STEAM ON THE FRONTIER: DISTRICT HEATING IN DENVER, 1880-1995

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ABSTRACT

In late 1879 a group of Denver businessmen led by pioneer John W. Smith incorporated the Denver City Steam Heating Company to supply heat and power to their frontier town. The following summer they installed a Holly district steam system, including a boiler plant and several thousand feet of underground steam pipe laid under unpaved streets. On November 5, 1880, the company began supplying steam to downtown Denver. Henry M. Porter, Smith's son-in-law, became president of the company in 1888 and replaced the distribution system with larger pipes in anticipation of asphalt paving. Although rarely meeting the financial expectations of its owners, the system grew over the years and in 1909 was acquired by a predecessor to the Public Service Company of Colorado. The Denver steam system is the oldest commercial district heating company in the world and continues to supply steam for heating and cooling to a large portion of downtown Denver from its original plant location.

INTRODUCTION

The early history of district heating has largely been concerned with the first commercial system, built in Lockport, New York, in 1877, and the largest system, which started service in New York City in 1882. Some have assumed from this that there were no other systems built for many years, which is far from the truth. Several dozen commercial and institutional district heating systems existed in the nineteenth century and by 1917 more than 400 commercial systems alone were in operation. A 1992 census of district heating and cooling by the United States Department of Energy (DOE) estimates that at least 6,000 such systems are currently operating in the country. This paper presents the history of the oldest commercial system, incorporated in late 1879 as the Denver City Steam Heating Company and currently a part of the Public Service Company of Colorado.

EARLY DENVER

The first white settlements in the Denver area resulted from the discovery of gold at the confluence of Cherry Creek and the Platte River in 1859. Although not much gold was found there, a small commercial center developed to service the gold camps in the nearby Rocky Mountains. In March 1860 several small communities joined together as Denver City in hopes of gaining favor from the governor of Kansas, General James W. Denver. Some of Denver's early settlers stayed in the new city because they had no alternative, as was the case with George W. Tritch, a 31-year-old German-born merchant who settled there in early 1860 because "our money had run out, and knowing that we could go no farther we were content to remain" (Smiley 1901).

Others arrived with more resources, including John W. Smith, a 45-year-old Pennsylvania native who had settled in Atchison, Kansas, only two years earlier but decided that Denver held greater promise. He set out for Denver on June 3, 1860, in a light buggy with a span of mules, making the trip in three weeks. Smith arrived with more than $20,000 in cash, while his mules carried a quartz mill, a planing mill, and a grist mill. The first corn and wheat in Colorado territory soon passed through the grist mill, producing a net income of $100 per day for Smith. In 1865 he erected a large steam mill, but fuelwood cost more than $25 per cord, leading Smith to erect a water mill in its place. He built the American House in 1868, which for 10 years was the largest hotel in Colorado, and three years later started the Colorado Savings Bank, which was never incorporated or insured, relying solely on his wealth and reputation (Vickers 1880).

The 1860 federal census counted 4,749 people in Denver. Western migration was greatly reduced by the Civil War and a decade later census takers found the population increased by exactly 10. During the decade Tritch had started a successful hardware business and served as a city councilman. Smith had served on the first federal grand jury in the territory, served as president of the local board of trade, and was instrumental in starting construction of the Denver Pacific Railway and Telegraph Company. Working with Smith on the Denver Pacific was Henry M. Porter, a young (born 1840) entrepreneur who had moved to Denver in 1862 to build telegraph lines for the U.S. Army and by the end of the decade was successful enough to help raise the money for the Denver Pacific, and Colonel Leonard W. Eicholtz, superintendent of construction, who had gained experience as a civil engineer building military railways for General Sherman's March to the Sea. Porter and Eicholtz had both been born in Lancaster, Pennsylvania, but it is not known whether they knew each other before their work on the Denver Pacific.

Porter and Smith engaged in other business interests as well. They owned a large plot of land near the business dis-

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trict, and in December 1867 each of them donated a block for a new Colorado capitol building. That same year Erastus F. Hallack arrived in Denver. A native of Genesee County, New York, Hallack arrived to join his brother Charles in forming what became a very successful lumber business. In 1870, shortly after the first train arrived on the new Denver Pacific, Hallack became a stockholder and director of the Denver Water Works Company, which installed a Holly direct-pressure water supply system that first delivered water on January 10, 1872. Hallack had spent the first 33 years of his life less than 20 miles from the Lockport factory of the Holly Manufacturing Company, but any connections are unknown.

Porter married Smith's daughter Laura in early 1874 and industriously built a large financial empire around mining, transportation, and cattle. Smith's son Charles was sent east for schooling in 1875 at the age of 18 and returned a year later with a diploma from a commercial college in Williamsport, Pennsylvania. He worked as a railroad ticket agent until being employed by his father in late 1879.

DENVER CITY STEAM HEATING COMPANY

On December 15, 1879, Tritch, Hallack, Eicholtz, and Smith filed papers incorporating the Denver City Steam Heating Company with a capital stock of $500,000. That evening the four men, as corporate directors, met and elected the following officers:

President—John W. Smith
Vice-President—E.F. Hallack
Treasurer—George Tritch
Chief Engineer—L.H. Eicholtz
Attorney—J.W. Horner
Secretary—Charles H. Smith

The purpose of the company was "to sell and supply steam for the heating of stores, dwelling houses, and all buildings in the City of Denver, for motive power, cooking purposes and to such other purposes as steam may be required, by the Holly district system of steam heating." The company would offer $100,000 shares of stock for public subscription by Denver citizens, with any not subscribed locally to be "taken by parties east." Local citizens were reminded that Holly steam would eliminate fires caused by stoves and defective flues. The secretary and chief engineer, moreover, were to leave for a tour of steam companies in "Milwaukee, Detroit, Lockport, and a few other cities where steam is now used quite extensively, and to gather such other information and data as may facilitate the erection of works and the laying of pipes" (*Denver News* 1879).

