The Architecture and Engineering of Elevated Water Storage Structures: 1870-1940

by

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ILLUSTRATIONS

Chapter I

THE PLACE OF ELEVATED WATER STORAGE STRUCTURES IN NINETEENTH CENTURY WATER WORKS

Elevated water storage tanks became important components of municipal water systems and industrial complexes in the late nineteenth century. Municipalities and private utility companies under contract to communities planned and constructed water works facilities in response to pressures of concentrated populations. As communities grew larger and more dependent on water distribution systems, the need for dependable reserve supplies increased and the tremendous costs of constructing and operating water works resulted in a search for the most efficient means of operation. The construction of elevated reservoirs to insure storage for fire protection and to maintain constant pressure also became an accepted practice for industrial firms in the 1880's.

Because large numbers of communities and business enterprises which desired water works were located where natural reservoirs were not present and man-made ground reservoirs could not be easily created, the use of water towers, standpipes, and elevated tanks increased. Although the terminology for these structures varied in the late nineteenth century, by 1900 a fairly standard vocabulary had been developed, and it is adhered to throughout this paper: a water tower is a tank supported on a brick, stone, or concrete tower; a standpipe is a wrought iron, steel, or concrete column rising from a ground level foundation and containing water for its entire length; an elevated tank is a wood or metal tank supported on an open trestle.

(Figure 1) These structures also were symbols of industrial or municipal improvement and reflected the prosperity and progressive outlook of their sponsors. Although a single element in an often complex storage and distribution system, the elevated water storage structure was the most visible component of a water works costing thousands of dollars and often employed the most advanced principles of civil engineering. These structures therefore merit examination not only because they were early public works in many communities, but also because they were important in technological and architectural history. In examining engineers' approaches to their design and construction, valuable insight can be gained into the aesthetic issues confronting engineers of the period.

Few historians have considered the historical or architectural significance of elevated water storage structures. Histories of individual water works written in the late nineteenth century generally focused on local history rather than on placing a particular water works in a larger context. The most relevant work to date, "The Formative Years of the Chicago Bridge and Iron Company," details Chicago Bridge and Iron Works' (CBI) entrance into the elevated tank fabrication field when bridge building was unprofitable in the early 1890's. This work provides information about the role of one major tank manufacturer between 1893 and 1903; it does not explore the activities of other tank companies or private engineers in the late nineteenth century, or the evolution of the elevated tank after 1900.[1] Carl Condit's American Building Art: The Nineteenth Century considers the materials and structural elements like the truss and iron frame essential to the development of the elevated tank, but limits discussion of the use of these forms to bridges and building construction. Some work has been done to

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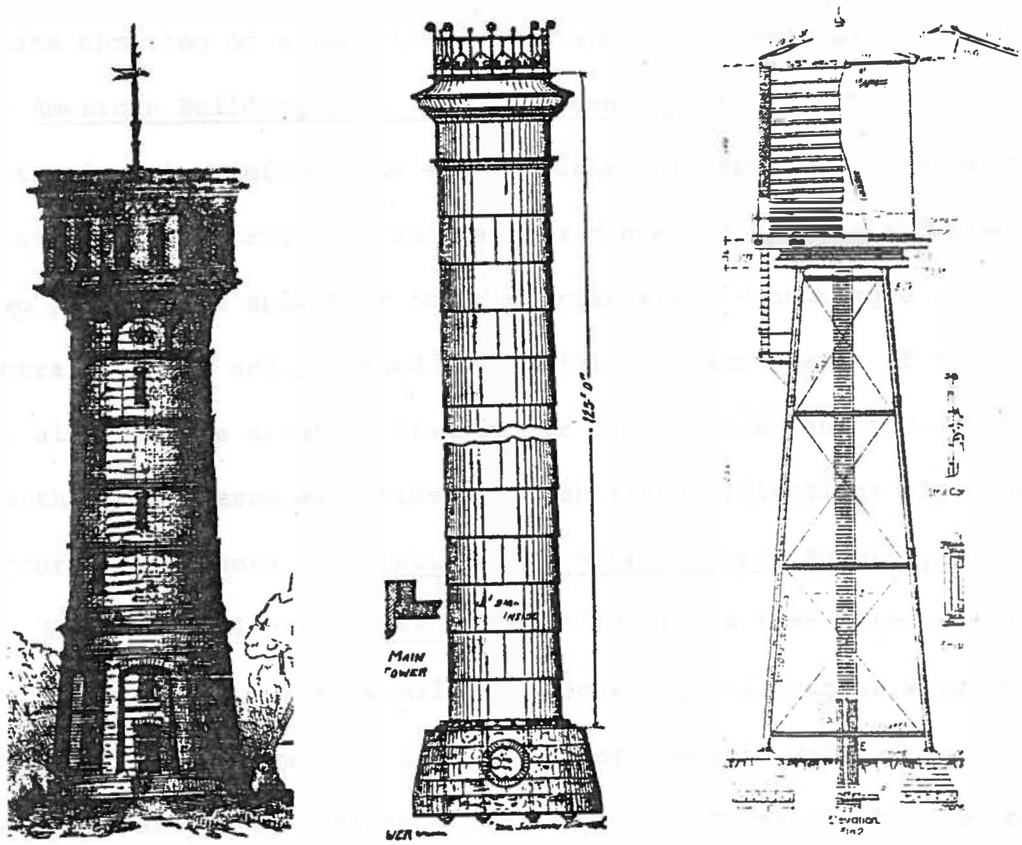
[1] Eli Woodruff Imberman, "The Formative Years of the Chicago Bridge and Iron Company" (University of Chicago, unpublished PhD dissertation, 1973).



a. Water tower   b. Standpipe   c. Elevated tank

Figure 1. Water tower, standpipe, and elevated tank. The three major forms of elevated water storage structures of the nineteenth century. (not to scale)
Source: Water tower: "Iron Plate Reservoirs," Scientific American Supplement (August 28, 1886), p. 8877. Standpipe: "The Water Tower at Asbury Park," The Sanitary Engineer (September 2, 1886): 321. Elevated tank: "The Belmond Waterworks," The Engineering Record (May 1, 1897): 470.

identify and document extant examples of elevated water storage structures, but data collected at present cannot be considered representative of the range of types originally constructed or now remaining.[2]

The changing architectural treatment of elevated water storage structures between 1880 and 1940 documents a continuing search for appropriate phrasing of a conspicuous and symbolic structure. Condit has noted in American Building Art: The Nineteenth Century that while historical architectural styles defined the surface dress of important nineteenth century structures, structural innovations concealed by this architecture were also part of the spirit of the Victorian era. Picturesque architecture both contrasted with and provided the vehicle for acceptance of technological changes, allowing the greatest freedom for the engineer and the designer.[3] These aesthetic concerns are evident in published collections of recommended architectural treatments like Designs for Water Towers, Pumping, and Power Stations (1893) and Elevated Tank Designs (1931). A continuing dialogue in the engineering journals reveals the technological changes which made possible major transformations in the form of elevated water storage structures. Engineers' and architects' designs for these structures can thus be examined

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[2] About twenty-five structures have been individually listed in the National Register of Historic Places, with numerous other examples included as part of factory complexes or historic districts. The Historic American Engineering Record has documented several masonry water towers and some related structures like range lights. The HAER state inventories have located major examples in most surveyed states. The Minnesota Historic Sites Survey is actively identifying and evaluating water storage structures in the State, largely because of the presence of State staff member Robert Frame III, a member of the Society for Industrial Archeology. Material from these files reveals a wide variety of masonry, metal, and concrete structures, including several modest but rare examples.

[3] Carl Condit, American Building Art: The Nineteenth Century (New York: Oxford University Press, 1964), p. 267-68.

in the context both of significant changes in technology and of American architectural tastes of the late nineteenth and early twentieth centuries.

Water works facilities proliferated in the United States in the late nineteenth century. Eighty-three municipal water works were in use by 1850, ranging from crude wood pipe systems carrying a gravity flow one or two miles to complex systems with long aqueducts or expensive pumping machinery servicing thousands of customers. Twice as many systems were built between 1850 and 1870 as had been in use before, giving a total of 243 by 1870 and 598 by 1880. The most significant growth occurred in the 1880's and 1890's, however: between 1880 and 1890, nearly 1300 water works systems were added. By 1900, over 3300 systems were functioning or under construction, with large numbers of tiny unincorporated communities possessing rudimentary systems by 1896.[4] (Figure 2)

The use of water works in industrial complexes also increased, although statistics from them are not as readily available as those for municipal systems. Because the needs of industrial concerns could be equal to those of the residential community, and constant supply was critical to factory operation, factory water systems were often independent of public systems. Factory works served two functions: providing large supplies of water for the factory processes themselves, and acting as reserve supplies for fire protection not subject to the pressure changes and possible interruption of the city water system.

Technological innovation and active promotion of the water works industry by the business and engineering communities were also forces in the

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[4] M. N. Baker, The Manual of American Waterworks (New York: Engineering News Publishing Company, 1897), passim.

Growth in number of United States water-works since 1800

	Total	Public	Private
1800	16*	1	15*
1810	26	5	21
1820	30	5	25
1830	44	9	35
1840	64	23	41
1850	83	33	50
1860	136	57	79
1870	243	116	127
1880	598	293	305
1890	1,878	806	1,072
1896	3,196	1,690	1,489
1924#	9,850	6,900	2,950

*Since this table was originally compiled one additional works, privately owned, in existence before 1800, has come to light, but as the figures up to 1896 have been before the public for many years and the change is so slight, with percentages not affacted after the first few lines, it has not seemed worth while to remake the table.

#Estimated.

Figure 2. Community waterworks, 1800-1924.
Source: The American Water Works Association, Water Works Practice: A Manual (Baltimore, The Williams & Wilkins Company, 1926), p. 10.

wider acceptance of the construction of water works. In 1875, the editor of Engineering News asserted that the field of community water supply had not received sufficient attention from the profession, and suggested that engineers stimulate business by doing water works plans free of charge during slow periods.[5] An editorial in The Sanitary Engineer commented that "the question of supply of water to our large cities, including their suburban towns, is becoming more serious every day."[6] The engineering press reported water works construction and prominently featured news of technological developments. Engineering News, The Engineering Record, and The Manual of American Waterworks, published at regular intervals, informed readers of facilities under construction, products available, and contractors performing this work in various regions. A formal network of water works institutions was organized in the 1880's, including the American Water Works Association (1883) and the New England Water Works Association (1882). These supported scholarly inquiry and exchange among practicing engineers and served as a vehicle for disseminating information about current practices. Also significant was the increase in the number of engineers who had had some experience or training in water works construction. Engineering schools incorporated water works principles into their curricula; some, like the University of Michigan, sponsored important work which now forms part of

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[5] "The Water Supply of Small Towns," Engineering News 2 (February 15, 1875): 18.

[6] "Water Supply of Cities," The Sanitary Engineer 7 (April 19, 1883): 457.

the body of resource material on water works theory in the 1890's.[7]

Between 1870 and 1890, the character of a typical water works system also changed dramatically. Older systems were progressively upgraded, taking advantage of technological advances, and the manufacture of water works fixtures and equipment was increasingly directed toward the lucrative market represented by the large numbers of small cities and towns. Summarizing the sweeping changes in water works practice in the second half of the century, the authors of Public Water Supplies wrote:

> Among the more important improvements were the perfection of cast iron pipe; the improvement of pumping machinery, whereby the duty was greatly increased; the manufacture of smaller pumps on a commercial scale, thus greatly reducing the costs to small towns; the adoption of direct-pumping systems for small towns, thus also in many cases reducing first cost; and the development of the ground and artesian water supplies in the Western States.[8]

Increased use of elevated water storage structures was another of these improvements. Between 1880 and 1890, the number of pumping systems employing some form of elevated water storage rose dramatically, paralleling the widespread construction of water works facilities themselves. Statistics gathered between 1880 and 1882 indicated that sixty-nine of eight hundred public water systems--less than 10%--pumped either to a tank or a standpipe; by 1885, 164 of a total 997 water works--16%--were so equipped; in 1888, 501

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[7] The Proceedings of the New England Water Works Association and the American Water Works Association were regularly published through the 1880's, as were journals of engineering societies like The Technic, published by the Engineering Society of the University of Michigan. See also J. J. R. Croes, Statistical Tables from American Water Works (New York: Engineering News Publishing Company, 1887), p. ii.

[8] F. E. Turneaure and H. L. Russell, Public Water Supplies (New York: John Wiley and Sons, 1924), p. 8.

of 1632--30%--pumped to a tank or standpipe.[9] By 1899, one writer on water works stated:

> The bona fide direct pressure system of water-works has now passed into history, for no one acquainted with even the elements of water-works management thinks of building a plant without a small reservoir, standpipe, or elevated tank to supply the sudden large demands for water for fires, while pumping machinery is being speeded up to the increased duty.[10]

Water towers and standpipes were used with increasing sophistocation within water systems, resulting in a greater concern in the engineering community about better and more visually appealing elevated water storage structures.

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[9] J. J. R. Croes, Statistical Tables from the History and Statistics of American Waterworks (New York: Engineering News Publishing Company, 1883, 1885, 1887), passim. In 1883, 40 of the 69 were described as "standpipes" and 29 as "tanks." In 1885, 45 standpipes were noted, 119 tanks; in 1888, 287 standpipes and 214 tanks. These figures are inconclusive, however, because of the lack of consistent use of terms in the 1880's.

[10] John Goodell, Water-Works for Small Cities and Towns (New York: The Engineering Record, 1899), p. 215.

Chapter II

THE WATER TOWER AND THE STANDPIPE

The elevated water storage structures most often used in American water works in the 1870's and 1880's were different from those of the 1890's and the twentieth century. Two forms were common in the 1880's--a tank of wooden staves or iron or steel plates elevated on a stone or brick tower; and a standpipe, or tube of metal whose height was greater than its diameter, in which the column of water rising from ground level was used to support water at a useable level.[1] The water tower was generally the more attractive, more expensive, and safer of the two.

In the seventies and eighties, engineers and architects adhered to standard architectural treatments for the exteriors of water towers and standpipes, attempting to harmonize the structures with a community's civic image, its Victorian architecture, and, perhaps most importantly, with its vistas and landscapes in the areas where the structures were erected. One result was the construction of several major water towers with traditional exteriors concealing innovative engineering features within. Another result was the usually futile attempt to camouflage the metal standpipe with inexpensive applied ornamentation. A third was the concealment of standpipes within brick shells to resemble--in architecture if not in structure--the traditional masonry water tower. In each case the variance

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[1] In small towns, and where timber was the best available material, tanks elevated on wooden trestles were also in use.

between engineering requirements and Victorian aesthetics is evident.

The use of water towers in the United States coincided with the first era of major water works construction around 1800. The Center Square water works, Philadelphia, in use between 1801 and 1815, employed an engine to raise water to two cylindrical reservoirs approximately thirty feet by fifty feet and forty feet by fifty feet, supported on timber beams. (Figure 3) These reservoirs, as most other parts of the water works including the boilers, were constructed of wood, a material easier to obtain than cast iron.[2]

Cast iron was used in other early American tanks, and at least some of these were imported from England, whose iron production outstripped that of the United States in the early nineteenth century. One tank imported in 1799 served as part of the water system of the Manhattan Company in New York City. (Figure 4) Measured and drawn prior to destruction in 1898, the tank consisted of three courses of consecutively numbered flanged cast iron plates twenty-eight inches wide and sixty inches high and one inch thick. The tank was forty feet in diameter and fifteen feet deep and supported on a cylindrical stone foundation. Each plate was a cylindrical section reinforced by brackets and connected to adjacent plates by bolts and secured with iron hoops. A ten inch pipe entered the side of the tank.[3]

In the Manhattan Company tank decoration of the exposed tank was confined to a flat bead creating an ornamental panel in the center of each plate. The Center Square tanks, however, illustrate the practice, (preferred later in the century) of enclosing the tank in an architecturally imposing

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[2] "The History of the Steam Engine in America," The Engineer 42 (November 3, 1876): 306-312.

[3] "A Curious Historical Water Tank," The Engineering Record 37 (April 23, 1898): 451-452.

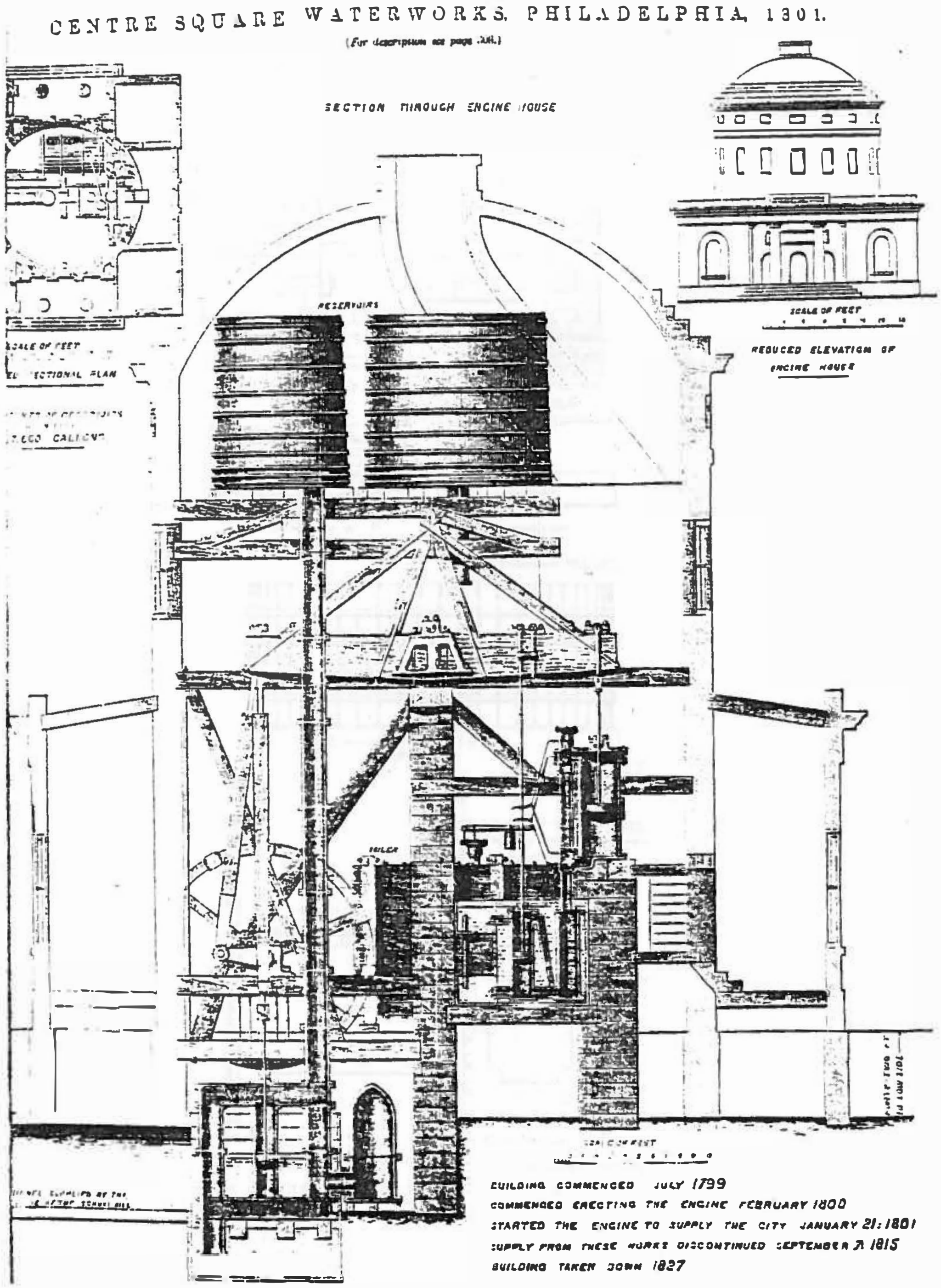
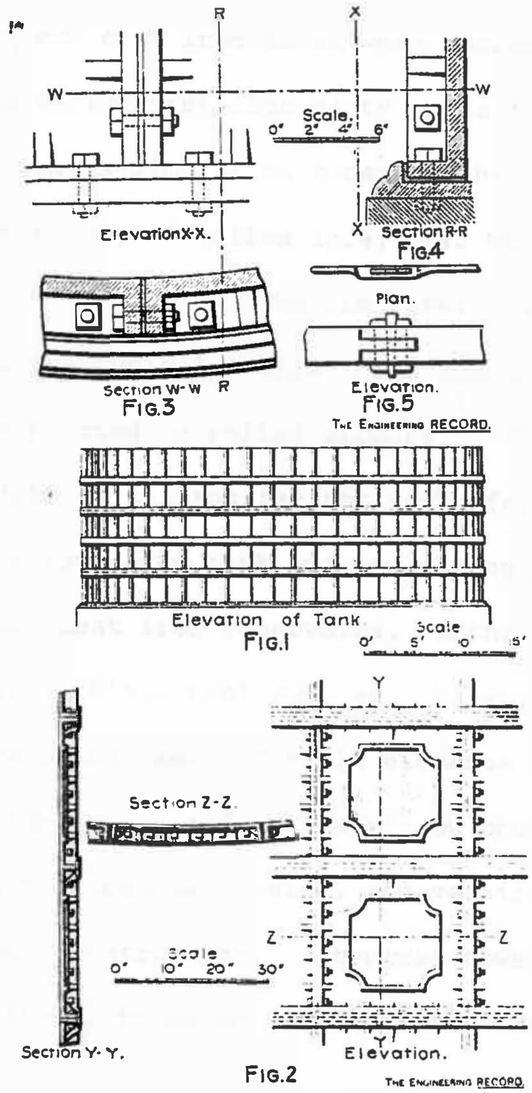


Figure 3. Center Square, Philadelphia water tower (1801). Source: "The History of the Steam Engine in America," The Engineer 42 (November 1876): 307.



TANK OF THE MANHATTAN COMPANY, NEW YORK CITY.

Figure 4. Manhattan Company, New York water tower (1799). Capacity: 150,000 gallons.
Source: "A Curious Historical Water Tank," The Engineering Record 37 (April 23, 1898): 452.

structure. At Center Square, the classicism suggested by designs of architects like Jefferson and Ledoux was chosen.

According to The Engineering Record, the Manhattan Company tank illustrated "practice long abandoned" in tank construction. While this was true in America, where cast iron tanks were uncommon by 1870, English engineers continued to design cast iron plate tanks through the late nineteenth century. Details similar to those of the 1799 Manhattan Company tank were present in the 700,000 gallon Ince, near Wegan, water tank (1880).[4] (Figure 5) The Congleton, Chesire water tower (1883), also of cast iron, illustrates the typical English plan combining a masonry tower and flat bottom tank supported on rolled girders.[5] (Figure 6) Wrought iron was also used widely by the English for tanks for masonry water towers; the general plan of the tower and tank and its piping system were similar to those for cylindrical cast iron reservoirs. Although some towers like Congleton had classical architectural sources, the Romanesque and Victorian Gothic styles were more often used. Certain elements of these styles like the use of brick and stone, deep and narrow window openings, and greater emphasis on asymmetry, picturesque massing, and vertical effects encouraged their use in water tower construction. A typical tower had simple trim executed in brick and stone, breaking the tower into several stories, and

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[4] "Water Tank at Ince," The Engineer 49 (January 16, 1880): 53.

[5] A variation of this type including a square tank was occasionally used by English engineers. The Colchester water tower (1883), designed by a Mr. Clegg, combined a square tank with additional features to counteract the stresses peculiar to a square tank. See "Colchester Water Tower," The Engineer 57 (February 15, 1884): 133. The Wallasey water tower, designed by Robert Robinson, civil engineer, prior to 1876, was of similar design. See William Humber, The Water Supply of Cities and Towns (London: Crosby Lockwood and Company, 1876), p. 135, plate I.

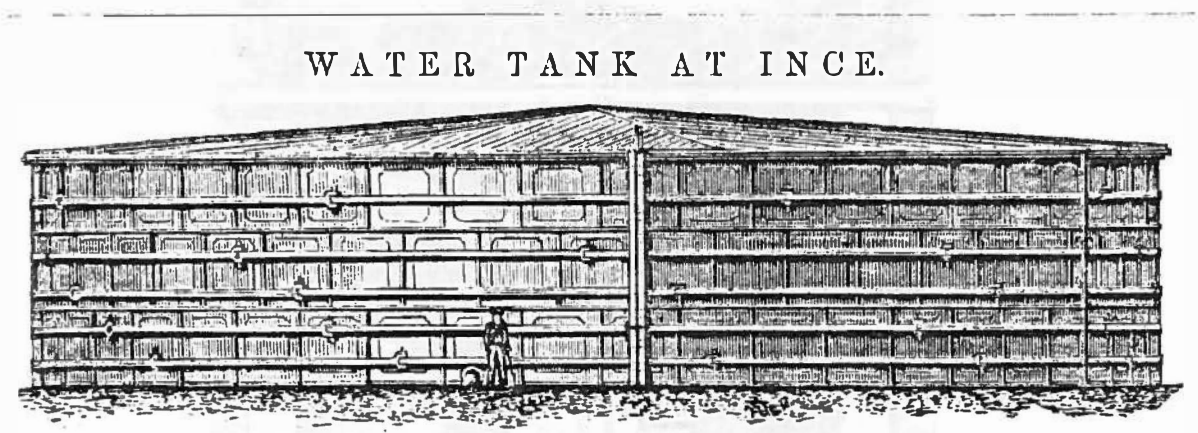

Figure 5. Water tank at Ince, near Liverpool (1880). Capacity: 700,000 gallons.
Source: "Water Tank at Ince," The Engineer 49 (January 16, 1880): 53.

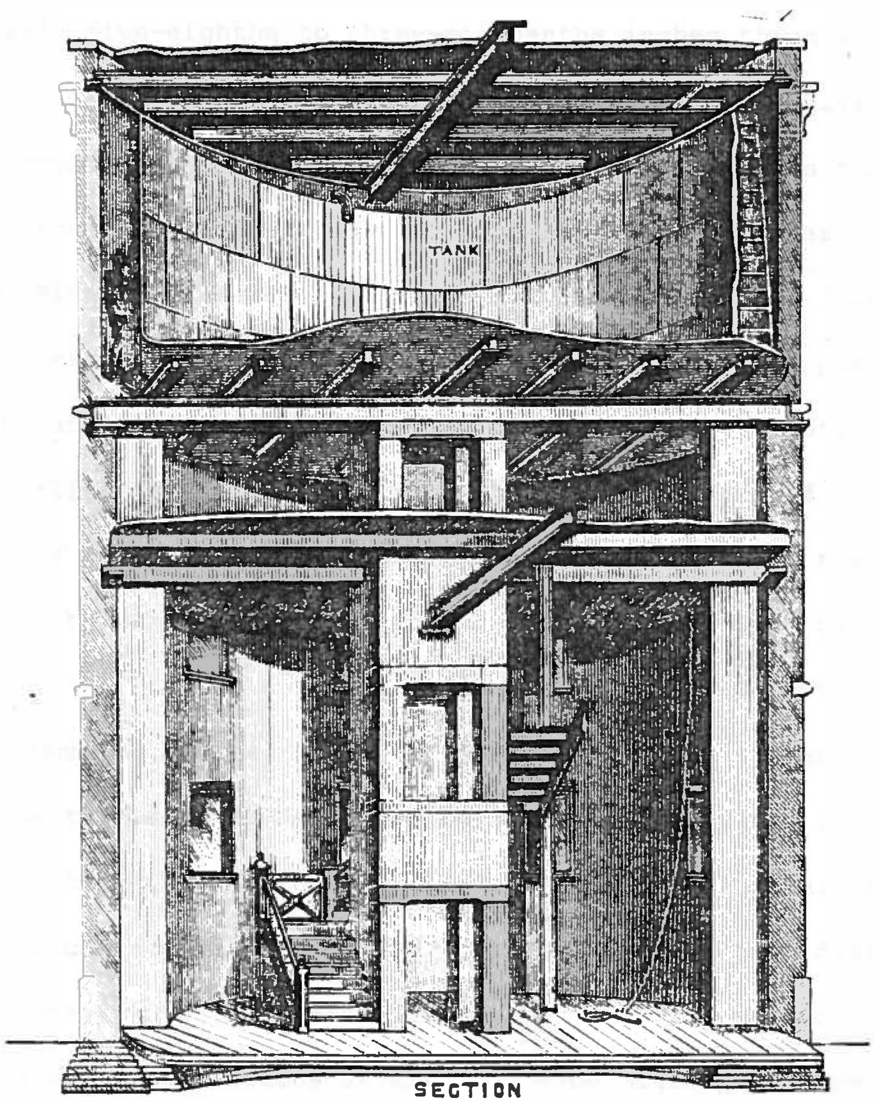

Figure 6. Congleton, Cheshire water tower (1883). Capacity: 50,000 gallons.
Source: "Water Supply of Small Towns," The Engineer 55 (May 18, 1883): 279.

terminating in a turret. (Figure 7)

By 1880 a standard formula similar to that used in England had evolved for the water tower in America. The tank itself was fabricated of wrought iron, although steel came into wider use in the eighties. Plates were generally five-eighths to three-sixteenths inches thick and riveted in rings, with horizontal double riveting and vertical single riveting. The tank was supported on I beams or girders and did not include the open shaft or core staircase popular in England. The 1884 Yonkers water tower designed by David M. Nichols of New York City is a typical example. (Figure 8) Resting on a masonry foundation, the tower was octagonal in plan and built of brick and ashlar masonry to a height of seventy-eight feet. Supported within the walls fifty-three feet from the ground was a grid of two tiers of fifteen inch I beams forming a rigid floor and distributing the weight of the tank and its contents equally to the walls. The 50,000 gallon tank, eighteen feet in diameter and twenty-five feet high, was serviced by a Worthington pumping engine through a twelve inch inlet and eight inch outlet pipe. Access to the tank was gained by a staircase located in the annular space between the tank and tower walls.[6] Architectural detailing was similar to that of Clacton-on-the-Sea. The tower was divided into distinct stories by stringcourses and pointed arch window openings with Gothic surrounds. A deep cornice and castellations at the roof line highlighted the uppermost portion of the tower.

American water towers and those designed on the Continent began to

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[6] "Yonkers Water Works High Service Tower," American Contract Journal 12 (November 18, 1884): 184.

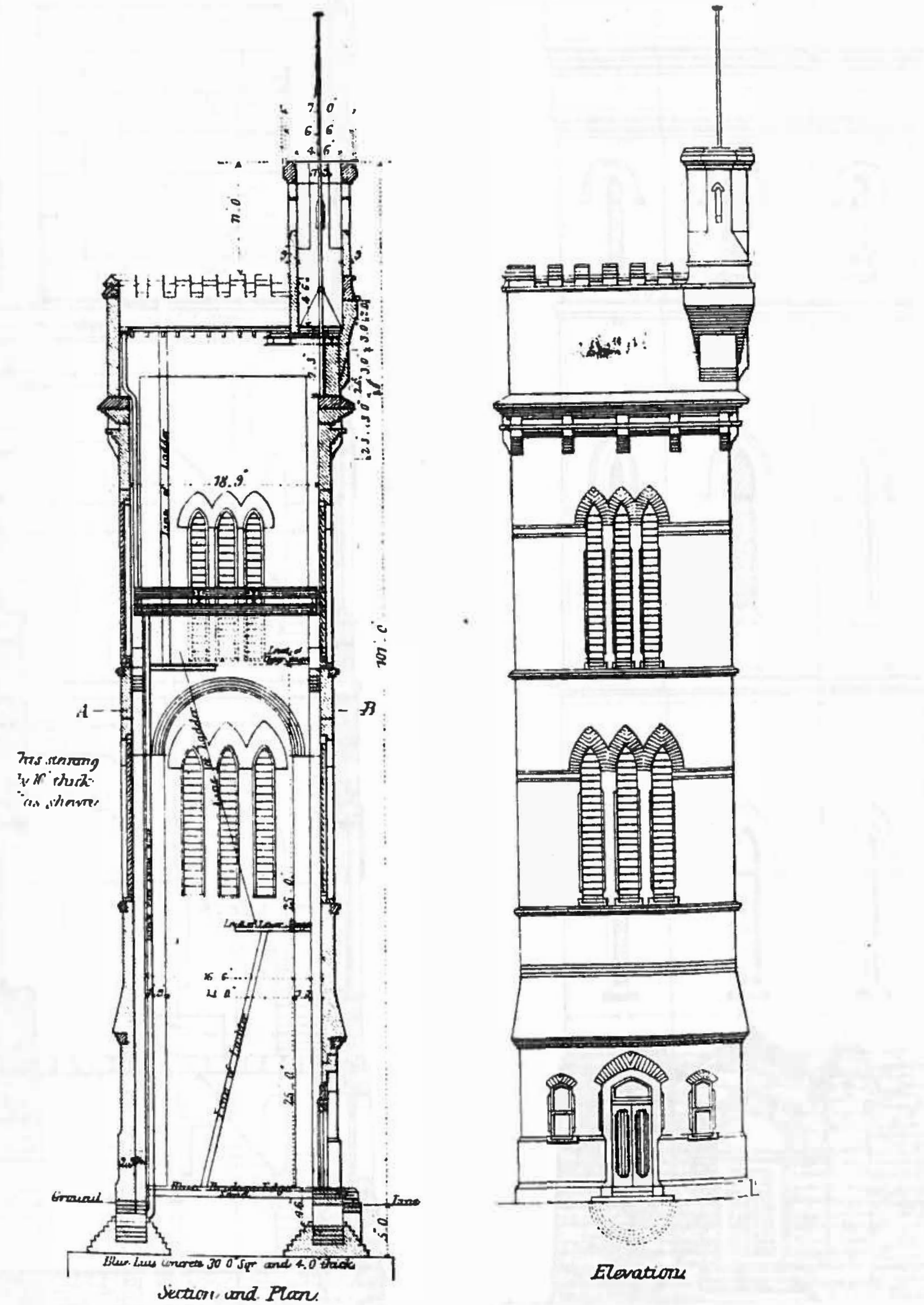

Figure 7. Clacton-on-Sea, Essex water tower (1882). Capacity: 30,000 gallons.
Source: "Water Supply of Small Towns, No. III, Clacton-on-Sea," The Engineer 53 (June 2, 1882): 396.

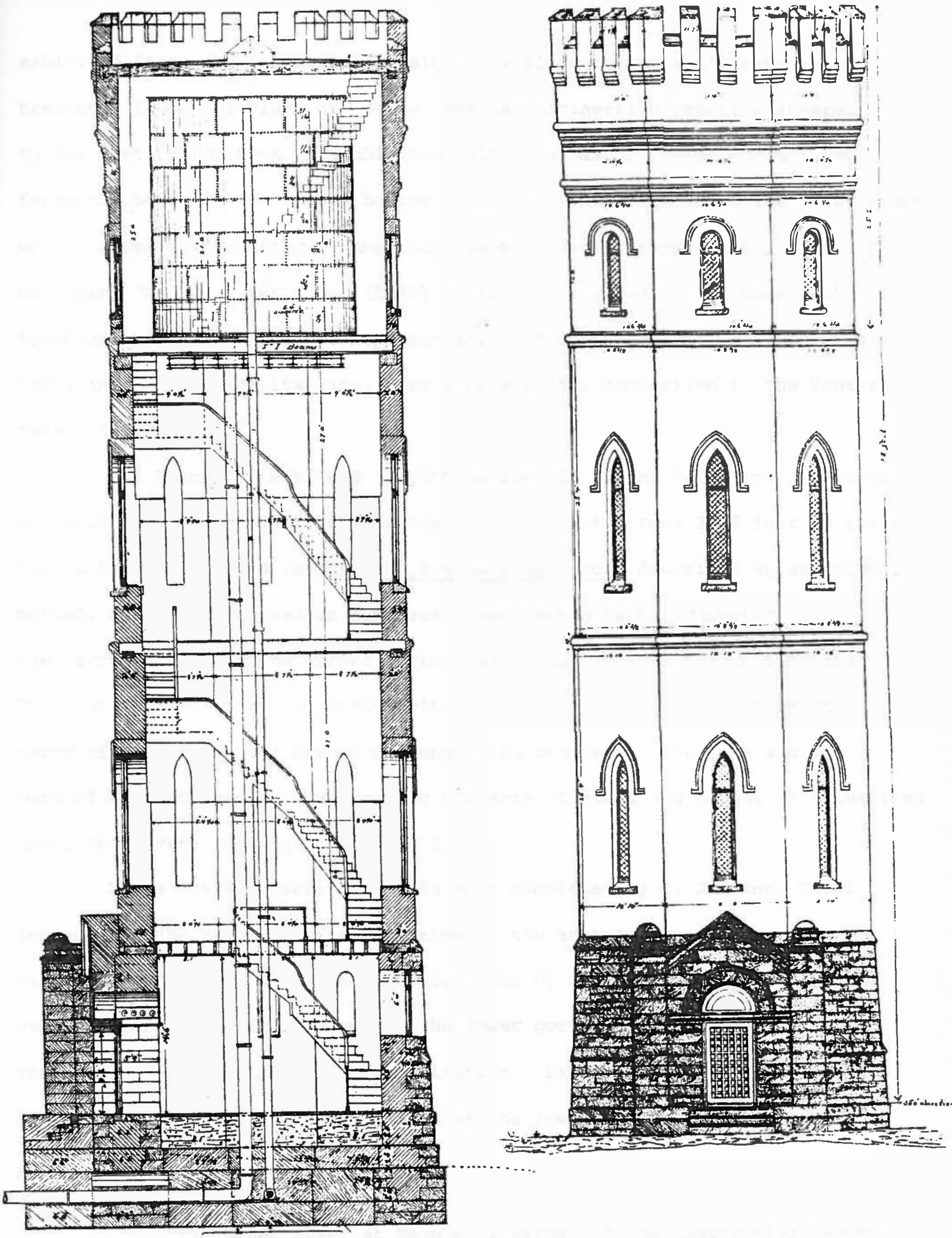

Figure 8. Yonkers, New York water tower (1884). Capacity: 50,000 gallons.
Source: "Yonkers Water Works High Service Tower," <u>American Contract Journal</u> 12 (October 18, 1884): 185.

exhibit differences in internal design as well as in external architectural treatment in the mid-1880's. While American engineering practice adhered to the flat bottom tank in combination with the masonry tower through 1900, Europeans began to use curved bottom forms within masonry shells, a development which ultimately transformed American elevated water storage structures. The Mannheim, Germany water tower (1885), first illustrated in the American technical press in 1892, was representative of a new generation of European tanks and, because of its date, serves as a useful comparison to the Yonkers tank. (Figure 9)

The Mannheim tank held 527,000 gallons in a tank 52.8 feet in diameter and 28.9 feet deep, with the spherical portion of the tank 35.7 feet in radius. The tank was supported in what The Engineering Record described as an unusual method, although one used in numerous other German tanks. Riveted to the circumference of the curved bottom was a conical ring of one inch iron. The plates forming the supporting ring were riveted in between these two parts of the bottom and rested on supporting brackets. The tank and rim were of wrought iron with supporting brackets of steel and piping of galvanized iron, to prevent rusting.[7] (Figure 10)

While the engineering details were completed by O. Smreker, Chief Engineer of the Mannheim Water Department, the architecture of the tower was chosen through a design competition, won by G. Halmhuber. The tower consisted of quarry faced stone in the lower portion and brick and stone in the upper, and was classical in inspiration. Pilasters and segmental arches with keystones formed the outer plane of the lower wall surface; a second

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[7] "The Water Tower at Mannheim, Germany," The Engineering Record 26 (September 3, 1892): 219.

