PROSPECTIVE UNIT OPERATION OF OIL AND GAS RESERVOIRS IN PENNSYLVANIA

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FOREWORD

The merits of every facet of unit operation of oil and gas reservoirs have been presented many times by innumerable authorities of the petroleum industry. However, this paper, which again delves into this vital subject, has been prepared for the especial consideration of the state of Pennsylvania.

The author, who has been interested in or connected with the petroleum industry since 1937, makes no pretense of presenting a paper that covers all angles of a very complex subject, nor does he claim any particular originality. Yet if by one more presentation of the art of conservation, as exemplified by unit operations, one more sovereign state can be convinced to adopt these procedures in its primary gas and oil production, then in a measurable way our great heritage of natural petroleum resources will be conserved for greater ultimate ready availability to mankind.

The author is not at all disturbed by the fact that presently there probably exists little opportunity in Pennsylvania for extensive application of unit operations of the type and purpose he contemplates. Yet natural gas producers of the present might well embrace the plan as of now, and as any good rugged oil man should be, the author is optimistic about future Pennsylvania discoveries in gas and oil. He is anxious that they benefit by the advances that have been made by petroleum engineers in the techniques of reservoir engineering.

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I. INTRODUCTION

The magnificent oil and gas industry of the United States was evolved in the Commonwealth of Pennsylvania with the discovery of the Drake well in 1859. Throughout the years Pennsylvania has played a glorious part in the industry and has remained a state of proven oil and gas production potential.

Yet today something in the nature of over 80 per cent[1] of all Pennsylvania's crude production is achieved by secondary recovery methods. Today's generation of oil men in Pennsylvania have been most aggressive and enterprising in developing the art and technique of secondary recovery, and in consequence have acquired world-wide acclaim. Frankness requires recognizing that excellent as this has been, it is a salvage operation which endeavors to remit production errors of the past which stemmed from ignorance as to good engineering techniques, and indifference as to waste and conservation. It has nothing to do with preparing for the future.

Pennsylvania geologically has a wholesome prospect ahead for the discovery of gas and oil reservoirs in deep zones.[2] No significant state-wide drilling has been conducted in zones below 5,000 feet, but in addition to geological indications, results from some drilling for gas in the deeper zones has strengthened future prospects in these areas when some day economic incentives justify the necessary drilling.

The gas operators were not forward looking when they failed to legalize at an early stage the underground storage of gas in natural "gas tight" formations hundreds of feet beneath coal veins, in the same local gas fields which once produced all the gas used in Pennsylvania. In consequence the Pennsylvania natural gas industry is engaged in a virtual fight for existence as a result of the submission to the Legislature by the coal interests of the Kent

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[1]References at end of paper.

Anti-Gas Storage Bill, House Bill No. 1240. While subscribing to the attitude so strongly held by all petroleum men, i.e., "he who governs least, governs best," it still is only a part of wisdom to insure that the laws will permit carrying out the necessities of the business.

Educated oil and gas men today have come to realize that oil and gas reservoirs must be operated as a unit if modern technology is to be applied successfully, and ultimate production efficiency immeasurably increased beyond the low rates of the past. Yet nothing in the laws of Pennsylvania as they exist now would permit or aid in effecting, on the part of the industry, unit operation of new oil or gas fields. The errors of the past would inevitably be repeated. Then there would be no end to the salvage function,--secondary recovery. More often than not, secondary recovery in deep zones is apt to be unsuccessful, either because of increased engineering difficulties, or because of greatly increased operating costs.

II. PURPOSE

Unit development and operation of oil and gas reservoirs is generally essential, starting in the very early primary stages of the reservoir's life and continuing on until abandonment, if conservation of natural resources, protection of correlative ownership rights, and achievement of ultimate operating economies is to be assured.

These advantages are readily achievable. The objective of this paper is to convince Pennsylvanians to immediately enact a statute that will enable oil and gas production management to implement unit development and operation of the natural gas reservoirs presently being found, and in the exploitation of the new oil reservoirs to be found.

III. PENNSYLVANIA'S OIL AND GAS OPERATIONS, PAST AND PRESENT

"Secondary recovery operations in the United States are restricted largely to fields where primary recovery has been obtained by the action of dissolved gas drive. Fields in which active natural water drives are in operation are generally not so well adapted to secondary-recovery operations . . . after the primary-recovery phase, due to low residual-oil content . . . better reservoir-performance efficiency in more recently discovered dissolved gas-drive fields should eliminate, in part, the necessity for future application of secondary-recovery methods. If oil had been produced efficiently in many of the older fields, it is doubtful whether there would be such a high present activity in secondary-recovery operations. Therefore, secondary recovery, in a sense, is a salvaging operation which can be avoided under certain conditions in the future by more efficient development and operation of oil fields. In this, studies of primary-pressure control undoubtedly will play a very important part . . . ."[3]

"The oil sand-rocks which stretch under adjacent farms are not only affected but often absolutely controlled by a few thoughtless operators who own or lease territory adjoining that in which a pool well has been found. Developing a bed of rock is but a race between the owners of the surface above it, as to who shall first exhaust the basin of oil below the surface, common to all parties. All this is highly disastrous; and the result has been that whereas the sand-rock, if kept free from the surface water and pierced only by a moderate number of holes will last 8 to 10 years, the average life of a well has not practically reached three years. We do not exhaust our beds of sand-rock, but destroy them. We pluck the apple, so to speak, by rooting up the tree. Had it been possible from the start to regulate drilling, it can hardly be questioned that one-third of the wells that have been drilled, would have brought us as great a return as we have had from them all thus far, and at one-third the cost of producing."[4]

