

BEFORE

THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Application of)	
Duke Energy Ohio, Inc., for an)	Case No. 12-1685-GA-AIR
Increase in Gas Rates.)	
 In the Matter of the Application of)	
Duke Energy Ohio, Inc., for Tariff)	Case No. 12-1686-GA-ATA
Approval.)	
 In the Matter of the Application of)	
Duke Energy Ohio, Inc., for Approval)	Case No. 12-1687-GA-ALT
of an Alternative Rate Plan for Gas)	
Distribution Service.)	
 In the Matter of the Application of)	
Duke Energy Ohio, Inc., for Approval)	Case No. 12-1688-GA-AAM
to Change Accounting Methods.)	

DIRECT TESTIMONY OF
ANDREW C. MIDDLETON, Ph.D.

ON BEHALF OF

DUKE ENERGY OHIO, INC.

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_____	Management policies, practices, and organization
_____	Operating income
_____	Rate base
_____	Allocations
_____	Rate of return
_____	Rates and tariffs
<u> X </u>	Other: Manufactured Gas Plant

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I. INTRODUCTION AND PURPOSE

1 **Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.**

2 A. My name is Andrew C. Middleton, and my business address is P.O. Box 58,
3 Mount Sidney, VA 24467.

4 **Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?**

5 A. I am the President of Corporate Environmental Solutions LLC, which is
6 headquartered at 1348 Beulah Rd., Pittsburgh, PA 15235.

7 **Q. PLEASE SUMMARIZE YOUR EDUCATION AND PROFESSIONAL**
8 **QUALIFICATIONS.**

9 A. I have a Bachelor of Science with distinction in Civil Engineering from Virginia
10 Polytechnic Institute & State University, awarded in 1971; and a Master of
11 Science Degree in Sanitary Engineering also from Virginia Polytechnic Institute
12 & State University, awarded in 1972. In 1975, I earned a Ph.D. in Environmental
13 Engineering from Cornell University. I have been a Registered Professional
14 Engineer in the Province of Ontario since 1975. I am also Board Certified in the
15 area of hazardous waste management by the American Academy of
16 Environmental Engineers.

17 **Q. PLEASE SUMMARIZE YOUR PROFESSIONAL EXPERIENCE.**

18 A. My professional work experience is detailed on my Curriculum Vitae, provided as
19 Attachment ACM-1, which lists my numerous positions. My experience includes
20 service from 1981 to 1988 as Vice President of the Environmental Resources
21 Department of Koppers Company, with responsibility for management of all
22 environmental issues, including operation of more than 50 chemical and allied
23 products plants and more than 50 previously operated plants and disposal sites,

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1 including superfund sites. I founded, and was President of, Keystone
2 Environmental Resources, Inc., a subsidiary of Koppers, offering environmental
3 consulting, analytical, and remediation services through offices in the United
4 States (U.S.) and Canada, focusing on wood treating sites, manufactured gas plant
5 sites, byproduct coke oven sites, chemical plant sites and the design and operation
6 of industrial wastewater and groundwater treatment systems. In this position, I
7 was a principal investigator for a research project funded by the Gas Research
8 Institute on assessment and remediation of manufactured gas plant sites. Starting
9 in July 1988, I served as President of Haniel Environmental Services, Inc., the
10 U.S. branch of a German company specializing in site remediation.
11 Subsequently, I was a Principal with ThermoRetec Consulting Corporation, an
12 engineering and remedial services company specializing in on-site treatment of
13 organic wastes. My work involved day-to-day management of Superfund sites,
14 site remediation, environmental audits of industrial facilities, and other related
15 matters. I moved from this position to be General Manager of ThermoRetec's
16 Site Management and Closure Division and then to serve as Senior Vice President
17 of The RETEC Group, Inc. In 2001, I founded Corporate Environmental
18 Solutions LLC.

19 **Q. PLEASE DESCRIBE YOUR DUTIES AS PRESIDENT OF CORPORATE**
20 **ENVIRONMENTAL SOLUTIONS LLC.**

21 **A.** I am responsible for technical, operational, and business affairs. I provide senior
22 consulting services in the areas of corporate environmental management,
23 environmental risk characterization and management, environmental dispute

1 resolution, site assessment and remediation, and treatment of industrial
2 wastewaters.

3 **Q. PLEASE PROVIDE AN OVERVIEW OF YOUR EXPERIENCE WITH**
4 **MANUFACTURED GAS PLANT SITES.**

5 A. My industrial experience included a large number of environmental projects
6 relating to byproduct coke plants and other facilities involving the production,
7 processing, and handling of tar and tar chemicals, including ones addressing
8 industrial wastewater treatment and industrial site investigation and remediation.
9 All of these projects provided experience relevant to manufactured gas plant
10 (MGP) sites. As an environmental consultant, I have worked on over 300 MGP
11 sites, including visits to at least 145 sites. My scope of work on the vast majority
12 of those 300 sites included a review of historical information about each plant. In
13 the course of my research concerning these 300 MGPs and the manufactured gas
14 industry in general, I have also seen and reviewed information concerning
15 numerous other MGPs. I have testified on seven occasions before state public
16 utility commissions regarding MGPs. I have also testified about MGPs in a
17 number of lawsuits across the U.S. in depositions and affidavits, as well as twice
18 in court proceedings, where the courts recognized me as an expert on
19 manufactured gas plants.

20 **Q. HAVE YOU PREVIOUSLY TESTIFIED BEFORE THE PUBLIC**
21 **UTILITIES COMMISSION OF OHIO?**

22 A. I have not previously testified before the Public Utilities Commission of Ohio
23 (Commission). A list of my previous experience testifying before similar agencies
24 in other states is included in Attachment ACM-1.

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1 Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY IN THESE
2 PROCEEDINGS?

3 A. My testimony will address the history of the manufactured gas industry in the
4 U.S., industry practices with regard to generating and managing residuals from
5 gas manufacture during the time when the MGPs were operational, and the
6 development of understanding with regard to the contaminants that resulted from
7 those operations, along with the current industry practices with regard to
8 remediation of the resultant issues.

II. HISTORY OF THE MANUFACTURED GAS INDUSTRY IN THE U.S.

9 Q. PLEASE PROVIDE AN OVERVIEW OF THE HISTORY OF GAS
10 MANUFACTURING.

11 A. Although "gas" was first named in 1609, the first gas company was not founded
12 until over 200 years later in London in 1812. The first U.S. gas company was
13 founded in Baltimore in 1816. A century later, by 1920, the U.S. had over 1,000
14 manufactured gas companies. However, by 1970, utility-owned or -operated
15 MGPs were almost non-existent, with manufactured gas having been replaced by
16 natural gas across the U.S. The 150-year period from 1816 until the mid-1960s
17 defines the era of manufactured gas (MGP Era). During the MGP Era, the U.S.
18 manufactured gas industry began, matured, and ended. Various gas-making
19 processes, gas storage vessels, and gas purification equipment were developed
20 and modified throughout much of the MGP Era.

21 With regard to the size of this industry, in 1985 the Radian Corporation
22 issued a report on a survey of historic MGP locations in the U.S. for the period
23 1880-1950. This report included a list of historic locations by city and state and it

1 identified over 1500 such locations. Attachment ACM-2 is a map of the U.S.
2 showing the number of locations by state based on this report. The list includes
3 90 locations in the state of Ohio. These numbers likely understate the total
4 number of MGPs. The Radian report was based on a survey of gas directories in
5 the decade years beginning in 1880 and running through 1950, but not all MGP
6 locations were identified in the survey. For example, the survey did not include
7 all locations before 1880 and it did not necessarily include all multiple locations
8 in a given city. However, it documents that there was a large number of MGP
9 locations across the U.S. and provides insight into the parts of the country where
10 they were located.

11 **Q. HOW WAS MANUFACTURED GAS MADE?**

12 A. Three types of gas-making processes generally dominated the manufacture of gas
13 in the U.S. during the MGP Era: coal gas, carburetted water gas (also known as
14 just "water gas") and oil gas, typically with heat contents in the range of 500-600
15 British thermal units per standard cubic foot of gas (Btu). As will be discussed
16 below, one form of oil gas manufacture resulted in a higher heat content of around
17 1000 Btu, which is near that of natural gas.

18 Coal Gas Manufacture (or Coal Carbonization)

19 Coal gas manufacture, also known as coal carbonization, which began in
20 1816, had two primary process configurations: retorts and byproduct coke ovens.
21 Retorts were the first apparatus used and they were smaller vessels more widely
22 used by the gas industry throughout the MGP Era than the larger byproduct coke
23 ovens.

1 In either case, bituminous coal was heated to a high temperature in a
2 closed vessel (*i.e.*, a retort or a coke oven) in the absence of air. Attachment
3 ACM-3 is a schematic diagram of the coal gas process. Heating of bituminous
4 coal resulted in the volatile portion of the coal, approximately 30% by weight,
5 being driven off as hot gas, which was then cooled and purified through various
6 processes. The hot gas emanating from the closed vessel was first immediately
7 quenched with water, which cooled it and condensed coal tar. Quenching
8 occurred in a hydraulic main, which was a pipe continuously flowing with water
9 and also receiving the hot gas from the retorts or ovens. The resulting coal tar and
10 water mixture flowed to quiescent basins for separation, with substantial recycling
11 of the water back to quenching and recovery of the coal tar. Following
12 quenching, the coal gas went through further purification steps to remove
13 additional gas constituents. The purified gas was stored in gas holders prior to its
14 distribution. The remaining part of the coal was coke, which came out of the
15 retorts or ovens in a red hot state that needed quenching with water. Coke was a
16 high-carbon material used as fuel (*e.g.*, under the retorts), in metallurgical
17 processes, or as feedstock to the carburetted water gas process. Today, coke is
18 still manufactured from bituminous coal in byproduct coke ovens for use in
19 metallurgical processes.

20 Attachment ACM-4 contains drawings of the front and side views of a
21 coal gas retort bench containing six individual retorts. The front view shows that
22 the retorts typically had a D-shaped cross section. The sectional side view shows
23 the length of the retorts back into the bench. The firebox at the bottom received
24 coke, which was burned to generate the heat for the retorts.

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1 Attachment ACM-5 shows pictures of a byproduct coke oven installation.
2 These installations were much larger than retort benches. The individual ovens
3 were narrow, tall rectangles that could be opened on both ends. Coke ovens were
4 constructed in long rows called batteries. The firebrick structure below and
5 between individual ovens contained passageways. These ovens were heated by
6 burning gas within these passageways.

7 Carburetted Water Gas

8 Carburetted water gas manufacture made gas from coal or coke plus some
9 form of oil, in three cylindrical vessels in series. T.S.C. Lowe invented the
10 carburetted water gas process in the 1870s and, by the early 1900s, it had become
11 the dominant process in the U.S., surpassing coal gas manufacture. In many
12 locations, coal gas and carburetted water gas were both used at the same time.

13 The process was cyclical alternating in first heating of the firebrick in the
14 second two vessels by burning coal or coke in the first vessel and then in making
15 gas in all three vessels by steam and oil addition. Attachment ACM-6 shows a
16 schematic diagram of the carburetted water gas process. True water gas (also
17 referred to as blue gas) was first made by reacting red-hot coal or coke with steam
18 in the generator, the first of the three vessels used in the process. To generate
19 sufficient heating or illuminating capacity to be distributed to the public, true
20 water gas had to be carburetted. This was accomplished by passing the true water
21 gas into a second vessel, the carburetter, where the gas was sprayed with oil or an
22 oil fraction (*e.g.*, a light or heavy fuel oil). The oil or oil fraction vaporized,
23 began thermally cracking to form gas, and was finally converted permanently to
24 gas in the third vessel, the superheater.

1 As with coal carbonization, the gas was immediately quenched upon
2 exiting the gas generation equipment in a wash box to cool it and condense
3 carburetted water gas tar. The resulting tar and water mixture flowed to quiescent
4 basins for separation, with substantial recycle of the water and recovery of the tar.
5 Following the wash box, carburetted water gas went through further purification
6 steps to remove additional constituents and then flowed to the storage and
7 distribution system.

8 Carburetted water gas manufacture was more flexible in operation than
9 coal gas manufacture, and it also converted most of the coal or coke to gas, in
10 contrast to coal gas, which resulted in a substantial amount of coke.

11 Carburetted water gas tar was similar, but not identical, to the coal tar
12 produced by the coal gas process. The difference resulted from the use of
13 petroleum in the gas manufacturing process rather than solely bituminous coal as
14 for coal gas manufacture.

15 Oil Gas

16 Oil gas manufacture had three general process configurations: small-scale
17 oil gas, West Coast oil gas and high-Btu oil gas. These processes made gas from
18 crude oil or some fraction of oil, often in conjunction with the use of steam.
19 There were many equipment configurations for the small scale oil gas processes,
20 which were used predominantly in the 1800s. In this testimony, the term "oil gas"
21 will mean either the West Coast oil gas process or the high-Btu oil gas process
22 (*i.e.*, excluding the small-scale oil gas processes).

23 The West Coast oil gas process was first used in major installations in the
24 early twentieth century on the West Coast and continued to be used throughout

1 the MGP Era, including installations on the East Coast. The West Coast oil gas
2 processes were first developed in the 1890s with the first major oil gas plant
3 beginning operation in 1902 in Oakland, California. Oil gas manufacture was
4 economically beneficial in situations where crude oil was more readily available
5 and less costly than coal, such as on the West Coast of the U.S. in the early 1900s.

6 Attachment ACM-7 includes schematic diagrams of two configurations of
7 the West Coast oil gas process. The process was cyclical and it relied on one
8 (single-shell oil gas) or two vessels (two-shell oil gas) filled with firebrick in a
9 manner to create gas passageways. In the first cycle, oil was burned in the vessels
10 to heat the firebrick to a high temperature. In the second cycle, manufacture of oil
11 gas occurred by injection of steam and additional oil into the hot vessels, which
12 caused a reaction to form gas.

13 As with the carburetted water gas process, the hot gas exited the vessel
14 into a wash box, in which it was quenched with water. This quenching caused,
15 depending on the process, lampblack and/or oil gas tar to separate from the gas.
16 Lampblack was fine carbon particles in the gas. The relative proportions of
17 lampblack and tar in the hot gas depended on the operational conditions of the oil
18 gas process. For example, the oil gas process could have been configured and
19 operated to produce more lampblack and less tar. Also, depending on the
20 configuration and operation of the wash box, the degree of separation of
21 lampblack and tar could have been affected. For example, primary removal of
22 lampblack from the gas could have been accomplished in the wash box, with tar
23 removal in subsequent purification steps, by the design and operation of the wash
24 box. The resulting lampblack-water mixture or oil gas tar-water mixture typically

1 flowed to quiescent basins for separation of the water and recovery of the
2 lampblack and tar. Following the wash box, gas was further purified to remove
3 additional constituents.

4 After conversion to natural gas, many gas companies used the high-Btu oil
5 gas process for supplementing natural gas supplies in times of high demand (*i.e.*,
6 peak shaving). The high-Btu oil gas process was generally developed for
7 application when gas companies were switching from manufactured gas to natural
8 gas. High-Btu oil gas was a modification of oil gas manufacture that resulted in
9 the manufactured gas having a heat content of approximately 1000 Btu per cubic
10 foot, thus allowing it to be compatibly mixed with natural gas. Typically, the role
11 of this process was to be on standby such that, during periods of peak demands
12 (*e.g.*, colder winter times), it could be activated to supplement natural gas
13 supplies. This process was often used just a few days or weeks per year. The
14 high-Btu oil gas process could be developed either by modifying a carburetted
15 water gas process or a regular oil gas process. Its operation was similar to that of
16 the oil gas process.

17 Other Processes and Gas Sources

18 In addition to the three major processes, there were at times other gas-
19 making processes used less frequently than those discussed above (*e.g.*, refinery
20 gas reforming or rosin gas manufacture).

21 Lastly, there were instances where gas companies purchased the excess
22 coal gas made in byproduct coke ovens owned and operated by non-utilities (*e.g.*,
23 steel companies). As necessary, the gas companies purified this gas made by

1 others to a quality satisfactory for distribution to their customers. Typically, this
2 purification was for removal of sulfur compounds to a lower required standard.

3 **Q. WHAT WAS THE VARIABILITY OF THE VARIOUS PROCESSES FOR**
4 **THE MANUFACTURE OF GAS?**

5 A. The 1924 edition of Brown's Directory of American Gas Companies provided a
6 breakdown of the types of MGPs listed in that edition:

7	• coal gas plants:	201
8	• [carburetted] water gas plants:	429
9	• oil gas plants:	35
10	• mixed: coal & water:	151
11	• mixed: water & oil:	49
12	• mixed: water & coke oven	8
13	• other variations:	23
14	• distributing (gas purchased):	88
15	• byproduct coke ovens:	82
16		Total 1,066

17 This breakdown illustrates the predominance of water gas and coal gas plants in
18 the early twentieth century of the MGP Era.

19 **Q. WHAT RESIDUALS DID MANUFACTURED GAS CONTAIN THAT**
20 **NEEDED TO BE REDUCED IN LEVELS BEFORE DISTRIBUTION OF**
21 **THE GAS?**

22 A. The vaporous residuals in hot manufactured gas exiting the gas-making
23 equipment that most commonly required reduction in levels before distribution
24 were tar and sulfur compounds, especially sulfide compounds, for all of the
25 manufacturing processes discussed above. In the case of coal gas, the vaporous
26 residuals also included ammonia and cyanide compounds. If a carburetted water
27 gas or oil gas process used crude oil, the vaporous residuals also included cyanide
28 compounds. At times, some MGPs also removed other vaporous residuals, such

1 as a mixture of benzene, toluene, xylenes and other volatile compounds known as
2 "light oil," as commercial byproducts. In the case of oil gas processes, lampblack
3 required removal before distribution of the gas.

4 **Q. HOW WAS MANUFACTURED GAS PURIFIED?**

5 A. Gas purification removed the residuals described above to recover commercial
6 byproducts and to make the gas suitable for distribution and use. Attachment
7 ACM-8 is a schematic diagram of the overall general gas manufacturing,
8 purification, and storage processes. As described above, the first step in
9 purification was the quenching of the hot gas with water. This occurred in the
10 hydraulic main for coal gas manufacture and in the wash box for carburetted
11 water gas and oil gas manufacture. This quenching step condensed much of the
12 tar vapor resulting in a tar-water mixture for further handling. Where lampblack
13 was present, its removal occurred in this first quenching step. Further removal of
14 remaining tar was accomplished generally by the use of condensers and scrubbers.
15 Additional equipment, such as tar extractors or Cottrell precipitators, was used at
16 some plants as it became commercially available. At coal gas plants, ammonia
17 removal, typically through water absorption, was the next step after tar removal.
18 At some coal gas plants and at byproduct coke ovens, absorption of ammonia into
19 sulfuric acid was used. Depending on the process and scale of operation, light oil
20 and the chemical, naphthalene, may have also been removed, typically by oil
21 scrubbing.

22 The most common last step before gas storage was hydrogen sulfide
23 removal. Prior to the 1880s, lime absorption was the typical process. In the
24 1880s and afterwards, iron-oxide beds became the dominant process. Around

1 1920 and afterwards, some larger plants used a liquid sulfur removal process
2 which had been developed around that time. In the case of coal gas and oil gas
3 plants using crude oil, hydrogen sulfide removal also accomplished cyanide
4 removal from the gas.

5 After hydrogen sulfide removal, the gas went into storage prior to its
6 distribution.

7 **Q. HOW WAS GAS STORED?**

8 A. There were three general types of gas holders used to store manufactured gas: 1)
9 low-pressure, water-seal; 2) waterless, low-pressure; and 3) high-pressure.

10 The low-pressure, water-seal, gas holders were the most common form of
11 gas storage during the MGP Era. This type of holder consisted of a water tank,
12 the holder itself, which could have had multiple telescoping lifts, and structural
13 components and piping. Attachment ACM-9 is a diagram of a low-pressure,
14 water-seal holder with a below-ground, masonry water tank. The water tank was
15 filled with water that sealed the gas within the holder. The holder itself moved up
16 and down within its superstructure as gas was added or removed from it.

17 The waterless, low-pressure holder consisted of a very large, vertical tank
18 with a disk floating on the gas inside. Attachment ACM-10 illustrates a low-
19 pressure waterless seal holder. The purpose of the disk was to contain and
20 pressurize the gas. The disk moved up and down in the interior of the tank as gas
21 was added and removed, respectively. The seal between the perimeter of the disk
22 and the inside of the holder was typically wetted with recirculating tar.

