X. WELL COMPLETION AND PRODUCTION PRACTICES

A. INTRODUCTION

After drilling is completed, the operator assesses the well's production potential. Usually logs are run to determine whether the well is capable of producing commercial quantities of oil or gas. Should the log interpretation be positive, the well will be completed and stimulated. If the well cannot be produced, the site will be restored and the well plugged and abandoned in accordance with the Department regulations. The completion rate of 85 to 95 percent for New York State gas wells is much higher than other states. However, most New York State wells are economically marginal from the national perspective.

B. PRODUCTION

After the well has been stimulated, a production wellhead is installed, the completion rig is removed. Producing wells and their associated facilities usually cover only 10 to 15 percent of the original drillsite. The existing regulations do not address the need for partial site reclamation between the drilling and production phases of a successful well. Operators are only required to remove waste fluids from drilling pits within 45 days after the cessation of drilling operations. Conscientious operators also immediately reclaim the other portions of the wellsite that are not needed to support production operations so the land can be returned to productive use. Any portion of the well site not needed for production equipment should be regraded as much as is feasible, so it is similar to the adjacent terrain. The topsoil that was set aside earlier should be replaced and vegetation should be re-established to stabilize the soil. If this partial reclamation is not undertaken, soil erosion and other associated problems may continue throughout the producing life of the well (30+ years) and have serious long term impacts on land and soil resources. **It is recommended that partial**

surface restoration after the cessation of drilling operations and disposal of drilling fluids within 45 days after the cessation of drilling operations be required for all wells.

