What is Manufactured Gas?

Manufactured gas should not be confused with natural gas, the primary fuel gas of our day. Manufactured, or artificial gas, was produced from coal, coal and oil mixtures, or from petroleum.

Almost without exception, in the US manufactured gas was produced by means of three processes:

- Coal Carbonization
- Carburetted Water Gas
- Oil Gas

Coal Carbonization / Coal Gas Process

This was the primary, commercial mode of manufacturing gas from ca 1816 to 1875. After 1875, newer processes and technologies gradually replaced coal carbonization.

Coal gas was produced through the distillation of bituminous coal in heated, anaerobic vessels called retorts. In this process, coal was broken down into its volatile components through the action of heat in a nearly oxygen free environment.

During the retorting phase, approximately two-fifths of the coal's weight was converted into volatile non-solids or gases. Most of the remaining amount of the coal was converted into solids, primarily coke. From the retort, the gases were drawn off into a device known as the hydraulic main where some of the vapors were converted to liquids and remained in gaseous state.

The liquids, or liquors as they were often referred to, consisted of (contaminated) water and coal tar, and its associated wastes.

The remaining vaporous material was coal gas. After exiting the hydraulic main, the gas ran through a condenser where the gas cooled and additional coal tar and other impurities were removed.

Quite often, the gas was next funneled through a device known as an exhauster, which further cooled the gas.

The coal gas, however, still contained impurities, primarily gaseous ammonia and sulfur compounds. These were removed by "washing" the gas in water and by running the gas through beds of moist lime or moist iron oxides.

After this final purification process, the coal gas passed through the station meter, where it was measured, and on to gas storage holder. From the holder the gas was distributed via street mains to the consumer.

Carburetted Water Gas Process

In 1873, Professor L. Lowe of Pennsylvania invented the carburetted water gas process—a technological advance that spurred on the growth of America’s manufactured gas industry. At its core, the process consisted of enriching a form or coal gas, known as water gas (blue gas) and thus increasing its caloric / energy value. By injecting oil into a vessel containing heated water gas, the oil and vapor combined, forming a gaseous fuel with a thermal content of approximately 300-350 Btu per cubic foot.

Within a few short years, carburetted water gas came to dominate the manufactured gas industry in the US, as residential and industrial consumer alike demanded the more efficient fuel source.

Typically, a carburetted water gas plant consisted of a brick-lined, cylindrical, steel vessel, the generator, the carburetor (carburetter), and a superheater. It was in the generator that the coal or coke was distilled to generate gaseous product. As the gas was drawn off from the generator and passed into the carburetor, the oil was introduced into the vapor. The oil-gas mixture then traveled down through the carburetor and up through the superheater. During the course of its passage through the superheater, the oil was thermally cracked and became "fixed" – thoroughly mixed and bonded with the coal gas. Carburetted water gas was, then, a mixture of the gaseous products of coal and petroleum.

From the superheater, the carburetted water gas was fed into a sealed wash box where the gas cooled slightly, allowing some the impurities in the form of coal tar (and associated wastes) to condense and settle out. The gas was then passed through the condensers where it was cooled even further, and additional coal tar and impurities were removed.

The gas was also passed through a scrubber, a device that brought the vapor into direct contact with water, thus removing even more impurities from the gas.

Depending upon the size and design of the plant, some facilities employed additional mechanical scrubbing devices to produce carburetted water gas. Common scrubber processes included:

The wire drawing or friction method - - while still heated, the gas was driven through a series of fine orifices. As a result of friction and changes in the velocity of flow, impurities, including coal tar, settled from the vapor.

The shaving scrubber method - - the vapor was passed through beds of absorbent materials (wood chips, lime and iron oxides were sometimes used), thus removing coal tar and other contaminants from the gas.

Direct current electrical precipitation method- - electrical currents were passed through the vapor, charging the particles of coal tar and other impurities in such a manner that they precipitated out from the gas.

After scrubbing, the gas was moved into the relief holder, which served as a reservoir that provided a continuous gas supply to the exhauster. From the relief holder, the gas passed through the exhauster, through the final stage purifiers, into the station meter, and on to the storage holder. From there the gas entered the distribution system and was delivered to the consumer.

Oil Gas Process

The oil gas process is the only one of the three manufactured gas processes discussed here that did not use coal as a raw material.

The first large-scale oil gas plant went on line in Oakland, CA, in 1902. The process as a whole was very similar to carburetted water gas process. In essence, the oil gas process consisted of thermo-cracking oil in a steam environment to produce the raw gas rather than distilling coal. The oil was heated and cracked in a vessel similar to the generator used in the carburetted water gas process. From there the gas passed to a vaporizer, where it was enriched with additional injections of oil and then routed through the superheater. After exiting the superheater, the gas was scrubbed and processed for distribution in much the same way as was carburetted water gas

Many of the same waste products associated with the production of coal gases, notably tars containing PAHs, were also generated during the manufacture of oil gas.

How Many Manufactured Gas Plants Were There?

The US EPA and others estimate that from ca. 1815 to ca. 1960 over 50,000 manufactured gas plants operated in the United States. How many operated at a given time is difficult to say--a handful of commercial plants operated in 1816, nearly 400 in 1860. Approximately 700 plants operated in 1890, 900 in 1900, and over a thousand manufactured gas plants in 1905.

There were perhaps 1,300 plants producing manufactured gas in 1909. By the 1920s, the manufactured gas industry had reached its maturity in the US. In 1921, it was estimated that over 9 million domestic customers used manufactured gas to heat their homes, cook their food and fuel their household appliances. Manufactured gas served an estimated 46 million individual Americans in some 4,600 communities across the land. Residential customers consumed over 326 billion cubic feet of manufactured gas in 1921.

The numbers are more difficult to discern in later years, but there is a substantial decline in the number of manufactured gas plants in operation as the century progressed. In 1939 there were perhaps as few as 100 plants in operation producing gas and coal / coal tar byproducts. The post war years saw an increase in the number of such plants with approximately 170 in operation in 1947.

By the late 1950s only a few plants operated, largely supplying feedstocks to a chemical industry that was ever increasingly relying upon the petroleum industry for its raw materials. By the mid-1960s the remaining plants closed due to a lack of demand for coal and coal tar by-products.

Where Were Manufactured Gas Plants Located?

At the onset of the Civil War, every state in the Union (as well as the District of Columbia) except for Arkansas was home to at least one manufactured gas plant. Circa 1860, New York led the nation with 61 gas works operating within its borders, followed by Pennsylvania with 48 and Massachusetts with 45.

Number of Manufactured Gas Companies in the US, ca. 1860

State	Number of Companies	Capital	Coal Gas Plants	Resin / Oil Gas Plants
Alabama	3	320,000	3	0
Arkansas	0	0	0	0
California	9	1,790,000	9	0
Connecticut	14	953,000	14	0
Delaware	3	244,300	3	0
District of Columbia	1	500,000	1	0
Florida	1	30,000	1	0

Georgia	6	559,160	4	2
Illinois	13	2,595,000	13	0
Indiana	7	605,000	7	0
Iowa	5	355,000	5	0
Kansas	1	200,000	1	0
Kentucky	5	905,000	5	0
Louisiana	2	1,540,000	2	0
Maine	10	905,300	9	1
Maryland	6	780,000	3	3
Massachusetts	49	4,759,000	45	4
Michigan	8	745,000	8	0
Minnesota	1	200,000	1	0
Mississippi	4	212,000	4	0
Missouri	4	775,000	4	0
New Hampshire	9	425,000	9	0
New Jersey	19	1,849,610	17	2
New York	71	12,780,250	61	10
North Carolina	8	187,000	0	8
Ohio	30	3,338,600	29	1
Oregon	1	50,000	1	0
Pennsylvania	48	5,657,700	48	0
Rhode Island	7	1,344,090	6	1
South Carolina	2	767,800	2	0
Tennessee	4	663,000	4	0
Texas	3	225,000	3	0
Vermont	8	216,000	6	2

Virginia	11	1,030,000	10	1
Wisconsin	8	778,650	8	0
Not enumerated above	50	6,200,000	50	0
Grand total	431	54,485,460	396	35

Source: ***FIRST CENTURY OF NATIONAL EXISTENCE; THE UNITED STATES AS THEY WERE AND ARE ..., BY AN EMINENT CORPS OF SCIENTIFIC AND LITERARY MEN. ILLUSTRATED WITH OVER TWO HUNDRED AND TWENTY-FIVE ENGRAVINGS*** (Hartford, CT: L. Stebbins / San Francisco, CA: F. Dewing & Co., c1872), page 147.

