# 19th Century Petroleum Technology in North America

by

Emory L. Kemp

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Michael W. Caplinger

Sponsored by

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Institute for the History of Technology and Industrial Archaeology

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*Dedicated to*

Patricia McGee

and

Charles Fairbank

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# Abstract

The Appalachian and the Ontario oil fields in Canada were the earliest developed oil fields on the continent. Appalachia dominated national oil production in the United States until about 1900, when the midwest and southwest fields suddenly began producing prodigious quantities of oil and quickly out-paced the eastern oil region. Therefore, the eastern oil fields and the 19th century equipment and techniques employed there represent a period of the modern oil industry very different from the new methods and equipment used after about 1900. These two factors combine to make a convenient cutoff point for a contextual discussion of early drilling and pumping technology. The Historic American Engineering Record and the Institute for the History of Technology and Industrial Archaeology's previous work on the subject (the Volcano Oil Field documentation, the Allegheny National Forest Oil Heritage Project, the Kanawha Valley Salt Industry Documentation Project, and Canada's Petrolia Oil Field Project) provides the foundation for this illustrated monograph focusing on early oil well drilling, pumping, refining, storage, and transport techniques and equipment.

This monograph traces the development of rod and cable-tool drilling techniques from antecedents in the salt industry (ca. 1820), to Drake's Well and early Canadian efforts, to the perfection of cable-tool drilling in the latter 19th century. Likewise, the history of central power oil-pumping technology will be traced from the prototype systems used at Volcano and Petrolia (ca. 1860), to the mature central power pumping technology used in the Allegheny National Forest (ca. 1900). While pumping through central power systems will be a focus, single-well pumping (or pumping on the beam) will also be discussed in depth.

# Foreword

*"I will work a work in your days*
*which ye will not believe."*
*Habakkuk 1: 5*

The authors are pleased to present herein the results of more than a decade of research on the technology of oil production. The material naturally falls under the following headings: drilling, pumping, refining, and transport. In an effort to provide a historical context, certain technologies developed which have ancient origins and are discussed as a prelude. The focus, however, is on the developments of the North American petroleum industry in the 19th century. The next century saw the mainstay of the industry move to the southwest in the United States and overseas along with much more sophisticated drilling and refining techniques. Thus, the geographical shift together with the rise of new technologies represents a separate chapter in the history of oil.

The linkage of the salt and petroleum industries is explored in the setting of the Great Kanawha Valley of West Virginia. Still, in West Virginia, the unique endless wire pumping system at Volcano, near Parkersburg in Wood County, represents the story of the adaptation of the use of wire rope power drives, ca. 1860, from factories to pumping a series of wells. Moving north from West Virginia to western Pennsylvania, the birthplace of the American oil industry, the most significant invention was the central power. A geared eccentric device capable of pumping numerous wells connected by rods or wire ropes. A number of manufacturers produced various central powers together with steam engines and later natural gas engines to drive them.

Little-known in the history of 19th century petroleum history is the role of oil development in southwestern Ontario, Canada. This predates, by several years, the rise of the oil industry in western Pennsylvania centered on Drake's Well. It is not merely a case of being the pioneers in terms of modern industry, but also the location of the "jerker line" rod system for pumping a large number of low producing wells from a single source and the Canadian "rod system" for drilling wells.

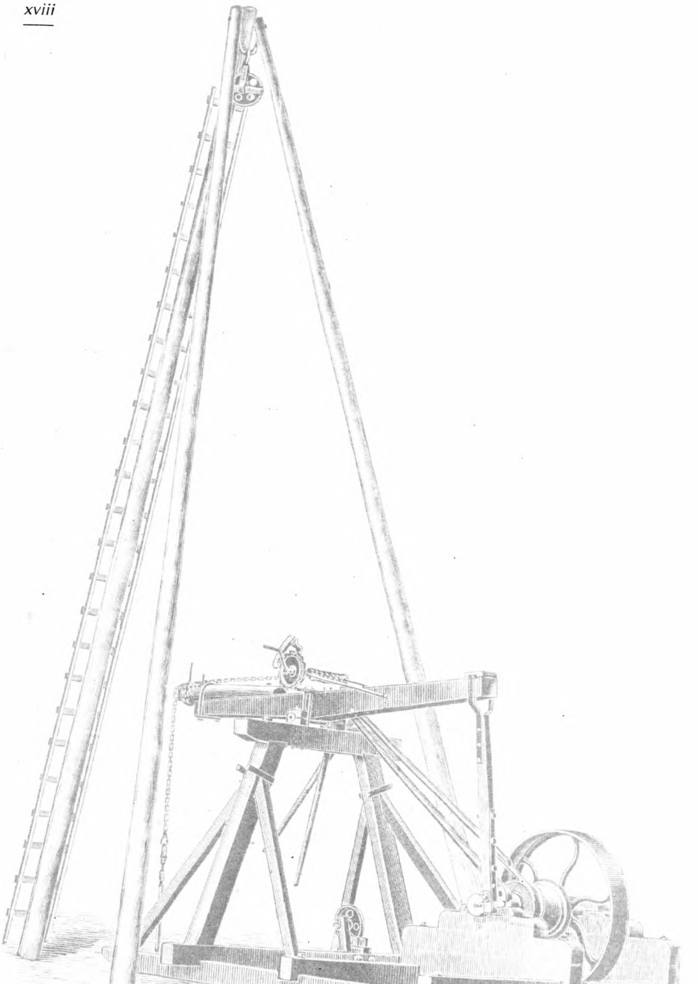
Distilling and refining of oil paralleled the developments in drilling and pumping. Borrowed from other industries, fractional distillation already had a long history tracing it origins back to alchemy and the more mundane art of alcohol production. Refining consisted of first treating oil with acid followed by a water rinse and neutralization by caustic soda. From a commercial perspective, refining and transport systems are both clearly associated with establishing of monopolistic practices in the industry, notably by John D. Rockefeller and his associates.

Using wagons, barges, railway tank cars and finally pipelines, oil was moved from the wells to refinery and thence to the public clamoring for kerosene for their lamps and other petroleum products such as lubricating oil. Gasoline really did not become an economic factor until the 20th century.

# Acknowledgments

Over the years, the authors have been involved in documenting three case studies at Volcano, western Pennsylvania, and Oil Springs, Ontario. In each case, the documentation consisted of measured drawings, archival photographs and a written history of the site. These projects were undertaken by the Historic American Engineering Record of the US National Park Service. We wish to commend all those members of summer teams who made these studies possible. The documentation of the Allegheny Nation Forest site was a joint effort with the Institute for the History of Technology and Industrial Archaeology, the US Forest Service, and the National Park Service. We are most grateful to all associated with these ventures.

We have been blessed with outstanding support from Charles Fairbank, Robert Cochrane, and Hugh Clouse, our partners in the Oil Springs project. In addition, we received support from Parks Canada, and would especially like to commend the late John Light as well as the staff of The Oil Museum of Canada.



CHAPTER 1

# Background History and Geology of the Modern Oil Industry

*The well-known Italian historian Benedetto Croce once declared: "History consists of essentially in seeing the past through the eyes of the present and in the light of its problems and the main work of the historian is not to record but to evaluate."*

This perspective is exemplified in our computer age with questions on the origin and development of the modern computer, which so dominates all aspects of life in the 21st century. Thus, historians have inquired about the origin of the modern computer. Although the abacus is of ancient origin, the father of the modern computer is now recognized as Charles Babbage and his mechanical calculating engines. Because of modern interest in computers, his name has risen from obscurity to prominence amongst historians of technology. There is even a Charles Babbage Institute devoted to the history of computers.

Whereas coal was the fuel that powered the Industrial Revolution in the 18th and 19th centuries, in our day it is petroleum. Thus, the object of our research is to establish the technical history of the petroleum industry in North America, and identify the leaders associated with the development of this technology.

In the beginning of the modern era, the oil industry could be found stretching along the ridges of the Appalachian mountains from the Great Kanawha River, in the south in West Virginia, northward to central Pennsylvania. The fields were scattered, and it took some years for their entire extent to be realized.

In the United States, these separate Appalachian oil fields dominated the industry until the turn of the 20th century, when the industry's impetus moved to the American southwest. Equally important, oil seeping to the surface to form gum beds became the center of the Canadian industry located between Sarnia and London in Ontario. Similar to the American experience, the Canadian oil industry later moved west, to Alberta.

By considering the history of the early modern oil industry in geographic terms, the development of the technology can be seen in an examination of three case studies placed in the context of the North American oil industry. The enquiry begins with the technology of the salt industry in the Great Kanawha Valley in West Virginia, and moves to the Volcano oil field near Parkersburg in West Virginia. Still farther north, the Pennsylvania oil fields border on the Allegheny River and they become the undisputed leader in 19th century oil production. At a slightly earlier date, Canadian entrepreneurs began marketing oil in Lambton County, Ontario. Thus, the case studies epitomize the technology of 19th century oil industry.

## The Origin and Nature of Petroleum

Petroleum is the general term for a complex mixture of gaseous, solid, and liquid hydrocarbons. It is a naturally occurring substance usually found tapped deep beneath the earth's surface, but at certain places it emanates from ground "seeps." These seeps were the first clues to its existence, and they supplied human 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, which is the subject of this work. Until the 1850s, in Pennsylvania, West Virginia, and Ontario, the market for illuminating and lubricating oil had been supplied by the whale-oil industry, coal-oil distillation, and gas produced 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. The origin and occurrence of oil within the earth have 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. 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 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 and natural gas 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 held within the rock matrix. This reservoir strata is nearly always sandstone, 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 by density 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 quality and 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 Ontario 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, 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 faults. In Pennsylvania, West Virginia, and Ontario, the most common traps are anticlinal folds.

This aspect of petroleum geology developed in the Appalachian region's oil fields, especially in West Virginia and Pennsylvania, were intensely studied after 1859. In 1861, T. Sterry Hunt[1] 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 the 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 geologist 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 19th century and in the 20th, 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.

A succinct statement by Cochrane and Fairbank[2] on the Oil Springs field:

> Oil Springs in Enniskillen Township of Lambton County was the site of the first commercial extraction of oil for industrial use. The progressive development of the field has been superimposed on a stratigraphic section. The gum beds at surface were first used as a source of asphalt in 1854. Then in 1858 it was discovered that free oil would seep from porous lenses in the glacial drift into a well hand-dug to 14 feet. The thickness of the glacial sediment varied from 46 to 80 feet (14.0-24.4m), and most wells were dug in the floodplain of the Black Creek where the glacial cover had the least thickness. Regionally, the bedrock is the black shale of the Kettle Point Formation; however, at Oil Springs, this formation has been removed by erosion and the bedrock is the Widder beds of the Hamilton Group. The bedrock limited the depth of hand-dug wells,

and the spring pole method of drilling and steam-powered rigs were used to tap the deeper reservoir. Fractures in the thin carbonates of the Widder beds yielded oil from the bedrock at slow rates. In 1859, a well drilled by J.M. Williams reached the top of the Middle Lime (a.k.a. Rockport Quarry by geologists) at a depth of 146 feet. Regionally, the Rockport Quarry is about 15 feet (4.5m) thick and consists of grey and brown very fine-grained impermeable limestones. However, on the Oil Springs anticline, this formation was fractured and yielded 60 barrels of oil/day in the Williams wells. Some of the subsequent wells drilled into this formation flowed oil to surface at low rates.

On January 16, 1862, after punching through 157 feet of rock, Hugh Nixon Shaw drilled the first hole into the top of the Dundee Formation at 203 feet. Although the top of the Dundee consists generally of an impermeable medium brown micritic and bioclastic limestone, the fractures at this location yielded rather spectacular flows of oil. Oil gushers had come to Oil Springs. However, the lives of flowing wells were limited; within one year all but two of the flowing wells had died. Fractured reservoirs typically have high initial flow rates and rapid declines. Wells were eventually drilled into the main oil pay zone across the interval 369-441 feet (112.5-134.5m) in the Anderdon Member of the Lucas Formation. This zone yielded oil at slower rates and is still producing oil after 138 years. The practice of deeper drilling continued at Oil Springs. In 1913, natural gas was discovered at 1,900 feet in a small incipient reef of Silurian age; Oil Springs was one of the first villages to have street lamps powered by natural gas!

Even with the success of anticlinal theory, locating oil was still a hit-or-miss prospect. For one thing, experimental drilling is still required to determine if a structural trap holds 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 geophysicists have 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 have provided more tools for the modern petroleum geologist.

## In the Beginning

Indigenous peoples around the world used petroleum, which had seeped to the surface, for both external and internal medical purposes as well as a waterproofing agent. It was, however, in Mesopotamia that petroleum in various forms was widely used. It, therefore, is appropriate to examine the ancient technology of the Middle East and its possible links to the modern oil industry. Supported by archaeological evidence, the use of petroleum products emerged by 3000 B.C. from Sumerian, Assyrian, and Babylonian sources.

Rock asphalt was "refined" by heating in a vessel with a sieve bottom. Other sources of bitumen were the many seeps throughout the area. Waterproofing for both boats and baskets relied upon liquid asphalt. Perhaps the basket floating the baby Moses was waterproofed as a result of an application of asphalt or its derivative. Oil from petroleum saw widespread use as an illuminant in lamps. Perhaps the most enterprising use was in building large structures with asphalt in a land nearly devoid of stone suitable for construction and a scarcity of fuel to fire hard burned bricks. When mixed with suitable fibers, a mastic was formed and widely employed in building for masonry work, floors, and walls. The mortar for brickwork contained a high proportion of bitumen, about 35 percent, while a reduction to approximately 24 percent for floor and wall surface treatments was used. Other applications included hydraulic structures and a major use in road building, techniques not resumed until the 20th century.

Perhaps the most impressive application of asphaltic mastic is in the cone mortar construction from the fourth millennium B.C. at Erech in Mesopotamia. In this technique, closely spaced long clay cones were inserted into the mortar providing a circular external pattern while at the same time, stiffening and strengthening the wall. Singer, et al, reports:

> The 'Sublime Porte' in the Red Temple complex at Erch (Uruk), Mesopotamia. The colonnade stands on a raised terrace at the approach to a sanctuary. It is composed of four pairs of cylindrical brick columns each about 1.5m in diameter. The side walls are relieved by projecting half-columns. All these features, including the face of the terrace, are completely encrusted in cone mosaics, their painted heads forming a rich variety of patterns. Fourth millennium B.C."

While one might not classify the architecture as sublime, it represents a unique example in the history of building arts, not to be subsequently repeated. In fact, it was not until the modern establishment of the petrochemical industry that bitumen-based materials first arise as a major industry.

Based upon archaeological evidence, the origin of the arch probably arose in places like Khorsabad, Mesopotamia in the construction of culverts and drains. The mighty arch and dome structures of the Romans, and the later use of the arch in Medieval and Renaissance monumental structures are the decendents of the humble arch waterproofed with asphalt.

With the conquest of the Mesopotamia area, ca. 600 B.C. by the Persians, the art of building with asphalt and asphalt products disappeared only to be replaced by masonry and brickwork based upon products of lime for use as mortars. This tradition reached new levels of grandeur in the hands of first the Greeks and later Romans. It was the tradition which served as the basis of European building arts until modern times. As a result, bitumen-based technology all but vanished in the civilized world.

Having forsaken the asphaltic building art, the Persians and Arabs turned their attention to the refinement of crude oil, developing primitive distillation methods to produce illuminants.

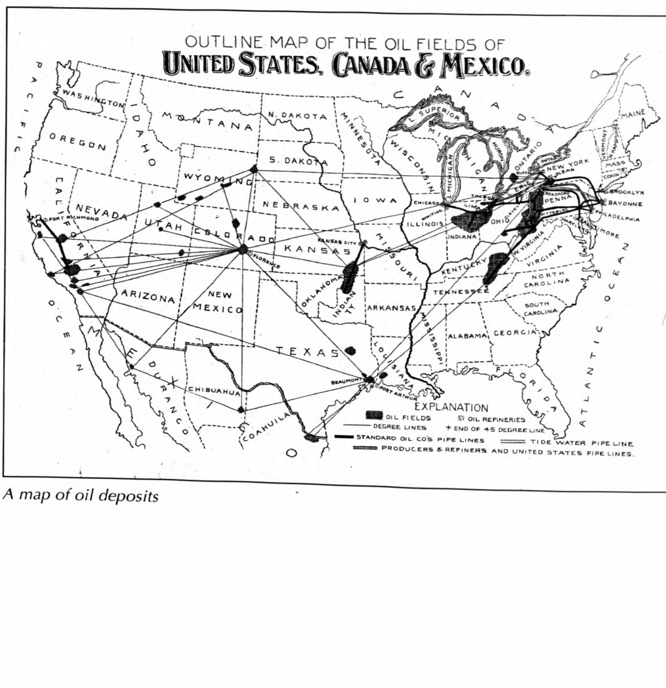
This refining technique found use in Europe through transmission of this Arabic technology through Spain and Italy. One only has to mention the military use of "Greek fire" to realize the importance of distilling crude oil or even asphalt to produce a light highly flammable liquid. These developments are dated as early as 750 A.D. when distillation techniques developed. At the same time, the retort was introduced. Simple distillation formed the basis for oil refining in North America beginning in the mid-19th century. Marco Polo visited Baku on the Caspian Sea in 1272 and reported on the abundance of crude oil. This field was later developed in the 19th century by Canadian oil men and became one of the great oil fields in the world.

At best, the link between ancient distillation practices and 19th century oil industry is a tenuous one. The most significant and important link, however, is not based upon asphalt and oil, but rather on salt, the subject essential to the life of man and beast. Salt was secured from the evaporation of brine and sea water or the mining of rock salt. In the quest for salt, both the methods of drilling and pumping were developed. It was salt recovery techniques which were used in modified form in the early oil fields. To explore early modern oil technology the developments are discussed thematically under the headings of drilling, pumping, storage, refining, and transport.

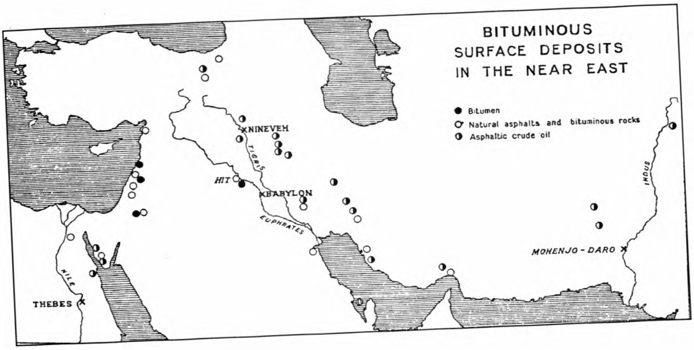
### *Chapter 1 - Endnotes*

1. T. Sterry Hunt, chemist, served with the Geological Survey of Canada. Gray, Earle, The Great Canadian Oil Patch, 2nd ed. (Edmonton, Al, June Warren Publ. Ltd. 2004) 36.

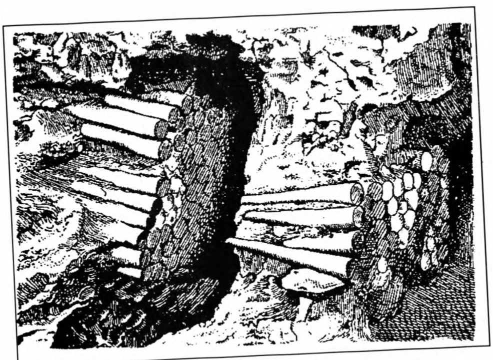
2. An unpublished guide, Northern Prospects in the 21st Century, 2000 Eastern Section, American Association of Petroleum Geologists. 29th Annual Meeting, Oil Heritage Tour of Lambton County: The Birthplace of the Canadian Oil Industry, by Robert O. Cochrane, Cairnlins Resources Ltd. & Charles Fairbank.



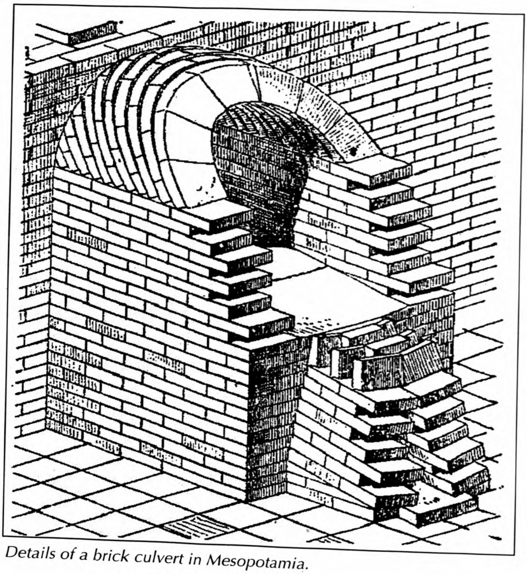

*A map of oil deposits*



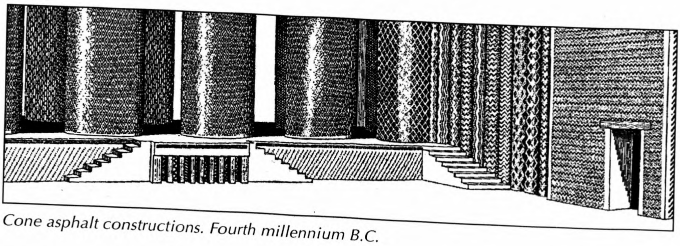

*Bituminous deposits in the ancient near east.*



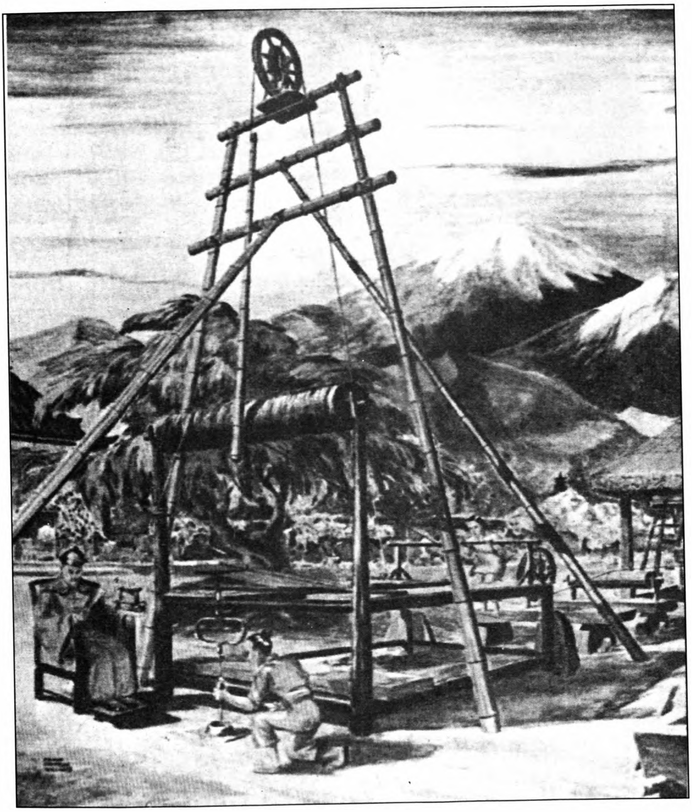
*Brick and Asphalt construction of the red temple in Mesopotamia. Fourth millennium B.C.*



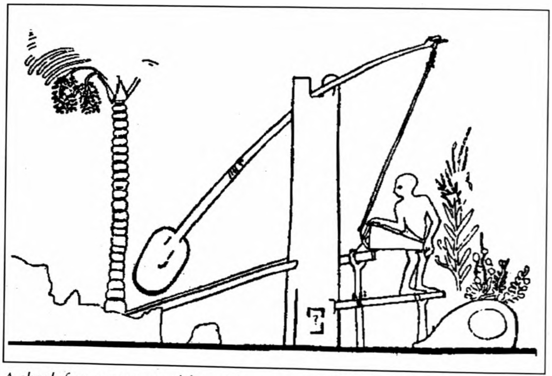
Details of a brick culvert in Mesopotamia.



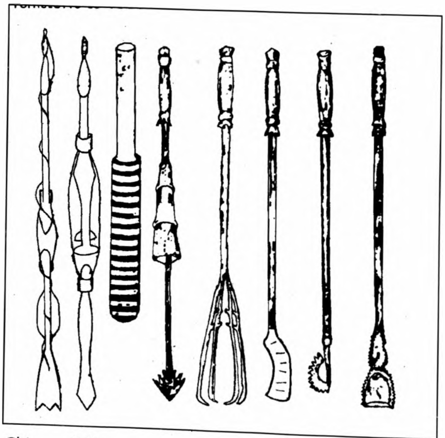
Cone asphalt constructions. Fourth millennium B.C.



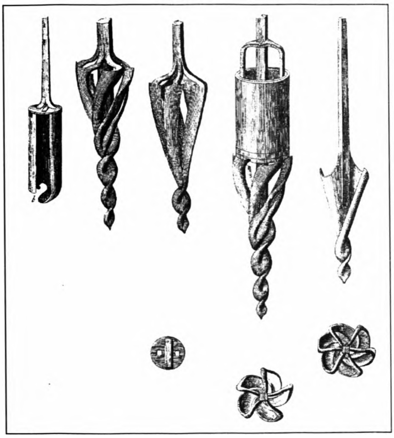
Details of a Chinese drilling rig.



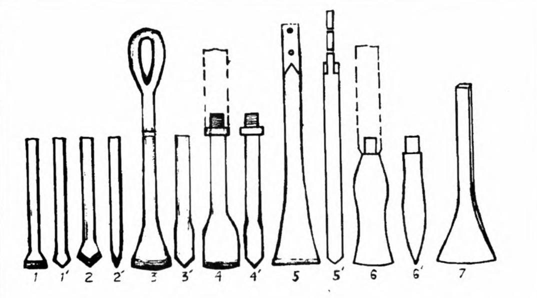
A shaduf or swape, used for raising water in the ancient world and employed again in the salt works in the Kanawha valley



Chinese drilling tools used from prehistoric times.



*The French employed rotary drilling techniques. This illustrates the well tools*




Drill bits, early 1800's: (1) and (2) quarry bits; (3) Ruffner, 1808, from Morris description; (4) Morris, late 1820's; (5) Prud'homme, 1823; (6) overall, 1828; and (7) Disbrow, 1830.

*A display of early drill bits from the late 18th century to circa 1830*

14

CHAPTER 2

# Drilling

## Drilling

The drilling for water or brine is a most ancient technology, which occurred in pre-historic times. In the first place, wells were dug by hand throughout human history and well into the early phases of the modern oil industry. In fact, the techniques of timber cribbing to prevent "cave ins" were regularly employed in the 19th century. Noted later, this technology was used to dig down to bedrock at Oil Springs, Ontario, and elsewhere before drilling was started. For drilling at more substantial depths and especially for advancing a bore hole through rock, percussive drilling was used. The documented origins center in Sichuan Province in China where this type of drilling was applied to brine wells. Dug wells were recorded as early as 480 B.C. Percussive drilling began as early as 300 A.D. in this remote Chinese province. These deeper wells produced brine but also natural gas, which the Chinese used in evaporating pans to produce salt.

By the time of the Tang Dynasty (618-906 A.D.), wells reached depths of 850 feet. It was a remarkable but little known achievement. Although, in part conjecture, the procedure began with a hand-dug shaft carried down to solid rock and in most cases cribbed with wood to prevent cave-ins. In place of the later use of casing pipes, the driller filled in the shaft around a centrally placed column of stacked stones with drill holes pierced in each stone, some 8-14 inches in diameter.

Percussive drilling was the only way to reach greater depths. Propelled by a man jumping on a "spring-loaded" platform, bamboo rods raised and dropped a chisel-like cast-iron drill bit on the solid rock. Progress was slow, depending on the hardness of the rock. A day's drilling might have advanced the hole a foot or so at best. With little change, this system not only survived, but dominated the early 19th century quest for crude oil under the name of, "spring-pole" drilling. Not only was bamboo used in drilling, bamboo tubes with a bottom flap valve were used to bring brine to the surface.

The fertile mind of Leonardo da Vinci (1452-1519) produced sketches of a means of sinking shafts using a rotating boring tool. In essence, the bit used for percussive drilling took the form of an auger. At the beginning of the 19th century, Prudhomme presented information on a rotation system which also added percussive bits to the "drilling string." The rotation motion was effected by hand twisting of the iron or wood drill rods.

A very noteworthy well was bored to a depth of 1,083 feet (330m) near St. Nicholas d'Abremont, France, in 1795, presumably using the Prudhomme rotary drilling tools. Thus, from ancient times to the end of the 18th century, some of the record wells include:

- Brine wells, China, 1600s AD., 2,000 feet plus
- Oil wells, Peschelbronn, Alsace, France, 1785-94, 300 feet plus
- Water well, Le Harve, France, 1792, 269 feet
- St. Nicholas d'Abremount, Alsace, France, 1795, 1,000 feet plus.

## Kanawha Salt

The foregoing discussion provides a context for the "state of the art" in oil and asphalting techniques up to the eve of the 19th century, which saw not only the pioneering work that established the modern petroleum industry, but also the companion development of the salt industry as the basis of the flourishing chemical industry in the Kanawha Valley and elsewhere in North America. It is not the intention to present, however briefly, the history of the North American chemical industry, but rather to focus on the origin of the salt industry in the Kanawha Valley as the precursor of the first petroleum industry centered in the Appalachian region, particularly in West Virginia and western Pennsylvania, and to a lesser extent, in northwest Ohio and southern Ontario.

The transfer of salt technology and its transformation in selected geographical areas for use in the tapping of oil resources represents a key development in the oil story. This development occurred in the German-speaking areas of central Europe and will be dealt with under the section on pumping. Nevertheless, one must stress at this stage in the development of the story that the ancient spring pole method of drilling water and brine wells remained in use throughout the 19th century.

To discover the origins of oil well pumping in North America, one must return to the salt industry in the valley of the Great Kanawha River in western Virginia (later West Virginia). Numerous accounts relate the history and some of the legends of the Ruffner family[1], John Dickinson, Elisha Brooks, Daniel Boone, and the salt licks used by buffalo, deer, and other animals before the entry into the area by European settlers. As the native Americans knew, salt was desired not only for seasoning food, but more importantly for food preservation. This need grew rapidly with European settlement before the advent of early ice boxes and later mechanical/electrical refrigeration. The quantities required, for example, two bushels of salt necessary to preserve a half ton of pork.

Naturally occurring salt licks begin about three miles upstream from Charleston, West Virginia on the banks of the Great Kanawha River, and extend upstream beyond Malden on both sides of the river. Secured by John Dickinson in 1785, his claim for 502 acres constituted one of the very earliest land acquisitions along the river. This purchase included a salt spring on Campbell's Creek. Failing to work the land or produce salt, he sold the property to another Virginian, Joseph Ruffner, in 1794. Purchasing this site unseen, Ruffner paid 500 pounds sterling to Dickinson. Having sold his property in the Valley of Virginia, he moved his family into this wilderness location in 1795. Two years later in 1797, Ruffner senior leased land to Elisha Brooks. Thus, it was Brooks who built and operated the first salt evaporation furnace in the Valley. This began the commercial manufacturing of salt. Apparently Brooks produced approximately 150 pounds of salt per day. The iron oxide in the salt gave the product its sobriquet of Kanawha Red.

In seeking a greater and stronger supply of brine, the Ruffner brothers investigated the Great Buffalo Lick in 1806, three years after inheriting the property on the death of their father. What resulted was a seminal event in the history of drilling for both salt and oil. The spring of brine issued from a quicksand offered the possibilities of tapping the source below the ooze. To accomplish this penetration below the ooze, the Ruffners's used a four-foot-diameter hollow sycamore tree called a "gum." With the gum braced in a vertical position, a working platform was erected on the top of the gum with men digging out the ooze inside. The waste material was removed with a "swape." This ancient device consisted of a spring pole supported by a forked support near the midpoint of the length. The one end was positioned over the gum and supported a converted whisky barrel by means of a rope. Men inside excavated the material and loaded it into the barrel, which was raised by pushing down of the other end of the balance beam. Using this procedure, the gum was advanced 13 feet to rock. Breaking through a six-inch layer of rock, water flowed freely into the gum but was of fairly low salt context. Another well was dug farther away from the river bank, but it also failed to produce stronger brine. Returning to the original well, the gum was advanced to a bed at approximately 17 feet where the bottom was sealed against the influx of surface water. Although the brine was stronger, the flow was weaker. Thus, the Ruffners determined to drill into the bedrock using the ancient spring pole device supporting a 2.5 inch diameter percussion bit attached to a spring pole by a rope. By this means, a drill hole was advanced 40 feet into the rock in 1808.

Later, in 1831, William Morris made a most significant improvement in well drilling with devices called "slips," or in the oil region "jars." The "jars" consisted of a short chain of three links inserted between the drill bit at the bottom and the wood drill rods. Whiteshot states that this most successful improvement in drilling was never patented.

