Application Note
Vapor Recovery Units

Oil & Gas: Upstream

Introduction

Oilfield production has traditionally captured high value crude oil while venting or flaring lesser-value natural gas. Demand for natural gas combined with increasing environmental regulations have driven many upstream companies to implement Vapor Recovery Units (VRU's). In this paper we will examine how vapor recovery units work and look at the benefits of optical oxygen measurement in the vapors that are captured by these systems.

Separation Basics

Once drilling is completed, an emulsion comprising of oil, hydrocarbon vapor, and water is derived from an oilfield well. Vapor (primarily methane) and water are separated from the oil in the free water knockout (FWKO) drum (Figure 1). The remaining fluid, mostly crude oil, will go through a heated separator to further remove water and gas from the oil. At each point, pressurized gas can be captured and metered directly into the sales gas line. The remaining crude oil will be pumped to bulk storage tanks where it awaits shipment via truck to the refinery.

While the crude oil settles in the storage tanks a mixture of hydrocarbon vapors begins to fill the free space above the liquid. This vapor will include residual methane (CH_4) and a blend of longer chain hydrocarbons such as ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{12}), hexane (C_6H_{14}), and others. These heavier hydrocarbons are referred to as the natural gas liquids (NGL). Hazardous pollutants such as benzene, toluene, and xylene (BTEX) may also be present in the vapor.

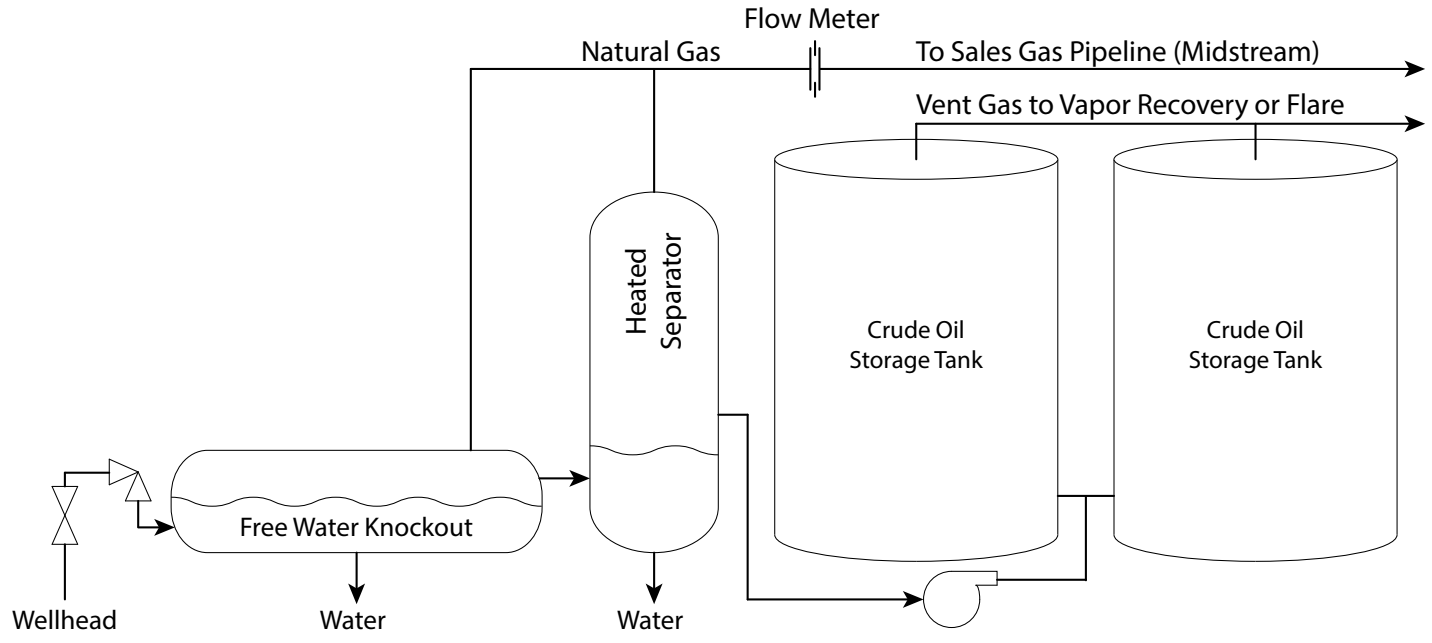
Vapor Recovery Fundamentals

The gas venting from the crude oil tank has traditionally been overlooked. Due to the NGL content this recovered gas often has higher BTU value than the methane captured at the upstream separators. These NGL's can be sold to petrochemical facilities, used for gasoline additives and marketed as high value specialty fuels. Capturing this gas is the job of the vapor recovery unit.

