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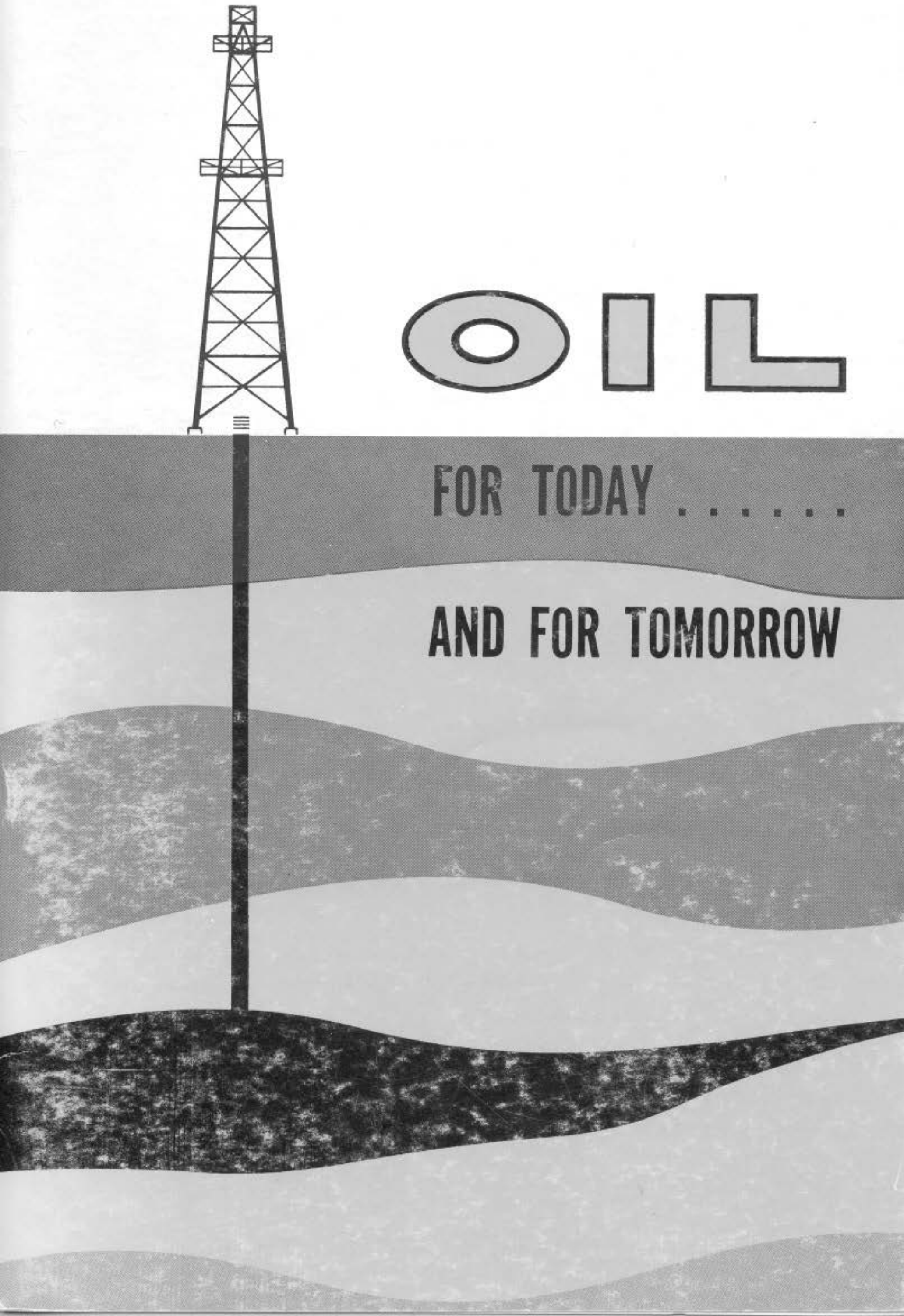
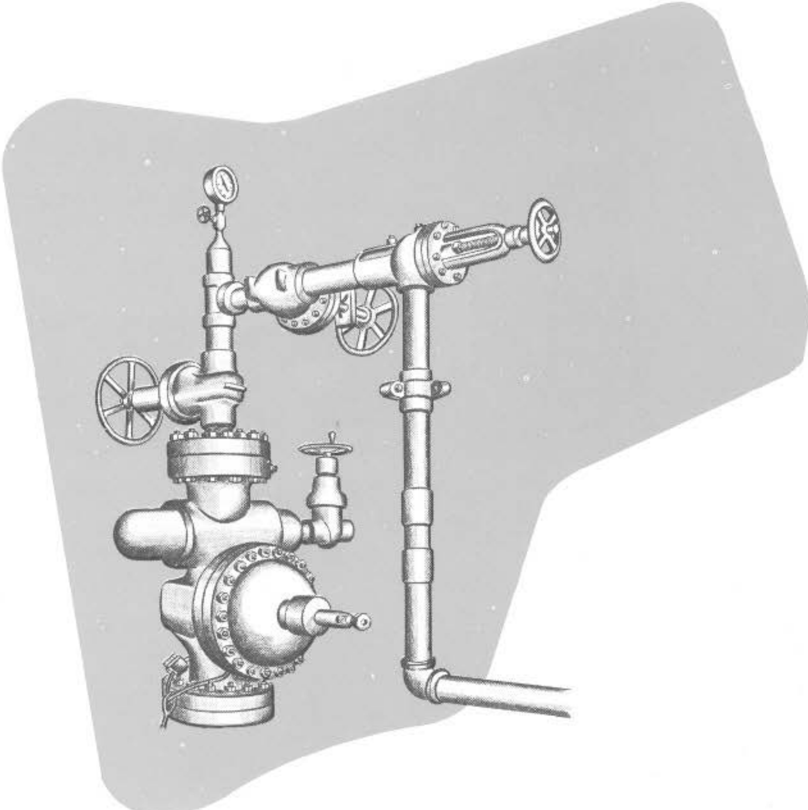
OIL

FOR TODAY . . . . . .

AND FOR TOMORROW





This is a modern oil-field "Christmas Tree." Some imaginative oil man called it that because he thought it looked like the Christmas tree of tradition.

Its heavy valves help control underground energy, the driving force without which oil cannot be produced.

Oil does not produce itself!

The Christmas Tree is truly a symbol of efficiency.

OIL FOR TODAY—
AND FOR TOMORROW

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INTRODUCTION

Edward F. Arn

Chairman of the Interstate Oil Compact Commission

and

Governor of the State of Kansas

Oil and gas are of great importance to every man, woman, and child in the United States.

Whether you are an industrialist, laborer, mechanic, banker, lawyer, doctor, farmer, engineer, teacher, office worker, or housewife, you are dependent upon oil and gas. Some of the clothes you wear, the furniture in your home, the equipment in your office, the telephone, nylon, and numerous other articles of common use, are products made from oil and gas. It is the principal source of the fuel and lubricants necessary for modern machinery. What would our life be without machines?

Oil is an exhaustible and irreplaceable natural resource. Its formation requires millions of years. A barrel of oil used is gone forever. Its production and conservation are most important. It has truly been said that "oil is everybody's business."

In time of peace oil is vital to the whole economy of the country and to our standard of living. It makes our way of life possible. In time of war it is indispensable for our protection and security, and without it our lives are in jeopardy.

The Interstate Oil Compact Commission was formed in 1935 to advance the cause of oil and gas conservation. The Compact Commission is devoted to the advancement of good conservation programs through laws and regulations by state authority.

This booklet is intended for the general public. It is an informative and interesting account of how oil is formed, and how it is produced in the best way to prevent its waste and to bring about the maximum ultimate recovery. It is a part of the Commission's educational effort to foster conservation practices through good laws and the application of scientific principles. It tells how oil occurs in the ground, how it is produced, how underground reservoir energy can be controlled so as to produce the greatest amount of oil with the least waste. It tells how property and correlative rights are protected in order that each producer and land owner may receive his just and proportionate part of the oil and gas underlying his land. It tells how conservation is accomplished by operating an oil reservoir as one physical unit. It tells of the relation between excessive production and waste. It tells how good conservation programs and laws and regulations have been developed and of the benefits that have resulted.

The articles: "The Early Days of Oil" and "The Origin, Occurrence and Production of Oil" were compiled from various authoritative sources. The article "Property Rights and Oil Production" was prepared by Mr. George W. Hazlett, Lawyer and authority on oil and gas law. The article "Conservation in Production Through Unit Operation" was prepared by Mr. Herman H. Kaveler, Petroleum Engineer and Management Consultant. The article "Excess Oil Production Causes Waste" was prepared by Mr. H. B. Fell, Independent Oil Operator and

Vice-President of the Independent Petroleum Association of America. The Article "Maximum Oil Production Through Conservation Laws" was prepared by Mr. Earl Foster, Executive Secretary of the Interstate Oil Compact Commission.

Lt. General Ernest O. Thompson contributed the article "Conservation for Freedom—Under State Laws," calling attention to perhaps one of the most important aspects of conservation, namely, assurance of an adequate supply of oil and gas for national security and for freedom. General Thompson has been a member of the Texas Railroad Commission for the past twenty-one years. He is recognized for his monumental contributions to the cause of the prevention of waste of oil and gas. He has perhaps had more experience in conservation and the administration of conservation law than any other person in America.

This booklet, though sponsored by the Commission, represents the views of the respective authors in the absence of formal endorsement by the Commission.

The Interstate Oil Compact Commission considers an enlightened public to be the greatest support of good conservation programs. When the public realizes its dependency on and its benefits from oil and gas, sound conservation practices and laws will follow.

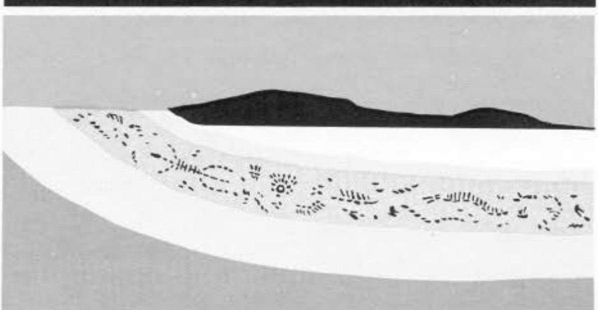
Edward F. Arn

EDWARD F. ARN

THE GENESIS

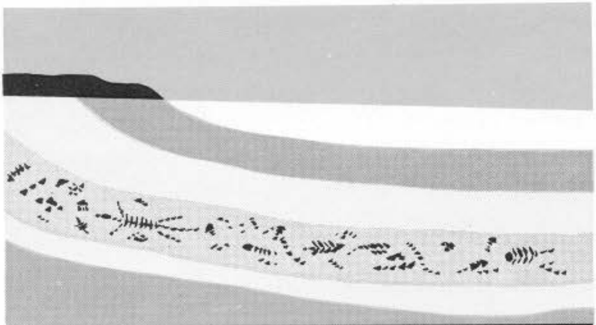
Some Scientists Believe Petroleum Formations Began Millions of Years Ago, When Tiny Marine Creatures Abounded in and Near the Seas as They do Today . . .

As Marine Life Died, it Settled to the Sea Bottom, and Became Buried in Layers of Mud and Sand

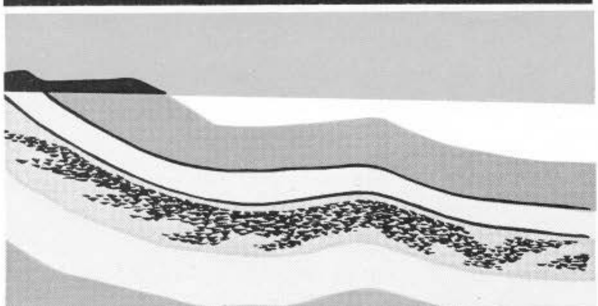


The Organic Matter, Held in Mud and Silt, was Changed to Gas and Oil Probably by Gradual Decay, Heat, Pressure, and Possible Bacterial and Radioactive Actions.

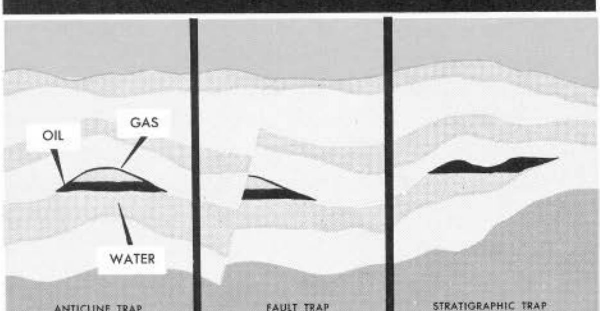
OF OIL



As Millions of Years Passed, Pressure Compressed the Deeply Buried Layers of Mud, Silt, and Sand into Layers of Rock.



Earthquakes and Other Earth Forces Buckled the Rock Layers . . .



The Petroleum Migrated Upward Through Porous Rock Until it Became Trapped Under Non-Porous Rock.

THE EARLY DAYS OF OIL

Primitive man ascribed divine powers to fire and water. There is evidence that oil and natural gas seeping from the earth when set afire, perhaps by lightning, were paid devotion as a sacred element. The Zoroastrians, or "Fire Worshippers," built their altars near the burning gas seepages at Baku on the Caspian Sea, and rendered homage to this manifestation of a great imprisoned spirit.

Oil in the Ancient World. Ancient peoples used petroleum centuries before the Christian era. Noah caulked the ark with "pitch," evidently a form of petroleum gathered from the seepages of Mesopotamia. Job told of a rock which "poured me out rivers of oil." The "slime" used as mortar in building the Tower of Babel and other ancient structures is believed now to have been petroleum. Nehemiah is reputed to have used oil for altar fires. He called it "naphtar" or "nephtoj," from which may have been derived the modern word "naphtha." Ancient Egyptians used pitch as an axle grease for their primitive chariots.

Numerous legends indicate the Greeks recognized the usefulness of oil. They destroyed a Scythian fleet by pouring oil on the sea and setting it afire. Belisarius, famous general of the later Roman Empire, adapted this idea of using "burning water." In his campaign against the Vandals in northern Africa, he smeared swine with oil, ignited the oil, and drove the squealing, blazing porkers into the terrified ranks of the enemy. Crude oil mixed with ashes served the Syrians as fuel. There are records indicating that the early Chinese made use of both oil and natural gas.

The early uses of petroleum were so remarkably varied as to be almost prophetic of its many and various modern uses. Yet petroleum is mentioned more frequently in legend and in early history as a medicine for the ills of man and beast than for any other purpose. The first Europeans coming to America found the Indians using crude oil as a medicine and as an ointment, while certain tribes regarded oil springs with religious reverence. The early settlers of New York, Pennsylvania, and Ohio considered "rock oil," as they called it, a potent cure for every type of ailment.

Colonial America Finds Oil. The possibilities of oil were not entirely lost upon visionary minds among the American colonists. George Washington, visiting what is now part of West Virginia in 1753, learned of the existence of oil in the Kanawha River valley. He recognized its possible importance sufficiently to acquire petroleum-bearing lands. Listed in his will as among his more valuable holdings was a tract containing a "burning spring." He wrote:

> "This tract was taken up by General Lewis and myself on account of the bituminous spring which it contains, of so inflammable a nature as to burn as freely as spirits and is as nearly difficult to extinguish."

Benefit and Nuisance. Although oil, commonly used as a medicine in the United States of 1800, was regarded by some as a benefit, others saw it only as a nuisance. They were the brine-well operators of Pennsylvania, Ohio, West Virginia, Kentucky, and Tennessee upon whom the country was largely dependent for its supply of salt. The presence of petroleum which contaminated salt or salt water in underground beds was a misfortune which too frequently necessitated the abandonment of productive salt wells.

Oil As a Side Line. Some enterprising businessmen, however, utilized this stepchild of the salt brine wells. Best remembered of them is Samuel M. Kier, a salt merchant, who built a profitable side-line business by bottling petroleum and selling it as "Kier's Rock Oil," as a medicine. In advertising, he used reproductions of American "greenback" bills of various denominations, on which were vignetted pictures of his plant at Tarentum, Pa., and the derricks used in boring and pumping the brine wells.

Light and Lubrication. As early as 1819 petroleum had come into demand as an illuminant for homes and factories in Ohio because of the increasing shortage of whale oil, up to then the principal illuminant other than tallow candles. Larger cities throughout the world had taken a page from Herodotus (circa 450 B.C.) and were using "coal-oil" and coal-gas lamps for street lighting. Attention also was being focused upon oil by Adolph Schreiner's invention of the first modern oil-burning lamp in Vienna in 1850, and by the search for a lubricant capable of overcoming friction, principal deterrent to continuous operation of newly developed industrial machinery.

"Greenbacks" and Ideas. "Rock oil" or petroleum came to attention as having value as an illuminant and as a lubricant. One day in the summer of 1857, George H. Bissell, a New Haven, Conn., businessman visiting New York, saw in the window of a Broadway drug store a display of "Kier's Rock Oil" with their pictures of salt-well derricks. Bissell and some friends recently had acquired a 100-acre tract of land having an "oil spring" near Titusville, Pa. They had received from Professor Benjamin Silliman, of Yale University, a favorable report on the use of petroleum as an illuminant. It occurred to Bissell, as he gazed into the window, that the Titusville spring might be increased in oil production by boring and pumping just as salt properties were developed.

Drilling for Oil. Bissell's syndicate engaged a 40-year-old railroad conductor as director and superintendent of the Titusville properties of the Pennsylvania Rock Oil Company and the successor Seneca Oil Company. His name was Colonel Edwin Laurentine Drake. He was destined to become known as the founder of the American petroleum industry by reason of being the driller of the first commercial oil well.

Drake reached Titusville in May 1858, and immediately encountered difficulty in obtaining working associates with sufficient zest for experiment to abandon the primitive method of obtaining oil by digging trenches and collecting the natural seepage. For weeks Drake had to struggle with the difficulties of boring a well.

In April 1859 he obtained the services of William A. Smith, Tarentum blacksmith, who had had experience in drilling brine wells, and of his sons, Samuel and James. Drilling operations were begun in June near an old oil spring on the bank of Oil Creek. Numerous delays and discouragements harassed the drillers, and the project had won the name of "Drake's Folly" even before hard rock was encountered at 36 feet.

To Drake's credit was the first use of a "drive pipe" to keep earth from caving as the hole was bored deeper. He also used a steam engine to raise the drill suspended from a cross-beam, thus eliminating the hard physical labor of the "spring pole" arrangement used by the Chinese for centuries before. In those ways "Yankee" ingenuity made its first expression in creating an industry that is typically American in its origin and in its world wide influence.

Oil Is Struck. Drake's persistence and "Uncle Billy" Smith's primitive drilling machinery became the butt of jokes. Friends tried to dissuade them. Even Drake's employers became discouraged with the tedium of drilling only three feet of rock a day. The oil, they said, might be hundreds of feet down.