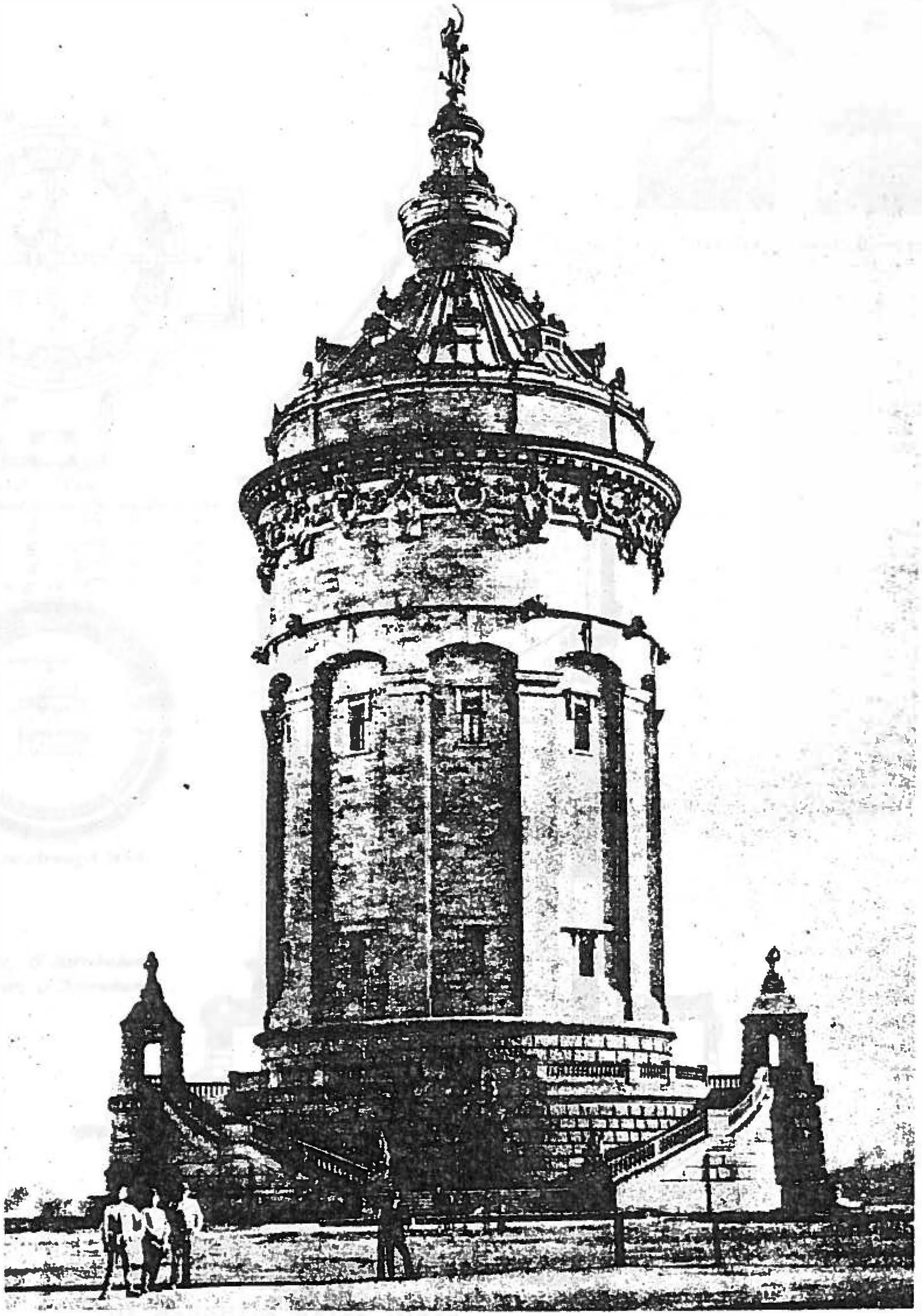
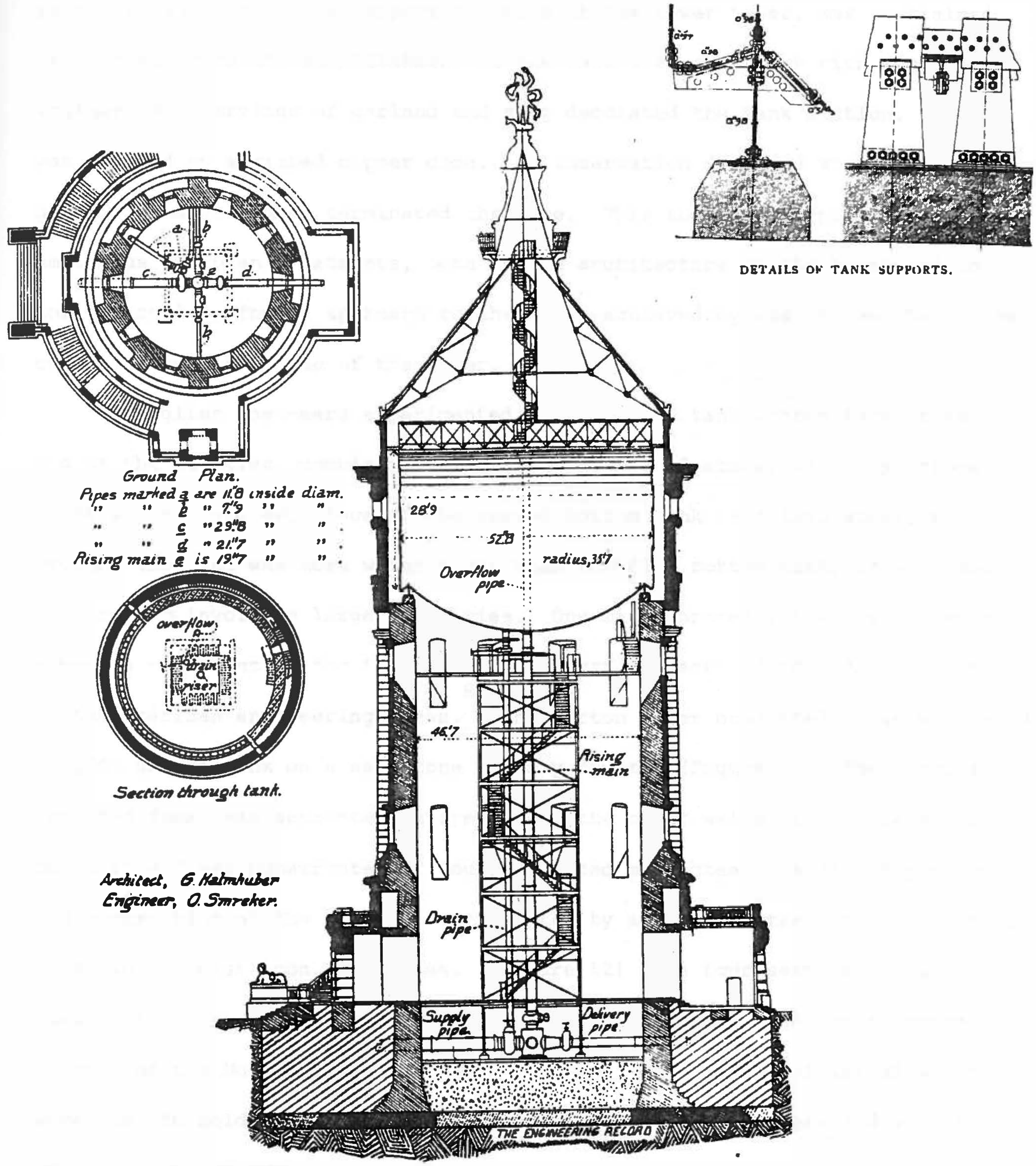


Figure 9. Mannheim, Germany water tower (1885): exterior. Capacity: 527,000 gallons.
Source: "The Water Tower at Mannheim, Germany," The Engineering Record 26 (September 3, 1893): 11.



THE MANNHEIM WATER TOWER.

Figure 10. Mannheim, Germany water tower (1885): section and detail of tank connection.
Source: "The Water Tower at Mannheim, Germany," <u>The Engineering Record</u> 26 (September 3, 1892): 219.

recessed plane contained small windows. This section of the tower, its pilasters suggesting the support function of the lower tower, was restrained in comparison to the embellishment of the tank area above. A rich band of statuary and carvings of garland and swag decorated the tank section, which was covered by a ribbed copper dome. An observation deck and statuary suggesting aquatic themes terminated the dome. This tower was typical of ambitious European treatments, both in the architecture of the tower and in the controlled, formal approach to the tower achieved by use of two staircases curving around the base of the tower.

English engineers experimented with the new tank bottom form at the end of the eighties, combining the new engineering features with traditional architectural styles. Because the curved bottom tank used less steel or wrought iron and was more water tight than the flat bottom tank, it was ideal for projects involving large capacities. One major project, the Norton water tower, a component of the Liverpool water system, received considerable notice in the American engineering press.[8] The Norton tower consisted of an uncovered 780,000 gallon tank on a sandstone masonry tower. (Figure 11) The tank, an inverted dome, was supported entirely upon the outer walls of the tower; the basin itself was constructed of double-riveted mild steel plates. Expansion and contraction of the tank was accomodated by a ring of steel rollers resting on a ring of cast iron bed plates. (Figure 12) The four service pipes passing into the tank bottom served no support function. The architectural sources of the Norton tower were Roman, intending to recall classical water works in the bold and simplified design. Alternating pilasters and slightly

[8] "The Norton Tower of the Vyrnwy-Liverpool Water Supply," The Engineer 72 (September 18, 1891): 231-34; "The Norton Water-Tower of the Vyrnwy Aqueduct," Engineeering News 26 (October 10, 1891): 331.

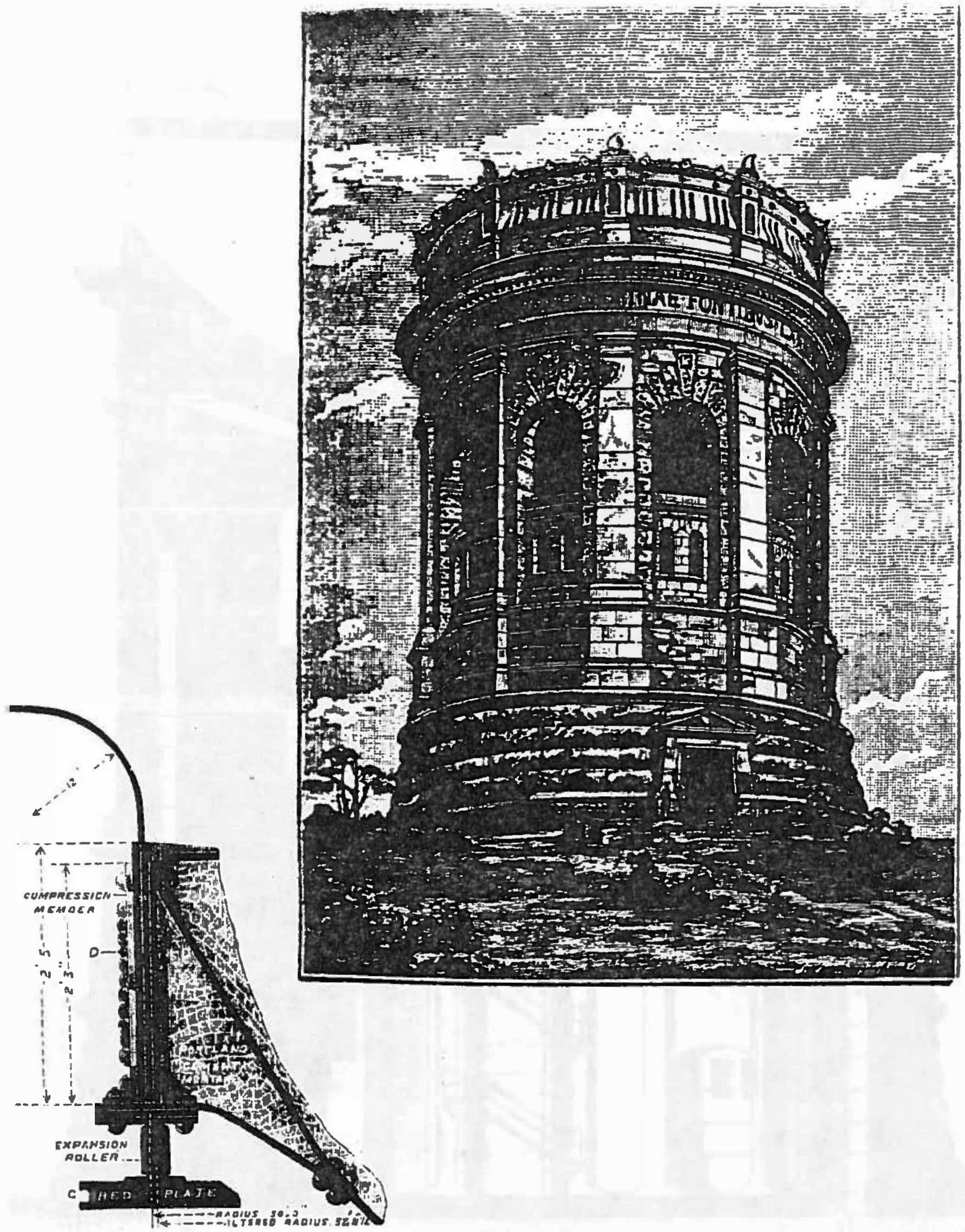


Figure 11. Norton, Liverpool water tower (1891). Exterior and detail of tank connection (inset). Capacity: 780,000 gallons. Source: "The Norton Water-Tower of the Vyrnwy Aqueduct," Engineering News 26 (October 10, 1891): 111.

1891. THE ENGINEER. 2

NORTON TOWER, VYRNWY AQUEDUCT, LIVERPOOL WATER SUPPLY

MR. G. F. DEACON, M. INST. C. E., ENGINEER

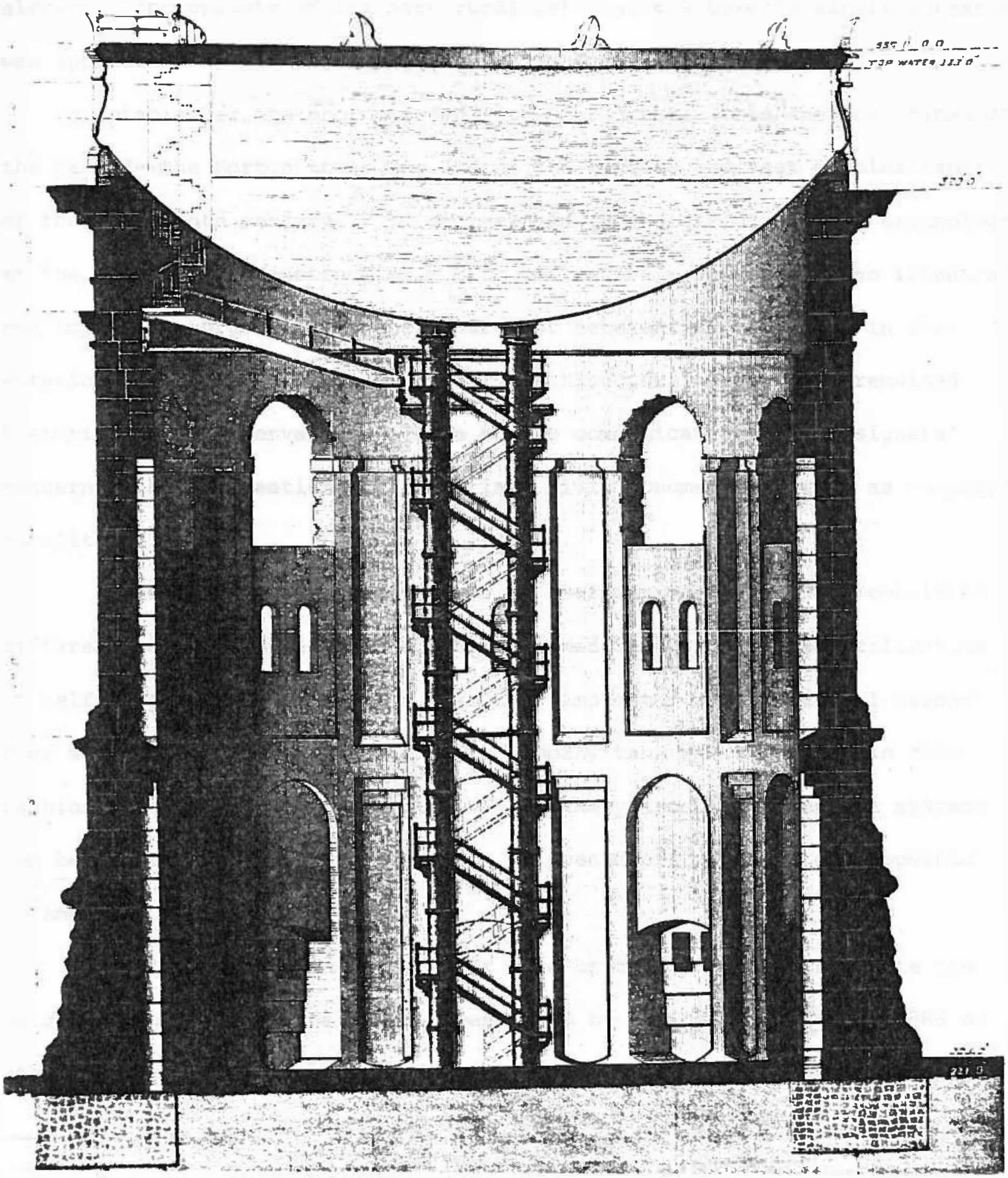


Figure 12. Norton, Liverpool water tower (1891): section.
Source: "The Norton Tower of the Vyrnwy-Liverpool Water Supply," The Engineer (September 18, 1891): 231.

recessed arches with deep voissoirs of rough faced stone supported a frieze with Latin inscription. A deep cornice separated the lower tower from the tank area; the exposed steel tank itself formed the uppermost decorative element. Appropriate of its more rural setting, the tower's single entrance was approached at ground level rather than by a formal staircase.

Notable for its enormous capacity--far greater than American tanks of the period--the Norton tower was one of the largest and most complex tanks of the nineteenth century.[9] It represented the height of British technology at the time of its construction. With the Mannheim tower, it also illustrated how important structural advances were not necessarily reflected in the exteriors of the towers--that in fact, architectural treatments remained historical and conservative. These towers communicated their designers' concern with the creation of appropriate civic monuments as well as municipal facilities.

Alternative structural systems in American masonry towers consisted of different means of supporting a flat bottomed tank rather than utilization of self-supporting tank bottoms. In the simplest forms, a central masonry pier was employed; the 1799 Manhattan Company tank was supported in this fashion. A few published examples of genuinely innovative support systems can be located which merit discussion as precursors of later developments in America.

The 1883 Weehawken water tower used brick arches to distribute the weight of the tank to the tower. Described by Engineering News in 1886 as "the most important structure of its kind in the country," the tower was

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[9] The Norton tower remained one of the largest tanks in the world through the 1920's. The Water Tower 7 (April 1921): 12.

designed by John F. Ward and F. C. Withers to provide high service in Hoboken and Weehawken.[10] (Figure 13) The one hundred forty foot tower contained an iron tank thirty feet in diameter and thirty feet high--roughly 150,000 gallons--with living and store rooms for the engineer ("Director") in the lower portion of the tower. The tank, weighing 624 tons when filled, was supported on brick Gothic arches which "though considered bold at the time when built, have the advantage over any scheme of iron trussing or beams, that there is practically no springing of the bottom of the tank when filled or emptied."[11] The arched ribs and spandrels were one foot thick, and the small floor arches the same. Three tie rods had been built into the walls to take the thrust of the large arches but had proven unnecessary.

The Pullman, Illinois water tower, designed in 1882 by S. S. Beman, incorporated wrought iron columns and simplified Bollman form roof trusses to support a 550,000 gallon tank.[12] (Figure 14) The trusses rested on four wrought iron columns extending through the enclosed space below the tank to the

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[10] In localities where topography varied radically, water service to the more elevated areas was often provided independently of that for the lower sections. John Ward, engineer of the Weehawken water tower, was a civil engineer prominent in water works design. F. C. Withers was a noted mid-nineteenth century architect whose work included major buildings in New York, New Jersey, and Pennsylvania in the Victorian Gothic and Queen Anne styles. The tower is one of his few known industrial works and may be the last surviving nineteenth century water tower in the state. Terry Karschner, National Register of Historic Places Nomination Form-Hackensack Water Company Complex, p. 8-3.

[11] "The Weehawken Water Tower," Engineering News and American Contract Journal 16 (November 6, 1886): 292.

[12] Beman, a young New York architect, left Richard Upjohn's office in 1879 to design George Pullman's model company town in Chicago. Pullman's 1800 homes and public buildings were his first major independent commission; later work included commercial and residential buildings in major Mid-western cities and Ivorydale, a second factory community, designed for Proctor and Gamble. Henry F. and Elsie Rathburn Withey, Biographical Dictionary of American Architects (Deceased) (Los Angeles, Hennessey & Ingalls, 1970), p. 18.

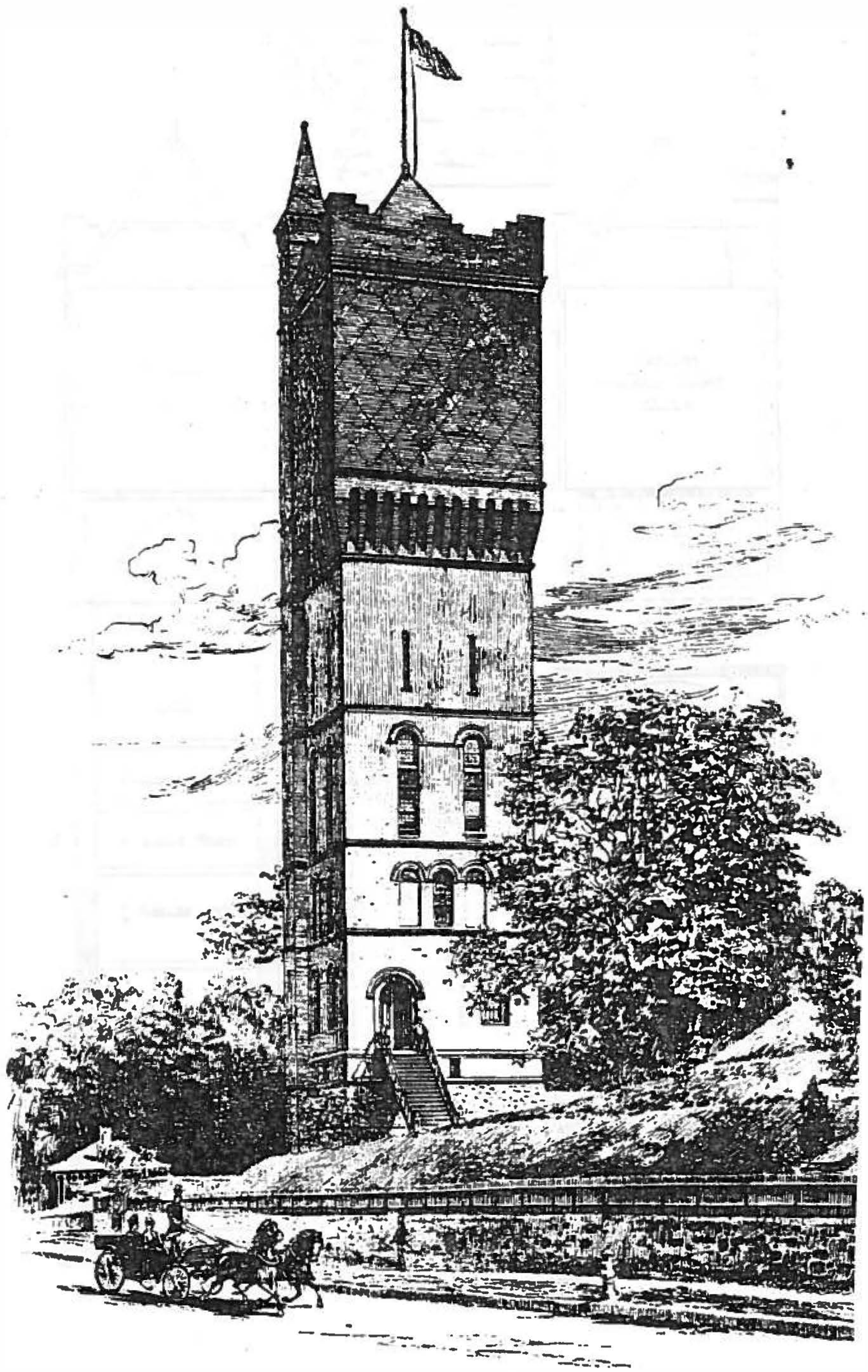

Plate I.—Water Tower at Weehawken, N. J.

Figure 13. Weehawken, New Jersey water tower (1883). a. Perspective. Capacity: 150,000 gallons.
Source: "The Weehawken Water Tower," Engineering News and American Contract Journal 16 (November 6, 1886): 292.

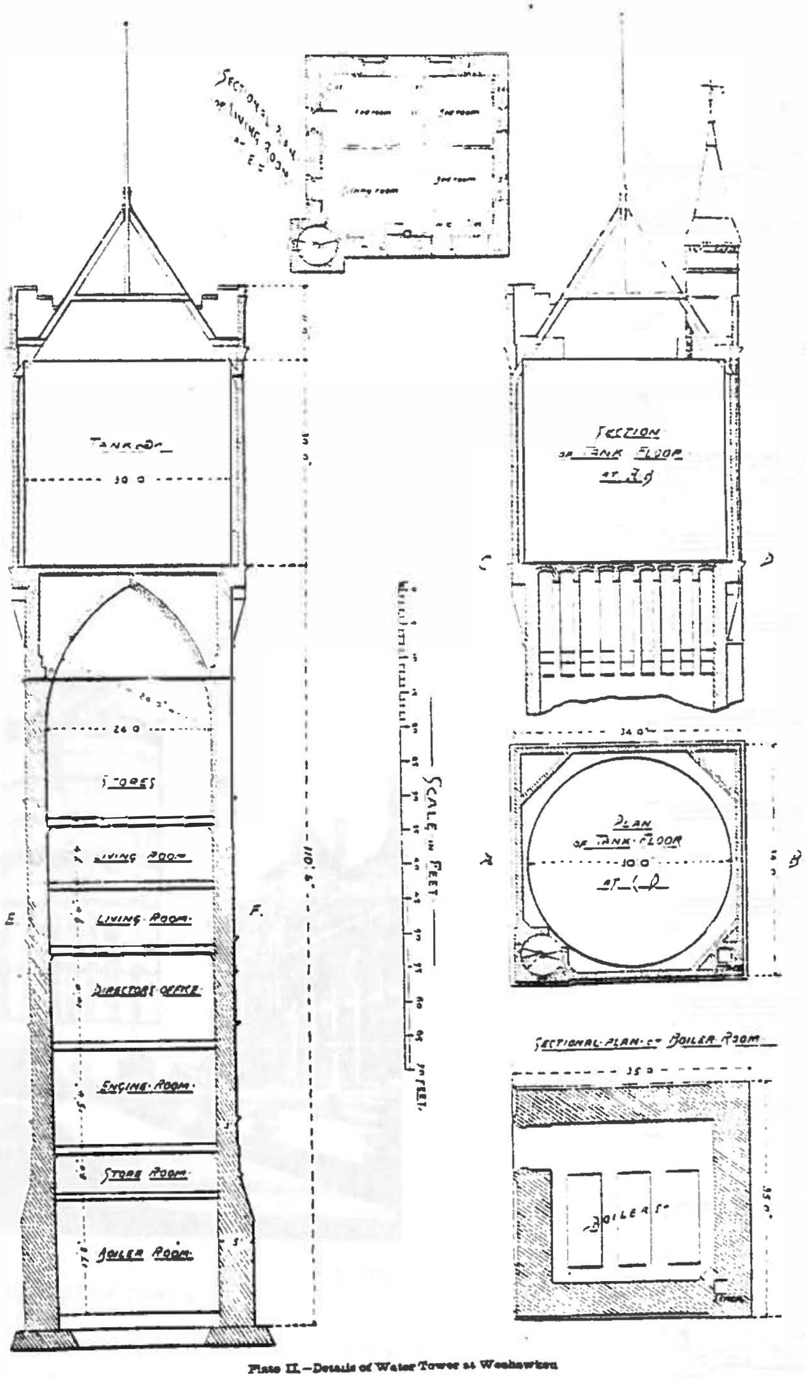

Figure 13. Weehawken, New Jersey water tower (1883). b. section. Source: "The Weehawken Water Tower," Engineering News and American Contract Journal 16 (November 6, 1886): 293.

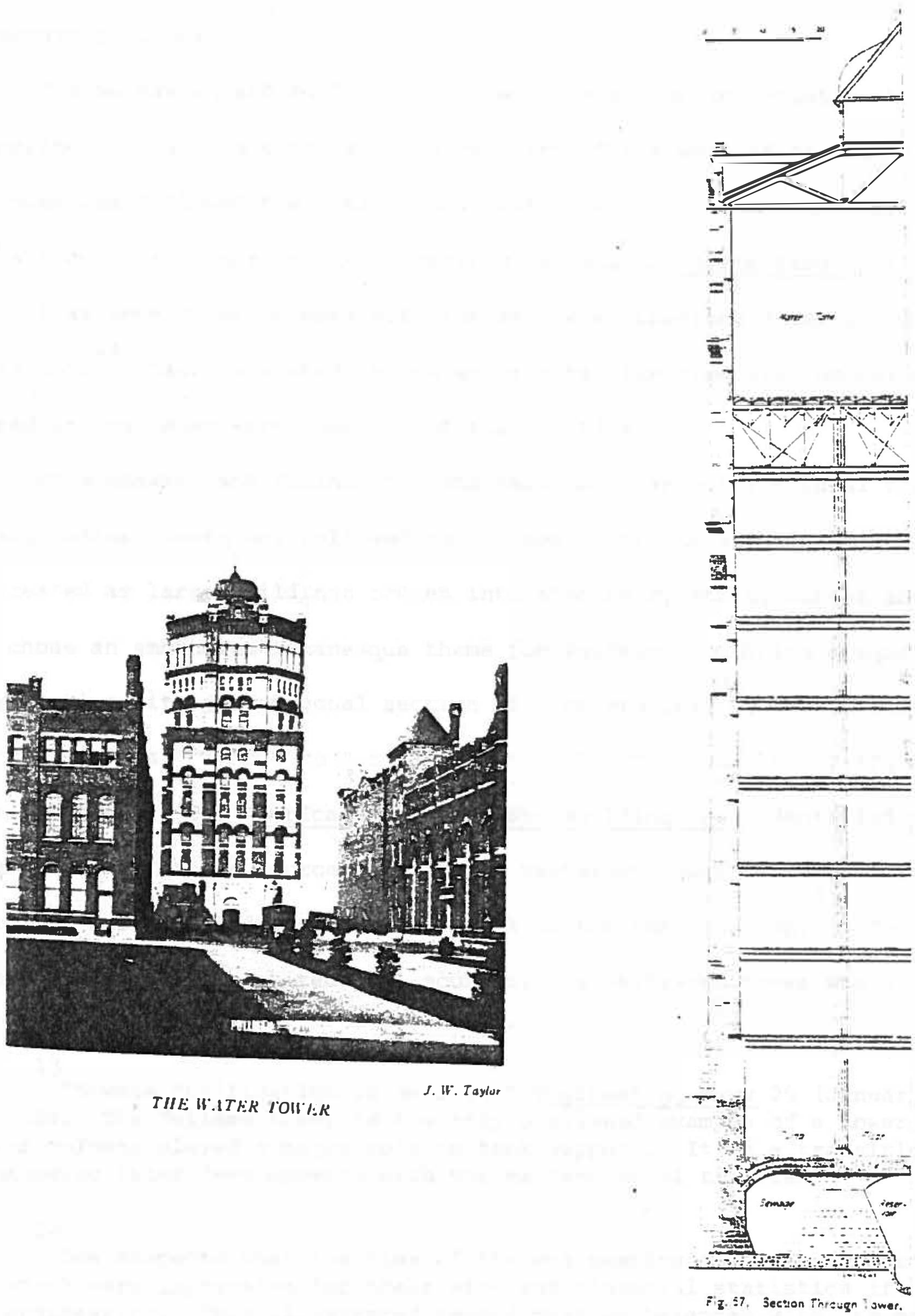

Figure 14. Pullman, Illinois water tower (1883): exterior and section.
Capacity: 550,000 gallons.
Source: "Sewege Purification in America," Engineering News 29 (January 12, 1883): 26.

tower foundations. The lower stories of the tower were originally used for manufacturing purposes.[13]

The Weehawken and Pullman towers were large and important works whose engineering sources are obscure. The majority of the work of the eighties and early nineties followed the established pattern of floor beams and flat bottom tank, although references to iron trussing systems in Engineering News in 1886 suggest that some other schemes with innovative engineering details had been carried out.[14] Tanks elevated on wooden or metal trestles also occasionally appeared in the water works manuals of the eighties.

At Weehawken and Pullman the standard American architectural formula for large water towers was followed in the design of the exteriors. Both towers were treated as large buildings broken into stories by stringcourses and windows. Beman chose an ambitious Romanesque theme for Pullman, combining a square base of six stories with an octagonal section of five stories, with continuous bands of arched windows. A dome roof reminiscent of European designs of the eighties covered the tank. The American Architect and Building News identified the Pallazzo Vecchio as the source of Withers' Weehawken tower design, because of the Moorish-influenced diagonal patternwork in the tank section.[15] In spite of its more identifiable architectural sources, the Weehawken tower was a less

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[13] "Sewage Purification in America," Engineering News 29 (January 12, 1893): 26. The Pullman tower is the only published example of a tower in which interior columns played a major role in tank support. It is a transitional form foreshadowing later developments with the exposed metal trestle.

[14] One suspects that the bias of the engineering journals favored major works which were impressive for their size and financial statistics if not for their engineering. This illustrated record must be balanced with the more comprehensive accounting of water works facilities in annual publications which report the full range of towers and tanks.

[15] "Water Tower for the Hackensack Water Company, Weehawken, New Jersey," American Architect and Building News 14 (September 8, 1883): 114, plate 402.

sophistocated work than Pullman. At Weehawken, the lower stories were comparable to the Yonkers water tower and English work of the period. At Pullman, a more unified concept including expression of the interior features--the continuous masonry pilasters echoing the wrought iron support elements, and the transition from a square base to octagonal section highlighting the tank. More important are the shared characteristics of these two large towers: the use of brick and cut stone in the tower bases, the articulation of the tank portion of the tower, and the effects achieved by varying textures, materials, and colors. The addition of a full domed roof or asymmetrical elements like the turret at Weehawken was not unusual in the more elaborate American masonry water tower.

The masonry supported tank was desired by communities because it could be constructed from local materials which could be less expensive than steel or iron for a standpipe shipped long distances. Because local workmen often had a sound understanding of masonry construction techniques, responsible contractors could be more easily located. Also, there was not a waiting period for materials, as sometimes occurred with wrought iron or steel standpipes.[16]

The masonry water tower was perceived as the most attractive elevated water storage structure available in the seventies and eighties. The prevailing architectural tastes, with their emphasis on evocative, historical European styles, complex silhouettes, and massive masonry work, were easily applied to the water tower. Most major American towers of the period were either Gothic or Romanesque in style, while architects in England and on the Continent also chose Classical and Renaissance motifs. Gothic styling with narrow pointed arch windows was particularly practical because the tower section

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[16] Engineering News 35 (January 16, 1896): 45.

not require lighting unless uses were planned for the lower floors. Also, the insulating effect of the tower was reduced if large windows were used. The architectural treatment chosen for the exterior of a tower depended on the prosperity of the community and on the characteristics of available brick and stone. Most architects avoided direct quotation from historical sources, instead combining elements of various styles in new designs with Medieval, Roman, or aquatic themes. Many did not differentiate water towers from other towers associated with churches or public buildings: the aesthetics of the masonry water tower fell within the scope of public architecture of the late nineteenth century. The design was often unrelated to the engineering features of a given tower: the structurally advanced Weehawken tower and the less sopistocated Yonkers tower share the same aesthetic approach.

On a vernacular level, examples from the eighties document functional brick or stone piers with few stylistic pretentions. The Florence, Alabama water tower, erected in 1887, is representative of this type, with unadorned but impressive stone base supporting a steel tank.[17] (Figure 15) These simple masonry towers were commonly erected by communities striving for more than a cypress tank on a wooden trestle. Many communities chose a wood trestle and tank as their first water storage structure because it was significantly cheaper and required less time and skilled labor to erect than a masonry tower. A related consideration was the availability of metal for the tank itself; it was easier for remote communities to purchase a wood tank and trestle with erection

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[17] Alabama Historical Commission survey files. In northern environments, the masonry work often extended up to enclose and insulate the entire tank. Railroad service tanks were also among the more modest water storage structures, using simple wooden trestles or brick towers. (Figure 16)

Figure 15. Florence, Alabama water tower (1887). Capacity: 294,000 gallons.
Source: Alabama Historical Commission.

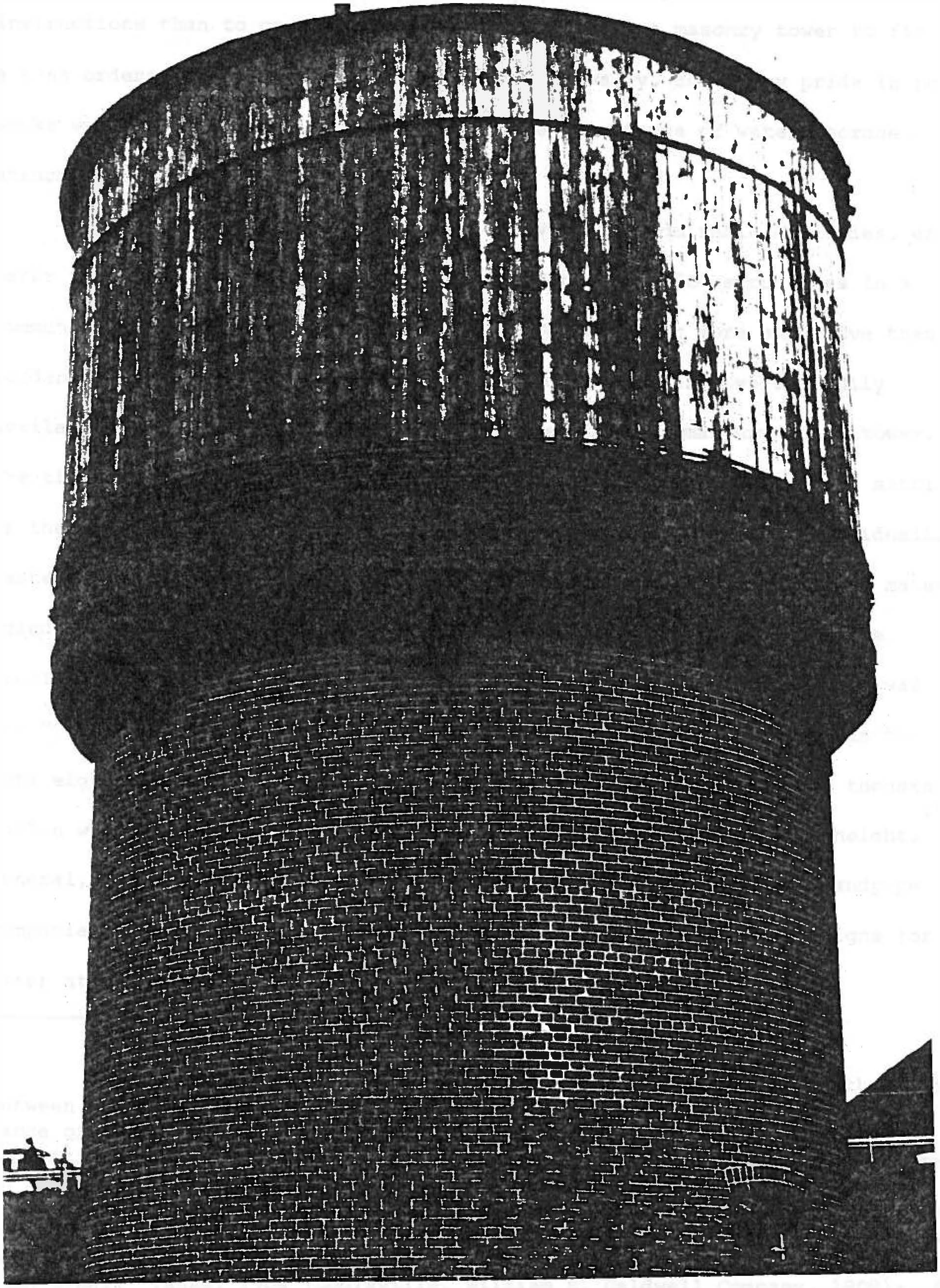

Figure 16. Railroad Service water tower, Hazelton vicinity, Pa.
Source: C. Dubie.

instructions than to coordinate the construction of a masonry tower to fit a tank ordered from the nearest iron works. Finally, community pride in public works was a major factor in upgrading of the appearance of water storage structures.[18]

Even in its simplest form, masonry work had admirable qualities, and a water tower possessed a scale and solidity matched by few structures in a community. An ambitious design could be expensive--far more expensive than a wooden tank and trestle, and, where steel and wrought iron were readily available, the standpipe was also competitive with the masonry water tower. The time required to build the foundations and tower and to allow for setting of the masonry often created delays. Also, it appears that the individualized tastes of more prosperous communities and the use of locally available materials ruled out design standardization which might have reduced costs or made problems in tower design more predictable. One interesting exception was the "George C. Morgan Special Water Tower," popular in the mid-west in the late eighties and early nineties, which featured a twenty to thirty thousand gallon wrought iron or steel tank on a brick tower 100-150 feet in height.[19] In general, however, the windmill and wooden tank manufacturers and standpipe companies were responsible for the introduction of standardized designs for water storage structures.

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[18] It appears that tank size was not a significant factor in the choice between wood or metal. The Manual of American Water Works in 1890 listed a range of existing wood and metal tanks from 20,000 to 100,000 gallons, the capacities generally sought by moderate sized communities. The Caldwell Company in 1908 offered standardized wood tanks ranging from 150 to 123,000 gallons, and steel tanks from 500 to 100,000 gallons. A 50,000 gallon wood tank cost $630; in steel, $1082. A 100,000 gallon wood tank cost $1114; in steel, $1842. Wood maintained a clear cost advantage, as well as having better insulating qualities than steel. Tanks, 1908 (Louisville, William E. Caldwell Company, 1908): 4-6, 17.

[19] Dozens of these water towers were built for small communities in Ohio and Illinois. Baker, Manual of American Water Works: 1897, passim.

In the eighties, the standpipe was the major competitor of the masonry water tower. The standpipe was inexpensive, profitable to iron works contractors in the expanding iron and steel industry, and assumed to be simple to design and erect. Its basic form was a product of the industrial era, with no architectural pretensions.

Standpipes in the nineteenth century were fabricated of wrought or cast iron or steel plates of varying thickness, riveted together in rings much like the tanks contained in masonry water towers. The first standpipes were narrow as compared to their height; their function was to provide a cushion of water to pump against to prevent sudden changes in pressure in the distribution system. Later, water storage capacity was seen as an added advantage.[20] The Gravesend, Long Island standpipe (1886) was a good example of the early storage standpipe in spite of its short life: two hundred fifty feet high, it was sixteen feet in diameter for the first fifty feet of its height, then eight feet in diameter to its top. (Figure 17) Constructed of steel plate manufactured by Schoenberger and Company of Pittsburgh, and erected by the Robinson Boiler Works of Boston, the pipe burst near its base during a test filling.[21] The tall narrow form was more prone to failure because of the extreme pressures within the tube; the variable

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[20] J. N. Hazelhurst, Towers and Tanks for Water Works (New York, John Wiley & Sons, 1901), p. 5.

[21] The engineering community was not in complete agreement about the cause of the Gravesend failure. Several prominent engineers agreed, however, that the reduction in diameter from sixteen to eight feet was a major design flaw. John Ward, engineer of the Weehawken water tower, attacked the tapered form of the standpipe and argued that a twenty by twenty foot tank on a high trestle would have cost less and had greater effective capacity. John F. Ward, "The Fall of the Gravesend Stand-Pipe," Engineering News and American Contract Journal 16 (November 13, 1886): 316.

