

FloReg™ Inflow Control Device (ICD)



Weatherford's *FloReg* ICD provides uniform inflow distribution in horizontal and deviated wellbores and reduces water or gas production for more efficient reservoir drainage. Combined with our high-quality sand screens, the device provides superior sand control.

Solving your sand control challenges

Extend the life of your well with our proven inflow control technology

Weatherford's *FloReg* device has earned a reputation for extending the life of wells by delaying the production of unwanted fluids.

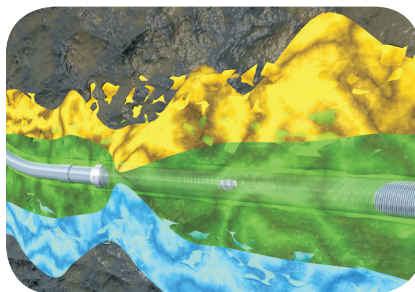
Designed to help evenly distribute the inflow throughout a horizontal wellbore, the *FloReg* ICD reduces the tendency of early water or gas production, enabling the reservoir to drain more efficiently while maximizing production and recovery.

Reducing early water or gas production in horizontal wells

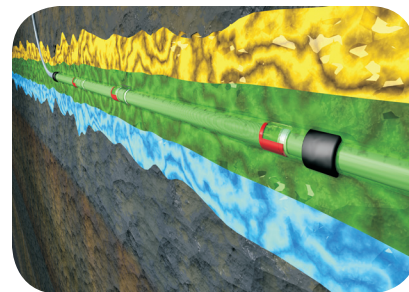
Horizontal wells are an established method for hydrocarbon recovery. In formations that can be completed horizontally, the wellbore offers a great contact area with the productive layer, enabling lower drawdown and improving recovery.

However, the early onset of unwanted fluids in horizontal wells can lead to a loss in production and reserves extraction, and ultimately, a decrease in profitability.

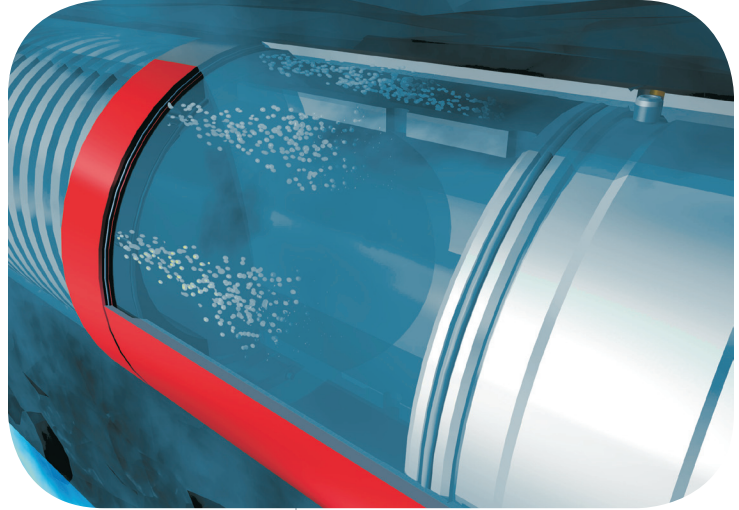
In homogeneous formations, as the length of the horizontal section increases, its resistance to flow increases in the form of fluid-flow friction effects, generating a higher pressure drop at the heel, compared to the pressure drop at the toe. This occurrence eventually leads to premature water/gas production. However, the *FloReg* ICD provides uniform production and flow contribution along the wellbore in horizontal wells.