Late one sultry summer afternoon "Uncle Bill" and his son, Sam, withdrew the iron bit from the well to measure the depth, which previously had been 69½ feet. When the bit was within a few feet of the top, a dark-green liquid bubbled and frothed. Rigging a crude bailer, they lifted several gallons of oil to the surface. Then "Uncle Billy" mounted his mule and started for Titusville, a mile away, carrying a sample to prove to the countryside that "Drake's Folly" was a dream come true. And the American oil business was born!

THE ORIGIN, OCCURRENCE, AND PRODUCTION OF OIL

Some Common Misconceptions. For seventy years after Colonel Drake drilled his well in 1859 people knew relatively little about oil in the earth. In ignorance, many strange and many romantic ideas were expressed, some of which persist to this day.

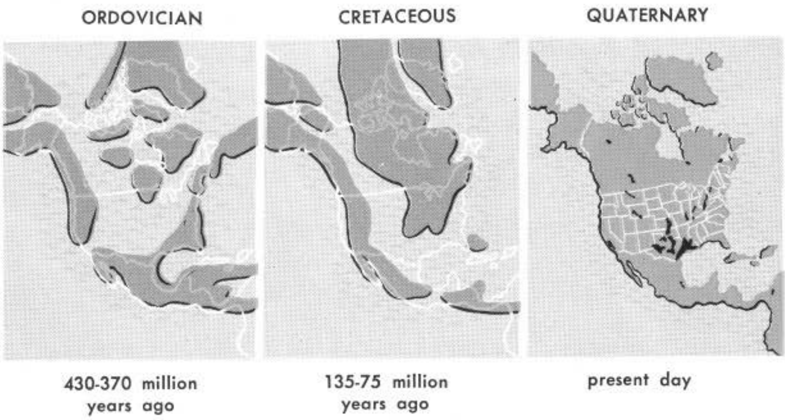
A common belief is that oil lies in the earth as a river or lake extending under and flowing beneath large areas. Some of the early law pertaining to oil and gas was based upon that notion. A tale was told of a driller who lost his watch down a well in Pennsylvania and, years later, found it in the oil flowing from a well in Texas. Even today many people think an oil "pool" is a body of liquid, like water in a cistern, and that one can siphon or pump oil out of the earth at any rate desired, until the pool is empty. Nothing is farther from fact. The truth is that oil (petroleum) is found in rock. Indeed, its name is derived from the Latin words "petro" meaning rock, and "oleum" meaning oil. Nevertheless, long usage has fixed the word "pool" as equivalent to a quantity of oil dispersed in rock in the earth. The word, therefore, has special meaning in the oil business.

Another common misconception is that oil flows out of the "pool." The public thinks of an oil well as a "gusher" spouting forth wealth and riches to the owner of a well. The facts are that oil cannot produce itself from the earth; that there is nothing in oil itself which causes it to rise up and flow out of wells; and that oil moves into a well only if it is pushed or expelled from rock by the gas and water associated with it, supplemented in many cases by the force of gravity.

In order to understand the meaning of "Conservation" in relation to the production of oil, one must have some knowledge of the nature of an oil pool, of the behavior of fluids in the pool, and of the manner by which methods of operation influence the extent of the recovery of oil from the pool. It is the purpose of this article to present in outline some of the highlights of present knowledge on the subject. An effort has been made to treat the subject in an understandable manner, as free as possible from technical terms, and general statements are made to minimize detail and confusion. The scientific features of the article are based upon material contained in the published literature; principally in the following books, each a symposium of the views and writings of many noted petroleum engineers named therein: "Oil and Gas Production," compiled by the Engineering Committee of the Interstate Oil Compact Commission, published in 1951 by the University of Oklahoma Press under the sponsorship of the Commission; "Petroleum Conservation," published in 1951 by the American Institute of Mining and Metallurgical Engineers, under the editorship of Stuart E. Buckley and under the sponsorship of the Henry L. Doherty Memorial Fund; and "Progress Report on Standards of Allocation of Oil Production Within Pools and Among Pools," published in 1942 by a Special Study Committee and Legal Advisory Committee on Well Spacing and Allocation of Production of the American Petroleum Institute.

The Drama of Oil. The user of liquid fuel in a late-model, streamlined automobile is rarely aware that he is a participant in the final act of a fascinating drama whose scenes span a period of several hundred million years. Nevertheless, such is the case when gasoline is burned in the engines of motor vehicles. The consumption of lubricants, kerosene, diesel fuel, and other petroleum products marks the end of this drama.

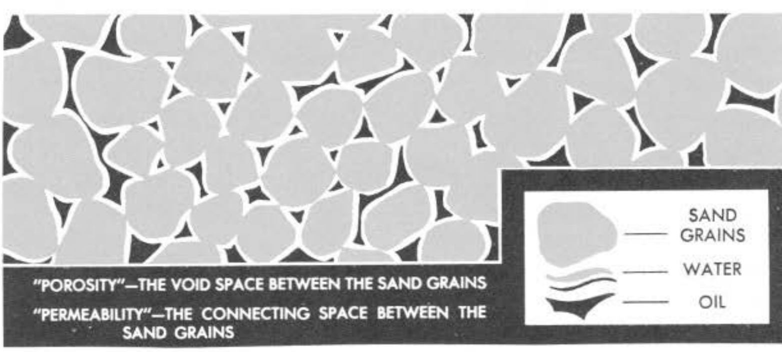
The age of the earth is almost incomprehensible. It is estimated to be more than two billion years. The major changes that affect the surface of the earth have been, and continue to be, scarcely perceptible during the lifetime of an individual. However, given sufficient time, nothing is more changeable than the "everlasting" hills. The mountains of today are of relatively recent age, geologically speaking. Many of them occur in areas that have been repeatedly occupied by the sea. In many instances ancient sediments left by the sea carry fossil remains of marine life. After the mountains are worn away through the slow processes of erosion and the waste material is transported to lower areas, including the ocean, the sea may return to submerge extensive areas of land. Later, portions of the eroded lands again may be raised into mountains or highlands. The newly created landscapes in turn yield to the same erosional and deformational processes. Over a period of hundreds of millions of years the cycle of land destruction, submergence, deposition, and elevation may be repeated over and over again with greater or less intensity.



The Origin of Oil. A generally accepted and wholly adequate theory concerning the origin and accumulation of petroleum has not yet been devised. It is commonly believed that low forms of both plant and animal life provided the primary source material for oil and gas. Subsequent putrefaction of the organic matter in conjunction with bacterial action may have eliminated the constituents other than fats, oily substances, and related materials. Through modifications not yet fully understood, these remaining substances were changed to gaseous and liquid hydrocarbons. Much laboratory and field work supports these views. Compaction of sediments, especially muds, causing a marked reduction in pore space, may represent an important cause of movement of water and oil and gas upward and outward into porous rocks known as *reservoir horizons.* Those portions of the reservoir horizons which carry economically recoverable concentrations of oil and gas are called *reservoirs.* Accumulation of oil in the reservoir itself evidently occurred as a result of buoyancy, the propulsive force of moving gas, and the circulation of underground water.

Oil Occurs in Rock. The sediments deposited in the seas form shales, sandstones and limestones. The shales are too dense and solid to permit oil or gas to remain in them. The sandstones and the limestones, on the other hand, have void space—called "porosity"—in which oil and gas generated in the earth might accumulate.

The sandstone rock is usually hard and firm because the grains of sand from which the rock was formed were cemented together. In most instances, space remains between the grains of sand. The rock is part void space. One might picture the grains of sand forming a sandstone by comparison of the sand grains to potatoes in a bin, or oranges in a crate. Between the potatoes in the bin or the oranges in the crate there is void space, and the void space is interconnected. In similar manner the spaces between the grains of sand in sandstone are interconnected. When 30% of the bulk volume of a sandstone is void the rock is said to have a porosity of 30%. If the sandstone is fine-grained or dense and highly cemented, the degree of porosity may range downward to a value of zero, the porosity of solid rock. Likewise, the network that interconnects the pore spaces between the grains of sand may be relatively large or relatively small. When the connecting spaces are large, fluid substances will flow through the porous rock with relative ease. When the connecting network is small, fluid substances will flow through the porous rock with difficulty. Technologists measure the relative size of the network of channels connecting the inter-grain void spaces in terms of the "permeability," which is a purely relative measure of the ease with which a fluid will move through one network of pores as compared to another. Thus, sandstone as a class of sedimentary rock may be porous and permeable.



"POROSITY"—THE VOID SPACE BETWEEN THE SAND GRAINS
"PERMEABILITY"—THE CONNECTING SPACE BETWEEN THE SAND GRAINS

The limestone rock which is formed mainly from the shell life of the sea is probably dense and solid when first formed. Limestone is soluble in percolating waters and may have had void spaces formed in it by such action. Limestone may also be fractured and fissures may form in a manner to create void space. The porosity of limestone rock is low if only fracturing occurs. It may be high if percolating waters leach and dissolve the rock. Thus, the porosity and permeability of limestone is induced in the rock, whereas the porosity and permeability of sandstone is a remnant of the original condition of the sand as it was deposited.

As will be shown later, the texture of the reservoir rock may vary in different parts of the reservoir, and thus there may be variations in the porosity and permeability of the reservoir rock in a single reservoir.

Accumulation of Oil and Gas. Very little, if any, of the oil and gas found in an oil reservoir originated in the reservoir. In fact, the pores in the reservoir rock were filled with the brine of the sea in which the rock was formed before the oil and gas moved in and displaced water. However, all the water was not forced out. In practically all oil reservoirs water exists in the pore spaces along with oil and gas. It is called "connate" water. An important thing about connate water is that to the extent it occupies pore space there is no room in that space for oil and gas.

Oil and gas, being lighter than the water which occupies most of the openings in the earth's crust, moved upward into porous rock out of the muds in which they originated. When they found a continuous upward route they reached the surface of the earth, as in the case of an oil seep; but if in the course of their journey they encountered obstacles which they could not penetrate and which they could not get around except by moving downward, migration stopped and oil and gas accumulated.

The Trap. Oil and gas in the earth may accumulate in commercial quantities if the porous rock is formed into subterranean traps by the buckling and folding of the earth. These traps are of three major kinds. All of them consist of layers of porous rock covered by layers of non-porous rock.

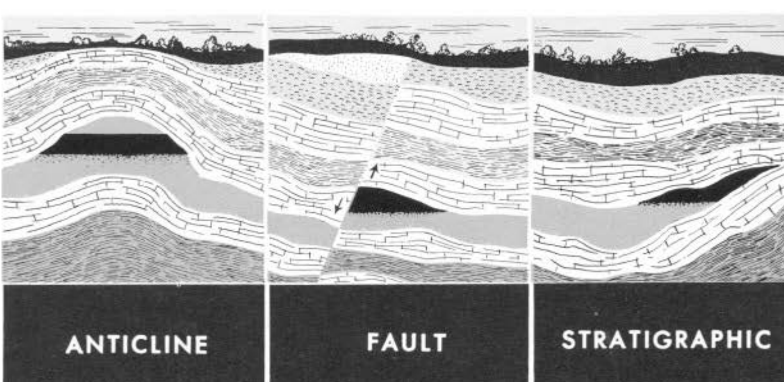
For example, porous rock may have been folded upward, producing a formation shaped like an upside-down bowl or saucer. Oil and gas may collect at the top of such an inverted bowl and be kept from escaping by an overlying non-porous layer. This kind of trap is known as an *anticline.*

A second kind of oil trap is formed at a fault, or break in layers of rock. The rock on one side of the break has slipped up or down so that an uptilted end of a porous layer is thrust against a non-porous layer and thereby sealed. This is called a *fault trap.*

In a third type of oil trap, buried sandstone that may once have been an old beach tapers off like a wedge, ending between layers of rock that are not porous. Here the oil moves through the sandstone until it can go no farther and collects to form an oil reservoir. This type of accumulation is called a *stratigraphic trap.*

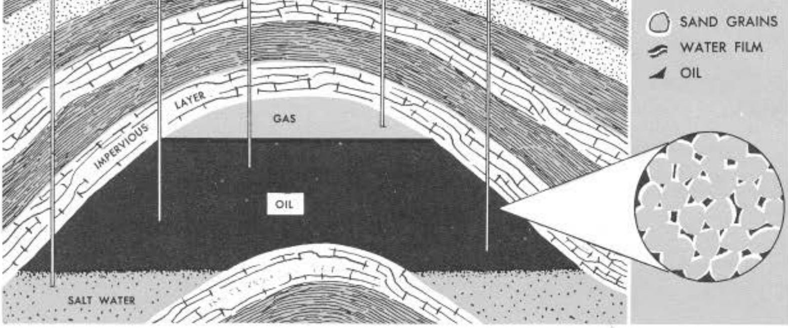
It can be seen, therefore, that oil is not everywhere underground as air is above ground. It accumulates only here and there in traps. The petroleum geologist does not look for oil itself but tries to find traps. They may lie near the surface or miles deep. They may be of almost any size or shape.

The functional importance of a trap is that it serves as a reservoir or as a tank for the accumulation of petroleum above salt water originally occupying the porous rock. The heavier salt water confines the petroleum within the impermeable roof covering the porous rock.



Distribution of Fluids Within an Oil Reservoir. The normally liquid and normally gaseous constituents of petroleum are mutually soluble. The oil dissolves gas; the amount of gas which can be dissolved in a certain amount of oil depends chiefly upon the pressure under which the oil and gas are confined. Under the pressure and temperature of the reservoir, all the gas associated with the oil may be in solution. On the other hand, more gas may be associated with the oil than the oil can dissolve, and in this latter case the excess gas accumulates at the top of the reservoir to form a *gas-cap*. As the pressure in an oil reservoir is lowered to some point which will vary in different reservoirs, a further decline in pressure will release gas from solution.

The fact has been stated that during the period of accumulation of oil and gas in the reservoir trap, some of the buried sea water was displaced. In the course of time, the forces of gravity separated the mixture of gas, oil and the remaining water into layers. This arrangement is somewhat similar to the separation that can be seen when a mixture of gas, oil and water is placed in a glass bottle and allowed to stand for a short time. Since gas is the lightest and water is the heaviest of the three fluids, gravitational forces will cause the gas to rise to the top and the water to settle at the bottom, the oil forming a layer between the gas and the water.



The gas layer is called the *gas-cap;* the oil layer is called the *oil zone;* and the water layer is called the *water zone.* The line of demarcation between the gas-cap and the oil zone is called the *gas-oil contact,* and the line between the water zone and the oil zone is called the *water-oil contact.*

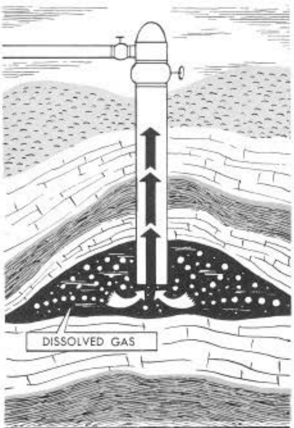
Reservoir Mechanics. Oil does not produce itself. Crude oil, as it exists at the surface, possesses no energy with which to expel itself from the pores of rock. If poured on a sandstone rock, it would be absorbed with little tendency for any to escape, even though the rock has porosity and permeability comparable to that of reservoir rock. It is necessary that crude oil be associated with an energy source before it can be moved into the bottom of a well and raised to the surface of the earth.

The principal sources of natural energy, one or more of which are present in all commercially productive oil reservoirs, are:

1. the expansion, as a result of pressure reduction, either of gas which has come out of solution from the reservoir oil or of free gas initially present in the reservoir;
2. edge or bottom water encroachment, also a result of reduction of pressure; and
3. gravitational force.

Either gas expansion or water encroachment provides the principal energy for most oil reservoirs. Both become operative only with a release of pressure. A hole must be bored into the reservoir rock to release reservoir pressure. It provides a connection between the high-pressure oil reservoir and the low pressure existing at the earth's surface. The pressure release causes a pressure gradient within the reservoir toward the bottom of the well bore. Natural energy sources become active and move oil into the well bore, whence it is brought to the surface either through natural energy or by means of artificial lift.

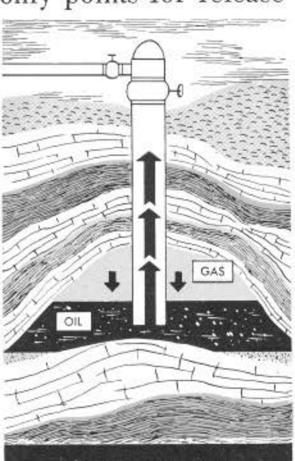
Dissolved-Gas Drive. It has been noted that gas is usually dissolved in oil under pressure. Such gas is called *solution-gas.* An oil reservoir in which the energy for production of oil is obtained mainly from expansion of solution-gas is classified as one controlled by solution-gas expansion or dissolved-gas drive.



DISSOLVED GAS DRIVE

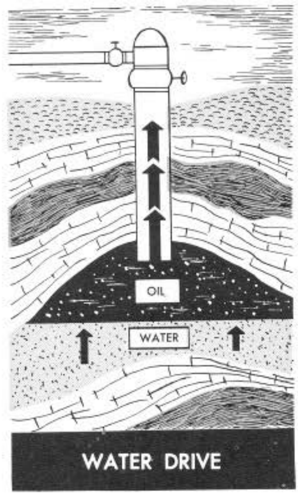
In the dissolved-gas drive, gas escapes from solution within the oil upon reduction of pressure and drives the oil from the reservoir into the well. Drives of this type are characterized by rapidly declining pressures and an increasing amount of gas necessary to produce a barrel of oil, with rapidly increasing gas-oil ratios (the number of cubic feet of gas produced with a barrel of oil). High gas-oil ratios are usually indicative of inefficient operation, unless the produced gas is re-injected into the reservoir. Because gas is a relatively inefficient medium for displacing oil from a partially depleted oil sand, and because the amount of gas available is limited to that initially dissolved in the oil, the dissolved-gas drive gives comparatively low oil recoveries.

Gas-Cap Drive. It has been said that in those reservoirs where the amount of gas exceeds the amount dissolved in the oil, the excess gas exists in a free state as a gas-cap above the oil zone. During the time that no gas is being produced from the gas-cap, wells drilled into the oil zone of the reservoir constitute the only points for release of pressure. This pressure reduction is transmitted through the oil zone to the gas-cap and allows the compressed gas in the gas-cap to expand and move downward, forcing the oil ahead, as a piston sweeping downward. This action is similar to the expulsion of water from a siphon type of soda water bottle. The energy for producing oil in a gas-cap drive type of reservoir comes from both expanding gas-cap gas and solution-gas as pressures are released. Even though a gas-cap is not present at the time of discovery, gas freed from solution will migrate to the vacated space at the top of the structure



GAS-CAP DRIVE

to form a gas-cap, called a *secondary gas-cap*, which also expands as oil is produced. Gas-cap drive, even if not originally existent in a reservoir, often can be brought about by "pressure maintenance" operations which will be hereinafter described. A gas-cap drive is more efficient and results in a greater recovery of oil than a dissolved-gas drive.