By the opening decade of the 20th century, the manufactured gas industry served customers in every state in the Union. While it might be expected that the more populous states would have the most plants, this does not appear to have been a firm rule.

In 1909, New York led the nation with 141 plants in operation. However, Iowa was a close second with 117 gas works. Nor does it seem that those states most often associated with the coal mining industry necessarily had vastly more gas works than did their coal-poor neighbors. Yes, Pennsylvania had 78 plants, but Nebraska, not typically thought of a coal producer was home to 48 manufactured gas plants.

Number of Manufactured Gas Companies in the US, ca. 1909			
State	Number of Gas Plants	State	Number of Gas Plants
New York	141	Kansas	12
Iowa	117	South Carolina	12
Pennsylvania	99	South Dakota	12
Illinois	78	Washington	12
California	74	Tennessee	11
Massachusetts	64	Colorado	10
Michigan	55	Vermont	9
Wisconsin	49	Arizona	8
New Jersey	47	Mississippi	8
Indiana	53	Oregon	8
Nebraska	48	Rhode Island	8

Minnesota	43	North Dakota	6
Ohio	38	Oklahoma	6
Missouri	29	Arkansas	5
Connecticut	28	Delaware	5
Texas	27	Louisiana	5
Virginia	21	Montana	5
Maine	19	West Virginia	4
Maryland	18	District of Columbia	3
Georgia	15	Idaho	3
Kentucky	15	Nevada	3
New Hampshire	14	Utah	3
North Carolina	14	New Mexico	2
Alabama	13	Wyoming	1
Florida	12		

Source: US Bureau of the Census. ***THIRTEENTH CENSUS OF THE UNITED STATES TAKEN IN THE YEAR 1910: VOLUME 10, MANUFACTURES (1909), REPORT FOR PRINCIPAL INDUSTRIES***, US Department of Commerce, Bureau of the Census (Washington: GPO, 1913).

By the 1920s when the industry had matured and was beginning to decline, gas works could be found in communities as large as New York City and as small as Missoula, Montana. From Bangor, Maine, to Santa Rosa, California - - from STATESVILLE, North Carolina to Waterloo, Iowa, the manufactured gas industry supplied the residential and industrial needs of the nation.

A brief review of US EPA records reveals that former manufactured gas plants are found across the width and breadth of America, in small towns and large cities alike. A review of EPA's records demonstrate that manufactured gas plants operated in industrial zones and in relatively rural settings.

According to EPA the following communities are home to former manufactured gas plants:

Asheville, NC	Fayetteville, NC	Osceola, IA
Augusta, GA	Flemington, NJ	Pawtucket, RI

Belle Plaine, IA	Gadsden, AL	Penns Grove, NJ
Beloit, WI	Goldsboro, NC	Pleasantville, NJ
Belvidere, IL	Greenville, NC	Pueblo, CO
Boonville, MO	Hannibal, MO	Putnam, CT
Brookfield, MO	High Point, NC	Raleigh, NC
Burlington, IA	Huron, SD	Rocky Mount, NC
Burlington, VT	Iowa City, IA	Salem, NJ
Cape Girardeau, MO	Jacksonville, FL	Salina, KS
Carroll, IA	Junction City, KS	Salisbury, NC
Cedar Rapids, IA	Kansas City, MO	Santa Rosa, CA
Charleston, SC	Kinston, NC	Sedalia, MO
Cherokee, IA	Le Mars, IA	Sheldon, IA
Chillicothe, MO	Lewes, DE	Sioux City, IA
Clear Lake, IA	Lexington, MO	St Joseph, MO
Clinton, IA	Louisiana, MO	St Louis, MO
Clinton, MO	Manhattan, KS	St. Augustine, Florida
Colorado Springs, CO	Marengo, IA	Statesville, NC
Columbia, MO	Marshall, MO	Swedesboro, NJ
Concord, NC	Mason City, IA	Trenton, MO
Concordia, KS	Mexico, MO	Trenton, MO
Creston, IA	Middletown, NY	Vinton, IA
Decorah, IA	Millville, NJ	Washington, NC
Dubuque, IA	Moberly, MO	Waterloo, IA
Durham, NC	Nevada, MO	Wellington, KS
Elizabeth City, NC	New Bern, NC	Wellington, KS
Excelsior Springs, MO	North Platte, NE	West Paterson, NJ

Fairfield, IA	Nyack, NY	Wildwood, NJ
Fairmont, MN	Ocean City, NJ	Wilmington, NC

Given that tens of thousands of gas works operated in the US over the course of a century and a half, this list only scratches the surface.

In the course of a century or more, it is only natural that many communities were home to multiple manufactured gas plants. Some sources estimate that over time there may have existed as many as 1,000 gas works in New York City and the Five Boroughs. Chicago may have been home to as many as 85 plants, while Baltimore, San Francisco, and Los Angeles each hosted at least 30 gas works. As many as 50 plants operated in St Louis, Missouri over the years. Other communities that played host to multiple gas plants at various time include: Boston, Denver, Detroit, Kansas City (MO), New Orleans, Pittsburgh, Sacramento, Salt Lake City, Seattle, and Washington, DC.

Who Owned and Operated Manufactured Gas Plants?

Although many municipalities across the country owned and/or operated gas works, especially during the Progressive Era (1880-1920), the majority of plants in the US were owned by corporate entities. In 1904, over 91 percent of manufactured gas plants were under corporate ownership. By 1909 that figure had decreased somewhat, to approximately 84 percent, but throughout the history of the industry, corporate ownership was the rule rather than the exception.

- From circa 1870 to circa 1960, many railroad companies operated manufactured gas plants at their larger yards and terminals. These facilities, known as Pintsch plants, produced compressed illuminating gas for use in passenger rail cars.

- Between 1845 and 1945 many military installations, posts, and bases operated manufactured gas plants.

- From the 1820s into the 1950s and 1960s many private homes were equipped with domestic / residential gas plants.

- Between 1850 and 1950 it was quite common for large institutions--hotels, resorts, hospitals, prisons, colleges, schools, etc—to own and operate their own gas works.

- From circa 1880 to circa 1950 many industrial facilities operated their own, onsite gas works and manufactured what was known as Producer Gas. Producer Gas was used as fuel to power machinery and equipment and to feed furnaces or kilns in smelters, iron and steel plants, brick, and cement plants

- Between 1912 and 1940 many cities were home to bottled manufactured gas plants. These facilities produced manufactured gas that was compressed into bottles / gas cylinders for sale to a variety of customers.

- From ca 1910 to the 1990s, the US Bureau of Mines operated manufactured gas plants at various times and various locations across the country. Some were pilot plants to showcase new technologies and processes, others were experimental plants to develop these technologies and to test coal and other fuels.

- Between circa 1890 and the present, hundreds of so-called "merchant coke works" operated in the US. While the primary product of these plants was coke, gas, and coal tar (and associated waste / byproducts) were produced at these facilities.