Homogenous formation without ICD
Water and/or gas breakthrough

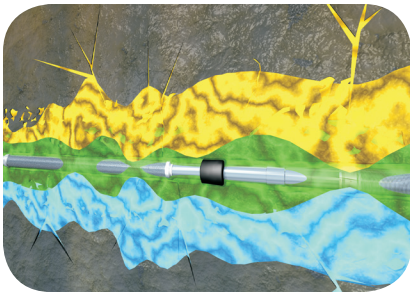


Homogenous formation with *FloReg* ICD
Uniform inflow profile

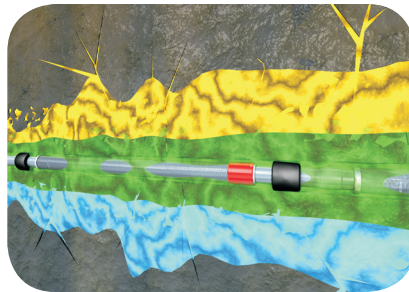


Weatherford offers a solution for reducing early water or gas production in horizontal wells—our *FloReg* ICD, which can be supplied with your choice of our high-quality sand screens. The device enables a predetermined setting of the desired pressure drop (heel-to-toe) along the production string, using multiple open or closed flow ports to provide the required reservoir management.

By reducing the tendency of early water or gas production, the *FloReg* ICD enables the reservoir to drain more efficiently while maximizing production and recovery. The device provides uniform production and flow contribution along the wellbore in horizontal wells, extending the well's life.



Heterogeneous formation without ICD
Water and/or gas breakthrough



Heterogeneous formation with *FloReg* ICD
Uniform inflow profile

In heterogeneous or fractured formations, the premature water/gas production process can be greatly accelerated by high permeable formations or fractures, impairing the overall well performance and recovery. Because the *FloReg* ICD reduces the tendency for early water or gas production, the well's overall performance and recovery are greatly enhanced.

Selecting the right sand screen to use with the *FloReg* ICD

FloReg ICD and Maxflo® screen produce results

In conjunction with Weatherford's conventional sand screens, the *FloReg* ICD has been installed in many wells around the world. To maximize hydrocarbon recovery and delay water or gas production, the results showed that:

- The wells performed better than expected.
- Production rates are above expectations.
- Water and gas ratios have also been lower than expected.

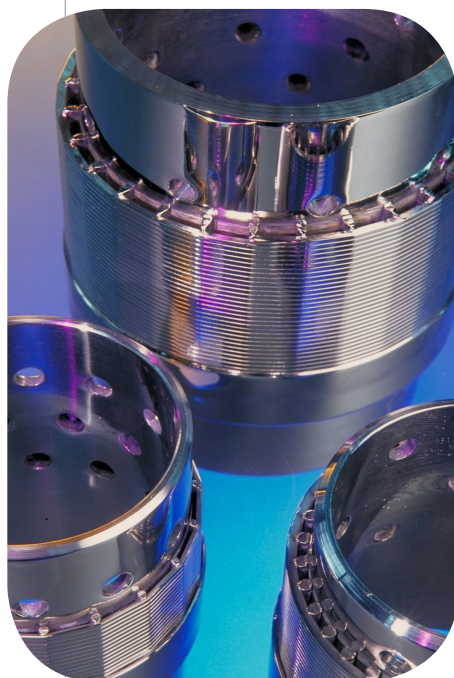
The *FloReg* device improved the reservoir's drainage by reducing hot spotting and enabled flow into the *Maxflo* screen to be redistributed throughout the well.

Weatherford's sand screen selection criteria is researched and developed in our laboratories, as well as based on industry standards. It is essential to ensure the correct screen recommendation for every application, eliminating plugging and excessive production of small sand particles. To determine if you should use a wire-wrap or metal-mesh screen, our high-level selection criteria is established from the percentage of fines combined with the uniformity coefficient.

