Increase Oil Production and Reduce Chemical Usage through Separator Level Measurement by Density Profiling

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ABSTRACT

Three phase, horizontal, gravity separation vessels are the principle method of extracting oil and gas from unwanted produced water and solids prior to transportation. Traditionally, oil production separators have used separate single point transmitters for interface and bulk level measurement. This paper shows how a profile of the different layers as opposed to single point measurement can enable oil production and chemical usage to be optimized.

INTRODUCTION

In oil production, well fluids are routed to Production Separators. These vessels are long horizontal cylinders, typically three metres in diameter and up to 25 metres in length with a weir positioned close to one end. Well fluids enter the separator as a mixture of oil, water, gas and sand. As the fluids flow along the vessel they start to separate, under gravity, into their constituent parts. In order to have within-specification oil flowing over the weir and uncontaminated water at the water outlet, it is necessary to control the flow-rate. The only way to control this effectively is to accurately measure the levels of the various phases at the weir. Often, in a separator there is not a distinct interface, but rather a continuous graduation from one phase to another, e.g. from water to emulsion to oil, or

from oil to foam to gas. In these cases, phase identification by simple interface detection is difficult at best, and impossible with many conventional instruments.
To aid separation, expensive and environmentally unfriendly chemicals, de-emulsifiers, anti-foam agents and scale inhibitors are injected into well streams. The re-heating of fluids is also an aid to separation.

TRADITIONAL LEVEL INSTRUMENTS

Traditionally, production separator level measurement is done by using separate, single point instrument transmitters for oil / water interface and bulk oil level. There are numerous types of level instrument available, the most common being displacement systems, differential pressure, capacitance probes, microwave radar, ultrasonic, thermal conductivity and radioactive. Of these types probably only two, displacement and capacitance are suitable for interface measurement and have been extensively used until now. These two principles are examined in more detail here.

Capacitance Probes

Capacitance probes or similar admittance probes, operate by measuring electrical characteristics which will be dependent on the levels of fluids in contact with the probe. As an interface level rises on the probe, the measured admittance or capacitance changes as the probe goes from complete immersion in oil (0% on the interface level range), to complete immersion in water (100% on the interface level range). The problem with this method is that if the electrical characteristics of either fluid change significantly from the expected values, as will happen when different wells are introduced to the vessel or when emulsions are formed, then the admittance or capacitance measured will change. This will be interpreted incorrectly as a change in level resulting in misinformation being presented to the operators and inappropriate control actions. These instruments are only suitable where a well defined step change in densities is evident i.e. a step change from 100% oil to 100% water, in practice this is rarely the case

Displacement

Displacement instruments consist of a submerged body (displacer) suspended in the fluid, the weight of which is balanced by upward force exerted on it by a particular level of fluid. As the level changes, the force increases or decreases and this results in a small movement in the displacer which indicates the change interface level. The force exerted depends on the densities of the fluids involved, therefore if this characteristic changes significantly then this will be interpreted as a change in level. If the displacer is immersed in an emulsion it will give an output corresponding to the average density over its range hence giving a false interface reading. These instruments are again only suitable where a well-defined step change in densities is evident i.e. a step change from 100% oil to 100% water.

Problems & Issues

Most conventional instruments are installed either inside a vessel or in a bridle.
Due to the maintenance issues, i.e. a vessel would need to be isolated to access an internal instrument, generally instruments are installed in a bridle. Bridles are designed to duplicate conditions inside the vessel, but this is virtually impossible – there are usually only two tapping points, therefore fluids only at the density of the tapping points can enter the bridle and the temperature of the bridle is unlikely to be the same as the vessel. Moreover, there is a time delay between process changes in the vessel and in the bridle. The most significant problems with bridles are blockages - sand and wax deposits being the main culprits.
In oil production separators the lack of accurate measurement of the levels of oil and water as well as any sand, emulsion or foam means that facilities are often operated at less than their design capability. Incorrect separation information can cause a high concentration of oil to be carried through the water outlet, overloading downstream de-oiling equipment and causing oil slicks to be discharged to sea. It can allow a high concentration of water to be carried over with the oil phase and hence cause downstream knock-on separation problems. Foam carry over through the gas outlet can cause rapid build up in downstream flare-liquid knock out vessels. Sand accumulation reduces the working volume of the vessel and therefore its efficiency. All of these problems can result in unnecessary trips or production and environmental problems. As a result, output, quantity and quality, suffers; spend is high on effect chemicals; maintenance is intensive; and there is a high risk of discharging water containing oil into the sea.

