Sand Control Solutions

HALLIBURTON

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Preface

Sand control is vital to reliable production in many sandstone reservoirs where sand can present a major obstacle to well production. The petroleum industry spends millions of dollars each year to prevent and repair sand control problems including:

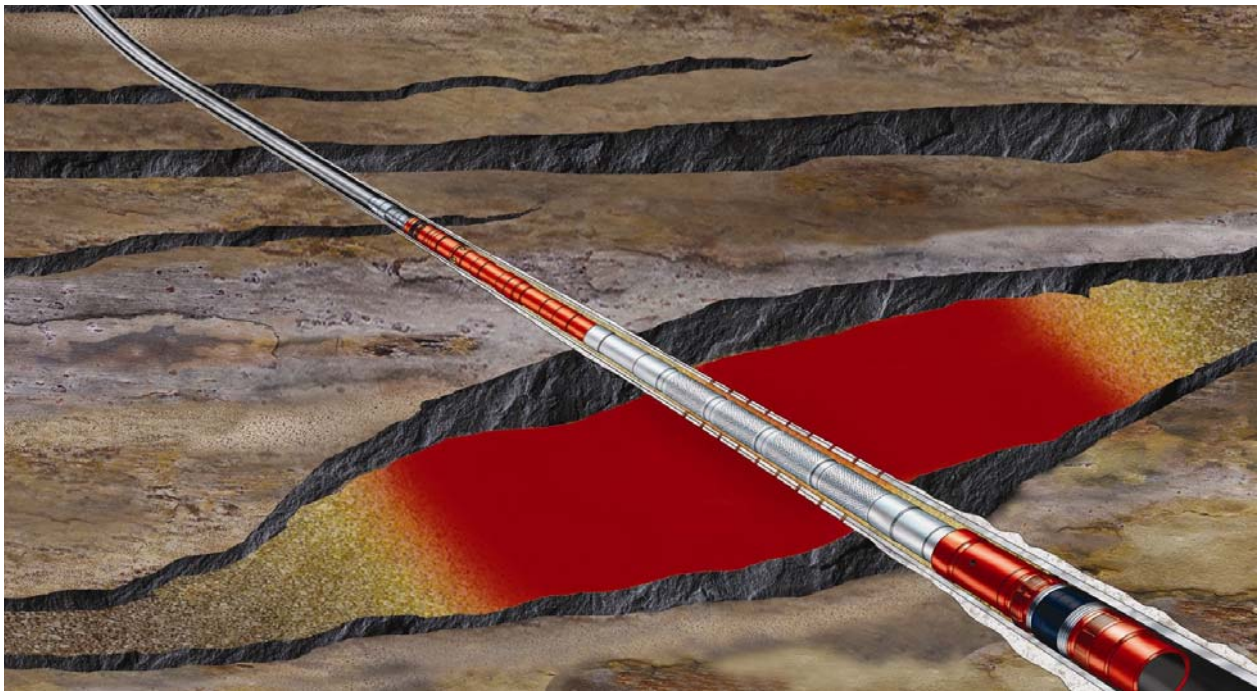
- Reduced production rates
- Sand bridging in tubing and casing
- Erosion of downhole and surface equipment
- Disposal and removal of sand
- Casing damage from compressive loading caused by subsidence

Halliburton Sand Control Services

Halliburton provides a single source of solutions to these and other sand control problems. Halliburton offers dedicated equipment and total services for gravel packing, high-rate water packs, frac pack treatments, horizontal screen-only completions, and horizontal gravel packs as well as a variety of formation stabilization systems—all of which can be supported with computer simulated designs.

Halliburton believes proper well candidate selection and treatment designs, excellence in onsite delivery, safe execution, and post-treatment reporting and analysis are the keys to a successful sand control program.

Halliburton Sand Control Services start with an in-depth analysis of the reservoir and well conditions. Once a sand control method has been chosen, the design of the related fluid systems and downhole equipment can begin. Halliburton provides specialized surface and downhole equipment including gravel pack packers, inflow control technology, and screens to inhibit movement of formation sand into the wellbore, surface pumping equipment, fluid systems, and filtration systems. Sand Control Completion Services are customized to suit individual well and reservoir requirements designed to capture the best value from the asset.



HAL25134

High-Rate/High-Volume Beyond Red Zone® FracPac™ System for Reservoirs with High Potential

Qualified Personnel

Halliburton Sand Control personnel have the expertise and experience to understand the special concerns of operators with sand production problems. Dedicated, highly qualified Halliburton engineers and technicians conduct developmental projects with a variety of downhole completion tools and systems. With ongoing fluids research, our professional personnel provide expertise in developing fluids, acid formulations, gelling agents, formation stabilizers, and processes that enhance the productivity of wells with the potential for sanding problems.

Halliburton service specialists and other field technical support personnel are among the most experienced in the industry, learning from knowledgeable veterans and receiving extensive training on the job and in the classroom. For customers, we offer special training seminars to familiarize them with Halliburton equipment and operations.

Training Centers

Training provided by Halliburton is designed to match or exceed that of any other service company. Major training centers are found in the following locations although much of the education is conducted in the individual locations around the world through home study courses and on-the-job training.

- Sandersville, Mississippi
- Carrollton, Texas
- Duncan, Oklahoma
- Houston, Texas
- Montrose, Scotland
- Ipoh, Malaysia
- Cairo, Egypt
- Villahermosa, Mexico

Quality, Health, Safety, and Environment Program

Rather than focusing only on a quality system such as ISO-9001, Halliburton has chosen to develop a business system which incorporates quality, health, safety, and environmental requirements in one single management system. The Halliburton Management System (HMS) defines our processes and includes quality, safety, environmental, and occupational health check points.

Health, Safety, and Environmental Policy

Halliburton recognizes the importance of meeting society's needs for health, safety, and protection of the environment. We work proactively with employees, customers, the public, governments, and others to use natural resources in an environmentally sound manner, emphasizing the safety of employees and the public as well as the needs of future generations. We are dedicated to continuous improvement of our global health, safety, and environmental processes while we supply high-quality products and services to customers. To meet these responsibilities, we manage our business according to the Health, Safety, and Environmental (HSE) principles.

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Halliburton Training Centers deliver training solutions to grow the competence of our personnel in meeting our customers' needs

Research and Development

With Halliburton's extensive sand control experience, customers are provided with advanced technology and outstanding personnel to solve problems efficiently and effectively. Halliburton research and development efforts are carried out in various locations:

- Carrollton Technology Center – Carrollton, Texas
- Houston Technology Center – Houston, Texas
- Pune Technology Center – Pune, India
- Aberdeen Technology Center – Aberdeen, Scotland

Singapore Technology and Manufacturing Center

The Completion Technology and Manufacturing Center in Singapore significantly expands Halliburton Completion Tools technology and manufacturing capacity. Complementing our Carrollton, Texas facility in the Western Hemisphere, the Completion Technology and Manufacturing Center serves as the new global headquarters for Completion Tools, allowing for the delivery of high-quality products to a broad and growing customer base in the Eastern Hemisphere.

This vast state-of-the-art facility includes manufacturing, technology, and administrative space. Technology laboratories and test facilities house complex processes such as high-alloy material precision machining, electrode discharge machines, and small deep-hole gun drilling. In addition, deep well simulators, high-pressure/high-temperature testing facilities and a deep horizontal well enable all aspects of engineering testing and simulated systems integration testing.

Completion Technology and Manufacturing Center in Singapore

Carrollton Technology Center

Halliburton Research and Development for Sand Control Tools at the Carrollton Technology Center features an 11,000 ft² (310 m²) laboratory and testing complex. The center's engineering test facilities provide engineering analysis and support, high-temperature/high-pressure testing, and tool prequalification to API and ISO requirements. The center also includes two working test wells with rig accessories, slickline, and electric-line operations as well as flow testing capabilities which allow Halliburton to simulate actual well environments before running new tools in a customer's well.

Rheology Laboratory

Rheology research includes use of flow loops in various applications. Medium-scale loops test fluids developed in the research centers, while large-scale flow loops obtain full characterization of the rheology of fluids for gravel and frac packing.

Other rheology laboratory analysis studies the effects of high-pressure gases and liquids on materials at elevated pressures and temperatures. A slow-strain rate tester tests the cracking resistance of nickel alloys and other high-alloy metals.

Polymer Laboratory

A polymer laboratory tests and evaluates the latest polymeric materials for both surface and downhole applications. Equipment includes test cells capable of testing seal materials up to 500°F (260°C) and pressures of up to 30,000 psi (2067 bar). In addition, extensive studies are conducted on the effects of organic amine corrosion inhibitors on elastomers. Halliburton's research in seal materials has yielded elastomer compounds unrivaled in the industry.

Metallurgical Laboratory

Mechanical testing and certification performed in the metallurgical laboratory provide analysis and daily support for manufacturing. An important function of the metallurgical lab is supplying materials recommendations to customers based on individual well data. Heat treatment tests determine if alloys will function downhole as needed. A scanning electron microscope can examine the surface of a failure to determine the cause, whether it be environmental embrittlement, incorrect chemistry, or overstress.

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Carrollton Technology Center

Deep Well Simulator

A unique deep well simulator at the Halliburton facilities in Carrollton, Texas tests full-size, downhole tools in hostile environments. For example, high-temperature/high-pressure packers may be tested in simulated conditions up to 1,000°F (537°C) and 30,000 psi (2067 bar) hydrostatic pressure. Other testing uses two rig-equipped test wells, also located onsite, to confirm tool compatibility, operating sequences, and service techniques.

Mike Adams Test Well Facility

As the demand for energy increases, the drilling and completion of wells continues to forge new boundaries. Higher pressures, hotter wells, and tool complexities require state-of-the-art facilities. Named in memory of one our most respected Test Department leaders, the "Mike Adams" test well is designed to be safe, operationally efficient, and best in class for downhole testing of tools for both vertical and horizontal applications.

The Mike Adams facility is a modern drilling rig running on clean, quiet electric power with SCR controls. This big bore well has a cased hole configured with 20-in. × 13 3/8-in. × 10 3/4-in. × 9 5/8-in. casing. The 9 5/8-in. casing kicks off the vertical bore through a 16° per 100-ft radius in a horizontal section. The facility features a doghouse with a safe viewing room for customers, modern data acquisition system, dressing facilities, and office area.

The Carrollton facility also includes a second test well used primarily as backup during peak periods of use of the Mike Adams test facility. This backup test well can be used for full scale testing of packer, safety valves, Sliding Side-Door® devices, wireline tools, coiled tubing units, snubbing units, and pumpdown installations. The facility is equipped with a variety of popular casing and tubing sizes to allow installation and testing of well completion tools and service equipment.

High-Temperature Test Facility

The high-temperature test facility (HTTF) is used to test experimental designs for use in high-temperature/high-pressure wells. The HTTF has five below-ground heated test cells and one rapid cool down cell. The HTTF is ideally suited for testing packers per ISO 14310/API 11D for all "V" class ratings. Each test cell is designed to accommodate assemblies up to 30-ft (9.14-m) and 30-in. (762-mm) diameter and has a temperature range up to 700°F (371°C). The device undergoing testing receives uniformly heated air to simulate severe temperatures down hole. The rapid cool down test cell employs a self-contained chiller unit capable of cooling to 32°F (0°C).

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Halliburton's state-of-the-art research and testing facilities, which include the deep well simulator (shown) accelerate the development of new equipment technology already in demand by the petroleum industry.

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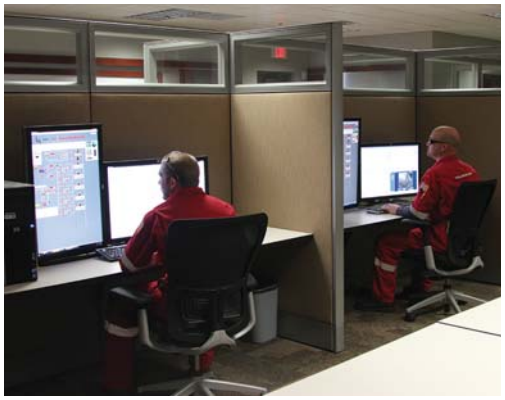
Mike Adams Test Well

The HTTF control room contains Allen-Bradley touch screen controllers and a PC-based data acquisition (DAQ) system, which uses software to store information in a format that can be analyzed or charted. Information can be printed directly from the DAQ system in a line chart format for immediate review. Cameras safely monitor the test cell area for potential problems without exposing technicians to high pressure or temperature. A gantry crane above the simulator facilitates safe handling of long, heavy assemblies.

A special inert gas system makes the cell's sealed/contained atmosphere nonflammable. An oxygen analyzer and alarm system monitors cell atmosphere, and controls are provided to maintain inert mixtures for lower explosion limit control. The only system pressure limitations are imposed by the physical parameters of the test fixture and casing joints. Through this system, Halliburton can accelerate development of new equipment technology already in demand by the petroleum industry.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The high-temperature test facility allows us to test equipment for use in high-temperature/high-pressure environments without exposure to extreme conditions.

Houston Technology Center and Pune Technology Center

Formation evaluation is one of the first steps in a successful sand control job. Since no two wells are exactly alike, careful analysis of formation sand samples and fluids is critical to every Halliburton sand control design. This is true whether the technique is chemical consolidation, combination systems, mechanical gravel packing, or running a premium screen, prepacked screen, wire-wrapped screen, or slotted liner.

Evaluation includes analysis of samples of formation sand, produced crude oil, and formation brine. Extensive knowledge of pretreatments and gravel pack procedures helps ensure fluids will be compatible with each other and with the formation.

The North Belt Campus in Houston, Texas is home to Halliburton's largest technology center—the Houston Technology Center. At 215,000 ft², it is the largest Halliburton facility globally. The primary sand control focus is fluid development and field support, Geomechanics testing, analytical testing, and core flow testing.

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Houston Technology Center

Halliburton's Fluids Center of Excellence for the Eastern Hemisphere, the Pune Technology Center in Pune, India, supports the key technology areas of Fluids Chemistry and Engineering, Fluids Delivery Systems, and Reservoir Knowledge. The engineers and scientists at the center are dedicated to finding innovative solutions for the ever-evolving energy industry.

Housed in the 66,000 ft² Pune facility is a broad range of research, development, and support activity, including teams and laboratories dedicated to Cementing, Production Enhancement, Baroid Drilling Fluid Systems, and Sperry Drilling. The Pune team is committed to delivering consistent quality service in accordance with ISO 9001:2008 requirements. Working in collaboration with other Halliburton Technology Centers, further expands our capabilities to open virtually unlimited problem-solving possibilities.

The labs in Houston and Pune provide sand control support from a production enhancement fluids/analytical/ Geomechanics perspective for both new product development and technical service/field support.

Pune Technology Center

Production Enhancement Division

The Production Enhancement Division helps customers manage and improve well production for new or already-producing wells and includes acidizing, fracturing, sand control, conformance technology, and coiled tubing technologies. Our capabilities make use of equipment, facilities, telecommunications systems, and a global network of real-time applications, combined with our extensive knowledge and experience.

Sand Control product development personnel work on a variety of systems that will aid in the sand control completion. These systems include carrier fluids for fracturing/gravel packing, formation stabilization products, fluid loss products, etc.

The field support or Technical Service group tests the wide range of Halliburton products used in sand control completions. Testing includes:

- Regain permeability testing of cores following treatment fluids such as formation stabilization systems, carrier fluids, fluid loss control materials
- Sieve analysis
- Large scale testing of products (typically in Halliburton's Duncan, Oklahoma test site)

Analytical Chemistry

Analytical Chemistry laboratories in Houston and Pune house the electron microscopes, Nuclear Magnetic Resonance, and X-Ray diffraction tools as well as other high-tech equipment used to investigate samples from the field. Halliburton's experienced scientists use these tools to perform time-sensitive tests on samples, cores, and fluids to find answers for clients. Depending on the nature of the sample material, testing might require use of multiple instruments to paint a complete picture of the situation. Some of the tests include:

- Inductively Coupled Argon Plasma Spectrometry (ICP) to identify concentrations of metals in brines, clays, and soil samples
- FTIR microscopy to obtain an infrared spectrum of data like absorption, emission, and photoconductivity from a specific region of a sample
- Thermal Gravimetric Analysis (TGA) to analyze the decomposition of a sample material
- Loss on ignition
- Particle size analysis
- Scanning Electron Microscope (SEM)
- X-Ray diffraction

Other tests such as testing of corrosion inhibitors and formulations, dynamic fluid loss testing, and conductivity testing are performed at the Duncan Technology Center.

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Geomechanics

The Halliburton Geomechanics laboratory is one of only a few labs capable of performing a digital core analysis. Other capabilities include:

- Complicated mechanical fracture-type studies of loosely consolidated sandstone
- Specialized tests and fracture studies on actual field cores
- Simulated downhole conditions while studying fractures of those cores

The Geomechanics lab provides fast, cost-effective tests under pressures and temperatures found in the reservoir, including:

- Numerous mechanical properties under both confined and unconfined conditions
- Polyaxial, triaxial, and uniaxial testing for Young's Modulus, Poisson's Ratio, and compressive strength
- Ultrasonic velocities
- Brinell hardness test
- Brazilian tensile strength
- Mohr failure envelopes
- Fracture toughness
- Thick-wall cylinder strength
- Proppant embedment
- Fracture stimulation
- Fluid compatibility

The Geomechanics laboratory's sophisticated machinery can examine samples larger than most other labs in the world with the ability to exert more than a half-million pounds of force on samples.

Besides physical testing, sophisticated numerical simulation capabilities with supercomputer computation power enhance understanding of Geomechanics to help design creative Geomechanics tests. The data collected can be used for sanding studies in concert with Halliburton's Consulting & Project Management Group.

All oilfield disciplines come together in Geomechanics. The insights developed here have helped Halliburton become one of the world's most efficient oilfield service companies.

Field Support Laboratories

In addition to the facilities in Houston and Pune, Halliburton has field support laboratories in various locations around the world. These laboratories can provide localized support and also conduct quality control of the chemicals to be used on the job.

Manufacturing Facilities

Manufacturing facilities for downhole sand control equipment are found at the following locations:

- Carrollton, Texas
- New Iberia, Louisiana
- Lafayette, Louisiana
- Arbroath, Scotland
- Jurong, Singapore
- Johor, Malaysia

The following Halliburton locations manufacture surface sand control equipment:

- Duncan, Oklahoma
- Arbroath, Scotland

Lafayette Manufacturing Center

System Design Capabilities

Halliburton offers an extensive array of software packages that support job design for sand control completions. These include (but are not limited to):

Reservoir Modeling

- QuikLook® service – Numerical simulator primarily intended for reservoir fluid management. It is the first simulator designed specifically for use by practicing engineers. QuikLook service is a 3D, three-phase, four-component, non-isothermal reservoir simulator that numerically solves the differential equations for multi-dimensional fluid and heat flow through a porous medium. The QuikLook simulator is used to design various completion and exploitation strategies. It may also be used to optimize design and evaluate various reservoir treatments such as conformance and fracturing.
- NETool™ simulator – Steady-state, network-based simulator used for calculating multiphase fluid flow through a well completion and near-wellbore region. Once the reservoir description is obtained, it can be imported directly from the reservoir software without modification or simplification.
- Landmark Graphics PRIZM™ well log analysis package – A well log analysis program developed by GeoGraphix.
- StiMRIL™ integrated stimulation process – Integrates magnetic-resonance imaging (MRI) analysis and reservoir simulation into a stimulation treatment design for creating an accurate reservoir model.

Completion Design Modeling

- P-MAX™ program – Predicts maximum pressure where a premature sandout occurs during pumping (the mixed fluid suddenly stops moving into reservoir during sand-control operation). The P-MAX program is capable of modeling multiple pumping schedules as well as taking into account the ballooning and water hammer effect.
- WEM™ system analysis program (PE Moseley and Associates, Inc.) – Used to evaluate/optimize sand control completions in the design phase and performance evaluation. It is a reservoir inflow, wellbore surface flow simulator used to model multiphase flow, reservoir performance, and tubing performance characteristics of the well.
- Landmark Graphics' PROFILE™ system – Enables any engineer—from rig supervisor to completions engineer to business analyst—to quickly visualize currently installed and historical wellbore information and downhole equipment in the form of wellbore schematics and reports.
- Cyberstring® program – Advanced tubing movement program that calculates the movements, forces, temperatures, and stresses occurring in the tubing string and downhole tools during well operations, including major well operations—setting packers, pressure testing, injecting, producing, circulating, and shutting in.
- CyberWell® electronics system integration test – Allows for integration of multiple tool systems together to maximize operations on each trip in the well. Its broad capabilities also help quicken turnaround time without sacrificing crucial job planning.
- WELLCAT™ program – Primarily used for modeling thermal effects during production operations although it has multiple other capabilities.
- ShockPro℠ service – Used to evaluate mechanical risk factors of all well components to help ensure all aspects of Health, Safety, and Environment (HSE) and Service Quality are covered. This information helps determine the peak pressure applied to a packer. Once dynamic failure criteria have been established, the software can be used to examine whether potential problems may occur with a given perforating assembly.
- SurgePro℠ service – Helps design perforating assemblies and procedures to achieve optimum well productivity. It can be used to predict wellbore and gun pressurizations, wave propagation, perforation damage, determines the maximum dynamic pressure and load that can be safely applied to packers, plugs, tubulars, and casing.
- PerfPro® perforating service solutions – A systematic approach to delivering engineered perforating systems. The process includes perforation flow modeling and damage assessment performed with a fully 3D finite-element model.
- Completion fluids graphics (CFG) – Proprietary software tool from Baroid determines optimal displacement fluids based on actual wellsite specifications.
- 3L Communications / Jaycor GPS2001 gravel pack simulator – A pseudo 3D model of flow of gravel and fluids in deviated wells and perforations for the design and evaluation of gravel pack treatments. The GPS can handle both vertical and horizontal gravel packs.
- Force (filtercake erodibility) – Hole displacement solids and excess wall cake removal are critical to the ultimate productivity of horizontal completions. This tool incorporates the findings of Halliburton's extensive research of this process.

Stimulation Modeling

- Stim2001™ software package – Proprietary software package for selection of potential candidates for many types of stimulation including acidizing, fracturing, and reperforating.
- Material Library – Calculates and displays the engineering properties of Halliburton materials.
- SS-MAP™ program – Organizes the critical reservoir/formation mineralogy/treatment fluid interrelations into one comprehensive, user-friendly program to optimize treatment fluid design and improve sandstone acidizing success.
- FracproPT® program – Principal software tool for design and modeling of hydraulic fracturing treatments. It is the Gas Research Institute (GRI) fracture-stimulation engineering software supported by Pinnacle Technologies.
- StimPlan™ program (developed by NSI Fracturing Technologies, Inc.) – A fracture design simulator with special modifications for tip screenout designs. At tip-screenout initiation, fracture extension is stopped, and the program calculates a width increase based on the increase in net treating pressure. This program will analyze complex formations composed of multiple productive layers with varying fluid-loss coefficients.
- GOHFER® grid oriented hydraulic fracture extension replicator (Barree & Associates) – Easy to use, realistic 3D fracturing design simulator that uses a finite difference method to compute the fracture growth, fluid leakoff, proppant transport, and acid reactivity, which sets it apart from other such simulators on the market.
- HzGPSim™ program – Predicts and models horizontal gravel packing in open and cased holes. It models the alpha/beta wave mechanism for horizontal gravel packing and calculates required injection and return rates, expected bottomhole treating pressures, alpha/beta wave heights, predicted time for end of alpha/beta waves, and minimal rate below which premature screenout occurs.
- Sieve™ Plus program – PC-based program calculates and plots sieve analysis results.
- AcidCalc™ program – PC-based program calculates acid and brine mixes.
- Darcy, Forchheimer, Ergun programs – Darcy calculates pressure, flow rate, and viscosity relationships using Darcy's linear flow equation. It can be used to estimate the gravel height above the gravel pack screen using sandout conditions conforming to Darcy flow through the pack in the blank annulus above the top of the screen. The Forchheimer program calculates pressure, flow rate, and viscosity relationships using non-laminar linear flow equation. This program estimates the height of gravel above the gravel pack screen at sandout conforming to non-laminar flow through the pack in the blank annulus above the top of the screen. The Ergun program calculates pressure, flow rate, and viscosity relationships using the Ergun program linear flow equation for a bed of spherical particles. It can estimate height of gravel above the gravel pack screen at sandout conforming to laminar or non-laminar flow through the pack in the blank annulus above the top of the screen.
- Max Rate-Max Pressure™ calculator – Calculates rate, surface pressure, bottomhole pressure, and skin relations. It is used to simplify planning and monitoring of matrix acid treatments using high matrix rates to improve the uniformity of zonal treatment distribution. This concept is described in SPE17154, SPE20623, and SPE24781 by Paccaloni, et al.
- K-Max™ calculator – Calculates the components volumes of a K-Max™ or Z-Max™ pill in various fluid weights.
- Sand Transport – Various sand transport data exists, including slip velocity calculations, terminal particle settling velocity, Gibbs critical transport velocity, single particle settling velocity Newtonian fluids, Stoke's Law, fall rate in water, single particle settling in non-Newtonian fluids (Moore correlation), etc.
- Sand/Screen Sizing – Takes the data from Sieve™ Plus program or other means of determining D_5, D_{10}, D_{50}, D_{40}, D_{90}, D_{95}, fines content, etc. and uses it to determine a gravel or proppant mesh for gravel packs or FracPac™ treatments.
- FracPac-N℠ fracture design service – A fracturing treatment normally includes a minifrac and step-rate test with results from the procedures used to calibrate the frac model. Although extremely valuable in low permeability (hard rock) formations, field data has shown that data obtained from a minifrac treatment and step-rate test are not always accurate enough to provide optimized frac geometry in high permeability (hard rock) frac pack treatments. FracPac-N service replaces these steps with a process that helps optimize frac pack treatments, saving rig time and fluid costs.

