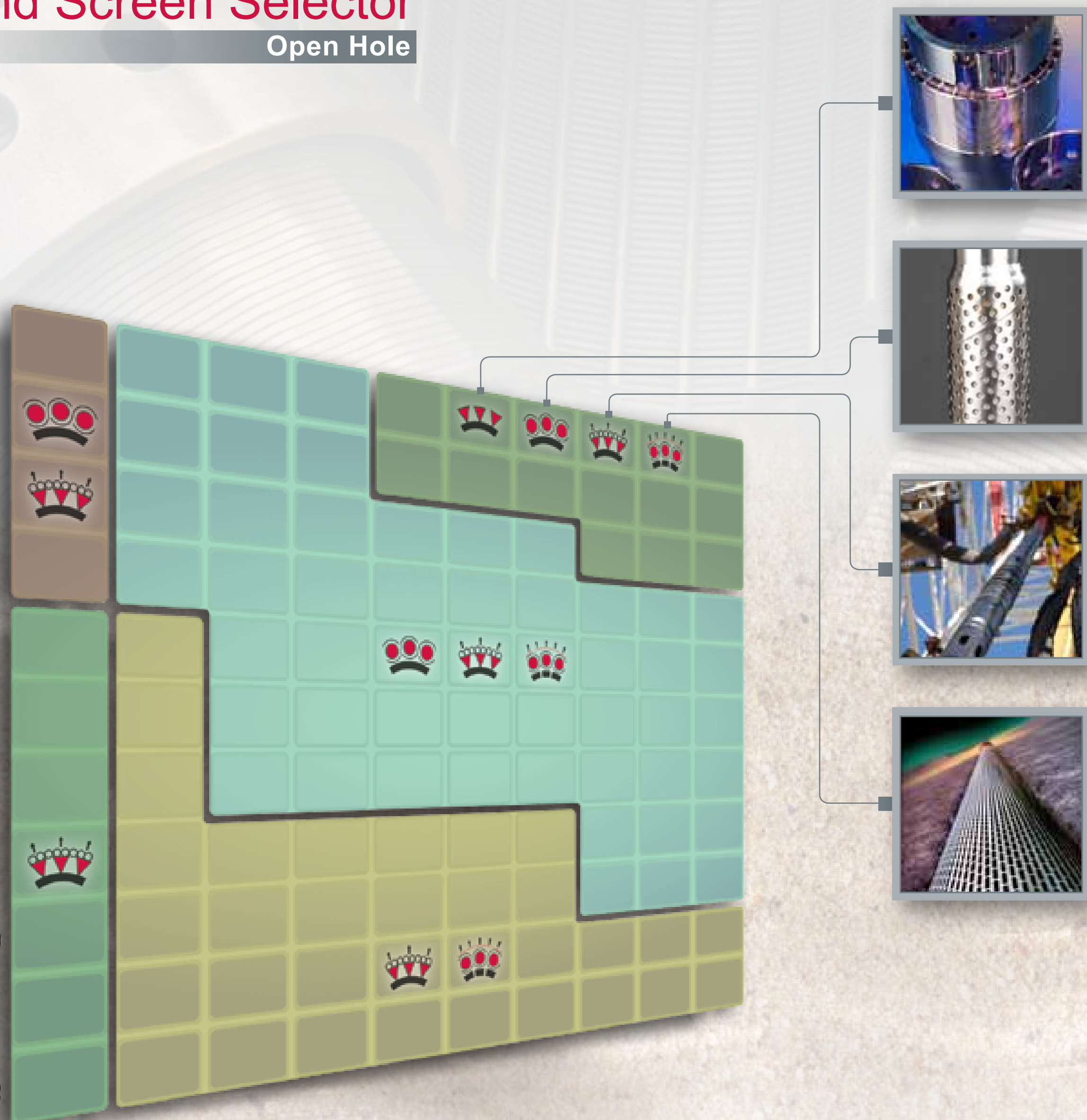
Weatherford®

Sand Screen Selector

Open Hole



Drilling

Evaluation

Completion

Production

Intervention

Sand control

- Conventional well screen
- Expandable sand control
- Gravel pack
- Inflow control
- Reservoir isolation
- Specialty screen

Expert guidance on sand control technology selection and application for openhole completions.

Solving your sand control challenges.

It's all about the sand...

Oil and gas reservoirs exist in all types of sand, but formation sand particles in a well stream can hinder production, causing major problems with flowlines and surface production equipment. Knowledge of reservoir sand properties—such as particle size, particle size distribution (PSD) and particle size uniformity—is central to the design of sand-control completions. The choice of well screen, based on the reservoir PSD and other considerations, can have a far-reaching effect on the productivity and efficiency of a producing well.

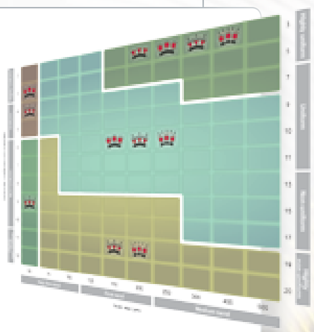
Why is selecting the right well screen so important?

Sizing that is **too small** can lead to total or partial plugging, forcing hydrocarbon production through non-plugged sections. This situation causes what is known as "hot spotting," which can lead to screen erosion.

Sizing that is **too large** can lead to unacceptable production of sand, which in turn can lead to erosion of sand screens and surface equipment. Excessive sand production rates can result in loss of the well.

...selecting the appropriate screen...

Weatherford's Sand Screen Selector is a planning tool that guides you through the process of choosing the most effective sand-control method for your wellbore completion. Weatherford combines sand-control technology and expertise to provide you with a detailed engineering evaluation, analysis, and the well screen to meet your reservoir sand-control challenges.



...and applying the technology.

We will work with you to refine the completion design before detailed operational planning and wellsite execution. We have made every endeavor to include all applicable information; however, you can learn more about our applied technology through Weatherford's technical papers.

FEA MODELING

"FEA Modelling of Expandable Sand Screens," Jones, C. & Watson, K., 2008 Abaqus Users Conference

"FEA Modelling of Expandable Sand Screens Interactions with Rock Formations," Watson, K. and Jones, C., Simulia Customer Conference, May 2009

SAND RETENTION

SPE 64398
"Screen Selection for Sand Control Based on Laboratory Tests," 2000

SPE 82244
"Media Sizing for Premium Sand Screens: Dutch Twill Weaves," 2003

SPE 98308 – MS
"Sand Retention Testing: The More You Do, The Worse It Gets," 2006

EROSION

SPE 107437
"Development, Verification and Application of a Screen Erosion Model," 2007

122269
"Sand Control Screen Erosion – When are you at Risk?" 2009

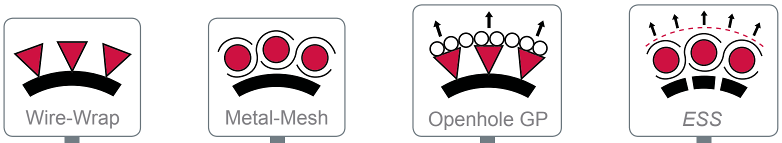
SOLIDS AND FLUIDS CONTROL

SPE 68933
"Evaluation of Filter Cake Flowback in Sand Control Completions," 2001

SPE 98287 – MS
"Expandable Sand Screens and Drilling Fluids: Laboratory Testing for Successful Field Application," 2006

Sand-control portfolio

We offer all types of well screens, including ESS® expandable sand screens, stand-alone screens, and gravel packs. Our technologies are designed to minimize sand production and maximize ultimate production.