Before constructing such a system, the company had to obtain a franchise from the city to use the streets. Although Denver in 1880 had a population of 35,629, a gas light company, 8 miles of street railroads operated with 20 cars and 50 horses, and 200 miles (322 km) of streets, none was paved and there were no public sewers, making the installation of pipe rather straightforward. The incorporators, who were individually and collectively among the richest men in Denver, petitioned the Denver City Council for a franchise shortly after the new year and it was granted. The ordinance, is its entirety, read:

Steam Heating Company

Be it ordained by the City Council of the City of Denver:

Section 1. That the Denver City Steam Heating Company, a corporation organized under the laws of the State of Colorado, are hereby authorized and empowered to use the streets, alleys and avenues in said city, under such rules, regulations and restrictions as the City Council may hereafter adopt, by digging trenches and laying of main and small pipes and expansion junction service boxes, as far as may be necessary and proper to convey and furnish steam from the boiler station or stations for heating the various buildings, or a portion of them, for motive power, and such other purposes as steam may be used for in the City of Denver, by the Holly District system or any other system of steam heating that said company adopt.

Passed by the City Council of the City of Denver, and approved by me this fifth day of January, A.D. 1880

R. Sopris, Mayor (TBS 1881).

The *Denver Daily News* reported this the next day and thoughtfully included an article about the continuing travails of Francis Spinola's New York City steam-heating enterprise, which had petitioned for a franchise in July 1878 and just received permission from the city to install pipes, although construction did not begin for nearly two years. As was the case in many smaller communities, steam franchises were granted rather casually to people of substantial local reputation. It did not hurt that Denver did not yet have a large nest of lawyers, for several issues were left hanging (such as granting Smith's company an exclusive franchise) for at least five years. Although the council debated the issue for two more months, the matter was finally dropped.

The day after the franchise passed, the stock books were opened for subscription in Smith's office in the American House, which he was in the process of selling.[1] Smith's son Charles, as promised in December, was off on his inspection trip to the east, although there is no evidence that Eicholtz

[1]An anonymous typewritten "History of Company Steam System" (circa mid-1960s) in the Public Service Company files suggests that Smith installed the system primarily to heat the American House, but this seems implausible since he did not even own the hotel when the system was installed and it would have been a very small portion of the system load. On the other hand, district steam would have made the hotel more marketable. Smith also paid off the depositors and closed his Colorado Savings Bank in January 1880.

accompanied him. Charles visited the Detroit Steam Supply Company and the London City (Ontario)Steam Heating and Manufacturing Company before proceeding to Lockport "with one of the Hollys." After inspecting the system in Lockport, where he enjoyed a steam-cooked meal at Birdsill Holly's house, he stopped by the Troy Steam Supply Company, which he reported "is the nearest to perfection and is obtaining better results from consumption of coal than even the Lockport company is. Everything is systematized, a record of every pound of coal consumed and every pound of water evaporated is known to the fraction." Charles sent detailed letters about his findings to the Denver Tribune, providing a unique snapshot of these four companies by an outside observer (*Denver Tribune* 1880a).

Soon after Charles Smith departed Lockport for Troy, Edgar P. Holly, son of system inventor Birdsill Holly, was called to Denver. Edgar was the superintendent of construction at the Holly Steam Combination Company and was responsible for every Holly steam system. The *Daily News* sent a reporter to interview him in his room at the American Hotel. Holly spoke at length about the system he planned for Denver, which would include a brick boilerhouse at the foot of 16th Street with room for 20 boilers, 6 of which would be installed initially. He went on to describe in detail where the 23,000 feet (7,010 m) of underground steam pipe would be installed, which has been reproduced on a current Denver street map (Figure 1). The system would include 2,400 feet (732 m) of eight-inch (203-mm) main, 8,600 feet (2,621 m) of six-inch (152-mm) main, and 4,800 feet (1,463 m) of four-inch (102 mm) main, with the remaining 7,200 feet (2,195 m) measuring three inches (76 mm) and smaller. The mains would be "wrought-iron pipe, lap-welded and covered with asbestos and other non-conducting materials" (*Denver Daily News* 1880).