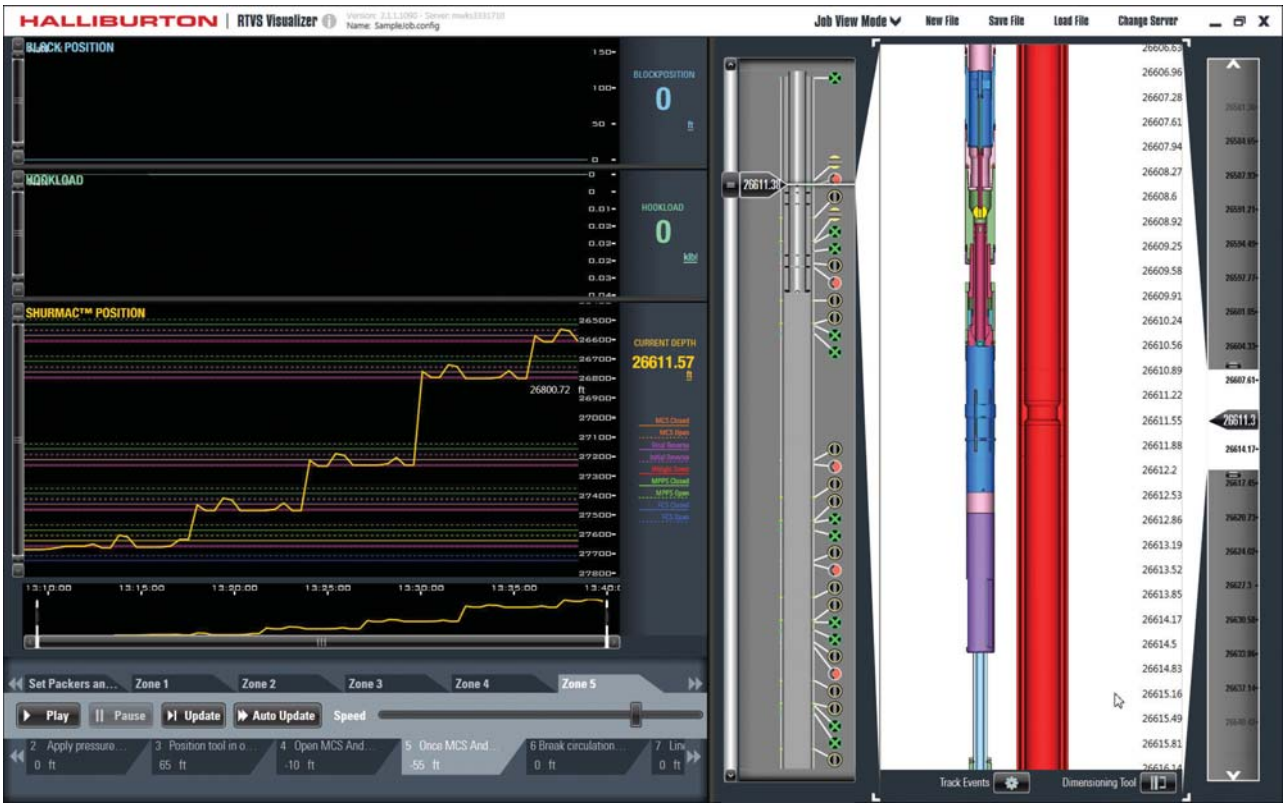
Real-Time Monitoring

- Real-Time Visualization Service (RTVS) software package – Developed to assist Halliburton completion teams in planning and monitoring complex completions. During pre-job planning, a simulator is available to validate the expected interaction between the service tool and the sandface completion string based on the proposed completion plan.

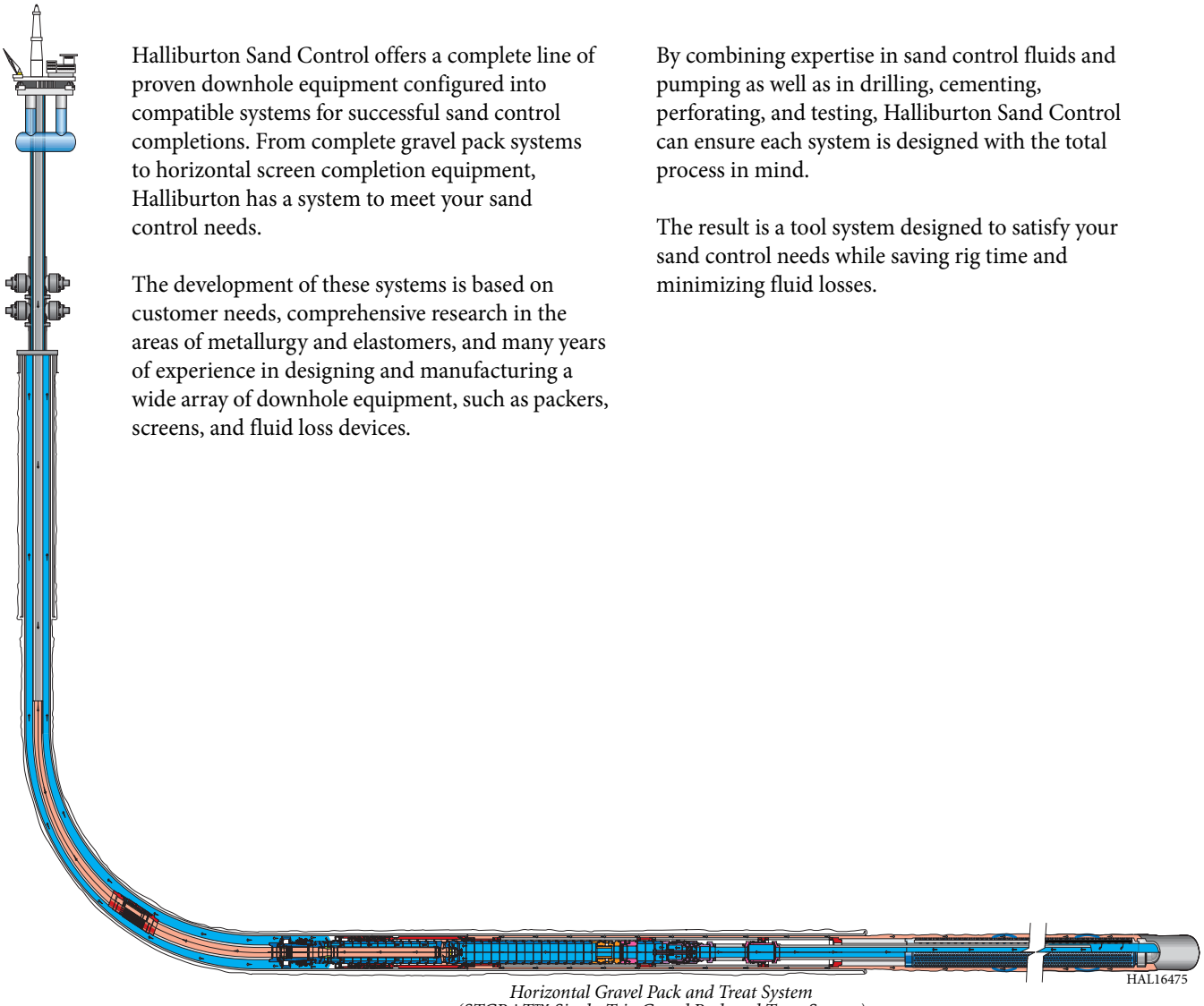
  During the job, a 2D/3D visualizer provides the capability to monitor real-time downhole tool positions and movements (squeezing, circulating, and reversing) as each interval is treated. RTVS is strictly a passive system using surface data sources.

After the job, recorded tool movement data can be replayed for post-job reviews. The RTVS system assists in ensuring no unexpected component interaction occurs as the service tool traverses the sandface assemblies.

Since late 2007, RTVS has been used to support all Halliburton ESTMZ™ tool installations to date; including system integration tests, field trials, and commercial installations in the US, Gulf of Mexico, and Asia Pacific. The service is described in technical paper OTC 23626 "Sand-face Completions Enter the Real Time Age with a One-of-a-Kind Downhole Visualization Tool."



Downhole Tool Systems



Horizontal Gravel Pack and Treat System
(STGP&T™ Single-Trip Gravel Pack and Treat System)

Halliburton Sand Control offers a complete line of proven downhole equipment configured into compatible systems for successful sand control completions. From complete gravel pack systems to horizontal screen completion equipment, Halliburton has a system to meet your sand control needs.

The development of these systems is based on customer needs, comprehensive research in the areas of metallurgy and elastomers, and many years of experience in designing and manufacturing a wide array of downhole equipment, such as packers, screens, and fluid loss devices.

By combining expertise in sand control fluids and pumping as well as in drilling, cementing, perforating, and testing, Halliburton Sand Control can ensure each system is designed with the total process in mind.

The result is a tool system designed to satisfy your sand control needs while saving rig time and minimizing fluid losses.

Halliburton Sand Control Systems

	Well Design												Completion Design									Sand Control Treatment											Additional System Features			Service Tool Features		
	Cased Hole	Open Hole	Liner Conveyed	Vertical	Deviated	Horizontal	Uphill	Single-Zone	Stacked Zones	Zonal Isolation	Single Trip Multizone	Multilateral	Screen Only Filtration	Gravel Pack	High-Rate Water Pack	Extension Pack	FracPac™ System	RedZone® Frac Pac System	Beyond RedZone® FracPac System	15K psi FracPac System	Influx Balance	Water/Gas Coning Mitigation	Borehole Support	Integrated Filter-Cake Treatment	Sandface Monitoring	Washdown Capability	Pressure Maintenance	Post-Treatment Capability
FracPac™ Systems	√	√		√	√			√	√							√	√	√	√	√						√									
Gravel Pack Systems	√	√		√	√	√	√	√	√	√				√	√	√										√	√								
STGP&T™ Single-Trip Gravel Pack & Treat Systems		√			√	√	√	√		√				√	√											√	√	√							
STMZ™ Single-Trip Multizone Systems	√	√		√	√	√					√			√	√	√	√																		
ESTMZ™ Enhanced Single-Trip Multizone Systems	√	√		√	√						√	√			√	√	√	√	√							√									
Liner-Conveyed Gravel Pack (LCGP) Systems		√	√	√	√	√		√		√		√		√	√								√			√	√								
Dual-Zone SmartWell® Systems	√			√	√	√			√				√	√	√	√	√	√	√							√									
Sandface Instrumentation (SFI) Systems	√	√		√	√	√		√		√						√	√	√	√						√	√									
Standalone Screen Systems		√	√	√	√	√		√		√			√										√	√		√	√	√							
Equiflow® Inflow Control Technology		√			√	√	√	√	√	√		√	√	√								√	√				√								
Stacked Fixed Absolute Isolation Systems	√			√	√				√					√	√	√	√																		
STPP™-GH Single-Trip Perf Pack Systems	√			√	√			√								√	√																		
Through-Tubing Systems	√			√	√			√					√	√	√	√	√																		

Sand Control System Solutions

	Lower Completion Packer Assembly Base Case Components (Top to Bottom)						Screens*
Standard Gravel Pack Systems	VTA Packer[1] VGP Packer[1]	MCS Closing Sleeve[2]	Makeup Sub[5]	EGF Flapper Valves[2] IB Valves[2] FS2 Valves[2]			PetroGuard® Wrap
Alternate Path Gravel Pack Systems	VTA Packer[1] VGP Packer[1]	MCS Closing Sleeve[2]	Makeup Sub[5]	EGF Flapper Valves[2] IB Valves[2] FS2 Valves[2]			PetroGuard Shunt System CAPS℠ Concentric Annular Pack Screen Service
Standard FracPac™ Systems	VBA Packer[1] VCA Packer[1] VCH Packer[1]	Heavy Wall Upper Extension	MCS Closing Sleeve[2]	EGF Flapper Valves[3] ShurShot® Valves[3] IB Valves[3] FS2 Valves[3]	MSJ Shear Joint[4]		PetroGuard Mesh DS
Red Zone® FracPac Systems	VBA Packer[1] VCA Packer[1] VCH Packer[1]	Red Zone Extension	MCS Closing Sleeve[2]	EGF Flapper Valves[3] ShurShot® Valves[3] IB Valves[3] FS2 Valves[3]	MSJ Shear Joint[4]		PetroGuard Mesh DS
Beyond Red Zone® FracPac Systems	VBA Packer[1] VCA Packer[1] VCH Packer[1]	Red Zone Extension	Beyond Red Zone MCS Closing Sleeve	EGF Flapper Valves[2] ShurShot Valves[2] IB Valves[2] FS2 Valves[2]	MSJ Shear Joint[4]		PetroGuard Mesh DS
STGP&T™ Single-Trip Gravel Pack & Treat Systems	VGH Packer[1] VCH Packer[1]	MCS Closing Sleeve[2]	Positioning Nipples[6]	Makeup Sub	FS2 Valves		PetroGuard Mesh DS with PetroGuard Shunt System and with Upstream Downstream Differential (UDD) Valves [7] PetroGuard Mesh DS with CAPS Service and with UDD Valves[7]
Non-Compliant Standalone Screen Systems	VTA Packer[1] VGP Packer[1] VBA Packer[1] VCA Packer[1] VCH Packer[1]	MCS Closing Sleeve[2]	Makeup Sub[5]	EGF Flapper Valves [2] IB Valves[2] FS2 Valves[2]			PetroGuard Mesh DS PetroGuard Wrap

Sand Control System Solutions

	Lower Completion Packer Assembly Base Case Components (Top to Bottom)							Screens*
Compliant Standalone Screen Systems	VTA Packer[1] VGP Packer[1] VBA Packer[1] VCA Packer[1] VCH Packer[1]	MCS Closing Sleeve[2]	Makeup Sub[5]	EGF Flapper Valves [2] IB Valves[2] FS2 Valves[2]				PetroGuard® Swell
Stacked Fixed Absolute Isolation Systems	VTA Packer[1] VGP Packer[1] VBA Packer[1] VCA Packer[1] VCH Packer[1]	MCS Closing Sleeve[2]	Makeup Sub[5]	Isolation System with Slimline DuraSleeve® Sliding Sleeves				PetroGuard Mesh DS PetroGuard Wrap
Sandface Instrumentation (SFI) Systems	Scoop Head Assembly	Splice-Sub	SFI Hydraulic-Set Retrievable Packer	MCS Closing Sleeve with Cable Protection	Makeup Sub[5]	FS2 Valve		PetroGuard Line and Cable System
STPP™-GH Single-Trip Perf Pack Systems	VBA Packer[1] VCA Packer[1] VCH Packer[1]	MCS Closing Sleeve[2]	EGF Flapper Valves[2] ShurShot® Valves[2] IB Valves[2] FS2 Valves[2]	Mechanical Retrievable Packer	Hydraulic Release	Auto-Release Gun Hanger		PetroGuard Mesh DS
Liner-Conveyed Gravel Pack (LCGP) Systems	VCH Packers[1] VGH Packers[1]	Makeup Sub[5]	MCS Closing Sleeve[2]	Cementing MCS Closing Sleeve	ZoneGuard® Packers Swellable Packers	Shrouded MCS Closing Sleeve	EGF Flapper Valves[2] IB Valves[2] FS2 Valves[2]	PetroGuard Mesh DS
LCGP Systems Multilateral with FlexRite® Technology	VCH Packers[1] VGH Packers[1]	Disconnect Tool	ZoneGuard Packers Swellable Packers	Shrouded MCS Closing Sleeve	Makeup Sub[5]	EGF Flapper Valves[2] IB Valves[2] FS2 Valves[2]		PetroGuard Mesh DS
STMZ™ Single-Trip Multizone Systems	VGP Packer[1]	Upper Sealbore	MCS Closing Sleeve	Makeup Sub[5]	Hydraulic Isolation Packers Slipless Isolation Packers			PetroGuard Mesh DS
ESTMZ™ Enhanced Single-Trip Multizone Systems - Cased Hole System	VCH Packer[1]	Makeup Sub[5]	Upper Sealbore	MCS Closing Sleeve	Hydraulic Activated MSJ Shear Joint[4]	Hydraulic Isolation Packers		PetroGuard Modular Screens with Mid-Joint and Frac Circulation Sleeves
ESTMZ Systems - Openhole System and Multilateral with FlexRite® Technology	VCH Packer[1]	Makeup Sub[5]	Upper Sealbore	Shrouded MCS Closing Sleeve	Hydraulic Activated MSJ Shear Joint[4]	ZoneGuard Packers Swellable Packers	Frac Circulation Sleeves Production Sleeves	PetroGuard Modular Screens with Mid-Joint and Frac Circulation Sleeves

Sand Control System Solutions

	Lower Completion Packer Assembly Base Case Components (Top to Bottom)					Screens*
Passive EquiFlow® Inflow Control Technology	VTA Packer[1] VGP Packer[1] VBA Packer[1] VCA Packer[1] VCH Packer[1]	MCS Closing Sleeve[2]	Makeup Sub[5]	EGF Flapper Valves[2] IB Valves[2] FS2 Valves[2]		Adjustable ICDs with PetroGuard® Mesh DS Or Adjustable ICDs with PetroGuard Wrap
Autonomous EquiFlow Inflow Control Technology	VTA Packer[1] VGP Packer[1] VBA Packer[1] VCA Packer[1] VCH Packer[1]	MCS Closing Sleeve[2]	Makeup Sub[5]	EGF Flapper Valves[2] IB Valves[2] FS2 Valves[2]		Autonomous ICDs with PetroGuard Mesh DS Or Autonomous ICDs with PetroGuard Wrap

*Screen types are interchangeable between systems.
[1]Packer selection depends on pressure ratings, temperature, service requirements, casing size, running speed, etc. Refer to pages 3-2 through 3-7 for further details on Versa-Trieve® packers.
[2]Refer to pages 3-20 and 3-21 for further details on MCS closing sleeves.
[3]Fluid loss device selection depends on opening methods, pressure requirements, casing size, etc. Refer to pages 3-22 through 3-28 for further details on selection criteria.
[4]Refer to page 3-32 for further details on MSJ shear joints.
[5]Refer to pages 3-32 for further details on makeup subs.
[6]One-way and two-way positioning nipples are required to operate the ROC™ Reverse-Out Check tool of STGP&T™ service tool assembly.
[7]Refer to pages 3-53 for further details on Upstream/ Downstream Differential (UDD) valves.

Standard FracPac™ Systems

Several very effective gravel packing techniques are available. Each technique has special advantages and is designed for unique applications.

FracPac™ Systems

In the 1990s, industry experts introduced the concept of increasing the pack-sand volume placed outside the casing (high-permeability fracturing). These frac packs required even more specialized tool designs to withstand the high flow rates and proppant volumes being pumped at high pressure. Synthetic proppants became more frequently used since they were more resistant to crushing and had higher permeability under high confining stress. However, because synthetic proppants can be significantly more erosive than sands, they pose additional design problems for tool designers. Sand control continues to evolve. New tool systems, fluids, and chemicals are continually being developed for improved sand placement and pack performance.

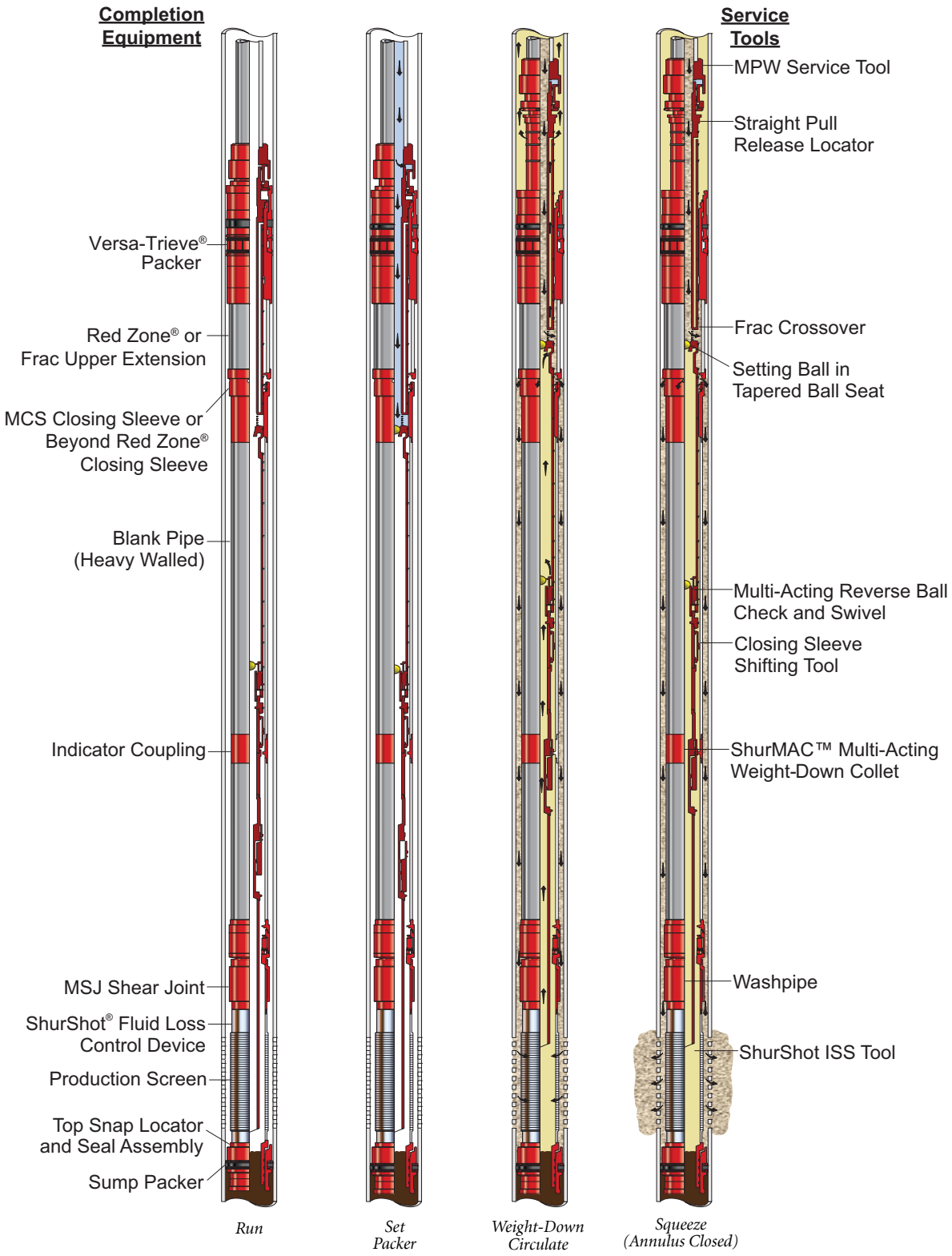
FracPac℠ completion services combine the stimulation advantages of hydraulic fracturing with the most effective techniques available for sand control in poorly consolidated, high-permeability formations. Whether the job is a new completion in a formation known for sanding or a recompletion of a well with existing damage, FracPac™ systems provide a short, wide fracture for bypassing skin damage near the wellbore. Highly conductive proppant is then placed from the leading tip of the fracture all the way to the borehole. This tip-screenout (TSO) method controls sand production both by minimizing radial flow velocity at the wellbore and by stabilizing sand directly at the fracture rather than allowing it to reach and accumulate at the wellbore.

The practice of applying fracturing and sand control in a single treatment has existed for several years. Now the methods, tools, and materials are being designed to take full advantage of the theory behind tip-screenout fracturing as applied to poorly consolidated, high-permeability formations. In such formations, fracture conductivity is the key design factor to effectively bypass damage and provide stimulation. FracPac completion services create the short, wide fractures that promote maximum conductivity to develop maximum productivity potential.

Because FracPac systems can reduce drawdown and flow velocity at the wellbore, formation sand production caused by formation failure or solids migration is reduced. As an investment in higher production rates over a longer production life, a FracPac system completion can offer enhanced benefits compared to a standard gravel pack.

Halliburton has developed systems that provide optimum performance levels for every FracPac system application. From the basic FracPac system to the higher rate Red Zone® tool system to the industry leading Beyond Red Zone® system tools, Halliburton can provide the right solution to meet your sand control frac pack needs.

FracPac™ System



Red Zone® and Beyond Red Zone® FracPac™ Systems

Halliburton's Red Zone® and Beyond Red Zone® FracPac℠ services are complete packages that include pumping and tool system design, tool system analysis, and job execution. Beyond Red Zone FracPac services provide the highest rates and volumes available in the industry.

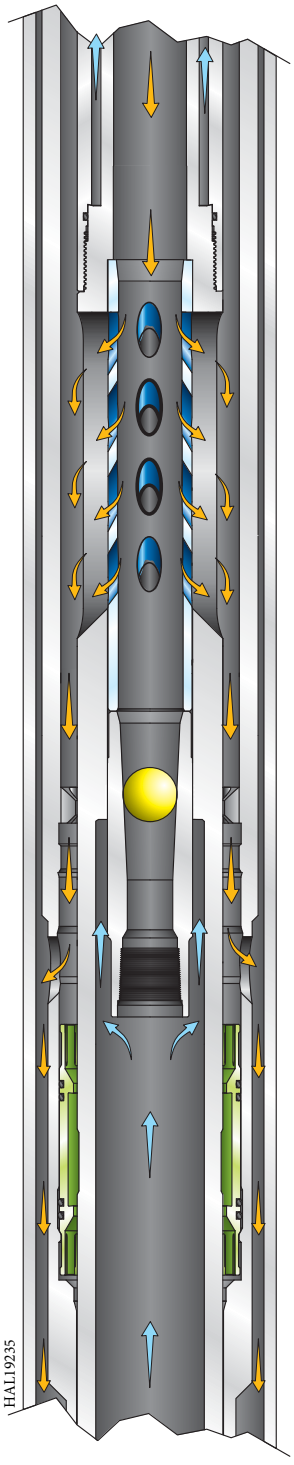
Jobs are analyzed for optimum pumping rates and volumes. Selection and positioning of the service tool, upper extension, and closing sleeve is followed by analysis of the pumping schedule to verify suitability of the system under extreme conditions. Analysis uses one of several tools that may include COSMOSFloWorks™* solid fluid flow modeling, Halliburton's proprietary erosion modeling, or more advanced analysis tools.

The system incorporates the multi-position service tool with Versa-Trieve® packers to provide for ultra high-rate, large proppant volume sand control pumping treatments. The multi-position tool is used to carry the gravel pack assembly downhole and to set the packer. Once the screen assembly is positioned across the perforated interval, a ball is dropped down the workstring. Pump pressure is applied to set the Versa-Trieve packer and either pressure, straight pull, or a combination will release the multi-position tool. In the run-in position, the crossover is located in the sealbore below the closing sleeve. Once the packer is set and the service tool released, the ShurMAC™ collet positions the crossover above the closing sleeve exit ports.

