What Makes an ICD Truly Autonomous?

Simply saying an ICD (inflow control device) is autonomous doesn’t mean it’s true. Putting nozzles in series does not make an ICD autonomous; it must do more. To be autonomous, the flow characteristics inside the device must actually change. An autonomous ICD must have a geometry that alters the flow path preferentially restricting the flow of unwanted fluids.

An autonomous ICD has the ability to respond to changing well conditions without any action by the operator. When unwanted fluids reach the wellbore, the autonomous ICD changes the way the fluid is moving through the device. This results in increased restriction to flow while other zones producing oil continue production with minimal restriction.

*Per Advanced Well Equipment Standardization Group (AWES)*
INCREASE WELL NPV WITH AICD COMPLETION

Advanced Completions Modeling Capabilities

Proper design and modeling to address potential knowns and unknowns and life of the well conditions are critical for optimizing ICD and AICD completions. Characteristic equations, based on full scale flow data, have been created to describe flow performance. Halliburton has embedded EquiFlow AICDs performance into a suite of numerical simulators including NETool™, QuikLook®, and Nexus® software to model everything from near-wellbore performance to full field evaluation, and perform dynamic coupling with other industry reservoir software as needed.

NETool is a steady-state wellbore simulator capable of modeling multiphase flow from near-well region, passing through complex completions up to the wellhead. Dynamic wellbore/reservoir coupling with several industry-standard reservoir simulators is available for recovery prediction and optimization of the entire field.

QuikLook software is a transient analysis that allows long-term study of the AICD completion in a reservoir.

Nexus software is a full physics simulator that couples flow models across the surface and subsurface to accurately model multiple reservoirs and their interaction with surface facilities.

Applications

When water/gas breakthrough occurs, the EquiFlow AICD significantly restricts unwanted fluid production from that specific section while promoting increased oil production from other compartments in the completion. It is installed as part of the completion string and is highly beneficial for wells needing production to be balanced over long horizontal reservoirs or in formations with high permeability variances. A through-tubing solution using an AICD inner string is also available. Typical applications include wells experiencing heel-toe effects, breakthrough of water/gas, permeability differences, and water or gas challenges in horizontal or layered reservoirs.

An EquiFlow AICD comes in four different versions that address viscosity oil ranges from very light oil to very heavy oil.

**EquiFlow® AICD Specialized Designs**

<table>
<thead>
<tr>
<th>Design</th>
<th>Oil Viscosity Range</th>
<th>Oil Type</th>
<th>Fluid Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range 1</td>
<td>0.3 – 1.5 cP</td>
<td>Very Light</td>
<td>Water and Gas</td>
</tr>
<tr>
<td>Range 2</td>
<td>1.5 – 10 cP</td>
<td>Light, Medium</td>
<td>Water and Gas</td>
</tr>
<tr>
<td>Range 3</td>
<td>3 – 200 cP</td>
<td>Light, Medium, Heavy</td>
<td>Water and Gas</td>
</tr>
<tr>
<td>Range 4</td>
<td>150+ cP</td>
<td>Heavy, Very Heavy</td>
<td>Water and Gas</td>
</tr>
</tbody>
</table>
Range 1 and Range 2

» Fluidic sensor highly sensitive to fluid properties to differentiate from very light oils
» On/off switch upon water or gas breakthrough
» Bi-stable switch: two stable flow patterns, which can freely alternate depending on the produced fluids
» Flow pattern has direct path to the exit resulting in low pressure drop
» Second divergent path induces spinning, thus increasing pressure drop and reducing flow rate

Flow Reduction EquiFlow® AICD Range 2 vs Nozzle ICD

Comparison of an EquiFlow AICD to a nozzle ICD at 30 psi pressure differential, 20 cP oil, 0.6 cP water

Range 3 and Range 4

» Gradual change in restriction of unwanted fluid
» High pressure drop for low viscosity fluids and low pressure drop for high viscosity fluids
» Two possible paths: tangential path to induce rotational motion/spinning or multiple radial passages toward a direct exit, which can freely alternate depending on the produced fluids

Flow Reduction EquiFlow® AICD Range 3 vs Nozzle ICD

Comparison of an EquiFlow AICD to a nozzle ICD at 30 psi pressure differential, 20 cP oil, 0.6 cP water
Available Sizes

<table>
<thead>
<tr>
<th>Design</th>
<th>Basepipe Size (in.)</th>
<th>Max OD (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range 1 and Range 2</td>
<td>4 1/2</td>
<td>5.875</td>
</tr>
<tr>
<td></td>
<td>5 1/2</td>
<td>6.875</td>
</tr>
<tr>
<td></td>
<td>6 5/8</td>
<td>8.000</td>
</tr>
<tr>
<td></td>
<td>6 5/8</td>
<td>8.290</td>
</tr>
<tr>
<td>Range 3 and Range 4</td>
<td>2 7/8</td>
<td>3.795</td>
</tr>
<tr>
<td></td>
<td>3 1/2</td>
<td>4.670</td>
</tr>
<tr>
<td></td>
<td>4 1/2</td>
<td>5.670</td>
</tr>
<tr>
<td></td>
<td>5 1/2</td>
<td>6.670</td>
</tr>
<tr>
<td></td>
<td>6 5/8</td>
<td>7.830</td>
</tr>
</tbody>
</table>

None of the EquiFlow® AICD designs have any protrusion into the basepipe

**FEATURES**

» Operates autonomously
» No moving parts, electronics, dynamic sealing surfaces or connections to the surface
» Functions as a passive ICD prior to water/gas breakthrough
» Requires no intervention
» Functionality or efficiency not affected by downhole orientation
» Each device functions independently for precise response to the reservoir
» Allows injection of reservoir treating fluids
» Self-regulating depending on produced fluids

**BENEFITS**

» Facilitates accelerated recovery
» Maximizes ultimate recovery
» Increases reliability through design simplicity
» Minimizes undesired fluid production
» Helps reduce cost and risk associated with unwanted fluid production
» Delays onset of unwanted water or gas production

**PERFORMANCE AND FIELD CASE STUDIES**

The EquiFlow AICD has been installed in very light to very heavy oil reservoirs and a variety of unique field applications:

» Ecuador: decreased water cut 34%, increased oil recovery 16% (SPE 166495)
» UAE: decreased water cut 47%, increased oil production 400% (SPE 177927)
» Brazil: successful horizontal openhole gravel packs with EquiFlow AICDs

**EquiFlow® AICD Through-Tubing Solution**

The EquiFlow AICD can also be deployed as an inner string within existing completions having a slotted liner or screens in place. The tool is paired with a slotted shroud that protects the AICD and acts as a coarse debris filter. This provides the capability of better reservoir management through the deployment of the AICD technology into existing wells and fields in order to increase the reserves.

For more information, contact your local Halliburton representative or visit us on the web at www.halliburton.com

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