# THE NATURAL GAS INDUSTRY IN OKLAHOMA AND THE SOUTHWEST

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Bachelor of Science

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Stillwater, Oklahoma

1949

Submitted to the Department of Geography

Oklahoma Agricultural and Mechanical College

In Partial Fulfillment of the Requirements

for the Degree of

Master of Science

1950

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PREFACE

This study is an outgrowth of early experiences of the writer. He spent his youth in the San Luis Valley in southern Colorado where the only fuels commonly used were wood and coal. He became acquainted with natural gas upon being employed as a chemist by the Gramps Refining Company, Alamosa, Colorado, in 1941. The comparative advantages of natural gas as an industrial fuel were immediately apparent. Later in Oklahoma, the convenience of natural gas as a household fuel made a further impression and kindled a growing desire to know the true significance of this source of energy which was accepted so casually by native Oklahomans. The desire was stimulated by the growing realization that Oklahoma needs to develop her industries in order to create a well balanced economy.

This research problem was attempted in the hope of determining the true importance of natural gas to Oklahoma and of Oklahoma's natural gas to others. Oklahoma's industry, however, is so related to and affected by production in other southwestern states that a reliable analysis must consider also these other producing areas.

What are the present and potential uses of natural gas? How great and dependable are the reserves? What are the problems of exploration, production, distribution, and consumption? This study will attempt to analyze these problems, but above all, it will seek to determine the best uses of this great power resource for the development of the state of Oklahoma and the advancement of the welfare of Oklahomans.

Certain related aspects that are influential upon but not a component part of the natural gas industry have been omitted. No attempt is made to discuss technologic methods in detail, as they are beyond the scope of this study. The public utility rules and regulations are an entity outside the industry and are regarded only through their limiting effect on the magnitude and the functions of the natural gas industry. The scope of the consuming branch of the industry was limited to the general types of consumers, as beyond this point the study becomes one of marketing and public utility functions which were regarded as a separate field of study. Labor is given only brief mention as the Oklahoma natural gas industry employed only 420 full-time workers in dry gas production in 1940 and 1941. The petroleum industry had more than 15,000 workers during this same period but it was impossible to separate the labor responsible for the production of wet gas from that which was producing petroleum.

The writer wishes to express his indebtedness to R. W. Boyd, Manager, Tide Water Associated Oil Company; Ruel S. Harris, Manager, Gas Department, Shell Oil Company; Robert P. Reid, Accountant, Phillips Petroleum Company; Prof. Leonard F. Sheerar, Director, Division of State and Industrial Planning, Oklahoma Planning and Resources Board; Ray L. Six, Associate Professor of Geology, Oklahoma A. and M. College; Elmer E. Capshaw, Gas Engineer, Oklahoma Corporation Commission; The Honorable Robert S. Kerr, United States Senator from Oklahoma; and to the Library Staff of Oklahoma A. and M. College for their aid in this study.

Particular thanks are due Professor Robert C. Fite who ably assisted the writer in this study, to Doctor Edward E. Keso for his aid in the final arrangement of the thesis, and to Professor George S. Corfield for his guidance in the use of source materials.

The writer especially acknowledges the encouragement and patient assistance given by his wife, Jaclyn Louise Hyde, who aided in typing and correcting the manuscript.

Emmett J. Hyde

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# INTRODUCTION

Natural gas has risen in the last fifty years from a nuisance frequently associated with oil discovery to an industry that turns the wheels of fortune and vibrates the halls of Congress. Enormous quantities of natural gas that once was flared over the landscape is now harnessed by industry to produce heat, light, and power and pour new wealth into the coffers of Oklahoma and other states of the Southwest.[1] The industry's distribution system etches the landscape with pipe lines from New York to California. Even the local citizen, who grew up among wildcats, gushers, and boom towns, sometimes does not know that those lines are part of a billion dollar industry. In spite of the paramount importance of natural gas, its production, conservation, and utilization has been ignored too frequently in preference for the simpler and more lucrative production of petroleum.

## Organization of the Study

The various functions of the natural gas industry logically fall into a well defined pattern. The first function, that of production, must actually exist before the industry can become an entity. The activities of exploration, acquisition of drilling rights and the actual drilling operations become complimentary factors of production.

Production must be developed before transmission facilities can be provided; yet the extreme fluidity of natural gas renders it most difficult to transport.

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[1]The "Southwest," as defined for this paper, includes the states of Texas, Louisiana, Oklahoma, Kansas, and New Mexico. Geographic terminology sometimes includes the states of Colorado and Arkansas, but their production of natural gas is so limited that their influence on this study is negligible.

The only means that has been devised to transport natural gas economically is through expensive high-pressure pipe lines.

The potential consuming markets for natural gas have no significance until production has been developed. These areas become actual markets after they have been connected with production by adequate pipe line facilities.

The ultimate value of the complimentary functions--production, transportation, and consumption--depends on the stability of this source of energy. Proven reserves assure the market of a fixed deliverable quantity of natural gas over a definite period of time. It seems logical to evaluate the natural gas industry through careful consideration of the four subdivisions: production, transportation, consumption, and reserves.

## Source Materials

Special attention is directed to the pioneering work by Elmer E. Capshaw, Gas Engineer for the Oklahoma Corporation Commission. Mr. Capshaw prepared *Exhibit No. 146, Natural Gas Investigation,* for a special report presented to the Federal Power Commission. The work consists of a geologic report on the production and reserves of twelve pools having reserves in excess of twenty billion cubic feet of natural gas in 1945. This work has been drawn on heavily for basic materials in the analysis of Oklahoma's natural gas industry. More recent data have been drawn from a variety of sources to supplement Mr. Capshaw's report and to aid in a more complete analysis of the industry.

Personal interviews and correspondence with men associated with the problems of natural gas provided much information of the more elusory nature. Sources of data most helpful among government publications were the documents of the Federal Power Commission and the Department of Interior. The primary state documents were the publications by the Oklahoma Planning and Resources

Board. Trade journals of the petroleum industry are numerous and carry information of the most recent nature about the natural gas industry.

## Nature of Natural Gas

Natural gas, a gaseous hydrocarbon mixture, is composed primarily of methane and ethane and contains other gaseous substances in varying quantities and qualities. The origin, amount or extent is not known. It is recovered from subsurface strata either in a relatively pure state or in association with petroleum.

A typical analysis of Oklahoma's natural gas is 86 per cent methane, 10 per cent ethane and the remainder made up of such gases as hydrogen, carbon dioxide and oxygen.[2] Varying amounts of propane and butane may be present and are removed in the form of liquified petroleum gas which is referred to in the industry as LPG. Pentane, Hexane, and heptane are removed, if present, in the form of "natural" or "casinghead" gasoline. Nitrogen and carbon dioxide are not removed, but if the gas has a resultant low B.t.u. because of an excess of these constituents, it is not used in transmission lines.

Natural gas is classified as "dry," "lean," or "wet" according to the quantity of natural gasoline present. Gas containing less than one-tenth gallon of gasoline vapors per thousand cubic feet is "dry" gas. "Lean" gas contains from one-tenth to three-tenths gallon per thousand cubic feet. "Wet" gas contains more than three-tenths gallon of gasoline vapors per thousand cubic feet. Wet gas flows from an oil well and is collected at the mouth of the well as "casinghead" gas.[3] This gas may be treated to remove the liquid

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[2]Mineral Resources 1946, Oklahoma Planning and Resources Board, p. 23.

[3]Henry A. Ley (ed.), Geology of Natural Gas (1935), pp. 1074-76.

fractions known as casinghead or natural gasoline and the remaining is known as "residue" gas.

The amount of hydrogen sulfide present determines whether or not the gas is "sweet" or "sour." "Sour" gas is differentiated from "sweet" gas because it contains more than ten grains of hydrogen sulfide per thousand cubic feet of natural gas. "Sour" gas is seldom used in its raw state, except by the carbon black industry, because of its corrosive and lethal qualities. Removal of the hydrogen sulfide may cost as much as three cents per thousand cubic feet. The carbon black industry uses this gas in its raw form and consumes much of the "sour" gas production.

When gas was found in early oil wells, the driller regarded the discovery with the same disparity that existed whenever the well was a "dry hole." The majority of early operators could not market the gas and generally allowed the well to flow freely in the hope that it would "drill itself in," as petroleum sometimes followed the unchecked flow of natural gas. This waste of gas was tremendous and reduced the energy available to force petroleum from the well. Great care is used in modern fields to maintain a high gas pressure if possible. Through proration and unitization, the production of gas or oil is carefully controlled by regulatory bodies or by agreement among a majority of the operators.[4]

Gas rights are sometimes divided unequally among a number of people. The share of the proceeds from production, or the "royalty," is divided among the holders of the mineral rights in proportion to the share of the producing area held by each owner.

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[4]A discussion of this phase of the natural gas industry is given in Nelson Lee Smith and Harrington Wimberly, United States Federal Power Commission Docket G-580, Natural Gas Investigation Report (1948), pp. 66-79.

The natural gas industry of the United States is largely confined to the Southwest. This area produces most of the gas, consumes more than half of the production and provides most of the natural gas in interstate commerce. Texas is the largest state in all three functions. Of the twelve largest gas fields having more than 50 per cent of the reserves in the United States, nine are in Texas. Louisiana, Oklahoma, Kansas, and California are also notable producers, consumers and, excluding California, exporters of natural gas.

Oklahoma's major natural gas region is in Texas County. Much of the gas produced here is exported to midwestern markets. Other major fields are located in the central and south-central portion of the state where they are primarily utilized in the production of petroleum with some residue gases being marketed. These pools represent potential power within an area of undeveloped industrial resources.

The Nemaha Ridge divides the state into the older producing area to the east and the relatively untapped area known as the Anadarko Basin to the west (Fig. 3, page 94). Recent activity in the Elk City field has strengthened the belief, that with increased depth of drilling, this area is one of the major potential regions from which added supplies of natural gas are possible.

The development of this region is based on the phenomenal improvements in the technology of the natural gas industry. Oklahoma was the first southwestern state to become a leader in natural gas production in the United States. This industry is surpassed in value only by petroleum among Oklahoma's mineral products.

# CHAPTER II

## THE HISTORY OF NATURAL GAS

A knowledge of some of the events causing revolutionary changes in fuel consumption in the United States is necessary to understand the problems of the natural gas industry. The evolution has been from the extremely simple to the exceedingly complex. Even our leading statesmen cannot agree in the halls of government as to how it shall be best utilized in the service of mankind.

Ancient peoples knew of natural gas but were frightened by its weird, ill-smelling properties when it issued from the earth. It was not unnatural when they either avoided it entirely or accepted it as a gift from whatever gods they knew and regarded it with reverence.[1] One such adaption of these gas seeps was made by the Fire Worshipers of ancient Persia. This religion was revived in Biblical times by the Magi who were Zoarastrian priests and astrologers as early as 1,000 B. C. The elaborate ritual centered about the "eternal fire" that burned near the great temple at Baku on the shores of the Caspian Sea.[2]

Many students of the ancient Greeks agree that the "mephytic vapors" inhaled by soothsayers were natural gas "seeps." The vapors, then as now, produced unconsciousness and the visions which followed were thought to be of divine origin.

The Chinese were the first entrepreneurs of natural gas. In their quest for salt brine they drilled holes deep in the earth, some believed to be in

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[1]S. J. Magee, "The History of Gas," Bradstreet's, LXVI (July 21, 1928), p. 483.

[2]Max W. Ball, This Fascinating Oil Business (1940), p. 317.

excess of one thousand feet deep. The method used the same principle of lifting a heavy rod and dropping it to crush the rock deep underground, that is known today as the cable tool drilling rig. Natural gas issued from some of these wells. The Chinese also developed the first natural gas pipe line by leading gas through bamboo tubes to their salt pans where it was burned to hasten the evaporation of the water. The Japanese had salt wells as early as 615 A.D., but the gas found was not used.

The city of Genoa, Italy, was one of the first recorded places in western Europe to use natural gas. The city had lights in 1802 from natural gas brought from wells and "seeps" at Amiano on the Taro, in Parma.[3]

The odors of sour natural gas are somewhat reminiscent of sulfur. Religious persons, inhaling natural gas, logically deduced these unnatural emanations were from hell and surrounded the progress of the industry with superstition and sorcery for centuries. Any person attempting to use and control natural gas was plainly a disciple of the devil.

## Early American History

The early colonists of this country made many references to natural gas among their writings but considered it a phenomenon without earthly use. The French Jesuit Priests in their travels in the Ohio Valley reported burning pillars of fire that were probably burning natural gas seeps.[4] A tract of land in West Virginia which had natural gas entering its springs was dedicated

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[3]Maynard M. Stephens and Oscar F. Spencer, Natural Gas Engineering (III, 2d ed., 1948), pp. 1-2.

[4]C. C. Brown, "Natural Gas," Gas Age Record, IV (January 5, 1929), cited in Maynard M. Stephens and Oscar F. Spencer, Natural Gas Engineering (III, 2d ed., 1948), p. 3.

as a National Park by George Washington in 1775.[5]

The modern phase of the natural gas industry began in 1821, about forty miles from Buffalo, New York, at the little farm village of Fredonia. Numerous stories have arisen from the legendary discovery of natural gas in this country. Most of them agree that small boys cast burning branches into Canadaway Creek near Fredonia only to have it burst into flame. Most of the local citizens were awed by this unnatural phenomenon and avoided the creek. One pioneer, needing a water supply, set about digging in the creek bottom to divert some of the stream. His efforts were rewarded by large bubbles coming from the channel he was digging. The pioneer decided his need of water was not so great and departed hastily.

A gunsmith, William Arron Hart, heard of the peculiar bubbles. He made a strong drill and proceeded to dig into the shale bottom of the creek. After sticking a bit in the shale, he moved to a nearby site and drilled the first of many dry holes. Mr. Hart then moved again and struck America's first natural gas well--at a depth of 17 feet. He drilled for ten more feet and inserted a lead pipe long enough to extend 25 feet out of the well into a device that demonstrates American ingenuity at its best. The device consisted of a pit in solid rock filled with water, and upon which floated a square sheet-iron tank of some 1200 gallons capacity. Gas from the well was piped into the tank which was open at the bottom, and as gas was withdrawn, the tank settled into the water measuring the remaining quantity of gas. A three-quarter inch lead pipe was installed to the village located a few hundred feet away.

The first consumer of natural gas was a tavern. The tavern had a burner

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[5]Louis Stotz and Alexander Jamison, History of the Gas Industry (1938), p. 69.

with five jets that gave as much light as ten candles. Burning of natural gas probably was received with comparable awe to that of the atomic explosions some 124 years later. The popularity of Fredonia's "catastrophic lights" drew hundreds of stage-coach tourists to behold and marvel. Just as the taverns 128 years later were forced to add television to meet the competition of their competitors, the shops opposite the Abel House, where America's first natural gas was utilized in a commercial endeavor, had to add gas lights. Curiously enough, the thirty-six clear gas lights each cost less than half the price of a candle.[6]

William Tompkins took a page from Chinese history by becoming the first industrial user in the United States when he evaporated salt water by natural gas heat.[7]

Colonel Drake's well at Titusville, Pennsylvania,in 1859, stimulated the natural gas industry by turning the efforts of Americans toward perfecting better methods and equipment for drilling wells. Much natural gas in Pennsylvania and Ohio was reported at an early date to have been used to fire boilers, or light and heat houses.

Several factories at Erie, Pennsylvania, were using natural gas from a nearby well in 1860. The superiority of natural gas as a fuel was soon recognized. Many other factories over the eastern part of the United States adapted its use wherever cleanliness and careful heat control was necessary to a manufacturing process. The slow appreciation was suddenly replaced by enthusiasm and there was a rush of capital into the industry; large sums of money were

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[6]Charles Morrow Wilson, Oil Across the World (1946), pp. 27-30.

[7]C. Woody Thompson and Wendell R. Smith, Public Utility Economics (1941), p. 18.

invested in gas territory, gas wells, and pipe lines.[8] The gas industry failed to develop as a cognizant part of the petroleum industry until the latter part of the Nineteenth Century.

Pennsylvania, West Virginia, Indiana, and Ohio produced 94 per cent of the value of natural gas in 1903. Indiana's production had declined from the previous year while the others had increased. The United States' production in 1903 was 99.3 per cent of the entire world's total production with the remainder produced in Canada. Gas production in that year was estimated to be equivalent to almost 12 million tons of bituminous coal.

There were 627,047 domestic consumers and 7,222 manufacturers using heat, light, and power from natural gas in 1903. Almost 4.5 million people were believed to be benefited from this new fuel.[9]

The Appalachian area still lead in production in 1910. Over seventy million dollars worth of gas was produced in that year. The ranking states were West Virginia, Pennsylvania, Kansas, Ohio, and Oklahoma. The mid-continent gas industry became united by the influence of eastern management and capital by 1912.

There was an excess supply of natural gas developed in the United States until 1933. This problem was not one for the producer, as he had always done his job too well, but one of transportation for the transmission lines were even at this late date far behind the need to serve America.

Early Transmission.--The early gas wells were handled for the most part by unskilled men. Men in search of oil have allowed untold billions of cubic

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[8] F. H. Oliphant, Mineral Resources of the United States (1902), p. 631.

[9] F. H. Oliphant, Mineral Resources of the United States (1903), p. 719.

feet of natural gas to escape in the hope that oil would follow. Had there been even an elementary knowledge of the engineering principles involved in the transmission of natural gas, the history of this industry would undoubtedly be another story. An early contractor attempted to furnish a gas light for a lighthouse but failed because he could not get the gas to flow down hill from the well to the beach, as he had no means of applying pressure.

Early pipes were made from choice pine logs, turned and bored to proper size inside and out. One such log system was recently removed at Marietta, Ohio, after seventy-three years of service. The first attempt at a long-distance metal conduit was a 2-inch line from a well five miles from Titusville, Pennsylvania, in 1872.[10] A ceramics industry in East Liverpool, Ohio, installed gas burners in 1873 using similar lines from nearby fields. The Etna Iron Works of Etna, Pennsylvania, laid a 6-inch pipe for seventeen miles from the Butler County fields in 1876. Over 335 miles of pipe line were owned by one company in Pittsburgh as early as 1884. One year later, ninety-one mills and factories in Pittsburgh were using natural gas.[11]

George Westinghouse organized the Equitable Gas Company of Pittsburgh about this time. By 1890, his company had a 36-inch line extending from twenty-one miles south of the city. The problem of obtaining large diameter pipe soon became acute, as cast iron pipe was not practical for high pressures, and screw-joint pipe was limited to much smaller diameters. A coupling joint was soon perfected and marketed which is still being used. The construction of the first 36-inch line was from one-quarter inch steel plates riveted together like a boiler. Compressor stations evolved about this time and the industry

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[10] Thompson and Smith, op. cit., pp. 18-19.

[11] Stephens and Spencer, op. cit., pp. 7-8.

began to extend itself.

Use for illumination, although popular, is not a great consumer of natural gas. The greatest development was in the industrial field. Industries needed large amounts of natural gas in relatively short periods of time. As a result, many short wrought iron lines, of less than 8-inch diameter and carrying pressures under 80 pounds per square inch, were constructed. Commercialization of natural gas remained focused on the Appalachian area, but fields in Indiana and Illinois were developing rapidly.

The Indiana Natural Gas and Oil Company laid two parallel 8-inch pipe lines from wells near Greentown, Indiana, to Chicago, in 1891. These 120-mile lines were made from wrought iron with screw couplings. Booster stations were not used but a compression station at the source provided an initial pressure of 524 pounds per square inch. This high-pressure transmission line marked a new era for natural gas.[12]

Early Measuring Systems.--The common opinion of early natural gas users was that the resource was inexhaustable. Such an idea lead to the belief that since it was produced at little cost, it should be made available at low prices. It was not measured in most cases because meters had not been perfected.

The early methods of charging for gas were a flat rate per dwelling, or by the more scientific means of considering the number of fires per dwelling. The quantity consumed was of small consequence. Most of the natural gas was used for illumination and did not consume large quantities per gas burner. The one hundred street lights at Fredonia, New York, in 1825 were limited to

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[12]F. Lloyd Wilson, James M. Herring and Roland B. Eutsler, Public Utility Industries (1936), p. 71.

about eighty-eight cubic feet in twelve hours as this was the maximum deliverable quantity by the gasometer. The rate for these street lights was $150 per light per year.[13] The standard rate of many early gas companies was $12 per quarter for small burners and $18 for large ones.[14] The fallacy of this practice was soon recognized by the larger companies. Efforts were begun to devise a system to meter natural gas by volume measure. The meter used for manufactured gas in England was brought to this country but was not too satisfactory. An efficient natural gas meter was not developed until 1896. Many methods of passing the cost of meters on to the consumer soon appeared. Some companies rented the meters, others sold them, and still others charged a percentage of the fittings and meter cost to the consumer.

Industrial consumers paid the same rate as domestic consumers. This did not encourage new industry and held back industrial adaption of natural gas for a time. A sliding scale was later developed to allow industry to use natural gas at a more reasonable rate. The small companies continued to charge a flat rate until about 1896 when the meter was adapted throughout the East. The lag by these companies created a problem for the government recorders, since statistics were collected, on one hand, on the basis of volume measurement and on the other by the value of the product or the estimated value of a comparable quantity of coal or wood.[15]

Shift to the West.--The leading state in the production of natural gas prior to 1909 was Pennsylvania. From 1909 to 1924, West Virginia was the major producer. In 1924, the Mid-West became the leader as the oil-soaked state of

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[14]Stotz and Jamison, op. cit., p. 16.

[15]W. T. Griswold, Mineral Resources of the United States, Part II (1905), p. 799.

Oklahoma reigned supreme. Her reign was the shortest of any of the states, for by 1930 her massive neighbor to the south, Texas, claimed the crown and has retained that position to the present time.[16]

The first oil well by Colonel Drake at Titusville, Pennsylvania, in 1859 caused a drilling "rush" that produced many new oil and gas wells. The equipment was rapidly revised, and the improvement of drilling techniques added to the discoveries. Natural gas was used at this early date for industrial and domestic purposes in Pennsylvania and nearby Ohio. Several factories had used local supplies of natural gas in Erie, Pennsylvania, as early as 1860.