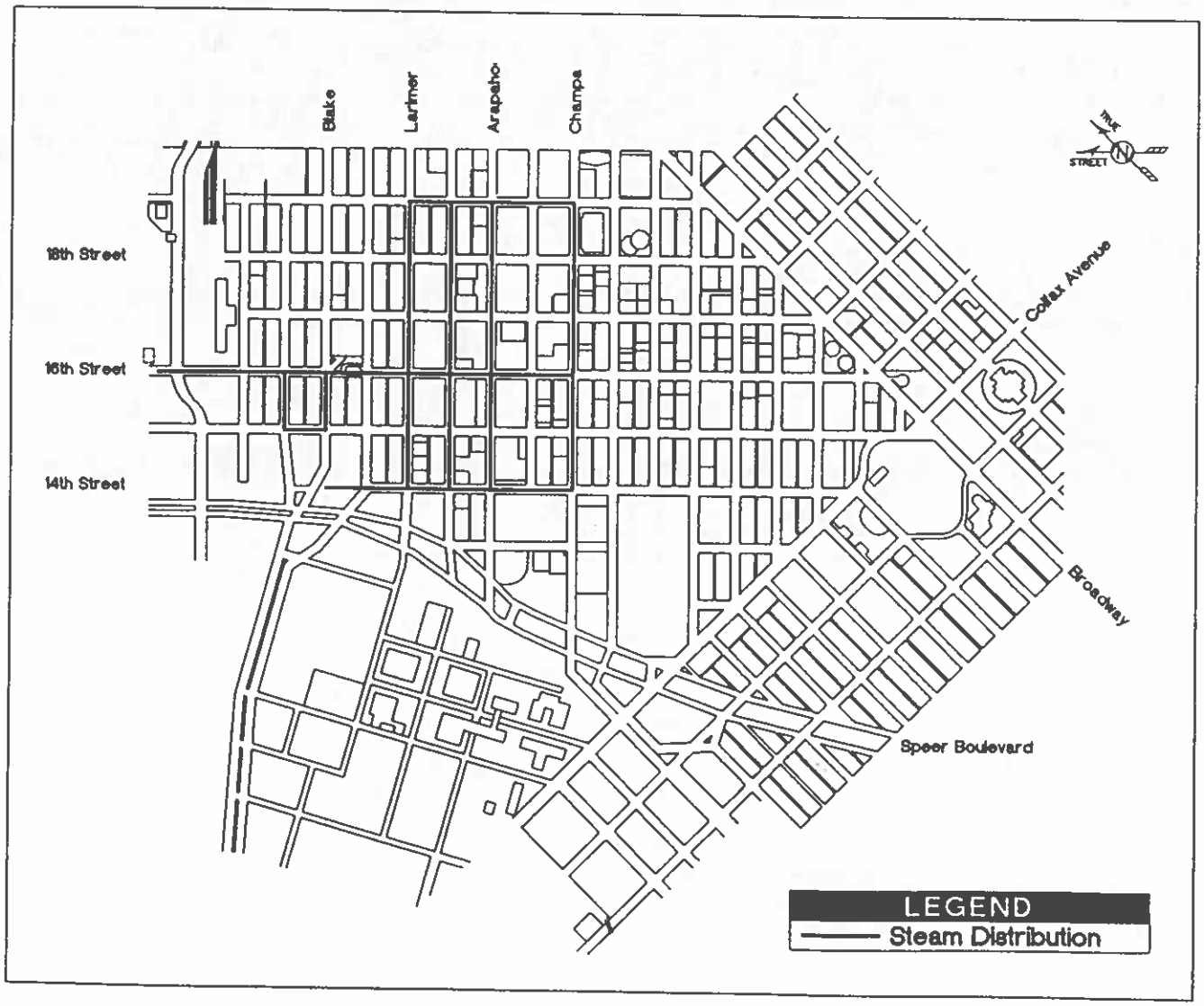

Figure 1 *Denver City Steam Heating Company proposed distribution system, January 1880.*

Holly went on to describe the various uses for district steam. In addition to providing heat and power, steam cooking appliances had been adapted to the Holly system and demonstrated to a number of skeptical audiences with great success. At this point, President Smith appeared and reported that more than half of the stock had been taken and that he wanted "the works put up and the pipes laid in first-class style" (*Denver Daily News* 1880). He also assured the reporter that each of the 39 sections of pipe could be isolated in case of damage or failure, limiting any potential interruptions. Furthermore, steam could be provided to street hydrants for use by fire engines and for snow removal, in addition to being used directly as a fire-suppression agent. With the addition of "a small contrivance, which takes up little room," an apartment could be instantly flooded with steam, which "will put out any fire quite as quickly as water and with far less damage" (*Denver Daily News* 1880a).

Company officers were anxious to begin work as soon as possible and in early April they decided not to wait for an exclusive contract for steam supply with the city council, which still had not reached a conclusion on the matter. They had sold $80,000 of stock and paid $10,000 to the Lockport company for exclusive use of the Holly patents in Denver.The steam plant, which was originally to go on 16th Street, was moved three blocks north to a site purchased from the Denver Gas Company, which already had a dedicated rail spur for coal delivery. Six 100-horsepower (981-kW) boilers were to be installed, as per the original plan, and the laying of pipes was to begin on May 1.[2] The president of the Holly Steam Combination Company, Dr. D.F. Bishop, was in Denver on April 12, probably to negotiate and sign construction contracts (*Lockport Daily Journal* 1880). Work began on the boiler plant on May 10, when contractor William Egerer began excavations for the stone foundations (*Denver Times* 1880).

Smith must have indeed received the first-class installation he expected, because a fairly thorough search of Denver newspapers found no references to mishaps, traffic jams, dangerous open trenches, and other happenings that can be found in every other city that installed an early steam system. The next notice announces the successful testing of the steam on November 3, 1880, and within the next day or so it was supplying heat and power to its first customers, which included Wall & Witte's wagon works, W.J. Kinsey's agricultural implement and wagon shop, Leach & Co.'s cracker bakery, George Tritch's hardware store, Mayor Barker's office, and several others (*Denver Tribune* 1880b; *Denver Daily News* 1880b; Crofutt 1881).

[2]"Steam Heating," *Denver Daily News*, April 7, 1880. Recently found ledger books of the Holly Steam Combination Company suggest that the payment for rights was substantially larger, with the $10,000 probably representing only an initial payment. A May 22, 1889, letter from H.M. Porter indicates the value of the Holly rights then was $50,000.

Smith's doctor advised a change of altitude and the 68-year-old pioneer moved to Oakland, California, in 1883, where he invested in railroad and mining stocks before his death at age 80 on November 16, 1895. He was worth more than $500,000 when he left Denver and by 1891 was a millionaire (McGrath 1934).

City directories show Hallack as president for a year after Smith left, followed by John J. Reithmann through 1887. William Ridley, an English immigrant who was hired as superintendent in the early 1880s, remained with the concern for nearly 30 years and apparently lived at the plant for some time, which was not an uncommon practice. Henry Porter, who had been away from Denver for many years, had purchased a large portion of the initial stock and in 1888 was elected president of the firm. Porter's substantial business empire generated voluminous papers, many of which are now in the collections of the Colorado Historical Society in Denver. Even though the original records of the steam company are apparently lost, Porter's correspondence and his 1932 autobiography reveal quite a bit about the steam business in Denver, including its financial performance from 1883 to 1888:

Year	Revenue	Expense	Profit
1883	$34,343	$23,673	$10,669
1884	$39,189	$25,000	$14,189
1885	$36,466	$24,165	$12,301
1886	$39,022	$26,876	$12,156
1887	$40,773	$25,419	$15,354
1888	$40,841	$26,135	$14,706

Although most building owners made decisions about heating based solely on costs, the safety aspect of district steam service was no less important, if not as easily quantified. Dangers of on-site boilers became even more pronounced as elevators and other power machinery requiring the use of higher boiler pressures became more common. A forceful reminder occurred in Denver at midnight on August 18, 1895, when a 40-hp (392-kW) boiler exploded in the basement of the Gumry Hotel, demolishing the entire building, which then caught fire and incinerated many of the survivors of the explosion. Twenty-two people were killed and "a score of others were horribly mangled, some of whom were not rescued for 10 hours after the explosion." The hotel proprietor, who was killed in the explosion, had discharged the previous boiler operator and replaced him with 16-year-old Elmer Loescher to save the trained operator's $25 weekly wages. On the night of the explosion, Loescher had banked the boiler fire at the end of his normal 8 a.m.-to-11 p.m. shift, and had fled Denver after the explosion. He was captured and charged with murder, but was exonerated by a coroner's jury. Denver quickly passed boiler inspection and licensing laws, based on New York City codes (Anon. 1895).

