VI. PHYSICAL PROBLEMS IN THE SEPARATION OF OIL AND GAS

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The more important benefits derived from separating oil and gas mixtures at the oil well are: (1) delivery of stable oil into the stock tanks; (2) clean gas available for gasoline plant and fuel; and (3) decreased fire hazard. If the oil and gas mixture flowed directly into stock tanks without being separated under the control of proper separating apparatus, the gas in leaving the oil would carry the lighter hydrocarbons along as a spray, which would result in a decreased volume and gravity of the oil. A publication of the Bureau of Mines on the Cromwell Oil Field in Oklahoma states that on certain leases where the oil and gas mixture flowed unrestrictly into ordinary tanks, "the ground and vegetation for hundreds of yards were soaked with oil, carried up through the risers and vents as a spray with the escaping gas, and scattered by the wind." But on other properties using oil and gas separators properly regulated no such loss of oil by spray occurred. If the greatest profit is to be made through the sale of oil and gas, some efficient means of separating them must be utilized.

One of the earliest gas traps on record was used in Oil Creek, Pennsylvania, about 1865, to save gas for fuel. A barrel was set on top of the flow tank, the oil and gas mixture entered through a hole in the top, the gas flowed out another opening in the top, and the oil dropped to the bottom. The oil went into the tank through a U-tube which provided an oil seal and prevented the gas from entering the tank. This early trap embodied the basic principle of gas-trap construction. There has been an evolution from this first, very primitive separator to the modern, complex, high pressure type which is so constructed as to gain maximum efficiency through use of certain physical principles. The present separators have fluid-level controls, pressure regulators, and contain scientifically designed baffling and flow systems. The following discussion will embody certain features found in some oil and gas separators on the market today and the physical laws affecting separation.

There are certain fundamental physical and chemical laws that apply directly to the problem of separating oil and gas mixtures. Philosophers and scientists have experimented with liquids and gaseous mixtures for centuries, and their findings and results are applicable to a certain degree in separating gaseous hydrocarbons from oil. Effect of gravity, centrafugal force, momentum, impingement, and adhesion and laws involving these are discussed in this paper.

Some Physical Properties

A great number of physical laws are involved when pressure is changed in a separator. In 1803 Henry discovered the law of absorption of gases, showing that the quantity of gas dissolved by a liquid increased directly as the pressure. This would give a straight line curve if pressure were plotted as the abscissa and amount of gas dissolved as the ordinate. This law is valid only if gas used is pure and uncontaminated by other gases with different physical properties. This condition is never present in separators because the gases asosciated with the oil are composed of numerous different hydrocarbons, all having different physical properties. The deviation from Henry's law is due to the selective solvent action of the oil for the different components of the gas. This is in accordance with Dalton's law advanced in 1807, proving that the quantity of gas dissolved by a liquid from a mixture depended upon the partial pressure of that particular gas; that is, each dissolved in the liquid as if all others were absent. In certain cases where chemical combination takes place between the gas and the oil, the laws of Henry and Dalton are not rigidly followed. The selective absorption and selective retention of the constituents of natural gas by oil is dependent upon the physical and chemical properties, pressure, and temperature of the oil and gas. Van Mills, Heithecker, Daw, Calkin, Parkhurst, and Beecher have analyzed different oils and gases and tested their respective solubilities. Natural gas containing large amounts of ethane, higher hydrocarbons, and carbon dioxide is very soluble in most oils, while gas containing oxygen and nitrogen is not soluble. The solubility of a gas diminishes with increasing temperature. The decrease can be calculated from Clausius-Clapeyron equation in cases where this may be expected to hold, but is of no practical importance in field separation problems.