New York operators drilled a well for oil four years later near West Bloomfield, New York. It took two years to drill 480 feet and they were unlucky enough to strike a large gas flow. They allowed the well to produce at an estimated 200,000 cubic feet per day in the hope that it would "drill itself into oil."[17] The project was abandoned after a time and the well was left flowing without regard to the waste incurred. Five years later a gas company was organized to use the gas. It constructed a twenty-five mile line to Rochester, New York, out of Canadian white pine. An estimated twenty-five acres of timber were used to form the line. The project failed when the high pressures cracked the logs and reduced the transportable gas pressures to less than one pound per square inch. The loss was estimated at $1,500,000.[18]

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[16]Thompson and Smith, op. cit., p. 19.

[17]Early drillers found some gas wells would produce oil after a time if the gas were allowed to flow freely. The early term for this was "drilling itself into oil."

[18]Stephens and Spencer, op. cit., pp. 6-7.

A curious parallel to the Fredonia discovery located "the Gas Belt" of Indiana in 1886. Ten miles north of Muncie, Indiana, on the Mississinewa River, a railroad bridge was under construction. When the abutment was dug, the odor of natural gas was noticed. A nine-hundred foot well brought in a large amount of natural gas and the rush was on. Reserves covered an area of seven thousand square miles. The gas was squandered. Manufacturers were offered free gas. Poor methods of production and distribution wasted millions of cubic feet. Public opinion rebelled when newspapers suggested the gas should be metered to prevent waste. By 1907, the reserves were so depleted that the people returned to the use of manufactured gas.[19]

Natural gas came to the West in 1873 when the Acres Mineral Well at Iola, Kansas, came in. The gas was used for illumination and the water from the well was used in a sanitarium which was constructed nearby these medicinal waters. The Paola district was discovered nine years later. This gas was used to illuminate the town of Paola. Rapidly thereafter, fields were brought in near Coffeeville, Cherryville, and Independance, Kansas. Zinc smelters at Cherryville established natural gas as a permanent industry in 1898.[20] The Kansas Natural Gas Company was the first important western natural gas transportation company. It constructed a 16-inch line from the Allen, Neosho, and Wilson fields to Kansas City, and another 16-inch line to the Joplin, Missouri, area from the Montgomery field. A number of cement and brick factories were built near local supplies of natural gas. Kansas supplies soon declined and the developed markets were forced to search elsewhere for supplies of natural

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[19] Stotz and Jamison, op. cit., pp. 81-82.

[20] L. C. Snider, Oil and Gas in the Mid-Continent Fields (1920), pp. 282-283.

gas by 1909.[21]

Texas, California, and Louisiana all began production about 1900. Texas has a small strike at Nacogdoches in 1887, but Spindletop, near Beaumont in 1901, was the first large strike of both oil and gas. The Jennings field in Louisiana, shortly after Spindletop, was the beginning of much activity in that state. The Coalinga field of California was opened in 1896 and became the first major strike on the west coast although natural gas had been gathered from artesian water near Stockton since 1864.[22]

## History of Oklahoma's Natural Gas Industry

Natural gas grew up with Oklahoma, in fact, the industry was well established long before Indian Territory and Oklahoma Territory were united to become a state in 1907. The industry has been overshadowed by petroleum but has evolved until its value was $42,340,000 in 1943 as compared to $146,000,000 for petroleum.[23] Few Oklahomans realize the importance of this mineral which has long been regarded as a "poor relation" of petroleum. Early growth of the industry in Oklahoma was based on cheap natural gas. Lead and zinc smelters and glass plants were able to compete with the rest of the nation due to low cost fuel available in quantity. Early industrial centers were Collinsville and Bartlesville. Sand Springs and Henryetta followed soon after. Glass is manufactured now in Okmulgee, Henryetta, Sand Springs, and Sapulpa. These

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[21]Stotz and Jamison, op. cit., pp. 82-84.

[22]Arthur Rohman, "Outlook for Natural Gas Industry in California," Public Utilities Fortnightly, XLV (February 16, 1950), p. 213.

[23]Mineral Resources 1946, Oklahoma Planning and Resources Board, pp. 22-26.

are referred to by the local Chambers of Commerce as the glass centers of Oklahoma. The natural gasoline industry also developed in Oklahoma and by 1939 claimed three of the largest manufacturers of that product in the United States.[24]

The first sign of natural gas in Indian territory appeared in 1902. A few wells at Red Fork in the Creek Nation produced a small amount of gas that was used for domestic purposes.[25] Numerous wells were drilled during the following year. Pawhuska was using natural gas by 1904. At Lawton, the gas from an earlier well was used as boiler fuel to drill a new well. Newkirk, Kay County, had an oil well failure due to striking gas.[26] Torches from the gas were burned for some time in the streets for light, but the well finally made water and was lost. Further expansion at Red Fork had allowed some gas to be used for general fuel purposes.[27]

Early in 1903, Colonel J. M. Guffey and John Galey, formerly of Pennsylvania, laid a 2-inch line from a well in the Osage Nation to a brick plant in the small village of Tulsa. They added a 2-inch, then a 3-inch line into the town to meet demands of four hundred customers in 1905. This line was sold for $1,250,000 shortly thereafter.[28] The value of natural gas produced and

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[24]Frank B. Long, "Natural Gas in Oklahoma," Gas Age, LXXXIII (April 27, 1939), p. 33.

[25]F. H. Oliphant, op. cit., (1902), p. 264.

[26]Early drillers regarded natural gas as a valueless and very dangerous substance. A well striking gas was usually abandoned if oil did not appear soon after inception of the gas.

[27]F. H. Oliphant, op. cit., (1903), p. 738.

[28]Joseph Bowes and F. W. Peters, "History; Financial Structure; Management; Oklahoma Natural Gas Company; Case Study," Gas Age, LXXXIV (December 21, 1939), p. 22.

sold in Oklahoma and Indian territories was $360 in 1902 and $1,000 in 1903.[29]

The southern part of the state commenced production when the Wheeler pool in northern Carter County was developed by the Santa Fe Railroad Company in 1904. This pool was used as a source of natural gas three years later for Ardmore. A great many small pools have been found nearby since then. Some of the more famous are the Cruce pool and the Loco pool in Stephens County, and the Fox pool in northern Carter County.[30]

Twenty-four of the forty-five gas wells in the Indian and the Oklahoma territories in 1904 were being utilized. Many large wells were found that year. On January 1, 1903, there were only two gas wells on the Osage Reservation but by the end of 1904 there were thirty. The gas provided power for operating the wells and for continued drilling.

Domestic fuel was delivered to consumers in Tulsa, Bartlesville, Ochelata, Pawhuska, and Red Fork. Romona was piped for gas that year. Two brick plants and a glass factory were built at Red Fork, to use the cheap fuel.[31]

Some large gas wells were developed in Oklahoma and the Indian territory in 1906 but due to the lack of a market they were shut in. Several pipe lines were constructed to draw on these wells. Most of the gas was delivered to domestic consumers at a flat rate, as meters were not being used. The cities supplied with natural gas in 1906 were Cleveland, Claremore, Inola, Collinsville,

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[29]Belle Hill, Mineral Resources of the United States, Part II (1903), p. 721.

[30]A complete discussion of the gas pools between and south of the Arbuckle and Wichita mountains of Oklahoma to 1932 is given in Geology of Natural Gas edited by Henry A. Ley, pp. 575-603.

[31]F. H. Oliphant, Mineral Resources of the United States, Part II (1904), p. 783.

Oologah, Gotebo, Okmulgee, Blackwell, and Wagoner.[32] The deepest producing gas well in Oklahoma at this time was a 2,100 foot well in the Osage Nation which produced gas at pressures up to 620 pounds per square inch.

Eighty-seven of the 315 producing gas wells in 1907 were shut down due to a lack of a market. Some of the wells could produce as much as 40,000,000 cubic feet daily.

Over 11,000 domestic consumers were being supplied with gas valued at slightly less than $250,000 in 1907. A flat rate was still being charged. Oklahoma City and Ardmore began using natural gas in that year. Oklahoma's statehood was barely a month old when Oklahoma City celebrated the arrival of natural gas into the city with gay festivities on December 28, 1907.[33] Giant gas flares were lighted at the four corners of the city to add to the gaity.[34] Gas used for industrial purposes was valued at $162,892 in 1907. Most of this gas was used in ice, electric, brick, and power plants. Field use (the use of gas in the field for production purposes) was also a large consumer of gas. A large zinc works started operations in Bartlesville in that year.[35] The value of natural gas was beginning to be realized about this time.[36]

Industrial consumers used most of the gas produced in Oklahoma in 1908. The price varied from 1.5 cents to 15 cents per thousand cubic feet. The industries using the gas were smelters, cement works, brick plants, and field

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[32]Belle Hill, Mineral Resources of the United States, Part II (1906), p. 733.

[33]Bowes and Peters, loc. cit.

[34]Manufacturers Record, CXIV (September, 1945), p. 85.

[35]Belle Hill, Mineral Resources of the United States, Part II (1907), p. 342.

[36]The Daily Oklahoman, (October 23, 1949), p. 10.

operations. Domestic use doubled during 1908, but due to the lack of markets about 25 per cent of the 374 wells were shut in. The constitutionality of a state law prohibiting exportation of Oklahoma gas to other states was being questioned by the United States Supreme Court.[37] Operators were in favor of this action for their product had become a drug on the market.

The rise of Oklahoma was more rapid in 1908 than any other state. The Caney Well, drilled in the Cherokee Nation in 1906, across the state line from Caney, Kansas, had become one of the greatest producers ever completed. With the removal of the law prohibiting exportation of gas from the state, a small quantity was moving across the border.[38] A 16-inch line was under construction by the Quapaw Gas Company from Washington County, Oklahoma, to Joplin, Missouri, to supply the demands of the smelters located there. Kansas smelters were also trying to get Oklahoma gas.

Over a million dollars worth of gas was consumed in 1909 by industrial consumers at an average price of 4.9 cents per thousand cubic feet. This was almost double the consumption of the previous year. Oil field operators were the largest consumers, followed by zinc smelters, cement, and brick plants. Domestic consumers were paying up to forty-seven cents per thousand cubic feet. The large gas districts of Oklahoma were the Hogshooter, the Collinsville, and the Copan. The Hogshooter was the largest gas pool at this time.[39] It supplied smelters at Bartlesville and cement plants at Dewey.

The repeal of the exportation law opened new markets for gas. Large quantities were piped from Oklahoma to Kansas to supply domestic consumers,

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[37]Belle Hill, Mineral Resources of the United States, Part II (1908), p. 338.

[38]Belle Hill, Mineral Resources of the United States, Part II (1909), pp. 289-290.

[39]Ibid., p. 290.

zinc smelters, and cement plants. Other lines exported large quantities to the Joplin area where it was used domestically and in the mines and mills. Even with this expansion, many wells capable of producing millions of cubic feet per day were shut in.[40]

Oklahoma's first carbon black plant was built in Coalton in 1911. Several natural gasoline plants were built to use the wet gas from the wells that had been shut in. Zinc smelters and cement plants bought $169,000 worth of gas and brick plants used $57,500.[41]

The rise in the price of crude oil gave impetus to drilling in 1912. The Cushing pool in Creek County opened several very large gas wells. Local demands for gas were increasing, thus decreasing the exports to Kansas and Missouri. There were thirteen natural gasoline plants and the demand for their product was growing rapidly.[42] They were located in Creek, Nowata, Muskogee, and Washington Counties. The Glenn pool in Creek County was especially rich in natural gasoline.

In 1913, steps were taken to eliminate the terrific waste of natural gas. The United States Bureau of Mines sent two men to Oklahoma to demonstrate a new method of drilling aimed at preventing waste. Oklahoma operators were indifferent and expressed views that it might prove expensive to adapt the new method.[43] Two wells were drilled which would have wasted over 20,000,000

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[40]Belle Hill, Mineral Resources of the United States, Part II (1910), p. 319.

[41]David T. Day, Mineral Resources of the United States, Part II (1911), p. 308.

[42]Belle Hill, Mineral Resources of the United States, Part II (1912), pp. 331-350.

[43]Belle Hill, Mineral Resources of the United States, Part II (1913), pp. 1443-1444.

cubic feet of gas daily using the old drilling method but the new procedure prevented the loss of any appreciable quantity of gas. The wells were filled with mud under pressure and the pores of the rock were sealed off as the drill penetrated them. Many new wells were successfully drilled into the gas cap of the Cushing field, using the new process where previously, under similar conditions, it had been impossible to keep the tools in the hole. The Cushing field expanded its yield so that by 1916 it was producing the major portion of the natural gas in Oklahoma.

By 1920, the supply of natural gas was not sufficient to supply the demand during the winter. The Home Development Company brought in the first well in the Guymon-Hugoton field in Texas County in 1922.[44] Little immediate development followed in this portion of the Anadarko Basin due to its geographic isolation in respect to markets. This field was not considered a competitor to the natural gas pools in eastern Oklahoma because the gas transmission lines from that area would be a major undertaking for a large company (Fig. 2, page 87).

No major fields in eastern Oklahoma were found from 1919 to 1921 to bolster the supply in spite of an intensified search for gas. Gasoline plants were constructed to provide added supplies of residue gas.[45] Many towns were added to the transmission lines and extensions were constructed to new areas. Oklahoma became the largest producer of natural gas in 1924 and held this position until 1929 when Texas took the lead.

The supply situation became reversed by 1929 and 1930. The Seminole field and the Oklahoma City field came in while the Crescent and Edmond field

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[44] Joseph A. Kornfeld, Natural Gas Economics (1949), p. 148.

[45] R. S. McBride and E. G. Sievers, Mineral Resources of the United States, Part II (1921), p. 343.

followed shortly thereafter.[46] Gasoline plants provided an excess of residue gas for sale in that area.

Tulsa had to rely on distant sources for natural gas by the late 1930's. Fields serving this area were the Seminole, Quinton, South Stroud, and Edmond. Gas was brought from as far away as the Cement field during cold waves.[47] One of the largest dry gas wells ever tested in the history of the natural gas industry was completed in the Cement field (deep) in 1938. It produced over 224,400,000 cubic feet daily at open flow.[48]

Construction of high-pressure transmission lines from the Guymon-Hugoton field was underway by this time. Wells were being drilled there in the effort to produce large reserves of natural gas. As has been the case of natural gas during most of its history, the production phase of the industry must be developed before facilities are constructed to market the gas.

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[46]Long, op. cit., p. 34.

[47]Robert W. Ducker, "Gasways Keep Pace: Transmission and Distribution; Oklahoma Natural Gas Company; Case Study," Gas Age, LXXXIV (December 21, 1939), p. 32.

[48]Long, op. cit., p. 62.

## CHAPTER III

## THE PRODUCTION OF NATURAL GAS

The production of natural gas includes all the activities incident to the exploration and location of gas lands, the drilling of wells, the extraction of raw gas from the well, and the preparation of this raw gas for transmission in very high-pressure conduits.

The geologist does not search for natural gas, but for a structural trap within the earth in an area believed to contain oil or gas. The deduction that such a condition exists is communicated to the leasing department of the gas company. The leasing department gains control of the mineral rights of the area believed to have petroleum and natural gas. Control of as large a portion of the pool as possible is usually attempted to prevent competitors from entering the field and capturing fluid hydrocarbons through migration to wells on the outside leases.

Problems related to competition between integrated companies and primary production companies are very real. An integrated company may produce a portion of its natural gas, buy the rest and transport it through transmission lines to the market where it is sold. A profit is derived from all of these functions. A primary producer derives a profit from the sale of natural gas. The two are entities and create a need for separate governmental regulation of them.

A well is dug, usually by a contractor, for either of the companies. The improvement in technology has increased the depth and the cost per well. With an increase in depth, gaseous hydrocarbons are found to be more prevalent. The gases are very fluid and move into a well as long as there is a lower pressure at the vent than in the well. As the natural gas issues from the well it is separated from other fluids and solids, and the gas is sent to the market.

The natural gas industry was somewhat localized until large reserves were proven to exist in small areas. Gas reserves were suddenly regarded as a potential supply of energy and the quest for this substance acquired a new incentive. These reserves are located in the Southwest where more than 75 per cent of the production in 1949 was located. New outlets are needed as a vast over-development has occurred in these fields.

Oklahoma was the third largest producer of natural gas after Texas and Louisiana in 1949. The companies are large and centered in the Guymon-Hugoton field. Natural gas has contributed more than $66,000,000 to the economy of the state. If this major contribution is to continue, a healthy industry must exist to absorb the inherent risk of drilling for natural gas.

## The Exploration and Location of Gas Lands

There are three general methods of locating a supply of natural gas. If sufficient "risk" capital may be obtained, a well may be drilled even without a rational purpose in the selection of a particular site. A second method is the encountering of natural gas in the quest for petroleum. The most recent addition to the modes of exploration is the scientific effort enjoined in the search for a formation that will produce natural gas. Many scientific instruments are used to locate these structural traps. No effort is spared to utilize scientific method in order to eliminate the risk as much as possible.

Limitations.--Alderfer and Michl place four limitations on the production of petroleum that could be applied equally to natural gas.[1]

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[1]E. B. Alderfer and H. E. Michl, Economics of American Industry (1942), pp. 234-35.

1. The process of natural replacement of natural gas is not significant enough to alter the limited supply of this resource available in the earth at the present time.

2. The amount of natural gas is not known. The supply is calculated for the country, individual fields, and even individual wells, but these estimates of the experts are to be regarded as the best evaluation obtainable for the amount of natural gas in any one of the three above-mentioned areas.

3. Natural gas is an extremely mobile substance. The direction and extent of movement depends on the nature of the formation, the pressure applied through petroleum and water deposits, and other circumstances. These limitations upon scientific production create an element of chance that cannot be ignored.

4. Natural gas is subject to the "law of capture." Originally the ownership of land in this country also encompassed the rights to oil and gas. By capturing a large amount of gas through the production of this resource, a portion of the quantity underlying the producing strata outside of his sphere of ownership would migrate into the well where it could be produced. Various social complications have arisen from this practice.

Art of Discovery.--The prospector must be equipped with a firm foundation of the characteristics of petroleum, with its manner of formation, accumulation and migration, its associations and occurrence in nature, and be able to apply this knowledge in the field to the location of new deposits. This ultimately required a combination of technical and practical ability plus the power to reason and deduce facts which must often be based on very uncertain evidence. At best the prospector may only estimate with all the information obtainable that it may or may not be feasible to attempt a well. The location of the well is a critical operation, since although a stratigraphic trap may be deduced the local conditions are generally not known before drilling. Even though the prospector has estimated each possibility and has found a structure suitable for trapping petroleum through his exhaustive scientific methods, the well may not prove productive and provides one of the inherent risks of petroleum exploration.[2]

Leasing of Gas Lands.--After the geologic departments have located a possible gas trap, the land department must secure the right to drill in the area. This is the acquisition of the right to enter a definitely described parcel of land, for a determined period, to prospect for and to reduce to possession, and remove and market natural gas.[3] These gas rights are acquired for a consideration by contract with the owner or owners of the mineral rights to the land or by purchase of the mineral rights. The contract with the owner is such that an annual rental will be paid until the well is started, or producing well is completed, in addition to a primary payment commonly called the "bonus." The option to resume rental payments if the well does not produce rests with the operator, who by failing to meet the contract stipulations, surrenders his rights to the area.

When gas is found in sufficient amounts to be produced, a portion of the production, usually one-eighth of the field price for the gas or a certain amount per thousand feet withdrawn from the well, is paid to the owner and is commonly called the "royalty."[4] A lease generally specifies a "delay rental"

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[2]Lester Charles Uren, Petroleum Production Engineering (I, 3d ed., 1946), p. 51.

[3]Samuel S. Wyer, "Principles of Natural Gas Leasehold Valuation," Transactions of the American Institute of Mining and Metallurgical Engineering, LVI (1916), p. 783.

[4]Henry A. Ley (ed.), Geology of Natural Gas (1935), p. 1104.

payable periodically until such time as the operator completes a well on the lease or until a well is started.[5]

Control of Gas Lands by Leasing.--Production activities of integrated natural gas concerns have expanded to include operations in as many as eight states. Some large companies have held gas titles to eight million acres or more of lands, of which more than 850,000 acres are producing gas from as many as 9,600 wells. A large portion of the unproved leaseholds are lands on which a concern expects to discover gas in the future as it exhausts its present proved and producing gas lands. Some unproved leaseholds are obtained with the intention of preventing competing companies from gaining access to the field. Only a small part of the unproved leasehold is expected to be productive.[6]

Divided Rights Within the Field.--When the surface rights are divided above a gas field, one of the operators may drill into the highest portion of the sand where gas naturally concentrates and remove the bulk of the gas before the other tracts are drilled. This creates pandemonium in the field since gas is extremely fluid and will migrate from areas outside the penetrated strata into the new well. When drilling wells adjacent to producing properties there is a greater possibility of encountering gas from the same formation.[7]

More wells are ultimately drilled than would be necessary to economically produce all of the available gas from the formation. This increase in capital expenditure may be avoided through unitization of a field. When a field is unitized, the operators produce their proportionate share of the gas and will

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[5] John C. Diehl, Natural Gas Handbook (1927), p. 18.

[6] Ley, op. cit., p. 1105.

[7] Diehl, op. cit., p. 19.

drill as few wells as possible to produce this gas. Offset wells are drilled to regain as much of the gas as possible before the older well draws gas from the unproducing areas. It is a common practice in the petroleum business to develop the exterior of your leased area first before the center is "brought under the bit."

The Problem of the Structure of the Producing Company.--Some of the operators have different intents and purposes in production from a field. An operator that is a producer of natural gas for sale to pipeline companies will not have as long a view of the rate of production as those companies having an integrated structure. These integrated companies will not gain all of their profits from the production of the gas and will not be as favorable toward flush production as the primary producer. On the other hand the primary producer of natural gas must maintain a larger reserve of capital to cushion the shock of a possible depression when gas utilization decreases and sales to integrated pipe line decrease because the integrated companies produce their own supplies of gas insofar as it is possible. This situation compares to the large automobile manufacturer's tapered integration policy, in regard to the method used to obtain a portion of their materials from other producers when conditions are unusually good, but utilize their own source exclusively when the need is not greater than the amount they can produce in their own plants.

In 1927, John Diehl said that no legal and satisfactory way had been found to enable operators of adjoining properties to pool their interests and to overcome uneconomic over-drilling of the gas field, so that large potential reserve fields have been drained through self-interest.[8] About this same time,

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[8]Diehl, loc. cit.