PROFILER INSTRUMENT

Density profiling instruments can define all the fluids inside the vessel to a greater degree than conventional instruments. In place of the traditional two single points, oil / water interface and bulk oil level, an operator can see all the phases and the quality of the interfaces. This can enable the separator in-spec oil throughput to be increased and the chemical usage to be reduced. The Density Profiler measures the density and the extent of different phases within a vessel. It maps different densities of materials such as gasses, liquids and interface levels between phases within a vessel. These materials can be separated into different user variable density bands or phases. The interface of the various phases can then be calculated with respect to the vessel height.
The information provided is used to control the interface levels and to determine the effect of chemicals injected.

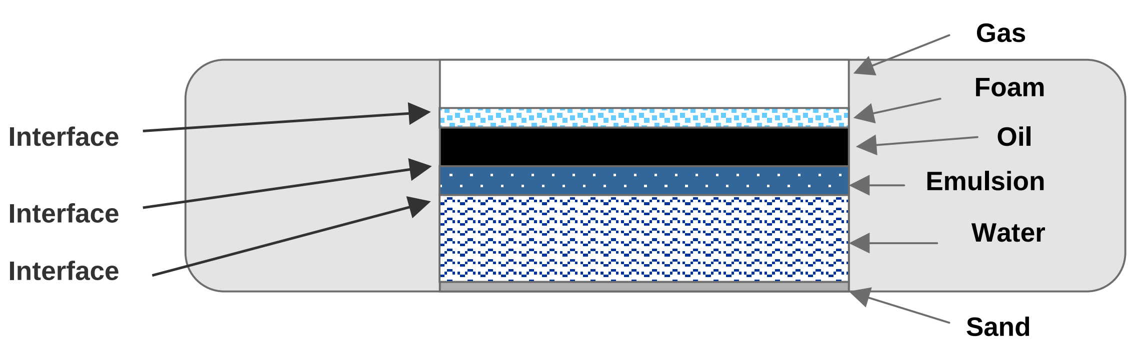

Figure 1: Profile based on different densities

THE TECHNOLOGY

A density profiler is housed in dip-pipes (sealed pockets similar to thermo-wells) installed within the separator through a single 6” flange.