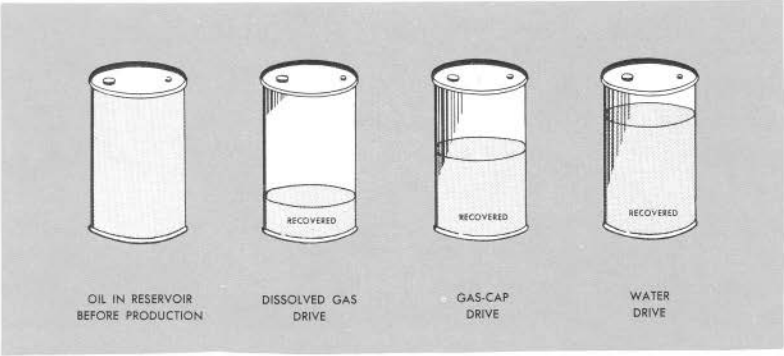
Water Drive. Some porous permeable reservoir rock cover large areas and may be quite thick. Accordingly, they may be of size and volume as to hold a very large volume of water permeably connected with the oil which is trapped in the structurally highest part of the reservoir. In that circumstance, the amount of energy stored in compressed water becomes the dominant source of energy supply. Gas may be present with the oil, but its energy content may be much less than that of the associated water.

In such a situation, the pressure decline caused by production of oil and gas from the pool extends to the vast body of water. In response, the body of water expands to fill the pore spaces voided by oil and gas and reservoir pressure is maintained. A very efficient operation results when the production of oil and gas is at a rate to be equal to the rate at which the "water drive" may encroach and just balance the decline of pressure caused by oil and gas produced.

When a reservoir is produced by water drive, a greater recovery of oil can be obtained than by either dissolved-gas drive or gas-cap drive.

Gravitational Force. The force of gravity also supplies a source of energy for producing oil. It acts ceaselessly on the reservoir fluids in all types of reservoirs; but only where the permeability of the reservoir rock is high and the structure dips sufficiently, or the reservoir rock is thick, does gravity become active enough to furnish the dominant driving force for production.

Combination Drives. Solution-gas drive, gas-cap drive, water drive, and gravitational force are sometimes treated as distinct types of reservoir control. All four forces are usually active in any reservoir, even though one may predominate during different stages in its life.



Comparative Results From Efficient Operations

Each Oil Reservoir Distinctive. No two oil reservoirs are exactly alike. Each is individual. Each has distinct characteristics which influence the extent of the recovery of the oil and gas from that particular reservoir, including: shape, or what the petroleum engineers call the "geometry" of a reservoir; porosity and permeability of the rock; the chemical and physical composition of the rock; the amount, distribution and composition of the connate water; the chemical properties of the oil and gas; the specific gravity and the viscosity of the oil; and, above all, the relative amounts and locations of the gas-cap (if any), the oil zone, and the water zone.

Even a single reservoir may possess variations in reservoir characteristics. The thickness of the oil and gas-bearing sands may vary substantially throughout the reservoir. It is quite probable that the porosity and permeability of a reservoir rock and the amount of connate water will vary in different parts of the reservoir. Each reservoir must be studied carefully and a determination must be made as to whether it is subject to or can be made subject to gas-cap drive or water drive, or both, or can be produced only under dissolved-gas drive. That determination, in turn, should determine the location of wells at the best positions on the structure to make most effective use of the reservoir energy, and should govern many other operating practices.

The Reservoir as the Producing Unit. One of the most important things necessary for a proper understanding of efficiency in the production of oil is that the reservoir as a whole is the "common source of supply."

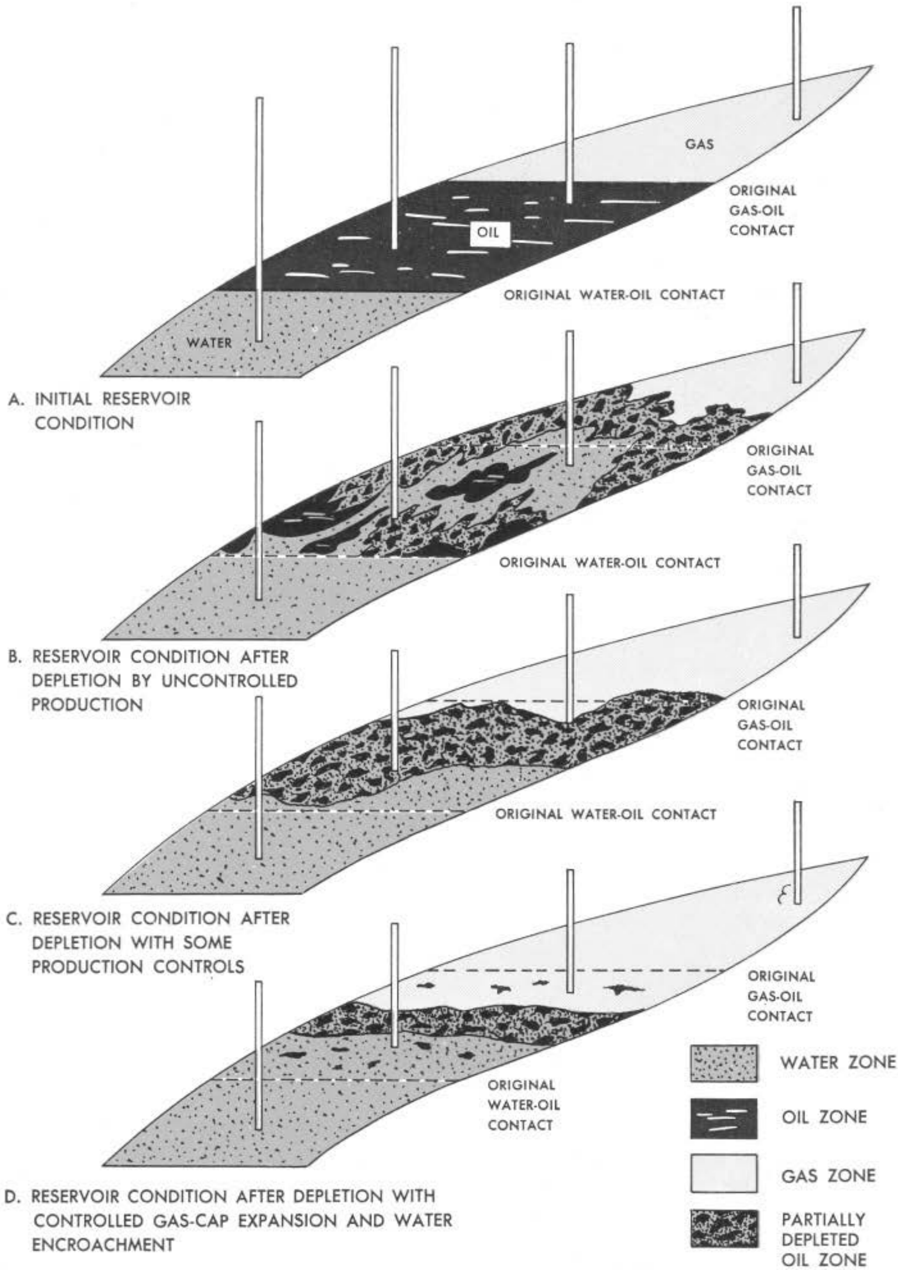
Oil is recovered from rock through wells by a displacement process. Briefly, the process may be described as follows: When a well in a reservoir is opened, the pressure in the porous rock at the well is reduced and oil, with gas or water or both, flows into the well. The flow will continue unless the reservoir pressure falls low enough, as a result of production, to be in balance with the pressure in the well. So long as flow continues, the oil and gas and water throughout the reservoir move through the permeable network connecting the pore spaces within the entire reservoir. Thus, the reduction in pressure at the face of the well created by the outflow of oil with gas or water spreads through the reservoir in a manner comparable to the wave that spreads out from a stone cast into a pool of water. The wave, highest at the point at which the stone struck the surface of the water, spreads with diminishing force over the entire pool, to reach every point along the shore line. In like manner, the pressure reduction created by a producing well spreads its influence to all the pore space permeably connected to the rock at the well, causing the gas and the water, or both, and its accompanying oil to expand and move from all points toward the producing well. In this sense, an oil pool is a "common source of supply" of oil and of energy available for its production.

The expanding gas or water moves through the rock toward the well and the production of some gas or water or both must occur with production of oil. A portion of the expanding gas or water remains behind in the reservoir and fills the pore spaces voided by the oil produced. Each barrel of oil recovered thereby takes its toll not only of the store of oil available for production but of the store of energy represented by compressed gas or water also produced or left to fill the vacancy created by the produced oil.

Each barrel produced from a pool represents one less remaining to be recovered. At the same time, there is also less energy available, to the extent of the energy consumed to recover the produced barrel. That oil recovery is a depletion process is perhaps a matter of common knowledge. It is known that once-flush fields all come to the same final state when production can no longer be obtained at a profit and the pool must be abandoned.

Practical Aspects of Primary Producing Forces. Some of the principles which have been discussed are illustrated about as simply as possible in the book of the Interstate Oil Compact Commission's Engineering Committee previously referred to, as follows:

> "A stratigraphic-type reservoir in its initial or discovery condition is illustrated in the sketch, View A. This trap is fairly persistent and is connected to a source of water energy. The reservoir rock has considerable dip and good permeability. The oil in the reservoir is saturated with gas and a gas-cap is present.
>
> "If each well in this reservoir were produced wide open, much oil otherwise recoverable would be left in the reservoir. Uncontrolled production of wells completed in the gas-cap would develop a low pressure therein, so that oil would move into the gas-cap. A significant amount of oil would be made unrecoverable by wetting the gas-cap rock and wasting the energy of the gas-cap. The water-drive would be ineffective since production by the down-structure wells would make it impossible for the encroaching water to keep up with the rate of oil production. The reservoir would not be controlled by water-drive, but by solution-gas expansion, because the method of operation would compel it to be so. A reasonable estimate of ultimate recovery by such a method of operation is 15 to 25 per cent of the initial oil-in-place. Distribution of fluids in the reservoir when further production is uneconomical would be as shown in the sketch, View B.
>
> "The reservoir could produce as a solution-gas expansion type under certain restrictions and recover greater oil volume. If all wells in the field were restricted to rates of production that voided equal volumes of reservoir space, there would be



A. INITIAL RESERVOIR CONDITION

B. RESERVOIR CONDITION AFTER DEPLETION BY UNCONTROLLED PRODUCTION

C. RESERVOIR CONDITION AFTER DEPLETION WITH SOME PRODUCTION CONTROLS

D. RESERVOIR CONDITION AFTER DEPLETION WITH CONTROLLED GAS-CAP EXPANSION AND WATER ENCROACHMENT less tendency for oil to move up structure and be left in the originally dry gas-cap. Approximately 20 to 30 per cent of the original oil-in-place could be recovered and the reservoir left in the condition as shown by the sketch, View C.

"The same reservoir could be produced under solution-gas expansion and gas-cap expansion and recover 30 to 45 per cent of the oil if (1) all gas wells were shut in and (2) oil wells completed below the gas-oil contact and those at the water-oil contact produced only enough water to prevent water encroachment on the oil zone.

"A greater recovery could be realized from a reservoir of this type if oil production and gas production were both strictly controlled. The reservoir would be a combination water-drive and gas-cap expansion reservoir if gas wells were shut it, high gas-oil ratio wells were restricted, and the combined rate of oil and gas production from wells in all parts of the reservoir limited to the rate at which water entered the reservoir. In this operation 45 to 75 per cent of the oil-in-place could be recovered and the reservoir left similar to that shown by the sketch, View D. Such efficient operations are feasible only where the owners of wells on individual tracts agree that production shall be taken from those wells which are located most advantageously on the structure."

Control of Reservoir Performance. Conservation in the production of oil means the use of the most efficient methods to the end that the greatest ultimate recovery from the reservoir can be effected. It is not possible to get all of the oil out of an oil reservoir. Physical forces, such as capillarity and surface tension, stand in the way. Nevertheless, conservation means that we should not leave in the reservoir any oil that efficient methods can economically recover.

There are many factors in the production of oil from a reservoir over which the operators can have no possible control. They cannot change the original geology of the oil reservoir and its surroundings, including the texture of the producing formation, the original reservoir contents of gas, oil and water, and the characteristics of those fluids. On the other hand, as we have seen, there are available at least four possible methods of recovering the oil, each different from the others and some more efficient than the others. If there is no adequate natural gas-cap drive or water drive in a reservoir, the first question is whether it is possible to substitute an efficient gas-cap drive or water drive for the dissolved-gas drive which exists and which we have seen is less efficient. In most cases the answer to this question is affirmative, for the simple reason that it is frequently possible to inject produced gas to create a secondary gas-cap, and, except under very unusual circumstances, it is possible to inject water, if necessary, into the edges of a reservoir to bring about a water drive. The basic question in conservation, therefore, is not so much whether the operators can bring about more efficient operation, but which operation should be chosen and how that operation can be made as efficient as possible.

The ultimate recovery will be dependent upon the degree to which it is possible to make the advancing gas or water invade the entire reservoir and upon the uniformity with which the advancing gas or water performs its function in displacing or flushing the oil content of the reservoir rock as the front advances. Two aspects of this uniformity are important: first, the front must advance with an over-all surface sufficiently regular to permit selective production of oil and to avoid dissipation of the advancing gas or water, and, second, the advancing front must have displaced oil not merely from selected portions of the reservoir rock but, insofar as possible, to the same degree from all portions of the reservoir rock behind the advancing gas or water. When consideration is given to the extreme differences in the texture encountered within a single oil reservoir it is obvious that the latter requirement is a very difficult one.

Efficient recovery of the oil from a reservoir is not taken care of by chance; it may be fulfilled only through careful and deliberate action by the producers. Experience has shown that one of the most essential factors in meeting these requirements is control of the rate of production. Excessive rates of withdrawal lead to rapid decline of reservoir pressure, to release of dissolved gas, to irregularity of the boundary between invaded and non-invaded sections of the reservoir, to dissipation of gas and water, to trapping and by-passing of oil, and, in extreme cases, to complete loss of demarcation between the invaded and non-invaded portions of the reservoir, with dominance of the entire recovery by inefficient dissolved-gas drive. Each of these effects of excessive withdrawal rates reduces the ultimate recovery of oil.

Secondary Energy for Production. One of the most important controls to increase recovery has been noted, namely that in the case of most oil reservoirs it is possible to substitute a gas-cap drive or water drive for the less efficient dissolved-gas drive. We come now to an equally important corollary proposition, which is that in most oil and gas reservoirs, natural energy for production can be supplemented to bring about increased oil recovery by injection of gas into a gas cap or of water into the water zone of the reservoir. If such injection takes place while the reservoir pressures are still high and most of the wells are still flowing, the operation is classified as *pressure maintenance*. If it is started after pressures have been substantially depleted and the field is in the pumping or stripper stage, it is classified as *repressuring*, or *water flooding*.

Maintenance of Pressure by Gas Injection. In *gas-injection operations*, wet gas produced with the oil is taken from separators and transported through a gas-gathering system to a gasoline plant where the liquefiable hydrocarbons are removed. After these liquid hydrocarbons have been removed, the *dry gas*, sometimes called *residue gas*, is compressed and returned to the gas cap of the reservoir through input wells to maintain pressure.

In some gas-injection operations gas produced from other reservoirs is purchased. This practice permits the injection of a gas volume equal to 100 per cent or more of the produced-gas volume. The result may be a pressure-maintenance operation rather than the retarded pressure-depletion operation which takes place when only gas produced from the reservoir is returned to the reservoir. If input wells are grouped on the high part of the structure and gas is injected into the gas cap, the oil recovery will be increased.

Maintenance of reservoir pressure by injection of gas is dependent directly and solely on the amount of gas injected. If the gas injection is confined to the gas produced with the oil the reservoir pressure will decline continuously, but usually only moderately; if gas from an extraneous source is injected in such quantity that the reservoir volume of injected gas is equal to the reservoir volume of all withdrawals the reservoir pressure will be maintained at its original value.

Maintenance of Pressure by Water Drive. Maintenance of reservoir pressure by *natural* water drive can be obtained through regulation of the production rate if the physical nature of the reservoir and its surroundings are such that water can feed into the oil-bearing portion of the formation at a small or moderate pressure differential in sufficient volume to displace the oil at an economic rate. The maintenance of pressure in a reservoir by *artificial* water drive involves much less difficult considerations than maintenance of pressure by natural water drive. The degree of maintenance is dependent solely on the amount of water injected in comparison with the reservoir withdrawals. If the volume of injected water is equal to the volume of withdrawals, the reservoir pressure may be maintained at its original value; if injection lags, the reservoir pressure will decline.

Secondary Recovery by Water Injection. As early as 1880, Pennsylvania producers discovered that an increase in oil recovery could be obtained by injection of water into oil reservoirs. Water, accidentally entering the oil sand, restored production in parts of the Bradford field that were thought to be exhausted, and proved that when the original wells were abandoned as unrecoverable, millions of barrels of oil remained in the oil sand. The mechanism of displacement of oil by water is no different in secondary-recovery operations from that in primary water drive. The same types of control must be exercised to assure efficient flushing of the reservoir.

Oil Reservoir a Bundle of Energy. To sum up in a few words the foregoing discussion of the nature of an oil reservoir or "pool" and the behavior of gas, oil and water in it, one may think of the reservoir as a vast bundle of energy. The energy is subject to control through regulation of pressure release; and pressure release is in turn controlled by well locations, the rate at which the oil and gas are produced, and many other operating practices. The energy can be wasted through inefficient practices, and it can be conserved through efficient practices. Finally, the energy can be maintained by pressure maintenance methods, and in some cases can be restored by secondary recovery methods.

The Engineering Committee of the Interstate Oil Compact Commission closed its book as follows:

"An analysis of the behavior of oil and gas reservoirs leads to the general conclusions that:

1. The rate of fluid production is an important factor affecting recovery of oil and gas;
2. The control of the rate involves an equitable allocation of the restricted production;
3. Production from that part of the reservoir which utilizes the available energy most efficiently is the best type of conservation practice;
4. An adequate number of wells must be drilled to produce the reservoir at an efficient rate—more than this number of wells constitutes excessive drilling and actual waste;
5. Most reservoirs need a supplement to the natural energy in the form of gas or water injection, or both;
6. Each reservoir has separate and distinct characteristics and the proper mechanics of reservoir operation must be determined for each;
7. Nature formed each oil and gas reservoir as a unit, a single common source of supply;
8. Maximum recoveries are possible only when a reservoir is operated as a unit without respect to surface boundaries and fences, and a fair and equitable division of the production from the entire reservoir can be made."

Conclusion. The eighth conclusion of the Engineering Committee mentioned above, that maximum recoveries are possible only when a reservoir is operated as a unit without respect to surface boundaries and fences and a fair and equitable division of the production from the entire reservoir can be made, brings into focus the second principal purpose of state oil and gas conservation laws.