While the gas captured by VRU's help increase revenue; additional benefits include the reduction of possible environmental impacts from drilling. The BTEX gases mentioned above are carcinogens which should be captured and treated. Methane is a greenhouse gas with a much higher capacity to absorb heat compared to carbon dioxide. Capture of Methane prevents release into the atmosphere. Vapor recovery provides an alternative to burning off the gas at the well site. Reduction of visible flaring helps the public perception of the industry. Many states have introduced specific legislation for oilfield gas capture. At the national level, the US EPA Quad-O regulations have also begun to mandate vapor recovery.

Figure 1

Onshore Oilfield Separation & Storage



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How it works
Gas vapor is drawn off the crude tanks through the suction line manifold (Figure 2). The manifold supplies the gas to a scrubber. The scrubber captures any residual liquid entrained in the gas. Condensed liquid is pumped off the bottom of the scrubber back into the crude tank. Gas vapor is routed from the top of the scrubber to the compressor. The compressor boosts the pressure of the gas to allow flow to the sales gas pipeline. At this point, the gas flow is measured so it can be documented for sales purposes.

Compressor control is critical in VRU design. Storage tank pressure is used to turn on/off the compressor. To avoid damage to the tank pressures as low as 5-10" of water must be accurately detected to start the compressor. Vacuum conditions must be avoided as outside air can be drawn into the tank and, in extreme cases the tank can be collapsed by excess vacuum. Pressure fluctuations may occur when the tank is emptied of crude oil or the thief hatch on top of the tank is opened to observe tank level or take a sample of crude oil.

The Dangers of Oxygen
In all cases described above, air can enter the system. Air contains oxygen which is detrimental to the gas being captured by the VRU. There are many reasons to monitor for oxygen in the gas stream.

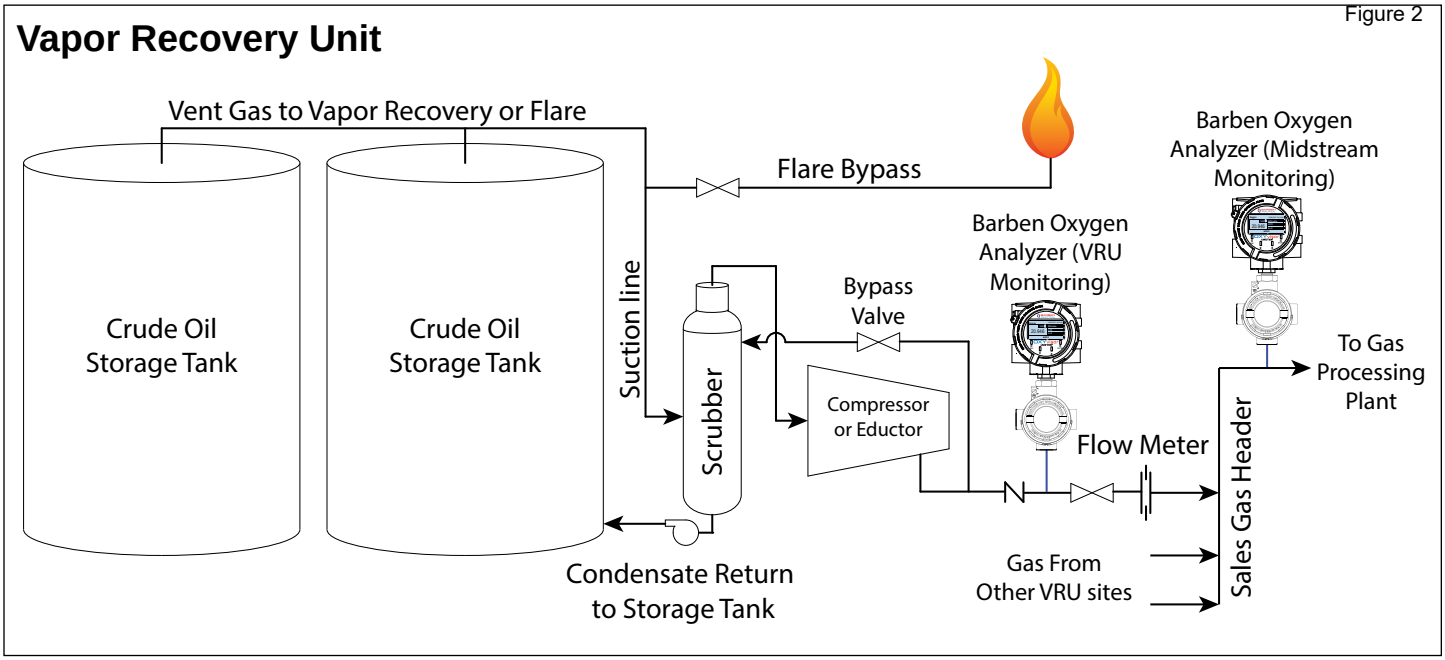
Corrosion - Oxygen combined with H_2S and CO_2 can form acidic condensation which harms piping.
Purification - Oxygen is detrimental to the amine sweetening process at the gas processing plant.
Explosive limits - Too much oxygen can allow the gas to become flammable.
Value - Air / oxygen in the gas stream reduces BTU content of the gas.