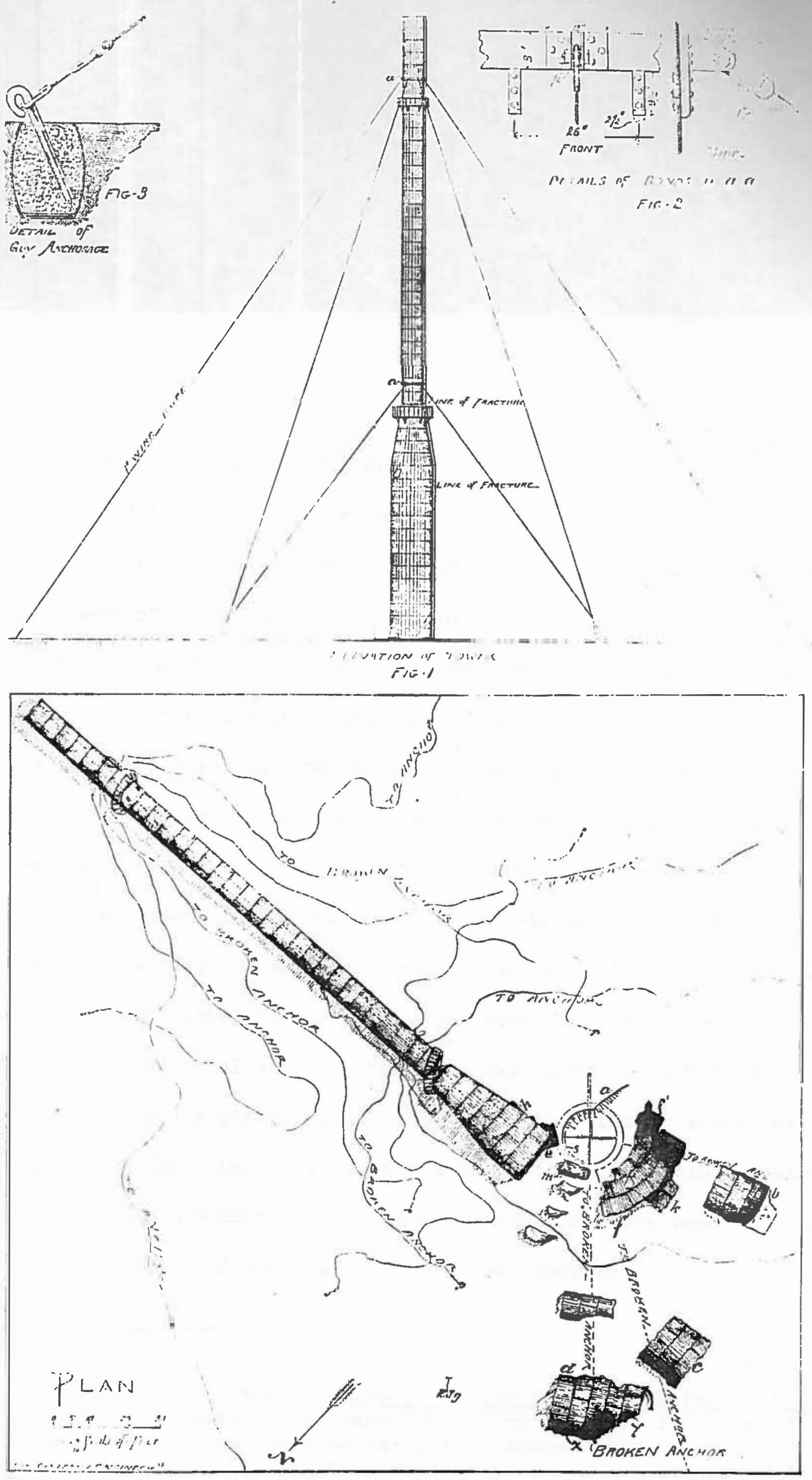

FIGURE 8.

Figure 17. Gravesend, Long Island standpipe (1886). Plan of destroyed standpipe. Capacity: 150,000 gallons.
Source: "The Bursting of the Gravesend Water-Tower," The Sanitary Engineer 14 (October 23, 1886): 495.

qualities of wrought iron and steel in the 1870's and 1880's; and the instability of the tall slender form.[22]

The standpipes commonly used in public water systems in the eighties were of more modest proportions than the Gravesend pipe. A survey in 1888 showed heights between twenty-five and two hundred fifty feet, with the majority in the eighty to one hundred twenty-five foot range. Diameters of five to forty feet were reported, with most in the fifteen to thirty foot range.[23] The typical standpipe of the eighties was a wrought iron or steel tube set on an even stone or concrete foundation. (Figure 18) The metal column was anchored to the foundation with rods extending through the bedplate into the foundation, and exterior brackets at the outside of the base and foundation. Additional support was often provided through guy wires attached to collars on the metal shell. Until the mid-eighties, a ladder to provide service access and angle bracing to maintain the circular shape were often riveted inside the standpipe. Once the role of ice formation in standpipe failures had been documented, interior obstructions were removed, and spiral ladders and systems of external bracing were substituted.

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[22] William D. Pence, Standpipe Accidents and Failures in the United States (New York: Engineering News Publishing Company, 1895), p. 87. Pence wrote that wrought iron had a better safety record than steel:

> Its process of making had been brought to a high degree of perfection prior to its use for standpipe construction, while in the case of steel, the grades ordinarily available during the earlier period of its use for this purpose lacked uniformity, and were often very deficient in the qualities essential to such construction.

[23] M. N. Baker, The Manual of American Waterworks: 1888 (New York, Engineering News Publishing Company, 1889), insert entitled "A Partial List of Standpipes in the United States." This was one of the first detailed listings of water storage structures in use in the 1880's. Because the term "standpipe" was applied to water storage structures in general, the list also included water towers and several elevated tanks.

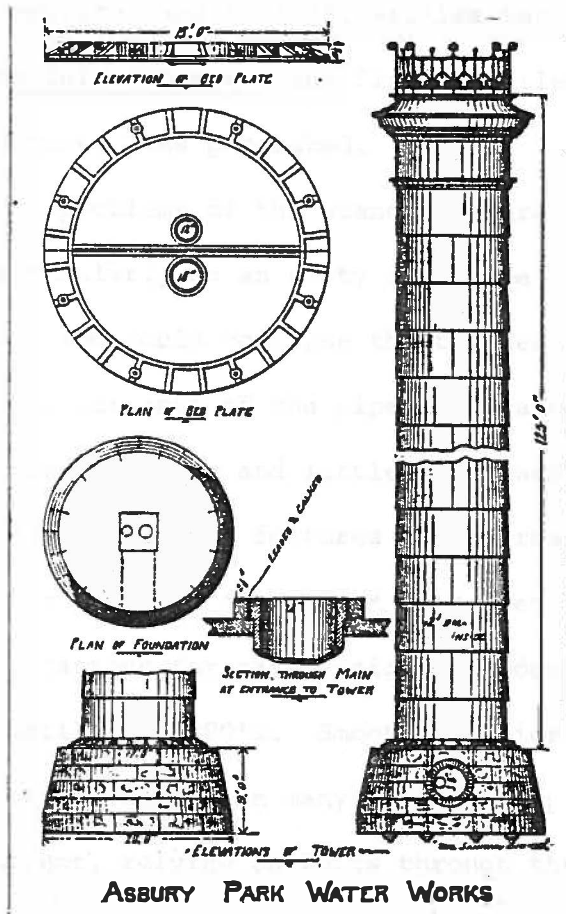

Figure 18. A typical standpipe of the 1880's: Asbury Park, New Jersey standpipe (1886). Capacity: about 100,000 gallons. Source: "The Water Tower at Asbury Park," <u>The Sanitary Engineer</u> 14 (September 2, 1886): 321.

The economics of standpipes were their greatest selling point, particularly for communities constructing their first water works system. The apparent simplicity of design and construction encouraged large numbers of boiler makers and iron works to enter the standpipe fabrication field in the 1870's. A subsequent rash of failures in the 1880's prompted concern in the engineering community, and in 1895, William Pence's Standpipe Accidents and Failures in the United States, the first detailed analysis of elevated water storage structures, was published.

Some of the problems of the standpipe were inherent in its form. The action of wind, particularly on an empty standpipe, created a vacuum on the far side of the tube and could collapse the thinner plates of the upper portion. The large exposed surface area of the pipe encouraged ice formation within the tube when temperatures were low and little water was withdrawn or pumped in. Blocks of ice formed on interior features and increased in size until thawing occurred; the falling ice then damaged or destroyed the standpipe.[24]

The specifications for safe design and sound construction were not widely recognized until the 1890's. Smooth interior surface were lacking and adequate foundations absent in many early standpipes. Early anchorages were often insufficient, relying on bolts through the bedplate, with no secondary support from brackets or guys. The Asbury Park standpipe (1886), a twelve by one hundred twenty-five foot standpipe, was anchored by eight screw bolts passing through the masonry base and secured below by cast nuts. This was the only attachment of the 100,000 gallon standpipe to its foundation.[25]

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[24] Pence, Standpipe Accidents and Failures, p. 78-79.

[25] "The Water Tower at Asbury Park," The Sanitary Engineer 14 (September 2, 1886): 321.

(Figure 18) The standpipes of the nineties, as represented by the twenty by seventy foot Roland Park, Baltimore standpipe (1892) and the twenty by one hundred thirty foot Chevy Chase standpipe (1895), used brackets or angle irons riveted to the lower courses of plates.[26] (Figures 19 and 20)

Considerable variation in design continued through the nineties, but standpipe engineering emphasized greater stabilization of the tube form, resulting in standpipes of larger diameter and slightly reduced heights. Greater attention was paid to site preparation, foundations, and construction techniques. Methods of construction which involved suspending workmen and materials from the partially completed shell were discontinued, and specifications discussing quality of materials and procedures like riveting grew more detailed.

These engineering considerations complicated aesthetic treatment of the standpipe. The engineering community believed that standpipes had little architectural merit, resembling "plain cylinders of iron thrust up into the air like enormous steam boilers, much elongated and set on end, or like very thick, unsharpened lead pencils, and they disfigure the landscape as a heavy black perpendicular mark would deface a fine painting."[27] The exposed standpipe required bracing against wind and because strains in the shell were to be avoided, embellishment of the cylinder to create complicated

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[26] "Standpipe at Roland Park, Baltimore," Engineering News 28 (September 10, 1892): 232; "Standpipe at Chevy Chase, Maryland," The Engineering Record 32 (September 21, 1895): 298. In 1893, brackets alone were also considered to be inadequate by some engineers. Only guys were useful in resisting wind pressure in the upper portion of the standpipe. Freeman C. Coffin, "Standpipes and Their Design," Engineering News 29 (March 16, 1893): 243.

[27] "Watertowers in Massachusetts," Engineering News 28 (September 8, 1892): 225.

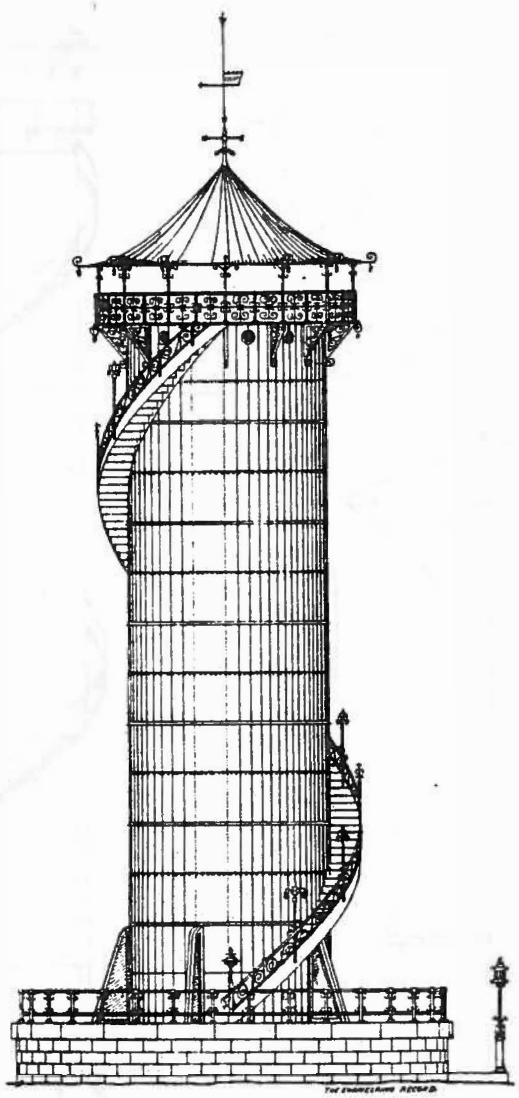

Figure 19. Roland Park, Baltimore standpipe (1892). Capacity: 150,000 gallons.
Source: "Standpipe at Roland Park, Baltimore," Engineering News 28 (September 10, 1892): 232.

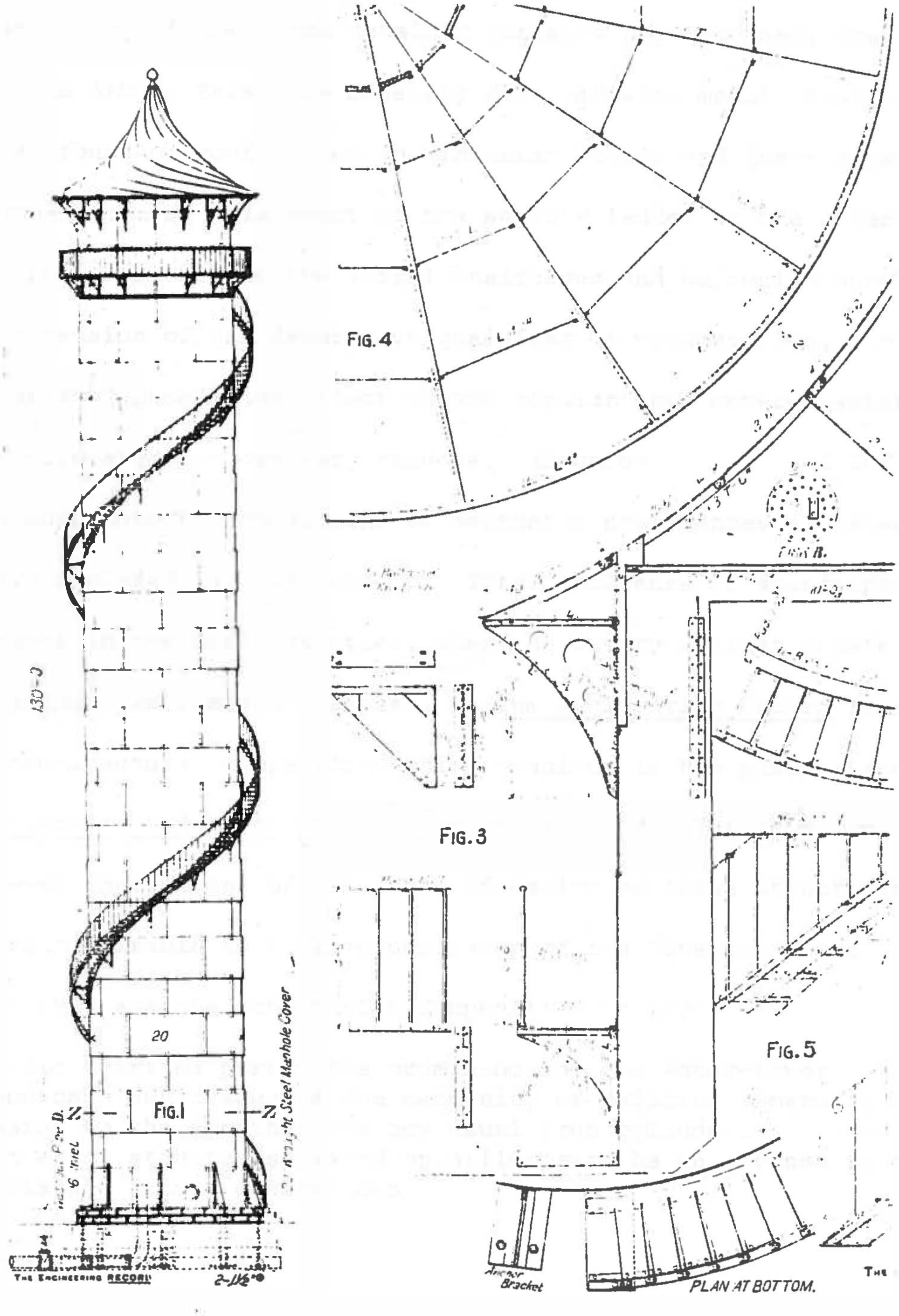

Figure 20. Chevy Chase, Maryland standpipe (1895). Capacity: 300,000 gallons.
Source: "Standpipe at Chevy Chase, Maryland," <u>The Engineering Record</u> 32 (September 21, 1895): 298.

or asymmetircal silohuettes was discouraged.

Any softening of the harsh metallic surfaces was welcomed, however. Early models like Asbury Park were modestly detailed with metal cresting typical of that found on roof ridges in Victorian Gothic and Queen Anne residential architecture. Placement of the service ladder on the exterior of the pipe resulted in attractive spiral staircases and balconies which allowed for expression of the decorative qualities of wrought iron. In the nineties, a turreted Queen Anne effect became popular when covered water supplies were advocated for sanitary reasons. (Figures 19 and 20)

Where environmental conditions or aesthetic preferences dictated, standpipes were enclosed in brick shells. Total enclosure of standpipes gained acceptance in the early nineties, when the outcry against unsafe and unattractive standpipes reached its peak.[28] The Engineering Record in 1889 sponsored an architectural competition which resulted in the publication of Water Tower, Pumping, and Power Station Designs in 1893. The editor of the periodical viewed improvement of the level of design of these structures as a civic gesture comparable to their sponsorship of the Tenement House Competition in 1878 and the School Plan Competition in 1879:

> To any public spirited person the prominence of the water-tower in the landscape would suggest the necessity of building something more pleasing to the eye than the now usual iron cylinder. . . .man. . . should not erect structures placed on hilltops to be an offense to the eyes of this and future generations.[29]

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[28] See also "Should the Building of Stand-Pipes be Abandoned?" Engineering News 33 (May 30, 1895): 353; Pence, Standpipe Accidents and Failures; "Watertowers in Massachusetts," p. 225.

[29] "Competition for Pumping Stations and Water-Tower Designs," The Engineering and Building Record 20 (November 30, 1889): 377.

A twenty by one hundred twenty foot standpipe was specified as the competition standard so that entries would be appropriate for the water works of a large number of communities.

In the awarding of prizes, "adaptability for the purpose desired," was the first criterion. This meant that the proposed design had to be suitable for the specified standpipe. The second and third criteria were respectively "architectural design" and "economy in the treatment"--two factors which most communities appear to have reversed in their own consideration of standpipe designs. Recognizing that in many cases "the simplest possible architectural expression is the only thing possible," the committee awarded first prize to a design that could serve as an example to any community of moderate means. This design, "Aquatio," consisted of an octagonal tower built of rough faced local stone pierced by randomly placed paired windows and capped with an observatory. The standpipe enclosure was rugged and individualistic, not representative of any particular "style." Its simplicity and uncluttered surfaces set it apart from much of the contemporary work and many of the other competition entries.[30] (Figure 21)

The second prize, selected for its architectural effects, was more ambitious, employing attenuated arches to emphasize the vertical standpipe within. The third prize, a rather static brick and stone tower relieved only by a spiral of window openings lighting the interior stair, lacked sufficient architectural merit to rate more highly. It did resemble the

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[30] The architect, Elmer Grey, received his early training in the firm of Ferry and Clas, Milwaukee. The Brickbuilder noted in 1915 that Grey "came into notice architecturally through his design for a water tower and pumping station which won first prize over mature competitors." Grey moved from Milwaukee to California in 1904; his mature work was characterized as "combining with perception of good proportions a sense of restrained enrichment, a sympathetic use of materials and choice of colors." His early published work included shingle and Tudor Revival styles, as well as more hybrid, original work. "Elmer Grey," The Brickbuilder 24 (1915): 146.

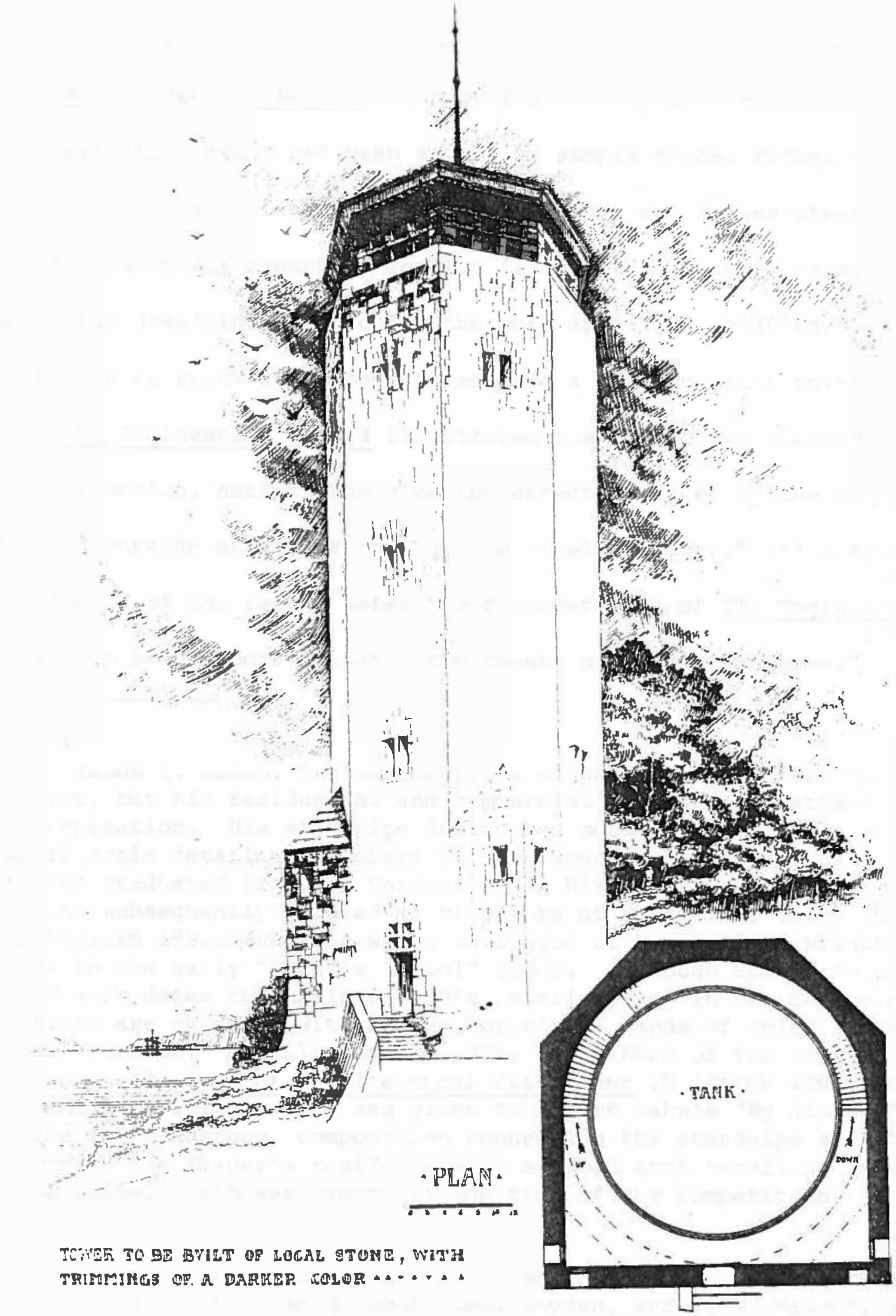

Figure 21. First prize design for an enclosed standpipe (1889). Capacity: 280,000 gallons.
Source: <u>Water Tower, Pumping, and Power Station Designs</u> (New York, The Engineering Record, 1893), n.p.

first prize design in its simplicity, bold massing, and large scale detailing.[31] (Figures 22 and 23)

The Engineering Record's judges found that "few designs were presented in which artistic effect had been sought by simple means, rather than by costly and formal architectural devices."[32] None of the seventeen designs which were chosen for honorable mention illustrated improved versions of the exposed metal standpipe. All chose the more appealing solution of encasing the standpipe in brick and stone to resemble a masonry water tower. In 1892, however, The Engineering Record illustrated the Des Moines standpipe, then under construction, noting "the pleasing effect produced by the canopied balcony and outside staircase on a simple steel cylinder," and boasted that "the influence of the recent water tower competition of The Engineering Record is tending to secure more artistic treatments of such structures."[33] (Figure 25)

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[31] James C. Green, the second prize winner, worked in New York and Connecticut, but his residential and commercial work did not attain more than a local reputation. His standpipe design was more refined than the others, with small scale detailing. Robert Closson Spencer, Jr., the third prize winner, had graduated from the University of Wisconsin as a mechanical engineer in 1886 and subsequently studied architecture at M.I.T. He chose Chicago for his practice in 1893, where he was a colleague of Frank Lloyd Wright's and a principal in the early "Prairie School" group. Although Spencer's earliest published work dates to the late 1890's, similarities in his choice and handling of materials are evident, with strong horizontal bands of color and expanses of plain wall surface. H. Allen Brooks, "The Early Work of the Prairie Architects," Journal of the Society of Architectural Historians 19 (March 1960), p. 2-10.

An honorable mention was given to Albert Kahn's "By Jiminy," a vigorous fieldstone and sandstone composition connecting the standpipe and its appended stairtower to the Keeper's residence with a broad arch recalling Richardson's Ames Gate Lodge. Kahn was twenty at the time of the competition. (Figure 24)

[32] Four architects and one civil engineer comprised the committee: Edmund M. Wheelwright, John M. Root, Amos Boyden, and F. A. Wright, architects, and Dexter Brackett, civil engineer.

[33] "The Standpipe at Des Moines, Iowa," The Engineering Record 25 (February 6, 1892): 156.

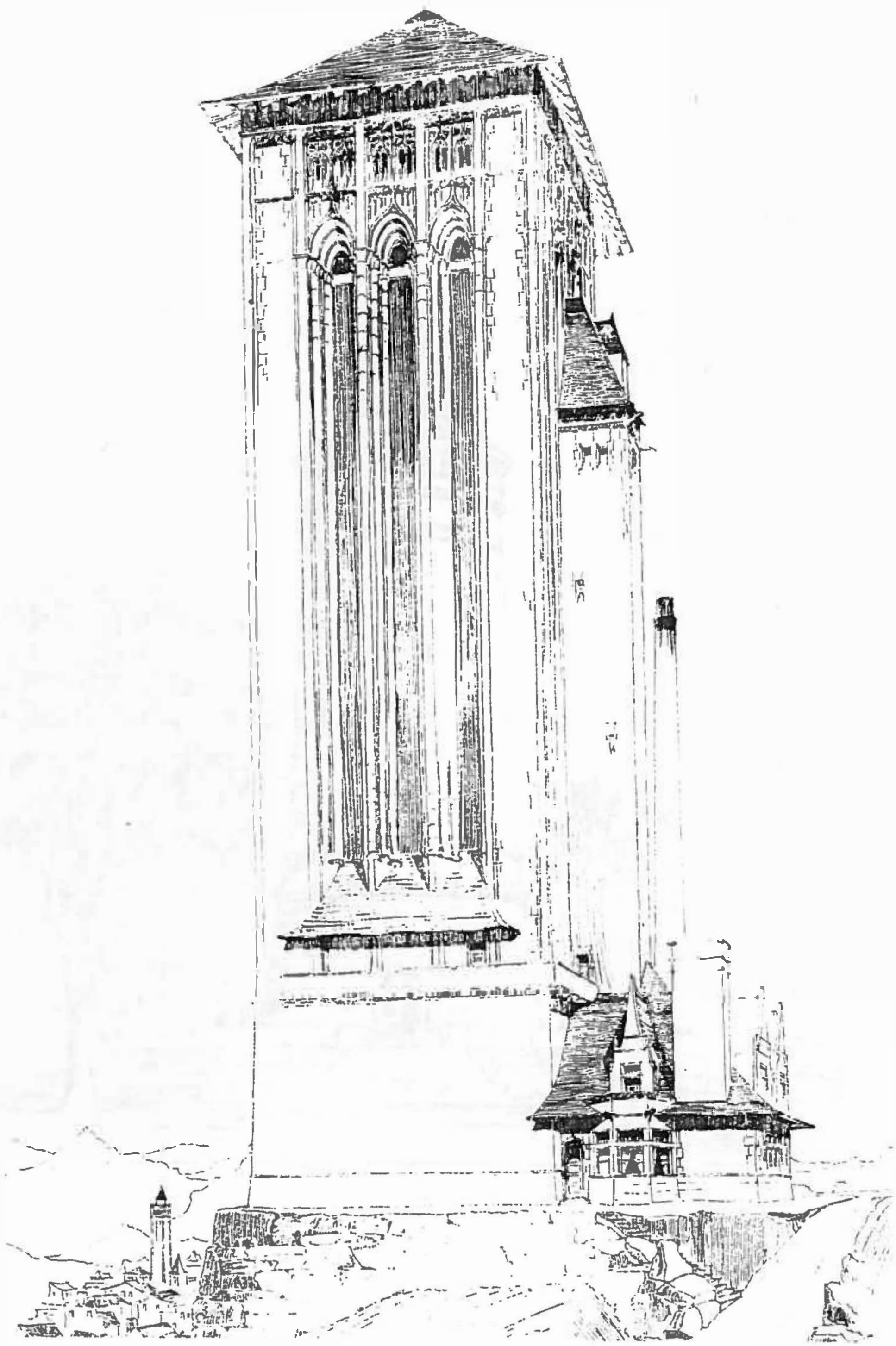


Figure 22. Second prize design for an enclosed standpipe (1889).
Capacity: 280,000 gallons.
Source: Water Tower, Pumping, and Power Station Designs (New York, The Engineering Record, 1893), n.p.

Figure 23. Third prize design for an enclosed standpipe (1889).
Capacity: 280,000 gallons.
Source: Water Tower, Pumping, and Power Station Designs (New York, The Engineering Record, 1893), n.p.

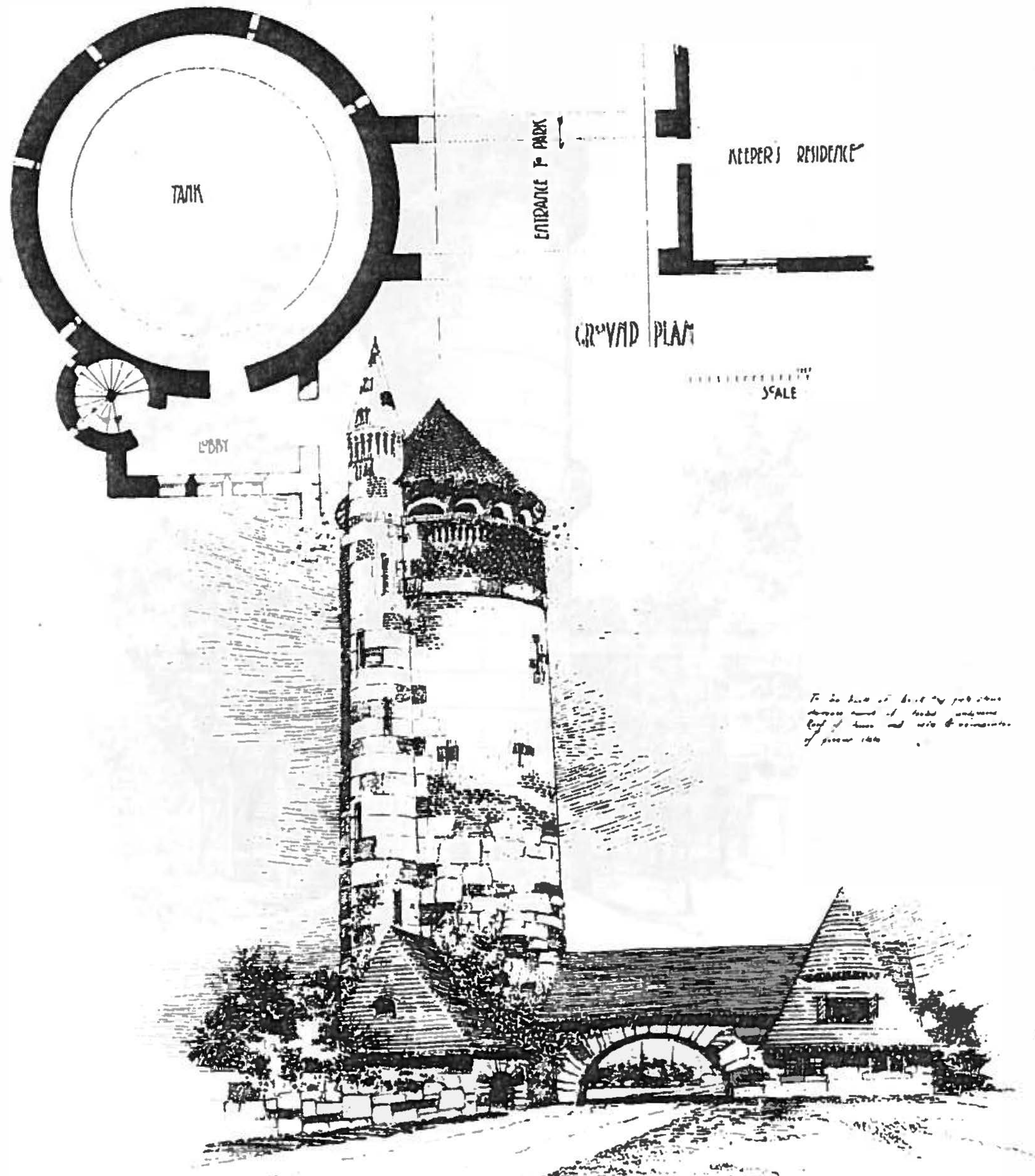
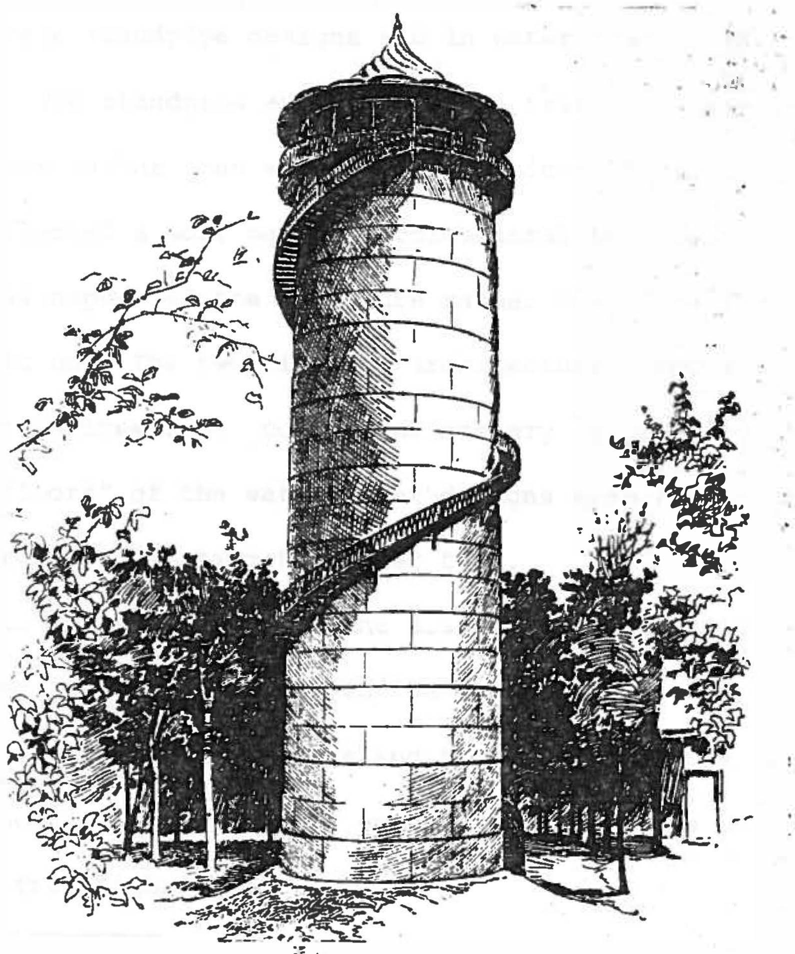


Figure 24. First honorable mention for an enclosed standpipe (1889). Albert Kahn's entry with Richardsonian influence. Capacity: 280,000 gallons.
Source: Water Tower, Pumping, and Power Station Designs (New York, The Engineering Record, 1893), n.p.



STAND PIPE AT DES MOINES, IOWA.

Figure 25. Des Moines, Iowa standpipe (1892). Regarded as an improved design resulting from 1889 competition. Capacity: 500,000 gallons.
Source: "The Stand-Pipe at Des Moines, Iowa," The Engineering Record 25 (February 6, 1892): 156.

It is noteworthy that other than this standpipe competition and an occasional notice of a recently constructed water tower in American Architect and Building News, the architectural community appeared unconcerned about the aesthetic issues related to design of elevated water storage structures. Also significant is the marked difference in architectural interpretation of the tower in these standpipe designs and in water towers like the Yonkers and the Weehawken. The standpipe enclosures were treated as single continuous wall surfaces rather than arranged in distinct "floors."[34] The competition designs reflected a more mature architectural treatment of the tower, emphasizing the vertical aspect of the structure rather than treating it like a tall narrow building. The two distinct architectural approaches were also suggestive of interior engineering: continuous masonry expressing the metal standpipe and the "floors" of the water tower designs symbolizing the load bearing grid of girders supporting the water tank.

It is important to make the distinction between the water tower and the enclosed standpipe because in the former the masonry work served a critical function--support of the girders and tank--while in the latter its role was of not structural, although the enclosure did provide insultation and some protection from high winds.[35]

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[34] The lower "stories" of some water towers were in use; in others, they were not although stories were expressed in the elevation. Enclosure of a standpipe did not create any useable interior space.

[35] The shell might also play a role in supporting the cylindrical shape of the standpipe. In one design patented in 1895 by Edward Flad of St. Louis, a brick casing provided insulation; it and six circular girders assisted in resisting wind pressure and in preserving the circular shape of the standpipe. Because the girders also supported the brick casing, the casing was only thirteen inches thick at its base and nine inches thick in the upper thirty feet. The pilasters and arches on the exterior were architectural embellishments which served no structural function. "An Enclosed and Wind-braced Standpipe, St. Charles, Missouri," Engineering News 34 (August 8, 1895): 92-93; U. S. Patent #548,635, October 29, 1895. (Figure 26)

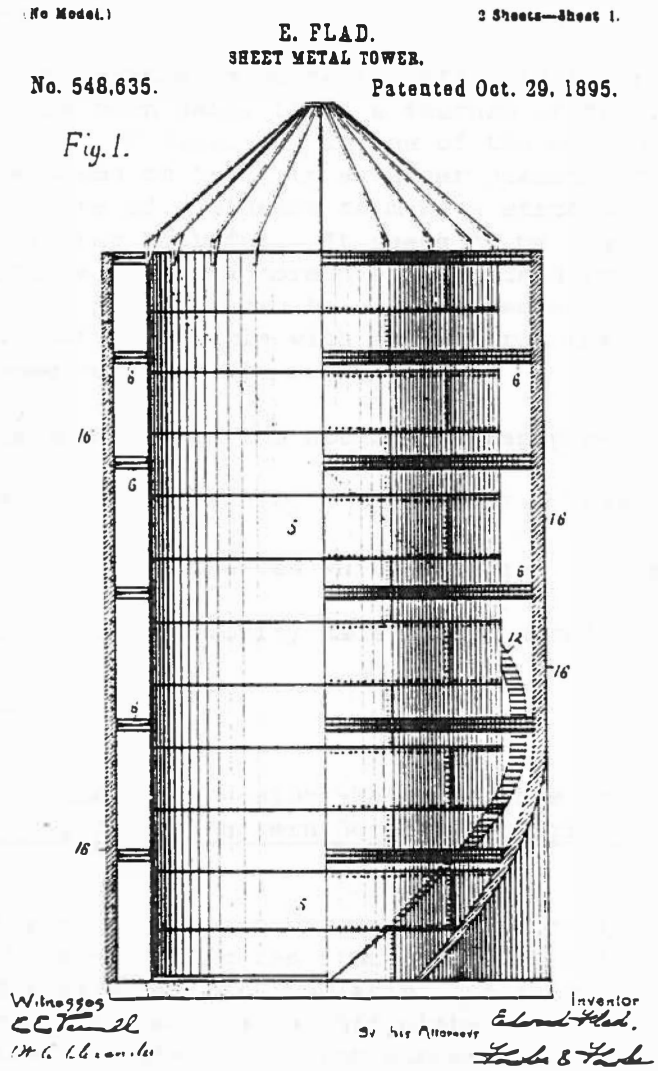

Figure 26. Enclosed and windbraced standpipe (1895).
Source: Edward Flad, "Sheet Metal Tower," U. S. Patent 548,635, granted October 29, 1895.

In the first decade of the twentieth century, reinforced concrete was heralded as a substitute for steel as a durable, inexpensive and attractive water container with the insulating qualities of brick. One optimistic engineer wrote in 1909:

> The matter of appearance is quite important in a structure of this kind, for, as has been said, it is a feature of the landscape from almost every point of view. It is one of the most difficult engineering problems to treat in a manner pleasing to the eye, and some of the efforts of engineers to make a structure of this kind beautiful are rather doubtful. It seems to me that the reinforced concrete standpipe offers a more pleasing field in this respect, and if a tank of this material can be constructed so as to be conservative and safe at a cost comparable with steel, from the standpoint of looks it deserves some considerable recognition.[36]

Early concrete standpipes like the Attleboro standpipe (1907) were seriously flawed and served as poor publicity. (Figure 27) Leakages proved impossible to seal and unsightly efflorescences which appeared on the exteriors countered the claims of aesthetic superiority made by the concrete industry.[37] It was

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[36] C. B. Burdick, "Discussion--Water Storage in Elevated Tanks and Stand Pipes," Journal of the Western Society of Engineers 14 (June 1909), p. 430.

[37] The Attleboro standpipe was initially described as "a reinforced concrete standpipe which may bring the standpipe back into favor with engineers." Its particular advantage was the insulating qualitity of an eight to eighteen inch wall of concrete rather than a thin plate of steel. Concrete was also an excellent choice for water with high concentrations of elements causing rusting of wrought iron or steel. An editorial in Engineering News noted:

> At a cost less than that of a steel standpipe, a reinforced concrete standpipe can be built which will outlast a dozen steel pipes, which will be far safer from accident, and which may be made an ornament to the landscape instead of an ugly blot.