The Interstate Oil Compact Commission's suggested Conservation Act contains this declaration of policy:

"It is hereby declared to be in the public interest to foster, to encourage, and to promote the development, production, and utilization of natural resources of oil and gas in the state in such a manner as will prevent waste; to authorize and to provide for the operation and development of oil and gas properties in such a manner that a greater ultimate recovery of oil and gas be had *and that the correlative rights of all owners be fully protected;* and to encourage, to authorize, and to provide for cycling, re-cycling, pressure maintenance, and secondary recovery operations in order that the greatest possible economic recovery of oil and gas be obtained within the state to the end that the land owners, the royalty owners, the producers, and the general public realize and enjoy the greatest possible good from these vital natural resources."

In this we see the double-barrelled purpose of a conservation law. The first has to do with obtaining a greater ultimate recovery of oil and gas, and the second has to do with the protection of "the correlative rights of all owners" of the oil reservoir.

Except in very rare cases, an oil reservoir underlies the property of many owners of the surface of land. Some oil reservoirs cover small areas; others cover many square miles. The movement of oil, gas and water in even the largest petroleum reservoir responds to or is influenced by pressure differences created by production of oil from any part of the reservoir. No surface owner of land overlying the reserve has exclusive control of such pressure if there are producing wells on other lands not owned by him, likewise overlying such reservoir. All owners of interests in every reservoir make common use of the expulsive forces which constitute the reservoir energy. The reservoir energy constitutes a common source of supply. It is clear, therefore, that any one producer or interest owner in an oil and gas reservoir can effectively prevent the practice of efficient methods of recovery in the reservoir. For this reason there is often a conflict between efficient methods and the exercise of individual property rights. The conflict of property rights is the chief problem to be dealt with in attaining conservation. The succeeding articles of this booklet consider this problem and offer ways in which it may be met.

PROPERTY RIGHTS AND OIL PRODUCTION

George W. Hazlett

Fortunately for the nation, most of the producing states have adopted statutes known as "conservation laws" for the regulation of oil and gas production. These states include all but one of the five largest producers (California being the notable exception). There are few producers in states having conservation laws who advocate return to old, unregulated ways. Effective conservation statutes are more than mere waste prevention measures, and because they necessarily impose restrictions on the use of land, belief persists that the ends of conservation can be achieved only through sacrifice of property rights long recognized by common law, and therefore sacred.

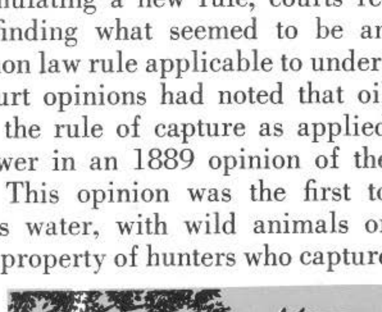
The Rule of Capture. Common law concerning oil and gas production is expressed in the "rule of capture" which holds that the landowner or his lessee acquires title to all that is produced through wells on his land, regardless of the source of the supply. If applied only to determine ownership of oil and gas after they are produced, this rule is proper and necessary, as practical considerations require that title to them follow title to the land on which they are produced. However, the rule has been uniformly applied to permit every landowner or his lessee to drill and produce as he pleases in order to capture for himself all production obtainable from his wells, without restriction beyond the requirement that he confine his activities to his own land. While this rule, like every rule of common law, was created by court decision, the freedom of action it allows has come to be regarded by many as the established and inviolable property right of every landowner, despite the fact that it is a comparatively recent development in common law.

In evaluating the rule of capture, it must be kept in mind that common law is a system of legal rules established by men sitting as judges, as distinguished from statutory law enacted by legislatures. As once said by the Supreme Court of the United States:

> ". . . the common law is but the accumulated expressions of the various judicial tribunals in their efforts to ascertain what is right and just between individuals in respect to private disputes." (*Kansas v. Colorado, 206 U. S. 46*)

Our courts "make" law in a very true sense, for the simple reason that a court cannot refuse judgment in a case before it merely because there is neither precedent nor statute to serve as a guide to decision. Whenever a development in science or industry presents to a court facts new to the law, the court has no choice but to formulate a new rule of specific application to the peculiar facts before it. If the rule appeals to other courts as an adequate solution to the new problem, a precedent is established which becomes as much a part of our common law as those recognized for centuries.

The commercial production of oil and gas that followed the drilling of Pennsylvania's Drake well in 1859 soon presented to the courts a new legal problem, as these substances were then entirely unknown to the law and but little known to science. In this instance, instead of formulating a new rule, courts resorted to reason by analogy, finding what seemed to be an appropriate solution in the common law rule applicable to underground waters. While other court opinions had noted that oil and gas were fluids like water, the rule of capture as applied to petroleum came into full flower in an 1889 opinion of the Pennsylvania Supreme Court. This opinion was the first to classify oil and gas, as well as water, with wild animals or *Ferae naturae*, which become the property of hunters who capture them, the court saying:



> ". . . water and oil, and still more strongly gas, may be classed by themselves, if the analogy be not too fanciful, as minerals *Ferae naturae*. In common with animals, and unlike other minerals, they have the power and the tendency to escape

without the volition of the owner. . . . They belong to the owner of the land and are part of it, so long as they are on or in it, and are subject to his control; but when they escape and go into other land, or come under another's control, the title of the former owner is gone." (*Westmoreland, etc., v. DeWitt, 130 Pa. 235, 18 Atl. 724*)

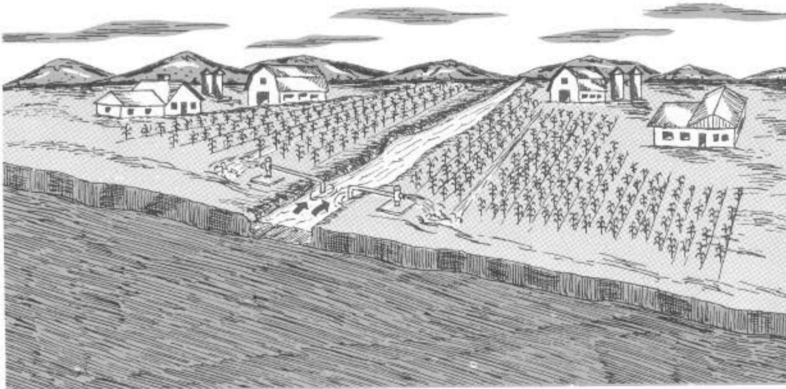
Seeking the origin of the rule thus announced, we find that it came into being in England on May 18, 1843. On that date an English court handed down the first decision recorded in Anglo-American jurisprudence concerning underground waters, in reviewing a dispute between adjoining landowners, one of whom by digging on his own land had destroyed the well of his neighbor. After noting that "the question raised before us is one of equal novelty and importance" and that "no case has been cited on either side bearing directly on the subject in dispute," the court reasoned thus:

". . . We think the present case . . . is not to be governed by the law which applies to rivers and flowing streams, but that it rather falls within that principle, which gives to the owner of the soil all that lies beneath his surface; . . . that the person who owns the surface may dig therein, and apply all that is found to his own purposes at his free will and pleasure; and that if, in the exercise of such right, he intercepts or drains the water collected from underground springs in his neighbor's well, this inconvenience to his neighbor falls within the description of *damnum absque injuria,* which cannot become the ground of an action." (*Acton v. Blundell, 12 M. and W. 324, 152 Eng. Rep. 1233*)

This rule, still known as the "English" rule, had found general acceptance in courts of the United States by the time the early oil and gas cases reached the courts.

The Rule of Correlative Rights. Surface waters, however, had many contacts with law long before 1843. In fact, the common law concerning waters of a surface stream is so ancient that the English court of 1843 was obliged to note that its origin had been "lost with the progress of time." That court stated the common law rule then and still in force in the United States, as well as in England:

"The rule of law which governs the enjoyment of a

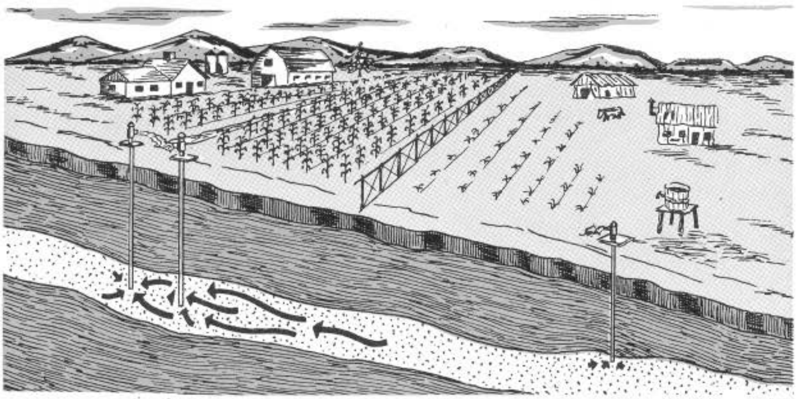


Sharing surface water under the older "Rule of Correlative Rights".

stream flowing in its natural course over the surface of land belonging to different proprietors is well established; each proprietor of the land has a right to the advantage of the stream flowing in its natural course over his land, to use the same as he pleases, for any purposes of his own, not inconsistent with a similar right in the proprietors of the land above or below; so that neither can any proprietor above diminish the quantity or injure the quality of the water which would otherwise naturally descend, nor can any proprietor below throw back the water without the license or the grant of the proprietor above." (*Idem.*)

In view of the obvious justice of this rule, long known as the rule of "correlative rights," why did courts find it necessary to formulate a different rule for underground waters? Court opinions show that the difference between the rule of correlative rights and the rule of capture is nothing more than the difference between knowledge and ignorance. As stated in the English opinion of 1843, subterranean waters "do not flow openly" but through "the hidden veins of the earth." In the first American underground water case, decided by the Supreme Court of Vermont in 1855, the reason for application of the rule of capture was stated thus:

"The secret, changeable, and uncontrollable character of underground water in its operation is so diverse and uncertain that we cannot well subject it to the regulation of law . . ." (*Chatfield v. Wilson, 28 Vt. 49*)



Taking underground water under the "Rule of Capture".

Six years later the Supreme Court of Ohio noted the difference between surface and subterranean waters:

". . . the law recognizes no correlative rights in respect to the underground waters percolating, oozing, or filtering through the earth; and this mainly . . . because the existence, origin, movement, and course of such waters, and the causes which govern and direct their movements, are so secret, occult, and concealed that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would be, therefore, practically impossible . . ." (*Frazer v. Brown, 12 O. S. 294*)

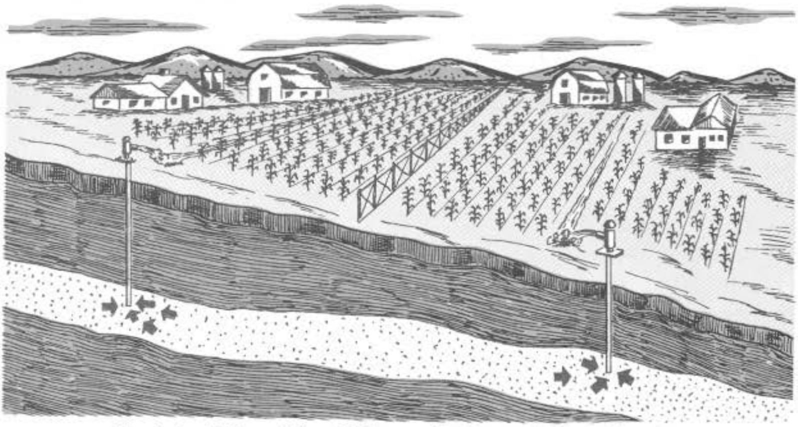
That adequate knowledge can change common law without the aid of legislation is demonstrated by more recent court decisions concerning subsurface waters. As investigations by geologists and hydrologists revealed the facts, and as underground water supplies became increasingly important in our economy, the courts of many states adopted what is known as the "American rule," to distinguish it from the English rule of capture, the new rule having been well stated by the Supreme Court of Nebraska in 1933:

"The American rule is that the owner of land is entitled to appropriate subterranean waters found under his land, but he cannot extract and appropriate them in excess of a reasonable and beneficial use upon the land which he owns . . . and if the natural underground supply is insufficient for all owners, each is entitled to a reasonable proportion of the whole." (*Olson v. City of Wahoo, 124 Neb. 802, 248 N. W. 304*)

The Supreme Court of California, by abandoning the rule of capture in an underground water case decided in 1902, was among the first to appreciate that the rule, instead of protecting, tended to destroy property rights. Concerning the position of landowners dependent on subsurface water supplies, if the rule should be continued in force, the court said:

> ". . . They will have absolutely no protection in law against others having stronger pumps, deeper wells, or a more favorable situation, who can thereby take from them unlimited quantities of the water, reaching to the entire supply, and without regard to the place of use. We cannot perceive how a doctrine offering so little protection to the investments in and product of such enterprises, and offering so much temptation to others to capture the water on which they depend, can tend to promote developments in the future or preserve those already made and, therefore, we do not believe that public policy or a regard for the general welfare demands the doctrine . . ." (*Katz v. Walkinshaw, 70 Pac. 633; 74 Pac. 766*)

This change in the common law of underground waters, stressing the importance of facts in the application of legal principles, leads to consideration of the "facts" presented to the courts that were called upon to decide the early oil and gas cases. To those courts, oil and gas were far more mysterious than subsurface waters; literally, all that was known with certainty was that sometimes when a hole was bored in the earth oil or gas came forth. Nineteenth century court opinions reflect the then general belief that oil and gas were constantly in motion, it being supposed by some that they moved more or less aimlessly through the earth, while others thought that oil existed in lakes or flowed in subterranean rivers. As late as 1902, it was possible for the New York Court of Appeals to say that "in some instances (oil) doubtless exists in pools," a misconception that persists today in application of the term "pool" to the petroleum reservoir. (*Wagner v. Mallory, 169 N. Y. 501, 62 N. E. 584*) In an early Kentucky case it was conceded by both sides that the oil there in question was taken from a well "bored down to a running stream of oil." (*Hail v. Reed, 54 Ky. 383*)



The Rule of Correlative Rights applied to underground waters.

Unquestionably, the rule of capture furnished an entirely logical and practical solution to the legal problem presented by these supposed facts; informed that oil, gas and water moved through the earth in uncertain courses, and that no one knew "whence they come or whither they go," courts properly refused to interfere with the landowner who brought them to the surface on his own land. The *facts* of the petroleum reservoir are in striking contrast to the suppositions of a few decades ago. We now know that oil and gas as they exist in the earth are securely locked in structural traps from which they cannot escape of their own volition, and that they move, even within the limits of the reservoir, only when it is penetrated by a well. Further, we know that oil and gas may be drawn into a well from distances up to thousands of feet. Of even greater legal significance is knowledge of the part played by natural reservoir pressure in supplying the energy required to force oil and gas through porous rock into the well bore. Today we know that loss of pressure in any part of a reservoir reduces the available energy throughout the pool, and that when the energy is entirely gone, oil and gas remaining in the reservoir are gone with it.

Had these facts, as well as present day knowledge concerning underground waters, been made known to courts of the nineteenth century, it is safe to say there would have been no rule of capture in our common law. Those courts were fully aware that the rule is entirely negative and represents complete absence of law in oil and gas production, except for the requirement that each producer confine his activities to his own land. By declining to interfere in conflicts between neighboring landowners, each seeking all he could obtain regardless of consequences to others, courts washed their hands of responsibility for an equitable adjustment between the right claimed by one owner to oil and gas within his land and the right asserted by his neighbor to drill and produce as he might please. In the English case of 1843 that gave birth to the rule of capture, the court concluded that the right of the defendant to dig as he pleased on his land was superior to the right claimed by the plaintiff to water for his well, although, by sanctioning destruction of plaintiff's well, the decision deprived him of a valuable property. Through application of the rule of capture to conflict between these two kinds of property rights in oil and gas production, American courts denied to the landowner enough interest in oil and gas within his land to entitle him to protection against abuses by his neighbors. By permitting boundary line drilling, the rule licensed any owner to take oil and gas from lands of his neighbor; by refusing to prevent production practices harmful to the reservoir, the rule licensed irreparable loss to all owners in the pool. Adopted in the erroneous belief that oil and gas were in constant unpredictable movement, and therefore not susceptible to regulation by law, the rule of capture gave the nod to the right of the landowner to do as he pleases and thereby destroyed another kind of property right.

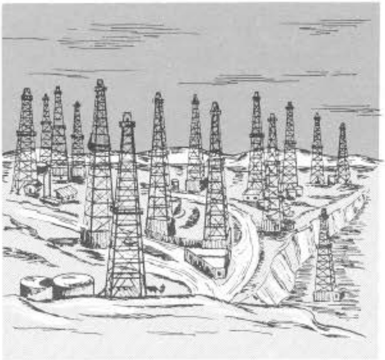
The Rule of Capture Results in Waste. The inevitable result of the rule of capture's complete lack of legal restraint has been to force producers into one drilling race after another, in which each sought to drill as many wells as possible, as quickly as possible, in order to capture for himself the lion's share of the spoils. Nearly every discovery of an important new oil field brought a mad rush of drilling that often produced more oil than the market could absorb. Whenever this occurred, the unhappy operator who could not find a buyer for his oil nevertheless continued to produce his wells rather than have his more fortunate neighbors drain oil from his lands. In field after field, with no other facilities available, this surplus oil was "stored" in pits dug out of raw earth, and even in open ditches; appalling quantities of oil were lost through evaporation and seepage, surface and underground waters were polluted, and serious fire hazards were created, sometimes with disastrous results.

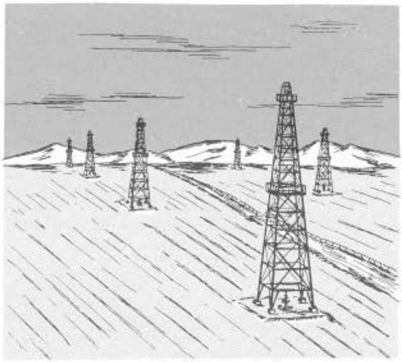
Conditions such as these prompted the first of the modern conservation laws, the "proration" statute adopted by Oklahoma in 1915, after rapid development of that state's Healdton and Cushing pools (then considered the greatest on earth) had glutted a market already saturated with oil. However, this situation was soon remedied by the petroleum demands of the First World War, and comparatively little use was made of the statute until 1930, after discovery of the great Oklahoma City oil field again created a serious problem. A couple of years later, the race to drill the most wells in the East Texas field—the most prolific so far discovered in the United States—once more flooded a market distressed by the business depression of the 1930's. The price of East Texas oil dropped to ten cents per barrel and less, with no takers in sight, and the situation became so acute that it was necessary to call out the State Militia to maintain a semblance of order; after millions of barrels had been forever lost the Texas legislature adopted a proration statute similar to that of Oklahoma. The example thus set was followed in Kansas, Louisiana and other states by adoption of conservation laws.

