UNITED STATES PIPE AND
FOUNDRY COMPANY PLANT
(US Pipe Plant)
Birmingham Industrial District
2023 St. Louis Avenue, at I 20-59
Bessemer
Jefferson County
Alabama

HAER No. AL-32

HAER
ALA
37-BES,
6-

PHOTOGRAPHS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
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ADDENDUM TO
UNITED STATES PIPE AND FOUNDRY COMPANY PLANT HAER No. AL-32
(U.S. Pipe Plant)
Birmingham Industrial District
2023 St. Louis Avenue at I-20,59
Bessemer
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HISTORIC AMERICAN ENGINEERING RECORD

UNITED STATES PIPE AND FOUNDRY COMPANY

(United States Cast Iron Pipe & Foundry Company)
(U.S. Pipe Company)

HAER No. AL-32

Location:	2023 St. Louis Avenue, Bessemer, Jefferson County, Alabama Bessemer Quadrangle UTM Ref. 16.502340.3697270
Dates of Construction:	1888-1976
Fabricator:	Howard-Harrison Iron Company
Present Owner:	U.S. Pipe Company
Present Use:	Cast-iron pipe manufacture
Significance:	The Bessemer plant of the U.S. Pipe Company was one of the first pipe factories established in Alabama, in a region that became synonymous with foundry production. U.S. Pipe owned and controlled the deLavaud patent for the centrifugal casting of iron pipe, installing deLavaud machines at Bessemer in 1934. The plant was also the last in U.S. Pipe, and one of the last in the country, to abandon traditional pit casting, removing the last pipe pit in the late 1950s.
Historian:	Richard O'Connor, August 1996

Chronology

1850s	Vertical pit casting established in America
1886	David Giles develops the revolving turntable at his Chattanooga, Tennessee factory
1888	Howard-Harrison Iron Company builds plant in Bessemer, Alabama
1899	Thirteen factories, including the Howard-Harrison plant at Bessemer, merge to form the United States Cast Iron Pipe and Foundry Company, the largest cast-iron pipe company in the world
1912	Major internal report sparks reorganization and technological modernization at U.S. Pipe
1916	Dimitri Sensaud deLavaud patents process for centrifugally casting iron pipe
1921	U.S. Pipe purchases rights to manufacture and distribute pipe produced by the deLavaud process in the United States
1934	deLavaud machines installed at Bessemer plant
	U.S. Pipe develops Super-deLavaud process to remove chill from pipe
1950s	Last casting pit removed from Bessemer plant
	U.S. Pipe begins manufacturing ductile iron pipe

Introduction

The transition in cast-iron pipe production from sand pit to centrifugal casting involved a fundamental shift in production paradigms that changed not only the production process, but the metallurgical and engineering qualities of the pipe itself. This report looks broadly at the evolution of technological change in the cast-iron pipe industry and uses the Bessemer, Alabama plant of the U.S. Pipe Company, the site of a 1996 documentation project by the Historic American Engineering Record, as a case study. U.S. Pipe purchased exclusive rights to the centrifugal casting process developed by Dimitri deLavaud soon after its invention, and has since developed the process and controlled its diffusion.

Throughout the late nineteenth and early twentieth centuries, manufacturers met rising demand for pipe by working within the confines of the age-old technological paradigm for foundry production. Defined by a series of discrete, labor intensive, time-consuming steps, foundry products, from one-of-a-kind Corliss engine blocks to the smallest joints and valves, required flasks, molds, and cores, and time for pouring, setting, removal and finishing. Despite significant improvements, such as the adoption of vertical pit-casting in the mid-nineteenth century and the turntable and fixed stations in the early twentieth, American pipe casting practice changed little in principle between the Civil War and World War I.

With the successful application of centrifugal casting to pipe production in 1918, Dimitri deLavaud shifted pipe founding's technological paradigm. Centrifugal casting eliminated sand molds and full pipe cores, substantially reduced the labor required, increased tensile strength and ductility, and increased metal density while reducing overall weight. But the transition was not instantaneous: large diameter pipe was pit cast until the 1950s, and the two processes co-existed at the Bessemer plant of the United States Cast-iron pipe & Foundry Company for over two decades.

Cast-Iron Pipe in America: the Early Nineteenth Century Context

Its long history notwithstanding, the popularity of cast-iron pipe was a nineteenth century phenomenon. As its use increased and its flaws became apparent, pipe production techniques changed in three distinct phases. First, casting position shifted from "on-side" and "on-the-bank" to vertical pit casting, eliminating some of the most common pipe flaws. Second, improvements to pits, including mechanized turntables, rammers and novel flask configurations swelled output. Third, by the end of the century, urban water engineers demanded pipe of consistently high quality, leading to the establishment of engineering standards and the greater homogenization of casting techniques. Yet, this evolution and transformation of a relatively new industry occurred within a foundry production paradigm that remained remarkably consistent with age old casting practices, so much so that the pipe casting factory of the World War I-era bore greater resemblance to a Civil War-era plant than it did to one built in the decade of the 1920s.

Cast iron water pipe made possible the delivery of large quantities of clean water in rapidly expanding cities suffering from water-born diseases (cholera, dysentery and typhoid) and raging conflagrations. Recognized widely for its longevity--iron pipe originally installed to supply water to the gardens at Versailles still functions--it was manufactured in a range of diameters, withstood ever-increasing compressive loads, could be laid underwater, and could be lined and coated to protect it from corrosion. Reflecting the extent to which cities had come to rely on cast-iron pipe, by the early twentieth century urban water engineers and pipe manufacturers cooperated closely to develop industry standards and specifications for pipe qualities, such as strength and size.

Cities in the early nineteenth century increasingly turned to cast iron pipe as they developed their water infrastructure. Until then, almost all urban pipe was bored log. Expensive, unreliable and requiring constant maintenance, it became increasingly untenable as water pressures increased and urban water systems became more extensive, and was entirely inadequate as gas lighting became widespread. In 1802, Philadelphia experimented with fourteen sections of six-foot pipe, sent its water works superintendent to England to observe the London system, and finally made the first major installation of cast iron water pipe in America in 1817. By 1822, approximately 30,000 feet of pipe in nine feet sections had been laid, with the largest twenty-two inches. Boston began using wood and lead in 1652, and did not make the transition to cast iron until 1840. The following year, the water committee voted to install cast-iron pipe exclusively in the future. Similarly, gas suppliers in New York, Rhode Island and Maryland followed the British example, adopting cast-iron pipe exclusively following the War of 1812.[1]

In the United States, iron pipe was initially cast at general purpose foundries equipped to handle large castings. Pipe production, in fact, was often a way to dispose of excess iron. "In earlier days," noted New Jersey pipe manufacturer Stuart Wood, "there were no special foundries for the making of pipe, but here and there charcoal blast furnaces began to make pipe in addition to other castings, in order to dispose of their output." In 1801, Weymouth Furnace, near May's Landing, New Jersey, received the first contract for casting iron water pipe from the Philadelphia water committee. During the next several decades, that foundry intermixed pipe making with the production of canon and other war materials for the army and navy in the War of 1812, fences for Independence Hall, and cemetery grave markers. Similarly, Monmouth Furnace near Freehold, New Jersey cast pipes as well as caldrons, pots, stoves and other items from the 1820s through the 1840s. The Millville, New Jersey furnace on the Maurice River, founded c. 1803, first made pipe in 1825 and constructed a special foundry for pipe production in 1834, the first such

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[1]Henry Jeffers Noble, *History of the Cast Iron Pressure Pipe Industry in the United States of America* (Newcomen Address, Birmingham, AL: Birmingham Publishing Company, 1940), pp. 10-13; William Davis Moore, *Development of the Cast Iron Pressure Pipe Industry in the Southern United States, 1800-1938* (Newcomen Address, Birmingham, AL: Birmingham Publishing Company, 1939), pp. 10-12, 19; Jesse Garrett, "Making Cast-Iron Pipe," *Journal of the New England Water Works Association* (Sept. 1896), pp. 34-36.

specialized facility in the United States.[2] By the 1840s, cast-iron pipe production appears to have become a specialized branch of manufacture.

Not only had foundries evolved to specialize in pipe production, but by the 1850s pipe casting techniques had changed in response to demands for better quality pipe. Until the early nineteenth century, standard practice had cast iron pipe horizontally using the "on-side" method in lengths from four to six feet. Cast in green sand molds with dry sand cores held in place by chaplets and reinforced with iron bars, iron was often delivered direct from the blast furnace through gates, with overflow directed to pigs. The first pipes made for the Philadelphia Water Works at Weymouth, NJ were cast in molds set in the pig beds, into which iron made from melting bog ore ran directly from the blast furnace. Pipe cast on-side had three shortcomings stemming from sagging cores: limited pipe length, diminished concentricity, and thin pipe walls. In addition, sand washed from the mold and slag from iron floated inside the mold, reducing iron content on the top-side and weakening the pipe. To remedy these problems, foundrymen began casting pipe "on the bank," forming the core and mold as before but raising one end of the mold before pouring. This reduced the tendency of the core to sag, concentrated sand and slag in one end of the pipe, which then could be cut off, and permitted casting pipe in lengths up to nine feet.[3]

Vertical Pit-Casting

Deficiencies in both "on-side" and "on-the-bank" casting, if not divine inspiration, led pipe founders to vertical casting, first in Britain in the 1840s and then in America the following decade. D.Y. Stewart of the Links Foundry at Montrose, England received the first patent for vertical casting in 1846. "According to a local legend," wrote W. Woodhouse in *The Foundry Trade*, "Mr. Stewart conceived his process while in Church, the root idea being suggested by the vertical columns in front of him." Six years later, English foundryman George Peacock brought the process to the Coller, Sage & Durham Foundry at West Troy, New York, where he took a position as superintendent, later engineering construction of works at Louisville and Cleveland. The practice began with large pipes, but soon spread to the smaller diameters. Within two years,

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[2]Noble, *History*, pp. 19-20, 25-6 (quote on p. 26); Arthur D. Pierce, in his study of New Jersey Pine Barrens iron, notes that "(b)y 1825, ...pipe moulding was so well organized (at Weymouth) as to be taken for granted..." Arthur D. Pierce, *Family Empire in Jersey Iron* (New Brunswick, NJ: Rutgers University Press, 1964), p. 109.

[3]N.a., *Handbook of Cast-Iron Pipe* (Chicago, IL: Cast-Iron Pipe Research Association, 1927), p. 27; Noble, *History*, pp. 15, 28; n.a., "Making Cast-Iron Pipes at the 'New' Works, Staveley Coal and Iron Company, Limited," *Foundry Trade Journal* (Feb. 23, 1928), p. 129; W. Woodhouse, F.I.C., "Cast-Iron Pipes," *Foundry Trade Journal* (May 7, 1936), p. 357; Garrett, "Making Cast-Iron Pipe," p. 40, 43; R.V. Riley, "Cast-Iron Pressure Pipe," *Iron and Coal Trades Review* (July 3, 1953), pp. 15-6.

the new technique had spread to the foundry of R.D. Wood at Millville, NJ, one of the country's largest, "and by 1860 it was to become the standard procedure in casting" pipe. Vertical pit casting predominated until the introduction of centrifugal casting in 1918, and was not phased out completely until the 1950s.[4]

Pit-casting is probably the oldest general foundry casting technique; but vertical pipe casting required specially-designed pits dedicated to the production of large quantities of relatively large items. Pits were constructed with stone or concrete retaining walls, and varied in diameter from approximately 20' in the 1880s to at least 74' in 1907; they also varied in depth to accommodate pipe in lengths of 12' and 16'. Pits were of uniform diameter, with the exception of space along one side that allowed the accumulation of empty molds. They were divided into three sections: the ramming pit, the drying pit, and the casting pit.[5]

Like "on-side" and "on-the-bank" casting, vertical pit-casting required the preliminary production of molds and cores. Pipe was cast at floor level in 12' lengths in molds set in pits approximately 13'-14' deep. Molds were baked sand forms shaped inside flasks, resting on a base, also called a chill plate (with socket ring for pipe cast bell down), with a core forming the pipe's inside surface. The outside of the mold formed tightly against the flask, a hinged ellipse clamped tight on the open side, resting in the base casting. A pattern lowered into the flask and resting on bearings in a conical depression in the base was centered and wedged at the top. Sand was then shoveled into the cavity between the pattern and the flask and rammed by hand until tightly packed. In place of hand-ramming, some foundries used a pattern with an expanded base (an inverted bell) that compressed the sand as it was drawn out of the flask. After the pattern was withdrawn and the interior of the mold coated with blacking, it was oven-dried overnight in preparation for casting the next day. In diameters of 3", 4" and 6", pipes were cast three per flask; diameters of 8", 10", 12", and 14" were cast two per flask; and diameters 16" to 72" were cast singly.[6]

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[4]W. Woodhouse, "Cast-Iron Pipes," p. 357; Noble, *History,* p. 34. There is some debate over who was the first foundryman to bring vertical casting to America. John Firth is also credited with beginning pit casting at the Delameters, Mott & Ayers Foundry in New York in the same year.