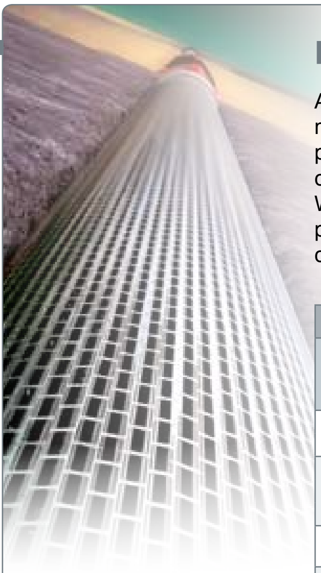


Wire-Wrap Screens

Wire-wrap screens consist of a shaped wire wound around perforated liner and are used alone or to support a gravel pack. For gravel-pack operations, the wire wrap should be sized to retain the gravel placed between the screen and formation while minimizing any production restriction. Wire-wrap screens are the appropriate choice for coarse, well-sorted sands. Weatherford originated the wrap-on-pipe, high-strength design and offers three direct-wrap options: **Dura-Grip® Ultra-Grip™** and ***Ultra-Grip* HD** screens. Alternatively, a slip-on, jacket-type design, called Super-Weld® screen, is available for less challenging applications.

Base Pipe			*Dura-Grip* Wire-Wrap Screens					*Ultra-Grip* Wire-Wrap Screens					*Ultra-Grip* HD Wire-Wrap Screens				
Size (in.)	Weight (lb/ft)	ID (in./*mm*)	End Ring OD (in./*mm*)	Screen OD (in./*mm*)	Weight (lb/ft)	Tensile Strength[1] (lbf/*kN*)	Maximum Bend Angle[2]	End Ring OD (in./*mm*)	Screen OD (in./*mm*)	Weight (lb/ft)	Tensile Strength[1] (lbf/*kN*)	Maximum Bend Angle[2]	End Ring OD (in./*mm*)	Screen OD (in./*mm*)	Weight (lb/ft)	Tensile Strength[1] (lbf/*kN*)	Maximum Bend Angle[2]
2-3/8	4.6	1.995 *50.67*	2.78 *70.61*	2.65 *67.31*	7.3	88,690 *394.5*	120°	N/A					N/A				
2-7/8	6.4	2.441 *62.00*	3.28 *83.31*	3.15 *80.01*	9.1	123,220 *548.1*	105°	N/A					N/A				
3-1/2	9.2	2.992 *76.00*	3.90 *99.06*	3.77 *95.75*	11.9	176,130 *783.5*	86°	4.01 *101.85*	3.88 *98.55*	12.6	176,130 *783.5*	86°	4.13 *104.90*	4.00 *101.60*	12.6	176,130 *783*	86°
4	9.5	3.548 *90.12*	4.40 *111.76*	4.27 *108.45*	12.2	182,210 *810.5*	75°	4.51 *114.55*	4.38 *111.25*	12.9	182,210 *810.5*	75°	4.63 *117.60*	4.50 *114.30*	12.9	182,210 *811*	75°
4-1/2	11.6	4.000 *101.60*	4.90 *124.46*	4.77 *121.15*	14.3	226,980 *1,009.7*	67°	5.01 *127.25*	4.88 *123.95*	15.0	226,980 *1,009.7*	67°	5.13 *130.30*	5.00 *127.00*	15.0	226,980 *1,010*	67°
5	15.0	4.408 *111.96*	5.40 *137.16*	5.27 *133.85*	17.7	297,450 *1,323.1*	60°	5.51 *139.95*	5.38 136.65	18.4	297,450 *1,323.1*	60°	5.63 *143.00*	5.50 *139.70*	18.4	297,450 *1,323*	60°
5-1/2	17.0	4.892 *124.26*	5.90 *149.86*	5.77 *146.55*	19.7	337,440 *1,501.0*	54°	6.01 *152.65*	5.88 *149.35*	19.4	337,440 *1,501.0*	54°	6.13 *155.70*	6.00 *152.40*	19.4	337,440 *1,501*	54°
6-5/8	24.0	5.920 *150.37*	7.03 *178.56*	6.90 *175.26*	26.7	472,340 *2,101.1*	45°	7.13 *181.10*	7.00 *177.80*	27.4	472,340 *2,101.1*	45°	7.25 *184.15*	7.12 *180.84*	27.4	472,340 *2,101*	45°
7	26.0	6.276 *159.41*	7.40 *187.96*	7.27 *184.65*	28.7	513,340 *2,283.5*	43°	7.51 *190.75*	7.38 *187.45*	29.4	513,340 *2,283.5*	43°	7.63 *193.80*	7.50 *190.50*	29.4	513,340 *2,283*	43°

[1]Screen tensile strength is based on entire screen assembly and L80 base pipe.
[2]Maximum bend angle for screen (° per 100 ft, or 30.5 m) may exceed allowable bend angle for some threads. See thread manufacturer's specifications. Maximum DLS (dogleg severity) is 50% of maximum bend angle.



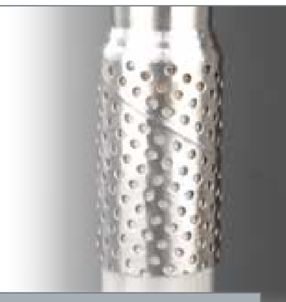
ESS® Expandable Sand Screens

A woven metal mesh is adhered to a slotted liner and protected by a perforated outer cover. The screen is mechanically enlarged downhole to expand compliantly against the wellbore, eliminating the annular space, providing borehole support, and removing the need to place gravel for filtration of formation sand. The sizing criteria recommended is that a weave will adequately retain sand with a D5 equivalent to the weave aperture. Weatherford's ***ESS* systems** provide retention of the widest range of sand types without the need for gravel-packing. These industry-leading, compliant systems provide high productivity and good reservoir management capability. They are operationally efficient and compatible with many openhole zonal-isolation techniques.