23 High pressure holders were either horizontal cylinders (a.k.a. "bullet
24 tanks," like current propane storage cylinders), vertical cylinders (Attachment

1 ACM-11) or spherical (*e.g.*, the Hortonsphere) (Attachment ACM-12). These
2 tanks received gas from compressors and stored the gas at higher pressures (*e.g.*,
3 30-60 pounds per square inch) than the low-pressure holders. These were
4 mechanically sealed, pressurized tanks, in contrast to the low-pressure holders.

5 Gas holders ranged in size from small (*e.g.*, 25,000 cubic feet in an early
6 low-pressure, water-seal holder) up to very large (*e.g.*, 20 million cubic feet for
7 waterless holders of the 1920s and afterwards).

8 **Q. WHAT RESIDUALS RESULTED FROM THE MANUFACTURE OF**
9 **GAS?**

10 A. As discussed above, purification of gas generated certain residuals: tar and some
11 form of sulfur removal residual from all of the major gas-making processes; some
12 form of ammonia residual from coal gas manufacture; and, at some plants, other
13 residuals like light oil or naphthalene. In addition to these residuals, wastewater
14 was generated by all of the major gas-making processes, coke was generated by
15 coal gas manufacture, lampblack was generated by oil gas, clinker was generated
16 by carburetted water gas manufacture, and ash was generated by burning of coal
17 or coke for heating retorts or making steam in a boiler house. These represent the
18 dominant residuals from gas making. Attachment ACM-13 is a table
19 summarizing these residuals and providing a brief description of them.

20 **Q. WHAT HAPPENED TO THE RESIDUALS FROM GAS**
21 **MANUFACTURE?**

22 A. Residuals included both byproducts and wastes. Byproducts were materials that
23 could be sold or be beneficially used at the MGP. Wastes were the converse –

1 materials that could not be sold or used beneficially. There were three general
2 methods for disposition of these residuals:

- 3 • Sale or Use as Byproducts: Various markets existed at different times for
4 byproducts. These markets changed according to external factors.
5 Byproducts could also be used by a gas company directly or as feedstocks
6 to other manufacturing processes to create more valuable byproducts.
- 7 • Use as Fuel: If residuals had sufficient energy content and had physical
8 and chemical characteristics that could reasonably facilitate use as fuel,
9 they could be burned to generate heat for the gas manufacturing process or
10 in the boiler house to generate steam.
- 11 • Disposal: If residuals could not be sold or used as byproducts or fuel, they
12 became wastes for disposal.

13 The viability of byproduct recovery was dependent on several factors.
14 Economical technologies had to be available to recover byproducts that would
15 meet market specifications, sufficient quantities of material had to be produced to
16 warrant recovery, and there had to be a market for the byproducts. The principal
17 motivation for byproduct recovery was to generate added revenue, reducing the
18 cost of gas to the consumer, thereby making manufactured gas less costly. As
19 part of their oversight role on behalf of the gas consumer, public service
20 commissions often received reports on the recovery and sale or use of byproducts
21 from manufactured gas companies within their respective jurisdictions.

22 **Q. WHAT WAS THE TYPICAL DISPOSITION OF COKE?**

23 A. Coke from coal gas manufacture was a high-carbon content byproduct that was
24 sold for use as fuel or as a component in metallurgical processes (e.g., steel

1 making), or was used at the MGP as fuel or as feedstock to the carburetted water
2 gas process.

3 **Q. WHAT WAS THE TYPICAL DISPOSITION OF TAR?**

4 A. Tar from any of the processes was a byproduct 1) sold for use in making
5 commercial products (*e.g.*, road tar and tar chemicals), 2) used as fuel at the
6 MGP, or 3) used at the MGP as a feedstock for producing commercial products
7 (*e.g.*, road tar and tar chemicals). In its raw state from gas generation, tar
8 contained varying amounts of water. As necessary and practical, tar was
9 dehydrated to make it a suitable byproduct. Various dehydration processes were
10 available to generate lower water-content tar, including heating and centrifugation
11 methods. None, however, proved to be completely practical on every high water-
12 content tar. If a high water-content tar could not be reasonably treated or the tar
13 could not be sold or burned, it was typically stored in tanks, gas holders, or onsite
14 ponds until it could be recovered for sale or use or until it was eventually disposed
15 of as a waste at some point in time, which may have been during a present-day
16 remedial action.

17 **Q. HOW WAS TAR COMMERCIALY USED?**

18 A. Tar is a complex mixture of hundreds of organic chemical compounds, including
19 many polycyclic aromatic hydrocarbons (PAHs). It had, and still has, many
20 beneficial uses. Various companies outside of the gas industry purchased tar
21 during the MGP Era to refine it into commercial products. The primary refining
22 process for tar was distillation into different fractions. The commercial products
23 made from tar included creosote as a preservative for railroad ties and utility
24 poles, road tar, bitumen used for tar roofs, tar coatings, and tar pitch used in the

1 manufacture of aluminum. Some gas companies refined the tar at the MGP and
2 sold the resulting commercial products directly to end users, such as state or
3 county road departments.

4 Substantial volumes of tar were put on the ground in paving roads and
5 streets or for dust suppression on roads and streets, including at locations in Ohio
6 (See Attachments ACM-14 – ACM-19 for road tar advertisements citing locations
7 in Ohio). For example, application rates were up to two gallons of tar binder per
8 square yard of road. On a 20-foot wide road, this would be 23,000 gallons of tar
9 per mile of road. In 1913, the Barrett Company stated that its product, Tarvia,
10 had been used successfully on over 50 million yards of roadways and pavements
11 in this country. For a 20-ft wide road, this quantity in square yards equates to
12 over 4,000 miles of roads and streets. At an application rate of two gallons per
13 square yard, this would equate to 100 million gallons of tar placed on roads and
14 streets.

15 Currently, coal tar (there is no current production of carburetted water gas
16 or oil gas tar) remains a commercial product used for a variety of purposes,
17 including the production of creosote, roofing bitumen, tar pitch for the aluminum
18 industry, and driveway sealer. In addition, certain shampoos (*e.g.*, Westwood-
19 Squibb Sebutone® tar shampoo) contain a USP-grade of coal tar.

20 **Q. WHAT WAS THE TYPICAL DISPOSITION OF AMMONIA?**

21 A. Ammonia from a coal gas process was typically recovered and sold as a chemical
22 source of ammonia or sold or given away as fertilizer. As an example of a
23 commercial use, in the early days of refrigeration, ammonia was the gas used in
24 the compressor equipment.

1 Q. WHAT WAS THE TYPICAL DISPOSTION OF LIGHT OIL?

2 A. In the manufactured gas industry, "light oil" was a liquid recovered from the gas-
3 making process that was made up primarily of volatile aromatic hydrocarbons
4 (e.g., benzene and toluene). Light oil was less dense than, and therefore floated
5 on, water. Without being refined, light oil could be used as fuel or sold as
6 commercial product for use as a feedstock in chemical manufacture. It could be
7 refined into motor fuel for mixing with gasoline or for use by itself. It could also
8 be distilled into its different fractions, thereby serving as a source for commercial
9 chemicals such as benzene. Light oil recovered from the gas of any of the
10 processes was typically sold as a commercial product, used at the MGP as fuel, or
11 processed at the MGP into other commercial products (e.g., motor fuel).

12 Q. WHAT WAS THE TYPICAL DISPOSITION OF RESIDUALS FROM
13 SULFUR REMOVAL?

14 A. There were three general types of material mixtures resulting from sulfur removal.
15 Spent lime was found, primarily in the 1800s, and spent iron oxides were found
16 from the 1880s until the end of the MGP Era. In addition, elemental sulfur was
17 recovered from certain liquid sulfur removal processes from the 1920s until the
18 end of the MGP Era. The typical disposition of these materials was as follows:

19 Spent Lime

20 Spent lime was a mixture of wet lime that had reacted with hydrogen
21 sulfide (and, in the case of coal gas, hydrogen cyanide) to form chemical
22 compounds of sulfide (and cyanide in the case of coal gas). Its use was
23 predominantly before the 1880s when iron oxide sulfur removal was developed;

1 however, its use afterwards continued at some MGPs. It was sold or given away
2 as a soil conditioner or disposed of as a waste.

3 Spent Iron Oxides

4 Spent iron oxide was a mixture of iron compounds, sulfur compounds, and
5 elemental sulfur, as well as the medium on which the iron oxide had originally
6 been fixed. This medium was often wood chips or wood shavings, but it could
7 have been other materials (*e.g.*, corn cobs) depending on the materials available to
8 the MGP. The purpose of the medium was to provide porosity together with a
9 surface for the iron oxide so that the hydrogen sulfide containing gas could flow
10 through a bed of the material and have the sulfide react with the iron. In the case
11 of coal gas and of oil gas using crude oil, the spent iron oxide also contained iron
12 cyanides, as the iron would react with the hydrogen cyanide present in these
13 manufactured gases. Iron cyanides typically converted to Prussian blue or ferric
14 ferrocyanide (FFC), which is a stable compound. Commercially, Prussian blue
15 was and is used as a blue pigment (*e.g.*, artist pigment or laundry bluing).

16 The sulfide removal capacity of the iron oxide could be regenerated
17 several times (known as revivification in the gas industry). Revivification was
18 accomplished by removing the iron oxides and placing them on the MGP site for
19 exposure to air, or by adding air to the gas entering the purification process.
20 However, at some point no further revivification could be attained and they
21 became "spent."

22 The spent oxides were typically used as fill materials, disposed of as a
23 waste, or sold or used as sources of chemicals. An example of this market is the

1 appearance in the 1910s in Brown's Directory Gas Companies of advertisements
2 seeking to purchase spent oxide.

3 Elemental Sulfur

4 Liquid sulfur purifiers were developed in the 1920s for use at larger scale
5 MGPs. The purification process was to scrub the gas with a solution that would
6 absorb the hydrogen sulfide and then treat the scrubber solution to remove the
7 sulfide so the solution could be recycled to the scrubber. In certain of these
8 processes, elemental sulfur was recovered. Elemental sulfur from liquid sulfur
9 purifiers was typically sold as a commercial product or disposed of as a waste if it
10 was not saleable.

11 **Q. WHAT WAS THE TYPICAL DISPOSITION OF ASH AND CLINKER?**

12 A. Ash resulted from heating the retort coal gas process by burning coke underneath
13 the retorts or by burning of coal or coke in the boiler to generate steam. It
14 consisted of the chemical compounds in coal that did not combust. Clinker was a
15 residual of the carburetted water gas process, being the remnants of the coal or
16 coke that did not burn or react in the gas-making process. It consisted of the non-
17 combustible compounds in coal or coke, along with unreacted carbon. Clinker
18 had a slag-like appearance.

19 Ash and clinker were not generally marketable in the U.S. Sometimes,
20 ash was used in building materials and clinker was used in applications like sports
21 running tracks. The majority of ash and clinker was used as fill or disposed of as
22 a waste.

1 **Q. WHAT WAS THE TYPICAL DISPOSITION OF WASTEWATER?**

2 A. Wastewater was the excess water from the gas making and purifying processes,
3 not recycled to the process. Substantial amounts of water were recirculated for
4 hot gas quenching, gas scrubbing, and gas cooling. Typically, the excess water
5 (*i.e.*, wastewater) became an effluent discharged to surface waters, to local
6 municipal sewerage systems, or to the MGP site itself, where its fate depended on
7 the local site hydrologic conditions.

8 **Q. WHAT HAPPENED TO RESIDUALS FOR WHICH THERE WAS NO**
9 **MARKET OR ECONOMIC USE DURING SOME TIME PERIOD IN**
10 **WHICH AN MGP OPERATED?**

11 A. If there was no market or economic use for any of the residuals produced, they
12 became wastes for disposal by the means customary at the time, as discussed in
13 Section III below, which included onsite disposal at the MGP site.

14 **Q. WHY WERE MGPS TAKEN OUT OF SERVICE?**

15 A. MGPs were taken out of service throughout the MGP Era for various reasons.
16 Some plants reached the end of their useful lives and were not replaced. Some
17 were closed when gas could be more economically provided by other larger plants
18 on a regional basis. Many were closed when the introduction of natural gas made
19 them obsolete. Some carburetted water gas plants were converted to high-Btu oil
20 gas plants for peak shaving during the 1940s and thereafter before being closed
21 permanently. Peak-shaving equipment operated intermittently for short periods of
22 time to provide gas during a period of high demand (*e.g.*, very cold winter days).

1 Once taken out of service, the plants were dismantled in whole or in part for
2 various reasons. One purpose was to reduce their assessed value for tax purposes.
3 Another was to allow for reuse or redevelopment of the land.

4 **Q. HOW WERE MGPS TAKEN OUT OF SERVICE?**

5 A. The procedures for taking a plant out of service generally entailed dismantling
6 and demolishing all of the above-ground structures and leveling the site, except
7 where certain buildings were left for future use. Below-ground tanks were filled
8 with building debris or other material to bring them to ground level. Bulk liquids
9 removed from tanks were sold or used as byproducts or fuel, as applicable and
10 practical, or disposed of as waste by means customary at the time. Some portions
11 were often left behind in tanks that were not completely removed (e.g., below-
12 grade water tanks of gas holders of below-grade tar separators). Below-grade
13 pipes were left in place along with the liquids they might contain that were not
14 readily removable. Salvageable materials, such as steel from tanks, were
15 recovered. Solid wastes from above-ground vessels, such as iron oxides, were
16 used as fill or disposed of as waste, including at the MGP site itself.

III. INDUSTRY PRACTICES DURING THE MGP ERA RESULTING IN
 PRESENT-DAY ENVIRONMENTAL IMPACTS

17 **Q. WHAT WASTE DISPOSAL PRACTICES DID THE MANUFACTURED**
18 **GAS INDUSTRY USE?**

19 A. In the manufactured gas industry, as in other industries during the 150-year MGP
20 Era from 1816 until the mid-1960s, when residuals could not be recovered and
21 sold or used as fuel or byproducts, they became wastes for disposal. Wastewaters
22 were typically discharged as effluents to surface waters, municipal sewerage

1 systems, or the MGP site itself. Solids were generally disposed of on land
2 including at the MGP site itself. For example, unusable tar was disposed of in
3 ponds or low-lying areas onsite or offsite. These disposal methods were widely
4 practiced during the MGP Era by MGPs, other types of industry, and
5 municipalities, and were considered to be acceptable and proper. Indeed, due to
6 the state of the technology at that time, there were no other feasible means of
7 disposal.

8 **Q. HOW WERE MGP RESIDUALS RELEASED AT MGP LOCATIONS?**

9 A. In addition to waste disposal at an MGP location, there were several other
10 activities related to the storage and transfer of liquids at an MGP that sometimes
11 resulted in releases of residuals to an MGP site. As liquid byproducts, such as tar,
12 were produced, they were pumped around the plant through piping networks to
13 above- and below-grade processing and storage vessels. Accidental leaks and
14 spills from pipes, pump seals and valves occurred. These incidents resulted in
15 releases of liquids to the site. In addition, leaks and spills of liquids from above-
16 and below-ground tanks, pits, and other vessels, such as gas holders, sometimes
17 also occurred, causing liquids to reach the surface or enter the subsurface of the
18 site.

19 The revivification process for iron oxides from gas purification was also a
20 means through which residuals or their chemical constituents could have been
21 released to the surface of the site. One means to revivify oxide was by spreading
22 it in thin layers on the ground so that air could oxidize the iron sulfide to iron
23 oxide, its reactive state, and sulfur (*i.e.*, *ex situ* revivification). When the oxides
24 could no longer be revivified, they were often removed from the purifier boxes

1 and placed on the ground. Depending on the circumstances, the oxide might be
2 stored on the ground at the MGP for extended periods of time. Eventually, if the
3 oxides could not be sold or used as the source of saleable chemicals, they were
4 used as fill or disposed of on other parts of the site or in offsite disposal areas.

5 Lastly, demolition and dismantling of an MGP often resulted in the release
6 of residuals to an MGP location. This occurred from disposal of waste or leaks
7 and spills during demolition and dismantling at the MGP location. To the extent
8 that residuals were left in below-grade vessels or pipes, these residuals remained
9 at the MGP location.

10 **Q. HOW DID PRESENT-DAY ENVIRONMENTAL IMPACTS RESULT**
11 **FROM HISTORIC MGP ACTIVITIES?**

12 A. Typical operating, disposal, and demolition/dismantling practices during the MGP
13 Era at former MGP sites resulted in environmental contamination of media such
14 as soil or groundwater, as contamination is defined today (*i.e.*, in 2012), which
15 often require remediation under current state or federal laws and regulations.
16 Additionally, pre- or post-MGP activities sometimes also resulted in releases of
17 the same or different chemicals to an MGP site or the spreading of chemicals left
18 behind at the cessation of MGP activities.

19 Beginning in approximately the 1970s, analytical technologies began to
20 become commercially available to measure relatively low concentrations of
21 chemical constituents in the environment, which provided a basis to begin
22 assessing impacts currently understood. A number of organic or inorganic
23 chemicals may possibly be present in now-measurable concentrations in
24 environmental media, such as soil or groundwater at or near a former MGP site as

1 a result of historic gas manufacturing activities. Organic chemical compounds
2 include the following groups: volatile aromatics (*e.g.*, BTEX), phenolics, and
3 polycyclic aromatic hydrocarbons (*i.e.*, PAHs). It should be noted that these
4 groups of compounds generally represent the chemicals possibly present at MGP
5 sites, but they may not represent what actually will be discovered at any specific
6 location. Current testing at a specific MGP site may or may not find any or all of
7 these chemical compounds.

IV. DEVELOPMENT OF AWARENESS OF POLLUTION ISSUES

8 **Q. HOW DID CONSIDERATION OF THE ENVIRONMENT CHANGE**
9 **AFTER THE END OF THE MGP ERA?**

10 A. The MGP Era ended in the mid-1960s before the first Earth Day in 1970, the year
11 that began a modern era of environmentalism (Environmental Era). From 1970
12 onward, the U.S. Congress enacted a series of laws revolutionizing the U.S.
13 approach to environmental regulation and management of air quality, water
14 quality, solid waste, industrial sites, and historic disposal facilities. A national
15 understanding of the impact of historic industrial operating and disposal activities
16 on soil and groundwater quality evolved in the 1970s, resulting in the passage of
17 the "Superfund" Act in December 1980. Laws, regulations, and guidance issued
18 under Superfund and state counterparts formed the foundations of the
19 environmental field of site remediation, a new field of practice in the 1980s.
20 Application of the site remediation process to MGP sites generally began in the
21 1980s and continues through the present as a significant post-MGP Era effort by
22 those deemed responsible for MGP sites.

1 With regard to U.S. EPA's involvement in MGP sites, as mentioned above
2 in Section II, the U.S. EPA engaged the Radian Corporation in the 1980s to
3 prepare a survey of MGP locations in the U.S., which report was issued in 1985.
4 More recently, in 1999, the U.S. issued "A Resource for MGP Site
5 Characterization and Remediation." This document was prepared in conjunction
6 with the Edison Electric Institute, the Utility Solid Waste Activities Group, the
7 American Gas Association, and individual utilities. It was a compilation of
8 innovative strategies and technical approaches for expediting site characterization
9 and source material remediation at former MGP sites.

10 **Q. DURING THE MGP ERA, WHAT WAS THE MANUFACTURED GAS**
11 **INDUSTRY'S UNDERSTANDING OF ENVIRONMENTAL IMPACTS**
12 **WITH RESPECT TO HOW THEY ARE UNDERSTOOD TODAY?**

13 A. Manufactured gas plants' operating, waste disposal, and demolition/dismantling
14 practices were consistent with the practices of other industries, governments, and
15 individuals throughout the U.S during that time. During the MGP Era, which was
16 prior to the Environmental Era, these practices throughout industry and society as
17 a whole were generally regulated by the principle of nuisance control (*e.g.*,
18 controlling offenses to the senses, such as smoke and odors in the air,
19 objectionable tastes in the water, or soot deposition). Nuisances were considered
20 temporary problems and were dealt with as discrete and separate situations in a
21 manner so as to eliminate the immediate offensive condition.