[5]This description is prior to the development of the turntable, or revolving pit. N.a., "Making Cast-Iron Pipe," *Iron Age* (Nov. 6, 1890), p. 788; n.a., "Modern Pipe Founding," *American Machinist* (Sept. 7, 1905), p. 304.

[6]N.a., "Making Cast-Iron Pipe," *Iron Age* (Nov. 6, 1890), p. 787; H.A. Croxton, "Modern Pipe Founding," *Iron Age* (July 19, 1906), p. 146. The description of vertical pit casting is generic, encompassing some refinements in vertical casting techniques and omitting others. Sources consulted do not permit detailed reconstruction of the evolution of pit casting techniques.

Cores forming the inner wall of the pipe required the same care in preparation as did the mold. Coremaking involved several discrete steps. Around a perforated steel or cast iron tube rotated slowly on a lathe-like device called a "strike" coremakers carefully and evenly built up four layers. First, a layer of hay rope was wound loosely against the metal tube. During casting, the heat of the hot metal burned the rope and permitted the tube to be extracted easily. A layer of loam averaging 3/4" thick (increasing with the diameter of the pipe) was added atop the hay rope, and cores were then mounted on cars and baked until dry, approximately five hours. A second layer of loam was then added, followed by a coat of blacking, and the cores were then remounted on the core cars and baked a final time, usually overnight, before being ready for insertion into the mold. In addition to molds and cores, specialized molds forming the base and socket and bead ring patterns are formed. Work on cores and ancillary components continued throughout the day, with all parts ready to be fitted together as soon as the larger pipe molds dried.[7]

Cranes and other devices capable of moving quantities of heavy equipment and products were essential to pipe founding. Large, hydraulic (electric by the early twentieth century) powered jib cranes anchored on islands in the center of the pits lifted and moved flasks, molds, cores, poured iron and shook out finished castings. These cranes carried their loads on running blocks suspended from trolley carriages moving in and out along the jib. Traveling cranes brought metal from the cupolas to the pits. After forming, cores were placed on racks on carriages running on tracks in the floor that carried them into drying ovens. In some of the better designed foundries in the early twentieth century, pipes moved on slightly inclined skids through testing and coating

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[7]According to veteran pipe founder H.A. Croxton, pipe diameter determined core bar material at the Massillon Iron and Steel Company: "...on sizes up to 12 in. the bar is made of wrought iron pipe while on sizes above 12 in. the core bars are made of cast iron." Croxton, "Modern Pipe Founding," p. 146; steel tubes were used at the American Cast-iron pipe Company in Birmingham, Alabama. N.a., "The American Cast Iron Pipe Company's Foundry," *Iron Age* (Feb. 7, 1907), p. 400.

"Many attempts have been made," noted *The Foundry*, "to produce pipe cores without the use of hay-rope, yet this material has never been successfully replaced. Its comparative cheapness in the United States has rendered it extremely difficult to find something more economical or a method which will really make better or cheaper cores." N.a., "Pipe Foundry of the Massillon Iron & Steel Company, Massillon, O.," *The Foundry* (Nov. 1903), p. 26. In the early twentieth century, some founders succeeded in replacing hay with excelsior, a wood composite, and "skilley," made from disintegrated waste paper. Y.A. Dyer, "Cast-Iron Pipe Manufacture in the South," *Iron Age* (Nov. 23, 1916), p. 1161; Frederick H. Lewis, "Cast Iron Water Pipe," *Cassier's Magazine* (May, 1895), p. 20; n.a., "Modern Pipe Founding," p. 307; Garrett, "Making Cast Iron...," p. 45; n.a., "Making Cast Iron," p. 789.

processes.[8]

The quality of iron used in pipe founding improved steadily throughout the nineteenth century, primarily the result of increased attention paid its chemical composition. Well into the twentieth century, pipe foundries depended primarily on blast furnace pig iron for their metal. As noted above, early castings were poured directly from the blast furnace, presenting obvious quality problems: if the iron ran good, the pipe might be good; if it ran bad, the pipe was bad. "The pig iron mixture," pipe founder H.A. Croxton observed, "does not always receive the attention it deserves." Croxton was a rare individual in the foundry business. Having established one of the first chemical laboratories in the industry, he preached the benefits of chemical analysis over observations of the iron's physical properties, or "fracture." Unlike the earliest iron cast directly from the furnace, he claimed to mix "not less than four different brands of iron....Each car of iron is analyzed before using and is handled accordingly. The coke is also analyzed, particular attention being paid to sulphur and ash." Y.A. Dyer, widely known commentator on the foundry industry, described the process for arriving at the correct iron composition at the Dimick Pipe Foundry in Birmingham, Alabama: pipe was "also regularly cast from mixtures of iron...made up with a view to the chemical analysis of the product...." Each carload of pigs was "numbered, sampled and analyzed and its analysis recorded." By the World War I era, chemical analysis of both pigs and cupola heats was standard practice among the largest pipe founders. "Nowadays," noted water works engineer William Conrad, "each manufacturer or foundry has its chemist... (who) not only analyzes the raw material but the finished product as well."[9]

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[8]N.a., "The American Cast-Iron Pipe Company's Foundry," p. 400; n.a., "Making Cast Iron Pipe," p. 788; History and Heritage Committee, American Society of Mechanical Engineers, *Landmarks in Mechanical Engineering* (West Lafayette, IN: Purdue University Press, 1997): "The Pit-Cast Jib Crane," pp. 191-3; Henry R. Towne, *A Treatise on Cranes* (Stamford, CT: E.S. Dodge Steam Printing House, 1883), pp. 65-72, 115-121.

[9]Croxton's associate, E.A. Kebler, of the large plant at Addyston, Ohio, recounted his own experience in 1924: "I came to the plant in the fall of 1883 as a chemist, and was probably the first chemist in the United States in a plant devoted entirely to the melting of iron in those days, and the idea of a chemist was ridiculed by the other pipe foundrymen," Noble, *History*, p. 37; Croxton, "Modern Pipe Founding," p. 146.

According to engineer Jesse Garrett, by the mid-1890s it was "prevalent practice to use about four varieties of pig iron from various localities and grades of ore..." "Making Cast-iron Pipe," p. 44. See also N.a., "Modern Pipe Founding," p. 303; Dyer, "Cast-Iron Pipe Manufacture in the South," p. 1161; William R. Conrad, "Cast-Iron Pipe, the Method of Manufacture and Its Inspection," *Journal of the New England Water Works Association*, Sept. 1921, p. 212.

In steel making, a parallel debate over the definition of steel ensued between proponents of chemical versus mechanical analysis. A significant issue, and one that concerned pipe founders, was the ability of chemical analysis to assist in the reproduction of iron with specific

The specific composition of iron required in pipe founding underscored the need for chemical analysis. Pig iron was graded at the blast furnace by its non-ferrous content--carbon, silicon, sulphur, manganese and phosphorous. But grading at the blast furnace was too general for foundry use, leading foundries to sort and classify pig iron based on their own needs. Then, as now, both manganese and phosphorous were contributed by the ore alone, carbon was taken from the fuel, and silicon and sulphur came from both. Blast furnace iron was graded commercially based primarily on its silicon and sulphur content--premiums were paid for iron high in silicon and low in sulphur. Scrap became a larger component of the melt in the twentieth century. As late as 1890, pipe founders relied on scrap only "as it arises incidentally from all castings and from condemned pipe." This had changed by the 1920s, according to consulting engineer William Conrad of Burlington, NJ, when scrap did "not mean just the fins, gates, and broken-up pipe, but (was) a very indefinite term, as the scrap dealer...gather(ed) in anything from old stove castings, agricultural machinery, sash weights, etc. up to the very finest grade of worn-out machinery...."[10]

The use of cupolas for melting iron, while prevalent in Europe, did not become standard practice in American pipe foundries until the industry abandoned its New Jersey bog iron location, where it depended on charcoal from the pine forests, and migrated to the anthracite region of eastern Pennsylvania. Anthracite as a fuel for melting encouraged foundries to adopt cupolas as melting furnaces. Coke was used almost exclusively by the early 1880s. Cupola size and capacity expanded in the late nineteenth and early twentieth centuries. By 1907, the two largest, most modern pipe foundries had installed cupolas with melting capacity that dwarfed that of earlier foundries. The Massillon Iron & Steel Company ran two 102" (outside diameter) cupolas melting 25 tons each per hour in 1903; ACIPCO (Birmingham) installed two 78" diameter Whiting cupolas melting 18-20 tons each per hour; U.S. Pipe at Scottdale, Pennsylvania built four 84" Newton cupolas melting fourteen to eighteen tons each per hour. Melting ratios of iron to coke had increased from ten to one in 1896 to over 11 to one in 1907.[11]

The actual casting process was labor intensive, time-consuming and dangerous. Production took place on a daily cycle, beginning approximately 5:00am and lasting until 2:00pm, "without

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characteristics. See Thomas J. Misa, *A Nation of Steel.* (The Johns Hopkins University Press, 1995), pp. 29-38.

[10]Cast-Iron Pipe Research Association, *Handbook,* p. 29; n.a., "Making Cast-Iron Pipe," p. 789; Conrad, "Cast-Iron Pipe...," pp. 212-3.

[11]Noble, *History*, pp. 13, 31; Garrett, "Making Cast-Iron Pipe," p. 44-5 (also contains good description of cupola charging and melting process); n.a., "The American Cast Iron Pipe Company's Foundry," p. 400; W.B. Robinson, "The Manufacture of Cast-Iron Pipe," *Iron Age* (December 5, 1907), p. 914; n.a., "Pipe Foundry of the Massillon Iron & Steel Company, Massillon, O.," p. 126.

interruption." Flasks and molds were placed in the casting pits, cores lowered by crane and centered by means of the chill plate at the base and, at the top, a ceramic ring with holes known as gates. Atop the gates sat the runner, into which molten iron was poured. The workman pouring the iron, known as the caster, possessed great skill and knowledge of the behavior of molten iron. Working in team with a crane operator who controlled the movement of the ladle carrying the iron, noted one contemporary, the caster kept "his runner filled so as to prevent any impurities which float on the top of the iron going onto the gates and spoiling the pipe; at the same time he must not pour the liquid over the runner and waste it." Casting began early in the morning, usually shortly after 5:00am. The iron cooled for several hours before the core bar was withdrawn and the flask raised out of the pit. On its way out, another workman, armed with a sledge hammer, knocked off two of the three clamps holding the open side of the flask together. Noted another observer, "the man who releases the clamps by which the molds are held together is, perhaps, the star performer." Once free of the pit, the flask tilted to a horizontal position and was taken to the discharge point, where the workman, who has followed the pipe through the factory, knocked off the last clamp, releasing the pipe onto rails. Flasks were then returned to the pit for filling and ramming. Core making, of course, continued without break.[12]

Quality concerned water works engineers and pipe makers alike, and over the course of fifty years pipe founders developed a system to insure high quality iron and uniform inside and outside dimensions and pipe wall thicknesses. By the 1890s, testing across a variety of specifications had become routine. The "weigh" pipe, the first casting each day, was measured by inside and outside diameter, lead room, socket depth, and wall thickness before being weighed to determine how closely it conformed to standard tolerances.[13] If met, carefully recorded specifications for the "weigh" pipe became template specifications for the rest of the cast that day. Each pipe was routinely tested to withstand 300 pounds per square inch (p.s.i.) pressure, and this was often supplemented by a hammer test, in which a pipe under water pressure was struck by a hammer. Specifications became increasingly more rigid around the turn of the century, and pipe makers regularly ran hydrostatic tests to 350 and 400 p.s.i. Additional physical tests measured deflection on sample bars. "If the pipe breaks at the mill," noted Ohio pipe founder H.A. Croxton,

> it is simply a matter of remelting the scrap, while if it breaks in the trench it causes all sorts of trouble and usually quite an expense account. There is a moral obligation which makes it necessary for all pipemen to replace any defective material, and while in a great many cases the cause is one for which the pipemen should not be blamed, at the same time there is very little to do other than settle

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[12]N.a., "Making Cast-Iron Pipe," p. 788; see also Conrad, "Cast-Iron Pipe...," pp. 212-3; N.a., "Modern Pipe Founding," p. 303.