"The next generation will gather from our oil history, with angry astonishment, a lesson of warning in political economy, only useless because coming too late."[5]

It is a matter of common historical knowledge to all oil and gas men that before the mechanics of reservoir behavior were understood, and even after they were understood, that wide-open flow production of oil and gas reservoirs was the practice everywhere. The Law of Capture which regarded oil as ferae naturae, made every neighbor a competitor in a hasty race to bring the oil and gas to the surface before it was drained out from under his land. Nature in designing the oil and gas reservoirs gave no consideration to the future metes and bounds of man's surface property rights. Consequently, reservoirs were

drilled with dense spacing patterns. Many of the wells were unnecessary and served only as a means of draining the neighbor's land. Gas was generally considered a waste product and was allowed to vent freely. No recognition was given to the expulsive force represented by gas for moving oil out of the sand pores of the reservoir. These wide open flow rates also caused inefficient water encroachment into the oil zone, trapping or cutting off oil areas. Consequently a great percentage of the oil was left dormant in the reservoir, much of it never to be recovered. These all were matters of underground waste.

These practices also caused great surface wastage. Production of both oil and gas was frequently in excess of storage, processing, and transportation facilities, resulting in loss by evaporation, overflowing of tanks, flaring of gas, or dumping of oil on the market at prices that virtually engendered economic chaos, even to the extent of necessitating martial law in certain areas. It is equally obvious that every unnecessary well is capital expenditure waste, which from a business angle vitiates profit likelihood.

The foregoing statement and the quotations immediately preceding it have been presented in order to give the picture of operations as they existed under the laws of the past and with flush pools. This condition was general in all producing areas, in Pennsylvania as well as other states, before the resources of the reservoirs were squandered, or control procedures established. Nor may it be thought that such practices are long past. Wholesale flaring of gas in Texas in incalculable amounts, has been brought under reasonable control only within the recent post-war years.[6]

Pennsylvanians need not be complacent on the grounds that their State is an area of secondary recovery, an art in which they are very competent. While acknowledging the difficulties that may exist, and perhaps unaware of all that is being done, it is the opinion of the writer that the State's research and development program is far too limited.

Partisan effort between competing industries, not educated contemplation, has motivated the Kent Bill.[7] Pennsylvania has 140 million barrels of proved recoverable petroleum reserves, yet it is more probable that the State's 160 oil pools actually contain at least two and one-half billion barrels. The difference between these two figures represents, in the writer's opinion, failure of management to organize under necessary state laws the production side of the oil and gas industry of the State so that known petroleum engineering and geological techniques can be fully utilized.

The oil and gas industry of Pennsylvania could move ahead by:

(1) finding new primary oil reservoirs;

(2) utilize in these the latest advanced techniques for producing known oil in the ground;

(3) applying advanced techniques to a greater number of the 160 known reservoirs;

(4) by making the present and advanced techniques cheaper to operate, or the margin of profit greater.[8]

The writer, while not denying that more technical development is urgently needed, feels that Pennsylvania's real problem lies in readjusting management and operating methods by obtaining legal sanction to unit operation of oil and gas pools in the developmental and primary stages. This action alone will substantially solve improvement items 2, 3, and 4 supra.

IV. THE LAW OF CAPTURE

The business of oil and gas production must operate within the framework of the law and is thereby shaped by the law. The form of law enveloping the acts of wastage, alluded to above, was in a major sense responsible for the lack of conservation in the past, and if left unchanged will again exercise the same destructive power on any new primary production, of either gas or oil in Pennsylvania.

A class of fugacious things to which property rights attach, and on the supposed analogy to which many oil and gas cases have been decided is that characterized by percolating waters. Since it was through analogy to this class that the so-called Rule of Capture[9] in oil and gas cases was established, it would be well to examine what the courts had in mind.

When oil was first discovered in commercial quantities, and until science and technology of petroleum engineering was firmly established, most oil operators, lawyers, and courts believed that oil either flowed in underground streams, as do percolating waters, or existed in underground lakes. It was further believed that there was no equilibrium condition existing in the subterranean reservoir so that the gas overlying the oil did not aid in the recovery of that oil. It was visualized as a flowing river of "black gold," meandering momentarily by chance beneath any given fee. Therefore, any owner of the fee, or his lessee might produce the maximum amount possible through his wells, obtaining ownership only when the oil was produced. Possession vested ownership in the oil regardless of where it might have come from. This was the essence of the Rule of Capture. Note that this was a Pennsylvania court ruling and is in effect today.

This Rule of Capture gave rise to two pertinent management or operational concepts: first, the lessee was obliged, by implied covenant,[10] to offset drill in order to protect his lessor against drainage; and secondly, the lessee had to produce his wells wide open in order to obtain maximum possible recovery under the prevailing conditions.