22 An example of the different perspective during the MGP Era as compared
23 to the present (*i.e.*, 2012) is related to iron oxide handling. As described above in
24 Section II, iron oxide was used to remove hydrogen sulfide and hydrogen cyanide

1 from gas. In the late 1800s and into the 1900s, there were newspaper articles
2 about people taking their children to gas plants when the purifying boxes with the
3 iron oxide were being opened to change out the media. According to these
4 articles, breathing the vapors from the purifying boxes brought relief to those
5 suffering from croup, colds, and whooping cough. In the present day, it is
6 difficult to conceive of something similar happening, independent of whether
7 such an activity would pose any significant risk as presently understood.

8 From 1816 until the present, surface water has been accepted as a proper
9 receptor of wastewaters. Discharge of wastewater to surface waters (*e.g.*, rivers)
10 was common for industries and municipalities during the MGP Era and continues
11 to be so today. However, the required degree of treatment of wastewaters
12 throughout this time period has changed significantly, especially during the
13 Environmental Era after passage of the amendments to the Clean Water Act in
14 1972. In 1972, regulations promulgated under the Clean Water Act mandated
15 controls on wastewater discharges across the U.S. based on best practical
16 treatment and subsequently best available treatment. Prior to 1972, a river's
17 capacity to assimilate wastewater discharge was a factor in regulating treatment of
18 wastewaters. The Clean Water Act changed this practice. Since 1972, there have
19 been increasing limitations placed on wastewater discharges based on current
20 understandings of impacts to rivers with respect to present water quality
21 standards. These Environmental Era requirements have also extended to
22 stormwater discharges and runoff from agricultural lands. Present-day regulation
23 of wastewater discharges contrasts greatly to regulation during the MGP Era.

1 From 1816 until the 1970s, land was accepted as the final receptor for
2 many kinds of wastes. Solid and liquid wastes from industries and municipalities
3 were disposed of in open dumps either onsite or offsite, and/or in low-lying areas
4 onsite. In the 1970s, the requirements for land disposal of industrial waste began
5 to change significantly, especially with passage of the Resource Conservation and
6 Recovery Act (RCRA) in 1976.

7 There are several significant examples of industries, other than the
8 manufactured gas industry, that also followed these disposal practices prior to the
9 1980s. In the iron and steel industry, solid wastes from byproduct coke plants
10 were disposed of on land, either onsite or offsite. These wastes consisted
11 primarily of ash, sludges from cleaning of process tanks and vessels, and spent
12 oxides or other gas cleaning solids (*e.g.*, off-specification sulfur). Additionally, in
13 the petroleum refining industry, oily sludges were disposed of on land. In the
14 wood-treating industry, waste liquids were disposed of in onsite ponds.
15 Additionally, sludges from the cleaning of tanks and vessels were disposed of in
16 onsite dump areas. All these practices continued until the 1980s, when
17 regulations promulgated under the 1976 RCRA mandated controls on land
18 disposal of wastes across the U.S. For example, in approximately 1980, a list of
19 commercial chemical products was issued under RCRA, which defined certain
20 products, when discarded, to be hazardous waste. However, it is noteworthy that
21 coal tar was not one of the commercial products in that list. It is also noteworthy
22 that, during the MGP Era, as described in Section II, streets and roads were
23 commercially tarred under the supervision of municipal, county, and state street
24 and road agencies. Present-day regulations on disposal of solid and hazardous

1 wastes developed from this act. These Environmental Era waste disposal
2 regulations have also required treatment of certain wastes prior to land disposal
3 and, also, incineration of certain wastes.

4 Municipal garbage, trash, and sludges from sewage treatment plants were
5 disposed of in open dumps during the MGP Era. These practices remained in
6 effect in the U.S. until the 1970s and 1980s, when regulations began to
7 systematically phase them out, in favor of sanitary landfills or controlled land
8 application, in the case of sewage sludges.

9 **Q. WHAT IS A REASONABLE INDUSTRY PRACTICE WITH RESPECT**
10 **TO THE OPERATION OF AN INDUSTRIAL FACILITY SUCH AS AN**
11 **MGP, INCLUDING DISPOSITION OF RESIDUALS FROM SUCH A**
12 **FACILITY?**

13 A. I consider an activity to have been a reasonable practice if the activity was one
14 which a reasonable business person, given the context of the legal standards and
15 state of knowledge at the time of the activity, would have engaged in.

16 **Q. HOW WOULD YOU CHARACTERIZE THE RESIDUALS HANDLING**
17 **AND DISPOSITON AND THE DEMOLITION AND DISMANTLING**
18 **PRACTICES OF THE MANUFACTURED GAS INDUSTRY?**

19 A. Based on my knowledge of the history of the manufactured gas industry in the
20 U.S., the practices for residuals handling and disposition and for demolition and
21 dismantling were fully consistent with those of other industries and municipalities
22 across the country during the MGP Era and were reasonable and prudent in view
23 of the circumstances and information available at the time.

V. CURRENT UTILITY PRACTICES CONCERNING
MGP SITE REMEDIATION

1 **Q. HOW DO UTILITIES GENERALLY APPROACH THE REMEDIATION**
2 **OF MGP SITES?**

3 A. Generally, utilities approach MGP site remediation in a manner consistent with
4 that of other entities in the U.S. Typically, the approach is a multistep process
5 beginning with initial involvement in a site and ending with site closure and no
6 further involvement in the site with respect to remediation. The initial
7 involvement is triggered by some event (*e.g.*, regulatory agency inquiry, site
8 redevelopment, or imposition of a right of way). In the overall process, the site is
9 first characterized with respect to contaminants present, after which an evaluation
10 is made as to the potential impacts of those contaminants on human health or the
11 environment, compliance of site conditions with applicable regulations, and the
12 actions necessary to make the site suitable for redevelopment based on reasonably
13 anticipated, future land use, which might include residential, industrial, or
14 commercial uses. Following this evaluation, remedial measures are developed for
15 mitigating the impacts or site conditions to acceptable levels. These remedial
16 measures can be categorized as 1) reduction-of-contaminant actions such as
17 removal of contaminated materials or treatment of the materials at the site, 2)
18 prevention-of-exposure-to-contaminant actions such as engineered controls (*e.g.*,
19 installation of site covers or containment walls) or establishment of institutional
20 controls limiting use of a site (*e.g.*, restrictive covenants recorded on the deed), or
21 3) immobilization-of-contaminant actions such as solidification of soils at a site.
22 If the remediation is being performed under the direct oversight of a regulatory

1 agency or of a designated professional, approval of the agency or professional is
2 obtained for the proposed remedial measures prior to implementation. Once
3 successful impact mitigation has been confirmed, the process is complete.

4 **Q. WHAT ORGANIZATION IS TYPICALLY THE ENVIRONMENTAL**
5 **REGULATORY AGENCY WITH JURISDICTION OVER THE MGP**
6 **SITE?**

7 A. Often, with regard to MGP sites, the state environmental agency with
8 responsibility for site assessment and remediation is the responsible agency,
9 although there are some MGP sites that are under the primary jurisdiction of the
10 U.S. EPA.

11 **Q. PLEASE GENERALLY DESCRIBE THE SITE ASSESSMENT AND**
12 **REMEDIATION PROCESS.**

13 A. The site assessment and remediation (SAR) process can vary in procedures and
14 details from state to state and from site to site. Generally, as used here, the term
15 "site" means an area containing chemicals of environmental interest with
16 boundaries that include the highest concentrations of the chemicals and the extent
17 that these chemicals have migrated outwards in concentrations of environmental
18 significance. A site may encompass more than one such area, in which case the
19 individual areas are sub-sites. The sub-sites may be known as "operable units" or
20 "areas of concern" or by other names, depending on the applicable regulations for
21 the location. Applicable regulations may also explicitly define the term "site" in
22 specific cases.

23 As a general illustration, Attachment ACM-20 is a diagram of elements of
24 the SAR process often applicable, recognizing that not necessarily every step in

1 this diagram will be carried out in every site situation. The steps in this diagram
2 are as follows:

3 Preliminary Assessment

4 The Preliminary Assessment (PA) is a first evaluation of the site, based on
5 information gained from sources such as historical records, site reconnaissance,
6 areal geologic and soil maps, and possibly relatively limited sampling. The
7 objective of the PA is to evaluate the site situation from this limited data and to
8 determine the next appropriate step. The PA evaluation often includes a
9 preliminary conceptual model of potential exposure pathways, concluding with a
10 qualitative risk assessment of potential impacts. It is possible that no significant
11 potential impacts or unacceptable site conditions exist and a PA can recommend
12 that No Further Action (NFA) is necessary. The dashed line from the Qualitative
13 Risk Assessment box in Attachment ACM-20 shows this pathway to Site Closure
14 box. The PA may also result in concluding that an Interim Remedial Measure
15 (IRM) is necessary to address a condition. IRMs encompass a broad range of
16 actions, including fencing to restrict access, removal of affected soil, covering of
17 part of the site, *etc.* Often, the PA might conclude that a site investigation is the
18 next appropriate step.

19 Investigation & Analysis

20 Often, the next step after the PA is an intrusive investigation of the site
21 with sampling of environmental media (*e.g.*, soil or groundwater) with analysis of
22 the data collected, sometimes concluding with a quantitative risk assessment.
23 Additional phases of site investigation might be necessary to fill data gaps since it
24 is at times difficult to completely plan in advance an investigation of a site with

1 unknown conditions at the start. The data analysis includes determination of the
2 extent of contamination, the migration pathways for individual constituents, and
3 site conditions, all of which support an evaluation of impacts. In addition, the
4 analysis of data also determines compliance with environmental regulations and
5 the need for actions to facilitate anticipated future site use. The results of the
6 investigation and analysis might conclude that an IRM is necessary, as described
7 above under the PA. Alternately, the results of this effort might conclude that
8 there is no significant risk and NFA is appropriate. When unacceptable risk or
9 site conditions are found, the next step is Remedial Action Development.

10 Remedial Action Development

11 This step is the development at a somewhat conceptual level of a remedial
12 action that will address unacceptable risk or site conditions. The scope of this
13 step can vary greatly depending on the nature of the site impacts to be considered
14 and the current or probable future use of the site. It can include an evaluation of
15 different alternatives to mitigate unacceptable levels of risk or site conditions.
16 This evaluation is often called a feasibility study (FS). However, in many
17 situations, an FS is not needed and the appropriate course of action may be
18 apparent with little need to compare a range of alternatives. Under any
19 circumstances, remedial actions may include a combination of the general
20 categories of actions described above: reduction-of-contaminants, prevention-of-
21 exposure-to-contaminants, and/or immobilization-of-contaminants.

22 Approval

23 Typically, the next step is gaining approval of the proposed remedial
24 action prior to proceeding. There can be some variation of this step from state to

1 state, depending on the individual regulations. For example, if a state regulatory
2 agency has direct oversight, then approval would be from the agency itself.
3 Another example would be where a state designates professionals authorized to
4 approve steps in the process in lieu of state agency approval.

5 Engineering Design

6 Detailed engineering design and specification often follows approval of
7 the proposed remedial action. This is necessary to convert the conceptual
8 remedial action into drawings, specifications, and detailed work plans, when that
9 is necessary for the work to proceed. The level of effort in Engineering Design
10 varies with the scope of the approved remedial action.

11 Construction Contracting

12 Once a remedial action has been designed, the next step is typically
13 engagement of contractors to implement the design.

14 Construction

15 This is the implementation of the remedial design, which can include a
16 wide range of activities.

17 Operation, Maintenance & Monitoring (OM&M)

18 Once Construction is complete, it may be necessary to operate, maintain,
19 and/or monitor a remedial system. Examples include groundwater treatment
20 operation, soil cover maintenance, and groundwater monitoring. Groundwater
21 monitoring where the objective is to confirm the natural decay of contaminants in
22 groundwater is a special category of remediation known as monitored natural
23 attenuation (MNA). It is also a possibility that none of these activities will be
24 required. If monitoring of the site should find that the impacts have not been

1 successfully mitigated, then it might be necessary to return to some earlier step in
2 the SAR process, including another phase of Investigation & Analysis to
3 determine what additional measures might be necessary.

4 Site Closure

5 Once Construction and, as applicable, Operation & Maintenance are
6 complete, Site Closure can be sought from the pertinent environmental regulatory
7 agency. Typically, Site Closure results from issuance of a document by the
8 regulatory agency confirming that no further remedial actions are necessary at the
9 site at that time. Examples of this document include a covenant not to sue, a no-
10 further-remediation letter, or a release-of-liability letter. The nature of this
11 document can vary significantly from state to state.

12 **Q. WHAT OTHER FACTORS MIGHT INFLUENCE THE SELECTION OF** 13 **REMEDIAL ACTIONS AT AN MGP SITE?**

14 A. In addition to an entity performing the site investigation and remediation process
15 with a state agency regulating the process, as described above, there are, at times,
16 third parties that may be involved or may have influence on the remedial action
17 for the site. These may include a third-party site owner, neighboring property
18 owners, the governing local body, local residents, or local organizations. In many
19 cases, community involvement is a significant driver in the decision to select a
20 particular remedial action for a site or in how that remedial action might be
21 implemented. Business or residential use of the property may involve temporary
22 relocation of current tenants of the building during remediation or permanent
23 relocation. Property owners may require compensation for disruption of their
24 businesses or residencies. In some cases the utility responsible for the

1 remediation may purchase the property to facilitate its remediation. Potential site
2 redevelopment may necessitate that additional remedial actions be performed so
3 that future use of the site is not restricted by materials that might be left onsite by
4 some remedial actions (*e.g.*, engineered barriers). Other governing agencies may
5 also be involved in instances when wetlands or surface water bodies are involved.

6 **Q. WHAT KINDS OF REDUCTION-OF-CONTAMINANT ACTIONS HAVE**
7 **BEEN GENERALLY USED TO REMEDIATE MGP SITES IN THE U.S?**

8 A. Remedial actions have been applied to MGP sites that have reduced the
9 concentration of contaminants present (*i.e.*, reduction-of-contaminant actions).
10 Reduction has been accomplished by two general means. One is physical
11 removal of the contaminated medium (*e.g.*, soil) from the site, with its disposition
12 offsite in an appropriate facility. Excavation of tar-contaminated soil followed by
13 its transportation to an offsite, appropriately-permitted landfill for final disposal is
14 one example. Another example is the pumping of contaminated groundwater with
15 its discharge to a city sewer for final treatment and disposal.

16 The second general means of reduction of contaminants is by treatment at
17 the site either *in situ* or *ex situ*. *In situ* treatment is application of a treatment
18 technology to the medium, leaving it in place at the site. An example is *in situ*
19 chemical oxidation (ISCO), which is effected by injecting chemicals (*e.g.*,
20 hydrogen peroxide) in the subsurface to destruct contaminants through a chemical
21 reaction. An example of an *ex situ* treatment technology is the excavation of
22 soils, with onsite treatment (*e.g.*, through thermal desorption) and disposition of
23 the treated soils back onsite.

1 **Q. WHAT KINDS OF PREVENTION-OF-EXPOSURE-TO-CONTAMINANT**
2 **ACTIONS HAVE BEEN GENERALLY USED TO REMEDIATE MGP**
3 **SITES IN THE U.S?**

4 A. Remedial actions have been applied to MGP sites that prevent exposure to
5 contaminants at the site. These actions fall into two general categories:
6 engineered barriers and institutional controls. An engineered barrier can be a
7 cover over the site, such as a soil cover or an asphalt cap, the intent being to
8 prevent people on the site surface from coming into contact with contaminants in
9 the subsurface of the site. Another example would be a vapor barrier placed
10 beneath the foundation of a building to be constructed, the intent being to prevent
11 the migration of volatile chemicals from the subsurface to the interior of the
12 building.

13 Institutional controls are procedures established for a site to control human
14 activities at the site. Examples include deed restrictions to prevent residential
15 construction on a site or to prevent installation of a well for drinking water. The
16 intent of an institutional control is prevention of exposure to chemicals by
17 procedurally controlling human activities.

18 **Q. WHAT KINDS OF IMMOBILIZATION-OF-CONTAMINANT ACTIONS**
19 **HAVE BEEN GENERALLY USED TO REMEDIATE MGP SITES IN THE**
20 **U.S?**

21 A. Remedial actions have been applied at MGP sites to immobilize contaminants.
22 An example is the *in situ* solidification/stabilization (ISS) of soil where cement is

1 mixed with soil resulting in the formation of a mass of soil solidified, along with
2 its contaminants, in place.

3 **Q. HOW HAVE THE ABOVE TYPES OF REMEDIAL ACTIONS BEEN**
4 **USED IN COMBINATION AT MGP SITES?**

5 A. It is common for combinations of the above actions to be used to remediate MGP
6 sites. An example is removal of contaminated soil such that a site could be reused
7 for industrial purposes with a deed restriction preventing use of the site for
8 residential purposes. A second example is installation of a vertical, engineered
9 barrier to prevent horizontal movement of groundwater with a groundwater pump
10 and treatment for reduction of the chemical concentrations in groundwater. The
11 individual or combination of remedial actions applicable to a particular MGP site
12 is highly specific to the conditions at that site, including its reasonably anticipated
13 future use. As such, from site to site the combination of remedial actions may
14 vary greatly.

15 **Q. WHAT HAPPENS TO CHEMICALS RELEASED TO AN MGP SITE BY**
16 **OTHER SITE USES?**

17 A. As discussed above, pre- or post-MGP activities sometimes also resulted in
18 releases of the same or different chemicals to an MGP site. Where this occurred,
19 it is often the case that the chemicals released by the non-MGP site uses are
20 commingled with those released during the MGP activities. The fact that they are
21 present in such locations necessitates their being addressed as part of the MGP
22 remediation. In these cases, chemicals released to an MGP site by other site uses
23 are part of the MGP site assessment and remediation actions.

1 **Q. HOW MIGHT A PLANNED SITE ASSESSMENT AND REMEDIATION**
2 **PROJECT CHANGE WITH TIME?**

3 A. As a site progresses through the various steps in the SAR process (*i.e.*, PA
4 through Closure), which may occur over years or even decades, additional
5 information is gathered through site investigation to help refine the remedial
6 actions that might be possible at the site or to show that additional remedial
7 actions will be necessary. For example, investigation data may indicate that
8 contaminants are in groundwater or are deeper in soil than originally estimated,
9 which may lead to the need to remove saturated soil (*i.e.*, below the water table)
10 or to pump and treat groundwater. Additionally, a governing state agency will not
11 typically approve the final remedy (and sometimes the interim steps in the
12 process, such as the site investigation report) without the approval of the site
13 owner. Therefore, remediation of third-party owned sites is highly influenced by
14 the site owner and the level of remediation that the owner is willing to accept to
15 give approval. This level of remediation may vary among property owners where
16 a site crosses multiple property lines or it may vary with a single property owner
17 over time. At each of the SAR steps shown in Attachment ACM-20, the
18 information gathered in the previous steps leads to refinement of the path forward
19 to address the contaminants on the site in light of the known information and
20 potential future site use at that point in time. Hence, it is not unusual for the
21 scope and level of effort to change over the course of taking an MGP site to
22 closure.

1 **Q. WHAT GUIDANCE HAS BEEN ISSUED FOR SITE ASSESSMENT AND**
2 **REMEDiation OF MGP SITES?**

3 A. The first guidance in the U.S. specifically focused on MGP sites was issued in
4 1984 by the Edison Electric Institute, "Handbook on Manufactured Gas Plant
5 Sites." I was a coauthor/editor of this document. This document provided
6 information on site assessment and remediation contemporary to that time. In
7 1987, the Gas Research Institute issued a four-volume set entitled "Management
8 of Manufactured Gas Plant Sites," providing additional information. I was in
9 charge of preparing Volume IV, "Site Restoration," which focused on remediation
10 technologies at the time. The Gas Research Institute updated and reissued these
11 documents in 1996. In addition to these past guidance documents, there have
12 been conferences and seminars on MGP sites, where additional information on
13 assessment and remediation topics is presented. In addition to these MGP-
14 specific documents, state agencies have from time to time issued guidance on site
15 assessment and remediation. These guidance documents are periodically
16 reviewed and updated by the state agencies. Generally, changes are made to
17 reflect changes in laws or regulations or in response to new information about the
18 potential adverse effects of individual chemicals. Changes can lead to changes in
19 the remedial actions that might be needed at any site. It is to be emphasized that
20 all of these are guidance and site-specific conditions might require variance from
21 the guidance to result in a scientifically sound process.