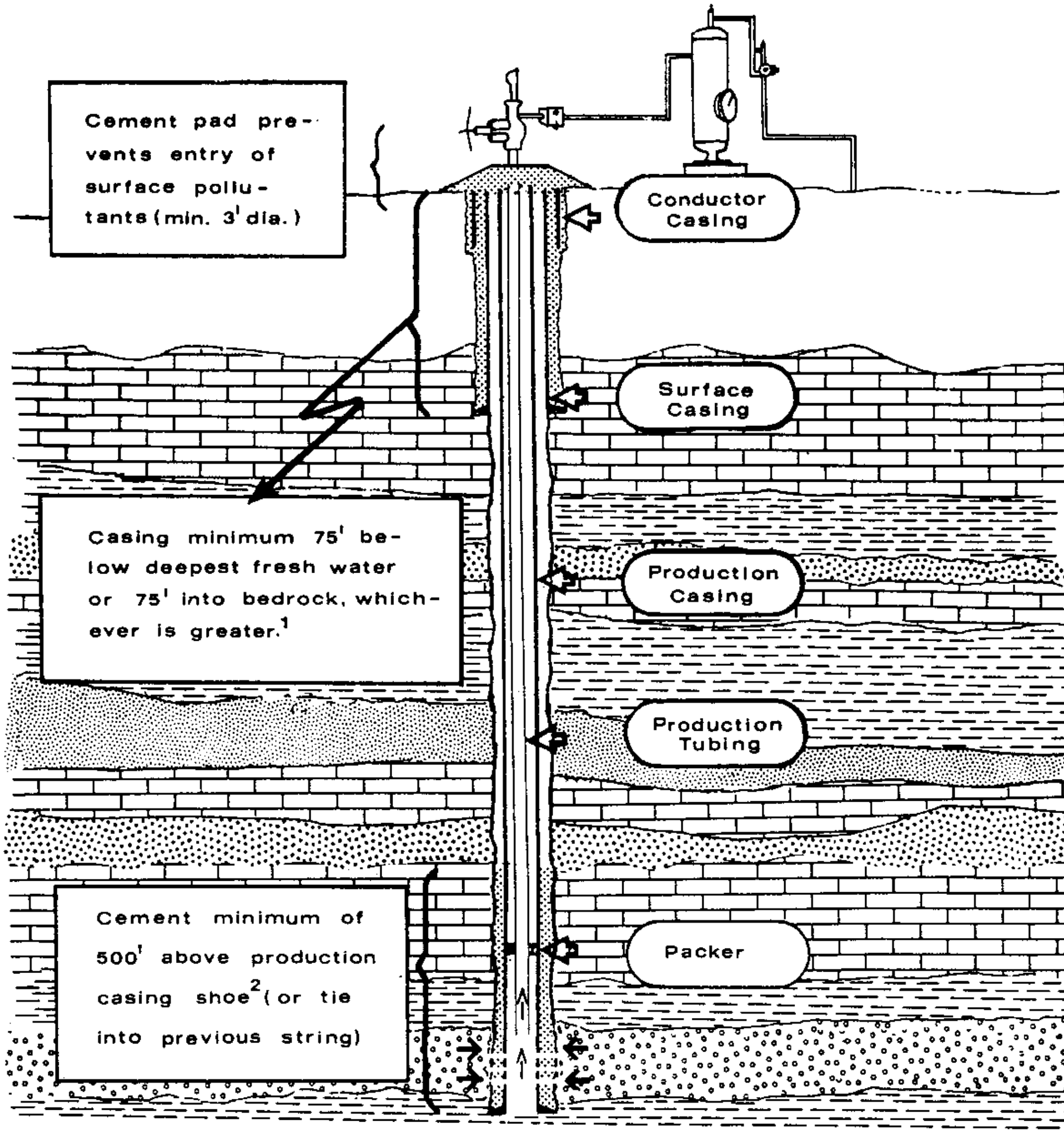
1. Gas Well Production

The production wellhead on gas wells is also called a Christmas tree. The Christmas tree is approximately 3' to 7' tall and consists of a series of fittings, valves and guages that provide control over the wellbore at the surface. The gas produced at the wellhead may contain light hydrocarbons, water vapor, sediment and other impurities. Since pipelines cannot accept gas with these impurities it must be treated. There are several types of equipment for treating gas, but separators with catalytic heaters and/or in-line waterdrip separators (desiccant dryers) are the kinds most common in New York State. The separator moves the gas through a series of extractors and into the gas line. Water and any other liquids accumulate at the bottom of the unit through gravity. Figure 10.1 represents a standard producing gas well.

Water in the gas in vapor form can also cause problems. As gas moves from the wellhead into the separator, its pressure drops. The drop in pressure causes the gas to expand which results in a drop in temperature. If the gas temperature drops to freezing, ice and/or distillates can clog the lines.

To prevent this, some operators suspend a vessel containing 5 to 15 gallons of methanol (antifreeze) over the wellhead so the methanol can drip into the production line and prevent freeze-ups. This system is less sophisticated, but is cheaper to install than a separator with a catalytic heater. The small catalytic heaters are usually positioned near the regulator or valves on the separator. Occasionally, operators will have to use a larger

FIGURE 10.1 - STANDARD PRODUCING GAS WELL



[1] However, the surface pipe must be set deeply enough to allow the BOP stack to contain any formation pressures that may be encountered before the next casing is run.

[2] Or 100' above the shallowest hydrocarbon zone, whichever is greater.

FIGURE 10.1

unit, known as a heater treater, for a high volume well. A heater treater warms the gas before it goes into the separator instead of just heating key parts of the unit.

Some operators prefer glycol gas dehydrators which approach the problem from a different angle. Instead of using heat or antifreeze to prevent water from freezing, the dehydrator completely removes the water.

After the water and other impurities are removed, the gas is sent through a meter and into the pipeline. The installation, operation and safety of gas pipelines is under the control of the New York State Public Service Commission which has detailed environmental regulations. DEC has regulatory control of gathering lines (less than 125 psi) which cross environmentally sensitive areas such as wetlands and protected streams. Gathering lines are non-Article VII lines but all non-Article VII lines must still comply with PSC safety regulations 16 NYCRR Part 255. The PSC has no jurisdiction over the oil gathering lines in New York State because none of them are high pressure (greater than 200 psi) or could be considered transport lines (going off the lease to distribution centers). Most of the oil in New York State is trucked or piped from stock tanks on the lease or central storage tanks to the refinery. DEC has safety and environmental jurisdiction of the oil gathering lines which transport the oil from individual wells to the production storage tanks located on or in close proximity to the lease.

a. Potential Environmental Impacts of Gas Production - Underground leakage of gas from the wellbore can be due to a poor cement job, insufficient casing, corrosion or a combination of other causes. When it does occur, however, it is often recognized by a build-up of pressure in the annulus. Operators are required to cement the production casing far enough up the well-bore to prevent the migration of any fluids and gases. However, if the operator failed to notice a minor gas bearing zone above the producing formation, cement might not seal it off. If not cemented off, the gas could migrate into the wellbore and increase the annular pressure.