Ownership of Manufactured Gas Plants, ca. 1909 (includes only those plants selling gas)				
	Number of Plants Owned by:			
State	Individuals	Corporations	Municipalities	Others
Alabama	0	11	2	0
Arizona	0	8	0	0
Arkansas	0	5	0	0
California	1	72	1	0
Colorado	0	10	0	0
Connecticut	0	27	1	0
Delaware	1	4	0	0
DC	0	3	0	0
Florida	0	11	1	0
Georgia	0	12	3	0
Idaho	0	3	0	0
Illinois	2	73	3	0
Indiana	1	50	1	1
Iowa	4	78	35	0
Kansas	2	9	1	0
Kentucky	0	15	0	0
Louisiana	0	5	0	0
Maine	2	16	0	1
Maryland	2	16	0	0
Massachusetts	1	58	4	1
Michigan	0	54	1	0

Minnesota	1	15	26	0
Mississippi	0	8	0	0
Missouri	1	26	1	1
Montana	0	5	0	0
Nebraska	12	25	7	4
Nevada	0	3	0	0
New Hampshire	0	14	0	0
New Jersey	0	45	1	1
New Mexico	0	2	0	0
New York	8	130	3	0
North Carolina	0	14	0	0
North Dakota	1	4	1	0
Ohio	2	36	0	0
Oklahoma	1	5	0	0
Oregon	0	8	0	0
Pennsylvania	1	98	0	0
Rhode Island	0	8	0	0
South Carolina	1	7	4	0
South Dakota	0	13	4	0
Tennessee	0	11	0	0
Texas	3	24	0	0
Utah	0	3	0	0
Vermont	0	9	0	0
Virginia	1	14	6	
Washington	0	12	0	0
West Virginia	0	3	1	0

Wisconsin	0	35	12	2
Wyoming	0	1		
Totals	**48**	**1,118**	**119**	**11**

Source: US Bureau of the Census. ***THIRTEENTH CENSUS OF THE UNITED STATES TAKEN IN THE YEAR 1910: VOLUME 10, MANUFACTURES (1909), REPORT FOR PRINCIPAL INDUSTRIES***, US Department of Commerce, Bureau of the Census (Washington: GPO, 1913).

What Types of Hazardous Wastes Were Generated At Manufactured Gas Plants?

Gas works produced a variety of largely hazardous waste products, almost all of which are found in what is referred to today as coal tar (and associated waste products). Among the toxic substances found in coal tar are:

- **Aromatic Hydrocarbons** - - comprised manly of phenols and cresols
- **Monocyclical Aromatic Hydrocarbons (MAHs)** - - the so-called BTEX series: benzene, toluene, ethylbenzene and xylene
- **Duocyclical Aromatic Hydrocarbons (DAHs)** - - comprised mainly of naphthalene and the light oils
- **Polycyclical Aromatic Hydrocarbons (PAHs)** - - the coal tars and medium and heavy oils
- **Others** - - the concentrated forms of trace minerals found in the coal, including cyanides, sulfur, and some heavy metals (arsenic, chromium, lead, etc)

Coal tar (and associated waste products) is "non-aqueous" in nature -- it does not have a high degree of solubility in water. As a tar-like substance, it does tend to "stick together." Coal tar (and associated waste products) thus forms what is known as dense, non-aqueous phase liquid (DNAPL). When coal tar is released into a body of water or aquifer it migrates downward until a low-permeability layer is encountered. There it resides, not dissolving, but slowly releasing toxic substances into the water.

Coal tar was often co-mingled with the lighter oils that were also a waste product of manufactured gas process. These light oils are also comprised of toxic substances and pose hazards on par with coal tar. The oils, which are light non-aqueous phase liquids (LNAPLs) also pose a threat to water supplies when introduced into aquifers. While coal tar sinks to the bottom of the aquifer, the oils float on top - - thus the aquifer is contaminated with toxic substances from above and below.

Other hazardous substances that may be associated with former manufactured gas plants could include scrubber packing and other materials that were used to clean and purify coal gas and marketable byproducts. Given that these media were chosen for their capacity to absorb contaminants, there is high probability that they are contaminated with PAHs, heavy metals and other toxics.

How Much Waste was Generated at Manufactured Gas Plants?

No firm rule can be given regarding the amounts of coal tar and other waste products generated by a given plant. Many variables influenced waste generation, including:

- plant size / capacity
- duration of operation
- type of gas produced at the plant
- the type of coal used to produce gas
- natural contaminants found in the coal
- etc.

Experiments conducted by the US Bureau of Mines in 1911 found that coal from the Pittsburgh, PA, area yielded as much as 155 pounds (07.75%) of coal tar per ton of coal processed into gas.

Samples of coal from other regions of the country yielded similar results.

US Bureau of Mines: Results of Individual Tests, 1911

Source	Coke - percent of total sample tested	Gas - percent of total sample tested	Tar Gas - percent of total sample tested
Blockton, AL	68.3	16.1	9.7
Oak Creek, CO	60.0	17.2	6.9
Sopris, CO	75	12.8	6.6
Harrisburg, IL	62.3	14.3	8.6
Hellier, KY	69.4	15.9	4.9
Hellier, KY #2	64.5	15.0	8.3
Saginaw, MI	59,5	14.6	7.9
Van Houten, NM	67.8	14.4	7.9
Van Houten, NM #2	70.00	15.2	9.8
La Follette, TN	66.8	16.8	9.4
Page, WV	75.5	14,0	9.7
Page, WV #2	71.2	12.8	7.2
Hanna, WY	500.2	21.5	6.3

Source: White, AH, and Perry Barker. ***COALS AVAILABLE FOR THE MANUFACTURE OF ILLUMINATING GAS***, Bulletin 6, edited by Herbert M Wilson, US Department of the Interior, Bureau of Mines (Washington: GPO, 1911).

The Pittsburgh sample may have been typical of the coal used to manufacture gas at the beginning of the 20th century. As determined by the Bureau of Mines, American coal yielded, on average, 7.92 percent coal tar per unit of coal processed into gas.

But how much coal tar could be generated at a given gas works? Again, given the variables, it is difficult to give definitive answers to this question.

A manufactured gas plant in Maine, which operated from 1853 to 1963, was found to contain over 400,000 gallons of coal tar in underground tanks and subsurface coal tar pools. While this may seem like a massive amount of wastes, sources estimate that between 1880 and 1950 approximately 11 billion gallons of coal tar were generated by the manufacture gas industry.

What was Done with Certain Wastes / Byproducts of the Manufactured Gas Industry?

Arsenic . . . Benzene . . . Chromium . . . Lead . . . Phenols . . . Polynuclear Aromatic Hydrocarbons (PAHs) . . . Toluene . . . Xylenes

As the manufactured gas industry grew--as millions of tons of coal per year were processed into gas--the industry soon found itself awash in waste products, most notably the substance known as coal tar. While one solution to managing wastes was the tried and true method of dumping them into the nearest waterway, this practice had its drawbacks. It was, at least to some, unacceptable in that coal tar and other manufactured gas wastes were toxic after all.

Another solution was to dispose of waste in vast pits or holding ponds at or near the gas plant, but this too was not a viable, long-term solution. The shear volume of waste products generated soon overwhelmed onsite storage capacity at many plants.

The most desirable, if not the most practiced, solution to this dilemma seemed to have been to turn a liability into an asset . . . to take what was a costly waste product and turn it into a profitable byproduct.

Soon chemists through Europe and the US were scrambling to find ways of using coal tar as the building blocks from which to create new and profitable products and goods.

The list of goods and products that were manufactured from coal tar spans the width and breadth of our modern material culture. It is no exaggeration to state that coal tar formed the very building blocks of our modern synthetic world.

If we examine just five of the COCs that are found in coal tar, we can begin to see how pervasive these compounds became in our modern world.

- Benzene
- Toluene
- Phenols
- Xylenes
- Polynuclear Aromatic Hydrocarbons (PAHs)

Benzene, also known as benzol, was discovered and distilled from coal tar in the early 1800s. Because of its wide use, benzene ranks in the top 20 in production volume for chemicals produced in the US. In both historic and contemporary terms, benzene has been used to manufacture numerous products including: polymers, resins and plastics such as Styrofoam® and in the production of nylon and other synthetic fibers. In the past and present, benzene was a component in the manufacture of:

- rubber, waxes, oils and lubricants

- dyes, inks and pigments
- detergents and solvents
- pharmaceuticals and pesticides.