1 **Q. HOW ARE INNOVATIONS IN MGP SITE ASSESSMENT AND**
2 **REMEDiation LEARNED?**

3 A. In addition to guidance document updates, the gas industry periodically
4 participates in meetings on MGP sites where there are often updates on MGP site
5 assessment and remediation strategies and technologies, including innovations for
6 possible consideration. For example, in March 2012, the "Fourth International
7 Symposium and Exhibition on the Redevelopment of Manufactured Gas Plants
8 Sites – MGP 2012" was held in Chicago. Sponsors included the Electric Power
9 Research Institute. This series of symposiums began in 1995 in Prague, Czech
10 Republic, with intermediate meetings in Reading, UK, in 2006 and in Mystic,
11 CT, in 2008. In the 2012 symposium, session topics included In Site Chemical
12 Oxidation (ISCO), *In Situ* Solidification/Stabilization, MGP Brownfields
13 Experience and Remediation Case Studies. At these meetings, innovative
14 investigative or remedial technologies are at times described, whereby new
15 technological possibilities are communicated for possible consideration.

VI. CONCLUSION

16 **Q. WERE ATTACHMENTS ACM-1 THROUGH ACM-20 PREPARED BY**
17 **YOU OR UNDER YOUR SUPERVISION?**

18 A. Yes.

19 **Q. IS THE INFORMATION IN ATTACHMENTS ACM-1 THROUGH ACM-**
20 **20 ACCURATE TO THE BEST OF YOUR KNOWLEDGE AND BELIEF?**

21 A. Yes.

22 **Q. DOES THIS CONCLUDE YOUR PRE-FILED DIRECT TESTIMONY?**

23 A. Yes.

ANDREW C. MIDDLETON, Ph.D., DIRECT

ACM-1

CURRICULUM VITAE

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EDUCATION

Rockingham County Public School System, Rockingham County, Virginia, 1954-1966.
Virginia Polytechnic Institute & State University, Blacksburg, Virginia, 1966-1971.
Awarded B.S. with distinction in Civil Engineering with Cooperative Education Option (1971).
Awarded M.S. in Sanitary Engineering (1972).
Cornell University, Ithaca, New York, 1971-74
Awarded Ph.D. in Environmental Engineering (1975).

PROFESSIONAL REGISTRATION

Registered Professional Engineer of Province of Ontario (No. 31596018) since 1975.

PROFESSIONAL SOCIETIES

American Society of Civil Engineers
American Society for Testing and Materials
Water Environment Federation

BOARD CERTIFICATION

American Academy of Environmental Engineers (board certified by eminence in the specialty area of hazardous waste management), BCEE

AWARDS

Recipient of 1995 New York Water Environment Association Linn H. Enslow Memorial Award for outstanding paper, "Treatment of Organically Contaminated Groundwater in Municipal Activated Sludge System."

Recipient of the 1999 PECO Energy (Philadelphia, PA) High Energy Excellence Award for work as a member of PECO's Environmental Insurance Recovery Team.

MEMBERSHIP/COMMITTEE ACTIVITIES

November 1995 – Present: *National Trainer for ASTM* for its risk-based corrective action (RBCA) standard (E1739). In this capacity, Dr. Middleton instructs at the two-day ASTM RBCA course being held nationally. He has instructed hundreds of students in numerous of these courses across the U.S.

2000 – 2006: *Member of the External Advisory Panel, Environmental Engineering Department, SUNY/Buffalo, Buffalo, NY.* As a member he advised the Environmental Engineering Department on the educational needs of the environmental engineering practice on matters related to environmental remediation, waste treatment and management and management of environmental affairs. This panel periodically met with the faculty of the Department regarding the undergraduate environmental engineering program.

1999 – 2004: *Member of the Environmental Technical Advisory Board, Alcoa, Pittsburgh, PA.* As a member he advised the Alcoa Corporation on technical topics related to environmental remediation, waste treatment and management and management of environmental affairs, including topics for research and development. This board met several times annually with Alcoa's environmental management and remediation teams.

1999 – 2002: *Chair, Water Environment Research Foundation (WERF) Project Subcommittee on "Enhancing Biodegradability of Refractory Aromatics in Wastewater: Pretreatment with Elemental Iron, 99-CTS-3."* WERF awarded this grant to the University of Delaware for research on the capabilities of elemental iron to pretreat recalcitrant organic compounds in wastewater to improve their treatability in biological systems. The subcommittee then provided oversight on the progress of the research including review of the interim and final reports.

1998 – 2004: *Chair, Water Environment Research Foundation (WERF) Project Subcommittee on "Evaluating and Optimizing Source Treatment Technologies to Improve the Biodegradability of Organic Compounds, 99-WWF-5."* This subcommittee solicited and awarded a WERF grant to San Diego State University for research on the capabilities of advanced oxidative technologies to pretreat recalcitrant organic compounds in wastewater to improve their treatability in biological systems. The subcommittee then provided oversight on the progress of the research including review of the interim and final reports.

EMPLOYMENT RECORD

November 2001 – Present: *President, Corporate Environmental Solutions LLC.* Dr. Middleton founded this company in 2001 to provide environmental services. He is responsible for technical, operational and business affairs. He personally provides senior consulting services in the areas of corporate environmental management, environmental risk characterization and management, environmental dispute resolution, site assessment and remediation, and treatment of industrial wastewaters.

September 1981 – 2001: *Civil Engineering Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania:* Intermittent teaching of graduate courses in contaminated water treatment. He developed an innovative approach for the water and wastewater treatment course by unifying the subject matter into a course on "Treatment of Contaminated Water." This course focused on selection and design of a treatment system based on the nature and concentrations of contaminants and the intended means of disposition using a matrix of individual unit processes. The approach is applicable regardless of whether the contaminated water is municipal or industrial wastewater, groundwater or storm runoff. This approach contrasts to separate courses for water, wastewater or groundwater treatment.

January 2001 – November 2001: *Senior Vice President, The RETEC Group, Inc.* In this capacity he was responsible for executive oversight of engineering, science and technology efforts across the company as well as his technical consulting client program management practices. Additionally, he managed the O&M Group and provided consulting and engineering services, project and program management and business development in environmental management; contaminated water treatment; and, in site assessment and remediation.

April 1999 – December 2000: *General Manager of ThermoRetec's Site Management and Closure Division.* Responsible for the division technical and business affairs including division P&L. This division had a Construction Group and an Operations and Maintenance (O&M) Group. The construction group carried out large civil remediation construction projects (e.g., excavation, sheet piling, slurry walls, landfill covers, contaminated water treatment plant construction) for industrial and utility clients. The O&M Group operated remediation systems (e.g., groundwater extraction and treatment, land treatment units for bioremediation of soil, soil venting, NAPL recovery, landfill leachate treatment) across the U.S. also for industrial and utility clients. Additionally, he provided consulting and engineering services in environmental management, contaminated water treatment, laboratory and field treatability projects on site assessment and remediation.

January 1990 – April 1999: *Principal of ThermoRetec Consulting Corporation.* Responsible for technical and business affairs of company. ThermoRetec (formerly RETEC) is an engineering and remedial services company specializing in on-site treatment of organic wastes. Day-to-day duties included project management of RI/FS's on Superfund sites, site remediation, environmental audits of industrial facilities, design and operation of treatment facilities for contaminated groundwater, soils, industrial and municipal wastewaters, permitting of industrial facilities, and remedial technology development. He also was the principal investigator on field research studies for site remediation. He served as a member of ThermoRetec's Board of Directors from 1990 until 1995.

June 1991 – December 1996: *Member of the Board of Directors of EnSys Environmental Products, Inc.:* EnSys was a biotechnology start up company developing and selling immunoassay test kits for the analysis of soil and water. During his tenure on the Board, EnSys went public in an IPO in 1993 and merged with Strategic Diagnostics, Inc. (symbol: SDIX) in 1996. Dr. Middleton provided advice on commercialization opportunities for new test kits, served on the Audit Committee and chaired the Compensation Committee of this publicly traded company.

May 1990 – December 1995: *Member of the Board of Directors of Remediation Technologies, Inc. (RETEC):* RETEC was a privately held company during his tenure on the Board. It tripled in size in this five-year period and became an acquisition of the publicly traded Thermo Remediation, Inc. (later renamed ThermoRetec) in December 1995. Dr. Middleton provided advice on strategic direction for the company as well as on technology commercialization.

July 1988 – December 1989: *President of Haniel Environmental Services, Inc. (HES).* Responsible for operations, technical matters and business affairs. HES was the U.S. branch of a German company specializing in site remediation. While in this position, his technical activities included managing soil gas surveys and *in situ* clean up of volatile organic compounds with soil venting and groundwater aeration systems, as well as general site decommissioning and remediation, project management of RI/FS's, and technical support of litigation. He served on the boards of directors of HES and its subsidiary companies during this his tenure as President.

June 1986 – June 1988: *President of Keystone Environmental Resources, Inc.* (also founder of Keystone). Responsible for management and leadership that grew the company from 90 employees to

over 250 with ten offices in the United States and Canada offering environmental consulting, analytical, and remediation services. Keystone was a wholly owned subsidiary of Koppers. Keystone specialized in the investigation and remediation of wood treating, tar-contaminated and chemical sites and in the design and operation of wastewater and groundwater treatment systems. He was also the principal investigator for Keystone's research project funded by the Gas Research Institute on assessment and remediation of manufactured gas plant sites and the director of the company's research and development efforts on new environmental technologies. He served on the board of directors of Keystone and continued as Vice President of Koppers Environmental Resources.

August 1984 – June 1986: *Vice President and General Manager of Pioneering Technologies (in addition to Environmental Resources):* Overall responsibilities for a program made up of a Materials Science Department, a Manufacturing Technologies Department, a Technical Information Department, and a Project Management Group; activities included research on polymer science and wood treating chemicals, computer-assisted drafting; instrumentation and control, systems design and installation, and computer and library facility management. Project management activities included facilitating use of a computer-based project management system throughout Koppers Science and Technology activities, especially on interdisciplinary teams. Additionally, Dr. Middleton directed this department's interactions with Koppers' venture investments in biotechnology and materials science.

June 1981 – June 1988: *Vice President and General Manager of Environmental Resources Department, Koppers Company, Inc., Monroeville, Pennsylvania:* Overall responsibility for management of Koppers environmental affairs. Included in Koppers operations were over 50 Chemical & Allied Products plants including 17 wood preserving plants, as well as other facilities producing metal products and road materials. In addition to the operating facilities, his overall responsibility included management of over 50 previously operated plants (wood treating and chemical plants) and disposal sites, a number of which are Superfund sites. His duties also included management of the environmental reserves for remediation of previously operated properties as well as developing an annual budget for activities on these sites. He built a multi-disciplinary staff of environmental engineers and scientists from 1981-1986, which was of such quality and capability that it was converted to a P&L subsidiary in 1986 (Keystone Environmental Resources, Inc.) to provide services outside of Koppers on a commercial basis.

February 1979 – May 1981: *Manager of Water Quality Engineering Section of Environmental Resources and Occupational Health Department, Koppers Company, Inc., Monroeville, Pennsylvania:* The objective of this section was to provide in-house water quality engineering services to Koppers Company. Projects included activated sludge treatability studies (bench-scale and pilot plant) at tar distillation plants; wastewater characterization studies at tar distillation and chemical plants; treatability studies for oil removal (bench-scale and pilot plant) at tar distillation and chemical plants; activated sludge plant startup at coke plants; preparation of activated sludge control programs at coke, chemical, and tar distillation plants; hydrogeologic surveys at tar distillation, wood preserving, and coke plants; fish toxicity studies on chemical and tar distillation plant wastewaters; priority pollutant surveys at chemical, coke, and tar distillation plants; development of wastewater treatment processes to achieve BAT for coke, tar distillation, and synthetic fuels plants. In this position, he also established a treatability laboratory program for wastewater, groundwater, sludge and soil.

June 1978 – January 1979: *Senior Research Engineer, Research Department, Koppers Company, Inc., Monroeville, Pennsylvania:* Responsible for water pollution control projects with Koppers Company, Inc., including activated sludge pilot plant study with continuous fish bioassays of effluent at a chemical plant; preparation of operational control programs at chemical sludge plants for coke and tar distillation plants.

July 1976 – May 1978: *Assistant Professor of Civil Engineering, SUNY at Buffalo, Buffalo, New York:* Teaching graduate and undergraduate courses in water and wastewater treatment and environmental engineering; acquiring and directing funded programs of research in water pollution control engineering, supervised graduate students and development of water pollution control laboratories; two students received Ph.D. degrees and nine received M.S. degrees in environmental engineering under his direction.

September 1974 – June 1976: *Assistant Professor of Civil Engineering, University of Ottawa, Ottawa, Ontario:* Teaching graduate and undergraduate course in water and wastewater treatment and environmental engineering; acquiring and directing funded programs of research in water pollution control engineering; supervising graduate students and development of water pollution control laboratories; seven students received M.S. degrees in environmental engineering under his direction.

September 1971 – August 1974: *EPA Post Masters Trainee, Cornell University, Ithaca, New York:* Study in the Environmental Engineering Ph.D. Program under Dr. A. W. Lawrence in Civil and Environmental Engineering School. In addition to his experimental research on the kinetics of microbial sulfate reduction, he also developed an approach for least cost design of wastewater treatment systems. He received a Ph.D. in environmental engineering.

September 1970 – August 1971: *Public Health Fellow, VPI&SU, Blacksburg, Virginia:* Study in Sanitary Engineering Program under Dr. E. M. Jennelle, Civil Engineering Department. He conducted experimental research on the water quality of a large, pumped storage reservoir near VPI for his Master's thesis. He received an MS in sanitary engineering.

March-June, September-December 1968; March-June, September-December, 1969: *Co-op student in Civil Engineering, Wiley & Wilson Consulting Engineers & Architects, Lynchburg, Virginia:* Worked as Engineering Design Assistant on municipal water and wastewater projects and as a land and route survey party member. The Co-op Program was part of his undergraduate work at Virginia Tech, from which he received a BS in civil engineering with distinction.

PUBLICATIONS (JOURNALS)

1. Middleton, A.C. and Lawrence, A.W., 1973. Discussion of "Optimal Design of Wastewater Treatment Systems by Enumeration," by G.F. Parkin and R.R. Dague, Journal Environmental Engineering Division, ASCE, 99, 960.
2. Middleton, A.C. and Lawrence, A.W., 1974. "Cost Optimization of Activated Sludge Systems," Biotechnology and Bioengineering, XVI, 807.
3. Middleton, A.C. and Lawrence, A.W., 1976. "Least Cost Design of Activated Sludge Systems," Journal Water Pollution Control Federation, 48, 395.
4. Middleton, A.C. and Lawrence, A.W., 1977. "Kinetics of Microbial Sulfate Reduction," Journal Water Pollution Control Federation, 49, 1659.
5. Middleton, A.C. and Rovers, F.A., 1976. "Average pH," Communications, Journal Water Pollution Control Federation, 48, 395.
6. Adamowski, K and Middleton, A.C., 1977. "Steady-State Dissolved Oxygen Model for the Rideau River," Canadian Journal of Civil Engineering, 4, 471.

7. Craig, E.W., Meredith, D.D., and Middleton, A.C., 1977. Discussion of "Simplified Optimization of Activated Sludge Process," by C.P.L. Grady, Jr., Journal Environmental Engineering Division, ASCE, 103, 1158.
8. MacInnes, C.D., Middleton, A.C., and Adamowski, K., 1978. "Stochastic Design of Flow Equalization Basins," Journal Environmental Engineering Division, ASCE, 104, 1277.
9. Craig, E.W., Meredith, D.D. and Middleton, A.C., 1978. "Cost Optimization of the Activated Sludge Process Using the Box-Complex Algorithm," Journal Environmental Engineering Division, ASCE, 104, 1101.
10. Westerndorf, J.R. and Middleton, A.C., 1979. "Chemical Aspects of the Relationship Between Drinking Water Quality and Long-Term Health Effects: An Overview," Journal American Water Works Association, 71, 417.
11. Fritz, J.J., Middleton, A.C., and Meredith, D.D., 1979. "Dynamic Process Modeling of Wastewater Stabilization Ponds," Journal Water Pollution Control Federation, 51, 2724.
12. Fritz, J.J., Meredith, D.D., and Middleton, A.C., 1980. "Non-Steady State Bulk Temperature Determination for Simple Aquatic Ecosystems: Stabilization Ponds," Water Research (U.K), 14, 413.
13. Habicht, M.H., Adamowski, K., and Middleton, A.C., 1981. "Potential Eutrophication of the Rideau River by an Urban Drainage Waterway," Canadian Journal of Civil Engineering, 8, 165.
14. Hughey, P.W., Meredith, D.D., and Middleton, A.C., 1982. "Optimal Operation of an Activated Sludge Plant," Journal Environmental Engineering Division, ASCE, 108, 349.
15. Smith, J.R., Luthy, R.G., and Middleton, A.C., 1988. "Microbial Ferrous Iron Oxidation in Acidic Solution," Journal Water Pollution Control Federation, 60, 518.
16. Meredith, D.D., Middleton, A.C., and Smith, J.R., 1990. "Design of Detention Basins for Industrial Sites," Journal Water Resources Planning and Management, ASCE, 116, 586.
17. Middleton, A.C., Nakles, D.V., and Linz, D.G., 1991. "The Influence of Soil Composition on Bioremediation of PAH-Contaminated Soils," Remediation, 1, 391.
18. Smith, J.R., Neuhauser, E.F., Middleton, A.C., Weightman, R.L, Linz, D.G., 1993. "Treatment of Organically Contaminated Groundwaters in Municipal Activated Sludge Systems," Water Environment Research, 65.

PUBLICATIONS (BOOKS)

1. Craun, J.C. and Middleton, A.C. (co-editors/authors), 1984. Handbook on Manufactured Gas Plant Sites, Washington, D.C.: Edison Electric Institute.
2. Unites, D., Nakles, D., Menzie, C., Middleton, A., and Helsel, R. (co-editors/authors), 1987. Management of Manufactured Gas Plant Sites, Vol. I-IV, Chicago, Illinois: Gas Research Institute.

PUBLICATIONS (CONFERENCE PROCEEDINGS)

1. Weyland, H.J. and Middleton, A.C., 1977. "Metals Recovery from Metallic Hydroxide Sludges Through Microbial Sulfate Reduction," Proceedings 9th Mid-Atlantic Industrial Waste Conference, Bucknell University, Lewisburg, Pennsylvania.
2. Lee, G.C., Meredith, D.D., and Middleton, A.C., Eds., 1979. "Proceedings of Hazardous Waste Management and Disposal Seminar," WREE Report No. 79-2, Civil Engineering SUNY/Buffalo, Buffalo, New York.
3. Bhattacharyya, A. and Middleton, A.C., 1979. "Development of Biological Treatment System Achieving BATEA for Coke Plant Wastewaters," Proceedings 11th Mid-Atlantic Industrial Waste Conference, Pennsylvania State University, State College, Pennsylvania.
4. Bhattacharyya, A. and Middleton, A.C., 1980. "Solids Retention Time: A Controlling Factor in the Successful Biological Nitrification of Coke Plant Wastes," Proceedings 12th Mid-Atlantic Industrial Waste Conference, Bucknell University, Lewisburg, Pennsylvania.
5. Bhattacharyya, A. and Middleton, A.C., 1980. "Enhanced Biological Treatment System for Coke Plant Wastewater Achieving Complete Nitrification," Proceedings 35th Industrial Waste Conference, Purdue University, Lafayette, Indiana.
6. Middleton, A.C., 1981. "Process Control for Activated Sludge Treatment of Coke Plant Wastewater," Proceedings: Symposium on Iron and Steel Pollution Abatement Technology for 1980, EPA-600/9-81-017, Philadelphia, Pennsylvania.
7. Middleton, A.C., Smith, J.R., Urbassik, M.R., Keffer, R.E., Sawchuck, P.W., and Edwards, G.E., 1984. "Industrial Wastewater Treatability Study Achieving BCT/BAT Treatment," Proceedings 16th Mid-Atlantic Industrial Waste Conference, Pennsylvania State University, State College, Pennsylvania.
8. Middleton, A.C., 1995. "Historical Overview of Manufactured Gas Processes Used in the United States," presented at International Symposium and Trade Fair on the Clean-up of Manufactured Gas Plants, Prague, Czech Republic; published in Land Contamination & Reclamation, Vol. 3, No. 4, pp.5-17 – 5-19.