A build up in annular pressure can be prevented by venting the annulus to the atmosphere and bleeding off the pressure. Some operators leave the annulus open continually which could raise minor air quality concerns. Some operators have installed pressure guages on the gas well annulus to monitor unwanted pressure build-ups. The annular pressure should not exceed the "normal" pressure gradient of the formation at the bottom of the surface pipe in the gas well. The following simplified formulas can be used to estimate the amount of gas pressure build-up which could occur in the annulus below the shoe of the surface casing before the formation at the shoe would be subject to breakdown.

$$f = P + K\,(Po - P)$$
$$P = Gp\,D$$
$$Po = S\,D$$

Where:

D = depth
f = fracture or formation breakdown pressure
Gp = pore pressure gradient
K = fracture gradient stress ratio
K is approximately equal to $\frac{\nu}{1-\nu}$ horizontal vertical stress ratio
ν = Poisson's ratio; $\nu \cong .3$ Middle and Upper Devonian Shales in New York
Po = total overburden pressure
P = formation pore pressure
S = total overburden gradient

Given:

D = 450 feet
Gp = 433 psi/ft. (freshwater)
K = .42 to .43 (very low ratio in rigid fractured rocks)
S = 1.0 psi/ft. (average)
Po = (1.0 psi/ft) (450 ft)
Po = 450 psi
P = (.433 psi/ft) (450 ft)
P = 194.8 psi
f = 194.8 + .42 (450 - 194.8) = 302 psi

Once gas escapes from the wellbore, under certain geologic conditions it can travel considerable distance either laterally or vertically and through natural fractures reach the surface or infiltrate a water zone. Gas in an aquifer can enter the water wells which tap it. The presence of gas in a water well presents a safety hazard. The gas can accidentally be ignited at the water tap or it can build-up inside the house in explosive quantities.

Methane, commonly known as marsh, sewer, natural or cooking gas, is a colorless, odorless and tasteless gas which is highly combustible. Methane is also slightly soluble in water and it becomes explosive in air at 5 to 15 percent by volume (NYS Department of Health, 1985).

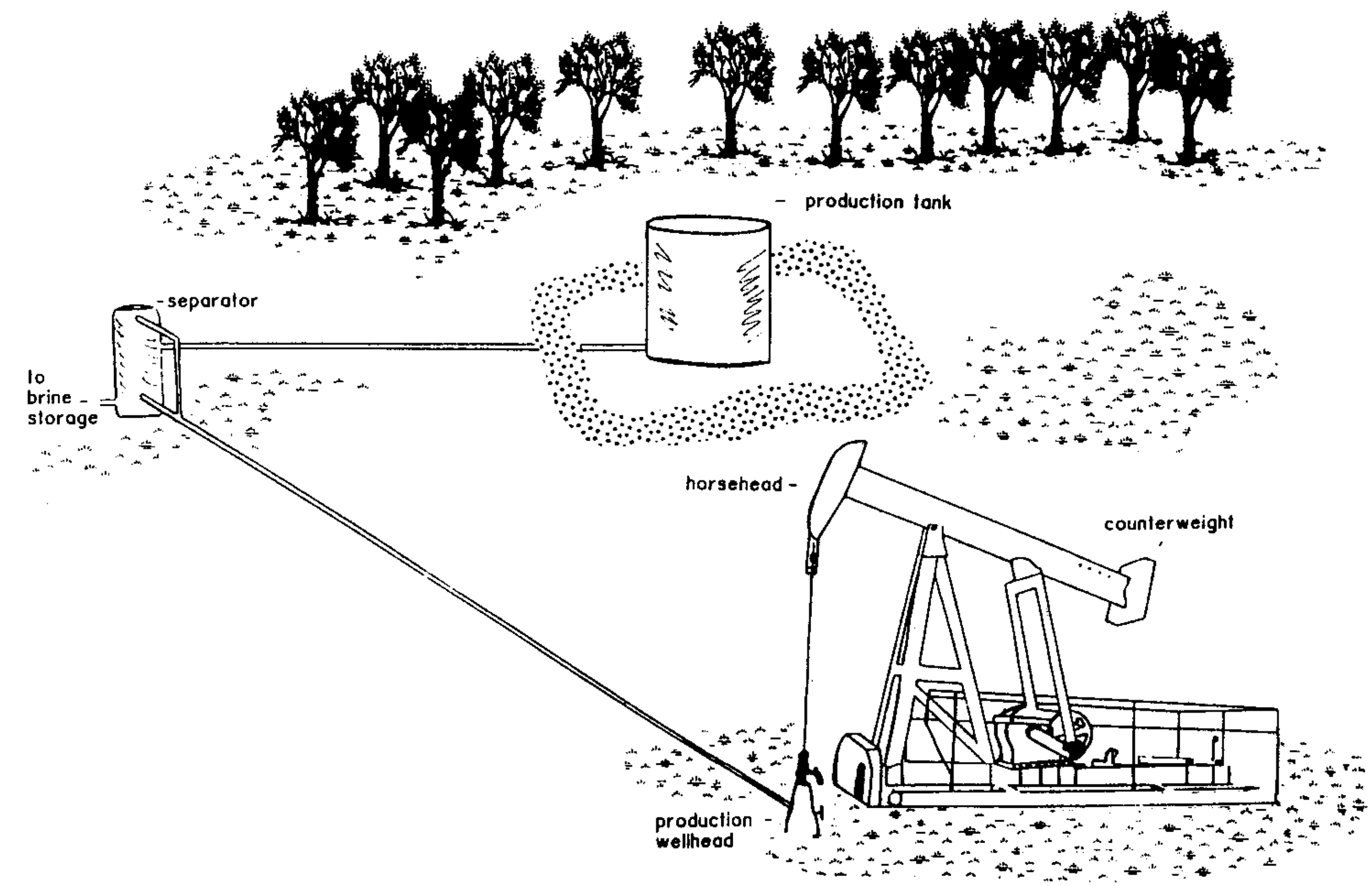
According to the New York State Department of Health, it has not been demonstrated that methane in drinking water produces any adverse health effects, but if water containing methane flows into a storage tank or poorly ventilated area such as a shower, adequate ventilation should be provided to prevent an explosion. However, explosion is not the only hazard associated with methane. Methane is an oxygen replacing asphyxient and if it is present in high concentrations, there is a danger of suffocation due to lack of oxygen (NYS Department of Health, 1985).