[13]"The slightest variation in the diameter of the core of even a six inch pipe will make a material difference in its weight," noted a correspondent for *Iron Age*, Nov. 6, 1890, p. 789.

the contractor's bill for damages.[14]

Testing was advocated primarily by water works engineers, led by the New England Water Works Association and then by the American Water Works Association, to "secure a better quality of pipe, without entailing additional cost on the maker." Existing tests left some problems undetected. Municipal engineers felt transverse tests that more reliably replicated field conditions were superior to standard tensile tests performed by pipe makers. By setting standards, the Committee hoped to eliminate common problems that characterized poor quality pipe that broke in shipment, was difficult to cut and trim in the field and, most significantly, frequently failed when subjected to a heavy water ram. Unlike typical hydrostatic tests at the pipe foundry, water lines in service contain a quantity of air, and a sudden demand for water or "the sudden closing of a valve will certainly produce a water ram." Strains from shrinkage caused the greatest number of problems for cast-iron pipe customers. Water works engineers complained that "(a) custom has grown among pipe makers...of removing pipe from the pit before it is sufficiently cool," creating problems that defied detection by even the most rigid turn-of-the-century testing procedures. The third problem, lack of uniformity in pipe wall thickness, usually the result of an out-of-center core, again caused strains as pipe walls cooled unevenly.[15]

Engineering demands for quality pipe imposed additional manufacturing costs and process considerations that stretched the abilities of high-tonnage pipe producers. By the 1920s, Engineering Society specifications required that pipe larger in diameter than 16" be cast bell down, or "down socket;" smaller sizes could be cast "up socket" or "down socket" "at the manufacturer's discretion." Iron in larger diameter, thick-walled pipe tended to erode the mold and mix with the sand, making the cooled iron "spongy." By casting bell down and allowing for waste to be cut off the spigot end, the integrity of the iron was improved. But this added a time consuming extra step to the manufacturing process. Other aspects of the design of molding and casting equipment contributed to improvements in pipe quality, particularly in the maintenance of consistent pipe wall thicknesses. In the ramming pit, empty flasks rested on stools, locked into place with lugs. Conical depressions, corresponding to the number of pipes to be cast in respective flasks, insured that patterns remained vertical and centered within flasks. Carefully machined cast iron patterns, larger in diameter at the butt end than at the stem, fit into depressions on the ramming stool and were locked on by holding plates clamped to the flask tops. In core

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[14]"Quote from "Modern Pipe Founding," *Iron Age*, July 19, 1906, p. 146; see also "The American Cast Iron Pipe Company's Foundry," pp. 399-402; n.a., "Pipe Foundry of the Massillon Iron & Steel Company, Massillon, Ohio," pp. 125-130.

[15] Noted the report of the Committee of the American Water Works Association: "(p)ressure exerted anywhere upon a mass of water is transmitted undiminished in all directions, and acts with the same force upon all equal surfaces, and in a direction at right angles to those surfaces." N.a., "Report on Specifications," *Iron Age*, March 19, 1891, p. 525.

formation, hay and loam were levelled to close tolerances during rotation by a fixed board on the core lathe. Cores were locked into place by a cap and wedge. The surest path to quality p[ipe lay in precise concentricity and consistent wall thickness.[16]

The lining of cast-iron pipes became common practice in the late nineteenth century as a way of preventing loss of carrying capacity due to the build up of deposits inside the pipe. Tuberculation develops when nodules of rust attach to the interior of the pipe when water with a low ph and low alkalinity reacts with cast iron. As the deposits grow, they cause friction in the line and increasingly restrict the flow of water. Possible remedies include alleviating the corrosion characteristics of the water, lining the pipe, or a combination of both. By the 1920s, drinking water could be treated, in most instances, to eliminate tuberculation. But many pipe systems carried. raw, untreated water from wells, springs or water sheds, where pipe lining was the only solution Until the 1920s, cast-iron pipe was lined with coal-tar pitch varnish. Once pipe left the flask, it was coated to resist tuberculation and corrosion. After heating evenly in an oven to 300 to 500 degrees, pipes were dipped in tar and tilted slightly to permit drainage. By the 1920s, engineers complained that the quality of pipe coating had deteriorated due to changes in the composition of the tar, which had become laden with undesirable by-products, possibly a result of recovery from gas producers.[17]

Both the short life-span of pitch coating and the lack of any control over its application led to the search for another material. Even as late as 1897, according to the Municipal Engineers' Special Committee on Coating of Cast Iron and Steel Riveted Pipes, after surveying forty-nine municipal water works, "(i)n but very few instances is any system of supervision or inspection as to the composition of the coating material or its method of application at the foundry maintained, and hence no assurance is had that the coating specified is really applied or that the covering which is applied possesses any merit as such...." Since the late nineteenth century, the American Pipe and Construction Company of Philadelphia had used successfully a very expensive, cement-lined, wrought-iron "Phipps" pipe at its Springfield Consolidated Water Company. In 1907, J.E. Gibson, an engineer with the company, ran a series of "valuation tests" comparing Phipps and cast-iron pipe. Both mains had been in use for twenty-five or thirty years, and the cast iron showed considerably more tuberculation than the cement-lined pipe, which retained its original

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[16]N.a., *Handbook*, p. 36; n.a., "Making Cast-Iron Pipe," pp. 787-9.

[17]Thomas F. Wolfe, "Linings for Cast-Iron Pipe," *Journal of the New England Water Works Association*, (Dec., 1936), pp. 412-22; U.S. Cast Iron Pipe Company, *Cast-Iron Pipe and Special Castings* (New York: 1906), p. 7; Lewis, "Cast-Iron...," p. 21; n.a., "Pipe Foundry of the Massillon Iron & Steel Company, Massillon, O.," p. 130; W.B. Robinson, "The Manufacture of Cast-Iron Pipe," *Iron Age* (December 5, 1907), p. 916; Conrad, "Cast-Iron Pipe...," p. 222; n.a., "Pipe-Molding Machine and Continuous Pipe Foundry at Coschocton, Ohio," *Engineering News* (June 15, 1911), p. 716.

carrying capacity. Gibson moved to Charleston, South Carolina in 1917, and discovered the water system laden with tuberculation. He interested the American Cast-iron pipe Company (ACIPCO) in Birmingham, Alabama in developing a process for lining cast-iron pipe with natural cement. The cement was applied with the pipe in vertical position, and a lining cone, or "bullet" inserted to the bottom with the projectile point facing up. Natural cement of the proper consistency and point-of-cure was then poured into the pipe and the cone withdrawn, spreading the cement evenly over the sides of the pipe. In 1923, ACIPCO developed a centrifugal process for applying the lining, and changed from natural to Portland cement. By 1930, ten percent of the industry's pipe was cement lined and, after further refinements in the process in the late 1930s, the practice became near-universal among cast-iron pipe manufacturers. Charles Wood, of the R.D. Wood Company made the case in 1924 that "it is now almost unanimously considered that cast-iron pipe, properly lined with a good cement, is what the world has been waiting for...."[18]

The transition to vertical pit-casting was an integral part of a general restructuring of the cast-iron pipe industry in the last quarter of the nineteenth century. In the first half of the century, the industry relied heavily on New Jersey's bog ores and plentiful charcoal supplies, but few plants of this era survived: by the 1940s, only two pre-Civil War pipe foundries still operated. The depression of the 1870s was accompanied by a lull in pipe plant expansion lasting until 1883, but the ten-year boom that began that year represented qualitative shifts in the tempo and location of plant construction. The closing of imports during the Civil War also encouraged domestic manufacture, sparking a burst of pipe mill activity lasting eight years, until quelled by the depression beginning in 1873. Pipe foundrymen began migrating west in the 1850s, following both population movements and iron and coal reserves. William Smith's Pittsburgh foundry is credited as among the earliest trans-Allegheny pipe plants; it was also a fertile training facility for western foundrymen. Strongly encouraged by the attention given water and sewage facilities at the Philadelphia Exposition in 1876, industry historian Henry Jeffers Noble argues that "the number of new plants erected in the eighties and early nineties exceeded the total number which had been previously operated in America," with the establishment of thirty-six new shops in the period. A total of nine new plants were located in Alabama, Virginia, Tennessee and Texas, the first stage in the industry's migration south.[19]

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[18]Special Committee on Coating of Cast Iron and Steel Riveted Pipes, "Coating of Cast Iron and Steel Riveted Pipes," *Municipal Engineering,* (Nov., 1897), pp. 280-7; J.E. Gibson, "Cement-Lined Cast-Iron Pipe at Charleston, S.C.," *Engineering News Record,* (Sept. 7, 1922), pp. 387-90); American Water Works Association, "Symposium on Cement Lined Water Mains." (Unpub. Proceedings, Wednesday, June 14, 1933), pp. 1-49; Moore, *Development*, pp. 29-30; Charles R. Wood, "Sandspun Pipe," *Mechanical Engineering,* (Nov. 1922), pp. 727-39.

[19]Noble, *History*, p. 29-30, 35, 55. America's pig iron production grew rapidly during the same period and, as before, some pipe plants were built to consume excess iron.

Innovation and Expansion

In the late nineteenth and early twentieth centuries, contradictory trends drove the cast-iron pipe industry through a series of reorganizations and, ultimately, to the adoption of centrifugal casting. Exacerbating earlier trends, the general demand for pipe grew exponentially as cities expanded water and gas systems. Absent changes in basic sand-pit casting technology, existing pipe founders enlarged their works and new foundries entered pipe production. Competition depressed prices and encouraged pipe makers to cooperate to control markets and allocate demand. The failure of this strategy led ultimately to the invention and diffusion of the deLavaud centrifugal casting machine in the World War I era.

As the industry expanded, pipe founding increasingly became a high tonnage business. "There is no branch of the foundry industry that is so dependent on tonnage for profits," noted contemporaries. One source estimated average pipe foundry output in the 1890s at seventy-five to one hundred tons per pit. In 1890, the largest plant in the country, the new Addyston Pipe and Steel Company at Addyston, Ohio, had five pits and was regarded by *Iron Age* as "the most extensive establishment in the country devoted to the manufacture of cast-iron pipe." In the decades spanning the beginning of the twentieth century, H.A. Croxton suggested, "the required amount which it is necessary to produce to enable the manufacturer to compete on a satisfactory basis has changed from 100 tons per day to 200 tons per day." In the context of a rapidly expanding market, it is not surprising that, by 1907, the newly erected Scottdale, Pennsylvania plant of United States Cast Iron Pipe and Foundry Company (hereafter USCIP&F) had a potential output of 750 tons per day from four casting pits.[20]

Expansion was intensive as well as extensive. Innovations in plant design and the mechanization of some processes permitted manufacturers to increase their output within the pit-casting paradigm. The 187.5 tons per day per pit average output of U.S. Pipe's Scottdale works was possible because plant design optimally located pits and equipment. Pits were linked in tandem to share cranes, electrically-powered rammers replaced hand ramming still prevailing throughout the industry, and core ovens were placed in banks of eight adjacent to each pit. The most significant innovations were the revolving tables, considered "distinct departures from ordinary pipe foundry practice," and the Giles rammer. Developed by David Giles, one of the pipe industry's true innovators, at his Chattanooga Foundry & Pipe Works in 1886, the greatly expanded "revolving

[20] Croxton, "Modern Pipe Founding," p. 146. Engineer Frederick Lewis observed that "A pipe foundry does not realize economy of production through any novel methods of foundry practice. The economy results from the manufacture of a great many pieces which are essentially alike." Lewis, "Cast Iron Water Pipe," p. 19; N.a., "Making Cast-Iron Pipe," p. 787; Robinson, "The Manufacture of Cast-Iron Pipe,"p. 909. The chairman of USCIP&F noted, in 1912, that "(t)he business is essentially one of tonnage, and is highly competitive..." United States Cast Iron Pipe & Foundry Company, "Early History of the Company," Typescript, 1912, p. 4.

pit" moved flasks through various stations--ramming, drying, core setting, and casting--before cranes removed them from the pits and the pipes were released. The diameter of the Scottdale pits was three times as large as those at Chattanooga. The rammer Giles developed could compress sand in two molds at once using a combination of mechanical and electrical means. Other pipe founders employed a variety of techniques to increase output, including rectangular pits, improved cranes, and reduced materials handling.[21]

Innovations improved foundry performance, but only two, the Herbert system at the Coschocton, Ohio plant of James B. Clow & Sons and the redesigned American Cast Iron Pipe Company (ACIPCO) at Birmingham, Alabama, altered the basic design of pipe casting as a series of time consuming, labor intensive, discreet production processes. Developed between 1907 and 1909 by Fred Herbert of Birtley, England, and first installed in its entirety at Cochrane & Company of Middlesbrough, England, Clow & Sons adopted the Herbert system in 1911. Methods at both plants eliminated many flask-handling steps in conventional pipe casting by ramming molds bell-end down, just as they were cast.[22] Two specific innovations at Clow & Sons made this possible: a new molding machine, and a new factory structure that eliminated circular pits and instead circulated flasks attached to trucks on a rail system through the various stages of preparation, casting and shake-out. After shake-out, flasks were pushed over the molding station where dual ramming machines formed two molds simultaneously. As molds traveled along the rails, they were blacked, dried, the cores set and, finally, the iron poured. After cooling, pipes were pulled from molds by chains and crane and dropped horizontally onto rails, from which they passed to the lathe, which cut off the end and turned the bead, the tar coating process, and testing. Flasks continued on the rails to begin the molding process anew. Output of one Herbert pit was thirty pipes per hour, or 600 per day of two ten-hour shifts. At ACIPCO, according to superintendent William Davis Moore, "the large ovens for drying molds were eliminated and the pits redesigned for continuous ramming, drying and casting..." A testament to their continuous operation,

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[21]Robinson, "The Manufacture of Cast-Iron Pipe,"pp. 909-916; Noble, *History,* pp. 70-1; n.a., "The Chattanooga Pipe Factory," *American Machinist*, Aug. 12, 1897, pp. 596-9; n.a., "Modern Pipe Founding," pp. 303-8; n.a., "The American Cast Iron Pipe Company's Foundry," pp. 399-402.