PRESENTATIONS

1. Middleton, A.C. and Jenelle, E.M., "The Influence of an Impoundment on the Priority of Effluent Treatment in the Upstream Watershed," presented at 26th Annual Meeting, Virginia Water Poll. Control Assn., Roanoke, Virginia, April 30, 1970.
2. Middleton, A.C. and Jenelle, E.M., "Processes Influencing Water Quality in a Pumped Storage Reservoir," presented at 8th Annual Meeting, Am. Water Resources Assn., St. Louis, Missouri, October 31, 1972.
3. Middleton, A.C. and Lawrence, A.W., "Cost Optimization of Activated Sludge Wastewater Treatment Systems," presented at 166th National Meeting, Am. Chem. Soc., Chicago, Illinois, August 30, 1973.

4. Middleton, A.C. and Lawrence, A.W., "Least Cost Design of Activated Sludge Systems," presented at 46th Annual Meeting, Water Pollution Control Federation, Cleveland, Ohio, October 22, 1973.
5. Adamowski, K and Middleton, A.C., "Water Quality of the Rideau River," invited seminar at 2nd Annual Science Education Day Conf., Kanata, Ontario, April 12, 1975.
6. Middleton, A.C. and Lawrence, A.W., "Kinetics and Engineering Significant of Microbial Sulfate Reduction," presented at 47th Annual Meeting, Water Pollution Control Federation, Miami Beach, Florida, October 8, 1975.
7. Middleton, A.C., "The Science of Environmental Impact Statement," invited seminar for Buffalo Section of ASCE Workshop on "The Preparation of Environmental Impact Statements," Buffalo, New York, February 8, 1977.
8. Middleton, A.C., "Design of the Activated Sludge Process," invited seminar for Buffalo Section ASCE Workshop on "Design and Operation of the Activated Sludge Process," Buffalo, New York, March 14, 1978.
9. Middleton, A.C. and Lawrence, A.W., "The Effect of Recycle Sludge Pumping Rates on the Activated Sludge Process," invited seminar for Buffalo Section ASCE Workshop on "Design and Operation of the Activated Sludge Process," Buffalo, New York, March 14, 1978.
10. Westendorf, J.R., Middleton, A.C., and Kasprzak, P.J., "Co-Disposal of a Combined Municipal/Industrial Wastewater Treatment Plant Sludge with Municipal Refuse in a Sanitary Landfill," presented at 52nd Annual Conference Water Pollution Control Federation, Houston, Texas, October, May 14, 1980.
11. Middleton, A.C., "Wastewater Treatment for Coke and Coal-Tar Distillation Plants," presented at the Spring Meeting American Coke and Coal Chemicals Institute, Hilton Head, South Carolina, May 19, 1981.
12. Middleton, A.C., "Hazardous Wastes," presented at Disaster Emphasis Day, Annual Conference, Church of the Brethren, Indianapolis, Indiana, June 23, 1981.
13. Hughey, P.W., Meredith, D.D., and Middleton, A.C., "Optimal Operation of an Activated Sludge Wastewater Treatment Plant," presented at The International Symposium on Real Time Operation of Hydrosystems, Waterloo, Ontario, Canada, June 25, 1981.
14. Middleton, A.C., "Removal of Priority Pollutants From Coal-Tar Condensate Water," invited speaker at The Fate of Wastewater-Borne Priority Pollutants Subjected to Biological Treatment, U.S. EPA Seminar, Washington, D.C., May 4, 1982.
15. Malik, D.P., Middleton, A.C., Bryant, D.L., Sgro, G.A., Fillo, J.P., Charna, R.B., and Maruhnich, E.D., "Water Usage and Treatment, Tennessee Synfuels Project," presented at ASCE Conference on Water & Energy: Technical & Policy Issues, Pittsburgh, Pennsylvania, May 1982.
16. Middleton, A.C., "BAT Regulations for Coke Plants," invited speaker at Fall Meeting, Manufacturing and Environmental Committee, American Coke and Coal Chemicals Institute, Indianapolis, Indiana, September 14, 1982.

17. Middleton, A.C., "Priority Pollutant Removal From Coke and Coal-Tar Distillation Plant Wastewaters By Biological Treatment," invited speaker at Biological Treatment, Priority Pollutants and BATEA Seminar, Philadelphia, Pennsylvania, December 10, 1982.
18. Middleton, A.C., "Wastewater Treatment For Coke Plants: Regulations and Capabilities," invited speaker at Eastern States Coke Conference, Pittsburgh, Pennsylvania, February 1983.
19. Middleton, A.C., "Land Disposal and Spill Site Environments," invited speaker at Genetic Control of Environmental Pollutants, University of Washington, Seattle, August 1, 1983.
20. Middleton, A.C. and Oster, L.A., "Projected Environmental Costs to Permit and Operate the PMA Methanol Plant," presented at the AIChE 1984 Summer National Meeting, Philadelphia, Pennsylvania, August 19, 1984.
21. Spencer, J.D., Middleton, A.C., Smith, J.R., Campbell, J.R., and Zeff, J.D., "Evaluation of Treatment Technologies for Contaminated Groundwater," presented at the Water Pollution Control Federation 59th Annual Conference/Exposition, Los Angeles, California, October 6-9, 1986.
22. Middleton, A.C., "Opportunities for Chemical Engineers in Hazardous Waste Management," presented to the Pittsburgh Section of AIChE, Pittsburgh, Pennsylvania, January 13, 1987.
23. Middleton, A.C., "Environmental Management," invited speaker at the annual meeting of the National Wood Window and Door Association, Maui, Hawaii, February 1987.
24. Hegnauer, A. and Middleton, A.C., "Environmental Considerations at Manufactured Gas Plant Sites," presented at the American Gas Association Distribution/Transmission Conference, Las Vegas, Nevada, May 1987.
25. McShea, L.J., Smith, J.R., Middleton, A.C., and Zeff, J.D., "Chemical Oxidation of Aqueous Pentachlorophenol and Phenolics by UV-Ozonation," presented at the American Institute of Chemical Engineers 1986 Summer National Meeting, Boston, Massachusetts, August 24-27, 1986.
26. Middleton, A.C., Presentation on bioremediation of wood treating wastes to Committee on Small Business, Subcommittee on Energy and Agriculture, U.S. House of Representatives, Washington, D.C., September 1987.
27. Hiller, D.H. and Middleton, A.C., "Die Abwicklung von Schadensfallen in den USA," presented at Harress Geotechnik-Umweltseminar, Kloster Banz, Germany, October, 21-22, 1988.
28. Smith, J.R., Fu, J.K., and Middleton, A.C., "Field Work Evaluating Engineered Biodegradation System Treatment of Soil Contaminated with Wood Preserving Chemicals," presented at Conference on Genetically Engineered or Adapted Microorganisms in Hazardous Waste Treatment, Washington, D.C., December 1988.
29. Middleton, A.C., "Co-Treatment of Groundwater in POTWs," presented at Management of Manufactured Gas Plant Sites Technology Transfer Seminar sponsored by EEI, EPRI, and GRI, Pittsburgh, Pennsylvania, April 19-20, 1989.

30. Middleton, A.C. and Hiller, D.H., "*In Situ* Aeration of Groundwater, a Technology Overview," presented at Conference on Prevention and Treatment of Soil and Groundwater Contamination in the Petroleum Refining and Distribution Industry, Montreal, Quebec, October 16-17, 1990.
31. Linz, D.G., Neuhauser, E.F. and Middleton, A.C., "Perspectives on Bioremediation in Gas Industry," presented at Environmental Biotechnology Symposium, Knoxville, TN, October 17-19, 1990.
32. Middleton, A.C., "A Historical Perspective of Manufactured Gas Plant Operations," presented at 1990 Manufactured Gas Plant Site Workshop sponsored by AGA, Boston, MA, October 31-November 1, 1990.
33. Middleton, A.C., "Past Operations and Present-Day Site Management," presented at MGP Technology Transfer Seminar sponsored by EPRI and GRI, Atlanta, GA, April 2-3, 1991.
34. Middleton, A.C., "Remediation Options and Technologies," presented at Manufactured Gas Plant Site Workshop sponsored by NEGA, Sutton, MA, October 9, 1991.
35. Saber, D.L., Smith, J.R., Lawrence, A.W. and Middleton, A.C., "Optimization of an Oil Recovery/Groundwater Treatment System Based upon Treatability Study/Engineering Evaluations of Superfund Site Clean-Up," presented at the AIChE 1992 Summer National Meeting, August 9-12, 1992.
36. Smith, J.R., Lawrence, A.W. and Middleton, A.C., "Sequencing Batch Reactor Treatment of Superfund Site Groundwater," presented at the 65th Annual Water Environment Federation Conference, New Orleans, LA, September 20-24, 1992.
37. Middleton, A.C., Lawrence, A.W., Morgan, D.J., Lees, M.G. and Hayes, T.D., "Biosparging Strategies for Containment and Remediation of Organic Contaminant Groundwater Plumes at E&P Sites Using Either Vertical or Horizontal Sparge Wells," presented at The Eighth International IGT Symposium on Gas, Oil and Environmental Biotechnology, Colorado Springs, Colorado, December 11-13, 1995.
38. Middleton, A.C., Draybuck, B.M., Grizzle, P.L. and Hayes, T.D., "Pilot Test of Biosparging at a Natural Gas Plant and Pipeline Facility," presented at the Ninth International IGT Symposium on Gas, Oil, and Environmental Biotechnology, Colorado Springs, Colorado, December 9-11, 1996.
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41. Middleton, A.C., "Future Needs to be Addressed by Environmental Engineers and Scientists," presented at the University at Buffalo, Buffalo, NY, October 22, 1999.

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43. Middleton, A.C., "Future Trends in Corporate Environmental Management," presented at the University of Pittsburgh, Pittsburgh, PA, March 22, 2000.
44. Hasel, M.J., Shamory, C. and Middleton, A.C., "Thermal Desorption of Heavily Impacted MGP Soils under New TCLP Exemption," presented at the GTI 14th International Conference on Site Remediation Technologies, Orlando, FL, December 2-6, 2001.
45. Middleton, A.C., "The Effect of Historical Issues on Risk," presented at the AGA MGP Workshop, Washington, DC, August 6, 2004.
46. Morgan, D., Mahfood, J., Malle, J., Middleton, A. and McGraw, D., "The Effect of Site Remediation Risk Level on Potential Incidence of Cancer within the United States," poster displayed at the Midwestern Risk Assessment Meeting, Indianapolis, IN, August 26, 2004.
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48. Bhattacharyya, A., Blayden, J.M., and Middleton, A.C. "Estimating Historic Tar Production at Manufactured Gas Plants," presented at the poster session of National Gas Technologies 2005 Conference, Orlando FL, January 30-February 2, 2005.
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51. Middleton, A. C. "Financial Strategies for Environmental Projects," presented at the MEA Environmental Management Conference, Colorado Springs, CO, September 28, 2005.
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53. Fernandes, A. F. and Middleton, A.C., "A Unified Multi-State Utility MGP Management Program," presented at MGP 2006 Conference, Reading, UK, April 4-6, 2006.
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55. Lynch, M.J., Sylvester, J.M., Hart-Lovelace, J., Jones, D.R., and Middleton, A.C. "Insurance Recovery for MGP Site Clean-Up Costs," presented at MGP 2006 Conference, Reading, UK, April 4-6, 2006.

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57. Middleton, A.C. "Influence of History of MGPs – Lecture 1," presented at EPRI MGP 101 Course, Philadelphia, PA, June 18, 2008.

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1. Middleton, A.C. and Lawrence, A.W., 1973. "Cost Optimization of Activated Sludge Wastewater Treatment Systems," EPM Technical Report No. 73-1, Department of Environmental Engineering, Cornell University, Ithaca, New York.
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3. Adamowski, K and Middleton, A.C., 1976. "Comprehensive Water Quality Study of the Rideau River from Long Island to Hog's Back Falls, June-July, 1975," Final Report to the Ontario Ministry of Environment, Kingston, Ontario.
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5. Uchida, A. and Middleton, A.C., 1978. "Water Quality Modeling of Mine Acid Drainage II: Laboratory Evaluation of Preliminary Model," WREE Report No. 78-3, Civil Engineering, SUNY/Buffalo, Buffalo, New York.
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9. Kasprzak, P.J., Meredith, D.D., and Middleton, A.C., 1982. "Effect of Primary Settling Tank Efficiency on Cost Optimization of the Activated Sludge Process," WREE Report, Civil Engineering, SUNY/Buffalo, Buffalo, New York.
10. Numerous other technical, research and expert reports have been prepared during employment outside universities.

FUNDED RESEARCH PROJECTS

1. "Design of Aerated Lagoons for Low Temperature Operation," funded by Research Office, School of Graduate Studies, University of Ottawa, for the amount of \$4,500, during the period March 20, 1975 to December 31, 1975 (Principal Investigator).
2. "Assessment and Control of Storm Water Pollution," funded by National Research Council of Canada, for the amount of \$16,500 during the period of April 1, 1975 to March 31, 1978 (Principal Investigator).
3. "Development of a Water Quality Model for the Rideau River," funded by Ontario Ministry of the Environment for the amount of \$12,065 during the period of May 20, 1975 to August 8, 1975 (Co-Principal Investigator).
4. "Microbial Production of Limestone from Gypsum," funded by the SUNY Research Foundation for the amount of \$2,100 during the period of January 1, 1977-December 31, 1980 (Principal Investigator).
5. "Phosphorus Solubilization during Anaerobic Decomposition of Algae," funded by National Science Foundation for the amount of \$52,887 during the period of October 15, 1977-March 31, 1980 (Principal Investigator).
6. "Co-Disposal of Wastewater Treatment Sludge and Municipal Refuse – City of Niagara Falls, New York," funded by City of Niagara Falls, New York for the amount of \$1,500 during the period of June 1, 1978 to September 30, 1978 (Co-Principal Investigator).
7. "Metals Recovery from Waste Metallic Hydroxide Sludges through Microbial Sulfate Reduction," funded by Environment Canada for the amount of \$30,000 during the period of January 1980 to May 1980 (Co-Principal Investigator).
8. "Development of MGP Site Remediation Methodologies," funded by Gas Research Institute for the amount of \$250,000 during the period of June 1986-June 1988 (Principal Investigator).
9. "Co-Treatment of MGP Groundwater in a POTW," funded by Gas Research Institute for the amount of \$250,000 during the period of June 1987-June 1988 (Principal Investigator).
10. "Pilot Scale Biosparging Project," funded by Gas Research Institute for the amount of \$226,000 during the period January 1994-April 1995.

PAST PROFESSIONAL ACTIVITIES

1. Lecturer, Short Course on Engineering Control of Industrial Wastewaters, Cornell University, June 1975.
2. Technical Advisor, Environmental Conservation Task Force, Greater Buffalo Development Foundation, December 1976-May 1978.
3. Organizer and Chairperson, Hazardous Waste Management and Disposal Seminar, SUNY/Buffalo, February 1979.

4. Associate Engineer, Conestoga-Rovers, Ltd., Waterloo, Ontario, 1976-78. Consultant to government and industry on water and wastewater treatment and waste disposal on land.
5. Member, Chemical Manufacturers Association (CMA) Five-Plant Study Work Group on Priority Pollutant Removal by Biological Treatment Plants.
6. Member, U.S. EPA TSCA Panel on Genetic Engineering of Microorganisms for Bioremediation, Washington, D.C., 1987.
7. Member, Environmental Advisory Committee, Fox Chapel Borough, PA, 1988-91.
8. Member, Industrial Advisory Committee, Gulf States Hazardous Research Center, Lamar University, Beaumont, TX, 1990-91.
9. Member, Technical Advisory Committee, New York State Hazardous Waste Management Center, SUNY/Buffalo, Buffalo, NY, 1988-95.
10. Organizer of Gas Research Institute Seminar on Risk-Based Corrective Action for Gas Industry Applications, Chicago, IL, 1996-97.
11. Developer and Lecturer in Courses on Operation of a Refinery Activated Sludge Wastewater Treatment Plant, Ergon Refining, Newell, WV, 1997-99.

HEALTH AND SAFETY

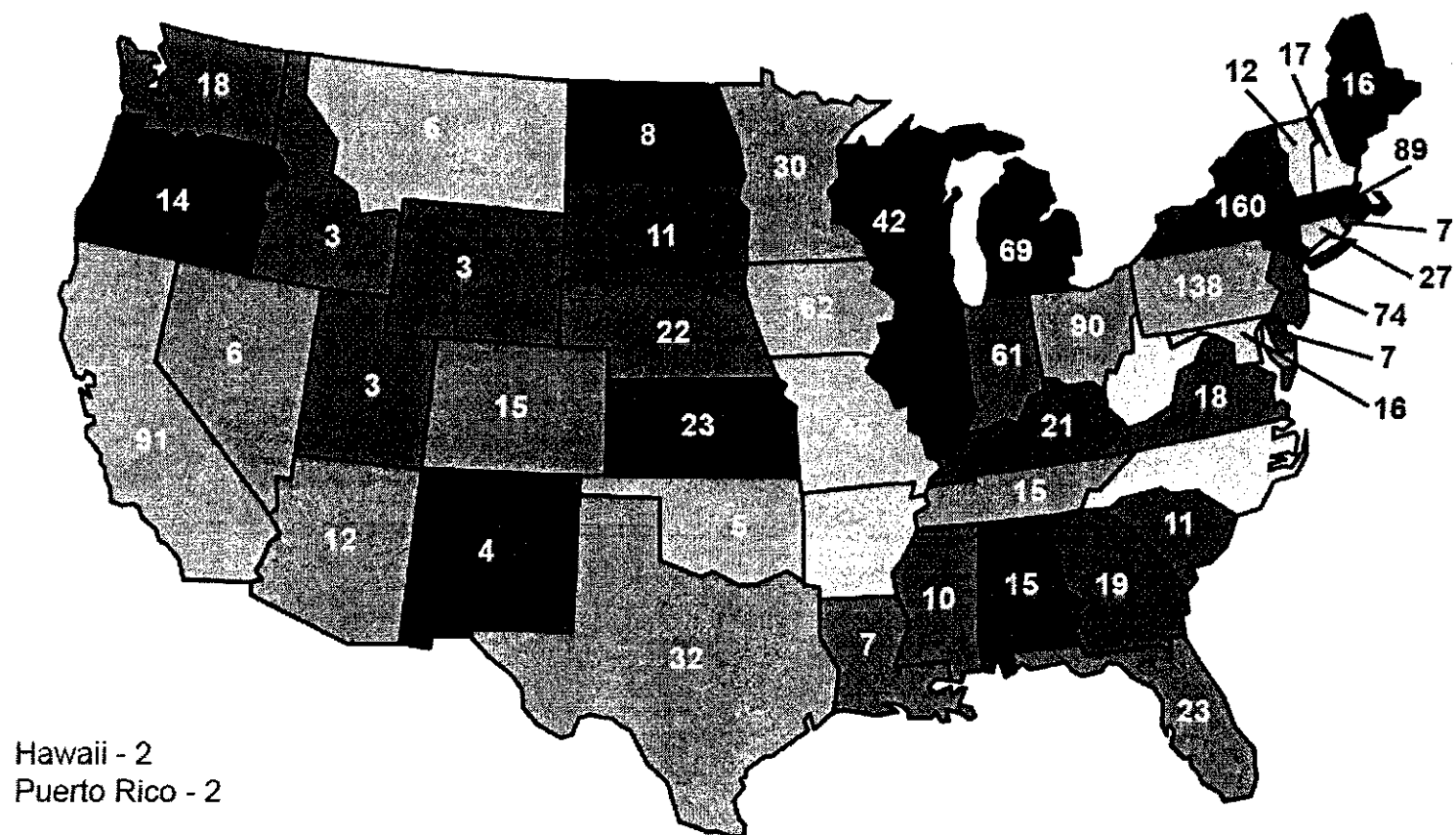
Current on 8-hour OSHA Hazardous Waste Operations Refresher
40-hour OSHA Hazardous Waste Operations Training, 1991
8-hour Hazardous Waste Supervisor Training, 1992
10-hour OSHA Construction Outreach Training, 2000
8-hour Competent Person Training (Trenching), 2000
Confined-Space Entry Training, 2005