Not only did William Morris secure a patent which had to be reissued in 1841, following the great patent office fire in Washington, but the narrative in the application presented details of improvements in the jars and provided the earliest information on drilling technology. So significant was this material that a full description was included in an appendix to the patent office.

The original chain links, while quite successful, tended to wear excessively. Thus, the device shown in the patent drawings is a decided improvement and set the standard for all subsequent jars. This simple device was (and still is) used on a worldwide basis.

During this time, an array of tools was developed or improved. In addition, first horse power and then steam power were used as early as 1810, although hand-drilling spring pole methods continued in the first half of the 19th century. The introduction of the walking beam for drilling and also pumping is of uncertain origin or date. As far as North America is concerned, it may have well been a case of independent invention, although earlier such mechanisms were used in France. As early as 1823 a walking beam was put on line for drilling in Louisiana. With strong French influence it is likely that this is a case of technology transfer. Thus, the walking beam may be a French import. The walking beam, as opposed to the spring pole system, could be connected to a horse treadmill or one of the ancient circular horse whims.

Concerning the Ruffners and their gum, having secured a much stronger brine through drilling into the rock and one of sufficient flow, the problem facing them was how to bring the brine to the surface without dilution from other flows encountered at shallower depths, together with the influx of surface water. Installing a wood casing into the bored hole, although crude, provided the answer. Iron, and later, steel casing appeared well before the oil boom in 1850s. Casings remain a standard and are used on a worldwide bases.

## Early Percussion Drilling Rigs

A drilling rig could be steam powered through a belt drive band wheel with an eccentric. One of the earliest authenticated walking beams was developed by W.H. MacGarvey in the 1860 and used in Canada and overseas. The earliest rigs used drill rods connected together from the walking beam to the drill bit. This "rod rig" persisted in Canada to such an extent that by the latter half of the 19th century it was referred to as "the Canadian system." Its longevity is associated with reduced costs, using locally grown wood for the rods, and connected with iron fittings often produced locally. Canadian drillers also believed that better control and drilling resulted from the rod system compared to the cable tool method. In the cable tool system, wire rope replaced wooden drill rods in American oil fields.

These two systems represented the majority of the rigs used in North America throughout the 19th century and into the early 20th century. There was, however, a flurry of activity beginning in the 1850s, which resulted in numerous patents for portable drilling machines.

Early, ca. 1820-1840, drilling apparatuses using spring poles could be said to be portable in the sense that the spring pole and its impedimenta could be easily disassembled and re-erected at a new site. With the introduction of the "walking beam" rig in the 1860s, skid mounted drilling rigs could be dragged from site to site. A surviving rig at the Drilling Museum in Ontario, Canada testifies to the longevity in service of skid mounted rod drilling rig, little has changed since the mid-19th century. A skid-mounted rig with a separate power source, originally steam, is on display at this museum. For purposes of definition, "portable" can be defined as a wheel or crawler- mounted rig. Thus, in the above example, only the power source can be considered as portable.

In the economically competitive world of portable drilling rigs, one of the earliest patents was assigned to Walker Hyde and dated March 7, 1865, and a second one in May of the same year. This compact drilling machine permitted the drilling team to move the drill rod in and out of the hole without stopping the motion. This patented device was, however, skid mounted only a semi-portable or "mobile" unit. In quick succession, patents for portable rigs were granted to John Dale, February 27, 1866 and L. Nelson, November 21, 1871.

At about the same time, 1867-68, Henry Kelly designed and built what appeared to be the first portable cable drill. The design was manufactured by an Osage, Iowa firm, Morgan, Kelly, and Tanneyhill Company. In 1904, the firm was reorganized under the name of Armstrong Quan Company. In 1910, the company did business under the name Armstrong Manufacturing Company. A rare survivor produced by this company can be found near The Oil Museum of Canada in Oil Springs, Ontario. The patent rights for the Armstrong portable rig were assigned to the Bucyrus-Eric Company in 1933.

F. S. Ward and E. Cooper were issued a patent on April 2, 1872 featuring a horse-powered treadmill driving a portable rig. Another patented design used a spring pole tripod derrick powered by a vertical boiler steam engine. The entire unit was compact and wheel mounted. To make the Downie machine[2] truly portable, the spring pole attached to a "dead man" in the ground was eliminated, and a rigid beam pivoted on a Sampson post and attached at the end of the rig chassis which permitted the entire unit to be wheel mounted. Other portable drilling rigs are listed by patent number and date and can be studied by referring to the patent office Internet web site.

## Early Rotary Rigs

An alternative to percussion drilling is the use of various rotary devices. Although of ancient origin, the rotary drill only became the dominant method of drilling oil wells in the 20th century. Like many mechanical inventions, rotary drills can trace their origins to Leonardo da Vinci, about 1500 A.D. The means of inducing rotary motion is the distinguishing feature in the various devices used. There may well have been earlier such devices, but this Leonardo da Vinci sketch is the first published information on record.

Concerning the three basic types of drill mechanism, Brantly states:

> There are three classes of devices used for rotating tools designed to bore holes into the earth: first, a threaded shaft which rotates through a fixed inside threaded box, such as a tractor engine-driven post or pole hole drilling machine, the Leonardo da Vinci type; second, a rotating or rotatable cylinder through which a shaft or drill rod passes and which rotatable cylinder carries a chuck at its lower end for rotating and holding the shaft and by means of which the shaft can be lowered as the cutting tool makes hole, such as the hydraulic cylinder, sleeve and chuck of a hydraulic diamond drill; third, a rotating or rotatable machine through which the drill shaft may pass and that carries a bushing which meshes with grooves or angles of the drill shaft, by which it may be rotated and through which the drill shaft may be lowered—for example, the usual hydraulic rotary drilling rig rotary table having grip rings or bushing.

One of the earliest patents was issued to Robert Beart in Britain in 1844 for a drilling machine using circulating fluid and a square cross-section stem. This was an early isolated case apart from the French who early on favored rotary drills. As far as North America is concerned, numerous patents were granted beginning in the 1860s and issued throughout the remainder of the century. One of the earliest patents in the U.S. was issued to L. Holmes in 1865. This machine represents the forerunner of the rotary table, which is a prominent feature of modern drilling rigs, but it also had the capability of up and down motion for percussion drilling in hard rock. Although many inventors and engineers were attracted to the possibility of practical rotary drilling machines, it really did not come into is own until the 20th century. This powerful technology has allowed wells of incredible depths to be drilled in various oil fields on a worldwide basis.

## *Chapter 2 - Endnotes*

1. Joseph Ruffner
Seeking Commercial opportunities, Joseph Ruffner in 1794 moved his family from the Shenandoah Valley in Virginia to the Great Kanawha Valley where he purchased land with the prospect of establishing himself in the salt industry. Joseph's sons, David and Joseph Jr., also entered the salt business. To increase production they commenced drilling a well of about 58 ft. in depth. This represented one of the earliest drilled wells in North America. Brantly, J.E., History of Oil Well Drilling, (Houston Texas, Gulf Publ. Co. 1971) 5-7 & 64.

2 Downie portable drilling machine
Using the ancient spring-pole system, Robert Downie is credited with the introduction of a portable steam driven spring pole rig. The first use, in 1878, saw the system used for drilling a water well. Apparently six or eight such rigs were fabricated for R.M. Downie and his brother by William Velte Co. of Pittsburgh and sold under the Keystone trade name. Brantly, J.E., History of Oil Well Drilling, (Houston Texas, Gulf Publ. Co. 1971) 654, 655, 660, 664, 665.

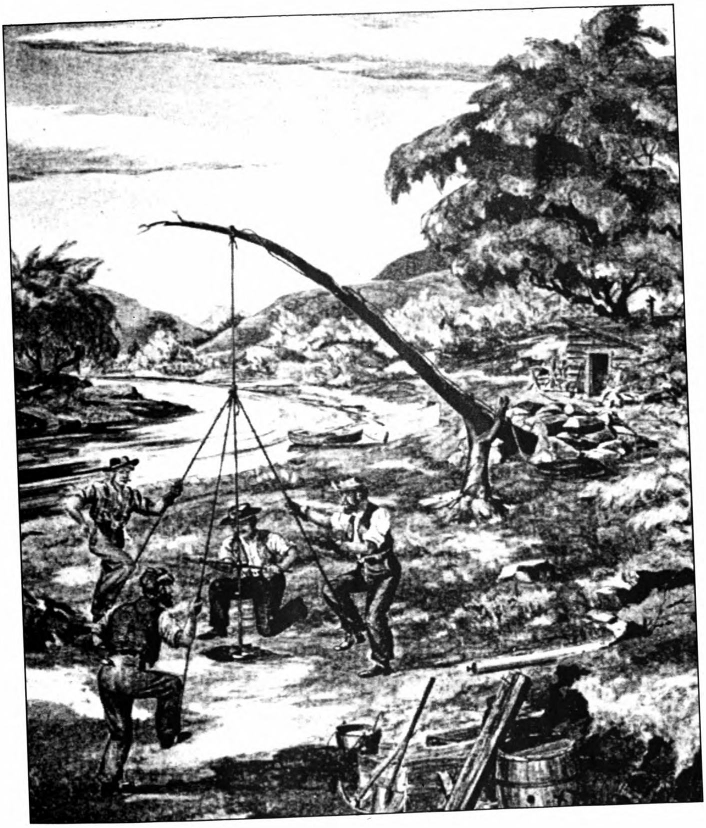
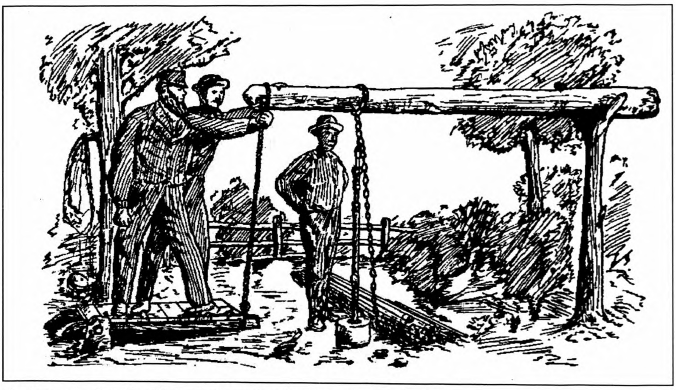


*Illustration of spring pole drilling techniques.*



Spring pole detail with a platform for "kicking down" the hole.

A spring pole drilling rig used in the Petrolia fields.

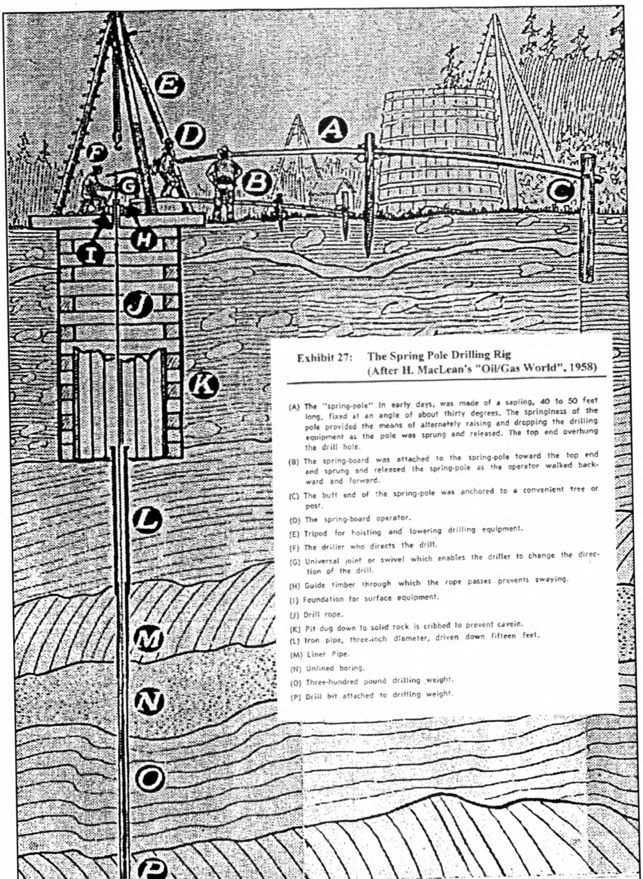
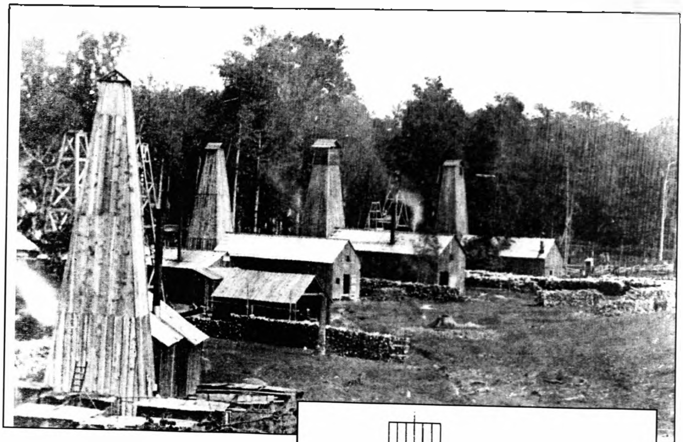
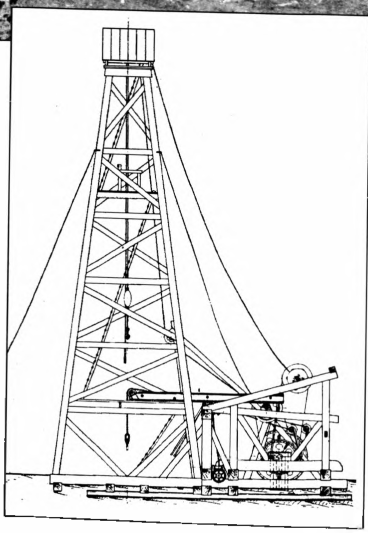



*Diagram of spring pole drilling techniques.*



Canadian Drilling Rigs in Petrolia oil field.



Details of a typical Canadian Drilling Rig employed in Galicia and elsewhere overseas.

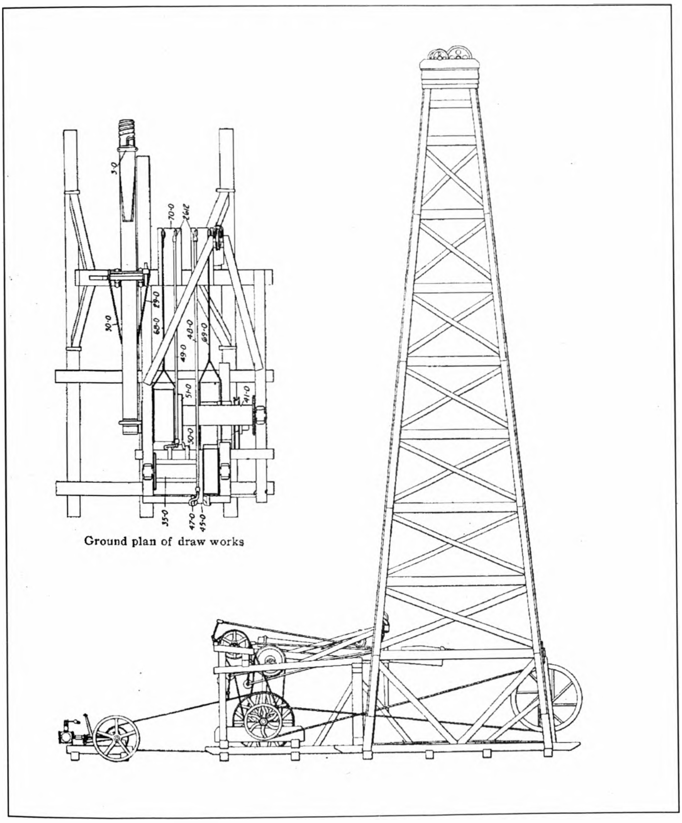



*Diagram of a Canadian Drilling Rig.*

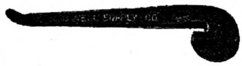
## WELL DRILLING TOOLS

FOR CABLE SYSTEM

### TOOL WRENCHES

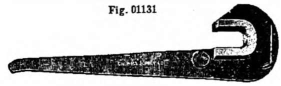
Two in a set, right and left hand

LEFT HAND
Fig. 01130



Form of wrench under 175 lbs.

RIGHT HAND
Fig. 01131



Form of wrench, 175 lbs. and heavier

LEFT HAND WITH LINER OR BUSHING
Fig. 01132

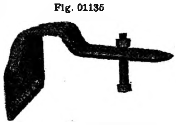
| Size of square........inches | 2½ | 2¾ | 3¼ | 3¼ | 3½ | 3½ | 4 | 4 | 4 | 4 | 4½ | 4½ | 4½ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight, each..........lbs. | 100 | 135 | 135 | 150 | 150 | 175 | 175 | 200 | 225 | 250 | 225 | 250 | 275 |
| Per set.................... | $21 00 | 27 50 | 27 50 | 30 50 | 30 50 | 34 50 | 34 50 | 39 00 | 43 50 | 48 00 | 43 50 | 48 00 | 52 50 |

| Size of square........inches | 4½ | 5 | 5 | 5 | 5 | 5½ | 5½ | 5½ | 5½ or 6 | 5½ or 6 | 5½ or 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight, each..........lbs. | 300 | 275 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 650 | 700 |
| Per set.................... | $57 00 | 52 50 | 57 00 | 66 50 | 75 00 | 84 00 | 93 00 | 102 00 | 111 00 | 151 00 | 162 00 |

Wrenches under 175 pounds have lifting handles only; 175 pounds and heavier have lifting handles and eyes.

| We recommend the following for this size square | 2¾ | 3¼ | 3½ | 4 | 4½ | 5 | 5½ or 6 |
|---|---|---|---|---|---|---|---|
| Use this weight wrench, lbs..........each | 135 | 150 | 175 | 250 | 300 | 400 | 600 |

RIGHT HAND
Fig. 01135

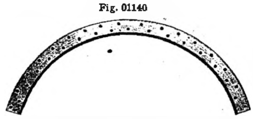


### LINERS OR BUSHINGS FOR TOOL WRENCHES

| | |
|---|---|
| 4 x 3¼ or 3½.......per set | $ 6 25 |
| 4½ x 4..............per set | 8 75 |
| 5 x 4, 4¼ or 4½......per set | 8 75 |
| 5½ x 4, 4½ or 5.......per set | 9 50 |
| 6 x 4...............per set | 10 25 |

LEFT HAND
Fig. 01136

WRENCH CIRCLE
Fig. 01140

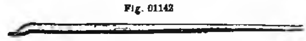


Regular ½ in. x 9 ft., weight, 65 lbs., $7 00

WRENCH CIRCLE HOOK
Fig. 01141

Steel, weight, 10 lbs...............$3 00

STEEL WRENCH BAR
Fig. 01142



1½" steel wrench bar, weight, 60 lbs., $3 50

The above outfit is little used, having been supplanted by Barrett's patent oil well jacks, see following pages.

*Illustrations of well drilling tools.*

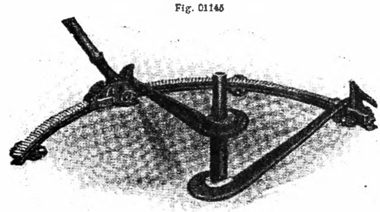
## WELL DRILLING TOOLS

FOR CABLE SYSTEM

BARRETT OIL WELL JACKS

No. 1 S. A.

Fig. 01145



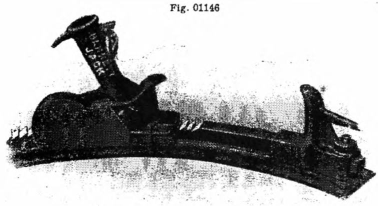
| Size No. | For tools with squares | Length of rack | Weight, lbs. | Price |
|---|---|---|---|---|
| No. 1 single acting | up to 4 inches | 8 ft., 5 in | 190 | $56 00 |
| No. 1 double acting | up to 4 inches | 8 ft., 5 in | 195 | 65 00 |

**The No. 1 S. A. jack is single acting After tightening joint the pawls are pulled out under tension by means of a lever and trip.**

**The No. 1 D. A. jack is double acting and automatically reversible After tightening joint, the jack will, by a half turn of the eccentric, reverse itself sufficiently to release pressure of pawls against rack, and the jack can then be pulled back to the end of the rack**

No. 2 D. A.—NEW STYLE

Fig. 01146

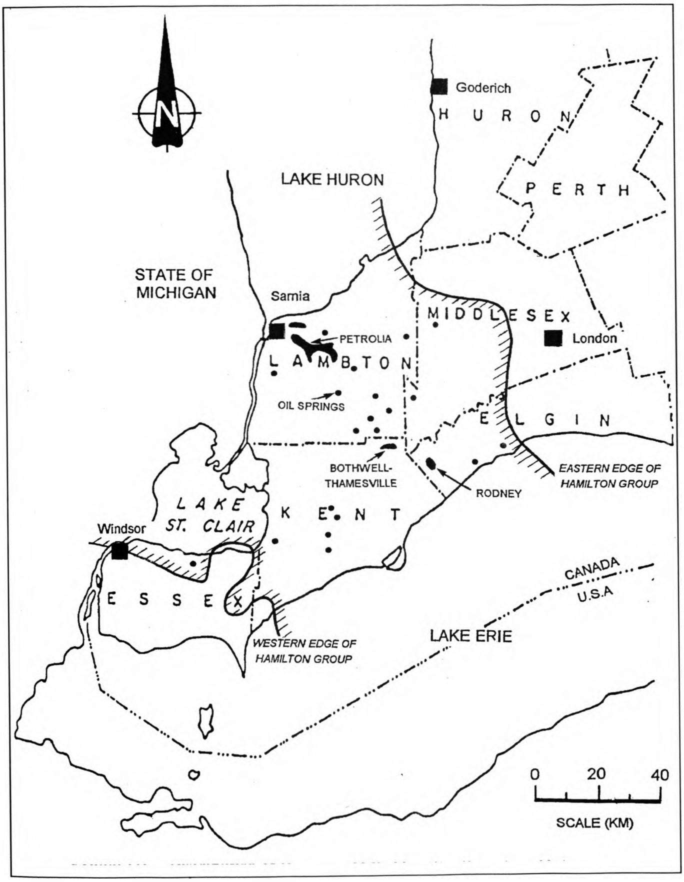


| Size No. | For tools with squares | Length of rack | Weight, lbs. | Price |
|---|---|---|---|---|
| No. 2 double acting | over 4 inches | 9 ft. | 420 | $102 00 |

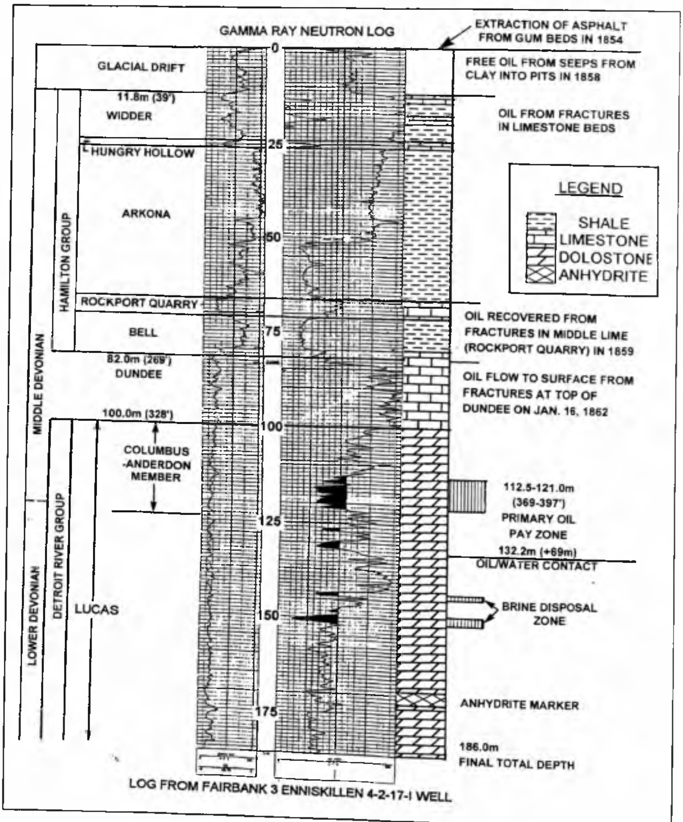
The No 2 D. A. New Style jack is double acting, automatically reversible, and is equipped with an exceptionally wide flanged rack which offers maximum resistance against lateral stresses

*Illustrations of well drilling tools.*

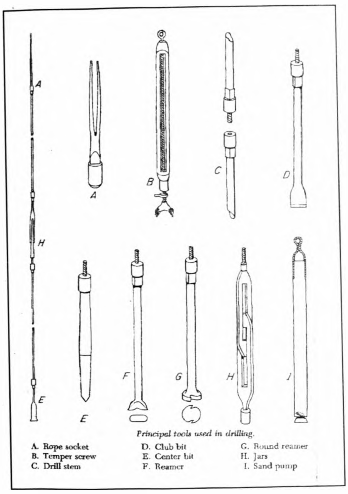

Men at Ontario Drilling Museum demonstrating the use of a well jack.



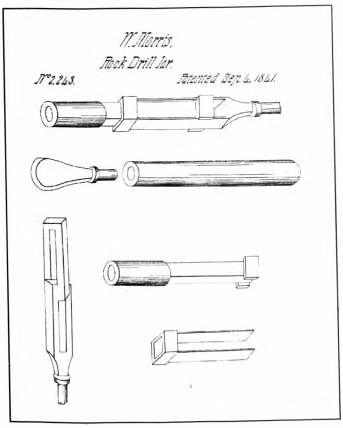

Oil field location in southwestern Ontario.




*Typical log section from Oil Springs, Ontario, field.*

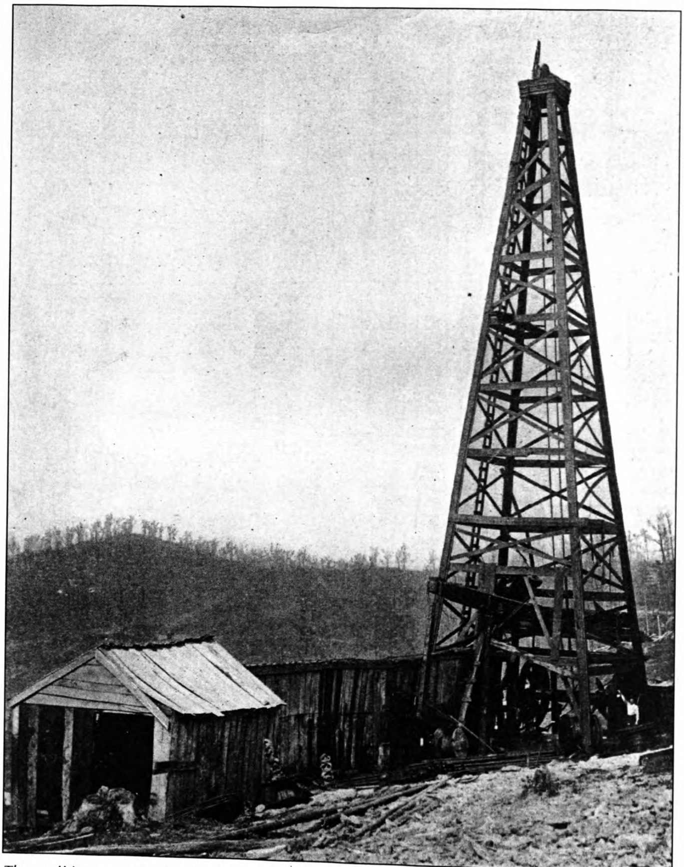



*Display of typical well drilling tools.*

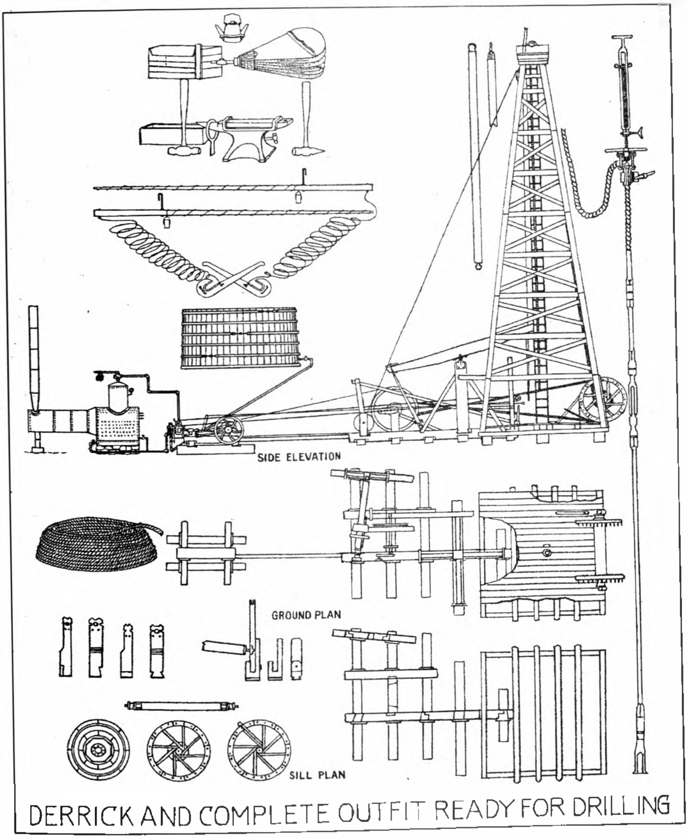



*Later patented jars by William Morris.*

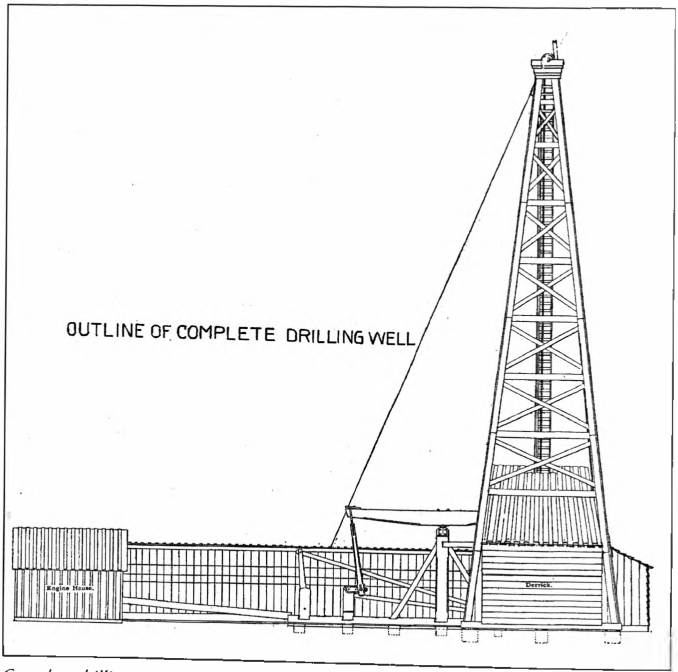
*A rare diagram of an original Morris jars used in both the salt and oil industries.*



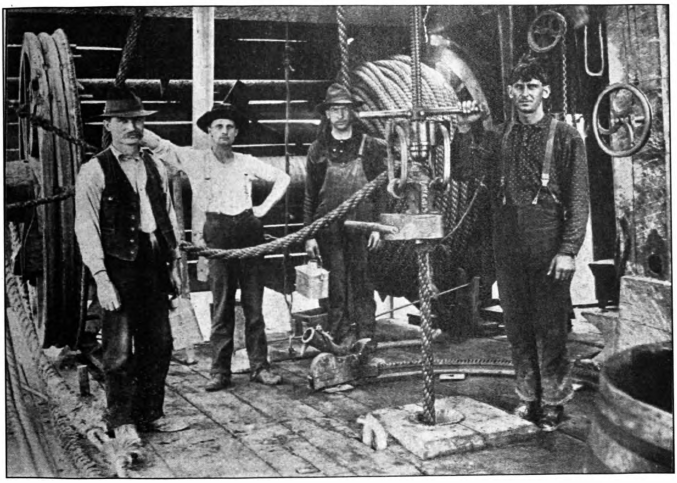
The well known Hoodoo Well in Wetzel County, West Virginia, illustrates a typical field facility.