R. Ardelt, a German manufacturer of turntables and ramming machines, claimed that these devices had been in use in Germany at least since 1880. R. Ardelt, "Cast-Iron Pipe Molding," *Iron Age,* May 4, 1911, pp. 1098-1100.

[22]Typically, molds were rammed bell end up to facilitate forming the bell, but the best pipe was cast bell end down, to permit capturing impurities in the spigot end, which then could be trimmed to remove poor quality iron. To cast high quality pipe, the completed mold had to be pulled from the pit, turned end-for-end and reset, although some manufacturers were loathe to invest the time and expense to do so, resulting in pipes weak in the bell end, exactly the place they should be strongest.

ACIPCO and the Clow foundry were the only plants in the United States to operate two ten-hour shifts before the introduction of centrifugal casting.[23]

Although resulting in increased economy, these innovations failed to confer on heir users an advantage sufficient to block the entry of new companies. Representing improvements on past practices and progressively smoothing a discreet process, they nonetheless retained the basic elements of sand-pit casting. The President of U.S. Pipe noted in 1912 that "(t)he present processes or methods though differing in many respects, are essentially of the same general scheme and are comparatively simple and unprotected save as to a few minor patents of questionable value, which may be avoided." Consequently, overall capacity continued expanding well into the twentieth century, making the industry highly competitive. Following the "ten lean years" 1873-83, during which only the Chattanooga plant was constructed in the United States, thirty-six new shops were constructed the following decade, with a notable trend toward the construction of southern plants.[24]

The intense competition and depressed economy of the 1890s encouraged the formation of cartels involving primarily (though not exclusively) southern firms. According to one student of the industry, "(a) recession started in late 1890, and deepened through 1891, 1892 and 1893. Full prosperity was not restored until 1896 or 1897." The first agreement, developed in the early 1890s among four closely located southern firms: Howard-Harrison (Bessemer, Alabama), Anniston Pipe (Anniston, Alabama), D. Giles (Chattanooga, Tennessee), and South Pittsburgh Pipe (South Pittsburgh, Tennessee). The second, known as the Southern Associated Pipe Works, was formalized in December of 1894, and included two additional firms: Addyston Pipe and Steel Company (Addyston, Ohio) and Dennis Long Company (Louisville, Kentucky). Both agreements "reserved to each of the companies the business of the gas and water companies of certain cities," generally those cities lying closest to the factory. In addition, any of the companies could secure bids on work in the region known as "pay territory" ("states and territories west of New York and Pennsylvania and south of Virginia and including the nongas, nonwater company business in the reserved cities"), provided they notified the Association auditor of shipments and paid a bonus into a pool, to be divided among members. Association members would protect each other by

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[23] In contrast, U.S. Pipe's Scottdale plant, with four large turntable pits, turned out 464 12" diameter pipes per pit per day. Robinson, "The Manufacture of Cast-Iron Pipe," p. 910-1; Moore, *History*, p. 29; n.a., "Pipe-Molding Machine and Continuous Pipe Foundry at Coschocton, Ohio," pp. 710-6.

[24]USCIP&F, "Early History of Company," p. 4; Noble, *History*, p. 55; Almarin Phillips, *Market Structure, Organizations, and Performance: An Essay on Price Fixing and Combinations in Restraint of Trade*. (Cambridge: Harvard University Press, 1962), p. 105.

submitting false bids over those of the highest "bidder" at the Association's bid "auction."[25]

The cartel agreements were dissolved in the precedent-setting case of United States v. Addyston Pipe and Steel Company. In 1896, suit was brought against the Southern Associated Pipe Works after a non-cartel member (R.D. Wood of New Jersey) underbid Association member firm Anniston Pipe Works for an Atlanta contract, and an Association secretary made available detailed information on bidding and bonus procedures, in exchange for monetary consideration. Although the Circuit Court of the United States for the Eastern District of Tennessee found for the defendants, the appeals court disagreed, and the Supreme Court affirmed their opinion. Writing for the three-man panel that heard the appeal, Justice Taft argued that the Association arrangement was "void at common law, because in restraint of trade, and tending to a monopoly." The Taft decision established the *per se* rule, in which combinations not otherwise authorized were unlawful *per se*, one of the pivotal interpretations of the Sherman Anti-trust Act.[26]

The United States Cast Iron Pipe and Foundry Company

Even prior to the Supreme Court's affirmation of the appeal dissolving the Association, cartels had given way to oligopoly, transforming the market dynamics for cast-iron pressure pipe. In May, 1898, the four principals in the original cartel (see above) merged to form the American Pipe and Foundry Company. Nine months later, the American joined Addyston, Long and seven other firms to become the United States Cast-iron pipe and Foundry Company. Firms joining U.S. Pipe were widely distributed in close proximity to all major pipe markets: two in Alabama, one in Kentucky, one in New Jersey, one in New York, three in Ohio, one in Pennsylvania and two in Tennessee (the West Superior, Wisconsin plant was never operated, and the Metropolis, Illinois plant was closed within months of acquisition). Moreover, noted one student of the industry, "none of the nine firms with daily capacity of less than 100 tons was involved in the merger." Finally, with the exception of W.D. Wood of New Jersey, the merger brought together the most technologically sophisticated pipe casting operations in the United States, including the Addyston and Giles plants, pioneers in advanced casting arrangements. The high concentration of capacity and favorable geographic location in one firm led economist Almarin Phillips to observe: "The structural characteristics of the market after the formation of United States Cast-iron pipe and Foundry were radically different from those existing previously."[27]

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[25]Phillips, *Market Structure*, p. 105.

[26]Others later questioned Taft's reading of the common law, suggesting that the combinations were perfectly consistent with common law so long as they were "reasonable." Phillips, *Market Structure*, p. 114. See also: Bittlingmayer, "Price-Fixing," pp. 75-85.

[27]Phillips, *Market Structure*, p. 115; Moore, *Development*, p. 38; Davis, pp. 77-8.

But ease of entry, foreign competition, and aging plants and equipment quickly canceled whatever benefits oligopoly bestowed. The new firm enjoyed modest success in its first two years, when it controlled a substantial portion of the market, and again from 1904-6, a boom period of generally high demand. Yet, within a few years, new and larger plants appeared in its competitive areas. In particular, National Cast-iron pipe and American Cast-iron pipe (ACIPCO) were launched in new, modern plants by managers with vast pipe making experience. By 1911, USCIP&F competed against twenty plants owned by sixteen firms with a total tonnage capacity exceeding USCIP&F's. Moreover, soil pipe makers like Central Foundry in Holt, Alabama (near Tuscaloosa) produced a specialty pipe with a "Universal" joint that competed favorably with classical hub & spigot pipe, and American casting in Birmingham made a popular light weight, short culvert pipe that cut into this ancillary market. Independent plants were widely dispersed in all of USCIP&F's major markets: six in the east (four of them quite large); five in the midwest; and several in Birmingham distributing west of the Mississippi and in the South. Foreign competition presented little threat to domestic markets, in part due to protective tariff rates; instead, European pipe makers dominated and foreclosed lucrative and expanding foreign markets. The works of both Stanton and Stavely in England, and Pont-a-Mousson in France, operated with considerable cost benefits stemming from almost complete vertical integration: each owned and operated coal and iron mines, blast furnaces, and by-product coke ovens. Small, inadequate home markets had forced the largest English, French and German pipe makers to seek out export markets in South America, Asia, Africa and Australia, while low shipping rates, established credit linkages, and a common metric system gave them even more leverage.[28]

USCIP&F recognized the poor condition of its plant and equipment as the biggest impediment to its performance. At the time of consolidation, noted the company's president in a detailed address delivered in 1913 to the managers of each facility, some of the firm's plants "were considered as efficient as any then existing...." But, he continued, "most of them had been in existence for many years; all differed more or less in methods, equipment and quality of product; and while improvements and additions have been made, ... plants can hardly be said to have kept pace with the modernizing tendency and development of the past ten to fifteen years." The most egregious practice related to the failure to invest in new machines and equipment. The company had set a standard reserve of ten percent of net earnings for replacement of existing machinery. This amount, noted the report, "had no direct relation to the value of ... buildings and equipment, their probable length of life and usefulness, nor did it comprehend anything like a proper amortization of their value over a stated term." In light of the figures supporting this charge, this was an understatement: in the consolidated company's first thirteen years, it spent an average of $130,600 per year on new equipment at its seven largest plants! Examples underscore the magnitude of the problem: one plant planning to replace a lathe in 1913 noted it was "not less than forty-four years old;" condemned boilers at Bessemer had been in service for twenty-three years "and when installed were second hand." Since depreciation and amortization funds were

[28]USCIP&F, "Early History," pp. 3-13; Bittlingmayer, "Price-Fixing," p. 89.

woefully inadequate, plant managers had to draw on "new improvement" funds to replace essential equipment, further impairing modernization efforts.[29]

The caustic 1913 internal analysis attributed the cause of USCIP&F's failure to perform to "the system itself," fully decentralized operations overseen by omnipotent Resident Managers. "...(P)lants were operated practically as so many separate units, each with a Resident Manager, who was in effect a law unto himself, except in so far as he more or less frequently came under the observation and direction of the Manufacturing Committee, the members of which were located at widely separated points." Many Resident Managers reported directly to no one in authority outside of accounting and sales, and even in the case of accounting, reports from Resident Managers were accepted at face value with no independent verification that costs reported were accurate. Production and engineering problems were worked out at individual plants, and little information was shared among managers, with the result that solutions to problems were invented anew at each factory and experiments were duplicated. Even the Manufacturing Committee neglected to keep minutes of its meetings.[30]

The 1913 report and recommendations represented a watershed in the company's evolution. The detailed analysis of past practices was an integral part of a complete corporate reorganization and plant and equipment modernization. General offices were centralized at the Burlington plant, although the President continued to work out of Burlington and Philadelphia, the Vice-President out of Louisville, Kentucky, and the General Counsel our of Chicago. A Traffic Department was established to determine the most favorable freight rates, a considerable expense in the overall cost of pipe, and new marketing strategies involved a completely rewritten catalog catering to the engineer. A Purchasing Department standardized and centralized the purchase of raw materials, formerly under the direct command of the Resident Manager. A new cost system called for daily and comparative reports from each plant, compiled by the "Department of Works Operating," that gave "a bird's eye view of shop conditions as evidenced by the records of first and second quality and bad castings and causes for rejects...." Results were reported to Resident Managers, with "the friendly rivalry thus engendered (leading) to an improvement in the quality of (the) product and (a lower) percentage of shop loss...." One study of rejections highlighted leaks in the spigot end and "dirty beads," and resulted in a firm-wide change to the European practice of casting all "pipe with risers and cut(ting) off the extension above the bead...." Aggregating the annual cost of hay rope for all plants at $120,000 led to a dedicated research effort for a less expensive alternative. Research was removed from the discretion of the Resident Managers and centralized at Burlington in the "Experimental and Research Bureau," staffed with chemical and metallurgical engineers. Finally, individual works were to be inspected regularly by the President or his

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[29]USCIP&F, "Early History," pp. 15- 22.