"Reinforced Concrete Stand-Pipe at Attleboro, Mass.," Engineering News 57 (February 21, 1907): 215.
By 1909, Engineering News reported that the structure had not lived up to engineers' expectations. Permanent ridges remained where the concrete forms had been removed. The surface was also vertically streaked with efflorescences, beginning at the form marks. Finally, the pipe had developed three small leaks. While sudden failure was not anticipated, continued degeneration of the concrete, in part from frost scaling, was anticipated. "Present Condition of the Attleboro Standpipe," Engineering News 62 (August 19, 1909): 199.

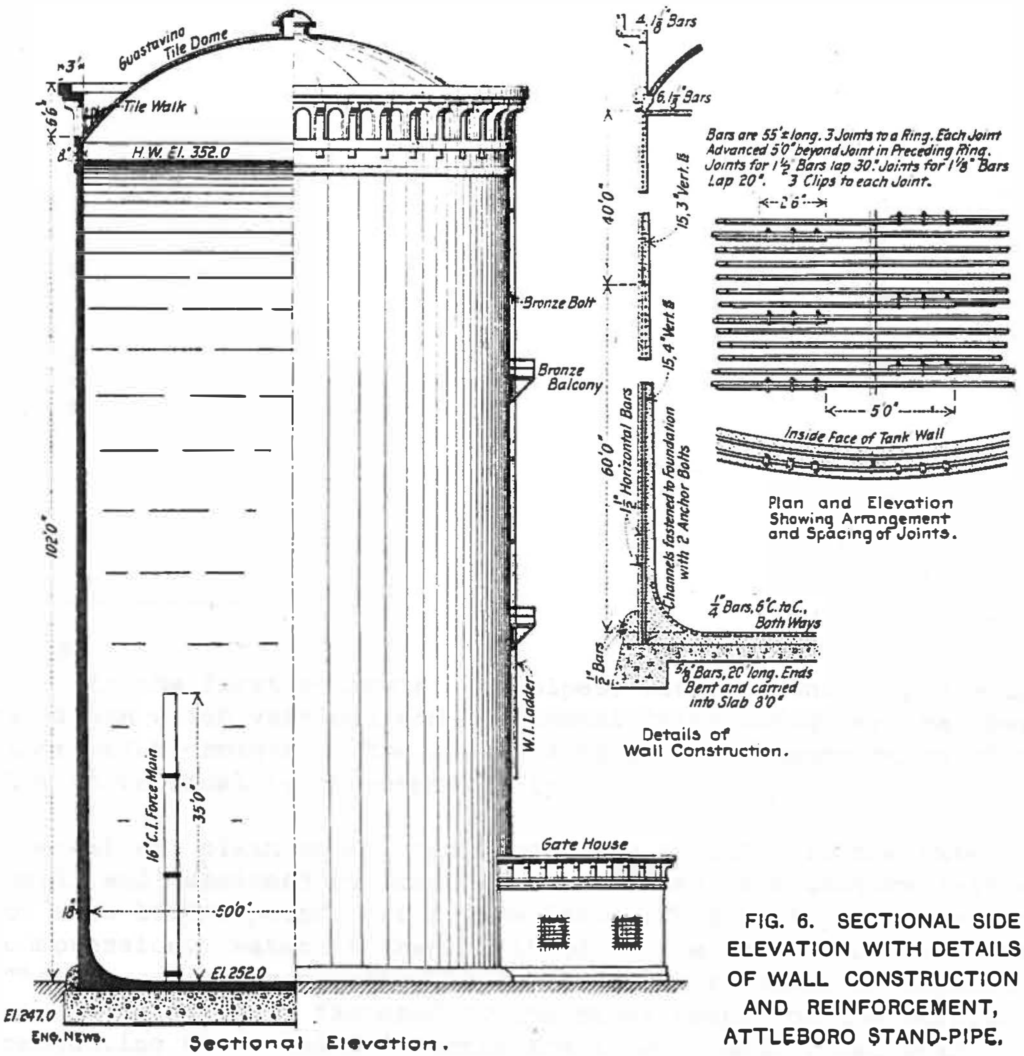

Figure 27. Attleboro, Massachusetts reinforced concrete standpipe (1906). Capacity: 1,500,000 gallons. Source: "Reinforced Concrete Standpipe at Attleboro, Mass.," Engineering News 57 (February 21, 1907): 213.

not until the 1920's that construction techniques were developed which improved water retention by pre-stressing the concrete.[38] The smooth surfaces of concrete were treated like masonry in early designs like Attleboro, and in small structures like the Ogilvie, Minnesota water tower (1917) with bold crenellations at the cornice line. (Figure 28)

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[38] In the first concrete standpipes, concrete was simply poured into forms within which vertical and horizontal reinforcing bars had been placed. The improved technique of the twenties called for construction of the concrete shell with vertical reinforcement only:

> Thereafter, plain round steel hoops are shrunk onto the exterior of the shell and tensioned by means of turnbuckles to a uniform initial stress of some 15,000 pounds per square inch. This will place the concrete in compression. Water is then admitted to the tank in order to test it. Then an outer three inch ring of concrete or gunite is applied over a wire mesh securely fastened to the steel hoops for the purpose of protecting the steel and furnishing it with additional bearing. . . The idea is to have a structure in which the concrete, even under load, will be in compression or at least not in tension.

Arthur Milinowski, "The Advantages and Disadvantages of Elevated Concrete Tanks for Water Storage in Minnesota," Journal of the American Water Works Association 10 (July 1923): 577.

In addition to engineering problems, acceptance of concrete was slowed by heavy lobbying carried on by the steel and iron works interests, which portrayed early concrete structures as frivolous experimentation. H. E. Horton, "Water Storage in Elevated Tanks and Standpipes," Journal of the Western Society of Engineers 14 (June 1909): 427.

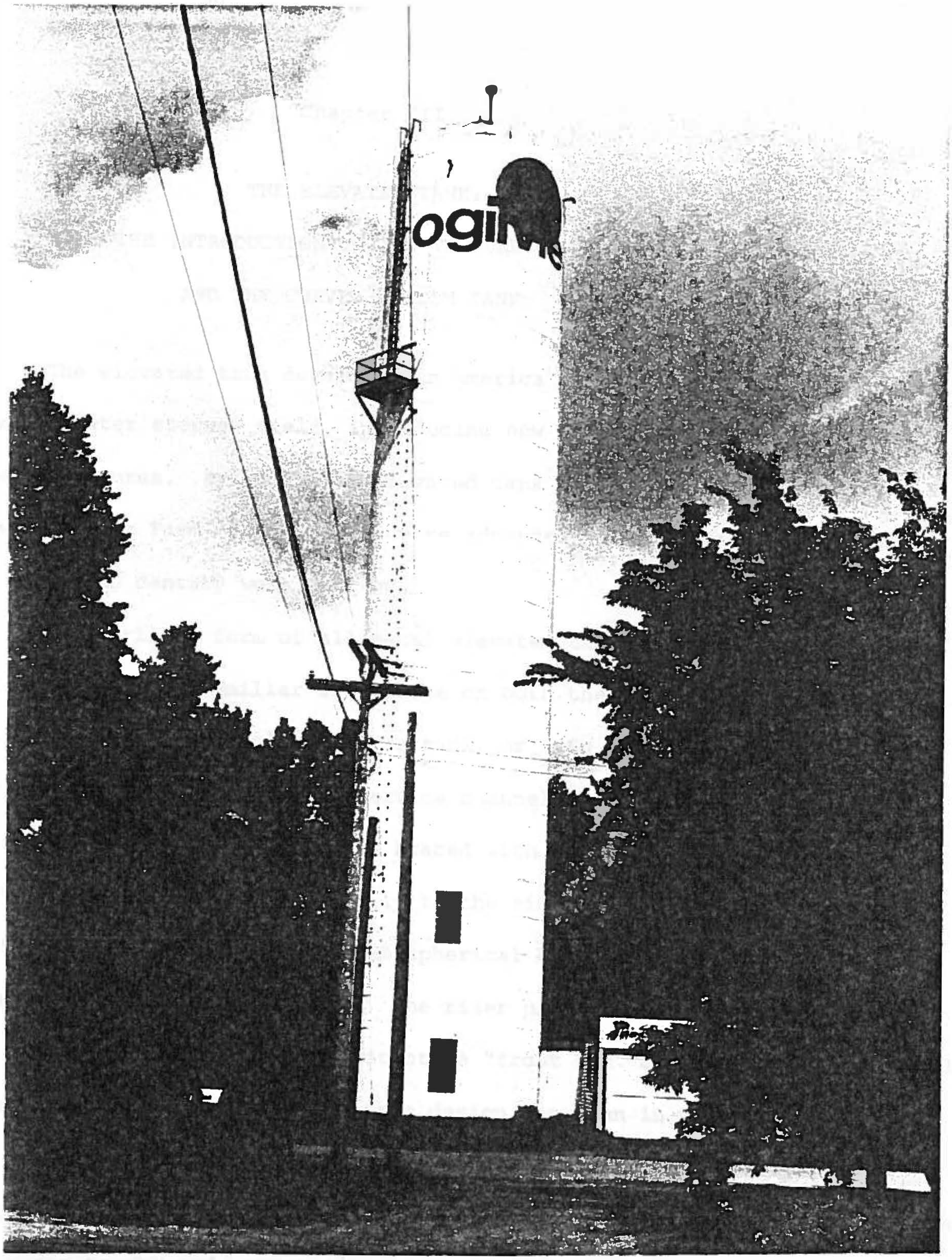

Figure 28. Ogilvie, Minnesota reinforced concrete water tower (1917).
Capacity: about 75,000 gallons.
Source: Minnesota Historical Society, State Historic Preservation Office.

Chapter III

THE ELEVATED TANK:

THE INTRODUCTION OF THE TRESTLE TOWER AND THE CURVED BOTTOM TANK

The elevated tank developed in America in the 1890's transformed the elevated water storage field, introducing new concepts into the design of these structures. By 1905, the elevated tank was the preferred structure and from its basic form of the 1890's more advanced water storage structures of the twentieth century were derived.

The earliest form of all metal elevated tank remains the most widely used type and is a familiar silhouette on both the urban and rural landscape. This form, the hemispherical bottom tank, or "tin man," consists of a four post trestle tower composed of lattice channels or other solid members and divided into three to five panels braced with tie rods. (Figure 29) The trestle posts are attached directly to the sides of a tank of riveted rings of steel plates having a rigid hemispherical bottom; the tank is capped with a conical roof with ball finial. The riser pipe enters the bottom of the tank and may be enclosed in a protective "frost box" casing of board or metal siding. With minor variations, this design has been in use since 1894.

The elevated tank was based on a safe and efficient, relatively inexpensive, and not unattractive design. Elevated tanks had cost advantages over water towers and, eventually, over standpipes. Foundations were required for four posts only, rather than an entire circular area. Open legs rather than a solid tube required less steel, and in the "classic tin man" form and

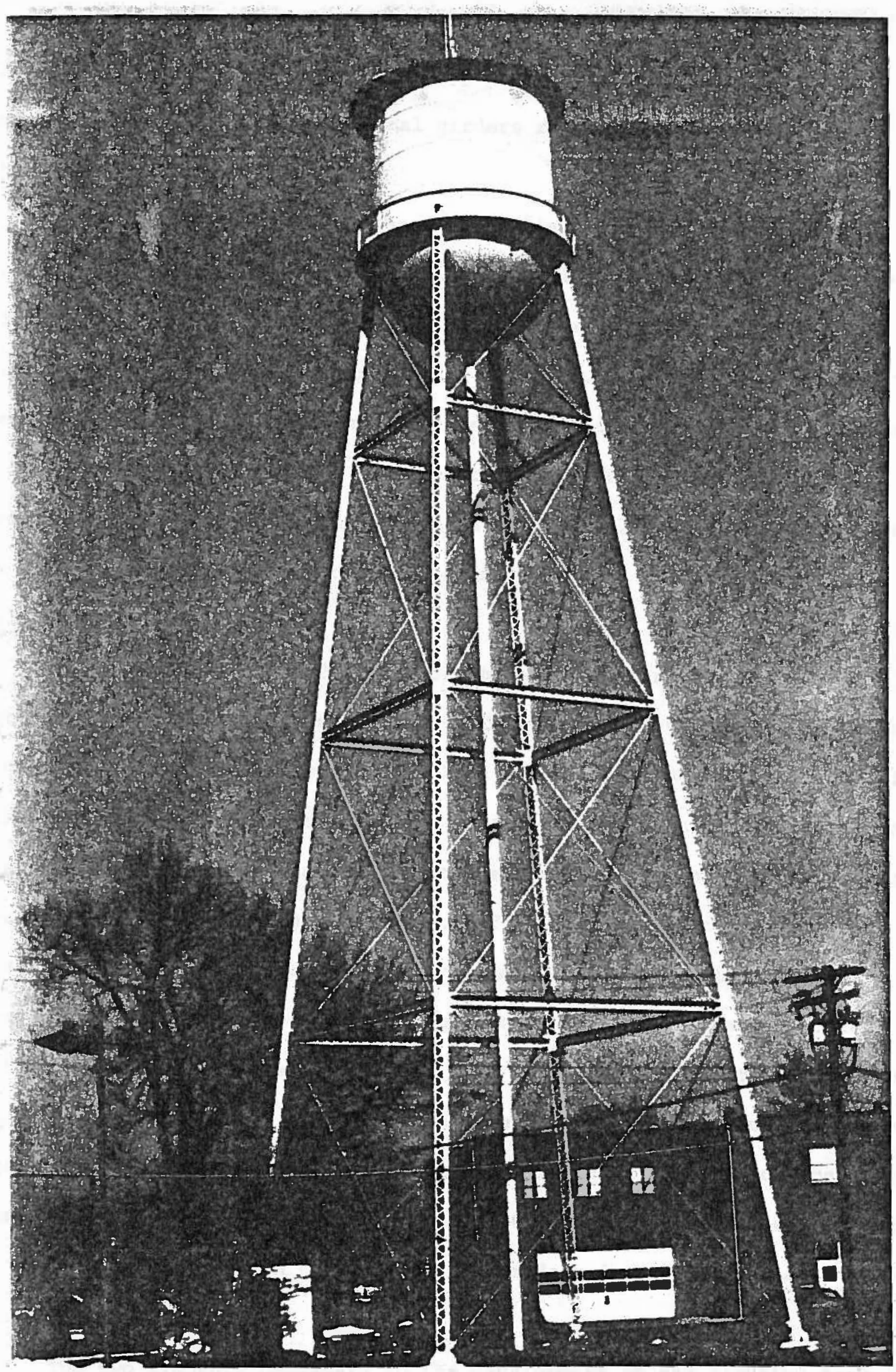

Figure 29. Classic form of hemispherical bottom elevated tank, Manassas, Virginia. c. 1920.
Source: Donald C. Jackson.

other curved bottom forms, the self-supporting tank bottom eliminated the cost and weight of the grid of metal girders required to support a flat bottom tank.

Sound engineering principles were applied to elevated tank design. Because the trestle tower's construction related to bridge building theory and techniques of the 1880's and 1890's, stresses in the tower could be calculated from formulae used in trestle building. The open framework of the trestle offered less wind resistance than the solid standpipe tube. Because of the greater diameter of the tank and better ratio of volume to exposed surface area, the elevated tank presented fewer problems with freezing than the standpipe. Finally, the curved bottom meant that collected sediment could be more easily removed.

The major innovative features of the elevated tank also presented problems in the early years of its use. The trestle post foundations had to be carefully placed to distribute the load evenly. If the tank or riser pipe leaked, the post foundations were more easily undermined than the foundation of a standpipe. Engineers argued about the number of supporting posts which were necessary and about the best method of joining the posts and the tank sides. Experiments were conducted with a variety of post materials and forms because rusting of complicated members or connections was a problem. Engineers and architects also believed that a greater number of posts improved the trestle's appearance. Finally, the riser pipe itself, of small diameter, required protective covering. All of these vulnerable features of the "classic tin man" were addressed in the twenty years following the erection of the first spherical bottom tank in 1893 and affected the changing aesthetics of tank design.

The two elements necessary to the development of the elevated tank were the trestle tower and the curved bottom tank. The curved bottom tank was perfected in Europe in the 1880's and first applied to American tank design in 1891; the trestle tower appears to have been derived from a variety of native sources including railroad tank practice, American bridge building techniques, and from windmill construction in the Midwest. Discussion of the development of these two apsects of the elevated tank is important because it illustrates American assimilation of European engineering and the diffusion, within the United States, of engineering practices from one type of structure to another.

Although the earliest uses of trestle towers to support metal and wooden water tanks are obscure, windmill and water tank catalogues dating from the mid-1870's illustrated tanks supported on wooden trestles. By the eighties, the Princeton, New Jersey elevated tank (1883) and the Lexington, Missouri tank failure (1885) documented successful and flawed use of metal trestle towers. Prior to 1890, the trestle tower and tank combination was considered as an alternative to the standpipe or masonry water tower for railroad service tanks or in localities where finances dictated inexpensive structures fashioned from locally available materials. The relative scarcity of examples of trestle towers in the engineering journals and water works manuals of the eighties suggests regional use of wooden trestles to elevate tanks of small capacity.[1] The evolution of the elevated tank trestle between 1870 and 1895 documents the transformation of a variable vernacular form into a standardized, simplified metal trestle which could be erected easily at any location.

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[1] Given the biases of the engineering journals, it is not surprising that few examples of wooden trestle towers appeared there. Most material concerning wooden trestle towers of the 1880's appeared in trade catalogues of windmill fabricators whose market was regional. Still, the attention accorded the Princeton tower in 1883 implied that it was revolutionary. Also, a partial list of water storage structures in the 1888 Manual of American Water Works included only three trestle towers in a listing of over 100 structures.

Several sources of trestle tower design and construction can be identified. First, methods of elevating cheap, low maintenance water tanks were developed by the railroads to meet their requirements for regular filling of steam locomotives. Second, and related to the needs of the railroads, the midwestern manufacturers of windmills played a major role in the spread of simple and inexpensive forms of wooden and steel towers, and some windmill tower patents themselves are possible sources of elevated tank trestle designs. Third, a parallel transition from use of masonry towers to metal trestle towers has been documented in lighthouses and range lights. Finally, direct links can be established to bridge design and to at least one prominent bridge engineer in the design of the Princeton elevated tank in 1883.

Water works engineers who in the early twentieth century reflected on the growth of their profession in the late nineteenth century identified railroad practice and innovative work done in small towns as the inspiration for elevating tanks on trestles:

> Previous to twenty-five years ago water was usually stored at an elevation, either in wooden tanks on wooden towers or in metal standpipes. . . The wooden tank supported on a low wood trestle was formerly almost universally used for supplying water to railroad locomotives. Wood tanks were later placed on higher wood towers for small town water supply. Later still, the wood trestles were replaced with steel and finally efforts were made to replace the wood tank with a steel tank. . . The design of the first steel tanks on steel towers followed closely the lines of the wood structure, the tank being flat and supported on a beam deck.[2]

The Lusk, Wyoming elevated tank (1886) is a good example of the early wood type for railway use.[3] (Figure 30)

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[2] "Development of Steel Tanks," The Water Tower 1 (July 1915): 2.

[3] According to Gregory Kendrick of the Wyoming State historic preservation office, this is the oldest and only surviving redwood tank in the State; it is likely to be among the oldest extant railroad tanks nationwide.

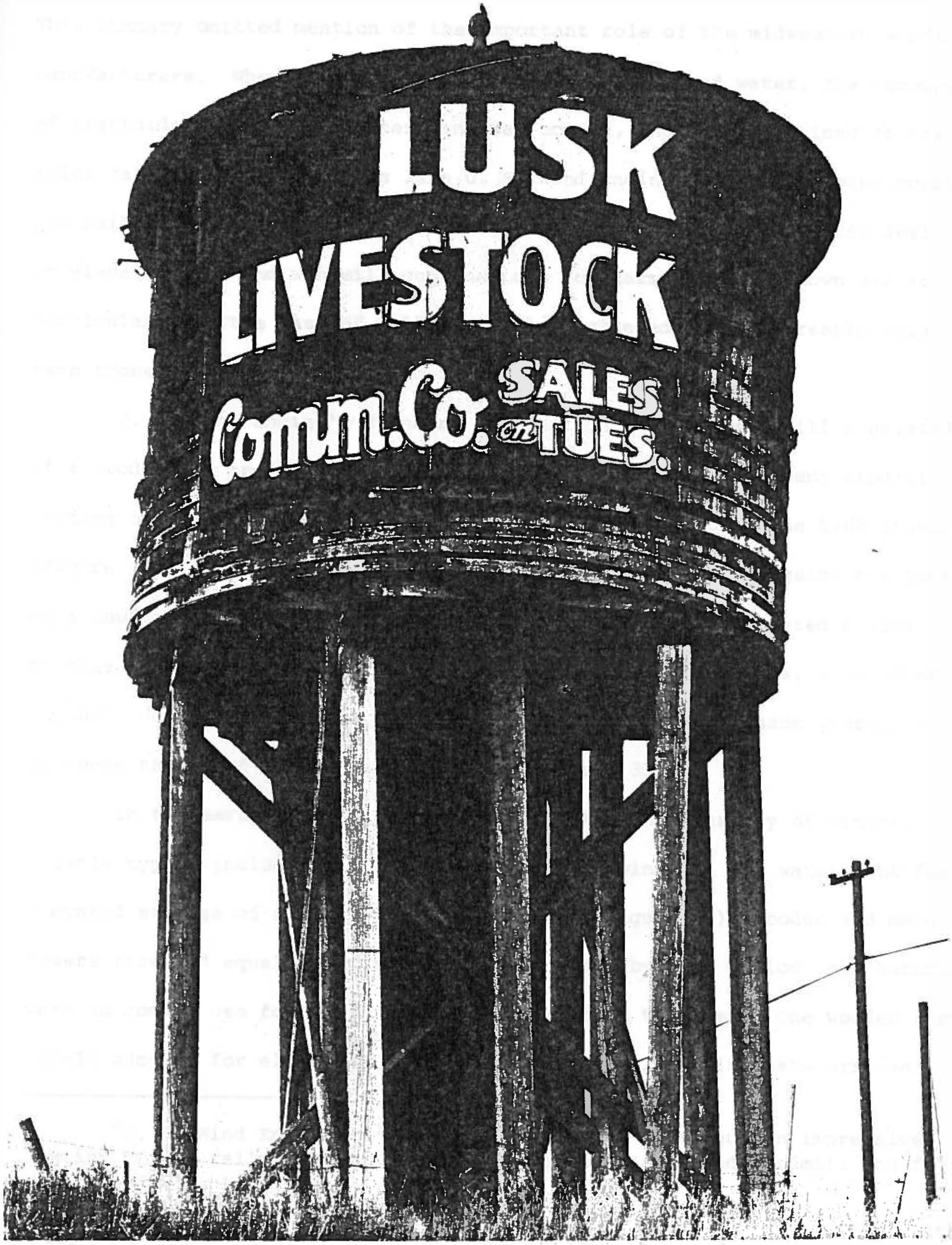

Figure 30. Lusk, Wyoming elevated tank for railroad service (1886).
Source: Wyoming Historical Commission.

This summary omitted mention of the important role of the midwestern windmill manufacturers. Where windmills were used to pump ground water, the combination of trackside windmill and water tank was common, and large portions of the sales catalogues of companies like U. S. Wind Engine and Pump Company courted the railroad water tank market in the 1870's.[4] These companies also dealt in elevated tank and windmill combinations for farm and small town use and, particularly in the case of village supply, achieved greater trestle heights than those required for railroad tanks.[5]

U. S. Wind Engine's standard combination tank and windmill consisted of a wood stave and iron hoop tank on a low platform and a patent windmill resting on the water tank platform and supported in part by the tank itself. (Figure 31) Variations in this form placed the windmill alongside the tank on a low trestle, while the Parsons' Colorado wind engine located a wind turbine on top of the tank itself. (Figure 32) In the 1870's, U. S. Wind Engine's domestic models for windmills alone exhibited the same trestle forms as those that held small elevated tanks. (Figure 33)

In the early 1890's, patents were granted on a variety of windmill trestle types, including at least one composite windmill and water tank for elevated storage of a small volume of water. (Figure 34) Wooden and metal towers received equal attention, confirming that by that period both materials were in common use for windmill and elevated tank trestles. One wooden form widely adopted for elevated tank trestles used twelve main posts arranged

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[4] U. S. Wind Engine in 1876 included in its catalogue an impressive listing of 100 railroad companies employing their railroad windmill and frost-proof wooden tank.

[5] The proliferation of patents originating in the Midwest for windmill towers and liquid storage tank trestles in the early 1890's identifies this region as a major market for both forms of trestle towers.

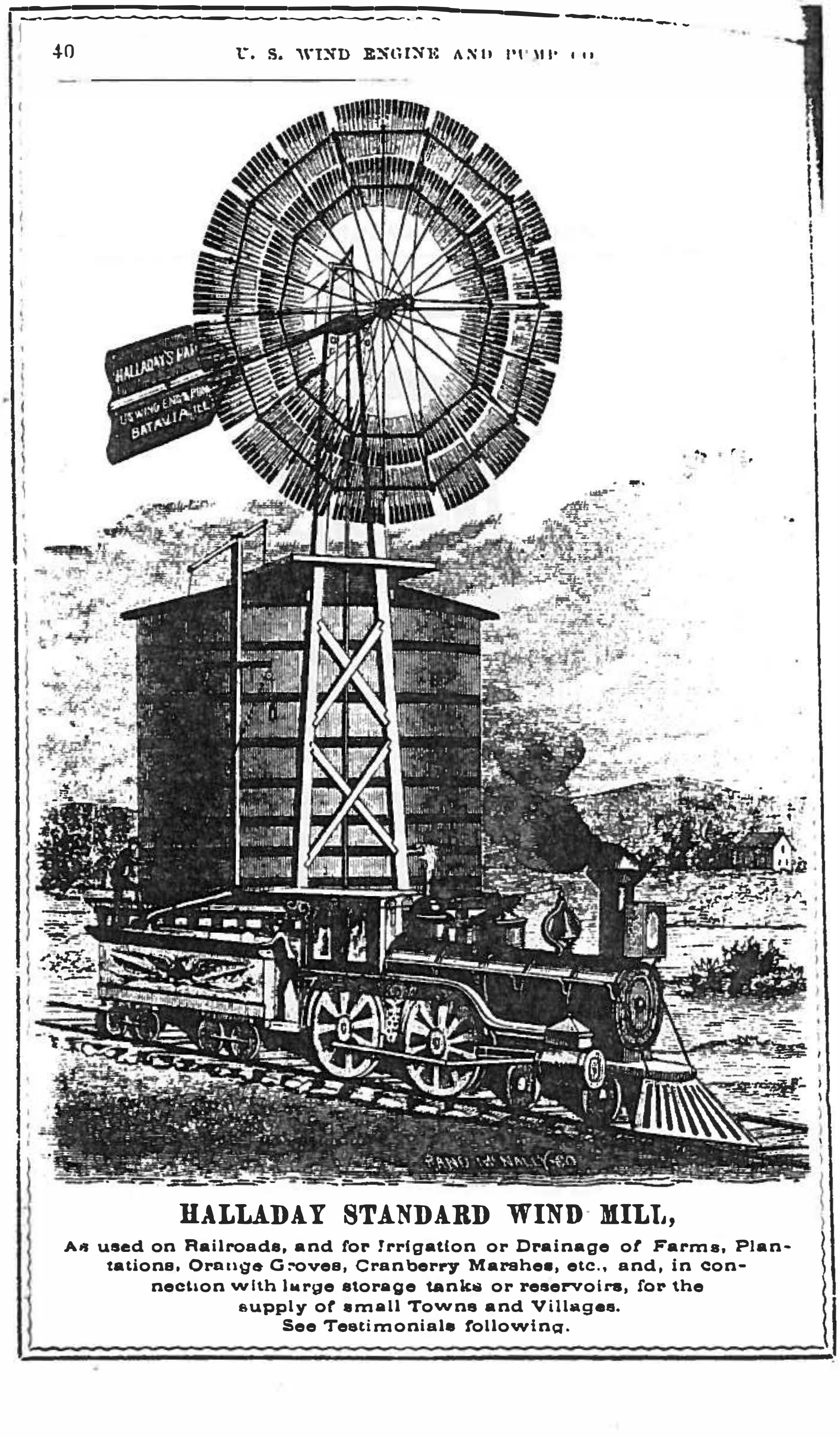


Figure 31. Elevated tank and windmill combination for railroad service (1870's).
Source: <u>U. S. Wind Engine and Pump Company</u> (Chicago, Rand, McNally & Co., c. 1876), p. 40.

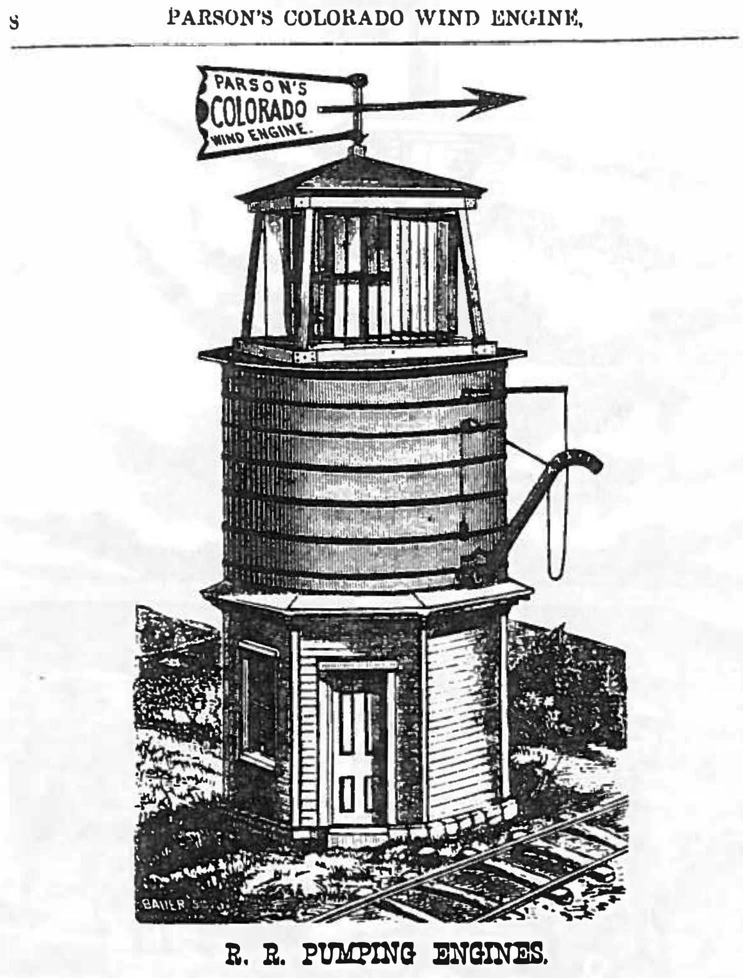
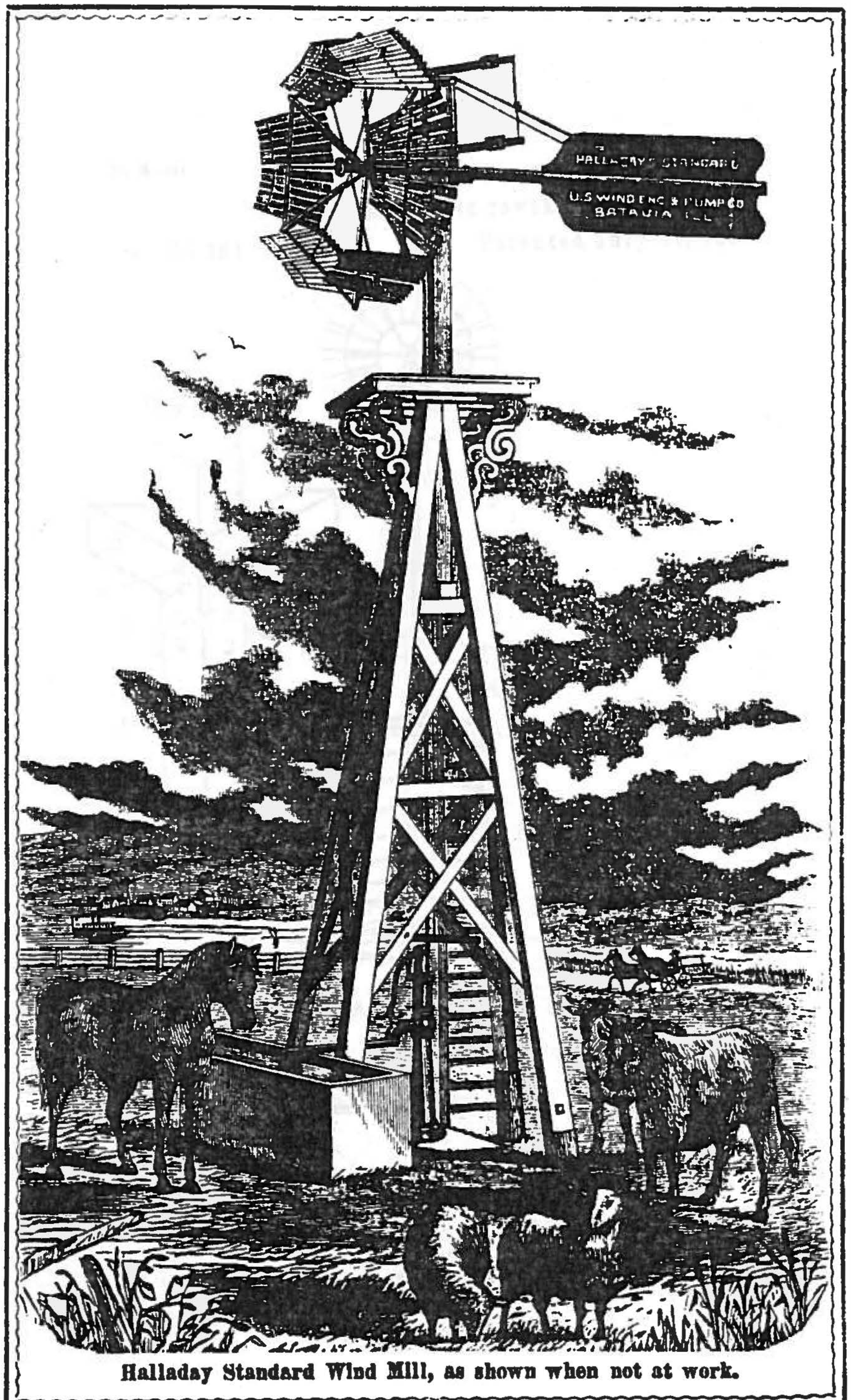


Figure 32. Elevated tank and wind turbine for railroad service (1870's). Source: Warren D. Parsons, Parsons' Colorado Wind Engine (San Francisco, D. Kerr, 1878), p. 8.



Halladay Standard Wind Mill, as shown when not at work.

Figure 33. Windmill trestle form of the 1870's.
Source: U. S. Wind Engine and Pump Company (Chicago, Rand, McNally, & Company, c. 1876), p. 2.

(No Model.)

LA VERNE W. NOYES.

WINDMILL TANK TOWER.

No. 523,864. Patented July 31, 1894.

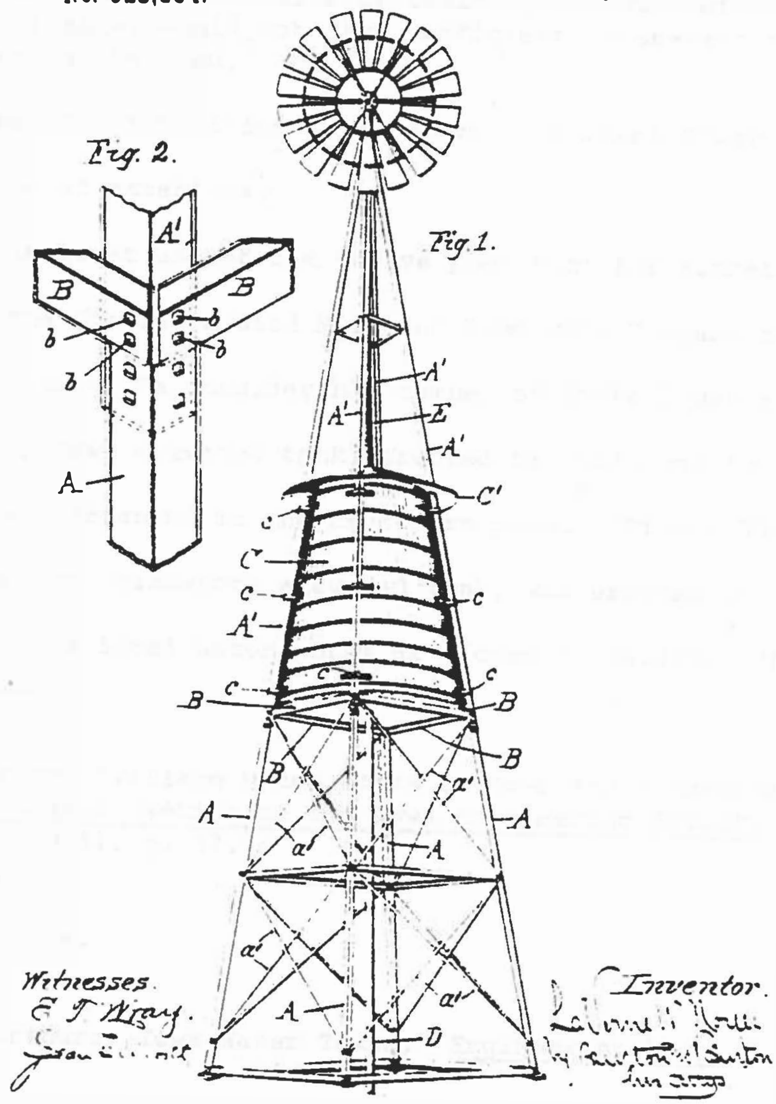


Figure 34. Elevated tank and windmill combination trestle tower (1894). Source: La Verne W. Noyes, U. S. Patent No. 523,864.

in a cruciform plan and strengthened with diagonal timbers. Support was provided directly to the tank bottom as well as through the timber or steel girder grid. In 1901 W. H. Jackson, an Iowa engineer, identified the rationale for use of the twelve post wooden trestle:

> With wooden towers it was found desirable to use twelve legs, and even more in case the tank was very large. This was because a lesser number of twelve by twelves, the size of lumber most suitable, would[6] not give sufficient cross-section to safely sustain the load.

Jackson stated that the transition to a twelve post steel tower was made by simple substitution of materials.[7]

While the earliest use of the twelve post form for either material is unknown, by 1894 the Challenge Wind Mill and Feed Mill Company of Batavia, Illinois had constructed "a considerable number of (metal) water towers." In the Parkersburg, Iowa elevated tank, erected by Challenge in 1893, twelve Larimer columns were arranged in the cruciform plan.[8] (Figure 35) A second example, the Lamberton, Minnesota elevated tank, was erected by U. S. Wind Engine in 1895 for the local water works at a cost of $4,468.[9] (Figure 36)

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[6] W. H. Jackson, "Village Water Works of Iowa and Minnesota," Proceedings of the Thirteenth Annual Meeting of the Iowa Engineering Society (Davenport, Iowa, The Society, 1901), p. 37.

[7] Jackson, p. 38.

[8] "The Parkersburg, Iowa Water Tower," Engineering News 33 (January 17, 1895): 34-35.

[9] Minnesota Historical Society survey files. A partial list of marketing catalogues available at the Library of Congress includes: U. S. Wind Engine (1870's-1890's); Empire Wind Mill Manufacturing Company (1870's); Eclipse Windmill Company (1870's and 1880's); Colorado Wind Engine (1870's); and Challenge Wind Mill and Feed Mill (1880's-1890's). A survey of windmills in Nebraska published by the Geological Survey in 1899 recorded and rated models produced by over a dozen companies. The technical and promotional literature from this period on windmills is a rich resource.

Figure 35. Parkersburg, Iowa elevated tank (1893). Capacity: 70,000 gallons.
Source: "The Parkersburg, Iowa, Water Tower," Engineering News 33 (January 17, 1895): 35.

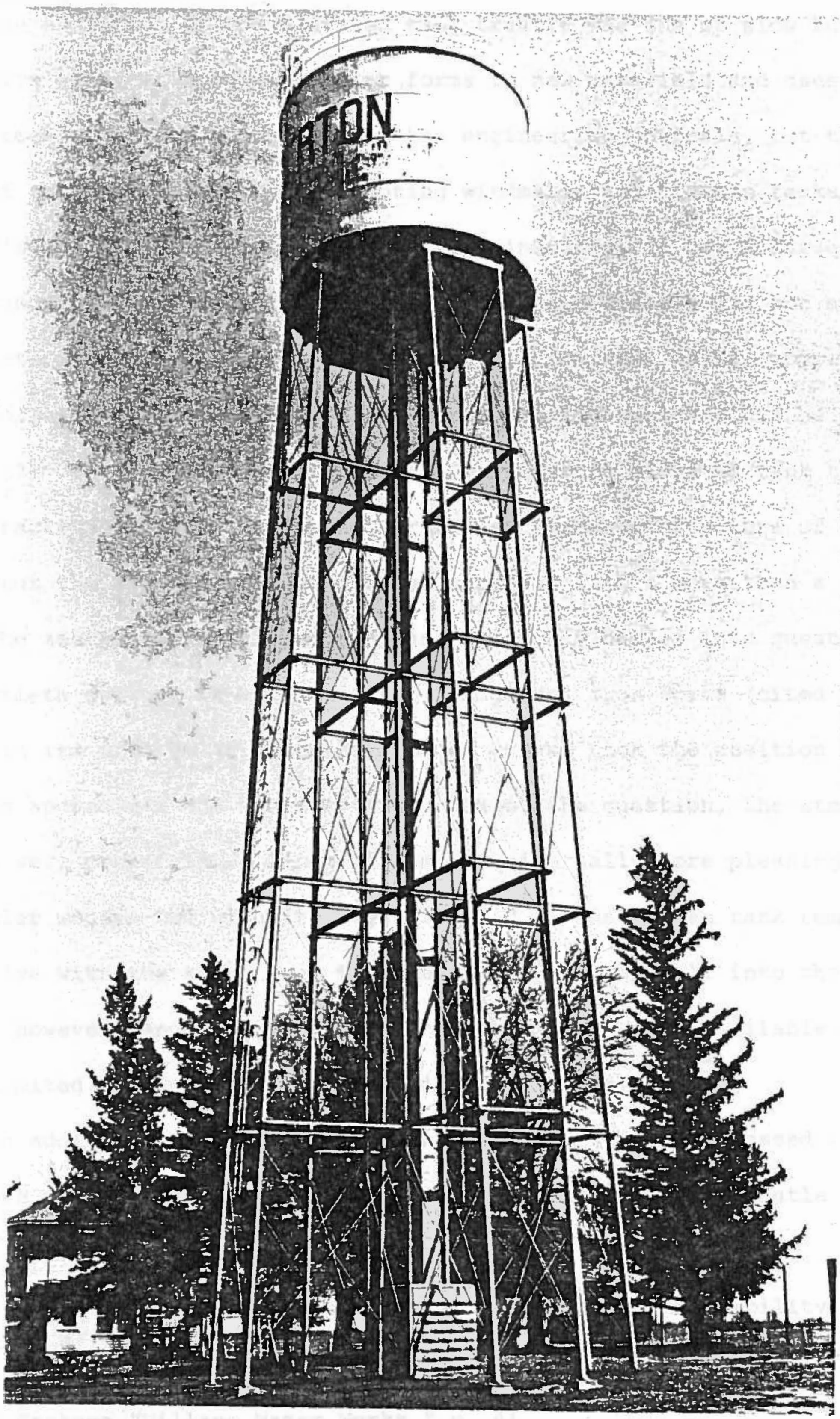

Figure 36. Lamberton, Minnesota elevated tank (1895). Capacity: about 70,000 gallons.
Source: Minnesota Historical Society, State Historic Preservation Office.