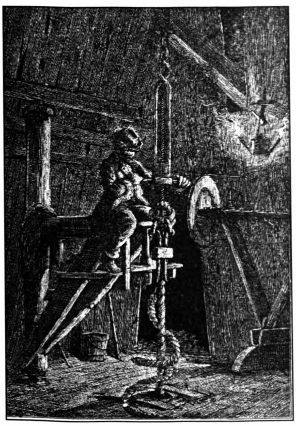

*Derrick and complete outfit ready for drilling.*



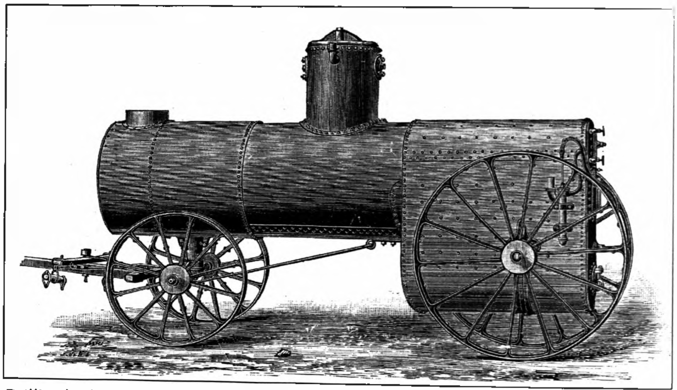

*Complete drilling rig showing engine house, derrick, and walking beam.*



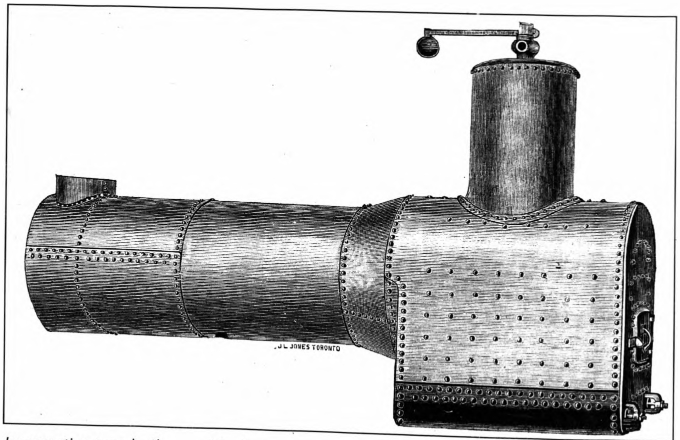
*Typical cable drilling operation using manila rope in Wetzel County, West Virginia.*



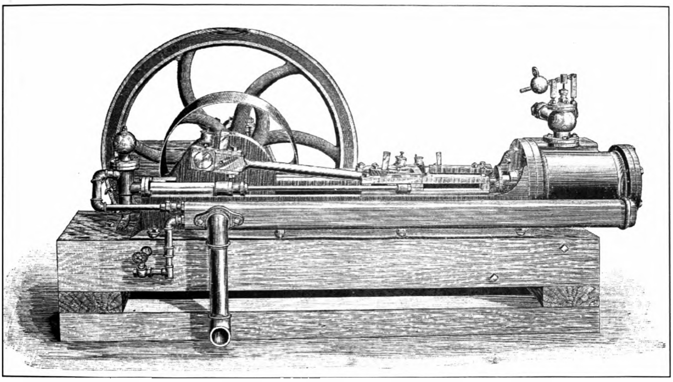
*An early etching of a well drilling operation. Note the manila rope, the tension device, as well as the primitive lighting arrangement. Drilling was continued around the clock.*



Drilling boiler used in the oil fields.




Locomotive type boiler used in the Canadian oil fields.



*A drilling engine sold through Oil Well Supply in Petrolia, Ontario, Canada.*

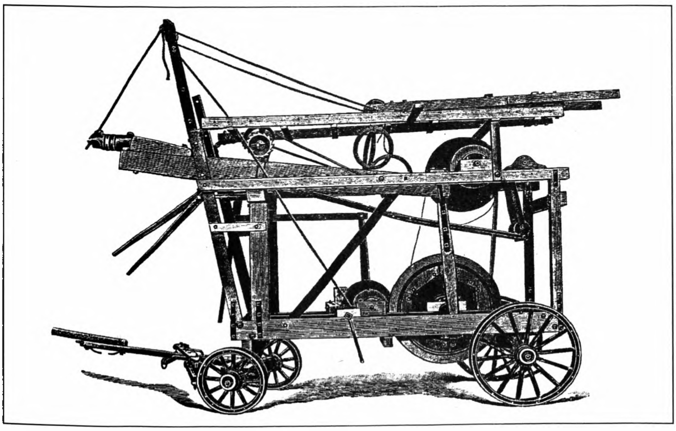
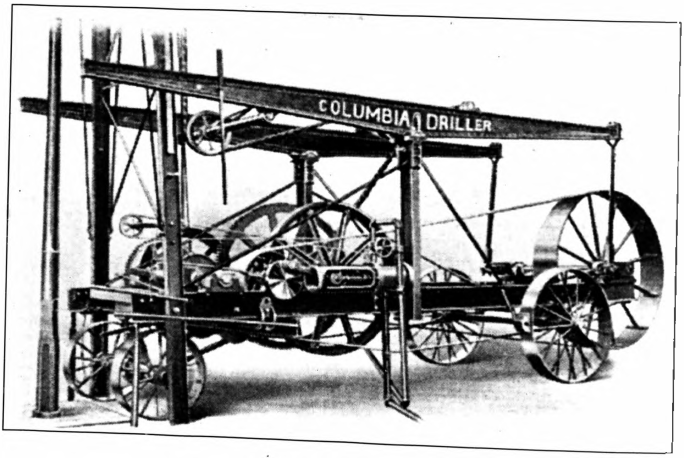
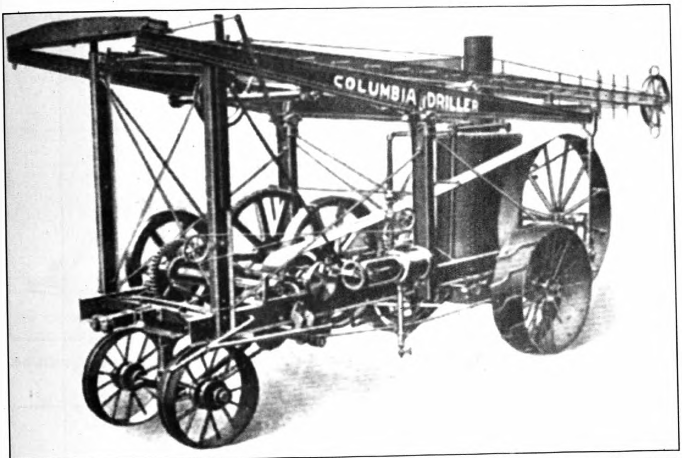
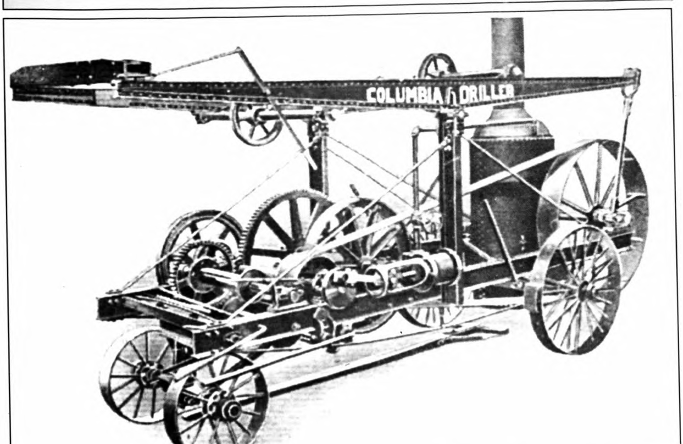


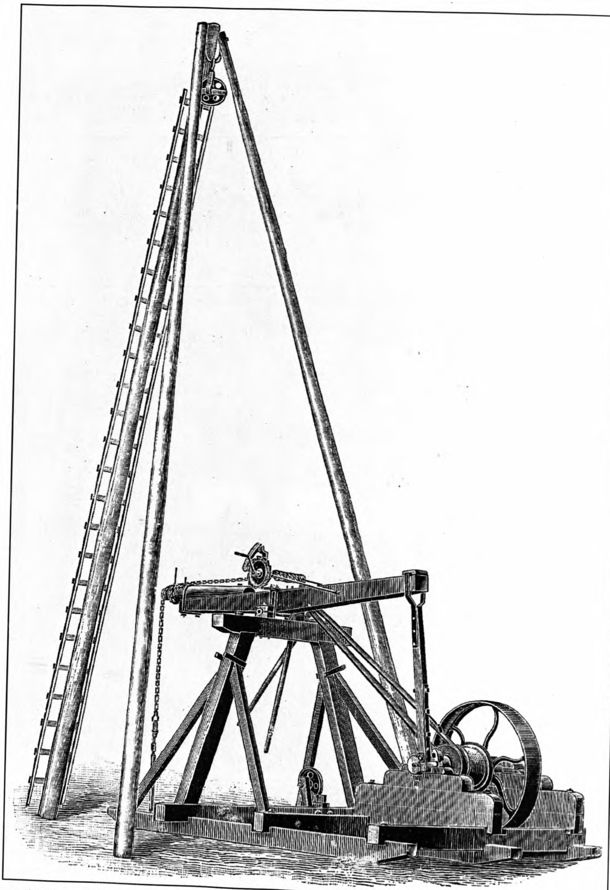
*Illustration of an early well drilling machine.*

A series of portable drilling rigs produced by the Columbia Company.

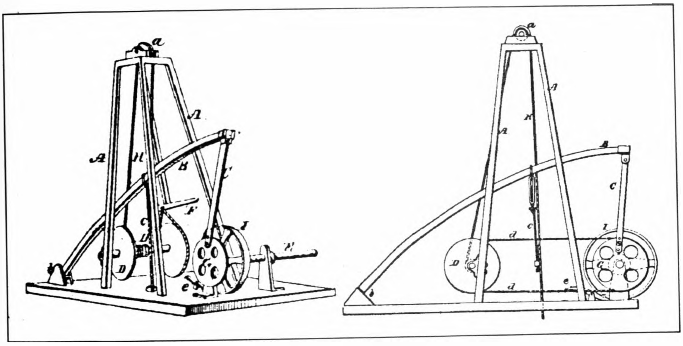



COLUMBIA DRILLER

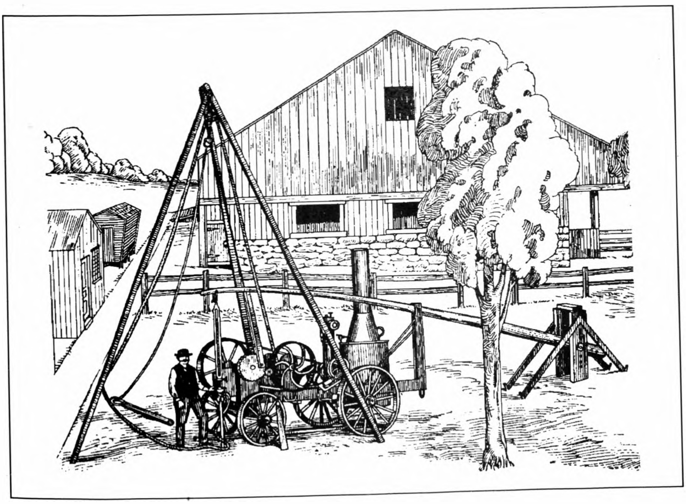

COLUMBIA DRILLER



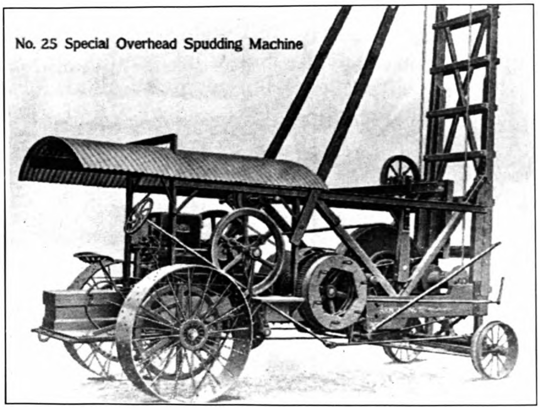
A drilling rig for wells up to 300 feet deep.



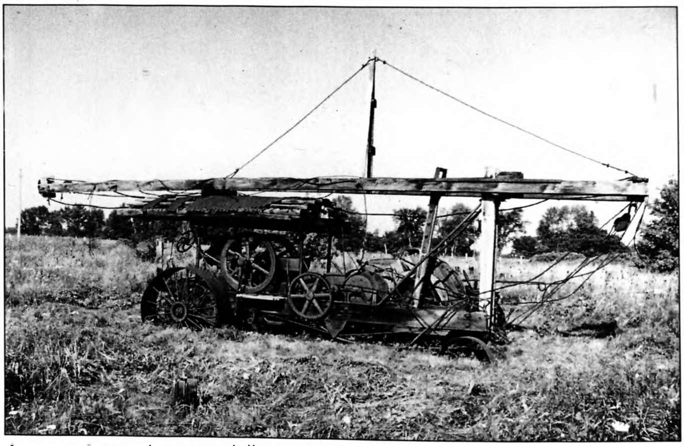
An attempt to make the spring pole drill system portable.



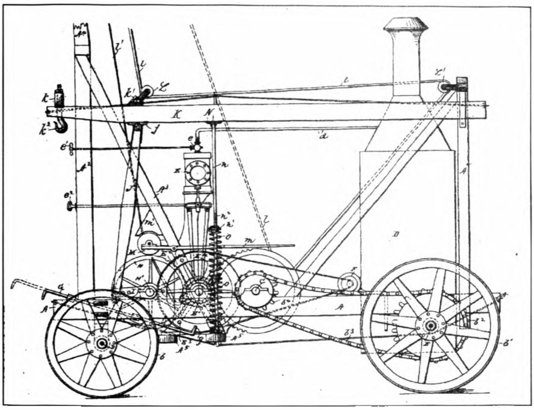
A well-known Downie portable drilling machine, 1878.



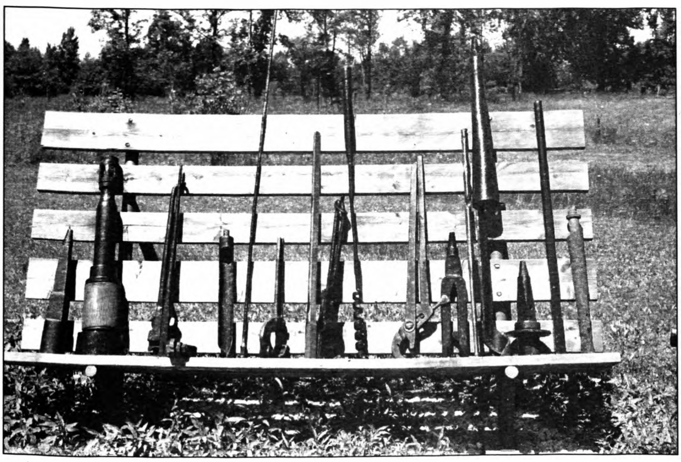

*An Armstrong portable rig, circa 1917.*



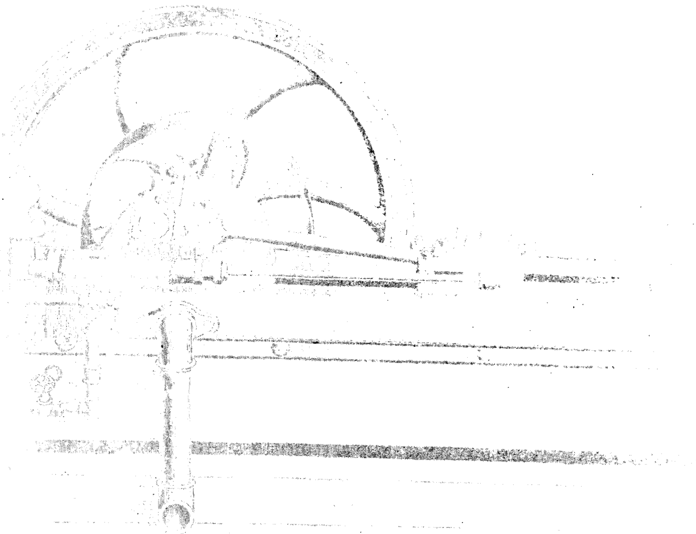
*A rare survivor, an Armstrong drilling rig on the Morningstar Property, Oil Springs, Ontario.*



*A Glenn portable drilling rig patented in 1892.*



*A display of drilling tools at The Petrolia Discovery, Ontario.*



CHAPTER 3

# Pumping Oil

## Raising Water

The need to raise water is associated with the earliest civilizations and continues to this day. The swape or shaduf arose in the Middle East before 1500 B.C. for raising water using the principle of the lever. The lever arm is weighted at the short end so that a water container can be raised with little effort. As noted earlier, this method was used by the Ruffners and presumably others in the Kanawha Valley at the beginning of the 19th century. Using the swape with a modified whiskey barrel, the gum employed by the Ruffners was excavated to bed rock before drilling commenced.

Another device was a chain or wheel of pots called a saqiya. The use of rags instead of pots represents a variant of this device. Also, while not a predecessor of the oil well pump, it is well to note the use of the Archimedean screw in ancient times.

One of the pumps for forcing water from the bottom of a well is credited to Philo of Byzantium. A century ago, in 1895, a Roman plunger pump was unearthed at Silchester in England. This ancient device represents one of the earliest pumps for raising water. With knowledge of piston-forced pumps for raising water or brine and by adapting the balance beam and rod system from drilling technology, a mechanical pumping system was at hand for use in the oil fields.

Rather than using a piston and cylinder, a very compact pumping device was developed in the Canadian oil field (and elsewhere) consisting of a brass barrel with ball valves top and bottom, such that during the downstroke, the ball valve at the bottom opens and admits oil into the barrel. Raising the barrel closes the bottom valve, and opens the top valve. Thus, a quantity of oil is raised up the casing with every stroke. By this action, oil can be raised from a great depth in a series of strokes of the balance or walking beam.

For very productive wells it was economic to install a power source at the well, which necessitated an operator and possibly an assistant. Before the advent of commercially available electric motors at each well head in the 20th century, the only feasible means was to install a steam engine at each well. Even with high quality lubricating oil, profits could not be made on low producing wells. These so called "stripper" wells required a unified system in which a central power source drove a series of wells. The development of centralized power equipment provided both inventors and manufactures an attractive opportunity for profit by patenting numerous central power systems. In a sense, the method adopted became associated with each of the producing areas namely; western West Virginia, western Pennsylvania, and southwestern Ontario. Since these remote pumping systems bear little relationship to each other, the three regions can be dealt with separately using a geographic approach. Since we started with salt in the Kanawha Valley, it seems appropriate to focus on the endless wire system installed in western West Virginia and centered around Volcano and Burning Springs some 35 miles east of Parkersburg, W.Va. Here, William Styles succeeded in introducing the endless wire system used in manufacturing locations to the task of pumping oil rather than powering factory machinery.

## The Endless Wire System

In factories, machine shops, textile mills, and elsewhere, the power needed to drive machines from a central source was transmitted throughout a building or factory by a series of iron line shafts and pulleys running overhead and linked to each machine with a belt and clutch. Power transmission by endless iron wire rope provided an alternative to line shafting, with less friction to overcome, and reasonable cost of installation. Nevertheless, the overhead shaft and belting system was associated with machine shops in the oil fields, notably the Baines Machine Shop in Petrolia, Ontario.

Colmar, in Germany, in 1850, witnessed the first installment of an endless wire rope power transmitting system. The inventor, the Hirn brothers, tried a riveted iron ribbon running over drums. The ribbon was about 2.5 inches wide and .04 inches thick. The idea was sound and worked well in providing power to a series of scattered buildings. The same principle was later tried in the United States for inclined planes. In each case, the riveted joints suffered excessive wear. The iron band also vibrated excessively under certain wind conditions. Wire rope offered a practical and economic replacement for the iron band. With four applications in 1859, by 1862 there were 400 sites using the method. As far away as St. Petersburg, Russia saw the installation of such a system at a military powder mill with numerous buildings scattered around the site as a safety measure—if anyone building blew up, the others would be unscathed.

An impressive application occurred at the famous falls of the Rhine at Schauffhausen. The area adjacent to the falls was too rocky and precipitous to locate a factory near the source of water power. The answer was to install a wire rope transmission system sending power from the falls, more than a half-mile distance, to a more suitable factory location. A very similar installation at a woolen mill in Italy is contemporaneous with the Colman factory and is extant.

In the case of the Schauffhausen wire rope installation, the two .75-inch-diameter wire rope transmitted 700 horsepower from the turbines at the falls, across the river some 370 feet, there driving two intermediate wheels before continuing up the bank of the Rhine and thence cross-country 1,500 feet in three spans supported by intermediate pairs of transfer wheels. From the first station, the system was extended a further 1,500 feet, transmitting an additional 400 horsepower. Thus, the total length of this wire rope system was 3,370 feet.

Another installation at the Bellegarde, France captured a portion of the power of the Valserin torrent some 15 miles from Geneva, Switzerland. The estimated total horsepower of the falls was estimated at 12,000 horsepower, but only a quarter of this was gained in the use of six 630 horsepower Jonval turbines in this installation. By using transmission wheels 18 feet in diameter, turning at 70 r.p.m.s, a line velocity of 3,920 feet per minute was obtained with a pair of 1⅓ inch diameter ropes.

These installations, together with dozens more examples, were an impressive demonstration of this new technology. It is little wonder that the Roebling Company of Trenton, New Jersey entered the business in America since they were the leading producers of wire rope in North America. From the aspect of technological advances, the publication of Washington Roebling's bulletin on transmitting power stands as a landmark in the advancement of the technology. First published in 1869, the second edition (dated 1870) is a short twenty-five pages but Roebling sets out the engineering principles for the design and operation of such a system even to the details of splicing the wire rope.

In his 1890 edition of Transmission of Power by Wire Ropes, Stahl discussed the opportunities for the transmission of power by various means such as steam engines and boilers, hydraulic engines, water-wheels, turbines and in using air, gas and oil engines, and importantly, electric motors and wires. In defense of wire rope transmission he states:

> For many years, rapidly moving wire ropes were undoubtedly the most efficient means of conveying power to great distances; but the rapid strides which have been made in the development of electrical transmission have limited the field of the useful application of wire ropes. There are, however, certain limits between which the transmission of power by wire ropes is yet more efficient than by any other methods; and these limits we will attempt to define.

## William Stiles and Endless Wire Oil Pumping at Volcano, West Virginia

In the same year, 1859, as the celebrated Drake's well began operation, Charles Shattuck prospected for oil on the banks of the Hughes River in West Virginia near a well-known site called Burning Springs. The two wells were dry, thus he missed the opportunity to rival Drake's well as the beginning of the oil industry in the United States.

Earlier in the Kanawha Valley salt industry, the discovery of oil in a salt well was considered a misfortune. Any oil brought to the surface was wasted in the river. The quantities involved in dumping oil into the river were such that it was called "Old Greasy." By mid-century, the situation had changed completely with oil and not brine as the sought after commodity. In an age before gasoline engines, the demand centered around illuminates. Eschewing the use of whale oil, because of its expense and diminishing supplies, the public turned increasingly to coal oil extracted from bituminous coal.

This increasing demand was met by the invention of a Canadian-born Abraham Gesner who, in 1846, demonstrated his new illuminate (which he dubbed kerosene) derived from bituminous coal in the Maritime Provinces. June 1854 marked the date of the U. S. patent for refining crude oil, distilled this time from asphalt or other bituminous substances. Before the advent of crude oil production, Gesner, together with British investors, intended to use Trinidad Lake asphalt to produce kerosene, but this was thwarted by the Canadian courts in 1852 because of a law on Crown Rights for coal mining which was interpreted as meaning any bituminous products. Thus, importing a bituminous material was considered to be illegal. As a result, Gesner moved his family to New York City in 1853 and formed the Asphalt Mining and Kerosene Gas Company (later the North American Kerosene Gas Light Company). Despite competing claims and intense competition in America and Britain, the means of producing kerosene oil started a rush to develop oil resources. In many ways, it developed into a "black gold" rush of similar intensity to the famous 1849 gold rush in California.

Returning to Shattuck and his activity at Burning Springs, his persistence paid off, for in the spring of 1860, together with two Pittsburgh friends and a brother of one, Samuel P. Karnes, he leased land from J. V. Rathbone which had on it an old salt well and he began to produce oil.

J. V. Rathbone, a local salt boiler and sometime farmer, drilled a well 303 feet deep which produced 100 barrels per day. Within three years, the Burning Springs field was producing enough oil to compete with the western Pennsylvania field centered around Titusville, which came online in 1859. In West Virginia this flourishing new industry suffered during the Civil War, and particularly at the hands of Confederate General W.E. Jones. During his celebrated raid, the entire oil field was torched. The conflagration was such that smoke could be seen 35 miles away in Parkersburg on the Ohio River.

With Rathbone being the leading figure at the Burning Springs field, a new field was opened up following the Civil War by Johnson Camden at Volcano, a short distance north of Burning Springs. To finance his purchase, a tract of 4,300 acres, Camden sold off shares. One such group from Philadelphia was William C. Stiles, Jr. whom with his partners founded the Volcanic Oil and Coal Company.

Stiles, along with at least one of his stockholders, had interests in Pennsylvania oil companies and experience in manufacturing in the Philadelphia area. Indeed, as executive director of the company, Stiles had toured the Pennsylvania oil fields in 1863. With falling prices following the Civil War and saddled with numerous low producing wells, some means of reducing the cost of pumping had to be devised or the company would be plunged into debt. Archival research has failed to confirm a direct connection between the endless wire system, apparently put online as early as 1871, and the promotion of endless wire power transmission with the first edition of Roebling's bulletin in 1869. Since neither Stiles nor the company he represented applied for a patent, no official correspondence exists on the Volcano endless wire system. While the overall concept of the endless wire power transmission was clearly already well established in Europe and by Roebling in America, many of the details of the Stiles invention were unique and it is believed to have been patentable.

Although not stated historically or patented, there were certain goals achieved with the Stiles system. It had to be flexible so that individual wells could be pumped or not, at the decision of the operator. As promoted by the endless wire suppliers, a system was needed with a minimum friction, and finally a system which could use, whenever possible, low-cost local materials. The Stiles endless wire system achieved all of these objectives. At first glance it seems like a rather crude, unsophisticated system with few refinements and no embellishments, which one could compare with steam engine technology at the time. A closer look at the system in operation revealed an ingenious series of designs which served in obscurity for more than a century.

The essence of the system is, of course, the endless wire rope drive coupled with the design of the pumping system at each well. From a central power house the single wire rope passed an "angle wheel" and engaged a drive wheel, and thence to a second angle wheel. Thus, with the angle wheels, the direction of the wire rope drive could be changed as the rope sped along its way from well to well. The European promoters indicated that a loop of three miles could be employed efficiently, if necessary. At Volcano, more than thirty wells were pumped from a central source over a considerable distance, but far short of the proclaimed three-mile limit. At such an extreme length, friction forces at each support reduced the efficiency to unacceptable limits. In the case of the endless wire system for pumping oil, frictional losses were kept to a minimum at each well head.

While the angle wheels were in essence idler wheels five feet in diameter, the main drive wheel had an 8-foot diameter. All of the wheels were constructed of oak or other hard woods, set on a radius like the spokes of a wheel, all held together with side panels on each side to hold the spokes in place and constrain the wire rope onto the periphery of the wheels. The wire rope thus ran on end grain of the spokes reducing the amount of wear. In the Roebling and other European applications, iron wheels were used so that the problem of slippage on the drive wheel had to be overcome by placing wood or rubber-like materials to grip the wire. In the case of the Volcano system with the rope running on end grain of hardwood spokes, slipping was of little concern to the operators.

To relieve friction, the wheels were mounted on wrought iron shafts with cast iron bearing plates on each side of the wooden wheels and bolted to the spokes. In documenting the site, it was noted that these plates were identified with a Volcano casting mark indicating that they were made locally together with the woodwork.

On the 8-foot-diameter drive wheel's shaft, the crank was mounted that connected to a walking beam driving a pump rod up and down at the well head. The "pitman" fitted rather loosely on the crank handle and could be engaged or disengaged by pulling the pitman sideways off the crank, or slipping the pitman on the crank while the wire rope was running. With a long reach of rope, the length of the rope changed with temperature. By making the angle wheel shaft adjustable, the rope could be tuned to the weather. The wheels and fittings, etc., were fabricated in the company machine and woodworking shop where wheels were also repaired as needed. This shop had an array of patterns and machines for the efficient production of components of the system. Thus, all aspects of the operation and maintenance of the system could be handled on site.

A detailed archaeological study of the power house failed to reveal any evidence of a steam engine that originated with the system, ca. 1871, which undoubtedly provided the system with power. The extant power at the time of the recording (1971) was supplied by a natural gas engine. This type of engine was widely employed in oil fields in Appalachia by the end of the century since natural gas was readily available in these oil fields. As a predecessor to the diesel engine, these engines ran with a "glow plug" similar to model aircraft engines. The plug, which looked like a tube of copper screen wire, was heated to a glowing red heat and inserted into the cylinder in place of the spark plug. The engine was then started by a man walking on the flywheel spokes. These temperamental creatures often backfired throwing the operator in the air.

During its years of operation, the interior of the power house, when the giant band wheels were running, was an awesome sight. A belt drive from the engine, which was fitted with a clutch and band wheel, was run to a counter shaft and wheel. Rather than just one endless wire loop there were two at Volcano. The larger band wheel was 17 feet in diameter while the smaller measured 12 feet. Borrowing an idea from overhead shaft drives for powering lathes or other machine tools, the endless speed would be regulated by the counter shaft wheels and the transmission wheels so that the r.p.m.s could be changed on the endless wire. The counter shaft wheel measured 4 feet 2 inches for the large transmission wheel, while the other counter wheel, which is belt driven by the 12-foot diameter wheel, had a band wheel of 3 feet 5 inches. Thus, the two loops operated at different speeds. While the power delivered to the first loop was 22 percent greater than the smaller one, it operated at a slower speed. Thus, the rate of pumping at the wells differed from loop to loop. No informant remains to explain why the differences were built in the system originally. A greater influx of water, however, in the second system necessitated removing more fluid to obtain the same quantity of oil with the surplus water being sent to waste.

The Volcano field using the endless wire method developed by William Stiles remained in production for a century. While the production of each well remained low, about a barrel per day per well or even less, the oil was of high quality suitable for lubrication purposes. The demand was steady with reasonable prices paid to the operators. The Stiles system was ideally suited for the situation, with low operating costs thanks to the central power driving a very low friction endless wire system. In a sense, it was rather like subsistence farming. In fact, the oil produced was collected on a regular basis like a milk company collecting milk churns from various farmers. Despite all of its advantages, the endless wire system was never popular in other oil fields. In fact, without additional information to the contrary, the endless wire system at Volcano remains as a unique aspect of 19th century mechanical engineering.

Moving from the Volcano oil field in western West Virginia to the great oil region in western Pennsylvania, where one encounters another system for the serial pumping of low-producing wells. The essence of the system focused upon the development and widespread use of the eccentric "power." These eccentrics were manufactured by various firms in the region and sold by catalogues. The commercial approach stands in marked contrast to both the endless wire system and the Canadian jerker-line which can be described as "home made" products.

## Oil Production in Western Pennsylvania

For purposes of analysis, the history of oil production in Pennsylvania can be divided into five 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 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[1].

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. 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.[2] 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[3]. The southwestern field includes Beaver, Lawrence, Allegheny, Washington, and Greene Counties[4].

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[5] 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 Bissell, a New York lawyer, who became interested in its commercial possibilities. Bissell found a partner, Jonathan G. Eveleth, and immediately bought the 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 investigate further the oil's properties. Silliman's April, 1855, report confirmed the petroleum's high quality, described the distillation process required to produce illuminating oil[6]

—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 Bissell and Townsend appointing Drake as a general agent for the company. By March 1858, Bissell and Eveleth's company had evolved into the Seneca Oil Company of Connecticut. [7]

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 feet below. Once to bedrock they began to drill, averaging about three feet a day. On Saturday, August 28, 1859, Drake and his crew had managed to drill to 69 feet ½ inches, 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.[8] 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 one-eighth of any profits generated by oil production on the property.

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, 17 in 1861, 20 in 1862, and 29 more in 1863.[9] Thus, of the 117 drilled to this time 77 struck oil and 41 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 pseudoscientific 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.[10] It and subsequent wells in the area were spectacular, flowing more than 1000 barrels 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 producing 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[11] 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 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.[12] Still, this price drop did not slow the quest for oil in northwestern Pennsylvania, or the rest of the country. Much oil and gas were 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.[13]

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. 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 from the initial Oil Creek boom, followed in quick succession by Pithole Creek (a tributary emptying into the Allegheny River some six 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.[14] 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 Well also known as the Frazier 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.[15]

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 Hickory Creek and Dennis Run, and the town of Petroleum Center arose along middle Oil Creek near the mouth of Benninghoff Run. But only the most productive wells remained in operation as the depression continued through 1867.[16] 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.[17] 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.[18] 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.[19]

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 developing 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 Standard Oil Company of Ohio and began consolidating control over numerous lessor companies.[20] 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.[21] 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 reached their maximum output.[22] Between 1888 and 1898, Pennsylvania's production remained at all-time highs—then came the inevitable slow decline.