Features

- Utilizes wear-resistant, carbide sleeve technology
- Retains ability to monitor live annulus pressure in all sizes
- Wear is concentrated on the service tool and packer's upper casing extension, not the wellbore casing
- Setting ball is gravitated to its seat below crossover and remains in place throughout the job (not reversed out)
- Washdown capability in some sizes
- Alternating squeeze/live annulus capability in some sizes
- Longer upper extension provides room for tool movement due to thermal effects

**COSMOSFloWorks is a trademark of Structural Research and Analysis Corporation.*



Flow Through Crossover Section of Red Zone® FracPac™ System

Benefits

- Helps increase the likelihood of incident-free sand placement
- Helps reduce cost and risk of individually completing multiple intervals
- Proper stimulation of high kH intervals (long intervals, high perm)
- No ball seat to shear eliminates the chance of pressure surges to the formation
- Treating pressure can be monitored in real time through the annulus for better pack evaluation
- Tubing movement due to pumping pressure and temperature effects can be compensated for prior to the start for better control of the job

Applications

- High kH, poorly consolidated reservoir intervals
- Multiple intervals requiring completion as one interval

Red Zone® FracPac™ System Maximum Tool Ratings

Tool Size	Flow Rate	Volume	Proppant
5-in. 2.55	20 bbl/min	175,000 lb	20/40 (SG2.71) Ceramic
5 1/2-in. 2.75	30 bbl/min	175,000 lb	20/40 (SG2.71) Ceramic
6 5/8-in. and 7-in. 3.25	40 bbl/min 25 bbl/min	400,000 lb 250,000 lb	20/40 (SG2.71) Ceramic 20/40 (SG3.56) Ceramic
7-in. (17-35 lb) 3.88	40 bbl/min	250,000 lb	20/40 (SG2.71) Ceramic
7 5/8-in. 3.88	45 bbl/min	750,000 lb	16/30 (SG3.56) Ceramic
9 5/8-in. 5.00	60 bbl/min	1.2 MM lb	20/40 (SG3.27) Ceramic
9 5/8-in. 6.00	70 bbl/min	800,000 lb	16/30 (SG3.56) Ceramic

Rating can be impacted by customer completion requirements.

Horizontal Gravel Pack Systems

HZGP Pressure Maintenance System

Horizontal gravel pack systems (HZGP) have become a popular method of completing horizontal wells. The simple field-proven horizontal gravel pack tool system provides a reliable method for maintaining and controlling pressure against the formation filter cake to prevent wellbore collapse. Using a computer simulator to design enhanced alpha/beta wave placement, the system maintains optimum screen coverage with predicted alpha/beta wave pressure curves. The damage-tolerant design of the PetroGuard® Wrap screen adds to the system's reliability. The HZGP system is consistently executed around the globe.

The HZGP tool system has a packer pre-setting mechanism to prevent the packer from setting prior to use. The system also provides standard gravel pack positions, an injection control device for acid spotting, and an activated ball check for hydrostatic maintenance. The system has washdown capabilities while running the packer and toe-to-heel and heel-to-toe circulation capabilities after setting. The lower telltale screen and shoe can be isolated after packing.

Features

- Simple, trouble-free installation
- Spiral centralizers ease running, maximize hole cleanup, and help aid in prevention of screen plugging
- Allows positive identification of the tool positions with tension and compression
- Pressure maintenance feature helps ensure pressure surges cannot occur during tool movement or packer setting
- Internal synergies of the system are proven to enhance execution
- Allows for running the screen, displacing the hole, setting the packer, circulating, gravel packing, and actuating the fluid loss device in a single trip

The HZGP system yields high production rates due to the utilization of a maximum screen size, which minimizes friction pressures, maximizes the chances of hole cleanup without the need for breakers, and maximizes hole cleanup prior to gravel placement.

A variety of numerical and physical simulation tools are available to assist in job planning including Halliburton's HzGPSim™ horizontal gravel pack simulator. The HzGPSim software program has been successfully used globally to predict and model horizontal gravel packing. The program offers several models for leakoff, including dependent leakoff. The program handles the effect of friction pressures and flow geometries and can simulate the effect of hole washouts. It incorporates friction correlations developed from experimental measurements of flow-through screen and washpipes. The HzGPSim program calculates required injection and return rates; expected bottomhole treating pressures; predicted heights of alpha and beta waves; time for end of alpha and beta waves; and minimum rate below which a premature screenout will occur.

Packer Test Assembly

Maintaining a fluid hydrostatic overbalance on the formation is critical to maintaining hole stability and successful gravel packing. Removing the fluid hydrostatic overbalance will allow the filter cake to lift off, creating additional fluid loss and/or allowing the openhole to collapse. To pack the horizontal section and maintain a hydrostatic overbalance on the formation, a packer test assembly can be run. This assembly provides additional flow control to allow pressure to be maintained during all phases of the completion. The assembly requires additional components to be included or designed into the gravel pack service tool. These additional components provide flow paths that control weight-down washdown circulation, provide for a packer testing position with fluid circulation into the open hole, shut off circulation through the actuated reverse ball seat, and reopen that path prior to final reverse circulation and actuation.

Screen Isolation Device

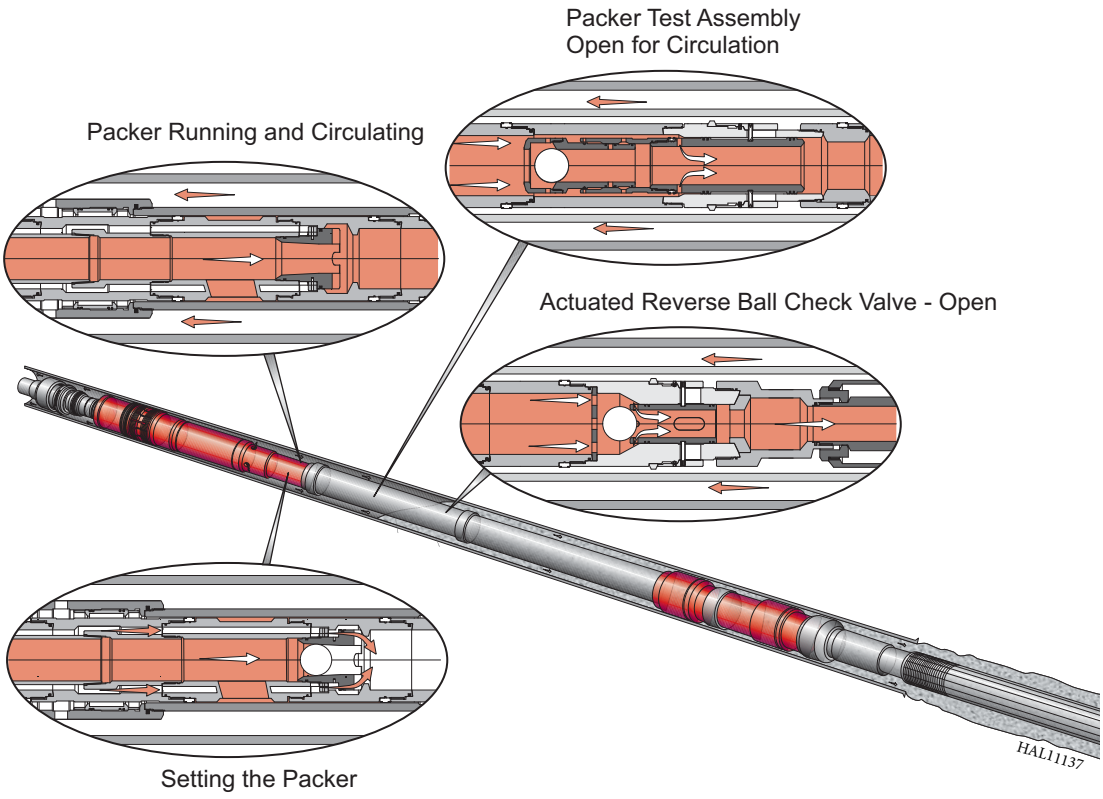
The screen isolation device is a washpipe-deployed plug used to permanently isolate the sacrificial screen and shoe after the gravel pack. When the gravel pack is complete, it is set in the upper sealbore (above the sacrificial screen) by a straight pull. It is locked in place by internal slips. The running tool is released by tension. During initial screen running operations, the plug is placed into a lower sub assembly with a latch looking upward. Once the screen is in the well, the washpipe is run with a mating Ratch-Latch™ tool on bottom and is stabbed and latched into the plug assembly.

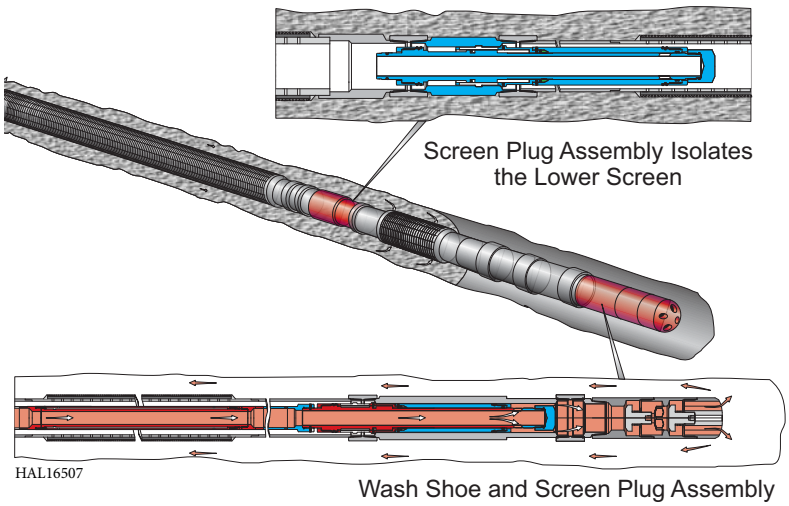
Locator Nipple

The locator nipple is an upper sealbore receptacle made up above the sacrificial screen. The sealbore receptacle provides a profile for latching the washpipe isolation plug after gravel packing. With the washpipe-deployed plug installed, both the sacrificial screen and shoe are isolated.

Other numerical and physical simulation tools available include:

- WAVE horizontal gravel pack simulator – Takes into account the complications arising from the CAPS™ geometry. It became an integral part of the HalWin™ program starting with version 2.6.0 and is based on the premise the pressure in openhole/shroud, shroud/screen, screen/washpipe annuli is equal at every point along the length of the assembly.
- Jaycor GPS2001 gravel pack simulator – Has variable casing, toolstring, and bottomhole assembly and allows for multiple formation input. It permits flow in three dimensions—down the wellbore, radially outward, and around the circumference.
- 56-ft flow loop
- Small scale GP model (3.75-in. ID, 12.5-ft length)
- Full-scale model (8.6-in. ID, 40-ft length)





Versa-Trieve® Packer/Multi-Position Tool Systems

Single-Zone Completion System

The Versa-Trieve® packer/MPA tool completion assembly with screen, blank, and lower seals is located in and isolated on its lower end with a Perma-Series® sump packer, or the assembly is bull-plugged on the end of the screen. A Versa-Trieve-type retrievable or PGP-type Perma-Series permanent gravel pack packer can be used as the upper packer. The upper packer is then set as described in "Section 3 Downhole Sand Control Components." This separates the MPA tool from the packer so it can move to the required positions.

Squeeze Position

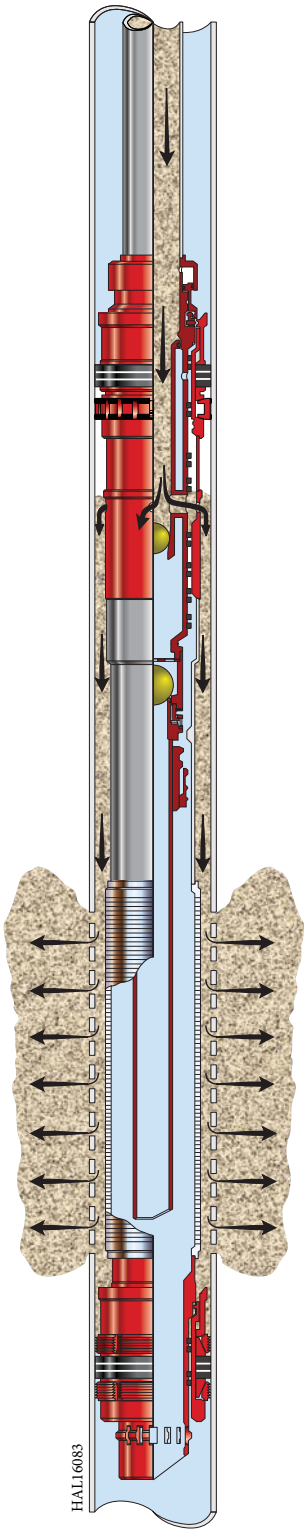
With the MPA tool fully in the packer bore (run-in, weight-down position), return circulation is prevented. All fluids pumped down the workstring are forced into the formation. This position is used to test the packer, obtain injection rates, and force acid or slurry into the perforations. This position does not expose the workstring casing annulus to workstring treating pressures.

Circulating Position

Raising the multi-position tool exposes a port on the upper end of the MPA tool that is sealed in the packer bore when the multi-position tool is fully in the packer. The opening of this port allows circulation down the tubing, out of the MCS closing sleeve, past the perforated interval, through the screen, into the end of the washpipe, up the washpipe and around the crossover sub, out the upper circulation ports, and up the workstring casing annulus. This position is used to circulate fluid and slurry to bottom, to take fluid returns to dehydrate a gravel pack slurry, or to monitor treating pressure on the annulus when performing a squeezing (frac pack) operation with the surface annulus choke closed.

Reversing Out Position

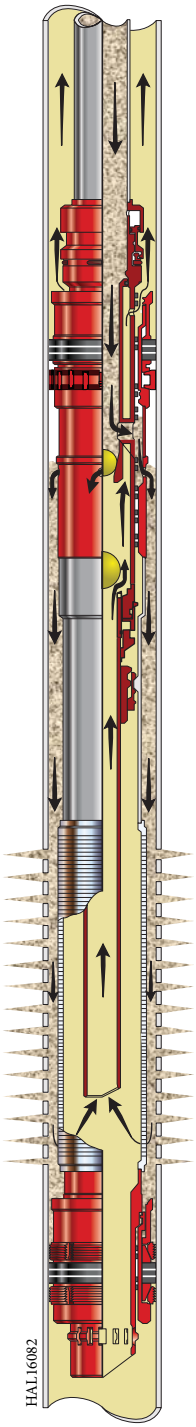
This position is obtained by raising the multi-position tool until its crossover ports are above the sealbore of the packer. The reversing out position is used when spotting fluids down the workstring, pickling the workstring, or reversing excess slurry out of the workstring upon completion of the gravel pack operation. Seals below the crossover ports of the multi-position tool remain in the packer bore while reverse circulating to isolate the formation from the applied pump pressure. Generally a reverse ball check is run in the washpipe to prevent fluid escaping the annulus above the packer into the formation through the circulation ports and down the washpipe. A ball check with weep tube may be utilized to prevent a swab effect during tool movement.



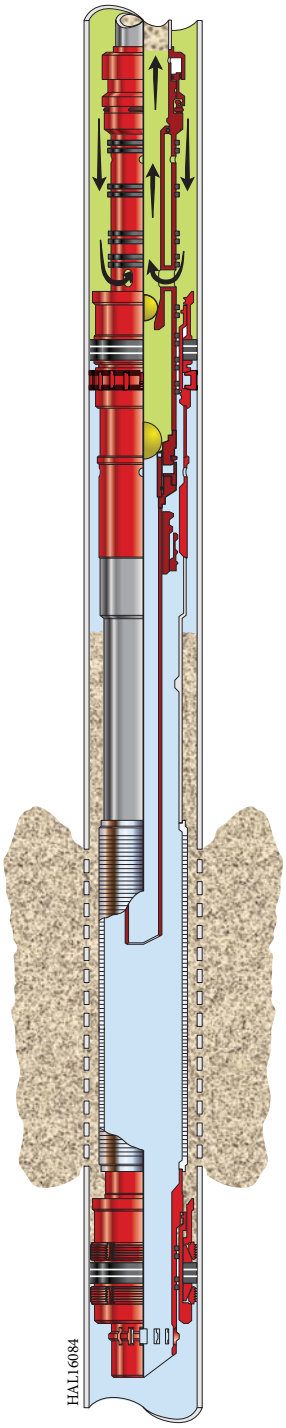
Squeeze Position

Production Tubing Run Into Place

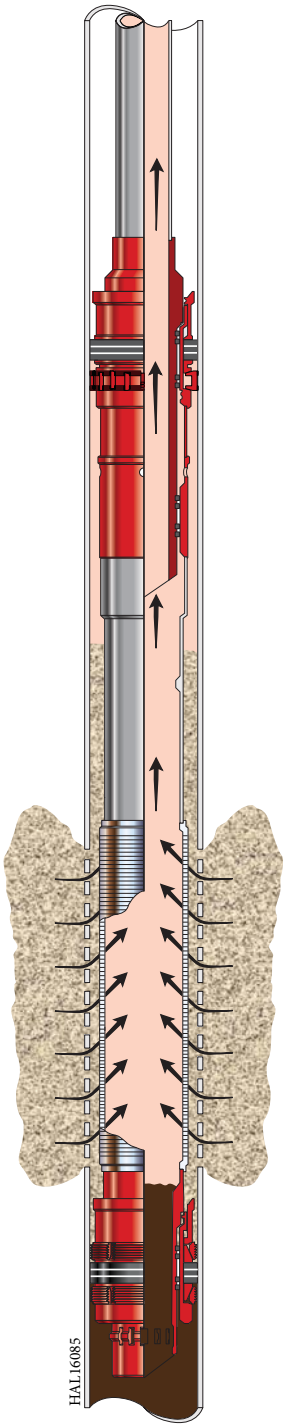
The production seal assembly is run in the well on the production tubing. The seal assembly is stung into the Versa-Trieve® packer and the sealbore of the flow sub. The seal assembly isolates annular fluids and directs well production up the tubing string.



Weight-Down Circulating Position



Reversing Out Position



Producing

Multizone Stacked Completion Assemblies

When a well with multiple zones must be completed and isolated, the lower zone is packed in the same manner as a single-zone installation. If the zones are conveniently spaced, the upper packer in the lower zone can be used to locate and form a base (sump packer) for the upper zone pack.

Perforation operations for the upper zone are performed once the lower zone has been completed. A packer plug is run into the upper packer of the lower zone to isolate the lower zone during perforating. After perforating and perforation cleanup, the packer plug is retrieved. The upper zone completion assembly is run on the multi-position tool (MPT) until the lower seal assembly locates the lower zone upper packer. Packer setting, testing, and gravel placement operations are performed as described previously.

If the upper zone is not sufficiently close to the lower zone, an isolation packer with tailpipe can be used to seal in the lower zone upper packer. This isolation packer then becomes the sump packer for the upper zone pack.

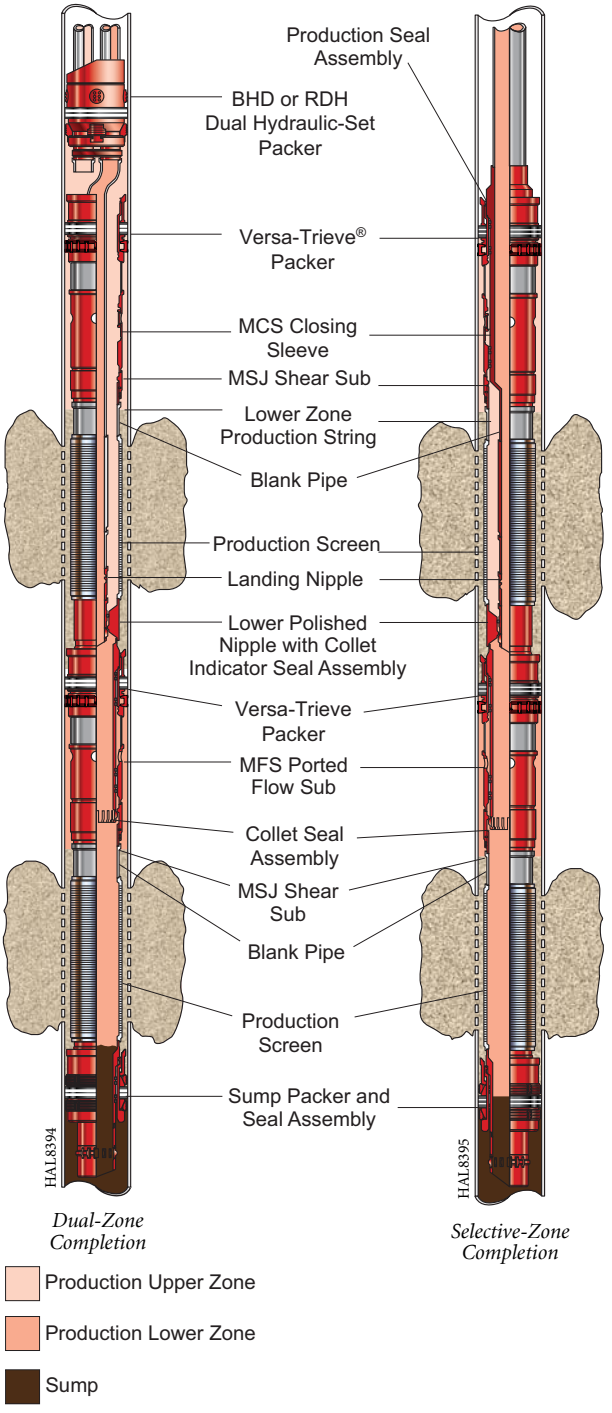
Dual-Zone Completions

For simultaneous independent production from two zones, a seal assembly is run on the end of the long string of a dual packer such as the DHC, BHD, or RDH dual hydraulic packers, which are described in the Halliburton *Completion Solutions* catalog. The seal assembly locates in the lower polished nipple, which is above or contained within the seal assembly that seals in the packer of the lower zone completion assembly. The lower zone is produced up the long string, and the upper zone flows concentrically up the annulus to the short string.

The Twin-Flow Absolute Isolation System (AIS) assembly is used in dual-zone completions requiring isolated production from each of the two zones simultaneously. The Twin-Flow AIS assembly also provides fluid loss control to the upper zone while production tubing is being run. Once the tubing is in place, pressure can be applied to the annulus down the short string or through a smart valve tied to the annulus above the gravel pack packer to activate and open the Twin-Flow AIS assembly. This will allow production from the upper zone.

Selective-Zone Completions

Seal assemblies are run to seal in both the lower sealbore and upper packer. Production tubing between the seal assemblies is spaced out to locate the lower set of seals in the lower sealbore. The lower zone is produced through the isolation string up the production tubing. A Halliburton DuraSleeve® Sliding Side-Door® production sleeve can be run in the isolation string to gain access to the upper zone, and an Otis® X-Line® or R-Line® nipple can be run just above the lower set of seals to isolate the lower zone as required.



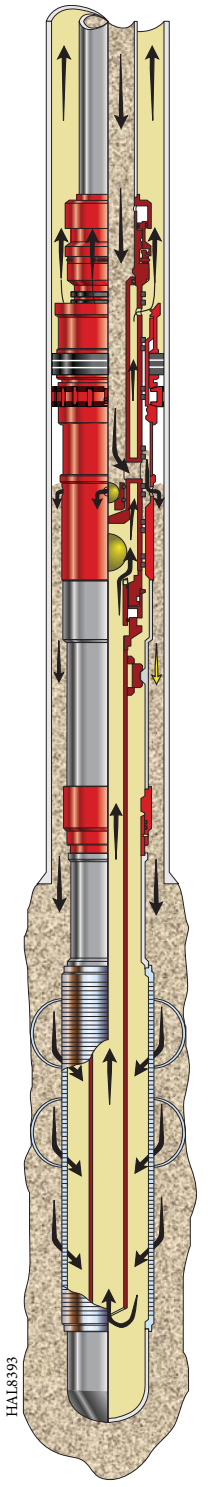
Openhole Tool System

Field-proven Versa-Trieve® packers and multi-position tools used in cased hole completions are also used in openhole completions. Openhole gravel packs eliminate flow restrictions caused by cased hole perforations.

In an openhole tool system, the screen is freely suspended in the openhole. Centralizing the screen permits a uniform pack around the screen to provide a uniform formation sand filter. The deviation of the wellbore and formation characteristics determine the type of centralizer. The type of screen selected can be important to the success of the completion and may differ from the screen normally selected for a cased hole completion. Borehole stability and cleanliness will also impact the success of the pack.

Specific openhole tool system designs exist for the shorter vertical wells, horizontal screen only, horizontal gravel packs, and horizontal gravel packs that need a post-gravel pack treatment. Consult your local Halliburton representative for the correct system for your well application.

See “Section 4 Screens” for screen-related options and “Section 5 Sand Control Production Enhancement Products and Services” for fluid-related options.



Versa-Trieve® Packer/ Multi-Position Tool System

Weight-Down Circulating (Live Annulus) System

The weight-down system is an operationally simple alternative to extending the length of the system to be able to locate positions. The weight-down systems allow the squeeze and circulating positions to be located with weight-down on the packer. This system of choice for many operators has a number of important benefits.

Features

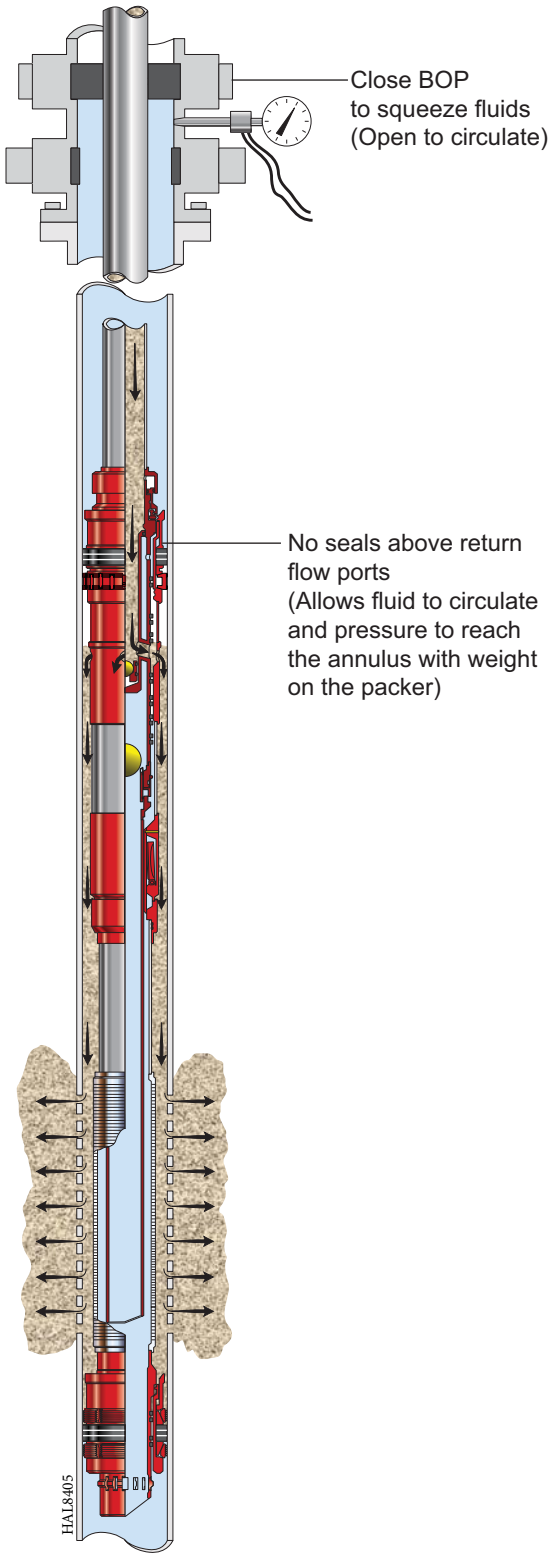
- Tubing movement due to frac pressures can be compensated for prior to the start of the job.
- Tubing elongation or contraction is controlled with weight on the packer.
- Reverse out position is not affected and is located in the same way as a conventional multi-position tool system.
- Squeeze and circulation flow can be controlled by the surface choke.
- Treating pressure can be monitored in real time down the annulus with the tool in the circulate position.

