HISTORIC AMERICAN ENGINEERING RECORD

ALLEGHENY OIL HERITAGE PROJECT: A CONTEXTUAL OVERVIEW OF CRUDE OIL PRODUCTION IN PENNSYLVANIA

HAER No. PA-436

Location: Pennsylvania

Significance: Western Pennsylvania is the birthplace of the modern petroleum industry, signified by the drilling of Edwin L. Drake's oil well near Titusville in 1859. Subsequent development of the Appalachian oil region, stretching from New York to Tennessee, revealed hundreds of oil fields which produced a particularly fine quality of petroleum, often called Pennsylvania Grade crude oil, that is still largely unsurpassed in its lubricating qualities. For thirty-five years western Pennsylvania led the nation in petroleum production, and techniques of drilling and pumping oil perfected in Appalachia found usage around the world.

Historian: Michael W. Caplinger, 1997

Project Information:

During 1997, the Historic American Engineering Record (HAER), West Virginia University's Institute for the History of Technology and Industrial Archaeology (IHTIA), and Pennsylvania's Allegheny National Forest (ANF) entered into a tripartite agreement to document six historic oil-pumping operations within the Allegheny National Forest using measured drawings and large-format photography. This project included the following contextual component designed to provide a broad overview of the history of oil production in Pennsylvania, and the history and operation of central power well-pumping systems. Six individual site descriptions (HAER Nos. PA-437, PA-438, PA-439, PA-440, PA-441, PA-442) augment this context.

Chronology

1854	Incorporation of the Pennsylvania Rock Oil Company
1858	Pennsylvania Rock Oil Company evolves into Seneca Oil Company and hires Edwin Drake to drill an oil well along Oil Creek, near Titusville
1859	Drake strikes oil, an event considered to mark the beginning of the modern petroleum industry, and the Appalachian oil region leads U.S. production for the next thirty-five years
1862	First attempts at pipelines to transport oil and alleviate transportation
1863	Centrally powered pumping systems begin to operate in the Appalachian region and southern Canada
1880	Oil pools in the Allegheny National Forest region flourishing
1890	Central powers common; Geer-Tiona central power constructed
1892	Pennsylvania produces 32 million barrels of oil–its all-time high
1895	Pumping engines converting from steam to well-head gas
1897	First bandwheel power patented
1909	Mead and Lockwood central powers constructed
1920	Golden Oil and McKenna-JoJo central powers constructed
1939	Mallory central power constructed
1950	Use of central power systems declining in deference to self-contained “unit pumpers”
1980	Central powers largely abandoned by this time
1990	Pennsylvania’s oil production drops to over just over 2 million barrels annually, about what the state produced in 1865

Introduction

Without petroleum, modern industrialized society would come to a grinding, screeching, friction-filled halt. Petroleum in its various forms is everywhere. It powers our engines, lubricates the moving parts of the world's machines, provides heat and light for millions, and its byproducts are the basic ingredient for hundreds of indispensable products. We have even deemed its continued supply a strategic necessity, and worthy of war. This most important substance is, like many of humanity's wants, a gift of the earth. Like other valuable minerals, there is a finite amount of it, and it is found only in certain places. The Appalachian mountain region in the eastern United States is one of these areas, and western Pennsylvania is an especially important part. It was here that, on August 27, 1859, Edwin L. Drake successfully drilled a 69 ½'-deep well specifically to produce oil, thus ushering in the modern petroleum age.

The subsequent development of Pennsylvania's petroleum resources gave rise to fortunes, boom towns, and an industry that remains active to this day. The formerly wild, sparsely populated region of western Pennsylvania was quickly pierced by speculators and wildcat drillers, and newly constructed railroads and pipelines vied for the petroleum trade. Indeed, Pennsylvania supplied 98 percent of the nation's needs until 1886, when petroleum production in the Midwest and Southwest began dominating the industry. Even after this, the Appalachian oil fields continued to produce, but only at a low level, buoyed by the higher-than-average price garnered for the superior-quality Pennsylvania Grade oil. For those interested in the technological aspects of crude oil production, the Appalachian oil fields, as the oldest developed fields in the country, provide a unique case study in the development of the petroleum industry, especially central-power well pumping systems.

The Origin and Nature of Petroleum

Petroleum is the general term for a complex mixture of gaseous, solid, and liquid hydrocarbons.[1] It is a naturally occurring substance usually found trapped deep

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[1]Petroleum can be divided into a succession of hydrocarbon compounds through refining. At the top of the list are the lightest compounds, gases such as methane, followed by increasingly heavy compounds like gasoline, kerosene, fuel oil, lubricating oil, paraffins, and asphalts. Those at the top are called the dry gases (highly flammable and odorless, non-liquefied), followed by slightly heavier wet gases, from which natural (liquid) gasoline is created by chilling, compression, or absorption. Below are the kerosenes (it and the liquid gasolines are collectively known as the naptha group), followed by the fuel oils, then lubricating oils. The lowest, and heaviest, are called the

beneath the earth's surface, but at certain places it emanates from ground "seeps." These seeps were the first clue to its existence, and they supplied humans' needs for "mineral oil" adequately for thousands of years. While there are many examples of petroleum's use down through history, only the demands of the industrial revolution spurred systematic attempts to discover and produce oil and gas using relatively modern methods of drilling and pumping.[2] Until the drilling of Drake's well in 1859 the market for illuminating and lubricating oil had been supplied by the whale-oil industry; gas by the coal-gasification industry. The depletion of whale populations and relative inefficiency of other chemical distillation methods pressed the search for mineral-based petroleum supplies. Its origin and occurrence within the earth has been the subject of debate ever since.

For many years the discussion over the events that created and trapped petroleum produced widely varying theories. Today, the general opinion holds that petroleum formed from the decaying remains of organic material deposited hundreds of millions of years ago. Ancient seas and shorelines were the most likely spots for such deposits, where vast quantities of microscopic (and larger) marine life and plant material were collected and sealed into sedimentary layers, the source rock, to await decay.[3] The exact manner in which these organisms were altered to petroleum is still somewhat vague, but--far beneath the earth--heat, pressure, and possibly biological processes

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semi-solids--wax or paraffin oils and asphalts. In addition to the hydrocarbons, petroleum can contain up to 5 percent oxygen, 1.8 percent nitrogen and 5 percent sulphur. See Max Ball, <u>This Fascinating Oil Business</u> (New York: The Bobbs-Merrill Company, 1940), pp. 21-24.

[2]The distillation of oil from asphalt-based petroleum was done in antiquity in the Middle East, and bitumens were long-used to coat ship hulls. Animal and vegetable matter also produces oil through distillation. Coal-gas illumination gained great popularity in such cities as Baltimore, Boston, and New York, prior to the 1850s. Oils could be extracted from coal as well, a popular method prior to the success of Drake's Well. See Harold Williamson and Arnold Daum, <u>The American Petroleum Industry: 1859-1899, The Age of Illumination</u> (Evanston: Northwestern University Press, 1959), Chapters 1-3.

[3]The salt inherent in such marine environments was also deposited in the rock. Its eventual mixture with ground water produced brine, from which the salt could be extracted. The salt industry, which arose in Appalachia in the early nineteenth century, developed the tools and techniques for brine well drilling that later made oil well drilling possible. In attempting to reach brine-bearing sands, salt drillers often lamented oil's presence, which could foul the brine. This occurred so often that oil seeps were considered good indicators of brine deposits.

transformed the organic material into petroleum. Usually the petroleum arising from the process migrates (horizontally and vertically) through the porous rock layers, dissipating into the surrounding strata and atmosphere. But where the source rock is overlain by an impervious layer, a cap rock, reserves of petroleum are trapped and coalesce in a porous reservoir strata. This is often called a “pool,” but the petroleum is usually not an underground lake, per se, but is still held within the rock matrix. This reservoir strata is nearly always sandstone,[4] but it can be found in limestone, shale, and other rock types.

The tendency of petroleum to migrate to higher places in the rock usually resulted in a pool’s gravitational separation into gas at the highest level, oil in the middle, and water lowest down. In certain exceptions, the Pennsylvania petroleum fields are one, this clearly defined separation did not occur because of the relatively gentle folding of the subsurface strata, and cap rocks closely overlying the source rocks, which hampered vertical migration.

Petroleum reserves vary greatly in their makeup. Pools are sometimes entirely gas, but most often they are an oil and gas mixture. Logically, gas could migrate farther than oil, and thus there are many gas-only pools in the otherwise mixed petroleum reserves of Appalachia and other petroleum producing regions. Chemically, local variations in both the original organic source material and the post-deposition transformation process account for the variety of petroleum types.

While attempts to locate petroleum prior to 1900 were largely governed by chance and misguided theory,[5] various scientifically based techniques were developed to predict the location of structural and stratigraphic traps which might overlie hidden reservoirs. Geologists eventually accepted that several different geologic conditions could form traps. Arched strata, such as anticlinal (upward) folds, were the most abundant of such natural traps. But traps could be formed in other ways, among them: a change in the porosity or density of the oil-bearing rock, salt domes, coral reefs, and impermeable

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[4]Such sandstone layers are not always continuous, monolithic structures. The fact that most sandstone deposits originated as shoreline beaches and sand bars resulted in the formation of “lenses.” These isolated, often elongated, formations can stretch for miles. Their thickness decreases near the edges until the formation is said to “lens out.” The sandstone formations of Appalachia exhibit the lens characteristic.

[5]The “belt theory” was one such misguided theory popular in the oil fields of northwestern Pennsylvania. It arose out of an incorrect interpretation of the lens phenomenon.

faults. In Pennsylvania, the most common traps are anticlinal folds.[6]

This aspect of petroleum geology developed in the Appalachian region's oil fields, especially in West Virginia and Pennsylvania, which were intensely studied after 1859. In 1861, T. Sterry Hunt suggested a correlation between anticlinal features and petroleum. I.C. White, West Virginia State Geologist, published his own theory on anticlinal folding in 1885 after studying that state's Volcano oil field. However, this method of petroleum prospecting did not gain immediate acceptance. This was in a large part due to the opposing views of Pennsylvania geologists John Carll, of the Second Pennsylvania Survey, and J.P. Lesley, the Pennsylvania State Geologist. Basing their opinions on conditions in western Pennsylvania, they considered the natural porosity of sandstones alone sufficient to account for petroleum accumulations in Appalachia. Both views were correct in certain aspects. Throughout the late eighteenth century and into the twentieth, however, drillers mistrusted or scoffed at the scientific methods and new fields were usually uncovered by wildcat wells. Following its use in discovering the vast petroleum fields in the Southwest after the turn of the century, White's anticlinal theory gained wide acceptance.

Even with the success of anticlinal theory, locating oil was still a hit-or-miss prospect. For one thing, drilling was still required to determine if a structural trap held oil. Fortunately, drilling became easier and drillers could penetrate to great depths. Since the 1940s, offshore drilling and production has added even greater challenges to the petroleum prospector. Twentieth century geophysics has produced magnetic, seismic, and gravitational tests and remote-sensing techniques that can indicate the presence of favorable subsurface traps that may contain oil. The development of aerial and space-based photography has provided more tools for the modern petroleum geologist.[7] Today petroleum is produced around the world, and scientists predict that the currently recoverable petroleum reserves will last at least another century.

The Appalachian Oil Region's Historic Role in National Production

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[6]W.A. Ver Wiebe, <u>North American Petroleum</u> (Ann Arbor: Edwards Brothers, 1957), p. 2. There are innumerable reference works on the general origins and nature of oil.

[7]Even today some fields are chance discoveries by wildcat drillers. Regardless, 99 percent of all wildcat wells are dry holes.

North America possesses several distinct petroleum producing regions. The historic development of production from the United States' various fields followed a generally east-to-west trend, beginning with the Appalachian district.[8] The districts vary widely in the type and amount of petroleum produced, overall production trends, and the makeup of the oil producing geologic formations. Most of these regions were discovered prior to 1900, but with Appalachia supplying nearly all the country's petroleum needs, most other fields produced at only a very low level for many years prior to reaching their highest output after the turn of the century.

Edwin Drake's oil well near Titusville in 1859 began large-scale development in the Appalachian Mountains, the nation's first and longest producing oil region.[9] The Appalachian oil fields were found to extend, in a long, thin belt lying on a northeast to southwest axis, along the western flanks of the Allegheny Plateau from western New York, through western Pennsylvania, western West Virginia, east Ohio, and east Kentucky, to east Tennessee. Geologically, the district lies in the Appalachian geosyncline, or Appalachian basin, which is dominated by Paleozoic sedimentary deposits laid down during the Missippian (280-345 million years ago) and Pennsylvanian 345-400 million years ago) periods. The basin stretches from New York to Alabama, and is bounded by the Appalachian Mountains to the east and a formation called the Cincinnati arch to the west in central Ohio.

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[8]David Levin, Petroleum Encyclopedia (New York: The Ranger Press, 1942), p. 93. Eventually, the lower forty-eight states' major producing districts consisted of: the Appalachian district; the Lima-Indiana district, consisting of northwest Ohio and northeast Indiana; the Michigan district; the Illinois-Southwest Indiana district, consisting of Illinois, western Kentucky, and part of Indiana; the Mid-Continent district, embracing Oklahoma, Texas (except the Gulf Coast), Kansas, northern Louisiana, Arkansas, and Missouri; the Gulf Coast district, including the Texas and Louisiana coasts; the Rocky Mountain district, covering Wyoming, Montana, Colorado, New Mexico, and Utah; and the California district. In the first years of the 1900s, the Mid-Continent, Gulf Coast, and California fields far out-paced production in the rest of the country. There are various ways to delineate the nation's petroleum regions, such as by geologic formation, for instance, but most follow the "district" categorization. The terms districts, regions, and fields are usually synonymous at this level.

[9]In some ways this is misleading, as oil was known to exist on many parts of the continent and had long been collected from various locales for medicinal purposes. Others were also drilling for oil in the Appalachians and Canada at nearly the same time as Drake. However, the completion of Drake's well is a convenient date, and it is widely considered the beginning of "industrial" large-scale production. For a countering view, see William McKain, Where it All Began (Parkersburg: McKain, 1995).

Nearly all the oil and gas in the region is recovered from sandstone reservoir rocks. Most often these reservoir sands are located at the boundary of the lower Mississippian and Upper Devonian systems. Usually the oil pools are found in anticlinal folds (some synclinal folds also produce oil here) and the depth of producing sands range from just a few feet to about 4000' below the surface. The average depth is about 1,800' In the last 30 years, advances in drilling technology have allowed discoveries of gas fields trapped in much deeper formations, 7,500' and more below the surface. Generally, production and drilling techniques were similar throughout the region.