The evolution of the elevated tank trestle was one of slow but progressive adaptation of vernacular forms to new materials and uses. The design process was not documented in the engineering journals, but the number of successful companies promoting windmills and trestle tanks in the 1870's and 1880's reflects an important industry, if not a large scale one. Standardized designs for the wooden tank and trestle did not attempt to incorporate architectural "styles" which would increase costs; companies instead offered decorative roof finials and brackets which could be added. (Figure 37) In some wood tanks like the Parkersburg elevated tank these paired brackets relate the tank to vernacular frame architecture of the period, but the typical wooden elevated tank was little more than a tub.

The aesthetics of the wooden tank were only called into question in the twentieth century when the Chicago Bridge and Iron Works (cited as CBI below), in its efforts to discredit wooden tanks, took the position that "to those who appreciate the architectural side of the question, the steel tank with its well proportioned lines is almost universally more pleasing than the angular wooden tub with its steel tower."[10] The wooden tank remained competitive with the steel tank for smaller capacities well into the twentieth century, however, and as one engineer noted, "since funds available are always limited, we scarcely have a choice in the matter."[11]

In addition to this tradition in wood, the 1880's witnessed a few structures consciously engineered to elevate tanks on metal trestle towers.

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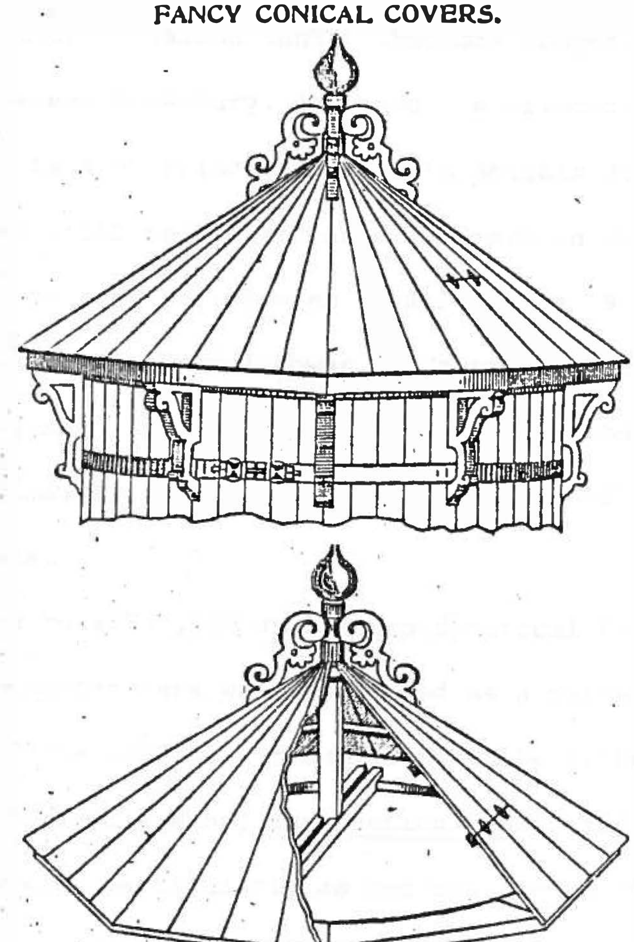
[10] "The Modern Elevated Steel Water Tank and Its Adaptability," <u>The Water Tower</u> 2 (June 1916): 6.

[11] Jackson,"Village Water Works," p. 41.



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8 " 0 "	500 "	27 00	22 " 0 "	2800 "	125 00
10 " 0 "	700 "	36 00	24 " 0 "	3300 "	150 00
12 " 6 "	1050 "	47 00	26 " 0 "	4000 "	180 00
14 " 0 "	1400 "	58 00	28 " 0 "	5000 "	225 00
16 " 0 "	1600 "	72 00	30 " 0 "	6000 "	255 00
18 " 0 "	2000 "	86 00			

Prices include the Fancy Brackets under eaves of Cover.
We will quote on Shingles for these Covers, too, when so desired.

WE ALSO BUILD STEEL TANKS OF ALL SIZES AND KINDS

Figure 37. Mail order decorative elements for wooden tanks (1908).
Source: Tanks, 1908 (Louisville, Kentucky, William E. Caldwell Company, 1908), p. 15.

The Princeton, New Jersey elevated tank was one outstanding early use of a fifty-five foot trestle to elevate a twenty by sixty foot wrought iron standpipe. (Figure 38) The trestle was divided into three panels, with posts composed of laced channels braced with tie rods. In I beam and timber grid supported the 120,000 gallon tank. Theodore Cooper, noted bridge engineer of the nineteenth century, designed the Princeton elevated tank.[12]

The elevated tank at Princeton met with acclaim at the time of its construction; it was still recognized as a landmark in the history of elevated water storage engineering when dismantled in 1915. In 1883, Engineering News hailed the "novel tower." Other elements of the design were primitive, however: the "tank" was a typical period standpipe atop which sat a meteorological observatory, and no claims of architectural superiority were made.

When replaced by a 537,000 gallon hemispherical bottom tank thirty-two years later, the Princeton tank was recognized as a reflection of the most advanced practice of the 1880's. In summarizing the differences between the old tank and its 1915 replacement, Engineering News cited "striking changes in elevated tank design, particularly as regards the relation between diameter and height, the shape and support of bottoms, and the character of the columns."[13] The most significant observation made by R. W. Becker, Chief Engineer for Tippet and Wood, was that the trestle tower "was built with channel columns facing parallel with the bents just as they would in a

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[12] Tippet and Wood, a regional fabricator of standpipes, erected the 1883 tank and its replacement in 1915. "Princeton Water Tower," Engineering News and American Contract Journal 10 (December 1, 1883): 578.

[13] Becker, R. N., "Old and New Water Tanks at Princeton, New Jersey," Engineering News 75 (January 27, 1916): 150.

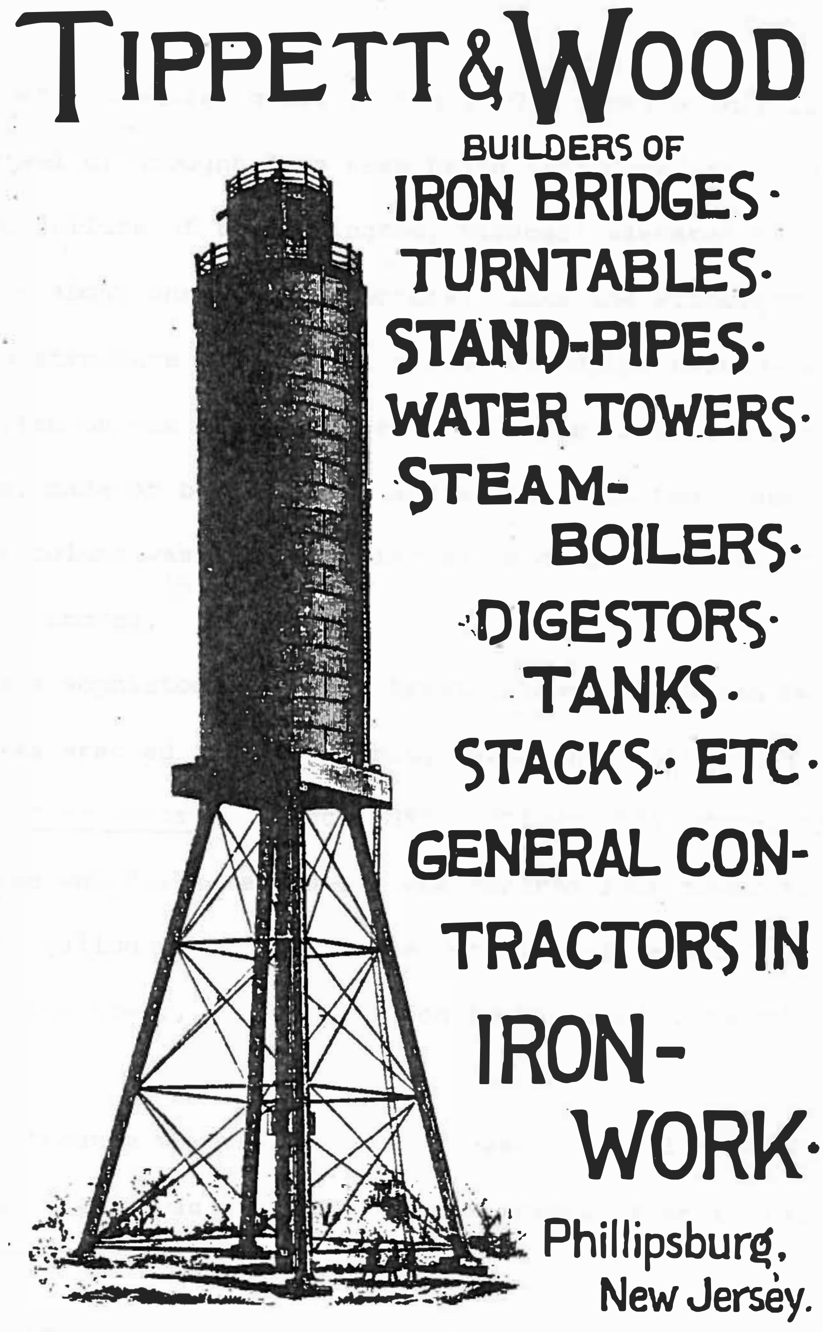

Figure 38. Princeton, New Jersey elevated tank (1883). Capacity: 120,000 gallons.
Source: M. N. Baker, The Manual of American Water Works: 1889-90 (New York, Engineering News Publishing Company, 1891), p. 760.

bridge."[14] This reflected Cooper's experience as a bridge engineer, and related the design of the first major metal tank trestle to other forms of civil engineering.

Most other metal trestle towers of the 1880's provide only limited insight into how steel or wrought iron were being introduced for use as water tank supports. The failure of the Lexington, Missouri elevated tank in 1885 recorded information about one other structure. Like the Princeton elevated tank, the Lexington structure was a tall, narrow standpipe twenty-two by one hundred feet supported on six fifty foot columns. The trestle columns were cylindrical in form, made of boiler plate and arranged in two concentric circles. The inner column was forty-two inches in diameter, while the outer five were thirty-six inches.[15]

A second, less sophistocated metal trestle tower which can be traced to a bridge works was erected in San Antonio, Texas and featured in The Engineering and Building Record in March 1888. (Figure 39) Here, four inch wrought iron gas pipe was fashioned into a one hundred foot tower to elevate a small private 6000 gallon water tank. The Detroit Bridge and Iron Works was responsible for the tower, a metal version of the wooden trestle towers of the 1880's.[16]

While wooden trestle towers were widely used in rural areas by the 1880's, use of metal towers was limited in that decade. Even by 1890, the

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[14] Becker, p. 150.

[15] Pence, Standpipe Accidents and Failures, p. 9. The structure failed during a test filling. Pence's sources attributed the failure to undermining of the column foundations by water which leaked from the joining of the tank sides and bottom.

[16] "Water Tower of Wrought Iron Pipe," The Engineering and Building Record 17 (March 24, 1888): 258.

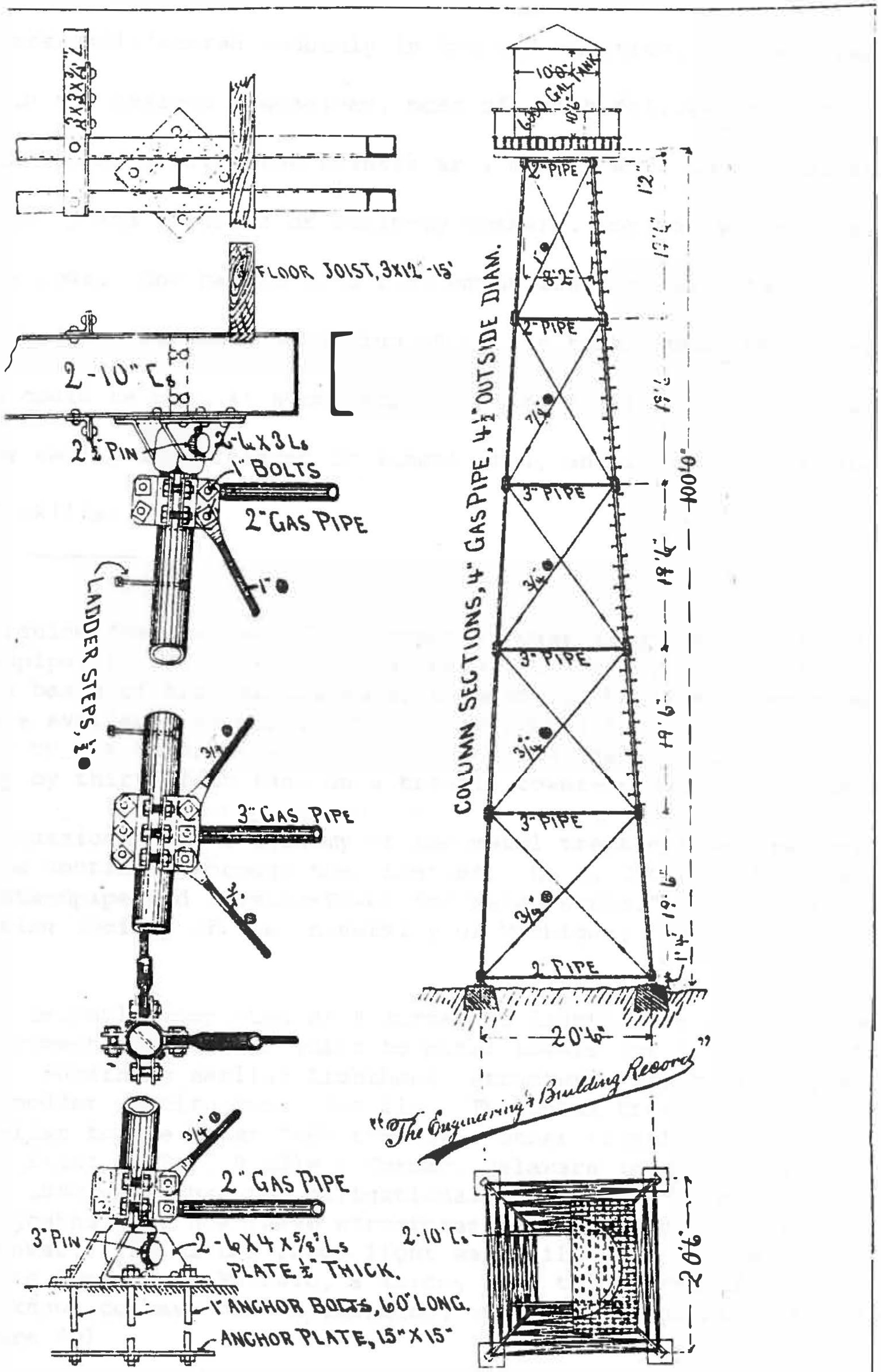

Figure 39. Elevated tank on wrought iron pipe tower (1888). Capacity: 6,000 gallons.
Source: "Water Tower of Wrought Iron Pipe," The Engineering and Building Record 17 (March 24, 1888): 258.

number of well publicized examples was small.[17] Designs incorporating metal trestle towers proliferated suddenly in the mid-nineties.[18] There was little remarkable in the designs themselves, most of which followed the cruciform plan or used Cooper's Princeton trestle as a model, with some combination of major vertical posts of solid or built-up members, horizontal members, and diagonal tie rods. One patent from 1892 emphasized the advantages of the metal tower and the elements of design which the tank companies adhered to: parts which could be cast at a convenient point of shipment, were standardized and could be easily interchanged or substituted, and could be assembled without special skills.[19]

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[17] Arguing for the use of the trestle tower as opposed to the traditional standpipe, H. S. Crocker in 1890 used the seven year old Princeton tower as the basis of his calculations, suggesting that few other good examples were available to copy. Crocker estimated that the cost of materials for a twenty by one hundred twenty foot standpipe was $6,700, while materials for a twenty by thirty foot tank on a trestle tower--providing comparable pressure although having only one quarter the capacity of the standpipe--cost $4,300. Discussions of the economy of the metal trestle tower as compared to the standpipe continued through the nineties. H. S. Crocker, "Relative Economy of Standpipe and Trestle-Tower for Water Works," The Technic (Ann Arbor, The Engineering Society of the University of Michigan, 1890), p. 72.

[18] A recently completed HAER survey of lighthouses ringing the Great Lakes has documented a similar shift to metal towers for light supports around 1900. Remaining earlier lighthouse structures are typically masonry towers with modest architectural details. The metal trestle tower used after 1900 was similar to the water tank trestle. Other trestle examples like the Liston range light (1876), Biddle's Corner, Delaware indicate that the metal trestle came into early use for navigational aids; these is no record in the engineering journals of how these structures may have had an impact on water storage, however. The Liston range light was built by a bridge works, the Kellogg Bridge Company of Buffalo, a strong link to an area of civil engineering known to have had an influence on the development of the elevated tank. (Figure 40)

[19] William E. Caldwell, U. S. Patent 487,902, December 13, 1892. Caldwell's tower was a metal and timber trestle in which metal was used for joints and tie rods, while the main vertical members were timber. This was a transitional form designed for domestic customers and small communities. Caldwell tanks was a major regional fabricator located in Louisville; Caldwell is still in business in 1980 and markets wood and metal tanks and towers.

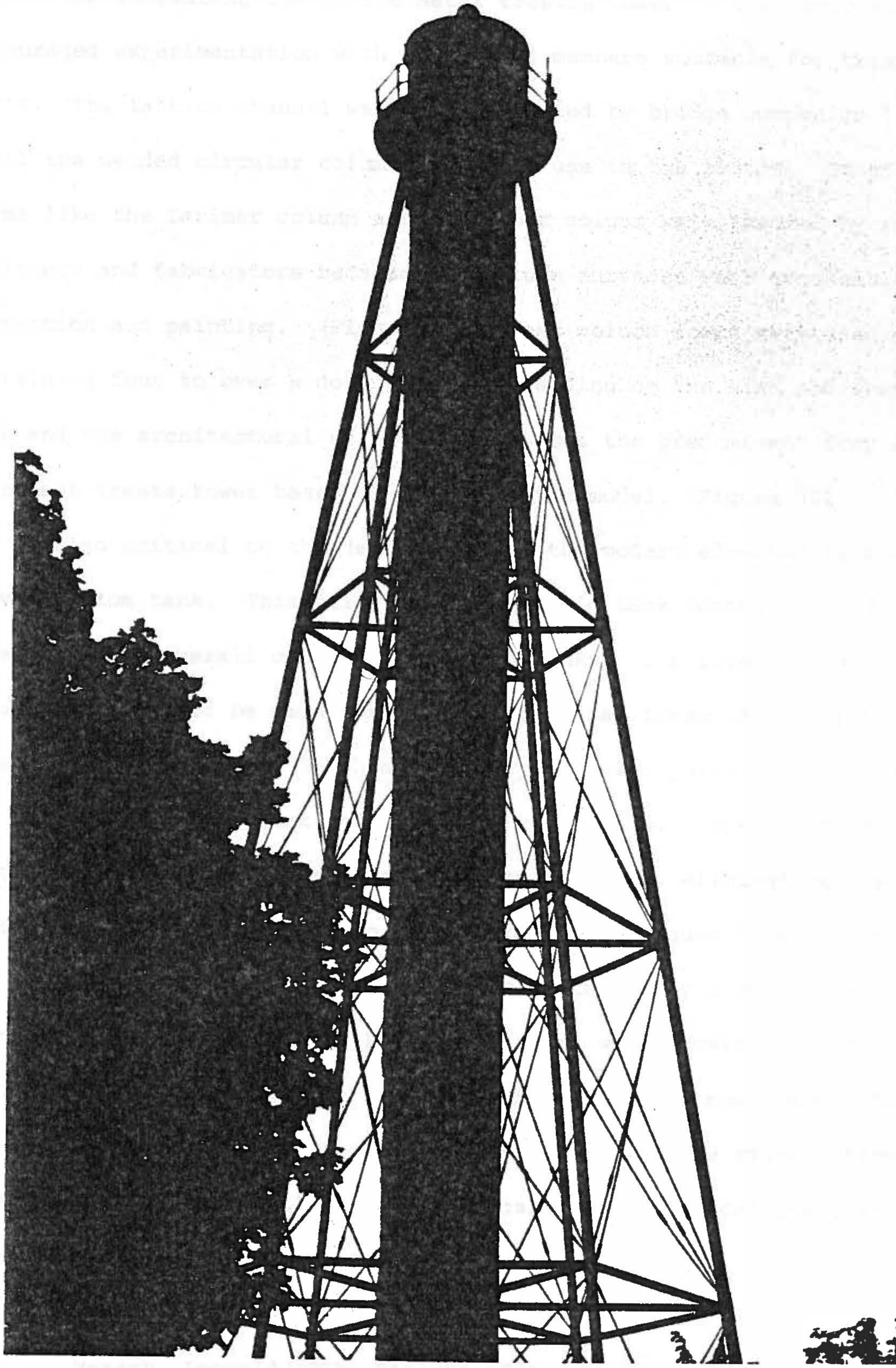

Figure 40. Liston range light, Biddle's Corner, Delaware (1876).
Source: C. Dubie.

The increasing use of the metal trestle tower in the early nineties encouraged experimentation with structural members suitable for trestle posts. The lattice channel was widely adopted by bridge companies like CBI until the welded circular column came into use in the 1930's. Other built-up forms like the Larimer column and the Z bar column were favored by some engineers and fabricators because all column surfaces were accessible for inspection and painting. (Figure 41) These column forms were used in towers containing four to over a dozen posts, depending on the size and shape of the tank and the architectural effect desired, but the predominant form was the four post treste tower based on the Princeton model. (Figure 42)

Also critical to the development of the modern elevated tank was the curved bottom tank. This self-supporting rigid tank bottom reduced weight, materials, and overall costs for elevated tanks. Its riveted seams were more even and could be made more water-tight than those of the flat bottom steel tank or wood tank, in which the perpendicular joining of the tank sides and bottom created a thick and imperfect connection. The new form of tank bottom improved the appearance of the elevated tank, eliminating the grid of girders and substituting a trim silhouette for the squat flat bottom tank.

First promoted by German engineers in the early 1880's, the curved bottom tank was used in major European masonry water towers in the 1880's and 1890's. The new tank was the work of Professor Intze, responsible for the introduction and spread of these tank forms which by the mid-eighties included a shallow spherical or hemispherical form, a conical form, and a complex counter-bottom form also used for gas storage.[20]

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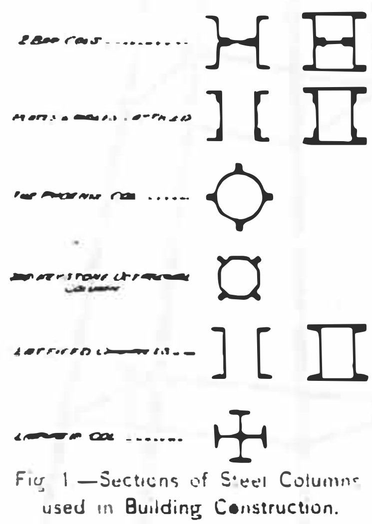
[20] Mensch, Leopold, "The Failure of the Water Tower at Fairhaven, Mass.," Engineering News 47 (January 20, 1902): 11.



1. Z Bar Column
2. Plates and Angles Latticed
3. Phoenix Column
4. Keystone Octagonal Column
5. Latticed Channels
6. Larimer Column

Figure 41. Lattice Channels, Larimer, and Z-bar columns. The other forms shown were considered to have too many connections and concealed surfaces to be useful for elevated tank trestle construction. Source: "The Steel Skeleton Type of High Buildings," Engineering News 26 (December 12, 1891): 560.

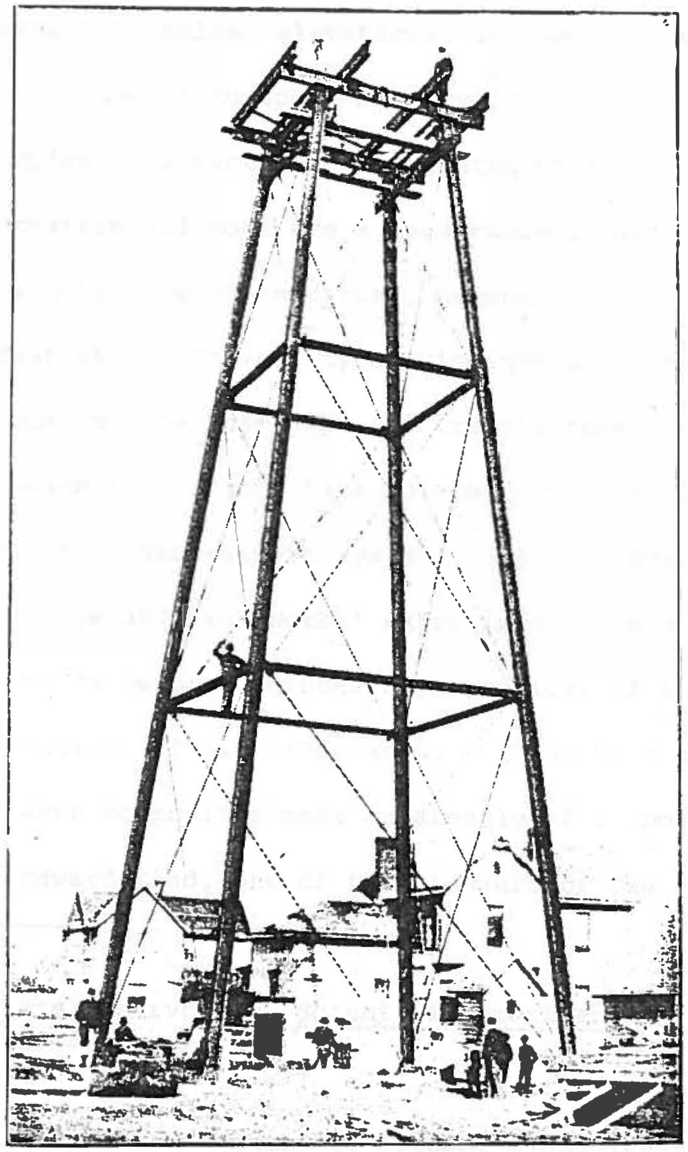


Figure 42. Standard four post trestle tower to support flat bottom tank. Source: W. H. Jackson, "Village Waterworks of Iowa and Minnesota," Proceedings of the Iowa Engineering Society (Davenport, Iowa, The Society, 1901), p. 32.

The initial discussion of these new tank forms in the United States was contained in an article entitled "Iron Plate Reservoirs," reprinted from Le Genie Civil in the Scientific American Supplement in 1886.[21] This work provided mathematical formulae, elevations, and sections of a variety of tank bottom forms in use in European masonry towers. Reference was made to a half dozen examples constructed on the Continent since the 1870's.

This information did not have a measurable impact on elevated tank design in America until the mid-nineties, however. H. S. Crocker, an engineering student at the University of Michigan who set out to calculate the relative economy of the standpipe and trestle tower in 1890 made no mention of the possibility of new tank bottom forms, or of elimination of the floor timbers or girder support system.[22] George Horton, writing in 1925 of Chicago Bridge and Iron Works' entry into the elevated tank field in 1893 referred to "a German engineering periodical of 1886 (in) which were illustrated designs of elevated tanks. . . the bottoms of which while self-supporting, were composites made apparently of a combination of cones and spheres."[23] Edward Flad, one of the pioneers of the all metal elevated

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[21] "Iron Plate Reservoirs," Scientific American Supplement 556 (August 28, 1886): 8874-8876.

[22] Crocker, "Relative Economy of Standpipe and Trestle-Tower," p. 72.

[23] George T. Horton, "Elevated Tank Construction," The Water Tower 11 (April 1925): 7.

Horton identified this 1886 work and a second source, The Theory and Practice of Modern Framed Structures, published in 1893, as the inspiration for CBI's hemispherical bottom tank. This second work contained Flad's 1891 design for a spherical bottom tank and an elevation of Flad's Laredo, Texas elevated tank of 1893.

tank, claimed to have independently arrived at the idea of the spherical bottom in 1887, while making preliminary plans and estimates for a water works in suburban St. Louis: "It occurred to me that a spherical bottom with the material in tension would be more economical (than a flat bottom tank and beams), so I based my estimate on a tank with a spherical bottom."[24] Although these plans were later abandoned, Flad and his consulting partner J. B. Johnson published the scheme on two occasions, in Engineering News in 1891, and in The Theory and Practice of Modern Framed Structures in 1893. Johnson and Flad stated they were prepared to build 50,000 to 200,000 gallon models on fifty to one hundred fifty foot towers, with ornamental ladder and balcony, for "costs considerably below that of a standpipe of equal effective capacity."[25] (Figure 43)

The publication of the Johnson and Flad 1891 design and the Laredo tank had immediate impact. Early in 1894 George Horton and his shop superintendent at CBI developed a method of dishing plates to create a spherical form:

> Our first experiment consisted in placing a pile ring on the lower block of a punch housing and with a large puncher as a plunger, working a plate into hemispherical form. The original plate as

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[24] Edward Flad, "My Elevated Tank," The Water Tower 11 (July 1925): 9.

[25] The "New Form of Water Tower" was described as an improvement over the primitive elevated steel tank, which was excessively expensive as support had to be provided for the tank bottom. In the proposed new design, the bottom was hemispherical and self-supporting, and easily built of flange steel. The bottom attached to the sides of the tank, which acted as plate girders to transfer the load to the eight steel columns. The exposed riser pipe entered the bottom of the tank through an expansion joint and was to be enclosed in cold climates. "A New Form of Water Tower," Engineering News 26 (August 15, 1891): 135.

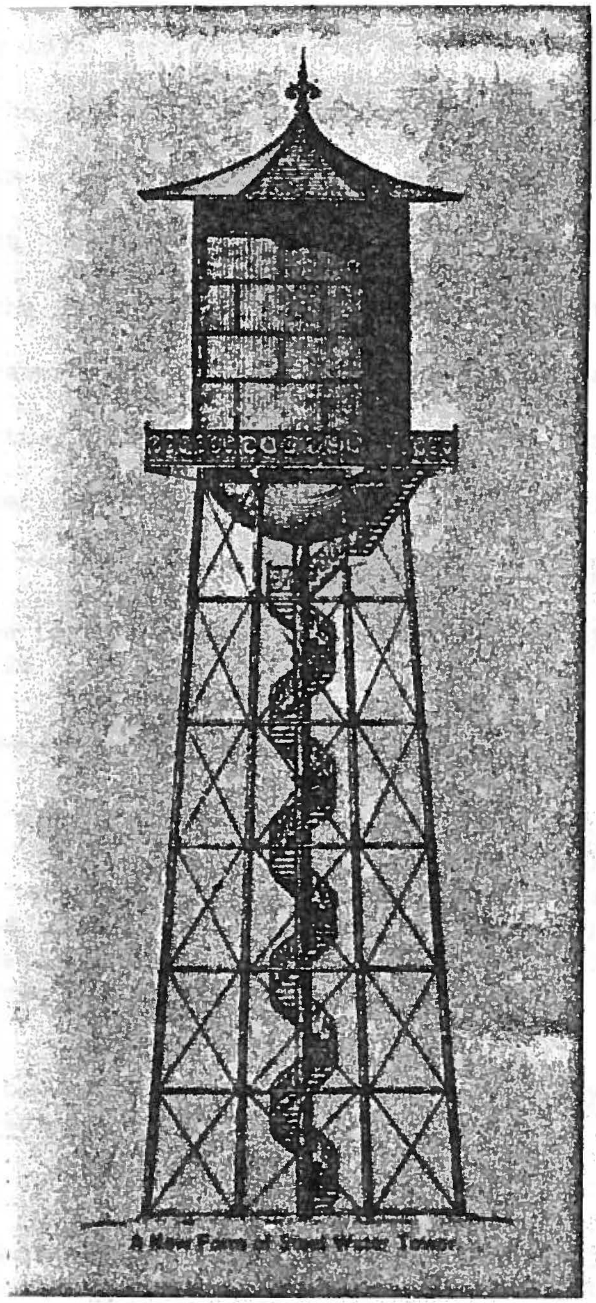

Figure 43. Johnson and Flad's "new form of water tower" with spherical bottom. Capacity: 50,000 to 200,000 gallons. Source: "A New Form of Water-Tower," Engineering News 26 (August 15, 1891): 135.

> dished, showing our present method of forming practical, still hangs in Mr. Horton's old office.[26]

This technique was critical to the widespread use of the hemispherical bottom form. By 1898, one water works engineer stated that "no trouble is experienced at the present time in securing favorable bids for the construction of elevated tanks with round bottoms from a number of reliable firms."[27]

Concurrent with the introduction of the spherical or hemispherical bottom tank in the U. S. was that of the conical bottom tank. Also discussed in "Iron Plate Reservoirs" in 1886, this tank form was losing popularity in Europe at that time.[28] Nonetheless, the simplest conical bottom form was an innovation in American tank design in 1893. Initially illustrated in an article entitled "Standpipes and their Design," which appeared in Engineering News in 1893, the first conical bottom tank was erected in Fairhaven, Mass. later that year.[29] (Figure 44)

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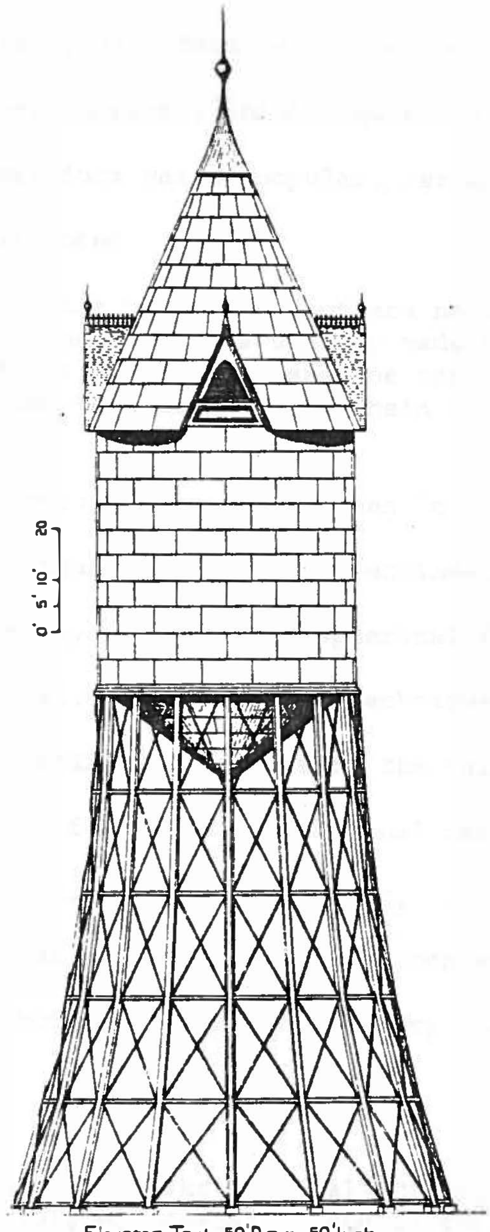
[26] Horton, "Elevated Tank Construction," p. 3. CBI lost $2,000 on the Fort Dodge, Iowa (1894) elevated tank, the first tank using the new dished plates, because "we made the bottom in many small plates and found it very expensive and had a good deal of trouble in assembling and making them." Design changes resulted in the successful Paris, Illinois (1895) elevated tank, the prototype for later CBI work.

[27] A. Marston, "The Elevated Water Tower of Iowa State Agricultural College," Engineering News 39 (June 9, 1898): 372.

[28] Writing in 1902 concerning the failure of the Fairhaven, Mass., conical bottom tank, Leopold Mensch of Cleveland stated that "the disadvantages of this kind of tank, more especially their property to leak at the junction between bottom and sides, were so well known in Europe that they were abandoned about fifteen years ago for tanks of more than 10,000 gallons capacity. Mensch, "Failure of the Water Tower at Fairhaven, Mass.," p. 11.

[29] Coffin, "Standpipes and their Design," p. 242-245. Coffin did not claim his design to be original, making specific reference to the 1891 Johnson and Flad scheme and the Norton water tower, both spherical bottom designs.



Elevated Tank, 50' Diam., 50' high.
Framed Steel Base, 100' high.
FIG. 8.

Balcony and Railing.
FIG 8a.

Figure 44. Coffin's design for elevated tank with conical bottom (1893). Capacity: 750,000 gallons. Source: "Standpipes and their Design," Engineering News (March 16, 1893): 245.

A serious competitor of the hemispherical form in the 1890's, the conical bottom was widely used because the bottom form was easier to fabricate than the hemispherical, which required a double curved surface. Until 1900, the conical form was as popular, perhaps more so, as other forms. One water works manual noted:

> The construction of the tank itself offers no features of special interest save that the bottom is usually made conical when steel framing is used for a support, unless the capacity of the tank is so small that is can be satisfactorily held on a platform resting on girders.[30]

Many examples of the conical form can be seen in the southeast, often built for industrial use. (Figure 45) By 1896, engineers had demonstrated that the economic advantage lay with the hemispherical form, which used less material than the conical.[31] Also, CBI's technique for fashioning dished plates and the widely publicized failure of the Fairhaven tank hastened the departure of the conical form from the national market. It continued to be used on a regional basis for small capacity tanks.

The hemispherical bottom form gained complete acceptance in the early twentieth century for both municipal and factory use. By 1910 the first

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30 John Goodell, Water-Works for Small Cities and Towns (New York, The Engineering Record, 1899), p. 244-245. Goodell referred to the Laredo tank as "one of the few in this country with a curved bottom, although the pattern is a favorite abroad."

31 In an 1896 thesis, James M. Raikes of the University of Michigan compared the flat, conical, and spherical bottom for elevated steel tanks, studying the amount of metal required, relative ease of manufacture and erection, facility for inspection, painting, and repair, and appearance. The conical and spherical forms were superior to the flat bottom tank in all matters related to inspection and repair and appearance, particularly because the grid of girders was omitted. But of the three forms, the spherical had the economic and design advantage because of the uniformity of plates. James M. Raikes, "Water Tank Bottoms," The Technic o.s. 12 (Ann Arbor, University of Michigan Engineering Society, 1896), p. 74-77.

Figure 45. Conical bottom elevated tank for factory service (undated), Columbus, Georgia.
Source: C. Dubie.

new tank form of the twentieth century, the elliptical bottom, had joined the hemispherical bottom tank. These tanks were later dwarfed by even more elaborate curved bottom tanks with capacities of a million gallons or more. Each of these later twentieth century forms was derived from its predecessors; all ultimately owed their existence to Edward Flad's spherical bottom scheme of 1891 and the Laredo, Texas elevated tank of 1893.

Chapter IV

THE ELEVATED TANK: 1893-1940

Three distinct phases of elevated tank design can be identified in the twentieth century. In the first period, 1893-1905, engineers experimented with application of a variety of design features to the Johnson and Flad and Coffin schemes of the early nineties. The second phase, which began in 1907 with the introduction of the elliptical bottom form, involved a modest attempt to increase tank capacities and to modify the appearance of the "tin man" of the 1890's.[1] The third phase, extending from 1928 to roughly 1940, was characterized by new tank types like the radial cone and spheriodal tanks, which vastly increased capacities, and by visually appealing forms like the watersphere, which exploited developments like improved welding techniques to create new tank aesthetics. The bulk of the elevated tanks extant today represent these three phases of tank design.[2]

Because many tanks of the nineties illustrate the progressive adaptation of basic forms into the most cost efficient structures, some discussion

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[1] It also appears that by the close of this second phase, the elevated tank market had come under the control of a few major firms like CBI, Caldwell, and Pittsburgh and Des Moines. More detailed research of individual company histories would be necessary to confirm this.

[2] Few of the ornamental tanks of the nineties have survived, and because their design was significant in the evolution of tank aesthetics, this chapter focuses on these structures rather than on the more recent forms, many examples of which are available for study. The innovations of the 1930's have had an immense impact on tank design, however, and the architectural approach of that period has remained the "modern" standard up to 1980.

of the Johnson and Flad and Coffin designs and the elevated tanks actually built from those designs is valuable. The Johnson and Flad design of 1891 proposed a hemispherical bottom tank on an eight post, six panel tower. (Figure 43) The web of tie rods, the spiral staircase, and the filigree balcony and canopy roof created a more delicate silhouette than the blunt metal standpipe. The tank itself, however, was relatively short and squat, composed of five or six rings of wide plates.