Benefits

- Helps minimize the effects of vessel heave (floating vessel operations)
- Simple operation

Various weight-down system options exist in the different size tools. These include:

- Ported locator
- Single acting weight-down collet-circulate system
- Single and ShurMAC™-circulate and squeeze system



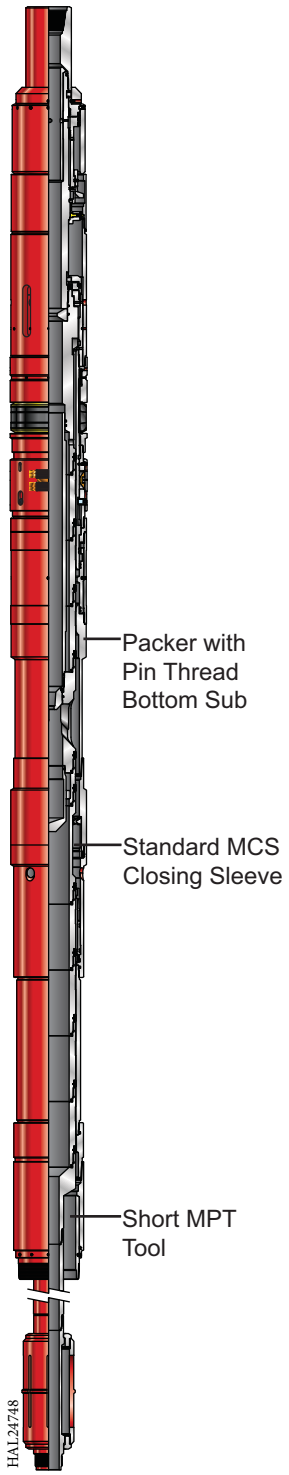
Weight-Down System
Squeeze Position

Short Weight-Down Circulating Tool System

This system was designed to be extremely short in order to isolate very closely spaced packed zones. The no-movement circulating position of the weight-down system allows the flow sub assembly to be substantially shortened. The upper extension is eliminated, and the MCS closing sleeve or MFS flow sub is screwed directly in an extended packer bottom sub. The shear joint is attached to the bottom of the MCS sleeve. Lower extension length can be minimal depending on tool design.

Weight-Down/Washdown Circulating Tool System

The washdown version of the weight-down system combines the features of the washdown system with the benefits of the weight-down system. Washing operations can be performed across the zone of interest followed by a weight-down circulating pack. With this system, the washdown crossover tool ports are initially located in the sealbore of the MCS closing sleeve or MFS flow sub assembly. Fluid can be circulated through the completion assembly as it is run into the well. The setting ball seals the crossover washdown port and allows application of pressure to set the packer. Once the tool is raised and subsequently lowered, a weight-down, positive collet prevents the tool from returning to its run-in, weight-down position. Fluid can now be circulated out the crossover ports that are properly positioned for weight-down circulating, FracPac™ system, or gravel pack operations.



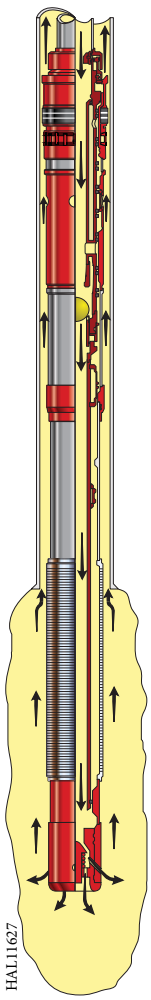
Short Weight-Down Packer and Service Tool Assembly

Washdown Circulating System

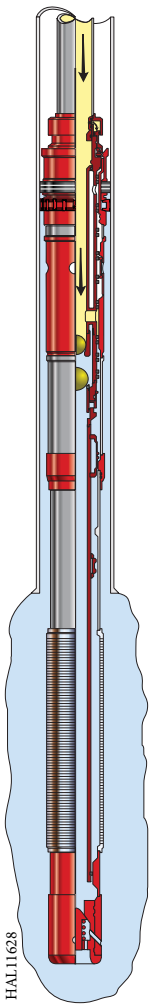
The Versa-Trieve® multi-position tool system for open or cased hole can be modified to a washdown gravel pack system. The washdown system allows circulation down the workstring and through the washpipe as the completion assembly is lowered into the well. A washdown shoe is attached to the lower end of the screen assembly; or, if a sump packer is used, the fluid can be circulated out through the end of the seal assembly. With a seal assembly, reverse circulation is possible.

With a washdown system, the MCS closing sleeve is run either with the sleeve in the closed position or the MPT crossover ports are positioned to seal in the sealbore of the closing sleeve. Fluids pumped down the workstring are prevented from escaping out the closing sleeve or crossover ports. A specially modified washdown multi-position tool crossover sub-assembly is needed to provide a flow path through the length of the tool. This flow path remains open until the setting ball lands in the tapered seat below the crossover and is caught by the specially designed tapered seat which wedges the ball into place and shuts off the washdown flow path. The washdown system can be used to remove hole stabilization material before gravel packing, to displace completion brines and spot acid, and to wash through minor areas of hole instability. The squeeze, circulating, upper circulating, and reverse positions are the same as those of other multi-position tools.

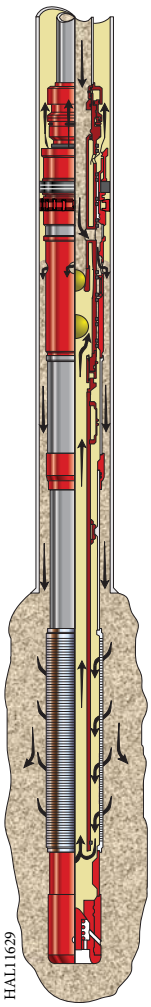
Refer to “Section 4 Screens” and “Section 5 Sand Control Production Enhancement Products and Services” for more information regarding openhole gravel pack completions.



Washing Position



Packer Setting Position



Circulating Position

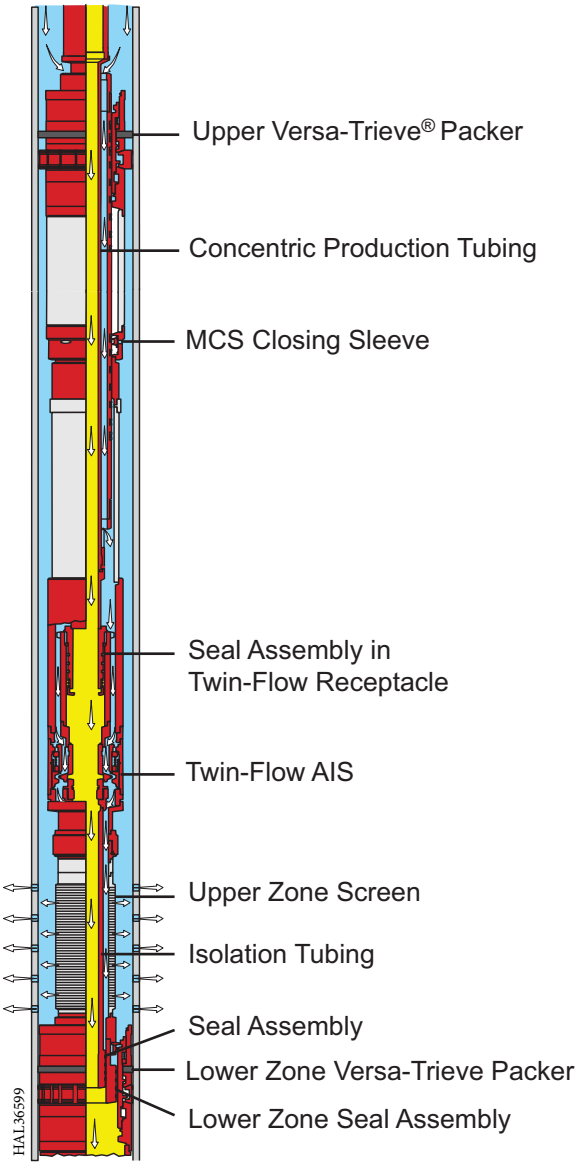
Absolute Isolation Fluid Loss Systems

The Absolute Isolation System (AIS) provides a means to isolate the screen adjacent to the producing interval immediately following completion operations. This system uses the concentric string below the multi-position tool as the isolation string to seal off the screened interval prior to pulling out of the hole with the workstring. This system has been particularly effective in stacked-zone completions. Where fluid loss and downhole flow between zones presents a problem for fluid loss flappers or chemical fluid loss methods, the AIS is a proven and reliable solution. Producing gravel packed intervals have been effectively isolated, packed, and selectively produced with this system.

Twin-Flow AIS System

Fluid loss control in ultra-deepwater completions utilizing SmartWell® system technology can present a challenge. To help alleviate these challenges, Halliburton engineered the Twin-Flow Annular Isolation System (AIS) valve, a hydraulically actuated fluid loss device. The valve allows the production of two discrete production paths through the valve while on production and manages fluid loss to the upper zone after stimulation. This valve is actuated only after the SmartWell system equipment is in place and is activated with a single hydraulic pressure cycle.

In addition to the Twin-Flow AIS valve designed for the uppermost zone of a SmartWell system completion, an additional Twin-Flow AIS valve was designed to manage fluid loss to both the zone of interest and to the zone(s) below the valve. This valve was designed to meet the challenge presented where the upper two zones of a triple-stack FracPac™ system completion were to be commingled.



STGP&T™ Single-Trip Gravel Pack and Treat System

The STGP&T™ single-trip gravel pack and treat system is a horizontal openhole gravel packing system that saves the extra trip needed to treat the formation. The system has all the beneficial features of Halliburton's conventional horizontal gravel pack tool system with an added treating feature to reduce rig time. It is normally used on horizontal gravel packs to treat the production interval after packing it.

The service tool incorporates all the functionalities to run and install the sandface completion, pump the sand control treatment, and spot in the same trip as a filter cake breaker system once the gravel pack is placed. When the lower completion service tool is finally retrieved, a shifter at the end of the washpipe closes the fluid loss control or reservoir isolation device that will be opened once the upper completion is installed. At that time, the well is ready for production with no further intervention required.

Our service tool offering includes tools specifically designed for long horizontal openhole applications that incorporate a hydraulic section combining the following specifications:

- High tensile load capability
- High running torque capability
- Soft release mechanism from the packer
- Contingency rotate to release

The service tool has also been designed to provide weight indications on surface when moved through the various tool positions. It incorporates a check valve assembly that locates in nipples or restrictions run as part of the lower completion packer assembly. Any time the tool is raised from the circulate position or lowered from the reverse position a weight indication is shown on surface, ensuring the operator knows the service tool position inside the packer assembly and related flow path. Similarly, an indication denotes when the tool converts to the treat mode once gravel pack pumping is complete, prior to spotting any filter-cake treatment.

Benefits

- Saves a trip into the well, saving time and money
- Reduces fluid loss potential and well control problems
- Conveys lower completion equipment to total depth safely
- Provides wash-down capabilities while running in hole
- Allows setting and testing of the gravel pack packer
- Maintains controlled hydrostatic pressure against the formation at all times
- Provides both a circulate and a reverse position for pumping purposes, achieved through tool reciprocation
- Provides a weight-down circulate position for simplified operations off of a floating drilling unit

STGP&T System Capabilities

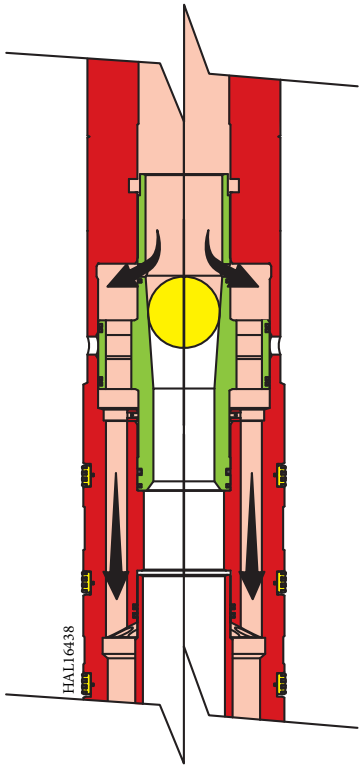
- Provides a means to re-establish circulation to the bottom of the service string for pump out or post gravel pack treatment for filter cake removal operations:
  - Ability to wash the entire interval as tool is retrieved
  - Eliminates a second trip for treating operations

Gravel Pack Fluid System Developments

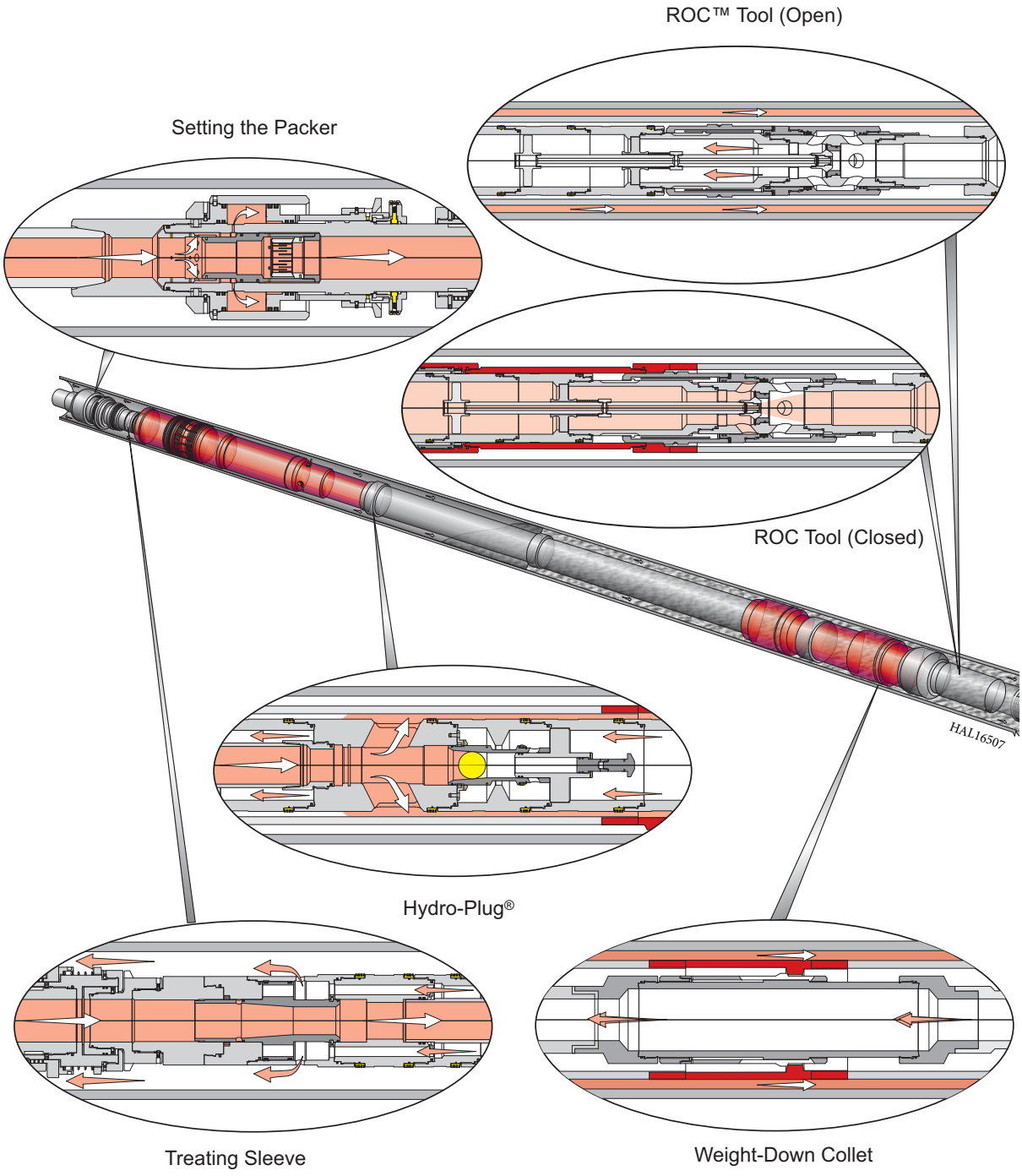
- N-FLOW™ delayed breaker systems
  - Works to remove filter cakes created with Baroid's DRIL-N® line of drill-in fluids for drilling openholes

Complete Products and Fluid Systems

- Clean drill-in fluids
- Pumping services
- Uphole completion equipment
- Intervention services
- SmartWell® system (6.00 bore system)



Treating Sleeve for STGP&T™ System


ROC™ Tool (Open)
Setting the Packer
ROC Tool (Closed)
HAL16507
Hydro-Plug®
Treating Sleeve
Weight-Down Collet

Multizone Gravel/FracPac™ Systems

STMZ™ Single-Trip Multizone Completion Systems

Halliburton is a leader in multizone systems that enable the isolation and gravel packing of all zones that require gravel pack for sand control in fewer trips.

With conventional multi-trip systems, the tools must be tripped out of the hole numerous times in order to perforate, clean up, complete, and gravel pack multiple zones. This is not only time consuming and expensive, it also exposes the formation repeatedly to potential damage. The STMZ™ single-trip multizone system accomplishes treatment and packing operations for all zones in a single trip. A single production isolation string isolates the well.

The STMZ system is applicable when the zones have equivalent bottomhole pressure and are similar lengths.

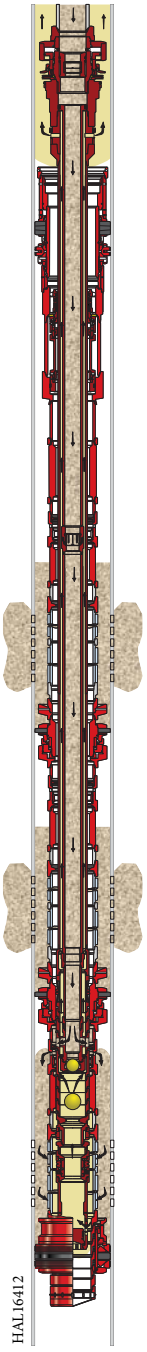
A unique retrievable packoff assembly, located in the upper packer assembly, isolates the completion interval from the annulus above the top packer. The multiple zones may be commingled and produced or may be selectively produced depending on the production seal unit configuration.

Features

- Perforating for all zones is done in one trip with tubing conveyed perforating or multiple trips with wireline. All zones are perforated first.
- Sand control completion tools are run for all zones in a single trip.
- The packing operations are completed in the same trip.
- The well is isolated with a single isolation string.

Benefits

- Quadra™ seal technology for lower service tool seal friction, longer life, and less sticking
- Helps reduce safety and operational risk
- Helps reduce rig time costs
- Helps reduce perforating costs
- Helps reduce hole preparation cost
- Helps reduce pipe pickling costs
- Helps reduce filtration costs
- Helps reduce completion tool running costs
- Helps reduce flowback and cleanup time
- Helps reduce potential for formation damage
- Can improve gravel packing fluid loss/control



STMZ™ Single-Trip Multizone System

ESTMZ™ Enhanced Single-Trip Multizone FracPac™ Completion System

The ESTMZ™ system is the latest in the single trip family. It is similar to the STMZ™ system and provides the same benefits. It is designed to address the multiple independent producing zones within a well and isolate each one. In addition, it is enhanced with greater pressure rating and proppant pumping capabilities. Benefits include the ability to profitably complete very deep, multizone reservoirs as compared to stacked FracPac™ completion systems.

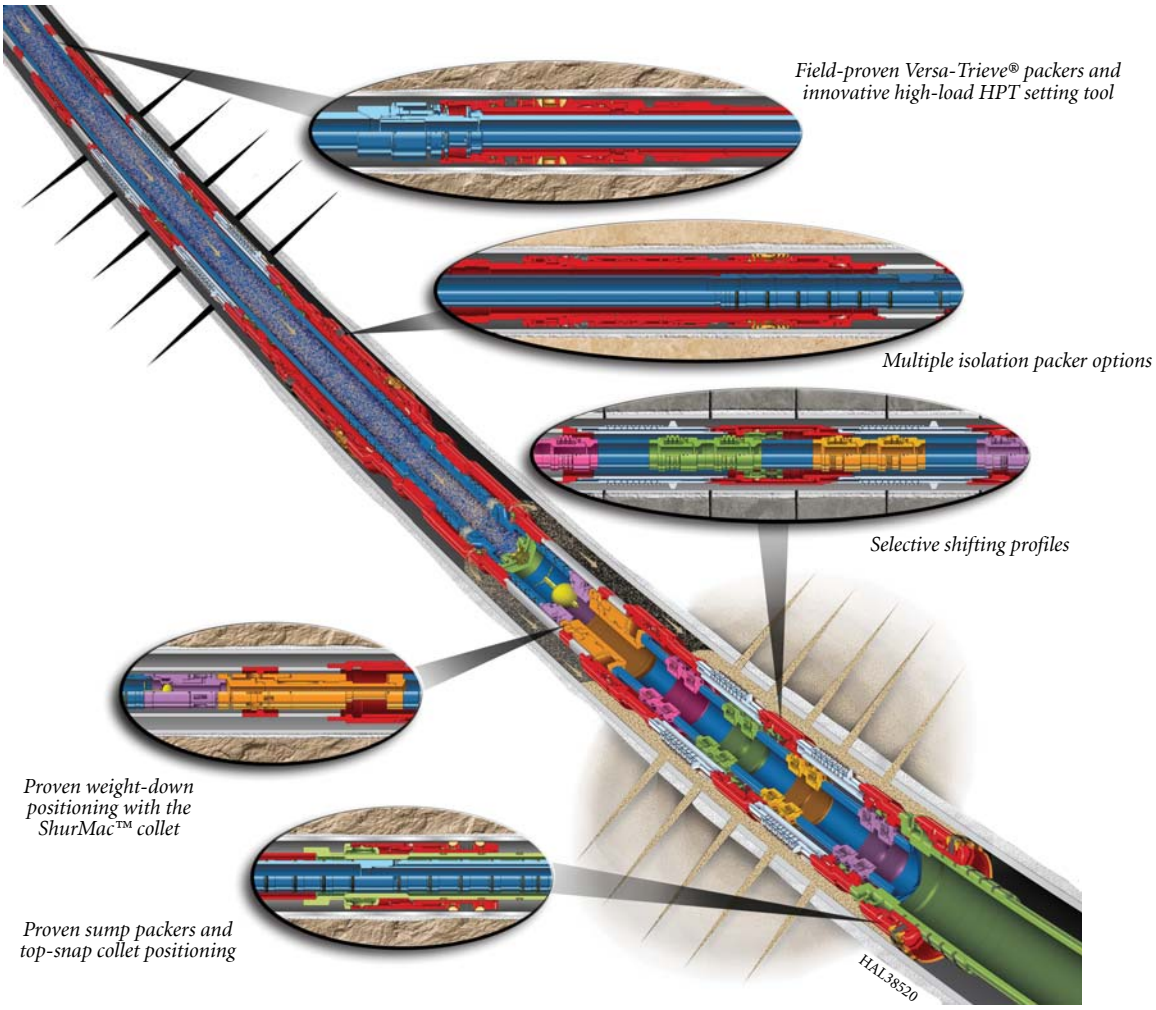
The ESTMZ system has frac pack rate and volume capabilities to enable optimum fracturing of five or more zones at rates of up to 45 bbl/min and proppant volumes up to 750,000 lb per zone. Size availability includes 9 5/8-in. cased hole, 8 1/2-in. openhole, and 7-in. cased hole systems.

Applications

- Multizone completions for cased and openhole installations

Features and Benefits

- One perforating trip—all zones
- One cleanup and de-burring trip
- One completion assembly trip
- Sequential packing process
- Higher frac pack rates and volumes
- Larger ID, 10,000 psi rated systems
- Modular screen for zonal isolation
- Fluid loss control/zonal isolation

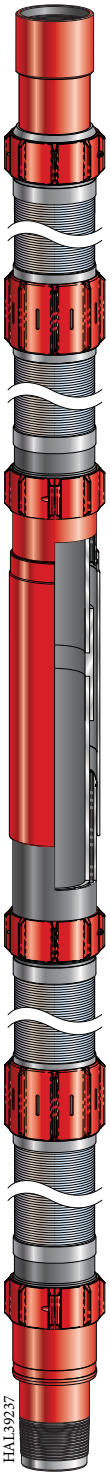


Dual Basepipe Modular Screen

This screen provides an annular flow path much like a fixed absolute isolation system when combined with mid-joint production and frac circulation sleeves. The modular screen is connected as a complete unit across each zone. Annular communication between joints is accomplished with the use of a bulkhead fitting on the inner basepipe. A single sleeve at the bottom of the screen is opened to allow flow. This eliminates the need for washpipe seals; thereby enabling the treatment of various zone lengths in the same wellbore.

PetroGuard® Modular Screen

By utilizing the Halliburton PetroGuard® direct-wrap technology, a single basepipe modular screen was created. The annular flow path is created by unique screen rib wires between the non-perforated basepipe and the screen jacket. Annular communication between joints is accomplished through a communication sleeve installed after torquing the premium basepipe thread. The screen can be configured with PetroGuard Wrap wrap-on-pipe or PetroGuard Mesh DS premium screen.



Modular Screen

Liner-Conveyed Gravel Pack Systems

The Liner-Conveyed Gravel Pack (LCGP) system provides a single-trip combination casing liner and screen assembly with the capability to place a sand control completion across the sandface and cement the liner above. Since the liner is combined with the screen into a single completion assembly, the screen does not have to pass through the liner, enabling the larger basepipe screen to be placed across the sandface. In some applications, use of the LCGP system may enable the reduction of a casing size in the well design.

The larger OD/ID screen across the sandface enables the use of larger gravel packing tools and larger screens to increase the open flow areas and reduce the pressure drop across the reservoir. This optimizes production and minimizes erosion.

In multilateral systems, liner disconnect can be incorporated to remove the upper portion of the liner when completing multilateral completions. Once activated, the liner packer and part of the liner can be removed from the lower assembly leaving the top of the liner below the lateral junction. The multilateral junction can be reconnected, if needed, when tripping upper completion equipment.