The fact that the Appalachian oil region was the nation's first producing field is not surprising. Native Americans had known of the oil seeps of western New York and Pennsylvania, and had made use of them for hundreds of years. Europeans first noted the occurrence of oil in the region in the 1600s. Then, the rise of the salt industry in West Virginia, Ohio, and Kentucky in the early 1800s provided a twofold stimulus. First, the general techniques of well-drilling were introduced in 1806 by the Rufner brothers in West Virginia's Kanawha Valley, and these techniques became well-understood by many in the region. Second, oil was often found in brine wells, and suggested that more might exist below in large quantities. Appalachia's relatively shallow oil fields facilitated their early discovery.

There were other factors at work also. The Appalachian oil region lay in close proximity to the major population centers of the east, with their demand for lamp oil and "medicinal" oil. Moreover, industrialization was underway there, demanding lubricants for machinery. Pioneer trunk line railroads had crossed the region in the preceding decade, linking up the Atlantic with the Ohio River and providing unprecedented access to Appalachia's mineral wealth. The rapidly growing railroad network needed lubricants as well, and added to the growing pressure to find large, sustainable petroleum supplies.

The Appalachian fields began production in 1859 with 2,000 barrels[10] of oil, increasing to over 2 million barrels a year in 1862. Appalachia's production level steadily increased, and it remained the only field of importance until 1886, a year it produced nearly 27 million barrels, or about 98 percent of the nation's total.[11] After 1886, production leveled off in Appalachia and averaged around 30 million barrels a year, but this fulfilled the nation's demand adequately and relieved the pressure for increased

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[10]One barrel equals 48 gallons.

[11]From 1860 onward small production levels were seen in California (and Colorado the year after) but these were only an insignificant fraction of Appalachia's and would not assume importance for another forty years. The Michigan district, discovered in 1865, was never a major producer.

production in the rest of the United States for another twenty years. Historically, Pennsylvania and West Virginia produced the large majority of Appalachia's total output, and New York the smallest fraction.

After the Appalachian field, the Lima-Indiana district was the next to rise to national importance with the discovery of large fields in northwest Ohio during 1886. Beginning with an average yearly production of over 1 million barrels, it did not immediately overwhelm the Appalachian fields in production totals, but afterwards the opening of this and other new districts continually wore away Appalachia's share of total output. By 1890 the Lima-Indiana district was producing 15 million barrels yearly, compared to Appalachia's 30 million barrels. The nearby Illinois-Southwest Indiana district was opened in 1889, with substantial production beginning around 1907, with over 24 million barrels.

During 1900, crude oil production in the United States amounted to nearly 64 million barrels, with Appalachia producing 57 percent, or 36 million barrels per year. This was Appalachia's peak production year. Afterwards, production in the East (the Appalachian, Lima-Indiana, and Illinois-Southwest Indiana districts) lessened in importance as the Mid-Continent, Gulf Coast, and California fields came to dominate.[12] Thereafter, production levels from the latter districts dwarfed those of the old eastern fields.

Still, Appalachian oil dominated a special niche in the market after 1900--high quality lubricating oil. Its usefulness as an aircraft-engine lubricant made it an especially valuable commodity as the century progressed. By 1930, the United States was producing about 896 million barrels of oil a year, with Appalachia supplying over 34 million barrels, or 3.8 percent of the nation's total. Up to that same year Appalachia had produced a total of 1.5 billion barrels, or 12 percent of the national total production over seventy-one years.[13] By 1940 the United States produced well over a billion barrels a

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[12]The large Mid-Continent district was first opened in eastern Kansas and eastern Texas in 1889, but did not produce over a million barrels a year until 1903. It increased rapidly to over 123 million barrels a year by 1915. After producing negligible amounts for many years, the California district rose to prominence in the 1890s, surpassing Appalachia's production by 1905.

[13]Ralph Arnold, Petroleum in the United States and Possessions (New York: Harper and Brothers Publishers, 1931), pp. 4-6. For yearly production totals of crude oil see p. 33. Arnold's figures are based on those calculated by the United States Geological Survey yearly reports, Department of the Interior; and the United States Bureau of Mines yearly reports, Department of Commerce. Production totals vary from source to source and should not be considered exact, but they are a good indication of

year, and Appalachia's share settled into an average contribution of around two percent, of which Pennsylvania was producing a full 1 percent. This breakdown of total production has remained largely unchanged since.

The demand for crude oil is a product of the oil's quality, which is usually determined by its "gravity" or weight. Low-gravity oils, while abundant, are in less demand and cheaper. Higher-gravity oils are rarer, and command a consistently higher price. The gravity measurement originally denoted "specific gravity" as determined by a water-displacement test, heavier oils displacing more water, and the measurement reflected as a ratio of volume of oil versus water displacement, the lower figures being heavier oils. Later, a development called the Beaum' (or A.P.I.) gravity scale reversed the measurement system, making larger numbers represent heavier oils. Pennsylvania Crude-standard oil had a specific gravity of about .8202, and an A.P.I. gravity of 41.0. The low specific gravity of Pennsylvania crude helped preserve production in the Appalachian oil fields and allow small-scale production by what would have been otherwise unprofitable wells. From a technological standpoint, this led to the development of ever-more efficient ways to pump wells, a fact discussed in more detail below.

Drilling and production in the United States have been governed by the price of oil, classic supply-and-demand responses to economic reality. After the initial discovery of oil at Drake's well in 1859, prices were up to $16.00 a barrel, but high production quickly lowered the price to a fraction of this. Appalachian oil averaged $1.80 a barrel after the initial period of extremely high prices, reaching a low of 56 cents per barrel in 1892, and a high of $5.35 a barrel in 1920. Between 1859 and 1930 the price of oil in the United States averaged $1.34 per barrel.[14] Well production in Appalachia averaged .6 barrels a day (the nation's lowest), while the national average was 8.4 barrels per day.[15] However, Appalachia's oil wells were the longest-lived in the country, and proved their worth in long-term production. On average, they returned 2.9 percent of their initial drilling cost per year.[16]

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general production trends. Unless otherwise noted, production totals in this report are gleaned form the U.S. Bureau of Mines yearly reports. These reports provide a wealth of information.

[14]Ibid., p. 45.

[15]Ibid., p. 41.

[16]Ibid., p. 49. Between 1859 and 1930, there were about 600,000 wells drilled in proven areas of the United States, of which some 330,000 were producing at the end of this period. A large portion of the total number of wells, 242,479, were drilled in the

It should not be overlooked that, beginning in 1882 with the Appalachian region, these districts commercially produced natural gas also.[17] Practically all oil fields produce natural gas with the oil. Early in the industry's history, the gas was simply vented to the atmosphere or flared, and untold amounts were wasted. Between 1882 and 1928, the United States produced nearly 21 billion M cubic feet of natural gas. Three districts, the Appalachian, Mid-Continent (beginning in 1886), and California (beginning in 1889) regions, produced approximately 95 percent of this total. Appalachia accounted for 53.6 percent, the Mid-Continent 33.5 percent, and California 7.9 percent of total production during this period. By 1930, however, Appalachia's yearly share of total production equaled only 21.8 percent, with the Mid-Continent producing 58.5 percent, of the total.[18]

Appalachia also provided another valuable derivative of crude oil, automobile-grade gasoline. The rise of internal combustion engines and the advent of automobiles and airplanes produced a previously non-existent demand for "natural-gas" gasoline. Between 1911[19] and 1928, the United States produced just over 10 billion gallons of natural-gas gasoline. Again three fields dominated; the Mid-Continent produced 60.2 percent, California 24.6 percent, and Appalachia 11.7 percent of the total. In 1928 the Appalachian field produced 5.9 percent of the total yearly gasoline output.[20]

In summary, Appalachia was the most important oil region in the United States between 1859 and 1900. Pennsylvania produced the overwhelming majority of oil from the region, especially during the early years. Overall, between 1859 and 1928 Pennsylvania accounted for 53 percent of Appalachia's total production, followed by West Virginia (23.9 percent), Central and Southeast Ohio (11.4 percent), Kentucky (6.4 percent), New York (5.2 percent), and Tennessee (0.1 percent).[21] The development of central power systems and the suitability of Pennsylvania Grade crude oil for refining

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Appalachian district (20 percent of these were dry holes). Of this number, 149,465 were still producing in 1930, and 93,041 had been abandoned. Over this seventy year period, the average cost for drilling and preparing a well for production in this region was $11,474.00, while the national average was just under $20,000.

[17]Natural gas usage began in Pennsylvania before 1882, but records on natural gas were not kept during this early period.

[18]Arnold, Petroleum, p. 34.

[19]Pennsylvania began production of natural-gas gasoline around 1904, near Titusville, but records were not kept until 1911.

[20]Arnold, Petroleum, p. 36.

[21]Ibid., p. 64.

into lubricating oil helped insure its dominance of a small, but important, part of production in the United States.

Basic Oil Well Drilling Techniques

The basic techniques of well drilling used in the early years of the Appalachian petroleum industry were adapted from salt and artesian well drilling. The simplest and most ancient method, spring pole drilling, was inexpensive and required few specialized tools.[22] For spring pole drilling, a stout, but flexible, tree trunk (the spring pole) was propped-up in the center with a forked trunk, one end of the pole secured to the ground, and a rope attached to the end of the pole over the spot to be drilled. A heavy, iron, chisel-like drill bit was attached to the rope, along with an iron rod to add weight, and hung to the bedrock. Other short ropes attached at the springpole's free end allowed two to four men to simultaneously apply a quick downward bend to the pole, usually by stepping on a loop in the rope, dropping the iron bit against the ground with considerable force (this spawned the phrase, "kicking down a well"). With each blow, the bit shattered the rock, and the debris collected in the slowly deepening hole. Every so often the bit was removed from the well, and a "bailer" lowered to the bottom to retrieve the debris.[23] Once the hole was cleaned out, the drilling rope was lengthened and the iron bit dropped back into the well to continue drilling, and the process was repeated. Although labor intensive, a spring pole could drill a well hundreds of feet deep. It was particularly effective in Appalachia's relatively shallow producing sandstones.

An additional development made in 1806 by the Ruffner brothers in (West) Virginia's Kanawha Valley, the conductor pipe, was an essential component for successful wells. They found that unwanted ground water was diluting the deeper brines they were trying to reach. The Ruffners solved this by using a hollowed-out log to line their drill hole down to the bedrock, where the groundwater was sealed out. This allowed the hole to be drilled deeper to the brine-bearing sandstones without groundwater interference. This conductor pipe also prevented the hole from caving in, and protected the sides of the hole from the rope and down-hole tools. Wooden tubing was eventually replaced with metal pipe. This gave rise to "drive pipe" which could be driven far down into the

[22]The Chinese were drilling brine wells with springpoles as early as 221 B.C.

[23]A small amount of water is kept in the hole to aid drilling. Debris at the bottom mixed with water and formed a slurry, which the bailer or a "sand pump" would lift out. Bailers were metal cylinders, with a flapper valve on the lower end. The bailing operation also provided an opportunity to sharpen or replace worn drill bits.

hole below the conductor to further protect the hole's sides from raveling.

During the salt- and artesian-drilling era, the techniques of springpole drilling were refined and mechanized, and steam power adopted. Cable-tool (or percussion) drilling, as the most popular technique came to be known, made drilling even deep wells vastly easier.[24] Cable-tool drilling got its name from the "string of tools" that descended into the drill hole on the end of a hemp (later wire-rope) cable. A tool-string could be quite lengthy, up to 40' overall, and incorporated various components connected by box and pin sockets. For instance, one might consist of a 6'-long bit, a 25'-long drill stem (a heavy iron rod which added weight and increased drilling force), a set of "jars" (two giant, telescoping, interlocking iron links that would "jar" the bit loose from the rock, but also add a sudden dropping effect to the bit on the cable's downward plunge), and a socket mated with the hemp cable from which to hang the entire assembly. Derricks (at first only wood, but later all-metal) were required above the drill hole to hold a pulley sheave and a block and tackle. The 40' to 60' height of the derrick allowed the tool string to be raised clear of the hole and hung to one side while the bailer was swung over the hole and dropped into the well. A bewildering array of in-hole "fishing" tools and drive pipe underreamers[25] were likewise developed. Fishing tools could retrieve lost bits, cut drilling rope, cut casing, and perform seemingly impossible tasks far down in the hole. Sometimes fishing tools did not work, however, and a well had to be abandoned if a bit got stuck at the bottom, or the tool string could not be retrieved.

In addition, by the time of Drake's well, the surface machinery was taking on a modern appearance and the drilling process becoming more involved.[26] Significantly, the springpole was replaced by a steam engine and mechanical drilling "rig." A percussion cable-tool drilling rig's basic machinery consisted of the (1)engine and boiler, (2)derrick and crown block, (3)"bullwheel" and drilling cable, (4)"sandwheel" and "sanding line" for the bailer, (5)vertical "bandwheel" with a center crank, and (6)the "walking beam," supported by the "samson post." Bandwheels were essentially large pulleys usually 8' to 10' in diameter, driven via a leather belt from the engine, which reduced the engine

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[24]Even after the advent of mechanized cable-tool drilling, springpoles were sometimes used by drillers who lacked the capital for a modern drilling outfit. There were other methods as well, such as using wooden rods in place of the drilling cable.

[25]Underreamers would enlarge the diameter of the hole below the drive pipe so the pipe could be driven farther down.

[26]For detailed descriptions of the drilling process and its machinery, see Raymond Bacon and William Hamor, The American Petroleum Industry (New York: McGraw-Hill, 1916), pp. 273-278, or especially J.E. Brantly, History of Oil Well Drilling (Houston, Texas: Gulf Publishing Company, 1971).

rpms and increased power. A crank on the bandwheel's axle imparted up-and-down motion (via a pitman) to the walking beam, the other end of which was connected to the drilling cable by the "temper screw."[27] The walking beam alternately raised and lowered the drilling tools at the bottom of the well to perform the drilling.[28] Bullwheels and sandwheels were spools for the drilling cable and sanding line, respectively. In addition to the tool string, bailers, and fishing tools, various hand tools, wrenches, and forge tools (to sharpen and repair bits, etc.) were required for the drilling process. Once the desired oil-bearing sand was found, the string of tools was removed and the well prepared for production--that is, if it was not a totally "dry hole."