Correlative Rights Enforced by Law. The typical oil conservation statute prohibits the waste of oil and gas and defines "waste" to mean not only physical waste but also: (a) the inefficient, excessive, improper use of, or unnecessary dissipation of, reservoir energy, (b) the locating, spacing, drilling, operating, or producing of any oil or gas well or wells in a manner which causes, or tends to cause, reduction in the quantity of oil or gas ultimately recoverable from a reservoir under prudent and proper operations, and (c) the production of oil and gas in excess of transportation or storage facilities, or in excess of reasonable market demands. The statute empowers an administrative agency of the state to determine at regular intervals the quantity that will be required to meet the demand for oil produced in the state. The quantity so determined must then be allocated among all the pools in the state on an equitable basis, the quantity allocated to a particular pool being its "allowable" production. When there is demand for all the oil that can be produced (as was the case during and for a few years after the Second World War) the administrative agency determines for each pool its "maximum efficient rate of production"—i.e. the maximum quantity that can be produced without unnecessary injury to the reservoir— and that amount becomes the allowable production for the pool. By whichever method determined, the allowable production for a pool must be prorated among all the wells in the pool in such manner that each producer will be allowed to produce his fair and equitable share of the allowable production.

Well Spacing. Application of the statute led naturally to the proper spacing of wells. Since the administrative agency was required to allocate allowable production from a pool so as to afford each producer opportunity to recover his fair share, the acreage attributable to a well had to be considered; obviously, a one acre tract should not be permitted to produce as much as a twenty acre tract, even though there is only one well on each tract. Moreover, experience had proved that a single well might be able to drain the oil from as much as forty or even eighty acres and that, in a gas pool, one well could drain a much larger area. Recognizing that the drilling of unnecessary wells is a waste of valuable materials and a needless burden on the landowner or his lessee, the modern well-spacing statute requires the administrative agency to "space" each newly discovered pool by dividing it into drilling units on a uniform plan; for this purpose, a "drilling unit" is defined as the maximum area that may be drained efficiently and economically by one well. If a drilling unit is composed of two or more separately owned tracts whose owners are unable to agree, the statute provides for the integration or "pooling" of interests in the separately owned tracts by order of the administrative agency; in such event, production from the one well permitted on the drilling unit is shared and expenses borne by the several owners in proportion to the acreage of their holdings within the drilling unit.

This brief outline of the proration and well-spacing statutes is intended only to indicate their objectives and is not to be considered a complete description. The adequate conservation law states in considerable detail the standards by which the administrative agency must be governed in applying its provisions. In addition, the agency is authorized to issue an order





only after notice and public hearing, at which any interested party may appear and present evidence. Protection against errors and abuses of authority is afforded by allowing recourse to the courts by anyone adversely affected by an administrative order.

While it cannot be denied that these conservation laws restrict the right of the landowner to do as he pleases, courts have welcomed them as the appropriate solution to a problem for which common law had given the wrong answer. Enacted primarily in the public interest to prevent waste of natural resources, these laws recognize that the landowner has sufficient interest in oil and gas within his land to justify protection against those who would deprive him of what is justly his. Where the rule of capture licensed the boundary line driller to take his neighbor's oil, conservation through well spacing makes it possible for each owner to produce from his own land without unnecessary expense. Where the rule declined to regulate withdrawal rates and permitted any producer to dissipate reservoir energy as he chose, conservation laws allocate production so that each owner may obtain his fair share of a greater recovery.

Unitization. The latest and perhaps most important development in conservation goes even further by giving owners of a reservoir opportunity to share in the greatest possible recovery through unitized operation of an entire pool, with allocation of all production in such manner that each owner receives his fair share of the recovery even though there is no production at all from his land. Maximum recovery is obtainable from many pools only by supplementing natural reservoir pressure by injection of gas or water. Because an effective program of this type necessarily causes movement of oil or gas from one tract to another, and frequently requires that some wells be shut down completely, such a program cannot be conducted unless all interests in the reservoir are unitized in order that surface boundary lines may be disregarded. Sometimes erroneously referred to as "compulsory," unitization statutes such as those of Oklahoma and Arkansas require that unitized operation be acceptable to a majority in interest of the affected owners, and therefore authorize legal compulsion only on an unwilling minority, and then only after an impartial administrative agency has determined that unitization is both necessary and feasible. So far as "compulsion" is concerned, the real question is whether or not the minority will be allowed to dictate the manner in which the reservoir is to be operated, when the cooperation of all owners is needed for maximum recovery.

Fortunately, there is no longer room for doubt concerning the validity of this kind of conservation legislation. The first and only pool-wide unitization case to reach the Supreme Court of the United States was decided May 12, 1952, on appeal from a decision by the Oklahoma Supreme Court which upheld the statute of that state. (*Palmer Oil Corporation v. Amerada Petroleum Corp., 204 Okla. 543, 231 Pac. 2d. 997*). Contention that the statute impaired contractual rights, and also contravened the due process and equal protection clauses of the Fourteenth Amendment to the Constitution of the United States, was summarily disposed of by our highest court in a unanimous decision which dismissed the appeal for failure "to raise any substantial federal questions." To the judges of the Supreme Court of the United States, the constitutional question was not even debatable. (*343 U. S. 390*)

In another recent decision, the Oklahoma Supreme Court said:

> "On the theory that the greatest good to the greatest number provides a proper motive, and that the conservation of natural resources furnishes the authority, the Legislature passed this law which substitutes an interest in the whole property for an interest in the separate property previously

owned by the affected owners. It was a bold legislative step, and it was not taken by the Legislature until it had spent years digesting the concept of a common source of supply as one mechanical unit for the production of oil and gas. Nature does not provide proper underground restraining barriers which will prevent one man's wrongful production practices from affecting the whole reservoir. Further, the energy of the reservoir is a unit, and its most efficient use comes when employed as a unit. . . ." (*Spiers v. Magnolia Petroleum Co., 206 Okla. 503, 244 Pac 2d. 852*)

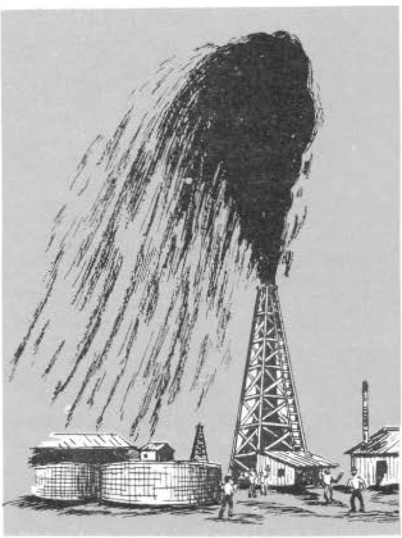
By treating the reservoir as the entity nature made it, pool-wide unitization stands out as a proper and necessary extension of the ages-old principle of correlative rights under which common law regulated surface waters as the common resource of riparian owners. Present-day knowledge leaves no alternative but to consider the petroleum reservoir as the common resource of those owning land within its limits; nature has made these owners tenants in common who are jointly interested in the reservoir as a matter of fact, however the law may describe their relationship. In recognition of that fact, and in order to conserve oil and gas in the public interest, while at the same time protecting the private interests of the reservoir owners, the unitization statutes declare that, when unitized operation of a pool is necessary for maximum recovery, and is desired by the majority, the minority will not be permitted to stand in the way of the common good of all owners. The statutes merely place the common interest of all owners in obtaining the greatest possible recovery above the right of any owner to produce as he chooses.

Actually, common law has never permitted the landowner to do as he might please on his own land. Our basic concept of private property is expressed in two centuries-old maxims of common law, one of which announces that "the landowner's dominion is not limited to the surface but extends from the center of the earth up to the sky," while the other comments that "each must so use his own as not to injure another," in realization that the right to own land is of little value unless its enjoyment is protected by reasonable limitations on the right of every owner to do as he pleases. These fundamental principles of common law are violated by the rule of capture, as it takes from the landowner a part of his dominion by denying protection of his property rights in oil and gas within his own land, and refuses to place any limit on the right of any owner to do as he pleases in oil and gas production. However justified by the false assumption forced on nineteenth century courts, the rule of capture is exposed by present day knowledge as mere license which protects no man in the enjoyment of property that is rightfully his, but affords legal refuge to those who seek more than is justly theirs.

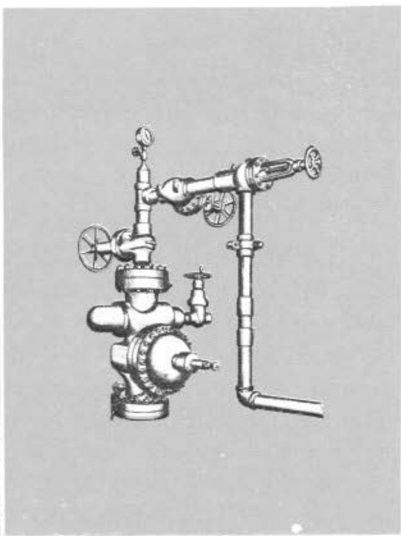
To quote from a much cited court opinion:

> "It is contrary to the spirit of the common law itself to apply a rule founded on a particular reason to a case where that reason utterly fails." (*People v. Appraiser, 33 N.Y. 461*)

The sole reason for the rule of capture is ignorance of the facts necessary for regulation of oil and gas production. By recognizing that this reason has utterly failed, and applying the common law's time-tested principle of correlative rights, the adequate conservation law restores and protects property rights that the rule of capture ignored.



UNCONTROLLED PRODUCTION



CONTROLLED PRODUCTION

CONSERVATION IN PRODUCTION THROUGH UNIT OPERATION

Herman H. Kaveler

Unit operation of an oil or gas pool is a *cooperative* effort to recover the maximum economic amount of petroleum in any common source of supply. It is the most effective and desirable substitute for the otherwise competitive race between individuals which results in recovery of less than the maximum economic amount of the resource. Unit operation is a practice of consolidating or integrating the separate lands overlaying a common source of supply whereby each owner receives a share of each barrel of oil and each cubic foot of gas produced in proportion to the share of the entire pool attributable to his separate property ownership. Unit operation removes property lines as the barrier to efficient oil production practices.

"Subsurface" waste occurs if there is failure to win from any reservoir all the petroleum that may be economically recovered, or, if recoverable oil and gas are lost from imprudent well drilling, completion or operating practices. Such waste—unseen and not self-evident to the layman—is as real and as objectionable as the surface waste that may occur after the petroleum is in commerce. Unit operation is the practical means to minimize subsurface waste. It also is the fairest and most equitable means for dividing a common source of supply among those entitled to share in production from a pool. It accomplishes all the objectives of a sound oil and gas waste prevention policy.

Surface waste prevention practices are well advanced because the remedy was more apparent. But oil reservoirs lie remote in the earth. The rock, and the oil, and the play of forces responsible for the production of petroleum from rock cannot be viewed and examined directly or studied as one might examine and test an object on the surface of the earth. No oil field can be depleted, restored and produced a second time, to judge whether one operating practice is better than another. The knowledge and understanding that prescribes the best way to operate an oil reservoir must be gained accordingly from scientific and technical studies and by inductive reasoning in the face of fact and experience. Such knowledge is not within the ordinary understanding of the general public, the majority of royalty owners, or many oil and gas producers themselves. If conservation of the petroleum resources is to be accomplished on a broad scale, then the need definitely exists to bring about a greater understanding of the basic principles involved. There is a best way to operate an oil reservoir. That way is unit operation. If it is adopted in every field that lends itself to such a program, the petroleum resource will be conserved. Such an objective is important enough to command the attention of every citizen. Conservation of petroleum is as important as the conservation of soil, forests, rivers, and other of America's natural resources. It may be more important, because petroleum is an exhaustible, irreplaceable, vital resource.

History. The idea of unit operation of oil pools was first publicly advocated by Mr. Henry L. Doherty in 1924, although the concept of the practice has evolved through several forms in the years following. As a waste prevention measure it is now understood to involve the consolidation of separately owned tracts overlying an oil reservoir as soon as possible after the reservoir is discovered, its limits defined by drilling of wells, and sufficient information has been gained to permit a fair and equitable division of the oil and gas among the owners. Some states have advanced in their understanding of the conservation problem to the point of having legislative enactments that put unit operation into effect. Offices of government at national and state levels, the American Bar Association, the Interstate Oil Compact Commission, a predominant majority of the oil producing industry, all recognize the merit of unit operation and advocate the practice. It is widely advocated. It deserves more general acceptance.

The Personal Element. The search for and the discovery of commercial deposits of oil or gas is a speculative and risky enterprise. Anyone fortunate enough to come into possession of lands underlaid by oil or gas has every urge to gain the most from his mineral wealth in whatever manner his judgment may dictate. Many owners think their interest is served best by individual effort and enterprise to capture as much as possible from a pool without regard to their neighbor's welfare. Advantages are sought which for selfish reasons an aggressive competitor is loathe to surrender. In that spirit, practices are usually employed that diminish rather than increase the value of the mineral resource each seeks to produce. The desirable alternative is a cooperative and joint effort among the operators in a pool.

Production, as distinguished from the preceding search for and discovery, and from subsequent refining, transporting and marketing, is an activity limited by some inflexible circumstances of nature. There cannot be unrestrained competition in the production operation as there is and should be in the other phases of the petroleum industry. If there is, then subsurface waste is probable. Such waste can be eliminated only by adopting unit operation as a practice within the framework of American principles of law and within the principle that all constructive private effort should be encouraged.

Unit operation of oil pools is not monoply; nor is it destructive of competitive enterprise. It is not un-American. Unit operation may permit recovery of twice to three times as much oil as may be recovered if the practice is not used. Is it un-American to adopt methods that extend a valuable natural resource to that degree? Is it un-American to conserve a vital resource in a manner that does not hinder the growth and expansion of any industry nor take from any individual his fair and equitable share of a common property?

A Reservoir Before Discovery of Oil

Three Basic Principles. The technical and practical considerations that justify unit operation as an effective and ultimate means to prevent subsurface waste can be stated in simple and understandable terms. Three basic principles apply:

Oil Does Not Produce Itself. The title of this paragraph is perhaps the most important fact necessary to an understanding of oil production operations. It is scientifically sound and may be briefly stated as follows:

Oil does not produce itself from the earth; rather it must be expelled from rock into wells through the agency of either compressed gas or compressed water present with oil in the rock; when a well is opened, a lower pressure point is created and the compressed gas, or water, or both, in the rock surrounding the well expands, moves toward the well, drives oil ahead, and expels the oil into the well as it enters the well along with the oil; the compressed gas or compressed water in the rock is the store of energy that accomplishes production of oil; after the oil with its accompanying gas or water driving agent enters a well, the oil may be removed to the surface by natural flow or by pumping.

This statement of fact is contrary to the popular notion that oil has a capacity to flow naturally from the earth. The public thinks of "gushers" but not of the natural gas or water that accompanies the oil from the rock. Yet the obvious fact is that crude oil will not squirt or gush forth from containers. The gasoline in the tank of an automobile does not flow out of the filler pipe. The kerosene in a lamp must be drawn up through a wick. These products of crude oil, like crude oil itself, must be pumped or otherwise forced out of containers. Expanding gas or expanding water in the reservoir rock deliver the energy to force oil out of rock into wells. Oil recovery is a displacement process. Oil to be recovered must be replaced in rock by gas or water.

Pressure Maintenance and Recovery. All the oil in porous rock cannot be recovered by any known economic process. Recovery is always less than 100% of the amount of oil initially in place. The porosity, permeability, structural attitude, depth, formation thickness of the rock, the fluidity of the oil and the like, are factors in determining the degree of recovery fixed by nature which are beyond human control and alteration. Yet other factors, particularly among them the amount of energy represented by reservoir pressure of gas or water available for expelling oil from rock, are subject to control and alteration. To this extent then, actual recovery may be a small or a large part of the petroleum economically recoverable from any reservoir.

Reservoir pressure is the important variable factor in oil recovery. When reservoir pressure is spent, oil production ceases. So long as pressure can be economically maintained, there is opportunity to recover oil—but not otherwise.

The production of a barrel of oil from a pool not only reduces the amount of oil remaining to be recovered, but it also takes its toll of the available reservoir energy. The recovery that may be obtained utilizing only the compressed gas or water *naturally* present is usually referred to as "primary" recovery. When the natural source of energy is spent, the primary recovery operation is at an end.

But, if reservoir pressure is as important as statements indicate, why not return to the reservoir the gas or water produced with oil to supplement the reservoir energy and maintain oil production by maintaining reservoir energy? That inquiry, often made by laymen who understand the first basic principle, is the key to accomplishing increased recovery of oil. This second basic principle may be briefly stated as follows:

The energy naturally available for production of oil may be conserved and the recovery thereby increased, but in most instances the natural energy must be supplemented by the injection of gas or water, or the re-injection of produced gas or water, for the purpose of artificially maintaining reservoir energy to accomplish greatest economic ultimate recovery.

Whenever reservoir pressure is maintained by the injection or re-injection of compressed gas or water, the industry refers to the operation as "secondary recovery." The best time to start secondary recovery operations is early in the life of a pool. Many such operations are going on in the United States at the present time. Many pools near depletion, and some even once abandoned, have been restored to production by "water flooding," which is pressure maintenance by water injection started after primary energy was exhausted.

The importance of pressure maintenance by secondary operations lies in the fact that it may result in twice to three times the economic recovery that could have been obtained otherwise. Such increases in ultimate recovery are too great to overlook if conservation of the petroleum resource is to receive proper consideration.

The Common Source of Supply. The third basic principle may be stated briefly as follows:

Although the right to drill and produce is a right arising from ownership of separate property defined and divided by survey lines on the surface of the earth, oil and gas are found in reservoirs, or pools, constituting common sources of supply—that is, in permeably connected pore spaces in rock,—undivided and unconfined beneath separate lands; there are no subsurface fences corresponding to those on the surface; oil and gas are fluid substances and are migratory; and the production from any well or wells on separate surface lands is in effect production from a common source of supply.

This fact is well established by scientific and technical data and is a matter of long standing practical knowledge to producers. It has been recognized for many years as is clearly indicated in the opinion written in 1900 by Mr. Justice White of the United States Supreme Court, in the now famous case of *Ohio Oil Company vs. Indiana, (177 U. S. 190).*

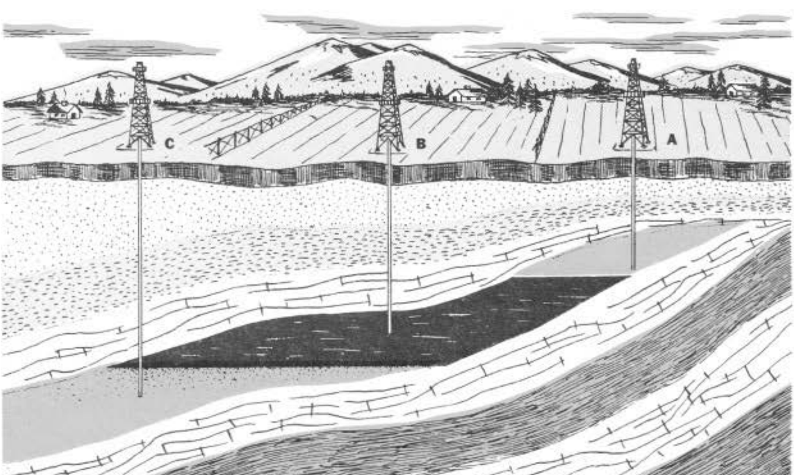
> "No one owner of the surface of the earth, within the area beneath which the gas and oil move, can exercise his right to extract from the common reservoir, in which the supply is held, without, to an extent, diminishing the source of supply as to which all other owners of the surface must exercise their rights."