Midstream gas processing companies will have their own specifications for oxygen content in natural gas which is normally specified as part of their contract with the upstream producers. <10 Parts-Per-Million (PPM) is a common specification to meet interstate pipeline tariff requirements. When oxygen levels exceed 10 PPM then the gas will be blended with higher quality streams or possibly even rejected due to high oxygen content. When the gas is rejected due to high oxygen content it will be flared off to prevent contamination of gas from other wellheads. The end result for the upstream producers are lost revenues and even potential environmental fines.

Oxygen Monitoring Techniques
Oxygen measurement at the vapor recovery unit has been problematic for many sensing technologies. Both paramagnetic and tunable diode laser (TDLAS) oxygen analyzers are relatively new technologies. These products work well in % oxygen measurements but lose their accuracy at the low part-per million levels required for these applications. Electrochemical oxygen sensors (sometimes referred to as a "Clark Cell") have typically been used for these applications because of their ability to measure at low O_2 levels. Unfortunately these sensors have their own application issues.

Electrochemical oxygen sensors function similar to a battery using a cathode and a lead (Pb) anode in an

Figure 2



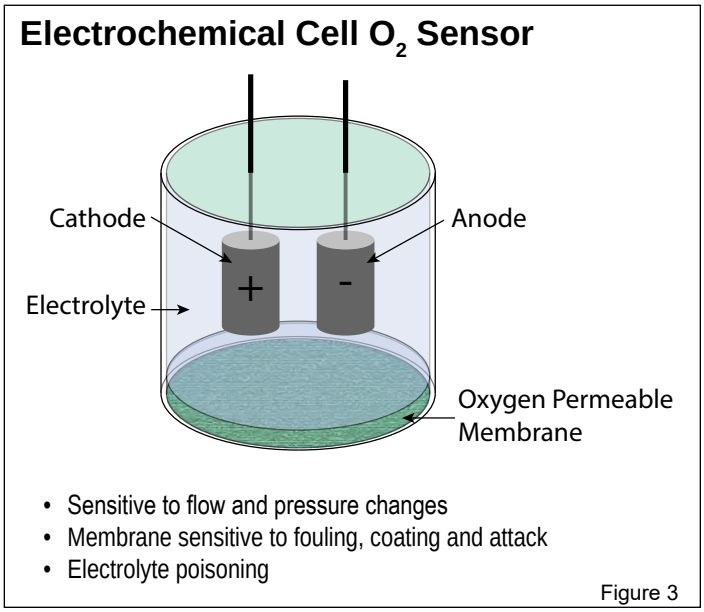
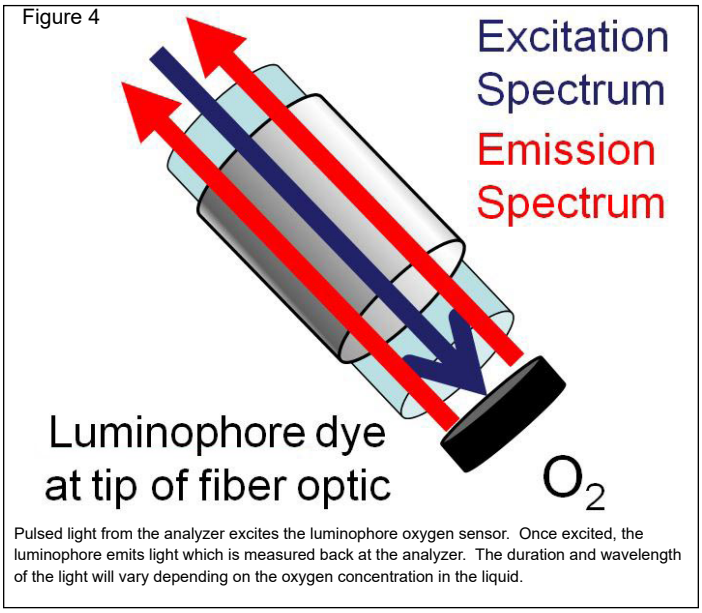