Oklahoma pioneered in the field of state control by introducing "proration" to coordinate production. Oklahoma has been a leader in this field since that time. Some of the significant accomplishments by the state have resulted from the efforts of United States Senator Robert S. Kerr. In his message to the legislature on January 2, 1945 (He was then Governor of Oklahoma), he urged the adoption of secondary recovery legislation which would allow the Oklahoma Corporation Commission to unitize all or a portion of an area if additional quantities of oil and gas could be economically produced by a unitization program. Action was to be based upon a petition filed by the owners of leases covering at least 50 per cent of the area. Small "get rich quick" operators objected strenuously, but Oklahoma would gain large quantities of petroleum which otherwise would be lost by the old methods of production. House Bill No. 339 became law in 1945 and has demonstrated the recognition by the State Government of the social value of conservation.[9]

## The Production of Gas Lands

Drilling follows the right to drill. Most wells are drilled by contractors, but a few of the larger companies have their own drilling departments. The companies engaged in primary production usually have drillers to maintain their own wells.[10]

Drilling the Well.--There are two basic types of oil and gas well drilling equipment.[11] The churn drilling methods utilize the striking force of a large heavy bit as it drops several feet against the bottom of the well. The hydraulic

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[9]Blakely M. Murphy (ed.), Conservation of Oil and Gas (1949), pp. 398-99.

[10]Fred W. Heisler, Natural Gas (1937), p. 54.

[11]For a detailed discussion of the basic types of drilling equipment the reader is referred to Lester Charles Uren, op. cit., Chapter IV, "Drilling Equipment and Methods: General Features."

rotary system uses a portion of the weight of the drill column to abrade the rock by rotating a drill bit.

The churn drilling method is used especially where the rocks are elastic or when entering a low-pressure producing formation.

The rotary method is used where very high pressures are encountered in the producing formation and in wells where the sides of the hole have a tendency to cave into the recess. A fluid under high pressure is circulated through the hollow drill stem to control formation pressures, cool the bit, remove the chipped rock by carrying it to the surface outside the drill column, and serves a number of other purposes.

The well progresses rapidly upon "spudding in" but usually decreases the daily footage of pipe with depth. Some exceptions to this may result from the inherent differences in the subsurface strata. Water formations encountered are carefully sealed off to prevent the interchange of fluids between strata.[12] Upon encountering a gaseous formation, the casing is either equipped with a screened or slotted attachment or is perforated by means of a gun to allow the gas to enter the pipe.

Production Costs.--Production costs will vary from well to well due to the complex factors involved. Topography, climate, geographic location in respect to transportation, and other physical elements become important through their limitations on site choice. Costs usually increase with the depth of the well. This factor is becoming critical by determining the minimum size of the

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[12]Natural gas, petroleum, salt water or fresh water in undergrownd strata must be contained in the formation in which they occur to prevent pollution or contamination of other fluids. Fresh water will drown a gas or petroleum formation and salt water will ruin artesian water if an interchange of fluids is allowed between the strata in a well.

company that can search for gas. The costs of drilling are such that usually the larger concerns are the ones that can afford the luxury of "wildcatting" in search of new reserves. Increased costs are also incurred in the higher costs of casing, packers, and surface attachments, to withstand the extreme pressures. A modern rotary rig is quite expensive; and as a result, the type of equipment becomes a factor in the cost of a well.

The 420 persons employed by the dry gas industry in 1941 is not a true manifestation of the number of workers. Of the 15,740 workers in the petroleum industry, a large number of workers within the industry do work applicable to both functions.[13] The geologists, land agents, seismograph crews and other men do work of a technical nature for the natural gas industry on a somewhat preparatory basis or incidental to petroleum production.

Movements of Gas in the Well.--Three factors govern the movement of gas to the hole bottom. (1) The formation or rock pressure is of primary importance in the energy that will be available. (2) The character of the sand determines the porosity which is a limiting factor to the rate of production and to the amount of gas available. (3) Other fluids in the formation with the gas may hinder the production of the gas.[14]

Large amounts of natural gas are produced in conjunction with petroleum. Since they are mutually soluble in each other, the natural gas must be separated from the petroleum. When the cap-rock is penetrated, the gas in solution effervesces and will move through the formation to the hole where it rises up the casing to the vent of the well. This movement carries oil along and causes a

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[13]*Petroleum Facts and Figures*, American Petroleum Institute (8th ed., 1947), p. 195.

[14]Heisler, *op. cit.*, p. 88.

well to produce petroleum naturally. As the gas pressure decreases, the flow of petroleum out of the well may be broken and rise in spurts or "heads" when enough gas accumulates beneath the oil to carry it to the surface. This gas is rich in the heavier hydrocarbons and as pressure decreases the concentration of hydrocarbons increases.

Treatment of Gas at the Well.--The job of separating the oil from the gas is generally accomplished by means of slowing down the velocity of the hydrocarbons with baffle plates, so the gas bubbles will strike the metal surface and burst. They then rise to the top of the separator where they escape through an outlet and undergo further treatment to remove natural gasoline and other hydrocarbons, water, and inert substances such as carbon dioxide, nitrogen, sulfur, and helium.[15]

Estimation of the Life of the Well.--Once natural gas is found, a careful estimate of the recoverable quantity available is necessary. If the amount to be removed is known, a simple arithmetic method may be used to estimate the number of years that profitable production may be expected. This does not allow for increased consumption that may occur, the physical limits that may be placed on a well in the waning years of production, or the addition of greater reserves in deeper or adjacent strata. Another proviso not generally noted is the field use of natural gas for the production of oil. Repressuring or pressure maintenance is considered by the petroleum industry to be a prior right before any gas is released for pipe-line sale.[16]

Other factors may also limit the estimated productive life of the gas

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[15] Ibid., pp. 89-91.

[16] United States Federal Power Commission, Docket G-580, Natural Gas Investigation, Natural Gas Reserves of the United States (1948), Staff Report, pp. 30-31.

field. Competing fuels could absorb a portion of the market causing transmission companies to fail. High fixed capital costs in this utility allow little flexibility in the quantity of natural gas transported. Governmental price increases granted to this industry may cause seasonal users to turn to a more economical fuel. The Federal Power Commission may restrict the number of outlets from a field. State severance taxes may limit end use by raising costs or eliminating profits.[17] Fredrick F. Blachly and Mirian E. Oatman say:

> In brief, the rate of consumption of natural gas, and the conditions by which that rate may be increased or decreased, are crucial factors in determining how long the supply of natural gas will last. The factors governing consumption, unlike the fixed quantity of supply, are variables that can be manipulated by human action.[18]

Maintaining Production.--The maintenance of field supply must necessarily be the primary concern of a successful gas company. The conception of the company was realized only after there was a reserve large enough to be commercially exploitable. As wells are drilled, the gas field is brought under production. The field may have only a portion of the area operating at any one time but as new demands are placed on the wells that cannot be met by the existing improvements, it is necessary to drill new wells on non-operating reserve lands. The industry is limited by the maximum deliverable gas that can be physically produced from a well at one time.[19] If depletion continues, wildcats may be drilled in an attempt to locate unknown reserves. Demand on a field is not a stable one but fluctuates violently. The production department must maintain sufficient gas for any day's maximum requirement, winter

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[17] Fredrick F. Blachly and Miriam E. Oatman, Natural Gas and the Public Interest (1947), pp. 21-22.

[18] Ibid., p. 22.

[19] Diehl, op. cit., p. 13.

or summer.

In a single day the demand for domestic use may increase 200 per cent and within the range of a year as much as 1100 per cent. All of these factors must be considered to maintain a reliable flow to the domestic consumer.[20] The return from the enterprise must be such that gas companies can accumulate a capital reserve to meet the financial strain that comes with the maintenance of reserves for the company.

## Trends of Production in the United States

Since 1902, the period during which we have a record kept by the United States Bureau of Mines for Oklahoma, the marketed production of natural gas has shown an overall increase. Between 1906 and 1917, production grew from slightly below four hundred billion cubic feet to almost eight hundred billion cubic feet, or almost doubling itself during this period.

In 1923, marketed production of natural gas exceeded one trillion cubic feet. In 1936, the production doubled the figure of thirteen years before. Production exceeded four trillion cubic feet in 1946 and amounted to more than six trillion cubic feet in 1949.[21] With proved recoverable reserves of one hundred and eighty trillion cubic feet, our supply of natural gas in the United States will last at least thirty years. The early natural gas industry was a firmly entrenched industry in the Appalachian area. The large reserves of West Virginia, Pennsylvania, and Ohio were piped to the industrial centers of the Appalachian area. The industry reached its first peak during World War I. Technological improvements in engineering developed better wells and

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[20]Ley, op. cit., p. 1107.

[21]Charles J. Deegan, "Reserves are Up," Oil and Gas Journal (March 16, 1950), p. 57.

better distribution systems with sufficient capacity to keep ahead of the phenomenal demands of the industry. Domestic users, from 1906 to 1917 increased from 875,000 to 2,431,000 customers which represented an increase in consumption from 110 billion cubic feet to 258 billion cubic feet of gas. Industrial uses increased from 279 billion cubic feet in 1906 to 537 billion cubic feet in 1917. With the decline in the five years of depression after World War I, it was necessary to further perfect engineering methods, services to the consumer, and develop better transmission and distribution methods.[22]

Rise of the Dry Gas Era.--There has been an increasing trend from oil production to gas production. In December of 1919, the discovery well of the Hugoton field near Liberal, Kansas, opened vast reserves that were to change to location of the industry almost completely. As long as natural gas was produced as a derived demand from oil wells there was a sufficient, but limited, amount of gas available but not in the quantities needed to guarantee the necessary investment to span the miles to distant markets. With the steady increase in production from 1920 to 1929, there was an added incentive to use this reserve located in the western areas. The high pressure line was developed in time to help link the mid-western market to the areas of great reserves. High pressure transmission lines helped launch a major national industry from 1928 to 1932, by providing Denver, Kansas City, Detroit, Indianapolis, Chicago, Minneapolis, and St. Paul with a reliable source of energy.[23]

Search for Gas.--With the advent of the natural gas transmission lines, the prospector became aware of the potentialities of natural gas, which had

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[22]Maynard M. Stephens and Oscar F. Spencer, Natural Gas Engineering (III, 2d ed., 1948), pp. 11-12.

[23]E. DeGolyer, "The Natural Gas Industry," Petroleum Engineer, XX (December, 1948), p. 148.

long been regarded as the poor relation of the oil industry, and proceeded to develop large quantities of natural gas not in association with petroleum. This placed a new burden on the natural gas industry by forcing the exploration for gas to be financed by the natural gas companies instead of the petroleum industry. When the quest for natural gas was assumed by companies directly interested in producing this commodity for the market, the recoverable reserves increased from more than sixty trillion cubic feet in 1936 to 180 trillion cubic feet at the end of 1949. The addition of 120 trillion cubic feet of recoverable natural gas placed a solid foundation under exploitation and production of natural gas. It allowed the producing companies to guarantee delivery of large amounts of natural gas for periods of at least twenty years.

Geographical Distribution of Natural Gas in the United States.--There is an unequal geographical distribution of natural gas production in the United States (Table 1). Texas alone produced almost half of the natural gas in the United States in 1949. The next ranking states of importance were Louisiana, Oklahoma, California, Kansas, New Mexico, and West Virginia in that order. Concentration of production in the Southwest is indicated by the pipe-line net extending from this area.[24] These southwestern states produced slightly more than 75 per cent of the net production of 6,245,041 million cubic feet produced during 1949. All of the producing states east of the Mississippi River delivered only 4.6 per cent of the total production of the United States in 1949. The state of California produced 8.3 per cent to place fourth in the order of 1949 production. Production of 256 million cubic feet by New Mexico approaches the 287 million cubic feet produced east of the Mississippi River.

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[24]See Fig. 1, page 60.

TABLE 1

NET PRODUCTION AND RESERVES OF THE UNITED STATES--1949

| | (Million Cubic Feet at 14.65 psia at 60° F.) Net Production[a] | Reserves Dec. 31, 1949[b] |
|---|---|---|
| Texas | 3,023,714 | 99,170,403 |
| Louisiana | 805,726 | 26,687,811 |
| Oklahoma | 567,335 | 11,625,979 |
| California | 543,488 | 9,991,635 |
| Kansas | 323,283 | 14,089,560 |
| New Mexico | 256,706 | 6,241,003 |
| West Virginia | 180,000 | 1,715,233 |
| Wyoming | 72,339 | 2,173,677 |
| Pennsylvania | 70,000 | 621,680 |
| Mississippi | 68,950 | 2,528,696 |
| Arkansas | 59,185 | 874,190 |
| Ohio | 47,000 | 652,571 |
| Illinois | 40,130 | 233,192 |
| Montana | 37,925 | 803,471 |
| Colorado | 24,828 | 1,227,095 |
| Michigan | 17,438 | 214,911 |
| Utah | 6,313 | 65,577 |
| Indiana | 6,250 | 25,200 |
| New York | 3,700 | 66,685 |
| Miscellaneous | 731 | 23,105 |
| Total | 6,245,041 | 180,381,344 |

[a]Net production equals gross withdrawals minus gas injected into underground reservoirs. Changes in underground storage are excluded.

[b]Charles J. Deegan, "Reserves are Up," Oil and Gas Journal (March 16, 1950), p. 57.

Special mention should be given to West Virginia which produced more than half of the production east of the Mississippi River. West Virginia received almost one-fourth as much in revenue in 1947 as Texas which produced almost six times as much natural gas.[25] Geographical location with respect to market gives the entire Appalachian region a price advantage of about fourteen cents per thousand cubic feet above that received by the southwestern states.[26] This advantage is quite lucrative but the states of Texas, Louisiana, Oklahoma, Kansas, New Mexico, and Arizona enjoy a more remunerative industry as a result of greater volume. Some market areas enjoy competition between these regions but seldom do producers of natural gas compete in a local market area.

In 1925, the average price of natural gas was eleven cents per thousand cubic feet. The price decreased to only 4.9 cents per thousand cubic feet during the next twenty years. This was largely due to the large quantities of low-priced gas produced in Texas and used in increasing amounts by the carbon-black manufacturers and other industrial consumers.[27]

Over-development of Natural Gas Areas.--According to Ley, in 1933, there was an excess supply of developed natural gas in the United States.[28] Only 6 per cent of the daily open-flow volume of gas wells was withdrawn each month. This was responsible for a slow rate of return on investments in gas

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[25]United States Congress, Senate, A Bill to Amend the Natural Gas Act, Hearings before a subcommittee of the Committee on Interstate and Foreign Commerce, U. S. Senate, 81st Congress, 1st Session, on Senate Bill 1948, May 17, 18, 24, 26, and 31, and June 7 and 8, 1949, p. 361.

[26]Ibid., p. 20.

[27]Stephens and Spencer, op. cit., pp. 12-13.

[28]Ley, op. cit., pp. 1105-6.

gas producing properties. Income was not enough to meet fixed costs. Exceptions were noted in isolated areas serving nearby markets which proved extremely lucrative in some cases. The price paid the producer had decreased due to the rapid development of natural gas resources, over-supply, and widespread inter-communicative pipeline systems. Declining prices have been the natural course of events for large scale production and distribution of most products since mass-utilization of energy sources revolutionized industry. The idea expressed by Ley is further proven by the fact that the number of producing wells increased less than 10 per cent between 1935 and 1945.[29] This indicates a tremendous deliverable amount of natural gas already developed in the areas of largest supply. The trend cannot remain dormant, for as the reserves are depleted, new wells must be drilled to maintain a sufficient quantity to guarantee long time production. Potential production is in the gas producing areas since 60 per cent of the gas came from this source in 1935 while only 40 per cent was associated with oil production. By 1944, the gas wells produced roughly 64 per cent of the natural gas with only 36 per cent attributed to petroleum gas.[30]

## Natural Gas Production in Oklahoma

The period from 1938 to 1948 may be termed as the time during which the natural gas industry in Oklahoma came to maturity. This industry has been hampered by two serious deficiencies--the lack of development of high pressure lines capable of transporting gas to geographically extended markets in an economic manner, and lack of dependable long time reserves upon which the

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[29] Joseph A. Kornfeld, _Natural Gas Economics_ (1949), p. 107.

[30] _Petroleum Facts and Figures_, _op. cit._, p. 72.

expenditure of capital for the long distance lines could be economically sound. Previous to this period the natural gas industry had been geared to the residue gas from oil production. This derived demand could not be depended upon for more than a base for a local marketing system. The inception of gas development on a reliable basis in the last twelve years is the story of the largest dry gas field in the world, the tri-state Hugoton field, or more specifically the portion in Oklahoma referred to as the Guymon-Hugoton field.[31]

TABLE 2

SELECTED INDICATORS OF ECONOMIC ACTIVITY IN OKLAHOMA*

| Item | 1940 | 1946 | % Increase |
|---|---|---|---|
| Cash Farm Income ($000) . . . . . . . | $214,585 | $502,535 | 134 |
| Value of Mineral Production ($000). . | 235,535 | 326,148 | 38 |
| Value of New Construction ($000). . . | 86,000 | 128,000 | 49 |

*Source: United States Department of Commerce.

Rank of the Oklahoma Natural Gas Industry.--Oklahoma ranked fifth among the states in value of mineral production in 1943. Some indicators of economic activity are presented in the above table to show the value of minerals within the state of Oklahoma. Minerals are recognized as one of the basic resources of the state of Oklahoma (Table 2). The position of minerals as the second most important source of income is significant. It diversifies the economy of the state and helps place a more stable foundation under its economic structure. A break down, by selected industries according to the 1947 Census of Manufactures shows the major group of petroleum and coal products in re-

[31]Murphy, op. cit., p. 403.

lationship to other major industries in Oklahoma (Table 3). Petroleum and coal products add the highest value of all industries through manufacture. The natural gas industry does not make a heavy contribution here since it is used primarily for a fuel rather than a basic raw material for manufacturing. The number of workers in Oklahoma has increased for most industries since 1939. Petroleum and coal products rank second to food and kindred products in the number of factory workers employed.

TABLE 3

COMPARATIVE DATA OF SELECTED MANUFACTURERS IN OKLAHOMA--1947*

| | Number of Establishments | Production Workers | Value Added by Manufacturing ($000) |
|---|---|---|---|
| All Industries . . . . . . . . . . . | 1,740 | 44,302 | 341,027 |
| Food and Kindred Products. . . . . | 643 | 10,966 | 75,969 |
| Printing Industries. . . . . . . . | 374 | 3,057 | 27,542 |
| Petroleum and Coal Products. . . . | 40 | 6,352 | 79,875 |
| Stone, Clay, and Glass Products. . | 86 | 3,956 | 23,411 |
| Machinery (except electrical). . . | 126 | 4,906 | 37,134 |

*1947 Census of Manufactures.

<u>Structure of Oklahoma's Natural Gas Industry</u>.--The structure of the industry is characterized by large industrial units. Of the 744 producing wells in the Guymon-Hugoton field during September, 1949, five companies produced 88 per cent of the natural gas from 87 per cent of the producing wells.[32] The major interstate pipe line systems, namely, Cities Service Gas Company, Natural Gas Pipeline Company, and Phillips Petroleum Company, are

[32]Computed from photostated material submitted by the Honorable Robert S. Kerr, Senator from Oklahoma.

the principal producers of the area, and they also buy some gas from the smaller producers.

Location of Natural Gas Production in Oklahoma.--Natural gas is produced in fifty-five of Oklahoma's seventy-seven counties. Dry gas is produced in nine of the counties while the other forty-six produce casinghead gas. The location of the fields and the major pipe line systems is shown in Figure 3, page 94.

TABLE 4

OKLAHOMA'S NATURAL GAS FIELDS--1945[a]

| Field | Production (Million cu. ft.) ( at 16.4 psia ) | Reserves[b] |
|---|---|---|
| Apache. . . . . . . . . . . . . . . . . | 2,100 | 85,000 |
| Cement, East. . . . . . . . . . . . . . | 13,000 | 60,000 |
| Cement, West. . . . . . . . . . . . . . | 17,000 | 80,000 |
| Chickasha (deep). . . . . . . . . . . . | 23,000 | 160,000 |
| Cumberland . . . . . . . . . . . . . . | 16,000 | 225,000 |
| Edmond, West. . . . . . . . . . . . . . | 195 | 355,000 |
| Erick . . . . . . . . . . . . . . . . . | 3,000 | 27,500 |
| Guymon-Hugoton. . . . . . . . . . . . . | 42,000 | 7,697,000 |
| Pauls Valley. . . . . . . . . . . . . . | 18,000 | 54,000 |
| Pauls Valley, East. . . . . . . . . . . | 4,300 | 45,000 |
| Quinton . . . . . . . . . . . . . . . . | 4,000 | 32,000 |
| Velma . . . . . . . . . . . . . . . . . | 2 | 60,000 |
| Total. . . . . . . . . . . . . . . | 143,597 | 8,880,500 |
| Miscellaneous[c]. . . . . . . . . . . . . | 168,291 | 625,500 |
| Total Oklahoma . . . . . . . . . . | 310,888 | 9,533,000 |

[a]Elmer E. Capshaw, United States Federal Power Commission Docket G-580, Exhibit No. 146, Natural Gas Investigation (1945).

[b]Individual consideration is limited to fields having a reserve in excess of 20,000 million cubic feet.

[c]The production of these fields is generally used for field or very local uses.

Table 4 portrays the significance of the Guymon-Hugoton field. The production of 42,000 million cubic feet by far exceeds the (deep) Chickasha field. The Guymon-Hugoton field is specifically developed for gas while many of the others are oil fields that are attempting to conserve gas pressures and are even returning some residue gases from gasoline plants back into the formations. A large amount of gas is used in the field for oil production.

Value of Production.--Oklahoma produced $282,000,000 in mineral products in 1945. Petroleum and by-products made up 92.8 per cent of this production. Natural gas valued at $66,143,000, accounted for more than 23 per cent of the value of petroleum products in that year.[33] This was the highest annual value of natural gas production in Oklahoma to that date.

The 1949 production of natural gas almost doubled the 1945 figure.[34] The most recent data given for natural gas production by the Bureau of Mines was $1,028,318,000 in 1946.[35] The natural gas industry, through exploration and production has delimited 180,381,344,000,000 cubic feet in reserves. Natural gas would not be a very significant resource if both reserves and production were not present in sufficient quantity. A further development is necessary before it can be consumed. Pipe lines connecting these areas of production to the areas of potential market must be constructed before a practical use can be made of the natural gas.

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[33] Petroleum Facts and Figures, op. cit., p. 77.

[34] Charles J. Deegan, "Reserves are Up," Oil and Gas Journal (March 16, 1950), p. 57.

[35] H. Backus and F. S. Lott, Minerals Yearbook (1947), p. 823.