An oil and gas pool and its energy is in fact a "unit." It is a common fund. Consequently, the petroleum and the energy of production must be divided and shared in any event. The subsurface "unit" of supply—undivided by nature—must be divided in some manner. The best way to accomplish that division is to form a unit of the mineral ownership—dividing the oil and gas while it is in the reservoir—and thereafter operate the consolidated properties as good practice and sound technology, not divided surface ownership, dictates. Otherwise, the division must be accomplished by capture on separate leases, and less than the maximum economic recovery is the result.

A Typical Example. A typical situation encountered to some degree in the operation of every oil reservoir may now be examined by reference to the accompanying illustration.

The separate surface ownership is represented as three tracts labeled "A," "B," and "C." There are other separately-owned tracts covering the pool in its areal extent, but the three shown represent three general classes of lands in every oil field. One is "high" on the structure ("A"); one is "low" on the structure ("C"); and the other is intermediate ("B").

A common source of supply, a body of porous, permeable rock disposed as a half-anticline constituting a trap and shown in cross-sectional view, lies beneath these lands. A natural gas-cap occupies the structural high under leases such as "A." The body of porous rock is not completely filled with oil and gas. Some of the original salt-water remains under land such as "C." Lands structurally lower than "C" would have no oil or gas in-place in the particular reservoir under consideration. Land such as "B" would have mostly oil in-place. The oil present in the reservoir is saturated with gas in an amount fixed by the character of the oil and gas and by reservoir temperature and by the pressure existing at any time.



Reservoir at Beginning of Production by Separate Owners

If a natural gas-cap is not present, then, during the productive life of the pool, gas would tend to accumulate at the structural high under leases such as "A" and form a "secondary" gas-cap to pose to some degree the same gas-cap problem to be discussed in the following:

Suppose that lease owner "B" drilled the "discovery" well and no other drilling occurred. Then, "B" would have oil wells. As oil is drawn from wells on "B" lease, the reservoir pressure at that location would decline below initial values and there would be movement of oil, gas and water throughout the reservoir. The free gas in the gas-cap would be a source of energy moving downward on the oil, tending to "cushion" the pressure decline and maintain the reservoir pressure on "B" lease. The gas-cap would effectively supplement the energy of the solution gas in the oil. The recovery mechanism from this source would be a "gas-cap" drive.

If the body of rock were extensive enough beyond the limits of production, there could be sufficient water in the reservoir to permit a sensible pressure maintenance effect due to the expansion of water up-structure toward the lower pressure point beneath "B" lease. The water-drive, if it existed, would probably be more effective as a recovery mechanism than would the gas-cap drive. Either would be more effective than if only the gas in solution in the oil in the reservoir were the energy available for production.

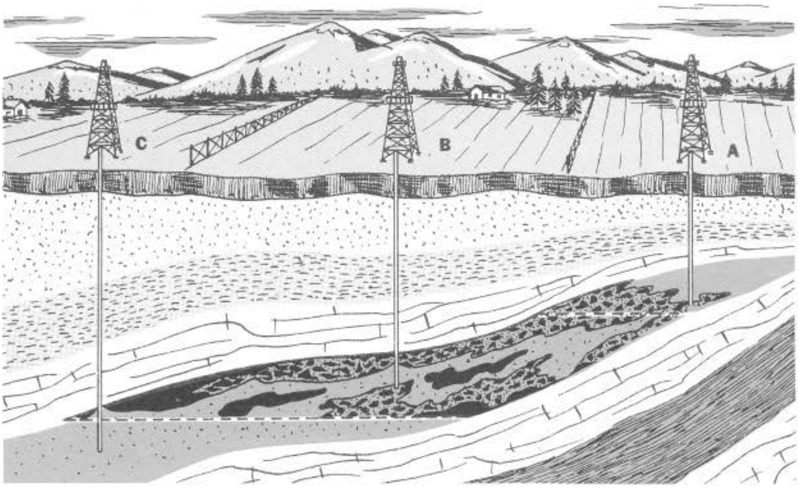
If "B" were the only operator—or if "B" owned the entire pool, as happens in rare instances in the United States—he could gather the gas or water (or both) produced with the oil from his wells and return the gas and water through injection wells drilled for the purpose to artificially maintain the energy of production. Such a pressure maintenance operation would substantially increase oil recovery. If the water-drive were active enough, "B" might make other use of the produced gas and maintain the reservoir pressure by natural water-drive. As a single owner, left to his own judgment, "B" could carry on oil recovery operations within every standard set for conservative waste-prevention practices.

But "B" is not alone! His conduct, if he were but part owner of the entire pool, is governed by the conduct of others. In a sense, he is not in position to engage in "free" enterprise. He must match the conduct of his neighbors if he is not the owner of the entire pool.

Discovery of oil production by "B" would lead the owner of tract "A" to drill upon his lands to determine whether or not he too might have the good fortune to find oil. Suppose owner "A" drills on his lease. He finds the formation structurally high, his wells are gas wells, or at best, productive of some oil at a "high gas-oil" ratio. Owner "A" might sell the gas produced to recover his investment and perhaps a profit. On the other hand, oil is more valuable than gas, and Owner "A" might elect to produce his wells at a high rate, flare the produced gas, and hope to pull some oil up-structure by creating a low enough reservoir pressure. Owner "A" would be favored if a strong water-drive existed tending also to move oil up-structure past "B."

The situation is not improved when lease owners such as "C" find their leases productive of some oil and gas. Owner "C" would produce some water along with oil. He would produce water with oil in order to lower the reservoir pressure in the hope of draining oil or gas down-structure to his lease. The natural water-drive would be thereby impaired. Owner "C" would attempt this for his own personal gain even though the water drive would be an effective recovery agent for oil under other areas of the reservoir.

Pressure Depletion. What are the competitors to do in these circumstances? Owners "A" and "C" cannot serve their individual purposes except by production of excessive quantities of gas and water which are the sources of energy—the life blood—of the oil production. Certainly "A" and "C," and for that matter "B," cannot operate so as to maintain reservoir pressure. Owner "B" must do all in his power to overcome drainage of oil from his lands. Owners "A" and "C" must seek to create such drainage. Any effort to maintain reservoir pressure—short of such an effort concurrently by all three—would react to the detriment of one or more of them as competitors seeking to capture oil. Thus, in the ordinary circumstance, there must be pressure depletion and the production of only so much oil as might be recovered by that wasteful procedure. When "A," and "B," and "C" find their wells in the same common source of supply the flag is down, the race is on, and selfish interest is likely to govern the



Low Recovery After Depletion by Competing Owners

effort of each lease owner to capture as much oil as possible without regard to the welfare of others, or the public interest.

The "forest" of derricks drilled into a common source of supply in some oil fields is but evidence of the struggle between offset owners to capture as much oil as possible from a reservoir before a neighbor has an opportunity to do the same. Drilling of excessive numbers of wells in the race to divide a common source of supply of oil and its energy of production represents economic waste just as real as physical waste.

The seriousness of the conflict between separate surface owners in their race to divide a common source of supply which each must draw upon to exercise his property rights, lies in the fact that the ultimate recovery under these conditions is usually 20 percent of the oil in place, or less. That is far less than the recovery would be if owners such as "A," "B," and "C" were to cooperate with each other by agreeing to a division of the oil and gas while the oil and gas are in the reservoir, and thereafter work together to reduce the greatest amount of it to possession.

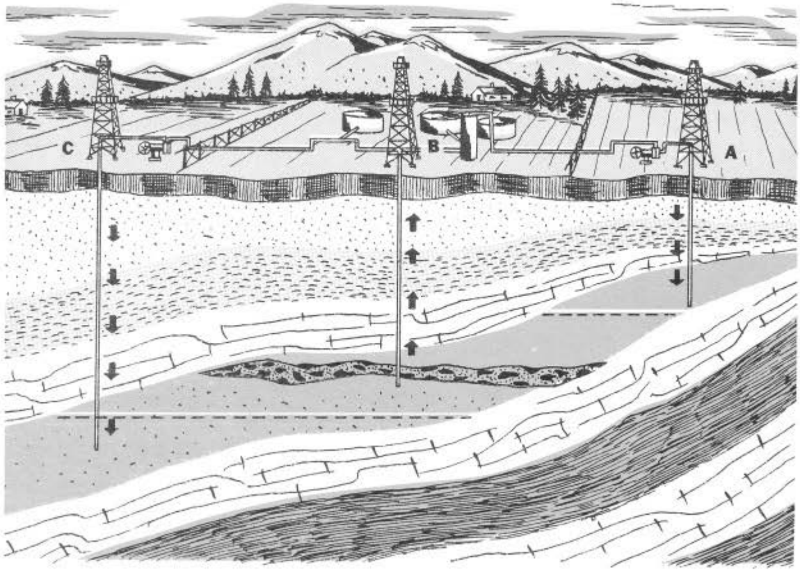
A Unit and Its Result. If a unit were formed, the reservoir would be operated in an entirely different manner. Efficient production practices that would utilize the primary as well as the secondary sources of reservoir energy of production could be and would be adopted.

The first step that "ABC" *unit* would take would be to close the wells producing excessive quantities of gas or water and take the oil to be produced from the wells that would yield the production with minimum expenditure of the available reservoir energy. The second step that "ABC" *unit* could take and would take, if necessary, would be to return the gas produced with the oil to the reservoir by injecting the gas into the gas-cap or the structurally high part of the reservoir. If substantial amounts of water were produced with oil the produced water could be returned to the reservoir through injection wells located in the structurally low part of the reservoir. Thus, reservoir pressure and reservoir energy could be artificially maintained by a "secondary recovery" operation concurrent with utilizing the forces of "primary" recovery. It is neither necessary nor desirable to wait until a pool is depleted of its primary energy before adopting the methods of secondary recovery. Postponement of secondary recovery methods is the least economic way to accomplish maximum recovery.

"ABC" *unit*—free to adopt every efficient economic production practice would yield a recovery of oil in the range of 40 to 60 percent, or even more, of the oil in place. That is to be compared with the fact that "A," "B," and "C" competing with each other would recover 20% or less of the oil in place. Furthermore, "ABC" *unit* would in all likelihood conserve a substantial part of the natural gas initially present, and that gas would be available for sale after it served its purpose in oil recovery. Otherwise, a very large part if not all of the natural gas would have been wasted.

The typical situation that has been presented demonstrates that conservation cannot be fully accomplished unless producers in a reservoir adopt a unit plan operation. Otherwise there is little or no opportunity to adopt effective pressure maintenance operations such as are here discussed. Certainly, the "secondary recovery" pressure maintenance step and the closing in of the more inefficient wells could not be done in the absence of a unit plan.

Conclusion. A petroleum reservoir is by nature a unit. That is to say, a reservoir is a common source of supply from which owners of surface lands are entitled to draw shares of oil and gas and the energy available for its production as an exercise

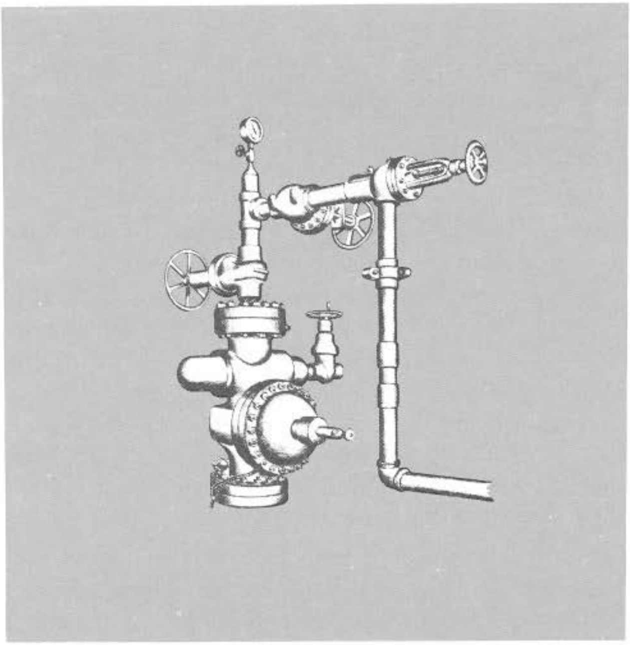


Higher Recovery After Depletion by Gas and Water Injection

of their property rights. The inevitable necessity for sharing the content of a petroleum reservoir poses the most difficult problem in the conservation of petroleum. If such sharing must be accomplished through the competitive operation of wells on separate lands, such competitive sharing leads inescapably to less than the maximum economic recovery of the petroleum. Scientific and technical fact and the experience of the industry itself suggests, as an alternative, unit operation, which involves a division and sharing by the owners of the oil and gas in a reservoir as soon as the reservoir is defined by drilling and sufficient information has been obtained to permit determination of the share that each is entitled to have of the petroleum to be recovered. Thereafter, the owners are free to adopt whatever production practices are found to yield the greatest economic recovery of their common fund. The production operation is then made a unit, consistent with the fact that the reservoir is a unit in the subsurface. Unit plans of operation permit owners to cooperate for the benefit of all. Correlative rights are preserved. The maximum ultimate recovery of oil and gas is thereby accomplished.

It is a striking fact that no one has ever successfully maintained that the unitized operation of an oil and gas field did not accomplish a very substantial increase in ultimate recovery, did not achieve the ultimate in conservation of both oil and gas, or did not give to every owner his fair and equitable share of the increased amount of oil and gas that is produced. When the case for unitized management of common sources of supply is examined from an operating, engineering, regulatory, and conservation point of view, the evidence is preponderantly in favor of that practice. It has not been difficult, therefore, to state the case in favor of the need for more general use of the unit method of production of oil and gas.

Unit operation of a common source of supply often doubles, or even trebles, the oil recovery from a reservoir. The increased recovery of oil through unit operations is measured in millions of barrels. That is oil which otherwise would not be recovered.



EXCESS OIL PRODUCTION CAUSES WASTE

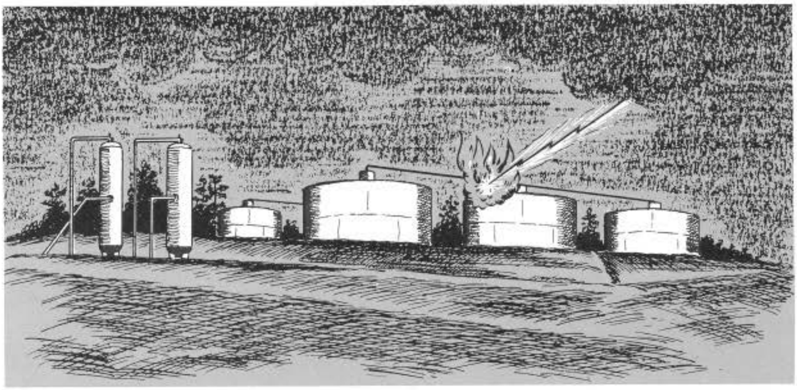
H. B. Fell

The limitation of production of crude oil so that it will not be materially in excess of the reasonable market demand is a physical waste prevention measure and is essential to the conservation of the petroleum resources of our nation.

In the early days of the petroleum industry engineering did not enter into the production of crude oil to any material extent, and little or nothing was known about reservoir conditions—in fact, it was the generally accepted theory that it was detrimental to shut in or restrict the flow of oil from a well.

Prior to 1915, state laws were designed to prevent some types of physical waste above ground, such as fires, escape of oil and gas from the well, wasteful burning of oil and gas, and abandonment of unplugged wells. These laws dealt largely with individual wells. There was no effort to control the amount of production from the wells, or to deal with a field as a whole, or with what is now generally called "underground waste."

Producers recognized the migratory nature of petroleum. To get as large a share as possible of the oil produced from a reservoir, producers drilled up properties as rapidly as possible and produced wells to full capacity. The frequent result was the production of more oil than there was a market demand for or transportation facilities to handle. On such occasions, companies having pipe lines into the field would take the full production of their own properties and from properties of some other producers, leaving some producers without a market outlet. The producers without an outlet, in order to prevent their oil from being drained from under their properties, were forced to continue to produce their wells and store the oil in such manner as they could. This sometimes necessitated the building of earthen storage or dams in dry creek bottoms, to be used as containers for this oil. Heavy rains came and washed out these dikes, resulting in actual physical loss of the oil. Not only did physical waste result but the small producer was confronted with a critical situation. Without transportation facilities or market outlets, he was at the complete mercy of the producer having such facilities, and he was often forced to dispose of his properties at a great sacrifice.



First General Conservation Law. The situation thus created finally became so bad in the Healdton and Cushing Fields of Oklahoma that the independent producers, to protect themselves from ruin, urged and brought about the enactment of the first general conservation law of any state. This was the act of the Oklahoma Legislature of 1915. The producers had determined by experience and by trial-and-error method that regulation under laws was the only solution to waste prevention. The 1915 Oklahoma law defined waste as including "economic waste, underground waste, surface waste, and waste incident to the production of crude oil or petroleum in excess of transportation or marketing facilities or reasonable market demand." The law also provided that when the full production of a field could be had only under conditions constituting waste as defined, the production could and would be limited to the amount that could be produced therefrom without waste. It also provided that each well within a pool, when production was so limited, was to be allowed to produce its pro rata part of the allowed production from that pool. Further, it provided that the market demand for the state was to be equitably divided between pools within the state. It is interesting to observe, in the definition of waste contained in the Oklahoma law of 1915, that "underground" waste was included. Even at that early time, some were beginning to realize that a too rapid rate of production from a reservoir results in underground waste, also.

The period of excess production that occasioned the adoption of the 1915 Act in Oklahoma was followed by a period of oil shortage during the latter part of World War I. That Act, therefore, was more or less dormant in its application to the limitation of production to meet market demand during those years of shortage. Nevertheless, in the usual style of recurring periods of "feast and famine" there was again a period of excess production of oil in the late 1920's and early 1930's. During that time, other states followed Oklahoma and enacted similar laws limiting production to market demand. In the years that have since passed, great technical progress has been made in learning how to best conserve the Nation's petroleum resources, and long experience has now demonstrated that limitation of production to market demand is essential to effective conservation.

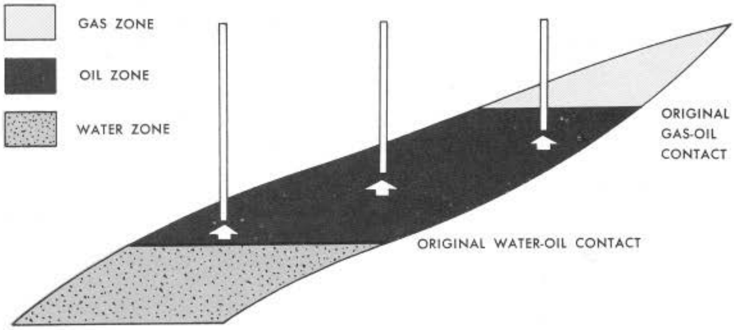
The Connally Act, enacted by the Congress in February, 1935, serves to support state limitations on production of oil by prohibiting shipment in interstate commerce of petroleum produced in excess of quotas set by state agencies.