Figure 3



Pulsed light from the analyzer excites the luminophore oxygen sensor. Once excited, the luminophore emits light which is measured back at the analyzer. The duration and wavelength of the light will vary depending on the oxygen concentration in the liquid.

electrolyte solution. An oxygen permeable membrane allows oxygen molecules to enter the cell where they react with the electrolyte creating a voltage response to the changing oxygen level (Figure 3). H_2S and trace amounts of BTEX gases can poison the electrochemical cell causing drift, frequent recalibration and eventual death of the cell. Often a sample line scrubber is installed upstream from the electrochemical cell to remove the contaminant gases. The scrubber adds to the maintenance and complexity of the sample system. Condensed moisture can also create measurement error by plugging the permeable membrane of the electrochemical cell. Coalescing filters to block water and hydrocarbons must be used (and maintained) to ensure good performance. Over time, whether due to poisoning or age, the output of the cell begins to drop. As this occurs, the measurement will trend towards 0% oxygen. Such low readings gives the end-user a false sense of security that their vapor recovery unit has no outside air contamination in the gas vapors. In reality high levels of oxygen could be entering the pipeline and creating havoc with the downstream equipment.

Optical Oxygen Measurement - A New Approach

Fluorscent quenching technology is relatively new approach to gas phase oxygen measurement. This sensing technique relies on an oxygen sensitive luminophore dye coating exposed to the process gas. When the luminophore is excited by a blue light source it luminesces or "glows" back with a red light (Figure 4). The presence of oxygen at the luminophore has a quenching effect of reducing the intensity of this luminescent light as well as shifting the wavelength of the light. Both intensity and wavelength are used in conjunction with each other to accurately measure oxygen to part-per-million levels.

Advantages of optical oxygen measurement in vapor recovery applications include the following:

- Greatly reduced maintenance compared to competitive technology
- High measurement accuracy at low part-per-million oxygen levels
- No poisoning by contaminant gases such as H_2S
- Ability to measure in the presence of condensed moisture
- Optical sensor fails "high" thus preventing a false sense of security in the measurement

Figure 5



The **OXYvisor** Optical Oxygen Analyzer & BOS Sensor shown above.