SYSTEM EXPANSION

These numbers show that the Denver City Steam Heating Company was a solid and going concern. It is therefore not surprising that shortly after becoming president Porter recommended to the stockholders that the company undertake a major expansion. He explained to them how bonds could be used to cover the added cost and that the increased income from sales would cover the debt service on the bonds and double the company's income. Compared to the company's performance in 1887, expanding the plant would triple its income to $120,000, while expenses would only increase to $60,000, resulting in a quadrupling of annual profits to $60,000. He offered a detailed breakdown of the expenses (Porter 1888):

Item	Existing	Proposed
Labor	$5,000	$15,000
Expense	$2,500	$2,500
Salary	$2,500	$2,500
Coal	$14,000	$38,000
Taxes	$1,000	$2,000
Total	$25,000	$60,000

In addition, Ridley had calculated that switching from coal to residual oil from the Florence oil wells would reduce annual expenses by the following amounts (Note: It is unclear whether these savings are already incorporated in the numbers above or represent additional savings to be realized by converting to oil.):

Labor handling coal	$10,000
Labor on fire boxes	$2,000
Labor on coal	$4,000
Ash hauling	$2,000
Additional savings	$2,000
Total	$20,000

Part of the expansion was driven by the city's proposal to pave downtown streets with asphalt, which would have greatly hampered the ability to maintain the underground piping network. Pipes would be rearranged, relaid deeper in the ground, and many enlarged to handle more business, including replacing the 8-inch (203-mm) main from the plant with new 14-inch (356-mm) pipe. The improvements were estimated to cost $100,000, or as much as the original distribution system had cost in 1880. The American District Steam Company in Lockport often took bonds as partial payment from steam companies, and in February 1889 Porter wrote to B.D. Hall, president of that company, asking him to purchase $20,000 worth of bonds rather than the $15,000 agreed upon earlier. Porter reported to Hall that the company had "a good demand for steam and do not have enough capacity" (Porter 1889). The steam company would also start sharing the streets of Denver that year with the district cooling pipes of the new Colorado Automatic Refrigerating Company, which began operating on August 8, 1889, from a plant that was not far from the American House. Cooling was provided by distributing ammonia under pressure and expanding it on customers' premises to make ice, keep foods cold, or take "a few degrees of heat and humidity from a restaurant dining-room, a public hall, business office, or hospital" (Branson 1894). The refrigerating company used steam-driven absorption machines, but although its plant was adjacent to the steam mains, it made its own steam because the steam company did not provide continuous year-round service. A business establishment could now pay one company for heat and pay another to take it away.

Porter, meanwhile, contacted the Rollins Investment Company of Denver in May 1889 and instructed it to prepare a mortgage on the company's property and to issue $100,000 of 10- to 15-year bonds bearing 6% interest. As might be expected, substantial information had to be provided to potential bondholders; this is included in the correspondence sent to Rollins. A list of principal stockholders shows that several prominent Colorado businessmen had held stock since the founding of the company, including former governor John Evans, ex-senator H.A.W. Tabor, and bank president D.H. Moffatt. The total value of the plant was broken down as follows:

9½ lots on 19th & New Haven	$100,000
15 large tubular cast boilers	$42,000
2 large surface mills	$3,000
Boilerhouse 75 by 142 ft	$10,000
3 miles main pipe 8 in. to 3 in.	$80,000
1¾ miles surface pipe	$20,000
City rights to streets	$25,000
Holly patent rights to Denver	$50,000
To be expended in expansion	$100,000
Total	$430,000

Porter and Ridley traveled east to contract with the American District Steam Company for pipe, pipe coverings, and various other fixtures, as well as installation. The work was undertaken, but when payment was requested the bonds had not been sold and Porter had to put up the money himself. What had appeared to be a sure money-making proposition now turned into a heavy burden for Porter, but rather than write off the investment, he became determined to make good on it. Although the steam company was only a small part of his holdings, for the next 18 years he made a monthly record of the income and expenses, while leaving the day-to-day operations in Ridley's hands. As early as 1890 he started contacting potential purchasers of the company and in the meantime maintained the system in good order and occasionally added new boiler capacity when the demand re-

quired it. With Porter's blessing, Ridley at one point even attempted to buy the plant with some assistance from another Denver investor, but they were unable to arrange financing.

Everyone involved with the company appears to have maintained cordial relations, excepting perhaps the American District Steam Company, which held both stock and bonds in the company. Charles R. Bishop, president of the Lockport firm, sent a letter to Porter in February 1900 expressing their concerns about "the poor record" of the company and offered their assistance in improving the plant's financial performance. Porter replied that he "would be pleased to have any suggestions from you that would enable us to get the concern on a paying basis." The reply from Lockport suggested that Porter install economizing coils and attempt "linking up with a street railway or power company" (Bishop 1900a, 1900b; Porter 1900).