That this Rule of Capture is wrong from an economic point of view,[11] from an engineering standpoint, and from the physical facts themselves, is easily shown. Nevertheless, that this Rule is the one in effect practically, is equally apparent in the reading of the cases, regardless of the dicta or holdings of the courts.[12]

Speaking of the Rule of Capture: "this much we know, that a rule of law . . . which is based on the assumption that he owns all of the oil and gas he can produce from those wells, regardless of whether or not he has drained his neighbor's lands, and which says that the remedy of the neighbor, in order to fully protect himself is to drill as many wells as he can, is a rule which approves and sanctions hasty developments, disorderly operation, and immeasurable waste as well as the complete destruction of correlative and co-equal rights."[11]

Again speaking of the Rule of Capture: "although courts in adopting the theory of ownership in situ have ostensibly repudiated the theory of ownership by reduction to possession, the doctrine of Capture still underlies the property law of oil and gas throughout this country."[12]

The basis on which the courts ruled to establish the Rule of Capture has been shown previously. Present knowledge of the physical aspects of a reservoir completely refute the oil reservoir concept of ferae naturae, of fugacious things. Oil or gas to accumulate must have: (a) source beds; (b) porous and permeable reservoir rock, usually sandstone; (c) an impermeable cover or cap rock; and (d) a "trap" where the oil may enter but cannot escape.[13] We have here, once in a "trap" a corporeal part of the realty. The common law that he who has seisin owns that and only that within his metes and bounds to the very center of the earth certainly is the proper law.

It does not take any great understanding of the techniques of oil or gas production to see that if fewer wells are needed and the full amount of

available energy is utilized in these fewer wells then the gas or the oil can be brought to the surface at less cost per barrel of oil over the entire field. If instead of the Law of Capture a law of ownership of oil or gas in place in the fee can be established so as to protect ownership rights regardless of drainage, then no excess number of wells to protect lessors against drainage will be needed, nor will there be the necessity of rapidly depleting the reservoir energy with resultant high gas-oil ratios. Royalty owners and operators alike will benefit from orderly and economical production. This will satisfy desideratum number 4 for Pennsylvania (see page 6) for both oil and gas operators, i.e., incentive through greater profit margins.

Since the year 1898, when Indiana first began regulating the production of natural gas, most oil producing states have enacted some legislation modifying the pernicious effects arising from the Rule of Capture. One of the latest and best of the new enactments is the statute for Oklahoma, which provides for unit operations.[14] In effect all this type of legislation has recognized, on the grounds of a sovereign's right to exercise police power to achieve conservation of natural resources, that an operator cannot wastefully produce all oil and gas he wishes. This legislation, in the following growing number of states, recognizes in some way the desirability of unitizing the production of an entire pool:

> Alabama, Florida, Georgia, Washington, Oklahoma, Arkansas, Louisiana, California, Texas, Arizona, Illinois, Indiana, Kansas, Kentucky, Mississippi, Montana, New Mexico, N. Carolina, Colorado, N. Dakota, S. Dakota, Utah, Wyoming, Nebraska, U. S. Federal Government.

Apparently, of these states, Florida, Alabama, Georgia, Washington, Oklahoma, Arkansas, and Louisiana have compulsory unitization provisions.[15] These steps are of great interest to petroleum engineers since it is a realization of their concept of the proper way to produce oil.

These enactments mean that the Rule of Capture as laid down by the courts has not been satisfactory to the legislative bodies, and that the oil industry could not modernize under it. Some stringent modification of the Rule of Capture, which approximated recognition of ownership of oil and gas in situ as part of the fee, was required.

It is interesting to note that in the states listed above, some, such as Georgia, Florida, Washington, have compulsory unitization laws in advance of any significant oil or gas production. But far more significant is it that the first of the oil states, Pennsylvania, is completely missing from the list.

V. PENNSYLVANIA LAW

It is now pertinent to review the legal status of oil and gas production in Pennsylvania. As has been stated, the modern concept of oil conservation is derived from the geological and engineering knowledge accumulated since the drilling of the Drake well. This knowledge was not available in time to enable the Commonwealth to profit by the warnings of those who anticipated the early exhaustion of the primary energy in the State's oil and gas reservoirs. The law had no suitable common-law concepts to meet the problems that arose with the first phase of the business of oil and gas production. In common with most other jurisdictions the State Supreme Court ruled that oil and gas was ferae naturae subject to the Rule of Capture.[9] As has been stated, this concept worked to bring about unnecessary drilling and early exhaustion of reservoir expulsive energy.

The only Pennsylvania legislative enactments in the nature of conservation statutes are the well-plugging acts and related aids to secondary recovery. There has been a long series of such bills and enactments, known as well-plugging laws, which have had for their purpose the prevention of drowning by water of strata capable of producing oil and gas. The Act of 1921 as amended in 1927 and 1929 permits wells producing from the Bradford, Kane, Haskell, and certain other sands to remain open for water flooding, repressuring by air, gas, and other liquids for the purpose of recovering the oil and gas contained therein, in other words, secondary recovery.[16]

In 1941 the Governor was authorized by the General Assembly to execute, on behalf of Pennsylvania, the Interstate Compact to conserve gas and oil. But the Assembly inserted a priviso that such participation should not prohibit or prevent water flooding or require or necessitate the enactment of conservation

statutes, unless and until the General Assembly shall determine by law that such statutes are advisable or necessary to prevent physical waste of oil or gas.[17]

Several conservation bills have been presented to the legislature. A House Committee in 1887 unfavorably reported a bill to prevent waste of natural gas, and refused to concur in a Senate proposal to prevent the escape and waste of natural gas, provide for the closing of gas wells, and for compensation to owners of the land in certain cases.[18] In 1913 a bill was introduced to create a petroleum and gas well commission to regulate location, drilling, casing, protection, operation, abandoning, plugging, and filling of oil and gas wells. This bill failed of passage, and a like fate met a similar bill in 1917.[19]

In 1933 a full-fledged conservation statute was submitted. After defining waste as both underground and surface waste together with that resulting from oil produced in excess of transportation, marketing facilities, or market demand, the bill declared conservation of the State's natural gas and oil resources to be essential. It proposed establishment of a Pennsylvania Oil Commission to insure that these resources were drawn on only as needed by commerce. The Commission was to be empowered with full authority to write proration orders and to prohibit drilling of unnecessary oil wells and inlet wells for repressuring of air, gas, or water. The bill also proposed the joining in with neighboring states to form an "interstate compact" as a fact finding and advisory committee as to production requirements.