Applications

- Sidetrack completions in existing wellbores
- Slimhole primary completions
- Isolating nonproductive sections of a zone
- Multilateral wells requiring sand control
- Stand-alone screen completion with or without a cemented liner
- Gravel pack completion with or without a cemented liner extends to just below the multilateral junction

Features and Benefits

- Maximizes system production flow bore
- Eliminates a liner run and associated clean out and liner testing time
- Saves drilling fluid and conditioning time
- Openhole gravel pack or stand-alone screen completion in fewer trips
- Uses external casing packers (ECP), Swellpacker® systems, and/or cement to isolate the liner
- Eliminates the screen size reduction normally associated with a standard liner-based well design
- Helps eliminate openhole transition concerns (rathole) associated with deepwater wells, which can frequently lead to gravel placement issues
- Compatible with all screen types
- Liner can be cemented using fluid displacement or conventional cementing pumpdown plugs to provide positive pressure confirmation

HAL38550

Dual-Zone SmartWell® Deepwater Systems

Dual-Zone SmartWell® Deepwater Systems combine leading technologies into a robust system designed to optimize production in subsea, deepwater completions, including stack packed sand control wells. This system allows dual or multizone flow, using SmartWell interval control valves (ICV) to regulate and maximize production from each zone. Downhole permanent gauges allow continuous monitoring of the well's production. And the Twin-Flow absolute isolation system (AIS) enables separate production flow paths in dual-zone sand control completions.

During the completion phase, fluid loss control is achieved using the Twin-Flow AIS for the upper zone, and the FS2 valve for the lower zone, while running the upper completion. Both technologies permit remote pressure opening without intervention.

The use of the continuous sealing long space-out travel joint (CS-LSOTJ) simplifies the space out procedure when landing the subsea hanger. The benefit of this technology grows as water depth increases. The CS-LSOTJ maintains sealing for zonal isolation over its adjustable extended stroke length. Production or injection flow is then optimized through the ICVs. The CS-LSOTJ also enables running of the upper completion in a single trip.

System components work in unison to offer unique benefits to the overall completion design. The system, as well as the individual components, is designed to extend the life of the well by using the most reliable equipment in the industry. Performance is assured through integrated completion design that enables safe, efficient operations offshore.

Features

- Dual or multizone applications
- Independent zonal fluid loss control
- Compatible with leading edge Beyond Red Zone® FracPac™ system technology
- Intelligent well capability

Benefits

- Minimizes completion cost and economic risk
  - Single-trip upper completion
  - Remote fluid loss device activation
  - Compatible system design
- ICVs optimize productivity
  - High overall production rates
  - Increases well longevity
  - Proven long-term performance and reliability

Typical Dual-Zone Intelligent Completion Characteristics

- 9 5/8 to 13 3/8-in. casing sizes
- 1,000 to 10,000-ft water depth or greater
- Two to three zones
- FS2 fluid loss control – lower zone
- Twin-Flow AIS fluid loss control – upper zone
- CS-LSOTJ long space-out sealing travel joint
- SmartWell ICVs with permanent downhole gauges
- HF1 upper completion packer
- DepthStar® subsurface safety valve

HF-1 Isolation Production Packer

The isolation production packer is used as a production tubing anchor to prevent wellbore pressure and production from entering the casing above the formation. It diverts oil and gas flow into the production tubing, protecting the subsea tubing hanger and production casing from high pressure and corrosive fluids.

Upper ICV

The upper ICV diverts upper zone production into the tubing through the surface-regulated ICV choke. The choke is controlled at surface through the attached control lines, allowing the upper zone to be produced in a controlled and optimized flow. In turn, flow is co-mingled with the lower zone in a controlled manner to maximize production from both zones simultaneously.

Lower ICV

The lower ICV diverts lower zone production into the tubing through the surface-regulated ICV choke. The choke is controlled at surface through attached control lines, allowing the lower zone to be produced in a controlled and optimized flow. In turn, flow is co-mingled with the upper zone in a controlled manner to maximize production from both zones simultaneously. By optimizing flow from both zones, pressure drops from each individual zone is lower, while realizing maximum production—resulting in extended and more incremental production throughout the life of the well.

Continuous Sealing Long Space-Out Travel Joint

The CS-LSOTJ is designed to unlock from the running position and collapse in response to a non-shearing compressive load after landing a production seal assembly into a sealbore packer below. After the LSOTJ collapses, production tubing can be lowered with ease to land the subsea tubing hanger into the subsea tubing-head spool. It is important to note under these circumstances, a standard shearable travel joint could shear and collapse prematurely while attempting to push the bottom seals through the subsea blowout preventer (BOP) and wellhead. This could result in a misrun of the completion string. The LSOTJ does not use shear pins and can be pushed through difficult entry points. In addition to being critical to landing the production tubing, the CS-LSOTJ performs the following functions:

- Serves as a safety function or shock absorber when passing through the BOP or the liner top
- Serves as stroke adjustment between the two fixed points of the gravel-pack packer seals and subsea tubing hanger
- Designed such that lower-production tubing and seals can be relocked to the production tubing, so retrieving can be accomplished in one trip instead of two
- Allows a tension and pressure test of gravel-pack packer seals to verify production tubing has landed correctly
- Can be re-locked downhole if activated during the running process
- Includes an emergency shear release feature

Lower production tubing serves as a conduit for any type of intervention with sandface completions. Note extensions above the CS-LSOTJ will stroke downward over the production seals and lower production tubing as the subsea tubing hanger is lowered to the landing position.

Production Seals

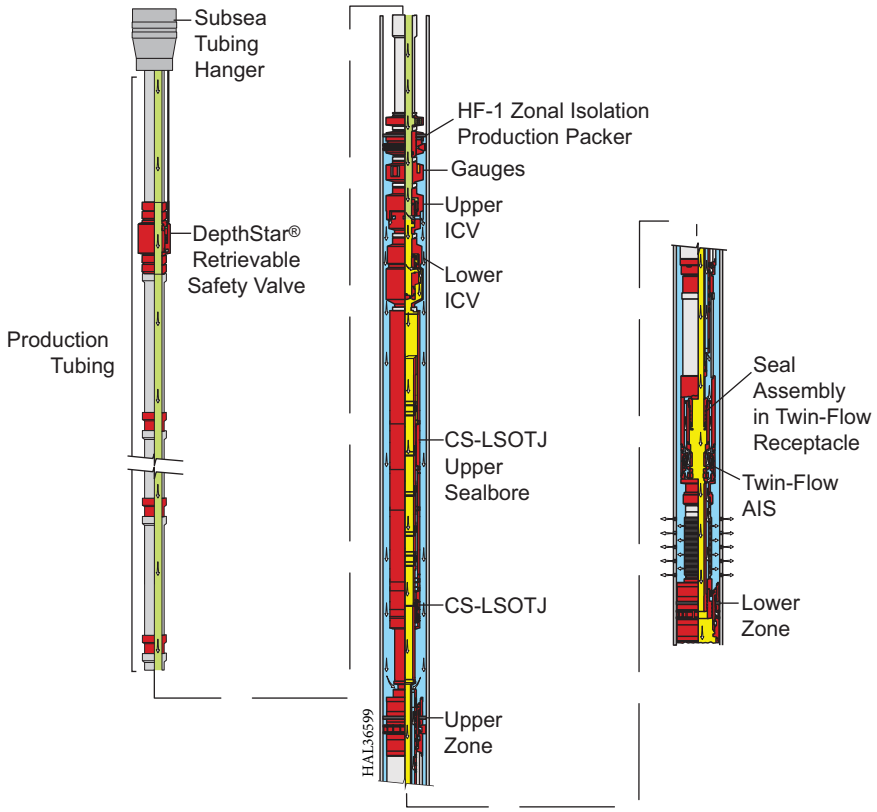
Production seals function by sealing into the upper PBR and separate the lower zone from the upper zone. They maintain sealing integrity during the life of the well and serve as a conduit for any type of intervention with the lower zone. Length between seals must be less than the sealbore length to ensure continual sealing integrity.

Twin-Flow Absolute Isolation System (AIS)

The Twin-Flow AIS hydraulically actuated fluid-loss device serves as a fluid-loss device for the upper zone. Only after production tubing-related equipment and the tubing hanger are landed will this device be opened.

Upper and Lower Zone Sand Control Completion

These are typically dual zone FracPac™ completions.



Standalone Screen Systems

When properly executed, standalone screen systems provide highly reliable sand control with less operational complexity—offering a lower cost option when compared to gravel packing or other openhole completion strategies.

Standalone screen completions are typically configured as both openhole and horizontal completions. After the reservoir section is drilled, a basepipe-deployed mechanical filter sized to restrict solids production will be positioned across the chosen intervals.

Halliburton offers an array of screen products designed to meet any wellbore challenge and maximize well production while maintaining acceptable solids control levels. The PetroGuard® screen family includes prepacked screens, wire-wrap screens, mesh screens, and compliant screen systems all of which can be used as standalone screens.

The wire-wrap screen family offers simple, reliable prepack and slip-on jacket technologies. The robust, fine-tuned PetroGuard® Wrap product is a direct wrap solution that is especially valuable in standalone screen completions with challenging well environments, trajectories, and borehole conditions where the screen system will be pushed to the limit without compromising filtration performance while in deployment. Directly applying the wrap wires over the ribs while mounted on the basepipe results in a tight fit, durable screen assembly. Halliburton's proprietary gauge control and verification process functions in real time during the wrapping operation, which allows for closer tolerance screen gauge and reduced cost.

Mesh screen products offer several filtration design options including the PetroGuard Mesh product line. Featuring a multi-layered, single woven non-bonded layer, the PetroGuard Mesh DS screen maintains Halliburton's standards of reliable filtration efficiency and quality in a cost-effective design. The PetroGuard Advanced Mesh screen brings leading-edge filtration technology to the upstream industry. This unique technology is formed from a series of custom-designed, diffusion-bonded surface filter layers to give precise pore size control and provide the highest solids retention and plugging resistance possible.

More advanced standalone screen completions requiring proactive borehole support can use the PetroGuard Swell compliant sand screen system that combines the proven technologies of mesh filtration and Swell Technology. This combination delivers the screen to the sandface, providing wellbore conformance and preventing and delaying sanding and solids production.

Features

- Direct wrap technology
- Single layer mesh screens
- No-weld technology
- Gradient pore technology
- 360° conformance

Benefits

- Unconsolidated sands exclusion
- Reliable and robust filtration technology
- Maximum sand retention
- Maximum plugging resistance
- Maximum borehole support
- Borehole instability and fines migration mitigation
- Deployment in extended reach horizontals

HAL22249

EquiFlow® Inflow Control Technology

Horizontal sand control completions have become increasingly more attractive to operators looking to maximize reservoir contact and thus reduce drawdown. Improvements in drilling technology have allowed for longer well lengths which present new complexities and challenges in production/injection control. Differences in influx from the reservoir can result in premature water/gas breakthrough, leaving valuable reserves in the ground. EquiFlow® Inflow Control Technology is designed to improve completion performance and efficiency by balancing inflow across the sandface throughout the length of a completion.

EquiFlow® Inflow Control Devices

In an EquiFlow inflow control device (ICD) completion, openhole packers are used to segregate the horizontal section into compartments or zones. Typical ICD applications include wells experiencing "heel-toe" effects, breakthrough of water/gas, permeability differences, and water challenges in high viscous oil reservoirs. By using EquiFlow inflow control technology, the reservoir inflow from high productivity zones can be reduced while improving low productivity zones and sweep efficiency.

The EquiFlow ICD consists of an annular chamber on a standard oilfield tubular and is considered a passive technology. If a screen is required, the reservoir fluid is produced from the formation, through the sand screen, and into the flow chamber. The flow continues through a set of nozzles, which creates a pressure drop and then into the pipe through a set of ports. Nozzle quantity and ID are designed to provide the pressure drop needed for optimum completion efficiency. Simulation software is used prior to installation for optimum configuration of the EquiFlow ICD with no need for specialized installation time.

EquiFlow Adjustable Inflow Control Device

Today's reservoir challenges call for optimum completion solutions, and since no two reservoirs are alike, having multiple options can be a significant plus. EquiFlow Adjustable inflow control devices combine the inflow balancing benefits as standard fixed ICDs with additional flexibility to reconfigure the ICDs if required. Placement of these ICDs is typically incorporated into the design phase of a project. For applications where design flexibility is needed, the EquiFlow adjustable ICD allows the operator to configure the device closer to the time of installation. It also helps improve logistics and reduce delivery time.

EquiFlow Inject Inflow Control Device

Similar in approach to EquiFlow ICD for balancing inflow throughout the completion in producing wells, the EquiFlow Inject system balances the fluid injected into the formation in injection wells. Water injectors frequently suffer from imbalanced placement of the injected fluid due to one or more of the zones accepting excessive injection rates and volume. The primary reason for this is permeability differences or thief zones along the wellbore. With imbalances in the injection rates, problems can arise including ineffective reservoir drainage and breakthrough of injected fluid into producers.

HA138821

EquiFlow® Autonomous Inflow Control Devices

The EquiFlow® autonomous inflow control device (AICD) increases recoverable reserves and extends well production. Using innovative dynamic fluid technology, the device can differentiate between fluids flowing through it to maximize oil production.

The EquiFlow AICD works like a passive ICD during oil production, yet restricts the production of water and gas at breakthrough to minimize water/gas cuts dramatically. It uses no moving parts, does not require downhole orientation, and uses the dynamic fluid properties to direct flow.

AICD technology employs an engineered system of flow paths and channels to control fluid flow. Using the fluid selector's output, the flow switch, or “fluid crossroad”, directs the majority of the selected fluid down one of two separate paths based on the fluid's properties. Finally, the fluid restrictor restricts the flow of unwanted fluid (gas and/or water) from entering the wellbore, yet provides very little restriction to the production of the desired fluid.

The EquiFlow AICD is designed to be a simple, reliable, and cost-effective solution to the limitations of passive inflow control by maximizing reservoir performance, and minimizing undesired fluid production.

Features

- Easily configured for use in various applications
- Robust construction
- Simulation software for optimum configuration
- Operates autonomously
- Contains no moving parts, electronics, or connections to the surface
- Requires no intervention
- Will cease flow restriction if unwanted fluid recedes
- Designs available to produce oil and restrict water or gas
- Each device functions independently for precise response to the reservoir

Benefits

- Helps reduce water and gas production associated with
  - Heel-toe effects
  - Breakthrough of water/gas
  - Permeability differences
  - High oil viscosity wells
- Helps increase productivity and recovery
- Increases reliability through design simplicity
- Minimizes undesired fluid production, helping reduce associated costs and risks
- Delays onset of unwanted water/gas production

HAL33700

STPP™-GH Single-Trip Perf/Pack Completion System

The STPP™-GH single-trip perf/pack system provides cost-effective, single-run completions that combine perforating and frac packing a zone of interest in a single string.

With the STPP-GH system, the guns are detached from the packer and screen assembly before perforation to eliminate impact loads. After perforation, the auto-release gun hanger mechanism allows the expended guns to drop to the bottom of the well. After the well is perforated, the CHAMP® IV packer is lowered and set below the perforations and the Versa-Trieve® packer is set above the perforations. The service tool is released from the Versa-Trieve® packer and positioned for pumping operations.

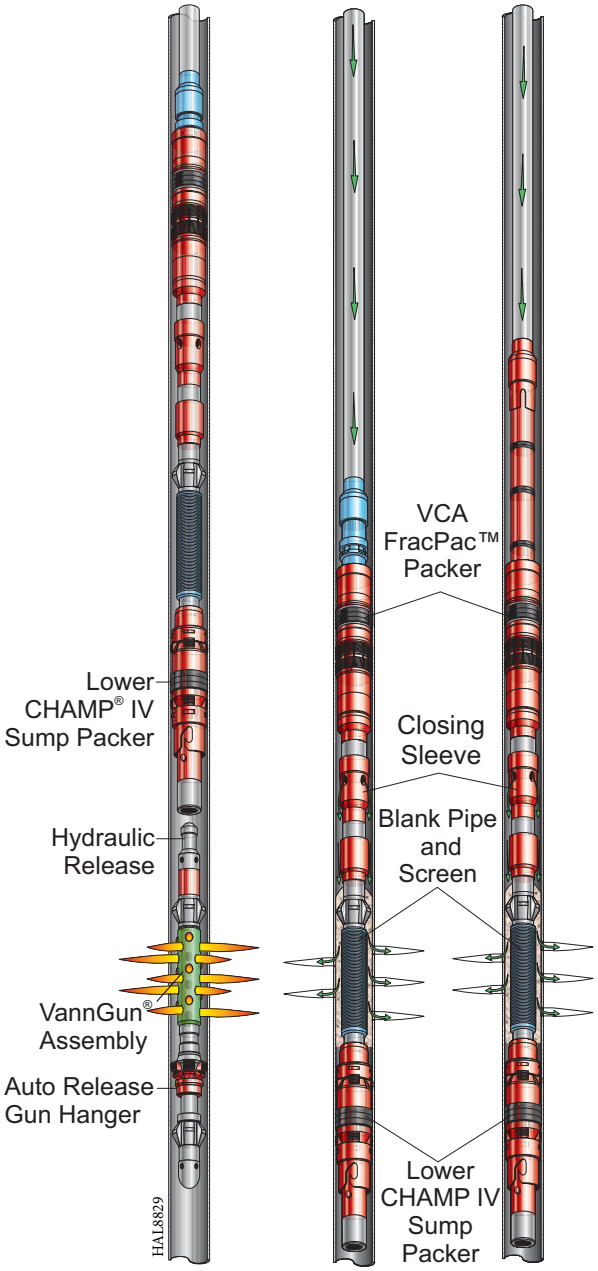
The STPP-GH system can also be configured for multiple perforating gun location options as well as screen options including the CAPS™ screen.

Features

- Auto-release gun hanger system
- Sand Control FracPac™ system technology
- Tubing-conveyed perforating technology
- Mechanical packer technology
- Eliminates mechanical shock of perforating
- Minimizes pressure shock
- Well control operations achieved with a modified OMNI™ valve design

Benefits

- Combines multiple operations in a single trip
- Flexible system allows performance of water pack, high-rate water pack, frac pack, slurry pack, or gravel pack operations
- Reduces rig time and associated costs
- Reduces safety and operational risks
- Minimizes fluid loss
- Maximizes net present value
- Reduces well control risks
- Reduces formation exposure
- Reduces debris management
- Higher rate of return



STPP™-GH Installation

Through-Tubing Systems

Halliburton through-tubing systems are designed to be run on braided line, reeled tubing, or jointed pipe. They can be set on bottom or located in landing nipples or tubing string. Through-tubing systems are applicable for short, perforated intervals. A squeeze pack is performed by pumping through reeled tubing or jointed pipe. Existing production tubing can be used, or a concentric string can be run. Systems are available from 2 3/8-in. (60.33 mm) to 4-in. (101.60 mm) tubing sizes.

Features

- Run on braided line, reeled tubing, or jointed pipe
- Applicable for short, perforated intervals
- Available in 2 3/8 to 4-in. tubing sizes

Benefits

- Can run existing production tubing or concentric string
- Can be set on bottom or located in landing nipples or tubing string

Through-Tubing Circulating Sand Control System

Through-tubing circulating tool assemblies are available for some tubing sizes and provide the means to perform a circulating gravel pack through-tubing with coiled tubing.

Packoff Method

The packoff method uses a through-tubing gravel pack screen with blank spacer pipe and packoff seal assembly. It can be placed inside casing or existing gravel pack screen and spaced out and packed off inside the production tubing. The method is used when top of perforation is less than 100 ft (30 m) below the end of production tubing.

Fluted Hanger Method

The assembly consists of a lower screen and blank pipe, fluted hanger, stinger with “G” packoff element, and “G” slip stop. Bow spring centralizers with stops are used to centralize the screen in the casing. The assembly can be run on coiled tubing or on wireline. The fluted hanger running assembly consists of an overshot, a fluted hanger, and retrievable receptacle plug.

Locator Hanger Method

The locator hanger system is identical to the fluted hanger system with the exception of the locator. Instead of a fluted hanger, a modified “S” holddown pump locator is used to locate in an “S” landing nipple. The “S” holddown pump locator is modified to give additional fluid bypass.

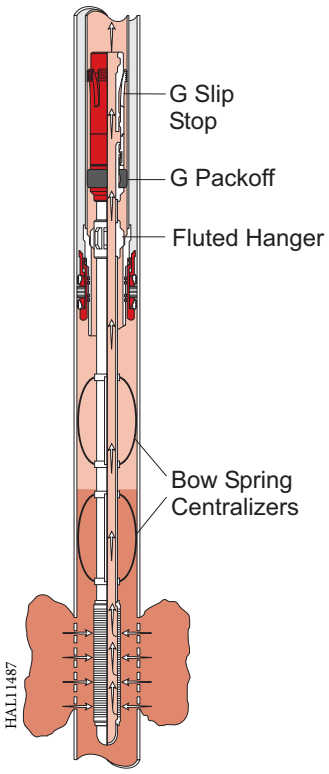
Washdown Method

The washdown method uses a prepack with gravel pack screen washed into place (applicable for both casing and tubing). It is used in treating intervals with maximum lengths of 50 to 60 ft (15 to 18 m).

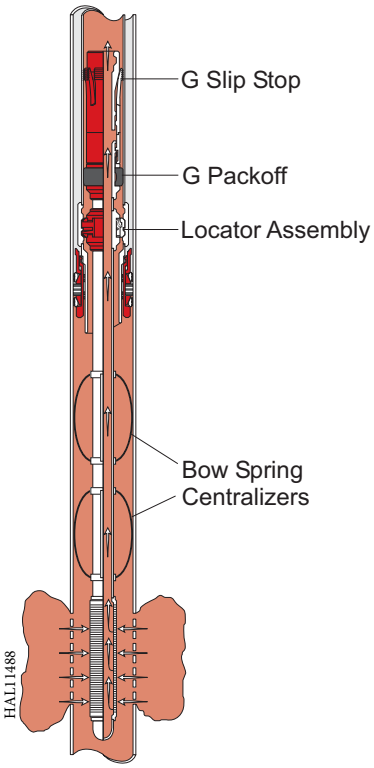
The washdown method consists of a lower jet shoe, screen, blank pipe, and hydraulic disconnect. Inside the screen and blank pipe, an inner tube is spaced, running from the hydraulic disconnect down to the shoe. The system is run on coiled tubing.

Concentric Screen Method

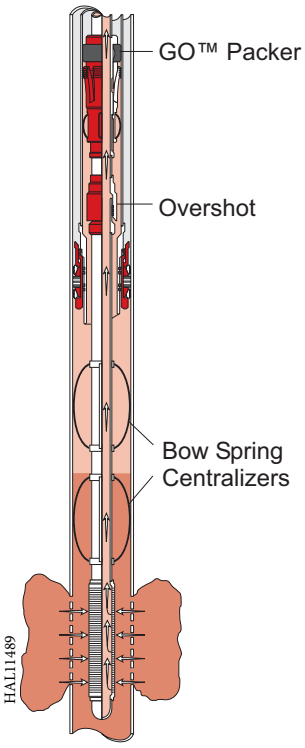
The concentric string completion is available for 2 7/8-in. (73.03 mm) and larger tubing sizes. As depicted, a concentric tubing string is run back to surface. The annular area provides a gas conduit for lift gas if required. The assembly consists of a bull plug, screen, blank, and hookup nipple. This illustration depicts the production mode with an overshot and a reciprocation set GO™ packer.



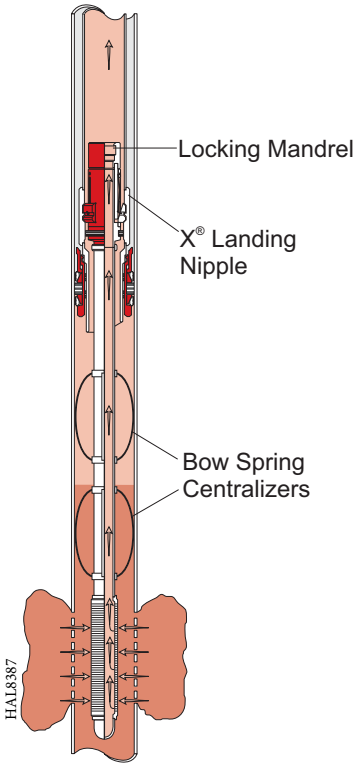
Fluted Hanger



Locator Hanger



Concentric Screen



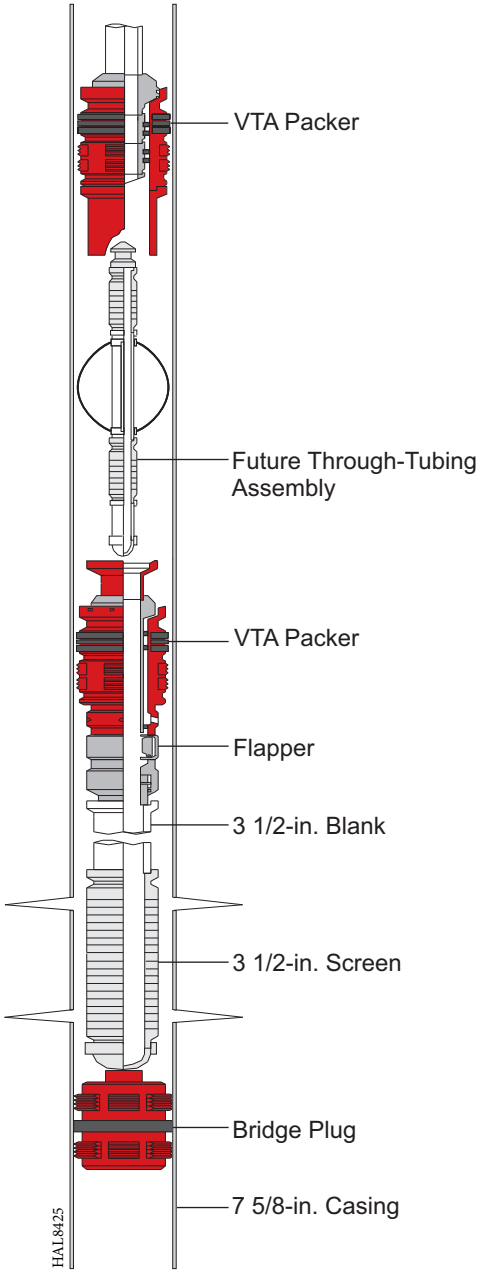
X® Lock and Landing Nipple

Rigless FracPac™ System/High-Rate Water Pack

This system allows an operator to control sand production across a lower zone via a gravel pack or FracPac™ system and at the same time ensures the completion assembly above the lower zone is optimized for a future through-tubing pack on an upper zone. The lower zone is packed as normal. If necessary, a spacer assembly and upper Versa-Trieve® packer are stung into the gravel pack Versa-Trieve packer and set. When the operator decides to shut off production from the lower zone and access the upper zone, a through-tubing bridge plug is set in the blank pipe above the lower zone. The upper zone is perforated. A dual-screen assembly (also known as a vent screen) is placed across the upper zone, and a high-rate water pack or a FracPac system treatment is performed to place sand in the perforation tunnels and around the screen assembly. Excess sand is washed clear of the upper screen using coiled tubing. The well can then be placed on production.