## CHAPTER IV

## TRANSPORTATION OF NATURAL GAS

Whenever withdrawals are made from reserves, the gas usually is processed to remove those constituents that are valuable as by-products or detrimental to equipment. Natural gasoline is one of the by-products that is important enough to be an industry in its own right. Water and sulfur are removed to prevent damage to the pipe line.

The recent developments in the technology of pipe lines has changed the history of the industry from a local utility to a national necessity. Transmission lines have increased from small local distribution systems to large 30-inch lines extending from the border of Mexico to New York City.

These long supply lines are subject to sudden withdrawals by consumers in periods of cold weather. This problem has partially been solved by injecting surplus gas into underground formations near consuming points to be withdrawn as needed. The line pressure is also increased to a maximum in anticipation of these sudden withdrawals. ~~Another method of meeting irregular demands is using liquified petroleum gases.~~

Limitations placed on pipelines are more economic than physical. The length of the line increases the delivery cost per unit of gas. Gas is transported more cheaply in large diameter pipe than in smaller pipe. Construction costs of the line vary directly with its length and diameter.

There are fifty-one large pipe lines in the United States. The industry is dynamic as evidenced by the fact that a recent entry into the field was capitalized at $200,000,000.

The Federal Power Commission restricts unrestrained expansion of the natural gas industry by authorizing only those projects that are believed necessary for public convenience.

Preparation of Natural Gas for the Pipeline

Most natural gas contains some constituents that are removed, either for their value, or because they have undesirable effects on transmission equipment, or because they dilute the natural gas and lower its fuel qualities. Some of these components are natural gasoline and heavier hydrocarbons, nitrogen, carbon dioxide, sulfur compounds, water vapor, or helium.

The marketed production of natural gas in 1946 was in excess of four trillion cubic feet. Approximately 92 per cent of this production was processed in gasoline and cycling plants for the valuable hydrocarbons.[1] These hydrocarbons increase the supply of residue gas by making it feasible to process small quantities that would otherwise be flared or burned as boiler fuel.

Extraction of Hydrocarbons.--There are three methods of extracting natural-gas liquids from natural gas. (1) The earliest method developed was the compression and cooling method. Natural gas was compressed and cooled and the liquids were collected. In spite of their low cost and simple design, the compression plants were inefficient and were soon replaced. (2) The Charcoal Absorbtion process was developed about twenty years ago. Natural gas was passed through activated charcoal which removed natural gasoline from the casinghead gas. The charcoal was then heated and the natural gasoline recovered. (3) The oil absorbtion process has entirely replaced the charcoal process. Natural gas is sent through an absorbent oil and the natural gasoline content is removed.[2] Live steam forced through this oil recovers the natural

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[1]H. Backus and F. S. Lott, Minerals Yearbook (1947), p. 822.

[2]Nelson Lee Smith and Harrington Wimberly, United States Federal Power Commission Docket G-580, Natural Gas Investigation Report (1948), pp. 93-94.

gasoline. This latter method is preferred because of its high extraction efficiency and close operational control.

Desulfurization.--Gas containing more than ten grains of hydrogen sulfide per thousand cubic feet is known as "sour" gas and is unfit for commercial distribution as a fuel. Three areas of the United States have substantial volumes of "sour" gas; the western and northwestern portions of the Panhandle field in Texas, the Permian Basin in western Texas and southeastern New Mexico, and southern Arkansas. Almost one-half of the 1944 production of 527,000,000,000 cubic feet of natural gas in the Panhandle field was "sour" and was almost entirely consumed in the manufacture of carbon black.[3] New methods of treatment of "sour" gas have been developed to economically remove the sulfur. A recent process using tripotassium phosphate solution to absorb hydrogen sulfide is proving exceptionally efficient.[4]

Dehydration.--Water vapor in natural gas comes from contact with an aquifer in production or from the absorbtion oil in natural gasoline plants. Gas hydrates resembling snow collect in transmission lines whenever water is present and conditions within the line are favorable. This hydrate forms very rapidly when a critical point is reached and will "freeze-up" a line and stop the flow of gas.[5] The problem of gas hydrates intensified as the working pressures increased. In 1914, companies transporting natural gas reported this phenomenon.[6] The high pressure line accented the problem of hydrates

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[3] Ibid., p. 99.

[4] The Oil and Gas Journal, XXXXVIII (March 23, 1950), p. 192.

[5] J. I. Morris, "Basic Problems in Gas Dehydration," World Oil, CXXVIII (December, 1948), p. 64.

[6] H. C. Miller and G. B. Shea, "Technical Research by the Bureau of Mines in Oil and Gas Production, Refining and Utilization," Information Circular 7171, Bureau of Mines (1941), p. 69.

as they form at higher temperatures if the pressure is increased. The recent use of high pressure gas to lift oil in the wells has required the removal of water vapor to prevent the formation of hydrates in the well.[7]

Dehydration of natural gas has evolved from an art to a science. The inflamable gas hydrates that form in natural gas lines have been studied intensively. Knowledge of the characteristics of the formation of hydrates in the line is constantly being improved. There are several methods of preventing hydrates: by installing drips to catch water that condenses; heating the gas line above critical temperatures; adding lubricants or inhibitors to the line; partial dehydration of the gas before it enters the line and operating the line at low pressure.[8] Each gas line has certain characteristics that must be studied before the method of dehydration may be selected.

The problem of gas hydrates was taken up by the Bureau of Mines in 1935 when it initiated an extensive investigation of freezing of high-pressure transmission lines.[9]

## High Pressure Transmission Lines

The evolution of high pressure transmission lines has changed natural gas from a local to a national industry. In comparatively recent times, improvements in design, construction, and operation of pipe lines have made possible the economical transportation of natural gas in large volumes over long distances.

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[7] R. C. Buchan et al., "Dehydration of Natural Gas," The Oil and Gas Journal, XXXXVIII (April 6, 1950), p. 74.

[8] The reader is referred to J. I. Morris, op. cit., pp. 194-196.

[9] H. C. Fowler, "Developments in the American Petroleum Industry 1914-19," Information Circular 7173, Bureau of Mines (1941), p. 17.

Evolution of Line Size in the United States.--The trend from pipe lines below twelve inches to those above twenty inches is shown in Table 5.

The first large interstate transmission line was built in 1925. Its total length of 217 miles was sectioned into 18-, 16-, and 14-inch segments.[10] Construction of 1,840 miles of 20-, 26-, and 30-inch transmission lines is under way with completion expected in 1950.[11]

TABLE 5

MILEAGE DISTRIBUTION OF NATURAL GAS LINES[a]

| Size | 1937-1941 Per cent | 1946 Per cent | 1947-1951[b] Per cent |
|---|---|---|---|
| 12" and below . . . . . . . . . . | 50 | 17 | 3 |
| 14" to 18" . . . . . . . . . . . | 20 | 26 | 5 |
| 20" to 30" . . . . . . . . . . . | 30 | 57 | 92 |
| Totals . . . . . . . . . | 100 | 100 | 100 |

[a]Johnson G. Lawton, "Gas Logistics," Gas Age (June 24, 1948), p. 26.

[b]Prediction.

The mileage of natural gas lines increased from 154,000 miles in 1932 to 259,000 miles in 1948. During the same period, lines transmitting manufactured gas decreased from 87,000 miles to 67,000 miles.

Component Parts of the Pipe Line.--A pipe line is a necessity in the transportation of natural gas since the other modes of transportation are not

[10]"Natural Gas," Fortune, XXII (August, 1940), p. 58.

[11]E. Holley Poe, "Is Natural Gas Essentially a Transportation Industry?" Public Utilities Fortnightly, XLIV (October 27, 1949), p. 555.

adaptable to such large-volume low-value goods. "Gas is in truth the most mobile, the most fugitive, and yet the least transportable of all fuels."[12]

Pipe Joints.--A joint is the means of bringing together in a gas-tight union two lengths of pipe. There are three types of joints commonly used in the natural gas industry. (1) The screw joint is the joining of two lengths of pipe by a screw coupling. (2) The tendency of the screw joint to leak prompted S. R. Dresser to develop a coupling that clamped tightly about the flush ends of pipe segments. This coupling is very easy to install, requires no special labor, and allows the pipe to expand and contract without breaking. (3) Welded lines are less expensive than the other types and are stronger at the weld than the original pipe. Occasional loops or joints must be provided to allow the pipe to expand or contract. Long segments may be welded in one piece and the entire length joined to the line by an expansion joint of the Dresser type.

Laying the Pipe.--A ditch is dug to allow the pipe to be placed at sufficient depth to avoid frost, protect the pipe from damage, help counterbalance the internal pressure of the pipe by the overburden of the soil, and to allow cultivation of the soil over the pipe.[13]

Pipelines placed in the ground without a protective covering will deteriorate rapidly. In 1915, pipe lines in the western United States were protected by an addition of a heavy coat of bitumen enamels wrapped with especially prepared roofing paper either in a spiral or longitudinal direction. A tar-like compound was added to protect couplings and collars. The Rio Bravo Oil Company covered a 4-inch pipe with concrete in an attempt to prevent corrosion by a

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[12] Ibid., p. 551.

[13] Maynard M. Stephens and Oscar F. Spencer, Natural Gas Engineering (Ill. 2d ed., 1948), p. 219.

salt water swamp in 1916. The pipe was not submerged but suspended on pilings treated with creosote.[14] Later protective devices for pipe lines are: (1) improvements of the bituminous enamels; (2) rubber sleeves over the line; or (3) by sending currents of electricity through the pipe in order to change the polarity in areas where acids are present in the soil.[15]

The pipe line assembly may be divided into four groups; the gathering system in the field, the compressor station, the main transmission lines, and the distribution lines. The gathering system is usually many small lines from the wells to the gasoline plant or compressor. The compressor station is designed to maintain the working pressure in the line. Reciprocating, two and four cycle engines as well as the newer introduction of centrifugal pumps are used. The main transmission line is a seamless gas tight conduit usually of steel. Booster pumps are located at strategic points along the main transmission line to maintain an even pressure throughout the line. When the gas in the transmission line is turned into the distribution line, it usually passes through a pressure regulator to decrease the pressure, in some cases from above one thousand pounds per square inch to the nominal two- to six-ounce pressure required by domestic appliances.[16]

## Supplementary Reserves for Peak Demand

An increase in demand during winter cold snaps creates a problem of sending sufficient volume of gas through the mains to meet this sudden demand. Various means have been devised to cope with the problem.

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[14]Miller and Shea, loc. cit.

[15]Stephens and Spencer, op. cit., pp. 221-224.

[16]E. De Golyer (ed.), Elements of the Petroleum Industry (1940), pp. 443-448.

Underground Storage.--One solution has been underground storage. It should be safe, reliable, easily installed, simple to operate and have low investment and operational costs.[17] There are two general types of storage fields; small fields containing only two or three trillion cubic feet of natural gas with a high deliverability for peak load conditions, and larger pools for balancing the system by absorbing surplus gas during the summer months and maintaining pressure under peak loads in the winter months.[18] This sustains the load factor[19] over the year at a high figure.[20] The increased annual load factor tends to eliminate the interruptable service to industrial concerns by providing a surplus of gas during peak withdrawals.[21]

The forerunner of underground storage was the Big Zoar Well south of Buffalo, New York. It belonged to the United Company that was piping gas from Pennsylvania to Buffalo. The well was a fifteen million cubic foot producer, but due to formation "tightness" the pressure would drop to only 800,000 cubic feet per day in a short time. This well was located very near Buffalo and was not used for normal production but was turned into the line when a sudden cold snap caused increased consumption and a decrease in delivery pressures. The addition of pressure in the line from the Big Zoar Well would

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[17] D. V. Meiller, "Underground Storage of Gas," Public Utilities Fortnightly, XLII (October 7, 1948), p. 482.

[18] E. G. Dahlgren, "Underground Natural Gas Storage," Gas Age, IC (May 29, 1947), p. 18.

[19] The daily load factor is defined as the ratio of the average daily demand to the system capacity.

[20] Distributing companies contract to deliver surplus natural gas at a reduced rate to industrial consumers subject to termination of use whenever the domestic withdrawals approach 100 per cent of the load factor. This service is usually offered during the summer months and is known as interruptable service.

[21] S. B. Irelan, "Winter Supply Problems of Transporters," Petroleum Engineering, XXI (December, 1949), p. D-18.

cushion the deliveries until demands decreased. The well was worth thousands of dollars to the company through its emergency use.[22] Actual gas storage operations began in the Big Zoar field on June 15, 1916, after wellhead pressures decreased to 48 pounds per square inch. In nine years, nearly two billion cubic feet of gas were injected and withdrawn. The maximum amount stored at one time was three hundred million cubic feet at a pressure of 215 pounds per square inch.[23] Following the Big Zoar field, other experimental storage projects and the widespread development in 1926 of the Dominguez, Brea-Olinda and other storage pools in California placed this phase of the industry on a sound basis.

As early as 1919, F. S. Panyity presented one of the first formal attacks on the problem of decreased pressures during periods of sudden increased demand.[24] A local gas field that has been exhausted could be utilized to store the summer surplus and supplement the demands of the consuming area whenever they exceeded the amount of gas that could be turned into the line at the producing field.

Approximately seventy storage pools were located in Arkansas, California, Kansas, Kentucky, Michigan, New Mexico, New York, Ohio, Oklahoma, Pennsylvania, and West Virginia in 1947. About fifty of these were located in Ohio, Kentucky, West Virginia, Pennsylvania, and New York.

The seventy storage pools in the United States have a delivery capacity

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[22] Eugene Coste, Discussion of L. S. Panyity's paper, "Natural Gas Storage," Transactions of the American Institute of Mining and Metallurgical Engineering, LXI (1919).

[23] Miller and Shea, *op. cit.*, p. 68.

[24] F. S. Panyity, "Natural Gas Storage," Transactions of the American Institute of Mining and Metallurgical Engineering, LXI (1919), pp. 617-18.

of 1,500,000,000 cubic feet per day while working storage capacities are 120,000,000,000 cubic feet with a maximum storage of 250,000,000,000 cubic feet.[25]

Storage in the Line.--A natural gas pipe line is, first, a conduit for gas and second, a storage reservoir. Pressures may be increased in the line during slack withdrawal periods to the maximum in order to supply a greater amount of natural gas when it is needed.[26] A northern Illinois utility company developed an underground battery of large-diameter pipe filled with gas at pressures in excess of 2,250 pounds per square inch. This method places the gas very near its consuming point and can be fed directly into the mains. The costs are believed to be less than the large low-volume tanks commonly in use.[27]

Liquification.--Another method being used for gas storage is liquification by cooling natural gas to $-260^{\circ}$ F. and storing the liquid in Fuller's earth. Gas can be decreased to 1/300 of its original volume by this method. The gas is released when the temperature is restored.[28]

Even though many means are used to alleviate the shortage at the market, the main source of gas is in the producing field. Gas is routed from market areas having mild weather to those suffering from a sudden cold wave. Every engine is driven at full capacity and all possible wells are turned into the

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[25]Dahlgren, loc. cit.

[26]Joseph Joffe, "Storage Capacity of Long Pipelines," Chemical Engineering, LVI (November, 1949), p. 112.

[27]F. S. Lott and H. Backus, Minerals Yearbook (1946), p. 834.

[28]The Oil and Gas Journal, XXXXVIII (March 30, 1950), p. 59.

line to keep the pressure near normal.[29]

## Economics of Pipe Line Operations

The basic factors influencing the economic and financial operations of natural-gas transportation lines are the large investment required and the fluctuating nature of the market demands for the transported gas.

Basic Economic Principles.--The delivery cost per unit increases directly with the length of the line for a given diameter.

A line operated at capacity volume will have a lower unit cost as the diameter of the pipe increases. The volume capacity increases more rapidly than the cost of increased diameter.

There are no increased savings to be realized from constructing longer units as the cost per mile remains constant with increased length.[30]

Capital Investment.--Capital investment in the industry is based on the volume of gas to be delivered on a peak day and the distance over which the gas must be transported.[31] Capital expenditures of the natural gas industry have increased at a rate exceeding that of most businesses. The dollar volume of all private domestic investments increased about four times between 1939 and 1948. The electric utility industry increased five times. The natural gas industry's capital expenditures increased over twelve times. Actual cash outlay was from a little less than $50,000,000 in 1939 to $630,000,000 in 1948.[32] If the sale of the Big and the Little inch pipe lines is included in

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[29] "How Pipelines Operate," Science Digest, XXVI (November, 1949), p. 65.

[30] Joseph A. Kornfeld, Natural Gas Economics, p. 223.

[31] Smith and Wimberly, op. cit., p. 252.

[32] Edmond M. Hanrohan, "What's Ahead for Natural Gas Expansion Financing?" Public Utilities Fortnightly, XLIII (January 6, 1949), p. 13.

1948, the expenditures would be above $770,000,000. The estimated capital investment in 1949 was $948,000,000. The American Gas Association committee on economics, estimates that $3,500,000,000 will be spent from 1948 to 1952 inclusive.[33] The investment of $1,750,000,000 from 1948 to 1952 inclusive on new transmission facilities is expected to more than double the interstate transportation of natural gas. The thirteen major transporters had an aggregate daily delivery capacity of 4,340,000,000 cubic feet on January 1, 1946. By April 1, 1948, these companies together with five new companies had filed applications for certificates to construct and operate additional transmission facilities that will have a combined capacity of 6,223,500,000 cubic feet.[34] This would bring the total daily delivery capacity to 10,563,500,000 cubic feet.

TABLE 6

TOTAL TRANSMISSION PLANT INVESTMENTS OF NATURAL GAS COMPANIES IN 1945*

| Item | Per Cent |
|---|---|
| Land and Land Rights . . . . . . . . . . . . . . . . . . . . . . | 3 |
| Pumping, Measuring, and Regulating Structures . . . . . . . | 5 |
| Pumping, Measuring, and Regulating Equipment . . . . . . . . | 14 |
| Mains . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | 78 |
| Total . . . . . . . . . . . . . . . . . . . . . . . . | 100 |

*Nelson Lee Smith and Harrington Wimberly, United States Federal Power Commission Docket G-580, Natural Gas Investigation Report (1948), p. 253.

[33]Owen Ely, "1948 Review of the Gas Industry," Public Utilities Fortnightly, XLIV (October 27, 1949), p. 586.

[34]Louis J. Zitnik, "The March of the Gas Transmission Lines," Public Utilities Fortnightly, XLV (April 13, 1950), p. 484.

Table 6 shows the division of capital expenditures on transmission facilities. The relatively high cost of the mains is evidently a limiting factor to the expansion of pipe line systems.

The proportionate increase in construction costs in 1946 was less for large diameter pipe than for smaller pipe (Table 7). At the average book costs of pipe lines constructed prior to 1946, it would cost $306,000 to build a hundred-mile 24-inch transmission line. A similar line in 1946 would cost $104,000 more.

TABLE 7

CONSTRUCTION COSTS OF PIPE LINES IN THE UNITED STATES*

| Diameter of Pipe in Inches | Cost Per Mile of Line | | Cost Per Inch of Diameter Per Mile of Line | |
|---|---|---|---|---|
| | Pre-1946 av. | 1946 | Pre-1946 av. | 1946 |
| 4 | $ 3,400 | $ 6,000 | $ 850 | $1,500 |
| 8 | 7,100 | 12,000 | 900 | 1,500 |
| 12 | 12,000 | 18,500 | 1,000 | 1,550 |
| 16 | 17,700 | 25,000 | 1,110 | 1,600 |
| 20 | 24,000 | 33,000 | 1,200 | 1,650 |
| 24 | 30,600 | 41,000 | 1,300 | 1,700 |

*Nelson Lee Smith and Harrington Wimberly, United States Federal Power Commission Docket G-580, Natural Gas Investigation Report (1948), pp. 253-4.

Demands for Natural Gas.--The demands on natural gas lines are of three types: (1) the stable domestic demand derived from general household use; (2) the space heating demand causing a large withdrawal during cold periods; and (3) the interruptable industrial consumers demand. The stable domestic demand does not fluctuate greatly during a season. The load factor of this demand would be quite high over a period of a year. The space heating demand is a seasonal demand that forces the producer to construct larger lines if he wants to serve this market. These lines would have a very high load factor during the cold months and a very low load factor during the warm months. The interruptable industrial demand is a device resorted to by pipe line companies to increase their annual load factor by sale of surplus gas to industrial consumers during periods of low domestic consumption. The price is much lower than domestic gas and the supply may be decreased or entirely stopped if peak domestic demands approach the maximum load factor.

## Principal Pipe Lines of the United States

Physical evidence of the greatest network of pipe lines in the world does not exhibit itself by huge ramifications. The boosting stations at frequent intervals are the usual indicators of this vast web. Actual lines may become evident where they span a stream on a suspension bridge, or they may remain buried twenty-five feet below the bed of the river. Lines vary from two inches up to thirty-six inches in diameter and in length up to the 1,840-mile trunk line from the lower Rio Grande Valley to 134th Street, New York City.

Pipeways.--The great concentration of reserves in the Mid-Continent and Gulf Coast areas has led to the establishment of pipeways to consuming areas throughout most of the United States. There are four general pipe-line highways to markets (Fig. 1). (1) The most obvious is the route of the Super-Inch pipe line of the El Paso Natural Gas Company from the Texas Panhandle and West Texas fields along the southern boundary of the United States to California. (2) The route of the partially completed line of the Trans-Continental Gas Pipe Line Corporation extends from the lower Rio Grande Valley along the Gulf Coast to the southern edge of the Appalachians where it follows the eastern foothills of the mountains to New York City. (3) The route of the Big and Little-Inch pipe lines from East Texas leads northeast to Ohio where they turn almost due east to New York City. (4) The routes from the Hugoton and the Texas Panhandle field also travel northeast to the Chicago-Detroit market.

These lines serve intermediate areas with natural gas but most of it is delivered to the California, the Chicago-Detroit, or the Appalachian-New York markets. As the reserves decrease in these market areas, transmission of natural gas will have to be increased or other sources of fuel be used.

Recent Development of the Net.--The natural gas industry was centered in the Appalachian states until 1920. During this year, vast quantities of natural gas became available from the oil fields of Oklahoma, California and the Gulf Coast of Texas and Louisiana. Development of welded steel and seamless pipe provided an added incentive and loosened the physical bonds of the natural gas industry.[35] The welded line had been used for short distances before 1926, but after that date it was widely used in the construction of long-distance transmission lines. Pipe lines of varying lengths, up to three hundred miles had been built to serve 3,500,000 customers in twenty-three states with more than one trillion cubic feet of gas consumption per year. The major areas of development were the Monroe field in northern Louisiana and the Panhandle field in Texas. The huge supply of gas and the improved technology of high-pressure lines led to a rapid expansion of natural gas transportation lines.