The bill failed of passage not only in 1933, but also in 1935.[20] In the meantime secondary recovery operations at Bradford had substantially increased production in that area. In 1937 a bill was enacted requiring notice and final report to the State on drilling of wells more than 2500 feet deep. The geological information so gained becomes public information.[21] In 1939

a bill, similar to the 1935 Conservation Act, was presented to the legislature.[22] Its stated purpose was to protect crude oil resources from waste and destruction. This bill failed to pass, as did another bill entitled the Migratory Fuel Control Act, which declared gas a "migratory mineral resource." One of the purposes of this bill was to compensate land owners for gas removed from their land by wells on property owned or leased by others, i.e., compensating for the inequities of the Law of Capture. The bill also set up a proration system over gas wells, and to some extent controlled the financial return.[23] All in all it, under the guise of conserving gas reserves, actually went overly far into controlling business profits.

The foregoing bills, presented in the name of conservation, generally emphasized conservation in terms of surface operations and of limiting production to a governmental authority's idea of market demand. None clearly expressed the purport to be a requirement that private enterprise operate its pools so that high grade unit technology would eliminate underground waste and at the same time protect the correlative rights of the respective owners. Since the bills did not pass, it remains that even after these many years of abortive legislative activity Pennsylvania remains as it started, i.e., an exponent of the invidious common law doctrine of Rule of Capture.

The prevention of waste and the protection of correlative rights of landowners is the true function and proper ultimate goal of gas and oil conservation laws and conservation administration. Unitization agreements which refute the Law of Capture and grant and yet limit every owner to ownership in situ of the oil or gas that underlies the fee: (1) eliminate the necessity of overproduction in order to defeat offset drainage, (2) reduce development costs by diminishing the number of wells and the duplication of facilities, (3) increase ultimate production by providing for the application of good petroleum production practices, which must be applied to the reservoir entity,

and (4) permit the normal free enterprise laws of supply and demand to operate since it was the Rule of Capture which mandated production even though an inconsequential and non-profitable market existed. Of particular attractiveness to private enterprise is that in contrast to proration forms of statutes which result in government authority describing in detail what wells shall be drilled, where, and how much each well shall produce, a statute which provides for unit operation merely grants the legal environment that insures the right of private enterprise to have unit operations if the majority of owners desire it in the interest of conservation. From then on if the law is properly administered, business and operational functions of producing the reservoir are strictly a matter of business and technical judgment of private enterprise.

Sufficient has been said to make clear that Pennsylvania should soon initiate action to enact a law providing the legal environment for private enterprise to sponsor unitization.

VI. THE RESERVOIR

A. General

A descriptive picture of the physical aspects of the petroleum reservoir as known today will lead to easy comprehension of the necessity for producing the reservoir as a unit from the time of discovery to abandonment, i.e., unitization.

A petroleum reservoir is a single, natural underground accumulation of oil or gas that has a single pressure system which is affected equally throughout by pressure increase or decline in any part of the reservoir, and which is so independent of any other reservoir that production effects in it have no effect outside the reservoir. In other words, a reservoir is a closed container.

Underground petroleum reservoirs have been termed "oil pools" so generally that a misconception exists that oil is in underground rivers or lakes and can be drained therefrom. Oil is found generally in the pores of sandstone and limestone. In these interstices oil lies dormant unless there is an expelling agent. A displacing fluid or expelling agent provides the only means of recovering the oil. This displacing fluid is the energy mechanism which drives the oil toward the well through the permeable sandstone structure, and it is also the substance which physically occupies the space vacated by the oil.

To claim the underground oil in maximum amounts, i.e., to have conservation, the energy of the displacing media must be efficiently used. Reservoirs are classed in terms of the displacing media: (1) dissolved gas drive, (2) gas cap drive, (3) water drive.

Underground reservoirs, until vented by man, are in a state of compression approximately equivalent to the hydrostatic pressure of a column of water at that depth, i.e., one-half pound per square inch per foot of depth. This pressure is transmitted to the reservoir by the underground water which forms the lower seal of the oil accumulation. Oil almost invariably has natural gas associated with it. This pressure either completely or partially, according to the amount of pressure and the amount of gas, dissolves the gas in the oil. Aside from becoming the source of energy for "dissolved gas drive," the gas renders the oil less viscous and therefore more mobile.

When more gas is present than can be dissolved in the oil under the reservoir pressure and temperature conditions, the excess gas in conforming with the law of gravity occupies the pore space in the reservoir above the oil accumulation and forms a "gas cap." Since this gas cap is under pressure, and as long as man does not vent it by heedless drilling of the gas cap zone, it becomes, because of its ability to expand, a "gas cap drive" displacing medium for ejecting the oil.

As indicated above, many petroleum reservoirs are surrounded by large volumes of compressed water (this water is salty, and is in such immense volumes that even a small percentage of compression results in large volume changes). It therefore becomes an energy source for ejecting the oil by "water drive."