As constructed in Laredo, Texas in 1893, the tank omitted the elaborate decorative scheme. (Figure 46) The eight main posts were reduced to four, with eight auxiliary struts introduced in the uppermost panel to assist in transferring the tank weight from the circular girder to the trestle posts. The curved stair was omitted and the emphatic roof and balcony were altered, saving material and weight.[3] The result was a stripped down version of the 1891 design, although the overall proportions of the Laredo tank, with better height to diameter ratio, were more elegant.

The Coffin scheme of 1893 and the Fairhaven tank reflect similar modification of the original design. Coffin's model incorporated a five panel trestle of eighteen legs with parabolic curves; the tank was composed of rings of plates five feet high and covered by a steeply pitched roof with a finial and four cross gables with decorative cresting in the Queen Anne style. (Figure 44) As constructed, the tower was reduced to twelve posts and the sweeping curve of the trestle was omitted and the tank's diameter reduced, resulting in a tank of thinner proportions.[4] (Figure 47) While the

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[3] The cost of the tank was $8,271; its weight, 119,700 pounds. A comparable standpipe twenty feet in diameter and one hundred twenty feet high would have cost $11,100 and weighed 160,000 pounds. "The Laredo Water Tower," The Engineering Record 29 (March 10, 1896): 240.

[4] The reduction in the number of trestle posts resulted in part from the reduction of the tank's diameter and capacity.

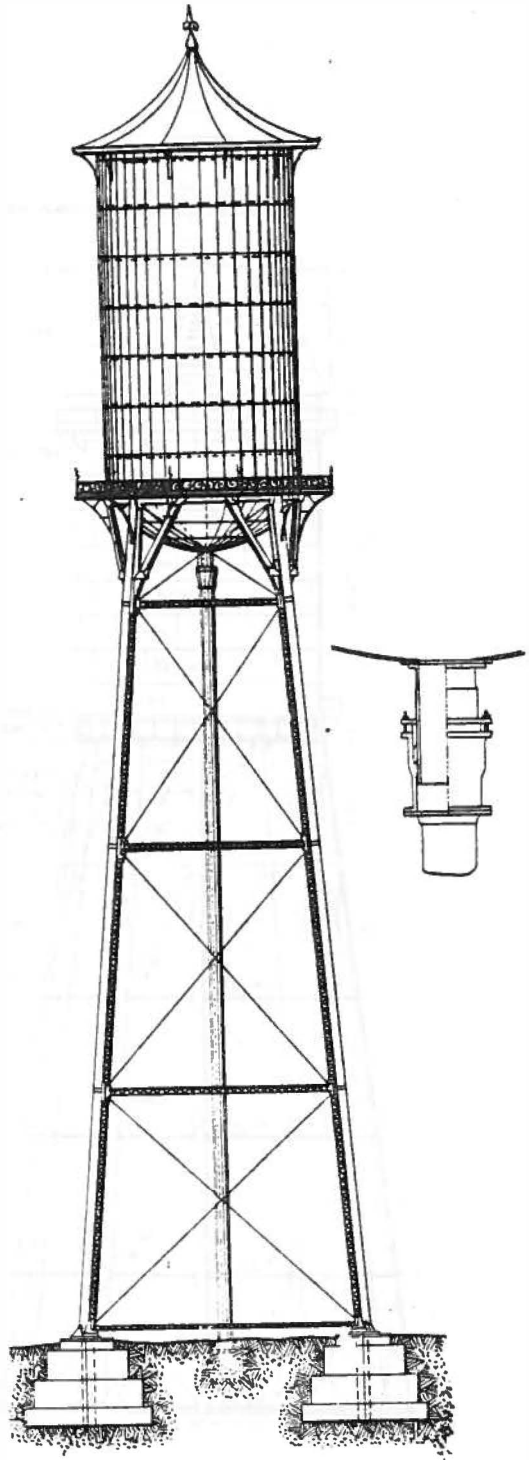

Figure 46. Laredo, Texas spherical bottom elevated tank (1893). Capacity: 85,000 gallons.
Source: "The Laredo Water Tower," The Engineering Record 29 (March 10, 1896): 240.

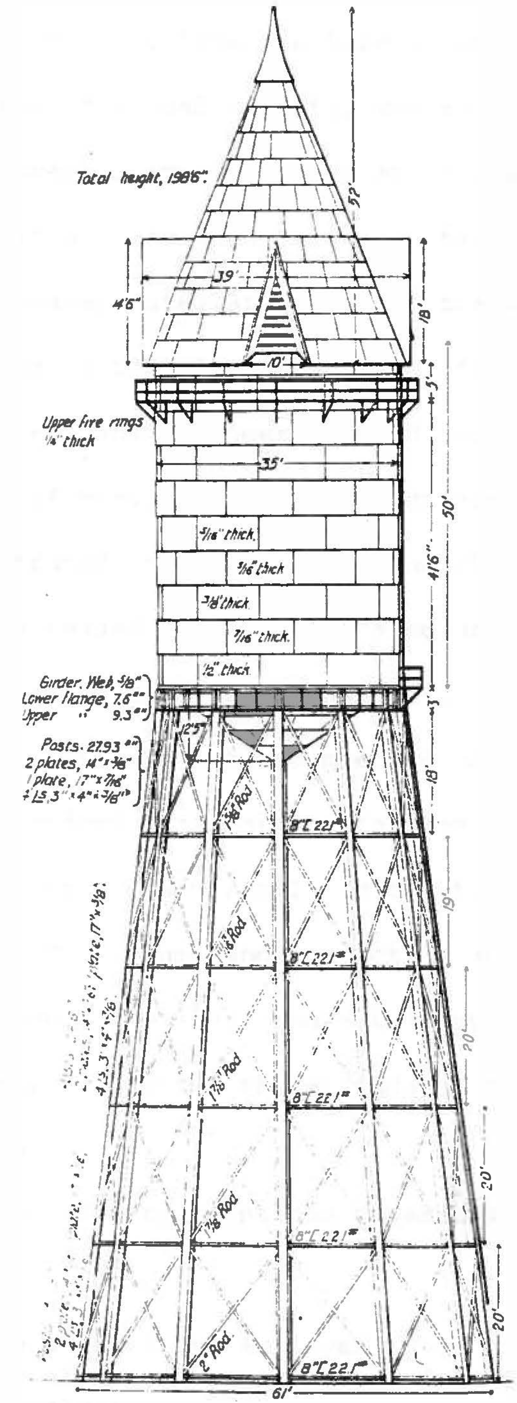

Figure 47. Fairhaven, Massachusetts conical bottom elevated tank (1893). Capacity: 383,000 gallons. Source: "The Fairhaven, Mass., Standpipe," The Engineering Record 25 (February 24, 1894): 205.

roof retained its steep pitch, the decorative elements were eliminated, leaving a cone pierced by four small gables to allow air circulation in the tank. In the Fairhaven tank, like the Laredo, an effort to conserve materials, usually at the expense of visual effects, was evident. In the Flad design and structure, the overall impression is still one of a standpipe resting on a trestle; the Coffin scheme and Fairhaven tank reached toward more pleasing lines and greater integration of the trestle and tank.

The connection of trestle posts to the tank sides was a central issue in early elevated tank engineering, and one directly related to the aesthetics and costs of various designs. Engineers initially believed that too few posts concentrated strains on the tank shell; on the other hand, many posts greatly increased costs. Flad's solution in Laredo was four main posts and eight shorter angled posts connecting to an intermediate circular girder.[5] (Figure 48) In 1894 a technique was pioneered by Horace Horton of CBI that became standard practice in elevated tank construction. CBI's method attached the four posts directly to the tank sides rather than to an intermediate member. The column and connecting angles were riveted directly to the tank sides through the shell and a balcony girder was added at the connection to take the horizontal thrust induced by the connection of the columns.[6] (Figure 48)

The CBI method of attachment had several advantages over the Flad

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[5] This technique was later employed in other tanks like Flad's Murphysboro, Illinois elevated tank (1899) and in CBI's New York Shipbuilding Company elevated tank (1901).

[6] This method was initially criticised by other engineers, who believed "the rivets would not take equal loading and some would shear off, thus putting greater loading on the ones adjoining, which would in turn shear and eventually the whole thing would fall." Horton, "Elevated Tank Construction," p. 8.

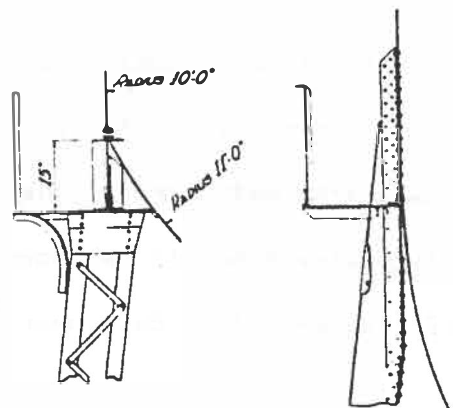

Fig. 2A Fig 2B

Figure 2a—Method Used by Mr. Flad to Support Laredo Elevated Tank
Figure 2b—Tank Connection Without Skirt, Designed by Horace E. Horton

Figure 48. Two methods of trestle and tank attachment. On the left, Flad's method using a fifteen inch circular girder extension of the tank sides to attach column posts. (Note "triangular" enclosed space created.) On the right, Horton's method of tapered posts riveted directly to the tank sides.
Source: George T. Horton, "Elevated Tank Construction," The Water Tower 11 (April 1925), p. 8.

method. First, the fifteen inch circular girder or extension of the tank shell was eliminated, removing an intermediate member which was expensive and complicated to attach. Horton's design, employing a full hemisphere connected directly to the sides and posts, omitted the circular girder, the flanging of the tank bottom edge, and the inaccessible space within. The Horton technique was cleaner in design, less complicated in erection, and easier to maintain.

CBI's first use of this form of connection was in the Fort Dodge, Iowa elevated tank (1894), the first true hemispherical bottom tank, and the next major elevated tank constructed after Laredo and Fairhaven. Although the Fort Dodge tank received little coverage in the engineering press, it was similar in its engineering to the Paris, Illinois elevated tank (1895). (Figure 49)

More slender in its proportions than the Fort Dodge tank, the Paris tank was cited in the Engineering Record in 1897 as a good example of the new form of elevated tank. The tank was twenty-two feet in diameter and forty-one feet high from the lowest point of the hemispherical bottom to the roof line, giving a capacity of 106,000 gallons. The tower, whose columns were "designed to correspond with viaduct practice" was one hundred eleven feet high and divided into three panels. The tank bottom was formed of nine large plates rather than the larger number used in the Fort Dodge tank.[7] A lattice railing to protect occupants of the balcony was the only added feature. The striking simplicity of CBI's design was immediately apparent, and the Paris elevated tank became a prototype for thousands of elevated tanks in the "classic tin man" form.

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[7] See page 87, footnote 26. "A Steel Water Tower," The Engineering Record (February 27, 1897): 272-73.

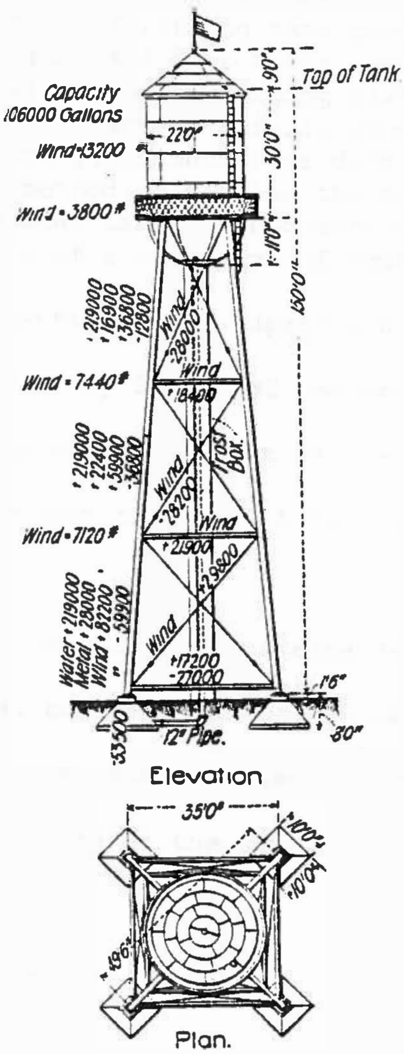

Figure 49. Paris, Illinois elevated tank (1895). Capacity: 106,000 gallons.
Source: "A Steel Water Tower," The Engineering Record 31 (February 27, 1897): 272.

In publicizing the Paris elevated tank, Horace Horton made sweeping statements about CBI's support of the hemispherical bottom tank:

> We are fully committed to the use of a hemispherical bottom for tanks. Its advantages have been acknowledged repeatedly, but the mechanical difficulties of forming have prevented their general use. The Chicago Bridge and Iron Works Company has developed an economical mechanical method of forming plates to build a hemispherical bottom, which very materially reduced the cost of the tank on the tower, and gives much less difficulty as to making it watertight than any method of placing the tank on a frame platform. The cost of the elevated tank was not much more than half what would have been the expense of a standpipe of equal diameter and height.[8]

In spite of Horton's assertions, the superiority of the "Horton tank" was not considered proven in 1897. By 1898, CBI had erected over a dozen hemispherical bottom tanks while retaining an interest in the market for standpipes, metal towers for flat bottom wooden and steel tanks, and an occasional conical bottom model.[9]

Two tanks dating from 1898 illustrate design variations of the hemispherical and conical bottom forms of the early nineties. The elevated tank at the Iowa State Agricultural College in Ames was designed by A. Marston, Professor of Civil Engineering at the school.[10] (Figure 50) Here, the

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8 "A Steel Water Tower," p. 273.

9 George Horton acknowledged in 1925 that CBI continued to erect less advanced designs at the request of its customers. Horton, "Elevated Tank Construction," p. 7-9; "History of Chicago Bridge and Iron Works," The Water Tower 1 (November 1914): 4-5; "Our Sales Department," The Water Tower 3 (September 1916): 2-3. CBI's 1902 New York Shipbuilding Company elevated tank was a good example of an attempt to accomodate a customer. Here, CBI reverted to Flad's form of trestle connection with four posts branching into twelve, a rarely used technique by 1900.

10 Believed to be the largest tank in the West at the time of its erection, the hemispherical bottom tank had a capacity of 160,000 gallons. A. Marston, "The Elevated Water Tank of the Iowa State Agricultural College," Engineering News 39 (June 9, 1898), 370.

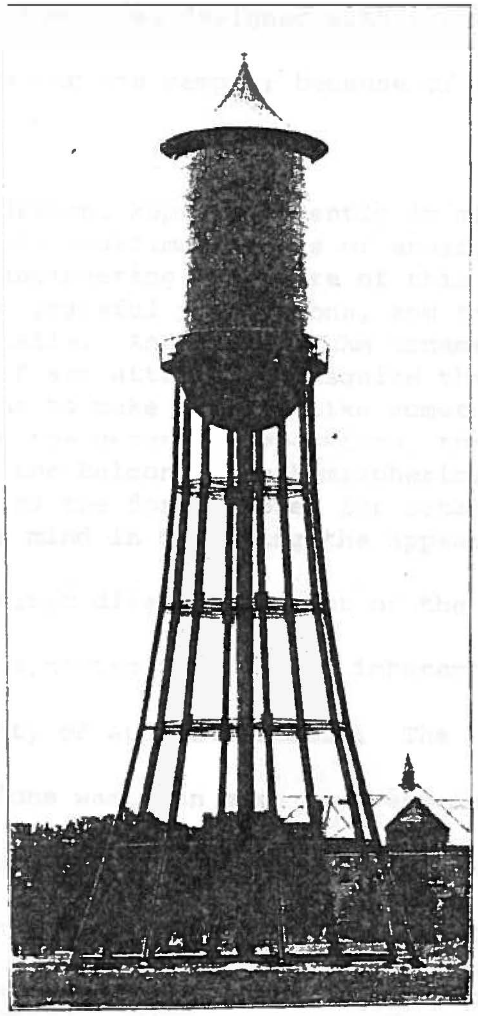

Fig. 1.—View of Elevated Water Tank of the Iowa State Agricultural College.
A. Marston, Assoc. M. Am. Soc. C. E., Engineer.

Figure 50. Ames, Iowa elevated tank (1898). Capacity: 106,000 gallons. Source: A. Marston, "The Elevated Water Tank of the Iowa State Agricultural College," Engineering News 39 (June 9, 1898), p. 370.

the column sections were straight between panel points, but these points were placed on arcs of circles of three hundred twenty foot radius, tangent to the vertical sides of the tank to create the appearance of curved posts. Uniform lengths of column sections between the panel points allowed for duplication in the shopwork. The tower was designed with great height and capacity to ensure fire protection for the campus; because of its conspicuous location, the engineer,

> in preparing the design, kept prominently in mind the appearance of the tower. The only legitimate means of enhancing the architectural appearance of an engineering structure of this kind are to select pleasing lines and graceful proportions, and to employ only neat, strong looking details. Any use of sham ornament is out of place. The same is true of any attempt to disguise the true purpose of the structure by trying to make it look like something it is not. In the present design the general proportions, the curving outlines of the tower proper, the balcony, the hemispherical bottom, the cornice, the curved roof, and the forms chosen for details were features which the writer kept in mind in designing the appearance of the tower.[11]

Marston provided the first direct statement of the aesthetic the elevated tank manufacturers were moving towards--an inherently graceful structure freed from the necessity of applied details. The tendency to strip away architectural concessions was even more apparent in the early work of CBI. In fact, the Fort Dodge and Paris elevated tanks were more exculsively engineering works than the tank at Iowa State Agricultural College, which toyed with the picturesque in its tower and tank roof.[12]

A second tank completed in mid-1898 illustrated a similar treatment

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[11] Marston cited Coffin's 1893 scheme as the source of his design. Marston, "The Elevated Water Tank of the Iowa State Agricultural College," p. 271.

[12] CBI erected and used in its advertising and sales catalogues several elevated tanks similar to Marston's. These appeared alongside the classic tin man and carried the notation "special design." (Figure 51) The Engineering Record 45 (June 20, 1903): 43 (Advertisements).

Figure 51. Chicago Bridge and Iron Works' Special Tank Designs. Source: Advertisement, The Engineering Record 45 (June 20, 1903): 43.

of the tower. Designed by R. N. Ellis, civil engineer and water works superintendent, the Jacksonville, Florida elevated tank was centrally located in a park and designed to be "as sightly as possible, to harmonize with its surroundings."[13] (Figure 52) Unlike Marston, who selected only the concept of strong flowing lines in the tower and changed the tank bottom form and omitted all architectural detailing, Ellis adopted Coffin's scheme with little modification. The roof followed Coffin's scheme of a deep cone with four crested gables and galvanized iron finial. The five panel steel trestle tower was composed of ten posts and was one hundred feet in height, inclined on a slight curve, with a diameter of sixty-five feet at the base and thirty feet at the top. The posts were composed entirely of Z-bar columns.

One additional example of this splayed leg trestle was the 1902 Grand Rapids, Wisconsin elevated tank, designed by Loweth and Wolff of St. Paul. The Grand Rapids tank consisted of a 150,000 gallon conical bottom steel tank on a steel trestle. Although only four posts were used, the splayed leg effect visually related the Grand Rapids elevated tank to the multiple post Fairhaven, Iowa State, and Jacksonville designs.[14] (Figure 53) This tank illustrates that some element of individuality, whether achieved through the addition of decoration or modification of the basic form to more

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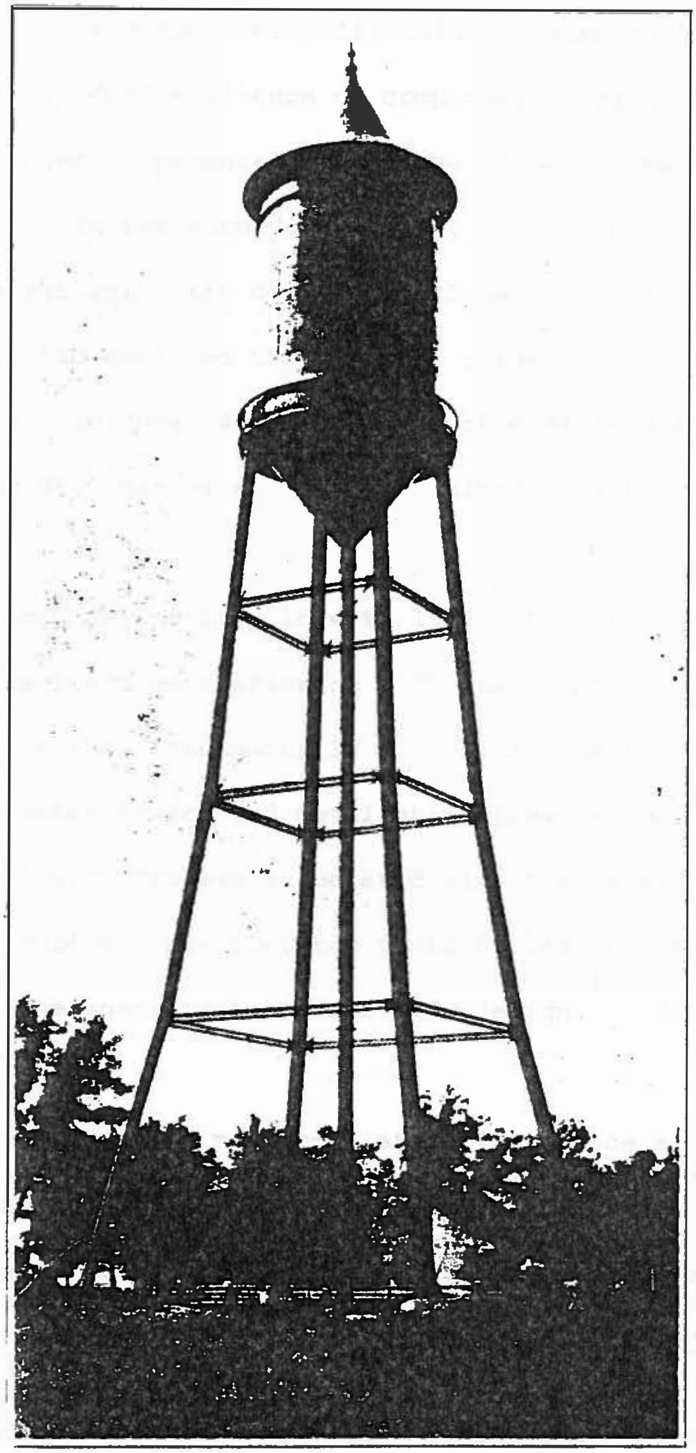
[13] R. N. Ellis, "The Elevated Water Tank at Jacksonville, Florida," Engineering News 41 (April 27, 1899): 258. R. D. Wood and Company of Philadelphia, who later used this tank in their advertising, were the contractors.

[14] "The Water Tower at Grand Rapids, Wisconsin," The Engineering Record 44 (November 8, 1902): 440.

[illegible] GALLON TANK ON STEEL TOWER.

Tank, [illegible] diameter x 15' deep. | Tower, 45 diameter at base x [illegible] high.

Figure 52. Jacksonville, Florida elevated tank (1898). Capacity: 250,000 gallons.
Source: Water and Gas Works Appliances (Philadelphia, R. D. Wood & Co., 1908), p. 101.



THE WATER TOWER AT GRAND RAPIDS, WIS.

Figure 53. Grand Rapids, Wisconsin elevated tank (1902). Capacity: 150,000 gallons.
Source: "The Water Tower at Grand Rapids, Wisconsin," The Engineering Record 44 (November 8, 1902): 440.

pleasing lines and proportions, was pursued by most small engineering and contracting firms.

Edward Flad's Murphysboro, Illinois elevated tank of 1899 also suggests that individual engineers or companies chose a particular design scheme and continued to promote it in spite of advancements and simplifications made by others.[15] In the Murphysboro tank, the arrangement of the trestle, including the eight auxiliary columns, followed that of Flad's Laredo tank of 1893. Also, Flad employed the circular girder method of attaching the tank and trestle. (Figure 54) A method of insulation similar to that used on the St. Charles standpipe resulted in a board and batten tank covering.[16]

These tanks dating from 1894 to 1902 document designs typical of those used in the first generation of all metal elevated tanks. The creation of these structures was fundamentally different from the design and construction of masonry water towers and metal standpipes in the 1880's. First, the trial and error design process associated with the water tower and the standpipe was avoided. Few elevated tanks failed; those that did fell clearly outside the specifications for safe design.[17] Second, the archi-

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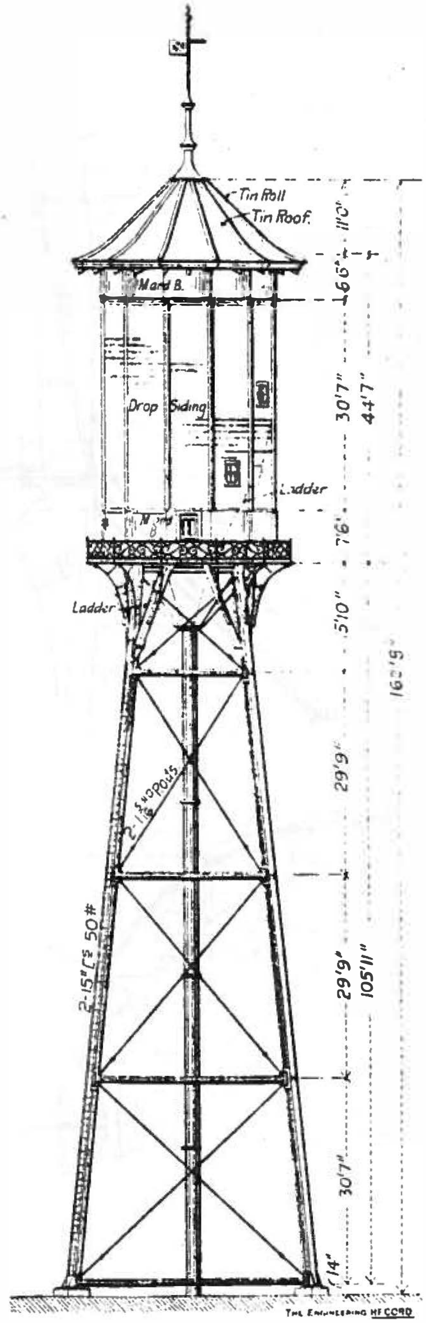
[15] This was probably more cost effective. Once an engineer had a design in hand and knew its production requirements, it was cheaper to bid on that design than to spend time working up another scheme.

[16] Five circular girders carried a sheathing of weather boards around the tank, leaving a two foot air space; the riser pipe was similarly encased. "New Water Tower at Murphysboro, Illinois," The Engineering Record 42 (July 7, 1900): 6-8.

[17] More engineers practicing in the nineties had had professional training. While engineers had been unable to predict the behavior of a large masonry mass like a brick or stone tower, specifications and calculations of stresses in metal trestles were possible by the nineties. See Theodore Cooper, General Specifications for Iron Railroad Bridges and Viaducts (New York, Engineering News Publishing Company, 1885).



THE MURPHYSBORO TOWER.

Figure 54. Murphysboro, Illinois elevated tank (1899). Capacity: 108,900 gallons. a. Elevation.
Source: "New Water Tower at Murphysboro, Illinois," The Engineering Record 42 (July 7, 1900): 7.

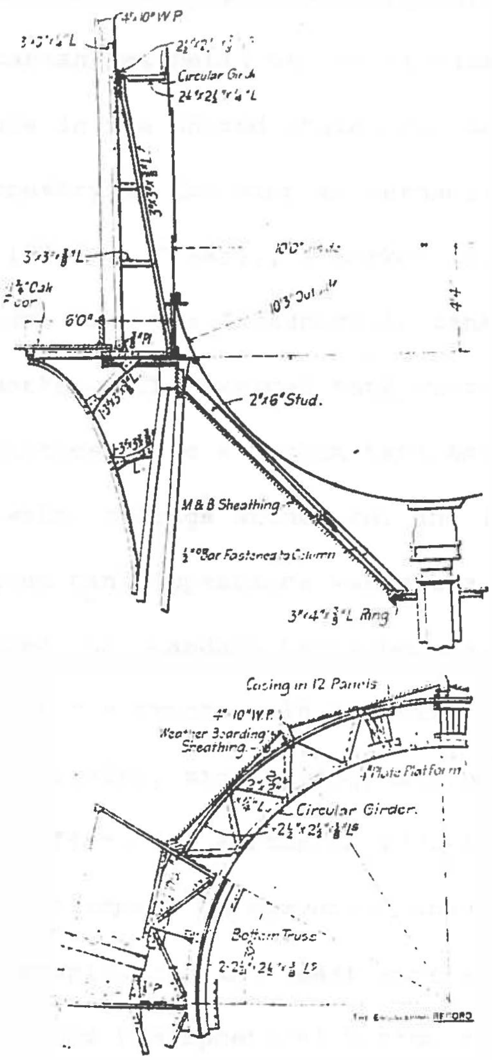


Figure 54. Murphysboro, Illinois elevated tank (1899). b. Detail of tank and trestle attachment.
Source: "New Water Tower at Murphysboro, Illinois," <u>The Engineering Record</u> 42 (July 7, 1900): 8.

tectural effects of the early elevated tanks derived from their uniqueness as structural types and from their arrangement of the structural elements themselves. Elaborate applied decoration, considered essential to the standpipe, was abandoned early in the design of the elevated tank.[18]

The utilitarian aesthetic of the elevated tank which gained almost immediate acceptance in the United States can be attributed in part to the elevated tank's ancestry in the simpler vernacular wood tanks and trestles of the 1870's and 1880's. Clearly, a market existed for the more artistic elevated tank designs like the Jacksonville tank, but this was a secondary "specialty tank" market. The typical tank customers at the turn of the century were communities where a wooden tank and trestle or standpipe had been the previous water storage structure, and industrial plants and institutions, where elevated tank appearance was not a significant factor. This large market welcomed the standard hemispherical bottom tank.

Elevated tank construction in the first decade of the twentieth century focused on refining, simplifying, and popularizing the forms developed by Flad, Coffin, and Horton in 1891-1894. The form of the 1890's which had the greatest impact on elevated tank design in the twentieth century was the least complicated and least expensive form, directly derived from the Paris, Illinois hemispherical bottom tank.[19]

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[18] Although the costs of elevated tanks were generally lower than those of standpipes or water towers, economy of materials was important. The competitive edge in the elevated tank market was quickly secured by companies like CBI which developed standardized designs. Standardized designs conserved materials, and minimized design, fabrication, and erection costs because company work crews became familiar with the limited number of products which the company offered. J. E. O'Leary, "Standardized Elevated Steel Water Tanks," Journal of the American Water Works Association 15 (September 1925): 190-98.

[19] These structures met the basic engineering requirements and, for their capacities, were never improved upon.

The next three decades were rich in experimentation, resolving the remaining problems of the classic tin man, and designing new tank forms to meet the greater storage demands of growing communities. The major issue of the ensuing years was that of building safe and efficient tanks with larger and larger capacities within the confines of available technologies. The major aesthetic issue was that of transforming the classic tin man formula into smoother, more rounded forms as architectural tastes changed in the teens and the twenties. Also, the adaptation of industrial and municipal tanks for advertising purposes transformed the elevated tank into a promotional device and a commercial archeology art form.

The elliptical bottom tank (1907) was the first response to the need to store larger volumes of water while limiting the range of pressure for a full and empty tank. George Horton of CBI wrote in 1925:

> As time passed it became apparent that a tank with a hemispherical bottom was not generally the most desirable form. We found that something of the same arguement which favors building an elevated tank instead of a standpipe straight up from the ground, existed between a high tank of small diameter and shallow ones of larger diameter. The more nearly constant the head remains as the tank is filled and emptied, the generally better, of course that the total vertical height of the tank should be a minimum. . . We discovered that a hemispherical bottom tank is very much limited in this respect. As the diameter increases, the height reduces so fast that the tank becomes all, or nearly all, bottom--an entirely unsuitable form, objectionable not alone on account of appearance but because the shell would not have sufficient girder strength to carry the load to the columns. A bottom in the form of a spherical segment would answer but, as I have said before, induces heavy stresses at the point of its connection to the shell, difficult to provide for.[20]

The elliptical bottom elevated tank was designed to have a relatively

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[20] Horton, "Elevated Tank Construction," p. 10. Limitations on feasible capacities while keeping the tank depth at about twenty-five feet were 175,000 gallons for the hemispherical bottom and 300,000 gallons for the elliptical bottom form. Twenty-five feet depth was considered the maximum acceptable in situations where modest variation in pressure was required. "The Radial-Cone Bottom Tank for Elevated Water Storage," Engineering News-Record 108 (February 25, 1932): 280.

shallow tank with large diameter. (Figure 55) The elliptical bottom eliminated the need for both the expansion joint at the junction of the riser pipe and the tank, and enclosure of the riser. Expansion joints tended to wear out and leak but were necessary in the rigid hemispherical bottom tank form. Differences in expansion and contraction of the steel tower and the iron riser pipe would cause the pipe to bend or break . The elliptical bottom, on the other hand, was nearly flat at the point of connection with the riser, enabling a riser to larger diameter to be riveted directly to the tank bottom. The bottom plates acted as a diaphragm to take care of expansion and contraction.[21] Risers for elliptical tanks varied from thirty to seventy-two inches and required no enclosure because of their greater diameter. This larger, rigid riser also acted as an additional supporting column, and stored water, increasing the overall capacity of the elevated tank. Other features, including isolation of sediment and ease of cleaning, made the elliptical bottom tank an attractive choice where large storage needs suggested its use.

In 1919, CBI reported that the elliptical bottom tank had been adopted widely in the municipal water works field, largely because of its low variation in pressure, self-cleaning features, and absence of maintenance costs. The hemispherical bottom steel tank retained control of the insurance and industrial fields.[22] CBI leaders believed that the "sturdy, stable

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[21] "Our Elliptical Bottom Tank for Combined Sprinkler and Mill Service," The Water Tower 5 (August 1919): 4-5.

[22] Some tank companies continued to profit from production of a limited number of tank styles, indicating a very strong market for the classic hemi-spherical bottom tank, even into the 1920's. By 1927, The Caldwell Company's catalogue offered two basic options--the wooden tank on a metal trestle, and an all metal hemispherical bottom tank. Caldwell Tanks and Towers of Wood and Steel: 1927 (Louisville, Kentucky, W. E. Caldwell Company, 1927).

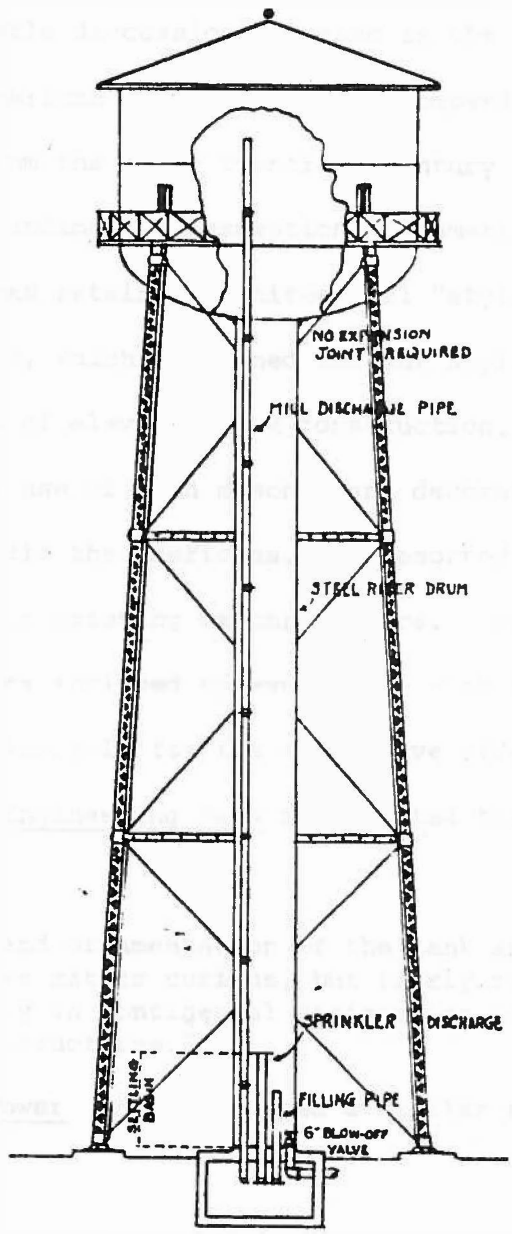

Figure 55. Standard elliptical bottom elevated tank for factory service (1919).
Source: "Our Elliptical Bottom Tank for Combined Sprinkler and Mill Service," The Water Tower 10 (August 1919): 4.

appearance of the elliptical bottom tank appealed to community leaders.[23] Its horizontal lines strongly contrasted with the tin man form, whose tank proportions and conical roof had a vertical emphasis appropriate to its late Victorian origins. (Figure 56)

In the 1910's, little discussion occurred in the engineering journals about the aesthetics of American elevated tanks. Comparison of several European designs dating from the early twentieth century with their American counterparts reveals the fundamental assumptions of American tank aesthetics. Moderate size European tanks retained architectural "styles" much longer than their American counterparts, which abandoned blatant stylistic references after the first generation of elevated tank construction. European architects and engineers made greater use of both masonry and decorative metal work in a single tank design than did the Americans, who resorted to such combinations only when replacing tanks in existing masonry towers. European engineers and designers were also more inclined to experiment with the use of metalwork or reinforced concrete exclusively for its decorative effects. (Figure 57)

As early as 1902, Engineering News illustrated the Antwerp Iron and Steel Works elevated tank:

> The dove-cote housing and ornamentation of the tank and its supporting standard are to our eyes rather curious, but fairly represent a quite prevalent tendency in Continental engineering to aestheticize prominent engineering structures.[24]

An article in The Water Tower in 1926 echoed a similar note:

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[23] Horton, "Elevated Tank Construction," p. 11.

[24] "Elevated Water Tower at the Plant of the Antwerp Iron and Steel Works," Engineering News 48 (October 16, 1902): 321.

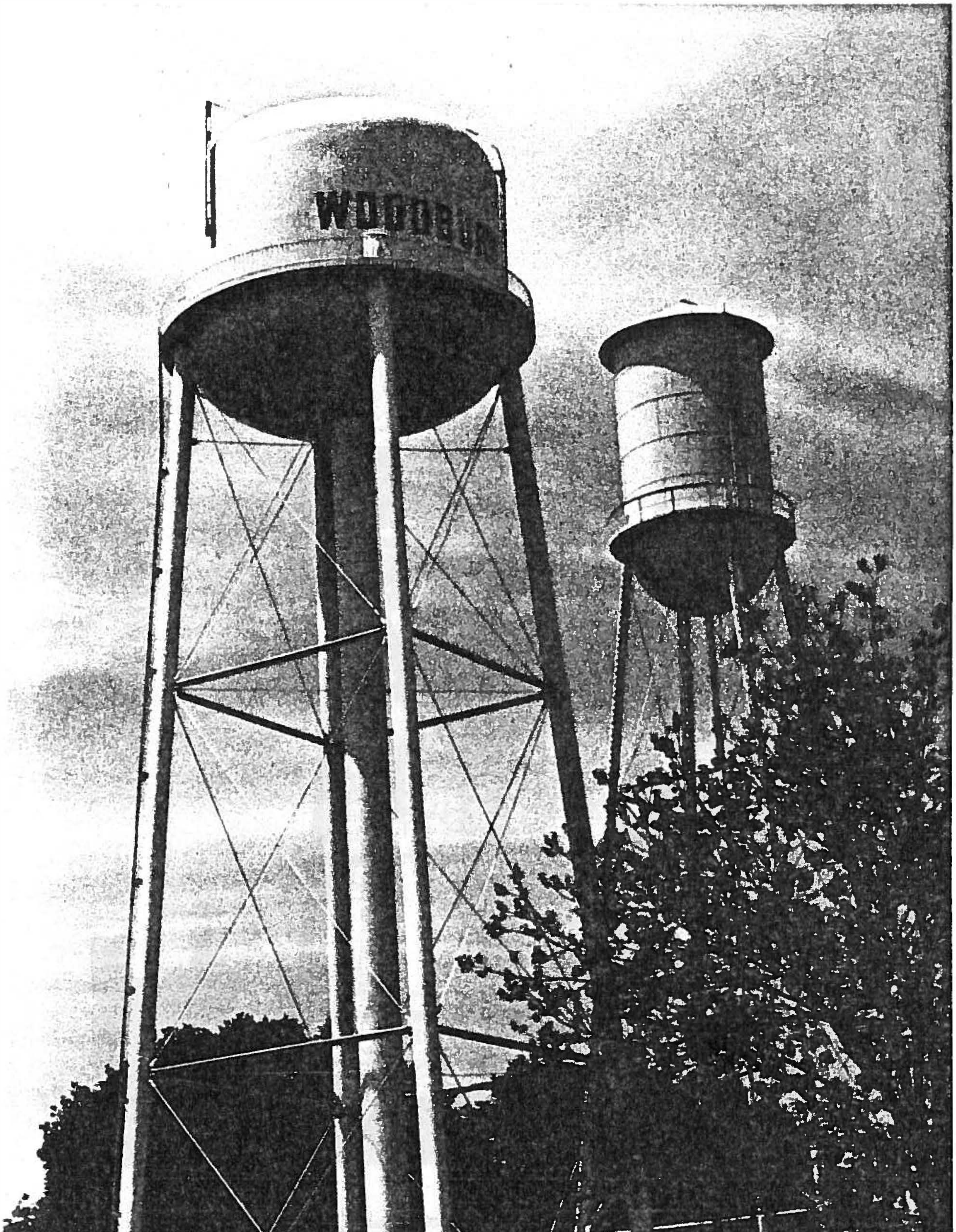

Figure 56. Classic "tin man" hemispherical bottom and elliptical bottom tanks, Woodbury, Georgia.
Source: C. Dubie.

Fig. 2. Elevated Water Tank at the Plant of the Antwerp Iron & Steel Works.