[30]USCIP&F, "Early History," pp. 23-25.

appointed assistant.[31]

Labor problems plagued the company, and it grappled with a host of corporate welfare solutions. During 1912, shortages of skilled workers resulted in "shut-downs of a very material percentage of...capacity." Pipe-making competed against jobs in other industries where wages had been steadily rising. Moreover, the report lamented the increasingly transitory character of employment in the pipe works. "No longer do you have a large percentage of your men steadily in your employ, and there are few instances, compared with the many in shops abroad, England especially, where jobs pass from father to son." To attract "the better class of men," the company looked at the broad range of corporate welfare measures then gaining currency among larger employers: insurance, home outreach, sanitary working conditions, and wage and incentive plans. But any attempt to improve working conditions was subject to the bottom line: "No thought of paternalism is permissible, nor can it be in any sense a matter of charity. Rather must the basis be economic - 'for the good of the Company.' The uplift of employees is merely a secondary or natural sequence."[32]

Engineering practices were designated for a complete overhaul. The Engineering Department, established in the spring of 1912, surveyed plant conditions company-wide and discovered a range of problems in support functions critical to efficient operation. Engineering drawings "lacked uniformity in almost every direction; size, scale, treatment, etc." Collecting, indexing and classifying approximately 7500 drawings at Burlington, the Engineering Department established standard dimensions and scales for all future drawings. More importantly, the department was now in a position to compare and contrast manufacturing methods at various shops "in the light of carefully analyzed step by step process costs..." Property maps were in a similar state of disarray from plant to plant, and the department undertook title searches and obtained copies of deeds and easements to accurately plot a uniform set of maps to provide "a comparative value in the study of plant layouts. After gathering and analyzing data on power plants, motors, cranes and other support equipment, the department established a system to record daily "coal used, water evaporated, steam pressure, and temperature of feed water, etc....(to) make it possible to locate weak spots and correct them." Other support activities were also scrutinized, such as machine shops and supply houses. Pattern storage was discovered to be particularly inefficient, with patterns "stored in almost indescribable confusion and in places where apparently it is sometimes cheaper to make a new pattern than hunt for an old one." In addition, the Engineering Department directly supervised major construction and development at the various plants: the new pipe shop and crane reconstruction at Birmingham, new boilers at Addyston and Bessemer, a new compressed air plant for operating rammers and pneumatic core cutters, and a 700 feet bulkhead at Burlington, a remodeled railroad track, press house addition for the eighty-four inch

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[31]USCIP&F, "Early History," pp. 26-34.

[32]USCIP&F, "Early History," pp. 68-9.

hydraulic press, and a laboratory at Scottdale, and "timetabling shop operations at Birmingham and Bessemer..."[33]

A detailed survey of existing manufacturing facilities suggested reducing the number of plants and expanding and consolidating operations. By modernizing Bessemer and further expanding the recently acquired Birmingham plant, USCIP&F could approximate the 200,000 tons combined annual output of its four principal southern shops (Anniston, Bessemer, Chattanooga and Birmingham). In addition to Bessemer's coke ovens, the Birmingham and Bessemer plants were slated to share a Resident Manager and centralized supervising and accounting operations; on the other hand, Anniston was currently considered one of the company's most efficient facilities. The projected savings of $70,000 per year would permit the expenditure of $700,000 (amortized over ten years) on the enlargement and modernization of Bessemer and Birmingham. Plants at Cleveland, Ohio, Buffalo, New York, and Louisville, Kentucky were considered obsolete and the report recommended they be abandoned, as had the Superior, Wisconsin plant. The Burlington, New Jersey factory was recommended for enlargement and modernization "to meet the keenest competition" as the firm's only east coast plant." In the years immediately following the report, pipe casting facilities at Bessemer were completely modernized. Two original stationary casting pits, used for diameters from four to twelve inches, were replaced by Giles turntables measuring fifty feet in diameter and casting pipe in sixteen as well as the more traditional twelve feet lengths. The pits used both Giles and Burlington rammers. This would be the last modernization Bessemer would undergo until the installation in 1934 of the deLavaud casting machines.[34]

Like officials at USCIP&F, early twentieth century pipe founders throughout the industry were aware that plant modernization led to increased profits. Consequently, pit casting underwent a spate of technological innovation and plant redesign in the years just prior to World War I. Most companies converted to gas, either natural or coal, to fire larger ovens for curing molds and cores. Automatic mold rammers and sand conditioning equipment became commonplace, as foundries became larger and iron tonnages grew. The replacement of traditional pits with turntables and other flask-handling configurations represented the most significant change in production technique and brought the flask-mold-core process, inherently a batch operation, very close to continuous production; yet, pit-casting remained fundamentally a discrete process encumbered by delays at a variety of points.

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[33]USCIP&F, "Early History," pp. 35-8.

[34]USCIP&F, "Early History," pp. 47-65; Moore, *Development*, p. 39. The most radical modernization proposal required four years, up to $3,500,000, and the construction of a massive new works on the Great Lakes, with the consequent shrinkage of the company to "five or six large units so modernized and effective as to be able to meet any competitive conditions. The Great Lakes plant was never built.

Centrifugal Casting: Pipe Making Becomes Continuous

Refinements in pit casting practices took place as innovators sought other methods of casting iron pipe. The economics of pipe production drove much of the innovative activity. Demand came in the form of large orders from municipal water and gas companies, and tended to fluctuate with economic cycles. Sand-pit casting offered little or no flexibility to meet swings in demand; one could not run a partial pit profitably, since costs for melting, labor, fuel and utilities remained fixed. Inventories were expensive, especially in the short run. Economies of scale offered some advantages, but transportation costs were a significant part of the cost of pipe, suggesting a premium on plants dispersed near large markets and reducing the advantages of large plants that could capture the economic benefits of large-scale output. The inefficiencies of pit-casting led to other technologies, particularly centrifugal casting, described in 1924 as a technology that "revolutionizes the whole system of pipe manufacture, and permits of the introduction of labor-saving devices, at the same time improving most considerably the conditions under which the worker can operate." Moreover, it significantly enhanced pipe quality. USCIP&F's research engineer, John Capron, readily acknowledged the economic impetus to the new technology: "(t)he deLavaud process was developed essentially to give a method of economically casting pipe of uniform section.[35] It is of little surprise, then, that parallel centrifugal casting methods emerged once the basic idea had been proven feasible.

Since the early nineteenth century, centrifugal casting had been considered a possible, even likely technology, particularly for high-tonnage, straight-design products. John Capron believed in 1927 that "(t)he nineteenth century closed with most of the elemental research on centrifugal casting completed." Thorough patent research and analysis led Howard Taylor, an Associate Professor of Metallurgy at MIT and Charles Register of the Army's Ordnance Department, to a similar conclusion in their comprehensive *Bibliography of Centrifugal Casting*: "(t)he basic features of the art were clearly covered by patents prior to the twentieth century." They listed twenty-nine patents for centrifugal casting issued before 1900, and a total of forty prior to the first centrifugal cast pipe patent issued Dimitri S. deLavaud and Fernando Arens in 1916. English patents for centrifugally casting "hollow bodies" date to 1809, while the first issued in the United States for pipe cast in this manner was granted to Thomas Lovegrove in 1848. The earliest centrifugal casting patents were little more than intuitively logical ideas set to paper, with no successful factory trials; it was not until the second half of the nineteenth century that inventors succeeded in centrifugally casting metal products. The first items produced by this method were either small or non-ferrous. In 1873, lead sheets cast horizontally as tubes and then split and flattened were highly regarded for their "uniformity in thickness and freedom from defects." Less than ten years later, "sound, clean" locomotive drive wheels were cast by F.W. Webb of Crewe, England. In

[35]E.J. Fox and P.H. Wilson, "Modern Methods of Pipe Manufacture by the Centrifugal Process," *Foundry Trade Journal* (August 14, 1924), p. 131; John D. Capron, "Reviews Progress in Centrifugal Casting," *Foundry* (July 15, 1927), p. 565.

Sweden, J.L. Sebenius succeeded in eliminating blow holes from small steel ingots by rotating molds on a yoke attached to a revolving hub. Clearly, the high quality of objects produced by centrifugal casting encouraged inventors throughout the nineteenth century.[36]

"Design, as well as the huge tonnages of pipe required in normal times," Taylor and Register observed, " make it ideally suited to centrifugal casting methods and it is natural that the art should be developed around this product." Many of the elementary mechanical problems of centrifugally casting "heavy ferrous castings on a large scale" were worked out in the design of machines for the manufacture of pipe, including the type and temperature of the mold, the delivery of the metal, the method of mold rotation, and the axis of rotation.[37]

DeLavaud began his experiments with a fellow engineer, but after branching off on his own had little trouble interesting a variety of pipe makers who transformed his rudimentary machinery into an efficient process. The initial patents for the centrifugal casting machine were in the name of D.S. deLavaud and F. Arens, associates who had worked on the invention in Brazil. Soon after, the two parted company, and subsequent patents are in deLavaud's name only, including all major patents taken from 1916 through 1922, in which deLavaud refined most aspects of his and Arens' innovation. By 1917, deLavaud sought to introduce the machine in the United States, and had a prototype built at Buffalo, NY. He interested only the Canadian firm National Iron Works, Limited, of Toronto, which began production immediately. The Centrifugal Cast-iron pipe Company and the International deLavaud Mfg, Corp., Ltd, were soon organized, and by 1919 Latin American interests were controlled by the Companhia Braziliera de Metallurgia, at Sao Paolo, which had installed a bank of twenty machines in its plant there. "Until the latter part of 1922," USCIP&F research engineer S.B. Clark recalled, "deLavaud pipe had been produced on a relatively small commercial scale. Previous to this time, the process was in a state of rapid change. The casting machine originally brought to the United States by deLavaud in 1916 had been so modified as to be scarcely recognizable."[38]

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[36]Howard P. Taylor and Charles L Register, *Bibliography of Centrifugal Casting*. (Chicago: American Foundrymen's Society, 1949), pp. 1-15; Capron, "Reviews Progress," p. 565.

[37]Taylor and Register, *Bibliography,* pp. 1-15; Capron, "Reviews Progress, p. 565.

[38]Constrained by deLavaud's patent on the water jacket, Arens was forced to develop his water-cooled patent using a continuous spray. This produced hot spots unless the mold were kept spinning, even during pipe extraction, scoring the pipe's outer surface and unduly wearing the mold. Riley, "Cast-Iron Pipe," pp. 15-18; n.a., "Centrifugally Cast Pipe in South America." *Iron Age* (September 25, 1919); John D. Capron, "The Centrifugal Casting Process," *The Blast Furnace and Steel Plant*, (August, 1927), pp. 378-9; Capron, "Reviews Progress," pp. 564-568; S.B. Clark, "Cast-Iron Pipe Produced Centrifugally by the deLavaud Process." (Typescript of

By the time USCIP&F purchased the American rights to the deLavaud process in 1921, the basic operation of the system had been established. A predetermined amount of iron, enough for one pipe, was delivered at a constant rate into a rapidly revolving steel mold via a refractory-lined pouring basin or ladle, and trough. A head core and plug were placed into the hub end of the mold to form the larger-diameter hub and block the flow of iron out of the mold. (At this point, after 1934, the mold was coated with a slurry, a process discussed below in relation to super-deLavaud pipe.) The deLavaud "machine," as it is still called, was a cylindrical steel mold, slightly inclined to the horizontal, revolving on rollers within a water jacket. In one configuration, the ladle and trough were stationary and the machine traversed steel rails, covering the trough in the upstroke, as a finished pipe was being extracted, and receiving the iron for the next pipe in the downstroke. As soon as sufficient metal was deposited to form the bell, the machine was retracted at a constant speed to its initial casting position. In a second configuration, the machine remained in place while the trough and pouring ladle traveled the length of the mold, the flow of iron was commenced, and the trough and ladle were slowly retracted, forming the pipe as they withdrew. The pipe was then extracted and the process repeated. The second configuration was less continuous; currently, it us used for pipes of the largest diameter.

