**EquiFlow® autonomous inflow control device helped Repsol recover extra 21,000 barrels of oil.**

EquiFlow® autonomous inflow control device reduced water production 34%, increased oil recovery up to 16%, and had a dramatic return on investment.

**OVERVIEW**

In Ecuador, Repsol has a heavy oil field that often produces more than 90 percent water within the first few weeks. To produce more oil, Repsol sought a way to delay water breakthrough. Halliburton began deploying a new generation of autonomous inflow control devices (AICDs) for Repsol in 2012. With no moving parts, the EquiFlow® AICD has proven in laboratory flow testing that it can reduce unwanted water by more than 50 percent simply by changing flow behavior. Lighter viscosity fluids take a longer, more tortuous route through the device than oil which takes a short, direct route. EquiFlow AICDs work as a system, slowing production from high water zones which in turn promotes production from adjacent high oil zones. Post-job production results showed that the EquiFlow AICD helped Repsol recover an extra 21,000 barrels of heavy oil compared to standalone screens in just 300 days. Repsol realized a dramatic return on its investment.

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<th>CHALLENGE</th>
<th>SOLUTION</th>
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<td>Reducing operator intervention to retard water flow</td>
<td>Next-generation, autonomous inflow control devices</td>
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<td>Inflow control devices have proven their benefits since the 1990s. They delay water and gas from breaking through, so the field can rely longer on primary recovery. But when unwanted fluids eventually do break through, traditional passive ICDs are ill-suited to retard their influx.</td>
<td>Halliburton’s EquiFlow AICD responds autonomously to the type of fluid being produced at any given time without any connection to the surface or intervention by an operator. It reduces flow rates from zones where water has broken through, promoting production from zones with oil.</td>
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<td>Improve oil recovery in a mature field</td>
<td>EquiFlow AICDs improve oil recovery</td>
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<td>To offset costs, Repsol had to keep oil production high in Ginta. This became increasingly difficult due to a strong water drive and heavy oil (60 cP). But traditional standalone screen completions challenged the operator to achieve a total surface oil rate.</td>
<td>The EquiFlow AICD is counter-intuitive, producing viscous 60 cP Ginta oil much more easily than light, less than 1 cP, water. This promotes production from high oil zones and discourages production from high water zones, allowing the operator to recover more oil than conventional completions.</td>
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<td>Optimizing completion string design</td>
<td>Defined zones and EquiFlow AICD quantity</td>
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<td>Each reservoir is unique with varying permeability profiles and oil-water saturation levels. Halliburton and Repsol worked together to design an optimum completion for this particular application that took into account variance among different zones in the wellbore.</td>
<td>The permeability profile led Repsol to complete the well with five zones created by Halliburton’s Swellpacker® systems. Fluid influx was balanced in the horizontal by varying stage length, as well as the placement of packers and EquiFlow AICDs. This prevented fluid coning and increased oil recovery.</td>
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*Solving challenges.*
By harnessing the power of fluid dynamics, Halliburton’s EquiFlow AICD can help reduce water influx by more than 50%. The high viscosity of oil enables it to take the shortest route to the center. The low viscosity of unwanted fluids makes them shoot past the short route and take a longer, more tortuous path. This promotes oil production while retarding the flow of unwanted fluids.

A CASE STUDY: Increasing oil recovery and reducing water influx

At the initial stage of well production, post-job production results showed EquiFlow AICD completion outperformed a standalone screen completion by reducing water production as much as 34 percent.

Post-job production results also showed EquiFlow AICD completions increased heavy oil recovery up to 16 percent compared to standalone screen completions.

Why It Works
The distribution of EquiFlow AICDs in the wellbore helps balance pressure from toe to heel and compensate for local changes in reservoir permeability. Without the AICDs, water would rise unevenly, breaking through at the most permeable point and stranding reserves elsewhere. The AICDs help delay breakthrough until as much oil as possible has been produced along the length of the wellbore. When water does eventually break through at some point, the AICD changes flow behavior in that zone by creating a greater restriction. This allows more oil to be produced from other zones.
Water breakthrough was stranding Repsol's heavy oil in Ecuador

Unlike many fields where water production may not become a problem for years, wells in Repsol's Ginta field begin producing water within weeks of completion. The heavy oil field is in a jungle environment near the headwaters of the Amazon. All produced water must be treated and reinjected to minimize environmental impact – an expensive procedure.