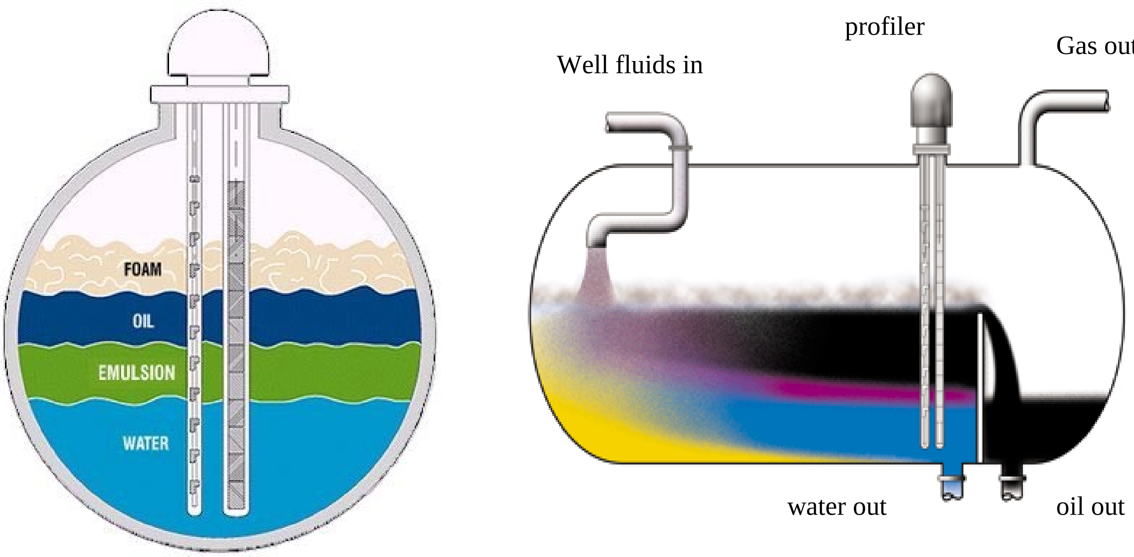

Figure 2: Views of profiler in vessel

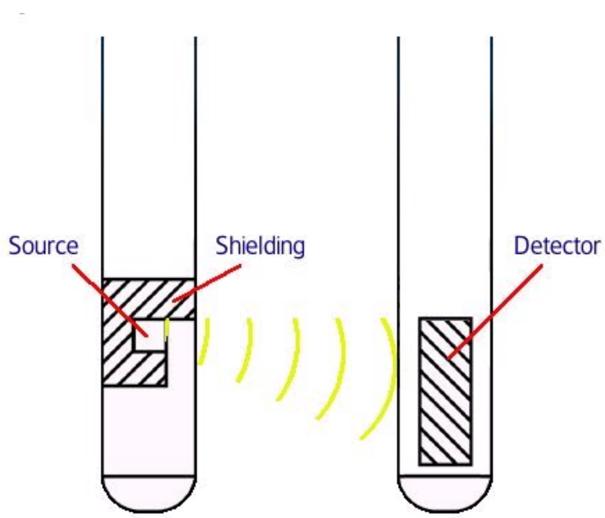

Figure 3: detail of single source and single detector

A narrow dip-pipe holds an array of Americium-241 sources, a low energy gamma emitter. The other dip-pipes hold radiation detectors made up of a vertical array of up to

96 Geiger Muller tubes, each one 28mm in height. Each tube is matched to the radiation source on the same plane. On the screen the fluid density at each 28mm channel is depicted.

