.

"Wire-wound pipes for light pressures are often provided with mortise and tenon ends, dispensing with the necessity of sleeves. Under the head of wire-wound pipe in the tables a few cases have been grouped of bored-log pipe, which is wound not with wire, but with flat iron or steel. Such pipe is often jointed by metal sleeves, generally riveted iron or steel.

"The wood surface in continuous-stave pipe is, with a few exceptions, uncoated, while sectional pipe is heavily coated, the coat consisting of asphaltum and tar, with sawdust on the outer skin.

"The investigation has had in view especially the life of pipe as affected by the durability of the wood. The life as given in the tables refers to the wood alone, and is further confined as to sectional pipe to wood in the pipe sections and not to wood in the sleeves. Figures followed by the plus sign show age rather than life. The information collected is based mostly on reports received from managers or owners, and in small part on personal observation. It is not as complete as is desirable, which, however, is not due to failure to elicit further information.

"Reviewing the information as grouped under its headings, it may be estimated that under conditions of continuous water pressure the life of various kinds of wood pipe may be as follows:

Wood	Condition	Years
Fir	—Uncoated, buried in tight soil	20
Fir	— " " " loose "	4– 7
Fir	— " in air	12–20
Redwood—	" buried in tight soil, loam or sand, and gravel	25+
Fir	—Well coated, buried in tight soil	25
Fir	— " " " " loose "	15–20

"Under conditions interfering with complete saturation of the wood, the life is cut down materially. These conditions are in the case of uncoated pipe brought about by open soil and low water pressure. The effect of coating appears to be equivalent to tight soil cover, with possibly the additional advantage of tar in the coating acting as a disinfectant. The effect of unfavorable conditions as to lack of complete saturation is serious in redwood, resulting in a life which may be shorter than 15 years, but is much more marked in fir, where it may be as low, in spite of coating, as six years.

"It is quite possible that the life of individual pipe is not merely affected by surrounding conditions, but may have been shortened by the quality of the individual pieces or the treatment of the wood. The wood from the bottom of a tree is close grained and likely to last longer than from the top of the tree, even though free from sap. Bastard-sawn staves, especially in fir, resist penetration of the water in the pipe to a greater extent than diagonal or vertical-grained wood and may show a shorter life. Again, too rapid kiln drying, which may at times have been practiced on lumber from which staves for wire-wound pipe were run, may have partially destroyed the vitality of the wood.

"In this investigation it has not been found practicable to differentiate between the causes which in this manner may have shortened the life of the wood in pipe, nor to ascertain what has been the effect of permitting some sap in the wood from which decay may have spread to the adjoining sound wood. Unquestionably much wire-wound pipe has been manufactured without being subjected to strict supervision and inspection.

"Wood pipe is not suitable in cases where it can not be kept full and under pressure during periods of use. Coating can not under such conditions be expected to afford protection against decay. Coating should be continuous and heavy, not less than onesixteenth inch to be fully effective, and should preferably consist of more than one individual coat of a mixture of asphaltum and tar, or an application of gas tar followed by one or more applications of refined coal tar. Little experience, however, can be quoted in support of all-tar coating."

From this report it will be noted that the life of wood pipe is dependent on a number of conditions—character of soil, degree of saturation of the wood, quality of wood, kind of coating, etc.

Even with all these conditions perfect, there is always the danger of collapse from external pressure when the pipe is emptied, as is frequently necessary in all water lines. This was disastrously demonstrated at Lynchburg, Va., August 16, 1913, when a section of the 30-inch wood main of the gravity system bringing the city's water supply from Pedlar River, collapsed for a length of 35 to 40 feet at a point about 21 miles from the city and large portions of the city and suburbs were without water for nearly two days. Another interruption of the water service was caused by a bad leak in the line which occurred October 20, 1915, and *The News*, the leading daily paper of that city said, editorially, in its issue of October 21, 1915—"At any time we may have another and more serious break in the line of pipe extending from Pedlar to the city, for which we have no defense. Thus Lynchburg remains *a threatened city—imperilled by the menace of water famine.*" (Emphasis is theirs.) Plans were already well under way at that time for changes in the supply system which involved the ultimate abandonment of the wood pipe line, which had been in use less than ten years, and the city will for many years have to carry the burden of this costly experiment.