Methane is a natural metabolic by-product of the bacteria which live in the intestinal tract of most animals and many insects. The primary source of methane released into the atmosphere is biological, although urban areas also contribute to methane emissions mainly through the leakage of natural gas from utilities, cars, transmission lines, etc. The non-biological sources of methane account for the release of 30 to 60 megatons per year but this is only 8 to 15 percent of the total emitted to the atmosphere; biological emissions account for the remaining 85 to 92 percent (Science News, 1985).

Gas pollution of air and ground water is sometimes mistakenly blamed on gas wells. Gas that occurs naturally in wetlands, landfills and shallow bedrock has also been known to seep to the surface and/or contaminate water supplies. The highly fractured Devonian shale formation found throughout western New York, is particularly well known for its shallow gas pockets. In his 1966 report on the Jamestown Aquifer, Crain explained that natural gas could occur in any water well in the area "which ends in bedrock or in unconsolidated deposits overlain by fine-grained confining material. Depth is not of primary importance because pockets of gas may occur in the bedrock at nearly any depth." As an example he cited a water well that reportedly produced 9.5 million cubic feet of gas per day when it was first drilled. The gas flow declined rapidly and was unmeasureable after several days. This report concurs with the observations of members of the oil and gas industry who have drilled through minor gas bearing zones in the vicinity of this aquifer. Wetlands and landfills are also possible sources of methane contamination of groundwater. Depending on the amount of organic matter in the wetland or landfill, the depth of burial, time of burial and several other factors, sizeable quantities of gas can be generated. In fact, methane recovery wells have been drilled in at least three landfills in New York State for energy production, and methane has to be vented from many others (Phaneuf, 1987, personal communication #55).

Produced Brine - During gas well production, small quantities of formation water are brought to the surface with the gas. The separator removes the brine from the gas and sends it to a storage tank or brine pit. Operators in the past were allowed to use brine pits in association with gas wells for brine storage and disposal. Brine pits are not environmentally acceptable and are no longer permitted by the DEC or the Federal Environmental Protection Agency which considers them brine disposal wells. All existing brine disposal pits are scheduled for elimination within 3 years from June 1984. When production begins, the well may produce less than one barrel of

FIGURE 10.2 SUCKER ROD PUMPING SYSTEM



brine a day and frequently none. As the well gets older the volume of brine may increase up to five barrels a day. Large quantities of brine that must be disposed of also result from occasional maintenance operations such as swabbing. Most of this brine is disposed of by road spreading. Brine from the production stage poses the same kind of environmental concerns associated with formation water produced during drilling operations.

2. Oil Well Production

The equipment necessary for oil production is different from that for gas production. The production equipment on oil wells typically includes a pump, (Figure 10.2), a separator, and stock tanks.