Porter's reference to getting the company on a paying basis referred to the operating losses that the company had endured for the previous couple of years. Although expenses had remained fairly constant in relation to the 1882-88 period, income had dropped significantly. Instead of generating a net operating profit of about $1,000 a month, the company was now losing that much, with Porter loaning the difference. The $100,000 invested in 1889 appears to have added nothing to the company's revenues and it is not precisely clear why. The most likely reason is that the company ended up serving the same customers that were connected to the original system, since it appears that additional piping to serve new customers was not included and Porter was very reluctant to invest the additional capital that would have been necessary to reach new customers, especially since the business district was growing away from the area served by the original network.

The company's decreased revenues may have been at least partially due to high steam rates. New York attorney Charles H. Toll advised Porter in September 1899 that he "ought to supply it cheaper . . . you are getting a much higher price per thousand cubic feet of room heated than the New York company is getting." The New York Steam Company was then using a substantial number of steam meters, while Denver had not installed any. Porter was attempting to interest Gamaliel C. St. John, president of the New York Steam Company, "to get up a small syndicate to take it over and run it," for the steam business was "entirely out of my line of thought and I would like to get rid of it." The revenues for the 1898-1899 heating season were only $27,683, while the expenditures were $36,093, resulting in a net loss of $8,410 (Porter 1899).

As if the Denver financier needed more problems with his steam company, its state charter expired at the end of its 20-year life and Porter had apparently neglected to renew it. The City of Denver took the opportunity to declare the 1880 steam franchise, which had no time limit, null and void due to the charter lapse. Since forcing the company out of business in the middle of winter could force great hardship on "the thousands of people and thousands of dollars worth of goods being protected against the cold," the city gave them a year to wind up their affairs and go out of business (*Denver Times* 1900). Porter managed to renew the state charter and took up a battle with the city fathers that stretched over a year until a new franchise was approved in October 1901. The almost nonexistent restrictions in the 1880 document were replaced with stipulations that limited the company to a specific area of downtown Denver, requiring it to post a $25,000 bond and to pay a tax of 1% of gross receipts for the first 5 years, 2% for the next 5 years, and 3% for the remaining 10 years of the franchise, with the books of the company "subject to inspection at all times by the auditing committee of the city of Denver, or by a special committee appointed for that purpose by the mayor or the city council" (Anon. 1907).

Porter's interest in selling the company was probably not lessened by this incident and he wrote to Chicago engineer William H. Schott in July 1903 asking for his advice on how to improve system operation, but it is obvious that Porter is trying to interest Schott in purchasing it. Schott had installed many district heating systems in the Midwest and asked for information about the company. The Denver company was then heating 165 buildings and had a capacity of 3,500 hp (34 MW), with 15 100-hp (981-kW) boilers, 2 500-hp (4,905-kW) boilers, and 1 1000-hp (9,810-kW) boilers, with steam pressure of 45 to 60 psig (310 to 413 kPa) maintained at the plant. The company was still charging by the cubic foot of heated space or per square foot of radiation. The anticipated gross earnings for the year were estimated at $46,000, with operating expenses of $36,228, taxes of $1,000, and $30 for insurance. The company had burned 19,500 tons of coal the prior season at an average price of $1.10, and during the November 1903 coal strike had paid from $2.00 to $2.65 per ton, with some purchased at $5.00 per ton. After much prodding from Porter, Schott inspected the system in July 1904 and found it to be in bad condition, but he expressed some interest in reconstructing it for Porter (Porter 1903-04; Schott 1903-04). In May 1905 Benjamin F. Seadler, secretary of the New York Steam Company and a stockholder in the American District Steam Company, visited Denver and talked to Porter. Seadler wrote to Charles R. Bishop in Lockport that Porter "did not want to talk steam at all," since they were apparently "having trouble with their pipe line." Seadler thought that the plant was not in the right location, since after it was built "the town grew just the other way." He advised Bishop to correspond with the Denver company and assist them in reducing expenses, which would "tend to make them feel better and maybe want to do some extension work."[3]

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[3]Letter from Benjamin F. Seadler to Charles R. Bishop, May 9, 1905, in Seadler's letterpress book in the possession of Orson L. St. John, Greenwich, CT. St. John is the son of Gamaliel C. St. John, former president of the New York Steam Company and American District Steam Company. My thanks to Mr. St. John for use of this material.

SYSTEM PURCHASED BY DENVER GAS AND ELECTRIC COMPANY

After other options evaporated, Porter turned to Henry L. Doherty of the Denver Gas and Electric Company, of which Porter was also a stockholder and director. Over the next five years he negotiated with Doherty for the purchase of the steam company by Denver Gas and Electric. Steam rates were raised 10% in 1907 to improve the balance sheet and Porter wrote in his autobiography that he "finally induced Doherty to buy the plant for the Gas and Electric Company, and we took our pay in their bonds, and all the shareholders got back the money they put into the stock when first issued, with a little more for dividends, but not much. They as well as myself were glad to get out of it" (Porter 1932).

Ridley stayed on with Denver Gas and Electric and soon passed the system on to his son, Arnold W. Ridley, who remained superintendent until his death in the early 1940s. At least two of Ridley's grandchildren also worked in the steam department of the Public Service Company. The steam company was merged into the Denver Gas and Electric Company in 1911, which itself was reorganized as the Public Service Company of Colorado in 1923 (Fisher 1989).

Doherty, an archetypal public utility personality, saw tremendous potential in the steam system and almost completely rebuilt it between 1910 and 1912. Interestingly, seven different types of mains were installed during this period, apparently in an effort to test several manufacturers' products. Steam and condensate meters replaced the former flat rates, greatly improving the system's financial status. Doherty's purchase of the steam company was not entirely driven by the potential profits from selling steam, however. He was more concerned with the imminent threat to electric sales caused by his electric customers installing their own cogeneration plants. At least 18 such plants were installed in Denver between 1909 and 1911, most of which, according to company documents, operated at least 25 years, with the last operating until 1949. Renovating the steam system kept electric customers on line until rates dropped low enough so that cogeneration was economically unattractive. Customer installation of cogeneration plants was halted, at least until electric rates began to rise in the 1970s (PSC1954).