In the middle field discoveries around Warren, Clarendon, Sheffield, and Kane 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.[23]

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 nine million barrels in 1891. In the southwestern district, beginning in the late 1880s, large-production wells were struck in Allegheny and northern Washington counties.[24] 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 water 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 20th century.

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 the 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 20th century progressed. Regardless, Pennsylvania's output dropped from 13 million barrels in 1900, to less than eight 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 20th century, supplying crude oil for refilling 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. In the early 1900's 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.[25]

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 required an extra-high-quality lubricant, and again Pennsylvania grade crude was the ideal source.[26] 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.[27]

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 southern Pennsylvania were more receptive to air or gas repressurization.[28] 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.[29] Even the oldest fields around Titusville saw renewed production levels, and the slow decline in production was reversed. From eight 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.[30] 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.[31] 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 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 one 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 embargoes of the 1970s, increased demand in the 1980s, and the Persian Gulf War in the early 1990s steadily pushed oil prices to unprecedented highs.[32] 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 20th century. It also led to the interesting case of a technological development, the central power process of multiple oil-well pumping, being used into the late 20th century.

## Oil Well Pumping and Central Power Systems[33]

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

To pump a well, first a string of metal tubing, two to three 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 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 Sampson post supporting the walking beam. This was a standard pumping outfit for single wells, and widely used in oil fields through the early 20th century.[34]

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,[35] 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 Sampson 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.[36] 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-inch 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 paraffin in the tubes, a broken sucker rod, or other problems could require 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.

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, the machinery was required to pump a well for only a short period a few times a week.[37] 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 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 13 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 inches) to the wells nearly a half mile away.

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 Yate's-style push-pull powers, which remained popular up into the early twentieth century.

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 pump operator 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 40 shallow wells could theoretically be pumped by a well-balanced, high-powered system, 15 to 20 was a more common number.[38] 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 of

West Virginia and Ontario as well as Pennsylvania. 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 horizontal, single-cylinder steam engine/boiler combinations used for drilling.[39] 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.[40] 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.[41] 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 wherever a reliable gas supply was available. These horizontal, semi-portable, single-cylinder engines became the mainstay of drillers and pumpers.[42] They ranged in size from 10 to 60 horsepower, with 20 to 35 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 crank initially 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.[43] 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

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.[44] 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, ca. 1875 in this country, but long before in Germany. Initially, these systems 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 20th 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.[45] 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, Pennsylvania, when he began designing his "Device for converting Motion in Oil Pumping Apparatus," otherwise known simply as a power.[46] 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-inch 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 balance properly the loads on the machine, two eccentrics were generally placed 180 degrees apart, and three eccentrics 120 degrees apart.[47] 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.

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 pumping wells on the beam, bandwheel powers were wooden wheels 12 to 20 feet 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.[48] 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.[49] 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.[50] These were usually preferred because they were lighter, operated more smoothly, gave less wear on the belting, and were more rigid. Also, they were prefabricated, making for easier transport and construct 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.[51] 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, 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 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 two inches in diameter and 16 to 22 feet long, with forged wrought-iron couplings riveted to the ends.[52] They broke easily however, and required frequent repairs and adjustments. Steel lines were round, one inch or less in diameter, and 20 to 30 feet 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 feet, either on poles, tripods, or tree limbs) which swung like a pendulum when the lines reciprocated.[53] Or, shackle lines could be supported by "friction posts," which were usually short lengths of reused two-inch 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).[54] 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 power. At the take-off post, the initial 10-foot-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. This discussion is also applicable, in part, to the Canadian jerker line system.

## Air Powers

At about the same time, the end of the 19th century, compressed air offered a safe method of supplying power to mining machinery to replace time-honored pick and black power methods of mining coal in underground mines. Because of inherent frictional losses associated with great lengths of air line, this method became obsolete rather quickly in both mines and in the oil fields.

"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.[55] 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, but with increasing frictional losses.

## Pump Jacks

The original means of pumping a well was to use a walking beam pivoted in the middle with a Pitman at one end, which raised and lowered the pump in the well. Walking beams predominated in both the Volcano/Burning Springs field and the Oil Springs/Petrolia oil field in Canada. On the other hand, a number of proprietary metal devices called "pump jacks" replaced the walking beam method of pumping wells throughout Pennsylvania and elsewhere as new fields were opened farther south and west in the United States. Many of these devices are featured in oil well catalogues.

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"[56] and "indirect lift"[57] Manufacturers offered different types of jacks built either of wood, cast parts, structural steel I-beams, tubular steel, or a combination thereof. 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. 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 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. [58]

## 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 19th 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 1900s. 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 utilitarian 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 inches 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.[59] 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 power-*house 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 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.

## The Canadian Experience

Leaving Drake's Well, 1859, and the subsequent development of eccentric powers for pumping a series of wells in Pennsylvania, attention now shifts to Lambton County in southwestern Ontario, Canada. Although less well-known than Edwin Drake's Well in western Pennsylvania, the exploitation of oil reserves at Oil Springs and Petrolia has international significance in the very earliest phases of the modern oil industry.

A common thread throughout worldwide history of oil focuses on the discovery of petroleum seeping out of the ground. Lambton County was no exception to this pattern. Oil migrating to the surface combined with clay to produce a "gum" in the swamps located in the middle of the county. Native Indians were familiar and, in part, used the bituminous material for medicinal purposes and as a waterproofing agent.

The possibility of producing asphalt from the gum beds attracted Charles Nelson Tripp from upstate New York, ca. 1849-50. By 1852, he had begun manufacturing asphalt under the banner of International Mining and Manufacturing Company. It was this company which sent a sample to the Paris Exhibition in 1855 and received an award. The result of this commendation, an order for asphalt to pave streets in Paris, was forthcoming. With inadequate transport available the order could not be filled.

As indicated above, elsewhere there was the period of intense interest in the production of illuminates, first from coal and then crude oil. Spurred on by Gesner's patent for the production of what he called kerosene, increased interest developed in the gum beds of Lambton County. As a result, asphalt production became less important than the discovery of oil and the production of kerosene. The new emphasis on oil resulted from the arrival of James Miller Williams from Hamilton, Ontario. With a shared interest in Tripp's land, the pair attempted to locate oil at Bothwell in neighboring Kent County. The effort failed so they returned to Oil Springs where in the summer of 1858, they dug a 14-foot-deep well which produced oil in marketable quantities. Even before Drake's Well in Pennsylvania, Williams was producing, refining, and shipping oil products. Fortunately, the Great Western Railway completed a line to Sarnia passing through Wyoming (Canada) north of Petrolia. After a five-mile journey on rough roads, the oil was delivered to the rail siding in Wyoming for shipment to Hamilton. Later, refineries were built in Petrolia and oil was shipped to Sarnia to be transported on the Great

Lakes. By 1866, a spur line was completed to Petrolia from Wyoming.

Drake's Well came on line in August 1859 followed that autumn by a 146-foot-deep producing well owned by Williams at Oil Springs. This well produced 60 barrels per day. By 1861, the small Oil Springs pool witnessed 400 wells producing oil. At least 32 wells were drilled into the bedrock. An American wildcatter, Hugh Nixon Shaw, drilling on what is now Fairbank Oil Company Properties, brought in the first gusher in Canada, which before it was controlled dumped large quantities of oil thus polluting Black Creek, and thence, the Sydenham River, which in turn discharged its black matter into the Lake St. Clair dividing Canada and the United States. By the end of 1862, there were 1,000 wells producing 12,000 barrels of oil per day. The great oil boom was not to last. Production reached an apex in 1862, and declined rapidly when many wells ceased flowing and thereafter required pumping. In an effort to facilitate the movement of oil, Williams had built a plank road to Wyoming from Oil Springs in 1863, and two years later, in 1865, a plank road all the way to Sarnia, some 25 miles distant.

Attracted to the possibility of "striking it rich," Captain B. King from St. Catharines, Ontario, began a 40-year oil boom in Petrolia when his oil well turned into a gusher and produced 265 barrels per day in 1866. The pool proved to be much larger than that at Oil Springs, continuing to produce to this day. The spur railway line, completed in 1866, insured the growth of Petrolia as a town. Many refineries were built during this period in Petrolia. Their refined products could be readily transported by rail and later pipeline. Thus, by 1866 both oil fields were supplying oil to local refineries, and the means of transporting both crude and refined oil products by means of plank roads, and more significantly, by railway.

The low production of individual wells proved a serious problem for oil men who could hardly afford to place a steam engine at each well complete with an operator. The answer came from yet another entrepreneur, J.H. Fairbank who arrived in Oil Springs in 1861 as a land surveyor. Low producing wells, called stripper wells, were also a feature of the Appalachian fields requiring new solutions to make pumping oil profitable. In the case of Volcano, the solution was the endless wire system of the 1870s, whereas by the end of the 19th century both eccentric powers and band wheel eccentrics were employed in western Pennsylvania. Before either of these methods of serial pumping of oil, J.H. Fairbank devised the jerker-line system in 1863, which could work a series of wells from a single power source. At first the power was steam, but conversion to electricity was made in the 20th century. With a dearth of natural gas in these fields, natural gas engines were not employed.

The essence of the system was a pair of parallel rods driven from a gear train and an eccentric, which imparted a reciprocating back-and-forth motion. Like the earlier "telegraph" system, the jerker rods were supported by small diameter, say one-half-inch, round wrought-iron (and later steel) pendulum rods suspended from a light overhead framework. The pendulum arrangement resulted in a nearly frictionless support system requiring a small-horsepower engine (or later, an electric motor) to drive the system. Many of the wells produced less than a barrel of oil per day.

Horizontal oscillating cast-iron wheels, variously described as field wheels or spiders, enabled the jerker lines to change direction. Single lines were run off the main pair of jerker rods to operate a walking beam pumping system at a single well. If necessary, single lines could effect a change of direction with horizontal triangular frames. Optimally, jerker-lines were balanced by matching each well with one in the opposite direct so that sucker rods in one well were raised (the upstroke), while those in the opposite well (on the downstroke) were lowering under the weight of the rods, and helping to raise the rods in the opposite well (on the downstroke). This helped minimize the load on the engine. This system is still being used commercially in Lambton County, and especially on the Fairbank field.

J.H. Fairbank never applied for a patent, thinking his invention didn't qualify for patent protection. Perhaps he was aware of jerker-line power systems used in the salt industry in central Europe. While Fairbank chose not to apply for a patent, in 1879, Edward Yates of Philadelphia was issued a U.S. patent for a system similar to the Canadian system. It was called the Yate's "push-pull" power, and substituted iron rods for wooden jerker-lines of the Fairbank system. The Yate's system was called a "rod line" and old sucker rods were often recycled.

Rod systems for transmitting power have an ancient origin. Agricola illustrated such a system for mine drainage in the 16th century. Before the age of steam power, water and wind power drove pumps to clear mine workings. Multhauf illustrates a

"Stangenkunst" consisting of a water wheel, field rods connecting the eccentrics on the water wheel with a Kunstkreuz, which converted horizontal to vertical motion. This was a rocking cross-shape device clearly illustrated in a number of ancient publications. Although difficult to date accurately, this system was in use as early as 1550. Also in the 16th century, Stangenkunst ("Stanggang" in Swedish) was introduced into Sweden at about the same time. At Pershyttan, such a system is preserved in working order. At one time the remote power system for widespread application in the Bergslangen area of Sweden.

Moving in both time and place to 18th-century Germany, one can see a water-powered twin jerker-line system in the Salt Museum at Kosen. It is nearly a sole survivor of this type of water-powered pumping unit featuring not only jerker-lines but vertical star-shaped timber Kunstkreuz. Like a wheel the star shaped kunstkreuz converts horizontal motion into vertical movement for pumping. Also displayed are pump jacks, which were a later introduction closely resembling those used in the Pennsylvania field in the 19th and 20th centuries.

The Kosen Kunstgestange serves as an example of the use of this method in the salt producing regions of middle Europe. After 18 years working at Sulza, Germany, Jacob Abraham Christner moved to nearby Bad Kosen to construct a salt works. He also engaged in a similar adventure in Dresden for the Elector of Saxony, but had little success. Not deterred, he developed the Kosener Society to try again to establish a salt works at Kosen. A treaty was signed with the Elector in 1714 to construct a salt works at Kosen and at Poserna to supply the Elector with salt and saltpeter for making gun powder. The terms of the treaty were generous for the Society, but they failed to produce salt and its members fled Saxony in 1717 to avoid the wrath of the Elector.

Later, a miner reminded a new Elector (who also ruled Poland as King August II) of the possibilities presented by the Kosen salt works. In the same year, the Elector ordered the shafts in the earlier salt works to be dewatered. Johann Gottfried Borlach under took this work and was successful where others had failed. On July 1, 1730, at a depth of 147 meters, brine was discovered of sufficient strength, four percent, to make the operation viable. By ca. 1734, the Kunstgestange was in operation. A century later, in 1818, the rod-line pumping system was restored to its original condition. It is this restoration that visitors can see today at Bad Kosen.

## Canadian Oil Production History.

Because the Canadian field at Oil Springs was developed at the birth of the oil industry, production records do not exist before 1917. So much oil flowed into the creeks during the initial drilling and there were so many producers and refiners with no regulation or inspection that the cumulative production is difficult to estimate. R.B. Harkness (1928), after much detailed research, estimated the cumulative production at the end of 1916 at seven million barrels (1.1 million $m^3$). At the end of 1996, the cumulative oil production was 1.56 million $m^3$ (9.81 million bbls). In 1996, there were about 450 operating wells in the field and the total annual oil production was 5,647$m^3$ (35,515 bbls).

Between 1917 and 1954, there was a slow decline in the annual production and a reduction in the number of active wells from 1,228 to 623. The annual oil production per well was gradually increasing as the poorer wells were suspended.

In 1954, Mr. N.E. de Mers and his brother Victor introduced to Oil Springs the concept of waterflooding, or repressurization, and segments of the field were flooded. The result was an increase in annual production by a factor of 2.8 between the years 1954 and 1965. The water started to break through into the producing wells in 1970 and, after that event, the waterfloods were mostly suspended.

The Oil Springs field was revived when the oil prices started to rise in 1973. The increase in annual oil production correlated exactly with the crude oil price. Indeed, at the Oil Springs and other stripper fields all over the world, the current level of activity depends on the price of crude oil.

It is interesting to note that the increase in oil production at Oil Springs preceded the increase in the number of active wells in 1980. In that year, the Government of Canada instituted a two-tiered pricing regime, and newly activated wells received the higher price. So although the annual oil production for the field did not change, those operators with the new wells did derive a short-term benefit from the price structure. In 1986, the price fell drastically and the annual production started to decline once more. Since 1992, the annual oil production from the field has stabilized at 5,500$m^3$ (34,600 bbls)/year, the same level as it was in the year 1928.

## Oil Springs Still Producing Oil

Unlike certain West Virginia and Pennsylvania fields which have ceased production, the Oil Springs pool is still producing oil in commercial quantities. Indeed, with more than 450 wells in operation, current production levels equal and in some years exceed the production in 1920. The production system at Oil Springs utilizes the Fairbank's jerker-line of 1863 for the majority of the wells.

In addition to the historic artifacts at the Oil Museum of Canada in Oil Springs there is the working field at The Petrolia Discovery, and numerous historic sites at Petrolia. The Little Red Bank was the world's first oil exchange. Baines Machine Shop, complete with early machine tools, still produces all of the "bits and pieces' necessary to keep oil flowing. At Petrolia Discovery, a visitor can witness the great Fitzgerald Rig operating not under steam, but by an electric motor driving an oil producing jerker-line. The Petrolia Discovery also features early oil pipe line pumping equipment. Alas, the extensive number of refineries, once the center of oil refining, has left little trace of their industry not only at Petrolia, but also at London and Sarnia.

### *Chapter 3 - Endnotes*

1. John Harper and Cheryl Cozart, *Oil and Gas Developments in Pennsylvania in 1990 with Ten Year Review and Forecast* (Harrisburg: Pennsylvania Geological Survey, 1992), p. 4.
2. 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.
3. Among this region's major pools are: Tidioute, Titusville, Oil Creek, Tarkill, Bullion, Fagundus, Pithole, Cashup, Sugar Creek, Reno, Brady's Bend, Baldridge, Butler 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.
4. The southwestern field is made up of four smaller Districts. The Beaver County district includes Beaver and Lawrence Counties, in which the Smith's 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.

5. This was a lumber company active along oil creek. It was lighting its mill with oil lamps by 1850.

6. Silliman also noted the lubricating qualities of the oil.

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

   Jonathan G. Eveleth
   George H. Bissell, practicing lawyer in New York City, formed a company for refining and marketing oil. Eveleth served as a law partner with Bissell and was involved with the formation of the oil company which later hired Col. Drake. Brantly, J.E., History of Oil Well Drilling, (Houston, Texas, Gulf Publ. Co. 1971) 157.

   James Townsend
   A new Haven banker, acquired the Pennsylvania Rock Oil Company which was moribund and proceeded to establish the Seneca Oil Company. Subsequently, Townsend hired Edwin Drake to drill the famous Drake Well. Gray, Earle, The Great Canadian Oil Patch, 2nd ed. (Edmonton, Al, June Warren Publ. Ltd. 2004) 46.

8. This was in the Titusville pool.

9. 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.

10. Rouseville was awash in oil upon the discovery of 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.

11. 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.

12. Sisler, et al, *Contributions*, p. 57.

13. Ibid., p. 64.

14. Bacon and Hamor, *The American Petroleum Industry*, p. 219-220.

15. Giddens, Birth, p. 140

16. 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.

17. 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.

18. Indeed, in the 1870s there were across-the-board increases in output in each of the major fields. Per year production rose from five 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.

19. 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).

20. 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, *The American Petroleum Industry*. pp. 260-261.

21. 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, *The American Petroleum Industry*. pp. 262-265.

22. The Bradford field declined to just over five 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.

23 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).

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

25. 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, nine 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.

26. 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.

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

28. 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.

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

30. 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.

31. Ring, *Appalachian Region*, p. 278.

32. 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 range. However, the price quickly dropped through 1998 to its lowest levels since WW II.

33. 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 Machine 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.

34. 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.

35. Along with reducing the engine pulley's r.p.m.s, the bandwheel's momentum helped smooth the transmission of the power from the engine to the walking beam.

36. Sucker rods were usually 16 feet long and about two feet in diameter, made of hickory or ash (later, all metal), and connected with metal box-and-pin screw joints.

37. 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 20th century other

methods of fracturing oil-bearing rocks were developed. Among these was 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.

38. 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.

39. 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.

40. 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 more easily, an important consideration for drilling because of the continual need to raise tools out of the borehole, or pull tubing or sucker rods.

41. 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 its 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.

42. 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 Pennsylvania-based engine producers.

43. George, *Surface Machinery,* p. 24.

44. George, *Surface Machinery,* p. 69.

45. Ibid.

46. Ross, *Allegheny Oil,* p. 66.

47 George, *Surface Machinery,* p. 73.

48. Ross, *Allegheny Oil,* p. 67.

49. Eccentrics without slip rings gave a side-to-side motion of six to ten inches to the shackle lines along with the reciprocating movement.

50. Ross, *Allegheny Oil* p. 67.

51. See HAER No. PA-441, Geer-Tiona Central Power. 52. George, *Surface Machinery,* p. 77.

53. 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.

54. George, *Surface Machinery,* pp. 76-87.

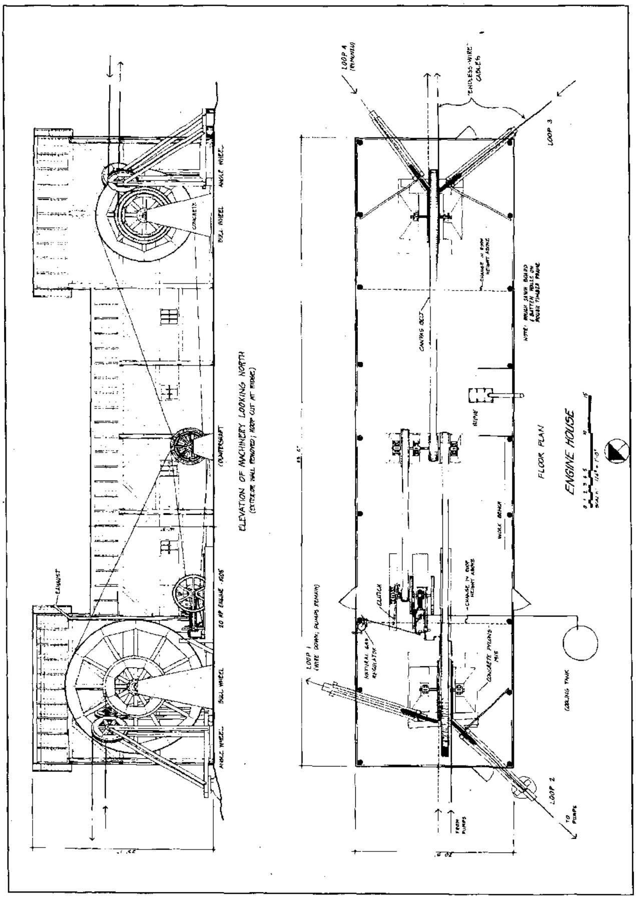
55. See HAER No. PA-442, McKenna-JoJo Central Power.

56. 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.

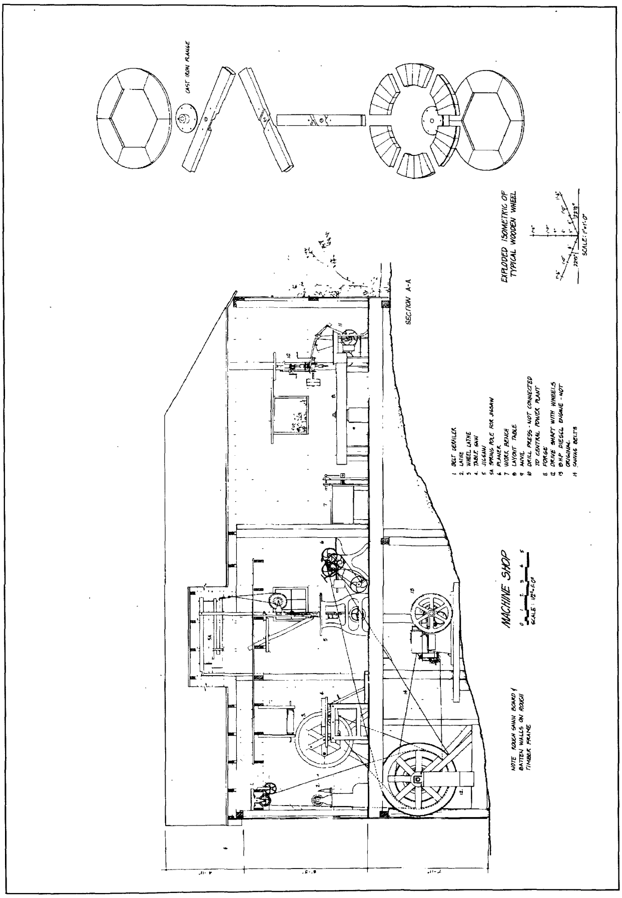
57. The Oklahoma jack was the most popular type of indirect lift. Other types offered by manufacturers were the O.K. jack, the Paova jack, and the Maloney jack. Indirect-lift jacks were sometimes all referred to as "Oklahoma" jacks.

58. George, *Surface Machinery,* pp. 86-89.

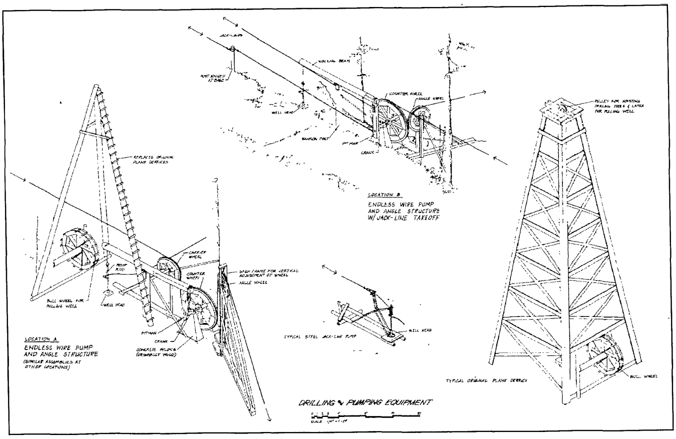
59. All of the octagon powerhouses documented have wood-shingle roofs. Wood shingles evidently perform better under high wind conditions (70 to 100 miles per hour) than asphalt shingles.



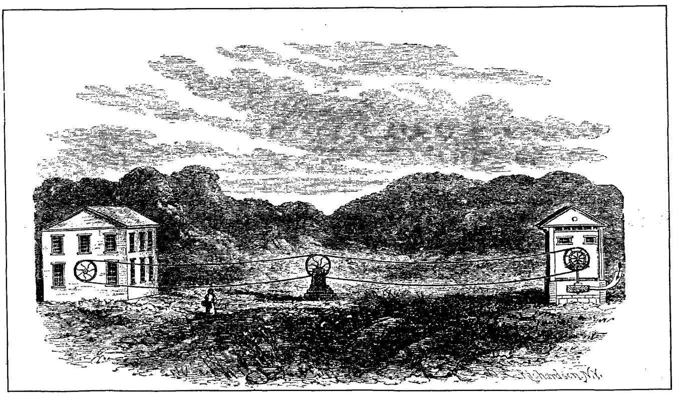

*Volcano endless wire power house.*



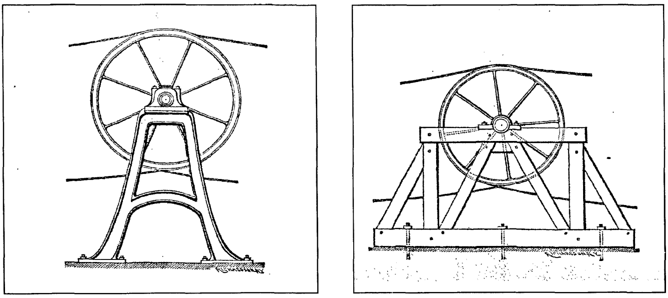

*Section view of Volcano machine shop and details of a wooden wheel.*



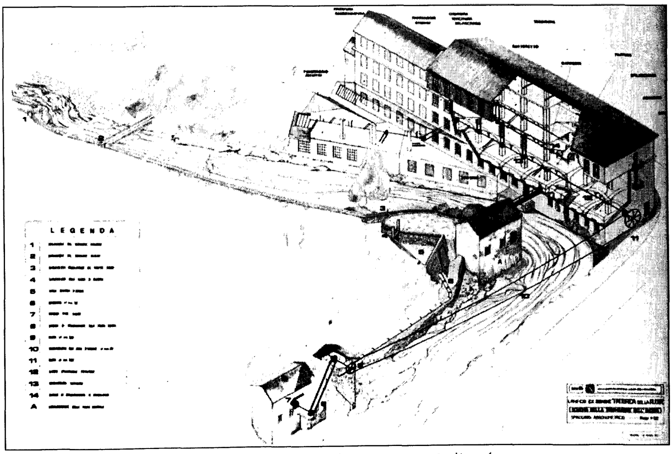

*Details of endless wire system at Volcano, West Virginia.*



*The endless wire system depicted with a turbine driving the endless wire on the right and the factory on the left.*

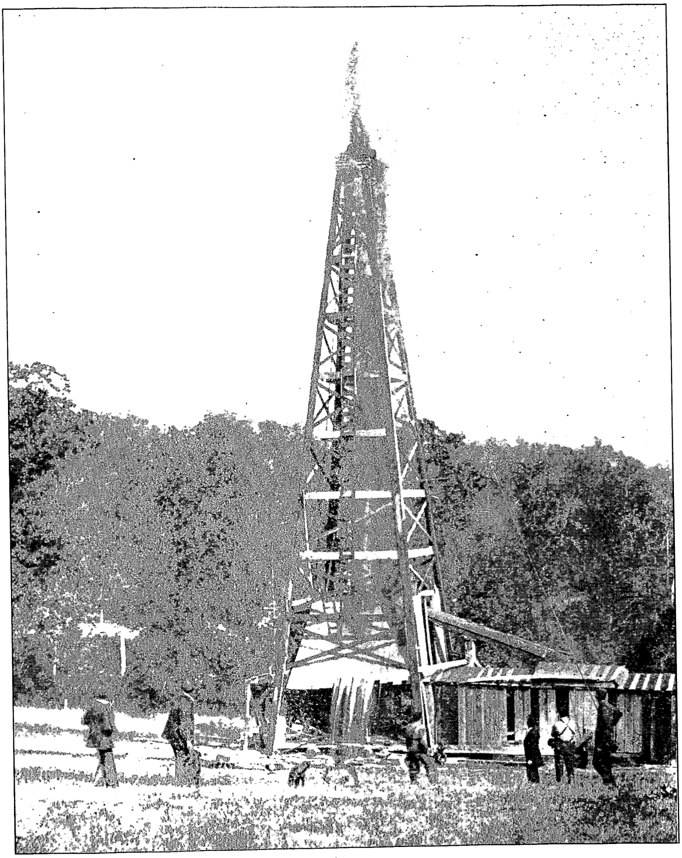


*Support wheels for the endless wire system used in Europe*



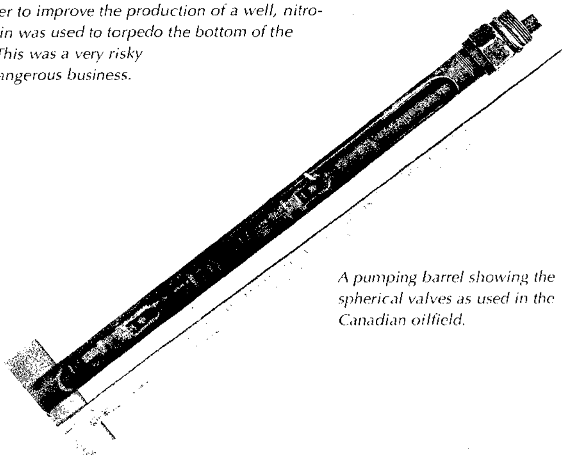
*An illustration of the endless wire system used to power an Italian factory*

*An extant endless wire system in Italy.*

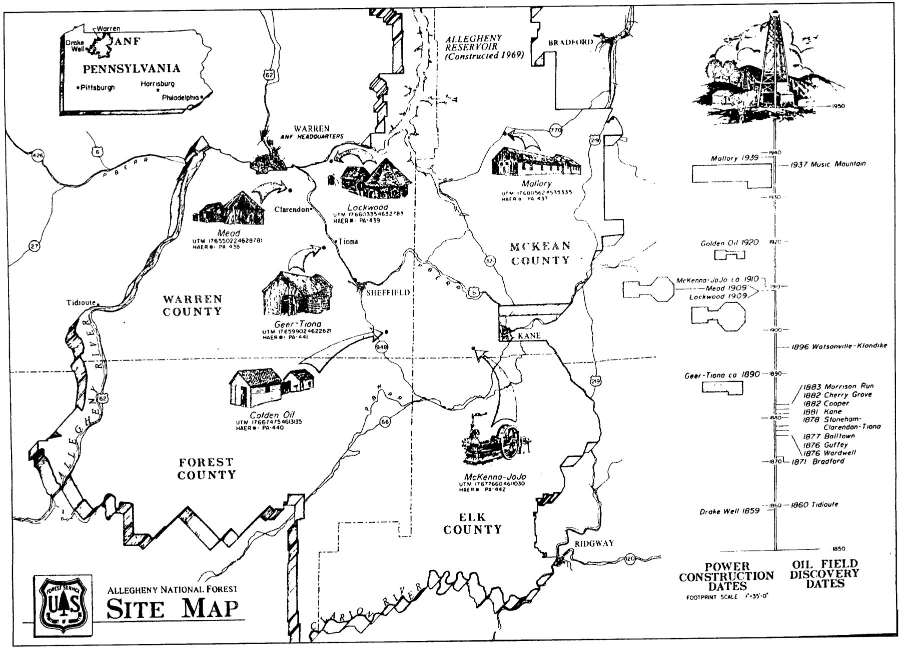


*A flowing oil well not needed to be pumped*

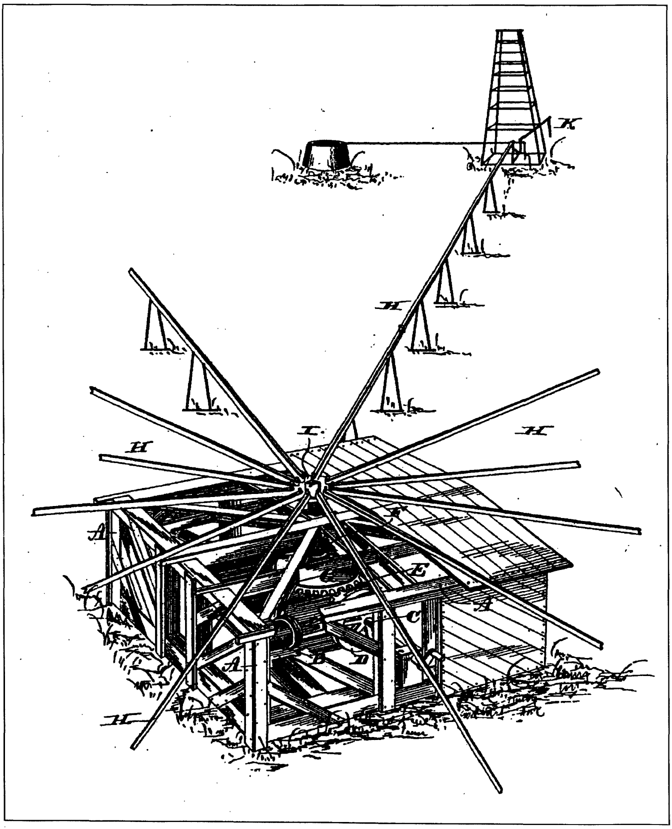
In order to improve the production of a well, nitroglycerin was used to torpedo the bottom of the well. This was a very risky and dangerous business.