Many different types of drilling rigs and derricks were eventually developed, including portable ones. The most popular non-portable rigs were the "standard rig" and the "California rig." The standard rig, the smallest type, was used mostly in Appalachia.[29] The larger "California rig" and even larger "California Imperial rig" were usually metal, and used in the mid-western and western oil fields where deeper wells and different subsurface conditions required longer (and heavier) casings and, in turn, taller, stronger derricks and more substantial machinery. By ca. 1900, rotary drilling rigs were in use and eventually superseded cable tool drilling in most regions. During rotary drilling, water or mud compounds are pumped down through the hollow drill stem, through the drill bit, and back up the hole to the surface, carrying along with it the debris from the bottom of the hole. Cable tool drilling remained popular and adequate for most needs in Appalachia long after its use in other regions was superseded by rotary rigs.

An Overview of Oil Production in Western Pennsylvania

For purposes of analysis, the history of oil production in Pennsylvania can be divided into periods based on broad production trends: the preparation period (the decade prior to 1859); the pioneering period (from 1860 to 1886) when Pennsylvania supplied nearly

[27]The temper screw allowed the rope, and the drill tools, to be turned to ensure even drilling at the bottom of the hole. It also allowed the tools to be lowered slightly every few strokes without unhooking the walking beam.

[28]The crank could also be disconnected from the walking beam for a process called "spudding," or creating the first 50' or so of a well until it was deep enough to hold the tool string and the walking beam hooked up to continue the drilling. During spudding, a rope was connected to the drilling cable and tied directly to the crank. The crank jerked the rope on each revolution, which in turn jerked the drilling cable and caused the drill bit to rise and fall in the hole.

[29]Drake's drilling outfit fits the description of a standard rig.

all the nation's oil; the mature, settled-production period (from 1887 to 1922) when the state's production peaked but the industry expanded out of Appalachia and production levels began a steady decline; the period of secondary recovery and renewed exploration (1922 to 1941) when new methods of oil field rejuvenation temporarily increased production; and the modern period (since 1942) which has seen a slow but steady decline in production to current levels.[30]

Today it is known that Pennsylvania's oil fields run in a southwest to northeast belt through the western half of the state. The oil region encompasses, from north to south, Tioga, Potter, McKean, Warren, Crawford, Elk, Forest, Venango, Clarion, Jefferson, Armstrong, Butler, Mercer, Lawrence, Allegheny, Beaver, Washington, and Green counties. The 300-plus oil pools that have been found in Pennsylvania are often grouped into four regions called--in order from northeast to southwest--the northern field, middle field, lower field, and southwestern field. The northern and middle fields have traditionally dominated production in the state.

The northern field lies on the border with New York, and consists of north and central McKean county, and a small portion of Cattaraugus County, New York, and small outlying pools in Potter and Tioga counties. It was the second major field developed in Pennsylvania, after the lower field.[31] The middle field includes southern and western McKean County, Warren County (except the extreme southwestern section), northwestern Elk County, and northern and eastern Forest County.[32] The lower field encompasses western Forest, southwestern Warren, and all of Crawford, Venango, Armstrong and Butler counties (the lower field is home to Drake's well, and many notable events in the early oil industry).[33] The southwestern field includes Beaver,

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[30]John Harper and Cheryl Cozart, <u>Oil and Gas Developments in Pennsylvania in 1990 with Ten-Year Review and Forecast</u> (Harrisburg: Pennsylvania Geological Survey, 1992), p. 4.

[31]See Appendix for a chronological listing by discovery date of Pennsylvania's oil pools. New York's Allegany district is often included in the Northern field but it never contributed more than 8 percent of the field's total output. The northern field includes the Bradford, Kinzua, Windfall Run, and Smithport pools.

[32]This region includes the Clarendon, Warren, North Warren, Balltown, Cooper, Sheffield, Glade Run, Stoneham, Tiona, Grand Valley, Sugar Run, Dew Drop, Wardwell, Kane, and Elk pools. This region is sometimes further divided into the Warren district, Tiona district, and middle district.

[33]Among this region's major pools are: Tidioute, Titusville, Oil Creek, Tarkill, Bullion, Fagundus, Pithole, Cashup, Sugar Creek, Reno, Bradys Bend, Baldridge, Butler

Lawrence, Allegheny, Washington, and Greene counties.[34]

The story of Pennsylvania oil production goes farther back than Drake's 1859 well. Native-Americans and early settlers made use of mineral oil from Oil Creek (a tributary of the Allegheny River in northwest Pennsylvania) prior to the 1800s for medicinal purposes. It was reported to cure rheumatism, arthritis, sprains, and nearly every other human affliction. The development of a mineral-oil market in the East led to further investigation into its properties and possible uses of northwestern Pennsylvania oil during the years leading up to Drake's well. These investigations focused on the seeps and oil springs in the Oil Creek region, which became central Franklin County.

Around 1848, Samuel Kier of Pittsburgh began selling bottled medicinal oil collected from his father's salt wells at Tarentum, Pennsylvania. Having burned the oil in the salt-making process at the plant, he knew its potential as an illuminant. He was soon able to distill it into an illuminating oil by removing some of its more objectionable qualities, such as the bad odor and soot created when burned. Kier quickly found a market for the oil in western Pennsylvania (especially Pittsburgh), and New York City, and its price rose from 75 cents to $2.00 per gallon. The Tarentum works and other skimming operations could not supply the increasing demand, however, and the push began for a stable supply.

About 1853, Francis Brewer, a Titusville doctor, carried an oil sample taken from the Brewer, Watson and Company[35] farm on Oil Creek to Dartmouth College scientists for examination. The scientists deemed it a valuable oil, fit for lubricating and illuminating purposes. While the sample was at Dartmouth, it happened into the possession of George Bissel, a New York lawyer, who became interested in its commercial possibilities. Bissel found a partner, Jonathan G. Eveleth, and immediately bought the

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Cross Belt, Scrubgrass, Gas City, Enterprise, and Church Run. The Franklin district is considered a sub-district of the field because of its especially valuable lubricating oil.

[34]The southwestern field is made up of four smaller districts. The Beaver County district includes Beaver and Lawrence counties, in which the Smiths Ferry, Ohioville, Slippery Rock, and Freedom pools are found. Allegheny County and part of Washington County make up the Allegheny County district, which includes the Shannopin, Brush Creek, Milltown, McDonald, and Gibsonia pools. The Washington County district stands alone, and includes the Canonsburg, Burgettstown, Linden, and Dague pools. Likewise, Greene County makes up its own district and includes the Blackshire, Fonner, Mt. Morris, Bristoria, Dunkard Creek, and Nineveh pools.

[35]This was a lumber company active along oil creek. They were lighting their mill with oil lamps by 1850.

Brewer and Watson Farm, forming the Pennsylvania Rock Oil Company of New York in December of 1854. They took another oil sample to the prominent Yale scientist Benjamin Silliman, Jr., to further investigate the oil's properties. Silliman's April, 1855, report confirmed the petroleum's high quality, described the distillation process required to produce illuminating oil[36]-- kerosene--and immediately spurred the interest of other capitalists. In Connecticut, Townsend had persuaded an acquaintance, Edwin L. Drake, to purchase stock in the company. Drake became further involved and was sent to Titusville to examine the Brewer and Watson Farm, and his report led to Blissel and Townsend appointing Drake as a general agent for the company. By March 1858, Bissel and Evenleth's company had evolved into the Seneca Oil Company of Connecticut.[37]

Drake returned to Titusville in 1859 and prepared to drill a well on the Brewer and Watson Farm. Drake had no experience in well drilling, so he hired a Tarentum blacksmith and salt-well driller, William A. "Uncle Billy" Smith, to aid in the operation. Drake erected an engine house and derrick, purchased a six horsepower horizontal steam engine, and set about sinking a drive pipe to the bedrock 32' below. Once to bedrock they began to drill, averaging about 3' a day. On Saturday, August 28, 1859, Drake and his crew had managed to drill to 69'-½", when the tools were removed. Upon visiting the well the next afternoon, Uncle Billy Smith found oil floating atop water in the hole, and the first step towards large-scale industrial production in the United States was complete.[38] Thereafter, Drake's well produced less than 25 barrels of oil per day (BOPD). Through the end of 1859, oil sold at about $20.00 a barrel, and the Drake well represented a potential motherlode of profits. This did not last. The per-barrel price of oil quickly dropped into single figures with the sudden influx of supply.

Drake's well was an instant phenomenon. In response to the news, farms along Oil Creek were quickly bought up in hopes of similar success. In the mad search for oil-producing properties in these early days, proximity to Drake's well was the best indicator of probable success, and for the next five years the Oil Creek Valley was the center of intense activity among speculators, hopeful investors, and upstart oil-drillers. Former farms along Oil Creek, and up and down the Allegheny River from the mouth of Oil Creek at Oil City, were quickly bought or leased by prospective oil developers. Oil leases quickly became standardized, generally giving the landowner 1/8 of any profits generated by oil production on the property.

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[36]Silliman also noted the lubricating qualities of the oil.

[37]The company was organized in Connecticut because stockholders were better protected under that state's laws.

[38]This was in the Titusville pool.

Drilling proceeded slowly, however, partly because of the difficulty in procuring equipment and manpower. Drilling was still a time-consuming process as well. Drillers using human-powered springpoles and scraped-together equipment immediately began drilling along the banks of Oil Creek, where again and again they struck oil and only the unlucky came up dry. Ten producing wells were completed the next year, seventeen in 1861, twenty in 1862, and twenty-nine more in 1863[39]. Thus, of the 117 drilled to this time seventy-seven struck oil and forty-one had been dry holes. With the shallow wells costing just a few hundred dollars to drill, and the high likelihood of success, it was a seductive business.

In the ensuing search for clues for subterranean oil, it was readily apparent from experiences with oil seeps and salt wells that oil was found in the presence of water. Furthermore, Drake had drilled his well just yards from the waters of Oil Creek. This bolstered the notion that oil, like water, flowed below ground, mimicking the topography of surface features. This led some to drill directly in the creek beds, until large wells began to be struck on the hilltops, thus subverting this theory. Such beliefs, born in Pennsylvania and followed by other pseudo-scientific methods such as dowsing and belt theory, would remain common until after the turn of the century.

The experiences of successful (and unsuccessful) producers and wildcat drillers soon led to the study and mapping of northwestern Pennsylvania's oil fields, and the first attempts at explaining and predicting the presence of oil. Drillers concluded that the oil was held in a series of three sandstone layers, and these oil sands were called, from top to bottom, the first, second, and third oil sands, respectively. They were partially correct, but their system was too simple--there were many more than three oil bearing sands in the region.

Drake's well and the others that followed required pumping from the outset, but this soon changed. The first flowing well (in which pressure in the well forced the oil to the surface, sometimes spewing forth from the well head in geysers) was struck on the Buchanan farm in the summer of 1860. With the sudden influx of supply, prices had fallen to a few dollars per barrel when, in April, 1861, at nearby Rouseville another well began producing prodigious amounts of oil.[40] It and subsequent wells in the area were

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[39]J.D. Sisler, et al, Contributions to Oil and Gas Geology of Western Pennsylvania (Harrisburg: Pennsylvania Geological Survey, Fourth Series, Bulletin M19, 1933), p. 43.

[40]Rouseville was awash in oil upon the discovery this well. Dozens of people were visiting the well site in mid-1861 when it caught fire. This inadvertent blaze killed 19 people and destroyed a large part of the town. The early history of Pennsylvania oil-production is replete with such conflagrations.

spectacular, flowing over 1000 barrels or more a day. However, after the initial outflow period, which could last months, flowing wells had the disheartening tendency to rapidly decrease production and require pumping, or stop production altogether. With flowing wells being discovered almost every month, there was little reason to pump low-production wells and oilmen simply moved on to drill a new well. For comparison, consider that Drake's well and one other completed on Oil Creek the same year produced about 2,000 barrels[41] during the remainder of 1859. Pennsylvania's output soared after 1859, to 500,000 barrels in 1860, and over 3 million by 1862. Small levels of production began in New York, West Virginia, Kentucky, and Ohio, but Pennsylvania provided very nearly all of Appalachia's total output for many years and and likewise led the nation's production.

Some of these flowing wells along Oil Creek were legendary. The Funk (or Fountain) well produced 300 barrels a day for over a year before suddenly going dry. The Empire well, drilled in September of 1861, produced 3,000 barrels a day for eight months, slowing to 1,200 barrels by May 1862 before production dropped to nothing. In October of 1861, a well drilled by William Phillips on the Tarr farm on lower Oil Creek began flowing 4,000 barrels a day, probably the largest flowing well in the region's history.

Supply overwhelmed the limited demand for oil. Prices dropped from $1.75 per barrel in January of 1861, to 10 cents by October, and as low as 5 cents per barrel before stabilizing.[42] Still, this price drop did not slow the quest for oil in northwestern Pennsylvania, or the rest of the country. Much oil and gas was wasted in this period, as there were often inadequate holding tanks or barrels on the site and the oil often flowed away into the creeks. It is estimated that 10 million barrels of oil were lost by 1862.[43]

There was also the intractable problem of transporting the oil to market. Lack of transportation links to the oil region meant that, for the first years, much of the oil had to be hauled (in barrels) over poor roads in wagons to the nearest railhead or shipped by barge down Oil Creek to Oil City on the Allegheny River, and on to Pittsburgh, the major distribution point. Water fluctuations and winter ice complicated the latter route. The lack of rail connections also meant that equipment was often in short supply, spurring the rise of local manufacturers specializing in oil equipment, supplying the fledgling industry with drilling tools, steam engines, and well pumping apparatus. Many related

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[41]Complete production totals for Pennsylvania, 1859-1990, are included in the Appendix. Production figures were not accurately kept until 1876, these early figures are estimates.

[42]Sisler, et al, Contributions, p. 57.

[43]Ibid., p. 64.

industries, such as barrel making and crude oil refining, prospered. The influx of oil workers to the region likewise supported industries that supplied food, clothing, and entertainment. There were those who were striking it rich also, and reinvesting their money into more drilling and other aspects of the local economies.

The onset of the Civil War dampened development somewhat, and the unstable economic situation temporarily curtailed capitalists' drive to invest in the industry. Oil prices remained low throughout the first years of the Civil War, but began to recover in the latter years of the conflict. The glut of oil and extremely low prices brought oil producers along Oil Creek together to demand a steady minimum per-barrel price, in which they were somewhat successful. Prices rebounded, and by 1864 the oil fields of Pennsylvania were ripe for further development. The approaching end to the war set off a speculative boom.

In addition, railroads began to enter the oil region, providing further impetus for development. Corry, in northwest Pennsylvania, was the nearest rail connection to Titusville. Both the Philadelphia & Erie, and the Atlantic & Great Western railroads passed through the town. From Corry, the Oil Creek Railroad was built 27 miles south to Titusville by 1862. It continued 2 miles on down Oil Creek as far as the Schaffer farm but no further. Beginning in 1862, the Atlantic and Great Western Railroad began building south from Corry to Meadville, reaching Franklin the next year, and finally Oil City in March of 1865.[44] The line continued to Pittsburgh in 1866, and other feeder lines began to spread through the region.

