INDUCED GAS FLOTATION PROCESS PERFORMANCE

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INTRODUCTION

Separation of oil and water has been important in crude oil production historically. Some oils and produced brines do not mix with enough stability to seriously complicate handling. Water in oil emulsions are more common than the oil in water type, often called "reverse emulsions" or "O/W's". We will see, however, that there are problems in clarifying produced water, or more specifically removing trace amounts of suspended oil and solids from this water. This discussion will bear upon resolving the more stable dispersions of oil in water that are encountered in oilfield production practice. Therefore, it will concern clarification of that water by several methods including the induced gas flotation process (IGF).

GRAVITY SEPARATION

In fields that produce reverse emulsions or relatively stable dispersions of oil and/or solids in water it has been common practice to separate the two immiscible phases by adding chemical, agitating, then providing quiet settling time. The mechanism involved is chemical coagulation or coalescing of microscopic oil/solid particles into droplet size. This both increases size of particles and reduces the total number of dispersed particles. Agitation provides both distribution of chemical and the contact between individual micro particles that promotes coalesence. Depending on the oil droplet size achieved quiescent settling allows reasonably fast gravity separation - thus clarification of the water. Gravity separation follows Archimedes' principle and its speed is indicated by Stokes' Law. The time required is influenced by the square of particle diameter and proportionally by difference in density of the two phases. Depending on the stability of a dispersion, the effectiveness of a chemical and the time (volume) available for settling this method is an acceptable solution to the water clarification problem.

INDUCED GAS FLOTATION (IGF)

For several reasons it has become profitable if not essential to clean produced water better and faster than in the past. We have practical, economic, legal and perhaps survival pressures for improving our ability to clarify waters. Over the past decade, a process has been developing that provides such capability. In late 1969 Tretolite Div. sold the first WEMCO Depurator. This IGF machine and a chemical flotation reagent formed a process for cleaning produced water ahead of sand filters in a waterflood operation in California. Since then about 500 of these machines have been placed in petroleum industry service world-wide. At least four other manufacturers now make IGF units, and several companies of manufacturing chemists react organic chemicals for use in the process.

IGF increases the speed and effectiveness of separating reverse emulsions by using the same principles used in gravity separation but with an added concept. Chemical is used to increase size of suspended particles as in the gravity process. In addition, the machinery generates a multitude of gas bubbles and mixes them through the oil/water dispersion with considerable agitation.

The chemical also causes an attraction between oil droplets and gas bubbles that are brought into contact by the agitation. When this occurs, the speed of separation is accelerated tremendously because both the effective droplet diameter and its relative density are much more favorable as indicated by Stokes' Law. The oil droplet/gas bubble system (Fig. 1) has enormously greater size and much less density than the coalesced oil droplet, only, that we had working for us in gravity separation.

These oil/bubble systems rise rapidly to the surface and are skimmed over the side of the flotation cell as an oily froth. The result is that water left in the cell has been very quickly cleaned of dispersed material. The froth that is skimmed off collapses as the bubbles break. The resultant mixture of oil and water will readily separate by gravity because oil has been coalesced and the amount of skimmed water is only one to five percent of original volume. Skimmings are usually conducted back to the oil side of the production system. Effluent water from the IGF process is continously conducted to its end use or to further conditioning procedures. The process is usually a continuous operation.

FILTRATION

A variety of filters will also remove oil and solids from water quickly. Filtration removal mechanisms include absorption, flocculation, and straining. Chemical characteristics of this process play a role in its effectiveness also. Filter back-wash cycle or media replacement is governed by several factors including the amount of oil in feed water. Low contaminate level in the feed extends a filter run and improves economy of filter operation. In my experience, oil loadings of less than 40-50 ppm are required for practical satisfactory filter process operation.

The logical step wise method for clarifying produced (or other waste) water is:

1.) Gravity separation
2.) Induced Gas flotation
3.) Filtration

At times, it will be prudent to treat an effluent further but these three steps should complete the clarification process i.e., the removal of particulate/dispersed/suspended matter. Proper chemical treatment enhances each step. If effluent from step 1 is of satisfactory quality (considering intended use), there is no incentive to proceed further with clarification. The same logic holds true for step 2 or step 3. Starting at step 2 or 3 without providing step 1, or steps 1 and 2 penalizes the successive step unnecessarily. More important, it degrades final water quality and is ultimately less cost effective.

PERMIAN BASIN IGF

IGF machines have been put into service at three locations in Permian Basin oilfields. All are WEMCO Depurators used to clarify produced water for injection in waterflood projects. The oldest installation is a unit manufactured in 1972 that has a rated capacity of 100,000 B/D. It is in the North Cowden field where it was put on stream in October, 1978. In this system, sour water is separated from the production stream at free water knockouts and heater treaters. It is then pumped to surge tanks that feed the IGF machine. Effluent goes to clear water tanks, from which it is pumped into the injection wells. Skimmings are sent to a collection tank then back into the production stream at the FWKO's. Throughput averages about 52,000 B/D. Feed water quality has varied between 100 and 300 ppm dispersed oil - most recently between 100 and 225 ppm.