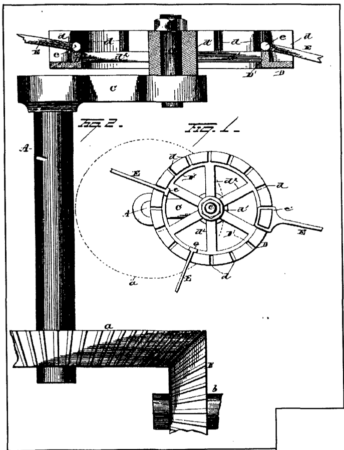
A pumping barrel showing the spherical valves as used in the Canadian oilfield.



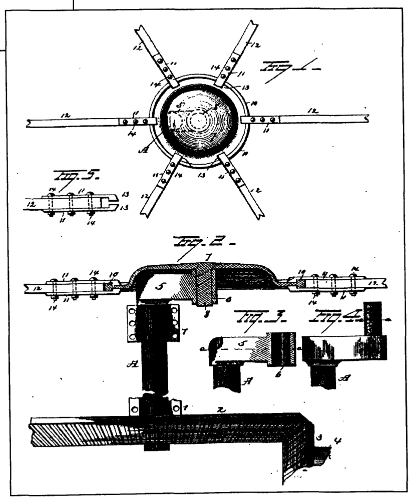

*A site map of various eccentric pumping locations in western Pennsylvania*



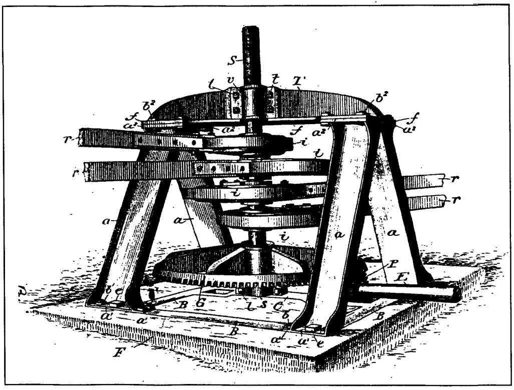
A patent drawing of Allen's eccentric method of pumping wells.



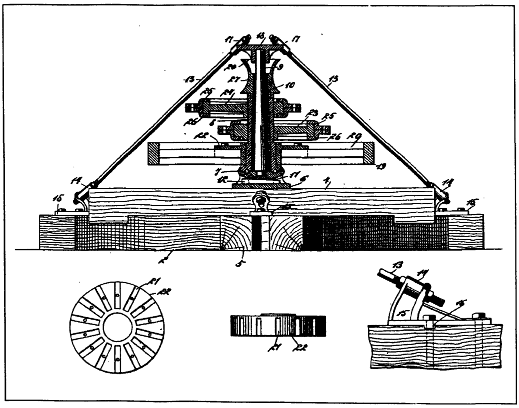
Details of the Allen system.



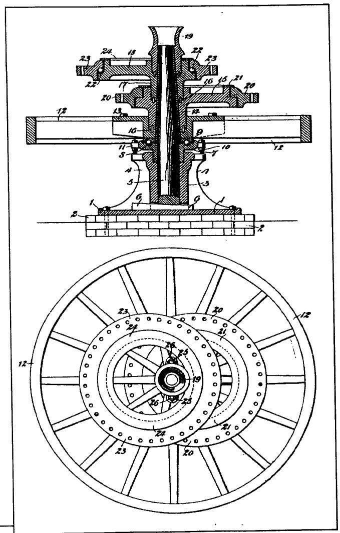
Details featuring the eccentric gearing for the Allen system.



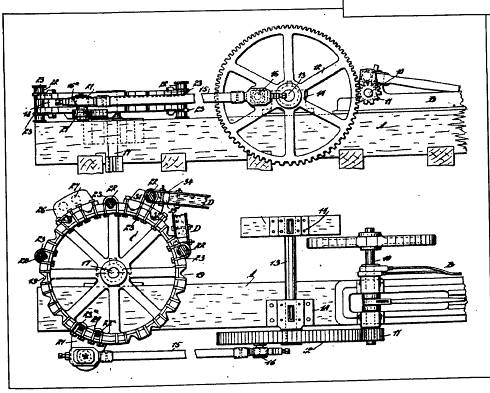
*A three-dimensional diagram of the Allen system.*



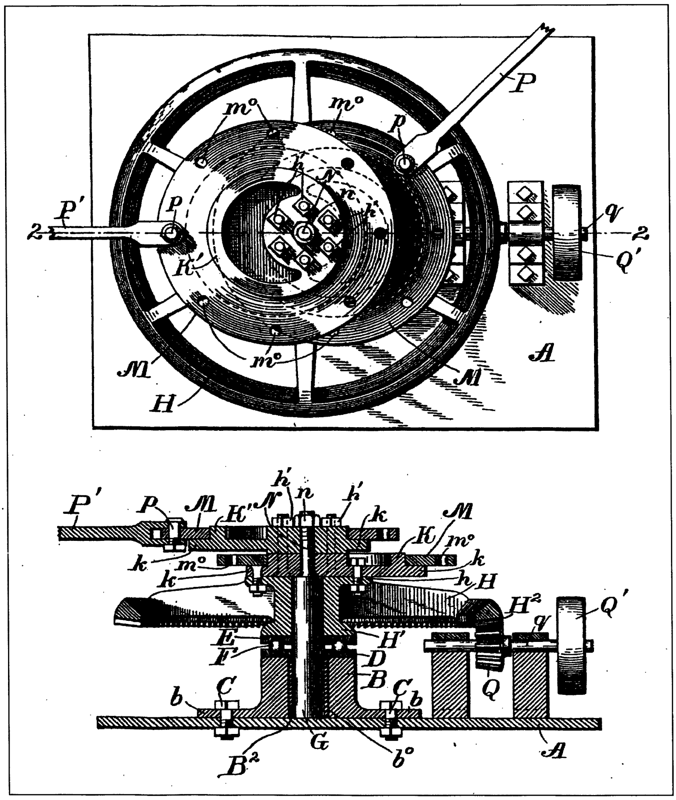
*A three-dimensional drawing of the Doyle pumping system. Please note that instead of using wire cable, belts were used in this system.*



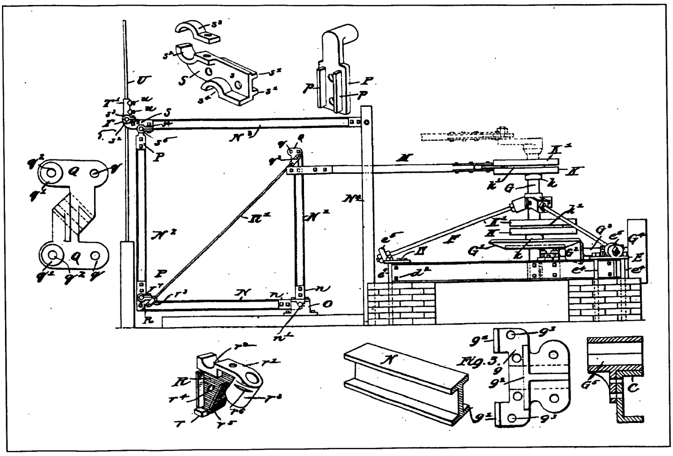
The Grimes eccentric power.



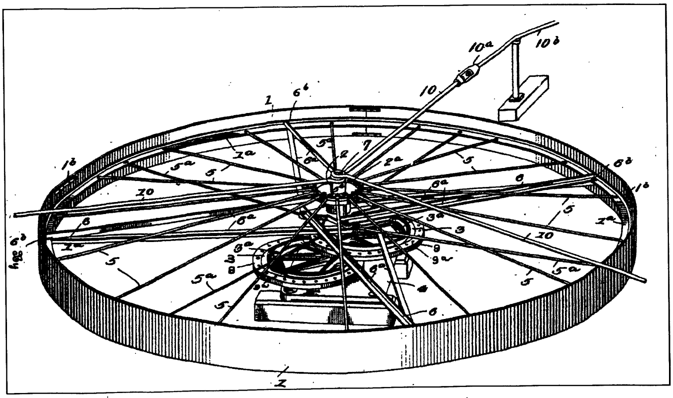
Details of the eccentrics of the Grimes system



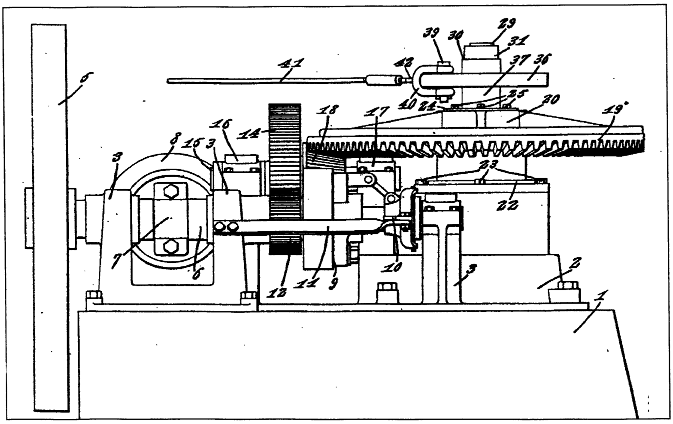

*A geared system for pumping wells*



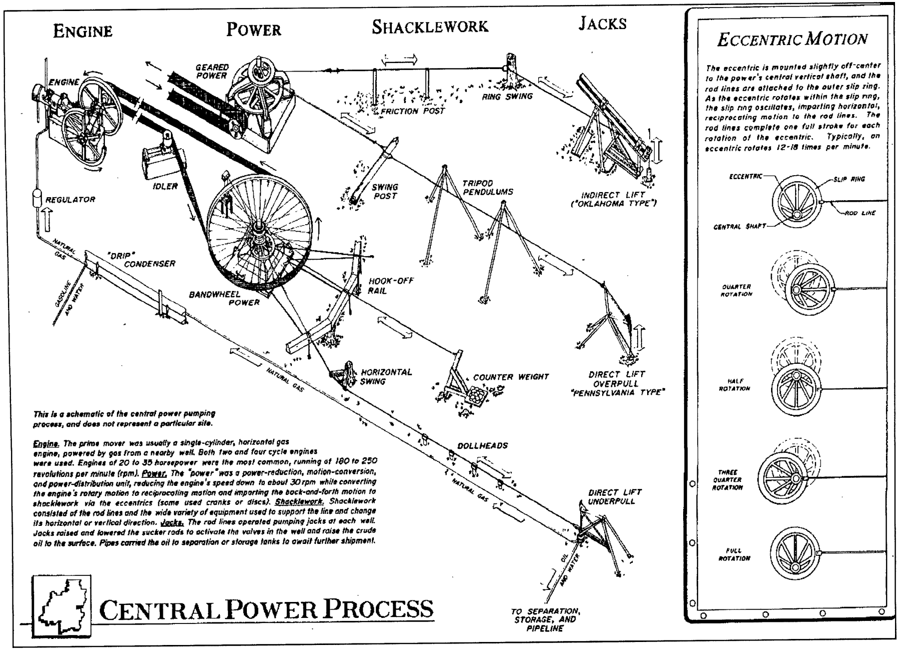
Details of the Maher patented eccentric system



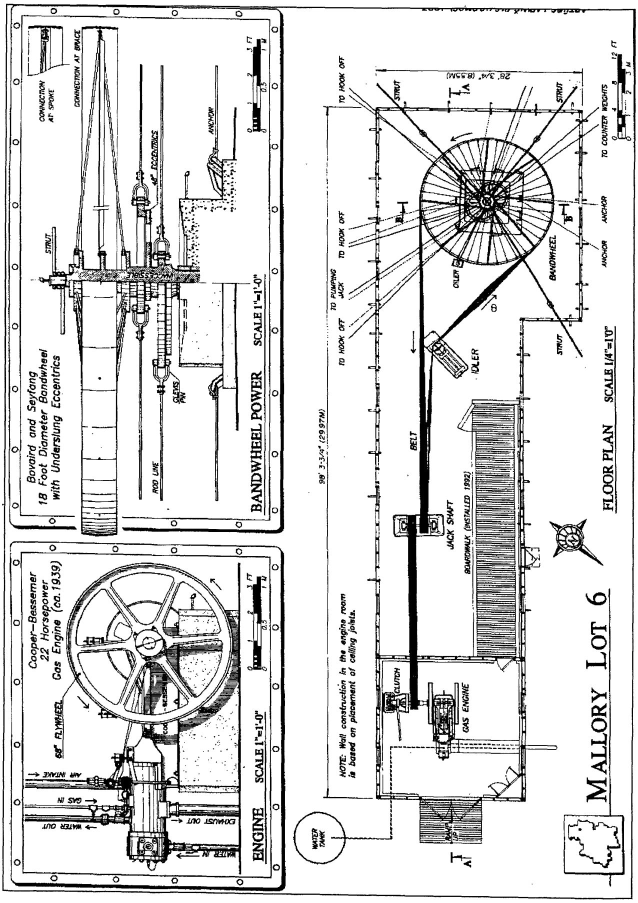
Details of a pumping rig complete with eccentric and pump jack



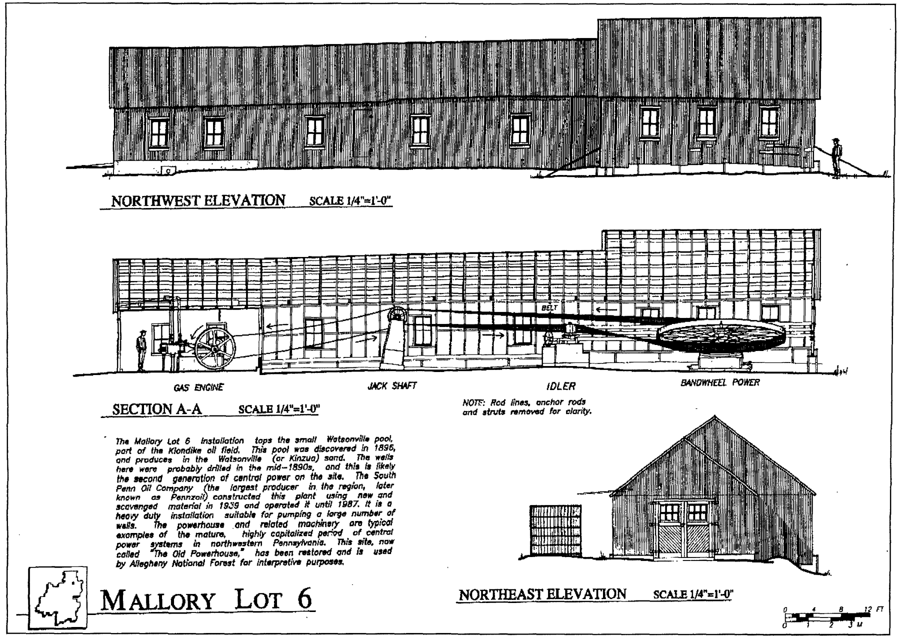
*A three-dimensional representation on patent drawing of a bandwheel eccentric.*



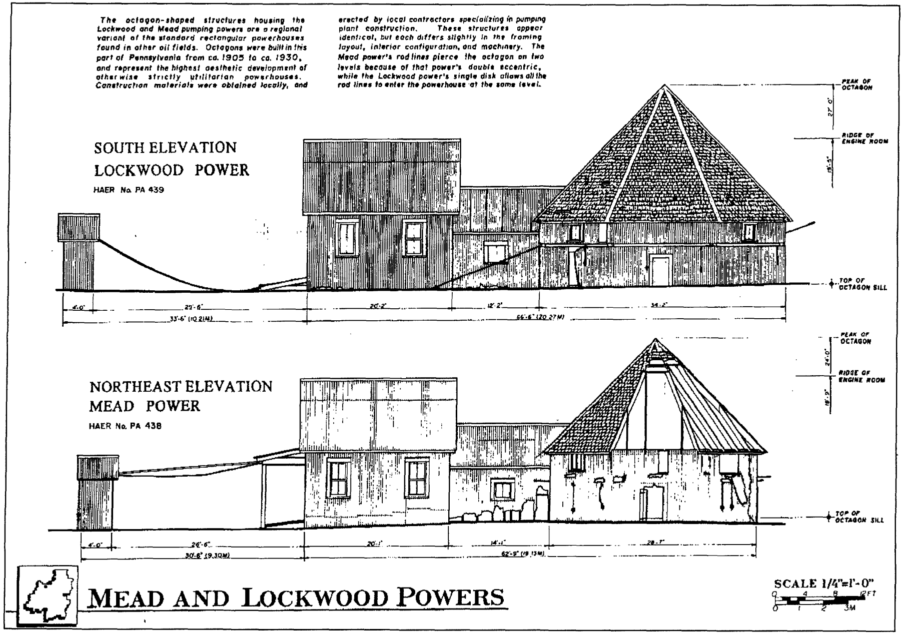

*Details of the combined gas engine and eccentric power system by Meister.*



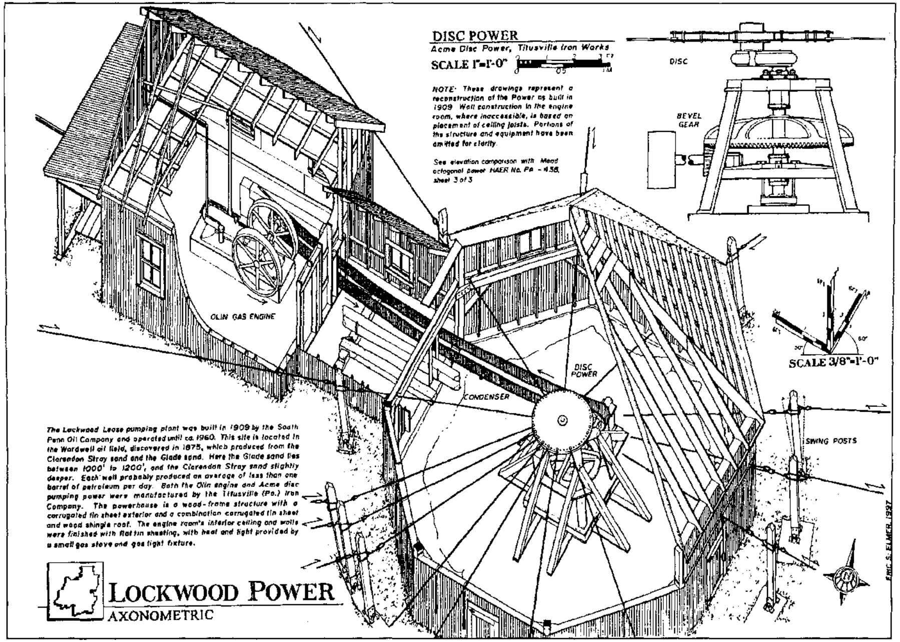

Illustrations of two different central power systems.



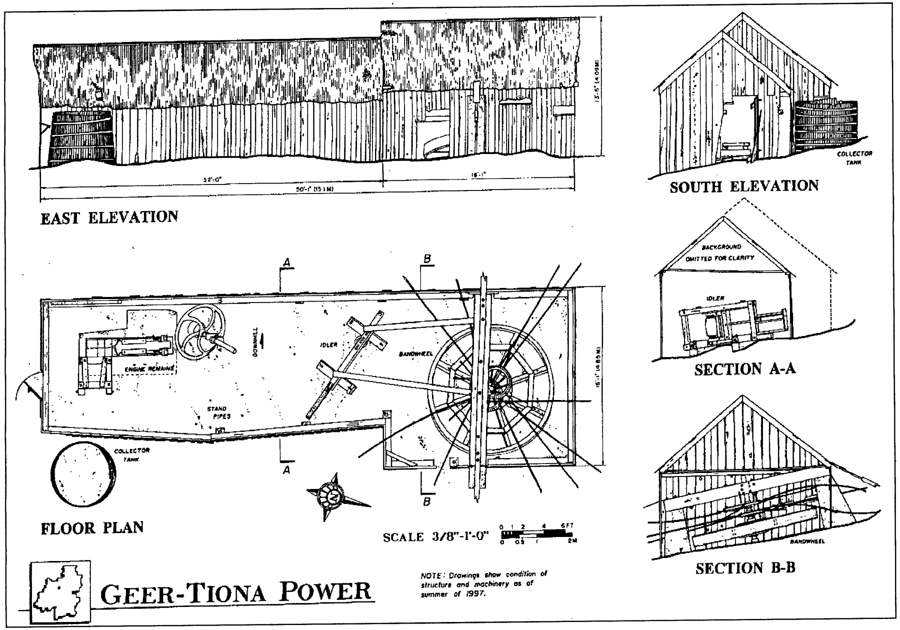

*The bandwheel at Mallory.*



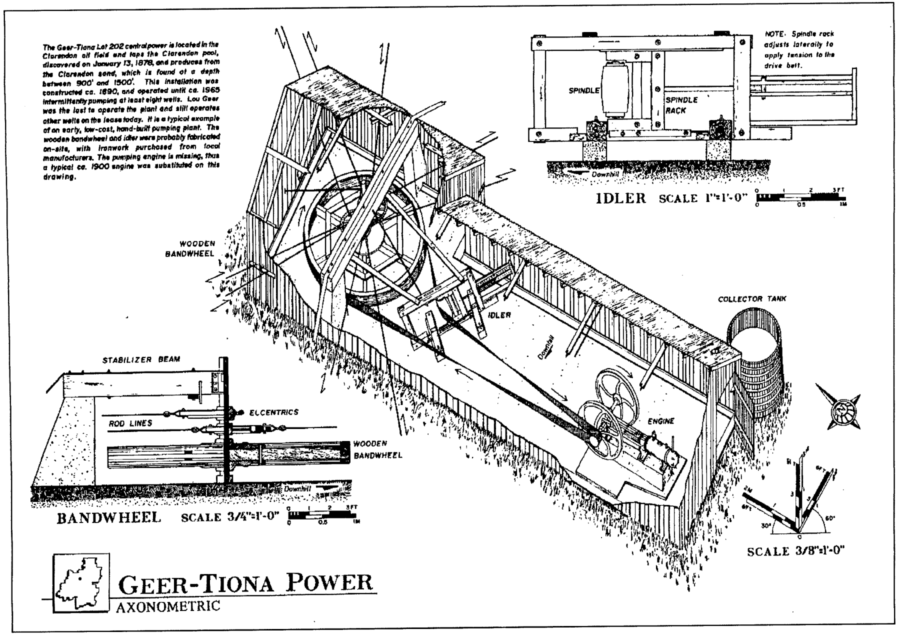

Elevation and sections of the Mallory rig.



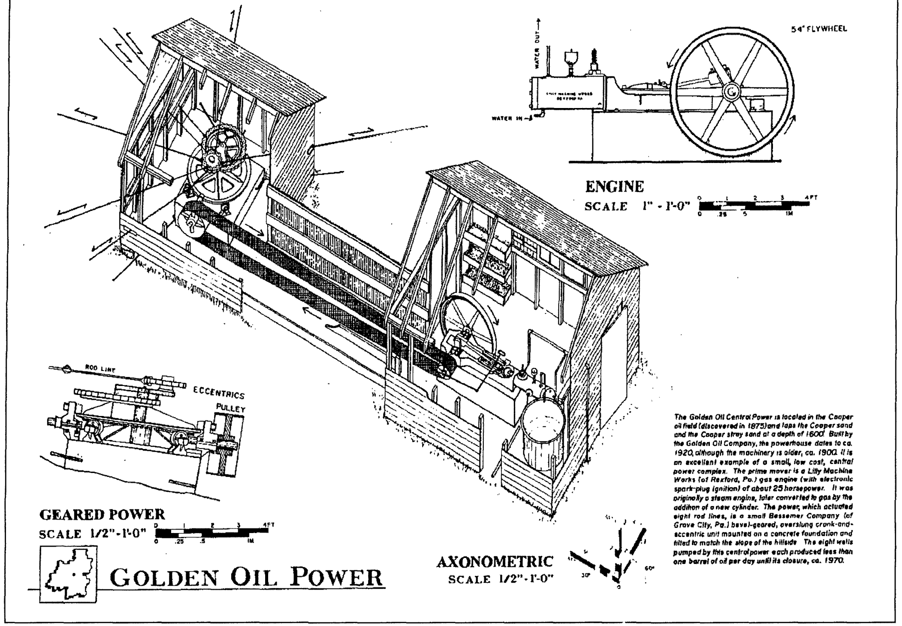

*Lockwood power house engine and eccentric.*



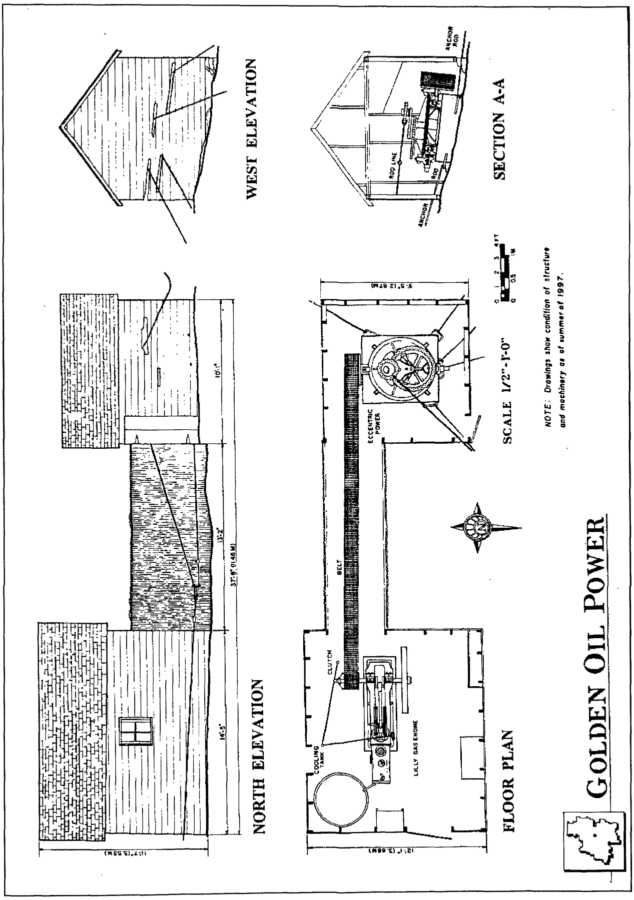

Mead and Lockwood powers.




Geer-tiona power rig.



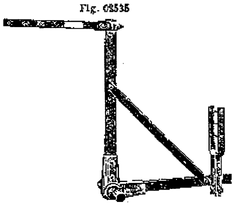

Cut away view of the Geer-tiona power house showing the engine and bandwheel




*Axonometric diagram of the Golden oil power.*

## SURFACE EQUIPMENT FOR PUMPING WELLS

Fig. 02535



### PAOVA PUMPING JACK

For wells ranging in depth from 600 to 1,500 feet.

When ordering, specify connections, whether for iron rods, wood rods, or wire strand.

**Weight, 180 lbs.**

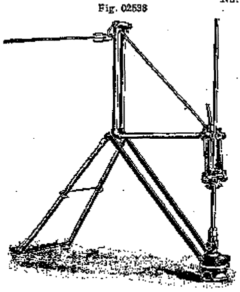
Price.......................................each, $18 00

**PARTS** (not illustrated)

Frame only..........................................$15 25
Adjuster casting and set screw......................80
Special bolt........................................30
Stirrup, complete with bolts........................1 50
Center piece for stirrup............................80

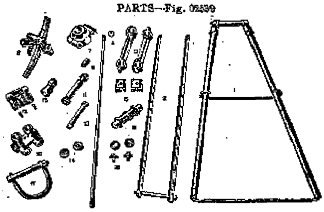
### JONES & HAMMOND PUMPING JACKS
No. 1 UPPER CONNECTION

Fig. 02538



**Weight, 235 lbs.**
Complete, each......$30 00

PARTS—Fig. 02539

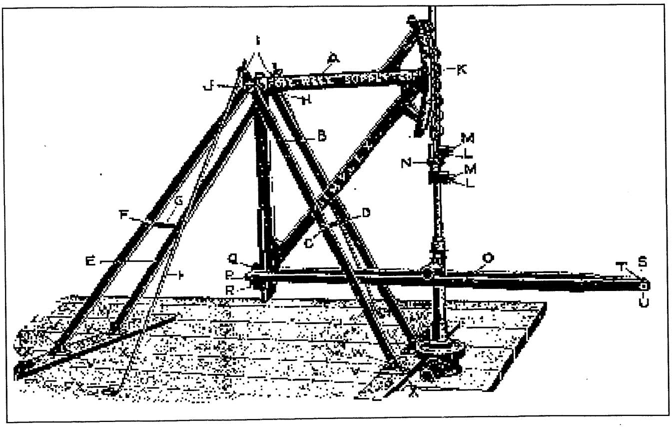


**PARTS**

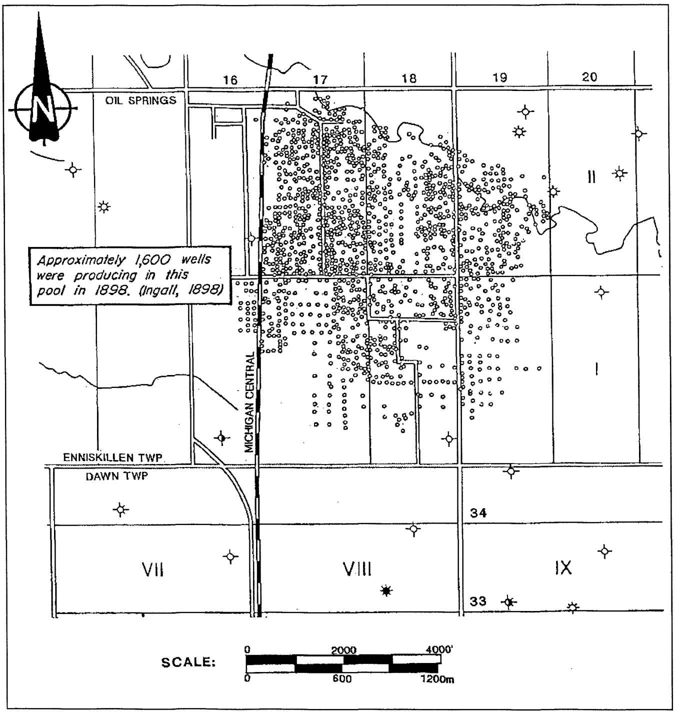
| Part No. | Name | Price | Part No. | Name | Price |
|---|---|---|---|---|---|
| 1 | Back brace, complete | $6 00 | 9 | Stay-rod nut | $0 40 |
| 2 | Front brace, complete | 4 00 | 10 | Corner casting | 2 00 |
| 3 | Side arms ........each | 1 50 | 11 | Trunnion pin, complete | 3 00 |
| 4 | Stay rod | 1 50 | 12 | Stirrup box | 1 50 |
| 4a | Stay-rod nut | 30 | 13 | Bolt and sleeve for stirrup | 50 |
| 5 | Polish rod clamps ........each | 80 | 14 | Nuts for trunnion pin ........each | 90 |
| 6 | Adjuster bar | 2 00 | 15 | Pipe socket for back brace | 40 |
| 7 | Tubing clamp | 3 00 | 16 | Side-arm nuts ........each | 30 |
| 8 | Arc | 5 00 | 17 | Stirrup | 2 00 |

Note:—When ordering parts always give name of part and part number, also state whether for No. 1, No. 2 or No. 3 jack.