Following 1926, there was a rapid expansion of the old transmission companies. Some of the larger ones were:

(1) Consolidated Natural Gas Corporation System

(2) Oklahoma Natural Gas Company

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[35]"Natural Gas Landmarks," Public Utilities Fortnightly, XXXXIV (October 27, 1949), p. 598.

# MAJOR NATURAL GAS PIPELINES IN THE UNITED STATES

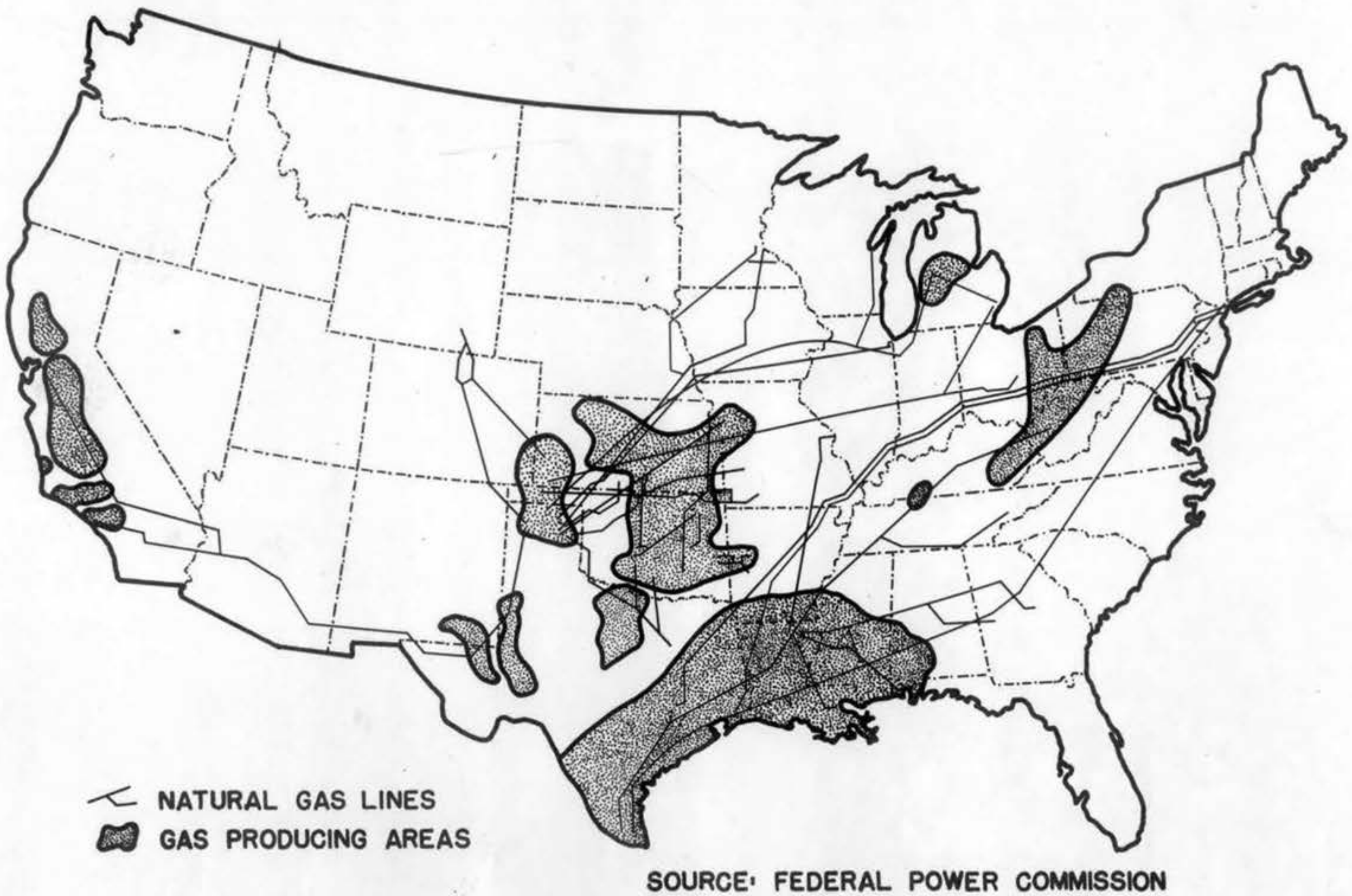


FIGURE I

(3) Columbia Gas and Electric System

(4) Arkansas-Louisiana Gas Company

(5) United Gas Pipe Line Company

(6) Lone Star Gas Corporation

(7) Cities Service Gas Company

A group of new companies appeared from California to New York City during this same period to capitalize on the growing natural gas market. The major companies in this group were:

(1) Interstate Natural Gas Company, and Southern Gas and Fuel Company from Monroe field, Louisiana, to New Orleans

(2) Mississippi Fuel Corporation from Monroe field, Louisiana, to St. Louis, Missouri

(3) Memphis Natural Gas Company from Monroe field, Louisiana, to Memphis, Tennessee

(4) Colorado Interstate and Canadian River Gas Companies from the Panhandle field, Texas, to Denver, Colorado

(5) Northern Natural Gas Company from the Panhandle field, Texas, to Minneapolis, Minnesota

(6) Southern Natural Gas Corporation from Monroe field, Louisiana, to Atlanta, Georgia

(7) Natural Gas Pipe Line Company of America and Texoma Natural Gas Company from the Panhandle field, Texas, to Chicago, Illinois

(8) Panhandle Eastern Pipe Line Company from the Panhandle field, Texas, and the Hugoton field in Kansas to Michigan.[36]

The above companies were in operation by 1932. Pipe line construction then lagged until the early 1940's. New lines were started in 1941. The Tennessee Transmission Company line was completed from the extreme southeastern tip of Texas and from Louisiana into the Appalachian area in 1944. It was a 24-inch line, 1200 miles long and was designed to operate at 750 pounds per

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[36]Smith and Wimberly, op. cit., p. 239.

square inch working pressure. This was 50 per cent above the working pressure of the lines built ten years before. The line was built to relieve the gas shortage resulting from the depletion of fields in the Appalachian area. It was the longest large-diameter pipe line ever built to that time.[37]

Texas Eastern Transmission Corporation bought the Big and Little Inch pipe lines in 1947 for $143,000,000. The Big Inch is a 24-inch line built as a war emergency measure in 1943 to convey 200,000 barrels of crude oil daily over the 1,254 miles from Longview, Texas, to Phoenixville, Pennsylvania, and via lateral lines to refineries at Philadelphia and Linden, New Jersey. The Little Inch is a 1,480 mile line, 20-inches in diameter, that was built a year later from Beaumont, Texas, to Linden, New Jersey. The combined lines, now converted to natural gas, serve markets in Missouri, Illinois, Indiana, Ohio, West Virginia, Pennsylvania, New Jersey, and New York. Conversion from a crude oil line to a gas line cost $50,000,000 and required two and one-half years. Twenty-five compressor stations were built at intervals of fifty miles. Over 500 miles of new line had to be constructed. The installed power plants are equivalent to the power of seventy Diesel locomotives.[38]

The El Paso Natural Gas Company constructed a 1,011 mile line from Dumas, Texas, to Blythe, California, in 1947. The importance of this line is indicated by the fact that deliveries were made almost three years in advance of the original plans.[39] First deliveries were made on November 13, 1947.

> The company's main line transmission system at the present time (February 10, 1950) is comprised of a 24" line from Dumas, Moore County, Texas Panhandle, to the Company's gasoline plant at Jal,

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[37] Poe, op. cit., p. 554.

[38] "How Pipelines operate," op. cit., p. 64.

[39] Backus and Lott, op. cit., p. 809.

New Mexico, a distance of 272 miles, and a 26" line from Jal, New Mexico, to Blythe on (the) Arizona-California line, a distance of 739 miles, and a loop of 685 miles of 30-inch and 102 miles of 26-inch. The original system of relatively small diameter lines in New Mexico and Arizona are now integrated into a general system. Application is pending for (a) line from San Juan Basin, northwest New Mexico, to Topeck, Arizona, a distance of 451 miles.[40]

The Transcontinental Gas Pipe Line Corporation expects to complete its 30-inch line from the lower Rio Grande Valley to 134th Street, New York City, by December 1, 1950. The Federal Power Commission granted authority to construct the line in May, 1948, at a total cost of $200,000,000. This sum was obtained from private capital. The authorized capacity of the line was 505,000,000 cubic feet daily at a working pressure of 800 pounds per square inch.[41] Almost 650 miles of the line had been constructed by April 1, 1950. Five of the twenty compressor stations had been constructed and fourteen were under way. Fourteen individual construction units are currently at work on the project. Steel for the pipe is being furnished by the Kaiser Steel Company from the Fontana, California, plant.

The source of the gas for Transcontinental's new line will be thirty-four fields extending six hundred miles along the Gulf. Reserves are estimated at nearly fifty trillion cubic feet. An increasing rate of withdrawals may be experienced in the future as a contract has already been signed to deliver one hundred million cubic feet per day to a New England pipeline company.[42]

Table 8 reflects the construction of these large lines. The mileage of

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[40]Correspondence from Robert P. Reid, Phillips Petroleum Company, Bartlesville, Oklahoma (April 13, 1950).

[41]Poe, loc. cit.

[42]Claude Williams, "The Story of Transcontinental," The Oil and Gas Journal, XXXXVIII (May 4, 1950), pp. 81-83.

natural gas lines without regard to the increased diameters has increased almost 70 per cent during this period while lines for manufactured gas decreased more than 20 per cent.

TABLE 8

MILES OF UTILITY GAS MAINS[a]
(000 omitted)

| Year | Total | Natural Gas | Manufacturers Gas | Mixed Gas | LPG[b] |
|---|---|---|---|---|---|
| 1932 | 254.8 | 154.6 | 85.1 | 15.1 | |
| 1933 | 261.0 | 160.1 | 85.1 | 15.8 | |
| 1934 | 262.2 | 162.7 | 83.5 | 15.8 | |
| 1935 | 265.2 | 165.6 | 83.2 | 16.4 | |
| 1936 | 270.4 | 173.6 | 79.9 | 16.9 | |
| 1937 | 274.6 | 177.1 | 80.6 | 16.9 | |
| 1938 | 277.9 | 181.8 | 79.2 | 16.9 | |
| 1939 | 281.7 | 184.4 | 80.0 | 17.3 | |
| 1940 | 286.8 | 189.0 | 79.8 | 18.0 | |
| 1941 | 292.0 | 192.6 | 81.1 | 18.3 | |
| 1942 | 296.2 | 196.5 | 81.0 | 18.7 | |
| 1943 | 299.7 | 203.2 | 77.6 | 18.9 | |
| 1944 | 307.5 | 212.4 | 75.9 | 19.2 | |
| 1945 | 310.8 | 218.1 | 72.0 | 18.7 | 2.0 |
| 1946 | 318.9 | 226.5 | 71.1 | 18.5 | 2.8 |
| 1947 | 331.4 | 242.9 | 68.0 | 15.8 | 4.7 |
| 1948 | 346.4 | 259.4 | 67.0 | 14.2 | 5.8 |

[a]E. Holley Poe, "Is Natural Gas Essentially a Transportation Industry?" _Public Utilities Fortnightly_, XLIV (October 27, 1949), p. 553.

[b]Liquified Petroleum Gases.

Interstate shipments of gas are dominated by Texas. She exported more than twice as much natural gas as Louisiana in 1946 (Table 9). More than three-fourths of the exported gas in 1946 was derived from the four southwestern states, Texas, Louisiana, Oklahoma, and Kansas. "Gas pipe lines now supply the country with more than five times the energy produced by the entire electric utility industry."[43]

TABLE 9

INTERSTATE SHIPMENTS OF NATURAL GAS IN 1946*

| State of Origin | Per Cent |
|---|---|
| Texas | 39 |
| Louisiana | 18 |
| Oklahoma | 13 |
| West Virginia | 10 |
| Kansas | 8 |
| Other States | 12 |
| Total | 100 |

*H. Backus and F. S. Lott, Minerals Yearbook (1947), p. 816.

## Principal Pipe Lines of Oklahoma

The three major pipe-line nets in Oklahoma in 1949 are shown in Figure 1, page 60. The Cities Service Gas Company has a large line extending almost due east from Texas County into Ottawa County. There is a southern extension of this system to the Cement field from Blackwell. Two loop lines serve the northwest corner of the state from the Texas Panhandle field enroute to Eastern Kansas markets. The Oklahoma Natural Gas Company's main line from the Cement field to Tulsa via Oklahoma City is supplemented by two 16-inch lines and an 8-inch line from the Quinton field to Tulsa. The Lone Star Gas Company has collecting lines from the Loco and Fox pools and has also obtained rights for

[43]"Gas Goes Boom," Readers Digest, LV (July, 1949), p. 100.

additional supplies from later pools. This gas is exported to Dallas, Fort Worth and other northern Texas cities where it has become an important fuel.[44] The Arkansas-Oklahoma Gas Company has a small net near the Poteau area and into the market area of Fort Smith, Arkansas.

The Oklahoma Natural Gas Company.--As early as 1939, the Oklahoma Natural Gas Company operated the largest gas gathering, transporting, and distributing system in the state.[45] The core for this system was constructed in the early days of statehood by three pioneers from Pennsylvania who laid the first major transmission line in the state from a point southwest of Tulsa to Oklahoma City.[46] From this modest beginning appeared some 2,104 miles of transmission lines and 1,934 miles of distribution lines serving over 600,000 people in ninety-six Oklahoma communities in 1939.[47] The Oklahoma Natural Gas Company collects gas from sixty-five fields scattered over the eastern and southern portion of the state. Main sources of supply are the Cement and Quinton fields. Twenty-one of the thirty-two counties touched by this system contribute reserves of gas. The main artery is a 12-inch line from Oklahoma City to Tulsa with a short 6-inch feeder line which taps the south Stroud field. The west Cement field is linked to the 12- and 16-inch lines from the Chickasha fields to Oklahoma City. An 8-inch line parallels this large line and the combined

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[44] Henry A. Ley (ed.), Geology of Natural Gas (1935), p. 516.

[45] Joseph Bowes and F. W. Peters, "History: A Case Study of the Oklahoma Natural Gas Company," Gas Age, LXXXIV (December 12, 1939), p. 22.

[46] Frank B. Long, "Natural Gas in Oklahoma," Gas Age, LXXXIII (April 27, 1939), p. 34.

[47] C. V. Daniels, "From Gas Sand to Gas Consumer," Gas Age, LXXXIV (April 27, 1939), p. 34.

daily delivery is eighty-five million cubic feet to Oklahoma City.[48]

Oklahoma Natural Gas Company has recently invested over $3,000,000 in 133 miles of new natural gas transmission lines connecting Garvin, McClain, and Stephens Counties to the existing system. The 68.4 miles of old line between Blanchard and Stroud was reconditioned to operate a pressure of a thousand pounds per square inch. It was necessary to remove, clean, recondition, coat, and re-lay this line to bring it up to standard. The repairs cost over one million dollars.[49]

Five oil companies are cooperatively building three natural gasoline plants, one at Maysville and the others at Antiock and Lindsay in the Garvin County area. Skelly Oil Company has constructed another on the Velma pool in Stephens County. These four plants will provide a large amount of residue gas to the three natural gas lines being constructed into the area by the Oklahoma Natural Gas Company. Sixty-six miles of 16-inch line, extending northeast from Maysville to a point six miles east of Wewoka, intersects another 16-inch line serving eastern and northeastern Oklahoma. The second is a 12-inch line running thirty-four miles west of Maysville to a point near Chickasha where it meets the main line from the Chickasha-Cement fields to Oklahoma City and northern markets. Another 12-inch line leads thirty miles south and west from Maysville, to the Skelly plant at Valma in Stephens County. A fifteen mile extension of 10-inch line southeastward from Velma connects with the Ardmore transmission net three miles west of Graham in Carter County.[50]

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[48] Robert W. Ducker, "Gasways Keep Pace: Transmission and Distribution," Gas Age (December 21, 1939), pp. 31-32.

[49] The Daily Oklahoman (October 23, 1949), p. 21.

[50] "Oklahoma Natural Completing Major Expansion Project," Gas Age, CIII (March 31, 1949), p. 22.

The Oklahoma Natural Gas Company had 3,398 miles of gas line in 1939 as compared to 5,496 miles in 1949. Natural gas lines in Oklahoma total about 8,000 miles. Oklahoma Natural Gas Company owns about 70 per cent of the state's mileage.[51]

Underground Storage.--There are two large underground storage fields in Oklahoma. The Osage reservoir is located two miles northwest of Tulsa, a major market area in Oklahoma. It has an area of almost two thousand acres. The field had 1,700,000,000 cubic feet in storage on October 31, 1946.[52] Five or six wells can deliver over thirty million cubic feet per day from this pool.

Two main transmission lines, a 14-inch and a 12-inch line, link the Haskell Storage field, thirty miles southeast of Tulsa to the supply system of the Oklahoma Natural Gas Company and the major markets in eastern Oklahoma. This field was developed in 1943 and covers an area of 5,320 acres. It is estimated to hold eight billion cubic feet with a delivery rate of thirty-five million cubic feet per day.

The Osage field is used for sudden loads while the large Haskell field is used to balance the seasonal loads. About 4,500,000,000 cubic feet per year will be stored and delivered from these fields. The greater available reserves will extend more reliable service to industrial consumers.[53]

Interstate Transportation of Oklahoma's Gas.--Oklahoma was exporting 19 per cent of her natural gas as early as 1921. Fourteen years later, in 1935, the quantity exported remained approximately the same but the intrastate market had reduced the ratio to only 9 per cent. From 1935 to 1945, the quantity

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[51] The Daily Oklahoman (October 23, 1949), p. 18.

[52] Dahlgren, loc. cit.

[53] W. R. Kubista, "Performance of Two Underground Gas Storages," Gas Age, IC (April 17, 1947), p. 47.

consumed in the state decreased slightly but the exports of natural gas increased from twenty-five million cubic feet to 122 million cubic feet, an increase of almost 500 per cent in ten years. The ratio of interstate deliveries to total supply increased until almost one-third of Oklahoma's natural gas was being exported. In 1946 the quantity consumed within the state decreased slightly while exports increased almost 23 per cent over the previous year (Table 10).

TABLE 10

INTERSTATE TRANSPORTATION OF OKLAHOMA'S NATURAL GAS*
(Million Cubic Feet)

| Consuming State | 1945 | 1946 |
|---|---|---|
| Arkansas | 4,612 | 4,133 |
| Illinois | 2,402 | 3,909 |
| Indiana | 3,985 | 6,971 |
| Kansas | 57,984 | 66,774 |
| Michigan | 6,541 | 12,794 |
| Missouri | 25,740 | 28,522 |
| Nebraska | 819 | 879 |
| Ohio | 5,030 | 8,263 |
| Texas | 14,409 | 17,981 |
| Others | 512 | |
| Total Exported | 122,034 | 150,136 |

*Source: Bureau of Mines

Arkansas was the only major market area receiving less gas from Oklahoma in 1946. The other states increased their consumption. The states of Kansas and Missouri received more than 55 per cent of Oklahoma's exports but increased their consumption only slightly over 1945. The areas responsible for increased exports in 1946 are Illinois, Indiana, Michigan and Ohio (Table 10). These states have a large potential market and shipments to them will probably increase.

The sales of natural gas from transmission lines may be to an operating utility at the city gate, sold directly through an integrated system dispensing the gas, or to large industrial consumers. The uses and rates are preferential with certain advantages and disadvantages experienced by each type of consumer.

# CHAPTER V

## THE CONSUMPTION OF NATURAL GAS

The increase in consumption is surpassed only by the potential consumption of natural gas. Natural gas is cheap, clean, and may be available throughout the year for domestic and commercial users. The extension of transmission lines is increasing the market areas with an ever increasing demand for this ideal fuel.

The states of Texas, Louisiana, Oklahoma, and Kansas produced 78 per cent of the natural gas entering interstate commerce as well as using more than 50 per cent of all the gas produced in the United States in 1946. Natural gas is so abundant in this region it has limited the development of some of the coal resources of the Southwest.

Domestic and commercial consumers are the "breadwinners" of the natural gas industry. They use only 21.5 per cent of the total amount of natural gas, but pay 62 per cent of the bill. The service rendered these consumers is as nearly constant as possible and the premium they pay is partially for this service.

Industrial consumers are the volume users of natural gas at a rate only one-fourth that of other consumers. The supply is usually of the interruptable typo. Industry using natural gas in the off-season is desirable as it balances the annual load factor. The multitude of uses of natural gas in industry is almost uncomprehensible.

Oklahoma's reliance on natural gas is very great. It provides more than 80 per cent of the energy in the state. The pattern of consumption follows that of the United States average except the value of the gas consumed in the industries is proportionately greater. This gas is used largely in the primary industries. The greater portion of Oklahoma's gas enters interstate commerce and is consumed in the Midwest.

TABLE 11

TOTAL ENERGY SUPPLY OF THE UNITED STATES*

| Source | 1946 Per Cent | 1949 Per Cent |
|---|---|---|
| Coal . . . . . . . . . . . . . . . . . . . . . . . . . | 48 | 38 |
| Oil (Including Imports) . . . . . . . . . . . . | 35 | 39 |
| Natural Gas. . . . . . . . . . . . . . . . . . . . . | 13 | 18 |
| Hydro-Electric Power . . . . . . . . . . . . . . | 4 | 5 |
| Total . . . . . . . . . . . . . . . . . . . . . | 100 | 100 |

*Edward Falck, "Will F. P. C. Regulation Affect the Fuel Markets?" Public Utilities Fortnightly, XLV (May 11, 1950), p. 597.

## Consumption of Natural Gas in the United States

Natural gas is one of the cheapest of all fuels.[1] If the industry were not regulated, the low cost of production could place it in more than a competitive position with the other fuels. There are only two fields of consumption in which natural gas has no fuel competitors. Carbon black may be made only from natural gas, and some other industries use natural gas as a catalytic agent or raw material in their manufacturing process.[2]

Natural gas provided approximately one-seventh of the total developed

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[1]Frederick F. Blachly and Miriam E. Oatman, Natural Gas and the Public Interest (1947), p. 40.