The development of sound oil and gas conservation laws and their effective enforcement have been, therefore, a gradual process. At the present time, laws of Oklahoma, Kansas, Texas, Alabama, Florida, Louisiana, Michigan, New Mexico, North Carolina, North Dakota, Arizona and Washington limit the production of oil or gas to reasonable market demand, and expressly authorize restriction of production so that it will not exceed such demand.

Reasonable Market Demand. It is important to understand that the words "reasonable market demand" mean a demand for oil established by reasonable current requirements, which includes current consumption and use within and without the state, and adequate above ground stocks. Adequate above ground stocks are those which will make it possible to provide a continuous supply of petroleum products to the consumer, but not at excessive levels which will create above ground physical waste. As a practical matter, production is never restricted *below* reasonable market demand. If any state should reduce its production below reasonable market demand, other states with excess productive capacity would immediately increase production to meet the demand. There is always competition between the oil-producing states for the available markets.

Reservoir Efficiency. The relation of excess production and physical waste can be understood in one of its aspects only after understanding that oil exists in sub-surface reservoirs and is recovered only when there is energy of production available in the reservoir in the form of compressed gas or compressed water. Thus, the oil production operation is bound by a peculiar circumstance not associated with the recovery of solid minerals such as coal. Experience and the technical knowledge respecting the oil recovery operation clearly indicates that the percentage of oil recovery from any reservoir is dependent almost entirely upon the efficiency of utilizing the water and gas under pressure. While other circumstances also apply, it is a fact almost universally accepted that reducing of the rate of withdrawal to the extent necessary to prevent the waste of reservoir energy will result in the greatest recovery of oil or gas from the reservoir. In most cases oil should be taken not only at the minimum rate to meet existing market demand but should also be taken as uniformly as possible from throughout the oil-bearing part of any producing reservoir. Producers refer to such taking as "ratable" taking.

Effect of Unequal Withdrawals. It has been brought out earlier in this booklet that oil and gas exist underground in porous rocks, and are usually held in traps beneath impervious shale or clay and above water. The trap is referred to as a reservoir or pool. It has further been shown that the method of operation of a reservoir has a material effect upon the amount of recovery of the oil. Experience has shown that uniform withdrawal of oil from over the oil bearing part of the reservoir leads to the more efficient utilization of the energy of production and leads to maximum recovery, whereas nonuniform withdrawals of oil may create conditions leading to lesser recovery. Whenever a part of the wells are closed due to lack of market, the producer with a market may produce large quantities of oil next door to his unfortunate neighbor who is without a market. If such a situation continues for any length of time, an excessive dissipation of the gas energy of the pool and irregular encroachment of water into the oil-saturated section of the reservoir will occur. The uneven encroachment of water is a particular evil because it traps oil and drowns oil-saturated sections, with the result that a large quantity of oil so trapped cannot be profitably recovered.



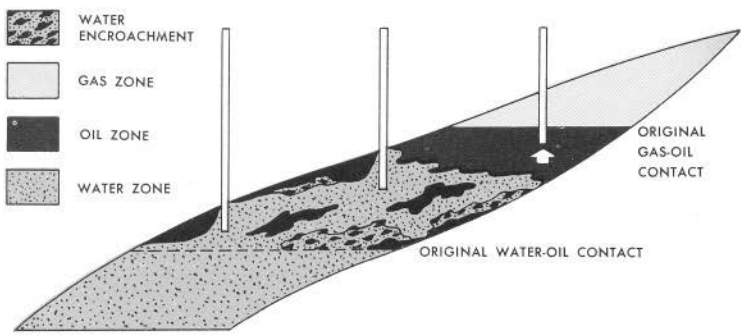
Oil Producing Ratably and no Trapped Oil, or Unequal Water Encroachment. Property Rights Protected.

Such trapping of oil takes place under the lands of owners other than the producer who enjoys the opportunity to take a disproportionate share because of his market advantage. Obviously, and equally serious is the drainage that occurs from the lands on which the wells are closed to the lands on which the wells are maintained on production, resulting in injury to the producer without a market.

The physical waste that occurs from production in excess of market demand or from disproportionate production from a reservoir is not a picture drawn from theory and speculation—it recounts actual circumstances common in the industry before adequate conservation laws came into force.

A Typical Example. The Railroad Commission of Texas made an order for the Panhandle Field fixing the production at 80,000 barrels per day. The evidence showed that if this quantity of oil were produced ratably over the field so that uniform well pressures could be maintained, no physical waste would result. In other words, the field could produce this quantity of oil by ratable withdrawals without dissipating the gas energy or causing too rapid encroachment of the water over the field or in localized areas. After the order was put into effect, one company announced that it would withdraw as a purchaser, and the market demand, therefore, dropped by the amount of its purchases. This resulted, according to the proof in the Danciger case (49 S.W. 2d 837), in leaving some 500 wells unconnected. These wells had no market outlet and were closed down, except for a few, the production of which was placed in storage.

Later another purchaser withdrew. The market demand for oil again decreased by the quantity of oil that purchaser had been buying and more wells were shut down. In the end, hundreds of wells were without a market. The result was that throughout the area leases which had closed down were offset by leases producing the allowable production fixed by the Railroad Commission's order. Later on, some of the companies which were continuing to purchase oil, extended their pipe line connections to a portion of the properties closed down. In doing this, the pipe line companies cut down their takings from all properties with which they had formerly been connected, and took ratably from all wells then connected.



Two Wells Without Market Shut Down. Trapped Unrecoverable Oil and Irregular Water Encroachment. Property Rights Damaged.

All of this resulted in some properties being entirely closed down; some were producing at a rate considerably below the allowable fixed by the Railroad Commission; some were producing at the allowable; and numerous producers were producing either to capacity or in quantities well above the allowable fixed by the order. This unequal withdrawal and disproportionate taking led inevitably to the dissipation of the gas energy of the pool and to the irregular and accelerated encroachment of water into those areas where the withdrawal of oil was more rapid. In addition to the actual physical waste that resulted, there were gross inequities to producers and landowners. There was actually the taking of one man's oil by another.

How Limitation to Market Demand Prevents Waste. There was simply no way by which storage of oil and unequal withdrawals of oil could be prevented in the Panhandle Field except by reducing the allowable production for the field to the new market demand resulting from the withdrawal of the two purchasing companies. The waste incident to the unequal withdrawals was brought about solely by the decrease in market demand. It was not due to any other cause. In order to prevent this waste, the Railroad Commission finally decreased the allowable production from 80,000 barrels to 40,000 barrels per day. After the allowable production was reduced to 40,000 barrels per day, the purchasers, in order to get the quantity of oil they needed, extended their connections to the then unconnected wells, and practically all of the properties in the Panhandle district shared in the existing market. Thereafter, there was a ratable sharing of the market by all producers. The unequal takings were removed and the waste incident to the storage of oil and to unequal withdrawals was stopped.

The Panhandle Field is but an example of a situation that occurred frequently and in many oil-producing districts. The peak crisis, of course, occurred in the period 1929-31, when Oklahoma City and East Texas flooded the American market with excess oil production. The grave situation in those two fields led to calling of State Militia and forced shut-down until some semblance of order was restored. Further, that crisis led states in later years to adopt conservation statutes, seeking to prevent waste by ratable taking in the manner that the Panhandle problem was finally solved. That the problem is forever with us is demonstrated by the fact that serious cases of production in excess of market demand occurred in the KMA Field in North Texas and in southern Oklahoma fields as late as 1938.

Economic waste occurs as a companion to physical waste occasioned by production in excess of market demand because the producer without a market will sell his oil at any price rather than store it, or permit his neighbor to drain it from beneath his land. The result is that the price finally falls to a point where oil cannot be profitably produced. The competitive bidding for a market aggravates the condition of unequal withdrawals and extends the physical waste. Economic waste incident to the production of oil in excess of market demand simply compounds the physical waste inevitably incident thereto. If the state intends to prevent physical waste of oil and gas, it must empower some authority to bring about ratable taking under a limitation of production to market demand. If it cannot bring about ratable takings, it cannot prevent physical waste.

Not An Abstraction. Market demands for oil is not an abstraction as some seem to think. It is not difficult to determine the current demand for crude oil and the increasing or decreasing trend in that demand. Crude oil in commerce is transported by pipe lines direct to refineries or to railroads and refined products from refineries to centers of distribution for consumption. Figures are available at all times as to the volumes of crude oil and its products in storage. Various agencies of the industry and agencies of Government, particularly the United States Bureau of Mines, continuously make available estimates of future demand. It is from these sources that state agencies charged with the enforcement of market demand statutes may derive reliable information that permits a realistic enforcement of such laws.

Essential to Small Producers. Limitation of production to market demand is not only essential as a waste prevention measure—it is equally essential to the protection of the small, independent producer and landowner. It is only by this means that they can be assured of a fair and ratable participation in the markets for oil and of a ratable production of oil from their properties. If this is not done, they lose oil to their neighbor by drainage. Furthermore, under such circumstances the price of oil which they produce is forced down, resulting in economic losses as well.

Not Monopoly or Price Fixing. Oil produced and held in above ground storage does not increase the amount of oil available to the public over what would have been available if it had remained in the reservoir until needed. It seems logical that the effect on price is similar. If there is an oversupply of oil in excess of market demand, irrespective of whether the oil is kept in the reservoir or put into surface storage until needed, the effect on price is similar. Oil can be made available from the underground reservoir by merely turning a valve. A barrel of oil on the well-side of the valve and a barrel of oil in above ground storage produces similar price effects. The public interest and national security is best served by holding the oil in its natural reservoir.

The prevention of physical waste through restriction of production to reasonable market demand by state authority does not create monopoly. There has never been an instance of a state agency restricting production to less than existing reasonable market demand.

Misinformed people believe the limitation of production of crude oil to reasonable market demand by conservation agencies of the states is simply price-fixing and not a conservation measure. This calls for careful analysis of the facts.

It must be recognized that any limitation of production, whether to an efficient rate of recovery or to reasonable market demand may, incidentally, affect price. A balance between supply and demand for crude oil tends to prevent violent and inordinate fluctuation in price, but it does not fix price at any given level. Regulating production to market demand is not an artificial restriction of supply for the purpose of raising or fixing price. It simply permits a more orderly market in which price is more stable than it might otherwise be, but in which the forces of a free market, such as cost of production, increasing demand, relative abundance and other factors, have full play in determining price.

The typical example given of the Panhandle field demonstrates that the limitation of production to market demand there ordered was not made as a price-fixing device. It was made to bring about the ratable taking of oil and to insure orderly and uniform production in the field, thus preventing the irregular and accelerated encroachment of water, the dissipation of the gas energy of the pool with resulting loss underground of oil, and the gross inequities as between producers. In short, it was purely and simply a conservation measure designed to effect, and actually effecting, the prevention of actual underground physical waste. It also provided equitable participation in production and markets by all producers and landowners.

The History of Product Prices. Those who would attack market demand as a price fixing measure need only examine the selling price of petroleum products through the years and the price of other commodities on the American market. It is historically true that more and more petroleum products, of improved quality, have been supplied to consumers at lower prices than the average price of all commodities during most of the last thirty year period. Gasoline for every citizen is not only available in great quantity, but it is available at a price that all can afford to pay. This is true through the history of the petroleum industry and particularly true of the period since 1930, after the principal oil producing states adopted limitation to market demand as an important step in developing a standard conservation policy.

GASOLINE PRICES AND TAXES*

Year	Price Excluding Tax	Taxes
1922	24.82	.38
1932	13.30	4.63
1942	14.46	5.97
1952	20.24	7.32

*Average (cents per gallon) in fifty representative cities

Excess Productive Capacity. Limitation to market demand has brought economic stability to the oil industry. But more than that, it has permitted the American petroleum industry to create an excess capacity to produce in order that the nation may have the security that comes from a plentiful supply of oil available for production if any emergency involving the military defense of the nation should arise. The Federal government, following World War II, urged the industry to develop an excess producing capacity of at least a million barrels per day above current requirements. Unfortunately, due to the economic conditions that have existed, this objective has not been accomplished. It certainly would be ill advised, under these circumstances, to produce oil in a manner that creates physical waste. This would jeopardize our national safety.

Conclusions. What is the difference between producing oil and storing it on the surface or leaving the supply in the earth to be produced when the need or the market requires? The difference is substantially that underground storage in reservoirs is non-wasteful, whereas surface storage is wasteful. Secondly, storage in the subsurface reservoir is without cost, while storage on the surface involves high cost for which the public would pay in increased prices for petroleum products. What is the difference between leaving every operator free to produce as he wishes as compared to permitting each producer to produce his share of the limited market that may exist from time to time? The difference is principally that no producer, large or small, would be willing to risk his capital in a search for new reserves or development of pools in the absence of reasonable assurance that having done that he would have the opportunity to produce his share of the oil required to meet reasonable market demand. Who would assume the risk of finding new oil fields in the face of uncertainty about future market? An oil well or an oil field has no value unless the oil can be sold at a price per barrel that is not only competitive with other sources of energy but which returns sufficient income to assure a reasonable profit from the enterprise of finding and producing it. What is the difference between producing fields wide open or restricting their production to reasonable market demand? The difference is that all experience and all technology point to the fact that a rate of withdrawal that will make maximum use of reservoir energy will result in the greatest ultimate recovery. If the production from all the pools in America were geared to meet the daily requirement for petroleum, then every producer has an opportunity to use more efficient reservoir control and to strive for maximum economic recovery. Thus, limitation to market demand brings order out of chaos. It brings economic stability. It brings opportunity to use the more efficient field operating practices. It preserves the correlative rights of all against the destructive practices of the minority. It prevents physical waste of oil and gas. The public interest and national security is served.

MAXIMUM OIL PRODUCTION THROUGH CONSERVATION LAWS

Earl Foster

The conservation of oil and gas by preventing waste and obtaining the greatest ultimate recovery is the most important single factor in oil and gas production.

The history of oil production has been divided, in the view of one outstanding authority, into three periods: "The Lamp and Lubricating Period" from 1859 to 1900; the "Motor Fuel Period" from 1900 to 1935; and, the present "Period of Conservation" beginning in 1935 with the signing of the Interstate Oil Compact. Such a division emphasizes the evolution of the oil industry. In the beginning there was limited use of the resource followed by an increasing use during the first three decades of the present century to reach finally a stage where oil became of such importance that an effort to conserve it became imperative. The year 1935 is important in the history of petroleum production because it marked the creation of the Interstate Oil Compact.

By present standards, early oil production practices were wasteful. In the years 1912 to 1916, and from 1926 to 1934, both periods of discovery of great and prolific pools, waste in the production of oil and gas reached peaks of extremity. Wells were flowed wide open without restraint and oil was produced far in excess of market requirements. Millions of barrels of oil were lost. Trillions of cubic feet of gas were wasted. Literally, flares of burning gas lit the countryside. Producers gave no thought to protection of the energy of the oil reservoir. Little was known of subsurface waste. Surface waste was recognized, but there was no adequate means to overcome it. In Texas and Oklahoma in 1930-1931, extreme waste was so apparent that the militia was called out to force closing of the Oklahoma City and East Texas fields to prevent further destruction of vital and irreplaceable resources. Conditions in the oil production industry were at a point where oil producers, state and Federal government officials, as well as private citizens, saw the need for some constructive and efficient action which would bring a measure of conservation into the development and operation of petroleum reservoirs.

State Rather Than Federal Law. Under our system of government, the state has the duty and responsibility to conserve natural resources. State governments were slow to act in respect to oil and gas conservation, even though the State of Oklahoma had passed a constructive conservation law as early as 1915. In the late 1920's there were extensive investigations on the part of committees of Congress, the American Bar Association, and oil associations and producers. The remedies suggested covered many and varied approaches to the problem. The Federal Conservation Board, created in 1924, rendered the last of five reports in 1932, and pointed to the advisability of the states assuming responsibility for the conservation of petroleum in spite of the fact that some thought conditions had reached a point where regulation by the Federal government was necessary. Secretary of the Interior Ray Wilbur suggested in 1929 the formation of an interstate compact of states to bring about petroleum conservation. The Oil States Advisory Committee, sometimes known as the "Governors' Committee," organized in 1931, recommended the passage of effective conservation statutes and the formation of an Interstate Oil and Gas Compact Commission. The Cole Committee, after its very thorough investigation of the oil and gas industry, recommended the formation of a compact between the states in its preliminary report to Congress in January, 1935.

From all the thought and study that was given, three general conclusions emerged: (1) Waste prevention could be effectively accomplished only by regulation under proper law; (2) state rather than Federal regulation was a course consistent with the rights and obligations of the several states expressed in the Federal Constitution; (3) a compact between the oil producing states would be a means of effectively carrying a sound conservation program to the national level.

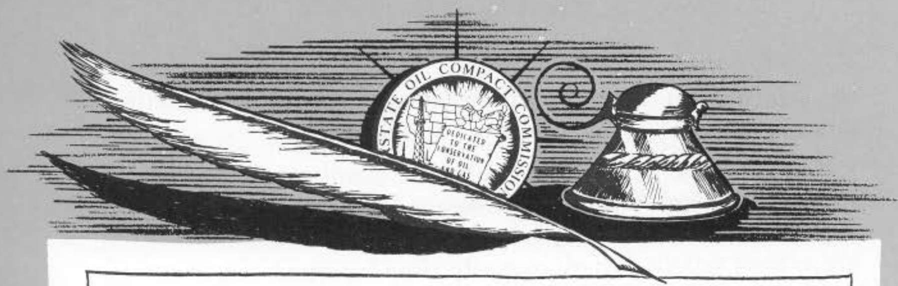
State Laws, Rules and Regulations. In the confusion that existed, not only were our natural resources of oil and gas being dissipated, wasted, and destroyed, but also property rights were being violated and the correlative rights of the owners were not being protected. New and different problems were being encountered. The conservation program was of necessity developed on a trial and error basis. Information was meager and cooperation was nil. Each of the oil and gas producing states began an intensive study of the situation and numerous laws were introduced in practically every state where laws did not exist, and amendments were presented in those states having statutes.

Considerable progress was made, but it was soon evident that an agency through which information could be distributed among the various states having the same or similar problems, was very important, and the Interstate Oil Compact Commission was formed.

State Compacts. Compacts between states are provided for under the Constitution. Four such compacts existed in Colonial days under the Articles of Confederation and more than one hundred and fifty have been formed since the Constitution was adopted. An interstate compact is a treaty between states to deal with problems common to the compacting states, subject to approval by Congress to prevent infringement on Federal authority or on powers reserved to non-compacting states.