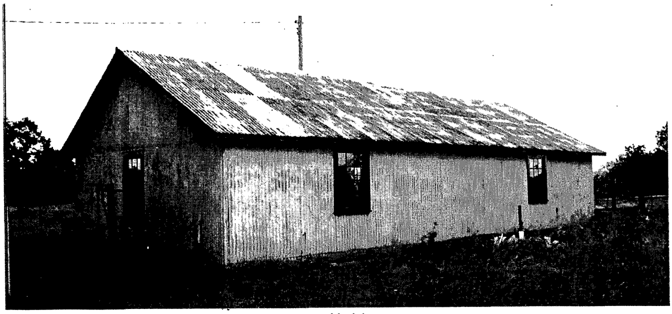
*Golden oil power details and rig elevation.*



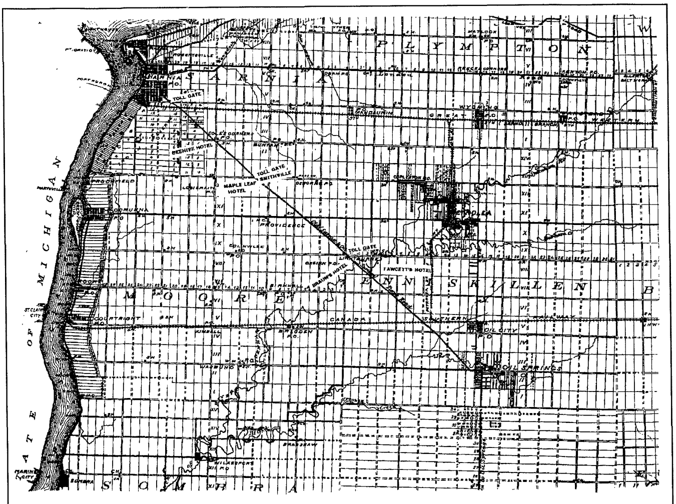

*Detail of an overpull pumping jack.*



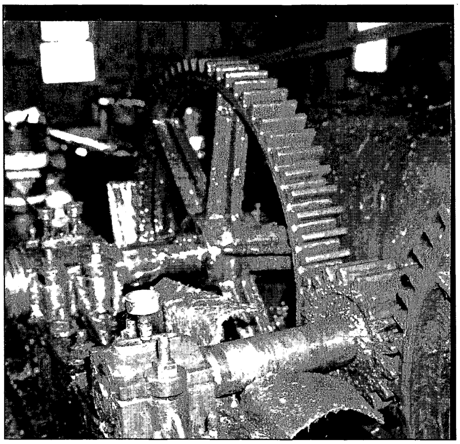

*Historical map of well locations in the Oil Springs field.*



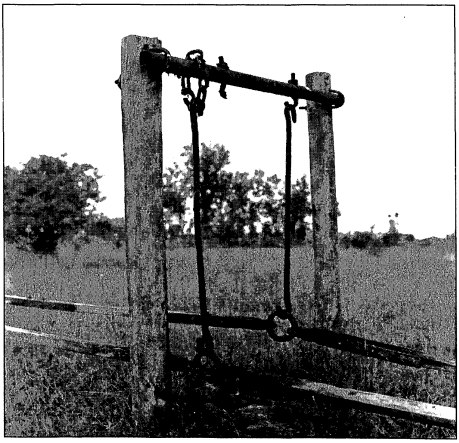
*Power house of the Orchard Rig, Fairbank oilfield.*



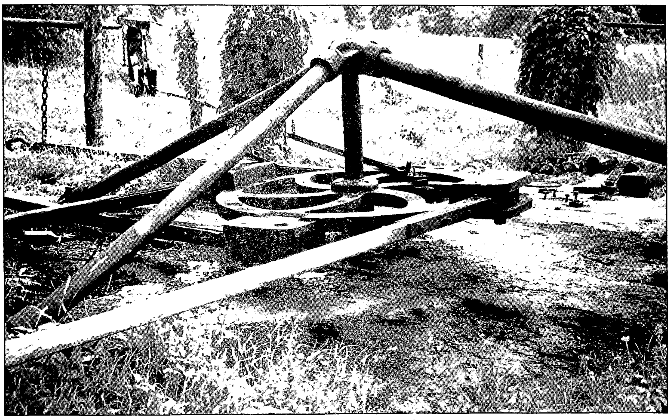

*Map showing Oil Springs and Petrolia with details of the railways and early Plank Road to Sarnia.*



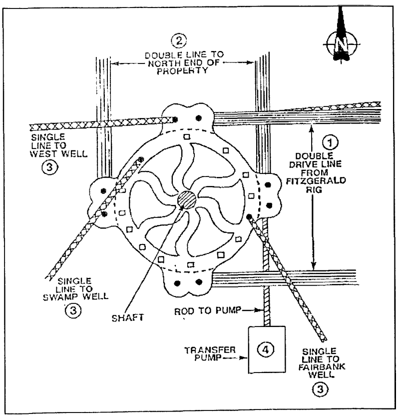
*Details of gearing in Orchard Rig.*



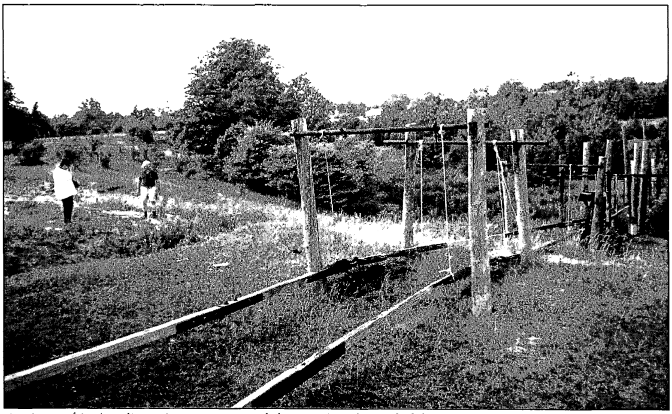
*Detail of jerker lines and supporting pendulum rods.*



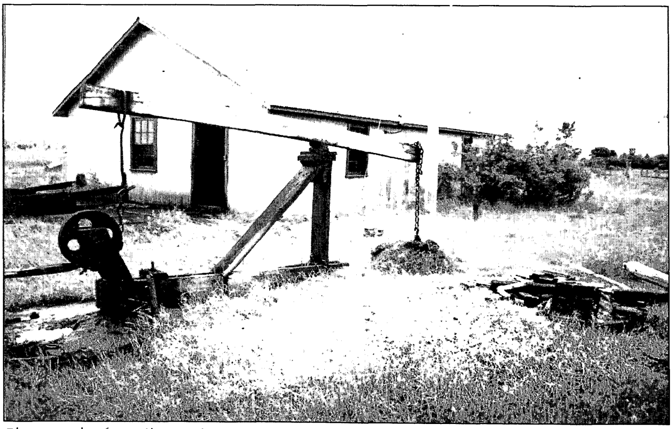
*Photograph of a field wheel or spider used in the jerker line system.*




*Drawing of a field wheel.*



A view of jerker lines in a portion of the Orchard Rig field.



Photograph of an oil pumping rig.

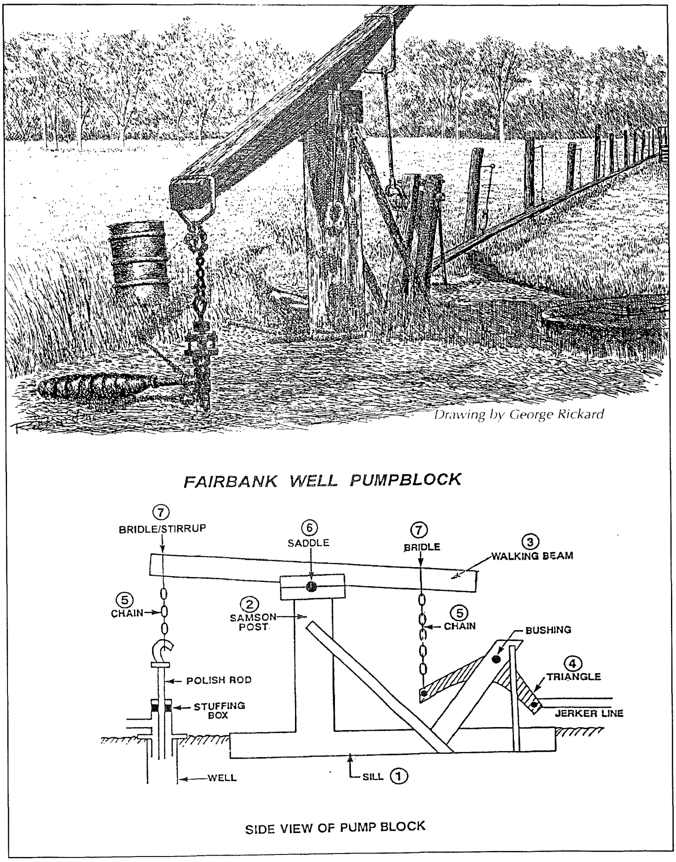
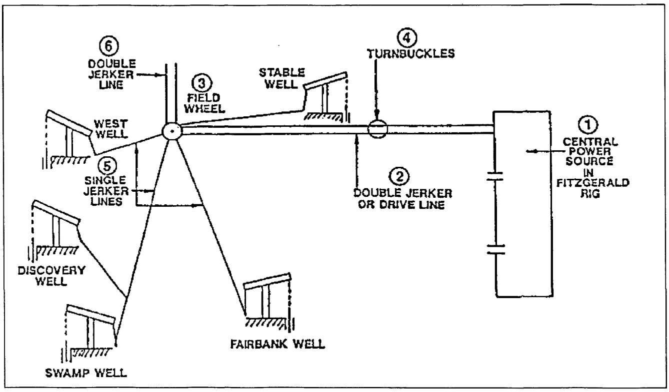
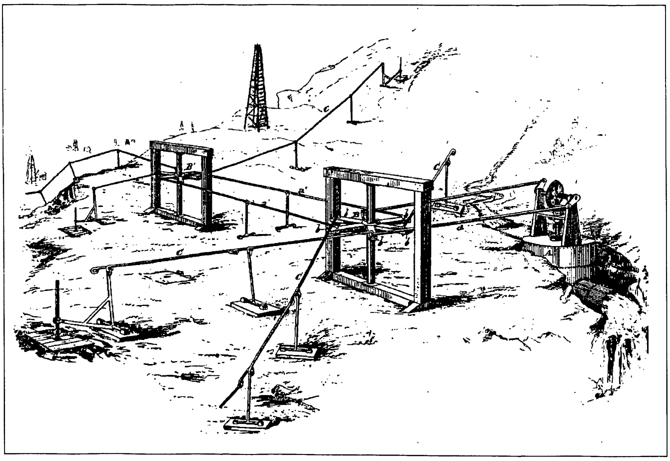


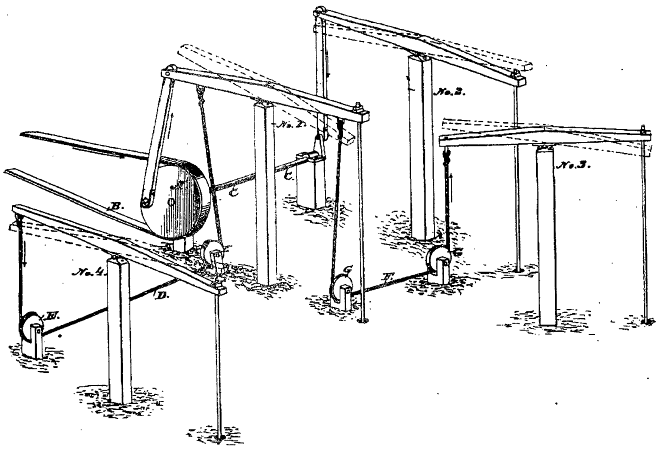

*Illustration of a walking beam pumping arrangement together with a sketch of the details.*




*Layout of a jerker line system for well pumping.*

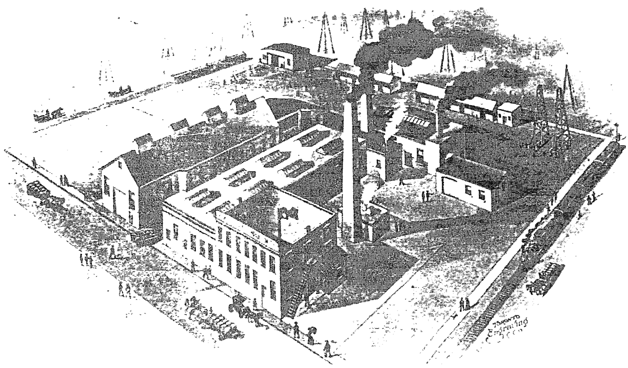


*A late patent by E.D. Yates on a jerker line system.*

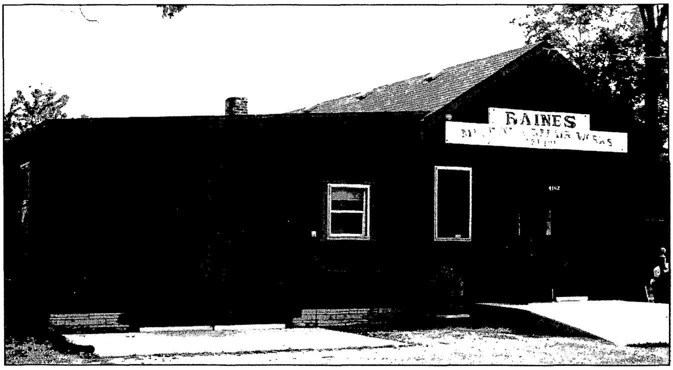



A Nickerson patent for pumping wells with a cable system, walking beam, and vertical eccentric.

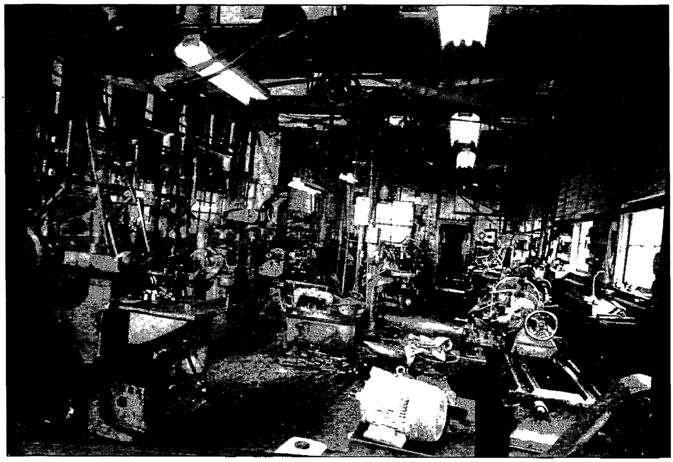

*Van Tuyl and Fairbank block in Petrolia, Ontario. This was the company associated with the Fairbank operation and supplied all of the necessary equipment to keep wells pumping.*



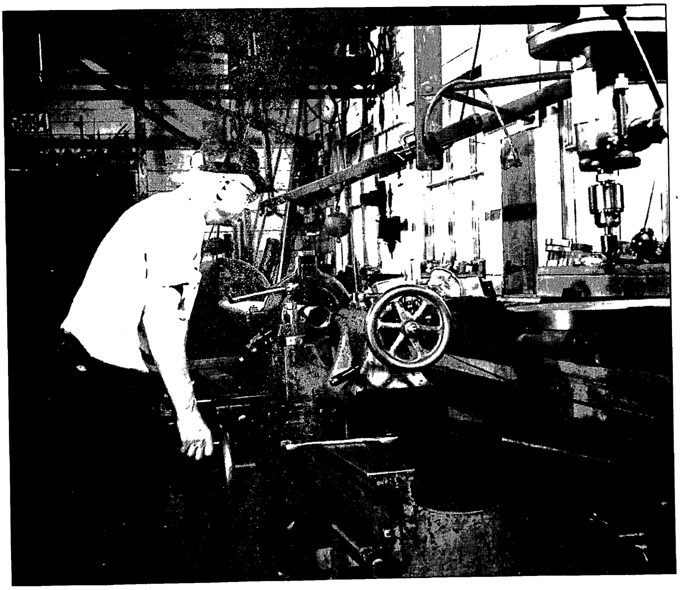
A bird's eye view of the Oil Well Supply Company of Petrolia.



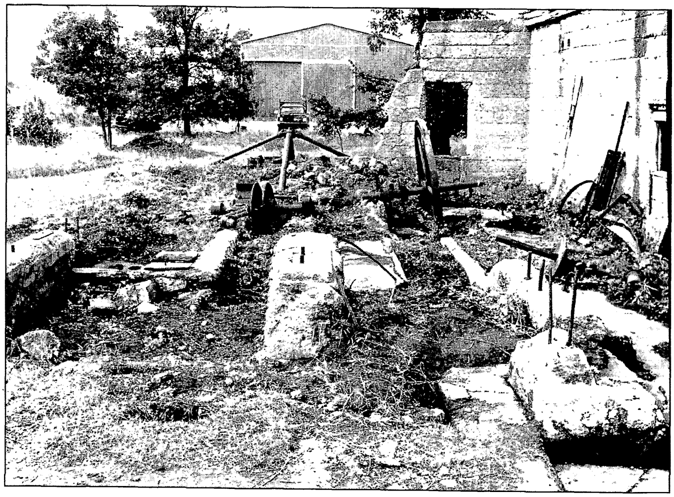

Front elevation of Baines Machine Shop which currently supplies the necessary equipment for oil pumping at Oil Springs and Petrolia



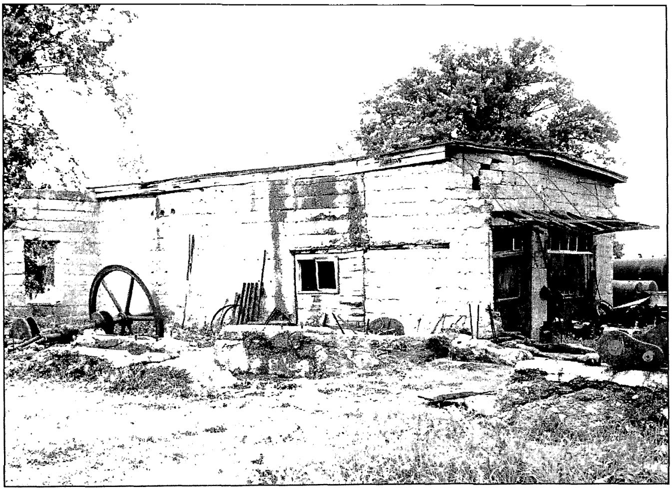
Interior of Baines Machine Shop.



*Albert Baines operating a lathe in the Baines Machine Shop*



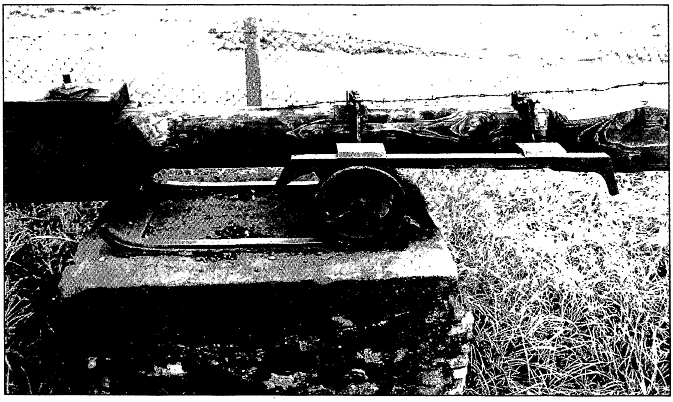
*Ruins of the steam engine rig, Fairbank Oil property.*



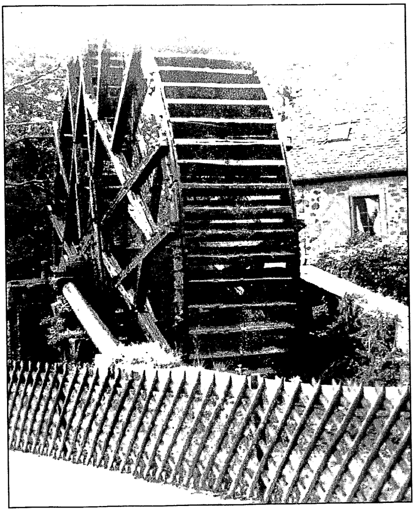
*The boiler house for the original steam powered jerker line system with the ruins of the engine shed in the foreground*



A method for raising water in a mine using an early jerker line idea. The water wheel is on the right and the mine on the left. Jerker lines were also used to power pumping units in the salt industry in German speaking part of Europe

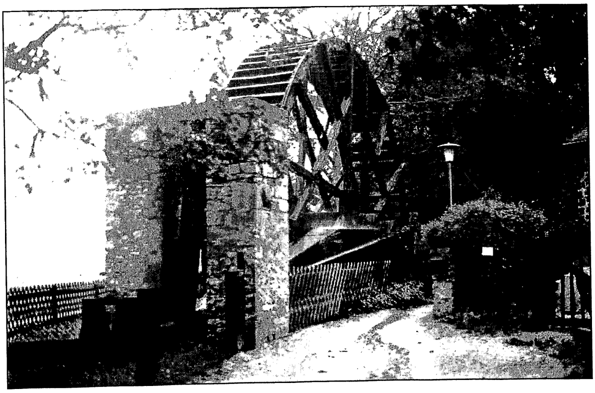


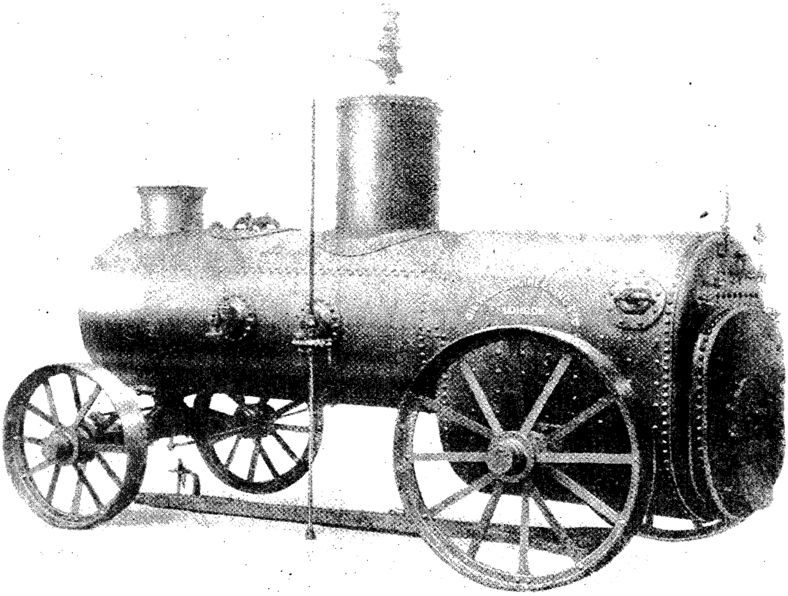
The support for the heavy jerker rods are shown in the photographs.



*The great water wheel which drives the jerker line system in Germany*

*An oblique view of the water wheel together with the jerker line system for pumping brine well.*





CHAPTER 4

# A Refiner's Fire

## Distillation

While the wood plank derrick serves as a symbol of the 19th century oil industry, in the 21st century the image shifts to a vision of giant refineries. Just as drilling methods were borrowed from earlier water and brine well drilling, oil distillation and refining incorporated earlier coal-oil production and paralleled the rise of the organic chemical industry.

At mid-century ladies' fashions embraced the newly developed anniline purple, which was identical to the rare, naturally occurring, mauve. One may wonder about the connection with anniline dyes and the burgeoning oil industry. With work in anniline dyes the British chemist, W. H. Perkin, Sr., effectively established the petro-chemical industry in 1856. Shortly afterwards, in 1858, Frederick August Kekule of Darmstadt, Germany revealed that an important difference resulted from benzine derived bituminous or petroleum sources. While showing the same number of molecules as other hydro-carbons, it formed rings rather than long chains. Kekule referred to these rings as aromatic compounds.

This newly-discovered principle lead to a clearer understanding of fractional distillation of petroleum products. Briefly, the various compounds associated with distillation are defined by the boiling points at which the various "fractions" separated, with the lowest boiling points associated with highly flammable fractions such as gasoline to heavier fractions which required much higher temperatures to vaporize. Thus, the various fractions of petroleum could be separated through distillation. In early distillation, empirical methods ruled the day, but later chemists found the means of determining the boiling points of various fractions of petroleum. With the main interest in producing kerosene, a sophisticated understanding of distillation was not really required in the 19th century.

A seminal contribution by the French chemist M.P .E. Berthelot established the principle "cracking." Simply stated, if any hydrocarbon, and particularly petroleum, is heated high enough in a still, the molecular chains will break and form lighter products.

More than a decade earlier in 1855, Benjamin Silliman Jr. in studying fractional distillation, concluded that petroleum was a compound of distillable portions but also heavy components which could not be distilled in the normal manner, but with sufficient heat would break down in into lighter components which then could be distilled. In modern parlance, he had unlocked the secret of, "cracking" which is such an important aspect of gasoline production. By using cracking (or destructive distillation technology), an increase of 20 percent or more of gasoline can be obtained from a given crude oil.

In the early days, small retorts sufficed to distill oil. These stills were typically cast iron and heated externally at the bottom. The vapor was lead off into a coil for condensation. This was essentially the same technique used in the production of moonshine, a crude homemade whiskey. These types of stills were first used in the production of coal oil. Later, wrought iron, and then steel, was employed in steel stills. The introduction of the horizontal cylindrical still rivaled the older vertical still. These time-honored methods persisted for many years in the oil industry.

Samuel Kier, of western Pennsylvania, built an enlarged still, holding from five to six barrels of oil. The refiners of western Pennsylvania and southwestern Ontario favored the use of horizontal cylindrical stills and even employed crude rectangular "cheese box" stills in the early days of the oil industry. When a charge had been distilled, the operator shut down and cooled off the still which allowed the hot tar-like residue to be removed by hand inside the still before the procedure was repeated. At best, it was a wasteful system with little regard to economy. The highly volatile first distillates were considered waste in the days before the use of gasoline. Kerosene was the prize while the residue was sometimes sold for fuel but further fractionated to yield lubricating oil. At the same time, experiments were underway to develop continuous stills. Despite valiant efforts by Samuel Van Syckel at Titusville, his improvements proved to be unsuccessful.

Used by oil men in Galicia, in Europe, a double-deck still allowed continuous operations for three or even four days. At the end of this cycle, the stills had to be shut down and the heavy residue removed. Alfred Nobel, in 1880-1881, demonstrated continuous or what was called in the field "bench stills" which he patented. Although vacuum distillation had been understood as early as 1855, it was not until 1879 that American engineers turned their attention to vacuum distillation. The vacuum lowered the boiling point of the various fractions of petroleum significantly improving the process.

## Steam Distillation

The inherent danger associated with direct firing under a still gave way to the much safer steam distillation. This was achieved by using wet or ordinary steam at or slightly above 212 degrees Fahrenheit (100 degrees C) inserted by a lance directly into the still. The water vapor from the condensed steam helped to lower the boiling point of the lighter fractions of oil, thus improving the efficiency of evaporation. Steam distillation was effective in the production of kerosene and lighter fractions leaving behind heavier oil products. The entire procedure was enhanced with the introduction of super-heated steam to release the various heavy fractions of oil thanks to the increased heat provided.

## Refining

There is more to processing oil than just distillation. An equally important aspect of the preparation of the oil products for the market is refining. Refining methods were based on chemical treatments borrowed from existing uses of sulfuric acid in the production of soaps and fats. Sulfuric acid was readily available at the time. Before perfecting the use of a steam super heater for distillation of oil, Gustave Adolphe Hirn (1815-1890) first used sulfuric acid to treat distillates which were washed with water and neutralized with caustic soda. This work was undertaken about 1850 by Hirn at Logenbach Refinery in Germany. These refining treatments based upon sulfuric acid migrated from Europe to Baku in Russia. In America, Gesner and Josiah Merrill recommended the use of sulfuric acid between 1854 and 1857 in reference to refining of kerosene. The oil was treated by stirring in sulfuric acid with mechanical stirring devices. This was later replaced with compressed air agitation which proved to be more efficient.

From the North American point of view, as early at 1857, Josiah Merrill and Samuel Downer, while involved with refining coal oil, worked out the methodology for treating petroleum subsequently followed in the industry. Their three-fold method was based on sulfuric acid followed by a water wash and neutralization with caustic soda rather than using soda ash, lime, or ammonia. Rather than treating crude oil, Merrill proceeded to refine the oil after distillation. The result yielded an effective and economic procedure. In a further contribution, Merrill introduced double distillation This secondary distillation removed all traces of either acid or soda and although more expensive, produced a superior product.

During the 1850s, the refining part of the oil industry came of age and set the standard which in many respects persist to this day. In evaluating production in the 1880s, Williamson and Daum said:

> The fact that the nation's largest three refineries, with weekly charging capacities of 2,000 barrels, and perhaps ten other approaching that capacity, were all built or in the process of construction before the end of 1862, suggests a scale of operations where diminishing returns rapidly set in. Pittsburgh had the largest concentration of refining, more than 50 plants with an aggregate capacity of 37,500 barrels weekly by 1866 yet only the standard Ardesco and Petrolite charge 2,000 barrels weekly, the Brilliant 1,500 barrels and three other 1,000 barrels. In the Region there were two atypical plants, the Humboldt at Plummer, charging 1,000 barrels weekly, and Downer's at Corry, charging 1,800 barrels which was complemented by his original refinery of similar size in Boston. The New York Kerosene Company, a converted coal-oil refinery, about completed the plants in this class. In the next lower scale of refineries at Pittsburgh, only a few exceeded 200-600 barrels weekly.

Despite the growth of industrial refineries and the consolidation of the industry around larger and ever larger refineries, oil was still delivered in barrels and manipulated by hand or rather primitive handling devices. Transport became a critical issue limiting refining development. The answer lay in the bulk transport of oil by water, by railway tank cars, by pipelines, or ships for Great Lakes and overseas distribution.

ORGANIZED UNDER THE MANUFACTURING LAWS OF OHIO.

No. 493 — 34993 Shares

STANDARD OIL COMPANY.

CAPITAL STOCK $3.500.000. ALL PAID.

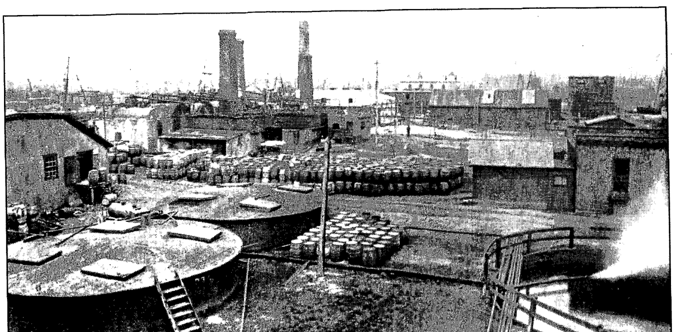
35.000 SHARES. $100 EACH.

This is to Certify that Trustees of Standard Oil Trust is entitled to Thirty four thousand nine hundred ninety three Shares of One Hundred Dollars each in the Capital Stock of the **Standard Oil Company**, transferable on the Books of the Company in person or by Attorney only on the surrender of this Certificate and due payment of all liabilities on the part of the holder to the Company; subject to the provisions of Law and the By Laws of the Company. This Certificate is valid only when signed by the President and Secretary.

Cleveland, O. Decr 23 1882

H. M. Flagler, Secy. — J. D. Rockefeller, Pres't.

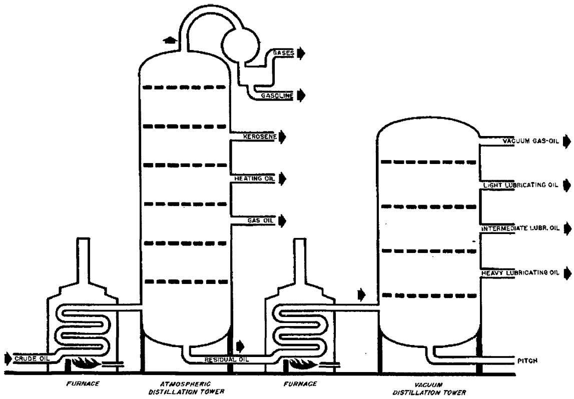
A capitol stock certificate signed by H.M. Flagler and John D. Rockefeller. It was the Rockefeller Trust which so dominated the refining and transport of oil throughout the 19th and early part of the 20th century in North America.



Canadian Oil Refining Company Limited in Petrolia in 1908.