Weatherford's sand screens that are compatible with the *FloReg* ICD include:

- Ultra-Grip™ *direct-wrap*, wire-wrap screen
- *Ultra-Grip* HD *direct-wrap*, wire-wrap screen
- *Maxflo* metal-mesh screen
- Excelflo® metal-mesh screen

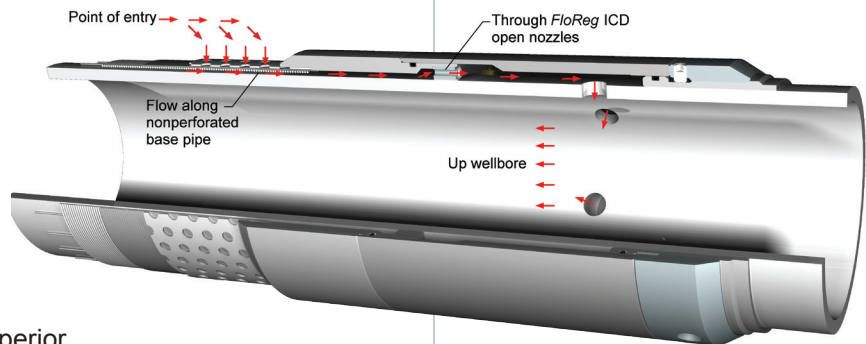
We recommend that empirical retention testing is performed on a screen selection to validate its appropriateness in retaining the actual formation sand.



In addition to screen selection, we can help with the proper material selection for special downhole corrosive environments. The extensive manufacturing capabilities of Weatherford's well screen plants enable us to respond quickly to your order requirements for any well in any part of the world.

Features and benefits of the *FloReg* ICD

- The *FloReg* ICDs are used to adjust the imbalance of inflow profile arising from fluid-frictional losses in homogeneous reservoirs and from permeability variation in heterogeneous reservoirs.
- By using the device, a greater percentage of the total hydrocarbon reserve can be produced; thereby superior drainage can be accomplished before the onset production of unwanted fluids.
- The setup operation of the *FloReg* ICD consists of installing specialized pins to shut off the required number of flow ports. This procedure is conducted offline, saving valuable rig time.
- The pressure drop of the device is dependent on fluid density and is insensitive to fluid viscosity; therefore, the device has the tendency to inhibit water production and encourage hydrocarbon production.
- The *FloReg* device prevents annular flow by evenly distributing the flow along the production string.
- The screen section mounted upstream of each *FloReg* device ensures sand control. Fluids flow from the formation and pass the screen and device before entering the production string through predrilled holes in the base pipe.
- The number of open-flow ports can be adjusted to the prescribed setting, based on the latest data. This procedure is conducted at surface, either before shipment or on location.
- The *FloReg* ICD's flow ports are made of tungsten carbide for proven erosion resistance.
- Each device is standard (rather than machined) to suit a specific application. This flexibility can translate into significant cost savings because it reduces the need for multiple screens held in inventory or on location.



In the development of Weatherford's *FloReg* ICD, the fluid and solid dynamics were laboratory tested and modeled using computational fluid dynamics (CFD) software to ensure product reliability.

Determining the optimum *FloReg* ICD setting through reservoir inflow modeling

Weatherford's technical centers of excellence are strategically located around the world in client-centric areas. These global facilities can provide the capacity and inventory to serve clients in any country or offshore location. Specific competencies provided at these facilities include:

- Petroleum and reservoir engineering
- Sand control
- Rock mechanics
- Laboratory testing and research
- Materials engineering



Weatherford uses near wellbore and completion software to establish the *FloReg* ICD setup, ensuring the appropriate pressure drop along the production string to achieve equal inflow distribution throughout the life of the well.

Using the reservoir and well properties provided by clients enables us to establish the baseline setup of the *FloReg* ICDs.

Reservoir simulation models and actual formation can vary enormously. Weatherford performs final on-site modeling to optimize the ICD setup from actual data as the reservoirs are drilled.

Extensive fluid-flow testing

The objective of the flow tests is to determine the flow coefficient (referred to as the discharge coefficient or C_d) for the flow port at realistic production conditions. In the flow testing, the pressure drop across the *FloReg* ICD was measured at various open-flow ports and flow rates. Also different fluid viscosities were used.