The boilers in the original steam plant were replaced with newer ones removed from retired small electric plants. The 15 original 100-hp (981-kW) boilers were replaced shortly after the plant was purchased and the remaining three boilers were replaced during the 1930s and early 1940s. In 1941, steam was provided by three 436-hp (4,277-kW) boilers and seven 150-hp (1,471-kW) boilers, for a total of 2,358 hp (23 MW), much less than the 3,500 hp (34 MW) operated by the steam company at the turn of the century. The 1889 idea of replacing coal with oil was finally realized in 1931, which, in turn, was replaced by natural gas in late 1947. Despite improvements to the steam system, by 1920 the company was suggesting that its 295 steam customers install their own heating plants, confident that lower electric rates would make it uneconomical for them to cogenerate their own power. By 1945 only 54 customers remained on the system and the rate was increased to 73 cents per thousand pounds (69 cents per GJ) of steam, with the intention of driving customers off the system, although the price was still less than the production cost of 75 cents per thousand (PSC 1965).

A postwar study recommended that the system be expanded rather than abandoned. As a result, a tieline was installed in 1948 to connect the system to the Zuni generating station, allowing use of cogenerated extraction steam from a 35-MW turbogenerator. Eight thousand feet (2,438 m) of pipe, most of it 14-inch (356-mm) prefabricated pipe, were installed to deliver 265 psig (1,826 kPa) of steam. The estimated cost for the new line was $125,000, but postwar inflation and other factors resulted in a final cost of $600,000. Several new mains were also built in the downtown area at the same time. The new steam source and connecting pipe were engineered to provide 300,000 pounds of steam per hour (88 MW), so a sales campaign was undertaken to bring the maximum connected winter load up to that amount. The original plant would become a reserve facility, retaining the ability to generate 120,000 pounds of steam per hour (35 MW) for emergencies and to supplement the Zuni station during peak electric load periods (PSC 1954).

Although the plan was merely to break even, the steam system showed a small profit in 1951 and by 1959 was generating $100,000 in profits on sales of $500,000. The Public Service Company made arrangements to purchase 30,000 pounds per hour (9 MW) of backup and peaking steam from the Denver U.S. National Bank in 1958 and 60,000 pounds per hour (18 MW) from the Hilton Hotel two years later, at which time eight of the older boilers were removed from the steam heating plant. In November 1962, the bank installed a new 40,000-pound-per-hour (12-MW) boiler strictly to furnish steam to the system. In November 1964, the company leased the boiler plant of the Colorado state capitol complex for 30 years, adding 60,000 pounds per hour (18 MW) of capacity to the system. The 188 customers in 1964 generated profits of $105,200 on revenue of $686,700. Eleven of these customers operated 16 steam absorption chillers providing 7,500 tons of cooling capacity (PSC 1965).

The increased business led to a decision to rebuild the original plant and reduce purchases from other parties. The plant had been in cold standby since the early 1960s, except for a short period in June 1965 when the Zuni plant was temporarily disabled by a major flood on the South Platte River. The venerable brick structure was demolished and replaced in 1972 by a prefabricated metal building that houses two natural-gas-fired boilers of 150,000 pounds per hour (44 MW) and 200,000 pounds per hour (57 MW). The company's sales force obtained a contract with the State of Colorado in December 1974 to provide up to 57,000 pounds per

hour (17 MW) of steam to the new Auraria Higher Education Center constructed on the edge of downtown Denver (*Rocky Mountain News* 1972) (see Figures 2 through 4).

The current average winter load to the company's 130 customers is about 160,000 pounds per hour (47 MW) and the average summer load is about 65,000 pounds per hour (19 MW). Peak system sendout occurred on December 23, 1983, when 510,000 pounds per hour (149 MW) were delivered to the system. The thermal energy department is aggressively marketing steam to new downtown customers as well as exploring several other opportunities to provide new district heating and cooling services. Energy sales increased somewhat in the 1970s and are now at the same level as during the mid-1960s.

Although district steam has been supplied in downtown Denver for more than a century, the record of steam sales and revenue (Figure 5) reveals the sporadic nature of the business as corporate management supported it and encouraged expansion or ignored it and even attempted to abandon steam service. At one time the Public Service Company provided district heating service in several Colorado and Wyoming communities, but only the Denver system has survived. Repeating the history of the early twentieth century, some Public Service Company of Colorado customers who generate their own heat have once again concluded that they can cogenerate electricity for less than they can buy it. As for the future of district heating and cooling in downtown Denver, it can be safely said that consumers of heating, cooling, and electricity in the Mile High City will continue to use energy, and if they are unable to buy it at a reasonable price, they will either go out of business, move elsewhere, or find alternative energy sources. It has always been so.