Benefits

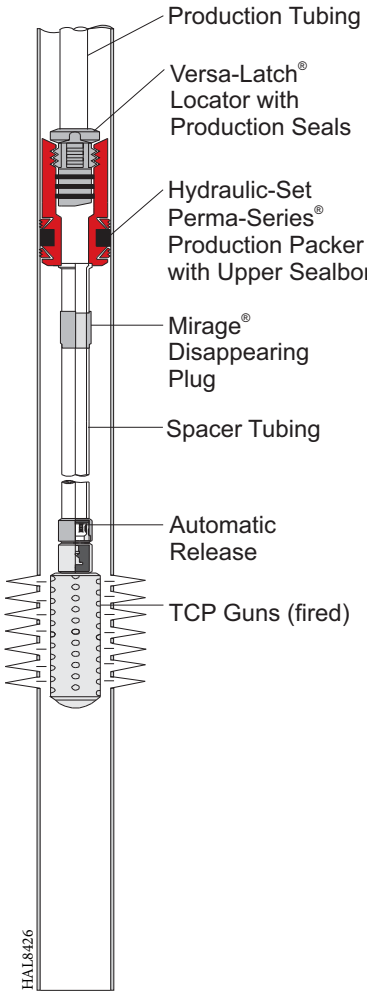
- Allows for control of sand production across a lower zone using a gravel pack or FracPac system
- Ensures optimized completion assembly above the lower zone for future through-tubing packing on an upper zone



Single-Trip Screenless FracPac™ System

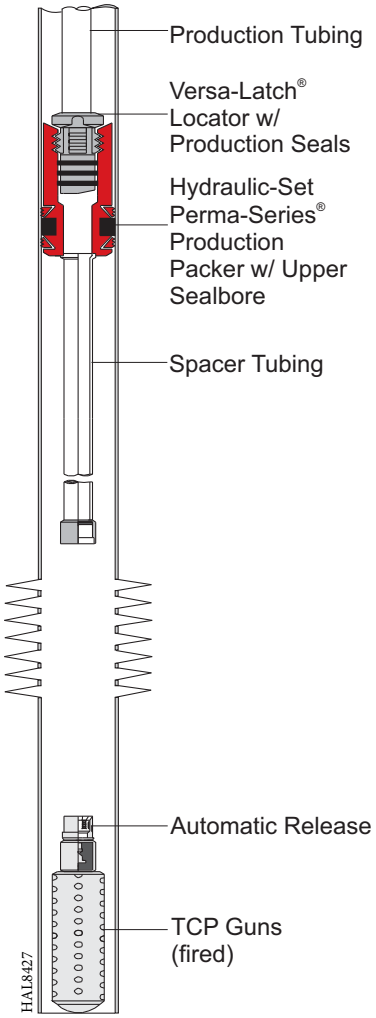
This system helps minimize fluid loss and save rig time while allowing the operator to perforate and begin fracturing operations on the same trip in the hole. The following assembly is run in the hole:

- TCP guns
- Automatic release
- Spacer tubing
- Mirage® plug
- Permanent or retrievable packer with ACME top sub
- Versa-Latch® locator with production seals
- Production tubing



Set Packer, Perforate Zone

The Halliburton 180° phased FracPac™ system guns are logged onto depth. The Christmas tree is nippled up. Applying tubing pressure closes the auto-fill feature on the Mirage plug and sets the packer. The packer can be tested prior to firing the guns with annulus pressure. Pressure cycles will dissolve the Mirage plug and fire the guns. The guns will then drop into the rathole, allowing the operator full access to the perforated interval. A FracPac system operation with resin-coated sand can then be pumped to break through any near-wellbore damage and control proppant flowback. Because of the 180° phasing of the FracPac system guns, the perforations will be oriented to allow flow into the fracture, resulting in a more complete packoff of the perforations with resin-coated sand. Any excess sand can be washed out of the hole with a coiled tubing unit.

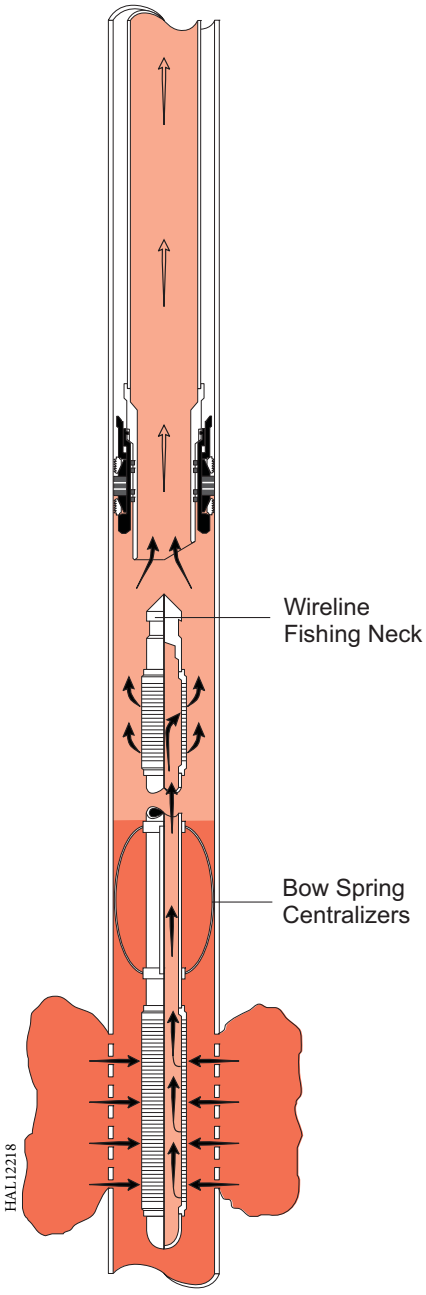


Guns Released, Frac Pack, and Produce

VentPac AF℠ Service

Vent screen completions are a reliable method of improving workover and completion economics. With this method, zones previously bypassed as uneconomical to complete may now, in many cases, be effectively monetized.

Completions using VentPac AF℠ service are, in some cases, producing over 30 MMscfd compared to a maximum of only 6 to 8 MMscfd from conventional vent screen completions while maintaining mechanical integrity of the completion. Halliburton's exclusive Antifluidization® service technology enhances pack conductivity and helps control fines migration and pack plugging.

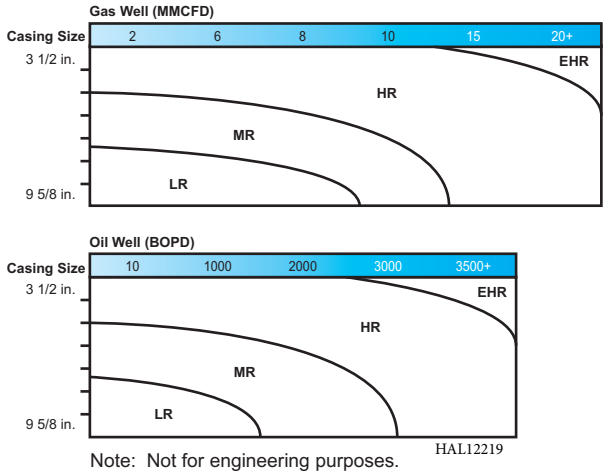


Features

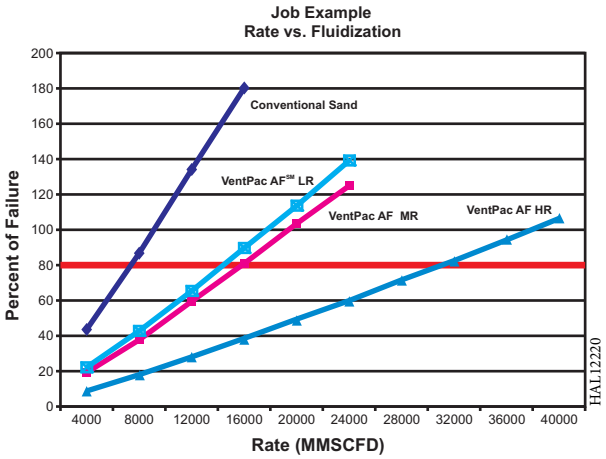
- Enhanced conductivity and fines control
- Unmatched execution – Halliburton has installed more successful high-rate completions than most service companies
- Predictable production rate window
- Close, multiple stacked pays can be completed independently if necessary
- Enhanced completion reliability
- Well suited for monobore and deepwater applications as well as recompletions in high-rate, deepwater applications
- Tailored to well conditions – Depending on flow velocity level and probability of proppant pack fluidization, one of several versions of VentPac AF^{SM} service can be applied for an optimum completion

Benefits

- Higher production rates while maintaining mechanical integrity, resulting in enhanced reserves recovery, accelerated cash flow, and improved completion NPV
- Helps reduce time exposure
- Helps provide higher production rates even with incomplete blank section coverage



Guidelines for choosing which version of VentPac AF^{SM} service will help provide an optimum completion.



The graph is a sample analysis from a gas well in the Gulf of Mexico with 90 ft of blank assembly in a well that was deviated 55° across the zone of interest. The casing size was 7 in. and the blank size was 1.660 in. The graph plots the rate of the well's producing relative to the fluidization point (failure point). The graph shows the varying versions of the VentPac AF^{SM} system and the associated achievable maximum production rates.

Downhole Sand Control Components

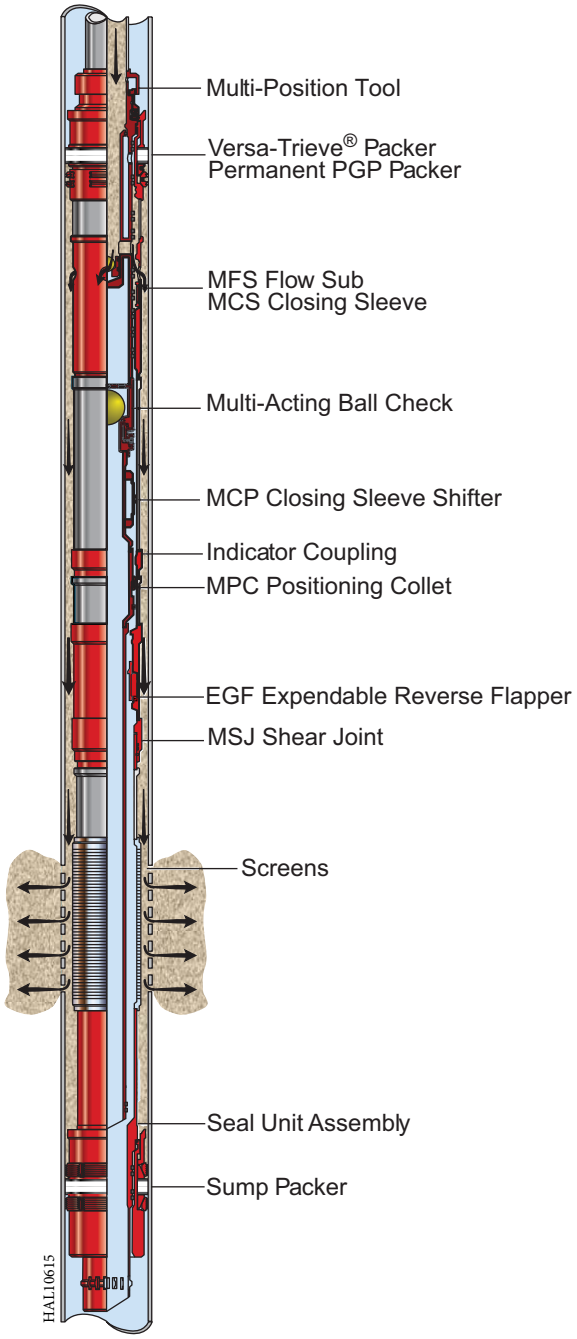
Introduction

Halliburton offers a complete line of retrievable and permanent sand control completion equipment. Sand control tools are available for applications from the shallow land well to the multizone, high-angled offshore well. These tools incorporate the latest technology for FracPac™ systems, high-rate water packs, cased and openhole gravel packs, extended reach, horizontal cased, multizone, and openhole completions.

Halliburton Versa-Trieve® packers, multi-position tools, and accessories are used in completions worldwide. This section is dedicated to components of standard Halliburton completion systems.

Each tool is designed at Halliburton's major technology centers in Carrollton, Texas and Singapore with the completion system in mind. Extensive checks made during tool development ensure proper function and operation. Additional checks are made with mating tools to ensure compatibility. SolidWorks®* computer modeling is used in the design to check function and operation on difficult geometry. Detailed drawings are produced from an engineer's computer model, and revisions to drawings are controlled throughout all manufacturing locations worldwide through a system meeting ISO 9001 requirements. This, combined with continuous feedback from our service personnel, provides for a consistent level of quality in all Halliburton Sand Control tools.

**SolidWorks is a registered trademark of Dassault Systèmes SolidWorks Corp.*



Downhole
Sand Control Completion

Sand Control Packers for Multi-Position Systems

Versa-Trieve® Packers—VTA, VBA, VCA, VCH, VDA, VBS, VGP, VGH, VSA

Versa-Trieve® packers are retrievable production packers designed for intermediate and high-pressure well applications. Numerous features in these compact packers incorporate the production features of permanent packers plus the added feature of retrievability. External components are easily millable if conventional release is not possible. Versa-Trieve packers can be either hydraulic- or wireline-set and are designed to be retrieved by a pulling tool with a straight pull of the tubing. When hydraulically set, Versa-Trieve packers are ideal for deviated or directional wells where it is difficult to run mechanical-set packers.

Applications

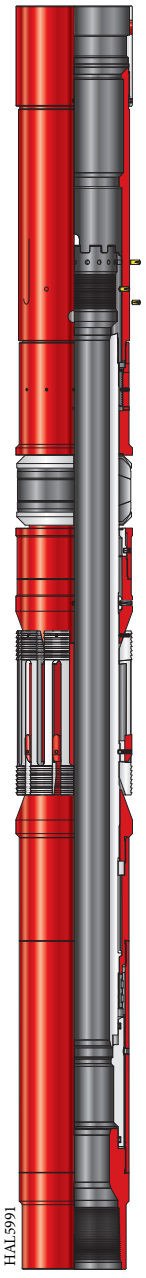
Versa-Trieve packers can be used in a variety of applications:

- Gravel pack
- High-rate water pack
- Ex-tension Pac℠ service
- FracPac℠ service
- Horizontal completion assemblies
- Production sealbore packer
- Suspending guns for tubing-conveyed perforating
- Stimulation

Features

- Packers can be run, set, and retrieved without any tubing rotation in most cases.
- The hydraulic setting mechanism is contained in the setting tool, reducing the number of potential leak paths left down hole.
- Scoop-head design saves time by providing a guide for landing seal units and accessories.
- Spring-loaded, case-carburized internal locking slips maintain maximum element compression.
- Multi-durometer element package is designed to seal against high and low pressures and against casing irregularities. (Standard nitrile or optional Aflas®* element packages are available. Special packer and element designs exist to suit high-pressure applications.)
- Element mandrel design on the VTA packers provides a positive means of locking the upper components to the slips. (The element mandrel allows for the full setting force to be applied to the elements and slips during setting operations. If milling operations are required, the upper components will not spin.)

VTA Packer



VBA/VCA Packer

**Aflas is a registered trademark of Asahi Glass Co., Ltd.*

- Lower anchor lug allows torque to be transmitted through the packer during running and pulling operations.
- Bi-directional case-carburized slips or a barrel slip hold the packer securely against well pressures in all casing grades (including V150) from above and below.
- Location of the slips beneath the elements simplifies releasing and retrieval. Debris is kept off the slips.
- A flow-isolated, C-ring release mechanism locks the packer in the set position until located and unlatched by the retrieving tool. Pushing through tight spots is safer than with traditional collet-release mechanisms.
- Packer is designed for simple release and retrieval.

Versa-Trieve® packers are available with the following top sub configurations:

- Versa-Latch® assembly
- upper sealbore assembly (VSA, VBS)

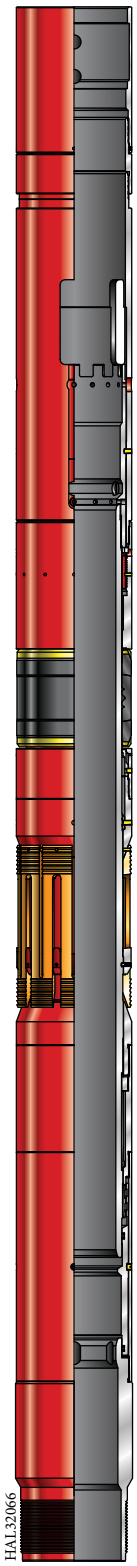
Threaded bottom subs are provided as a separate item for running gravel pack flow subs, sealbore extensions, or tubing tailpipe of varying types and sizes. The -Z designates the packer has no bottom sub.

VCH and VGH Packers

The VCH packer is a VCA packer specially designed for use with the HPT heavy hang weight soft release tool. The VGH packer is a VGP packer designed for the HPT tool.

Upper Sealbore Versa-Latch® Head

Bottom Sub



VCH Packer

VGP Packers

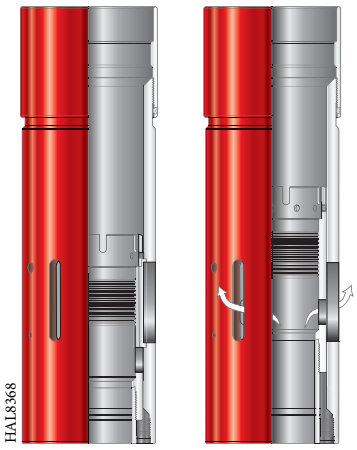
The Halliburton large bore Versa-Latch® gravel pack (VGP) style packer is an integral part of the Versa-Trieve® packer family of tools. It provides a larger bore than the VTA packers (in a given casing size and weight) by eliminating the element mandrel while still retaining many of the features of the Versa-Trieve packer line. Because the element mandrel is eliminated, the lower element retainer is pinned to the packer mandrel, and an additional set of anti-rotation pins has been included for ease of milling. The VGP packer also includes a top snap guide for collet locations.

Upper Sealbore VSA Versa-Trieve® Packer

For applications where a larger bore is required through the seal assembly, Halliburton can provide an upper sealbore packer head design that has a larger ID than the packer mandrel and can accept a short seal assembly and Versa-Latch® locator.

Weight-Down Versa-Trieve® and PGP Packers

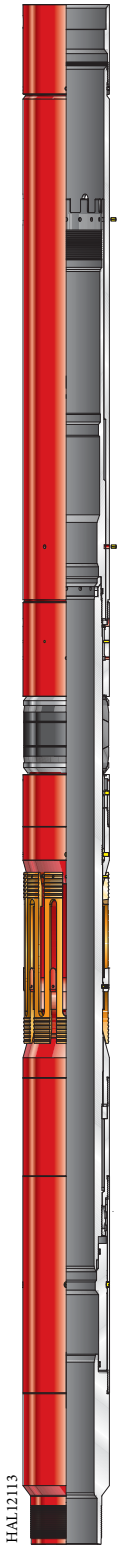
All packers described previously can be provided as weight-down packer designs for weight-down squeeze and circulate gravel packing and FracPac™ systems. Weight-down packers use the slots in the top sub and setting sleeve. These slots align when the packer is in the set position. This provides a flow path for return fluids during a gravel packing operation or pressure monitoring during a FracPac™ system operation.



Run-In Position

Set Position with Return Flow

VGP Packer



VSA Packer

Thermal Versa-Trieve® Packer

The thermal Versa-Trieve® packer is designed with a high-temperature elastomer package and o-rings, providing a packer suitable for extremely high temperatures. The elements are made of materials suitable for service where operations such as steam injection and "huff 'n' puff" exist.

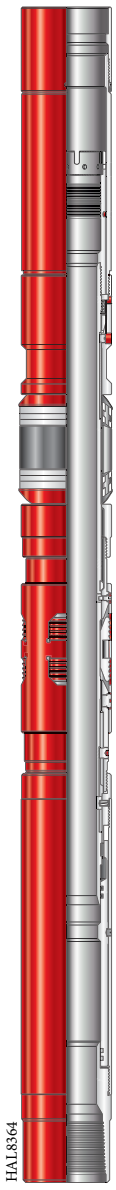
Sealbore and Millout Extensions

Halliburton packer sealbore extensions extend the polished surface below the packer. This enables the use of longer sealing units to compensate for tubing contraction or elongation. The extensions are available in standard 8-, 20-, and 24-ft (2.44-, 6.10-, and 7.32-m) increments.

Halliburton millout extensions provide a large ID below the packer sealbore or sealbore extension, which allows a single-trip packer milling/retrieving tool to be used when tubing is run below the packer assembly.

PGP Permanent Sealbore Packer

The PGP packer is a Perma-Series® permanent packer that has been modified so it can be run on the multi-position tool. The packer has an upper setting sleeve and a longer bottom sub with a thread that is compatible with standard flow subs and closing sleeves. The PGP packer has the benefit of withstanding higher pressures and temperatures than the retrievable Versa-Trieve family of packers but must be milled out when workover operations are required. Additional features and benefits of this packer are outlined under the Perma-Series sump packer.



Thermal Versa-Trieve® Packer

PGP Type Permanent Packer

Versa-Trieve® Packers

Casing Size		Casing Weight		Packer OD		Packer Bore		Production Seal Assembly ID	
in.	*mm*	lb/ft	*kg/m*	in.	*mm*	in.	*mm*	in.	*mm*
4 1/2	*114.30*	9.5-11.6	*14.14-17.26*	3.82	*97.03*	2.380	*60.45*	1.74	*44.07*
5	*127.00*	15-18	*22.32-26.79*	4.09	*103.89*	2.550	*64.77*	1.81	*45.97*
5 1/2	*139.70*	23-23.8	*35.22-35.41*	4.44	*112.78*	2.750	*69.85*	1.93	*48.95*
		20-23	*29.76-34.22*	4.50	*114.30*				
		17-20	*20.83-25.30*	4.60	*116.84*				
		14-17	*20.83-25.30*	4.67	*118.62*				
6 5/8	*168.28*	34.5	*51.34*	5.35	*135.89*	3.250	*82.55*	2.35	*59.69*
		28	*41.66*	5.53	*140.46*				
		24	*35.72*	5.73	*145.54*				
		20-24	*29.76-35.71*	5.73	*145.54*				
7	*177.80*	49.5-50.1	*73.66-74.56*	5.30	*134.62*	3.000	*76.20*	2.35	*59.69*
		49	*72.92*	5.35	*135.89*	3.250	*82.55*	2.35	*59.69*
		41-44	*61.01-65.47*	5.53	*140.46*				
		41-42.7	*61.01-63.54*	5.565	*141.35*				
		38	*56.55*	5.73	*145.54*				
		32-38	*47.62-56.54*	5.73	*145.54*				
		38	*56.55*	5.725	*145.42*	3.88	*98.55*	3.05	*77.47*
		32-35	*47.62-52.08*	5.82	*147.83*				
		32	*47.62*	5.89	*149.61*				
		26-32	*38.69-47.62*	5.92	*150.37*				
		26-29	*38.69-43.15*	6.015	*152.78*				
		26-29	*38.69-43.15*	6.00	*152.78*				
		23-29	*34.22-43.15*	6.00	*152.40*				
		23	*34.22*	6.14	*155.96*				
		23	*34.22*	6.19	*155.96*				
		17-23	*25.30-34.22*	6.19	*157.23*				
		17-20	*25.30-29.76*	6.275	*159.51*				
7 5/8	*193.68*	45.3-47.1	*67.41-70.08*	6.14	*155.96*	3.880	*98.55*	3.050	*77.47*
		42.4-47.1	*35.72-70.09*	6.19	*157.23*				
		39-42.8	*58.03-63.69*	6.275	*159.51*				
		39	*58.04*	6.44	*163.58*				
		29.7-39	*44.19-58.03*	6.44	*163.58*				
		29.7-33.7	*44.19-50.15*	6.56	*166.62*				
		33.7	*50.15*	6.58	*167.13*				
		26.4-29.7	*39.28-44.19*	6.62	*168.15*				
		24-29.7	*35.71-44.19*	6.68	*169.67*				
7 3/4	*196.85*	46.1	*68.6*	6.28	*159.96*	3.880	*98.55*	3.050	*77.47*
		46.1-48.6	*68.6-72.32*	6.19	*157.23*				
8 1/8	*206.38*	45.5	*67.71*	6.87	*174.5*	4.600	*116.84*	3.800	*96.52*
8 5/8	*219.08*	57.4-61.4	*85.42-91.37*	6.985	*177.42*	4.600	*116.84*	3.800	*96.52*
		60.7	*90.32*	7.00	*177.8*	4.600	*116.84*	3.800	*96.52*
		61.4	*91.37*	7.00	*177.8*	4.600	*116.84*	3.800	*96.52*
		55.83	*83.08*	7.125	*180.95*	4.600	*116.84*	3.800	*96.52*
		55.83-57.4	*82.94-85.42*	7.125	*180.98*	4.600	*116.84*	3.800	*96.52*
		52-54	*77.38-80.36*	7.16	*181.86*	4.600	*116.84*	3.800	*96.52*
		40-44	*59.53-65.47*	7.43	*188.72*	5.000	*127.00*	3.850	*97.79*
		28-36	*41.67-53.57*	7.63	*193.80*	3.880	*98.55*	3.05	*77.47*
		32-36	*47.62-53.57*	7.64	*194.06*	3.880	*98.55*	3.05	*77.47*
8 3/4	*222.25*	49.7	*73.96*	7.43	*188.72*	5.000	*127.00*	3.85	*97.79*

Versa-Trieve® Packers

Casing Size		Casing Weight		Packer OD		Packer Bore		Production Seal Assembly ID	
in.	*mm*	lb/ft	*kg/m*	in.	*mm*	in.	*mm*	in.	*mm*
9 5/8	*244.48*	70.3-71.8	*104.61-106.84*	7.89	*202.69*	5.000	*127.00*	3.850	*97.79*
		53.5	*79.62*	8.30	*210.82*	3.880	*98.55*	3.05	*77.47*
						5.000	*127.00*	3.85	*97.79*
						5.500	*139.7*		
						6.000	*152.40*	4.86	*123.44*
		47-53.5	*64.74-79.62*	8.30	*210.82*	3.880	*98.55*	3.05	*77.47*
						5.000	*127.00*	3.85	*97.79*
						6.000	*152.40*	4.86	*123.44*
		43.5-53.5	*64.73-79.62*	8.30	*210.82*	3.880	*98.55*	3.05	*77.47*
						5.000	*127.00*	3.85	*97.79*
		43.5-47	*64.74-69.94*	8.45	*214.63*	3.880	*98.55*	3.05	*77.47*
						5.000	*127.00*	3.85	*97.79*
						6.000	*152.40*	4.86	*123.44*
		40-47	*59.53-69.94*	8.46	*214.88*	5.000	*127.00*	3.85	*97.79*
		36-43.5	*53.57-64.73*	8.52	*216.41*	3.880	*98.55*	3.05	*77.47*
						5.000	*127.00*	3.85	*97.79*
		40-43.5	*59.53-64.73*	8.52	*216.41*	6.000	*152.40*	4.86	*123.44*
		36-40	*53.57-59.53*	8.60	*218.44*	3.880	*98.55*	3.05	*77.47*
						5.000	*127.00*	3.85	*97.79*
9 3/4	*247.65*	59.2	*88.10*	8.30	*210.82*	5.000	*127.00*	3.85	*97.79*
9 7/8	*250.83*	62.8	*93.46*	8.30	*210.82*	5.000	*127.00*	3.85	*97.79*
						6.000	*152.40*	4.86	*123.44*
		66.9	*99.56*	8.30	*210.82*	6.000	*152.40*	4.86	*123.44*
10 1/8	*257.18*	79.22	*117.89*	8.30	*210.82*	5.000	*127.00*	3.85	*97.79*
10 3/4	*273.05*	51-65.7	*75.90-97.77*	9.31	*236.47*	5.000	*127.00*	3.85	*97.79*
		60.7-65.7	*90.33-97.77*	9.34	*237.24*	6.000	*152.40*	4.86	*123.44*
11 3/4	*298.45*	65-71	*96.72-105.65*	10.30	*261.62*	6.000	*152.40*	4.86	*123.44*
11 7/8	*301.63*	71.8	*106.85*	10.34	*273.05*	6.000	*152.40*	4.86	*123.44*
13 3/8	*339.73*	68-72	*101.18-107.14*	12.13	*308.10*	6.000	*152.40*	4.86	*123.44*
						8.500	*215.90*		
		88.2	*131.26*			8.500	*215.90*		

Sand Control Sump Packers

Sump packers are typically used in combination with sand control systems. The sump packer is usually set with electric wireline and is normally considered a permanent installation. The packer is set below the perforations and is used for depth correlation of the production screen to the perforated interval.