Paraffin can be a major problem for New York State producers because it exists at a relatively high level in the oil. When the paraffin separates out of the oil it can plug the target formation, reduce production and clog equipment. Paraffin clogs in the small underground plastic flow lines attached to oil wellheads have also been known to cause the lines to rupture and leak. Therefore, paraffin treatment chemicals may have to be injected into the well as part of the production process.

When oil is produced from the reservoir it usually has brine and gas associated with it. Before the oil can be sold it must be treated. Most operators in New York State use a stock tank to separate the produced oil and water. The gas is drawn off the top of the separator and water and oil are drawn off the bottom. The brine and oil mixture is sent to a stock tank where it is separated gravitationally. The brine is then recycled for waterflood injection or stored for later disposal. The oil is periodically pumped out of the stock tank to central storage tanks and to the purchaser's refinery.

a. Potential Environmental Problems of Oil Production - Oil and brine can migrate from wells which do not have integrity. If the problem is due to a failure in the tubing or production string, losses in pressure and production volume will indicate remedial action is required. If migration is from an uncemented hydrocarbon bearing formation behind pipe, the problem can be detected by annular inspections. If the annulus is opened and the zones have sufficient pressure, oil and/or brine may flow to the surface. However, most formations in New York do not have enough pressure to bring a column of fluid to the surface. Instead, a column of fluid will develop to a specific height above the pressured formation. When the pressure exerted by the column of fluid equals the pressure of the producing formation, a static equilibrium develops. The depth of this subsurface fluid column could rise to the depth of a freshwater zone, and if the freshwater zone is not protected by surface casing, the oil or brine fluid column can enter the freshwater zone. Under these conditions, the source of contamination may not be recognized especially if this occurs in an improperly abandoned well. Fortunately, this situation is unlikely because of very low pressures in most producing formations.

The wells in the Bass Island trend are the only large volume oil wells in New York State. Because of their recent age and the strict conditions under which they were drilled and are operated, oil spills from these wells are rare.

Although oil spills are not common, when they do occur it is a serious problem because of the detrimental environmental impacts and the persistence of oil in the environment. Oil spills on surface waters are deleterious to aquatic life and can cause a fire hazard. As oil weathers, it sinks, and may kill benthic fauna and permanently alter the substrate.

The Department's existing regulations requiring a 50' buffer between wells and surface water bodies also provides some protection to surface waters. Although the existing regulations do not address the siting of storage tanks and other possible sources of oil pollution, DEC staff has the authority place restrictions on these well site facilities through permit conditions. For example, operators are required to install dikes around all oil storage tanks. The diked area around these tanks must have sufficient capacity to retain a minimum of 1 1/2 times the tank volume. **If an operator consistently has a problem with tank leakage or overflow, the Department can apply special permit conditions requiring the tank to be equipped with fluid level controls which will actuate an automatic shutdown of wells producing into the tank and prevent tank overflow. Fluid level monitoring and an automatic shut-down system may be specified as a permit condition or mitigation of a potential hazard in environmentally sensitive areas.** These controls can prevent spills if the truck that empties the tank is delayed by impassable roads or other causes.

In addition to its impacts on surface water quality, oil is also a concern to vegetation, soil and ground water quality. A coating of oil on vegetation can seriously damage or kill it. It can also cause longer term environmental damage by sterilizing the soil. A heavily oil saturated surface layer may come to resemble asphalt over time and effectively sterilize the soil for decades.

Overall downward movement of the oil is affected by: 1) oil composition, 2) soil permability, and stratification, 3) rate and duration of the spill. As oil moves downward through soil, some of it is adsorbed on soil particles and remains behind. In most spills, the volume of the oil is insufficient to reach the water table and the oil remains trapped in the soil (American Petroleum Institute, 1980). However, as rainwater later percolates through this zone, soluble oil components such as benzene, xylene and toluene (BTX) may still be flushed into the water table (American Petroleum Institute, 1980).

Crude oil varies in composition from state to state and even field to field. In general, however, BTX makes up roughly 2 percent of the crude oil produced in New York State (Oliphant, 1984, personal communication #51). Benzene is the most soluble of the three components and also the one considered to be the most dangerous. Benzene is a known carcinogen (U.S. Department of Health and Human Services) with a definite cumulative action (NYS DEC Division of Water, 1983c). Daily exposure to benzene by ingestion or inhalation of concentrations of 100 mg/l or even less will usually cause health problems if continued over a protracted period of time (NYS DEC Division of Water, 1983c).