By proper consideration of the three foregoing energy sources and the power of gravity to maintain segregation between gas, oil, and water, it is possible to jointly or selectively utilize this drive energy. If it is dissipated, the energy which provides the only means of recovering the oil is lost.

A "dissolved gas drive" is the least efficient method since the gas being more fluid and mobile than the oil escapes in quantities through the well bore in far greater amounts than the oil it produces, and if left to vent

freely will move little oil. Every bit of gas evolved from the oil reduces the pressure, therefore, the energy available. It also leaves the oil more viscous, therefore less mobile. "Dissolved gas drive" recovers only about 10 to 25 per cent of the oil originally in place.

"Gas cap drive," as long as it is not vented, and the gas dissolved in the oil itself is not dissipated to the extent that the oil becomes highly viscous, is an efficient drive mechanism with recoveries ranging from 30 to 50 per cent and occasionally as high as 75 per cent.

"Water drive" properly utilized is the most efficient production method. Initial production of oil brings about a reservoir pressure differential which results in movement of water into the oil bearing portion of the reservoir, displacing oil out of the pore spaces and forcing it ahead of the encroaching water front into the producing well. After the initial pressure differential has been established, it is possible, if the total production of fluids, i.e., gas, oil, and water, is restricted to the rate at which the water encroaches in the reservoir, to maintain the reservoir pressure with little further decline, and thereby insure the mobility of the oil. Recoveries usually range from 60 to 80 per cent of the oil in place.

Much more can be said, but the intent is limited to portraying a picture of the reservoir mechanism. Injudicious placement of wells, and improper rates of production through various wells can dissipate one or more of the forms of energy discussed above, and result in sizeable wastage of oil through underground loss.

As an aside, an order to indicate the scope of technology to be applied, consider the dissolved gas drive type of field which has become sealed off from the water table which originally imparted the reservoir pressure. This dissolved gas drive becomes purely a depletion method, and the oil rapidly loses its mobility as the dissolved gas is dissipated. Yet by a gas recycling

process the vented gas could be scrubbed of its desired hydrocarbons and then returned to the reservoir in order to maintain its pressure and the mobility of the oil, consequently magnificently enhancing the ultimate recovery prospect.

Reflect that secondary recovery by water drive can hardly ever do what careful production in the primary state could have done. Par exemple, as a result of wasteful and inefficient development under the Rule of Capture the reservoir gas was dissipated, and the oil lost its energy and mobility through increase in viscosity. Secondary recovery water drive can overcome that form of lost mobility only in part. The need for avoiding dissolved gas drive, and the unproductive dissipation of any of the energy drive sources discussed above must be quite apparent by now.

The significant conclusion is that the only means of applying the foregoing technology is for the State to provide a business and legal environment which will insure operating the reservoir under a single plan as a complete reservoir unit.

Before terminating the portrayal of reservoir characteristics, comment on gas reservoirs, both natural gas and condensate, is deemed pertinent.

B. Gas Reservoirs

Most of what has been said throughout this paper so far applies equally to gas production operation and oil production operation. Underground waste is not so pertinent with respect to normal gas reservoirs, but application of the Rule of Capture to the gas reservoir results in such unnecessary drilling expenditures that the business loses profit incentive.

Since gas, unlike liquid crude oil or water, is a highly expansible fluid, it may be recovered from a porous rock by the direct and simple procedure of allowing it to escape by expansion into a well. Should circumstances require maintenance of reservoir pressure, gas may be displaced by natural or artificial water drive in the same manner as oil is displaced. Pressure depletion and water drive are the only two processes employed for the recovery of gas.

The efficiency of the recovery of gas by the pressure-depletion or expansion process is high, reaching ultimate recoveries of over 90 per cent in reservoirs having reasonable formation permeability. There are cases, however, when the formation permeability is too low to sustain economic rates of production unless the reservoir is maintained at a high pressure.

As pressure declines a water front will invade the gas reservoir the same as it will an oil reservoir. If the formation permeability permits the water to influx at a rate adequate to maintain reservoir pressure while economic rates of gas production are obtained, then the cost of compression for delivery of gas to a pipe line is saved. The maintenance of water influx will also assist in acquiring a high rate of yield per well, and this is accomplished as it is in oil reservoirs by proper placement of wells with respect to the characteristics of the entire reservoir and the maintenance of a proper

rate of withdrawal. To drill or draw on the reservoir through unnecessary wells is waste of capital funds, and in effect results in lower profits if any, because of poor business management. Again the significant conclusion is that gas reservoirs must be operated under a unit plan if conservation, protection of correlative rights, and production economies are to be had.

C. Condensate Reservoirs

Condensate reservoirs, sometimes termed retrograde reservoirs, are a physical phenomenon. In deep reservoirs having very high pressures and temperatures, petroleum hydrocarbons instead of liquefying become gaseous and hold the oil in an oil in gas mixture. The nature of these reservoirs is such that reduction of pressure will cause a large part of its petroleum content to condense to liquid within the formation, and the resultant liquid saturation is too low ever to be recovered from the reservoir. These fields are found only in deep zones, from which will come the future oil of Pennsylvania. These reservoirs must be operated under a unit plan, normally calling for pressure maintenance coupled with a gas recycling system. Once again the significant conclusion is that a unit operation plan is required.