Effluent has varied from less than 10 ppm oil to more than 100 ppm. Recently it has been 50 to 90 ppm. This is not considered to be acceptable performance for this or any IGF machine in produced water service. The unit is being shut down for inspection and repair. Corrosion has perforated the top of the unit and there may be other damage to this machine. From past experience, I suspect a problem with chemical treatment also.

Another installation near Notrees includes a 25,000 B/D IGF unit. Flow scheme for this produced water is almost identical to the North Cowden system. This unit is also shut down at this writing. The problem is not with the flotation machine but in another part of the water side of this flood. In the past, water fed to the machine has varied from 50 ppm to 150 ppm oil and was colored black with iron sulfide. Effluent oil count has varied between 10 ppm and 30 ppm. Visual observations have shown that the iron sulfide had been removed. The process encountered a problem with excessive frothing in the machine. Cause was traced to a chemical paraffin dispersant treatment that is necessary on this lease to keep flow lines open and prevent bursting of these plastic lines when they become plugged with wax. The flotation machine problem was overcome by changing the flotation reagent and injecting a chemical de-foamer.

The only other IGF machine presently located in Permian Basin oilfields is a 38,000 B/D unit at Penwell. At this writing, this system is in final stages of hook-up. The flotation machine is scheduled for start-up in mid-February, 1981. It will be part of a waterflood system having the same general flow scheme as the two systems described above.

OIL PRODUCING INDUSTRY IGF

The general effectiveness of IGF machines in production practice throughout the free world may be somewhat better on average than the limited experience in West Texas. More of these machines are located in California and off our Gulf Coast than in other producing areas. There are a considerable number of units in Wyoming and the Latin American oil producing countries. A few are located in each of; Alaska, Alberta, Nigeria, the North Sea and South East Asia.

In California much of the produced water is fresh enough that it can be used as generator feed water in thermal stimulation. In the San Joaquin Valley, fresh potable water is at a premium because of the population density of the whole central and southern part of the state and because of the extensive demand for irrigation water. Produced water in the Kern River oilfield is actually used for irrigation of farm crops after oil has been removed. Produced water that is to be used for steam generator feed is clarified in a complete three step procedure. Settling tanks, FWKO's and heater treaters make the gravity separation; IGF machines handle the flotation step; and sand or mixed-media filters polish the water and provide a safety margin against oil that might get in water during an upset. Finally, this produced water is softened in ion-exchange resin bed softeners, dissolved oxygen is scavenged and the water is fed into oil burning steam generators. The gravity separated water may contain from less than 100 ppm oil to more than 2000 ppm oil. Effluent from IGF machines usually contains less than 5 ppm oil, sometimes zero ppm as determined by extraction methods.

At offshore platforms it is much less expensive to dump produced water overboard than to pump or barge it to shore for disposal. Environmental protection requirements vary in different locations; anywhere from a reported 10 ppm oil remaining to as high as 50 ppm oil being allowable. Characteristics of crude oil and crude/water dispersions vary but many at offshore Louisiana and Texas locations must be cleaned to 20-25 ppm in order to prevent formation of a visible sheen or slick downwind or downcurrent from the platform. As a consequence, many offshore operations clean produced water to somewhat below the 20-25 ppm level with IGF machines. Gravity separated water in the Gulf of Mexico varies from clean to carrying 200-300 ppm of dispersed oil. This range would cover most water produced with medium to light crude oils at any offshore location. North Sea water is cleaned to 15-20 ppm oil remaining. Machines in Lake Maracaibo clean produced water to 15-25 ppm after which it is filtered for waterflood injection. At Southeast Asia locations oil counts are being reduced to 15-20 ppm.

In Wyoming, much of the produced water is used in waterfloods. Part of it is cleaned to 5-10 ppm and put directly into the formation. Part of it is cleaned to 15-30 ppm by IGF then polished to less than 5 ppm by filtration before being injected. Some produced water is cleaned to 10-15 ppm with IGF and released to surface streams or marshes. Some water is handled this way in California, also. Currently, there is interest in thermal stimulation in Wyoming. At least one major company is in the construction stage of a steam drive project that will use produced water for generator feed.

We speak a great deal in terms of ppm oil while describing water quality. This is one valid description and it can be determined quickly and with good accuracy in the field. Suspended solids determination takes more time and requires laboratory equipment. Filterability studys also require time and special tools; it is however more relevant to the sub-surface injection operation.

CHEMICAL CONSIDERATIONS

Oilfield produced waters inherently contain both soluable and insoluable materials (chemicals) that are both organic and inorganic in nature. Some of them are surface active. Produced waters in different fields may vary considerably (fresh/briny, sweet/sour, TDS, temperature, etc.). In addition, different waters are sometimes mixed for surface handling.