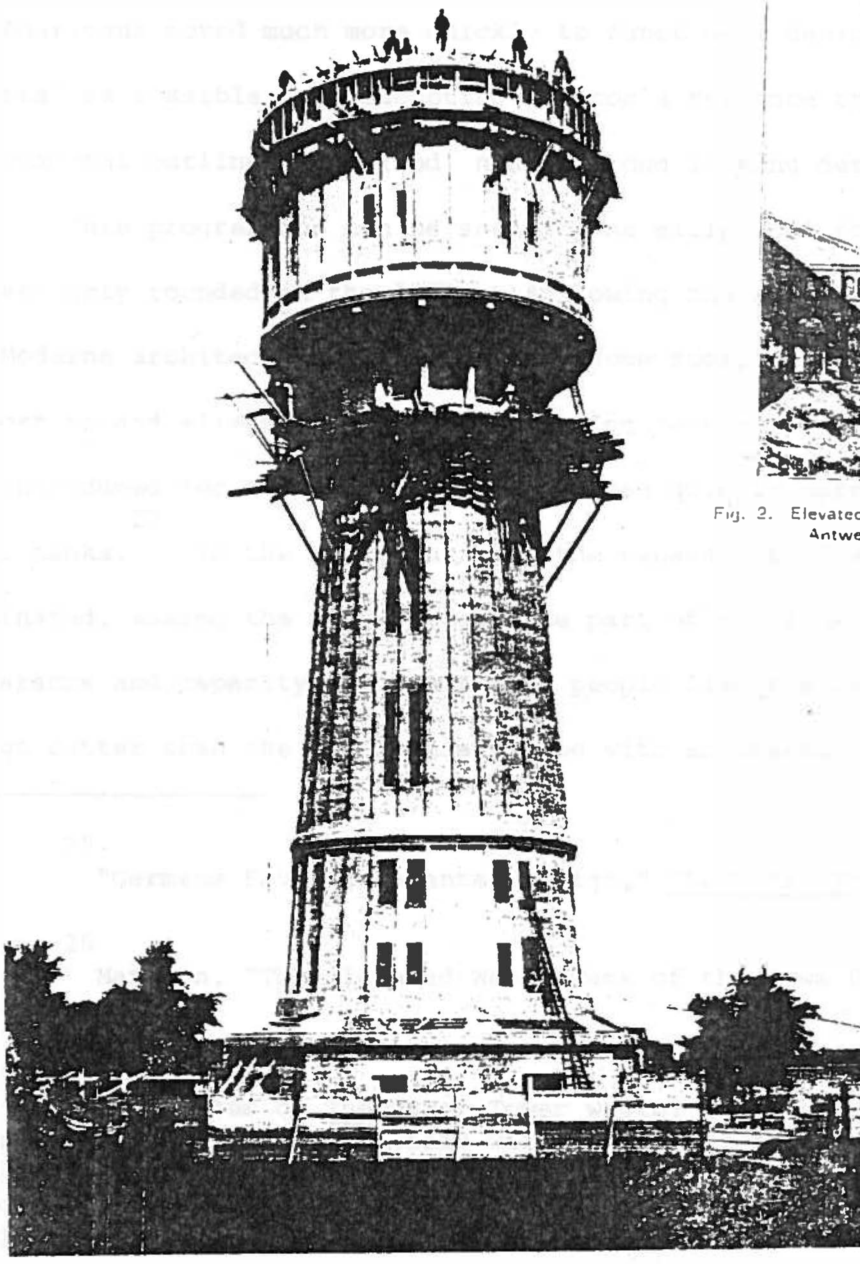

Figure 57. Brussels, Belgium decorated concrete water tower (1909). Capacity: 280,000 gallons. Insert: Antwerp Iron & Steel Works water tower. Source: H. Prine Kieffer, "A Concrete Water Tower of Interesting Construction," Cement Age (November 1909): 298; "Elevated Water Tower at the Plant of the Antwerp Iron and Steel Works," Engineering News 48 (October 16, 1902): 321.

> (The Homberg, Germany tank) presents quite a different appearance from the elevated steel tanks commonly seen throughout the United States. It is evident that German engineers make a special effort to improve the appearance of their tanks by the addition of ornamental devices. Many (American engineers) believe, however, that well-balanced proportions and simplicity of design make up for the lack of decoration.[25]

The Americans moved much more quickly to functional designs, using as little material as possible, and accepting Marston's reliance on "pleasing proportions and graceful outlines. . . (and) neat, strong looking details."[26]

This progression can be seen in the elliptical form, which became increasingly rounded in the 1920's, following the softened lines of Art Deco and Moderne architecture. In 1922, the dome roof, which was entirely self-supporting and eliminated the steel framing necessary to the conical roof, was introduced for railway tanks and its use quickly spread to municipal water tanks.[27] In the early thirties the separate roof was altogether eliminated, making the roof "a definite part of the tank as regards both appearance and capacity. A great many people like the appearance of this design better than the old standard type with an overhanging roof."[28]

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[25] "Germans Favor Ornamental Design," The Water Tower 12 (July 1926): 5.

[26] Marston, "The Elevated Water Tank of the Iowa State Agricultural College," p. 271.

[27] The editor of The Water Tower wrote: "We believe that most railroad engineers and operating officials will agree that the dome-roof tank is a more handsome structure than tanks with the old-style roof." "Dome Roof Another Improvement in Railroad Water Tank Construction," The Water Tower 9 (January 1922): 6.

[28] "Youngstown Elevated Tank has Dome Roof," The Water Tower 20 (January 1934): 6.

By that time, welding had replaced riveting for many connections and tubular columns were in use. As discussed below, each of these innovations which had a major impact on tank appearance was also an improvement in engineering which resulted in lower cost, easier fabrication, or quicker assembly.

One variation of the quest for functional and appealing elevated tanks was the introduction of advertising on elevated tanks. As corporate advertising became more common, company names and symbols were painted on the standard tin man which had been purchased to store water for factory processes or sprinkler systems. The new industrial advertising was governed by a search for "something novel and picturesque. . . schemes of imposing and striking appearance and individuality."[29] Tanks were transformed into three dimensional billboards--representations of products ranging from pineapples and tobacco cans to jars of Ovaltine: (Figure 58)

> It is now quite generally conceded that it pays to advertise, and on a journey in any direction one cannot fail to notice the ever-increasing number of advertisements we are erecting. . . The milk bottle at Toronto is a good illustration. This tank, standing high above surrounding buildings, holds the attention of all who come within vision, while at night, by projected light, it stands out majestically, grand and white, against a dark sky. Its advertising value is incalculable. . . No printed word appears. It is not necessary. The structure is one great and lasting shout, that stands night and day silently proclaiming CITY DAIRY.[30]

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[29] "A New Function for the Steel Tank," The Water Tower 2 (May 1916): 4. After 1915, CBI's all metal tank was competitive with the wooden tank on a steel tower which had remained popular for industrial use. In that year, CBI completed construction of shops at Greenville, Pa., specially adapted to the construction of steel tanks. Coupled with CBI's tank design which permitted easy fabrication and erection, the new tank shops made it possible for CBI to build a steel tank of small size for about the same cost as a wooden tank. Until that time, the cost of steel tanks of 40,000 gallons or less had been considerably more than that of wooden tanks on steel towers. "Development of Steel Tanks," The Water Tower 1 (July 1915): 2.

[30] E.G. Daniels, "It Pays to Advertise," The Water Tower 2 (January 1916): 7.

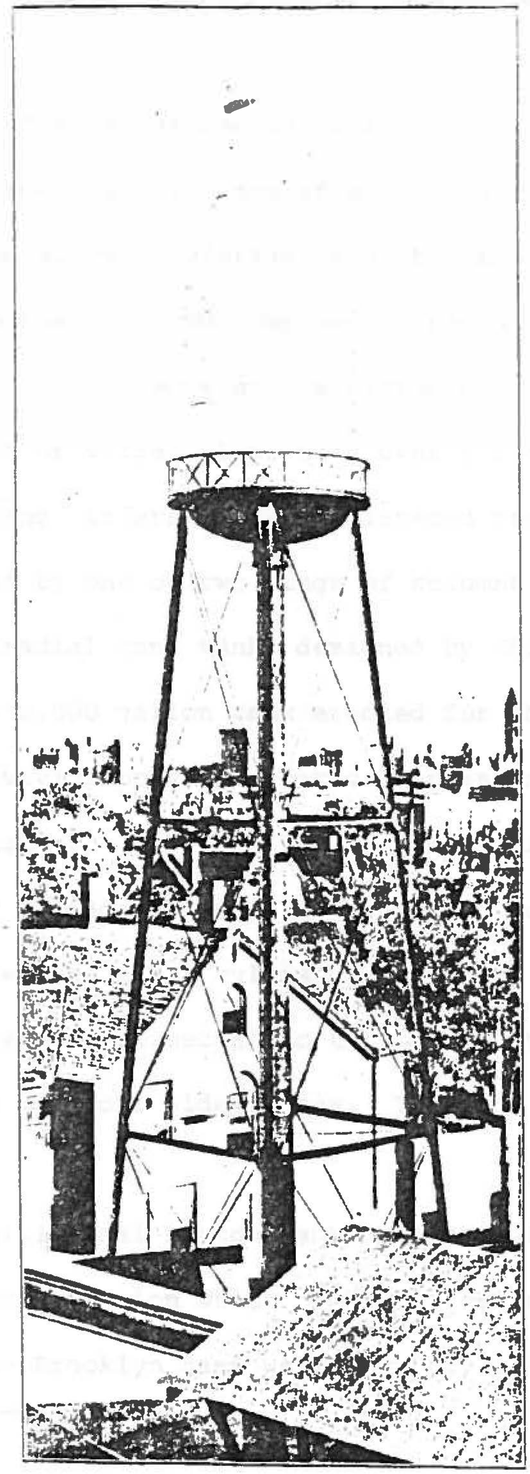

Figure 58. City Dairy Company Milk Bottle, Toronto, Canada (1915).
Capacity: 25,000 gallons.
Source: "Combine Novelty with Utility in Design of Steel Water Tank," The Engineering Record 72 (December 18, 1915): 772.

Town names also began to appear on elevated tanks at this period, suggesting that small communities identified their elevated tanks as important reference points.

A second major innovation in tank bottom design, the radial cone bottom, was introduced twenty years after the elliptical bottom. The design made possible large elevated storage capacity in a comparatively shallow tank. The tank bottom form was composed of radial troughs, each being a section of a cone with its apex at the center of the tank. Troughs were connected by a bent or welded plate hung over a radial supporting girder. The radial supporting girders were cantilevered from the large central riser and supported by one or two rings of columns.[31]

The first radial cone tank, designed by CBI and erected in Brooklyn in 1930, was a 1,250,000 gallon tank erected for the New York Water Service, one of the few surviving private water companies in greater New York. (Figure 59) The tank bottom consisted of sixteen radial troughs supported by an equal number of radial girders.[32] Thirty-two columns--two rings of sixteen--and the central riser cylinder--supported the girders. The inner ends of the troughs were connected to the top of the riser; the outer ends were joined to the vertical side plates. The tank was only twenty-seven feet deep.

Like the elliptical bottom tank, the radial cone bottom tank had a strong horizontal orientation which presented new problems for designers and engineers. The Brooklyn tank was awkwardly proportioned, its trestle

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[31] "The Radial-Cone-Bottom Tank for Elevated Water Storage," Engineering News-Record 108 (February 23, 1932): 279-80.

[32] "New York Water Service Corporation Installs New Radial-Cone Bottom," The Water Tower 17 (January 1931): 2.

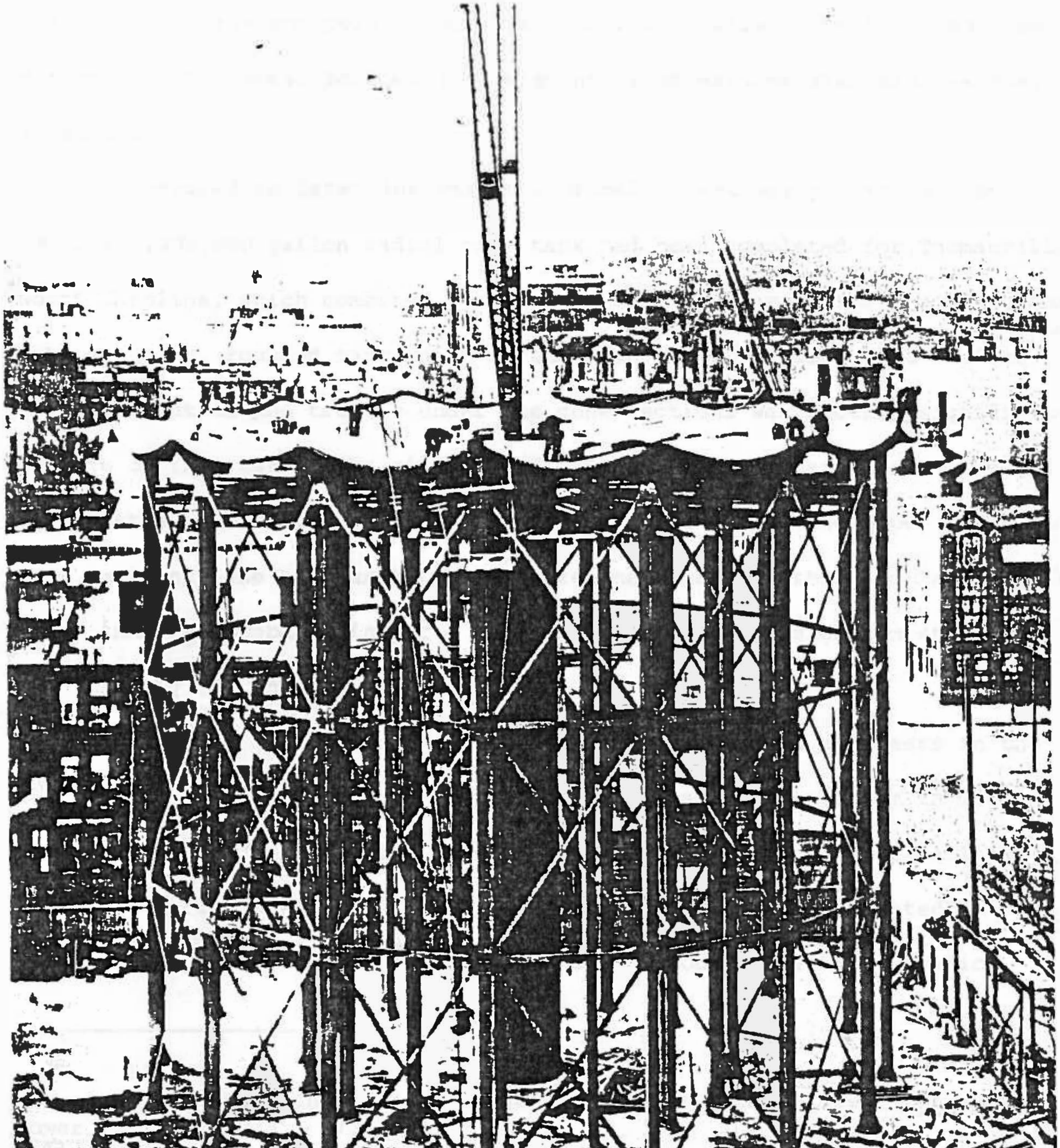

Figure 59. Brooklyn, New York radial cone elevated tank (1931): bottom form. Capacity: 1,250,000 gallons.
Source: The Water Tower 17 (December 1930): cover.

complex and the tank itself, squat and flat. The color scheme of dark trestle and light colored tank emphasized the disparity between the trestle and the tank and pointed out that the first radial cone tank had been designed by piecemeal borrowing of elements from earlier standard designs. (Figure 60)

Compared to later designs, the Brooklyn tank was primitive. By 1935, a 1,000,000 gallon radial cone tank had been completed for Thomasville, North Carolina, which combined a support system similar to the Brooklyn tank with a smooth, rounded tank which became standard for radial cone designs.[33] The placement of the trestle under the cone sections was another significant feature of this tank. The girders radiating from the riser extended beyond the trestle connection and stiffeners were introduced in the upper sides and roof section. The Deco architectural treatment used in this and later radial cone tanks was probably inspired by entries in a tank design competition sponsored by CBI in 1930. (Figure 61)

Elevated tank aesthetics had continued to trouble engineers in the 1920's. One popular means of concealing tanks was to paint them in lighter colors, white and light olive being popular, but as tank size dramatically increased in the late twenties, better overall design was advocated.[34] In 1930, CBI, a major fabricator, sought "to develop a general aesthetic

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[33] "New Tank Increases Storage Capacity at Thomasville," The Water Tower 22 (July 1935): 7.

[34] "Light Color Enhances Tank Appearance," The Water Tower 10 (July 1924): 4; "Making Water Works Structures Attractive," Journal of the American Water Works Association 23 (November 1931): 2010-11.

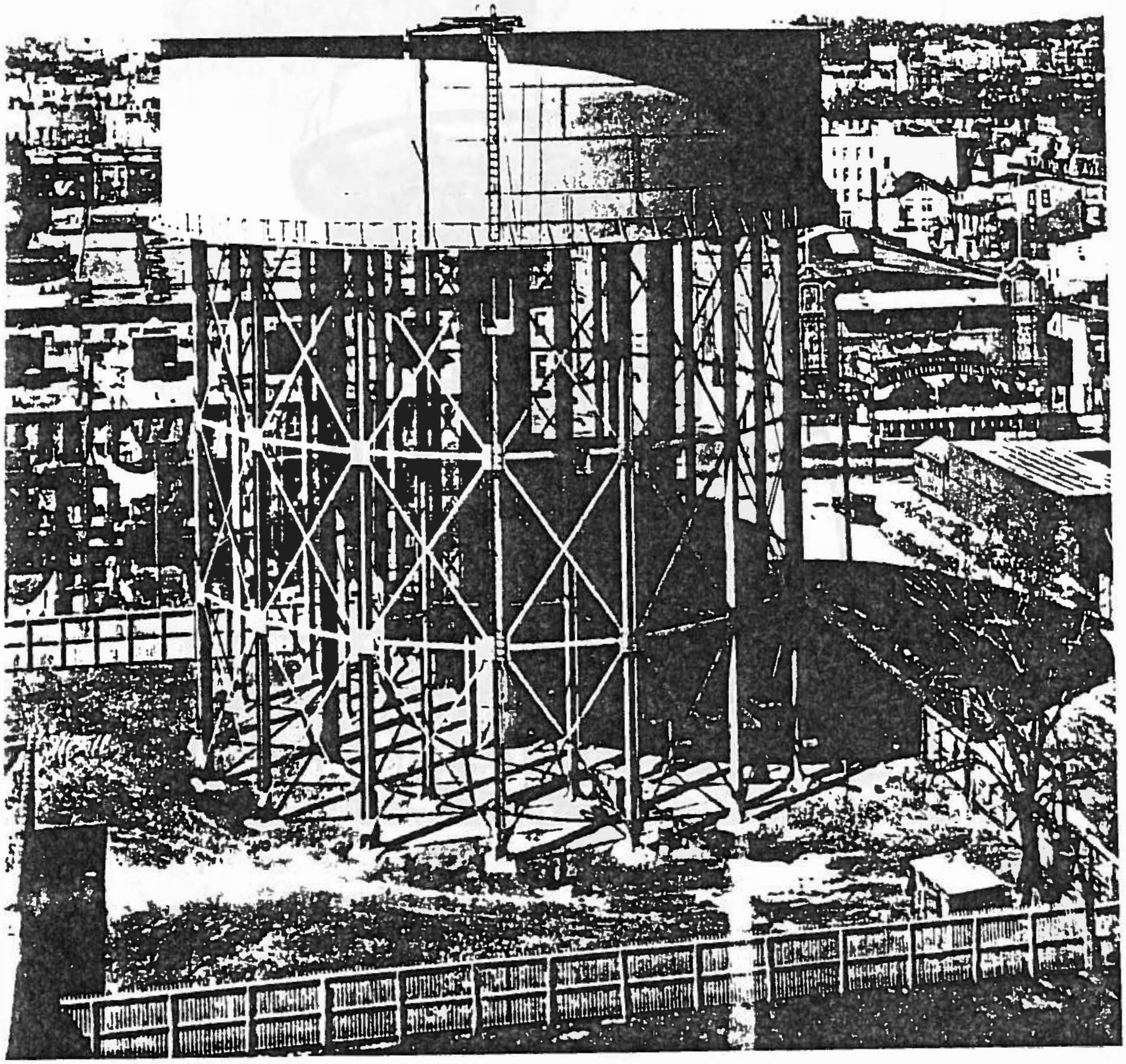

Figure 60. Brooklyn, New York radial cone elevated tank: completed tank. Source: The Water Tower 17 (January 1931): cover.

Figure 61. Thomasville, North Carolina radial cone elevated tank (1935).
Capacity: 1,000,000 gallons.
Source: "New Tank Increases Storage Capacity at Thomasville," The Water Tower 22 (July 1935): 7.

improvement in the character of elevated steel water tanks and their supporting structures," through an architectural competition similar to that sponsored by the Engineering Record in 1889.[35] A preface to the publication of the competition results stated:

> In as much as steel does not lend itself readily to the lines of masonry, the appearance of elevated tanks has often been subjected to adverse comment. . . sometimes strong enough to cause those responsible for the installation of an elevated tank to surround it with a meaningless enclosure in an attempt to conceal or disguise its identity. . . We may have carried precise engineering precepts too far and thus left our work gaunt in its bare utilitarian aspect. . . We may also have encouraged our customers to so narrow their requirements as to preclude developments along aesthetic lines.[36]

The 152 submitted entries fell into three major categories. The first group represented visual improvements to the popular hemispherical and elliptical tank forms. (Figure 62) Many of these used elaborate steel patternwork in the posts and reflected the decorative trends in European tank design. A second group proposed total enclosure and concealment of the tank and base. (Figure 63) A final group, much smaller in number, exploited the central riser pipe as the sole means of tank support; these were based on general European precedents and foreshadowed the popularity of the streamlined "watersphere" in the 1940's. (Figure 64)

Simplicity and strong detailing were characteristics shared by the prize winning designs. First prize was awarded for a tank which successfully

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[35] Foreword, Elevated Tank Designs (Chicago, Chicago Bridge and Iron Works, 1931), no page.

[36] One competition specification was that entries be designed for a 200,000 gallon capacity tank, much smaller than major tanks being built by the 1930's. CBI was anxious to provide models for small communities as the Engineering Record had done in 1889; this left unsolved the problem of good architectural treatment for the 1,000,000 gallon tanks which were rapidly coming into use, however.

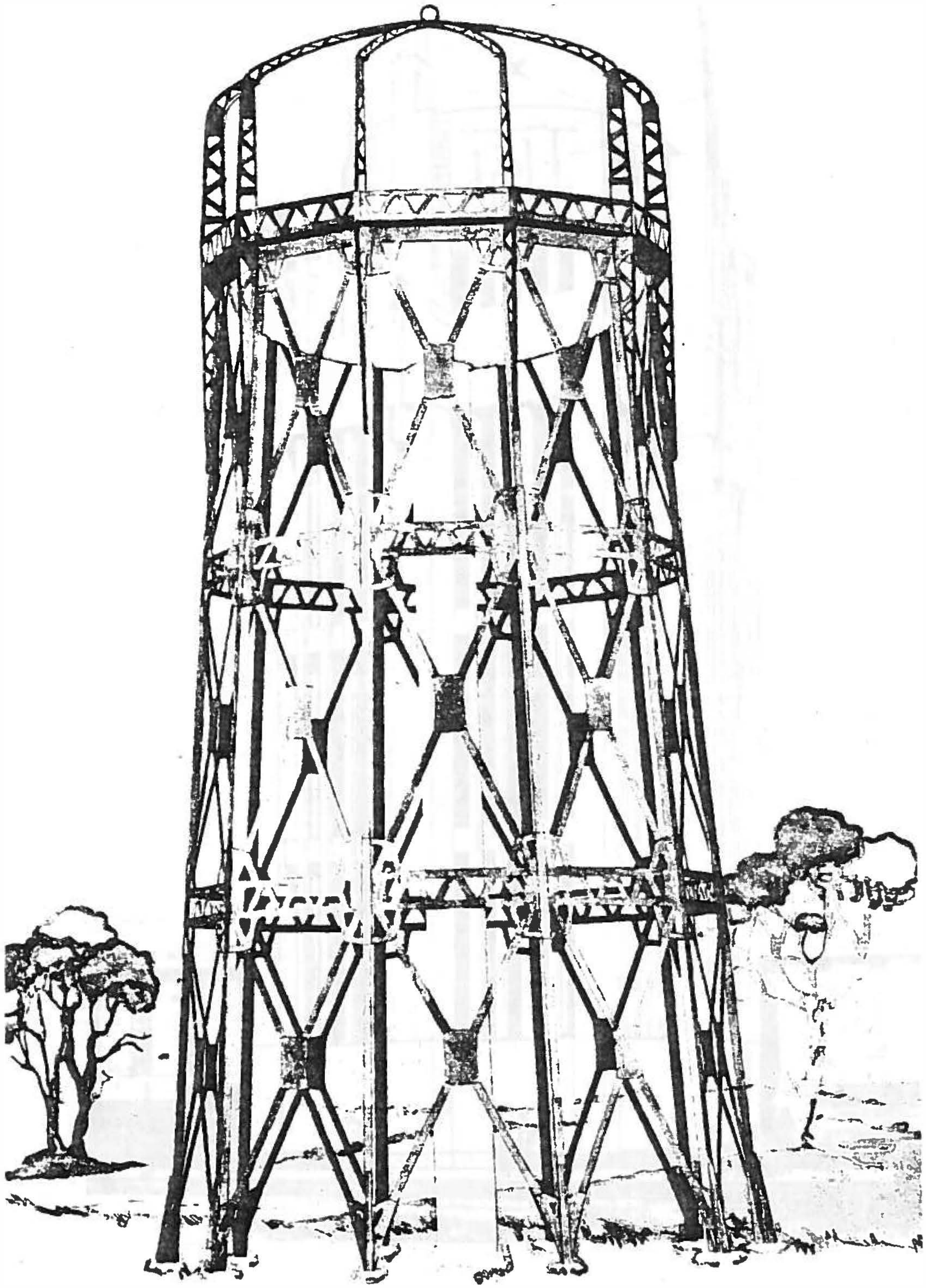

Figure 62. CBI 1931 competition entry: decorated elevated tank. Capacity: 200,000 gallons. Designer: Addison Morse Kinney. Source: Elevated Tank Designs (Chicago, Chicago Bridge and Iron Works, 1931), plate 12.

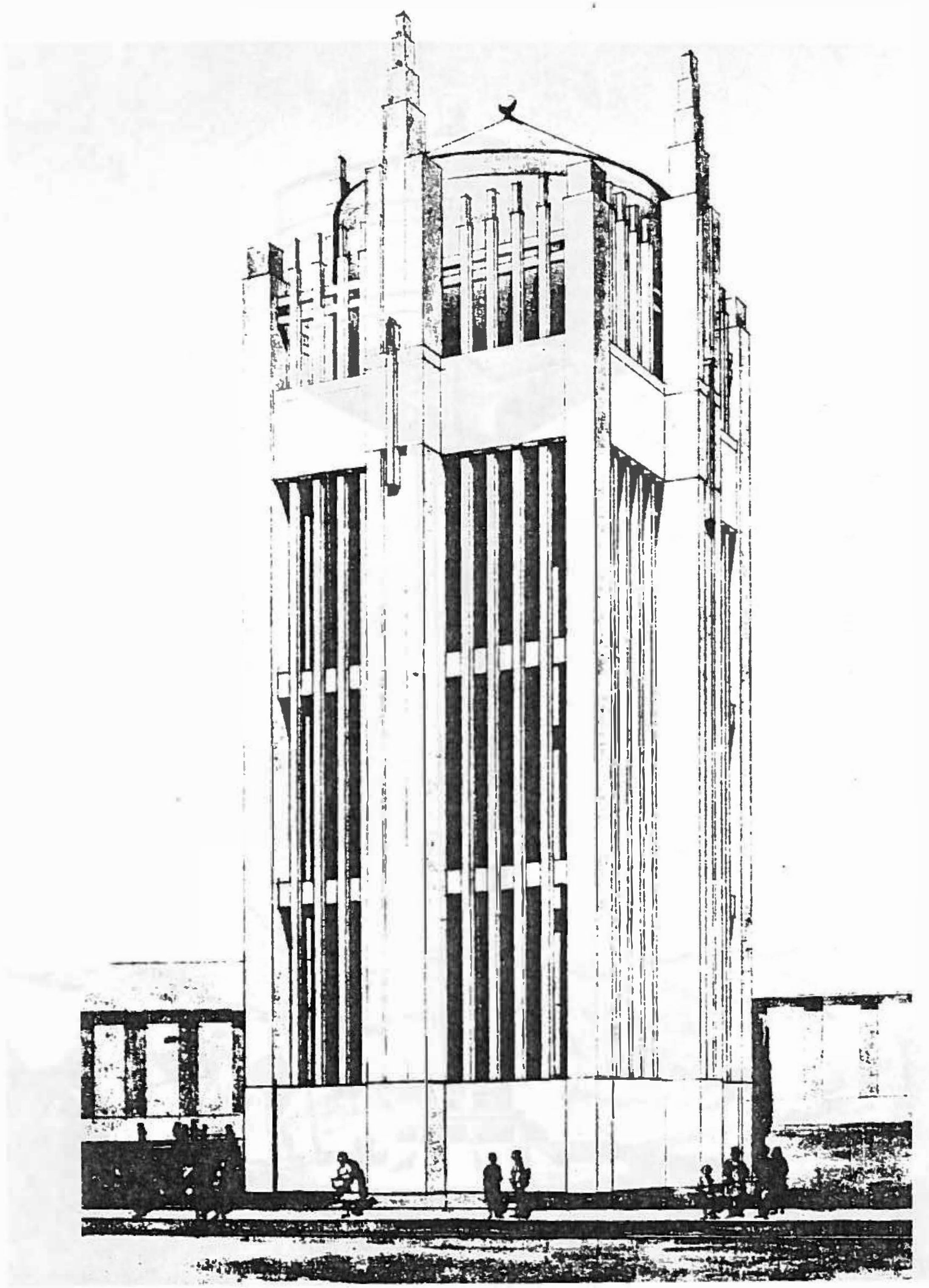

Figure 63. CBI 1931 competition entry: enclosed elevated tank. Capacity: 200,000 gallons. Designer: H. G. Hodgkins. Source: Elevated Tank Designs (Chicago, Chicago Bridge and Iron Works, 1931), plate 100.

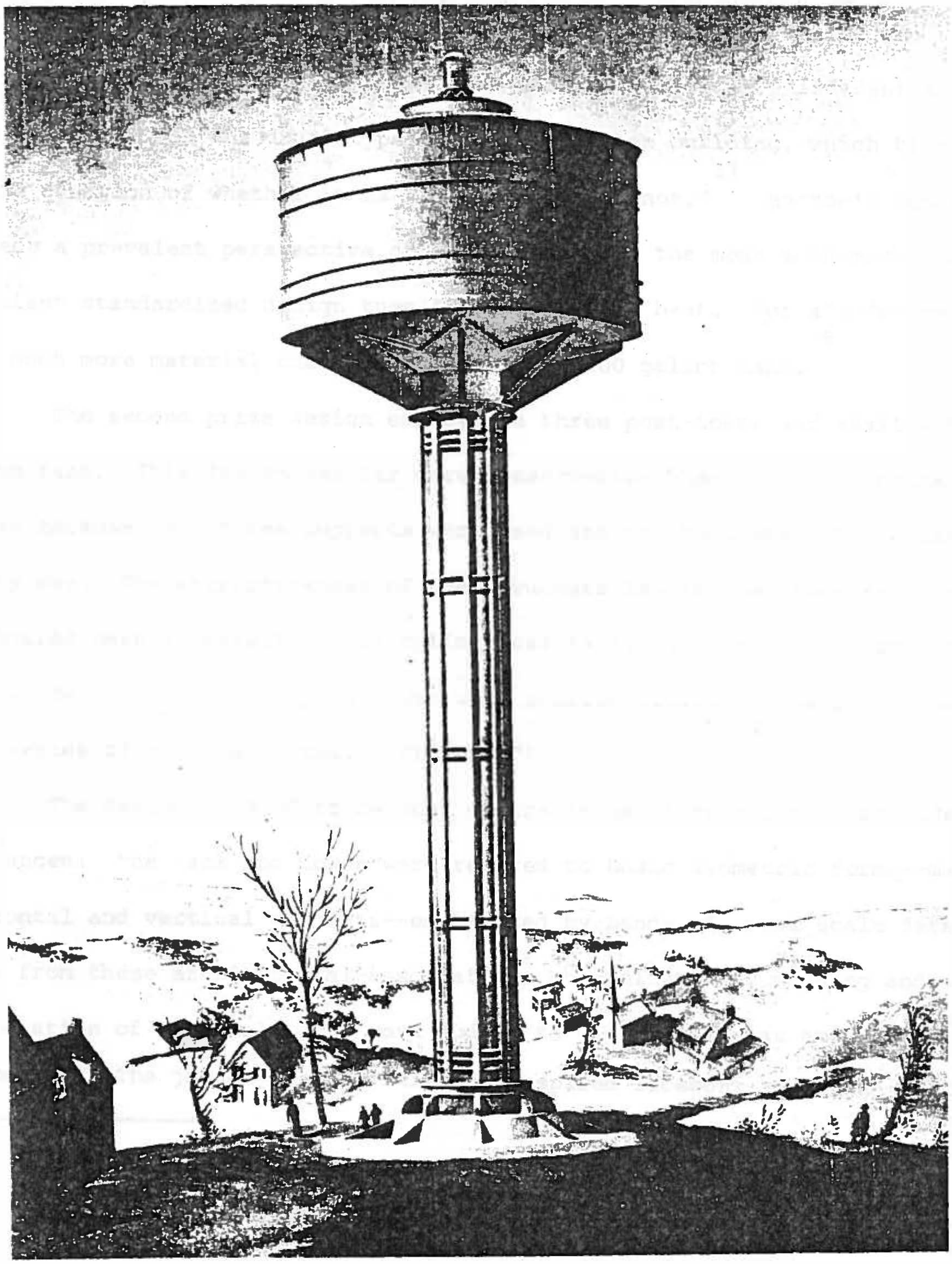

Figure 64. CBI 1931 competition entry: single pedestal elevated tank. Capacity: 200,000 gallons. Designer: Paul C. Chapman and James B. Rosser.
Source: Elevated Tank Designs (Chicago, Chicago Bridge and Iron Works, 1931), plate 73.

unified the tank and tower by giving the tower mass and weight through use of box girders and a wide riser. Vertical movement was suggested by a spiral stair and by carrying the column ribs through to the top of the tank. (Figure 65) George Horton described the winning design as "different and practical. . . not the usual type that we have been building, which brings up the question of whether it is really better or not."[37] Horton's remarks reflect a prevalent perspective of engineers, that the most economical and efficient standardized design then in use, was the best. Voita's design used much more material than the standard 200,000 gallon tank.[38]

The second prize design employed a three post tower and shallow flat bottom tank. This design was far more conservative than the first prize scheme because only three supports were used and the tank was not embellished in any way. The attractiveness of the structure lay in the geometry of the triangular base intersecting the cylindrical tank. (Figure 66) Third prize was awarded to a multiple post tower with shallow elliptical tank terminated in a series of circular forms. (Figure 67)

The designs judged to be most desirable had identifiable Art Moderne influences: the tank and tower were reduced to basic geometric forms--major horizontal and vertical elements--emphasized by bands of small scale detail. Aside from these architectural associations communicated by massing and manipulation of materials, the work judged to be superior was among the least ornamental. The judges avoided European-inspired lacework treatments of

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[37] "Making Water Works Structures Attractive," p. 1999.

[38] Eugene Voita, the designer, was a Chicago area architect like the other top six prize winners. Other winners: F. D. Chapman and C. M. Goldman, Evanston, Ill.; Howard Vader, Donald Blake, George Hossack. "Prize Winners Selected in Elevated Tank Competition," The Water Tower 17 (July 1931): 2.

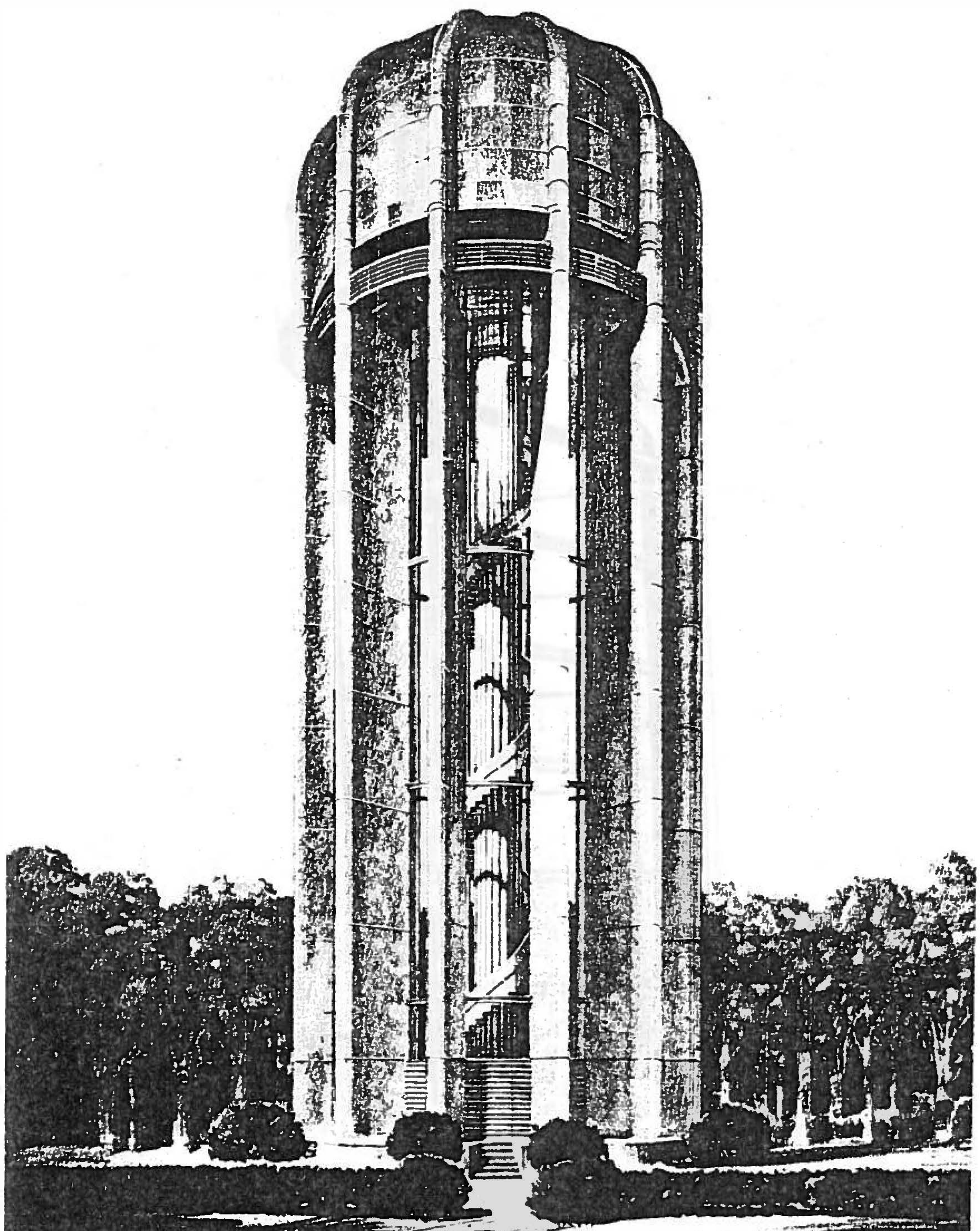

Figure 65. CBI 1931 competition entry: first prize design. Capacity: 200,000 gallons. Designer: Eugene Voita. Source: <u>Elevated Tank Designs</u> (Chicago, Chicago Bridge and Iron Works, 1931), plate 1.

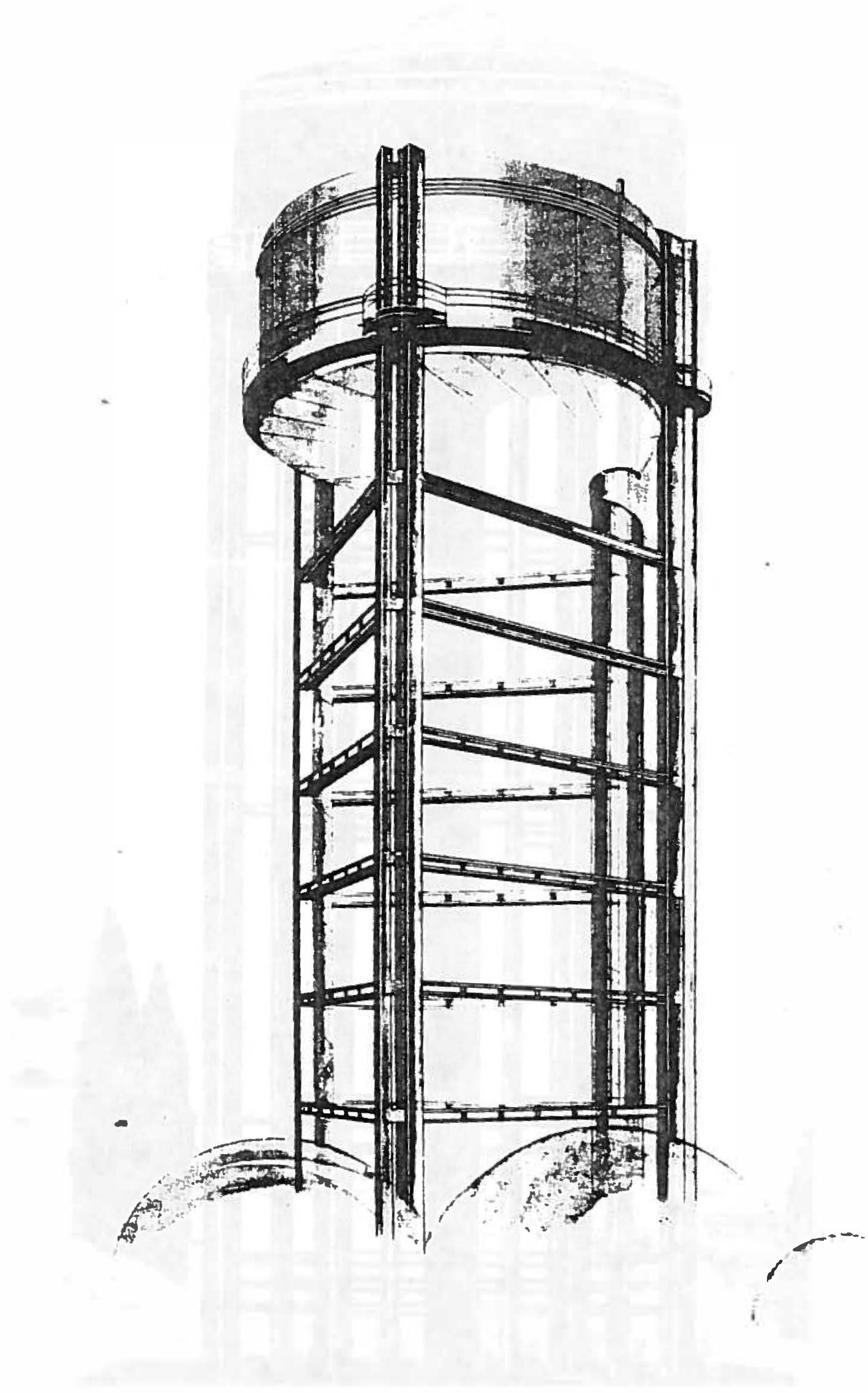

Figure 66. CBI 1931 competition entry: second prize design. Capacity: 200,000 gallons. Designer: F. D. Chapman & C. M. Goldman. Source: Elevated Tank Designs (Chicago, Chicago Bridge and Iron Works, 1931), plate 2.