It found use in print shops and dry cleaners, in the tanning and explosives industry, and was at one time used as gasoline additive. Benzene also has applications as feedstock / raw material in the chemical industry.

Perhaps two of the most famous (or infamous, if you will) products made from benzene were the pesticide DDT and the chemical building block, PCB (polychlorinated biphenyl).

Toluene has historically been used in many applications. One of its major applications was as a solvent used in the manufacture of: paints, paint thinners, fingernail polish, lacquers, and adhesives. In the past and present, toluene was a component in the manufacture of:

- dyes, inks and pigments
- detergents and solvents
- antifreezes and gasoline additives
- perfumes and cosmetics

It found use in the production of explosives, vinyl, rubber and in some printing and leather tanning processes. Toluene is used in the manufacture of artificial sweeteners and pharmaceuticals. Toluene also has applications as feedstock / raw material in the chemical industry.

Phenol (Carbolic acid) ranks in the top 50, in terms of volume, for chemicals produced in the United States. The largest single use of phenol is as an intermediate in the production of phenolic resins. It is used in the production of nylon and other synthetic fibers and in the manufacture of epoxies, resins and pastics. Phenol is also used as a germicide and slimicide (i.e. bacterial and fungicidal pesticide). Phenol is also used in commercial and household disinfectants, and in pharmaceuticals such as over-the-counter treatments for sore throats. Phenol also has applications as feedstock / raw material in the chemical industry.

Xylene (xylenes), a synthetic isomer, is also known as xylol or dimethylbenzene. Today xylene is primarily produced from petroleum, but was once a major product of coal tar. Xylene is one of the top 30 chemicals produced in the United States in terms of volume. It is used as a solvent in the printing, rubber, and leather industries. In the past and present, xylene was a component in the manufacture of:

- dyes and pigments
- perfumes and cosmetics
- paint thinners
- synthetic fibers resins, and plastics
- coatings for fabrics and paper products

Xylene is used as a cleaning agent / solvent and as an additive in aviation fuels and gasoline. It is used in the manufacture of pharmaceuticals, pesticides and herbicides. Xylene also has applications as feedstock / raw material in the chemical industry.

Polynuclear Aromatic Hydrocarbons (PAHs) comprise a group of more than 100 different chemical compounds that result from the incomplete combustion of organic materials such as coal, oil, wood, etc. Generally, PAHs are found co-mingled in complex mixtures. Certain PAHs are used in the manufacture of pharmaceuticals, dyes, plastics, and pesticides. PAHs also have applications as feedstock / raw material in the chemical industry.

Keeping in mind that these are only five of the scores of COCs that are present in coal tar, one can see the vast array of products and applications in which coal tar derivatives were used.

How were Wastes Generated by Manufactured Gas Plants Disposed of?

Arsenic . . . Benzene . . . Chromium . . . Lead . . . Phenols . . . Polynuclear Aromatic Hydrocarbons (PAHs) . . . Toluene . . . Xylenes

Commercial operations of manufactured gas plants began in the United States in the opening decades of the 19th Century. Commercial gas works operated 24 hours a day, 7 days a week, 52 weeks a year to produce the gas and chemical feedstocks demanded by their customers.

For over a century and a half the manufactured gas industry played a vital role in the nation's economy. More than 50,000 gas works operated at various times during that period.

During the life span of the industry, billions of gallons of extremely hazardous wastes were generated. One source estimates that during a 70 year period, gas works produced approximately 11 billion gallons of coal tar, this from an industry that operated for nearly 150 years.

A substantial amount of those wastes were shipped as feedstocks to the nation's chemical industry. A certain amount of those wastes found use as paving and construction materials. But the fact remains that an enormous volume of those hazardous materials were disposed in ways that today pose a threat to the environment and to human health.

Sometimes coal tar and other waste products from gas works were simply discharged into nearby waterways. Sometimes these wastes were deposited in nearby landfills or dumps. Often they were disposed of onsite at the gas works, poured into pits and underground tanks.

The theory behind the disposal of these wastes seemed to be out of sight . . . out of mind. And yet, given that coal tar (and associated wastes) is extremely resistant to biodegradation . . . given that the chemicals and compounds that comprise this waste are extremely persistent and long lasting . . . the hazards presented by manufactured gas wastes remain with us today.

Many communities are, today, home to former manufactured gas plants -- yet few in the community know of this potential hazard in their backyards. Gas plants were typically located in industrial areas. Often abandoned gas works were demolished and new facilities constructed on the site. Given that coal tars were often buried on site or in adjacent landfills, today few are aware of these waste deposits until the crisis erupts.

What are the Environmental and Human-Health Effects from Wastes Generated by Manufactured Gas Plants?

2-methylnapthalene . . . Acenaphthylene . . . Ancenapthene . . . Anthracene . . . Arsenic. . . . Benzene. . . Benzo(a)anthracene . . . Benzo(a)pyrene . . . Benzo(b)fluoranthene . . . Benzo(k)fluoranthene . . .Chromium . . . Chrysene . . . Cyanide. . . Dibenzo(a,h)anthracene . . . Dibenzofuran . . . Ethylbenzene. . . Fluoranthene . . . Fluorene . . .Indeno(1,2,3-cd)pyrene . . . Lead . . . Methylphenol . . . Napthalene . . . Phenanthrene . . . Phenols . . . Polynuclear / Polycyclical Aromatic Hydrocarbons (PAHs). . . Pyrene . . .Semi-Volatile Organic Compounds (SVOCs). . . Toluene. . . Volatile Organic Compounds (VOCs). . . Xylenes

For over a century and a half the manufactured gas industry played a vital role in the nation's economy. More than 50,000 gas works operated at various times during that period. During the

life span of the industry **tens of billions of gallons** of extremely hazardous wastes were generated by the industry . . . **tens of billions of gallons.**

As anyone who follows the nightly news is aware, there is an intense, ongoing debate among many in our society regarding the nature of the hazards and dangers posed by certain of the COCs that are a byproduct of our industrialized civilization. In most cases, the debate does not focus on whether or not these substances pose threats to the environmental and human health. The debate focuses on maximum contaminant levels (MCLs), the amount of these COCs needed to pose the threat.

Two branches of the US Department of Health & Human Services, the National Library of Medicine and the Agency for Toxic Substances and Disease Registry (ATSDR) provide information on these and many more COCs. Both of these agencies rely upon a wide range of sources for their information. Drawing upon this information one can see why many are concerned about the COCs found in coal tar and other wastes generated by the manufactured gas industry.

If we examine just a handful of those hundreds of COCs that are found in coal tar, we can begin to see the potential hazards posed by the wastes generated at manufactured gas plants.

- Arsenic
- Benzene
- Chromium
- Lead
- Phenols
- Polynuclear Aromatic Hydrocarbons (PAHs)
- Toluene
- Xylenes

The fact that all of these COCs have been found at current or former National Priorities List (NPL) sites, provides some sense of the extent to which they are of concern as environmental contaminants in the US. Of course, not all of those NPL sites are associated with the manufactured gas industry. NPL sites are those identified by US EPA as being the most serious hazardous waste sites in the nation and those that are targeted for long-term federal cleanup activities.

- Arsenic has been found in at least 1,014 of the 1,598 current or former NPL sites.
- Benzene has been found in at least 816 of the 1,428 current or former NPL sites.
- Chromium has been found in at least 1,036 of the 1,591 current or former NPL sites.
- Lead has been found in at least 1,026 of the 1,467 current or former NPL sites.
- Phenol has been found in at least 481 of the 1,467 current or former NPL sites.
- Polynuclear Aromatic Hydrocarbons (PAHs) have been found in at least 600 of the 1,467 current or former NPL sites.
- Toluene has been found in at least 851 of the 1,467 current or former NPL sites.
- Xylene has been found in at least 658 of the 1,467 current or former NPL sites.

Arsenic

Arsenic exists naturally and occurs widely in the natural environment. It is also a very common by-product of past and present industrial activities. Many of the anthropogenic arsenical compounds are especially soluble in water, thus presenting a threat to water supplies.