ESS Expandable Sand Screens			
Size (in.)	Running OD (in./*mm*)	Open Hole Size (in.)	Maximum Compliant Range (in./*mm*)
4	4.47 *113.54*	5-7/8	6.06 *153.92*
		6	
4-1/2	5.07 *128.78*	6	6.88 *174.75*
		6-1/8	
		6-1/2	
5-1/2	6.10 *154.94*	8-1/2	8.83 *224.28*
7	7.56 *192.02*	8-1/2	9.25 *234.95*

ESS Expandable Sand Screens	
Dutch Twill Weave	Weave Aperture (µm)
Petroweave 120	120
Petroweave 150	150
Petroweave 230	230
Petroweave 270	270
Petroweave 400	360

Metal-Mesh Screens

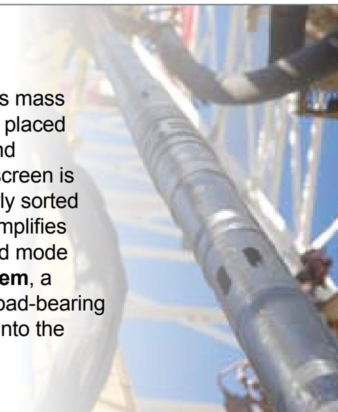


A woven single-layer or a woven—sometimes sintered—multilayer metal mesh is shaped and combined with a protective, perforated outer covering in a cartridge, or jacket, which is slipped over a perforated liner/base pipe. Metal-mesh screens reduce the risk of plugging at the screen face. The screen opening stops some of the produced sand until larger grains "bridge" on the screen surface. The sizing criteria recommended is that a weave will adequately retain sand with a D5 minimum to D10 maximum equivalent to the weave aperture. Weatherford's **Excelflo**® and **Maxflo**® screens provide reliable sand control ideal for short-radius, horizontal wells and stand-alone applications.

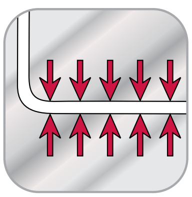
Base Pipe			*Maxflo* Metal-Mesh Screens				*Excelflo* Metal-Mesh Screens			
Size (in.)	Weight (lb/ft)	ID (in./*mm*)	Shroud OD (in./*mm*)	Weight (lb/ft)	Tensile Strength[1] (lbf/*kN*)	Maximum Bend Angle[2]	Shroud OD (in./*mm*)	Weight (lb/ft)	Tensile Strength[1] (lbf/*kN*)	Maximum Bend Angle[2]
2-3/8	4.6	1.995 *50.67*	N/A	N/A	N/A	N/A	3.08 *78.23*	7.9	88,690 *394.5*	120°
2-7/8	6.4	2.441 *62.00*	N/A	N/A	N/A	N/A	3.57 *90.68*	10.2	123,220 *548.1*	105°
3-1/2	9.2	2.992 *76.00*	4.22 *107.19*	13.5	176,130 *783.5*	86°	4.11 *104.40*	13.5	176,130 *783.5*	86°
4	9.5	3.548 *90.12*	4.72 *119.89*	14.4	182,210 *810.5*	75°	4.61 *117.09*	14.4	182,210 *810.5*	75°
4-1/2	11.6	4.000 *101.60*	5.23 *132.84*	16.9	226,980 *1,009.7*	67°	5.12 *130.05*	16.9	226,980 *1,009.7*	67°
5	15.0	4.408 *111.96*	5.74 *145.80*	20.8	297,450 *1,323.1*	60°	5.63 *143.00*	20.8	297,450 *1,323.1*	60°
5-1/2	17.0	4.892 *124.26*	6.24 *158.50*	23.2	337,440 *1,501.0*	54°	6.13 *155.70*	23.2	337,440 *1,501.0*	54°
6-5/8	24.0	5.920 *150.37*	7.38 *187.45*	31.1	472,340 *2,101.1*	45°	7.27 *184.66*	31.1	472,340 *2,101.1*	45°

All values are based on 316L screen jackets and L80 base pipe.
[1]Screen tensile strength is based on entire screen assembly.
[2]Maximum bend angle for screen (° per 100 ft, or 30.5 m) may exceed allowable bend angle for some threads. See thread manufacturer's specifications. Maximum DLS (dogleg severity) is 50% of maximum bend angle.

Openhole Gravel Packs



A gravel pack consists of a slotted or perforated liner placed in the well and surrounded by gravel. This mass of gravel forms a depth filter and excludes sand from the wellbore. In addition, openhole gravel packs placed around a wire-wrap or metal-mesh screen will stabilize the wellbore to a degree, further mitigating sand production. The gravel pack is sized to the formation sand, providing primary sand control, while the screen is sized to retain the gravel-pack sand. Openhole gravel packs are the appropriate choice for more poorly sorted sands and can be effective in long horizontal wellbores. Weatherford's **WFX sand-control system** simplifies gravel-packing operations by providing a reliable, fixed reference point that holds the right position and mode to avoid movement during critical phases of treatment. Installation of our **Model 4P gravel-pack system**, a well-established completion procedure that creates a reliable and durable downhole filter, keeps the load-bearing grains of sandstone reservoirs stationary, preventing them from breaking away and being introduced into the wellbore with produced fluids.



Optimum Drainage

FloReg™ Inflow Control Devices

Incorporation of inflow control devices (ICDs) in the screen design can extend the applicability for a wire-wrap or a metal-mesh screen. Weatherford's ***FloReg*** ICDs are designed to help distribute inflow evenly throughout a horizontal wellbore. ICDs reduce the tendency of water or gas coning, allowing the reservoir to drain more efficiently and thus maximizing production and ultimate recovery. When ICDs are combined with either wire-wrap or metal-mesh screens, they enable predetermined setting of the designed pressure drop (heel-to-toe) along the production/screen section, using multiple open or closed flow ports. The ICDs are fitted to the screen joints to balance the inflow profile from the production interval.

FloReg Inflow Control Devices									
		ICD		Flow Ports				ICD	
ICD Size (in.)	Suitable Screen Selection	Overall Length (in./*mm*)	OD (in./*mm*)	Quantity	Sizes (in./*mm*)	Length (in./*mm*)	Material	Base Material and Stress Intensity (ksi/*MPa*)	Elastomer Material*
2-3/8	Metal-mesh and wire-wrap screens	10.4 *264.16*	3.32 *84.33*	5	1/8 or 3/32 *3.175 or 2.381*	0.50 *12.70*	Tungsten carbide	13Cr 110 758 or L80 80 550	FKM95
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*						

*Alternative elastomer material is available.

Sand Screen Selector

Open Hole

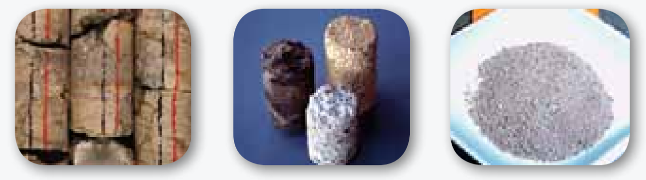
Expert guidance on sand control technology selection and application for openhole completions.

A Characterize the Reservoir Sand

If mechanical means of controlling sand production are to be used, the first step is determining the size of the formation sand so that the filter mechanism can be properly sized. Formation sand must be evaluated to determine the grain-size distribution.

Sample Selection

Sands should be representative of the proposed completion interval. Core samples or data from offset wells can be used if there is a high degree of certainty that they are representative of the sand to be retained.



Whole-Core Samples Sidewall-Core Samples Produced-Sand or Bailed-Sand Sample

Whole-Core Samples

The best source. Representative samples from whole core yield the most accurate information about in-situ grain size and grain-size distribution.