In his initial experimentation with centrifugal casting, deLavaud focused on the mold, which he believed caused the failure of earlier efforts. He quickly abandoned heated molds when it was found impossible to withdraw pipe until it had contracted sufficiently, at least three minutes. After trying various temperatures, he settled on a cold steel rotary mold, which permitted almost immediate pipe withdrawal. (According to Capron, deLavaud "had to pour the pipe himself as his foundrymen were afraid of the action of the hot metal on the cold mold.") Experimentation with alloys at USCIP&F greatly extended mold life. In 1923, molds were forged from nickel-chromium alloy and averaged approximately 1,000 pipes per six-inch mold; by the 1930s, they were forged from heat-treated, machined chrome-molybdenum steel and lasted for 3,000 pipes. A technique pioneered by chief of research Dr. F.C. Langenberg while stationed at Watertown Arsenal, a center of experimentation in centrifugal casting, reclaimed molds in which the bore had deteriorated through fire checks and cracks. The mold was placed on a mandrel and squeezed under water pressure as high as 50,000 pounds per square inch, returning it to the required inside diameter, after which it was machined and returned to service; the process could be repeated several times. This process stretched the active life of the mold, one of the most expensive items in the pipe shop.[39]

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address presented at the annual meeting of the American Society of Mechanical Engineers, Birmingham, Alabama, April 20-23, 1931), p. 3.

[39]Foundryman Edgar Custer, in a paper read before the Franklin Institute in Philadelphia in 1908, articulated the fervent interest of the foundry industry in finding a replacement for the disposable sand mold: "It has been the dream of every foundryman whose trade requires a large number of duplicate castings to make these castings in molds that would not only survive the

The mold and the iron delivery system were integrally related. One of the chief impediments to the centrifugal casting of long shapes was rapid cooling of the iron and its failure to distribute itself symmetrically along the length of the mold. Finally settling on a long, steel, refractory-lined, water-cooled pouring trough, within a few years deLavaud had perfected "a retractable pouring arrangement with end discharge." This was a critical integration of parts of the machine, noted R.V. Riley, research manager for the Stavely Iron and Chemical Company, Limited, the second largest British pipe maker. "The pouring spout ceased to be a static element but formed part of a pipe mould and pouring system having relative movement in a longitudinal direction." By this time (1918), deLavaud had moved the mold over the trough, developed a way to clean the pouring trough, repair the refractory lining, slowly withdraw the pipe, cool the mold, and distribute the metal in a water-cooled trough. Iron was delivered to the trough from a tilted ladle at a synchronized rate, facilitating the even distribution of the metal and uniform wall thickness. Finally, the trough was changed to a steel runner covered with cast iron "U" blocks coated with a ceramic material, especially important in the casting of small diameter pipe, and the machine was set on a slight incline to facilitate welding of subsequent spirals of molten iron.[40]

The power source shifted from hydraulic to direct drive. Power to rotate the mold was initially provided by a Pelton water wheel, with the water supply ingeniously carried by telescoping pipe through the center of the ram driving the machine forward and back. Still a common motive force, hydraulic power was more expensive than comparable power sources increasingly becoming available. More significantly, it lacked the control required to coordinate the precise movement and positioning of the various moving parts. Misalignment of the mold on its rollers, a common but difficult to correct phenomenon, necessitated constant compensating adjustment of the nozzle-intake valve, a duty unsuited to the Pelton wheel. After experiments with rope, belt and chain drives, researchers settled on a "direct-gear drive." Forged of steel and micarta, S.B. Clark, research engineer at USCIP&F, claimed that "these gears operate quietly at pitch-line speeds as high as 3500 ft. per min. and despite the fact that they are continually surrounded by vapor and steam, the average life is high. A direct current motor powered the direct drive.[41]

In at least one way, pipe produced by centrifugal casting appeared to hold no advantage over the traditional sand-pit method, and required additional equipment and treatment. Casting deLavaud pipe in a water-cooled mold and withdrawing it immediately imparted a chill to the exterior of the

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process but would also produce castings not only marketable but easily machined." Reprinted in "Casting Pipes in Permanent Molds," *Iron Age* (April 16, 1908), p. 1227; Clark, "Cast Iron," pp. 4-5.

[40]Riley, "Cast-Iron Pressure Pipe," pp. 15-17.

[41]Riley, "Cast-Iron," p. 15; Clark, "Cast-Iron Produced Centrifugally by the deLavaud Process," p. 4.

pipe, making it brittle and laced with casting strains. Annealing removed these flaws. Sand-pit cast pipe soaked in its mold for up to three hours, a process akin to annealing, removing strains and producing a pipe ready for testing, coating and shipping. Yet, here, too, the additional annealing process helped make deLavaud pipe more desirable. Common complaints among pipe buyers underscored the occurrence of hairline breaks in otherwise perfect metal, an indication of inherent strains. Annealing reduced strains and tensions in the metal, increasing its uniformity and stability.[42]

Annealing thus accompanied centrifugal casting into the pipe shop, becoming an integral part of the process and yielding an even better quality pipe. Annealing furnaces were new to pipe manufacture and underwent a considerable period of trial and development. The earliest ovens at USCIP&F were oil-fired, of limited capacity, (capable of treating five six-inch or three twelve-inch pipes at one time), made placement and removal of pipe difficult, had poor heat control, and were expensive to operate. Used extensively in Canada, only a prototype was built at Burlington before a new design was selected, a worm-shaft-driven, cam-type "continuous-wheel-conveyor" that moved the pipes slowly through the oven. The tendency of this conveying mechanism to warp small-diameter pipe led to the development of much longer, chain-drive, parallel-skid ovens that dropped temperatures slowly. With this installation, oven length had increased from fifteen feet to thirty-five feet and then to fifty-five feet; later in 1931 they were to increase to seventy-five feet in length and eighteen feet in width. Temperatures were originally regulated by hand, but a "system of automatic temperature control" was soon installed, resulting "in vastly improved conditions, and the trouble originally and frequently encountered due to under or overheated pipe was practically eliminated."[43]

In centrifugal casting, pipes are withdrawn red-hot from the water-cooled molds and immediately annealed. They enter the annealing furnace at approximately 1100 degrees F. and move through three zones--heating, soaking and cooling. Annealing structurally transforms the iron in two ways: In the heating zone, the temperature is raised from 1100 degrees F. to approximately 1720 degrees F., removing pearlite from the iron. Proceeding to the soaking zone, pipes remain at approximately 1700 degrees F. for a measured period to remove free carbide retained in the casting in its as-cast condition, and which tends to reduce ductility. In the cooling zone, the temperature is reduced in stages: pipes are force cooling to 1350 degrees F. and then slowly to 1280 degrees F.

Under the control of USCIP&F, machine modification and development proceeded rapidly, and output levels grew dramatically. When the company first acquired exclusive American rights to

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[42]Underwriters' Laboratories, *Report on deLavaud Cast-Iron Underground Water Pipe* (Chicago, IL: Extinguisher No 758, June 12, 1923), pp. 11-2.

[43]Clark, "Cast-Iron Produced Centrifugally by the deLavaud Process," pp. 6-7.

license and distribute the process, a six-inch deLavaud machine producing up to fifteen pipes per hour "was considered to be operating satisfactorily;" by 1926 that quantity had almost tripled to forty pipes per hour, in tonnage terms a figure equal to "the largest single-pit cast installation." At the same time, increases in pipe diameter reflected the company's growing sophistication with the technology. A machine capable of producing pipe fourteen to twenty inches in diameter was in use, and in 1928 machines capable of making pipe in lengths of eighteen feet were installed.[44]

USCIP&F's engineers early on recognized that "the force under which deLavaud pipes are cast, as well as the action of the cold mold and subsequent annealing, improves the physical properties and microstructure of the iron to a marked degree." Centrifugal force formed a much denser and stronger iron in which the carbon was distributed evenly throughout the pipe and silicon and phosphorous were low. In 1927, just three years after his company, USCIP&F, had installed the process at its Burlington plant, Capron argued that centrifugal casting at least doubled the strength of the iron, an opinion shared by Professor Peter Gillespie of the University of Toronto, who claimed that "the strength in tension and cross-bending, the resistance to shock and the stiffness are about twice as great for machine made iron as for the sand cast product." Metallurgists at the Stanton Company in England found superior performance by centrifugally cast pipe in extensive tests of bursting pressure, tensile tons, external pressure, breaking load, deflection at center, and modulus of rupture. The high tensile strength of centrifugally cast pipe, the result of successively welding together layer after layer of molten iron, resulted in thinner and lighter, yet stronger pipe. Moreover, the tensile strength of deLavaud pipe was uniform, unlike sand-pit cast pipe where cooling rates varied from mold to mold. On average, deLavaud pipe was estimated to be about twenty-five percent lighter than sand-pit cast pipe. This was reflected in revisions of pipe standards of the American Water Works Association, which had written its original standards to excess thickness to account for variations in pipe thickness characteristic of sand-pit cast pipe, but which could now be refined in light of the uniformity of deLavaud pipe. After tests conducted in 1923 at the request of USCIP&F, Underwriters' Laboratories endorsed pipe cast centrifugally by the deLavaud process for its practicability, durability, strength, reliability in service, and uniformity.[45]

By the late 1920s, both the industry and municipal water works engineers had embraced centrifugally-cast pipe. In 1926, centrifugally-cast pipe accounted for only 200,000 tons, or

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[44]Clark, "Cast-Iron Produced Centrifugally by the deLavaud Process," p. 3.

[45]John D. Capron, "The Centrifugal Casting Process," *The Blast Furnace and Steel Plant*, (August, 1927), p. 379; J.E. Hurst, "Some Notes on the Development of the Centrifugal Casting Process in Great Britain and Europe," (Need citation); Peter Gillespie, "Casting Pipe without a Core," *Gas Age Record*, Dec. 23, 1922;. Fox and Wilson, "Modern Methods," p. 137; Underwriters' Laboratories, *Report on deLavaud Cast-Iron Underground Water Pipe*. (Chicago, IL: Extinguisher No 758, June 12, 1923), pp. 51-7.

approximately 13%, of the 1.5 million tons of iron pipe produced; by 1929, that figure was approximately 400,000 tons, or 39%, of the 1.3 million tons turned out. More significantly, the percentage of centrifugally-cast pipe had been rapidly rising even as total pipe consumption had been falling.[46]

Despite its many favorable characteristics, deLavaud pipe had limited resistance to impact, an artifact of the chill imparted to the pipe by the rapid cooling of the iron against the cooled steel mold. The iron in deLavaud pipe had the high density characteristic of centrifugally-cast pipe, but possessed a more brittle structure in the outer half of the pipe wall. Under normal conditions of use in the field, this was of little consequence to end-users; it was the damage resulting from poor handling in delivery and laying, damage for which the pipe company was often responsible, that prompted the search for a remedy. Underwriters' Laboratories observed field breakage during unloading, but rationalized the breakage: "...it is extremely questionable as to whether or not any cast-iron pipe could withstand the same usage without failure." Nonetheless, USCIP&F considered it a serious drawback and established a research department in 1930, at the beginning of the depression, to study the problem and design a solution.[47]

Company engineers identified the source of the problem as the point of contact between iron and mold, where a condition known as "chill" was imparted to the pipe, and the remedy became the first project of the company's newly established research laboratories. After intensive experimentation, Dr. F.S. Langenberg and others at the Burlington laboratories determined that a small amount (just eight ounces for a ten-inch diameter pipe eighteen feet in length) of a finely-powdered ferro-alloy, distributed evenly over the inside of the mold, would prevent the development of the crystalline structure behind the brittleness of the pipe. Applied just ahead of the iron through a nozzle at the end of the trough, and held in place by centrifugal force, the ferro-alloy absorbed "a small amount of gas (air in this case, but other inert gases serve as well) which is tremendously expanded when the molten iron strikes." This created a cushion acting as an insulator between pipe and mold, preventing chilling of the pipe surface. The result was an iron structure throughout the pipe that is tree-like in appearance. Not only did it harden the pipe to impact, but it dramatically increased ductility. In combination with a new annealing process introduced at the same time that reduced reheating temperatures but prolonged exposure, Super-deLavaud pipe was claimed to be sixty-two percent more ductile, one hundred percent more shock proof, and "considerably more amenable to drilling, threading and machining." The company delayed announcing the modifications to the process for over a year, during which it secured patents and evaluated the responses of water works engineers superintendents, who

[46]N.a., "Centrifugal Pipe Increasingly Used," *The Iron Age*, January 9, 1930.