At high levels, arsenic can act as both a chronic and acute poison to humans and to animal and plant life. Indeed, arsenic has at times been widely marketed as a commercial pesticide.

Aside from its properties as a poison, there is a substantial body of evidence indicating that arsenic compounds are carcinogenic in nature. The Department of Health and Human Services (DHHS), the International Agency for Cancer Research (IARC), US EPA and the World Health Organization (WHO) believe that there is sufficient evidence to classify certain arsenical compounds carcinogens.

Benzene

Although benzene is commonly found in the environment, it appears that its ultimate source is past and present industrial activities. Benzene breaks down relatively slowly in water and soil. It is water-soluble and can pass through the soil into underground water..

At relatively high exposure levels, benzene is extremely toxic, even fatal, to humans and other organisms. The Department of Health and Human Services (DHHS), the International Agency for Cancer Research (IARC), and US EPA have determined that benzene is carcinogenic to humans. Benzene is known to cause blood disorders and damage to immune systems in humans and other organisms. Some studies indicate that benzene may be harmful to the reproductive organs and produce harmful effects on the developing fetus.

It is also worth considering that benzene served as the raw material from which such substances as DDT and PCB were manufactured.

Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and in volcanic dust and gases.

Certain chromium compounds do not appear to have adverse environmental or human health effects..

In humans, other chromium compounds have been linked to stomach ulcers, convulsions, kidney and liver damage, and at high levels to death. The Department of Health and Human Services (DHHS), World Health Organization (WHO), and the International Agency for Cancer Research (IARC) have determined that some chromium compounds are carcinogenic to humans.

It is believed that chromium can concentrate in human fetuses and that it can be transmitted from mother to infant through breast milk.

Reproductive disorders have been observed in animals that were exposed to certain chromium compounds. Death, skeletal deformities and impaired development of the reproductive system have been observed in newborn animals that ingested certain chromium compounds.

Lead

Although lead compounds are naturally occurring, most of the lead found throughout the environment comes from anthropogenic activities. Certain lead compounds are water-soluble and pose a threat to plants and animals and to human water supplies.

In humans and other animals lead acts as a central nervous system toxin. High levels of exposure may cause brain damage. Lead exposure is also linked to blood disorders, kidney damage, miscarriages, and reproductive disorders.

The Department of Health and Human Services (DHHS) and the World Health Organization (WHO) have determined that certain lead compounds are carcinogenic to humans.

Phenols

Although phenol occurs naturally, it is important to note that some phenol compounds are used as pesticides.

In humans, high exposure to phenols can result in: muscle pain, anorexia, liver damage, weight loss, blood disorders, and fatigue and to increased risks of respiratory cancer, heart disease, immune system disorders.

In animals, high exposure to phenols can result in: muscle tremors and loss of coordination, paralysis, severe injury to the heart, kidneys, liver, and lungs, followed by death in some cases.

Although animal studies suggest a link between phenols and cancer, it has not yet been definitively classified as a human carcinogen.

Polynuclear / Polycyclical Aromatic Hydrocarbons (PAHs)

PAHs are a group of chemicals that are formed during the incomplete combustion of organic materials. They can occur naturally, however, most PAHs found today in the environment are the result of anthropogenic activities. While ATSDR recognizes more 100 different PAHs, other sources estimate that there are as many as 3,000 possible combinations of PAH compounds.

In the environment PAHs are slow to breakdown or degrade and thus comprise long-terms sources of environmental contamination.

The Department of Health and Human Services (DHHS) has determined that the following PAHs are likely to be carcinogenic:

benz[a]anthracene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

The International Agency for Research on Cancer (IARC) has determined that the following PAHs are likely to be carcinogenic:

benz[a]anthracene and benzo[a]pyrene benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-c,d]pyrene,

US EPA has determined that the following PAHs are likely to be carcinogenic:

benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

Toluene

Although it is naturally occurring, most of the toluene found throughout the environment comes from anthropogenic activities.

In humans, toluene has been linked to headaches, confusion, and memory loss. Evidence also suggest that toluene can cause damage to the lungs, liver, and kidneys.

In animals, toluene has been observed to adversely effect the nervous system. Animals exposed to toluene may also show slightly adverse effects in their liver, kidneys, and lungs.

Toluene has not yet been definitively classified as a human carcinogen.

Xylenes

Although they are naturally occurring, most of the xylene compounds found throughout the environment come from anthropogenic activities.

In humans, exposure to xylenes can cause irritation of the skin, eyes, nose, and throat; and impaired functioning of the lungs, liver and kidneys. Xylene exposure can also result in damage to the nervous system. Exposure to very high levels of xylene for even a short period can result in death.

Exposure of pregnant women to high levels of xylene may cause harmful effects to the fetus. Animal studies indicate that xylene exposure may cause increased numbers of deaths, decreased weight, skeletal changes, and delayed skeletal development.

Xylene has not yet been definitively classified as a human carcinogen.

What Is the Cost of Cleanup at Former Manufactured Gas Plants Sites?

Many former manufactured gas plants must undergo environmental cleanup. In some instances, responsible parties are assessed cleanup costs at these sites. When no responsible or potentially responsible party (PRP) exists, state and federal governments bear the costs of cleanup.

The following are a few examples of what cleanup / remediation at these sites can involve.

From approximately 1888 to 1944, a manufactured gas plant operated on a 12-acre site near the confluence of two creeks near Stroudsburg, Pennsylvania. During the time that the plant was in operation, coal tars and other waste products were disposed of onsite in an open pit. In the 1980s, these wastes began leaking into the nearby waterways. The wastes were found to contain VOCs including benzene, toluene, and xylenes; various other organics including PAHs; and metals including arsenic.

The site was listed on the National Priorities List (NPL). NPL sites are those identified by US EPA as being the most serious hazardous waste sites in the nation and those that are targeted for long-term federal cleanup activities. State and federal agencies became involved in cleanup at the site.

Cleanup at the site involved the dredging and treatment of approximately 900 cubic yards of sediment from the waterways and the construction of barriers to prevent further seepage of wastes into the creeks. Cleanup / remediation also involved the removal of some 8,000 gallons of coal tar, and in situ treatment of hundreds of cubic yards of contaminated soils.

- US EPA estimated that cleanup cost at this 12-acre site would exceed $4 million dollars. Remediation activities are expected to continue for years to come.

From 1892 to 1932 a manufactured gas plant operated on a 1-acre site in Christian County, Illinois. It is believed that much of the coal tar produced at this plant was sold for feedstock or other uses and disposed of in offsite landfills. Despite the removal of wastes from the gas works, in the 1980s federal and state agencies determined that the site was contaminated and posed a threat to local ground water supplies. The site was named to the NPL.

The primary COCs found in association with the site were: VOCs, including benzene, toluene, and xylenes; and other organics, including PAHs and phenols.

Cleanup / remediation at the site involved removing over 12,000 cubic yards of contaminated soil, this included removing 9,000 cubic yards of soil down to the ground water table. The plugging and abandoning private drinking water wells in the area and providing affected residents with access to public drinking water supplies.

- US EPA estimates that the cost of cleanup at this **one acre site** will exceed $9.3 million including an annual Operations and Maintenance (O&M) cost of $401,400 for 30 years.

From 1878 to 1950 a manufactured gas plant operated at a 1.3-acre site in Jefferson, Iowa. The site was also used as a disposal site for coal tars and associated wastes from other gas works. In 1986, it was discovered that COCs from the site were contaminating local ground water supplies.

The primary COCs found in association with the site were: VOCs, including benzene, toluene, and xylenes; and other organics, including PAHs; and metals, including arsenic, chromium and lead.

Remedial action involved the removal of more than 3,800 cubic yards of contaminated soil and sediments from the site. Cleanup also included the pumping and treatment of an estimated 1.5 million gallons of contaminated ground water.

- US EPA estimates that the cost of cleanup at this site will exceed $5.8 million including an Operations and Maintenance (O&M) cost of $4,762,000 for 30 years.