The Interstate Oil Compact. The Interstate Oil Compact is a treaty, sanctioned by Congress in 1935, entered into by oil producing states for the purpose of assisting the various states in the formulation of sound oil and gas conservation programs, and for the purpose of public education in the necessity and methods for oil and gas conservation. The Interstate Oil Compact seeks to advance the technology of oil and gas production and to encourage methods of production which prevent waste of oil and gas under proper state laws which protect the correlative rights of all who own oil and gas producing properties. The Interstate Oil Compact establishes no collective power of enforcement. It can only provide an agency for education in waste prevention practices.

Membership in the Interstate Oil Compact is entirely voluntary. Each state in assuming membership pledges its effort to enact and enforce laws, rules and regulations that may be required to bring about the conservation of oil and gas produced in its own jurisdiction, and to participate in the accumulation



OUR OBJECTIVES

"Each state bound hereby agrees that within a reasonable time it will enact laws, or if laws have been enacted, then it agrees to continue the same in force, to accomplish within reasonable limits the prevention of:

"(a) The operation of any oil well with an inefficient gas-oil ratio.

"(b) The drowning with water of any stratum capable of producing oil or gas, or both oil and gas in paying quantities.

"(c) The avoidable escape into the open air or the wasteful burning of gas from a natural gas well.

"(d) The creation of unnecessary fire hazards.

"(e) The drilling, equipping, locating, spacing or operating of a well or wells so as to bring about physical waste of oil or gas or loss in the ultimate recovery thereof.

"(f) The inefficient, excessive or improper use of the reservoir energy in producing any well."

of information and the discussion of problems relating to conservation.

The work of the Interstate Oil Compact is accomplished through the Interstate Oil Compact Commission created under the Compact. The Commission is composed of one representative from each member state, usually the Governor.

The Commission holds from three to four meetings each year, and, in addition, accomplishes much of its work through various committees. The committees presently functioning are designated as: Engineering, Legal, Research and Coordination, Regulatory Practices, Public Lands, and Secondary Recovery and Pressure Maintenance Advisory Committee. Every member state is represented on every committee appointed by the Commission. The committees study legal and scientific problems, accumulate information from every source, and render reports to the Commission which are subsequently distributed to all of the states and to all who may be interested.

The Interstate Oil Compact Commission, through its system of committees and through its frequent meetings, is able to draw upon the talents of outstanding scientists, engineers, lawyers, and other experts throughout the nation, both in government and in industry. In that way, every source is available in formulating a sound oil and gas conservation program that may be put into effect in any state that seeks to accomplish petroleum conservation.

The Commission is controlled entirely by state officials and is financed by voluntary contributions from the states. The Commission accepts no contributions from any corporation, association, or individual. It carries no advertisements in its publications. It is supported entirely from public funds and is dedicated solely to the public interest.

Member States. When the Interstate Oil Compact was authorized by Congressional Act in 1935, six oil producing states entered the Compact. Since that time, sixteen states have become members. Four non-oil producing states and Alaska have joined as associate members, making a total of twenty-six states and one territory. In addition, non-member states, departments of Federal government and foreign countries send official observers to the meetings of the Compact Commission.

All the member states of the Interstate Oil Compact have enacted conservation laws and have issued rules and regulations under such laws. Most of these laws have been enacted since the organization of the Interstate Oil Compact in 1935. Many of the states have adopted practically all of the provisions of the suggested conservation act prepared by the Interstate Oil Compact Commission. Every member state has adopted one or more of the provisions of the suggested law. Many of the rules and regulations under such laws follow recommendations formulated by the Commission from its study of conservation practices and procedures.

Regulation But Not Control. Oil producers are traditionally "rugged individualists." They yield to no one in their abhorrence of governmental control of business, but they no longer regard oil conservation statutes as control of business. In no state having a conservation law has there been any attempt to convert conservation regulations into state ownership or into state control of the industry as a whole. There has been no attempt to control prices of crude oil or products or to control refining or marketing of products. There has been no attempt to socialize the oil industry. The conservation laws were adopted solely for the purpose of meeting an urgent necessity for a system of law and order under which oil and gas could be produced efficiently and under which a better method than unrestricted drilling and production would be provided to protect property rights. There are few, if any, producers who would like to go back to the old unregulated ways.

The position of the petroleum industry is set forth as one of the "fundamental principles" in the statement of "A National Oil Policy for the United States," formulated by the National Petroleum Council at the request of the Secretary of the Interior in 1949, as follows:

> "The operation of the American petroleum industry is grounded on state regulations of oil and gas production in the interest of conservation. State regulation under our constitutional system evolved as the legal and most effective answer to the problem of a widely dispersed natural resource. State authorities have proved effective in their protection of the public welfare, and the decentralized approach has been

highly successful in meeting the wide variety of conditions that prevail in different areas.

"When oil conservation problems have arisen involving coordination among states, instrumentalities have been developed to deal with them effectively, such as the Interstate Oil Compact to Conserve Oil and Gas, operating with the sanction and aid of the federal government."

The Interstate Oil Compact Commission is both important and unique. Important, because oil and gas are without doubt our most vital, irreplaceable, natural resources. Unique, because in its organization, duties, and responsibilities, it is different from any other organization in America. It is indeed a new device on an old vehicle. It has been called "the most powerful, powerless, organization in the world." Article II of the text of the Compact—"The purpose of this Compact is to conserve oil and gas by the prevention of physical waste thereof from any cause" has been referred to as the most powerful twenty-one words in the American industrial life.

The Achievements of Conservation. The achievements in oil and gas conservation over the last twenty years are highly impressive. The passage of laws, rules and regulations, and the promulgation of programs through state authority have proven of great benefit.

Robert E. Hardwicke of Fort Worth, Texas, one of the nation's outstanding authorities in the field of oil and gas conservation law, states as follows:

"Even in states where no comprehensive laws have been passed, most of the operators have followed efficient practices that have been developed, but often they were unable to do so because of practices of other operators. Experience has proved that the aid of state regulation is almost always necessary.

"It is believed that regulation under state conservation statutes during the last twenty years has resulted in a recovery of perhaps 50 per cent more oil than would have been recovered in the absence of regulation and has also offered a workable method of protecting property rights. Few realize how necessary is the program to adjust and protect property rights."

A survey made in 1949 by the Interstate Oil Compact Commission conservatively shows there has been produced in this nation at least *5 billion barrels of oil* that would never have been produced without the application of conservation methods, and the same survey further shows that at least *5 billion barrels of oil* will be produced in the future by the application of presently known methods that would not be produced without the application of these methods. The increased amount that will finally be recovered through good conservation methods cannot even be approximately estimated or prophesied because of the constantly improved practices that will be developed by continued research and improvements through conservation laws.

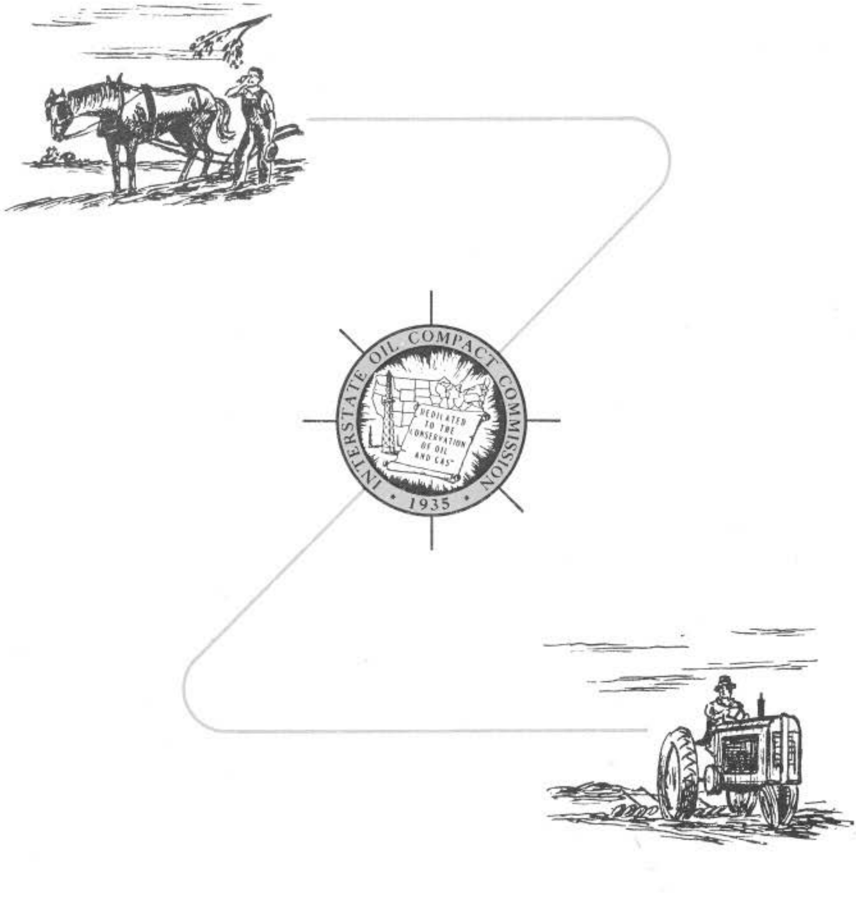
Oil for Today — And for Tomorrow. Conservation does not mean the hoarding of oil for the future at the expense of the present. Rather, it means the practice of methods which will produce plenty of oil this year, and next year, and year after year, over a much longer period of time than would be possible if such methods were not practiced. A plentiful supply, assured by conservation, obviously results in prices for petroleum products lower than would be possible under conditions of waste, now and in the future.

Benefits to the Public. That the security of the nation is dependent upon the conservation of oil is evident. The local or personal benefits of conservation are also of great importance. They have been well stated:

> "The public has a great and continuing interest in the preservation and further development of this system of conservation. Its immediately apparent benefits have included not only assurance of a stable supply of petroleum, in which every citizen has a stake, but consumers have been protected through the development of a supply adequate to meet present needs at a moderate price. The oil-producing areas have been specifically benefited in many ways. Stable and attractive communities with schools, libraries, churches, parks, and permanent populations deriving their support directly or indirectly from the steady income provided by oil and gas pools whose capacity to produce is sustained for a generation or more have replaced the boom towns with their shanties erected by the transients formerly attracted to each new oil discovery.

Steady tax revenues to both local and state governments have supported public institutions and highways. The permanent employment and stability of income to both private individuals and local governments have permitted long-range planning and the development of a healthful environment in which to develop good citizens."

Conclusion. The states and the Interstate Oil Compact Commission will march forward in cooperation with the industry and the citizens of this nation, fully realizing that it is only by continuous and constructive efforts under state authority that the maximum oil and gas will be produced with the least possible waste. Conservation is a constant and continuing problem.



CONSERVATION FOR FREEDOM - UNDER STATE LAWS

Lt. Gen. Ernest O. Thompson

Never in history has the United States been so rich, so strong, so powerful nor with brighter prospects of going ahead for peace and human freedom in the world.

We have built America by wise and efficient use of our resources. By wise state conservation laws we have given men the opportunity and incentive to find enough oil to make our great progress possible.

The wise conservation laws which have been passed by our foresighted state legislatures made the oil available to fuel World War II.

It is right that the state should enact such laws. Conservation and our oil and gas programs should be administered by state officials. They are at home. They are directly answerable to all of the people. They are familiar with the local production problems.

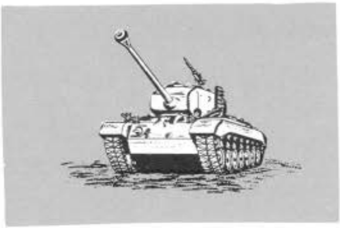
Before the enactment of state conservation laws, the oil industry went through periods of "feast and famine," "boom or bust."

I have been following oil and gas production problems nearly all of my life. I have been a member of the Texas Railroad Commission for the past 21 years. As a state official, I have seen the growth of our conservation programs.

The East Texas field has been an experiment in conservation. Early in its life, it was unrestrained and was produced with wide open, uncontrolled, wasteful practices.

Our Railroad Commission was given the job of putting into effect proper oil and gas conservation measures in the field. Several of our field orders were taken into court and struck down; however, after a special session of the legislature had passed proper conservation laws, our orders were sustained.

Since that time, this great field has been produced at a rate so that not only has the reservoir pressure been maintained, it has been increased. The industry put pumps on the wells, under the then current impression that all wells would shortly have to be pumped.



This was true under the wasteful practices of the past.

Many of these pumps are still standing idle today, probably never to be used. Good conservation is producing the oil the way nature intended.

Under these methods, instead of the one billion barrels to be recovered as estimated by the experts then, it is now estimated there will be $5\frac{1}{2}$ billion barrels recovered.

In addition to my duties as a member of the Texas Railroad Commission, I have also been privileged to serve my country as a citizen-soldier. Today, I am Commanding General of the Texas National Guard. As a member of the armed Forces, I know what the availability of this oil during times of emergency means to our country.

It is interesting to me, as a citizen-soldier, to recall that, after World War I, they said we would be out of oil in 14 years by taking the five billion barrels of the then known reserve and dividing by the annual consumption. It came out mathematically to 14 years. Since that time, we have consumed 26 billion barrels and now find ourselves with 30 billion barrels in reserve. We are not slipping backward under conservation.

It would have been a tragedy if conservation had not been developed so that we had excess producing capacity when the Germans attacked Poland in 1939 and the Japs attacked us at Pearl Harbor.

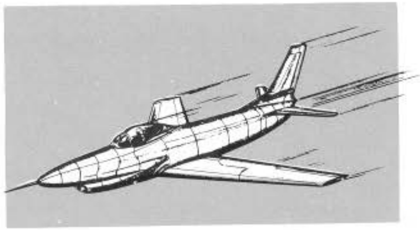
The East Texas field would have already produced all of its oil under old wasteful methods. During the War, this field supplied many planes, tanks and ships, due to the fact that conservation methods had made it available.

East Texas is still available if we were unfortunate enough to be faced with another emergency.

Much attention has been given here to the East Texas field, since it is, after all, the largest field in North America. Nevertheless, we, of the Texas Railroad Commission, pay equal attention to the smallest field and the smallest well.

Every barrel of oil produced by good conservation methods is an extra barrel for our economy and security.

Encouragement must be given to recovering the oil left by wasteful methods in our older fields.



Secondary recovery is fast being developed. More oil is being produced by these methods in some of our fields than was originally produced. This is extra oil for security under our conservation programs.

Ten long years of strict conservation and proration of production in Texas prior to Pearl Harbor made it possible for our nation to have all the oil it needed for the war effort in World War II.

We were never short of oil, although we were severely taxed in our producing ability many times during the War. We produced our fields to the limit. We had no extra ability to produce and rationing of civilian needs was necessary in order to conserve oil.

The story of the result of our efforts in producing petroleum and petroleum products for World War II is graphically told by the statement from the book, "A History of the Petroleum Administration for War, 1941-1945":

"World War II, beginning to end, was a war of oil.

"Almost seven billion barrels of it had to be brought from the ground between December 1941 and August 1945, to meet the requirements of the United States and its Allies, and nearly six billion of this enormous total came from the United States. That is *one fifth of all the oil that had been produced in this country since the birth of the industry in 1859.*

"A staggering output, to be sure, but the prodigious thirst of the war machine could not be satisfied with less, for oil was *the* indispensable material.

"It constituted *more than half* of all the tonnage of supplies that were shipped overseas. In several invasions, its tonnage was *more than 65 per cent* of the total.

"Incredible? Not to the men who had to supply it. Not —especially—to the men who had to use it. For oil did more than fuel and lubricate the ships and the airplanes and the motorized equipment. Oil was also heat and light and comfort and mercy. Out in the field, in the form of gasoline, it fueled the kitchens, it powered the radios and telephones, it warmed and illuminated the hospitals, it refrigerated the life-saving blood plasma, it heated the instrument sterilizers, it ran signal devices, water purification systems, and repair machinery. From oil came the toluene for TNT that went into bombs, the asphalt for airfields, the jellied gasoline for flame throwers, the kerosene for smoke screens, the wax for packaging food and equipment, the petroleum coke for aluminum.

"More than 500 different petroleum products were regularly used by the armed services. Without them, the warrior could neither fight nor live. With them, we were able to live and fight—and win."

Texas did its part or more than its part in meeting this increased demand. In 1938 Texas produced 468,781,632 barrels of oil. In 1945 it had increased its production that year to 751,045,143.

Today we are again in a state of preparedness. We need a much greater reserve capacity to meet an emergency. Our program of building tanks, planes, trucks, ships and rockets will be meaningless unless we have the oil to fuel them.

The only way this fuel can be made available is through good conservation programs in all of the states fortunate enough to have discovered oil.

In the last emergency we needed four million barrels of oil per day, but what would it be in another emergency? All of our machines take more fuel. The appetite of a jet plane is insatiable. A B-36 needs a large railroad car of gasoline to be fueled.

Oil for security must be available at home.

Another energy that is available to our nation today is the gas that is being conserved by our conservation orders. Gas that was formerly blown into the air in conjunction with the production of oil must be saved and utilized in order for the operator to produce his oil. Although some of the gas is re-injected into the producing formation to conserve the reservoir pressure, much is put into pipe lines and sent in all directions for industrial or domestic utilization.

This is energy that would not be available except for good conservation programs under state conservation practices. Gas that was formerly considered worthless now is valuable and sought after.

At the request of the President, I visited and reported on the Middle East oil fields. These potentials are enormous, but would this oil be available in time of war? Certain people we know are concentrating on building submarines, and a tanker is extremely vulnerable.

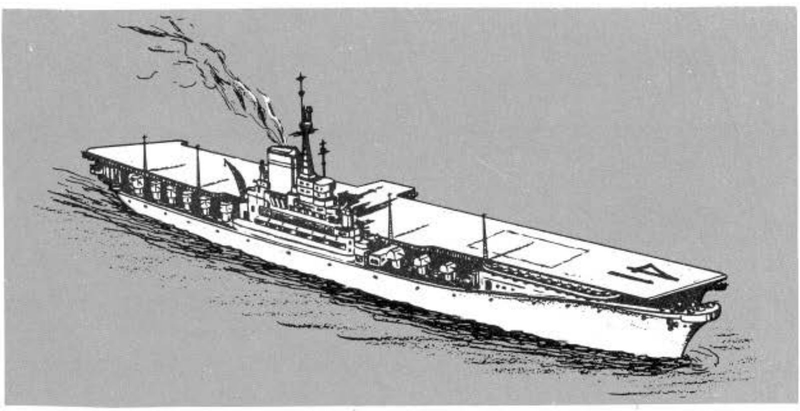
These great Middle East fields lie under the shadow of the Russian Bear, right at the border.

Testimony of high military officials before Congress is that the Persian Gulf fields could not be counted upon come War. What, then, does this mean? It means that our freedom and security depend and depend solely upon our hemispheric solidarity oil-wise.

This freedom and security can only be insured if our industry is given an assurance of full protection of strong state conservation laws. Laws that will guarantee equal protection for all in a favorable economic climate.

If every state continues and improves its conservation program so that oil at home is available to meet any emergency, our future is safe.

Freedom today has a new need to be safe. It must have an adequate, safe supply of oil and gas.



COMPACT MEMBERS

MEMBER AND ASSOCIATE MEMBER STATES

NON-MEMBER STATES

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