TESTIMONY

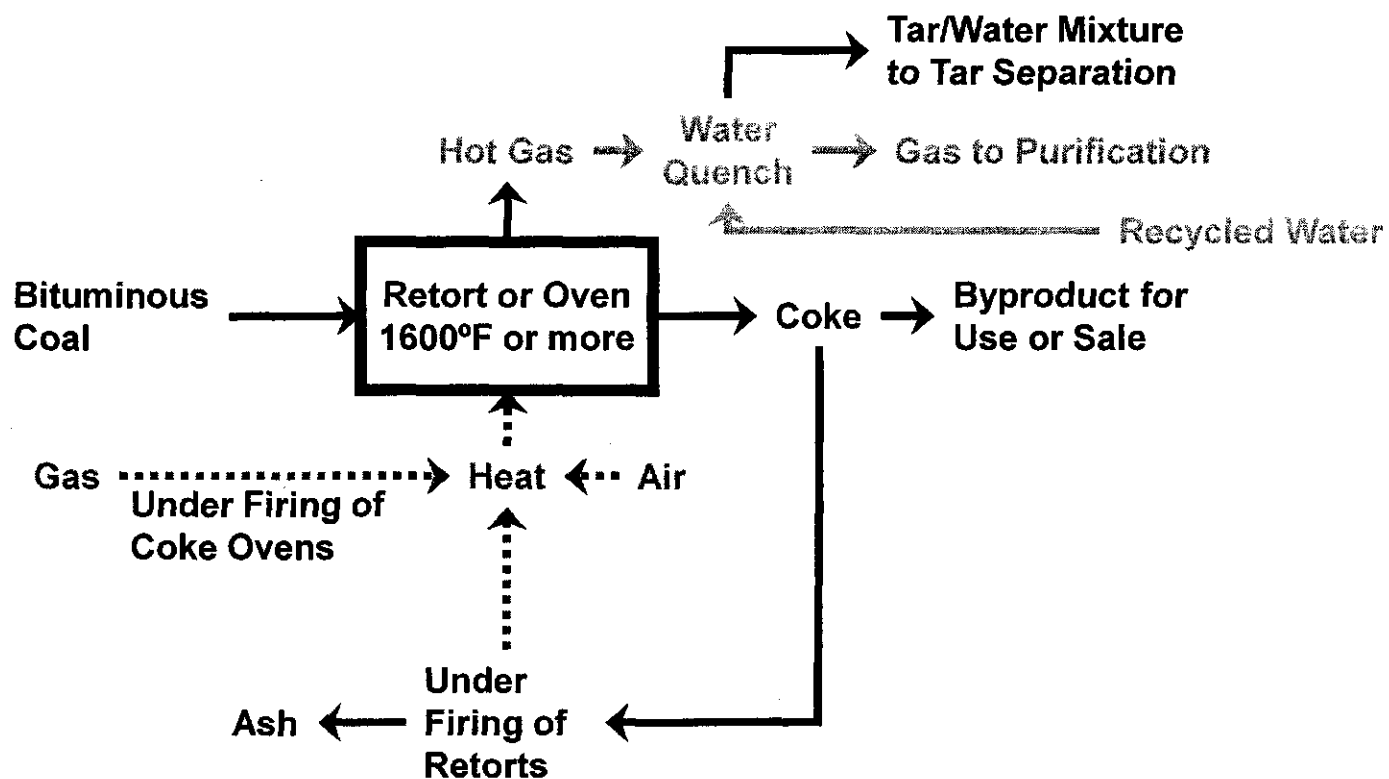
YEAR	TESTIMONY	STATE	CASE
1988-89	Deposition and trial testimony (expert witness) in Broderick Investment Co. vs. Ponderosa Timber regarding wood treating plants (Broderick Investment Co.)	CO	---
1989	Deposition and trial testimony (expert witness) in USF&G Co. vs. Colorado National Bank, et al. regarding wood treating plants (Broderick Investment Co.)	CO	Civil Action No. 86-Z-1033
1989-90	Pre-filed direct and rebuttal and cross-examination testimony (expert witness) before Massachusetts Department of Public Utilities regarding manufactured gas plants (Bay State Gas, et. al.).	MA	DPU 89-161

1991	Deposition testimony (expert witness) in Burlington Northern vs. Washington Natural Gas, et. al. regarding manufactured gas plants (Electric Utilities Group)	WA	No. C89-155TB
1991	Pre-filed direct and cross-examination testimony (expert witness) before Illinois Commerce Commission regarding manufactured gas plants (Peoples Gas Light & Coke, et al.)	IL	ICC: Docket Nos. 91-0080 through 91-0095
1991	Trial testimony (expert witness) in Escambia vs. Soule regarding wood treating plants (Escambia)	FL	---
1992	Rebuttal and cross-examination testimony (expert witness) before the New Jersey Bureau of Regulatory Commissioners regarding manufactured gas plants (South Jersey Gas)	NJ	BRC Docket No. GR91071243J
1992	Direct and cross examination testimony (expert witness) before the New Jersey Bureau of Regulated Utilities regarding manufactured gas plants (New Jersey Natural Gas)	NJ	BRC Docket No. GR91081393J
1992	Deposition testimony (expert witness) in Chemical Lehman Tank Lines vs. Aetna regarding wastewater management (Chemical Lehman)	NJ	Case No. 89-1543
1993	Pre-filed direct and cross-examination testimony (expert witness) before Indiana Utilities Regulatory Commission regarding manufactured gas plants (Indiana Gas)	IN	Cause No. 39353 Phase II
1993	Deposition and trial testimony (expert witness) in Broderick vs. Hartford regarding wood treating plants (Broderick Investment Co.)	CO	Civil Action No. 86-Z-1033 CA No. 90-1112
1993	Deposition and trial testimony (expert witness) in Washington Natural Gas vs. Aetna regarding manufactured gas plants (Washington Natural Gas)	WA	Civil Action No. 91-2-13506-1
1994	Deposition testimony (fact witness) in Koppers Company vs. Aetna regarding the Koppers Company, Inc. (1978-1988)	PA	Civil Action No. 85-2136
1994-95	Pre-filed direct and cross-examination testimony (expert witness) before the Michigan Public Service Commission regarding manufactured gas plants (Consumers Power Company)	MI	Case No. 4-10755
1995	Testimony (expert witness) before the Oklahoma Corporation Commission regarding groundwater remediation (Oryx, ANR and Conoco, Inc.)	OK	Cause PD No. 920024760
1996	Deposition testimony in Indiana Gas vs. Aetna regarding manufactured gas plants (Indiana Gas)	IN	Civil Action 1:95CV101
1996	Deposition testimony (expert witness) in Hickmon vs. Oryx Energy Co. regarding groundwater remediation (Oryx, ANR and Conoco, Inc.)	OK	Case No. CIV94-1524-T
1997	Deposition testimony (expert witness) in EnergyNorth Natural Gas vs. UGI Utilities, Inc. regarding manufactured gas plants (EnergyNorth Natural Gas)	NH	C-95-438-B
1997	Deposition testimony (fact witness) in Penn Fuel Gas vs. Pennsylvania Electric Co. regarding manufactured gas plant site investigations and remediation (1996-1997)	PA	---

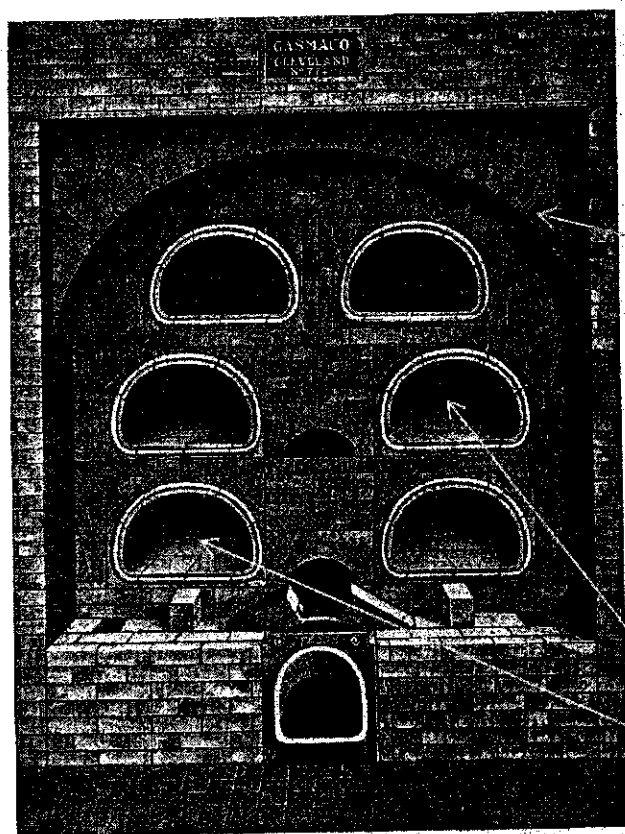
1999	Deposition testimony (fact witness) in Penn Fuel Gas vs. Aetna, et al. regarding manufactured gas plant site investigations and remediation (1996-1999)	PA	Chester Co., PA, Court of Common Pleas Civil Division No. 94-07744
2001	Deposition testimony (fact witness) in PSI Energy, Inc vs. Aetna, et al. regarding manufactured gas plant site investigations and remediation (1996-1999)	IN	Hendricks Co., IN, Hendricks Superior Court Cause No. 32DO1 9807 CP 230
2002-03	Deposition testimony (expert witness) in PECO Energy vs. INA, et al. regarding manufactured gas plants (PECO Energy)	PA	Chester Co., PA, Court of Common Pleas Civil Division No. 99-07386
2004	Deposition testimony (expert witness) in Bangor vs. Citizens Communications vs. Barrett et al. regarding manufactured gas plants (Citizens Communications)	ME	USDC, Maine, Civil Docket No. 02-cv-183-B-S
2004	Deposition testimony (30(b)6 witness, rebuttal expert witness) in PECO Energy vs. INA, et al. regarding manufactured gas plants (PECO Energy)	PA	Chester Co., PA, Court of Common Pleas Civil Division No. 99-07386
2005	Deposition testimony (expert witness, rebuttal expert witness) in Puget Sound Energy v. Alba General Insurance Co. et al. regarding manufactured gas plants (Puget Sound Energy)	WA	Superior Court of State of Washington No. 97-2-29050-3 SEA
2005	Trial testimony (expert witness) in Bangor vs. Citizens Communications vs. Barrett et al. regarding manufactured gas plants (Citizens Communications)	ME	USDC, Maine, Civil Docket No. 02-cv-183-B-S
2006	Deposition testimony (30(b)6 witness) in CGCU vs. Aetna Casualty & Surety Co., et al. regarding manufactured gas plants (CGCU)	IN	Marion Co., IN, Superior Court Cause No. 49F12-0407-PL-01986
2007	Deposition testimony (expert witness, 30(b)6 witness) in CGCU vs. Aetna Casualty & Surety Co., et al. regarding manufactured gas plants (CGCU)	IN	Marion Co., IN, Superior Court Cause No. 49F12-0407-PL-01986
2010	Deposition testimony (expert witness) in SIGECO vs. Admiral Ins. Co., et al. regarding manufactured gas plants (SIGECO [Vectren])	IN	Marion Co., IN, Superior Court Cause No. 49D05-0411-PL-2265
2011	Deposition testimony (rebuttal expert witness) in SIGECO vs. Admiral Ins. Co., et al. regarding manufactured gas plants (SIGECO [Vectren])	IN	Marion Co., IN, Superior Court Cause No. 49D05-0411-PL-2265
2011	Pre-filed direct testimony (expert witness) before Oregon Public Utility Commission regarding manufactured gas plants (NW Natural)	OR	UG 221



ACM-2: Map of U.S. Showing Number of MGP Locations by State According to Radian Corp. [1985]



ACM-3: Schematic Diagram of Coal Gas Manufacture



38. Cross-sectional Drawing of a Bench of Sixes. (Courtesy of The Machinery Company, Cleveland, Ohio).

Drawing of Front of Coal Gas Retort Bench of Six Individual Retorts [Morgan 1932, p.173]

Hydraulic Main

Bench

Individual Retorts

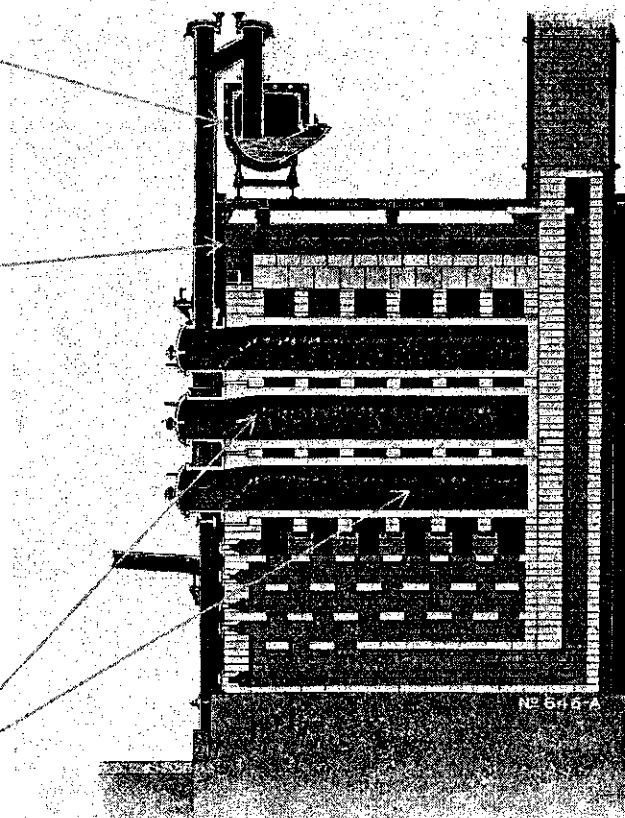


FIG. 28. Bench of Coal Gas Retorts Showing Off-take Pipe and Hydraulic Main. (Courtesy of The Gas Machinery Company, Cleveland, Ohio.)

Drawing of Side Sectional View of Coal Gas Retort Bench of Six Individual Retorts [Morgan 1931, p.150]

ACM-4: Drawings of Retort Coal Gas Apparatus

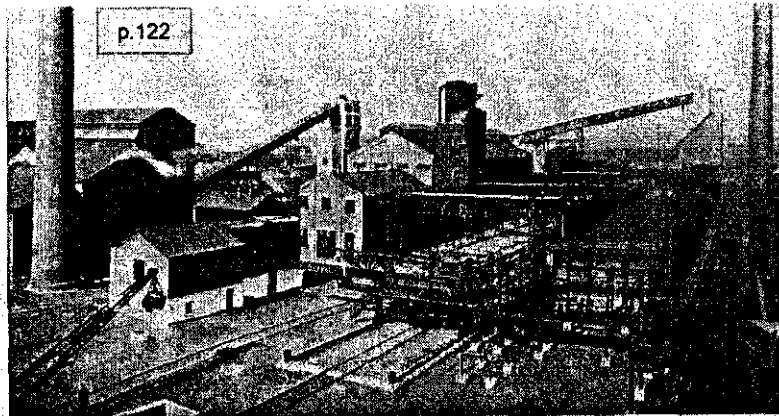
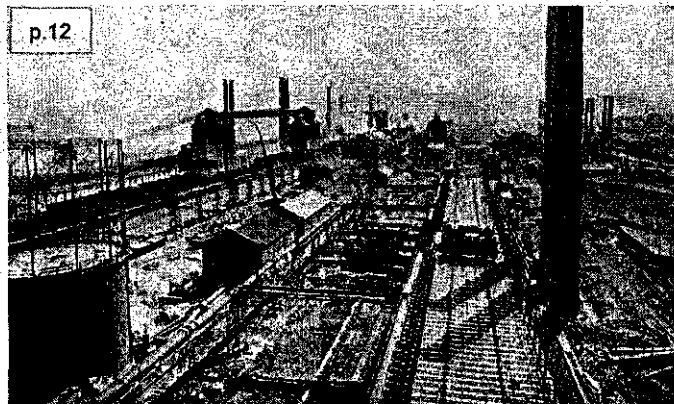


FIG. 20.—General View of Typical By-Product Coke Works, showing Ovens and By-Product Recovery Buildings.

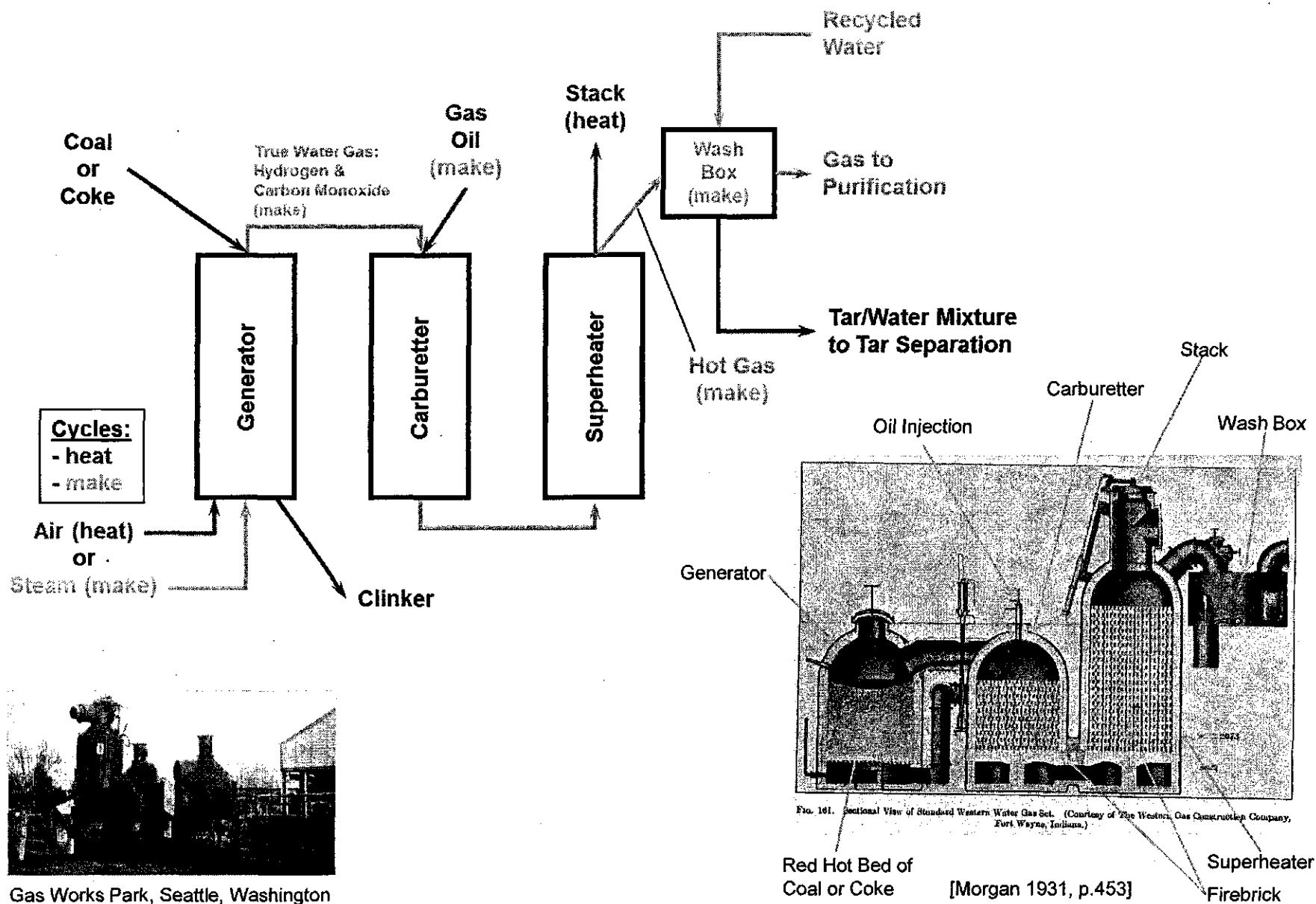


The Largest Coal Carbonization Plant in the World: By-Product Coke Works at the Carnegie Steel Co., Clairton, Pa. 134 Ovens in Three Rows, 18 Batteries (of which 366 ovens, in foreground, are under construction).