The major developments of the 1864-1866 boom again occurred in and around the Oil Creek area as new pools were discovered. In 1864, Cherry Run, a branch of Oil Creek, became the first area of activity apart the initial Oil Creek boom, followed in quick succession by Pithole Creek (a tributary emptying into the Allegheny River some 6 miles above Oil Creek); Benninghoff Run and Pioneer Run, both branches of Oil Creek, and Woods farm in 1865; the Stevenson farm in 1866; and the following year Dennis Run, Triumph Hill (near Tidioute) and the Shamburgh well along upper Cherry Run.[45] Each time, news of the discovery was followed by a rush to develop the area, and boom towns came and went with the flowing wells.

Pithole is the most famous of the early oil boom towns to spring up around a new producing area. Pithole began on January 8, 1865, with the United States, or Frazier,

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[44]Paul H. Giddens, The Birth of the Oil Industry (New York: The Macmillan Company, 1938), pp. 111-112. This book is one of the best histories concerning the early years of the petroleum industry in Pennsylvania.

[45]Bacon and Hamor, The American Petroleum Industry, p. 219-220.

well striking oil on the Thomas Holmdon farm on Pithole Creek. By June, four wells produced about 2,000 barrels per day, or one-third the total output of the entire state. Other wells on this and surrounding tracts quickly began producing large amounts, and the city of Pithole sprang up overnight on the farm. Incredibly, by September of that year Pithole was home to at least 14,000 people, and the pool was producing 6,000 barrels a day. The pool's high initial production dropped to nearly nothing near the end of the year, and as activity peaked elsewhere Pithole rapidly vanished.[46]

There was still the problem of getting the oil from the wells to the refinery or railroad. Oil pipelines, an important advance made during the 1860s, would have major future implications. Operators on Oil Creek were the first to attempt long-distance piping of oil. In 1862, L. Hutchinson used a short siphon-action pipeline on the Tarr farm to carry oil from his wells over a hill to a nearby refinery. The next year, a 3-mile pipeline was constructed from the Sherman well to the Miller farm on the Oil Creek Railroad. These early lines had technical problems, the most serious being leakage at the joints and neither were successful. There was opposition too, from the teamsters who made a living hauling the oil. The first practical pipeline, using improved pipes connected with screw sockets and a pumping engine to force the oil through the line, was constructed in 1865 by Samuel Van Syckel, of Titusville. It was a 4-mile line from Pithole to the Miller farm, carrying about 80 barrels of oil per day. Another was built in 1866 from Benninghoff Run to the Shaffer farm by operator Henry Harvey, and both of these were transferred to the Allegheny Transportation Company which successfully operated the lines.[47]

Quickly, other lines were built and piping oil became an industry of its own, although at first they only carried oil relatively short distances to refineries or railroad shipping points. By ca. 1880 large companies like Standard Oil became involved in pipeline construction and operation, laying an extensive network through the region that would eventually stretch between the Great Lakes and the eastern seaboard. This also effected the closure of many of the small local refineries in deference to large Great Lakes and coastal facilities. Pipelines became the preferred method of oil (and gas) conveyance for even long distances.

While the oil industry had enjoyed a period of higher prices during the Civil War, afterwards came the inevitable decline. During early 1865, oil sold for approximately $7.50 per barrel; by March of 1866, it had dropped to $2.50. Low production wells were abandoned, and new drilling was curtailed as the industry entered a depression. It did not fully stop development though, and in 1866 new pools were discovered on West

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[46] Giddens, Birth, p. 140.

[47] Bacon and Hamor, The American Petroleum Industry, p. 247.

Hickory Creek and Dennis Run, and the town of Petroleum Center arose along middle Oil Creek near the mouth of Bennehoff Run. But only the most productive wells remained in operation as the depression continued through 1867.[48] Developments shifted south (down the Allegheny River) in the late 1860s with discoveries in Butler, Armstrong, and Clarion counties. Wells had been drilled near the confluence of the Clarion and Allegheny rivers as early as 1863.

Wild price swings were a defining characteristic of the 1860-1870 period. Largely the product of reckless stock speculation and a lack of regulation and organization of stock sales, producers and stockholders organized to rationalize production and prices. After tentative, mostly unsuccessful, attempts at organizing in the mid 1860s, they formed the Petroleum Producers' Association of Pennsylvania in 1869, and by 1871 the establishment of oil stock "exchanges" such as the Titusville Oil Exchange began stabilizing prices.[49] By 1873, prices were low (less than a dollar per barrel) but stable.

The economic situation improved, demand increased and production levels responded with prices remaining viable.[50] By 1876, the discoveries in the upper reaches of the Allegheny River's watershed around Bradford captured the industry's momentum. Wells had been drilled around Bradford in the early 1860s, but production was negligible until 1876. With the rush of development, Bradford became one of Pennsylvania's most significant pools and remained so through most of the twentieth century. In 1882 Pennsylvania produced a staggering 27 million barrels yearly, of which the Bradford field alone accounted for 23 million, that field's historical peak [51]

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[48]Sisler, et al, Contributions, p. 43. By 1869 there were reportedly 1,186 producing wells in Pennsylvania, and 4,374 that had been dry holes or unprofitable and abandoned in the 10 years since Drake's well.

[49]Giddens, Birth, pp. 190-191. Exchanges were eventually established at Oil City, Petroleum Center, Franklin, Titusville, Pittsburgh, and Bradford, and other cities in the oil region.

[50]Indeed, in the 1870s there were across-the-board increases in output in each of the major fields. Per year production rose from 5 million barrels in 1870 to nearly 11 million barrels in 1874. After a slight drop in 1875 and 1876, output climbed to 13 million barrels in 1877, and by 1880 production had grown to 26 million barrels.

[51]Statewide production again fell for a few years, dropping to a low of 16 million barrels in 1888. Pennsylvania geologist J.F. Carll estimated that, up to August, 1887, 50,000 oil wells had been drilled in Pennsylvania (including the small section of New York in the northern fields).

This period saw the rise of a particularly potent force in the petroleum industry, the Standard Oil Company. It played a major role in stabilizing the production and price swings prevalent from 1860 to 1880. During the late 1860s, John and William Rockefeller were active in the refining, shipping and selling of petroleum, primarily from the Ohio oil fields, but also Pennsylvania and other states. The Rockefellers recognized that the industry needed a more stable price structure, as well as uniform standards for petroleum. In 1870, the Rockefellers (and other partners) created the Standard Oil Company of Ohio and began consolidating control over numerous lessor companies.[52] They integrated the various aspects of oil production into a single company, and built the most famous monopoly in American history. By 1882, through outright purchases and strategic agreements, the Standard Oil Company controlled much of the petroleum industry.[53] In 1882, a trust agreement among numerous companies resulted in the incorporation of Standard Oil Company entities in several states, each of which controlled the company's properties in that particular state. The Standard Oil Trust could not withstand the scrutiny of anti-monopoly sentiment, and in 1892 the federal government ordered the trust to liquidate. However, after some judicial wrangling, the company reincorporated as the Standard Oil Company of New Jersey in 1898, and continued operating until 1911. In 1911, Standard was finally broken into its thirty-three subsidiary companies. Although these companies were no longer controlled by Standard, for years after they were referred to as the "Standard Oil Group."

From 1888 to 1922, Pennsylvania entered its mature production phase as the oil fields

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[52]The Atlantic Refining Company was an early acquisition by Rockefeller. It was incorporated in Pennsylvania in 1870 to operate refineries at Philadelphia, Pittsburgh and Franklin, and to distribute petroleum in all cities and large towns in Pennsylvania and Delaware. This and related information on Standard Oil is from Bacon and Hamor, <u>The American Petroleum Industry</u>, pp. 260-261.

[53]In Pennsylvania, Standard Oil operated the National Transit Company, incorporated in 1881 with headquarters in Oil City. National Transit owned hundreds of miles of pipelines across Pennsylvania, and a network of feeder lines and storage installations in the western, oil-producing parts of the state. The company's lines also interconnected with those of Standard Oil controlled companies in Ohio, New York, and New Jersey. There were several Standard Oil-controlled companies in Pennsylvania. South Penn Oil Company, incorporated in 1889 with a capital stock of $12.5 million, produced crude oil throughout Appalachia, and was the leading producer-company in Pennsylvania's oil fields. The Galena-Signal Oil Company was another, incorporated in 1901 to manufacture lubricating and signal oils at plants in Franklin, Pennsylvania, and surrounding states. For a complete listing of the Standard Oil Group, see Bacon and Hamor, <u>The American Petroleum Industry</u>, pp. 262-265.

reached their maximum output.[54] Between 1888 and 1898, Pennsylvania's production remained at all-time highs--then came the inevitable slow decline.

In the middle field around Warren, Clarendon, Sheffield, and Kane discoveries in the late 1870s and early 1880s helped spur the state's record high production levels. Numerous pools were discovered along the Tionesta Creek Valley, and on the vast, high plateau drained by the creek's various tributaries. Production from the area averaged 400,000 barrels yearly through the period, reaching a high of 520,925 barrels in 1904. Some of the major pools in this area were the Warren, Wardwell, Morrison Run, and Dew Drop pools, along the Allegheny near Warren, and the Clarendon, Tiona, Cherry Grove, Cooper, Balltown, Sheffield, Watsonville-Klondike, and Kane pools along Tionesta Creek and its branches. This region is now part of the Allegheny National Forest and the sites recorded for this project are located in this area.[55]

Adding to the overall record highs, the lower district, which contained the old fields of Venango County along Oil Creek, as well as new pools in Beaver, and Butler counties, also reached its record high, producing over 9 million barrels in 1891. In the southwestern district, beginning in the late 1880s, large-production wells were struck in Allegheny and northern Washington counties.[56] The MacDonald field was the standout pool, producing a high of over 10 million barrels, or half the southwestern district's output, in 1891. Fortunately, the wild price fluctuations of the early years were a thing of the past, but oil remained cheap, less than $1 per barrel.

The high quantities produced in the new southwestern district pools, combined with flush production in the state's other fields, pushed Pennsylvania's production to its all-time record in 1892 of 32 million barrels. With the large supply, prices also bottomed out at 56 cents per barrel that year, before beginning a steady rise through the early twentieth century.

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[54]The Bradford field declined to just over 5 million barrels in 1890, yet the continual discovery of new pools increased overall totals. The all-time high, not surprisingly, was under the reign of Standard Oil.

[55]For a detailed history of oil production within the boundaries of ANF, see Phil Ross, Allegheny Oil, The Historic Petroleum Industry in Allegheny National Forest (USDA Forest Service, Eastern Region, Allegheny National Forest Heritage Publication No. 1, 1996).

[56]The southwestern district was slow to develop. First activity was in Greene county, which produced 93,034 barrels in 1888 and nearly 1 million in 1890, after which production slowed to an average 500,000 barrels per year.

After 1892, developments in other parts of the country helped ensure a general decline in Pennsylvania's importance. Fewer new fields were discovered in the state and the old fields were simply past their prime, dropping toward relatively minuscule output. Speculators, drillers and operators continued their practice of relocating to new sources of petroleum in other parts of the country, especially the Mid-Continent and California oil fields. Up to the 1890s, Pennsylvania had been the number one producing state in the nation; by 1920 it was number ten.

The demand for oil increased, however, as automobiles and airplanes became popular in this country. Per-barrel prices rose to over $5.00 in 1920, the highest since the years just after Drake's well. The lower and southwestern fields were home to most drilling activity between 1910 and 1920, but the northern fields, McKean, Vanango, Forest, and Warren, remained the most consistent producing counties as the twentieth century progressed. Regardless, Pennsylvania's output dropped from 13 million barrels in 1900, to less than 8 million in 1920.

While Pennsylvania's wells produced only small amounts by this time, the state's high-quality oil had found its permanent niche in the early twentieth century, supplying crude oil for refining into lubricants for the age of the auto. Pennsylvania's high-quality oil had been recognized from the industry's beginnings, and its beneficial characteristics were a continual motivation for further development of the state's oil fields. Early in the twentieth century, Pennsylvania's producer organizations began touting "Pennsylvania Grade" crude oil as an advertising phrase, and it became the hallmark of superior quality lubricating oils. Importantly, numerous products could be easily distilled from the crude. While kerosene (for illumination) was the main distillate during the early years, lubricating oil became the primary, and most lucrative, focus of refiners.[57]

First used as a lubricant for steam engines, the importance of Pennsylvania grade oil only increased with the advent of internal combustion engines. Fortunately, Pennsylvania grade crude was molecularly suitable for refining into various high-quality gasolines and motor oils, and refiners were able to improve their techniques in order to provide such products. Finally, the advent of high-speed aircraft engines in the first years of the twentieth century required an extra-high-quality lubricant, and again

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[57]Dewitt T. Ring, "The Oil Industry in the Appalachian Region," Appalachian Geological Society 1949 Bulletin (Charleston, West Virginia: Charleston Printing Company, 1949), p. 278. Upon refining, a typical barrel of Pennsylvania grade crude produced (in 1949) 25 gallons of gasoline, 9 gallons of lubricant, .83 gallons of Kerosene, 4.25 gallons of fuel oil, and 4.95 pounds of wax. Lubricating oil was the most commercially lucrative of these derivatives.

Pennsylvania grade crude was the ideal source.[58] The essential qualities required for airplane and automotive engines were adequate viscosity, high flash point, low volatility, low oxidation tendency, and low consumption. Pennsylvania's oil possessed all these characteristics, and by 1930 both the British Air Ministry and the U.S. Army had written specifications which effectively excluded all but Pennsylvania grade crude for their lubricating oil purchases.[59]

The refining industry in Pennsylvania had to meet these challenges, and by the 1920s the trend was set for the remainder of the century. In western Pennsylvania, numerous small refineries were constructed that operated using crude from the surrounding fields and specialized in manufacturing lubricating oils that supplied local, national, and worldwide markets. This was countered by a few large refineries in the Philadelphia area operating mostly on water-shipped import oil that went to supply the in-state and regional demand for lesser quality oils. A fraction of the crude oil refined in Pennsylvania was supplied to the refineries by pipelines from surrounding states. By 1931 there were forty-nine refineries in the state, with a total daily crude-oil refining capacity of 251,530 barrels.[60]

To the surprise of many, the downward production trend so evident just prior to 1920 was quickly reversed by a new technological development. First in the Bradford field, new methods of oil field rejuvenation were put into use beginning in 1922. Generally called "secondary recovery," these entailed various techniques of artificially repressurizing the old fields by injecting water, air, or gas into old wells, which forced more oil from the source rocks than would naturally flow. The method of recovery was largely governed by subsurface conditions and the nature of the producing sand. In the north, pumpers found the hard, fine grained sands of the Bradford field (and some smaller surrounding fields) particularly well-suited for water flooding. Those fields in

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[58]Noel Robinson, "The Value of Lubricants Made From Pennsylvania Oil," Proceedings of the First Petroleum and Natural-Gas Conference (State College, Pennsylvania: The Pennsylvania State College Mineral Industries Experiment Station, Bulletin 9, 1930), pp. 70-71.