[2]R. W. Hargrove, "Importance of Natural Gas in the National Economy," Gas Age, CII (November 25, 1948), p. 28.

energy in 1948.[3] During 1949, this increased until almost one-fifth of our energy was derived from natural gas (Table 11).

Geographical Distribution of Consumption.--More than four trillion cubic feet of natural gas was distributed to 12,437,000 consumers in thirty-six states and the District of Columbia, in 1946. The greatest portion is consumed by a comparatively small number of large industrial concerns in a few states. The ranking states are shown in Table 12. Texas consumed almost 35 per cent of all the natural gas produced in the United States in this year. The second

TABLE 12

STATES CONSUMING OVER 100 BILLION CUBIC FEET OF NATURAL GAS IN 1946*

| State | Million Cu. Ft. |
|---|---|
| Texas | 1,366,457 |
| California | 487,904 |
| Louisiana | 331,364 |
| Oklahoma | 245,981 |
| Ohio | 188,527 |
| Kansas | 175,820 |
| Pennsylvania | 158,587 |
| Illinois | 124,284 |
| West Virginia | 100,733 |
| Others | 2,779,657 |
| Total United States | 4,012,930 |

*Source: Minerals Yearbook (1947).

ranking state, California, was facing a critical shortage of natural gas until the El Paso Natural Gas Company's "Super-Inch" line was completed in 1947. More

[3] George Grover Oberfell, "Reserves of Natural Gas," The Oil and Gas Journal, XXXXVII, No. 46 (March 17, 1949), p. 118.

than half of the natural gas consumed in the United States in 1945 was in the four states of Texas, Louisiana, Oklahoma, and Kansas. These same states provided 78 per cent of the natural gas entering interstate commerce in 1946 (Table 9, page 65).

Natural gas has a monopoly in the sections of the country where it is most abundant. The greater convenience and cheaper price of gas as compared to coal or petroleum has almost eliminated these latter fuels as heat and power fuels.[4]

Domestic and Commercial Consumption.--Total consumption of natural gas was over five trillion cubic feet in 1949. Domestic and commercial consumers used approximately 34 per cent of this amount.[5] The nation's consumers increased in number more than one million during 1949, to 13,500,000. This more than doubled the increase of the previous year.[6]

The regional consumption of natural gas in the United States in 1945 is shown in Table 12. This figure shows consumption within political boundaries without regard to type of use. Domestic and commercial consumers contributed 62 per cent of the revenue although they used only 21.5 per cent of the total consumed gas.[7] Natural gas, marketed through pipe lines, averages four times as high to domestic users and two and one-half times as high to commercial users as it does to industrial consumers.

The low rate offered to industrial consumers is to utilize the pipe line

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[4]Hargrove, loc. cit.

[5]"Natural Gas-Whoosh!" Fortune, XXXX (December, 1949), p. 108.

[6]Survey of Current Business (1949 Sup.), United States Department of Commerce: Bureau of Foreign and Domestic Commerce, p. 133.

[7]Nelson Lee Smith and Harrington Wimberly, United States Federal Power Commission Docket G-580, Natural Gas Investigation Report (1948), p. 40.

at capacity load during periods of slack domestic demand. If this idle capacity is used to deliver large quantities of fuel at low rates to industry, the final domestic and commercial rates may be scaled down as the cost per unit of natural gas is less at a maximum load factor. The low rate is the method used to obtain quantity consumption. Service may be curtailed or interrupted at any time as domestic withdrawals approach the maximum load factor.

Industrial Consumption.--Industrial consumers use the greater portion of natural gas. They used 3.3 trillion cubic feet of natural gas in 1949 or about 66 per cent of the total production although they paid only one-fourth as much for services rendered as the domestic users. In 1948, 3,000 new industrial consumers were added to the 818,000 consumers of the previous year.

TABLE 13

NATURAL GAS CONSUMPTION IN THE UNITED STATES IN 1947*

| | Per Cent |
|---|---|
| Industrial | |
| Field Use | 21 |
| Carbon Black | 11 |
| Petroleum Refining | 8 |
| Cement | 1 |
| Electricity Generation | 8 |
| Other Industrial | 26 |
| Total | 75 |
| Commercial | 7 |
| Domestic | 18 |
| Total | 100 |

*"Natural Gas-Whoosh!" Fortune, XXXX (December, 1949), p. 112.

Field Use.--The largest single use of natural gas is in the field. Its increased value to field operations may be evidenced by the tendency to replace steam rigs with internal combustion engines. Some field users in southern Louisiana are paying as much as fourteen cents per thousand cubic feet for natural gas. This price is considered too high and a reduction in the use of this fuel may appear as a result of its increased cost.[8]

Field use includes the gas used for oil- and gas-well drilling and pumping, for operating natural gasoline plants and the gas lost, consumed, or preserved in oil "lift" operations. The chief use is for boiler fuel. This use is directly related to the availability of natural gas.

Carbon Black.--Within a short time after the development of new gas fields, carbon black plants usually appear. This industry is located near the field in order to obtain an abundance of cheap natural gas. Theoretically, carbon black manufacture may be regarded as a waste of a natural resource, but from a practical viewpoint, the carbon black plants recover a portion of the gas formerly vented into the air and have been among the first conservationists in the field. Modern carbon black plants are using sour gas that otherwise must be treated before it can be consumed as a fuel.[9] Carbon black is usually manufactured by burning natural gas with insufficient oxygen to allow complete oxidation. The carbon particles cling to a surface from which they are collected. There are about thirty-two pounds of carbon black in one thousand cubic feet of natural gas. Some recovery processes obtain 50 per cent of this, but the national average was 2.44 pounds in 1946. If the average yield could be in-

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[8]Leigh S. McCaslin, Jr., "Along the Gulf," The Oil and Gas Journal, XXXXVIII (March 16, 1950), p. 54.

[9]Maynard M. Stephens and Oscar F. Spencer, Natural Gas Engineering (III, 2d ed., 1948), pp. 19-20.

creased to five pounds per thousand cubic feet, the consumption of natural gas by the carbon black industry could be reduced about 250 billion cubic feet annually or about as much as commercial consumers used in 1946.[10]

Texas produces 82 per cent of the carbon black in forty-three plants, thirty-two of which are in the Panhandle field. Low cost sour gas is available in large quantities in this field.[11] Louisiana and New Mexico also produce carbon black.

Petroleum Refining.--Natural gas is used for oil refining in Texas, California, Louisiana, Oklahoma, and Kansas. These states consumed 95 per cent of the natural gas used for this purpose in 1945. Natural gas is not the prime fuel for this process, since excess refinery gases, fuel oil, and acid sludge provide more than half of the energy needed to operate the plants. Natural gas is not used in the refineries east of the Mississippi River.[12] Their fuels are largely those made at their own plants with no added transportation charges. This residual fuel has utilized products formerly burned or discarded as waste materials.

Cement Manufacture.--Natural gas used in manufacturing cement is largely confined to Texas, California, and Kansas. These states consumed 66 per cent of the gas used for this purpose with the remainder divided among ten states. This industry uses only 1 per cent of all the natural gas produced (Table 13, page 75). In 1945, only twelve cement plants used natural gas exclusively and

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[10]Smith and Wimberly, <u>op. cit.</u>, p. 371

[11]P. R. Taylor, "Effect of Introduction of Natural Gas on a Highly Industrialized Territory," <u>The Commercial and Financial Chronicle</u>, CLXVIII (December 9, 1948), p. 2416.

[12]Smith and Wimberly, <u>op. cit.</u>, p. 373.

106 of the 141 reporting cement plants used no natural gas at all.[13] Cement plants may regulate their use of natural gas to periods of low domestic withdrawal, especially, if favorable rates may be obtained. The lower cost of fuel coincides with the period of greatest demand for construction materials. The cement product, in a semifinished stage, is easily stored until it is needed. Coal producers, also suffering a loss of demand during the summer months, value their cement plant customers for the same reason and may also offer preferential rates on coal.[14]

Generation of Electricity.--The generation of electricity accounted for 8 per cent of the natural gas consumption in 1947 (Table 13, page 75). This generated 9 per cent of the total kilowatt-hours produced.[15] The proportionate use of other fuels has remained relatively constant in the electrical industry, while the use of natural gas has increased from 1.5 per cent in 1920 to 10.7 per cent in 1948. Most of the gas used in this industry is consumed in the Gulf Southwest and California. Texas consumes more than 30 per cent of the natural gas used in electrical generation.

Other Industrial Uses.--There were 31,800 miscellaneous industrial users of natural gas in 1945, including brick and pottery making, baking, and many other industries. Expansion is due to cheapness, ease of handling and control, simplicity of equipment, and efficiency of natural gas. The increased consumption of natural gas by these industries is encouraged by piping gas into

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[13] F. S. Lott and H. Backus, Minerals Yearbook (1945), p. 1239.

[14] Bituminous Coal Institute, Bituminous Coal Facts and Figures (1948), p. 68.

[15] Ibid., p. 118.

[16] American Gas Association, Gas Facts (1945-1946), p. 54.

industrial centers or by the migration of manufacturing concerns to the immediate vicinity of oil and gas fields. An example of the latter is the glass industry that has been attracted to the gas fields of Oklahoma, Texas, and California because this ideal fuel is cheaper and gives greater heat.[17]

Miscellaneous industrial users consumed at least 60 per cent of all natural gas moved in interstate commerce in 1945.[18]

Factors Affecting Price at Points of Consumption.--The proving ground for any fuel is its use by the ultimate consumer. The energy content provides a basis by which fuels may be compared by the consumer. By comparing the energy content and weighing the advantages and conveniences of any particular fuel by the consumer, evaluation of a fuel may be made. A factor of increasing importance has been the reliability of service. Certain fuels have become notorious through the periodic work stoppages that interrupt the movement of

TABLE 14

AVERAGE EQUIVALENT RETAIL FUEL PRICES PER MILLION B.T.U.*

| | 1935 | 1944 | 1947 |
|---|---|---|---|
| Natural Gas . . . . . . . . . . . . . . | $0.70 | $0.58 | $0.59 |
| Manufactured Gas . . . . . . . . . . | 2.05 | 1.74 | 1.70 |
| Bituminous Coal . . . . . . . . . . . . | .32 | .39 | .55 |
| Anthracite . . . . . . . . . . . . . . | .44 | .55 | .71 |
| Furnace Oils . . . . . . . . . . . . . | .47 | .57 | --- |

*Nelson Lee Smith and Harrington Wimberly, United States Federal Power Commission Docket G-580, Natural Gas Investigation Report (1948), p. 339.

[17] Vernon W. Brockmann, "The Glass Industries of the United States," p. 51.

[18] Smith and Wimberly, op. cit., p. 378.

fuel to market. The resultant of all these factors is the price that will be paid for a given quantity of fuel.

In the case of domestic consumers of natural gas, the choice among five fuels ranged from .39 cents per million B.t.u. for bituminous coal to $1.74 for manufactured gas in 1944 (Table 14). A coal trade journal recently emphasized that even though coal under-sells natural gas on a national average, there are millions of people willing to forego this saving for the convenience and cleanliness of natural gas. It would seem that if coal is marketed and burned in the style of twenty-five years ago, natural gas will continue to attract more home owners away from coal.[19] An increase in the price of coal from 1944 to 1947 has further reduced the resistance of home owners to convert to a fuel that appears to have a regulated price.

## Consumption of Natural Gas in Oklahoma

Only Louisiana and Texas are more dependent upon natural gas than Oklahoma. The abundance of this fuel limits the use of Oklahoma's 55 billion tons of coal reserves, but it is conserving this source of energy for the time when natural gas and petroleum may be less able to serve Oklahoma's energy requirements. Natural gas provides for more than 80 per cent of Oklahoma's total energy requirements (Table 15). The value of natural gas, produced in 1943, was $42,340,000 as compared to $146,600,000 for petroleum. These two ranking minerals produced almost 75 per cent of the income from minerals.[20]

Domestic and Commercial Consumption.--The 322,200 domestic consumers in Oklahoma paid more than thirteen million dollars for natural gas in 1946.[21]

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[19] "Natural Gas--Growing Coal Competitor," Coal Age (September, 1946), cited in Smith and Wimberly, op. cit., p. 339.

[20] Mineral Resources 1946, Oklahoma Planning and Resources Board, p. 3.

[21] H. Backus and F. S. Lott, Minerals Yearbook (1947), p. 823.

Slightly less than half of all the homes in Oklahoma used gas for cooking in 1939. Almost 9 per cent of the farm dwellings are served with natural gas. More homes use natural gas in the urban centers in the central and north-central portions of the state than in other areas. Fewer homes have this convenience in the southeastern portion of the state. The old fields, once serving portions of this area, have declined in production until they are no longer important. In LeFlore County, the home of the old Poteau field, only 19 per cent of the occupied units cooked with natural gas in 1940, while almost 70 per cent cooked with wood.[22]

TABLE 15

TOTAL ENERGY SUPPLY CONSUMED IN OKLAHOMA IN 1947*

| Source | Per Cent |
|---|---|
| Coal | 9.2 |
| Oil | 8.6 |
| Natural Gas | 80.6 |
| Hydro-Electric Power | 1.6 |
| Total | 100.0 |

*Bituminous Coal Institute, Bituminous Coal Annual (1949), p. 109.

The average cost in 1946 per thousand cubic feet was forty-six cents as compared to twenty-eight cents charged commercial consumers. Commercial consumers numbered only forty thousand but used more than 50 per cent as much gas as domestic users. Domestic consumers used 28,482,000 cubic feet while

22 Oklahoma County Basic Data, Market Research Department, Farm Journal, Inc. (1947), p. 40.

commercial users used 15,430,000 cubic feet. The larger volume at a higher rate for domestic users is the largest source of financial returns to the natural gas industry. The value of domestic and commercial consumption was $17,588,000 at the point of use.[23]

Industrial Consumption in Oklahoma.--Industrial consumers purchased over 202,069,000 cubic feet of natural gas in 1946, more than seven times domestic consumption, at an average of six cents per thousand cubic feet. The value of gas consumed in industry was $12,120,000 or about one million dollars less than the total domestic consumption. Field use accounted for more than 50 per cent of the total industrial use but contributed only 27 per cent of the value of the industrial consumption. Carbon black plants in Oklahoma consumed 5.5 per cent of the natural gas valued at $672,000. This was 7 per cent of the industrial consumption.[24] Electric utilities accounted for 7.2 per cent of all industrial consumption of natural gas in 1941.[25]

Of all Oklahoma's manufacturers, the manufacturers of petroleum and coal products use almost 50 per cent of the natural gas. They also pay 50 per cent of the total value of the gas used by Oklahoma manufacturers (Table 16). This industry is one of the major consumers of natural gas. The primary metal and the nonmetallic groups together used 33 per cent of the volume consumed and paid 32 per cent of the cost. Ordinarily the rate increases as the volume used decreases.

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[23]Backus and Lott, loc. cit.

[24]Ibid., p. 824.

[25]"Multiple-purpose Projects in Southwestern Region," Power Market Survey No. 609, Federal Power Commission, Fort Worth Regional Office (December, 1944), p. 160.

TABLE 16

CONSUMPTION OF NATURAL GAS IN OKLAHOMA'S MANUFACTURING INDUSTRIES IN 1947*

| Item | Million Cubic Feet | Cost |
|---|---|---|
| Petroleum and Coal Products . . . . . . . . . . | 28,614 | $2,925,000 |
| Primary Metal Industries . . . . . . . . . . . | 10,214 | 964,800 |
| Stone, Clay, and Glass Products . . . . . . . . | 9,012 | 919,600 |
| Food and Kindred Products . . . . . . . . . . . | 3,657 | 576,400 |
| Chemicals and Allied Products . . . . . . . . . | 2,755 | 184,900 |
| Others . . . . . . . . . . . . . . . . . . . . | 2,027 | 325,800 |
| Total . . . . . . . . . . . . . . . . . . | 56,279 | $5,896,500 |

*Source: Census of Manufactures 1947, MC 203.

The manufacturing industries in Oklahoma are important to the future development of the state. The abundance of cheap natural gas places Oklahoma industry in an advantageous position to compete with industry in other areas.

# CHAPTER VI

# NATURAL GAS RESERVES

Natural gas reserves are those gaseous hydrocarbon fractions that are estimated to be obtainable from areas known to have natural gas. The method of arriving at an estimation of the amount of natural gas recoverable in the future is an exceedingly complex study involving the porosity of the gas-bearing sand, the thickness and horizontal area of the producing bed, formation pressure and temperature, component fluids present in the reservoir, and the solubility of the gases in oil if the reservoir produces both oil and gas. The above factors do not become known until the records of production are studied for the field in question. Great care must be used in selection of data to represent an area since geological conditions may be extremely variable within the stratum of a field.

Natural gas reserves are those which have been estimated by the method described above or reserves which have not been explored sufficiently to allow an analysis of their potentialities. The latter is regarded as potential reserves while the first is known as proven reserves.

## Nature of Natural Gas Reserves in the United States

Natural gas has been discovered and proved in large quantities in the United States, Canada, Poland, Romania, the U.S.S.R., and the Netherlands Indies. The United States is the primary world producer and consumer. Ideal geologic conditions are responsible for the greater reserves in this country.[1]

Basing their estimation on recent additions and discoveries, leading

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[1]Henry A. Ley (ed.), Geology of Natural Gas (1935), p. 1100.

geologists have estimated the present reserves of natural gas will last at least forty years.[2]

Trend of Natural Gas Reserves in the United States.--Table 1, page 38, presented the current reserves as of January 1, 1950, in relation to production. Figure 2 shows the trend in the development of natural gas reserves in the United States from 1935 to 1950. Production has steadily increased except for a slight decline in 1938, but reserves have increased at a phenomenal rate. There were three times as many proven reserves on January 1, 1950, as had existed just twelve years earlier in 1937. This majestic increase has enabled natural gas companies to enter into long time agreements with industrial, commercial, and domestic consumers to provide an excellent fuel at a reasonable rate. Had natural gas reserves been confined to small pools, the exploitation, of necessity, would have been much more localized. Natural gas is available in quantity to the Midwest and Northeast because it has been concentrated in large enough pools to make major transmission-line expenditures feasible.

New pipe-line outlets and new markets appeared during 1949 but reserves again showed an increase similar to the previous year to reach a peak of 180,381,344 million cubic feet. An indication of a leveling off period may be noted as the ratio between inventory of proven reserves and annual withdrawals has decreased slightly. The 1948 ratio was 28.94 while the 1949 ratio was 28.88. The present pipe-line expansion program is very large and should cause this ratio to remain steady or decline for a number of years, barring another bonanza strike. Although the inventory ratio decreased,

[2]Ernest R. Abrams, "Why Life Insurance Companies Buy Natural Gas Pipe-Line Bonds," Public Utilities Fortnightly, XLV (April 27, 1950), p. 543.

a volume increase of 3.75 per cent was registered during 1949. This would indicate consumption increased proportionally.[3]

Geographical Distribution of Natural Gas Reserves by States.--About 89.5 per cent of the present reserves are located in the seven southwestern states of Texas, Louisiana, Oklahoma, Kansas, New Mexico, Mississippi, and Arkansas (Table 17). The state of California has approximately 5.5 per cent of the proven reserves, leaving 5.0 per cent in the Appalachian region, the Middle West, and the Rocky Mountain area.

TABLE 17

DISTRIBUTION OF NATURAL GAS IN THE UNITED STATES ON JANUARY 1, 1950*

| State | Per Cent of Reserves |
|---|---|
| Texas | 55.1 |
| Louisiana | 14.8 |
| Kansas | 7.8 |
| Oklahoma | 6.4 |
| New Mexico | 3.5 |
| Mississippi | 1.4 |
| Arkansas | .5 |
| Total Southwestern States | 89.5 |
| California | 5.5 |
| Appalachian, Rocky Mountain and Midwest Areas | 5.0 |
| Total United States Reserves | 100.0 |

*Computed from data given in Table 1, page 38.

Mr. E. DeGolyer, one of the countries foremost petroleum geologists, estimates that our petroleum reserves are close to 200 trillion cubic feet.[4]

[3]Charles J. Deegan, "Reserves are Up," The Oil and Gas Journal, XXXXVIII (March 16, 1950), p. 57.

[4]The Standard Oil Company, Natural Gas (1947), p. 9.