The test results showed that the *FloReg* ICD pressure drop is insensitive to fluid viscosity and can be predicted by simple theory.

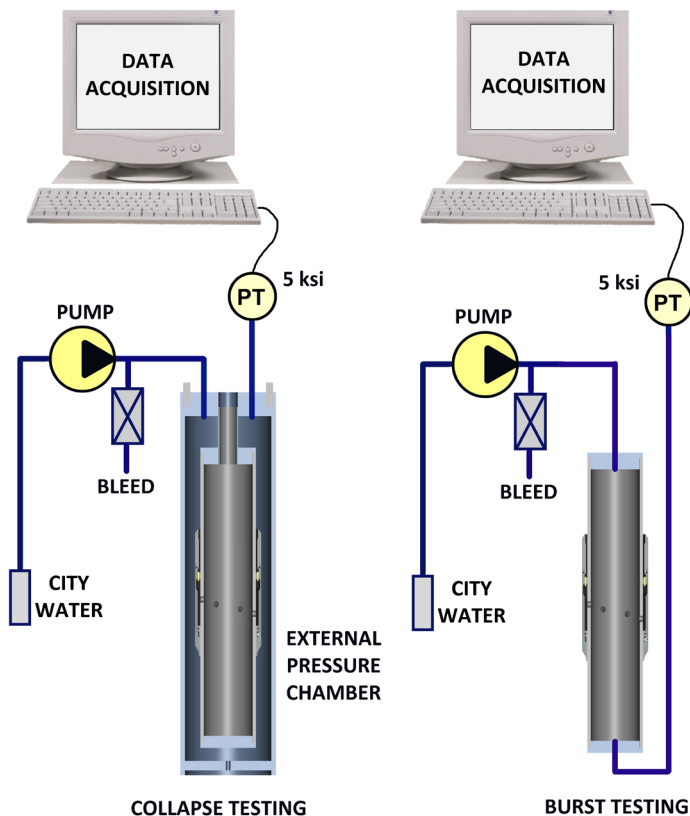
Burst and collapse testing

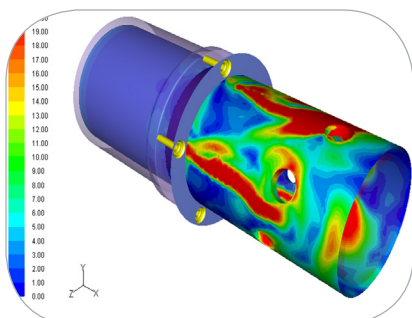
To provide a performance rating for the *FloReg* ICD, Weatherford conducted a series of burst and collapse tests on actual *FloReg* devices to ensure that the devices meet oil and gas industry requirements. During the tests, the samples were pressurized internally and externally to determine the devices' ultimate burst and collapse ratings.

The results showed that the devices meet required downhole performance specifications and provide operators with a reliable internal and external differential pressure capacity.

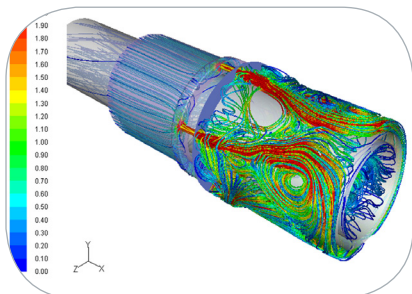


FloReg ICD sample prepared for burst test.