Wood Pipe, Conway, Arkansas, Replaced After Four Years by Cast Iron Pipe

This experience is typical of practically every municipality that has installed wood pipe for water supply in recent years, and the numerous failures of such pipe has occasioned much discussion in engineering publications, some of which are quoted, as follows:

Trans. Am. Soc. C. E., Vol. LXXIV—1911. (Pipes laid 1905–9 and tested 1909–10.)

P. 421—55 ¾-inch pipe—4 diameters measured—shortest diameter 54 1-16 inches, longest diameter 57 3-8 inches, showing flattening of the pipe.

P. 422—22-inch pipe seems to have been warped out of shape about an inch.

P. 430—"Evidence of considerable wear on staves." "The softer portions of the fir lumber had been worn down, leaving the harder parts to form small ridges approximately parallel to the axis of the pipe."

P. 432—"The water carries quite a large quantity of silt in suspension and the velocity under which pipe had been operating was 0.8 ft. per sec." (A very low velocity for a water supply line and yet this caused wear in the pipe staves.)

P. 473—"Unless the wood is kept saturated with water early decay may be expected." "To be successful the wood should be of uniform and permeable texture, similar to well seasoned, clear, white pine, cedar or redwood, with the grain normal to the circumference." "The use of fir or reservoir woods should be avoided except for temporary work or where cost makes the more porous woods inexpedient. If reservoir wood is used there should be no knots and the staves should be sawed with straight grain normal to the circumference, and not parallel to it, as in general practice. The fat layers prevent saturation and the pipes rot from the outside."

"Fir pipes laid in sandy clay showed signs of serious decay in a short life of five years and in one instance the metal banding was cut through by sand impinged upon it by a pin hole leak."

Trans. Am. Soc. C. E., Vol. LXX—1910.

P. 167—Wood pipe used for a large portion of a 128 mile water supply line on account of cheapness. Under heads over 130 pounds, however, cast iron used on account of ability to stand high pressures and preferred to steel on account of its greater durability.

Wood pipe was machine made, spirally wound and made by the Wykoff Wood Pipe Co., and the Michigan Pipe Co.

(Wykoff Pipe)—In some cases when the initial pressure and leaking between staves of dry pipe were great, the escaping air and water had lifted the coating into bubbles. At some points where this lifting was great enough to rupture the asphalt (coating) and the soil heavily charged with asphalt, some corrosion has begun (after only two years' service.)

The integrity and impermeability of the asphalt coat are quite as vital as constant saturation.

Note.—The velocity and discharge of new, well laid cast iron pipes is about three per cent less than that of wood stave pipe. While allowance must be made for deterioration in cast iron pipes due to tuberculation, the life is from two to four times as long on conservative estimation and with modern methods of pipe cleaning the original carrying capacity can be restored to cast iron pipes at very small expense.

In most cases the importance of the asphalt coating is recognized and apparently the life of the pipe is absolutely dependent on this protection; when it comes off the pipe decays rapidly.

Engineering and Contracting, October 15, 1913, P. 422.

Engineering News, February 6, 1913, P. 244.

In the above references emphasis is laid on the importance of using a protective coating. Several small leaks were caused by the cutting of the steel bands by the escape of silt-bearing water.

Engineering News, March 27, 1913, P. 635.