- Represents all sands present
- Rock fabric undamaged
- Can select appropriate samples

Sidewall-Core Samples

Acceptable source. Sampling from sidewall cores usually provides a good compromise. Shattering of sand grains during coring can result in distorted grain-size distribution data.

- Discrete locations
- Mud contamination
- Crushed grains

Produced-Sand Samples

Rarely yields results representative of the in-situ grain size and grain-size distribution. Analysis of produced sand usually indicates an exaggerated amount of fines present.

- Uncertain source
- Potentially incomplete distribution
- Higher proportion of smaller sand grains/fines may distort the screen sizing process

Bailed-Sand Samples

Least preferred source. Samples obtained with a sand bailer should be used with caution, as bailed samples will usually be skewed toward larger particles that have not been flowed to surface.

- Uncertain source
- Potentially incomplete distribution
- Higher proportion of larger sand grains may distort the screen sizing process

Particle Size Analysis

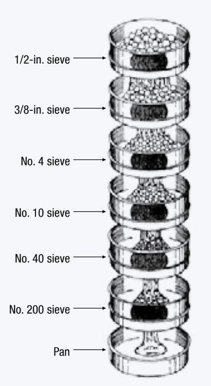
There are two common methods of particle size and particle size distribution (PSD) measurement: dry sieving and laser particle size analysis (LPSA). Results from the two techniques can vary and should be considered during screen selection.

Dry Sieving

The sample is cleaned, crushed, dried, weighed and then sorted, using a series of sieves with openings based on ASTM E1170. The weight of sand retained by each successive sieve size is recorded down to No. 325 mesh (44 μm).

The cumulative weight percent of each retained sample is then plotted as a comparison by the sieve aperture on semi-log coordinates to obtain a sand size distribution plot.

- Requires a sample size greater than 10g for a representative test
- Measures down to 45 μm
- Difficult to get good dispersion
- Measures the second-smallest dimension

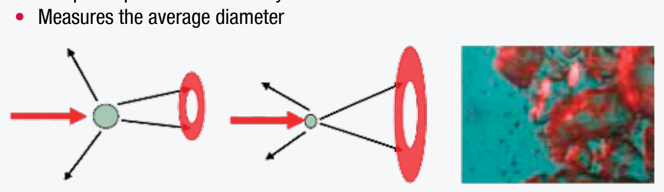


Dry-Sieve Process

LPSA

This technique uses the concept that the diffraction angle of light striking a particle is inversely proportional to the particle size. The sample is placed into the laser diffraction analysis (LDA) unit. The light diffraction caused by all particles is measured, determining the size of individual particles. This method is fully automated, as the LDA unit is connected to a computer, and analysis software will record and plot the grain-size distribution.

- Requires much less sand than dry sieving
- Measures down to 0.4 μm
- Sample dispersed ultrasonically in water
- Measures the average diameter



Laser Diffraction Process

RESULTS Grain-Size Distribution

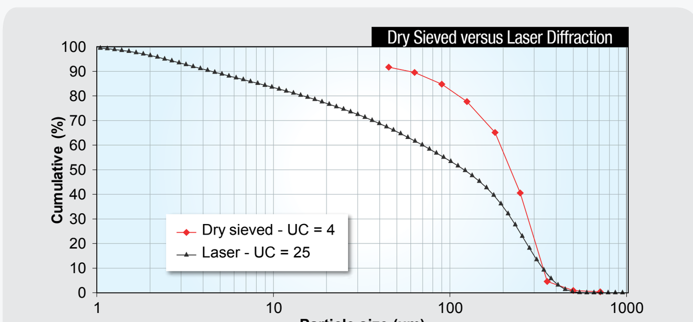
Percentile sand sizes can be obtained from the cumulative distribution where, for instance, the D10 value is the grain-size diameter from the distribution scale where 10% by weight of the sand is of a larger size and 90% is of a smaller size. Reading the graph at the 50% cumulative weight provides the median formation grain-size diameter. The grain-size distribution analysis plot establishes the degree of sorting in a particular sample. A near vertical analysis plot represents a high degree of sorting or uniformity. A more deviated or slanted plot indicates poor sorting of sand grains.

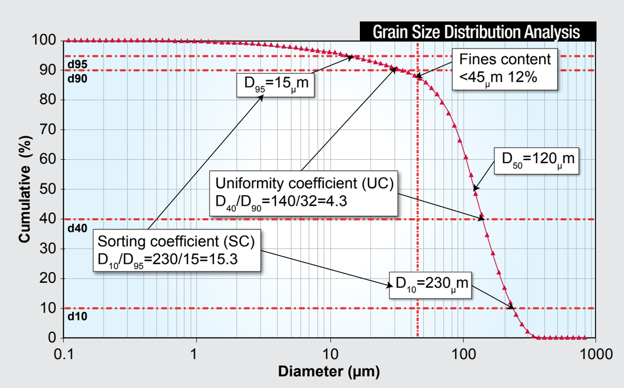
Uniformity Coefficient (UC = D40/D90)

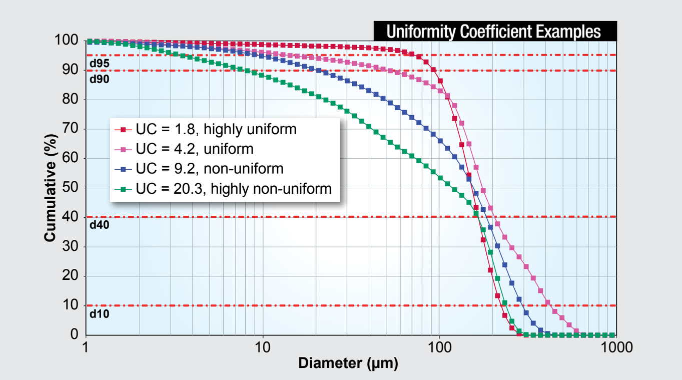
	Dry Sieve	LPSA
Uniform sands	<5	<10
Non-uniform sands	5 to 10	11 to 20
Highly non-uniform sands	>10	>20

Sorting Coefficient (SC = D10/D95)

	Dry Sieve	LPSA
Well-sorted sands	<10	<20
Somewhat sorted sands	11 to 20	21 to 40
Poorly sorted sands	>20	>40