Former Manufactured Gas Plants - A Legacy for the Twenty-First Century

Perhaps as many as 50,000 mmanufactured gas plants operated in the United States from ca. 1815 to ca. 1960. Today in scores of communities across America, the environmental effects of coal gas manufacturing are being addressed. From rural villages to urban metropolises, Americans are discovering that former manufactured gas plants (FMGPs) can, and often are, waiting to be discovered in their backyards.

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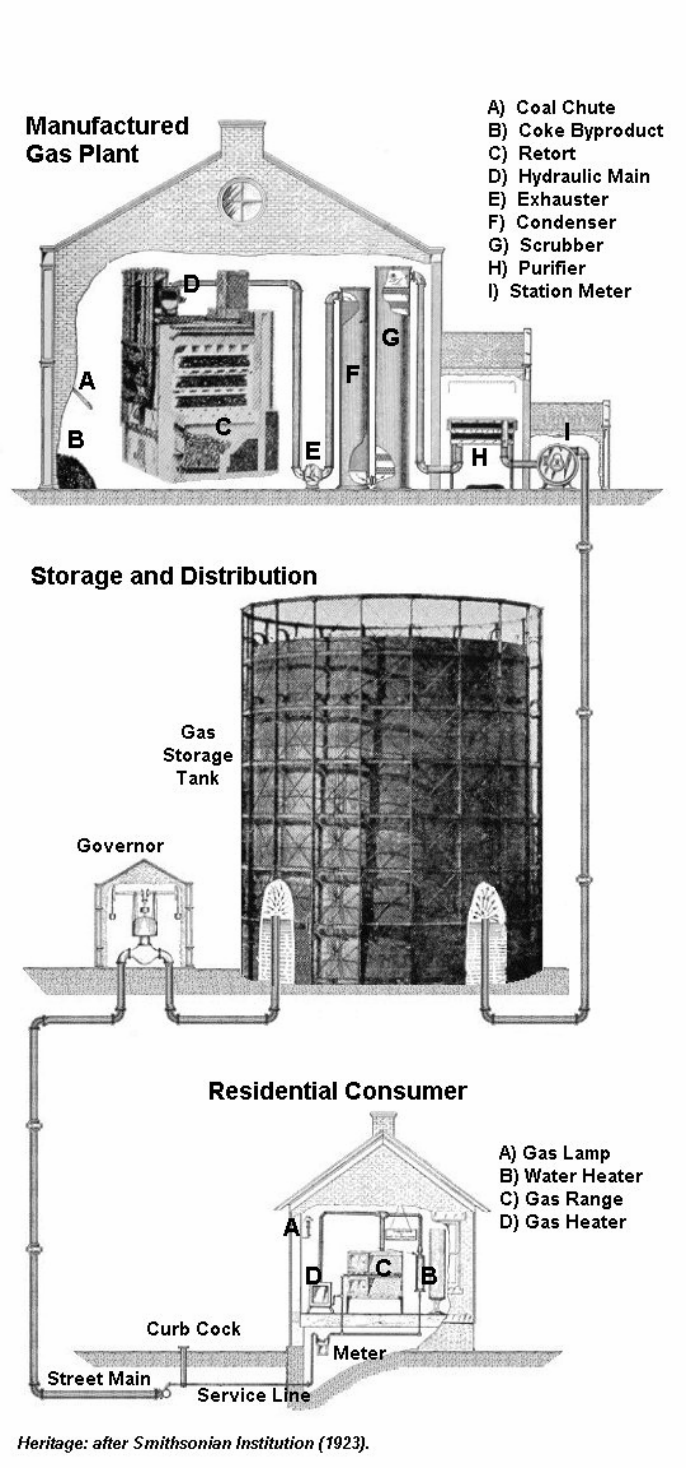
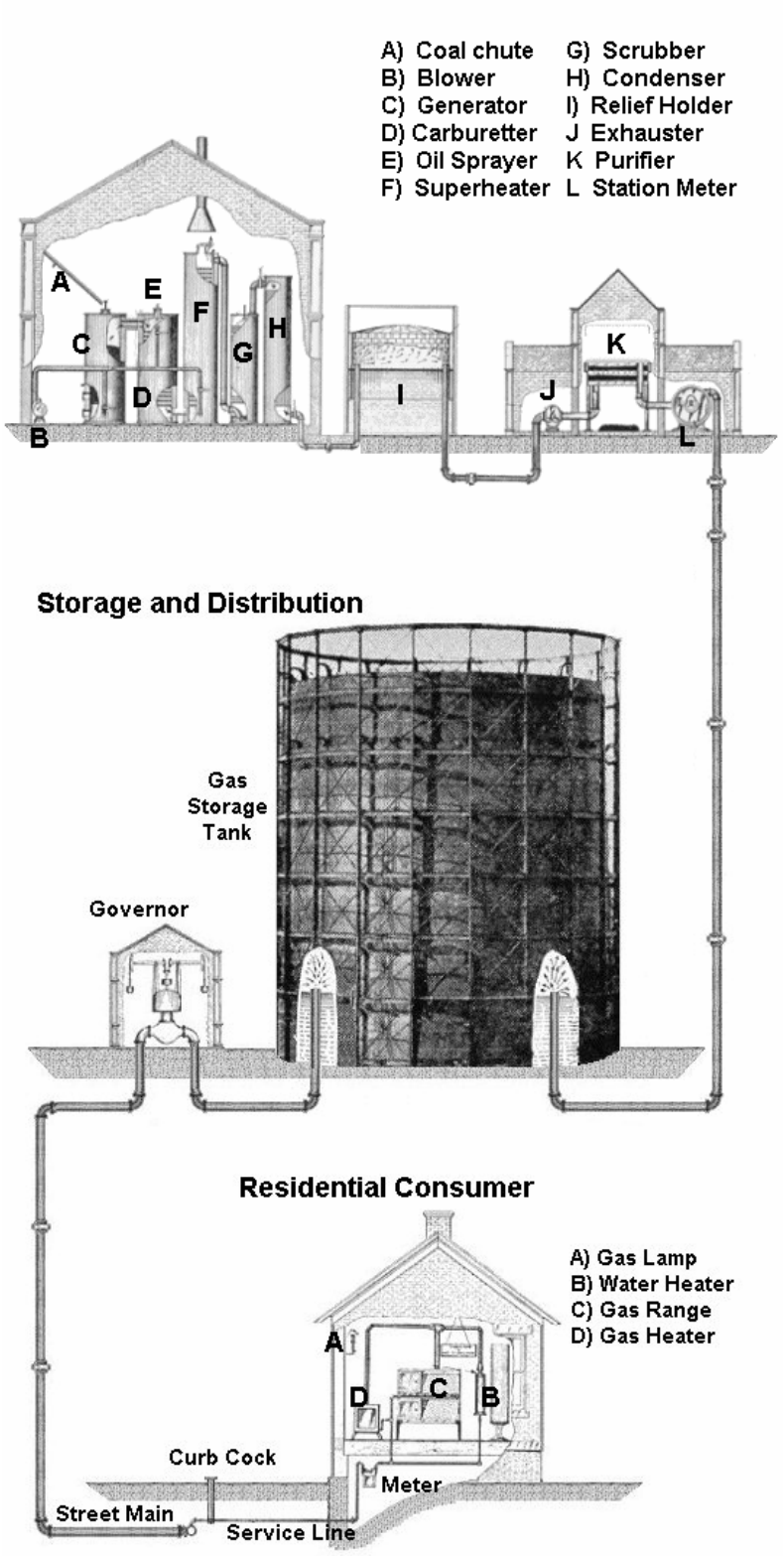
Illustrations and Photographs