Contours of shear stress (Pa)



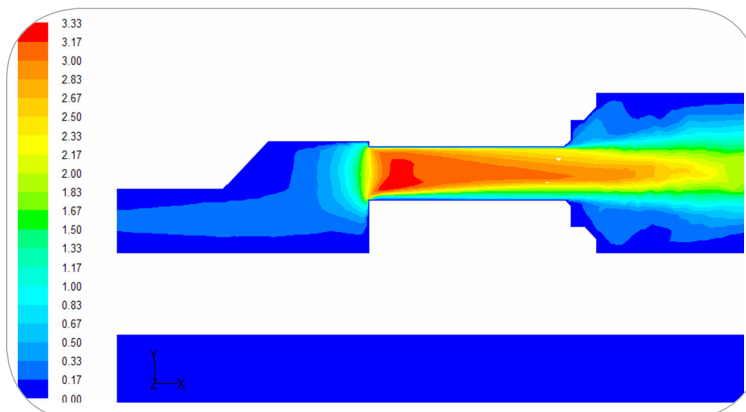
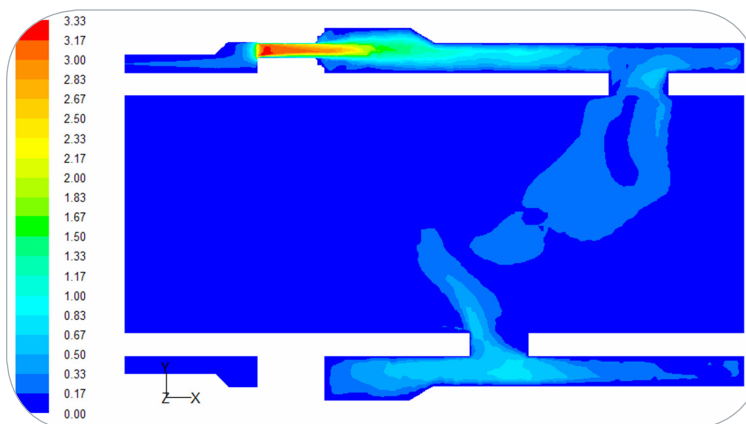
Path lines of flow colored by speed (m/s)

Erosion, mud flow-back testing of *FloReg* ICD

Weatherford conducted erosion tests on the *FloReg* ICD to verify that mud filter-cake flowback, fines production or sand production would not have any detrimental effect on the performance of the device.

A simulated 20-year erosion test was performed to estimate the erosion that would occur to an ICD during its design life in a well. Slurry was pumped using a triplex pump through a single tungsten carbide flow port at a flow rate of 40 bbl/d, and a sand concentration of 2,000 pptb.

The results showed that after a simulated maximum flow rate of 20 years, the erosion effect on the *FloReg* ICD was almost nonexistent.