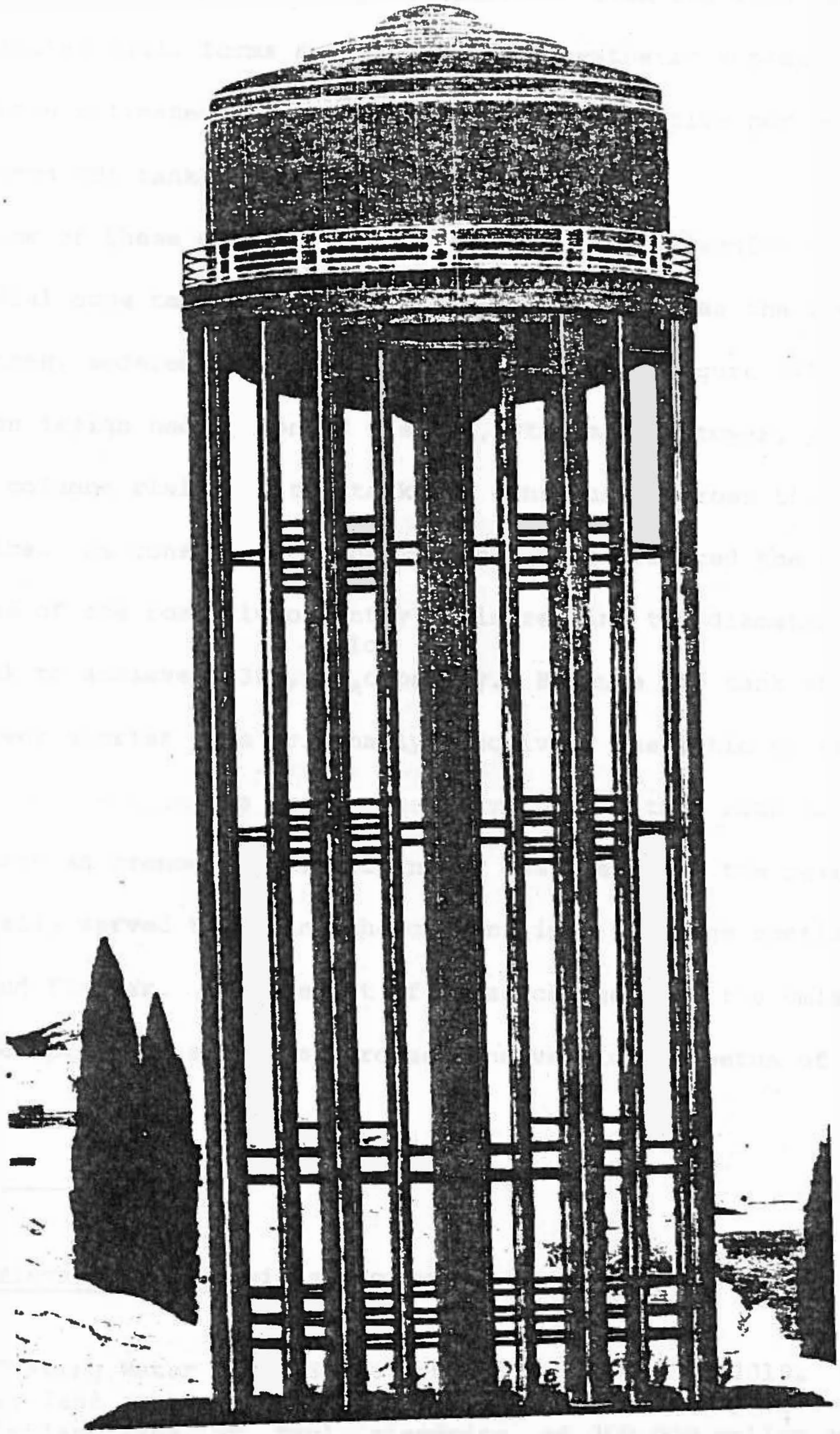

Figure 67. CBI 1931 competition entry: third prize design. Capacity: 200,000 gallons. Designer: Howard W. Vader. Source: Elevated Tank Designs (Chicago, Chicago Bridge and Iron Works, 1931), plate 3.

metalwork and condemned those proposing elaborate enclosures as "so economically unsound as to be impractical."[39] Even the less ornate designs which exploited basic forms and supports for aesthetic appeal were expensive: George Horton estimated they would add about twenty-five per-cent to the cost of a standard CBI tank.[40]

Some of these schemes were later adapted to disguise the proportions of the radial cone tank. The most widely publicized was the Towson, Maryland elevated tank, modeled on the first prize design. (Figure 68) Voita's competition design had presented a sleek, streamlined tower, with recessed planes of columns rising to the tank and continuing across the tank proper as deep ribs. As constructed, the Towson tank sacrificed the graceful proportions of the competition entry by increasing the diameter and depth of the tank to achieve a 300,000 gallon capacity. Because the tank shell was deeper and the tower shorter than originally conceived, the ratio of the tank mass to the supporting section was lost. The curve of the tank roof to join the sides was not as pronounced as originally designed, and the reinforcing ribs which visually served to extend the columns into the tank section were narrower and flatter. As a result of these changes and the omission of the ribbed riser pipe and spiral staircase, the vertical impetus of the design was lost.

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[39] Elevated Tank Designs, Foreword.

[40] "Making Water Works Structures Attractive," p. 2010. This was still considerably less expensive than construction of a masonry enclosure. In 1930 the Highland Park, St. Paul, standpipe, of 200,000 gallon capacity, was constructed and enclosed in a hexagonal tower of brick and stone at a cost of $71,500. Allowing about $20,000 for the cost of the standpipe itself, the architectural treatment of the tower cost $51,500--over two times the cost of the standpipe alone. "Tank Faced with Stone and Brick," Engineering News-Record 104 (May 22, 1930): 863.

Figure 68. Towson, Maryland radial cone elevated tank (1931). Capacity: 300,000 gallons.
Source: Donald C. Jackson.

Even in its reduced form, the Towson tank was heralded as " a very attractive addition to the landscape," and "the first serious effort to improve the appearance of these important and conspicuous elements of municipal water supply systems."[41] Engineering News-Record identified the supporting structure as the innovative feature because of its use of solid steel plate box columns with no vertical diagonal bracing.[42] The balcony, several feet below the bottom of the radial cone tank, served as a strut between the columns rather than as a ring girder at the junction of the tank cylinder and bottom plates. Instead, the plates of the cylinder extended below the lower shell and plate, to hide the girders and trough plates of the radial cone bottom. A popular paint scheme of the period--green graphite paint for the tower and arch ribs and aluminum paint for the tank itself--emphasized the architectural elements.

Another landmark in 1930's tank beautification was the first "Colonial" tank, the Tallahassee, Florida radial cone tank of 1932. (Figure 69) Like the Towson elevated tank, the Tallahassee tank was of relatively modest capacity--400,000 gallons. The tank itself was fifty-six feet in diameter and about twenty-four feet deep, with storage capacity extending seven feet into the domed roof. The tower represented a radical departure from earlier radial cone designs:

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[41] "Prize Design Tank Completed at Towson: Resident Lauds Appearance," The Water Tower 18 (July 1932): 3; "Architecture Applied to Elevated Steel Tanks," Engineering News-Record 110 (March 30, 1933): 403.

[42] The columns were of all welded construction and hermetically sealed in the shop to eliminate the possibility of corrosion. This was a major maintenance advantage of the welded column. Only the shell plates of the tank were field riveted. "Architecture Applied to Elevated Steel Tanks," p. 403-04.

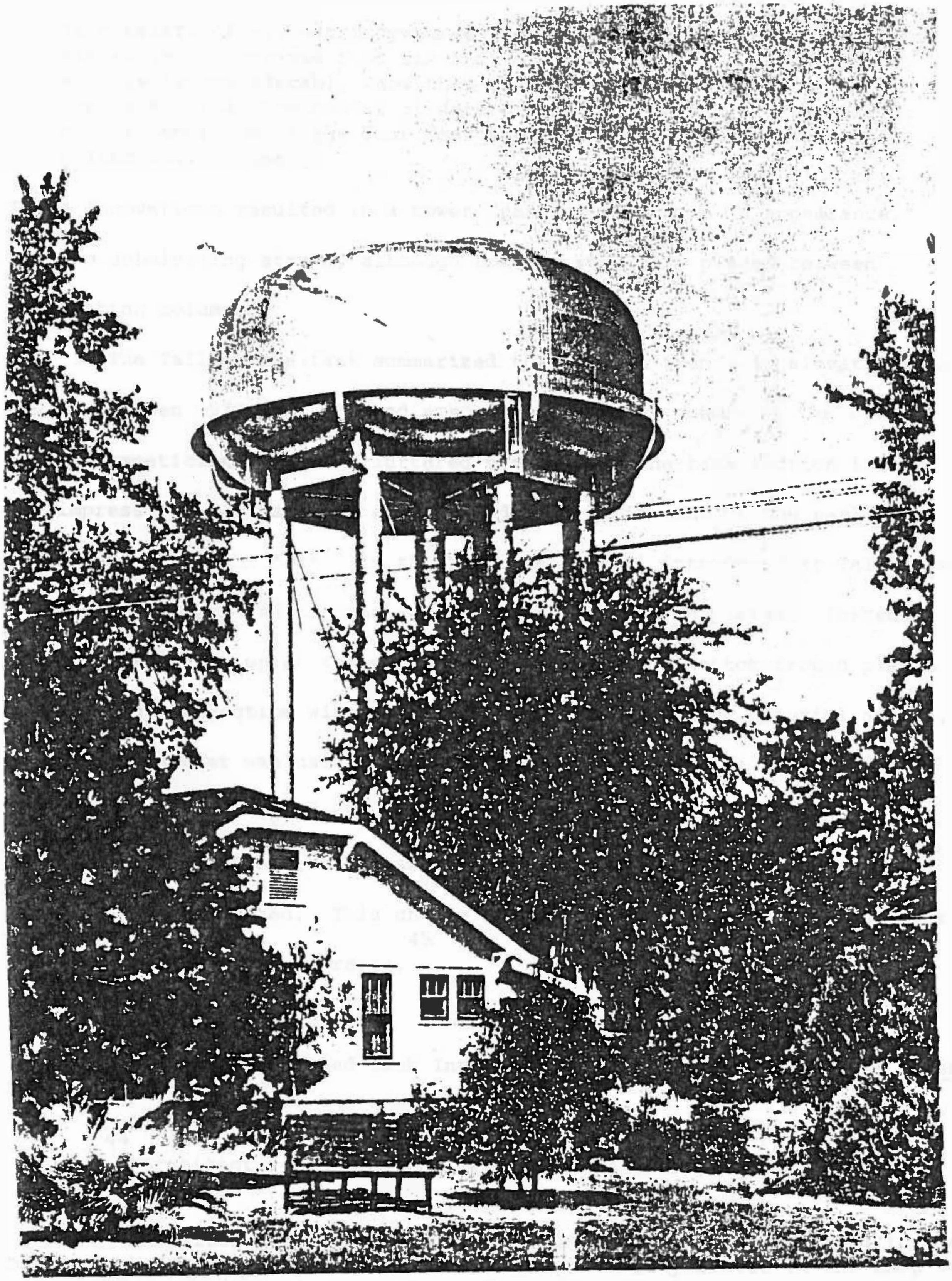

Figure 69. Tallahassee, Florida "Colonial" radial cone elevated tank (1932).
Capacity: 400,000 gallons.
Source: The Water Tower 19 (April 1933): cover.

> It consists of eight thirty-three inch diameter tubular columns placed in a forty-one foot six inch diameter circle. Inasmuch as this is considerably less than the fifty-six foot diameter of the tank shell, the radial girders of the tank bottom are supported on the inner end of the four foot riser and cantilevered over the cylindrical columns.[43]

These innovations resulted in a tower "particularly open in appearance," with no subdividing struts, although bracing rods were placed between alternating columns.

The Tallahassee tank summarized the general trends in elevated tank design between 1920 and 1930 and echoed the dominant themes of the 1930 design competition in its uncluttered elevation. The tank section itself was impressive, representing a logical design refinement of the earlier Brooklyn radial cone tank. In the "Colonial" model introduced at Tallahassee, the radial girders and troughs were not hidden by apron plates. Instead, the girders curved up at the outer ends, carrying the bottom trough plates to a tangent connection with the tank shell. In the first Colonial design, the balcony girder was used in the traditional fashion as a ring girder at the intersection of the tank shell and bottom plates.[44] The cylindrical columns, riser, radial girder, and structs were shop welded; only the tank shell was field riveted. This change in construction technique had a major impact on the tank's appearance.[45]

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[43] "Colonial Elevated Tank Installed at Tallahassee," <u>The Water Tower</u> 19 (April 1933): 3.

[44] "Architecture Applied to Elevated Steel Tanks," p. 404.

[45] "Architecture Applied to Elevated Steel Tanks," p. 404. As in the Towson tank, the cylindrical columns were hermetically sealed in the shop to protect inner surfaces from rusting. The tank at Tallahassee was designed by the Birmingham shop of CBI; its ornamental nature resulted from the necessity of placing it in an expensive residential neighborhood. "Colonial Elevated Tank Installed at Tallahassee," <u>The Water Tower</u> 19 (April 1933): 3.

The Towson and Tallahassee elevated tanks signaled new breakthroughs in the application of architecture to elevated water storage and, "by virtue of some radical departures in structural make-up. . . (achieved) a distinctive architecture in steel itself."[46] The introduction of welded plate columns and elimination of diagonal bracing rods and laced channel members simplified the tank silhouette. Changes to color schemes employing aluminum and green graphite paint enabled these tanks to blend against the trees and sky unlike the traditional black tin man.

The circumstances surrounding the design of these two tanks and others discussed by members of the American Water Works Association in 1931 confirm that decisions about elevated tank design had become a matter of community politics. The engineering community perceived a growing need to be responsive to community leaders and affected residents. In Towson and Tallahassee, the elevated tanks were constructed in residential areas, on conspicuous hilltop locations. At Tallahassee, "municipal officials were reluctant to put any kind of a structure in this area which would be objectionable."[47] Other communities were voicing similar objections: one AWWA member noted that in anticipation of objections to a proposed tank, the city water works engineer mounted a publicity campaign. The newspapers were convinced to support the need for a new tank, and a pamphlet was distributed by the meter readers to residents of the section where the tank was to be located. As a result, little criticism of the tank's design was

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[46] "Architecture Applied to Elevated Steel Tanks," p. 403.

[47] "Colonial Elevated Tank Installed at Tallahassee," p. 3. The city had made plans to construct a formal ornamental base with mirror pool and a four spray fountain around the riser. Floodlighting was to illuminate the upper portion of the tank at night. The theme of floodlit steel tanks was a prominent one in the 1930 design competition.

expressed.[48]

After 1930, improved styling was sought for tanks of all capacities. This trend is well illustrated by two forms widely used in the 1940's--the pedestal tank or "watersphere" and the fluted column spheroidal tank. Although the first watersphere was erected in 1928 and the fluted column concept was present in several CBI competition designs in 1930, widespread use of these two tank types was delayed until welding was reliable for elevated tank construction.

CBI designed and erected the first small 30,000 gallon watersphere for a boy's camp in Ponca City, Oklahoma in 1928. The structure was a simple sphere on a seventy-five foot circular column support. A spiral staircase built inside the supporting pedestal extended through the tank to a platform at the top. The cylindrical column was an economical method of supporting an elevated tank, and the plate surfaces were easier to maintain than traditional columns.

The new design was not widely used until 1940, when CBI became involved in the installation of six waterspheres of 100,000 to 250,000 gallon capacity. (Figure 70) The watersphere of the twenties had riveted joints and its construction proved to be difficult and expensive. By 1940, improvements in welding made all-welded construction possible.[49]

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[48] The tank's color scheme (not identified) was not judged to be acceptable, and repainting to olive green supports and aluminum top was anticipated. "Making Water Works Structures Attractive," p. 2013. It is apparent that residents were concerned about decreases in property values once an enormous elevated tank "moved in." An interesting study could be made of the impact of these large structures on the value of their immediate surroundings.

[49] "Welding Revives the Watersphere," The Water Tower 28 (January 1942): 4; "Water Towers of Welded Steel Plate are Striking Landmarks with Advantage of Easy Maintenance," Architectural Forum (May 1949): 129.

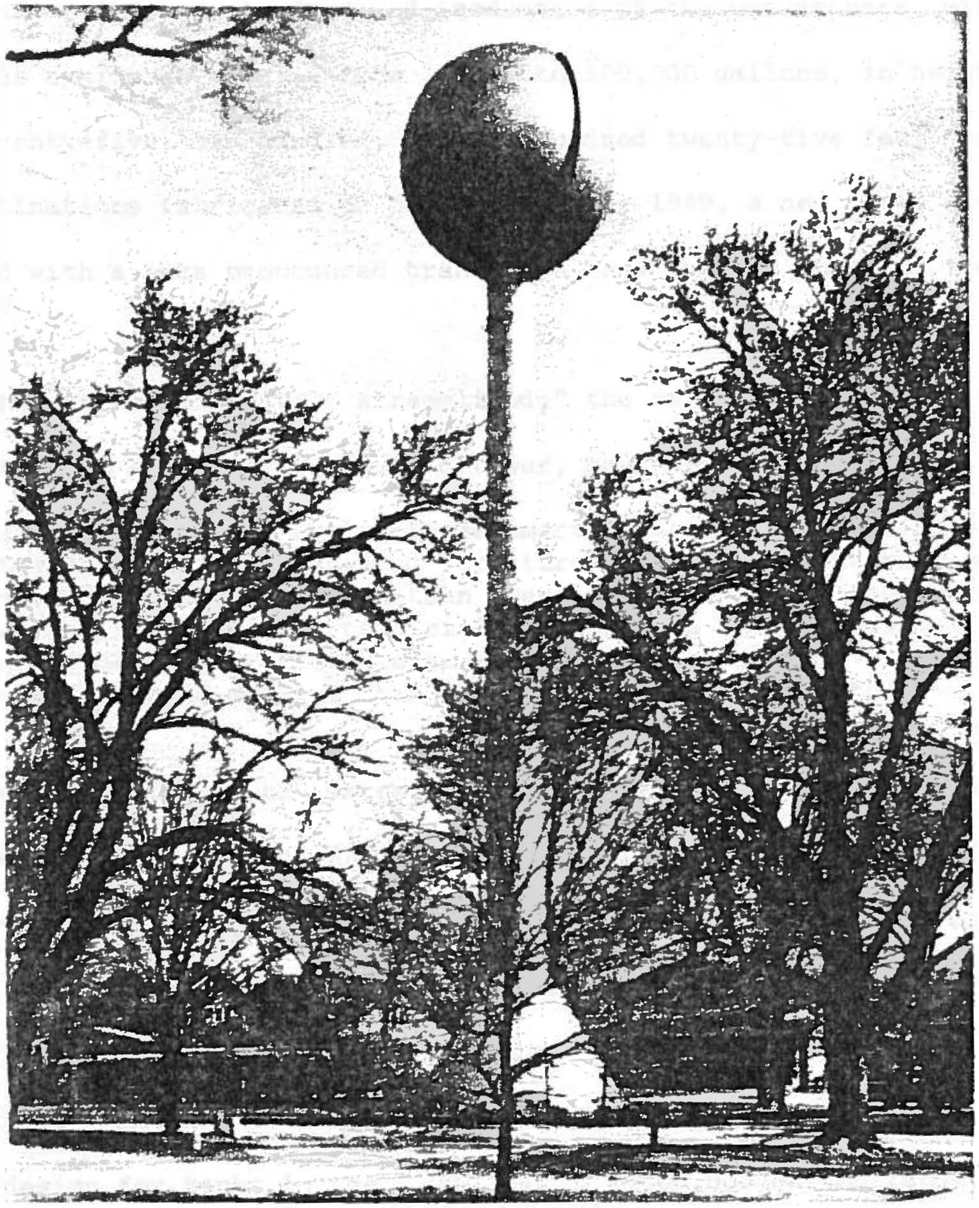

Figure 70. Typical watersphere of the 1940's: elevated tank at Eastern Illinois State Teachers College (1942). Capacity: 50,000 gallons.
Source: "Water System within a System at Eastern Illinois State Teachers College," The Water Tower 29 (January 1943): 6.

In 1949, an article in Architectural Forum reported that "more than one hundred of these striking knob-like steel water tanks have been erected on industrial and municipal sites throughout the country" in the past twenty years. CBI had standardized production of the watersphere, with seven sizes available ranging from 25,000 to 100,000 gallons, in heights of fifty, seventy-five, one hundred, and one hundred twenty-five feet, with other combinations fabricated on order. Also in 1949, a new model was introduced with a less pronounced transition from base to stem and from stem to tank.[50]

"Modern and completely streamlined," the watersphere reduced the elevated tank to a vessel, supporting tower, and base:

> As basic an example of truly native American architecture as only strictly utilitarian-engineered structures can be, the Watersphere was first designed in the Nineteen Twenties. Advantages then were the same as those today--its striking appearance and ease of maintenance. The large curved planes of its surfaces present much less of a painting problem than water tanks supported on the usual framing.[51]

Like the Colonial model, the watersphere was initially constructed for small storage volumes. Its design parallelled that of the Colonial tank in its use of rounded forms, welded construction, and elimination of all vestiges of the elevated tank of the nineteenth century. The watersphere was clearly the most popular tank style of the forties--one of the few which the architectural community itself took notice of and applauded. It was not a feasible design for tanks in the 1,000,000 to 2,000,000 gallon range, however.

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[50] "New Design Watersphere at Wauconda," The Water Tower 35 (March 1949): 6; "Pedestal Type Water Tower Serves Longmont, Colorado," Municipal Journal and Engineer (August 28, 1940): 1085.

[51] "Water Towers of Welded Steel Plate," p. 129-30.

One attempt at beautification of the largest tanks in use in the forties was the invention of the fluted central column. Publicized following the construction of a 2,000,000 gallon spheroidal tank in southeast Washington, D.C., the fluted cylinder created visual interest and acted as a supporting column for the bottom plates and tank contents.[52] The spheroidal tank form was a variation of the spherical tank and was used by CBI for large capacities. The Washington tank was 106 feet in diameter and thirty four feet deep, supported on sixteen four foot diameter cylindrical columns and a forty foot diameter central fluted column.[53] A skirt at the circumference of the tank concealed the joining of the tank and columns and acted as a circular girder. (Figure 71)

Engineers believed that the fluted column spheroidal tank was a solution to the aesthetic dilemma of the large tank: "the excellent appearance of the structure would not be objectionable to the residential neighborhood in which it is located."[54] Although the tank bottom form was different, the architectural treatment borrowed heavily from the Colonial model and other all welded tanks described above. The fluted central column feature was subsequently applied to the pedestal tank. (Figure 72)

The tanks identified as "modern" today are drawn from these last

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[52] R. M. Dowe, "Fluted Central Column New Feature in Tank Design," Engineering News-Record 136 (May 2, 1946): 734-36.

[53] This was an entirely new feature which CBI intended to patent. While structural, the fluted column did not contain water. A separate five foot diameter riser within the fluted column serviced the tank. "Spheroidal Water Tank at Washington Has New Fluted Central Support," The Water Tower 32 (May 1946): 4.

[54] "New 2,500,000-Gallon Hortonspheroidal Tank in Cincinnati Water Works System," The Water Tower 37 (July 1951): 5.

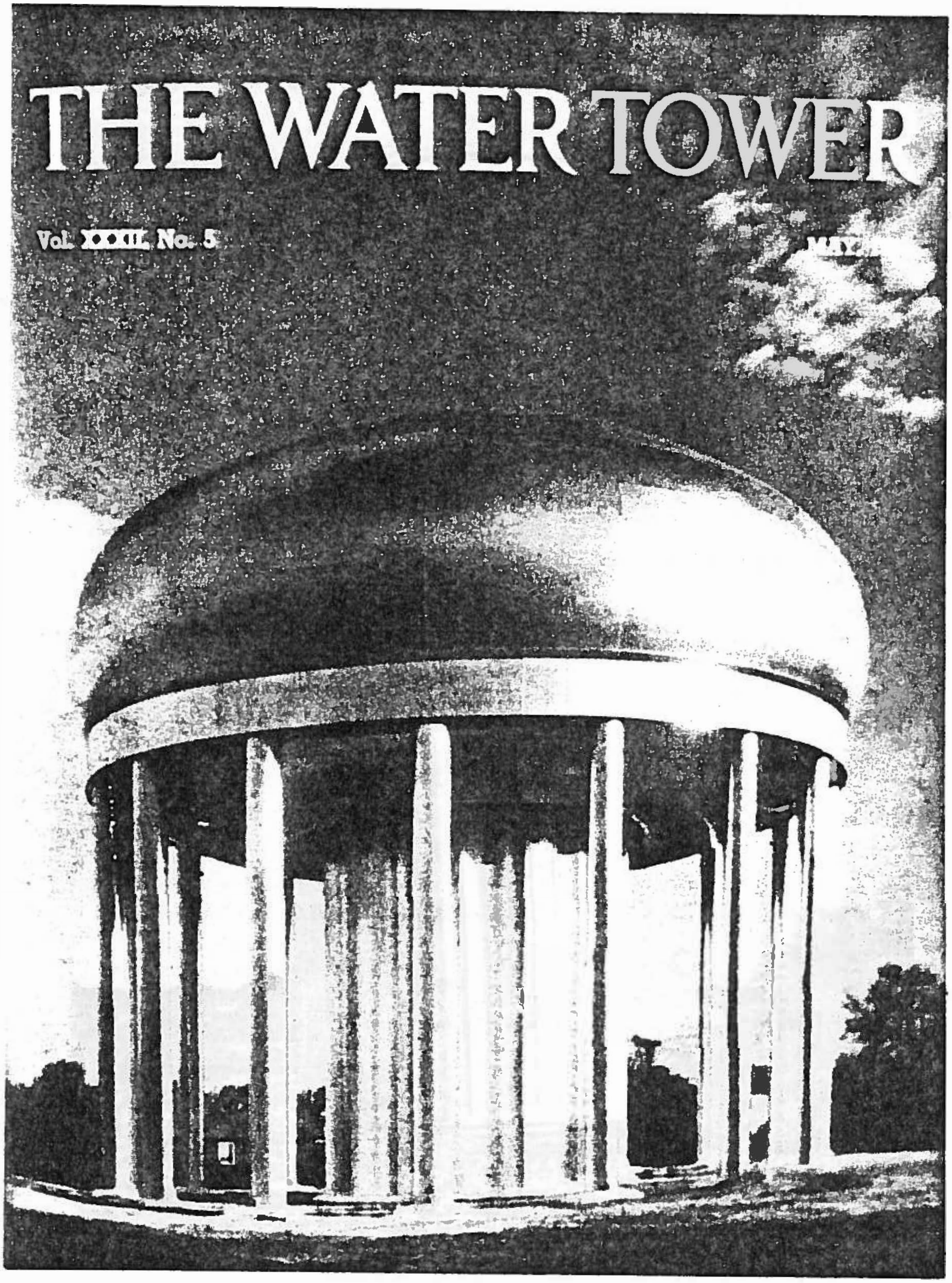

Figure 71. Washington, D.C. fluted central column spheroidal tank (1946).
Capacity: 2,000,000 gallons.
Source: The Water Tower 32 (May 1946): cover.

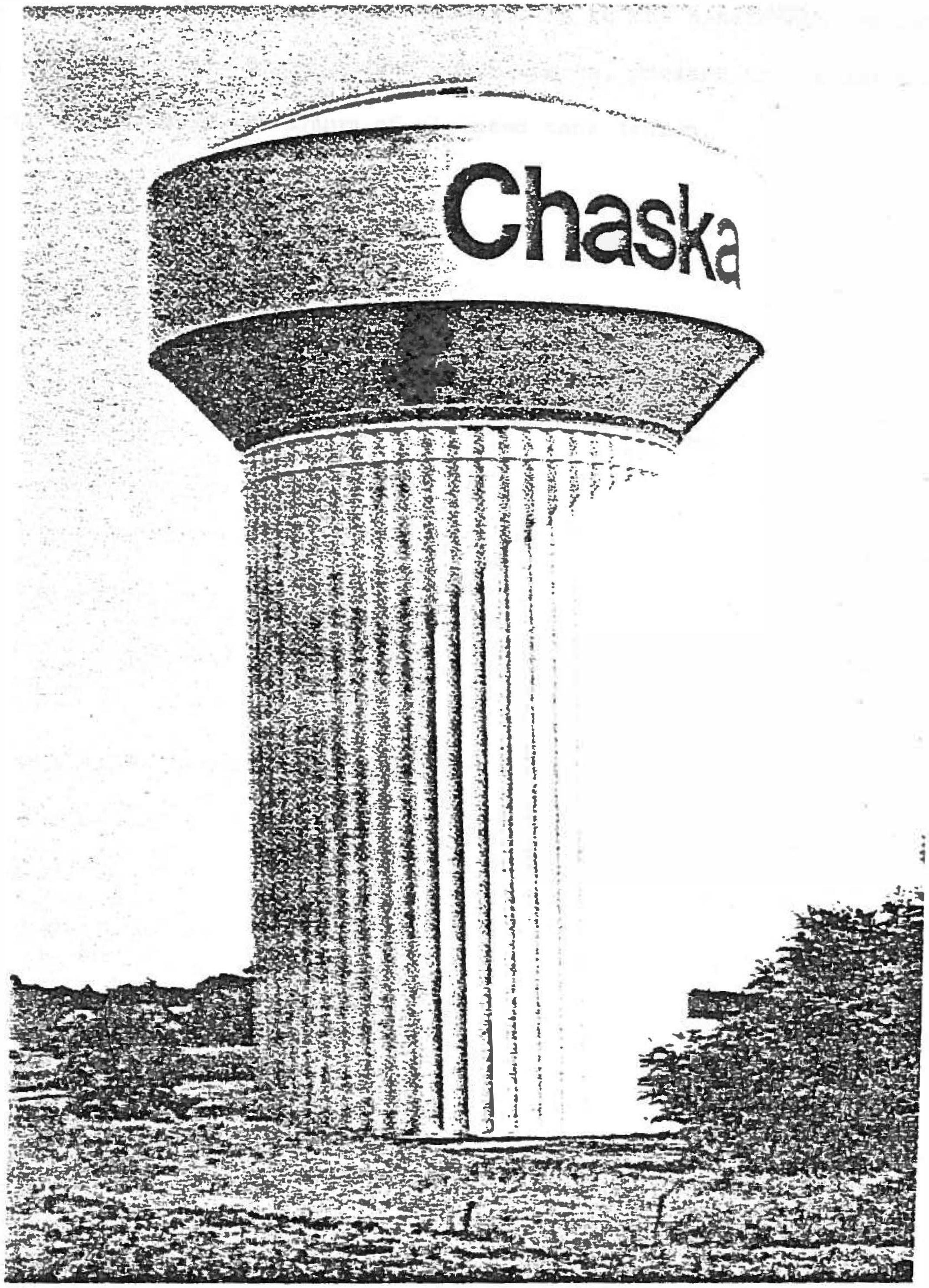

Figure 72. Fluted single pedestal elevated tank, Chaska, Minnesota.
Capacity: 1,500,000 gallons.
Source: Water Storage Bulletin No. 2000 (Oakbrook, Illinois, Chicago Bridge and Iron Works, 1977): 12.

three types--the watersphere, the radial cone, and the spheroidal tanks. But the tank forms discussed earlier in this chapter also remain in use today. They provide a significant visual link to the nineteenth century forms, and, along with their modern counterparts, present to the informed observer a remarkable continuum of elevated tank design.

CONCLUSION

Examples of the water tower, standpipe, and elevated tank forms discussed in this paper are scattered throughout the United States in small towns, cities, and industrial plants. Perusal of manufacturer's catalogues reveals that a variety of standpipes and elevated tanks are still available, ranging from modest size wood and metal tanks whose technology is essentially that of the nineteenth century, to more sophistocated designs of larger capacity. Each has its role in modern water storage practice and reflects a particular phase in the historical development of elevated water storage structures.

This paper has reviewed the architecture and engineering of elevated water storage structures from the late nineteenth to mid-twentieth centuries to provide a context for further study and, hopefully, for practical preservation efforts. Information has been presented here to outline the technological development of the water tower, standpipe, and elevated tank, and to sketch their structural relationships within a nineteenth century context. More specialized studies are needed to adequately understand the role of smaller standpipe companies and regional fabricators of elevated tanks. Surveys of extant structures may also assist in explaining how vernacular practice differed from the structures presented in the engineering journals and data gathered from better known examples. The role of innovation in railroad water storage and its transference to municipal water works merits further study, as does the ancestry of the metal trestle tower, which may provide valuable information about cross-overs of technology from one facet of civil engineering practice to another. In the area of architectural history, many water towers need to be evaluated in the context of other architecture in their communities and other work by their architects, as well as in the history of water towers in general. Finally, the local history of these structures--how communities participated in their design, erection, and use, and how community images were expressed in their water towers--is an unexplored topic.[1]

Certain conclusions can be drawn from the material presented here. First, it is clear that because special fields in civil engineering like water works engineering were not well defined until circa 1900, civil engineers who designed water works structures brought to this work a knowledge of other areas of civil engineering technology. Second, the design of elevated water storage structures was intimately related to the massive developments of the late nineteenth century iron and steel industry: as discussed in Chapters III and IV, the transition from the presence of many small standpipe contracting firms and iron works to a few major elevated tank manufacturers parallels the consolidation and rise of a few major steel works in the late nineteenth century. The simultaneous movement from individually designed structures to standardized tank designs and fabrication procedures resulted in an emphasis on simple, functional design and in a greater uniformity of elevated tanks across the nation. Most major aesthetic changes were dependent on changes in technology: the introduction of the elevated tank was dependent on the presence of reliable materials; the widespread success of the classic tin man was tied to the invention of a technique for fabrication of curved bottom plates; the radical changes in tank appearance in the 1930's were directly related to the perfection of welding

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[1] The Georgia State historic preservation office is presently considering a research project on community perceptions of water towers in small towns in the State.

techniques.[2]

The design of elevated water storage structures can be related to the architectural treatment of major public buildings in many communities. Nineteenth century water towers and decorated standpipes rank with Victorian city halls in their expression of growth, prosperity, and boosterism. Because public water service was a benefit of civilization shared by community members, these structures reflected the goals of the community: symbolized in the storage of water was the collective energy of the community and its aspirations for continuity and regeneration. To the extent that the late nineteenth century water tower, standpipe, or elevated tank protected the community against water shortage and destruction by fire, the symbolism of the brooding conical watchtower was appropriate. By the twentieth century, as these uses became less apparent,the elevated tank shed these specific symbolic references, embodying instead an ideal that public services should be efficiently provided in a controlled, modern setting. The water tower or standpipe and the elevated tank of the twentieth century each mirror the architectural and general aesthetic philosophies of their era--the Victorian architect and engineer striving for compatibility with the natural setting, and the twentieth century designer exploiting modern materials to achieve more detached, abstract forms.

Like other aspects of the built environment, these structures become part of a community's heritage of public architecture and local history. The remaining water towers and standpipes continue to serve as community landmarks, and, in many cases, as components of functioning water works. Similarly, a

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[2] Conversely, the reinforced concrete standpipe failed to have a significant impact on standpipe aesthetics in the first decades of the twentieth century because reinforced concrete technology had not yet been perfected.

cluster of elevated tanks on the horizon signals the location of a factory complex or other concentration of activity. Large numbers of early examples have been lost, however: masonry water towers have had their tanks and other interior features removed; many standpipes were superceded by elevated tanks; and early elevated tanks have been pulled down or left to rust when larger tanks were erected.[3] Wider awareness and preservation action is needed.

The preservation of the historical records of standpipe manufacturers and elevated tank companies is one important step in promoting understanding of the significance of these structures. CBI has a wealth of historical material, both company records and promotional material from the early twentieth century, which should be gathered into a well maintained company archive or donated to a responsible technical library. Other early companies like Caldwell tanks are still in business and may possess a wealth of significant data which could be made available to researchers and historians.

The identification of elevated water storage structures should be stressed as part of State historic preservation office and Historic American Engineering Record surveys. Most masonry water towers are now being included in historic sites surveys; increasing numbers have been listed in the National Register as part of community multiple resource nominations or thematic nominations focused on nineteenth century architecture or the work of a particular architect. Selected area surveys--particularly in the Midwest and Plains States--should be initiated for elevated tanks and associated forms like windmills to determine the full range of types present within a limited

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[3] Because the life expectancy of wooden elevated tanks was about twenty years with good maintenance, early examples of these structures are extremely rare.

area.[4] Interest could also be stimulated on a local level by publication of a technical information leaflet by the American Association for State and Local History.

Once more data has been gathered about relative significance of a state's elevated water storage structures, decisions can be made about preservation and further documentation of a variety of examples. Historical studies and measured drawings should be undertaken, particularly of early elevated tanks, before these structures are lost. These structures need to be brought to the attention of communities so that advocates for their preservation are created. Preservation of some types of tanks like the advertising tank of the twentieth century is a logical activity for special interest groups like the Society for Commercial Archeology.

Given the extremely specialized function of these structures, it is unlikely that "adaptive use" is a plausible future for many. Most nineteenth century water towers and standpipes are too limited in interior space for redevelopment; introduction of windows and other openings, particularly in metal or concrete standpipes, is contrary to their structural expression and significance. Similarly, the elevated tank is an isolated and relatively inaccessible environment.

Some structures still serve as water works components and other appropriate uses do remain. Many masonry water towers and decorated standpipes are now recognized as major community landmarks which symbolize

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[4] One significant technological link in the evolution of tank support was lost in 1957 when the Pullman water tower was demolished without any prior documentation. Known descriptions of that tower are limited to the single drawing which appeared in Engineering News in 1892 and was presented earlier in this paper.

the community's history. Some early elevated tanks are now receiving similar recognition, but most either continue in their original function or have been converted to advertising devices. This paper should assist in increasing appreciation of the more utilitarian forms of elevated water storage structures.

As one of the more visible aspects of public water works and civil engineering, these structures reflect how critical the control of water has been to the growth of towns and cities in the late nineteenth and twentieth centuries. Their impact has been immense, affecting both the everyday life and surroundings of most Americans. As preservationist's concepts of cultural resources are currently expanding to include new categories of sites and structures, the elevated water storage structure--and especially the elevated tank--will assume a more prominent place in industrial archeology and historic preservation.

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Baton Rouge Waterworks Company Standpipe, Baton Rouge, Louisiana.
Chicago Avenue Water Tower and Pumping Station, Chicago, Illinois.
E. Van Winkle Gin and Machine Works, Atlanta, Georgia.
Great Lakes Lighthouses Thematic Resources (Draft), various States.
Hackensack Water Company Complex, Weehawken, New Jersey.
High Bridge Aqueduct and Water Tower, New York, New York.
Kalamazoo State Hospital Water Tower, Kalamazoo, Michigan.
Kasson Water Tower, Kasson, Minnesota.
Kramertown Railroad Shops, Kramertown, Mississippi.
North Point Water Tower, Milwaukee, Wisconsin.
Old Fresno Water Tower, Fresno, California.
Raleigh Water Tower, Raleigh, North Carolina.
Rome Clock Tower, Rome, Georgia.
Roxbury Standpipe, Boston, Massachusetts.
Waldo Water Tower, Kansas City, Missouri.

State Historic Preservation Office Survey Data

Alabama Historical Commission Inventory Files: Florence, Alabama water tower.
Historic American Engineering Record Inventory Files: Blair Academy Standpipe, Blairstown, New Jersey.
Minnesota Historical Society Archives: Plan for Great Northern Railway Standard 100,000 gallon water tank on twenty foot tower; Northern Pacific Railway Standard Plan for Water Tank, 100,000 gallon capacity.
Minnesota Historical Society State Historic Preservation Office: Inventory forms: Kenwood Park Water Tower; Breezy Point Double Elevated Tank; Crow Wing County Elevated Tanks; Lamberton Elevated Tank; Ogilvie Water Tower; Washburn, Minneapolis, Standpipe.
Wyoming Historical Society Inventory Files: Lusk, Wyoming Elevated Tank.

Note on location of resource materials

The majority of the books and articles used to prepare this paper are available at the Library of Congress, Washington, D.C. The early issues of The Water Tower and sales catalogues of the Chicago Bridge and Iron Works are in the Public Relations Office of CBI, Oakbrook, Illinois. Information on many towers and tanks was obtained from the State Historic Preservation Offices in the respective states. The National Register of Historic Places nomination forms referenced were obtained from the files of the National Register Division, Heritage Conservation and Recreation Service, Interior Department; patent records were viewed at the U. S. Patent Office, Crystal City, Virginia. Several of the tank catalogues cited are in the collection of the writer.