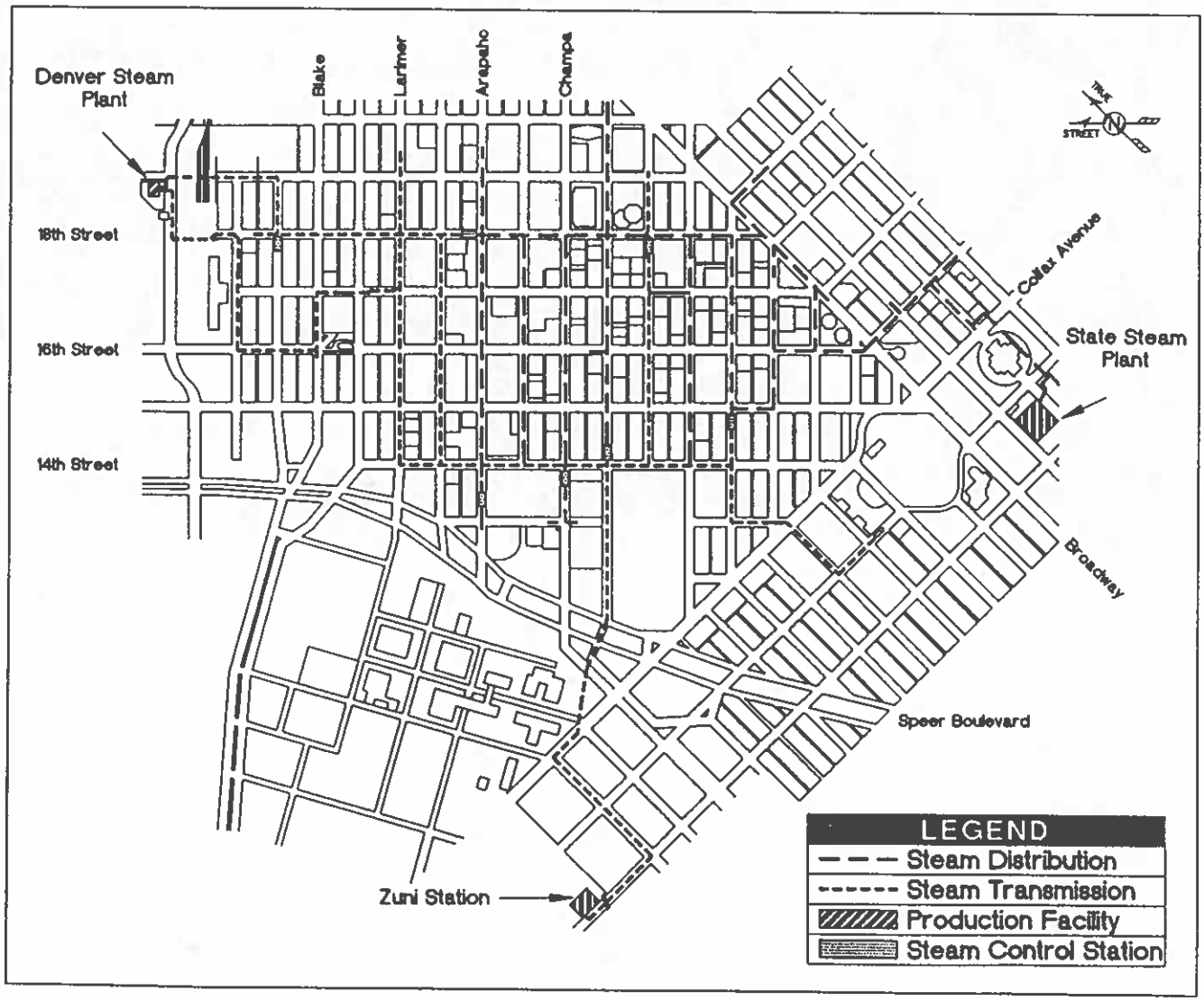

Figure 2 *Steam transmission and distribution system, July 1994.*

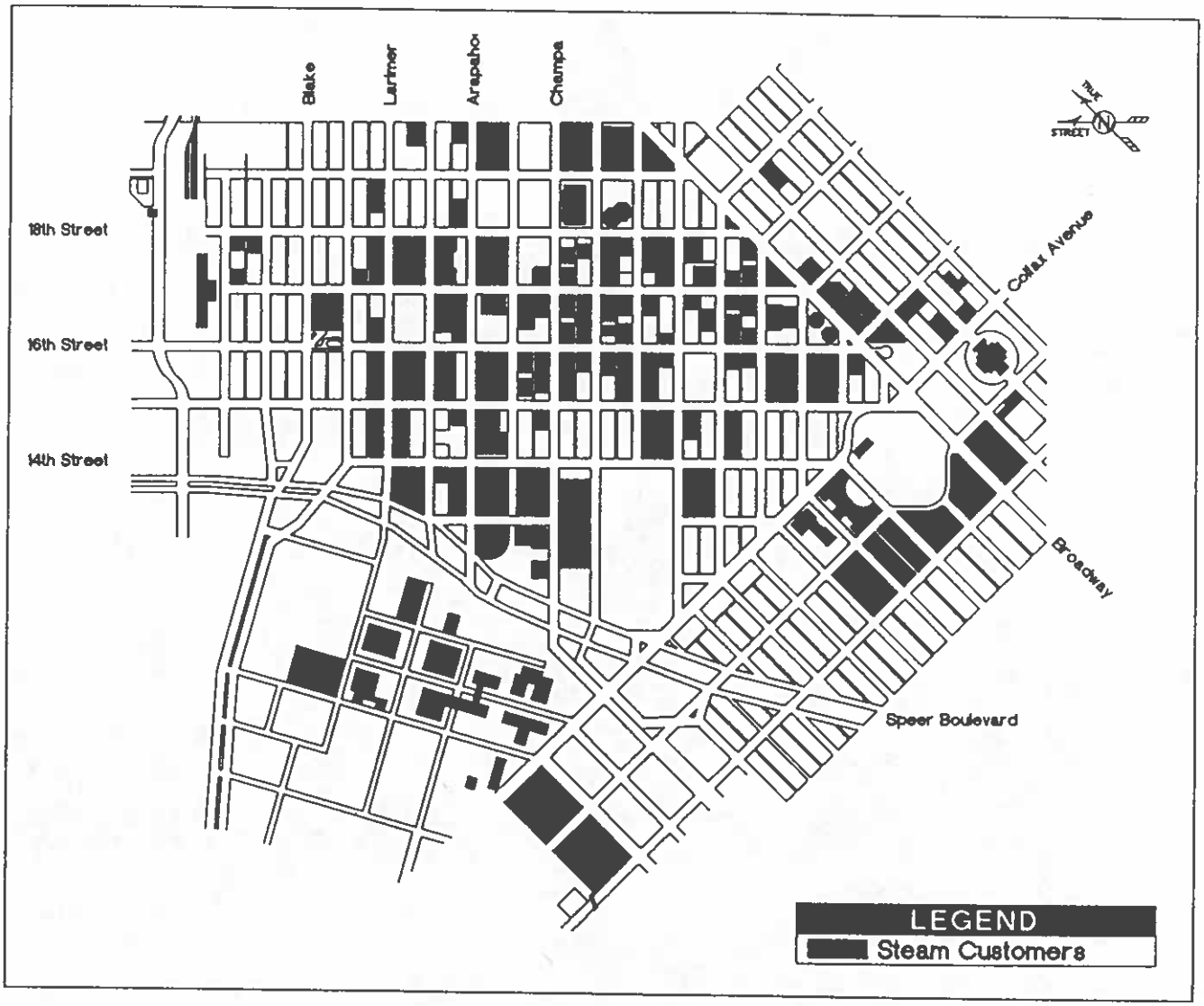

Figure 3 *Steam customer locations, July 1994.*

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