The Manufacture of Coal Gas



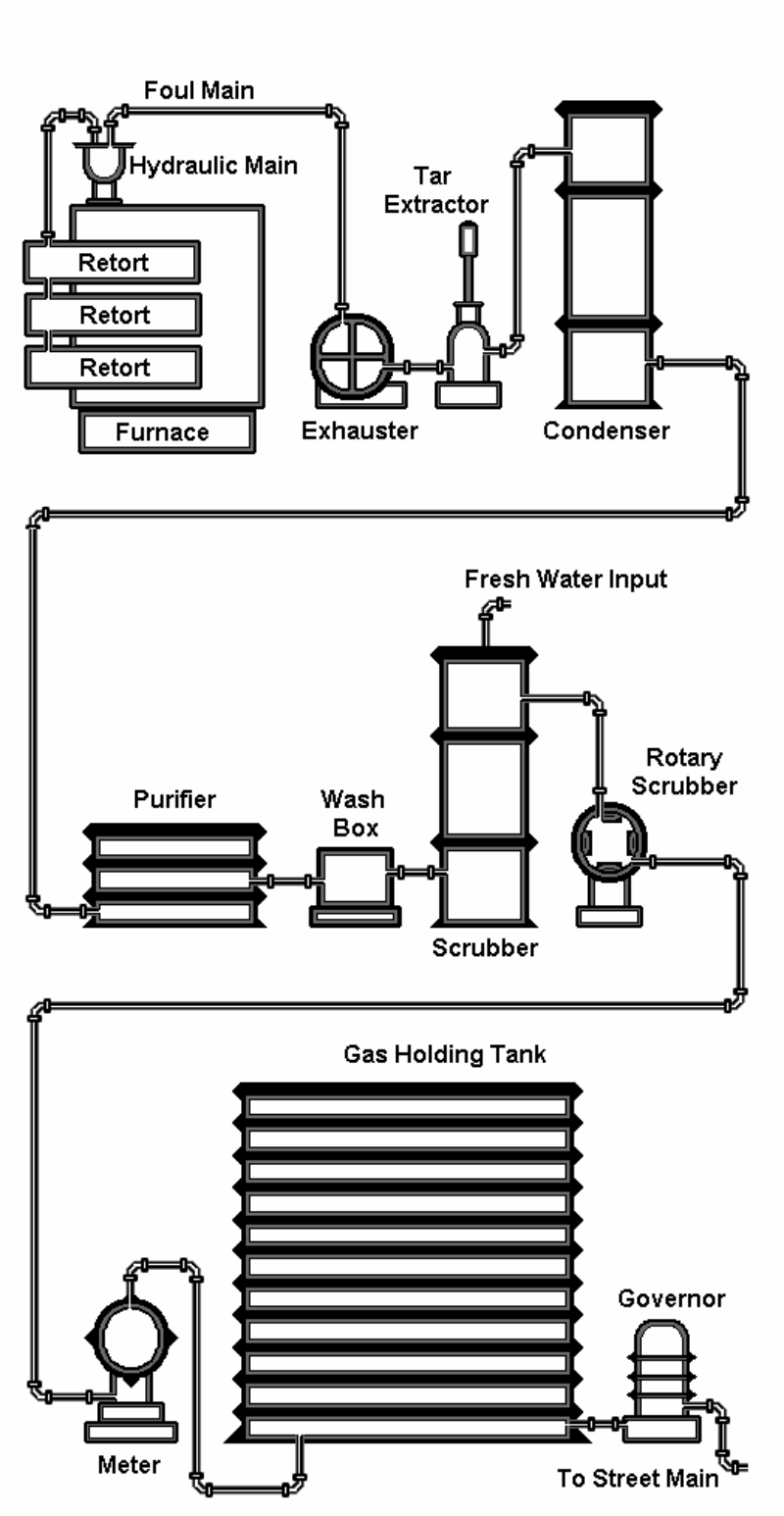
Heritage: after Smithsonian Institution (1923).

The Manufacture of Carburetted Water Gas



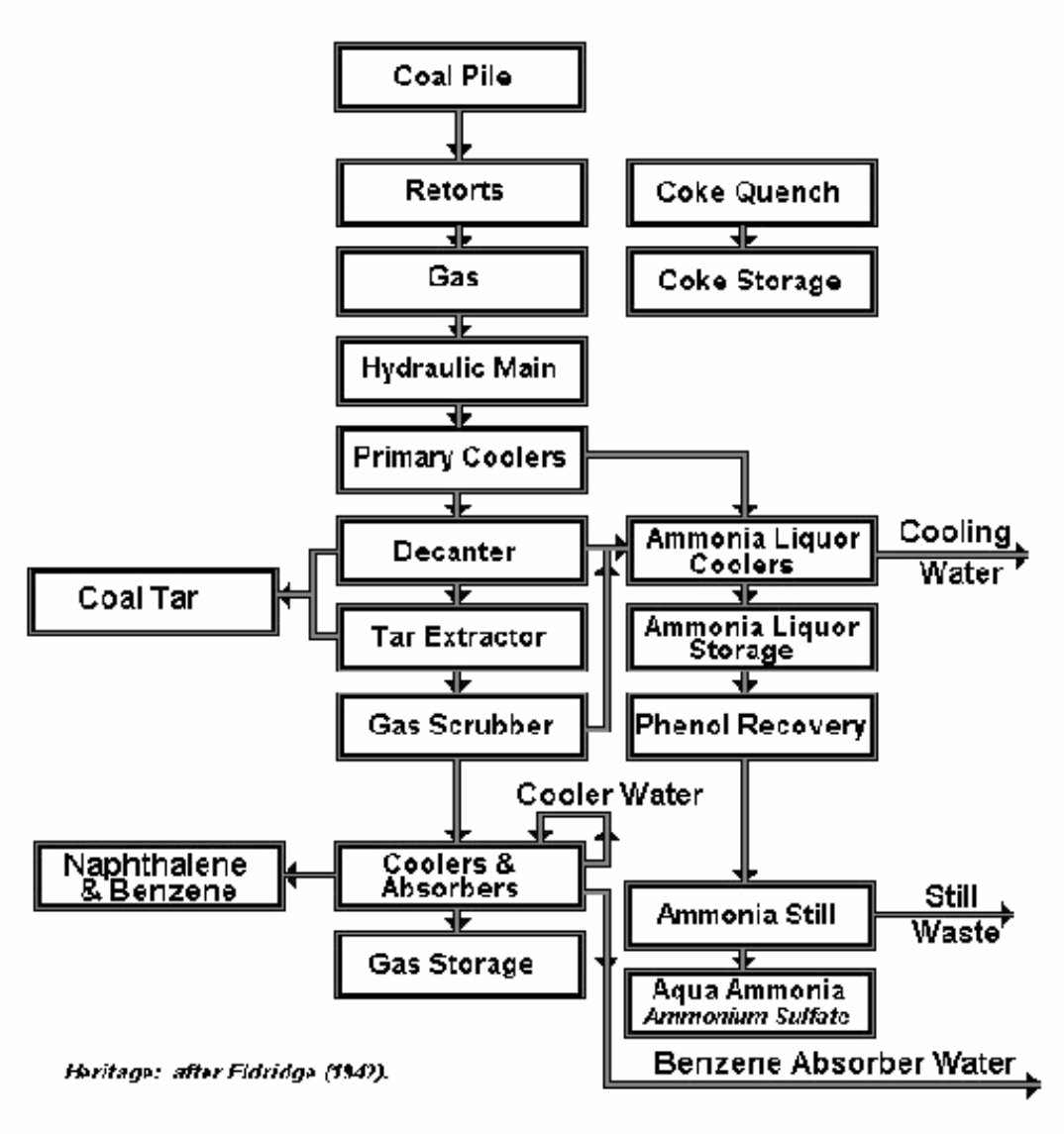
Heritage: after Smithsonian Institution (1923).