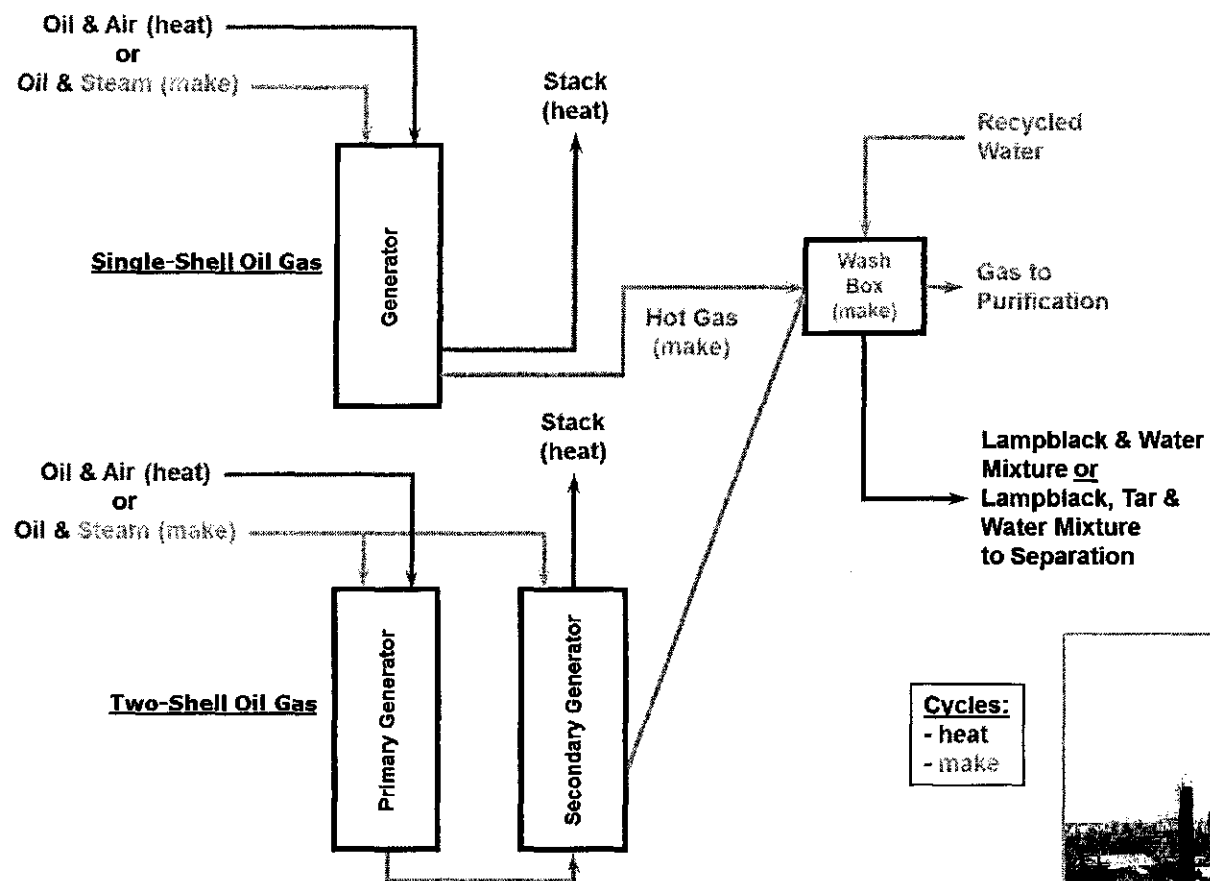


FIG. 58.—View Through Semet-Solvay By-Product Coke Oven, End to End, after 16 Years' Service.

ACM-5: Pictures of Byproduct Coke Oven Installations [Porter 1924]



ACM-6: Carburetted Water Gas ("Water Gas") Manufacture



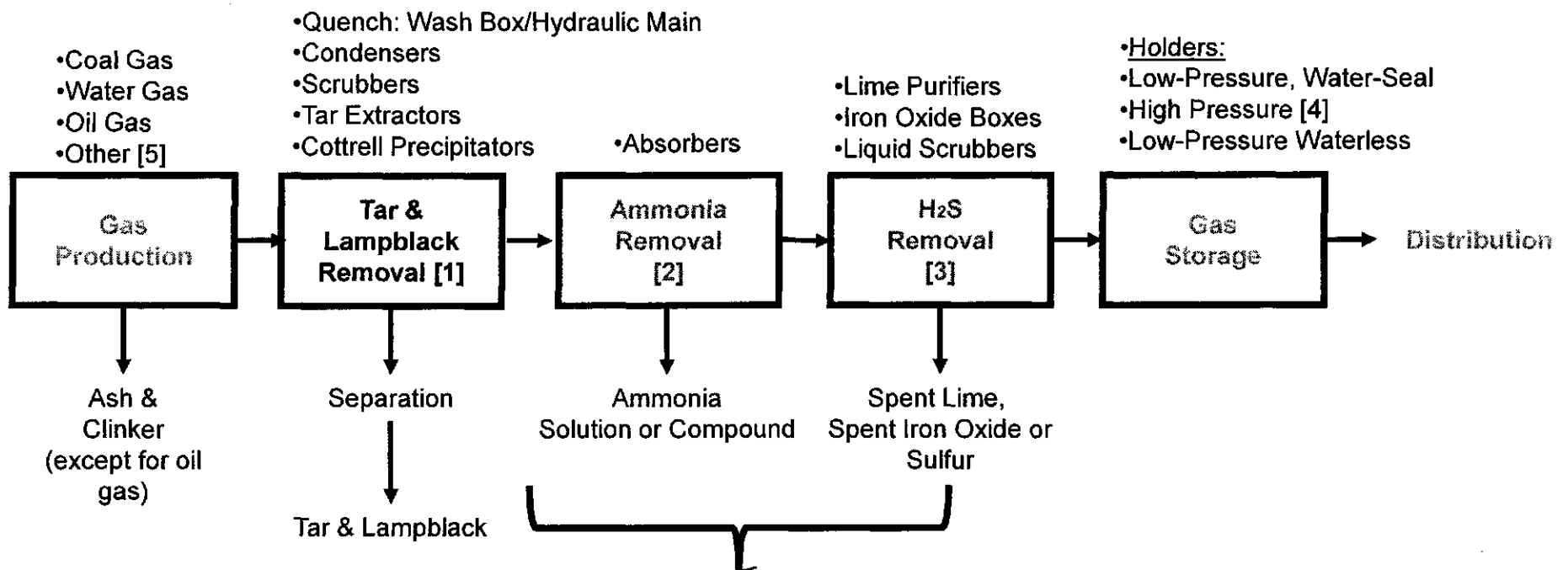
Cycles:
- heat
- make

Schematic Diagrams of Two Different Configurations of Oil Gas Apparatus



Picture of Oil Gas Generators in Gas Works Park, Seattle, Washington

ACM-7: Oil Gas Manufacture

**Notes:**

[1] Not all of these processes were necessarily at an MGP; water gas included a relief holder in this step to equalize gas flow from cyclical production; lampblack removal was for oil gas manufacture

[2] In coal gas processes only; water gas and oil gas did not typically contain significant ammonia

[3] For coal gas and oil gas using crude oil, cyanide would also be removed here; water gas did not typically contain significant cyanide

[4] Pressurization of manufactured gas generated condensate

[5] Depending on which other process, the gas purification steps may have varied from this diagram

Light Oil and/or Naphthalene recovery might also be incorporated in the gas purification steps depending on the process and scale of gas manufacture.

ACM-8: Schematic Diagram of the Overall General Gas Manufacturing, Purification and Storage Processes

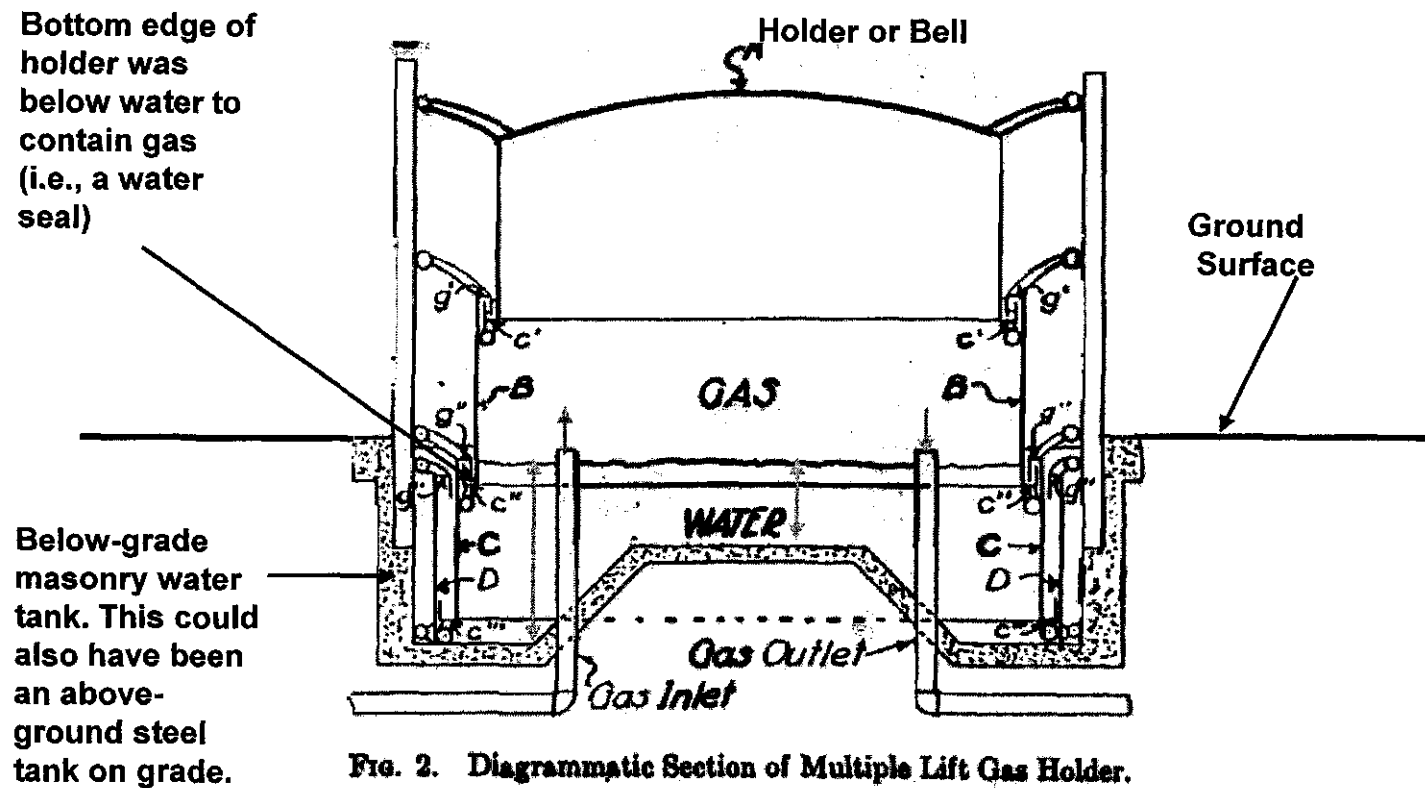


FIG. 2. Diagrammatic Section of Multiple Lift Gas Holder.

[Morgan 1935, p.5]

ACM-9: Low Pressure, Below-Ground, Water-Seal Gas Holder Diagram



FIG. 16. Twenty Million Cubic Foot M. A. N. Waterless Holder of The Peoples Gas Light & Coke Company, Chicago, Ill. 283 ft. Diameter by 408 ft. High. (Courtesy of The Bartlett Hayward Company, Baltimore, Md.)

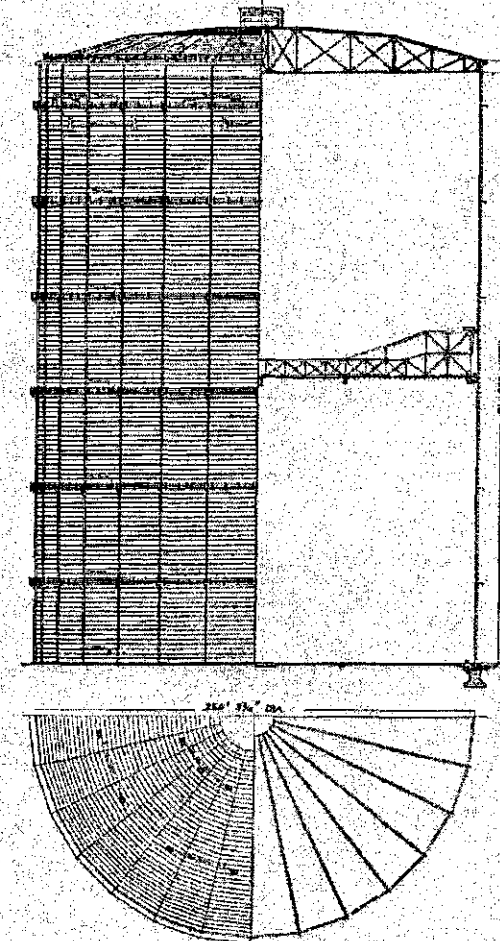


FIG. 13. Elevation and Plan of M. A. N. Waterless Holder with Capacity of Fifteen Million Cubic Feet. (Courtesy of The Bartlett Hayward Company, Baltimore, Md.)

[Morgan 1935, pp.34, 38]

ACM-10 Low Pressure, Waterless Seal Gas Holder Diagram

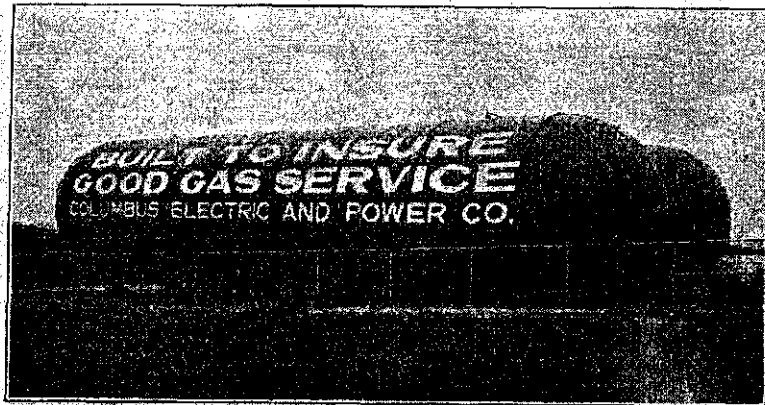


FIG. 26. Stacey Bullet High Pressure Gas Holder. (Courtesy of Stacey Brothers Gas Construction Company, Cincinnati, Ohio.)

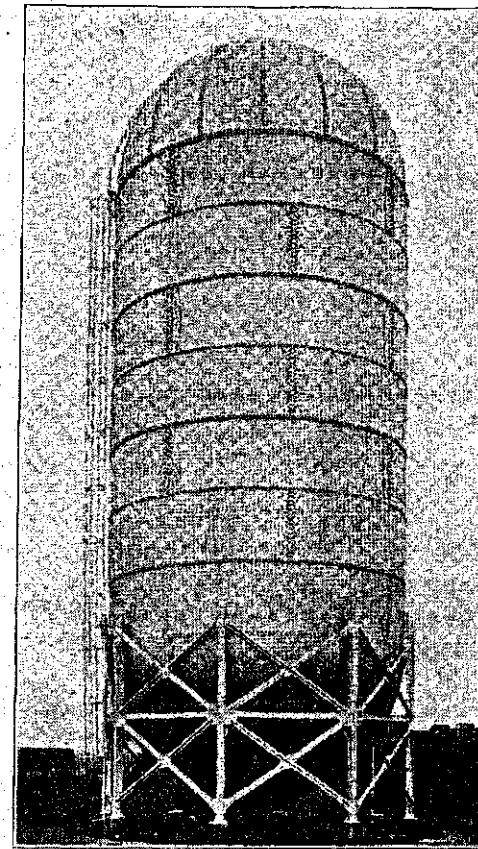


FIG. 25. Western Gas High Pressure Tower. (Courtesy of Western Gas Construction Co., Fort Wayne, Ind.)

[Morgan 1935, pp.56-57]

ACM-11: High-Pressure Cylindrical Gas Holders

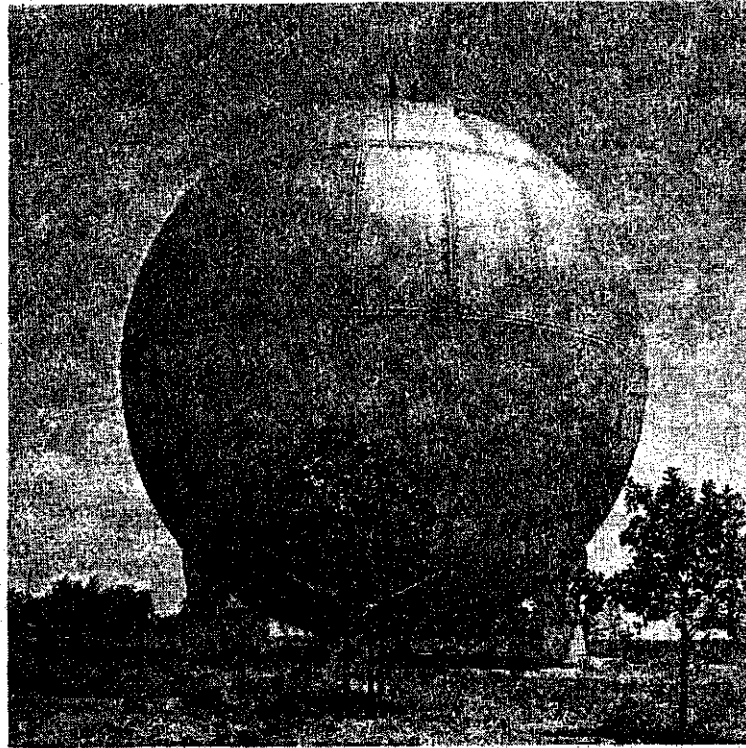


FIG. 27. Hortonsphere High Pressure Gas Holder, 57.5 feet in Diameter.
(Courtesy of Chicago Bridge & Iron Works, Chicago, Ill.)

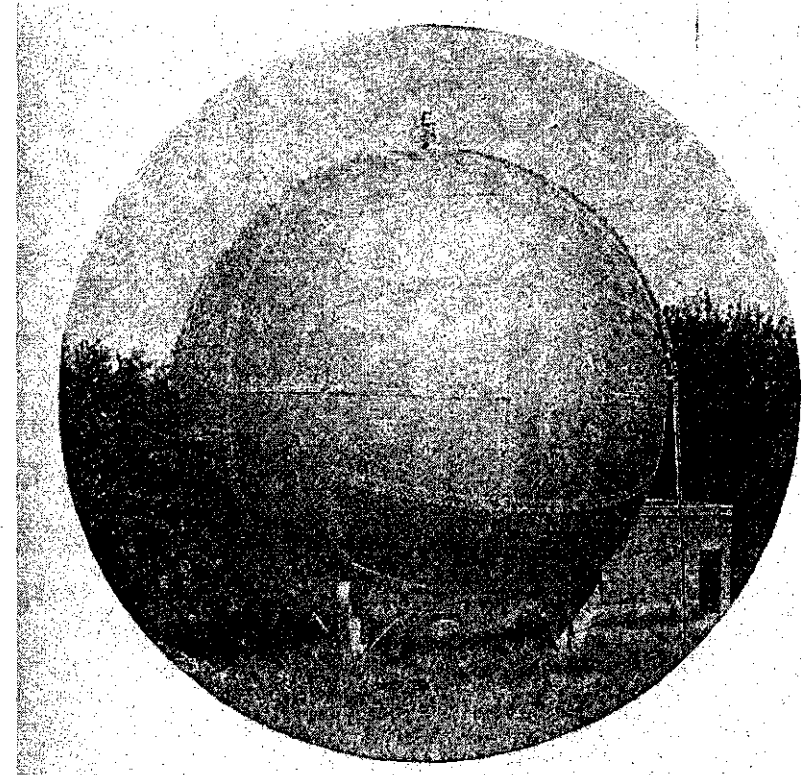


FIG. 28. Hortonsphere High Pressure Gas Holder, 40 feet in Diameter, Blends Well
with Background. (Courtesy of Chicago Bridge & Iron Works, Chicago, Ill.)

Morgan 1935, pp.60-61


ACM-12: High-Pressure Spherical Gas Holder

ACM-13: Table of Residuals from Gas Manufacture

Residual	Coal Gas	Carburetted Water Gas	Oil Gas	Description
Liquids				
Tar	x	x	x	Mixture of liquid hydrocarbons
Wastewater	x	x	x	Excess water from gas-making
Ammonia	x			Ammonia-water solution at coal gas plants where water was used to absorb ammonia
Light Oil	[1]	[1]	[1]	Mixture of liquid aromatic compounds including benzene and toluene at MGPs with light oil recovery
Solids				
Coke	x			Remnant of bituminous coal after heating in retorts or ovens, primarily carbon
Lampblack			x	Fine carbon particles resulting from manufacture of oil gas
Sulfur Removal				
Spent Lime	x	x		Primarily pre-1880s: Lime solids that absorbed hydrogen sulfide and in the case of coal gas, hydrogen cyanide
Spent Oxide	x	x	x	After the 1880s: Iron oxide coated media (e.g., wood chips) that absorbed hydrogen sulfide and in the case of coal gas, hydrogen cyanide
Sulfur	[1]	[1]	[1]	Elemental sulfur solids resulting from use of liquid sulfur removal
Clinker		x		Fused ash of coke or coal input to the carburetted water gas process
Ash	[2]	[2]	[2]	Ash remaining from burning of coal or coke for steam production

[1] Where this process was used; light oil recovery and liquid sulfur removal were not used at all MGPs

[2] In retort coal gas, coke was burned to heat the ovens; at other plants ash would have been generated if there were coal or coke fired boilers to produce steam.