The overall conclusion is that in order to apply ultimate technology to oil and gas reservoirs, management must be on a unit plan basis. Since the tract overlying the complete reservoir will normally be owned by many different owners the unit plan must also provide for protection of the correlative rights of the several owners. To do this the Rule of Capture must be replaced by the common law concept that ownership is of that and only that which is within the metes and bounds of each tract, i.e., law of ownership of oil and gas in situ. Of course, it must be engineeringly possible to determine the volume of oil and gas in situ underlying each tract.

That these concepts have acceptance in principle is shown by the Board of Directors of the American Petroleum Institute declaration in 1931:

"that it endorses, and believes the petroleum industry endorses, the principle that each owner of the surface is entitled only to his equitable and ratable share of the recoverable oil and gas energy in the common pool in

the proportion which the recoverable reserves underlying his land bear to the recoverable reserves in the pool."[24]

As to the engineering problem of determining the volume of oil and gas underlying each tract, it suffices to say that the following can be determined:

(1) the reservoir boundaries by geology and drilling;

(2) the productive acreage;

(3) the thickness of the producing formation;

(4) the net productive thickness of the formation exclusive of barren zones, such as lenses of shale;

(5) the porosity of the productive strata;

(6) the connate water content of the productive strata.

In general, from the above the amount of oil or gas underlying each property may be determined by applying the data to an analysis of each tract.

The conclusion stands forth then that unit operation of oil and gas reservoirs is technologically both desirable and possible.

VII. FORM OF UNITIZATION

It has been demonstrated that unitization or unit operation of gas and oil pools is desirable as a matter of good engineering, conservation, and sound economics. It then becomes a matter of providing the legal environment and business organization which will make implementation of unit operation feasible.

As Peter Q. Nyce, of the Mineral Section of the American Bar Association, stated in his paper "Cooperation between Engineers and Lawyers":[25]

> "It is therefore the function of the engineer to outline the conditions under which oil fields should be developed and of the lawyer to determine the method by which that can be legally accomplished."

The writer, while concurring with the foregoing quotation, considers that it is particularly the function and responsibility of the business man, i.e., management to so join the functions of the engineer and the lawyer that implementation of unitization is assured as a matter of policy.

Two general administrative methods by which unit operations can be effected merit consideration:

(1) by voluntary agreement of all owners under an enabling statute;

(2) by an order of an administrative agency requiring unit operation on the part of all owners, after having been petitioned for such an order by a specified percentage of the owners.

In theory, in the interests of complete freedom of private enterprise, procedure (1) above would seem preferable. But in practice it does not work. The adamancy of one tract owner can defeat the entire unit operation plan. Whatever the recalcitrant owner's motive may be, whether it be from mistrust of the plan or whether it be a desire to plunder the reservoir at the expense

of other owners, it is unthinkable, in the light of present understanding of physical aspects of reservoirs, that one or more rebellious lessees or lessors in a common source of supply should be allowed to deprive the remaining owners of the benefits of unit operations.

Since much of the beneficial result of unit operation is lost unless the plan is implemented at an early date in the reservoir's history, the effort to realize 100 per cent voluntary cooperation on the part of all owners has been found to be too prolonged, and defeats the objective. Therefore, unit operation by compulsion is the only worthwhile legislative enactment.

By compulsion, in no sense is it intended that the State force unitization on an unwilling majority. Instead the so-called compulsion statute merely provides the legal environment whereby an enlightened majority of owners, in the interest of conservation, good business economics, and protection of correlative and coequal rights may put into effect a unitization program without fear of sabotage by a recalcitrant few. The initiative comes from private enterprise, the plan and management of the operation is in the hands of private enterprise. The State, by the so-called compulsion statute merely enjoins the dissident minority from defeating the plan and operation promulgated by the preponderant majority, and thereby insures sound conservation combined with protection of the correlative rights of the several owners.

VIII. LEGALIZING AN AGREEMENT

Compulsory unit operation presupposes the enactment of enabling legislation. Most lawyers have concluded that there is no violation of the antitrust laws when the purpose of the unitization agreement is true conservation. Nevertheless fear of prosecution under the antitrust laws, unless legal absolution existed has invalidated many efforts to unitize.

The Sherman Antitrust Act[26] is the cornerstone of the antitrust laws and is pertinent. This act condemns: (1) restraint of trade; (2) monopolies. What is restraint of trade, and what constitutes a monopoly is left undefined by the statute.

Crude oil and its products constitute a sizeable portion of interstate and foreign commerce; millions of barrels moving daily in pipe lines, trucks and tankers. If operators enter into unitization agreements for the purpose of restricting the production in fields from which substantial quantities of oil move in interstate commerce, there is an effect on interstate commerce. Even though the unitization agreement relates to production, there may result a substantial economic effect on interstate commerce when the pinch at the well head reaches trade channels.

The recent decisions of the Supreme Court of the United States leave a definite realization that the Sherman Act reaches almost any activity which constitutes a restriction of trade.[27] The Federal antitrust laws apply not only to interstate commerce, but also any local or intrastate activity which asserts a substantial economic effect upon interstate commerce,[28] and it is immaterial that the commerce affected is in a small district.[29] If the effect is on interstate commerce, it does not matter how local the operation which applies the squeeze.[30]

Statutory authority is a prerequisite to unitization.