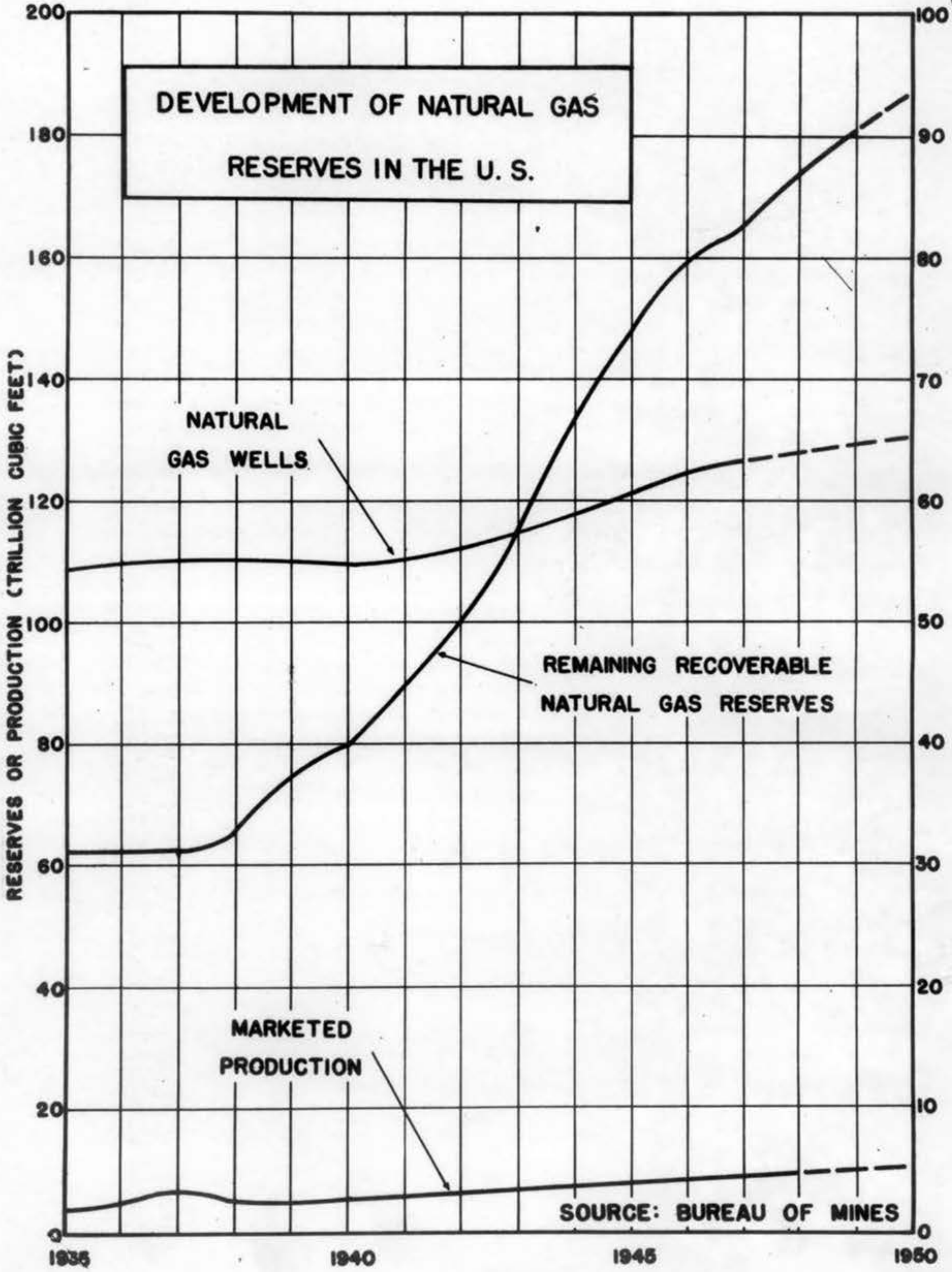
DEVELOPMENT OF NATURAL GAS
RESERVES IN THE U. S.
RESERVES OR PRODUCTION (TRILLION CUBIC FEET)
NATURAL
GAS WELLS
REMAINING RECOVERABLE
NATURAL GAS RESERVES
MARKETED
PRODUCTION
SOURCE: BUREAU OF MINES
0
20
40
60
80
100
120
140
160
180
200
10
20
30
40
50
60
70
80
90
100
1935
1940
1945
1950

FIGURE 2

Geographical Distribution of Major Fields.--Within the pronounced geographical concentration of natural gas reserves by states, they are even more localized inside the given states.[5] Almost half of the natural gas in the United States is contained in a small number of very large fields (Fig. 1, page 60). The time of discovery is sometimes emphasized too heavily since some of the major fields such as the deep Carthage gas field in Panola County in eastern Texas was discovered in 1936, but was not developed to any great extent until 1944.[6] Two years later there were over two hundred productive wells and the Carthage field was being acclaimed as the largest gas condensate reservoir in the United States. The present limits of the field are not known on the eastern side.[7]

Location of Industry to Natural Gas Reserves.--The concentration and location of gas fields at the apex of the large transmission lines to the Eastern and California markets is shown in Figure 1, page 60. The concentration of reserves provides a basis for changing the industrial outlook of the Southwest since more than 50 per cent of the natural gas is consumed within the seven state area. The major urban and industrial centers of the United States are far removed from the reserves of natural gas. If industry is to use natural gas, it must either move to the source or the gas must be transported to the market.

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[5]Twelve fields of the United States have almost half of the natural gas reserves. These fields are: The Hugoton field, Kansas, Oklahoma, and Texas; Katy field, Texas; Old Ocean field, Texas; Rio Vista field, California; Seeligson field, Texas; Agua Dulce-Stratton, Texas; Kettleman North-Dome field, California; Sheridan field, Texas; Pledger field, Texas; and the Monroe field, Louisiana.

[6]Nelson Lee Smith and Harrington Wimberly, United States Federal Power Commission Docket G-580, Natural Gas Investigation Report (1948), p. 40.

[7]F. K. Foster, "Carthage Gas Field Development," The Oil Weekly, CXXIV (December 23, 1946), p. 33.

The Federal Power Commission has not been overzealous in granting certificates of public convenience and necessity to pipe-line companies desiring to provide natural gas to new market areas. A twenty-year reserve of gas is required for the line, as well as a market guaranteed to absorb all the natural gas delivered. Few businesses can find a market which will agree to accept all of their product for such a long period of time. Natural gas transmission companies have been quite successful in meeting this requirement. The lack of large diameter tubing has previously held back expansion, but pipe is becoming a factor of expense rather than one of availability at the present time. This fact should permit the construction of major lines to the more favorable markets within the near future.

Future Supply of Natural Gas.--Natural gas is an irreplaceable resource. DeGolyer summarized the opinion of the petroleum industry on the status of this mineral:

> My judgement is that the present (1948) proved reserves of natural gas and the results of exploration and exploitation have been and are more than satisfactory enough to allow the reserves to the freely produced under good conservation practices.[8]

The number of gas pools being found each year is large. Although current efforts are rewarded by additional discoveries of gas fields, the average size is declining from those found in the early 1930's. From 1933 to 1938, there were twenty-two bonanza-type pools discovered but in the next six years only seven were discovered. In spite of a more diligent pursuit of natural gas, the newer fields are not as large and only a few major discoveries have been made in recent years.[9] In 1948, there were 112 new gas fields discovered and

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[8]E. DeGolyer, "The Natural Gas Industry," The Petroleum Engineer, XX (December, 1948), p. 148.

[9]E. DeGolyer, "Drilling Requirements Before and After VJ-Day," The Petroleum Engineer, XVI (December, 1944), p. 190.

forty-eight new gas pays developed in old fields. In 1949, there were 122 new gas fields found but only twenty-eight gas pay strata in the old fields.[10] The number of new fields is increasing while activity in old fields is decreasing.[11]

Additions to gas reserves will come from four sources. (1) Many fields that are producing from shallow strata have deeper potential reserves. A number of such pools have been discovered in Oklahoma. (2) Extensions of present fields will provide added reserves for future use. (3) Areas near known fields are excellent possibilities for new discoveries. With the constant improvement in drilling equipment, flanks of buried ridges such as the Nemaha may be explored at greater depths thus increasing the possibility of finding natural gas. (4) Potential discoveries also exist in those places not producing natural gas at present but having suitable sedementary rocks for the accumulation of natural gas.[12]

Wildcat wells drilled in search of oil have found and capped gas strata. These capped wells are brought into production as needed. The present supply developed from a reserve regarded as a liability only a few decades ago.

> The trend to deeper drilling for oil has probably accounted for some of the increase in gas reserves because with depth hydro-carbons seem increasingly to occur in gaseous phase. Inasmuch as constantly deeper drilling for oil will be the trend in the future it seems likely that the possibility of finding additional gas reserves in the deeper horizons will be increased concurrently.[13]

*Size of the Holdings of Reserves.*--An estimate showed that thirty-three

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[10] These statistics bear out E. DeGolyer's statement that the rate of discovery is declining as there were ten less fields located in 1949 than in 1948.

[11] Cecil W. Smith, "3.7 Per Cent Increase Made in Exploritory Drilling," *World Oil*, CXXX (February 15, 1950), p. 57.

[12] Smith and Wimberly, *op. cit.*, p. 54.

[13] DeGolyer, *op. cit.*, p. 148-149.

leading oil companies held about 116,000,000 acres of gas reserves in 1947, or 62.5 per cent of the total acreage. Earnings from the sale of natural gas represents a large portion of the total income of many of these large companies.[14] In comparison, there were only eleven automobile companies in the United States in 1940.[15] Concentration of only 62.5 per cent of the gas reserves in the hands of thirty-three large companies indicates a state of healthy competition between the companies in the natural gas industry. No block has control of the market such as exists in the automobile field among General Motors, Chrysler, and Ford.

## Natural Gas Reserves in Oklahoma

Oklahoma had 6.4 per cent of the natural gas reserves in the United States on January 1, 1950 (Table 17, page 86). Most of this is in the Guymon-Hugoton field in Texas County. About 80 per cent of Oklahoma's reserves are in this one field. They are a prime resource and are being developed rapidly. The dissipation of vast quantities of natural gas is not liable to occur in this large area due to rapid strides in proration and unitization of natural gas in Oklahoma. The eastern fields of Oklahoma have been exploited in the search for oil and are important to a more local area and are especially important as a source of power in the recovery of petroleum.

Geographical Distribution of Natural Gas Reserves by Counties.--The reserves of natural gas in Oklahoma have shown a shift from the south and east central portions of the state to the mighty Guymon-Hugoton field. In

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[14]Edward Falck, "Will F. P. C. Regulation Affect the Fuel Markets?" Public Utilities Fortnightly, XLV (May 11, 1950), p. 603.

[15]E. B. Alderfer and H. E. Michl, Economics of American Industry (1942), p. 139.

[16]L. C. Snider, Oil and Gas in the Mid-Continent Fields (1920), p. 286.

1916, there were thirty-one counties in the eastern half of the state producing natural gas profitably.[16] By 1942, production of dry gas in the western counties was becoming apparent. Ten counties were recorded as producing only natural gas, forty-two counties were producing both oil and gas in association, and only twenty-five counties were producing neither wet or dry gas.[17] Fifty-two counties were producing some form of natural gas during 1942. Additional reserves were located in four more counties by 1944.

The Oklahoma Planning and Resources Board listed the estimated reserves of natural gas in Oklahoma as of January 1, 1945, at 6,457 billion cubic feet. They qualify this figure by saying new fields are being constantly discovered and that the estimate can be considered conservative.[18]

TABLE 18

RECENT GAS DISCOVERIES IN OKLAHOMA

| Date | Reserves Million Cu. Ft. |
|---|---|
| December 31, 1945 | 10,079,938[a] |
| December 31, 1946 | 10,735,835[a] |
| December 31, 1947 | 11,350,864[a] |
| December 31, 1948 | 11,332,445[b] |
| December 31, 1949 | 11,625,979[b] |

[a]United States Bureau of Mines. [b]Oil and Gas Journal.

The United States Bureau of Mines listed for the first time in 1945 an estimate of the reserves for the state of Oklahoma. Since that time two additional estimates have been released.

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[17]Midcontinent Oil and Gas Association, Oil and Gas in Oklahoma (1943), pp. 34-5

[18]Mineral Resources 1946, Oklahoma Planning and Resources Board, p. 23.

Geographical Distribution of Major Fields.--There are twelve fields in Oklahoma having a reserve in excess of 20 billion cubic feet. The location of these fields in the state is shown in Figure 3. The reserves of these fields in order of their volume, as of September, 1945, is shown in Table 19.

TABLE 19

GAS RESERVES OF MAJOR FIELDS IN OKLAHOMA
September, 1945*

| Field | Billion Cu. Ft. | Per Cent of State Reserves |
|---|---|---|
| Guymon-Hugoton field . . . . . . . . . . | 7,697 | 81.0 |
| West Edmond field . . . . . . . . . . . | 355 | 3.7 |
| Cumberland field . . . . . . . . . . . . | 225 | 2.6 |
| Chickasha field (deep) . . . . . . . . . | 160 | 1.6 |
| Apache field . . . . . . . . . . . . . . | 85 | .9 |
| West Cement field . . . . . . . . . . . | 80 | .8 |
| East Cement field . . . . . . . . . . . | 60 | .6 |
| Velma field . . . . . . . . . . . . . . | 60 | .6 |
| Pauls Valley field . . . . . . . . . . . | 54 | .5 |
| Pauls Valley, East field . . . . . . . . | 45 | .4 |
| Quinton field . . . . . . . . . . . . . | 32 | .3 |
| Erick field . . . . . . . . . . . . . . | 27.5 | .2 |
| Total twelve major fields | 8,880.5 | 93.2 |
| Miscellaneous small fields . . . . . . . | 625.5 | 6.8 |
| Total Oklahoma . . . . . . . . | 9,533.0 | 100.0 |

*Elmer E. Capshaw, United States Federal Power Commission Docket G-580 Exhibit No. 146, Natural Gas Investigation (1945).

Although the Guymon-Hugoton field has by far the largest amount of natural gas in Oklahoma, it must be remembered that hundreds of small gas pools are being used to produce a more valuable product and are not to be disregarded even if much of the gas produced in this manner is used as boiler fuel near the place of its origin and is seldom recorded as having been produced.

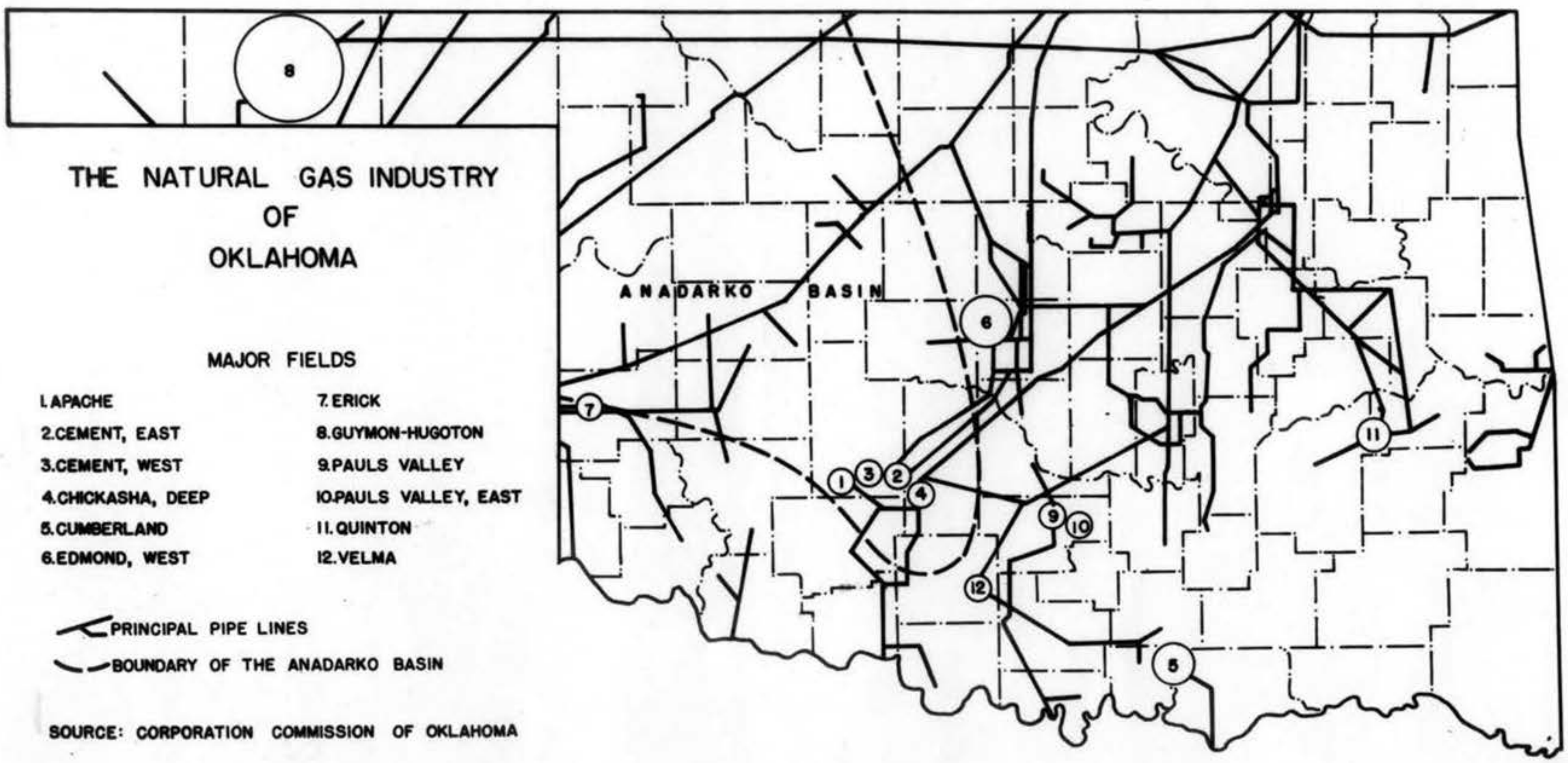
THE NATURAL GAS INDUSTRY
OF
OKLAHOMA
ANADARKO BASIN
MAJOR FIELDS
1. APACHE
2. CEMENT, EAST
3. CEMENT, WEST
4. CHICKASHA, DEEP
5. CUMBERLAND
6. EDMOND, WEST
7. ERICK
8. GUYMON-HUGOTON
9. PAULS VALLEY
10. PAULS VALLEY, EAST
11. QUINTON
12. VELMA
PRINCIPAL PIPE LINES
BOUNDARY OF THE ANADARKO BASIN
SOURCE: CORPORATION COMMISSION OF OKLAHOMA

FIGURE 3

Guymon-Hugoton Field.--The Guymon-Hugoton field was known to have large quantities of natural gas in reserve as early as the 1920's. Wildcats had successfully completed enough wells to allow an estimate of the area of the field, and although pressures were not regarded as great, the amount was believed to be very large. Large portions of the area were held in reserve. This reserve was held for later exploitation because of the lack of a market. It led pipe lines into the area, as competition and prices for natural gas increased in the Kansas portion of the field.[19] The discovery was made in the Allison No. 1, Sec. 4, T. 1 N., R. 12 E., in Texas County by the Home Development Company in 1922.[20] From this early start, little happened until 1940 when pipe lines entered the area and opened up a market for the cheap gas. Only the carbon black plants had previously followed the geographical shift of abundant natural gas from the Appalachian area to the Southwest. Most of the area was leased by brokers and assigned to the companies for whom they were leasing. These companies were Republic, Panhandle Eastern, Cities Service, Peerless Skelly, Cabot Carbon, Shamrock, Phillips, and Panoma Corporation. They each owned very large acreages.[21]

The proven area of the Guymon-Hugoton field is 933,760 acres or 23 per cent of the total Hugoton field. Forty-five per cent of this has been developed by some 659 wells or about one-third of the total wells of the Hugoton field. The Oklahoma wells have the highest deliverability of reserves in the Hugoton field, 2,437 million cubic feet per day as compared to 2,047 million cubic feet for the Kansas area. The Kansas wells have a daily deliverability

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[19]Blakely M. Murphy (ed.), Conservation of Oil and Gas (1949), p. 404.

[20]Joseph A. Kornfeld, Natural Gas Economics (1949), p. 148.

[21]Elmer E. Capshaw, United States Federal Power Commission Docket G-580, Exhibit No. 146, Natural Gas Investigation (1945), p. 8.

of only 1,855 thousand cubic feet as compared to 3,685 thousand cubic feet in Oklahoma and 3,530 thousand cubic feet in Texas. Due to the fact that the reserves are being drained by 1,112 wells in Kansas and only 659 in Oklahoma and 232 in Texas, the production figures for September, 1948, showed 13 billion cubic feet were produced in Kansas compared to only 8.7 billion in Oklahoma and 5.3 billion cubic feet in Texas. The total drain on the reserves has been 1.5 trillion cubic feet or about 5.1 per cent of the total Hugoton reserves. The remaining 94.4 per cent represents about 14 per cent of the total reserves of the United States. Oklahoma has about 4 per cent of the total United States reserves in the Guymon-Hugoton field.[22]

The Hugoton field serves local markets in Kansas, Oklahoma, and Texas, as well as markets in Illinois, Michigan, Ohio, Nebraska, Iowa, South Dakota, Minnesota, Colorado, and Wyoming. The gas is processed to remove natural gasoline and water before it is turned into the long-distance lines.

There have been two major contributions to conservation of Guymon-Hugoton reserves. The first was an order by the Oklahoma Corporation Commission establishing 640 acres as the spacing unit and establishing a formula for the allocation of allowables to gas wells in this field similar to proration of oil produced from common strata.[23] The second was a later order by the same body setting a minimum price of seven cents per thousand cubic feet at the well-head. Previous rates were approximately four cents per thousand cubic feet. Reford Bond, Commission Chairman, explained the action by saying "less than seven cents per thousand cubic feet at a pressure of 14.65 pounds

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[22]C. H. Keplinger, J. M. Wanemacher, and K. R. Burns, "Hugoton-World's Largest Dry-Gas Field is Amazing Development," The Oil and Gas Journal, XXXXVIII (January 6, 1949), p. 87.

[23]Oklahoma Corporation Commission Order No. 17867 (1945).

constitutes both economic and physical waste of a natural resource."[24]

The Guymon-Hugoton field has been dealt with in some detail due to its importance to the future supply of natural gas in Oklahoma. The smaller fields, although not as large as the Texas County field, are of vital importance to their local areas.

West Edmond Field.--The discovery of the West Edmond Field occurred in 1943. It is located in Canadian, Oklahoma, Logan, and Kingfisher counties, Oklahoma. Excluding the 40 per cent loss for gasoline, LPG,[25] plant fuel, lease use and drilling fuel, the reserves in 1945 were 350 billion cubic feet. From January, 1944, to September, 1945, the number of wells increased from 18 to 650. The gas is a solution gas produced at a gas-oil ratio of 2000 cubic feet of gas to 1 barrel of petroleum. The daily limit is 150 barrels of oil per well. In the central and southern part of the pool, forty-acre spacing is the rule but in the northern edge there is a condensate area where 160 acres is the unit. Many companies operate in the field under competative conditions. Oklahoma Natural, and Cities Service serve local markets in Oklahoma City, Burbank, and Tulsa, and have a surplus of gas to export to the north and northeast.[26] In 1947, the increase in residue gas available for transportation lines was largely due to an increase of natural gasoline plants in the field. The amount of residue gas available from this source will decrease in the future as a plant is being built to reinject this gas into the formation to keep the formation pressures as high as possible and thus ultimately recover much more oil.[27] As most of the gas thus utilized is being

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[24]Kornfeld, op. cit., pp. 242-243.

[25]Liquified petroleum gases.

[26]Capshaw, op. cit., p. 7.

[27]H. Backus and F. S. Lott, Minerals Yearbook (1947), p. 814.

preserved, the reserves of this pool will continue to be used until the petroleum is exhausted.

Cumberland Field.--This field is located in Bryan and Marshall Counties in the southern part of the state. It was discovered in 1940 and has had continual development of the reserve through deeper drilling and extension of the limits. In 1945, the field was believed to have 225 billion cubic feet of natural gas reserves or 93 per cent of its original reserves. Some of the added reserves are dry gas but as they are produced in conjunction with petroleum, they must be treated before being turned into the transmission lines. The Lone Star Gas Company operates a pipe line from the area to northern Texas. A gasoline plant is in operation in the field. Ownership of the field is almost entirely by the Pure Oil Company.[28]

Chickasha Field.--The Chickasha field is in Grady County. The deeper sands were brought into production in 1939 adding materially to the waning reserves in the former shallow field.[29] The 1945 reserves were estimated to be 160 billion cubic feet. The dry gas field is under proration and well spacing. Withdrawals in the deeper sands are made only when there is a demand, in order to save well pressure in the upper sands. The upper sands are produced as evenly as possible to obtain maximum production.[30]

Apache Field.--The Apache field is in Caddo County, Oklahoma. The gas produced is in solution and depends directly on the prorated allowables of oil. The gas-oil ratios are held to a minimum so the maximum amount of oil may be gained from the field. The field was found in 1941 and wells were

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[28] Capshaw, *op. cit.*, p. 6.