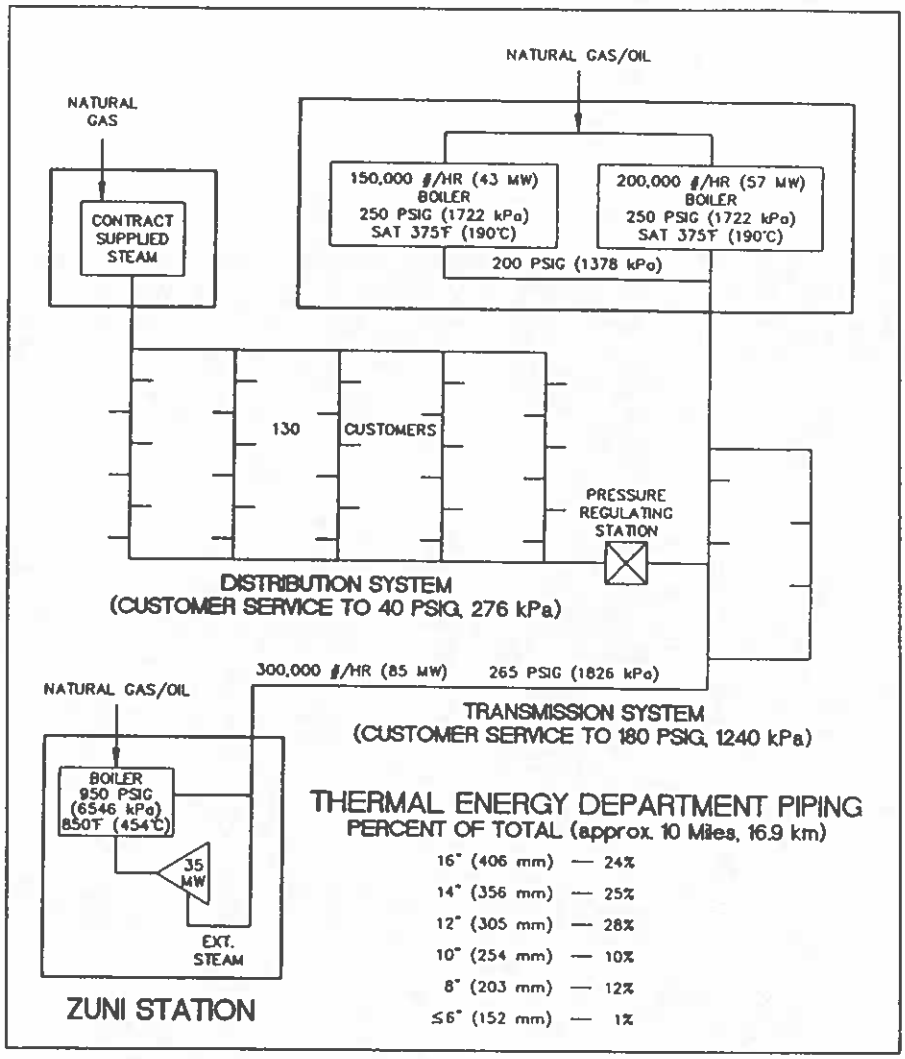

Figure 4 *Denver Steam Plant thermal energy department piping, July 1994.*

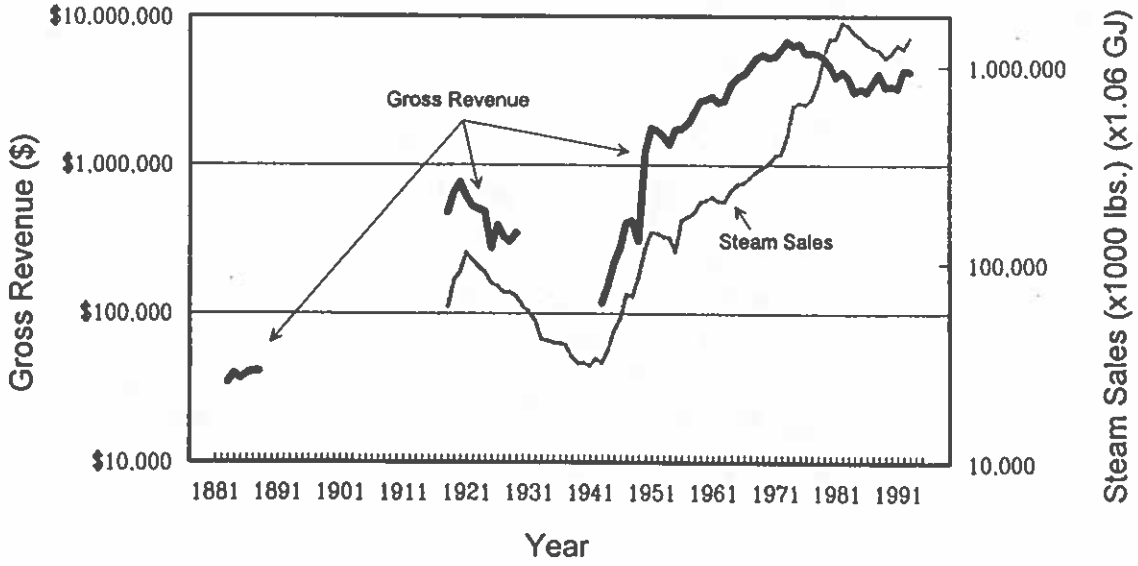

Figure 5 *Denver steam system—historic steam sales and revenue, 1880-1995.*