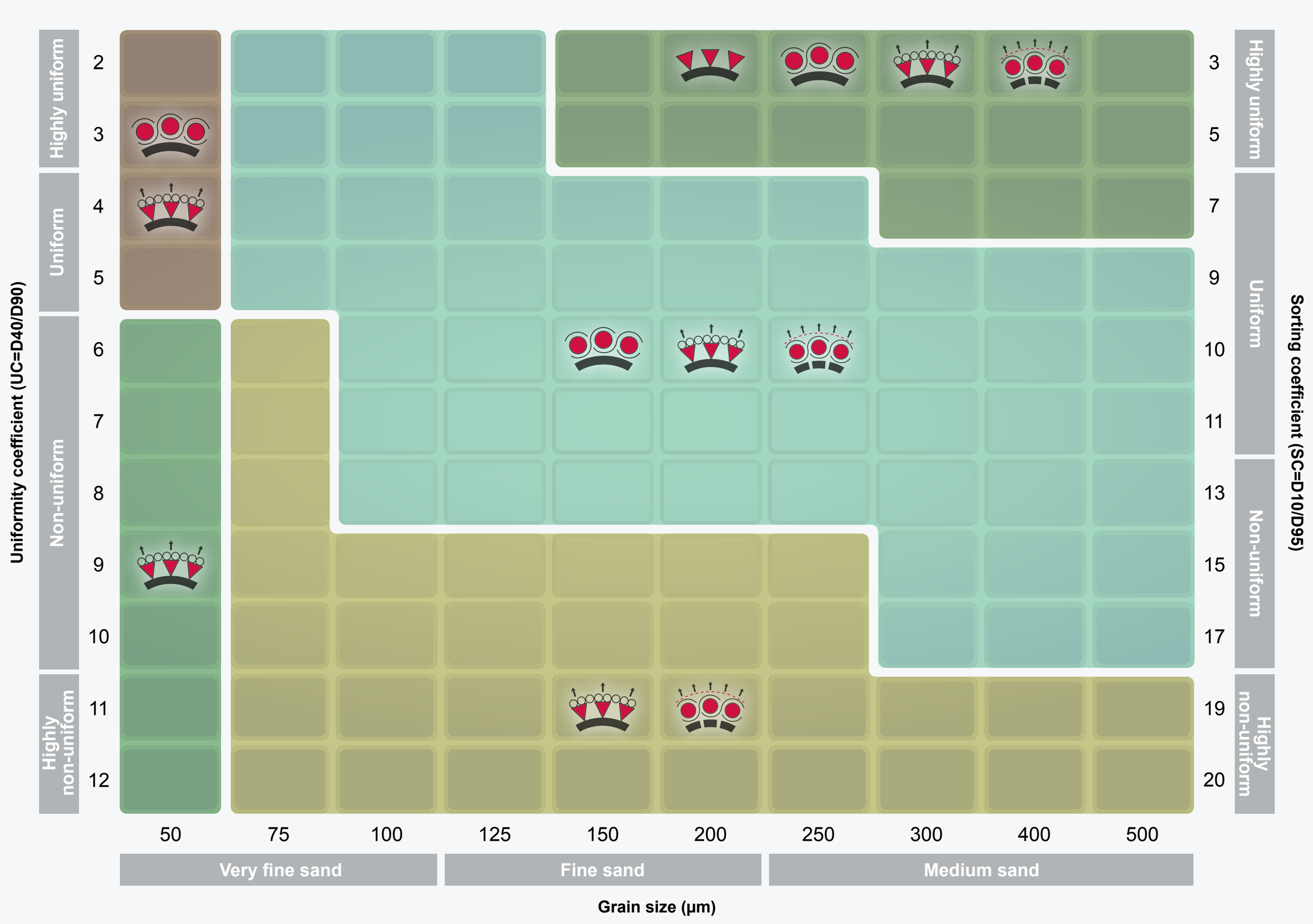


Grain-size distribution is typically expressed in terms of uniformity coefficient and sorting coefficient.

Example plots

B Assess Sand-Control Options

Selection of the optimal method to control a given sand or group of sands is based on the measured PSD. The grain size and sorting of the finest sand likely to fail and produce solids can determine the appropriate type of screen. For coarse, well-sorted sands, wire-wrap screens (WWS) or even slotted liners (SL) are suitable. As the sands become more poorly sorted and/or the fines content increases, metal-mesh screens (MMS), expandable sand screens (ESS®), and openhole gravel pack (OHGP) are more effective solutions.



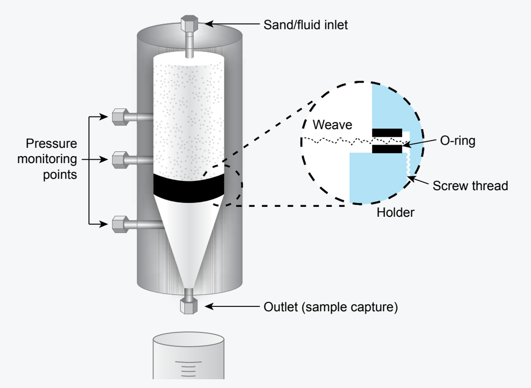
C Specify Filter Media

A screen recommendation based on a sand's PSD can be confirmed by sand retention testing. To determine the optimal filter media and aperture size, wire-wrap or metal-mesh filters are tested with each sand, using both slurry and sand-pack test methods.

Sand Retention Testing

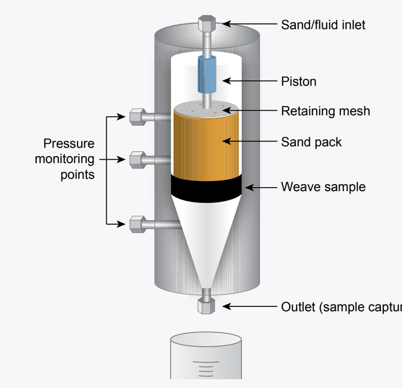
Slurry Test

Slurry tests simulate open-annulus/noncompliant borehole conditions. Sand is suspended in a slurry and flowed downward onto the screen. The test measures the weight of solids produced through the screen and the rate of pressure buildup across the screen versus the amount of sand contacting the screen.



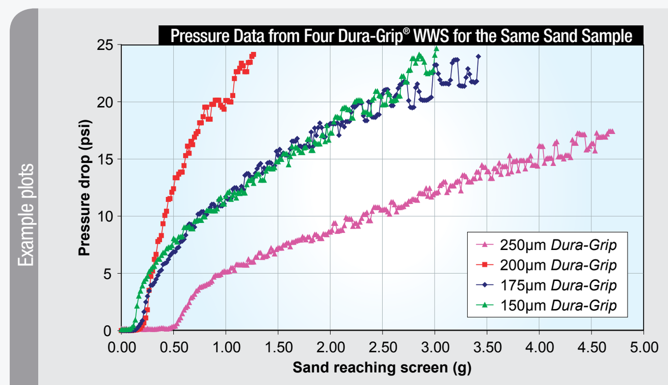
Sand-Pack Test

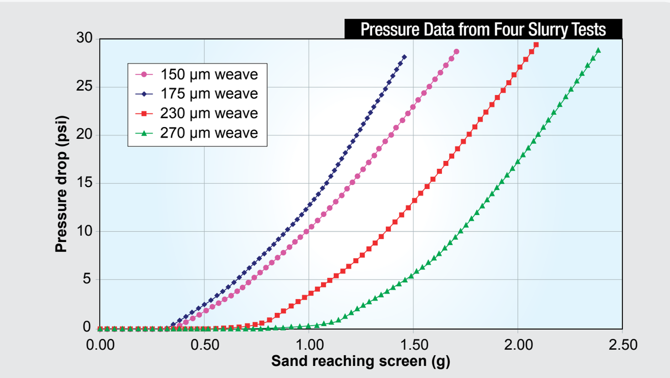
Sand-pack tests simulate compliant sand control or a collapsed borehole. Sand is placed directly onto the screen, and a wetting liquid is flowed through the sand-pack and screen. The test measures, by weight, the amount of sand passing through as well as the pressure drop.