[29] F. S. Lott and G. R. Hopkins, *Minerals Yearbook* (1940), p. 1059.

[30] Capshaw, *op. cit.*, pp. 5-6.

developed by 1942. Ninety-three per cent of the reserves or 85 million cubic feet were still available as of January 1, 1945. The field is twelve miles from a major pipe line and has no gasoline or extration plant. The reserves are such that they could be used for a local market.[31]

West Cement Pool.--The West Cement pool is also in Caddo County. The reserve is 80 billion cubic feet or 51 per cent of the original supply of wet gas. The field was opened in 1936 but was not developed until Cities Service completed their pipe line into the field. Six pipe lines now serve the area with connections to Oklahoma City, Burbank, and interstate pipe-line systems.[32] The development of this field created a problem in proration. Some of the operators were producing the gas from the cap while down-dip wells were relying on this gas for power to force their oil into the well. The Oklahoma Corporation Commission issued an order in 1943 dividing the allowable production among the wells by a formula which included an acreage, a potential and a pressure factor.[33] This order allowed the gas wells to produce only their fair share of the gas. The recognition that petroleum might be wasted by the unrestrained withdrawal of natural gas resulted in an established policy for dual production in Oklahoma.

East Cement Pool (deep).--The East Cement pool came in a year after the West Cement pool and extended to the west edge of Chickasha. The increased reserves came from gas found at lower levels and further reserves are expected to be located. Sixty billion cubic feet of wet and dry gas are estimated in the field. There is a competative net of pipe lines serving the pool. Volun-

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[31]<u>Ibid.</u>, p. 4.

[32]<u>Ibid.</u>, pp. 4-5.

[33]Oklahoma Corporation Commission order No. 16683 (1943).

tary proration is being practiced in some formations.[34]

Velma Field (deep).--Total reserves in the Velma field are comparable to the East Cement pool (deep). The location is in Stephens County, Oklahoma. Skelly Oil Company owns and controls the majority of the reserves. The gas cap is protected behind pipe and the gas produced is not marketed because a pipe line has not been built into the area. The gas is regarded as vital to maximum production of oil. The field was discovered in 1943 and was less than one per cent depleted in 1945.[35]

Pauls Valley Field.--North of the town of Pauls Valley in Garvin County is the Pauls Valley field. The discovery was made in 1942 and the field was rapidly outlined. The reserves are 54 billion cubic feet of solution gas. A small amount of gas is steadily produced due to the limitations placed on petroleum production in the field. The gas cap is not being produced but is sealed off to maintain high pressures. This conservation movement is a voluntary program of the producers in the field. A gasoline plant processes the gas and delivers the residue to the Lone Star Gas Company. An enlargement of facilities for treating gas is being planned.[36]

Pauls Valley Field (East).--Seven miles east of Pauls Valley is the Pauls Valley field (east). The field is in an early stage of development but reserves are estimated to be 45 billion cubic feet. Oil production is again the important concern but a potential source of gas for intrastate markets exists. Surveys are being made to determine the feasibility of building a gasoline extraction plant to process the gas and market the residue. A small

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[34]Capshaw, _op. cit._, p. 4.

[35]_Ibid._, p. 12.

[36]_Ibid._, pp. 9-10.

booster plant is sending the gas to a nearby refinery in Wynnewood, Oklahoma. The operators of the fields have voluntarily agreed to a twenty-acre diagonal well spacing.[37]

Quinton Field.--The Quinton field is in Pittsburg and Haskell County. Four small pools; the Quinton proper, the Featherston-Blocker, the Carney, and the Kinta are combined as the Quinton field. The Quinton proper was discovered in 1915 and the Featherstone-Blocker developed from a rapid extension to the east. The Carney was developed in 1922 and is the largest of the group. The Kinta field is a small field along a fault to the east of the Quinton.[38] Only 15 per cent of the original reserves remained in 1945 when they were placed at 32 billion cubic feet. The gas is dry and is marketed through two 16-inch lines and an 8-inch line to McAlester and Tulsa by the Oklahoma Natural Gas Company.[39]

Erick Field.--The smallest major reserve of over 20 billion cubic feet in Oklahoma is the Erick field in Beckham County. The first well produced lean gas in 1934.[40] The reserves had been reduced to only one-third or 27.5 billion cubic feet in 1945. The Westoak Gasoline Company built a plant to process the lean gas but was forced to shut down as the yield of natural gasoline was insufficient.

Other Fields.--The remaining 652.5 billion cubic feet of reserves in Oklahoma are divided among numerous small gas fields. No one of these has

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[37] Ibid., p. 11.

[38] Ley, op. cit., pp. 520-524.

[39] Ibid., pp. 522-523.

[40] Lean gas is gas containing slight amounts of natural gasoline that may be disregarded for ordinary fuel uses.

a reserve in excess of 20 billion cubic feet.[42] The value of these reserves may partially be measured by lengthening the life of modern oil fields and will result in an increased dollar value to Oklahoma. The reduced annual yields of natural gas from these fields will still be sufficient for small local markets, but the Middlewest and the Northeast will have to rely on the Guymon-Hugoton area or on possible new fields in the Anadarko Basin for their future supply.

Recent Trends in Oklahoma's Development.--Natural gas has been exploited in quantity from the eastern and southern parts of Oklahoma. The western half of the state, or the Anadarko Basin, probably has the greatest undiscovered reserves of oil and gas (Fig. 3). The sands and limes of oil legend fame are also found in the western basin. Some of these formations, especially those of Pennsylvanian and Permian origin, are thousands of feet thicker than their eastern counterparts. The Wilcox sand is here at a depth of from ten to twenty thousand feet.

Many major companies are now holding blocks of acreage in the Anadarko Basin up to 100,000 acres and are keeping the leases in good standing. The modern drilling rig is capable of reaching the Wilcox Sand even at the great depths in the Anadarko Basin. Wildcats are being drilled in this area and development is already commencing in some places. Garvin, McClain, and Grady Counties have reported a large number of new gas fields in the basin. No pipe lines were serving these new fields in 1946.[43]

The Elk City field was opened in 1947 in Beckham and Washita Counties. It produced 469 barrels of condensate and 5.7 million cubic feet of gas per

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[42] Ibid., p. 13.

[43] F. S. Lott and H. Backus, Minerals Yearbook (1946), p. 820.

day. This field may develop into a major strike.[44] In 1950 there were forty wells producing from a thick section of granite wash on the west side of the Anadarko Basin at depths of 10,000 feet. Unusually high gas pressures of 3800 to 4300 pounds per square inch have been encountered. A light gravity crude ($50^{o}$-$65^{o}$) is being piped through a 10-inch line to Cushing. The gas is being used for field production.[45]

Potentialities of Oklahoma's Natural Gas Reserve.--Reserves of natural gas that are high in sulfur content constitute the raw material for carbon black, an essential constituant in the manufacture of rubber tires. Sweet gas may lose its higher fraction of gasoline to build an aviation gasoline industry. These reserves also represent innumerable products through the use of chemistry. The Fischer-Tropsch process promises to turn these reserves into gasoline by combing the molecules of lighter gases into the heavier ones of gasoline.[46]

Notwithstanding these potentialities there is no comparable substitute for natural gas as a fuel in domestic heating or as a processing agent in the best treating of metals, plastics, glass, pottery, tile, cement, foods, etc. Through the realization of the potentialities of natural gas, Oklahoma can initiate a long time program of industrial utilization of our own natural resources such as limestone, dolomite, glass sand, clay, gypsum, and salt since the supplies of these are very great and the present uses are rather

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[44]"Oklahoma Activity Spurred by Pauls Valley Uplift Successes," World Oil, XCCVIII (February 15, 1949), p. 86.

[45]Roy F. Carlson, "Elk City Development Proceeding at an Active Pace," The Oil and Gas Journal, XXXXVIII (April 6, 1950), p. 66.

[46]A description of the Fischer-Tropsch process is given in "Synthetics, the Great Oil Reserve," Fortune, XXXVII (April, 1948), pp. 110-115.

small.

One of the great contributions by the reserves of natural gas to the economy of Oklahoma is through its use as a source of power in oil fields. The day of flush production of petroleum has passed and the accent is now on maintaining the production of natural gas at a point most profitable in terms of maximum recovery of petroleum. The gas used to help bring the oil to the surface can now be processed to remove the natural gasoline and then returned to the producing formation to bring forth more petroleum. The recovery of much larger amounts of petroleum is obtained by keeping a large reserve of natural gas in the oil fields.

# CHAPTER VII

## SUMMARY

The Japanese discovered natural gas in brine wells as early as 615 A.D., but the Chinese were the first to make use of natural gas, almost one-thousand years ago, when they piped it through bamboo lines to evaporate salt water. The first use of natural gas in Western Europe was for an illuminant in Genoa, Italy, in 1802.

### History of Natural Gas in the United States

Superstition retarded the development of natural gas in the United States. The sulfurous fumes were thought to be from brimestone and only disciples of the devil would approach them. In 1821, William Arron Hart drilled the first natural gas well which was seventeen feet deep. The gas was piped to nearby Fredonia, New York, and was used as an illuminant in the famous "catastrophic lights." Tourists ventured great distances to see these lights.

Colonel Drake's first oil well at Titusville, Pennsylvania, in 1859, stimulated the technological development of the drilling industry. At the turn of the century, Pennsylvania, West Virginia, Indiana, and Ohio were producing natural gas. The superiority of natural gas as a fuel was recognized and a rush of capital into the industry stimulated its development.

The significance of the natural gas industry grew with the development of high-pressure transmission lines. The technological progress in transportation evolved from lead pipes to pine-log tubes and later to cast iron pipes. The cast iron pipe was the ancestor of the present long-distance high-pressure lines.

Early gas services were supplied at a flat rate or according to the number of fires used. It was not until 1896 that a satisfactory method was devised to meter natural gas.

The industry has shown a gradual shift to the west. It was centered in Pennsylvania until 1909. West Virginia became the leader in 1909 and was the major producer until 1924 when Oklahoma replaced West Virginia. By 1930, Texas was producing more gas than any other state and has since increased her relative position among the states. Indiana, Kansas, and California developed large quantities of gas but never held the position as leading producer.

## History of Natural Gas in Oklahoma

The natural gas industry began in Oklahoma at Red Fork in the Creek Nation in 1902. Gas was used for domestic purposes as well as for a small brick plant. Colonel J. M. Guffey and John Galey, formerly of Pennsylvania, laid a 2-inch pipe line from the Osage Nation into the small village of Tulsa in 1903. The total value of the gas industry was $360 in 1902 and $1,000 in 1903. Development of gas holdings grew, and the state soon had an oversupply of natural gas in spite of the rapidly growing domestic and industrial consumption throughout the state. Smelters, brick plants, and glass plants were typical industries developing in the early years of the area.

It was only one month after Oklahoma became a state in 1907 that Oklahoma City was piped for gas. The large gas pools, such as the Hogshooter and the Caney, further increased the surplus production of the state. Oklahoma's first carbon black plant was built in Coalton in 1911 to use some of the natural gas. A revolutionary method of drilling with a fluid in the well was introduced in Oklahoma by the Bureau of Mines in 1913. This method reduced the loss of gas during drilling operations and sealed off gas strata to be used later. This method was first applied to the Cushing field, and wells were drilled into the very high pressure gas cap. This field developed until in 1916 it was the major natural gas field in Oklahoma.

Oklahoma's producing center has been displaced from the north-eastern portion of the state to the south-central and Panhandle areas. Development of the latter areas occurred largely after 1930. The Guymon-Hugoton field in Texas County was discovered in 1922 but little development occurred until the early 1930's. This area provided added quantities of gas for a growing market.

## Natural Gas Production

A supply of natural gas is found by locating structural traps in sub-surface strata. Large quantities of risk capital must be available to finance production. Even with the best methods known to man, the only way a supply of natural gas is actually proven to exist is by drilling into a structural trap containing gas.

The ownership of the right to enter a parcel of land, prospect for, reduce to possession, remove, and market natural gas is known as a "mineral right." This mineral right may be leased or sold to another person or company. It usually entails a "bonus" payment at the time of leasing, rental payments during the time before a well is drilled, and a portion of the production, usually one-eighth of the field price of the gas known as the "royalty." If one person does not own the entire area, persons holding rights within the area are paid a proportionate part of the royalty based on the area held by each person.

Natural gas is an extremely flighty fugitive substance. If a well is drilled, gas may be withdrawn, not only from beneath the land on which the well is located, but from beneath the surrounding area. This promotes uneconomic drilling along the boundaries of competing leases. Unitization is a means for competing private companies to agree on operation regulations and proportionate withdrawals to eliminate wasteful production. Proration is a legal means of attaining the same goal. 28-29 34 Oklahoma has pioneered in the field of legal conservation and can point with pride to the acreage spacing laws Many states limiting the minimum area of production per well in various pools, and her unitization laws granting a majority of owners the right to demand unitization of a pool in order to curtail production costs and yet obtain the maximum amount of petroleum from the pool.

Drilling follows the right to drill. The risk investment of drilling is usually too great for a single individual and has led to the development of huge corporations. 30 In the Guymon-Hugoton field of Oklahoma, there were five large operating companies in September, 1949, which produced 88 per cent of the natural gas from 87 per cent of the producing wells.

Two methods.

The trends of production have recently shown a tremendous increase. Production in the United States topped one trillion cubic feet as early as 1923, two trillion by 1936, four trillion by 1946, and a sizeable increase to six trillion cubic feet during 1949. At the current rate of production, known reserves will last at least thirty years.

The large increase in natural gas production occurred from the development of the industry as a separate unit. ~~It had long been a derivative industry geared to petroleum production.~~ 31 Discovery of the dry gas fields--Monroe, Panhandle and Hugoton, guaranteed sufficient reserves to make long high-pressure pipe lines feasible. Long lines were built by Cities Service Gas Company, Natural Gas Pipeline Company, and Phillips Petroleum Company from the Guymon-Hugoton field to markets in Oklahoma, Kansas, Missouri, and other mid-western states.

The pipe lines are a result of an unequal distribution of natural gas over the nation. Texas, Louisiana, Oklahoma, and Kansas produced more than 75 per cent of the natural gas in 1949. Texas produced two-thirds of this amount. The next ranking states were Louisiana, Oklahoma, California, Kansas, New Mexico, and West Virginia. The concentration of production in the southwest has caused an oversupply of natural gas in this area. A shortage of natural gas exists in the very large potential market areas of the northeastern and mid-western portion of the United States. The region east of the Mississippi River produced less than 5 per cent of the natural gas in 1949. See 45

Some industries requiring large quantities of cheap fuel have migrated to the area of oversupply. These industries include glass, brick, cement, clay, and tile plants.

The distribution of natural gas in Oklahoma is also one of concentration, although some natural gas is produced in fifty-five of Oklahoma's seventy-seven counties. The widespread oil fields of Oklahoma produce wet gas in forty-six of the fifty-five producing counties, with only nine counties producing dry gas. The wet gas is processed for natural gasoline and the residue gas is either returned to the formation or is sent through transmission lines to the market. With eleven of Oklahoma's major natural gas fields well distributed over the southern and eastern part of the state, natural gas is in a favorable position with respect to many of the mineral resources that could be developed. The major gas field is the Guymon-Hugoton field in the Oklahoma Panhandle. This field is by far the largest producing field in the state and represents a major power resource for industry.

## Natural Gas Transmission

Natural gas is usually treated in the field to remove water vapor, natural gasoline and hydrogen sulfide before it is turned into the transmission lines. The natural gasoline is a valuable product while the water vapor and hydrogen sulfide are removed because of their detrimental effects on equipment.

The evolution of high pressure transmission lines has changed natural gas from a local to a national industry. Major transmission lines were not developed until after 1925. The first large line averaged only 16-inches in diameter and was 217 miles in length. In 1950, a 30-inch line, 1874 miles long and reaching from the Rio Grande to New York City, will be completed at a cost of $200,000,000. This increase in size was made possible by such technological advancements as the construction of large-diameter seamless steel tubing and the technique of joining this tubing by the welding process.

As pipe lines increased in diameter and length, their costs also increased. The cost of a pipe line varies directly with its length, but the cost of increased diameter does not increase as rapidly as the volume capacity which makes it more economical to build large pipe lines.

Oklahoma offers an example of the solution of the problem of irregular demand. Gas is pumped into two underground storage fields near Tulsa during the summer for use during the winter when pipe line deliveries cannot meet withdrawal demands. This method is especially used in the Appalachian area where the extension of the pipe-line net is greatest.

The costs of construction of pipe lines are predominately those of the tubing. This item may cost as much as 78 per cent of the total cost, while land and pumping facilities represent only 22 per cent. The cost per mile of 16-inch line in 1946 was $25,000 while 24-inch line cost $41,000. The cost per square inch of cross sectional area of these same lines was $125.00 per mile of 16-inch line and only $91.00 for the 24-inch line. This tends to decrease construction costs of large diameter pipe in comparison to smaller diameter.

Capital investment of the natural gas industry increased twelve times between 1939 and 1948 while all private domestic investment increased only four times. The estimated capital investment in 1949 was $948,000,000. Large expansion programs are expected to double the interstate transportation of natural gas by 1952.

There are almost 260,000 miles of utility gas mains in the United States, supplying the country with more than five times the energy produced by the entire electric utility industry. In Oklahoma, the Oklahoma Natural Gas Company has about 70 per cent of the state's eight thousand miles of transmission line. Recent additions, by the Oklahoma Natural Gas Company, to large gasoline plants in the south will make greater quantities of residue gas available to Oklahoma markets in this area. Since the 1930's, Oklahoma has shown little increase in intrastate consumption of natural gas and has relied on exports of an irreplaceable resource for the expansion of the industry.

## Natural Gas Consumption

Natural gas provided almost one-fifth of the developed energy in the United States in 1949. This amounted to over six trillion cubic feet of gas to 13,500,000 customers. The Bureau of Mines estimated the value of natural gas consumed in 1947 exceeded one billion dollars.

Natural gas is largely produced in the Southwest and most of it is consumed in the Southwest. Texas is the major state in all functions of the natural gas industry. She consumes almost 35 per cent of the United States total.

Natural gas is no less important to Oklahoma. In 1947, it supplied 80.6 per cent of her total energy needs. Oklahoma consumed $29,708,000 worth of natural gas in 1946 but produced $74,698,000 worth. This means natural gas valued at $44,990,000 was exported from Oklahoma in 1946.

The types of consumers in Oklahoma follow the pattern of the national industry. Domestic consumers pay almost seven times as much per unit of gas as industrial users. Industrial users consume about seven-eighths of the total volume.

Field use of natural gas for the production of petroleum accounts for almost 50 per cent of the natural gas used for industrial purposes. Carbon black and electric utilities are also large consumers of natural gas. Among Oklahoma's manufacturing industries, petroleum refining, metal industries, and nonmetalic groups such as glass, cement, gypsum, and clay products are important consumers. Natural gas in Oklahoma is well distributed over the area where the raw materials for these industries are found and their expansion would add materially to the economic welfare of the state.

## Natural Gas Reserves

The entire natural gas industry is basically dependent on sufficient reserves to guarantee the capital investment of its other functions. The size and location of reserves will determine the amount of investment justified.

Additions to the proven reserves have increased steadily since 1935. Three times as many proven reserves existed on January 1, 1950, as had existed in 1937. Even though many new pipe lines and markets appeared in 1949, the reserves were 180 trillion cubic feet for a record high. The ratio of reserves to production indicates a healthy twenty-eight year reserve at the present rate of consumption.

Texas has 55 per cent of the United States reserves. Other southwestern states have 34 per cent of the reserves. This places the Southwest in almost complete control of this resource. The most efficient use of natural gas is of vital importance to the future growth of this area.

Oklahoma has more than 6 per cent of the total reserves of the United States. Of this 11.6 trillion cubic feet, 81 per cent is in Texas County in the Guymon-Hugoton field. No other field in Oklahoma has more than 5 per cent of the reserves. There are twelve fields in the state that have reserves larger than twenty billion cubic feet. These fields are distributed over the southern and western portion of Oklahoma forming a basis for future industrial and domestic development.

Oklahoma industry is widely distributed over the area of natural gas reserves. Most of the industry is located near the market and draws on reserves of natural gas for its manufacturing processes.

Oklahoma's reserves are sufficient to last almost thirty years at the present rate of production. New developments, such as the Elk City play in the Anadarko Basin, offer rich possibilities for future discoveries of natural gas. This vast area has scarcely been explored and will no doubt become the new frontier of Oklahoma's natural gas industry.

One of the most important means of extending the life of reserves is by obtaining the most efficient use of natural gas. Other means such as well spacing and unitization prevent physical waste in production. The reserves are vitally important as a power source in recovering petroleum. Through the wise use of natural gas, a much greater amount of petroleum can ultimately be recovered.

## Conclusion

The natural gas industry is suffering from growing pains. The rising price of coal and fuel oil has placed a premium on natural gas in the industrial East. Vast pipe lines are being laid to these areas that are blessed with huge reserves of coal. Should the trend of prices reverse itself and coal and fuel oil become much cheaper, the regulated price of natural gas would place it in an untenable position. Natural gas should be freed from price regulation. This premium rate on natural gas is placing an ever increasing drain on this resource that will rapidly deplete the reserves if consumption follows its present trend. 89

Not only should natural gas be freed from price regulation, but it should be separated into producing and transmission companies in order to maintain uniform policies throughout the industry.

Oklahoma is exporting vast quantities of natural gas to the industrial East at a nominal cost. Many of the products purchased from these areas could well be produced in Oklahoma from Oklahoma's bounteous natural resources and with Oklahoma's excellent labor. Natural gas provides a cheap source of power that places Oklahoma industry in an advantageous position.

Oklahoma needs manufacturing industries to widen the scope of her economy. The State Planning and Resources Board is conducting industrial clinics to accomplish this goal. The future industrial development of Oklahoma lies in the hands of those courageous men that realize Oklahoma has an abundance of resources that can be converted into wealth for the benefit of all Oklahoma.

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Typist: Irlene W. Sykora