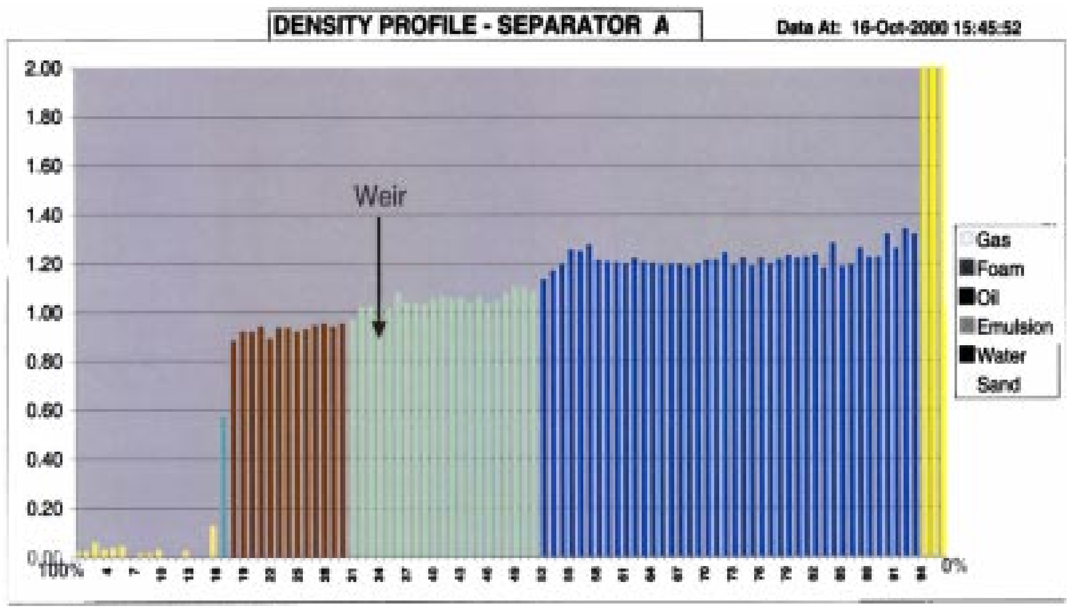

Figure 4: Actual screen dump of profile showing separator phase levels. 0% representing the bottom of the vessel and 100% the top.

Three dip-pipes project into the vessel, one collimator and two probe tubes. The narrower of these tubes holds a source-arming rod that contains a series of sources along its length. The rod is surrounded by a tube called a collimator which has small holes drilled in it at each source level. These holes direct a narrow beam of radiation towards a selected Geiger Muller (GM) tube in the probes, which are mounted in separate dip pipes.

Principle

Radioactive level measurement methods are normally based on absorption of radioactive radiation.
The absorption principle utilizes the attenuation of radiation passing through the process material increasing with increasing mass density. The difference in the absorption coefficient for radioactive radiation between gas, oil and water is sufficiently large to detect interface levels. Ion tubes (e.g. Gieger-Muller tubes) detect the radiation passing through the process material. An Ion tube is a gas ionization detector. An electric field is applied between two electrodes in a gas (e.g. argon) filled tube The radioactive radiation produces an ionization process in the gas and because of the electric field the free electrons and positive ions produce an electric current that is proportional to the amount of radiation.
A scintillation detector could measure absorbed radiation also. A scintillation detector, when subjected to radioactive radiation, emits light pulses which can then be detected by a photomultiplier.

The absorption principle was chosen for the density profiler and GM tubes for the measuring device as they offer much greater reliability than photo-multipliers and are more stable under temperature fluctuations. GM tubes are smaller in size and are not as expensive as scintillation detectors.

Titanium and Americium

Titanium was chosen for the dip pipes because it is transparent to the low energy 60KeV radiation emitted from the Americium sources. Americium-241 is the same sealed radioactive source as used in domestic smoke detectors. If steel dip pipes were used (which would be much cheaper than titanium) the radiation employed must have higher energy. To penetrate through steel would necessitate the use of the 660KeV gamma radiation produced by Caesium-137 sources. This high energy radiation is less sensitive to density changes, and this would make it necessary to employ a much larger source to detector separation, in the region of 500mm between the dip pipes, i.e. more than one vessel nozzle would be required. In addition, because radiation from Caesium is difficult to shield, the beam from each source would appear as a patch covering about 150mm vertical length on the detector assembly. This would mean that the vertical resolution, would be at least 150mm for a Caesium based profiler compared with 28mm for a Americium based profiler.
It is the use of low density, high strength titanium for the dip pipes, that make it possible to use low energy Americium-241 sources in the profiler. Americium is much easier to shield and allows a much smaller source to detector distance, this allows a single nozzle on the vessel and allows much improved vertical resolution, hence better density profile.