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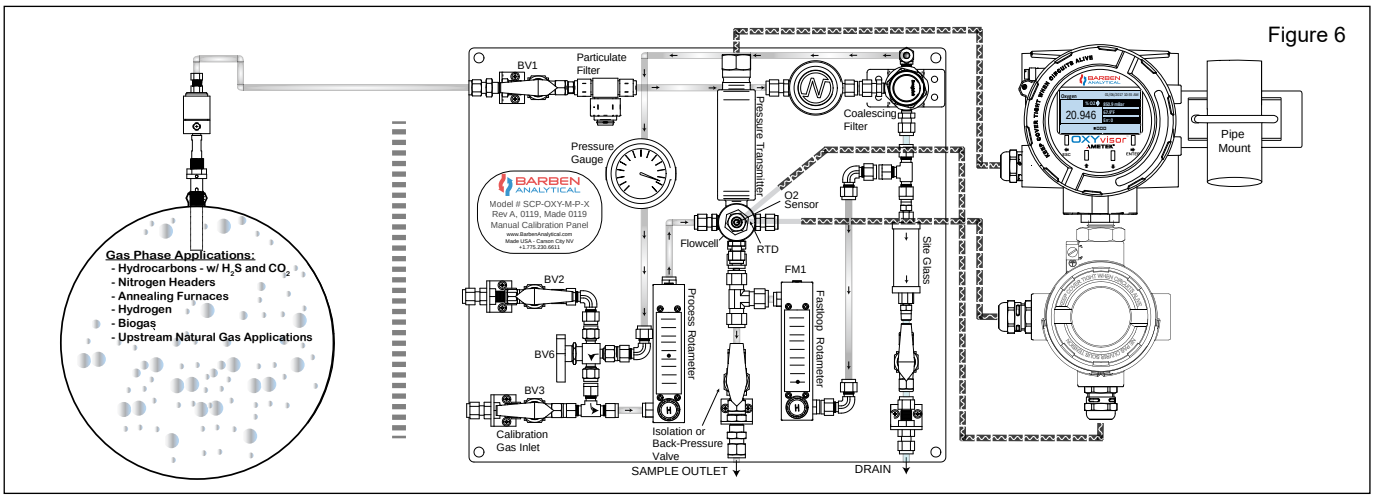
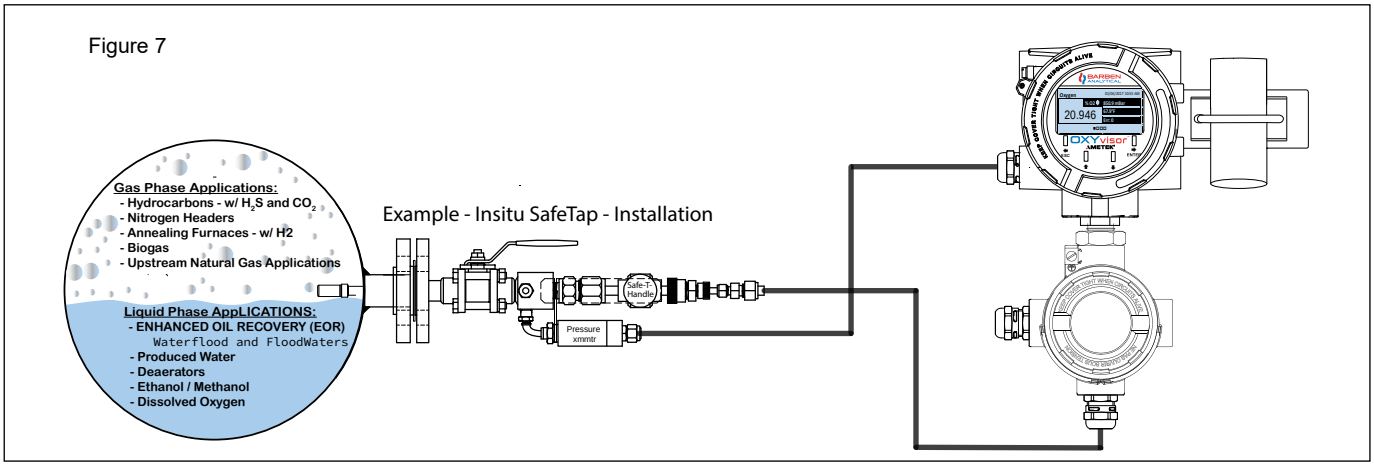
Barben Analytical recommends using our **OXYvisor** Optical oxygen analyzer in VRU applications. This product can be powered from conventional 120/240VAC or 24VDC (4 wire) for solar / battery powered applications. The BOS3 optical sensor with a range of 0 - 300 ppm is well suited for vapor recovery applications. The sensor can be supplied as a basic system that includes the OXYvisor Analyzer, BOS Optical Sensor and Flow Cell (Figure 5) or as a full sample conditioning panel which includes all of the ancillary tubing, valves, filters, and flow meters. The analyzer and related sensors ship pre-wired and mounted directly to the panel. The SCP panel can save considerable engineering and design work in new installations (Figure 6). The Insitu SafeTap Installation is shown in (Figure 7).

Figure 6



The SCP-OXY Sample Calibration Panel provides a convenient pre-engineered manual calibration solution for sample line installations.

Figure 7



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