"Absent the express authority to do so, a mineral lessee would have no right to pool the interest in the estate retained by the lessor with other lessors."[31]

The courts have refused to substitute decree for statutory compulsion of unitization of leasehold and royalty interests. Regardless of the circumstances, loss of reservoir pressure, waste, prospective economies, will of the majority, the courts have never imposed, enforced or compelled unitization in the absence of statutory authorization. Regardless of the merits of unitization, which the courts well recognize, the general view is:

"Such testimony manifestly goes only to the wisdom of legislation authorizing compulsory unitization or to the issue of constitutionality if such a statute was enacted."[32]

Legal absolution is necessary. Unitization agreements entered pursuant to state statutes authorizing voluntary agreements are lawful under state laws, but no immunity under Federal antitrust acts is had unless the unit operations are pursuant to a compulsory state order, rather than an approval order.[33]

In conclusion, to implement unitization, if the manifest and real purpose of unitization is to prevent waste little fear exists of condemnation by antitrust acts. Statutory authority is a must, and where a state administrative agency issues an order compelling unit operation of an oil or gas field, the operation would not be in violation of the Sherman Act, since it would be effective not by reason of any agreement but as a result of the state order.

IX. FORMATION OF A UNIT

Any proposed statute would come into force only upon petition to a state authority by a required percentage of the owners. A monumental task of private organizing among the owners confronts the owners interested in unitization before a petition and agreement can be placed before the appropriate state authority. The success of this effort is the responsibility of management.

A management or steering committee must be formed. Acquiescence to the principle of unitization must be obtained from the bulk of operators, and in general, committees must be formed on: geology, engineering, law, tax, accounting, cost participation, legal, and so on, varying according to the circumstances. Eventually the petition and agreement must be presented to the state authority.

Depending upon the enabling statute and local circumstances, these documents will incorporate in one form or another the following, as well as many other items:

(1) legal description of the proposed unit area;

(2) description of the oil and gas reservoir to be operated;

(3) statement of engineering methods to be employed: pressure control, gas cap drive; water drive, or conservation, recycling, gas, air or water injection;

(4) a statement that the operations will increase ultimate recovery, result in conservation of natural resources, and avoid waste;

(5) a contention that the gain will exceed additional costs, if any, of the operation;

(6) an allegation that a general advantage will adhere to the owners;

(7) a plat of the unit area;

(8) the proposed unit plan;

(9) a list of unit tracts;

(10) provisions for organizing the unit and voting;

(11) provisions for an operating committee, the selection of an operator, and the determination of powers and responsibilities of each;

(12) effective date and accounting for equipment;

(13) allocation of costs;

(14) procedure or formulae by which each tract will participate in the production;

(15) a plan for abandonment and liquidation;

(16) definition of rights retained by lessees;

(17) clarification of the effect of unitization on leases and other contracts affecting the unit area.

X. THE PROPOSED STATUTE

The Interstate Oil Compact Commission has promulgated and recommended to all oil producing states, the passage of a unitization law and published its recommended version.[34]

The provisions presented in the Appendix as the basis of an appropriate unitization statute are tailored, in part, after the Oil Compact version. This law should remove any fear or any basis for claim of fear of any probable prosecution under the antitrust laws, and should provide for compulsory unitization subject to petition by a majority, and bring with it the conservation benefits of unitization, protection of correlative rights, operating economies, and still leave actual operational management in the hands of private enterprise.

The writer presents one further caveat: Pennsylvania is rich in a variety of natural resources other than oil,--coal for example. Administration of the proposed statute for implementing unitization must be handed to an independent oil and gas commission reporting to the Governor of the State for executive review, who in turn should bi-ennially inform the Legislature of the Commission's activities. To place responsibility in any existing unit of the State government would, because of divided responsibilities and loyalties, nullify the hope for success.

XI. CONCLUSION

The inequities of production under the Rule of Capture are repeating themselves in the development of natural gas reservoirs presently being found in Pennsylvania, and it has been demonstrated that they will reoccur should flush oil production again be found. It has been concluded that unit operation of gas and oil reservoirs is sound in principle, technologically advantageous and feasible, has economic and financial incentives, is defensible at law, is necessary in the interests of conservation and the protection of owners' correlative rights, and should be implemented. Accordingly, at this time, in advance of new discoveries, and before entrenched and vested selfish interests can stay progress, it is recommended that the State of Pennsylvania establish a Pennsylvania Oil and Gas Commission that will report to the Governor to implement a statute in the nature of that presented in the Appendix.

APPENDIX

PROVISIONS FOR AN OIL AND GAS UNIT OPERATION STATUTE

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 each primary oil and gas reservoir as a unit so 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, and pressure maintenance 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.

. . . . . .

A Pennsylvania Oil and Gas Commission is hereby established having jurisdiction and authority over all persons and property, Public and private, necessary to enforce effectively the provisions of this Act. The Commission shall report directly to the Governor of the State, who shall in turn make a bi-ennial report to the Legislature on the operation of the Commission in carrying out its responsibility, hereby assigned to it, of implementing the following provisions:

(a) An agreement, for any one or more of the purposes stated herein, by two or more persons owning, claiming, or controlling production, leases,

royalties, or other interests in some oil field, gas field, or oil and gas field, or in what appears from geological or other data to be the same oil field, gas field, reservoir, or oil and gas field, is authorized and may be performed and shall not be held or construed to violate any of the statutes of this State relating to trusts, monopolies, or contracts and combinations in restraint of trade. If the agreement is approved or its implementation required by the Commission, after notice and hearing, and upon a finding by the Commission that the agreement is in the public interest, and is reasonably necessary to increase the ultimate recovery or prevent the waste of oil or gas and to protect correlative rights, the agreement may provide for co-operative marketing of gas or of any product extracted from, or separated therefrom, wherever it is impractical to deliver such gas or product in kind to the several owners and the Commission so finds.