[59]Ibid., 77. Pennsylvania grade crude oil contains no commercially useful levels of sulphur or aspalt, and contains the highest percent of saturated hydrocarbons in any crude.

[60]O.G.R. Hopkins and A.B. Coons, "Petroleum," Mineral Resources of the United States 1930 (Washington: U.S. Government Printing Office, 1932), p. 811.

southern Pennsylvania were more receptive to air or gas repressurization.[61] To repressurize a field, all of the drill holes tapping the pool had to be found and capped. Only certain strategically located wells were set-up for production, while some others were made pressure injection wells. For instance, "5-spot water flooding" (one of the most common techniques) required one central oil-extraction well surrounded by four evenly spaced water-injection wells. A pumping engine forced water down the injection wells, pushing oil toward the central producing well. With water flooding the Bradford field was given stunning new life, and secondary recovery soon came into widespread use in Pennsylvania.[62] Even the oldest fields around Titusville saw renewed production levels, and the slow decline in production seen in the early twentieth century was reversed. From 8 million barrels in 1920, output increased to over 19 million barrels at its renewed peak in 1937, the state's highest level in the twentieth century.[63] Incredibly, with the onset of secondary recovery, the Bradford field produced roughly 80 percent of the state's crude oil for the next 70 years.

The coming war highlighted the importance of Pennsylvania crude. The second world war was "the machine war," and showed that modern, mechanized armies are sorely reliant on petroleum for success. World War II also illustrated the extent to which Pennsylvania crude had come to dominate the specialty lubricating oil market. With the state's crude making up such a large share of domestic lubricant production, it was strategically very important to the Allied war effort. During the years the U.S. was involved in the war, Pennsylvania produced nearly 24 million barrels of lubricants, or 15.8 percent of total lubricant output of the United States during the conflict. Aviation oil was probably the most important contribution. In the final six months of the war Pennsylvania grade oil accounted for 32 percent of all oils used by aviation branches.[64] However, the war did have a detrimental affect on Pennsylvania's oil industry. To supply the needs of the country's armies, the domestic trade was sacrificed, and it took

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[61]Clark F. Barb and Paul G. Shelley, "General Information Regarding Production of Pennsylvania Grade Crude Oil," Production Data on Appalachian Oil Fields (State College, Pennsylvania: The Pennsylvania State College Mineral Industries Experiment Station, 1930), p. 9.

[62]The high output during secondary recovery meant temporarily lower prices--$1.88 per barrel by 1937.

[63]Around this time (ca. 1929), there were about 78,000 producing wells in the state, and each well produced an average .3 barrels of oil per day. Some 5,000 had been abandoned since Drake's well. Total revenue from crude oil between 1859 and 1929 had been over 1 billion dollars.

[64]Ring, Appalachian Region, p. 278.

some years for the overseas markets to stabilize after the war.

While the declining production levels had steadied somewhat during the war because of demand, the oversupply after the war removed any incentive for maintaining increased production. Also, secondary recovery could retrieve only a finite amount of oil, and production returned to a downward trend after World War II. This time there was no respite, even though new fields were discovered almost yearly, and crude oil production steadily dropped from nearly 18 million in 1940, to just under 12 million in 1950, 6 million in 1960, 4 million in 1970, to 3 million in 1990. The Bradford field finally dropped to only 17 percent of the state's total by 1990. The northern counties of Warren, Forest, Elk, McKean, and Venango remained the most important producers. Through this period Pennsylvania yearly production averaged slightly less than 1 percent of the nation's total output. Fortunately for operators, after 1940 prices began creeping back up, through the $4.00 range in the 1960s, to $11.51 in 1976. The oil embargos of the 1970s, increased demand in the 1980s, and the Persian Gulf War in the early 1990s steadily pushed oil prices to unprecedented highs.[65] This long-term trend toward higher prices gave Pennsylvania the situation of declining production levels, but increased overall profits during the latter part of the twentieth century. It also led to the interesting case of a late-nineteenth century technological development, the central power process of multiple oil-well pumping, being used into the late twentieth century.

Oil Well Pumping and Central Power Systems[66]

While petroleum sometimes flowed from a well under its own pressure, this was not usually the case. Most successful oil wells in Appalachia followed a pattern of high initial production (sometimes hundreds of barrels per day per well) followed by a rapid drop off to a few barrels per day--or week--or nothing at all. Thereafter, the well had to be mechanically pumped to recover any oil. By the 1870s, the "standard" pumping outfit was in use in Pennsylvania. Much of the surface equipment used to drill a well (the engine, bandwheel, and walking beam) could be used to pump it. This was a one-

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[65] In 1981 the per-barrel price was over $36.33, and in 1990 averaged $22.94, when the Persian Gulf conflict returned it to the $30.00 range. However, quickly dropped through 1998 to their lowest levels since WW II.

[66] See Phil Ross, Allegheny Oil. Ross's book is perhaps the best review of the historical development of central powers and much of the following is based on his work. H.C. George, Surface Machinery and Methods for Oil-Well Pumping Bureau of Mines Bulletin 224, Department of Interior, (Washington: Government Printing Office, 1925), gives the most detailed descriptions available of central power systems and related oil-well pumping machinery.

engine-one-well system in which a steam-powered engine pumped a single well.

To pump a well, first a string of metal tubing, 2" to 3" inches in diameter, with a “valve barrel” at the bottom, was placed in the hole. Inside this tubing, a long string of “sucker rods” was hung to the bottom of the well where it was connected to a standing valve in the valve barrel. On the surface, the well was set up with a standard pumping outfit (for pumping the well “on the beam”) consisting of a steam engine and boiler (located a short distance from the well in a protective wooden powerhouse to prevent accidental fires), a vertical wooden bandwheel/crank, and a stout wooden samson post supporting the walking beam. This was a standard pumping outfit for single wells, and widely used in oil fields through the early twentieth century.[67]

To operate the rig, a pumper would fire the boiler and bring the steam up to working pressure. Once the engine was started and brought to proper speed, the pumper engaged the clutch mechanism to transfer power to the pulley. A leather belt transferred power from the pulley to the vertical wooden bandwheel,[68] which turned a shaft and crank at its center point imparting up-and-down motion (via the “pitman” connecting rod) to one end of the walking beam, which is supported at the fulcrum point by the timber samson post. The well-end of the walking beam connected to the “polished rod,” which in turn connected (inside the “stuffing box” of the casing head’s “working barrel”) to the top of the string of sucker rods.[69] The casing head attached to the top of the well tubing, and was fitted with two or more take-off pipes that routed oil into the drainage lines and/or carried off gas. As the walking beam rocked up-and-down in roughly 16" strokes, the sucker rods likewise moved up-and-down to actuate the standing valves inside the valve barrel at the bottom of the hole. The oil was forced upward through the pipe in the small space between the sides of the pipe and the sucker rods and out through the casing head. Buildup of parrafin in the tubes, a broken sucker rod, or other problems could require the the sucker rods and/or tubes to be “pulled” and cleaned or replaced. Therefore the derrick used to drill the well was often left in place for use in pulling the rods or casing.

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[67]Often, production equipment was scavenged and reused from somewhere else--a common practice in oil fields. See Winston Davis, “Salvaging Oil Field Equipment,” Proceedings of the Eighth Pennsylvania Mineral Industries Conference: Petroleum and Natural Gas Section (State College, Pennsylvania: The Pennsylvania School of Mineral Industries, 1938), p. 1.

[68]Along with reducing the engine pulley’s rpms, the bandwheel’s momentum helped smooth the transmission of the power from the engine to the walking beam.

[69]Sucker rods were usually 16' long and about 2" in diameter, made of hickory or ash (later, all metal), and connected with metal box-and-pin screw joints.

So equipped, the machinery could pump the oil out much faster than it seeped from the petroleum-bearing rocks at the bottom of the hole. After a well aged and production leveled off, it was required to pump a well for only a short period a few times a week.[70] In the decade following Drake's well, there was little impetus for pumping low-production wells after their initial outflow, as new fields were continually being discovered and the drillers would simply move on to sink another well. There were exceptions, however, when the oil tapped by a well was of extremely high quality. Usually though, with oil prices extremely low, it cost too much to outfit and maintain an installation, and employ a pumper to operate it, for each well. As prices began to stabilize, pumping became more feasible, and economizing the process became the key to profitability. This drive for efficiency resulted in the popularization of centrally powered multiple-well pumping systems.

One of the first known cases of the central power concept being used to pump oil[71] occurred in the Oil Springs pool in West Virginia. This pool produced an exceptionally good lubricating oil, but each well produced only a tiny amount, forcing the operators to resort to pumping thirteen wells with a single 15 horsepower steam engine. It was called a "telegraph" system, in which long, thin wooden rods, suspended by hangers from wooden poles, transmitted power (with a reciprocating horizontal motion of about 20") to the wells nearly a half mile away.[72]

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[70]To increase production, a well could be "shot" or "torpedoed" with nitroglycerin to extensively fracture the oil sands at the bottom of the hole. Once fractured, the increased surface area could produce more oil. This technique was patented by E. L. Roberts in 1862, and the first attempt at torpedoing a well occurred in 1866 on the "Ladies" well, near Titusville. It and subsequent successes in the Pennsylvania fields made this a common practice in the industry, regardless of the dangers inherent in transporting and handling the extremely dangerous liquid. In the twentieth century other methods of fracturing oil-bearing rocks were developed. Among these were hydro-fracturing, where water, oil, or some other liquid was forced into the well under very high pressure to crack the rock at the well bottom.

[71]Similar systems were used as early as the sixteenth century in German mines to transmit power to pumps which removed water from the mine workings. See Diane Newell and Ralph Greenhill, <u>Survivals: Aspects of Industrial Archaeology in Ontario</u>, (The Boston Mills Press, 1997), pp. 128-129.

[72]Ross, <u>Allegheny Oil</u>, pp. 62-63. In 1871 another system of multiple-well pumping was in use at Volcano, West Virginia, a few miles from the Oil Springs. This somewhat anomalous system was termed "endless wire" pumping. The central engine's power was transmitted via an endless loop of wire cable, guided by pulleys, to

At about the same time, ca. 1863, Canadian operator named John Henry Fairbanks devised a "jerker" system in the oil fields of Ontario.[73] Two parallel rows of wooden rods were connected to two cranks powered from an engine, which set the rods moving back and forth. Like the telegraph system, the jerker lines were held off the ground by wire swings dangling from wooden poles. Horizontal oscillating wheels, called "field wheels" or "spiders" could change the direction of the two main jerker lines. Individual branches of jerker line were run off the field wheels also. Each single line connected to a pump jack, which converted the horizontal motion to the vertical motion needed to operate the sucker rods.[74] Optimally, jerkers lines were "balanced" by matching each well with one in the opposite direction, so that when the sucker rods in one well were being raised (the upstroke), those in the opposite well (on the downstroke) were lowering under their own weight and helping raise the rods in the well undergoing the upstroke. This helped minimize the load on the engine. Fairbanks' jerker system was the direct precursor to the system later put to use and perfected in Pennsylvania.

In the United States, Edward Yates of Philadelphia patented a very similar system on May 28, 1879. It was called the Yates "push pull" power, and substituted iron rods for the wooden jerker lines of the Canadian system. These were called "rod line" systems, as old iron sucker rods were often recycled and used for the jerker lines.

During the 1870s, the first real trend toward central powers in Pennsylvania was manifested in a different way--the use of a single boiler to supply steam via pipes out to a steam engine at each well. Increasingly, these boilers were fired, not by wood or coal, but gas from a nearby well. Then, a decrease in the value of oil in the early 1880s forced many pumpers to adopt the new central power idea to keep marginally productive wells active. By 1885, many clusters of wells in the older established fields were pumped by the Yates-style push-pull powers, which remained popular up into the early twentieth century.

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a standard bandwheel/walking beam arrangement at each well. HAER documented the remains of this system in 1971 (HAER No. WV-9) with measured drawings and large format photographs.

[73]Ross, <u>Allegheny Oil</u>, p. 64. Called "jerker" lines as the wooden rods operated only in tension, each line (in a cycle opposite its counterpart) alternately pulled by the engine and then returned mostly under the weight of the sucker rods in the well. Also see Newell and Greenhill, <u>Survivors</u>, Chapter 6, for a detailed description and history of the Fairbanks system which is still in operation.

[74]Pump jacks, right-angle levers that pivot on the apex, take the place of the samson post/walking beam arrangement of one-engine-one-well pumping. In 1877, Waldemar Plackross of Fagundus, Pennsylvania, patented the first pump jack.

Two developments in particular brought the central power concept to its mature phase: the Allen patented geared power of 1885 and the Grimes patented bandwheel power in 1897. With these inventions, all the essential components of the mature central power system came into common use in Pennsylvania: the prime mover, or engine; a power reduction/motion-conversion/power distribution unit (always called the "power" in oil-field parlance, not to be confused with the engine or prime mover); the shackle lines (also called pull, jerker, or rod lines) which transmitted the motion from the power out to the pump jacks; the pump jacks which converted the horizontal, reciprocating motion of the rod lines to vertical reciprocating motion; all to actuate the sucker rods and valves in the well that pumped the oil to the surface. The engine and power required a substantial concrete foundation to resist the immense strains put on the machinery, and both were enclosed in a protective powerhouse. Powerhouses lessened the chance for fires, but also held spare parts, tools, and gave the pumper and machinery protection from the elements. These equipment configurations were generally called central powers, but the term "jack plant" was also common. With the advent of gas- and oil-powered engines in the mid 1890s, costs were further lowered since the engine was powered by gas produced from the very wells it was pumping--a sort of low-cost perpetual pumping machine that required comparatively little manpower or maintenance to keep in operation. By ca. 1900, numerous oil-well supply companies developed standardized systems which could be purchased in-part or whole.

Certain factors controlled the use of central powers. Only relatively shallow wells, less that 3,000 feet deep, were suitable. While up to forty shallow wells could theoretically be pumped by a well-balanced, high-powered system, fifteen to twenty was a more common number.[75] The wells also had to be in relatively close, within a mile, proximity. Although the shackle lines could be routed over and around difficult terrain, extreme topography could hinder their use and was sometimes better suited to individual wells pumping on the beam.