The field has been producing since the mid-1990s. Water cut averages more than 90 percent and oil viscosity averages approximately 60 cP.

The operator worried that much oil was unrecoverable due to water breakthrough. As water breaks through in areas with high permeability, it reduces pressure on areas with low permeability and strands oil elsewhere in the reservoir. By equalizing inflow throughout the wellbore, operators can help avoid this problem.

Halliburton’s EquiFlow® autonomous inflow control device tested

To help control water, Repsol tested Halliburton’s EquiFlow® autonomous inflow control device (AICD). Regular inflow control devices have long helped operators delay the breakthrough of unwanted fluids. However, as conditions in a reservoir change, regular ICDs are ill-suited to fight off the unwanted fluid. EquiFlow AICDs have no moving parts and self-adjust to changing conditions based on fluid dynamics.

EquiFlow AICDs work by channeling fluids of different viscosities along different paths. The slow movement of viscous fluids allows them to take a somewhat direct route through the AICD while low viscosity water “shoots past” the direct route. It is then sent on a long, tortuous path. As a system, this decreases the amount and rate of water influx.

Compensating for permeability differences along the wellbore

By spacing EquiFlow AICDs at different intervals and different quantities throughout the wellbore, Repsol was able to compensate for permeability differences in the reservoir adjacent to the wellbore. Low permeability areas received less choke and high permeability areas received more through the placement and distribution of AICDs. Balancing pressure allows water to push oil toward the wellbore along a relatively straight path. This keeps water from breaking through early in one zone compared to the others so all the oil in the reservoir can be produced.

Erosion and mud-plugging tests prove reliability of tool

Repsol initially had concerns about EquiFlow AICDs failing due to erosion or fouling. Laboratory tests and previous field deployment indicated this would not be a problem and they proved to be the case in Ecuador. The devices are working reliably in Repsol’s Ginta field and are designed to continue working for the life of the well without the need for replacement.
EquiFlow® autonomous inflow control device reduced water production 34%, increased oil recovery up to 16%, and had a dramatic return on investment.

### Basis for comparisons
Reservoir heterogeneity made it difficult to judge the effectiveness of EquiFlow® AICDs by comparing production to offset wells. Therefore, Halliburton and Repsol used NETool™ nodal analysis software to model how wells would have performed using standalone screens. Several different scenarios were modeled for a 300 day duration. The results were then compared to actual production data from Ginta wells that had been completed with EquiFlow AICDs.

### EquiFlow AICD reduced water cut 34%
The EquiFlow AICDs reduced water production by 34 percent compared to standalone screens. Yet water reduction was not the most impressive finding.

### Total oil recovery increased by as much as 16%
The EquiFlow AICDs increased total recovery up to 16 percent during those 300 days. Repsol estimates it recovered an extra 21,000 barrels of oil. The value of that oil created a dramatic return on Repsol's investment in EquiFlow AICDs. The company also saved on the cost of water handling and expensive interventions.

### Reservoir management lessons learned
The critical time for maximizing the project's NPV is the initial production period. During this period, oil should be extracted as quickly as possible. There is a narrow window when oil closest to the wellbore can still outpace water before it breaks through. Repsol's future completions will have higher initial productivity indexes by installing more EquiFlow AICDs per well.

### Results will vary by reservoir
Repsol's rapid return on investment in EquiFlow AICDs should not be expected in every case due to many variables in each specific job. For instance, implementation of AICD technology in mature fields is different than in new fields. The speed of returns in Ecuador was a function of the high water cut so early in the life of the well. However, all wells eventually water out, and when they do, EquiFlow AICDs will prove their value.

### For more details
Additional information about this case study can be found in SPE 166495, *Autonomous ICD Installation Success in Ecuador Heavy Oil* by Brandon Least, Aaron Bonner, Rhandy Regulacion of Halliburton, and Robert Peñaranda, Tito Sampedro and Francisco Coloma of Repsol.

"Compared to our traditional completions, EquiFlow AICDs increased our total recovery while reducing our water production."

Robert Peñaranda,
Development Manager
Repsol