(b) Such agreements shall bind only the persons who execute them, and their heirs, successors, assigns, and legal representatives.

(c) The agreements of section (a) and (b) above shall deal with unit operation and other operations of a more extensive nature involving an entire field, pool, or reservoir.

(d) The Commission in order to insure maximum practicable recovery of underground resources of oil and gas, is authorized to regulate or require operations known as cycling, recycling, repressuring, pressure maintenance implementation of agreements made pursuant to subsection (a) hereof, or other operations similar in character, and it may require such operations if the order be made pursuant to the provisions of subsection (e) hereof. The order shall not be such as to occasion unnecessary drilling or producing operations.

(e) In the event a petition is filed with the Commission by persons claiming to be the owners or producers, or owners and producers, of at least sixty per cent (60 per cent) of the surface area of a field, reservoir, or

area (which may be a part of a field or reservoir) with respect to which unit operations are desired, stating that no regulation has been made as authorized in subsection (d) above, or that the existing regulation is or will be ineffective to prevent waste or to prevent a large amount of unnecessary drilling or producing operations, and declaring that the owners and producers and royalty owners are unable to agree upon unit operations, and requesting the Commission to issue an appropriate order, then the Commission shall give notice, and hold a hearing with respect to such petition. If, after such a hearing, the Commission finds that the owners or producers, or owners and producers, of at least sixty per cent (60 per cent) of the surface area of a field, reservoir, or area with respect to which unit operations are desired joined in the petition, and the Commission also finds that the petition substantially states the other facts as set out hereinbefore, then the Commission shall have jurisdiction and shall be authorized to require unit operations, including consolidation of interests, for one or more of such purposes stated in subsection (d), upon terms and conditions which are fair and reasonable under all circumstances. The Commission shall consider, among other relevant facts, the proposed plan or plans of operation which may be submitted, the evidence with respect to the facts in the field, reservoir, or area, and to the probable effect of the proposed operation upon the field or reservoir as a whole, if the proposed operations relate to a part of a field or reservoir, and generally upon the various properties therein or area thereof, and the cost of the construction and operation of any proposed plant or system. If the Commission decides that the evidence justifies the issuance of an order providing for unit operations for one or more of the purposes stated in the petition, it shall fix or approve terms and conditions for such unit operations which are fair and reasonable under all the circumstances and are in accordance with law, and authority is given to include provisions for the payment, and for

security for the payment, of the costs of the unit operations, which costs shall be limited to actual expenditures not in excess of those which are reasonable, including reasonable charge for supervision unless the persons affected agree otherwise. The Commission is authorized, for the purpose of carrying out an efficient program of operations, to provide in such order for the location, drilling, and operation of input and production wells without regard to property lines, and to provide for the distribution of production so that each tract, including a part thereof, within each consolidated area of the field, reservoir, or area will be allocated its just and equitable share of the total produced oil and gas for the consolidated area. If provision is not made in the order of the Commission for presuming production from each and every tract in each consolidated area by virture of production from one or more tracts therein, then a production share shall be fixed for each tract in the consolidated area, and it shall be presumed and considered that the production share fixed and made available to each tract in a consolidated area was produced by a well or wells located on that particular tract.

(f) Whenever it appears that the interested persons have agreed upon certain provisions or points for the regulation of the proposed program mentioned in subsections (d) and (e) hereinbefore, then such provisions or points shall be adopted by the Commission, subject to changes which are necessary to prevent waste and to conform with law, and the Commission shall give great weight to the recommendations made by a majority of the owners or producers, or owners and producers, of what appears to the Commission to be the productive area of the field, reservoir, or area with respect to which unit operations are desired.

(g) An order requiring unit operations shall not become effective for a period of thirty (30) days after the making of the order, and shall not then become effective if the owners or producers, or owners and producers, of forty

per cent (40 per cent) of the surface area of the field, reservoir, or area described in the order, shall file a written protest with the Commission setting out clearly the grounds for the protest, and suggesting changes which would be satisfactory to them. Upon the filing of a written protest, the Commission shall promptly determine from the evidence submitted at the hearing on the petition originally filed and from other evidence which may be submitted with the protest, whether the protest is sufficient to effect postponement of the effective date of the order. The determination shall be promptly announced. If the Commission feels that the protest is sufficient to effect postponement of the effective date of the order, then it shall promptly consider the protest and shall promptly take action thereon. The Commission may change the order in view of the protest, and may change any subsequent order properly protested, in an effort to make an order which will not be protested as provided for herein, but the order as changed shall not become effective for thirty (30) days after the date of the change, and not then if a protest as provided for herein be filed.

(h) No producer who refuses to comply, and who cannot be forced to comply, with an order of the Commission providing for such unit operations, shall permit any gas from his well or wells in the reservoir to escape into the air or to be wastefully burned, and the produced share for his well or wells in the reservoir shall be fixed so that he will not be permitted to produce more than his just and equitable share of the oil and gas in the reservoir, as such share is defined herein, and his operations shall be subject to all other applicable rules, regulations, and orders of the Commission.

. . . . . .

It is assumed that such an act would be part of a comprehensive act, or be tied into other acts, so that terms would be defined, such as "owner,"

"operator," "just and equitable share," "Commission membership," etc. The use of terms in the suggested act given hereinbefore would, of course, be changed if necessary in the light of such definitions.

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