# PETROLEUM

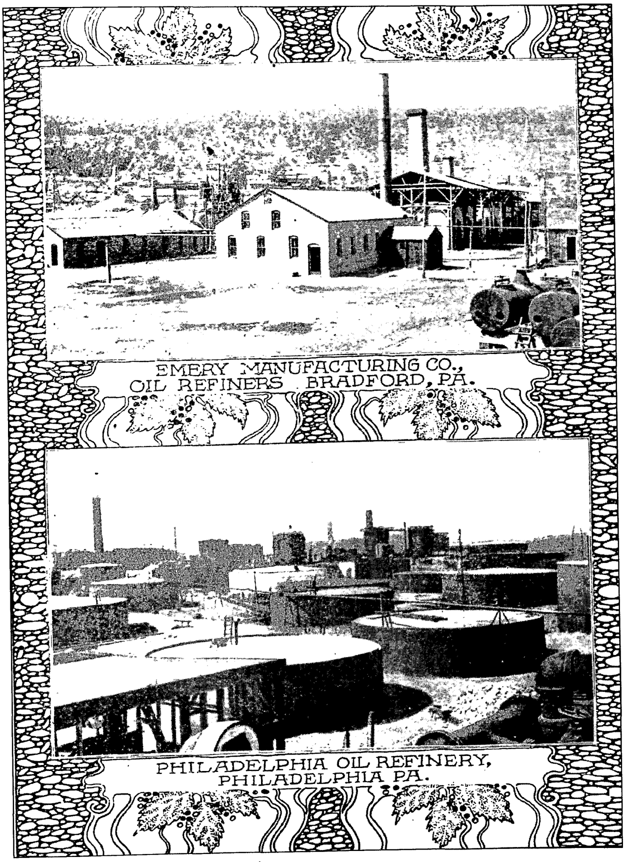
REFINING - DISTILLING
CRUDE OIL



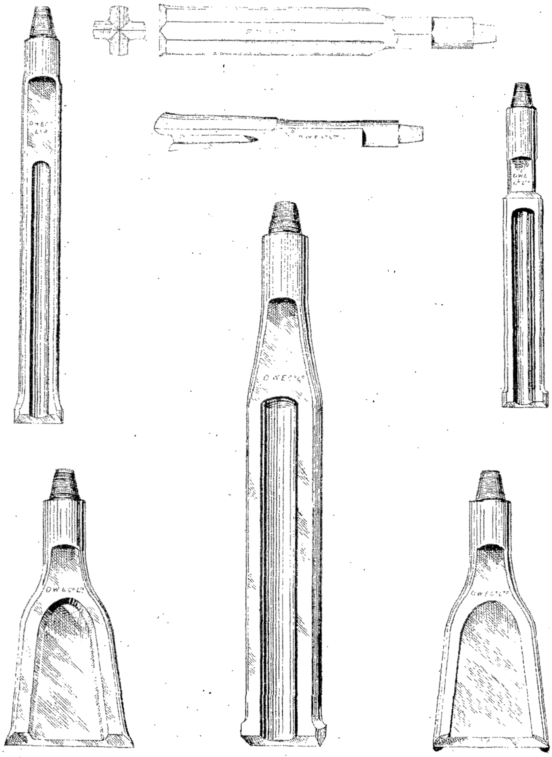

DISTILLATION, THE FIRST STEP IN OIL REFINING, SEPARATES CRUDE OIL INTO A NUMBER OF PRODUCTS. THE CRUDE IS FIRST HEATED BY BEING PUMPED THROUGH PIPES IN A FURNACE. THE RESULTING MIXTURE OF VAPORS AND LIQUID GOES TO A TOWER WHERE THE VAPORS RISE, CONDENSE ON TRAYS AND ARE DRAWN OFF THROUGH PIPES AS PRODUCTS.

THE PART OF THE CRUDE THAT DID NOT BOIL IN THE FIRST DISTILLATION STEP IS RE-HEATED AND DISTILLED IN A VACUUM TO MAKE IT BOIL. AGAIN, VAPORS RISE, CONDENSE AND ARE DRAWN OFF AS PRODUCTS. SOME OF THE VERY HEAVY OIL STILL DOESN'T BOIL. THIS IS MADE INTO HEAVY FUEL OIL USED IN FACTORIES AND SHIPS OR INTO ASPHALT.

*A diagram and description of refining and distilling crude oil.*




*Views of two refineries of the 19th century.*



CHAPTER 5

# Storage Facilities

One of the notable features found in the oil fields are tanks for storage and processing oil. In the beginning of the modern period, wooden tanks predominated, coming in various sizes. Small tanks located near a well called "day tanks" collected daily or even weekly production. Larger tanks stored oil as a stage in the transport to refineries. One can envisage an entire oil field dotted with derricks and tanks.

One of the most ingenious means of storing and processing oil occurs in the Oil Springs-Petrolia field in Canada. In geologic terms, the overburden in the area consists of dense impervious clay. Taking advantage of this condition, underground storage tanks are a unique feature of the Lambton County oil field, and a number of them are extant. These large tanks are built of horizontal rings of wood to resist lateral earth pressures and attendant earth slides. They also serve to receive oil and water from a number of wells, and to drain off the water associated with well pumping. In a number of cases, copious quantities of water were separated from the oil, being deposited into nearby water-courses. In most cases, the water exceeded the amount of oil and contained a significant percentage of salt. Because of environmental concerns, the brine is now pumped back into underground aquifers. Use of wood tanks persisted at Volcano in West Virginia until the end of its productive life. At Oil Springs, wood underground tanks are still in operation. A few above-ground day tanks survive even though they are not in production.

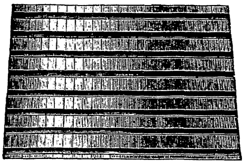
By the 1870s, riveted wrought iron tanks made their appearance in the oil fields in both countries. Wrought iron gave way to mild steel, and riveting to arc welding for tanks in the oil fields and at refineries. These changes were introduced slowly and some are now nearly a century old.

Tanks were not only used to collect oil from a number of wells and to separate out the water, but also used to remove gas vapors from the oil. Separators appeared with the opening of the western Pennsylvania fields, ca. 1865. These simple devices functioned by allowing the crude oil to flow from supply pipes into a chamber or tank. As the oil flows slow, the gas and oil mixture separated. The gas collected and was taken off through the top of the tank, and the oil layer rose above any water present. Later, after the turn of the century, ca. 1900, high-pressure separators were introduced, being more efficient in the removal of a higher percentage of gas. The first separator introduced into the American industry, in the Oil Spring region of Pennsylvania, appeared in 1865. Other separators that could condense the gas vapor into liquid gas, or drip gasoline, took on the appearance of long horizontal tubes sealed at both ends connected to supply and takeoff pipes. While separators supplied cheap fuel for the engine, capturing and collecting the most gaseous content of the oil also made accidental fires less likely. Nevertheless, much gas is still "flared off" at oil refineries.

*An underground separating tank, Fairbank oilfield.*

*A large underground tank for receiving oil from a number of wells pumped with the jerker line system.*

## OIL STORAGE AND TRANSPORTATION



### WOODEN TANK

Fig. 9143

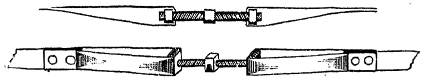
Made to order Prices furnished on application.

42 gallons equal one barrel, standard oil measurement.

### DIMENSIONS AND WEIGHTS

| Diameter feet | Length of staves feet | Number of hoops | Capacity gallons | Shipping weight lbs. | Diameter feet | Length of staves feet | Number of hoops | Capacity gallons | Shipping weight lbs. |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 3 | 158 | 220 | 12 | 12 | 12 | 9,658 | 3,091 |
| 4 | 4 | 4 | 321 | 361 | 13 | 6 | 6 | 5,378 | 2,138 |
| 5 | 4 | 4 | 587 | 505 | 13 | 8 | 8 | 7,363 | 2,556 |
| 6 | 4 | 4 | 720 | 586 | 13 | 12 | 12 | 11,333 | 3,481 |
| 6 | 6 | 5 | 1,145 | 776 | 14 | 8 | 8 | 8,540 | 2,765 |
| 7 | 4 | 4 | 983 | 694 | 14 | 12 | 12 | 13,146 | 3,796 |
| 7 | 6 | 5 | 1,559 | 921 | 14 | 14 | 13 | 15,449 | 4,280 |
| 8 | 4 | 4 | 1,294 | 840 | 15 | 6 | 5 | 7,160 | 2,530 |
| 8 | 6 | 5 | 2,031 | 1,096 | 15 | 8 | 8 | 9,804 | 3,093 |
| 8 | 8 | 7 | 2,781 | 1,372 | 15 | 12 | 12 | 15,090 | 4,130 |
| 9 | 4 | 4 | 1,623 | 971 | 15 | 16 | 15 | 19,070 | 4,943 |
| 9 | 6 | 5 | 2,577 | 1,260 | 16 | 6 | 5 | 8,147 | 2,686 |
| 9 | 8 | 8 | 3,529 | 1,563 | 16 | 8 | 8 | 11,155 | 3,370 |
| 10 | 4 | 4 | 2,006 | 1,124 | 16 | 12 | 12 | 17,170 | 4,529 |
| 10 | 6 | 5 | 3,182 | 1,454 | 16 | 14 | 13 | 20,179 | 4,080 |
| 10 | 8 | 8 | 4,357 | 1,784 | 16 | 16 | 16 | 23,187 | 5,678 |
| 11 | 4 | 4 | 2,428 | 1,307 | 18 | 8 | 8 | 14,118 | 4,091 |
| 11 | 6 | 5 | 3,850 | 1,679 | 18 | 12 | 12 | 21,730 | 5,370 |
| 11 | 8 | 8 | 5,272 | 2,079 | 18 | 16 | 16 | 29,184 | 6,750 |
| 12 | 4 | 4 | 2,891 | 1,414 | 20 | 14 | 14 | 31,334 | 6,850 |
| 12 | 6 | 5 | 4,582 | 1,843 | 20 | 16 | 16 | 36,035 | 7,734 |
| 12 | 8 | 8 | 6,274 | 2,280 | 24 | 16 | 16 | 51,889 | 10,400 |
| 11 | 11 | 10 | 7,405 | 2,632 | .... | .... | .... | ...... | ...... |

### TANK HOOP CONNECTION—WARE'S PATENT—Fig. 9146

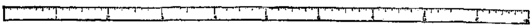


To tighten the hoops of wooden tanks

Complete............$1 00 Bolt only.........$0 50 Straps only per pair, $0 50

### GAUGE ROD—Fig. 9147

For measuring oil in tank



Per foot.........................................................................$0 20



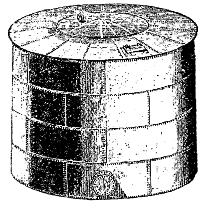
Oil well supply catalogue. Details of wood and steel storage tanks.

OIL WELL SUPPLY CO., PITTSBURGH, U. S. A. 305

## OIL STORAGE AND TRANSPORTATION

### STEEL STORAGE TANK

Fig. 9148



### SPECIFICATIONS OF STEEL TANKS

Ranging from 150 barrels to 35,000 barrels capacity, to hold either crude or refined petroleum. If tanks are required for water or liquids heavier than petroleum, heavier iron should be used.

### SPECIFICATIONS OF OIL STORAGE TANKS

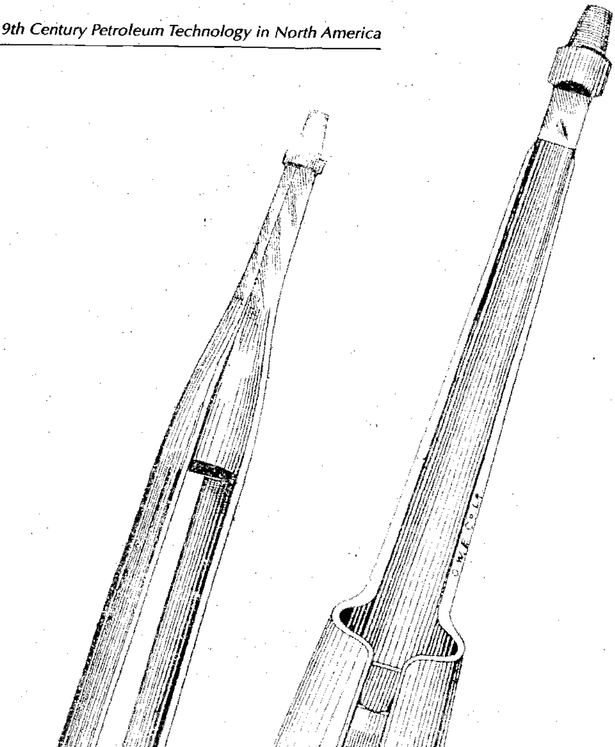
| Capacity (barrels of 42 gallons each) about | 150 | 200 | 250 | 300 |
|---|---|---|---|---|
| Diameter ... feet | 9 | 14 | 14 | 14 |
| Height ... feet | 14 | 8 | 10 | 12 |
| Number of rings in shell | 3 | 2 | 2 | 3 |
| Thickness of first ring (B. W. G.) | No 7 | No. 7 | No. 7 | No. 7 |
| Thickness of second ring | No 8 | No. 8 | No. 8 | No. 8 |
| Thickness of third ring | No. 8 | ..... | ..... | No. 8 |
| Thickness of bottom | No. 8 | No. 8 | No. 8 | No. 8 |
| Size of bottom angle ... inches | 2 x 2 x ¼ | 2 x 2 x ¼ | 2 x 2 x ¼ | 2 x 2 x ¼ |
| Size of top angle ... inches | 2 x 2 x ¼ | 2 x 2 x ¼ | 2 x 2 x ¼ | 2 x 2 x ¼ |
| Thickness of sheets for tight riveted roof | No. 12 | No. 12 | No. 12 | No. 12 |

| Capacity (barrels of 42 gallons each) about | 350 | 400 | 500 | ...... |
|---|---|---|---|---|
| Diameter ... feet | 14 | 18 | 18 | ...... |
| Height ... feet | 14 | 9½ | 12 | ...... |
| Number of rings in shell | 3 | 2 | 3 | ...... |
| Thickness of first ring (B. W. G.) | No 7 | No 7 | No 6 | ...... |
| Thickness of second ring | No. 8 | No 8 | No. 7 | ...... |
| Thickness of third ring | No 8 | ...... | No. 8 | ...... |
| Thickness of bottom | No 7 | No. 7 | No. 7 | ...... |
| Size of bottom angle ... inches | 2 x 2 x ¼ | 2½ x 2½ x 5/16 | 2½ x 2½ x 5/16 | ...... |
| Size of top angle ... inches | 2 x 2 x ¼ | 2 x 2 x ¼ | 2 x 2 x ¼ | ...... |
| Thickness of sheets for tight riveted roof | No 12 | No. 12 | No. 12 | ...... |

| Capacity (barrels of 42 gallons each) ... about | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 | 10,000 |
|---|---|---|---|---|---|---|
| Diameter ... feet | 30 | 30 | 30 | 35 | 43 | 54 |
| Height ... feet | 8 | 16 | 24 | 24 | 20 | 25 |
| Number of rings in shell | 2 | 4 | 5 | 5 | 4 | 6 |
| Thickness of first ring (B. W. G.) | No 7 | No 5 | No. 3 | No. 3 | No. 3 | No. 3 |
| Thickness of second ring | No. 8 | No. 6 | No. 4 | No. 4 | No. 4 | No. 3 |
| Thickness of third ring | ...... | No. 7 | No. 5 | No. 5 | No. 5 | No. 4 |
| Thickness of fourth ring | ...... | No. 8 | No. 6 | No. 6 | No. 6 | No. 5 |



*Oil well supply catalogue. Details of wood and steel storage tanks.*



CHAPTER 6

# Moving Oil: From Well to Refinery and to Market

When the medicinal benefits of oil were vigorously promoted to nearly the exclusion of other uses, the quantities required were minuscule. Small barrels of "Seneca Oil" could be transported on pack horses. The market quickly changed as oil became a leading source for the production of illuminates to replace whale oil, lard, and ultimately coal oil.

As an extractive industry like coal, oil it seems, usually occurs in obscure locations necessitating the movement of crude oil to refineries and then to market. Thus, transport becomes a critical obstacle in the production of petroleum products. The three case studies focused here, namely the Volcano oil field, the western Pennsylvania oil region, and the Lambton County oil field in Ontario required a means of moving oil. They shared a similar way of transporting crude oil and refined oil.

The Little Kanawha River, a small tributary of the Ohio River, but exceeding 150 miles in length, was a source of transporting oil in the early days. It allowed settlement to the interior of what is now West Virginia beginning before the American Revolution. Its shallow and convoluted course precluded it from becoming a major artery of commerce and industry. Nevertheless, as early as 1820, David Creel, a representative of Wood County, submitted a bill to the Virginia Assembly to convert the Little Kanawha River to a slackwater navigation rather than a free-flowing uncontrolled river. After much delay, in 1847, the Virginia Assembly authorized the formation of the Little Kanawha Navigation Company. Although numerous extensions to the act kept the vision alive, there was little progress. As the threat of war subsided by 1865, it allowed improvements to be made under the aegis of the new state of West Virginia.

The limited improvements made benefitted the oil industry, especially after the slack-water system of four locks and dams was opened for commerce in 1874.

With the discovery and production of oil in the Burning Springs, Volcano, and Hughes River regions, traditional means were used. Despite its treacherous channel, rafts and barges loaded with oil barrels made their way to refineries in Parkersburg. At one point, an ill-conceived system to alleviate jams on the river was undertaken by merely dumping oil barrels in the river and following them downstream to Parkersburg. This method resulted in numerous lost barrels and others broken up in countless snags. Excessive losses resulted in the early abandonment of the dumping method. After unloading at Parkersburg, the barges and rafts were hauled back to the oil fields by horses pulling the rafts along the river bed. It was an arduous undertaking for both man and beast.

In the Oil Creek area of Pennsylvania, rafts and barges were commonplace as oil moved to Oil City on the Allegheny River. Oil Creek, like the Little Kanawha River, presented the prospect of no movement on the creek because of low water during the dry season of the year. To overcome this difficulty, the freshet procedure was used. This dated back more than 400 years, to when French lumbermen floated lumber on the Yonne River by releasing water successively from one river dam to the next. A great flotilla of logs thus reached the Seine at the confluence of the Seine and the Yonne. Single gates installed in dams allowed a sudden discharge of water to pass down stream carrying vessels on the flood tide to the next dam and so on down stream. A rise of 20-30 inches on Oil Creek provided a public spectacle as the barge flotilla was swept down the stream. Lead barges often wrecked because they had not caught the full rise of the flood. These barges often stranded on sand bars and were usually demolished by successive vessels coming downstream on the freshet.

Although expensive, barrels proved to be a secure means of moving oil. Bulk transport seemed to offer a cheaper means of delivery, but leakage and loss of oil caused by wrecks discouraged the use of bulk transport. Larger navigable rivers such as the Ohio and Allegheny featured bulk transport in specially constructed vessels. The features usually were a series of individual tanks that would preclude the surging movement of oil, which if severe enough could even capsize a vessel.

The land-locked fields at Oil Springs and Petrolia, in southwestern Ontario, relied on specially designed horse-drawn wagons to deliver oil from the wells to the refinery near Petrolia. Before the appearance of rail or pipeline as a means of moving oil, a plank road of some 20 miles provided a more efficient means of getting to oil refineries, which were later located in Sarnia where Great Lake shipping was available. A number of these Canadian oil wagons remain on display at The Petrolia Discovery as a poignant reminder of this phase of the oil industry. In a similar manner, teams of horses drew barrels of oil from Burning Springs, Volcano, and the Hughes River region in West Virginia 36 miles to Parkersburg especially when shipping was not available on the Little Kanawha River.

To understand the leading role played by the western Pennsylvania oil fields and the magnitude of oil transported to Pittsburgh, it should be noted that beginning with Drake's well in 1859, the production burgeoned as recorded:

1862 - 172,000 barrels
1863 - 175,000 barrels
1864 - 268,000 barrels
1865 - 630,250 barrels
1866 - 1,250,000 barrels,
a decade maximum

The Great Lakes provided the means for American and Canadian oil companies to transport oil over a vast inland region. It was in this period that oil tankers made their appearance. From modest beginnings, giant oil tankers are amongst the largest ships at sea in the 21st century.

Railways offered an efficient and economic solution to oil transport not only to regional refineries, but to large population centers. At first, rail cars carried barrels racked up on flat cars which quickly gave way to the Densmore type tank car, which consisted of a pair of wooden tanks mounted on a flat car. These bore a close relationship to twin containers used to haul iron ore and coal in the early days of the railroads. The first shipment using these cars occurred in 1865, with a cargo with nearly 100 barrels from the western Pennsylvania field to New York City. Wooden tanks leaked so the original Densmore tank car was transformed to riveted wrought iron tanks. This precluded leakage in transit, but did not overcome a serious safety issue when the oil "sloshed" around in these open-topped tanks (resulting from the uneven tracks in the oil fields) and were quite dangerous in the case of a derailment or train wreck. The modern horizontal iron, and later steel, tank car made its appearance in late 1868. An earlier version resembled a box car with a 3/8-inch wrought-iron U-shaped bottom and wooden sides. A light floating unit on top was suspended a short distance below the sills whose primary function was to prevent an oil surge from over topping the tank. Credited to J. F. Keeler, this design was never popular and was quickly superseded by the ubiquitous horizontal boiler-type tank car so familiar to this day in North American railways.

Railways provided an all-weather means of transporting oil and petroleum products and later chemical solvents resulting from the petrochemical industry. In the case of Burning Springs, Volcano, and Hughes River oil field, the Northwestern Virginia Railroad passed near this field from Grafton to Parkersburg. Later, several branched lines off this B&O trunk line were constructed including the Laurel Fork and Sand Hill line and the Grahame Crystallized Rock Oil Company. This later line exploited rock asphalt, asphaltum, found in limited qualities in the area. Completed in 1898, the Little Kanawha Valley Railway reached Palestine and the oil fields in a direct link to Parkersburg.

North of the border in southwestern Ontario, the Great Western Railway line from London to Sarnia passed north of Petrolia and Oil Springs. To ensure the success of refineries at Petrolia and other commercial interests, a branch line connected Petrolia with the main line at Wyoming. Farther south, the Canada Southern Railway provided a link to its line from London to Windsor which passed from Dawn Twp. and Oil Springs into Petrolia. These companies were later absorbed by the Canadian National and Michigan Central railways. Thus, the area, at an early date, enjoyed two links for oil delivery. Still extant is a rare oil transfer point in Oil Springs for teamsters with oil wagons to discharge their oil, which was then transferred to awaiting railway tank cars.

The 1860s rail maps symbolize the cutthroat laissez-faire conditions in the infant petroleum industry. Special regional freight rates, kickback payments, and other business devices characterized the transport of oil from western Pennsylvania. The railway companies engaged in economic warfare. The battle was met to control the production of oil not at the well head but to secure the means of distribution and refining. The great Standard Oil Company early on emerged as the victor and effectively controlled the industry thereafter. Even the

Canadian Imperial Oil Company was acquired by Standard Oil Company and became part of its empire.

The railway era thus witnessed the founding by Rockefeller, Andrews, and Flagler, of the Standard Oil Company. Thoenen, in his book History of the Oil and Gas Industry in West Virginia states:

> The phenomenal rise of this company in the refining part of the oil industry, and later the spread of its activities and operations into the production and transportation areas of the business, began with the railroad competition for oil freight. To gain ascendency over their rivals, the railroads were willing to extend to the large refining interests special discriminatory rates that would equalize any disadvantage in the geographic position of the refinery.
>
> Whether the discrimination system originated with the railroads or the refining interests is still a debatable question. Whatever the origin, the control of transportation costs to their advantage permitted a few refiners to grow strong and edge out smaller competitors.
>
> The strategy of the Rockefeller interests in the struggle was based on a few fundamental principles. Starting in Cleveland, Ohio, the location of their first refinery, the Rockefeller, Andrews and Flagler firm absorbed, by purchase, the other refineries there, and became the largest and controlling refinery interest in the area. Then in the position of being one of the largest handlers of oil, they induced the competing railroads to give them special rates, rebates, and other considerations.
>
> During 1870 the newly created Standard Oil Company absorbed twenty of the twenty-five existing refineries in Cleveland. The fortunate position of Cleveland with its available water route via the lakes and the Erie Canal, enhanced the company's bargaining position with the warring railroads of that area.

## Oil Pipe Lines

Writing in 1905, Charles A. Whiteshot credits General S.D. Karnes of Parkersburg with the design of the first oil pipeline in 1860. For its day, it was a bold conception to run a six-inch diameter line from Burning Springs 36 miles to Parkersburg. Taking advantage of a drop in elevation, the design was to be operated by gravity. There is little doubt that such a system was badly needed, but it was never built. Whiteshot, together with J.L. Hutchinson, discussed the possibility of an oil pipeline with John Dalzell in Titusville. Dalzell later built a successful three-mile long pipeline from Sherman Farm well to the terminus of the rail head at Miller farm in 1875. During this time period, a number of experiments with wood, cast-iron, and wrought-iron pipes were undertaken as well as the possibility of operating systems by gravity.

Thoenen (1964) related a slightly different origin of the oil pipeline by suggesting that Samuel Van Syckel built the first successful pipeline in 1865 running from Pithole to the Miller farm rail head a distance of five miles. The earlier line could not be judged as a technological success since leakage and breaking continually dogged at the system. Despite fierce opposition by teamsters, pipelines were built and operated. Thus, by 1866, or a little later, the combination of rail transport and pipelines radically changed the way oil moved from well head to refinery and then to market. Like the early coal tramways in England, which brought coal to nearby canals or to sea ports for transport to distance places, the first oil pipe line served as an efficient means of gathering oil from numerous wells and delivering oil efficiently. In the case of the Van Syckel pipeline, it could deliver 80 barrels per day in a two-inch diameter pipe. Proudly proclaimed by its owner, the small diameter pipe could do the work of 300 wagon teams per 10-hour day. The rough casting surface of the pipes used by Karns resulted in unacceptable losses of oil in transit. Presumably Van Syckel used threaded joints which eliminated leakage. This system was clearly used later in a long-distance pipeline. The teamsters being threatened with their livelihoods harassed the construction of additional pipelines. A prominent oil pipeline was associated with Henry Harley. Demonstrations destroyed some of the pipelines, and the teamsters claimed legalized robbery of their livelihoods and the infringement of the right of common carriers, nevertheless, Henry Harley persisted in his laying of another pipeline. It was completed from Benninghoff to Shaffer farm, becoming both an engineering and economic success.

Despite Karnes early suggestion of a pipeline to Parkersburg from Volcano, the reality of such a line had to wait until after the Civil War in 1866. The success of the Pithole line encouraged local entrepreneurs to construct the line to Parkersburg. The West Virginia Transportation Company built and operated this line. Rather than introduce competition in the transport of oil to Parkersburg, the West Virginia Transportation Company already controlled rail transport rates on the B&O Railroad. The arrangement clearly resulted in the disadvantage of small producers when, in 1877-78, a rebate program with the Camden Consolidated Oil Company resulted in producers, which were not members of the local Producers Union being excluded from either the railway or the pipeline. It is interesting to note that these systems were later absorbed in the great Standard Oil empire.

In Ontario, a pipeline laid from Petrolia to Sarnia provided a link with the Petrolia refineries and a distribution port on the Great Lakes at Sarnia. Later, oil was pumped to the recently established refineries in Sarnia by the Imperial Oil Company. The pumping machinery from one of the four pumping stations is on display at Petrolia Discovery, a rare survivor of this important aspect of early oil history.

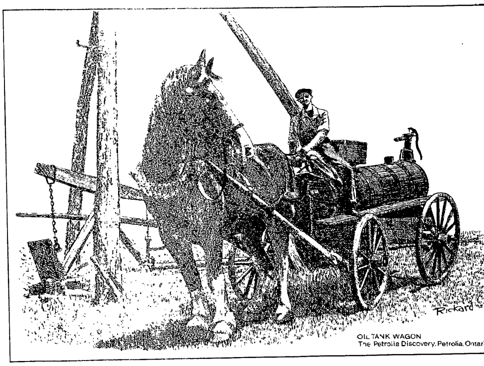
A revolution in pipeline engineering resulted in a continent-wide oil and gas network of pipelines. This movement started in 1881 when Standard Oil opened a major pipeline from Olean, New York, 315 miles to Bayonne, New Jersey, in the greater New York City area. Beginning with a single six-inch line, the system was expanded to a twin line in 1882, followed by a third six-inch pipeline in 1884, and finally a fourth line at the end of the 1880s. This quadruple pipe system had a capacity of 50,000 barrels per day to the New York area. Eleven steam-operated pumps drove the oil through the system, and were spaced at approximately 28 miles to provide the energy necessary to move oil from upstate New York, near the Pennsylvania border to the New York area. While the line, like a Roman road, ran straight over hill and dale and across 34 creeks and numerous streams and topped eight ridges, it kept close proximity to the Erie and the Susquehanna and Western railways so that coal could be delivered cheaply to the pumping stations. Apparently no thought was given to oil-fired boilers at the 11 pumping stations.

While a major advancement in oil transport technology, the construction techniques harken back to the first oil pipelines in the 1860s, and indeed, to the much earlier canal era. The pipe trenches, only 18 inches deep, were dug with oxen and men. In stony locations, the pipe was laid on the ground. A typical crew of 28 men could lay 200 18-foot pipes per day. The technique was not unlike canal and railway construction.

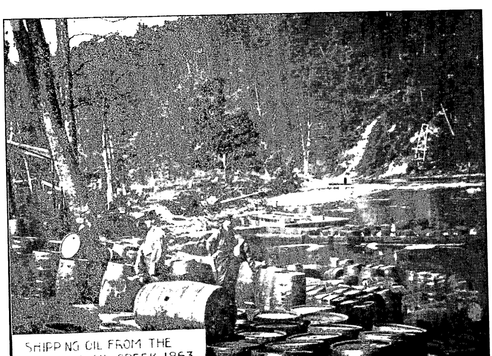
Lap forging formed the basis of the rolled wrought-iron pipe, tested to a bursting pressure of 1,500 psi. The weakness of earlier lines was in the joints, but in this case a tapered thread and socket provided a leak-proof device. The Olean pipeline served with reliability and economy until the last shipment was made in October 1927. The reason for its demise is not difficult to discover. During the 20th century the oil industry shifted to the southwestern part of the United States and came to dominate oil production in the entire country. With ever-larger oil tankers and an abundance supply of oil at Gulf coast ports, it was cheaper to send oil to New York by tanker than by inland pipelines.

By the turn of the 20th century, a network of pipes criss-crossed the middle Atlantic states and extended as far west as Chicago. As the dominance of the Appalachian oil region faded and gave way to the southwestern part of the United States, the network of oil and gas lines stretched from Texas and Oklahoma to the middle Atlantic states and into New England. Canada's export of gas and oil from the prairie provinces penetrated into the United States through a system of pipelines.

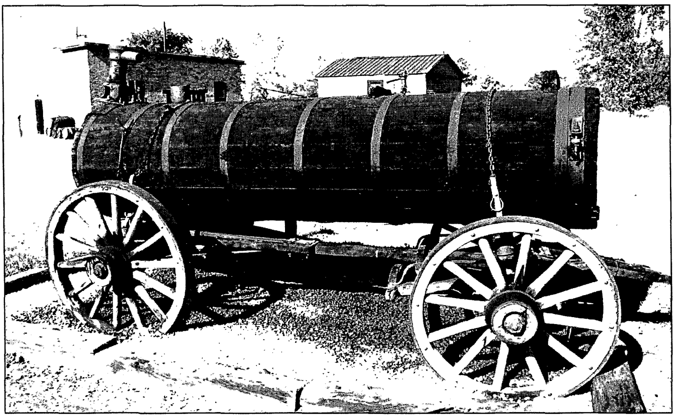
The 20th century also saw the completion of the Alaska pipeline, with its now-common political controversies. Pipelines are features on a worldwide basis and particularly in the Middle East. In many cases, these pipelines bring oil from vast land-locked areas across to ocean ports that feed supertankers to meet the world's insatiable appetite for oil products, particularly gasoline.