Solubility of a compound is generally considered to be one of the major indicators of a pollutant's potential for groundwater transport (Vershueren, 1983). However, several factors can affect both the form and solubility of benzene, xylene and toluene once they enter the groundwater system.

All three compounds are subject to biotransformation by micro-organisms that may be found in soil and groundwater (Wilson and McNabb, 1983). The occurrence and extent of the transformation will depend on the type and numbers of micro-organisms present, the availability of the other nutrients they need, and the level of oxygen present (Wilson and McNabb, 1983). The initial concentration of the aromatics can also be suprisingly important. At low concentrations (roughly 10 ug/l) an organic pollutant may not be present in sufficient quantity to enrich the microbes that could feed on it. At concentrations of 1,000 to 10,000 ug/l, microbe metabolism of the pollutants can entirely deplete the oxygen and/or other nutrients that are needed (Wilson and McNabb, 1983).

The solubility of benzene, xylene and toluene can be greatly altered by subsurface conditions, resulting in an increase or decrease in their rate of groundwater transport. For example, the solubility of benzene decreases with increasing water salinity (American Petroleum Institute, 1978 and 1980). In contrast, the solubility of benzene and other aromatics can increase whenever two or more water soluble organic compounds are present.

When an oil spill does have sufficient volume to reach the water table, it will spread out in a layer and begin to move in the direction of groundwater flow (American Petroleum Institute, 1980). As the oil travels through the soil and down to the water table it is still subject to environmental weathering and degradation which is slow in reference to the human timeframe. (Ertugrul and Harkness, 1982). An oil spill may occur suddenly or a small leak may develop undetected. Slow, unsuspected leakage over a long period of time is probably the most harmful, since extensive damage may occur before it is noticed (American Petroleum Institute, 1980). Depending upon local conditions, oil polluted water may travel underground for 20 years before it enters a water well. Appendix 3 contains a generalized oil spill transport model.

Produced Brine - Brines produced in association with oil in western New York contain sodium, chloride and roughly the same types of heavy metals found in gas field brines. Small amounts of benzene, xylene and toluene may also be present in oilfield production brines. The production brines are typically disposed of by direct discharge under a SPDES permit or road spreading under a Part 364 Waste Haulers permit. **A suggested revision to permit requirements, in primary and principal aquifer areas is to require operators to have an approved brine disposal plan prior to drilling a well.**

Air Quality - The most common air quality problems, during the well production phase, originate from oil stock tanks. Distillates and fumes escaping from stock tanks can often be recognized by offset landowners or by anyone frequenting the area. The existing regulatory program does not specifically address the siting of production facilities. However, adoption of the proposed 150' setback from residences should help decrease these air quality impacts.

3. Production Reports and Conservation of Resources

Operators must submit annual production reports so the information is available to government and industry for planning purposes. In addition, the information is needed to check the gas-oil ratio of wells producing both types of hydrocarbons. The gas-oil ratio is one indication of whether the operator is following wasteful production practices. If the gas which supplies the reservoir transport energy is depleted too quickly, the oil in the reservoir may end up trapped in the rock. Therefore, the Department can regulate the production rate which is dependent on the well's gas-oil ratio to prevent waste of the State's non-renewable natural resources.

Though provisions exist under the current regulatory program [6NYCRR Part 556.8] to require a notice of intention for other operations such as deepening plug back and conversion operations, the requirement has been ignored to some extent because of confusion with regard to interpretation of the exclusions given to any work conducted in the existing production zone. It is critical that the Department have accurate records of the existing condition of all wells under its regulatory authority. **For this reason, it is recommended that a notice of intention and a permit be required from the Department for any operation that will in any manner alter the casing, permanent configuration, or designated use and status of a well. It is not the intention of this recommendation to require a permit for routine well servicing. Notification and possible permit will be required for the following actions:**

- **perforate casing in a previously unperforated interval for the purpose of production, injection, testing, observation or cementing**
- **redrill or deepen any well**
- **mill out or remove casing or liner**

- run and cement casing or tubing
- drill out any type of permanent plug
- run and set an inner string of casing or liner
- run and cement an inner string of casing, liner or tubing
- set any type of permanent plug (bridge, cement, sand, gravel, gel, etc.)
- repair damaged casing by means of cementing, placing a casing patch, swaging etc.

The only action of those listed above that would require a permit fee would be the deepening of a well because Department financial security requirements are based on well depth.