Prime Movers

Animal power was used on some early central powers, but the steam engine quickly took over. Since Drake's well, steam engines were a common sight in the oil fields. They had first been used in the salt drilling industry, perhaps as early as the mid 1840s, and by the time of Drake's well in 1859 there were at least three different types of

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[75]See K.B. Nowels, "Surface and Subsurface Loads on Bandwheel Powers," Proceeding of the Second Petroleum and Natural Gas Conference (State College: The Pennsylvania State College, 1932). This is perhaps the only published scientific analysis of loads on bandwheel powers.

horizontal, single-cylinder steam engine/boiler combinations used for drilling.[76] By the early 1860s they were used (with auxiliary equipment, as described earlier) to pump wells which could not (or had ceased to) flow under their own pressure.

From 1859 to ca. 1895 the only types of prime movers available were steam powered, but by 1900 the trend toward gas and oil powered engines was in full swing.[77] A gas pumping engine had important advantages over its steam counterpart. It could be fired with gas from a nearby well head, removing the need for labor to fire, supervise, and maintain the water boilers. They were more efficient, plus generally safer and simpler to operate than a steam engine. Gas engines closely resembled steam engines; indeed, the first gas engines were often "half-breed" engines, where a steam engine was converted to gas by replacing the cylinder head and a few minor parts.[78] This was much cheaper than buying a whole new engine, and helped speed the transition to gas power during the 1890s.

Many oil well equipment manufacturers in Pennsylvania produced gas-powered pumping engines, and they became very popular throughout the nation's oil fields. These horizontal, semi-portable, single-cylinder engines became the mainstay of drillers and pumpers.[79] They ranged in size from 10 to 60 horsepower, with 20 to 35

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[76]J.E. Brantly, History of Oil Well Drilling (Houston: Gulf Publishing Company, 1971), p. 403. This is an excellent detailed historical study of all types of drilling equipment, including the development of oil-field engines.

[77]Steam engines continued to be used for drilling up into the 1920s. They could be more subtly controlled and could better handle power overloads than gas or oil engines. Also, their motion could be reversed easier, an important consideration for drilling because of the continual need to raise tools out of the borehole, or pull tubing or sucker rods.

[78]The Carrothers-Fithian Company (later the Bessemer, then Cooper-Bessemer Company of Grove City, Pa.) developed one of the first half-breed cylinder heads. The South Penn Oil Company alone placed some 10,000 Carrothers-Fithian half-breed cylinders on their pumping outfits in Pennsylvania and West Virginia. See David Keller, Cooper Industries 1833-1983 (Athens: Ohio University Press, 1983), pp. 33-34. Manufacturer B.D. Tillinghast, of McDonald, Pa., developed a dual gas and steam engine, which could be converted at will without major modifications. Often, the steam engine cylinder was used to drill a well, and the gas cylinder used for pumping.

[79]Pennsylvania was home to some of the country's most successful steam and gas engine manufacturers, supplying the needs of the oil industry around the world. Reid, Cooper-Bessemer, Bovaird & Seyfang, Franklin, Farrar & Tefts, were popular

horsepower being the most common used for pumping, and both two-cycle and four-cycle engines were used. One or two flywheels were attached to smooth the power transmission to the belting. For larger power plants, casing-head gas plants, or pipeline pumping plants, gas engines were built in larger sizes with much higher horsepower. These were often vertical engines with double or triple cylinders. Smaller gas engines (less than 10 horsepower) were sometimes used to drive auxiliary pumps. On gas engines which were used for both pumping and to pull tubing or swab a well, a reversing clutch could be installed to the side of the engine to facilitate reversing the engine's power. The only other option--removing, twisting, and reattaching the power transmission belt--was a time consuming process.

A pipe from a nearby casing head or separator tank carried gas to the powerhouse, first passing through a gasometer or regulator (these ensured a constant gas pressure), before continuing into the engine room and into the engine's cylinder. Gas pumping engines usually used "hot tube" ignition to ignite the fuel-air mixture in the cylinder, although engines with electrical sparkplug ignition were also developed and widely used. Gas engines were usually water cooled, with coolant water circulating through the water jacket surrounding the engine's cylinder, and dispersing its heat by passing through a coolant reservoir tank which could be located inside or outside the powerhouse. On larger engines the pumper employed a small air compressor to charge a compressed-air reservoir bottle. When the engine was ready to be started again, the compressed air was injected into the cylinder to initially crank over the engine since the flywheels were too heavy to turn over manually. Engine speed for pumping usually averaged 180 to 250 r.p.m., and was kept within safe limits by a governor on the throttle valve.[80] Moving parts on engines (and other equipment) needed constant lubrication, and either site-feed, splash-feed, or force-feed systems were used to keep friction to a minimum.

During the 1920s, electric motors were increasingly used to pump wells, and eventually superseded traditional gas or oil engines. Electric power supplied from larger commercial/public power plants could actually be thought of as the ultimate central power. Electricity could run a multi-well jack plant, or just a single well with unit pumpers powered by electrical motor running off the local power grid.

Powers

Pennsylvania-based engine producers.

[80]George, Surface Machinery, p. 24.

The r.p.m. reduction/motion conversion/power distribution unit, or power, was the key piece of equipment in central power systems. It converted the engine's rotary motion from, for example, 180 r.p.m., into a reciprocating motion of about 16 to 20 oscillations per minute that pulled the attached shackle lines an equal number of times.[81] Three different types of power were developed and in common use by ca. 1900: the push-pull power, the geared power, and the bandwheel power.

Push-pull powers, described earlier, were developed first. Initially, these were built of wood, with some metal fittings. Wood construction was problematic though, as wear, shrinkage, and loosening of the various fittings made them hard to keep properly adjusted. Eventually, all-metal push-pull powers were developed that alleviated this problem and they were used into the early twentieth century.

Geared powers came in three different configurations: The spur gear and crank-arm type, the bevel gear and disk type, and the bevel gear and eccentric type.[82] The first geared power, and actually the core design behind all three configurations, was invented by Pennsylvanian George Allen. Allen was in the refining business in Franklin, Pa., when he began designing his "Device for converting Motion in Oil Pumping Apparatus," otherwise known simply as a power.[83] The Allen power was actuated by a pulley-driven bevel gear, which turned a vertical shaft on which a crank, disc, or "eccentric" was mounted--offset--to create the reciprocal motion needed to give a 15" to 20" arc of travel to the attached shackle lines. Allen's design was much cheaper than push-pull powers, and geared powers became very common in Pennsylvania. Geared powers varied widely in their frame design (which could be wood, cast iron, steel, or a combination thereof), bracing, the layout of the reduction gearing, the number and configuration of cranks, discs, or eccentrics. Bevel-gear and eccentric type was probably the most popular in Pennsylvania. Depending on the number of wells to be pumped, one, two, or three eccentrics could be used. To properly balance the loads on the machine, two eccentrics were generally placed 180 degrees apart, and three eccentrics 120 degrees apart.[84] Eccentrics could be place above the gearing (called overpull) or below the gearing (called underpull). Although underpull eccentrics performed better and required less bracing, overpull eccentrics allowed the shackle lines to exit the powerhouse higher off the ground, an advantage in rough or brushy areas.

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[81]George, Surface Machinery, p. 69.

[82]Ibid.

[83]Ross, Allegheny Oil, p. 66.

[84]George, Surface Machinery, p. 73.

Bandwheel powers were equally common in Pennsylvania oil fields. George Grimes patented the first bandwheel power in 1897. Similar to the vertical bandwheel used in drilling and pumping wells on the beam, bandwheel powers were wooden wheels 12' to 20' in diameter, except they were placed horizontally, mounted on a vertical steel shaft. Eccentrics, each with a “slip ring,” were placed either above (overpull) or below (underpull) the bandwheel. A bandwheel was essentially a large pulley driven by a leather belt (from the engine) running around the face of its outer rim, negating the need for the bevel gearing. While its main function was reducing the engine’s r.p.m., the wheel’s momentum also made it function as a flywheel, smoothing out any dead spots in the engine’s power cycle and adding torque to the pull on the shackle lines.[85] Bandwheels were good for operating a large number of wells, but they required very heavy foundations and bracing. As such they were usually only used on larger operations. Like geared powers, up to three eccentrics could be mounted on the central shaft. The slip ring around the outer edge of the eccentrics was perforated for attaching the shackle lines, and as the eccentric turned, the slip ring imparted a straight back-and-forth motion to the shackle lines.[86] Bandwheels used a longer leather belt than geared powers, requiring an idler midway between the engine and bandwheel to maintain proper belt tension. Steel bandwheels were introduced in a 1913 patent for Wilbur O. Platt, President of the Joseph Reid Gas Engine Company.[87] These were usually preferred because they were lighter, operated smoother, gave less wear on the belting, and were more rigid. Also, they were prefabricated, making for easier transport and construction than wooden bandwheels.

Bandwheel powers were first designed for mounting in the horizontal plane, but the topography of Appalachia soon resulted in the “hillside power,” a bandwheel mounted parallel with a hillside’s slope.[88] The strains resulting from the tilted mounting required even heavier foundations, and more consideration for balancing the load on the eccentrics.

Shacklework

Shackle lines (also called rod lines, jerker lines, or pull lines) connected to the power,

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[85]Ross, Allegheny Oil, p. 67.

[86]Eccentrics without slip rings gave a side-to-side motion of 6" to 10" to the shackle lines along with the reciprocating movement.

[87]Ross, Allegheny Oil, p. 67.

[88]See HAER No. PA-441, Geer-Tiona Central Power.

and transmitted the reciprocating motion of the eccentrics or cranks out to a pump jack at each well. Various devices supported and guided the shackle lines between the power and the pump jacks, keeping the line taut without hindering the transmission of power. Also, devices just outside the power house allowed individual wells to be taken on or off the power. Wooden shackle lines were used in older systems, but wire cable or steel-rod lines performed better and became common after ca. 1900. Very often, old sucker rods were used for the shackle lines. Sucker rods and other wooden pull lines were usually hickory or ash octagon rods about 2" in diameter and 16' to 22' long, with forged wrought-iron couplings riveted to the ends.[89] They broke easily however, and required frequent repairs and adjustments. Steel lines were round, 1' or less in diameter, and 20' to 30' long with upset ends so they could be connected with clamps. Since shackle lines operated only in tension, wire cable could be used as well for the entire shackle line or spliced into sections of steel rod lines. One or more turnbuckles along the shackle line allowed for adjustments in the line's tension.

Each shackle line was supported along its length by metal hangers (mounted every 20' or 30', either on poles, tripods, or tree limbs) which swung like a pendulum when the lines reciprocated.[90] Or, shackle lines could be supported by "friction posts," which were usually short lengths of reused 2" pipe driven into the ground, or mounted on a pivoting base to allow a rocking motion. On friction posts, a grooved piece of wood (called a doll head) was attached to the top, to support the rod line. The doll head was kept lubricated to minimize friction.

Specialized shackle line devices were needed for other purposes: Taking a well off, or putting a well on, the power (either a "take-off post" or "hook-off rail"); guiding the shackle line up or down changes in elevation ("hold ups" and "hold downs"); and changing direction in the horizontal plane to carry the lines around obstacles ("butterflies" or swings).[91] These various mechanisms could be made of wood, steel, old pipe or casing; any combination of the various devices might be found along an individual shackle line.

Hook-off posts (sometimes called take-off posts) or hook-off rails served the purpose of keeping the shackle line in a horizontal plane as it exited the powerhouse, minimizing side-to-side movement, and providing a point to attach or detach a shackle line from the

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[89]George, Surface Machinery, p. 77.

[90]Poles, tripods, and hangers like most of the shackle line related equipment, could be built of wood or old pipe or casing, and usually were fabricated on site by the operator.

[91]George, Surface Machinery, pp. 76-87.

power. At the take-off post the initial 10'-long steel rod that attached to the eccentric could be hooked to, or unhooked from, the shackle line. Hook-off rails performed a similar function; used when the rod lines exited the powerhouse from underslung eccentrics at a low level. The eccentric rod and shackle lines were connected by either a C-link or a two- or three-hook connector link. When not hooked to a well, the eccentric rod was hooked to a counter weight to maintain a balanced load on the eccentrics, while the shackle line was hooked onto the “take-off rod” or guy cable mounted securely into the power’s concrete foundation. If the eccentric rod was not connected to a counterweight, the well in the opposite direction was removed to maintain balance. The counter weights assumed various forms, but the basic concept was to attach a weight equal to the weight on the line when it was operating the well. The counterweight pivoted on a mounting, mimicking the pull (in both weight and motion) required for the pump jack that the power would otherwise be operating. Often the counterweight (stones, old drill bits, jars, etc.) were simply laid in a tilted, bathtub-sized box configured to pivot on its lower end and called a “stone boat.”

Shackle lines followed the contours of the land, without any long supportless gaps (say, hung across a valley), that would cause the line to sag and be robbed of its reciprocal motion. Hold-ups and hold-downs both moved with a pendulum (or rocking) motion allowing the shackle line to reciprocate freely, but without any motion in the vertical plan that would decrease the stroke’s length. Hold-ups (or “swing posts”) were vertical posts mounted to a pivot on a ground plate or small foundation, with the top end connected to the rod line with stirrups and C-links. A hold-up would be used on a highpoint from which a shackle line descended to resist the downward force created by the line’s change to a downward direction. Conversely, a hold-down was a short pipe or pole, mounted similarly to a pendulum swing and located at a low point. The hold-down resisted any upward movement of the shackle line induced by a subsequent raising of the line’s altitude.

Changing direction in the horizontal plane required a “butterfly” (or horizontal swing, also called a hold-out) or a “ring swing”. A butterfly was a triangular wooden frame with one corner mounted (horizontally) to a pivot point (a tree or rock worked well), and the shackle lines connected to the remaining two corners. This allowed up to 90-degree turns in the shackle line, and also provided another point at which other wells could be attached or taken off the power. A ring swing was simpler, and used for lessor changes in direction. It consisted of three rings--one larger ring, attached to a suitable mounting spot (again, a tree or rock could be used as an anchor)--and two other smaller rings attached to the larger ring and connected to the shackle line.

Air Powers

"Air powers" or "air leases" were a rather anomalous development found particularly in the Bradford area of Pennsylvania. They appeared ca. 1920, but never gained wide use.[92] With this system, a centrally located gas engine powered an air compressor instead of the usual geared or bandwheel power; metal pipes or air hoses replaced the shackle lines. At the well heads, old steam engines were converted to pump jacks. Compressed air was sent through the pipes and injected into the steam engine cylinder, which powered a simple pitman/walking beam arrangement. These were called "Barcroft rigs" in Pennsylvania. There was also an "air-head" style pump jack which was a compressed air actuated piston/cylinder supported above the well and connected to the sucker rods. The air power system had the benefit of fewer moving parts (meaning less maintenance and loss of power) and compared to shackle lines power could be transmitted over longer distances.