Schematic: Manufactured Gas Plant

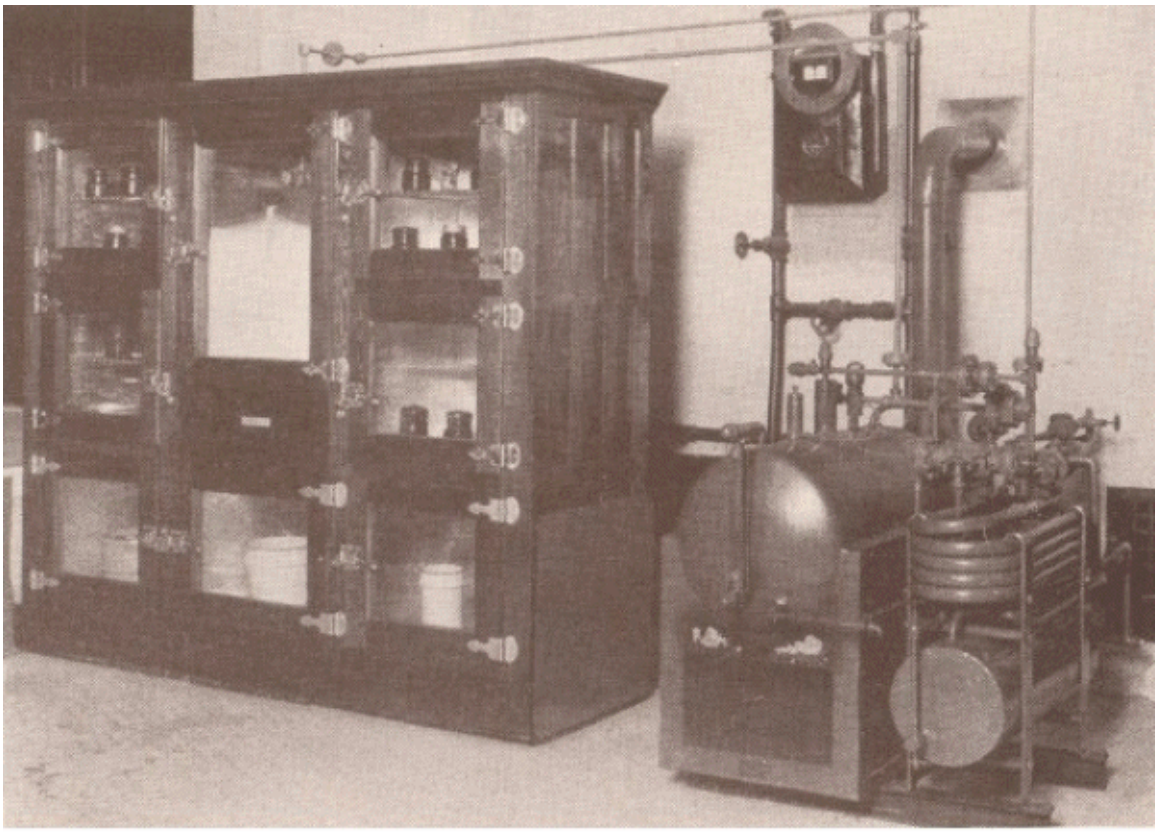


Heritage: after Norman (1922).

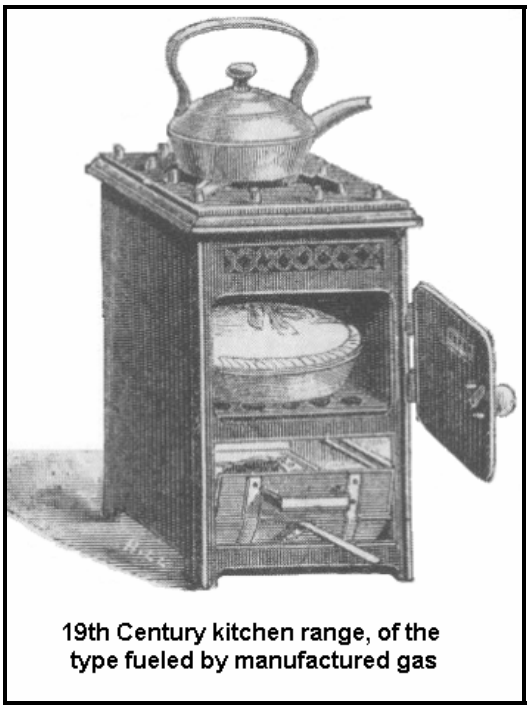
Flowchart: Coke & Coal Gas Manufacturing Process



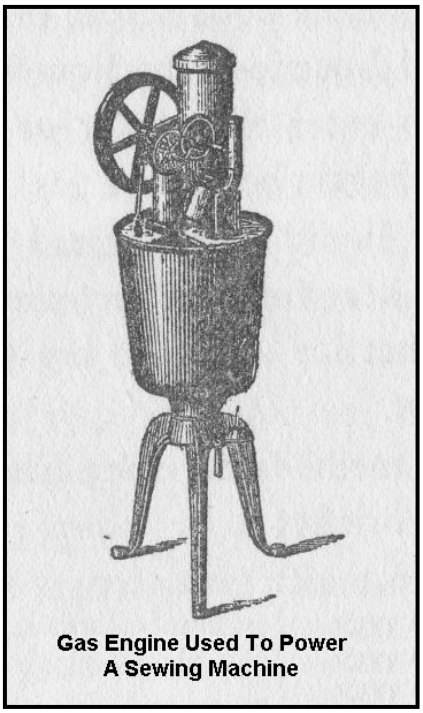
Producer-Gas Plant, St. Louis, Missouri, ca 1911
Source: Fernald and Smith / US Bureau of Mines (1911).



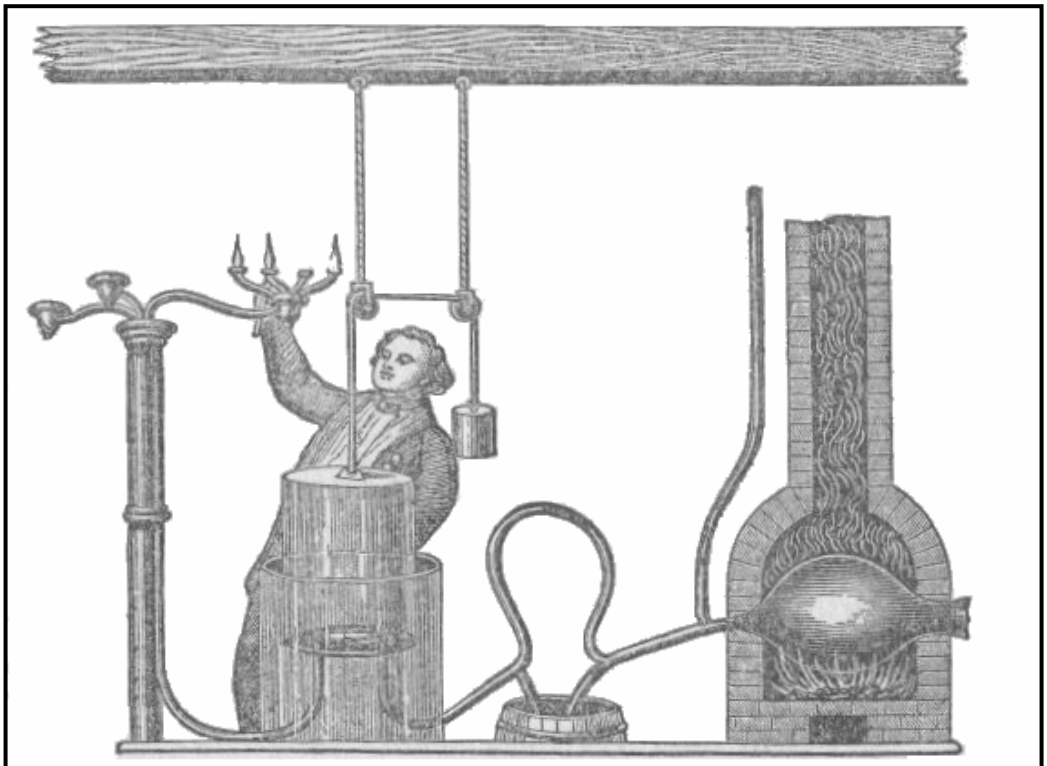
Producer Gas Plant used to fuel ice making machinery, ca 1920



19th Century kitchen range, of the type fueled by manufactured gas



Gas Engine Used To Power A Sewing Machine



Late 18th Century Experimental Manufactured Gas Plant