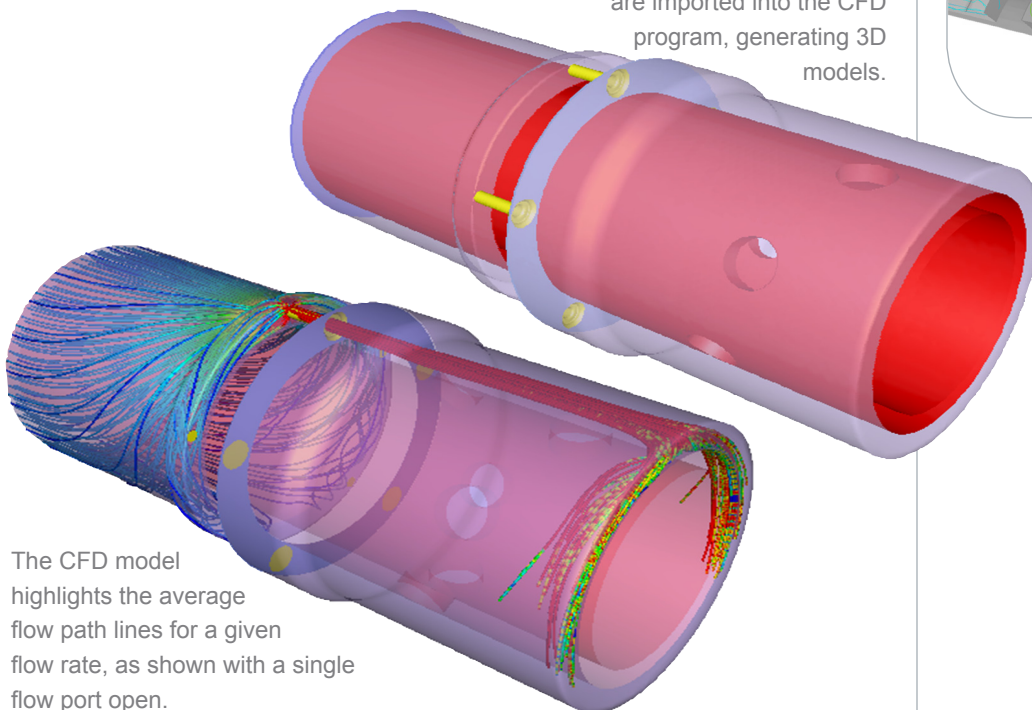


Computational fluid-dynamics modeling of *FloReg* ICD

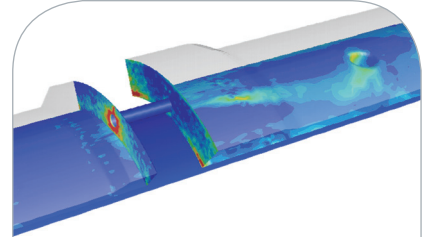
Weatherford analyzed the *FloReg* flow ports using CFD software (Ansys CFX Version 10.0, CD-adapco STAR CCM+) to investigate the effect of different fluid viscosities, water cuts and *FloReg* device settings on the pressure drop across the *FloReg* ICD. Also CFD modeling was used to verify that fines or sand production would not have any erosion detrimental effect on the performance of the device.

The *FloReg* device was analyzed as the fluid flows along the base pipe and passes through the flow ports and then through the holes in the production string. The CFD results confirmed that the pressure drops across the flow ports are insensitive to fluid viscosity.

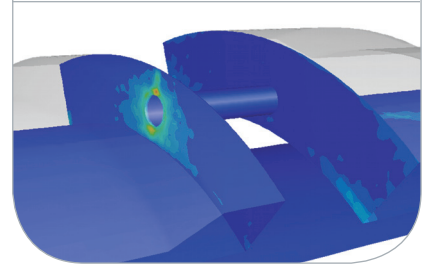
The *FloReg* ICD CAD files are imported into the CFD program, generating 3D models.



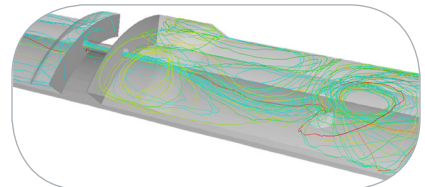
The CFD model highlights the average flow path lines for a given flow rate, as shown with a single flow port open.



Contours of erosion rate.



Contours of speed (1 port open).



Specifications

<i>FloReg</i> Base Pipe Size (in.)	<i>FloReg</i> Length (in./mm)	<i>FloReg</i> OD (in./mm)	Number of Flow Ports	Flow Port Size (in./mm)	Screen Selection
2-3/8	10.4 265.2	3.32 84.33	5	1/8 3.2 or 3/32 2.4	MMS ¹ or WWS ²
2-7/8		3.90 99.06	10		
3-1/2		4.44 112.78			
4		5.00 127.00			
4-1/2		5.44 138.18			
5		6.00 152.40			
5-1/2		6.50 165.10			
6-5/8		7.69 195.33			
7		8.12 206.25			

¹Metal-mesh screens – (Maxflo® and Excelflo® screens)

²Wire-wrap screens – (Ultra-Grip™ and Ultra-Grip HD screens)

Solving your sand control challenges

Weatherford provides the organizational capabilities, well screen technology understanding, system reliability and installation experience to address effectively your sand control challenges.

For the best sand-control solution for your wells, contact an authorized Weatherford representative, or visit **weatherford.com**.