Pump Jacks

A pump jack at each well converted the shackle line's horizontal reciprocating motion to a vertical reciprocating motion, which actuated the sucker rods and, in-turn, the valves in the well hole. After Plackross's invention of the pump jack in 1877, they assumed a wide variety of configurations but nearly all were classed as either "direct lift"[93] and "indirect lift."[94] Manufacturers offered different types of jacks built either of wood, cast parts, structural steel I-beams, tubular steel, or a combination thereof.[95] Sometimes jacks were built on-site by the operator using scavenged materials. Each type relied on a vertical triangular frame or "knee"--with one corner connected to the shackle line, one to a pivot mount, and the other connected directly, or indirectly through a steel pitman and walking beam arrangement, to the polished rod. On direct lift jacks, a curved mount at the polished rod-end of the knee (or walking beam in the indirect type) allowed for a

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[92]See HAER No. PA-442, McKenna-JoJo Central Power.

[93]Popular direct-lift jacks included the Hudson jack, Jones & Hammond jack, Simplex jack, Bessemer jack, and Norris jack. All were available from Pennsylvania's oil-well equipment suppliers. Indeed, indirect-lift jacks were sometimes called "Pennsylvania" jacks, and were first used in this state.

[94]The Oklahoma jack was the most popular type of indirect lift. Other types offered by manufactures were the O.K. jack, the Paova jack, and the Maloney jack. Indirect-lift jacks were sometimes all referred to as "Oklahoma" jacks.

[95]Another type of jack, evidently not used in Pennsylvania, consisted of a grooved wheel mounted vertically, on which a cable shackle line made a 90-degree turn from horizontal to vertical, and then attached to the polished rod.

straight, vertical pull on the polished rod. Direct lift jacks were classed either as "underpull" or "overpull," depending on the level at which the shackle line connected to the jack. Also, the length of stroke imparted to the sucker rods could be adjusted at the jack.[96]

Auxiliary Equipment

Cylindrical tanks always found in the vicinity of central power plants stored oil, cooling water for the engine, separated brine from the oil if the well made large amounts of water, or separated gas from the crude oil. Wood storage tanks (made of traditional iron hoops and staves) originated in the Pennsylvania oil fields around 1861, and remained popular until the 1920s and even longer in some areas. Riveted iron tanks gained popularity in the 1870s and were used through the 1920s. Both were superseded by the bolted steel-plate tank, first used in the mid1890s, and then the welded steel-plate tank in the mid 1920s. Iron and steel tanks both performed better than wood, but in some cases wooden tanks were used through much of the twentieth century.[97] Tanks came in a variety of diameters and heights, and like other well equipment, there was often a variety of styles and types mixed together on the same operation. Sometimes, smaller tanks or were made from old steam boilers turned on their end.

Certain tanks were not for storage purposes, but for separating out gas vapor from the oil under low pressure for it to be sent to the pumping engine or elsewhere. The first separator was introduced to the oil industry in the Oil Creek region of Pennsylvania in 1865. Simple devices, separators operated by allowing the crude oil to flow from supply pipes into a chamber or tank. As the oil slowed and settled, the gas/oil mixture separated; the gas was collected and taken off through the top of the tank, and the oil taken off through a pipe at the bottom. Later, after ca. 1900, high-pressure separators were introduced which removed greater amounts of gas.[98] Other separators that could condense the gas vapor into liquid gas, or drip gas, took on the appearance of long horizontal tubes sealed at both ends, connected to supply and take-off pipes. While separators supplied cheap fuel for the engine, capturing and controlling the most gaseous contents of the oil also made accidental fires less likely.

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[96]George, Surface Machinery, pp. 86-89.

[97]D.V. Carter, et al, History of Petroleum Engineering (Dallas: Boyd Printing Co., 1961), pp. 710-716.

[98]Ibid., p. 717.

Powerhouses

The structure which housed the engine, drive belt, and power was universally called the "powerhouse," although it could take on many different forms. Powerhouses originated with the earliest steam-powered drilling rigs, giving drillers and their engine a dry area to work in. They were immediately adopted to house the pumping engine, belt, and vertical bandwheel when pumping wells "on the beam." With the increase in equipment needed for central powers, the powerhouses expanded accordingly. They performed a variety of functions: protecting machinery, belting, and laborers from the elements; storage of tools, pipe fittings, and extra parts; and isolation of the engine to decrease the chance of accidental fires.

To build the powerhouse, the machinery was first set in place, and the structure built around it--so the machinery usually dictated the layout and size of the building. Through the late nineteenth century, powerhouses were built with wood. Some were built simply of notched logs, but most used balloon framing covered with siding topped by shingled or tar paper roofs until ca. 1890 when corrugated steel-sheet exteriors were introduced. Corrugated steel sheets became the covering material of choice by the early twentieth century. Some companies began using standard designs and materials, and complete prefabricated powerhouses became available from supply companies. Still, many remained idiosyncratic structures built on-site by the operator. Generally though, all were similar in that they were strictly utilitarian structures, usually rectangular, and built with economy in mind. Floors were often bare ground, but some had concrete floors in part, or all, of the building. The structure's foundations were usually minimal, but the machinery foundations could be quite substantial. Usually, interiors were sectioned and the engine room's interior walls completely covered in tin sheeting to prevent fires. Windows provided some light, but natural gas lighting was sometimes used. In colder climates a small gas stove in the engine room kept the operator warm. If large machinery needed replacement, a section of wall was removed, the new piece brought in, and then the wall was replaced.

Octagon-style powerhouses, a regional variant evidently found only in northwestern Pennsylvania, fall somewhere between standard and unique structures. An "octagon" powerhouse is similar to a normal powerhouse in every way, except that the room covering the power/eccentric unit is octagon-shaped in plan. These appeared in northwestern Pennsylvania ca. 1909, and were built, perhaps exclusively, by the South Penn Oil Company. Other than aesthetic quality, there are no currently agreed-upon explanations for this style of powerhouse.

The design of powerhouses had, by 1905, been mostly standardized into a utilitartian rectangular form. In northwestern Pennsylvania, however, something pushed powerhouse builders toward the octagon shape. The following reasons seem to make the octagon power superior to the standard rectangular power, at least in Pennsylvania.

(1) In addition to their elegant appearance they were simple to construct. A building with an octagon plan contains eight identical rectangular wall panels of equal dimension (one is left open in the interior into the beltway). Upon these, eight identical triangular roof panels sloping toward the center will form a sectional cone.

(2) Compared to a rectangular structure, an octagon provided more interior floor space around the circumference of the power allowing for the pumper to inspect, oil, and repair the machinery easier.

(3) Viewed in elevation, the octagon presents few clues to the reason for its design. Always, one wall faces you, and the slant of the conical roof draws your eye. Only in plan, however, does one plainly see the eight triangles that form the roof. Triangles are extremely rigid structural forms. In a standard hip roof, the weight is supported by parallel triangles in a row along a central axis. Usually this is sufficient for most climatic situations, but under high wind hip roofs are subject to axial weaknesses, i.e., the rafters can collapse on themselves like a deck of cards if wind pushes hard enough from one end. Also, hip roofs are subject to extreme snow buildup and, finally, the incumbent weight can overcome the load-sustaining capability of the roof. Great Lakes storms (lake effect snows) coming from the northwest routinely drop 30" of snow on this region. Equally violent storms periodically advance on this region from the South, West, and East; a product of its northern latitude, mountainous plateau, and proximity to the Atlantic Coast.[99] An octagon's conical roof negates this threat, shedding wind and snow easily from all sides. Furthermore, the triangles making up the conical roof add their rigidity to the walls they rest on--important considering that rods were often rubbing on the wall studs and cross members in a lateral motion (pulling on the walls, essentially). The structure around the power/eccentric continually underwent abuse by both the weapons of mother nature and the motion of the shackle lines. The octagonal shape and the strength of the roof resisted these threats. Compared to a rectangular powerhouse, the octagon powerhouse plainly appears more stable.

To summarize the octagon powerhouse design, its stealthy silhouette and strength must have made it superior to other powerhouse styles in this region. Its wind/snow footprint is minimalized, and it exhibits inherent structural stability which helps it resist the strains produced by wind, snow buildup, and the machinery inside. Add to this the extreme severity of northwestern Pennsylvania's winters. One might suspect that octagons were

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[99]All of the octagon powerhouses documented have wood-shingle roofs. Wood shingles evidently perform better under high wind conditions (70 to 100 miles per hour) than asphalt shingles.

used when the power was in spots particularly exposed to the elements such as ridgetops or north facing hillsides, or open wind-swept areas. If this reasoning is correct, its design could be considered the penultimate in powerhouse engineering, forced by the unique conditions in northwestern Pennsylvania.

Conclusion

Powered pumping systems strove for efficiency, simplicity, and durability in the effort to maintain cost-efficient production levels. This seemingly straightforward concept behind central power systems required an ingenious combination of power reduction, directional change, and power-distribution apparatus to transmit a single engine's motive power to, ultimately, the bottoms of wells that might be located a mile away and two-thousand feet below the ground. Their simplicity, efficiency and reliability, combined with the high quality (and somewhat higher price) of Pennsylvania Grade oil and the general increase in crude oil prices throughout the twentieth century ensured their survival in Appalachia long after their period of common usage elsewhere. There are a few, very rare scattered examples of functioning central powers left today...the rest have been abandoned in the last thirty years. Even here, they are quickly disappearing from the landscape--unappreciated and misunderstood. While but one component of the overall petroleum industry, these fascinating machines and the creative minds that spawned them are key elements of our nation's oil heritage.

Bibliography

Arnold, Ralph, and William Kemnitzer. Petroleum in the United States and Possessions. New York: Harper Brothers Publishers, 1931.

Bacon, Raymond Foss, and William Hamor. The American Petroleum Industry. Volume I. New York: The McGraw-Hill Book Company, 1916.

Ball, Max. This Fascinating Oil Business. New York: The Bobbs-Merril Company, 1940.

Barb, Clark, and Paul Shelley. "General Information Regarding Production of Pennsylvania Grade Crude Oil," Production Data on Appalachian Oil Fields. The Pennsylvania State College Mineral Industries Experiment Station Bulletin 6. State College, Pennsylvania: School of Mineral Industries, 1930: pp. 9-13

Beeby-Thompson, A. Oil-Field Exploration and Development. Volume I. London: The Technical Press Ltd., 1950.

Brantley, J.E. History of Oil Well Drilling. Houston, Texas: Gulf Publishing Company, 1971.

Carter, D.V., editor. History of Petroleum Engineering. The American Petroleum Institute. Dallas: Boyd Printing Company, 1961.

Crum, A. R., editor. Romance of American Petroleum and Gas. Volume I. Oil City, Pennsylvania: The Derrick Publishing Company, 1911.

Derrick's Hand-Book of Petroleum. Volume II. Oil City, Pennsylvania: Derrick Publishing Company, 1900.

Davis, Winston. "Salvaging Oil Field Equipment," Proceedings of the Eighth Pennsylvania Mineral Industries Conference: Petroleum and Natural Gas Section. The Pennsylvania State College Bulletin 25. State College, Pennsylvania: The Pennsylvania School of Mineral Industries, 1938.

Dickey, Parke. Oil Geology of the Titusville Quadrangle, Pennsylvania. Pennsylvania Geological Survey Bulletin M 22. Harrisburg: Commonwealth of Pennsylvania, 1941.

Fettke, Charles. Bradford Oil Field-Pennsylvania and New York. Pennsylvania Geological Survey, Fourth Series, Bulletin M 21. Harrisburg: Commonwealth of Pennsylvania, 1938.

George, H.C. Surface Machinery and Methods for Oil-Well Pumping. Department of the Interior Bureau of Mines Bulletin 224. Washington: Government Printing Office, 1925.

Giddens, Paul. The Birth of the Oil Industry. New York: The MacMillan Company, 1938.

____________. Early Days of Oil. New Jersey: Princeton University Press, 1948.

Hager, Dorsey. Fundamentals of the Petroleum Industry. New York: McGraw-Hill Book Company, 1939.

Harper, John and Cheryl Cozart, Oil and Gas Developments in Pennsylvania in 1990 with Ten-Year Review and Forecast. Pennsylvania Geological Survey, Fourth Series, Progress Report 204. Harrisburg: Commonwealth of Pennsylvania, 1992.

Hopkins, O.G.R., and A.B. Coons, "Petroleum," Mineral Resources of the United States. U.S. Department of Commerce, Bureau of Mines. Washington: Government Printing Office, 1930, p. 811.

Illustrated Catalogue of the Oil Well Supply Company. Pittsburgh: The Oil Well Supply Company, 1892.

Keller, David. Cooper Industries: 1833-1983. Athens, Ohio: Ohio University Press, 1983.

Langley, Seth. "Oil Well Pumping Methods and Equipment." Engineering and Mining Journal 109, No. 13 (March 27, 1920), pp. 748-754.

Leven, David. "Done in Oil": The Petroleum Encyclopedia. New York: The Ranger Press, 1942.

Lytle, William. Crude Oil Reserves of Pennsylvania. Pennsylvania Geological Survey, Fourth Series, Bulletin M 32. Harrisburg: Pennsylvania Geological Survey, 1947.

__________. Oil and Gas Geology of the Warren Quadrangle, Pennsylvania. Pennsylvania Geological Survey Bulletin M 52. Harrisburg: Commonwealth of Pennsylvania, 1965.

Lytle, William, and Joseph Goth. Oil and Gas Geology of the Kinzua Quadrangle, Warren and McKean Counties, Pennsylvania. Pennsylvania Geological Survey Mineral Resource Report 62. Harrisburg: Commonwealth of Pennsylvania, 1970.

The National Supply Company: Oil and Gas Well Supplies Catalogue. No. 14. Pittsburgh: The National Supply Company, 1906.

Nowels, K.B. "Surface and Sub-Surface Equipment Loads of Bandwheel Powers," Proceedings of the Second Petroleum and Natural Gas Conference. The Pennsylvania State College Mineral Industries Experiment Station Bulletin 11. State College, Pennsylvania: The Pennsylvania State College School of Mineral Industries, 1932.

Parkersburg Oil & Gas Well Drilling Equipment. Parkersburg, West Virginia: The Parkersburg Rig & Reel Company, 1921.