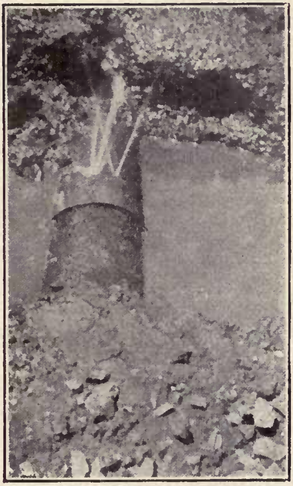
a. An inverted siphon 6,200 feet long of 38-inch continuous wood stave construction was built five years ago. During last irrigation season it became so badly impaired as to be unreliable for future service. It was found that the staves had rotted from the outside only. When buried in damp soil or submerged, pipe was sound.

The general conclusions given:

1. Wood stave pipe without a preservative coating, buried in dry volcanic ash soil and not under hydraulic pressure continuously will be subject to rapid decay.

2. Its life is much greater when the staves are exposed directly to the air.

3. Rapid decay would not take place if pipe was buried in wet volcanic ash soil.



Leak in Wood Pipe Line—This Line, 7 Miles Long, Was Replaced After One Year by Cast Iron Pipe

b. Experience at Tacoma, Washington.

Fourteen-inch wire wound stave pipe laid by city in 1903. Frequent repairs were necessary on account of leakage through open seams and usually cut bands were found. The open seams were attributed to the careless use of hydrants, causing water hammer thereby increasing the already high pressure. The consequent leakage churned up the sand backfill, cutting the bands and so aggravating the trouble. The pipe was replaced in 1910 with a cast-iron main.

During the summer of 1912 a section of 31-inch stave pipe laid in 1899 was replaced. Pipe was uncoated and laid in a light sandy loam and covered two feet; the pressure was forty pounds per square inch.

The staves were found to be water soaked and in fair condition on the inside. On the outside the bottom staves were good but a small amount of rot showed along the sides above the spring line. There was excessive rot along the top staves.

Along the top of the top there was not over one-half inch of sound wood, that part between the bands not having sufficient cohesion to stay on the staves which were removed.

The drying out of the backfill during the summer heat with the absorption of the surface moisture from the staves was the cause of the trouble.

Trans. Am. Soc. C. E., Vol. LVIII, 1907.

Experience with 18-inch wood stave pipe laid in 1895 for the city of Astoria, Ore. The staves deteriorated so much after ten years' use that very extensive renewals and repairs were necessary, involving an expenditure of more than one-third of the original cost of the pipe.

Important facts brought out here:

1. Staves which are constantly subject to water pressure from within and are buried in the ground may be very short lived.

2. The pipe laid above ground has not deteriorated to any considerable extent.

3. When buried its durability has depended upon soil conditions and the depth of backfill.

4. When the depth of backfill has exceeded two feet above the pipe and the material has been free from vegetable matter and has been of a fine and impervious character, much less deterioration has taken place.

5. Whenever the staves have been in contact with loamy earth or earth containing loamy vegetable matter or whenever they have been covered with porous material to a depth of less than two feet rapid decay has resulted.

6. Decayed staves were found all around the pipe.

7. Sound staves were frequently found contiguous to badly decayed staves.

8. The character of the grain, whether slash or grain edge, has not influenced the durability.

9. The bruising of the staves during the process of erection seems to have been one of the chief agencies in hastening decay.

10. Decay has been confined to the outside of the pipe.

In the discussion which follows the above statement of facts it appears that the experience with old wooden penstocks in New England is analagous to that with wood pipe elsewhere; *i.e.*, that it is subject to frequent renewals.

Regarding the preservation of wood constantly under water, experience with the old wooden Holyoke Dam is cited, where 6-inch timbers constantly under 20 feet of water were rotted until there was no more sound wood left than would form a little veneer on the water side which was preserved sometimes only one-eighth inch thick.

From the experience at Astoria it would appear that the light pressure at the summits where the pipe line came near to the hydraulic grade line—pressures say of less than 50 feet—were responsible in part at least for this deterioration.

Engineering News, November 20, 1913.

Experience with wood stave pipe of the Atlantic City Water Works.

The wood stave pipe is reported to be in first-class condition except that the wrought iron bands show some corrosion.