RESULTS Pressure-Buildup Data

For each sand sample tested, pressure buildup is plotted. The pressure buildup is initiated when a sand layer begins to form on the weave surface. As more sand accumulates on the screen, the pressure increases. The longer the time delay from the start of the test to the start of pressure buildup, the greater the amount of sand that has passed through the screen. If the sand is tested on a different screen and/or screen aperture, potential plugging may be identified by a steeper pressure rise.



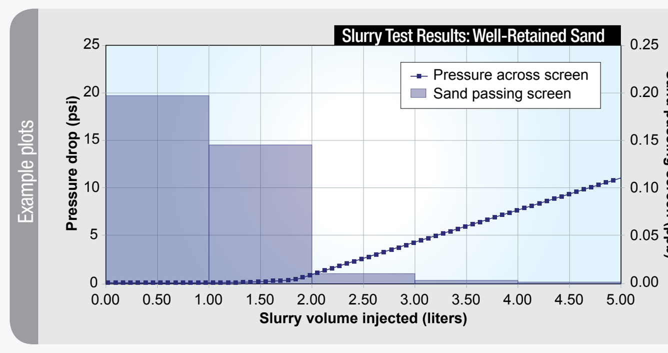


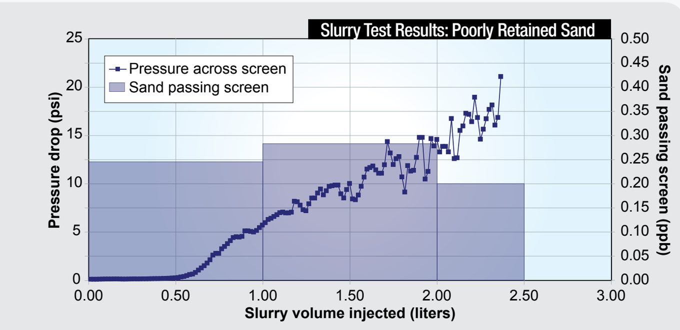
ESS weaves tested for the same sand sample. Note that the 175 μm weave has a steeper gradient.

Example plots

RESULTS Sand Retention Data

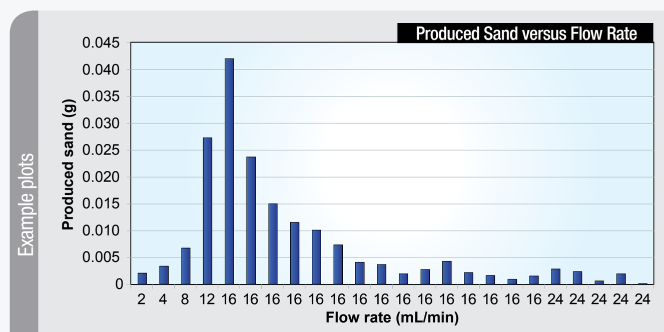
The amount of sand passing the screen in slurry tests and sand-pack tests is recorded. In slurry tests sand passes the screen until a layer is formed over the screen surface, after which, if good retention is achieved, little or no more sand will pass. If the sand is poorly retained, the pressure will be unstable and sand will continually pass through the screen.



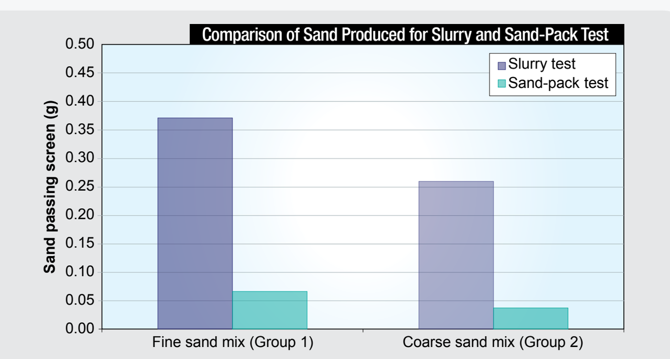


Example plots

Sand-pack tests also record the change in sand passing through the screen with flowrate. If the sand is well retained, the sand passed initially increases slightly with flowrate; but if the flowrate is held constant, stable bridges form in the sand-pack, and the passed sand decreases. If these bridges are disrupted (for example by a flowrate change), they are quickly re-established and the produced sand returns to a low, underlying level.



In general, more sand is produced in slurry tests. Slurry tests require time to build up the sand layer and bridges, whereas in pack tests the sand layer and bridges are already established when the tests start.



Example plots

D Refine Sand-Control Selection

Once the optimal filter media is identified, a specific sand-control method and screen selection can be refined. Key to selection of the most appropriate sand-control method is the ability to minimize sand production while limiting the impact on well productivity.

	Wire-Wrap	Metal-Mesh	ESS®	Openhole GP
Description of Filter	A shaped wire wound around a base pipe. The aperture is created by the gap between the wire wraps	A woven, single-layer or multilayer metal-mesh and protective perforated outer cover shaped over a perforated base pipe	Woven metal-mesh, protective perforated outer cover adhered to a slotted liner/base pipe	A wire-wrap or metal-mesh screen is placed in the wellbore; the surrounding annulus is packed with gravel of a specific size to retain the formation sand
Weatherford Products	Dura-Grip® Ultra-Grip™ *Ultra-Grip* HD Super-Weld®	Excelflo® Maxflo®	ESS®	Alternate path wire wrap or metal mesh or conventional wire wrap screen or metal mesh screen
Sand Retention Guideline	1 × D25	1 × D10	1 × D5 / D10	Gravel is sized from 5 to 6 times the formation sand D50. The screen is usualy sized to retain the gravel but can also be sized to retain the formation sand.

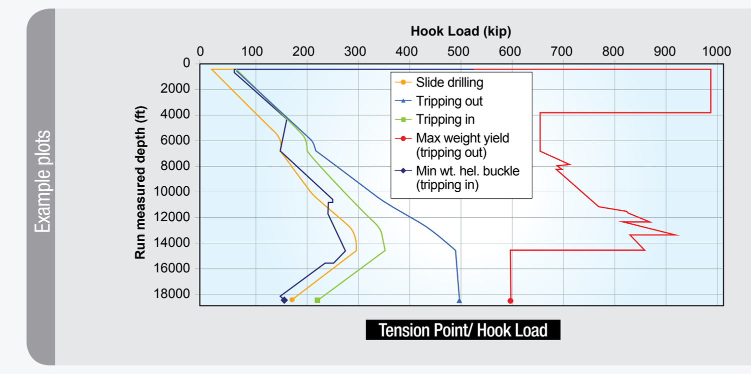
E Consider Completion Design

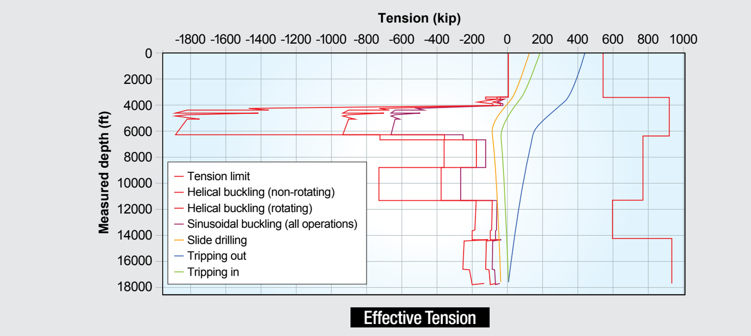
For any given reservoir, there may be several viable sand-control options. Detailed completion application engineering determines the most suitable of all possible sand-control options.