Settling of Oil Particles Due to Gravity

A particle of oil will settle out of the gas stream due to the influence of gravity, if the upward velocity of the stream is of small magnitude. The velocity of the gas stream through the trap is governed by regulating the trap pressure and the volume passing through the trap. Pence states, (personal communication) "We have found that above five feet per second (152 c. m./sec.) very little separation occurs, and good separation is below two and one-half feet per second (76 c. m./sec.)." From a mathematical formula developed by Sir George Strokes the terminal velocity of drops of liquids falling in gases varies directly with the square of the radius of the drop and the difference in density between the liquid and gas and inversely with the viscosity of the gas. The viscosity of a gas is independent of the pressure. The terminal velocity is proportional to the square of the radius if other conditions remain unchanged. Greatest advantage due to settling in separators can be obtained when particles are large, and it is obvious that the settling process can not be used with minute particles. There must be a small differential between the terminal velocity of the smallest particle that will settle and the upward velocity of the gas before all particles will settle out. It is evident that difficulties will arise in maintaining large volumes of gas at low pressures in a sufficiently low quiescent state for particles to settle out.

Centrifugal Motion as Applied to Separation

Where centrifugal action is applied, the oil and gas mixture is introduced at a tangent, or may enter the separator radially and be deflected immediately upon entering. The mixture takes a whirling action due to high velocity at entrance to the separator. The advantages obtained are that the oil will adhere to the side of the separator and flow to the bottom while the gas will go toward the center and rise. This keeps small oil particles from forming which would be carried on with the rising gas. Additional service is gained in that the oil is spread over a great surface and can impinge on the side of the separator, along which it will run to the bottom.

Some have pointed out a disadvantage that a liquid with a free surface rotating as a whole will have its surface curved, its lowest point lying on the axis of rotation. The false level thus created may cause difficulty in regulating the fluid level control on the separator. This is largely overcome by placing vertical quieting baffles which should extend from the bottom of the separator to above the oil outlet.

After the greater portion of the oil has been separated from the gas in passing through the first compartment of the separator, the gas is further centrifuged by directing it tangentially into small concial and cylindrical baffles. The oil exerts a greater pressure toward the outside of the containing vessel than the gas, and, thus the oil is thrown out of the gas stream and impinges on the side wall; remains there due to adhension between the oil molecules and the side of the separator, while the gas rises and passes out the top. It is evident that the diameter of the inner compartment should be small, in order to gain the maximum force for removing the particles from the gas.

Impact Separation

Another physical principle employed is impact separation in which the respective momentums of the oil and gas particles are utilized. The momentum of the oil particles in the gas depends upon mass and velocity. The momentum of the relatively large oil drops to that of the gas is high and is useful in separation. The gas with entrained oil particles goes at high velocity into a chamber. where it is caused to take a sudden change in direction of flow. The oil particles having relatively great momentum are thrown against a baffle which changes the direction of flow. If the baffle is provided with a louver-like wall which will keep the separated oil from again coming into the direct path of the high velocity gas, a fair separation should result. This method of separating oil from gas is most efficient when the oil particles are large. Any means possible that will keep the oil particles large should be utilized. If the oil particles are in a very fine mist, separation by either centrifugal action or impact is practically impossible. This type of separation, which is not feasible from practical standpoint, demands an efficient enmeshing surface which will offer a great surface for the oil particles to cling to, and a means of taking the oil particles out of the gas. This is accomplished by rapidly circulating the gas through a porous medium as steel wool, steel shavings, or excelsior which offers a great contact surface.

Results of Separation

If oil and gas mixture flow into the stock tanks at atmospheric pressure, the gas leaves, carrying away the lighter fractions of the oil, because the dissolved gas in the oil reduces the surface tension of the oil and makes it easy for the lighter hydrocarbons to escape from the surface of the oil. If separation takes place under proper separating apparatus, the gas is removed from the oil and the surface tension of the oil is increased. The oil with the increased surface tension will hold the lighter fraction when placed in the stock tanks.

Conclusion

The physical laws mentioned are only a few that enter into the separation problem, and have been treated in only a general sense. Their application in solving individual problems is rather limited at present, because there are no practical field methods of obtaining accurate data on the uncontrolable factors such as diameter of the oil particles in the gas, densities, viscosities, and chemical properties of the oil and gas. As more general data are assembled, it is hoped that empirical formulae may be developed which will greatly enlighten separator engineers; but for the present, solving of separation problems depends upon a thorough knowledge of the physical laws, combined with practical experience and common sense.