NOTE.—Nevertheless, when a new 48-inch

main was laid two years after the wood main, cast iron pipe was chosen.

Engineering News, May 7, 1914.

Rebuilding an old wood penstock, Gothenburg, Neb.

Penstock, built in 1890–1, originally covered with loose soil but wind and rain had uncovered portions and these had decayed badly. The inner surface was always sound but at the end of ten years leaks began to show up causing decay on the outer surface which allowed the staves to spring out of place under pressure.

Method of Attempted Repair of Wood Pipe Joint

Experience of the D. L. & W. R. R. Co.

About five years ago laid from 12 to 15,000 feet of 20-inch wood stave pipe in New Jersey and are now replacing this pipe with cast iron. Leakage so great that it would not pay to continue its use although strenuous effort was made to get it tight.

Company also laid about six miles of 12-inch wood stave pipe five or six years ago and has since made other arrangements for water supply. This pipe leaked badly.

Manufacturers of the pipe concluded that the pipe was sprung on account of excessive pressures due to reduction valves not working. In this case, however, the pipe was never subjected to a pressure above 100 lbs., and the pipe was well laid.

Replaced Wood Pipe Along D. L. & W. R. R., Jersey City, N. J.

NOTE.—Wood pipe is apparently not satisfactory in a pipe line where there are gates or other appurtenances of a water supply line that by quick closing may render fluctuations in pressure, causing water ram. The most satisfactory experience seems to be in uncovered lines subject to from 50 feet to 200 feet head of water.

Extract from the Decision of the Conservation Commission of the State of New York in RE: Water Supply Application No. 184, Village of LeRoy, P. 6:

"It is proposed to use wooden stave pipe for the supply line. It is specified that this pipe be made of Douglas fir, one and one-quarter inches thick, wound with wire. Experience in this State with wooden pipe has not been satisfactory, and there seems good reason to suppose that if the line is built as proposed it will leak badly, will frequently fail, and that its life will be short. As the continuous operation of this pipe will be depended upon to give fire protection for this village, the fragile nature of the proposed construction would be particularly unfortunate. It will be required that wooden pipe shall not be used in this line, but that it be constructed of standard cast iron pipe."

Wood Pipe Replaced With Cast Iron Pipe at Rogers Texas

The pipe line in question as proposed was to be about six miles long, and of 14-inch diameter, wire-wound wooden stave pipe.

In a letter dated August 7, 1915, to one of the makers of cast iron pipe, Mr. Frank Leahy, owner of the Rogers Water Works, Rogers, Texas, writes:

"Please hurry shipment on the cast iron pipe ordered from you. Am having lots of trouble with the wood pipe now in use and the City threatens to bring suit on account of the condition of the streets. It seems impossible to keep this pipe in repair, one leak following another so rapidly that I have been obliged to keep a force of men stopping the leaks. The bands have now begun to break and it is useless to attempt to keep in repair any longer. The only remedy is to replace it with iron pipe, and I trust that you will get this pipe to me as soon as possible."

This pipe maker wrote Mr. Leahy, asking permission to use his letter and under date of September 8, 1915, received the following reply:

"Your favor of the 7th, with enclosures received this morning. I am enclosing the last Kodak picture I have, which will give an idea of the trouble the wood pipe caused me. This picture was taken about a year ago. I replaced about 1000 feet of the pipe at that time. These extra bands cost me $1.25 each and you can know that it wasn't a nice job to put them on, either,

"I am not anxious to let people know that I have played the sucker when buying the wood pipe, but in order to keep others from making the same mistake, you may use the previous letter for what it is worth."

CONCLUSION

No reference has been made in the preceeding pages to concrete or clay pipe for the reason that neither of these is, or can be, used to any extent as pressure conduits, on account of their limited tensile strength.

Much additional data could be presented on metal and wood pipe, but it is felt that the foregoing is sufficient to enable any interested and open minded reader to decide what kind of pipe will best serve his own or the public's purposes.