The Well Path

Well conditions, build angle, dogleg severity, extent and size of washouts, reservoir thickness, completion length

Safe, damage-free deployment of sand screens is essential in any application. Well trajectory and the weight of the string are the critical factors in selection of the right work string, which is especially important in more challenging trajectories, such as horizontal and extended-reach wells. Detailed torque-and-drag (T&D) modeling is conducted during the completion design to ensure that the screens can be deployed safely and without damage. During installation of the screens, the same model assists monitoring of T&D.





Example plots

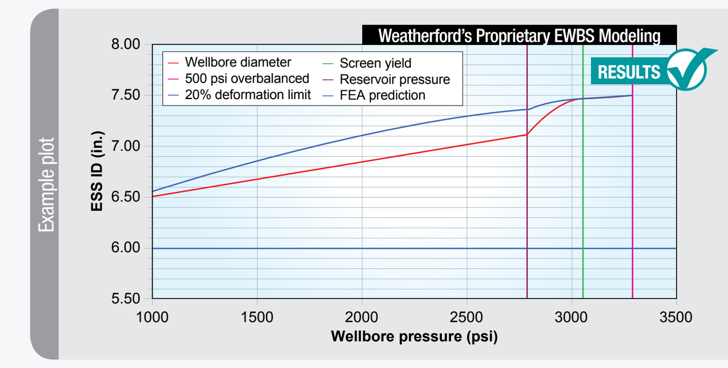
Reservoir Geomechanics

Rock unconfined compressive strength (UCS), pore/fracture gradient, downhole formation pressure, presence and severity of shales, overall reservoir section net to gross (NTG)

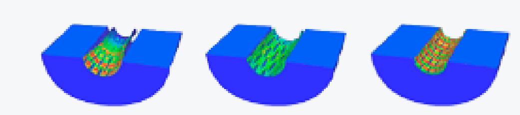
A geomechanical model (EWBS) has been developed to better understand the processes leading to excessive deformation and is used as a screening tool. It calculates the depth of a failed or yielded zone around a wellbore as a function of wellbore support from a mud overbalance or an expandable sand screen. The yielded zone grows as the mud support is removed and the well is drawn down and depleted. Volume changes in the yielded zone compress the *ESS* system.

For every *ESS* application, a detailed analysis should be conducted to ensure that, when expanded against the formation, the combined system has the required properties to withstand all depletion forces. For conventional well screens, this is usually an issue only in high-pressure, severely depleted reservoirs; in these conditions metal mesh may be preferred to the wire-wrap design.

Finite element analysis (FEA) has been used to model *ESS* screens to better understand the interaction of the expanded screen with the rock formation. FEA also allows the investigation of a wider range of configurations, such as the effect of an annulus or the interfaces between different formations.



Example plot

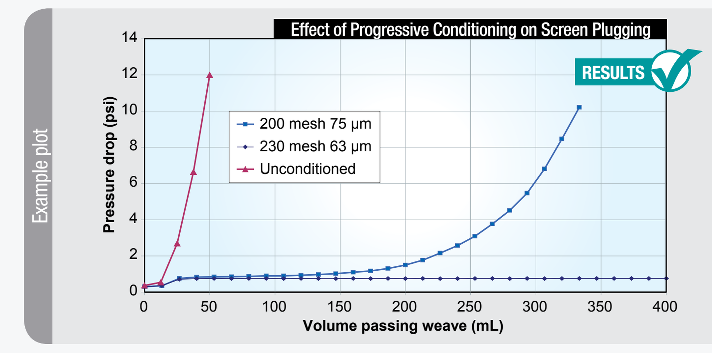


FEA Modeling

Fluids Program

Drilling and completion fluids, mud solids control, cleanup method (including computational-flow-dynamics—CFD—modeling)

There are two main concerns when considering drill-in fluid compatibility with sand screens: plugging the filter medium when running the screens in the hole, and displacing the filter cake back through the screen when production is started. The degree of conditioning required to prevent the drill-in fluid from plugging the screen during deployment is determined through laboratory tests. These tests measure the screen pressure drop caused by drill-in fluid subjected to progressively more stringent conditioning. Rig-site tests are also performed before screen deployment to ensure good conditioning and no plugging. Laboratory tests also evaluate the mud cake generated during the drill-in process as the mud passes through the screen on production startup. Core flood tests are conducted in pairs, one with the screen present and one without. Comparison of the return permeabilities from the two cases indicates whether the screen influences the mud-cake/filter-cake cleanup. If the return permeabilities are the same, the screen has no effect.



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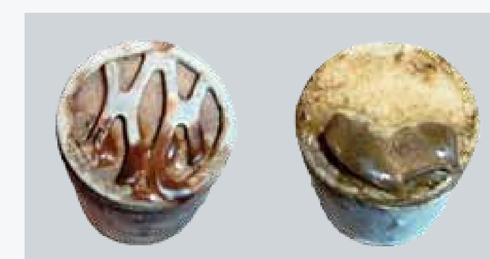
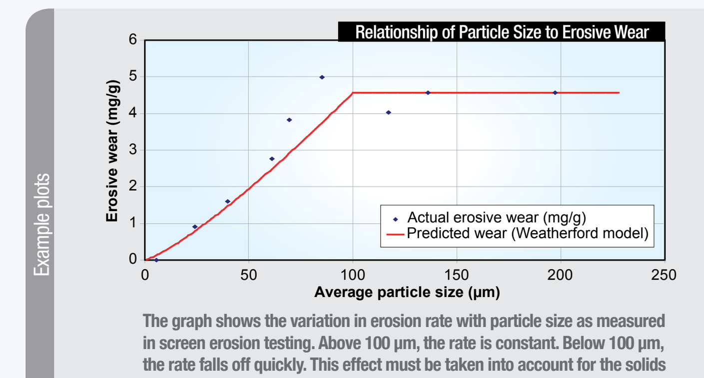


Mud residue after flowback tests on an *ESS* system.