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Prevents Dust -

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New York	Chicago	Pittsburgh	Boston	St. Louis	Cleveland	Chicagoo
Pittsburgh	Detroit	Birmingham	Kansas City	Minneapolis	St. Paul	Seattle

YORK ESTABLISHMENT 3100-10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

County Life, March 1915 – Middletown, Ohio

THE SATURDAY EVENING POST



Road Highway, between Toledo, Ohio, Tarvia built 1910

This 1910 car has chugged its last chug —this 1910 Tarvia Road is still good

IMAGINE the car pictured here snorting up to your door tonight. What a turning of neighbors' heads! Yet that car was modern when the Tarvia pavement was laid on the Dixie Highway — back in 1910. Those old-time autos have gone their way — replaced by smooth-running, modern cars. But the Tarvia pavement of the Dixie Highway, after fourteen years of ceaseless motor traffic, is as good as the day it was laid. And this section of the Dixie Highway between Toledo and Detroit is one of the nation's most heavily traveled trunk lines. Tarvia pavement is lasting. A Tarvia road can be kept good indefinitely, at little cost. Or to put it another way — to make a Tarvia pavement last indefinitely, only the most economical maintenance is necessary.

And these facts in addition:

- A Tarvia pavement will not wave, roll or rut.
- A Tarvia pavement is skid-proof, because of its granular surface.
- Thousands of Tarvia streets and roads have proved to tax payers that for the money spent — and remember it's your money — Tarvia gives more mileage and the most years of satisfactory service.
- On request, we will gladly send you descriptive booklets, construction data and complete specifications. Write to our nearest branch.

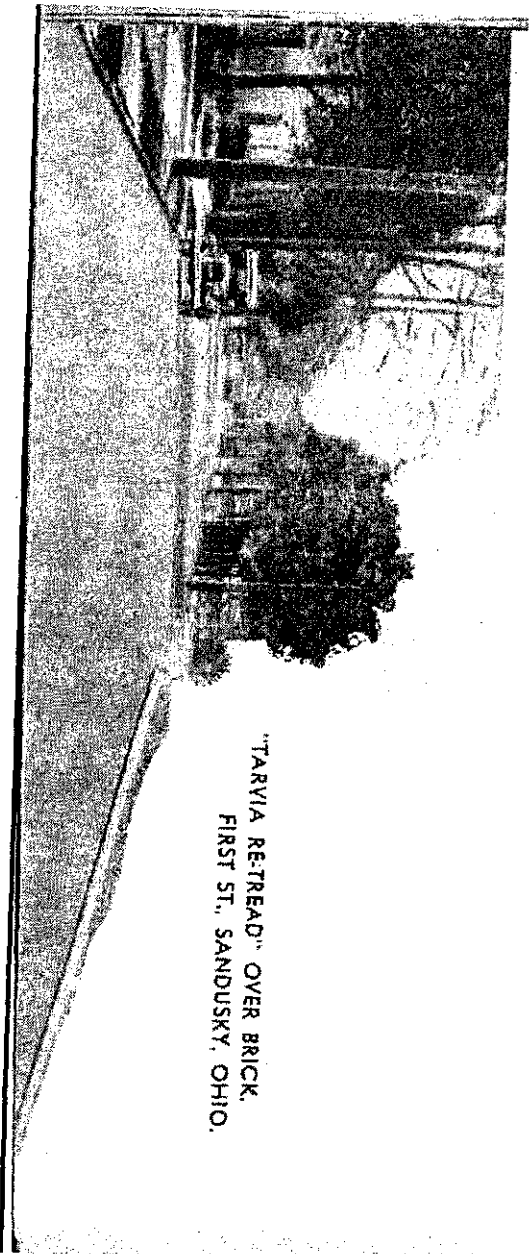
Saturday Evening Post August 1924 – Toledo, Ohio

**ACM-14: Examples of Tarvia Ads for Ohio Roads and Streets –
Middletown and Toledo**

TARVIA TREATED MACADAM IN ALLEN COUNTY, OHIO.

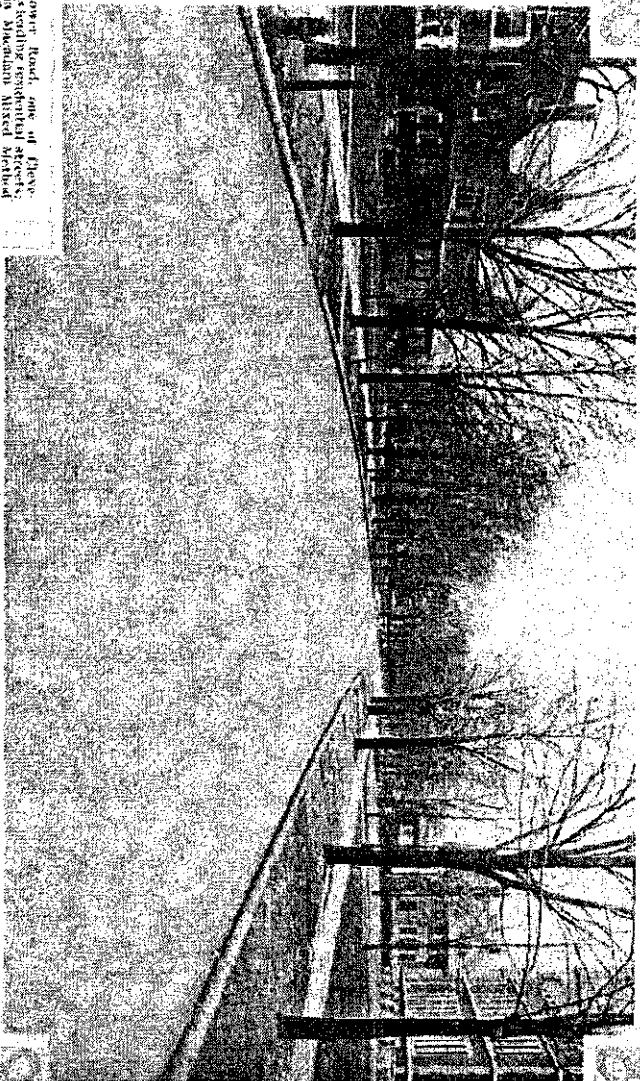


"TARVIA RE-TREAD" OVER BRICK.
FIRST ST., SANDUSKY, OHIO.



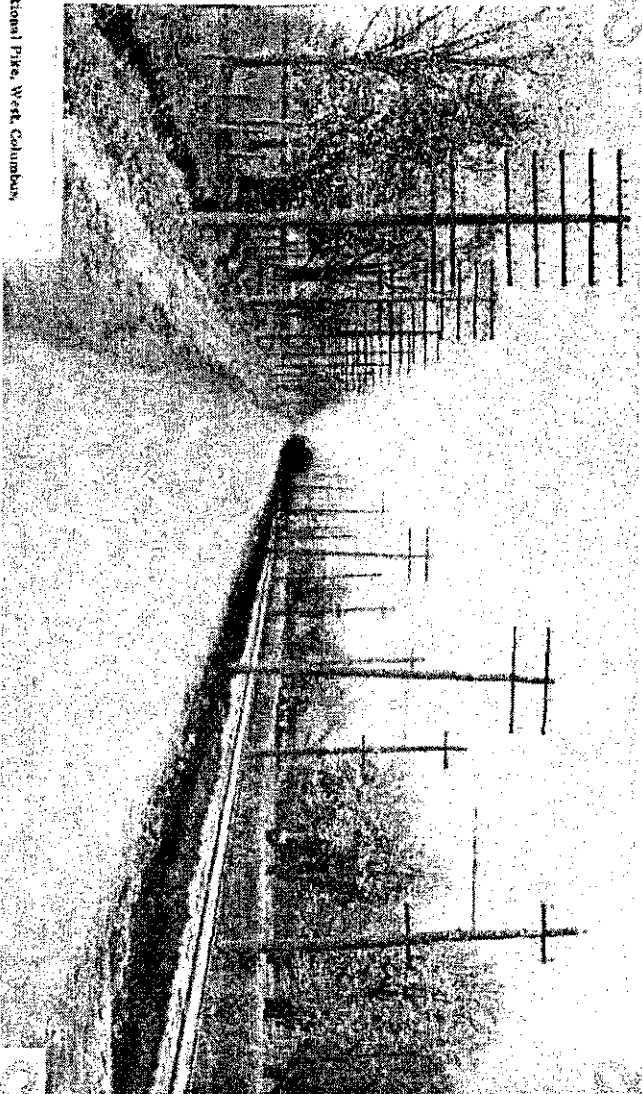
1935 Barrett Publication "Road Maintenance with Barrett Tarvia"

**ACM-15: Examples of Tarvia Ads for Ohio Roads and
Streets - Allen County and Sandusky**



Bellflower Road, one of five
new residential streets
in the new development
— 127 parking spaces on 100-foot
wide boulevard, completed
1985, to replace the old

Cleveland



National Pike, West Columbus,
O. Constructed with "Tarvia X"
and "Tarvia A"

Columbus

ca1915 Barrett Publication "Good Roads at Low Cost Tarvia"

ACM-16: Examples of Tarvia Ads for Ohio Roads and Streets – Cleveland and Columbus

Tarvia Re-Tread

Tarvia Re-Tread



ABOVE: LEWIS ROAD
CUYAHOGA COUNTY, OHIO

LEFT: RUPLE ROAD
CUYAHOGA COUNTY, OHIO



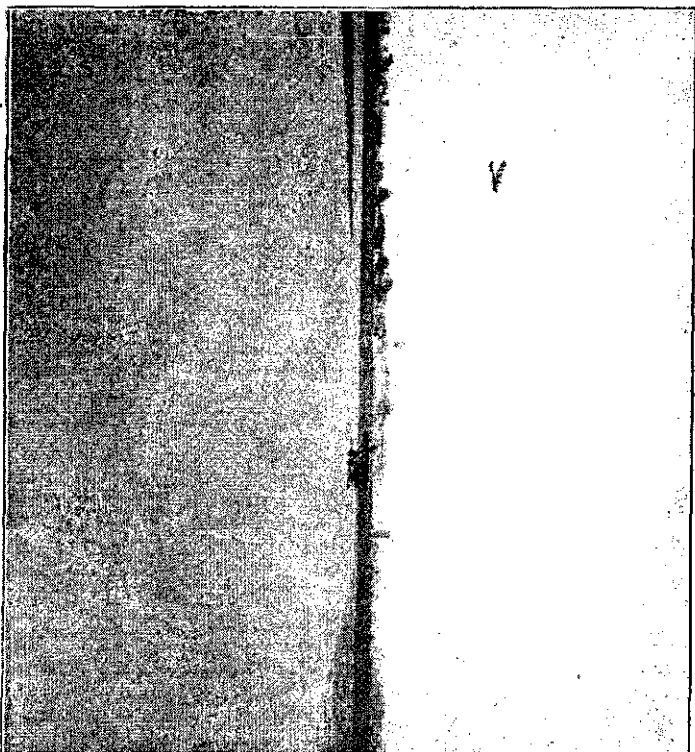
ABOVE: EAST ROAD
CUYAHOGA COUNTY, OHIO

RIGHT: SHELDON ROAD
CUYAHOGA COUNTY, OHIO



1929 Barrett Publication "Tarvia Re-Tread"

**ACM-17: Examples of Tarvia Ads for Ohio Roads and Streets –
Cuyahoga County**



DAYTON, OHIO, AIRPORT, "TARVIA RE-TREAD" RUNWAYS

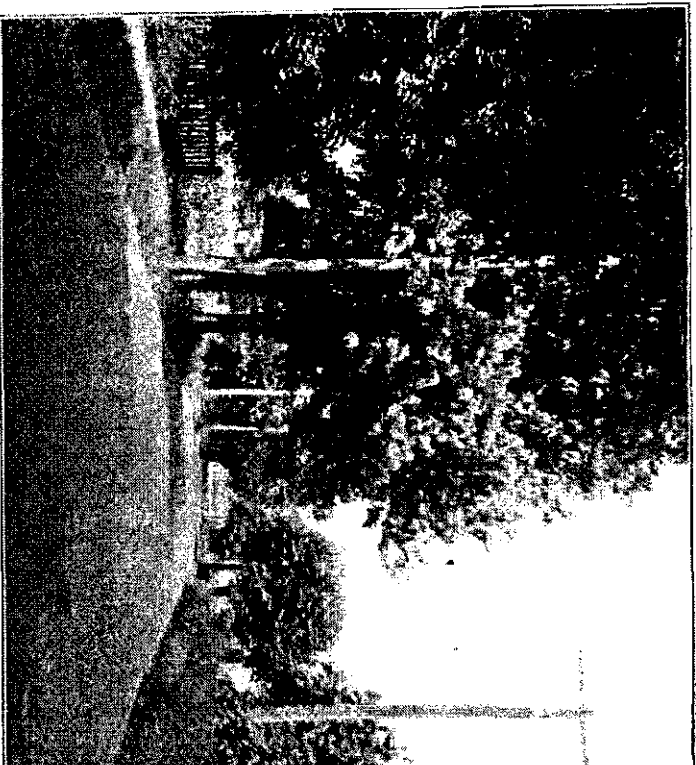
Tarvia Re-Tread



BOX ROAD, LUCAS COUNTY, OHIO

1929 Barrett Publication "Tarvia Re-Tread"

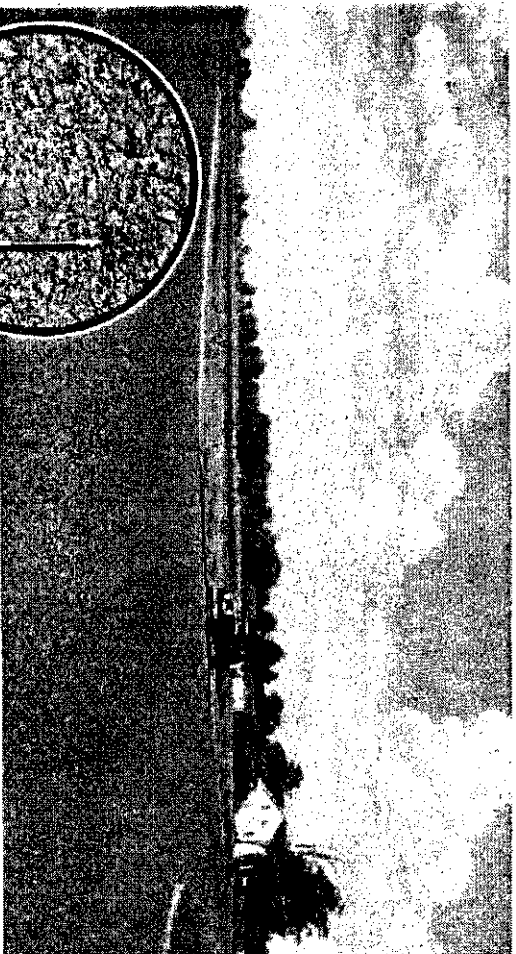
ACM-18: Examples of Tarvia Ads for Ohio Roads and Streets – Dayton and Lucas County



DE BOLT AVENUE, NEWTOWN, HAMILTON COUNTY, OHIO
1929 Barrett Publication "Tarvia Re-Tread"

*Junction Bensers Road and U. S. Highway
No. 59, Lucas County, Ohio. Tarvia-shield.*

Tarvia holds the stone aggregate firmly in place and



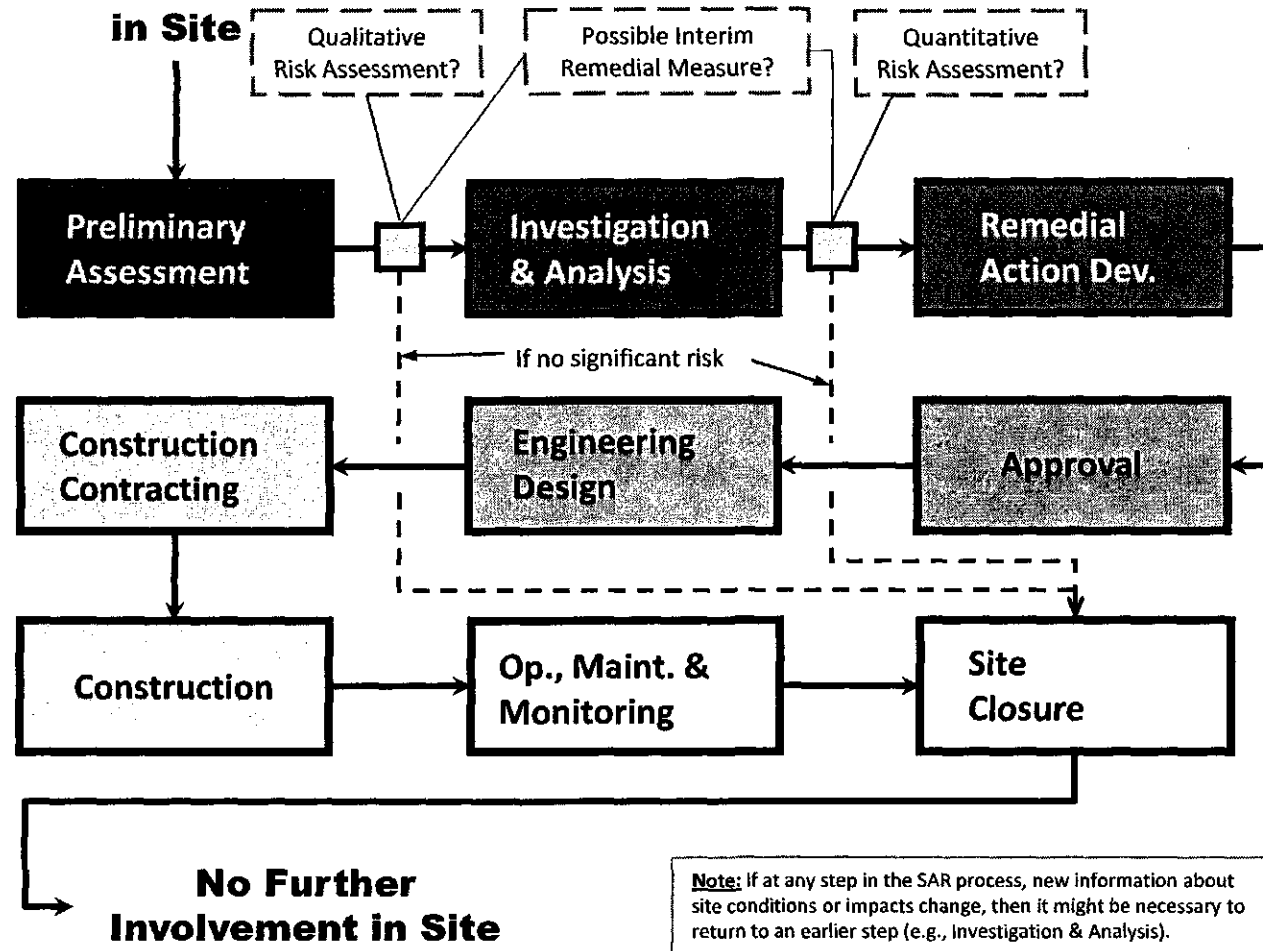
*Close-up view of a Tarvia road
showing the exposed rough
stone surface that provides
non-skid traction.*

exposed on the road, thus providing a slightly granular surface on which tires get a firm tread-hold. Beneath the surface Tarvia remains thickly viscous and retains its lasting binding power. There is no oily surplus to work up over the aggregate to form a slippery, dangerous pavement.

American City 1932

ACM-19: Examples of Tarvia Ads for Ohio Roads and Streets – Newtown and Lucas County

Initial Involvement



ACM-20: Overview of Site Assessment and Remediation (SAR) Process