In the practical consideration, ions (soluable chemicals) are not removed by gravity separation, flotation, or filtration. Soluable chemicals can, and do, strongly influence the surface chemistry that is important in an IGF system. It is common practice to inject additional surface active chemicals into produced fluids for one or more of the following purposes:

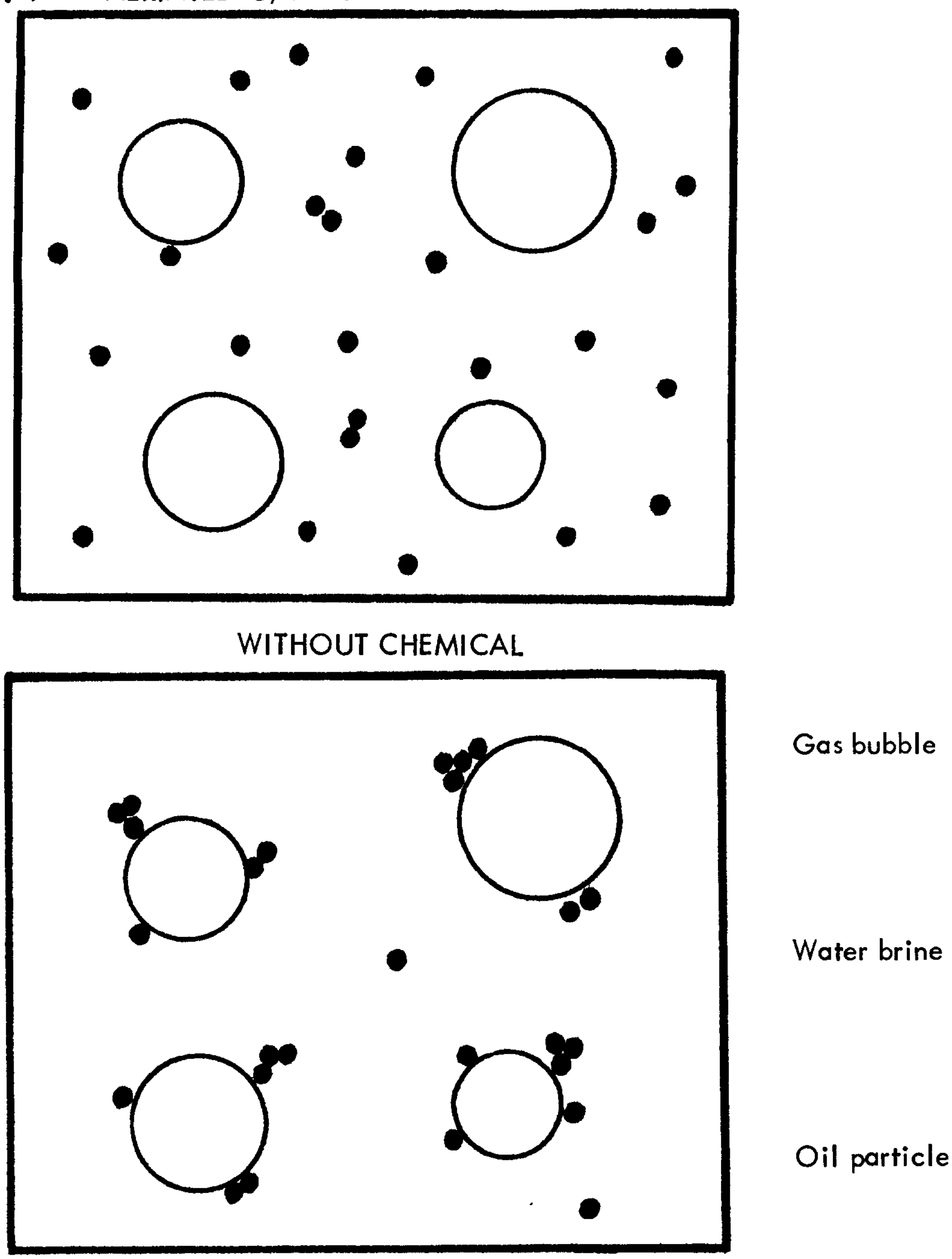
- Inhibit Corrosion/scale/wax
- De-stabilize emulsion
- Selectively wet/improve injection
- Enhance/inhibit foaming
- Improve filtration
- Aid flotation

The total chemistry of an aqueous system determines the effectiveness of an IGF process. At times, it is necessary to exert influence over as much of the chemistry of a system as can be controlled in order to obtain effective IGF. Hypothesis and presumption characterize much of the effort in this realm. We do, however, have experience and field or bench tests that allow us to achieve good results with this flotation process. IGF has become an accepted practice in clarifying oilfield produced water.

CONCLUSION

Produced water is sometimes "used" only in the sense that it is disposed of; but, much of it is re-used in pressure maintenance, water flooding, steam generator feed or for irrigation. The self interest of oil producers naturally concerns costs. This involves the protection of expensive injection/disposal wells and water treating equipment including; pumps, filters, softeners, steam generators with accessory machinery and instrumentation. In working to improve injectivity into deeper, tighter formations; and in providing maximum clarity in steam generator feed conditioning; producers have progressed beyond practical environmental considerations for waste water clarity. They are also making use of a resource once almost useless. The producers' self interest and the resultant technical and operational advances certainly go beyond any governmental mandate. I'm glad to have been part of the progress and I appreciate the innovative nature of the industry that provides our jobs and energy for our nation and the world.

Fig. 1 AERIATED O/W DISPERSION (MICROGRAPH)



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