The sump created below the sump packer provides a trap for debris that settles after perforating and for lost tools to fall through. Also, the sump allows logging tools to be lowered past the perforations so the entire interval can be surveyed for future operations.

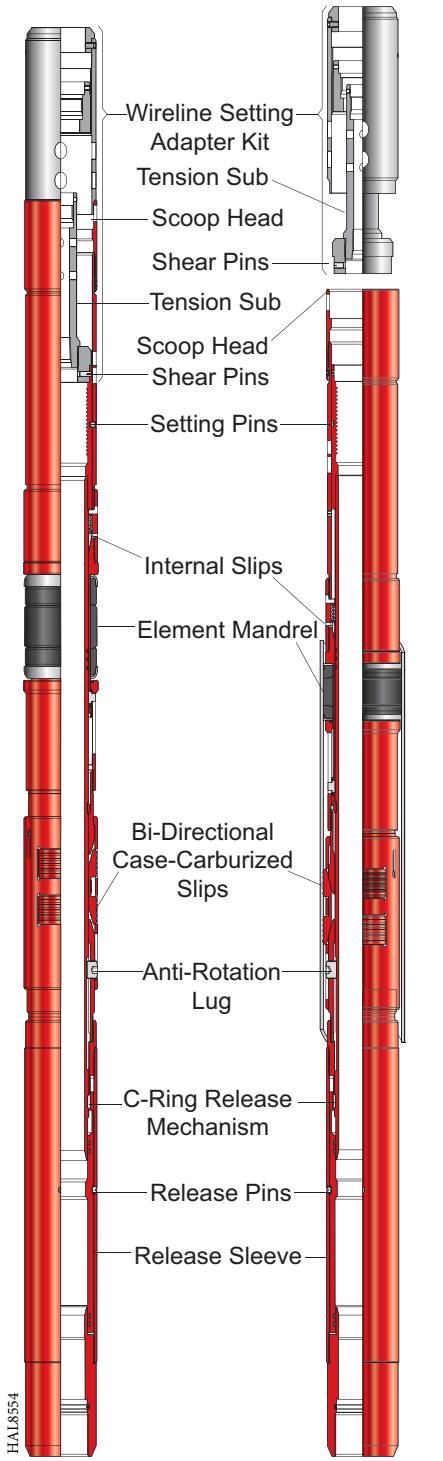
Any one of the Halliburton sealbore packers can be used as a sump packer. The packer may need to be a special version to mate with the sump seal unit or indicating collet.

Wireline-Set Perma-Series® Sump Packers

Halliburton wireline-set Perma-Series® packers are effective, differential production packers for single or multizone completions. These permanent packers may be electric-wireline or hydraulic set on the workstring. They are also designed to leave the packer bore free of all setting devices and maintain a large fluid bypass area through the packer. Operating envelopes—graphical representations of the safe combination of differential pressure and applied tubing loads—are available for most Perma-Series packers.

Setting Adapter Kits

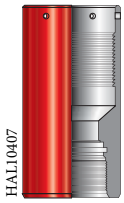
Halliburton adapter kits are designed to be attached to the packer and set with either a DPU® downhole power unit, conventional explosive-type wireline setting tool, or a hydraulic setting tool. When the setting tool is activated, the setting adapter kit sets the packer. When the prescribed setting force is applied to the packer, the setting pins in the wireline adapter kit separate to release the setting equipment from the packer so it can be retrieved.



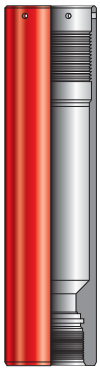
Setting Adapter Kit Run Position

Setting Adapter Kit Set Position

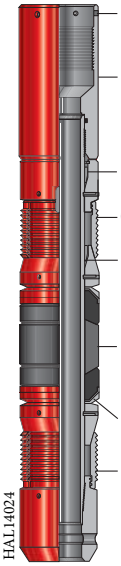
Wireline-Set Perma-Series® Sump Packers



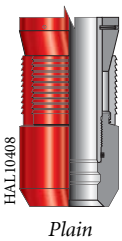
Short Versa-Latch® Receiving Head



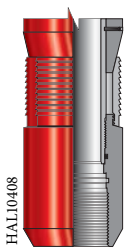
Versa-Latch® Receiving Head



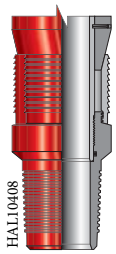
Perma-Series® Wireline-Set Packer



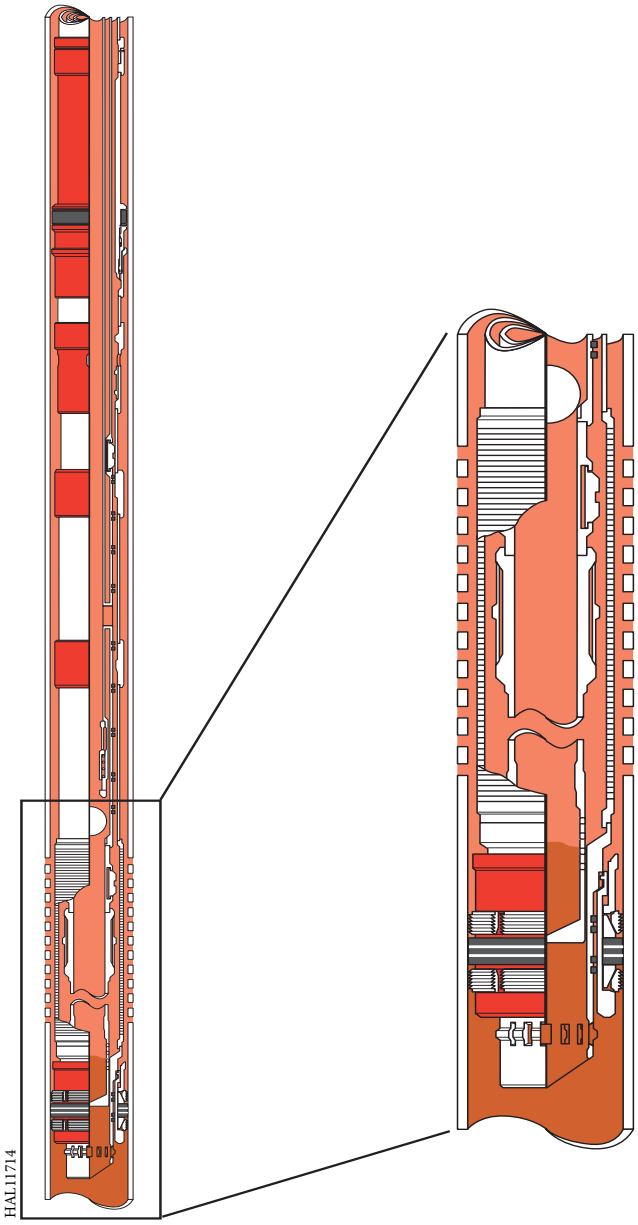
Plain Bottom Sub



Sealbore Extension Thread



Tubing or Millout Extension Thread



Sump Packer

Wireline-Set Perma-Series® Production Packers

Casing Size		Casing Weight		Packer OD		Sealbore ID		Seal Unit ID*					
in.	*mm*	lb/ft	*kg/m*	in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*
4 1/2	*114.30*	9.5-12.6	*14.14-18.75*	3.79	*96.27*	2.55	*64.90*	1.68	*42.60*	1.81	*45.97*	1.920	*48.77*
		9.5-12.6**	*14.14-18.75*	3.79	*96.27*	2.75	*69.85*	1.91	*48.51*				
		9.5-13.5	*14.14-20.09*	3.72	*94.49*	2.37	*60.33*	1.53	*38.86*	1.74	*44.07*		
		13.5-15.1	*20.09-22.47*	3.64	*92.46*	2.55	*64.90*	1.68	*42.60*	1.81	*45.97*	1.920	*48.77*
		13.5-15.1**	*20.09-22.47*	3.64	*92.46*	2.75	*69.85*	1.91	*48.51*				
		13.5-16.8	*20.09-25.00*	3.60	*91.44*	2.37	*60.33*	1.53	*38.86*	1.74	*44.07*		
5	*127.00*	15-21	*22.32-31.25*	3.96	*100.58*	2.55	*64.90*	1.68	*42.60*	1.81	*45.97*	1.920	*48.77*
		15-21**	*22.32-31.25*	3.96	*100.58*	3.12	*79.25*	2.39	*60.71*				
		23.2-24.2	*34.53-36.01*	3.79	*96.27*	2.55	*64.90*	1.68	*42.60*	1.81	*45.97*	1.920	*48.77*
		23.2-24.2**	*34.53-36.01*	3.79	*96.27*	2.75	*69.85*	1.91	*48.51*				
5 1/2	*139.70*	13-20	*19.35-29.76*	4.54	*115.32*	2.75	*69.85*	1.83	*46.48*	1.93	*48.95*		
		13-20	*19.35-29.76*	4.54	*115.32*	3.00	*76.20*	1.93	*48.95*	2.24	*56.90*	2.330	*59.18*
		13-20**	*19.35-29.76*	4.54	*115.32*	3.50	*88.90*	2.51	*63.75*				
		20-26	*29.76-38.69*	4.36	*110.74*	2.75	*69.85*	1.83	*46.48*	1.93	*48.95*		
		20-26	*29.76-38.69*	4.36	*110.74*	3.00	*76.20*	1.93	*48.95*	2.24	*56.90*	2.330	*59.18*
		20-26**	*29.76-38.69*	4.36	*110.74*	3.50	*88.90*	2.51	*63.75*				
		23-28.4	*34.23-42.26*	4.26	*108.20*	3.00	*76.20*	1.93	*48.95*	2.24	*56.90*	2.330	*59.18*
		23-28.4**	*34.23-42.26*	4.26	*108.20*	3.12	*79.25*	2.39	*60.71*				
6 5/8	*168.28*	17-32	*25.30-47.62*	5.47	*138.89*	2.75	*69.85*	1.83	*46.48*				
		17-32	*25.30-47.62*	5.47	*138.89*	3.25	*82.55*	2.35	*59.69*				
		17-32**	*25.30-47.62*	5.47	*138.89*	4.25	*107.95*	3.25	*82.55*	1.93	*48.95*		
		20-24	*29.76-35.72*	5.69	*144.45*	4.00	*101.60*	2.97	*75.44*				
		20-24**	*29.76-35.72*	5.69	*144.45*	4.75	*120.65*	3.85	*97.79*				
7	*177.80*	17-20	*25.30-29.76*	6.25	*158.75*	4.00	*101.60*	2.97	*75.44*				
		17-23	*25.30-34.23*	6.18	*156.97*	3.25	*82.55*	2.35	*59.69*				
		17-23**	*25.30-34.23*	6.18	*156.97*	4.25	*107.95*	3.25	*82.55*				
		20-26	*29.76-38.69*	6.00	*152.40*	4.00	*101.60*	2.97	*75.44*				
		23-38	*34.23-56.55*	5.69	*144.45*	2.75	*69.85*	1.83	*46.48*				
		23-38	*34.23-56.55*	5.69	*144.45*	3.25	*82.55*	2.35	*59.69*				
		23-38**	*34.23-56.55*	5.69	*144.45*	4.25	*107.95*	3.25	*82.55*	1.93	*48.95*		
		23-32	*34.23-47.62*	5.88	*149.23*	4.00	*101.60*	2.97	*75.44*				
		23-32**	*34.23-47.62*	5.88	*149.23*	5.00	*127.00*	3.93	*100.03*				
		32-38	*47.62-56.55*	5.69	*144.45*	4.00	*101.60*	2.97	*75.44*				
		32-38**	*47.62-56.55*	5.69	*144.45*	4.75	*120.65*	3.85	*97.79*				
		32-45.4	*47.62-67.56*	5.47	*138.89*	2.75	*69.85*	1.83	*46.48*				
		32-45.4	*47.62-67.56*	5.47	*138.89*	3.25	*82.55*	2.35	*59.69*				
		32-45.4**	*47.62-67.56*	5.47	*138.89*	4.25	*107.95*	3.25	*82.55*				
7 5/8	*193.68*	26.4-39	*39.29-58.04*	6.38	*161.93*	2.75	*69.85*	1.83	*46.48*				
		26.4-39	*39.29-58.04*	6.38	*161.93*	3.25	*82.55*	2.35	*59.69*				
		26.4-39	*39.29-58.04*	6.38	*161.93*	4.00	*101.60*	2.97	*75.44*				
		33.7-39	*50.15-58.04*	6.38	*161.93*	4.50	*114.30*	2.97	*75.44*				
		33.7-39**	*50.15-58.04*	6.38	*161.93*	5.25	*133.35*	4.00	*101.60*	1.92	*48.77*		
		33.7-45.3	*50.15-67.41*	6.18	*156.97*	3.25	*82.55*	2.35	*59.69*				
		33.7-45.3**	*50.15-67.41*	6.18	*156.97*	4.25	*107.95*	3.25	*82.55*				
		33.7-45.3	*50.15-67.41*	6.25	*158.75*	4.00	*101.60*	2.97	*75.44*				
8 5/8	*219.08*	36-49	*53.57-72.92*	7.26	*184.40*	4.00	*101.60*	2.97	*75.44*				
9 5/8	*244.48*	36-47	*53.57-69.94*	8.42	*213.87*	6.00	*152.40*	4.86	*123.44*				
		36-59.4	*53.57-88.40*	8.12	*206.25*	3.25	*82.55*	2.35	*59.69*				
		36-59.4	*53.57-88.40*	8.12	*206.25*	4.00	*101.60*	2.97	*75.44*				
		36-59.4	*53.57-88.40*	8.12	*206.25*	5.00	*127.00*	3.85	*97.79*				
		36-59.4**	*53.57-88.40*	8.12	*206.25*	6.50	*165.10*	5.00	*127.00*				
		40-53.5	*59.53-79.62*	8.22	*208.79*	6.00	*152.40*	4.86	*123.44*				
		40-53.5**	*59.53-79.62*	8.22	*208.79*	7.00	*177.80*	6.13	*155.58*				
		47-58.4	*69.94-86.90*	8.16	*223.11*	6.00	*152.40*	4.86	*123.44*				

*Thread type and size control seal unit ID
**Upper Ratch-Latch™ head style only

Intelligent Setting Tools

DPU® Downhole Power Unit – Intelligent Series Tool

The Halliburton DPU® Downhole Power Unit Intelligent (DPU-I) series tool provides unsurpassed reliability and quality assurance in setting wellbore devices such as plugs and packers. The rig-safe, non-explosive electro-mechanical DPU-I tool expands well intervention capabilities beyond the conventional tools. By generating a slow, precisely controlled linear force with real-time feedback, this tool optimizes setting and helps ensure maximum performance of a well completion even in the most hostile well environments.

The subsurface device (plug, packer, etc.) is attached to the DPU-I tool, which can be deployed on e-line, slickline*, or coiled tubing*. The stroke length, setting force, and rate at which the force is applied during the setting operation are displayed in real time for quality assurance purposes. The slow, controlled setting motion maximizes sealing and anchoring of the wellbore device especially in hostile and high-angle wells. When the designated setting force is achieved, the DPU-I tool separates from the subsurface device and can be retrieved from the well.

The DPU-I tool motion control and high linear force provides an alternative to jointed pipe or coiled tubing well interventions. At the well site, it can be easily adapted to set or retrieve devices based on intervention requirements.

DPU® Downhole Power Unit Intelligent Series

Applications

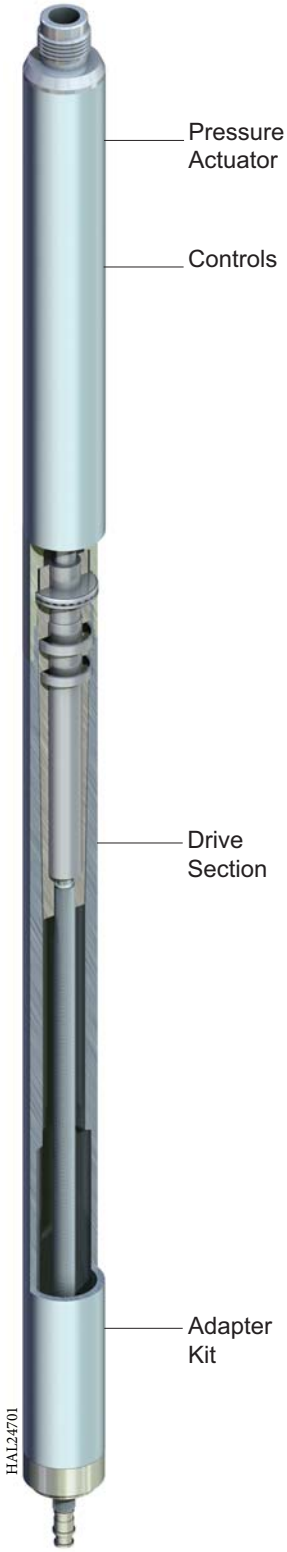
- New completions or workover operations requiring setting or retrieval of wellbore devices such as packers, sand control sump packers, bridge plugs, whipstocks, retrievable bridge plugs, subsea tree plugs, straddles, patches, and cement retainers
- Plug and abandonment or pipe recovery operations on e-line or slickline
- Mechanically punching holes in tubing for circulating kill fluid or installing remedial through-tubing gas lift capabilities
- Mechanical intervention with subsurface flow control or completion devices such as circulating sleeve or internal control valves
- Adaptable to wireline tractor conveyance for deepwater and/or high-angle well interventions

Features

- Offers more setting force (up to 100,000 lb/ft) than conventional explosive setting tools without the added danger of using explosives
- Multiple tubing/casing intervention options from 2 3/8 to 13 3/8 in.
- Industry-leading design offers dependable operation in any well environment up to 30,000 psi and 400°F
- Robust hardware and electronics capable of withstanding high-impact loads encountered during well intervention operations
- Slow, controlled application of force enables sealing elements and anchoring devices to conform to the wellbore

Benefits

- Can improve safety and reliability through non-explosive operation
- Helps reduce completion costs by saving time
  - Single flight heli-lift compliant for rapid deployment
  - Radio silence operations not required
  - Disruption of the cathodic protection system during operations not required
  - Military or governmental escort not required
  - Offshore explosive storage magazine not required
  - Redressing between operations not required
- Assurance on quality of setting wellbore devices provided by real-time feedback of setting force, stroke length, and displacement rate
- Intervention versatility enabled by dual setting and retrieving capability
- Conveyance flexibility with solutions on e-line, slickline, and coiled tubing
- Setting force and hydrostatic pressure rating meet ultra-deepwater well completion requirements



DPU® Downhole Power Unit – Intelligent Series Tool

OD		Pressure Rating		Temperature Rating*		Set/Retrieve Force		Stroke Length		Internal GR/CCL	Length		Weight	
in.	*mm*	psi	*bar*	°F	*°C*	lbf	*kN*	in.	*cm*		ft	*m*	lb	*kg*
4 1/2	*114.3*	30,000	*2068*	350/400	*177/204*	100,000	*445*	13	*33*	Yes	16.4	*5*	490	*222*
3 3/8	*85.7*	30,000	*2068*	350/400	*177/204*	70,000	*311*	13	*33*	Yes	14.36	*4.38*	300	*126*
2 1/2	*63.5*	30,000	*2068*	350/400	*177/204*	40,000	*178*	13	*33*	Yes	18.98	*5.79*	202	*92*
1 3/4	*44.5*	20,000	*1379*	350	*177*	15,000	*66.7*	13	*33*	Yes	16.83	*5.13*	92.5	*42*

*400°F (204°C) available with flask

eRED® Electronic Remote Equalizing Device

The eRED® valve is a retrievable, computer-controlled ball valve that can be repeatedly opened and closed by remote command. There are no connections to surface and no interventions are required to operate or communicate with the valve. It is deployed below either a lock or bridge plug and can be used as a downhole barrier or flow control device. With each use of the eRed valve, an intervention is eliminated from the operation—dramatically reducing rig-time and associated risks.

The valve has integrated pressure and temperature sensors to monitor well conditions and is pre-programmed to either open or close whenever a specified condition (known as a trigger) is detected. The triggers use a variety of well parameters including ambient pressure, temperature, time, or surface-applied pressure. Each time a trigger is detected, the eRED valve will react by either opening or closing as per its instructions. This process can be repeated time-and-time again without any form of intervention.

Applications

Any application where a wireline plug is used can be replaced by an eRED valve, achieving the same results but without repeated interventions, saving on rig-time and associated costs and risks. Often, more than one eRED valve is deployed in a single operation, multiplying the benefits. The valve can also be incorporated into the multi-position gravel pack service tool for use in high angled to horizontal wellbores for packer setting, thereby eliminating the need for dropping a packer setting ball.

- Packer setting device
- Deep-set barrier in extended reach or horizontal wells
- Shallow-set for tree testing and change out
- Completion deployment as the annulus short string plug
- Liner deployment with external swellable elastomer
- Barrier in temporary abandonments or light well intervention operations
- Barrier in TCP gun firing and stimulation operations
- Self-actuating flow control device
- Shut-in tool for pressure buildup tests with reduced interventions

Features and Benefits

- Remotely operated time-after-time – Removes multiple wireline runs from operations, saving time, money, and helping reduce risk
- Long battery life – Operational for at least 10 months for use in temporary abandonment operations or as a flow control device

HAL38775

- Run open or closed – Providing flexible deployment options and well control
- Extensive run history – Extremely reliable, field-proven technology used by the world's major oil producers
- No dedicated personnel required – Reduces the number of operations personnel, saving costs and helping reduce risk

Control By Remote Command

By applying a defined pressure for a defined time at surface, the operator can activate the Pressure Window Trigger. This allows direct communication to the eRED valve so it can be remotely operated. For example, applying 1,000 to 1,500 psi for 10 minutes could instruct the eRED valve to open. The eRED valve will ignore any pressure applied outside the defined values. This means pressure can be applied to tubing (for tubing integrity tests, packer setting, etc.) without risk of inadvertent activation.

Onboard data analysis allows the eRED valve to distinguish its own commands from other external factors such as naturally fluctuating hydrostatic or reservoir pressure. This enables the valve to behave as planned even if the downhole conditions change unexpectedly.

Independent Operation

A range of other triggers consisting of ambient well pressure, ambient well temperature, and a timer are also available. These triggers are used to provide a pre-programmed sequence for the eRED valve to follow without any input from the surface.

All the different trigger types can be used independently or in conjunction with each other to build more elaborate instructions. For example, the eRED valve could be set to close when it detects bottomhole flowing pressure lower than 1,000 psi but only after 100 days downhole. In addition, the Pressure Window Trigger can be used to manually cancel or override any trigger or permanently lock the eRED valve in its current position.

Hydraulic Isolation Packers

The Halliburton hydraulic-set isolation packer has no slips to anchor it in the casing. It is typically used to isolate discrete zones of a producing interval and is run as part of a continuous completion assembly that contains a packer with slips to anchor the string.

In multizone wells, such as a STMZ™ single-trip multizone assembly, the isolation packer isolates the production to prevent producing from more than one zone at the same time. The packer is set at a point below the piston of the packer applying hydraulic pressure. Pressure forces the piston up, shearing the driv-lok pins in the internal slip housing and expanding the elements outward to the casing ID. To retrieve, a straight upward pull on the tubing string is required. This packer has no casing slips, and it is necessary that another means of anchoring the tubing be provided.

Features

The packers isolate production to prevent multiple zones from producing simultaneously.

Slipless Hydraulic-Set Packer

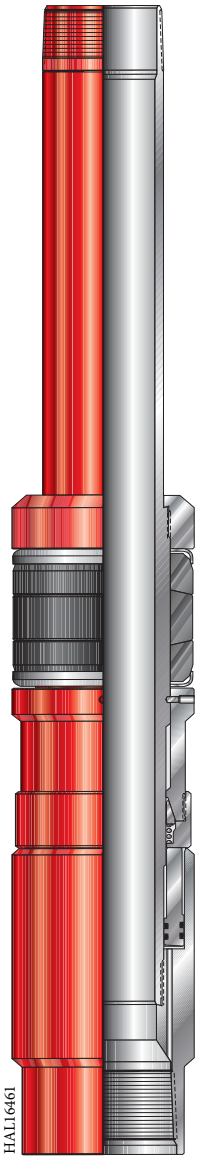
The slipless hydraulic-set packer provides economical zonal isolation for multizone systems.