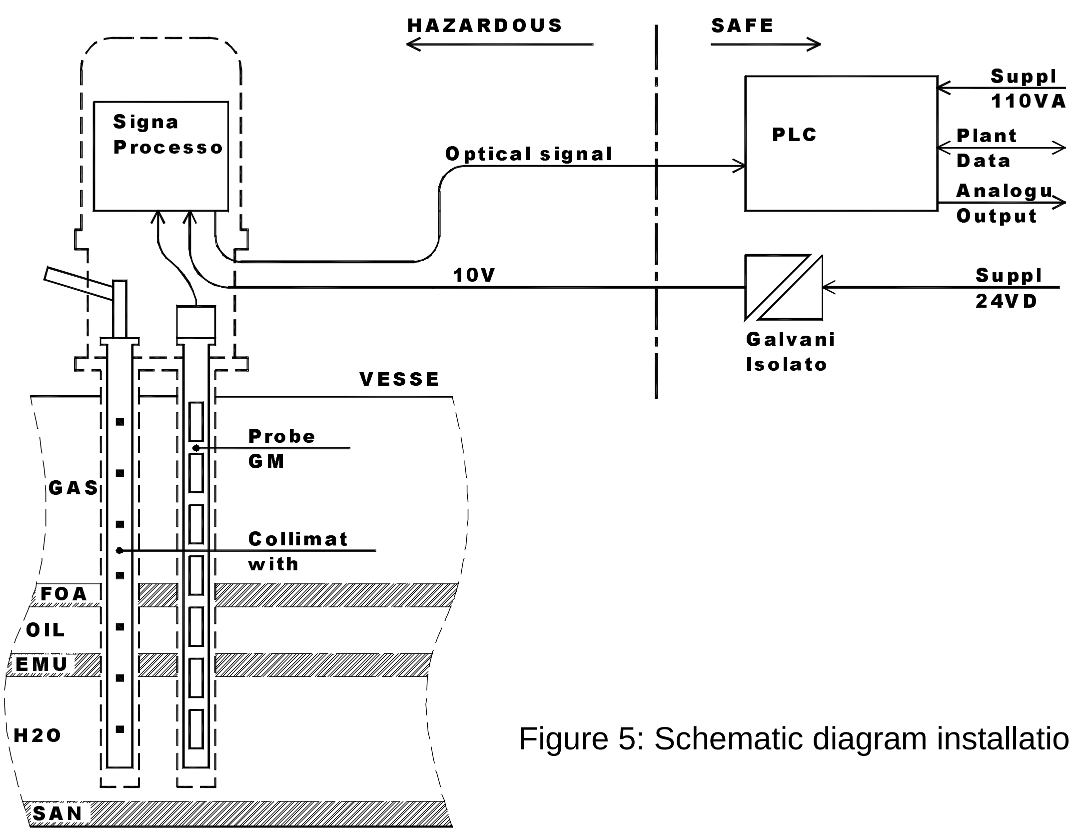

Figure 5: Schematic diagram installation

OPERATION

The material between the two dip pipes will attenuate the radiation, the intensity of radiation seen by a GM tube is related to the density of the intervening material. Each sensor produces a train of voltage pulses as its output signal. The rate at which these pulses are produced is directly proportional to the intensity of the radiation incident on the sensor and this is determined by the density of the process fluid at the sensor elevation.

Pulses from the GM tubes are counted in the Signal Processor unit mounted above the dip pipe assembly. The count period is user selectable so that the random nature of the radiation pulses can be smoothed out.

These counts are transmitted for analysis via a fibre optic link and an RS232 converter to a PLC that collects the information and calculates the density of the material for each individual GM tube. Thus a density profile of the vessel can be achieved. Density bands are allocated for each of the different phases, the top level of these phases can then be calculated with respect to vessel or instrument height. These heights and phase band thickness can then be used for control loop process variables.

CONCLUSION

Separation chemical usage can be reduced only when the effect of that chemical can be monitored directly on-line.

Increased oil production, i.e. throughput of a fixed facility, is only achievable by increasing the wellhead flowrates. Increasing wellhead flowrates will, by definition reduce the residence time. Reducing residence times will affect separation causing below-specification oil to be exported or recycled for subsequent re-separation. Residence times can only be reduced, and export oil remain within specification, when an accurate profile of the different phases of separation at the separator vessel’s weir is available.

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