Applications
- Exact location of gas entries in liquid-continuous flow and liquid entries in gas-continuous flow
- Multiphase flow analysis in wellbores of any deviation for production monitoring and remedial decisions
- Identification of water entries in high-rate gas wells
- Discrimination of condensate and gas entries
- Verification of bubblepoint pressure for single-phase fluid sampling

Benefits
- Direct measurements of gas and liquid
- Measurements independent of downhole conditions and fluid properties
- Flexibility of operations using conveyance by wireline, tractor, slickline or coiled tubing
- Enhanced reliability
- Improved efficiency and less deferred production time
- Real-time answers for quick decision making

Features
- Fiber optic technology
- Downhole measurements of gas and liquid optical properties
- Full wellbore coverage
- Borehole fluid image oriented using relative bearing measurement
- Combiable with other production services
- Data acquisition in surface readout or memory mode
- LWD tool shock specifications
- Real-time answer product with SPRINT® single-pass rate interpretation at wellsite

Shedding light with the GHOST Gas Holdup Optical Sensor Tool
With its unique ability to directly measure gas in the wellbore, the GHOST® Gas Holdup Optical Sensor Tool is the ideal production logging device for locating the first entry of liquid in a gas well or first entry of gas in a liquid well. The GHOST tool uses innovative sensing technology to enable direct detection and quantification of gas in multiphase flows. This new tool is part of the PS Platform® tool family. Its measurement complements the traditional production logging measurements to give even greater confidence in production logging answers. Regardless of completion type or wellbore deviation, the GHOST tool, with fiber optic technology, literally sheds new light on production logging.

Using fiber optic technology
The GHOST tool uses the optical properties (refractive index) of fluids to differentiate gas from liquid downhole. Within the tool body, light is emitted from an LED source, travels along an optical fiber protected from the downhole environment and arrives at a needle-size probe manufactured from sapphire. When the light reaches the tip of the probe, some of it is transmitted through the wellbore fluids, while the remaining light is reflected and travels back through the optical fiber. The reflected light travels through the Y coupler to a receiving photodiode and is converted into an electrical signal. The amount of reflection depends on the refractive index of the medium (gas or liquid) and the shape of the probe. The probe is designed so that the amount of reflected light is much greater when the probe is in gas than when it is in liquid.

In air or gas almost 100% of the light is reflected. In liquid less than 40% of the light is reflected. Because the properties of gas and liquid are so different,
it is relatively easy to distinguish the two. Although the measurable difference in the refractive indices of water and hydrocarbon liquids allows determination of three phases, the relative optical properties are not always distinguishable in a flowing well environment.

Making independent measurements for greater accuracy

Local measurements of the four optical probes are made independently. While logging, the probes pierce impinging droplets of gas in a liquid-continuous phase or liquid droplets in a gas-continuous phase. A threshold set by the software or by the field engineer determines the gas and liquid levels from the raw waveform. All peaks above the threshold are considered gas, and all those below are considered liquid. This direct gas and liquid holdup measurement is completely independent of downhole temperature, pressure, salinity, density, dielectric properties, viscosity, resistivity, nuclear interaction, phase velocity and well deviation. This independence assures accurate answers without the need for downhole calibration or environmental assumptions.

The percentage of gas at any given depth, called gas holdup, is the ratio of time spent by the probe in gas to the total scanning period. For a qualitative indication of phase entries, the bubble count (number of bubbles arriving during the scanning period) is computed for each probe. Values for both the ratio and count are transmitted uphole, and averaged outputs for holdup and bubble count are computed at surface from each of the four individual probes.

Defining three-phase production

In a well producing gas, oil and water at surface, the GHOST tool was run to determine the downhole contribution and depth of entry of each phase. From data obtained in a single descent, the SPRINT real-time answer product defined the amounts of gas, oil and water entering the wellbore and identified the entry points.

The first oil entry (A) was identified at the very bottom of the well using the bubble counts from the GHOST sensor.
and the FloView holdup tool. The large three-phase production entry (B), also located using the GHOST and FloView bubble counts, confirmed that only the top portion of this perforated interval was producing. The GHOST tool was able to determine that the top interval (C) was producing oil and gas with no water; its small probes were not adversely affected by the turbulent, high-velocity production. Only by using a combination of the GHOST and FloView holdups was a three-phase analysis possible.

**Calculating water cut**

A well with increasing gas/oil ratio shared a multiphase separator with three other wells, making it impossible to determine water cut from each well. The PS Platform tool string and GHOST sensor were run to

- determine the flow profile from the various perforation intervals
- calculate the water cut from this specific well
- determine if there was a dry gas entry into the wellbore
- provide information for a decision on adding perforations to the bottom interval.

The SPRINT wellsite product

- determined the flow profile and calculated the water cut
- identified a gas entry at the top of the upper perforation interval
- indicated the bottom perforation interval was producing only oil.

A log recorded after the new perforations confirmed the bottom interval was producing only oil, and the flow was diverted to a single separator. The gas/oil ratio measured by the GHOST sensor agreed with the log to within a few cubic feet per barrel. This information was used to redesign the field production strategy.
Identifying condensate production in a high gas/oil ratio environment

The gas disposal and reinjection system was operating at maximum capacity for this well, yet more oil production was required. The well was producing 5500 BOPD with a gas/oil ratio of 9600 scf/STB through a mono-bore completion consisting of a 7-in. liner and a tapered tubing string of 5.5 to 7 in. Velocities exceeded 8 m/s, and the flowing wellhead pressure was 1430 psi.

The GHOST tool was run in combination with the PS Platform string to determine the profile of the hydrocarbon production and discriminate the gas and condensate, which was critical to reservoir management. Before introduction of the GHOST sensor, identifying gas in a condensate system was difficult because of the small contrast in fluid density and lack of temperature variation.

The GHOST data determined the upper interval was producing at the original gas/oil ratio but the lower interval was experiencing lean gas breakthrough with a ratio more than three times that of the original. Most of the gas was coming from the upper 400 ft of the lower interval—just the opposite of the expected results.

A 90-ft interval of the upper section was reperforated and added 400 B/D of incremental oil production without increasing the gas/oil ratio at surface. This increase repaid the job and surveillance costs in less than two months. Without the GHOST measurement, this optimization would not have been attempted because of the danger of reperforating intervals with high gas/oil ratios.
This is one of many possible PS Platform configurations recommended for multiphase flow analysis.

GHOST Tool Specifications

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Max OD</th>
<th>Max temperature</th>
<th>Max pressure</th>
<th>H₂S</th>
<th>Measurement accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.1 ft [2.18 m]</td>
<td>Collapses to 11¼ in.</td>
<td>300°F [150°C]</td>
<td>15,000 psi [1035 bar]</td>
<td>Exceeds NACE standards for H₂S resistance</td>
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<tr>
<td>Holdup</td>
<td>7% with probe protector; 5% without probe protector</td>
<td></td>
<td></td>
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<tr>
<td>Relative bearing</td>
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<tr>
<td>Caliper</td>
<td>±0.25 in. [5 mm]</td>
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