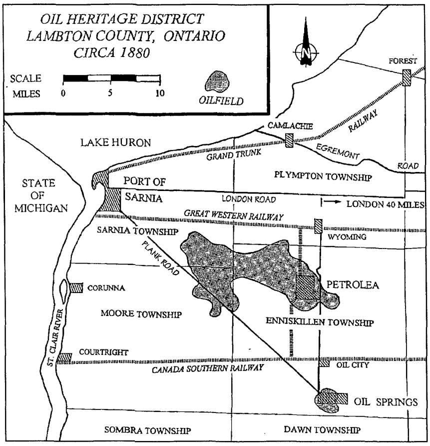

*Wooden oil tank wagon used to collect oil from various wells and transporting to collection stations as well as delivering oil over longer distances on the plank road to Sarnia and Wyoming in Ontario. Illustration by George Rickard.*



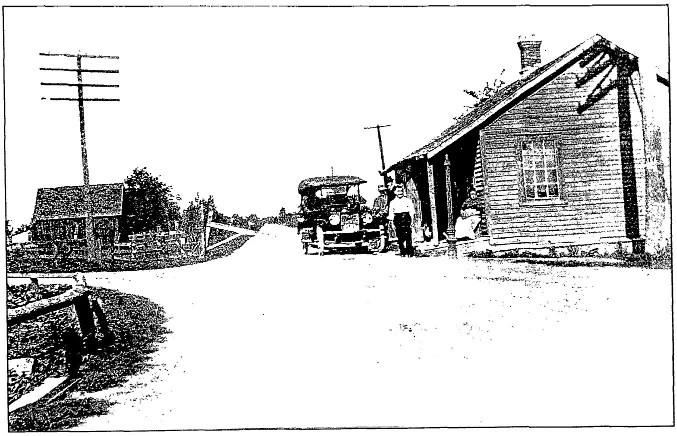

*Shipping oil from the Story farm, Oil Creek, Pennsylvania, 1863. Note the oil barrels which were the only means of transporting the oil at the time.*



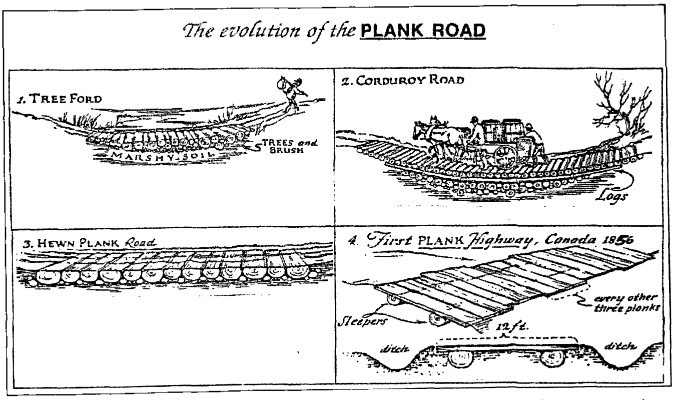
An oil tank wagon at Petrolia discovery.



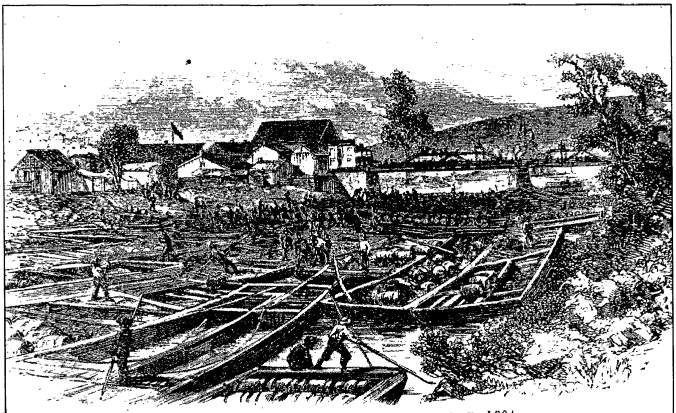

A map showing the plank roads from Oil Springs to Sarnia and from Oil Springs and Petrolia, to Wyoming to join railway connections.



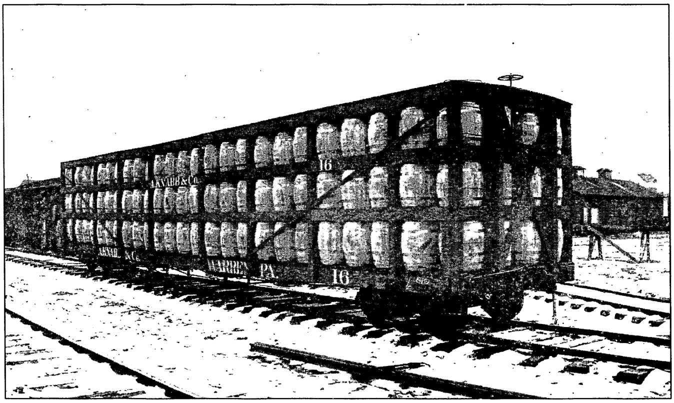
An early 20th century photograph of the toll gate on the plank road to Sarnia.



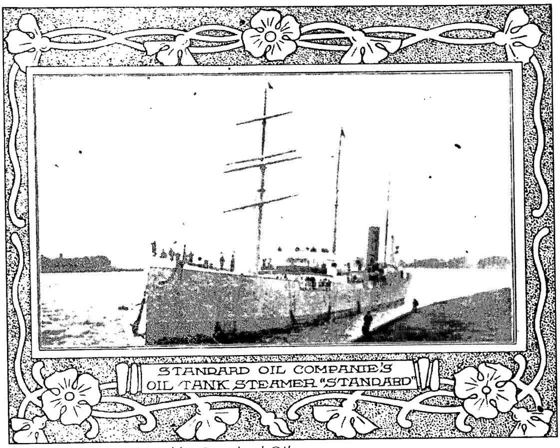

Details of various forms of wooden roads. The hewn plank road most nearly represents the two roads in Lambton County, Ontario.



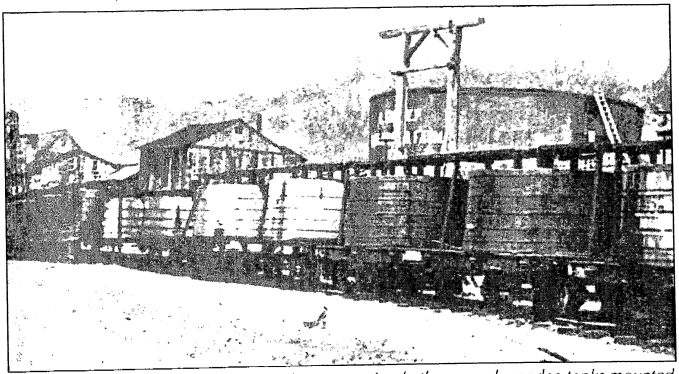

The great traffic jam when a pond freshet was released in oil creek, Pennsylvania.




Rare photograph of a railcar transporting barrels of oil.




*An early tanker owned by Standard Oil.*



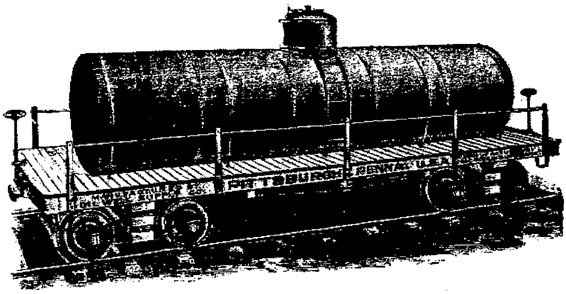
*The Densmore type railroad tank car. These were simply the normal wooden tanks mounted on flatcars. Similar arrangements were used for dry goods such as iron ore and limestone on other railway systems.*

OIL WELL SUPPLY CO., PITTSBURGH, U. S. A. 307

## OIL STORAGE AND TRANSPORTATION

TANK CAR

Fig. 9161



We furnish tank cars in any size with steel tanks from 4,000 to 6,600 gallons, mounted on trucks of 40,000 and 60,000 pounds carrying capacity, master car builders' standard, with air brakes. Prices furnished on specification.

### STEEL SHIPPING DRUM

Fig. 9154

With heavy hoops for rolling

PLAIN—ASBESTOS PAINTED OUTSIDE

| Capacity gallons | Dimensions over all: Diam., inches | Dimensions over all: Height, inches | Weight lbs. | Price |
|---|---|---|---|---|
| 5¼ | 11½ | 17½ | 17.7 | $2 50 |
| 10¼ | 14 | 20¾ | 21 | 3 25 |
| 15¼ | 15⅞ | 22¾ | 30 | 4 25 |
| 20¼ | 17⅛ | 26½ | 34.6 | 5 25 |
| 25¼ | 18¾ | 28¾ | 41.6 | 6 25 |
| 30¼ | 18⅞ | 29⅞ | 38 | 7 25 |
| GALVANIZED—INSIDE AND OUT | | | | |
| 5¼ | 11½ | 17½ | 19 | 3 25 |
| 10¼ | 14 | 20¾ | 27 | 4 25 |
| 15¼ | 15⅞ | 22¾ | 34 | 5 60 |
| 20¼ | 17⅛ | 26¾ | 39.5 | 7 00 |
| 25¼ | 18¾ | 28¾ | 48.5 | 8 50 |
| 30¼ | 18⅞ | 29¾ | 58 | 9 50 |

### MAILING CASES AND BOTTLES

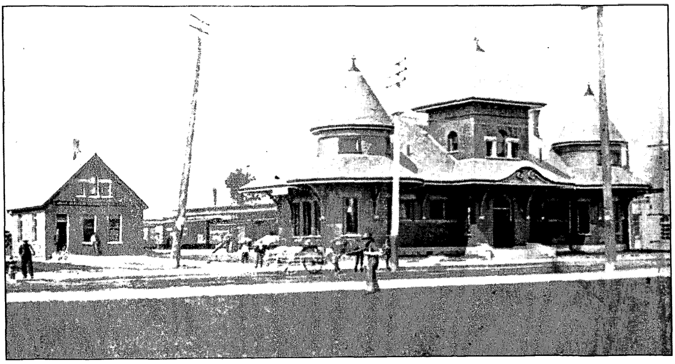
For samples of oil

Fig. 9156

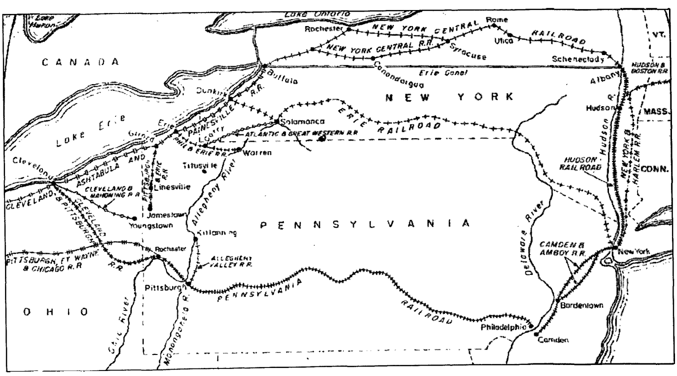
| No. | Capacity | Cases only: Per doz. | Cases only: Per 100 | Bottles only: Per doz. | Bottles only: Per 100 | Corks only per 100 |
|---|---|---|---|---|---|---|
| 560 | 2-oz | $1 45 | 8 00 | 90 | 5 50 | 60 |
| 583 | 4-oz | 1 95 | 10 00 | 1 20 | 7 50 | 60 |



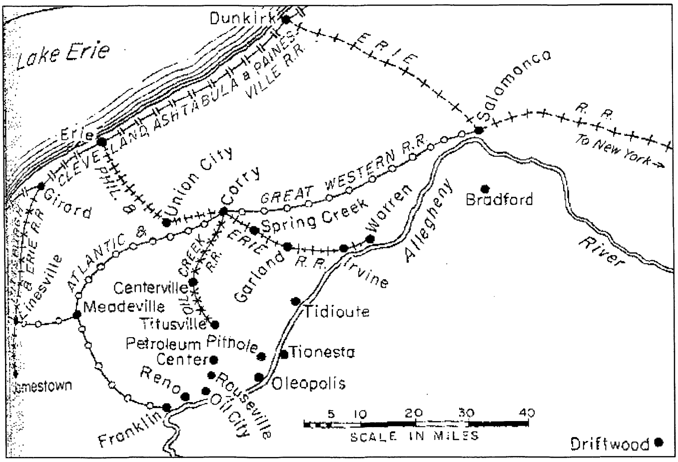
*A familiar tank car which superseded the earlier Densmore type. Also shown are dimensions of standard steel shipping drums.*



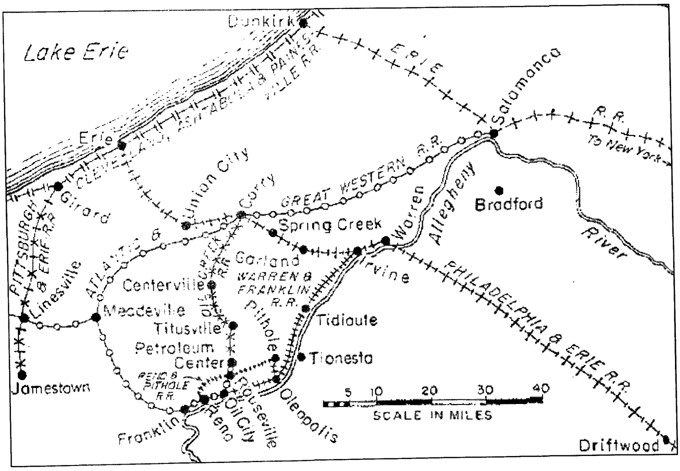
*A view of the Grand Trunk Railway terminus in Petrolia which serviced the large number of refineries in Petrolia.*



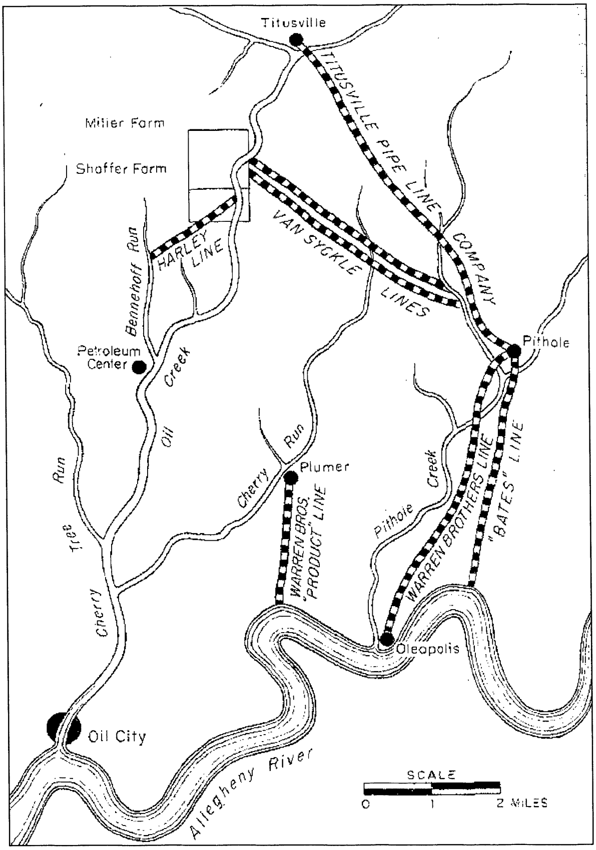

*Major railroad lines between Cleveland and eastern seaboard, 1861.*



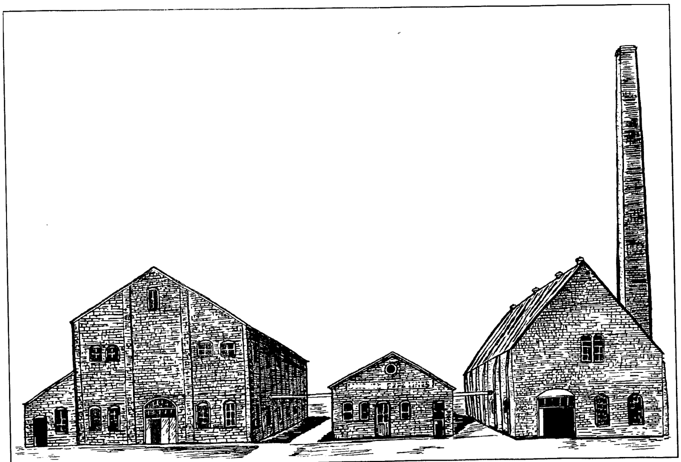

*Railroad facilities in the region, early 1865.*



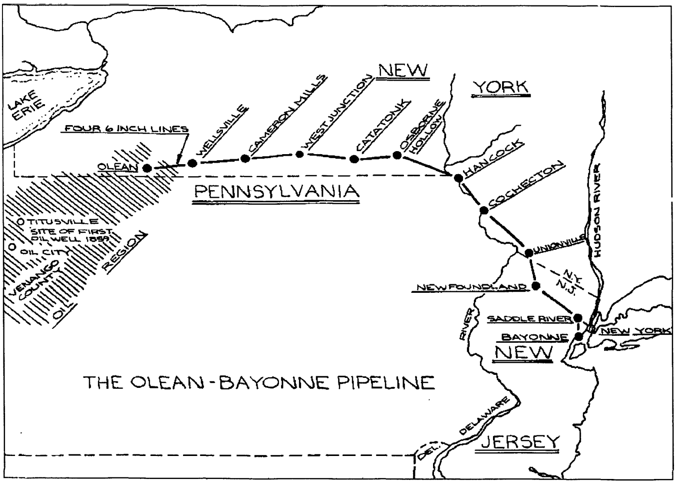

Railroad facilities in the western Pennsylvania region, 1866.



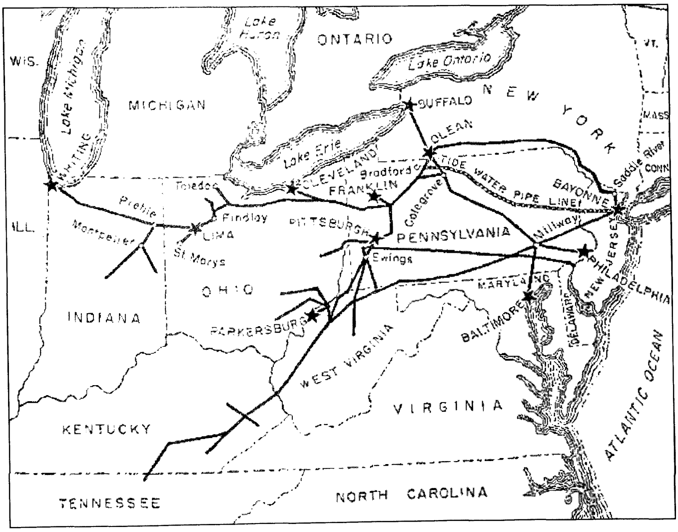

*Pipelines were initially used to bring oil from individual wells to collecting points, which are shown in this map in the western Pennsylvania region.*



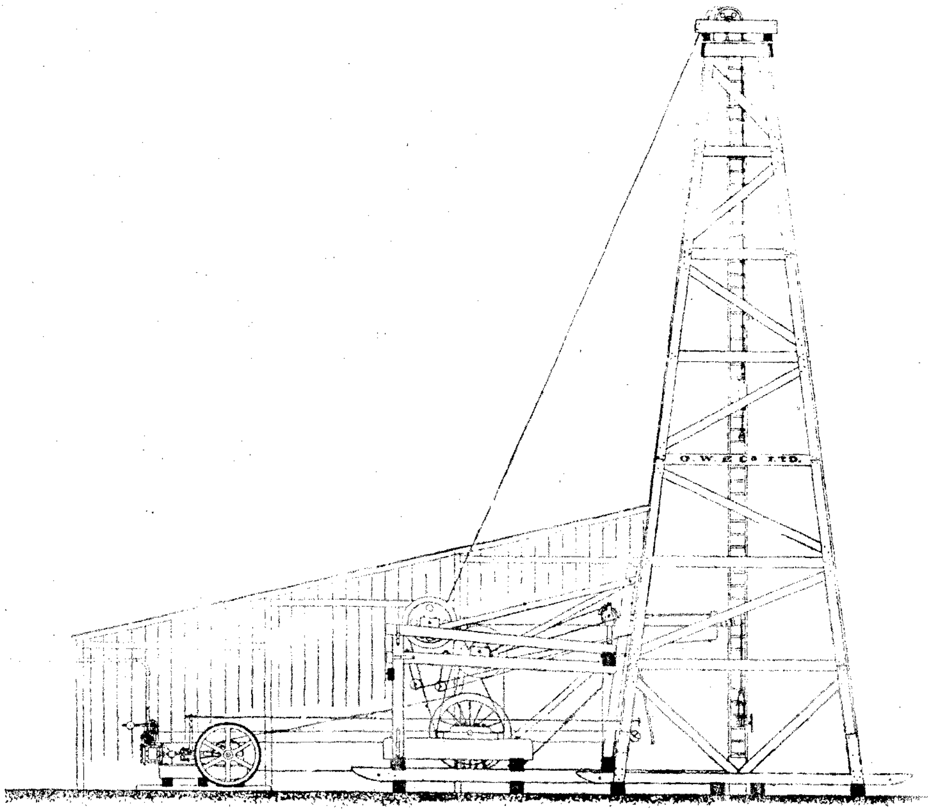
A typical oil pumping station on the Olean to Bayonne pipeline.




*Moving from gathering lines to long distance pipelines, the first oil pipeline of significance supplied oil from the western Pennsylvania field at Olean to Bayonne in the New York city area.*




*Standard trunk line system, circa 1900 in the middle Atlantic states.*



CHAPTER 7

# Summary and Conclusions

## Summary

This historical narrative has sought to emphasize a number of points, namely:

1. With concerns in the 21st century over continued stable supplies of energy, particularly oil, together with related problems regarding pollution, it is little wonder that historians have sought to understand the past record of oil and its influence on society since the 19th century. Such concerns have resulted in numerous publications on the subject ranging from economic and social studies (including the organization of the Standard Oil Trust) to central refining and the transport of oil by road, rail, ships, and finally pipelines. A rich source of information can be gleaned from local and regional histories as well. The number of publications is reflected in the selected bibliography appearing at the end of this work.
2. Despite the rich source of information, the origins, development, and transmissions of technology has not previously been examined in depth. Close links of overseas salt technology is discussed both regarding drilling and remote power transmission in terms of jerker lines, which are still in use in Lambton County, Ontario, Canada. By limiting the study both geographically and to developments in the 19th and early 20th century, the technological history lends itself to three case studies namely; the Volcano field in Virginia (now West Virginia), the extensive western Pennsylvania field, and the comparatively obscure Canadian oil fields at Oil Springs and Petrolia in Ontario, Canada. Thus, the case studies

are restricted to the Appalachia fields in the United States and the Canadian fields in southwestern Ontario. These three fields accounted for the majority of oil production in North American until well into the 20th century when the whole industry in the United States moved south and west and expanded production at unprecedented levels. In Canada at a much later date, oil was discovered in Alberta together with tar sands. These aspects of the industry, mostly after ca. 1900, are reserved for a later study.

3. Following the introductory chapter which sets the stage for early modern oil, drilling technology common to all three case studies is discussed. It begins with the spring pole method, which traces it origins to ancient Chinese quest for water and also brine for salt making. French drilling technology, which appeared not only in France but also in Louisiana, pioneered rotary drilling. This technology for drilling was not used in either the United States or Canada outside the New Orleans area. Whether using the rod or cable system, the early drillers relied on the percussion method, which consists of raising and releasing a string of iron tools to fracture the rock in the bore hole. Progress, by modern standards, was slow and laborious. Nevertheless, impressive depths were reached using the rod and cable systems throughout the early period. In these early days, percussion drilling systems, substituting steam power for manpower, generally replaced the earlier use of the spring pole system. American oil producers quickly turned to the cable system using manila rope, which in turn was replaced with wire rope before ca. 1900. The Canadians, on the other hand, continued with the rod system which was so closely associated with their drilling techniques that it received the sobriquet of the "Canadian method." Power units and other ancillary equipment are featured in the chapter on drilling. While all of the earlier ones were tailor-made and largely produced on site, by the middle and later periods of the 19th century a whole series of manufactured portable drilling rigs became available on the market.

4. The greatest diversity, and as a result, the most interesting aspect of the history of oil production, is found in disparate

methods invented to pump a series of low production wells. The output of many wells did not justify a pumping engine and engine tenders at each well. This led to three different remote serial pumping devices. Moving from south to north, the Volcano field used the endless wire system earlier employed in manufacturing in Europe and later in America. William Stiles adapted this endless wire system to the pumping of numerous wells.

In western Pennsylvania, later in the 19th century and early 20th century, eccentric "powers" were introduced by a number of manufacturers. While the endless wire and jerker line systems were linear, the eccentric powers, were a radial method with rods or jerker lines radiating from the central power source.

While the eccentric powers were factory made, the much earlier jerker line system of 1863 was in all respects locally produced. Essentially unchanged, the method is still in everyday operation in producing fields in Lambton County, Ontario and was in use in remote locals in West Virginia and Ohio. Similar systems for using water power to drive pumps to drain mines and to operate brine wells had their origin in central Europe as early as the 16th century. No direct link can be established between the Germanic system and the Fairbank method, but the intercontinental connections as proposed here are logical.

5. From the very beginning, the transport of oil became a serious obstacle in getting oil and oil products to market. The earliest solution was to use wooden barrels transported by wagons, by rafts, and also by ships. Bulk shipment provided an economic alternative to transportation by individual barrels. This eased the solution until oil financial trusts came to dominate the industry by controlling freight rates and excluding competition. The bulk shipment of oil resulted in preferential rates given to certain producers to the exclusion of others.

   Originally suggested by an oil operator in West Virginia, oil pipelines were first employed in western Pennsylvania. The earliest ones were simply gathering lines from well to storage tanks where the oil could be later moved to refineries or, indeed, to markets. All three case studies enjoyed the benefits of pipeline technology at some stage in their development.

6. Crude oil needs to be processed to provide a wide variety of petroleum products including gasoline, kerosene, and lubricating oil. Distilling techniques were known before the oil age and readily employed to produce oil products. By using high heat, the method of "cracking" resulted in an increased production of lighter fractions of the crude oil such as kerosene and gasoline, an important development in the 20th century age of the automobile. Cracking increased the yield of gasoline from crude oil by as much as 30 percent.

Refined distilled petroleum products required a treatment with sulphuric acid followed by washing and neutralization by caustic soda. During the period under discussion, the first distilling units were retorts fired externally underneath the distilling vessel. The vapors were conducted to a condensing unit. In some cases, for very high quality products, a second distillation was used. Later, long cylindrical distillation units came to dominate the field in both Canada and the United States.

## Conclusion

Our attempt to integrate 19th century oil technology into a common heritage has resulted in new insights into the rise of one of the most important industries in the modern world. By studying all the aspects of the subject, it is clear that much of the technology from the primitive spring pole drilling to various serial systems of pumping low production wells, (and then to distilling and refining) were borrowed from much older traditions in Europe and Asia., and then adapted to the use in the Appalachian/Canadian oil fields. Thus, the real contribution of those involved in oil production is the ingenious way they modified known technologies to suit local conditions.

Faced with similar problems of low-yield "stripper" wells, the jerker line and endless wire systems provided economic solutions. They hinged on the fact that they were very low friction systems, which could be driven by a small horsepower steam engine, gas engine, and later, electric motor. Although eccentric gearing was a well-known mechanical engineering method, the adaptation of the basic idea was unique in the western Pennsylvania oil fields. It was the eccentric powers that lent themselves to production by various machine and foundry companies to exploit an expanding market. In like manner, portable drilling rigs were heavily advertised along with pumping "powers" in oil equipment catalogues. A seminal invention was the procedure developed in the Kanawha Valley salt industry under William Morris who introduced his "slips" or "jars," which are still essential in the drilling of wells.

The worldwide oil industry has the stamp of Canadian oil men from Petrolia and Oil Springs. Seeking larger fields, Canadians established an international oil business in such places as Borneo in Asia, Baku in Russia, oil fields in Romania, and the Austro-Hungarian empire before the First World War, as well as South American ventures by Canadian wildcatters. Those overseas activities by Canadians provide a well-documented example of the transfer of technology. A rich collection of artifacts of this international technological empire are lodged in The Oil Museum of Canada in Oil Springs.

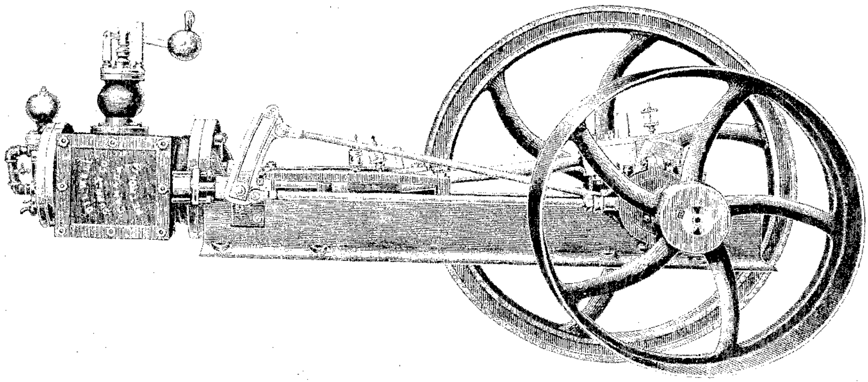
Thus, this study of the rise of the modern oil industry in the 19th and early 20th centuries celebrates the engineering aspect of an essential modern industry, which dominates international trade and has strong economic and political influences to the lives of millions of people on a worldwide basis.

## Oil Production History for the United States (in barrels)

| Year | Pennsylvania | Ohio | West Virginia | National Total |
|---|---|---|---|---|
| 1859 | 8,500* | --- | --- | 8,500 |
| 1860 | 650,000* | --- | --- | 650,000 |
| 1861 | 2,118,000* | --- | --- | 2,118,000 |
| 1862 | 3,056,000* | --- | --- | 3,056,000 |
| 1863 | 2,631,000* | --- | --- | 2,631,000 |
| 1864 | 2,116,200* | --- | --- | 2,116,200 |
| 1865 | 2,497,700* | --- | --- | 2,497,700 |
| 1866 | 3,597,500* | --- | --- | 3,597,500 |
| 1867 | 3,347,300* | --- | --- | 3,347,300 |
| 1868 | 3,715,800* | --- | --- | 3,715,800 |
| 1869 | 4,215,000* | --- | --- | 4,215,000 |
| 1870 | 5,659,000* | --- | --- | 5,659,000 |
| 1871 | 5,795,000* | --- | --- | 5,795,000 |
| 1872 | 6,539,100* | --- | --- | 6,539,100 |
| 1873 | 9,893,786* | --- | --- | 9,893,786 |
| 1874 | 10,926,945* | --- | --- | 10,926,945 |
| 1875 | 8,787,514* | 200,000** | 3,000,000** | 11,987,514 |
| 1876 | 8,969,000* | 32,000 | 120,000 | 9,133,000 |
| 1877 | 13,135,000* | 30,000 | 172,000 | 13,353,000 |
| 1878 | 15,164,000* | 38,000 | 180,000 | 15,379000 |
| 1879 | 19,685,000* | 29,000 | 180,000 | 19,914,000 |
| 1880 | 26,028,000* | 39,000 | 179,000 | 24,601,000 |
| 1881 | 27,376,000* | 34,000 | 151,000 | 26,286,000 |
| 1882 | 23,368,000 | 40,000 | 128,000 | 30,350,000 |
| 1883 | 19,125,000 | 47,000 | 126,000 | 23,450,000 |
| 1884 | 20,541,000 | 90,000 | 90,000 | 24,218,000 |
| 1885 | 18,118,000 | 662,000 | 91,000 | 21,859,000 |
| 1886 | 23,647,000 | 1,783,000 | 102,000 | 28,065,000 |
| 1887 | 20,281,000 | 5,023,000 | 145,000 | 28,283,000 |
| 1888 | 16,489,000* | 10,011,000 | 119,000 | 27,612,000 |
| 1889 | 19,591,000 | 12,472,000 | 544,000 | 35,164,000 |
| 1890 | 28,458,000 | 16,125,000 | 493,000 | 45,1824,000 |
| 1891 | 31,424,000 | 17,740,000 | 2,406,000 | 54,293,000 |

| Year | Pennsylvania | Ohio | West Virginia | National Total |
|---|---|---|---|---|
| 1892 | 27,146,000 | 16,363,000 | 3,810,000 | 50,519,000 |
| 1893 | 19,283,000 | 16,249,000 | 8,446,000 | 48,431,000 |
| 1894 | 18,078,000 | 16,792,000 | 8,577,000 | 49,344,000 |
| 1895 | 18,231,000 | 19,545,000 | 8,120,000 | 52,892,000 |
| 1896 | 19,379,000 | 23,941,000 | 10,020,000 | 60,960,000 |
| 1897 | 17,983,000 | 21,561,000 | 13,090,000 | 60,476,000 |
| 1898 | 14,743,000 | 18,739,000 | 13,615,000 | 55,364,000 |
| 1899 | 13,054,000 | 21,142,000 | 13,911,000 | 57,071,000 |
| 1900 | 13,258,000 | 22,363,000 | 16,196,000*** | 63,621,000 |
| 1900 | 12,625,000 | 21,648,000 | 14,177,000 | 69,389,000 |

* Including New York production  ** Estimated 1859-76  *** Greatest West Virginia production



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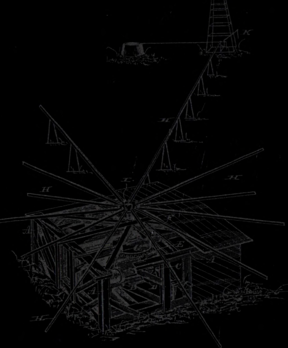

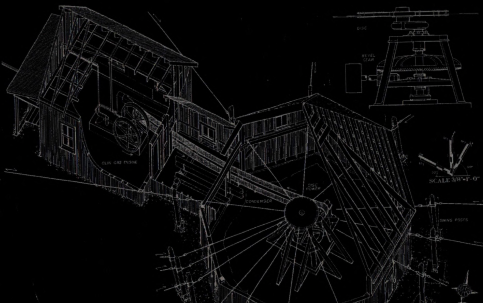
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