Pennsylvania's Mineral Heritage. Pennsylvania Department of Internal Affairs and The Pennsylvania State College School of Mineral Industries. Harrisburg: Commonwealth of Pennsylvania, 1944.

Pennzoil-The First 100 Years. Houston, The Pennzoil Company, 1989.

Ring, Dewitt. "The Oil Industry in the Appalachian Region." The Appalachian Geological Society 1949 Bulletin, Vol. 1. Charleston, West Virginia: Appalachian Geological Society, 1949.

Ross, Philip. Allegheny Oil: The Historic Petroleum Industry on the Allegheny National Forest. Warren, Pennsylvania: United States Department of the Interior, Allegheny National Forest, 1996.

Sisler, J.D., et. al. Contributions to Oil and Gas Geology of Western Pennsylvania. Pennsylvania Geological Survey, Fourth Series, Bulletin M 19. Harrisburg: Commonwealth of Pennsylvania, 1933.

Stephens, Maynard, and Oscar Spencer. Petroleum and Natural Gas Production. 2nd edition. State College, Pennsylvania: The Pennsylvania State College, 1951.

Ver Wiebe, W.A. North American Petroleum. Ann Arbor, Michigan: Edwards Brothers, Inc., 1957.

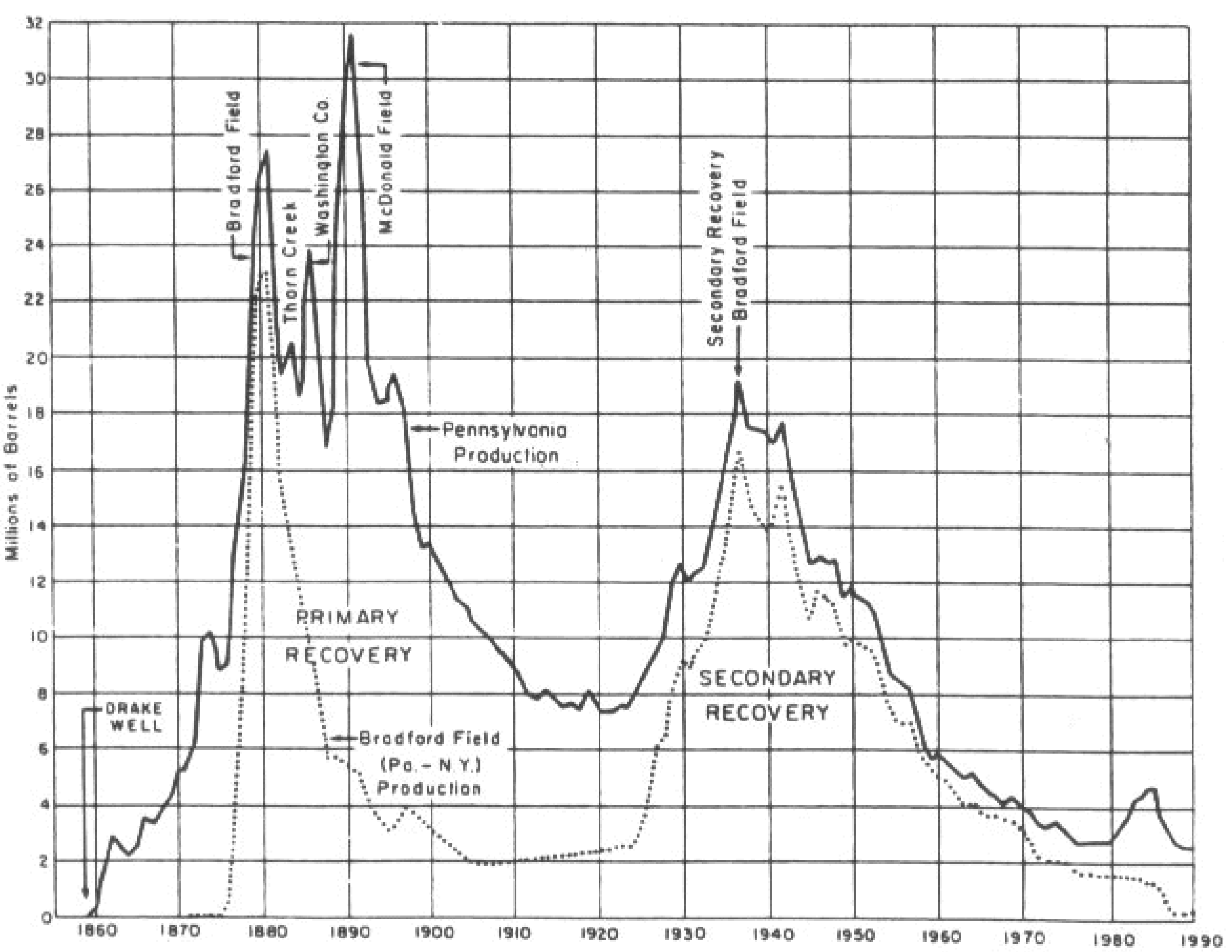
Whiteshot, Charles. The Oil-Well Driller. Mannington, West Virginia: Charles Whiteshot, 1905.

Williamson, Harold, and Arnold Daum. The American Petroleum Industry: The Age of Illumination, 1859-1899. Evanston, Indiana: Northwestern University Press, 1959.

Zook, Ralph. "Production and Consumption of Pennsylvania Grade Crude Oil." Proceedings of the First Petroleum and Natural-Gas Conference. The Pennsylvania State College Mineral Industries Experiment Station Bulletin 9. State College, Pennsylvania: The Pennsylvania State College of Mineral Industries, 1930.

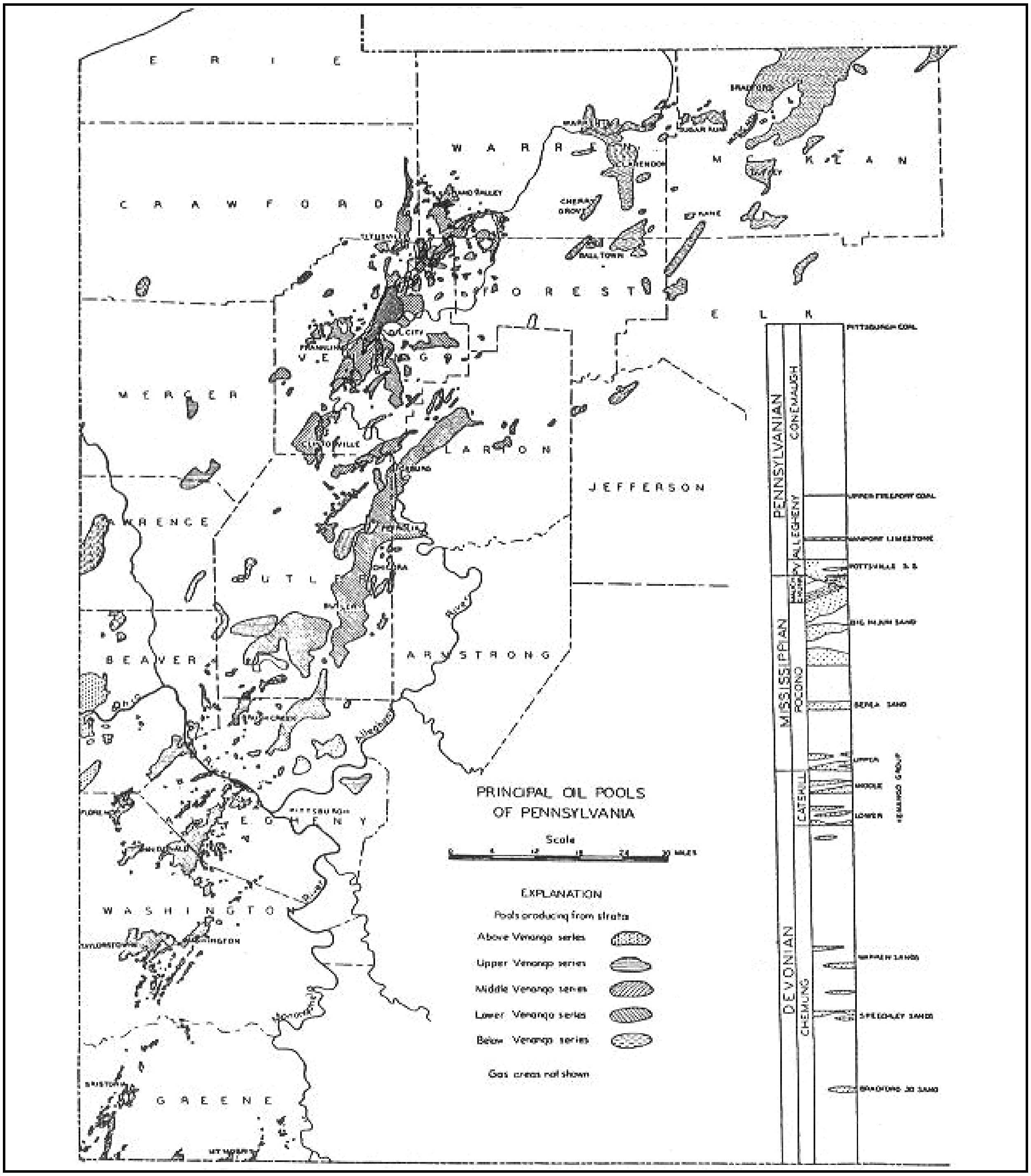
Appendix A

A graph showing production totals (with comments) for Pennsylvania, 1859 to 1990 (from Harper and Cozart, Oil and Gas, p. 4).



Appendix B

The oil pools of western Pennsylvania (from Pennsylvania's Mineral Heritage, p. 88).



Appendix C

The oil pools of Pennsylvania, listed by discovery dates up to 1928. These are not necessarily the flourishing dates of these pools.

Date, Name, County

1859, Titusville, Crawford

1860, Crooked Run, Butler
1860, Franklin, Venango
1860, Grand Valley, Warren
1860, North Warren, Warren
1860, Oil City, Venango
1860, Smiths Ferry, Beaver
1860, Tidioute, Warren

1861, Bradford, McKean
1861, Carmichaels, Greene

1865, Blackshire, Greene
1865, Northeast, Erie
1865, Pithole, Venango
1865, Pleasantville, Venango

1867, Dennis Run, Warren
1867, Oleopolis, Venango
1867, Shamburg, Venango

1869, Elk City, Clarion
1869, Petrolia, Butler

1870, Emlenton, Venango
1870, Fagundus, Warren
1870, Fosters, Venango
1870, Raymilton, Venango
1870, Sandy Creek, Venango
1870, West Hickory, Forest
1870, West Liberty, Butler

1871, Sugar Creek, Venango

1872, Cranberry, Venango
1872, Utica, Venango

1873, Concord, Butler

1874, Butler Cross Belt, Butler

1875, Bullion, Venango
1875, Glade Run, Warren
1875, Sheffield, Warren
1875, Smethport, McKean
1875, Summit, Butler
1875, Wardwell, Warren
1875, Winfield, Butler

1876, Economy, Beaver
1876, Garrison, Green
1876, Glade Mills, Butler
1876, Kane, McKean
1876, Kennerdell, Venango
1876, Whitley Creek, Greene

1877, Cookson, Allegheny
1877, Lafayette, McKean
1877, Lake Creek, Crawford
1877, Tionesta, Forest

1878, Clarendon, Warren
1878, Cornplanter, Warren
1878, Kushequa, McKean

1879, Cherry Grove, Warren

1880, Dewdrop, Warren

1881, Mansen, Elk
1881, Sackett, Elk

1882, Shannopin, Beaver

1883, Balltown, Forest

1884, Homewood and Swissvale, Allegheny
1884, Thorn Creek, Butler

1885, New Galilee, Beaver
1885, Oneida, Butler
1885, Washington-Taylorstown, Washington

1886, Mount Morris, Greene
1886, Pleasant Unity, Westmoreland
1886, Saxonburg, Butler

1887, Clifton, Allegheny
1887, Fayette, Fayette

1888, Canonsburg, Washington
1888, Clarion, Clarion
1888, Hallton, Elk
1888, Masontown, Fayette
1888, Nineveh Greene
1888, Shamburg, Clarion

1889, Hookstown, Beaver
1889, Waynesburg, Greene
1889, Wildwood, Allegheny

1890, Burgettstwon, Washington
1890, Chartiers, Allegheny
1890, Coraopolis, Allegheny
1890, Florence, Allegheny
1890, Glade, Butler
1890, Mars, Butler
1890, McCurdy, Allegheny
1890, McDonald, Washington
1890, Richhill, Greene
1890, Slippery Rock, Lawrence

1891, Clintonville, Butler
1891, Moon, Allegheny
1891, Muddy Creek, Butler

1892, Evans City, Butler

1893, Garvin, Butler
1893, Keown, Allegheny

1894, Glenhazel, Elk
1894, Homestead, Allegheny
1894, Little Mud Lick Creek, Armstrong
1894, North Washington, Butler
1894, Ormsby, McKean
1894, Venice, Washington

1895, Glenfield, Allegheny
1895, Lickskillet, Allegheny

1896, Bristoria, Greene
1896, Criders, Butler
1896, New Freeport, Greene
1896, Rosenberg, Butler

1897, Crows Run, Beaver
1897, Fonner, Greene
1897, Grays Fork, Greene

1898, Bellevue, Allegheny
1898, Broadtree, Greene
1898, Imperial, Allegheny
1899, Ingomar, Allegheny
1899, Lagonda, Washington
1899, Lantz, Greene
1899, Moon Run, Allegheny
1899, Shellhammer, Armstrong

1900, Aleppo, Greene
1900, Aten, Allegheny
1900, Carnegie, Allegheny
1900, Deer Creek, Allegheny
1900, Grapeville-Arona, Westmoreland
1900, Hammersley Fork, Clinton
1900, Leechburg, Armstrong
1900, Linden, Washington
1900, New Castle, Lawrence
1900, Ross, Washington
1900, Sharon, Mercer

1900, St. Marys, Elk
1900, Zelienople, Butler

1902, Unionville, Butler
1902, Zollarsville, Washington

1905, Bolant, Mercer
1905, Woodruff, Greene

1906, Dague, Washington
1906, Miola, Clarion

1908, Pine Run, Westmoreland

1910, Bessemer, Lawrence
1910, Callery, Butler
1910, White Ash, Allegheny

1917, Clugston, Allegheny
1917, Hookstorm, Beaver
1917, Knoxville, Tioga
1917, Monaca, Beaver
1917, New Bethlehem, Clarion

1919, Bellsano, Cambria
1919, McKeesport, Allegheny

1924, Campbell Farm, Allegheny
1924, Perry Township, Greene

1925, Morris Township, Greene
1925, Rutan, Greene

1928, Atlantic, Crawford