Erosion Potential

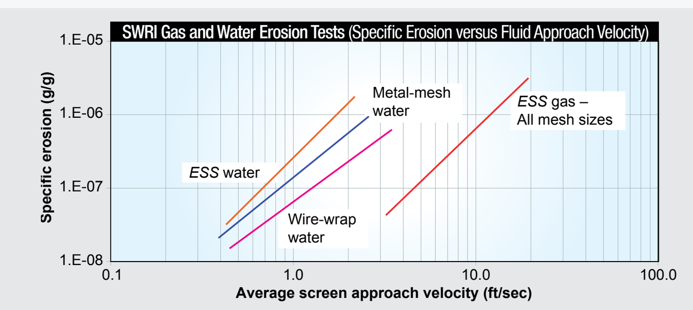
Fluid type, flux rate, solids loading, size distribution, mud filter cake

Erosion is usually considered a major risk in cased-hole sand-control completions but can also be a risk in high-rate openhole and water-injection wells. For compliant sand control, such as *ESS* and openhole gravel-pack systems, erosion is less likely to be an issue, as flux is distributed through the screen. In stand-alone screen completions with an open annulus, formation of hot spots is possible and can lead to high flux rates and rapid, erosion-related failures. Another consideration—mud filter cake that is not properly cleaned up—can result in worm holes, which can cause focused flow into the screen, leading to erosive conditions. The key to controlling this risk is an understanding of the erosion rate and how it affects the sand retention properties of the selected screen. An erosion model, developed by Weatherford, predicts probable time-to-screen-failure based on fluid type, flux rate, solids loading and size distribution. In this complicated, non-linear process, the erosion rate depends on velocity through the screen to the power between 2 and 3; size and concentration of sand particles; and fluid type.



The graph shows the variation in erosion rate with particle size as measured in screen erosion testing. Above 100 μm, the rate is constant. Below 100 μm, the rate falls off quickly. This effect must be taken into account for the solids which typically cause erosion in screens.

Data after G P Tilly, "A Two Stage Mechanism of Ductile Erosion", Wear 23 (1973) 87-96, Predicted Wear from Weatherford Screen Erosion Model



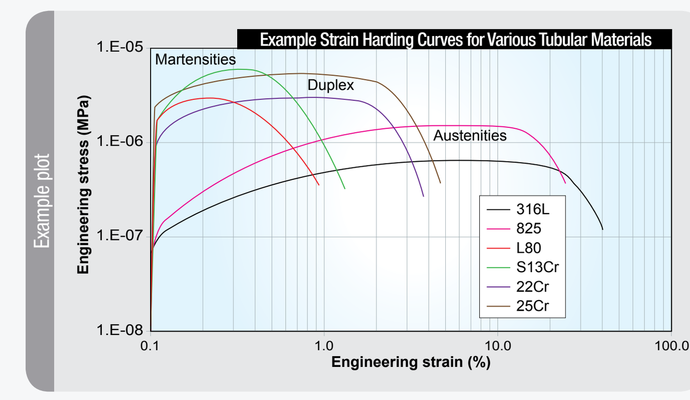
Erosion in air/gas is an order of magnitude less than water. Erosion rate is higher with an open-annulus system, such as MMS and WWS, due to annular flow and hot-spotting. *ESS* technology removes the annulus and annular flow, which more than compensates for the slightly higher specific erosion.

Example plots

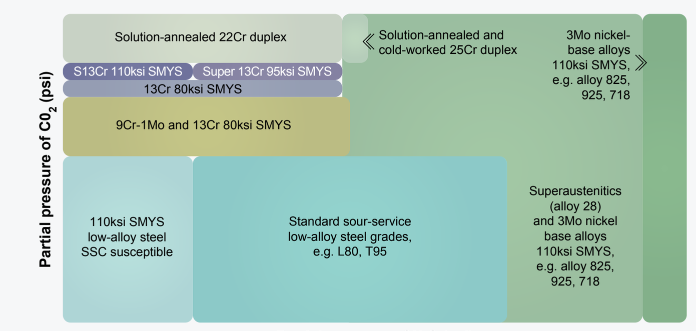
Corrosion Potential

Well parameters from pressure/volume/temperature (PVT) analysis, local well/field information; intervention work (for example, acidizing); metallurgy of production/injection tubing

Material selection for well screens is based on corrosion potential over the planned completion service life. There are no absolute, fixed guidelines for material selection; but Weatherford can assess well-specific parameters and reference environmental diagrams to assist with the selection. Typically, the metallurgy of the production/injection tubing is the starting point for the screen-material selection process. For *ESS* screens, Weatherford's extensive mechanical testing has shown which materials provide the best expansion performance. Testing has also revealed that austenitic stainless and nickel-based alloys have a low work hardening rate, providing excellent elongation.



Example plot

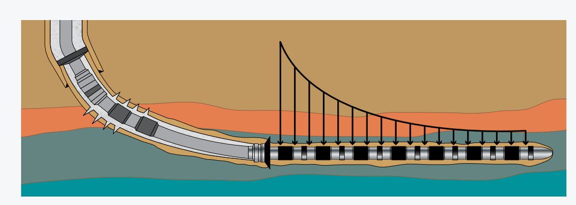


Environmental diagrams, like this one, are based on published literature and international documents and standards, such as NACE MR0175 and ISO 15156. These diagrams are conservative, as they cannot take into account all variations and permutations.

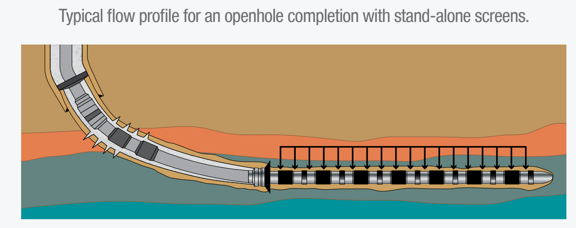
Reservoir Management

Flow rate/permeability profile, water/gas drive and location, expected drawdown, scale and plugging potential

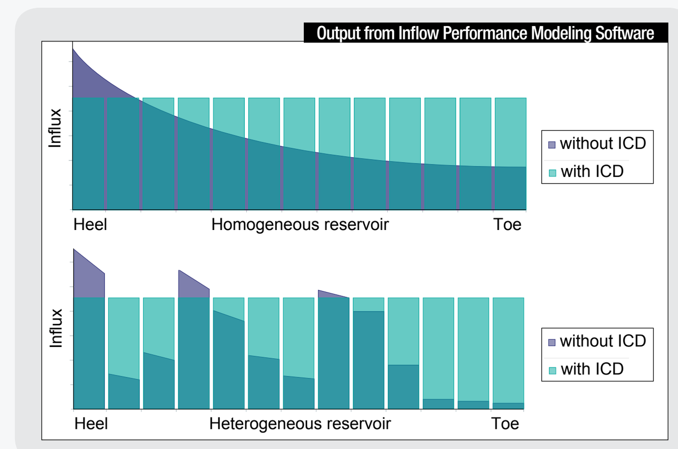
Balancing the inflow from the heel to the toe of the production interval can significantly delay potential water or gas breakthrough as well as increase total recovery. Integrated reservoir modeling tools are used to establish optimal inflow performance. Inflow control devices (ICDs), configured specifically for each application, ensure the appropriate pressure drop along the production string to achieve maximum well cleanup and reservoir drainage for ultimate recovery, to enhance the performance of wire-wrap and metal-mesh screens, and to extend their operational capability.



Typical flow profile for an openhole completion with stand-alone screens.



ICD technology, combined with screens, balances the inflow profile.



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