[47]Underwriters' Laboratories, *Report*, p. 51.

received Super-deLavaud favorably.[48]

Despite the 1924 prediction of Leon Cammen, a prominent pipe engineer that, with USCIP&F's adoption of centrifugal casting "on a big scale...it would not be an exaggeration to say that sand-cast cast-iron pipe is doomed," it was more than three decades before the company that held exclusive U.S. patent and distribution rights to the deLavaud process completely abandoned the pit casting process. USCIP&F had adopted centrifugal casting slowly, installing it first in its Burlington plant, and then in Birmingham. Not until 1934 did the company begin to cast pipe centrifugally at Bessemer, when it replaced a turntable pit, originally built in 1915 to cast four- and six-inch diameter pipe in twelve-feet lengths, with four centrifugal casters making eighteen feet pipe in diameters from four to twelve inches, and a fifth making fourteen to twenty-four inch diameters. Reflecting the superior quality of Super deLavaud pipe, Bessemer produced it as soon as the machines were ready, bypassing the first generation of deLavaud pipe. The Bessemer plant continued to produce sand-pit cast pipe until the late 1950s, and contained the richest mix of pipe making technologies among the company's six plants. Along with the deLavaud machines, Bessemer retained its two traditional sand-pit casting and one turntable operation.[49]

Centrifugal casting had proven its utility and superiority, but extensive patenting, particularly of the "permanent" metal mold, by deLavaud, USCIP&F, and other licensees, as well as some of the short comings of early deLavaud pipe itself, encouraged other pipe makers to experiment with variations of the centrifugal process. Almost all were some variation on a metal mold lined with sand. Arens himself, after splitting from deLavaud, continued to develop centrifugal pipe technologies, substituting a "closed, lined casting pipe" for the permanent mold, and a bottom-plug ladle for the trough. In Italy, Possenti and Scorza developed a green sand mold process in the mid-1920s that was soon installed in plants in Italy, Spain, France, Germany, Belgium, Holland, Brazil and Argentina. R.D. Wood and Company, one of the oldest American pipe firms, licensed its sand-lined, iron mold process through its Sand Spun Corporation of New York to some of the largest firms in the industry, including the Stavely Coal and Iron Company of

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[48]N.a., "What is Super-DeLavaud Pipe," *Water Works and Sewerage*, February, 1934, p. ; United States Pipe and Foundry Company, *Super-DeLavaud Cast-iron pipe*. (Burlington, NJ, 1935).

[49]N.a., "Improved Gray Iron Structure without Chill Obtained in Centrifugally Cast Pipe," *Iron Age*, February 8, 1934, p. 29.

Available evidence does not suggest why U.S. Pipe continued producing sand pit cast pipe at Bessemer even after it had installed deLavaud machines. Production statistics are not available for individual pits and machines, but one hypothesis is that pits were retained for the largest pipe diameters, for which steel alloy molds would have been very costly and machine production rates slow.

England.[50]

William Davis Moore, engineer and later president of American Cast-iron pipe Company (ACIPCO), was responsible for much of the research and development of the principal alternatives to deLavaud centrifugal casting. In 1922, two years before he was elected president, Moore began work on a sand-lined mold, centrifugal casting process, and experimented intensely with the equipment and underlying principles over the next three years. According to Moore, in 1926 the company set up the "No. 1 Mono-Cast Shop...consisting of twelve machines for making pipe in sizes 3-inch through 12-inch in 16-foot lengths. This was a completely mechanized shop with a capacity of two 6-inch pipe per minute, and was built for a 24 hour casting operation, which was an accomplished fact by the end of 1927." With construction of the No. 2 shop in 1930, the pit cast era at ACIPCO ended.[51]

Unlike the deLavaud process, Mono-Casting required the careful preparation of a disposable mold for each pipe cast, as had sand-pit casting.[52] Pipes were cast in individual flasks sent directly to the ramming station from the casting machines. Flasks were tipped vertical and lowered on ramming stools in groups of three, where patterns were inserted, centered and the ramming process begun. Sand was delivered through chutes and rammed into flasks in layers 3-1/2 inches deep and approximately two inches wide by pneumatic rammers delivering 600 strokes per minute under pressure of approximately 100 psi; ramming time was approximately ninety seconds per mold. Sand distribution had to be perfectly symmetrical so as to produce a concentric mold. Patterns were withdrawn as they were placed, in groups of three; flasks and molds were raised from the stools; and blacking was applied before flasks and molds were laid horizontally and moved onto the "skin-drying" run. Flasks and molds moved along the drying run past gas torches

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[50]Giuseppe Guerrini, "Improve Process for Casting Pipe Centrifugally in Green Sand Molds," *The Foundry,* (Oct. 15, 1928), pp. 832-835; Carl Pardun, "Innovations in Centrifugal Casting," *The Foundry Trade Journal,* (Aug. 27, 1925), pp. 175-6; n.a., "The Manufacture of Sand-Spun Pipes," *Engineering,* (July 24, 1931), pp. 93-8.

[51]Moore, *Development,* pp. 31-2.

[52]This and the following paragraph are based on N.a., "Centrifugal Pipe from Sand Molds," *The Iron Age,* (April 15, 1926), pp. 1055-1060; K.R. Daniel, "Centrifugal Casting of Pipe in Sand-Lined Molds," *Mechanical Engineering,* (August, 1951), pp. 644-8; n.a., "Sand-Spun Cast-Iron Pipe Manufacture," *The Foundry Trade Journal,* (July 15, 1926), pp. 45-52; n.a., "Now Cast Pipe Centrifugally in Sand Molds," *Canadian Machinery and Manufacturing News,* (March 21, 1929), pp. 39-43; Pat Dwyer, "Casts Pipe Centrifugally in Sand Molds," *The Foundry,* (July 1, 1930), pp. 98-102; n.a., "Manufacture of Centrifugally Cast Iron pipe," *Industrial Heating,* (June, 1951), pp. 1008-1022; n.a., "Centrifugal Pipe by a New Process," *Iron Age,* (June 5, 1924), p. 1660.

for approximately four minutes, drying the molds to a depth between 1/8 and 3/16 inch. The bell core and end plate were then positioned and completed flasks delivered to the casting machines in pairs.

The use of flasks and molds carried the differences between the two processes into the casting operation. At the casting machines, flasks rolled into the open top, which was then closed; a detachable clutch joined the motor and flask, and iron was poured into the ladle. Once the top was closed and the machine inclined slightly, the flask/mold was spun and the iron poured into the mold. When the proper amount of iron was deposited into the mold and the casting had set sufficiently to retain its shape, the machine was shut down and the finished pipe rolled out. The end plate and remnants of the bell core were removed and the pipe was then stripped from the flask before entering a cooling oven. Casting, stripping and cooling took approximately fifty minutes per pipe. Pipes were then coated, lined and tested.

Pipes cast centrifugally in sand-lined molds, as well as the process itself, compared both favorably and unfavorably with deLavaud pipes and process. Iron flasks were much cheaper than alloy steel molds and tended to wear better because they never came into contact with molten iron. Annealing was unnecessary since the iron was never chilled and dissipated its heat slowly. Pipes were formed in one unit, including the bead, as they had been in the sand pit casting process, and could be produced in varying thicknesses, depending on the thickness of the sand mold. On the other hand, sand molds had to be made for each pipe, and prolonged spinning and solidification period produced "a large deposit of mixed crystals, lighter alloy elements and impurities on the inside," requiring grinding or coating to eliminate.[53]

That all new processes developed in the 1920s and 1930s began from the premise of centrifugal casting attests to its overwhelming appeal. More than a maximum yield, centrifugal casting provided a pipe of unsurpassed quality, particularly when annealed, in the case of deLavaud. The development of Super-deLavaud enhanced those positive characteristics, giving the industry a light pipe of unprecedented strength and ductility. The development of ductile iron in the late 1940s (a subject not covered in this report) and its application to pipe in the deLavaud process enhanced the superiority of the process. By the 1980s, all centrifugal casting was by deLavaud machines.

Conclusion

The evolution of iron pipe casting technologies in the nineteenth and twentieth centuries responded to the urban demand for more and better pipe. Until the mid-nineteenth century, pipe casting differed little from the traditional foundry practices from which it had evolved. Growing demand plus the great expense in replacing poor quality pipe once it was in the ground led to the

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[53]Pardun, "Innovations," p. 175; Wood, "Sandspun," pp. 85-6

development of vertical casting techniques in the 1850s, which persisted in one form or another for over a century. Issues of quality and quantity continued to influence innovations in technique throughout the period. New England water engineers, in conjunction with manufacturers, developed and codified pipe standards that established minimum acceptable pipe quality and defined practices applicable to all manufacturers. For pipe makers, the new standards made the pipe of one manufacturer interchangeable with that of another (absent proprietary joints, of course), which permitted greater flexibility in bidding jobs and potentially a greater customer base; the standards also spread practices (and their attendant costs) designed to achieve good quality pipe to all pipe-makers.

The Howard-Harrison Iron Company plant at Bessemer was built in 1888 to take advantage of the swelling demand for pipe and the richly endowed natural resource base of the Birmingham area. Constructed in standard pipe-foundry fashion with four traditional casting pits, the radical economic swings of the 1890s drove the firm into the United States Cast Iron Pipe & Foundry Company, newly formed in 1899. Specific conditions characteristic of the iron pipe industry, exacerbated by poor management policies, canceled many of the potential benefits oligopoly could have bestowed on the firm. Modernized in the World War I era, the plant's steady pipe output throughout the 1920s, as other USCIP&F facilities devoted large parts of their productive resources to the new, yet far from perfect, centrifugal casting process, helped the company remain profitable as it developed the new technology. USCIP&F's exclusive control of the deLavaud patent in the massive North American market, and the company's ability to divert financial and scientific resources to the machine process' development, facilitated the success of the new technology and the company's market dominance.

That centrifugal casting should become the technology that shifted pipe making from a discrete to a continuous process was only partly a function of USCIP&F's role in its development. Long considered a viable process, it was especially adaptable for products where simplicity and uniformity in shape and large tonnage production were primary concerns. Technological difficulties presented some obstacles, and it was only when deLavaud himself violated conventional foundry wisdom by pouring hot metal into a water-chilled mold, that centrifugal casting of iron pipe became a reality. Centrifugal casting was, indeed, the path of escape from the grip of the casting pit; but the success of the American Cast Iron Pipe Company with its sand-spun "Mono-Cast" process, and that of European producers with other variations, suggests that deLavaud found one of several ways to implement the centrifugal technology.

If quality and quantity were the driving impulses in the development of the cast iron pipe industry in the nineteenth century, deLavaud technology delivered both in rich proportions in the twentieth. Centrifugal casting transformed pipe making from a discrete to a continuous process, increasing resource throughput and generating maximum returns on fixed investments. But the process carried a hidden benefit: deLavaud pipe is stronger and lighter than pit cast pipe and, when made of ductile iron introduced in the late 1940s, yielded a product that fulfilled the increasingly rigid demands of water works engineers. Whether deLavaud pipe can maintain its markets against the growing popularity of PCV pipe will be the next question.

Bibliography

A note on sources: No comprehensive history of the cast-iron pipe industry exists, nor is the industry treated to any great extent in the standard foundry reference texts. Consequently, this history has been assembled using a variety of sources, but primarily contemporary journal articles and technical literature published by various pipe companies. For additional historical references, see the *Bibliography* by Taylor and Register listed below.

Alabama Department of Industrial Relations, *The Iron and Steel Industry in Alabama* (Montgomery, AL: Alabama Department of Industrial Relations, 1950).

American Cast Iron Pipe Company. *A Picture Trip Through ACIPCO* (Birmingham, AL: American Cast Iron Pipe Company, n.d.).

American Cast Iron Pipe Company. *Monoloy Cast Iron Pipe* (Birmingham, AL: American Cast Iron Pipe Company, n.d.).

American Cast Iron Pipe Company. *On the Job with Large-Diameter Mono-Cast Centrifugal Pipe* (Birmingham, AL: American Cast Iron Pipe Company, n.d.).

American Cast Iron Pipe Company. *Pipe Progress* (Birmingham, AL: American Cast Iron Pipe Company, 1915ff).

American Cast Iron Pipe Research Association. *Cast Iron Pipe News* (Chicago, IL: 1935ff).

American Standards Association (ASA). *American Standard Specification for Cast Iron Pipe Centrifugally cast in Metal Molds for Water and Other Liquids* (np, A21 Sectional Committee, 1961).

American Water Works Association. *Standard Specifications for Cast Iron Water Pipe and Special Castings* (n.p., 1908).

American Water Works Association, "Symposium on Cement Lined Water Mains." (Unpub. Proceedings, Wednesday, June 14, 1933), pp. 1-49.

Ardelt, R. "Cast-Iron Pipe Molding." *Iron Age* (May 4, 1911), pp. 1098-1100.

Bittlingmayer, George. "Competition and the Nature of Costs: The Cast Irron Pipe Industry, 1890-1910." (Unpub. Ph.D. Diss., University of Chicago, 1981).

Bittlingmayer, George. "Decreasing Average Cost and Competition: A New Look at the Addyston Pipe Case, *Journal of Law & Economics* (Oct. 1982), pp. 201-227.

Bittlingmayer, George. "Price-Fixing and the Addyston Pipe Case." *Research in Law and Economics* (Vol. 5), pp. 57-130.

Boland, Simpson. *The Iron Founder, 2 vols* (New York: John Wiley & Sons, 1901, 1903).

Campbell, Harry L. *Metal Castings* (New York: John Wiley & Sons, 1936).

Dwyer, Pat. "Spins Pipe: Iron Molds Lined with Sand." *The Foundry* (Feb. 15, 1928), pp. 126-131, 156-8.

Dwyer, Pat. *Tales from the Gangway* (Cleveland, OH: Penton Publishing Co., 1923).

Dyer, Y.A. "Cast-Iron Pipe Manufacture in the South." *Iron Age* (Nov. 23, 1916), p. 1161.

Estep, H. Cole. "English Make Centrifugal Castings." *The Foundry* (March 15, 1922), pp. 217-22.

Fox, E.J. and Wilson, P.H. "Modern Methods of Pipe Manufacture by the Centrifugal Process." *Foundry Trade Journal* (August 14, 1924), p. 131.

Garrett, Jesse. "Making Cast-Iron Pipe." *Journal of the New England Water Works Association* (Sept. 1896), pp. 34-36

Gibson, J.E. "Cement-Lined Cast-Iron Pipe at Charleston, S.C.." *Engineering News Record* (Sept. 7, 1922), pp. 387-90.

Gillespie, Peter. "A Departure in Pipe Foundry Practice." *Journal of the American Water Works Association* (Sept., 1922), pp. 703-11.

Gillespie, Peter. "Casting Pipe without a Core." *Gas Age Record* (Dec. 23, 1922).

Gillette, H.P. "Why the Cast Iron Pipe Industry Needs Protection." *Water Works* (October, 1926), p. 463.

Guerrini, Giuseppe. "Improve Process for Casting Pipe Centrifugally in Green Sand Molds." *The Foundry* (Oct. 15, 1928), pp. 832-835.

Hallett, M.M. "German Production of Spun Pipe." *Foundry Trade Journal* (Feb. 6, 194), pp.

136-8.

History and Heritage Committee, American Society of Mechanical Engineers. *Landmarks in Mechanical Engineering* (West Lafayette, IN: Purdue University Press, 1997): "The Pit-Cast Jib Crane." pp. 191-3.

Hurst, J.E. "Large Diameter Centrifugal Pipe." *Iron Age* (June 11, 1925), pp. 1704-6.

Hurst, J.E. "Some Notes on the Development of the Centrifugal Casting Process in Great Britain and Europe." *Foundry Trade Journal* (Oct. 29, 1925), pp. 361-5; (Nov. 5, 1925), pp. 381-4.

Kreutzberg, E.C. "Opens Pipe Foundry in East." *Iron Trades Review* (Sept. 16, 1926).

Lewis, Frederick H. "Cast Iron Water Pipe." *Cassier's Magazine* (May, 1895).

McWane Cast Iron Pipe Company. *Cast Iron Pipe and Fittings* (Birmingham, AL: McWane Cast Iron Pipe Company, 1928).

McWane, R.C. *Pipe and the Public Welfare* (New York: Stirling Press, 1917).

MacKay, Jack W. "Development and Use of Specifications for Cast-Iron Pressure Pipe and Fittings." *Journal of the American Water Works Association* (July, 1956), pp. 863-88.

Menefee, F.N. and A.E. White, "A Comparison of the Physical Properties of Various Kinds of Cast Iron Pipe." *Report, Project Number 633*, Department of Engineering Research, University of Michigan (March 1, 1930).

Misa, Thomas J. *A Nation of Steel* (Johns Hopkins University Press, 1995).

Moldenke, Richard. *The Principles of Iron Founding* (New York: McGraw-Hill Book Company, 1917).

Moore, William Davis. *Development of the Cast Iron Pressure Pipe Industry in the Southern United States, 1800-1938* (Newcomen Address, Birmingham, AL: Birmingham Publishing Company, 1939).

Moore, William Davis. "Discussion of the New Law of Design of Cast Iron Pipe." *Journal of the American Water Works Association* (Oct., 1939), pp. 1655-74.

N.a. "The American Cast Iron Pipe Company's Foundry." *Iron Age* (Feb. 7, 1907)

N.a. "Brazilian Pipemaker." *Steel* (Jan. 25, 1943), pp. 68-70, 83.

N.a. "Centrifugal Pipe by a New Process." *Iron Age,* (June 5, 1924), p. 1660.

N.a. "Centrifugal Pipe from Sand Molds." *Iron Age,* (April 15, 1926), pp. 1055-1060

N.a. "Centrifugal Pipe Increasingly Used." *Iron Age* (January 9, 1930), p. 154.

N.a. "Centrifugal Pipe Output Increases." *Iron Age* (Jan. 3, 1929), pp. 78-9.

N.a. "Centrifugally Cast Pipe in South America." *Iron Age* (September 25, 1919).

N.a. "The Chattanooga Pipe Factory." *American Machinist,* (Aug. 12, 1897), pp. 596-9.

N.a. *Handbook of Cast-Iron Pipe* (Chicago, IL: Cast-Iron Pipe Research Association, various editions, 1927, 1952, 1967).

N.a. *Handbook of Cupola Operation* (Chicago, IL: American Foundrymen's Association, 1946).

N.a. "Improved Gray Iron Structure without Chill Obtained in Centrifugally Cast Pipe." *Iron Age* (February 8, 1934), pp. 26-9, 66.

N.a. "Making Cast-Iron Pipe." *Iron Age* (Nov. 6, 1890), p. 788.

N.a. "Making Cast-Iron Pipes at the 'New' Works, Staveley Coal and Iron Company, Limited." *Foundry Trade Journal* (Feb. 23, 1928), pp. 129-31.

N.a. "Manufacture of Centrifugally Cast Iron Pipe." *Industrial Heating* (June, 1951), pp. 1008-1022.

N.a. "The Manufacture of Sand-Spun Pipes." *Engineering* (July 24, 1931), pp. 93-8

N.a. "Modern Pipe Founding." *American Machinist* (Sept. 7, 1905), p. 304.

N.a. "Now Cast Pipe Centrifugally in Sand Molds." *Canadian Machinery and Manufacturing News* (March 21, 1929), pp. 39-43.

N.a. "Pioneer Swedish Centrifugal Pipe Foundry." *Foundry Trade Journal* (March 4, 1948), pp. 219-221.

N.a. "Pipe Foundry of the Massillon Iron & Steel Company, Massillon, O." *The Foundry* (Nov.

1903), p. 26.

N.a. "Pipe-Molding Machine and Continuous Pipe Foundry at Coschocton, Ohio." *Engineering News* (June 15, 1911), p. 710-6.

N.a. "Progress Report: Special Cast Iron Pipe Investigation" (Engineering Experiment Station, University of Illinois, 1928).

N.a. "Report on Specifications." *Iron Age* (March 19, 1891), p. 525.

N.a. "Report of Committee No. 9 on Standard Specifications for Cast Iron and Specials." *Journal of the American Water Works Association* (Dec., 1926), pp. 794-800.

N.a. "Research to Govern Specifications for Cast Iron Pipe." *The Foundry* (May 15, 1929), pp. 435-6.

N.a. "Sand-Spun Cast-Iron Pipe Manufacture." *The Foundry Trade Journal* (July 15, 1926), pp. 45-52.

N.a. "What is Super-DeLavaud Pipe." *Water Works and Sewerage* (February, 1934).

Noble, Henry Jeffers, *History of the Cast Iron Pressure Pipe Industry in the United States of America* (Newcomen Address, Birmingham, AL: Birmingham Publishing Company, 1940).

Palmer, R.H. *Foundry Practice* (New York: Wiley & Sons, 1926).

Pardun, Carl. "Innovations in Centrifugal Casting." *The Foundry Trade Journal,* (Aug. 27, 1925), pp. 175-6.

Phillips, Almarin. *Market Structure, Organizations, and Performance: An Essay on Price Fixing and Combinations in Restraint of Trade*. (Cambridge: Harvard University Press, 1962), p. 105.

Pierce, Arthur D. *Family Empire in Jersey Iron* (New Brunswick, NJ: Rutgers University Press, 1964), p. 109.

Riley, R.V. "Cast-Iron Pressure Pipe." *Iron and Coal Trades Review* (July 3, 1953), pp. 15-6.

Robinson, W.B. "The Manufacture of Cast-Iron Pipe." *The Iron Age* (December 5, 1907), p. 914

Schwarz, M.v. and A. Vath, "Centrifugal Castings and their Metallurgical Investigation." (Typescript, U.S. Pipe files)

Special Committee on Coating of Cast Iron and Steel Riveted Pipes, "Coating of Cast Iron and Steel Riveted Pipes." *Municipal Engineering,* (Nov., 1897), pp. 280-7

Stacey, H.A. and Fairchild, I.J. "Proposed U.S. Government Specifications for Centrifugally - Cast Iron Pipe." *Journal of the American Water Works Association* (Aug., 1927), pp. 208-18.

Taylor, Howard P. and Register, Charles L. *Bibliography of Centrifugal Casting* (Chicago: American Foundrymen's Society, 1949).

Stanton Ironworks Company Ltd. *Cast Iron Pipes* (London, Stanton Ironworks Co., 1930).

Stanton Ironworks Company Ltd. *Centrifugally Concrete-Lined Iron Pipes* (London, Stanton Ironworks Co., n.d.).

Towne, Henry R. *A Treatise on Cranes* (Stamford, CT: E.S. Dodge Steam Printing House, 1883).

Underwriters' Laboratories, *Report on deLavaud Cast-Iron Underground Water Pipe* (Chicago, IL: Extinguisher No 758, June 12, 1923), pp. 11-2.

United States Cast Iron Pipe & Foundry Company, *Along Large Cast Iron Lines* (Burlington, NJ: United States Cast Iron Pipe & Foundry Company, 1930).

United States Cast Iron Pipe & Foundry Company, *Cast Iron Pipe and Special Castings* (New York: 1906).

United States Cast Iron Pipe & Foundry Company, *Cast Iron Pipe for Industrial Service* (n.p., n.d.).

United States Cast Iron Pipe & Foundry Company, "Early History of the Company." (Typescript, 1912).

United States Cast Iron Pipe and Foundry Company. *General Catalogue.* (Burlington, NJ: 1925).

United States Cast Iron Pipe & Foundry Company. *Super-DeLavaud Cast-Iron Pipe* (Burlington, NJ: United States Cast Iron Pipe and Foundry Company, 1935).

United States Cast Iron Pipe & Foundry Company. *The U.S. Piper* (Burlington, NJ, United States Cast Iron Pipe and Foundry Company, 1927ff).

United States Cast Iron Pipe & Foundry Company. *Handbook of deLavaud Centrifugally Cast Iron Pipe* (Burlington, NJ: United States Cast Iron Pipe and Foundry Company, 1930).

United States Department of Commerce, Bureau of the Census. *Fourteenth Census of the United States. Volume X: Manufactures, 1919: Reports for Selected Industries* (Washington, DC: GPO, 1923), pp. 363-8.

United States Department of Commerce, Bureau of the Census. *Fifteenth Census of the United States. Manufactures: 1929. Volume II: Reports by Industries* (Washington, DC: GPO, 1933), pp. 913-4.

United States Department of Commerce, Bureau of the Census. *Sixteenth Census of the United States. Manufactures: 1939. Volume II, Part 2: Reports by Industries* (Washington, DC: GPO, 1942), pp. 207-9.

West, Thomas D. *American Foundry Practice* (New York: John Wiley & Sons, 1911).

Thomas F. Wolfe, "Linings for Cast-Iron Pipe." *Journal of the New England Water Works Association*, (Dec., 1936), pp. 412-22.

Wolfe, Thomas F., "Current Specifications for Cast Iron Pipe and How to Order Specifications." *Journal of the New England Water Works Association* (June 195), pp. 130-138.

Wood, Charles R. "Sandspun Pipe." *Mechanical Engineering* (Nov. 1922), pp. 727-39.

Wood, R.D. *Sand-Spun Centrifugal Cast Iron Pipe* (Philadelphia, PA: R.D. Wood & Co, 1932).

Woodhouse, W. F.I.C., "Cast-Iron Pipes." *Foundry Trade Journal* (May 7, 1936), p. 357.

ADDENDUM TO:
UNITED STATES PIPE & FOUNDRY COMPANY PLANT
(U.S. Pipe Plant)
Birmingham Industrial District
2023 St. Louis Avenue at I-20/59
Bessemer
Jefferson County
Alabama

HAER AL-32
HAER ALA,37-BES,6-

FIELD RECORDS

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