Features

- Set with applied pressure
- Multi-durometer element package with metal backup system

Benefits

- Low-cost isolation packer
- Highly reliable setting
- May include sealbore



Hydraulic Isolation Packer

ZoneGuard® SR (Short Radius) Packer

The ZoneGuard® SR packer is designed for situations where tight radius well conditions are anticipated. It uses a multi-durometer element package with a unique backup and deployment system to deliver unsurpassed sealing performance in a wide range of openhole conditions. The design includes an anti-preset feature to help protect against premature packer setting during running operations.

The packer can be used for zonal isolation in formation control, selective stimulation, and fracturing applications. It is run as part of the completion string and can be set either hydraulically with plug set below or with an isolation straddle tool when plugging is not possible.

Applications

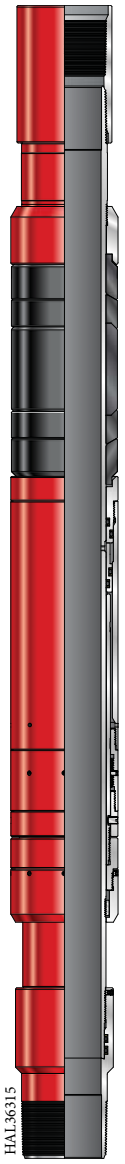
- Openhole applications (horizontal or vertical)
- Water shutoff
- Gas shutoff
- Stimulation
- Production testing
- Isolation
- Selective production
- Stage cementing

Features

- Small running OD
- Compact length for short radius well conditions
- Anti-preset feature
- Multi-piece/multi-durometer element package
- Adjustable setting shear value
- Internal locking system
- Long-term isolation reliability
- Hydraulically set plugged tubing and isolation straddle

Benefits

- Selective production management in horizontal wellbores
- Reliably control inflow or injection within selected wellbore sections
- Ideally suited for near-gauge conditions requiring higher differentials



ZoneGuard® SR Packer

ZoneGuard® SR (Short Radius) Packer

Maximum Metal OD	Minimum ID	Minimum Bore Hole	Maximum Bore Hole
in.	in.	in.	in.
5.65	3.850	5 7/8	6 1/4

ZoneGuard® HE Packer

The ZoneGuard® HE packer is designed for situations where a high-expansion sealing element is required and large variations in hole gauge diameter are anticipated. It uses a multi-durometer element package with a unique backup and deployment system to deliver unsurpassed sealing performance in a wide range of openhole conditions. The packer can be used for zonal isolation in formation control, selective stimulation, and fracturing applications.

The ZoneGuard HE packer is run as part of the completion string and can be set either hydraulically with plug set below or with an isolation straddle tool when plugging is not possible. The packer contains a hydrostatic assist feature, which helps maintain positive pressure on the packer at all times.

Applications

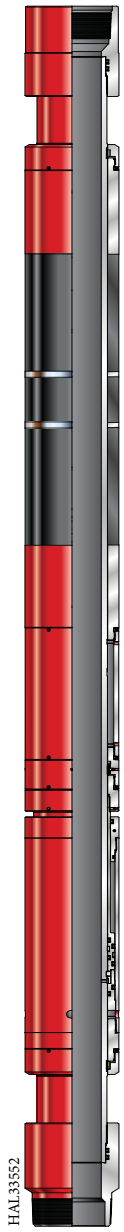
- Openhole applications (horizontal or vertical)
- Water shutoff
- Gas shutoff
- Stimulation
- Production testing
- Isolation
- Selective production
- Stage cementing

Features

- Small running OD
- Large element expansion capabilities
- Multi-piece/multi-durometer element package
- Adjustable setting shear value
- Internal locking system
- Long-term isolation reliability
- Hydraulically set plugged tubing and isolation straddle
- Hydrostatic assist allows positive pressure on element

Benefits

- Selective production management in horizontal wellbores
- Reliably control inflow or injection within selected sections of the wellbore
- Wide range of openhole isolation capabilities with one packer design



ZoneGuard® HE Packer

ZoneGuard® HE Packer

Maximum Metal OD	Minimum ID	Minimum Bore Hole	Maximum Bore Hole
in.	in.	in.	in.
5.625	3.49	6 1/8	8 1/4
8.000	4.88	8 1/2	11 1/2

ESTMZ™ Enhanced Single-Trip Multizone Completion System – Isolation Packer Options

The ESTMZ™ system design makes a conventional packer test on an individual isolation packer difficult to achieve. As a result, three isolation packer options are available. Two options are adaptations of existing hydraulic-set production packers and were selected on their field-proven reliability history. The dual element packer provides the added feature of testing between the element packages after packer setting. All three packer designs address the forces induced by thermal cooling and ballooning during frac treatment. Each packer design provides zone-to-zone isolation and anchors the screen between zones.

Dual Element – Testable Isolation Packer

A testable high-pressure retrievable hydraulic-set isolation packer was developed for use with the ESTMZ system. The 9 5/8-in. packer design includes two separate element packages that enable the packer to be tested between the element packages after the packer is set. All isolation packers are simultaneously set and tested. The packer is retrieved by applying a straight pull to the ESTMZ assembly.

Single Element – Isolation Packer

The HPH packer is a single element high-pressure hydraulic-set retrievable packer adaptable for use with the ESTMZ system as an isolation packer. The packer is based on the reliable hydraulic-set production packer. The packer is retrieved by applying a straight pull to the ESTMZ assembly.

Single Element – TNT Packer

The TNT packer is a high-pressure retrievable sealbore production packer adaptable for use as an isolation packer in the ESTMZ system to provide zone-to-zone isolation. The TNT packer is a cut-to-release design.

HP Dual Element Hydraulic-Set Retrievable Packer

HPH Hydraulic-Set Retrievable Packer

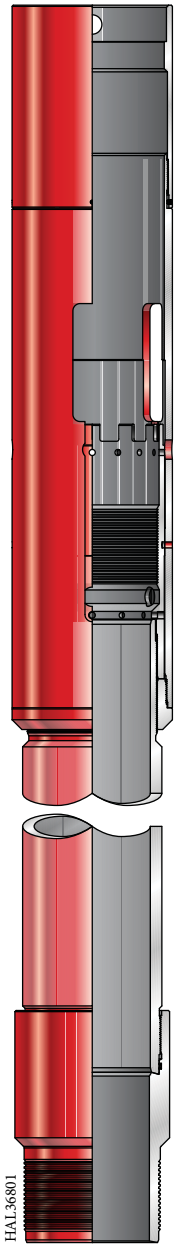
TNT Packer

Tieback Receptacle

This liner/screen running tool is used in openhole completions to run screens or liners. The tool allows the screen or a perforated liner such as a CAPS™ liner to be run in using a multi-position tool-type hydraulic setting tool without being attached to a packer. The screen is made up to the lower end of the screen running tool. The hydraulic running tool connects to the running tool as it would a packer and is run in with the tubing string.

Features and Benefits

- Lower cost than Versa-Trieve® packer
- Same hang weight capabilities when run on the multi-position tool
- Sealbore to connect to upper completion assembly
- Top sub to latch and retrieve the assembly
- Simple design and operation
- Can be used to run CAPS™ liners prior to running the packer and screen assembly



Tieback Receptacle

Flow Sub and Closing Sleeve Extensions

Both the MCS and MFS assemblies require upper and lower extensions. Upper extensions provide spacing between the slurry exit ports and the bottom of the packer for the various gravel packing positions. The lower extension covers and protects the multi-position tool seals, which extend below the crossover ports, from damage during transportation to the rig site. It is generally larger than the blank pipe. These extensions are specified by the Halliburton technical representative to meet the conditions present in specific well completions. Different lengths, strengths, metallurgy, and erosional resistance levels are required to meet tool positioning, FracPac™ system collapse pressure resistance, material corrosion, and flow erosion requirements of the completion design.

MFS Ported Flow Subs

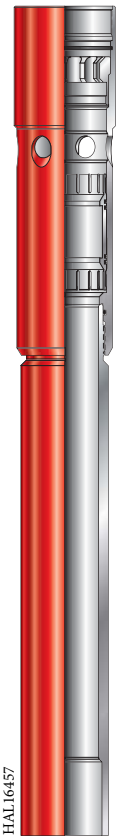
MFS multi-position flow subs are made up to an extension below the Versa-Trieve® packer. The multi-position tool packs off in both the packer mandrel and the polished bore section of the flow sub, which is below the slurry exit ports, to allow the gravel to be directed through the ports and around the outside of the screen. Carefully placed slurry exit holes optimize the distance between the slurry flow ports and lower honed bore for minimal dead space during packing and limit casing erosion during high velocity FracPac system slurry flow. Upon completion of the gravel pack, the ports should be isolated by installing a production seal assembly with an extension such that the seal assembly seals in the lower polished bore below the slurry exit ports. This prevents production of pack sand and formation sand back through the ports.

MCS Closing Sleeves

MCS multi-position closing sleeve assemblies provide casing annulus-to-tubing isolation for FracPac system, gravel pack, and horizontal completions. These sleeves are used in the following applications:

- Stacked gravel packs or frac packs
- Stack packs with upper sealbores
- Assemblies with short sections of blank
- Completions with fluid loss concerns or mechanical fluid loss devices
- Wells prone to kicks during tubing trips
- When seals will not be installed in the packer

The flow ports, like the MFS assembly, have been specially configured and tested to limit casing erosion during high-rate FracPac system operations. The unique closing sleeve collet arrangement holds the sleeve open during packing operations when the service seal unit is installed and holds the sleeve closed when the service seal unit is removed. These positioning collets do not drag on the polished bore. This minimizes closure forces and damage that can occur to the sealing surface while shifting the sleeve if collet fingers drag across the sealing surface. The sleeve has an enlarged ID to allow for easy passage of seals without contacting the sleeve. The sleeve is shifted by a self-releasing, positive-positioning tool installed on the washpipe below the service seal unit. Its field-proven, positive-shift mechanism provides assurance the sleeve is shifted after packing. The shifting tool releases on the slotted ring of the MCS sleeve that also maximizes flow bypass around the multi-position tool during packing. If necessary, the closing sleeve may be reopened and reclosed by simply lowering or raising the shifting tool through the sleeve.



HAL16457

MCS Closing Sleeve

HAL18362

MFS Ported Flow Subs

High-Rate MCS Sleeves

Critical Service MCS Sleeve with Quadra™ Seals

Halliburton's critical service MCS closing sleeve incorporates Quadra™ seal technology, which was developed for use in sand control applications. Quadra seals provide increased erosion resistance, lower stabbing forces, and greater resistance to seal damage during sleeve closure and opening. The new sleeve uses bonded elastomer seals that are molded onto the sleeve. In comparison, the conventional design uses multiple o-rings.

Halliburton's MCS closing sleeves provide for circulation and isolation in gravel pack, FracPac™ system, Red Zone®, and Beyond Red Zone® operations. The design provides large flow ports for circulation during fluid displacement and washing. A collet arrangement holds the sleeve open during washing operations and holds the sleeve closed when the washpipe is removed. The sleeve is shifted by a self-releasing, positive positioning tool installed on the washpipe. If necessary, the closing sleeve may be reopened and closed by simply lowering or raising the shifting tool through the sleeve.

Features and Benefits

- Utilizes Quadra seal technology
- Uses bonded elastomer seals molded onto the sleeve
- Provides circulation and isolation in gravel pack and FracPac system operations
- Provides large diameter flow ports for circulation during fluid displacement and washing
- Collet arrangement holds sleeve open during washing operations and closes sleeve when washpipe is removed
- Increased erosion resistance
- Sleeve can be reopened and closed by simply lowering or raising the shifting tool

High Shifting Force MCS Sleeve

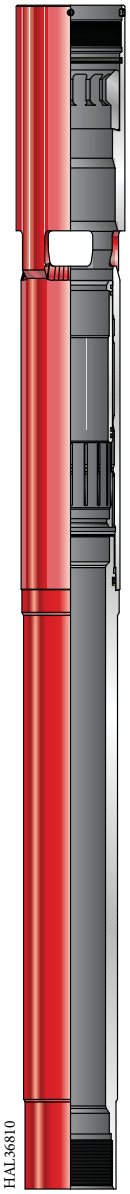
For applications where the closing sleeve may be exposed to tools running through the ID of the assembly, a high shifting load MCS sleeve has been developed.

Both designs provide unique features that improve the reliability of the MCS closing sleeve in critical applications. High shifting force sleeves with Quadra seals are recommended for applications where a seal assembly will not be run.

Beyond Red Zone® Sleeves

When the crossover mandrel is fitted with Halliburton's highest rated Beyond Red Zone carbide sleeve design, this special Beyond Red Zone design optimizes the exit flow profile and protects the inside of the casing from erosive wear that occurs at high rates of flow. The Beyond Red Zone sleeves are tested and proven to provide industry-leading performance ratings.

Closing Sleeve Assembly



Beyond Red Zone® Sleeve Assembly

Fluid Loss Control Devices

Halliburton leads the industry in fluid loss control solutions. From the proven ceramic flapper valves and ShurShot® ball dropper to the AIS systems and high-end valves like the FS2 valve, Halliburton delivers the correct solution.

Mechanical Fluid Loss Device Features

	Fluid Loss	Positive Isolation	Hydraulic Opening Pressure Up	Hydraulic Opening Bleed Down	Multiple Device Openings	Multiple Mechanical Actuation	Well Suspension	Single Selective	Upper Zone/Dual Production
Ceramic Flapper	✓								
CB Frangible Flapper	✓		✓						
ShurShot® Device	✓		✓						
FS2 Device	✓	✓		✓		✓	✓		
AIS	✓	✓				✓	✓	✓	
AIS with Hydraulically Activated Sliding Side-Door® Device	✓	✓		✓	✓		✓	✓	
Twin-Flow AIS-SH	✓	✓	✓				✓		✓
Twin-Flow AIS-SC	✓	✓	✓	✓			✓		✓
Twin-Flow AIS-LS	✓	✓	✓				✓		✓

Mechanical Fluid Loss Device Casing Size Availability

	5 in.	5 1/2 in.	6 5/8 in.	7 in.	7 5/8 in.	8 5/8 in.	9 5/8 in.	10 3/4 in.
Ceramic Flapper	✓	✓	✓	✓	✓	✓	✓	✓
CB Frangible Flapper				✓	✓	✓	✓	✓
ShurShot® Device	✓	✓	✓	✓	✓	✓	✓	✓
AIS		✓	✓	✓	✓	✓	✓	✓
AIS with Hydraulically Activated Sliding Side-Door® Device			✓	✓	✓	✓	✓	✓
Twin-Flow AIS-SH				✓	✓	✓	✓	✓
Twin-Flow AIS-SC				✓	✓	✓	✓	✓
Twin-Flow AIS-LS					✓	✓	✓	✓
FS2 Device				✓	✓	✓	✓	✓
IB4 Device				✓	✓	✓	✓	✓
IB5 Device							✓	✓

Frangible Flappers

Halliburton EGF expendable ceramic flappers and CB frangible metal flappers are designed to control fluid loss after gravel packing. They may also be run as an integral part of the packer assembly on horizontal completions for fluid loss control. The flapper design provides flapper protection during all service operations. Two versions of the preclosure flapper protection feature currently exist. One version is an internal flapper prop sleeve that is shifted and released by a shifting tool. The other is a removable sleeve that is pinned in place. It props and protects the flapper in the open position for running and service operations, then is removed by a no-go sub attached to the washpipe as the service tools are pulled from the well.

Both designs prevent washpipe, dragged through the flapper assembly, from coming in contact with the flapper. The wellbore is reopened by breaking the flapper. This can be done by slickline in vertical wells, by reeled tubing in horizontal wells, or by an extension of the production tube on the bottom of the production seal assembly.

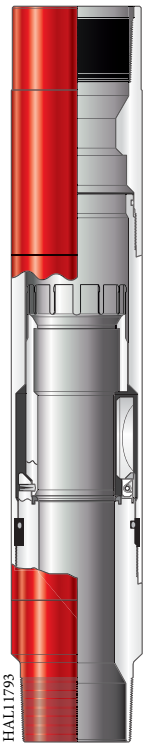
Materials were chosen to provide an extremely dense material which would fall to the bottom after being broken even in heavy completion brines, yet would break into fragments. Impact-type loads shatter the ceramic material. A metal flapper design is available for pressure expend operations. The frangible metallic flapper is calibrated for fracture pressures within a known fracture pressure.

Features

- Integral part of packer assembly for horizontal completions
- Fully retractable

Benefits

- Control fluid loss after gravel packing
- Prop sleeves protect against premature breakage
- Prevents washpipe from contact with the flapper



Frangible Ceramic Flapper (Internal Prop Sleeve Version)

EGF Flapper

Casing Size	Flapper Expanded ID		Housing OD*		Ceramic	Metal
in.	in.	*mm*	in.	*mm*		
5	2.11	*53.59*	3.815	*96.90*	✓	
5 1/2	2.40	*60.96*	4.02	*102.11*	✓	
	2.600	*66.04*	4.28	*108.71*		
6 5/8	2.765	*70.23*	5.26	*133.60*	✓	
7	3.01	*76.45*	5.35	*135.89*	✓	✓
	3.25	*82.55*	5.48	*139.19*		
	3.31	*84.07*	5.725	*145.42*		
7 5/8	3.435	*82.25*	5.93	*150.62*	✓	✓
	3.500	*88.90*	6.09	*154.69*		
9 5/8	4.87	*123.70*	8.250	*209.55*	✓	✓
	5.00	*127.00*	8.14	*206.76*		
	5.20	*132.08*	8.135	*206.63*		
10 3/4 and greater	5.52	*140.21*	9.00	*228.60*	✓	
	6.02	*152.91*	9.400	*238.76*		

*These dimensions are for reference only. Refer to the design specifications of the specific item to obtain the actual OD.

ShurShot® Ball Dropper and Catcher Assemblies

The Halliburton ShurShot® ball dropper fluid loss control device uses the proven technology of a collet catcher sub to provide post-gravel pack fluid loss control. A ball is attached to and later dropped from a running tool onto the collet catcher assembly, located in the blank pipe above the screen, thus sealing off the packed interval. The running tool is located on the end of the washpipe string. As it is pulled through the collet catcher assembly, a shoulder on the running tool engages a sleeve in the collet catcher assembly that pulls the collet fingers into a closed position. Additional tension shears the pin holding the ball in place and allows it to fall and seal off on the closed collet fingers. Once the production tubing is in place, pressuring up on the tubing causes the ball to be expended into the rathole. Sizes compatible with the most common screen basepipe sizes are available.

Features

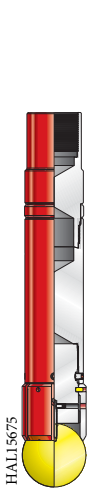
- Rugged – Unlike frangible flappers, the ShurShot fluid loss control device is not susceptible to damage during shipping or handling.
- Debris resistant – Well debris stacked on top of the ShurShot fluid loss control device cannot prevent pressure from reaching and expending the ball.
- Clean – ShurShot fluid loss control device ball is discharged to the rathole once the fluid loss control device is deactivated.

Benefits

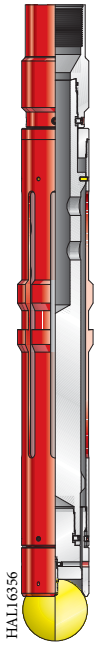
- Reliable installation and activation
- Easily deactivated without intervention
- No debris to plug up the subsea choke

Three types of ShurShot assemblies exist:

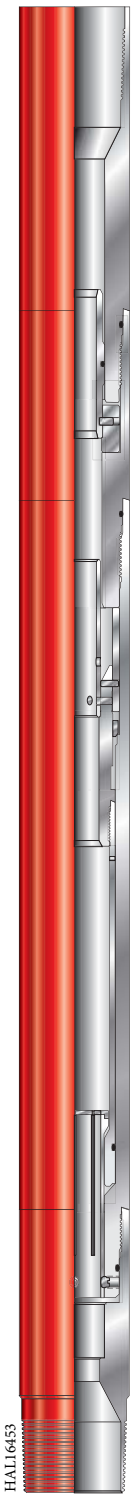
- STD – Single upper sleeve ShurShot assembly
- USR – Provides fluid loss control as the ball is dropped; used for high loss rate and low bottomhole pressure wells
- Stackable – Uses a collet to actuate the assembly; for stacked completion applications



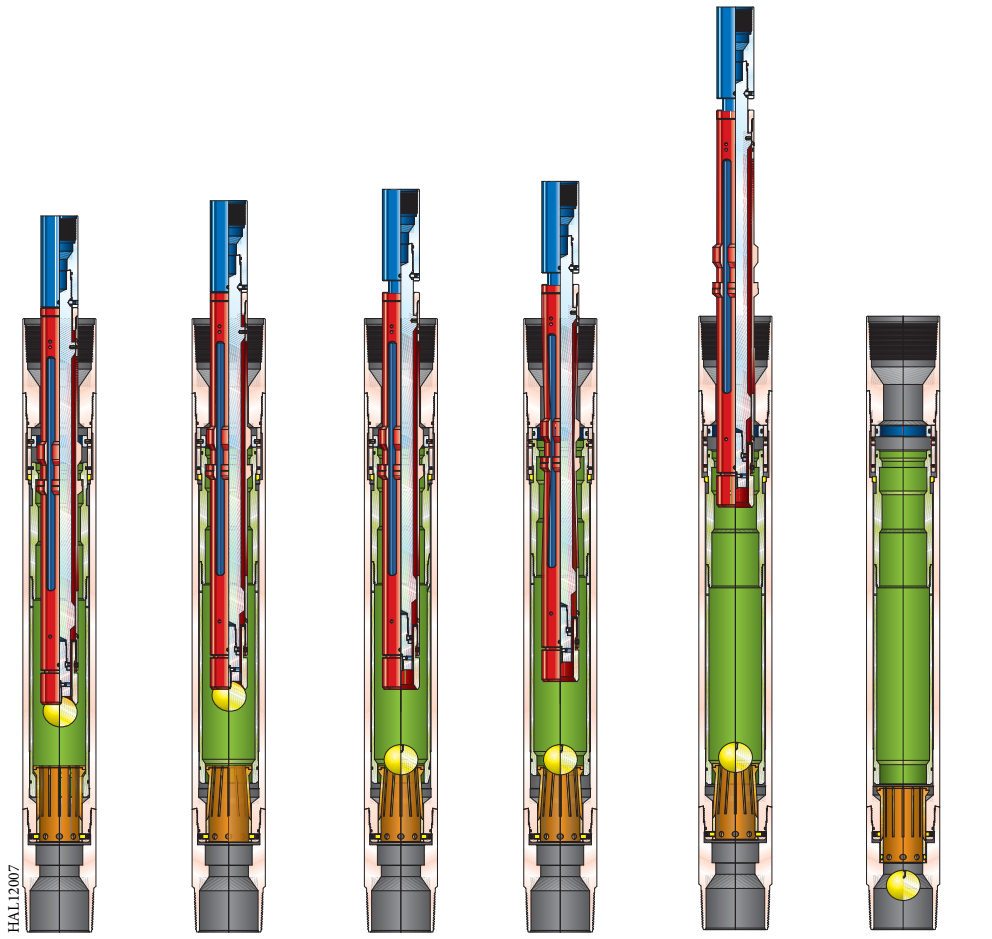
ShurShot®
Ball Dropper Assembly



Stackable ShurShot®
Ball Dropper Assembly



ShurShot® Sand Control
Fluid Loss Device
Upper Seal Ring Version



ShurShot® FCD Assemblies

Casing Size	Ball Size		FCD Type	Housing ID (Expanded)		Housing ID (Run)		Housing OD		Screen Size
in.	in.	*mm*		in.	*mm*	in.	*mm*	in.	*mm*	in.
5	1.750	*44.45*	1.61 USR	1.81	*45.97*	1.595	*40.51*	3.820	*97.03*	2 3/8
	2.125	*53.98*	2.110	2.39	*60.71*	2.160	*54.86*	5.020	*127.51*	2 7/8
6 5/8	2.500	*63.50*	2.47 USR	2.700	*68.58*	2.47	*62.74*	5.100	*129.54*	3 1/2
7	2.625	*66.68*	2.75 Shifter	2.870	*72.90*	2.870	*72.90*	5.35	*135.89*	3 1/2
	2.875	*73.03*	3.00 Shifter	3.120	*79.25*	3.120	*79.25*	5.300	*134.62*	3 1/2
7 5/8	2.750	*69.85*	2.65 STD	2.900	*73.66*	2.65	*67.31*	5.619	*142.72*	3 1/2
8 5/8	3.375	*85.73*	3.500 Shifter	3.60	*91.44*	3.500	*88.90*	6.52	*165.61*	4
9 5/8 and larger	4.500	*114.30*	4.12 STD	4.600	*116.84*	4.120	*104.65*	7.28	*184.91*	5 1/2
	4.500	*114.30*	4.625 Shifter	4.665	*118.49*	4.665	*118.49*	7.655	*194.44*	5 1/2

FS2 Fluid Loss Isolation Barrier Valve

For efficient asset management, Halliburton's FS2 fluid loss isolation barrier valve provides a reliable, interventionless solution for fluid loss control during well completion, eliminating potential formation damage.

The FS2 valve isolates the formation below the uppermost gravel pack packer before the upper completion has been installed and can be utilized in frac pack, gravel pack, and standalone screen applications. The valve provides a reliable means of:

- Preventing fluid loss to formations after completing gravel pack operations
- Isolating formations during up-hole operations throughout life of the well
- Helping to reduce costs on subsea or deep wells through the use of interventionless technology
- Use as a barrier in a well suspension system

The closure device is a proven, high-performance ball mechanism that provides a positive bi-directional seal in brine and oil-based mud environments. The debris-tolerant, non-translating ball design eliminates unnecessary movement within the mechanism during opening and closing operations, allowing operation in debris-laden environments.

Optimum FS2 valve placement is normally below the gravel pack or liner hanger assembly. Washpipe, located on the bottom of the service tool, is extended through the valve. A collet shifting tool is attached to the end of the washpipe, which on retrieval closes the valve, immediately isolating the formation and allowing inflow or positive pressure-testing above the ball. Remote actuation in the form of hydraulic pressure cycles is then used to open the valve after upper completion installation.

FS2 Fluid Loss Isolation Barrier Valve

Features and Benefits

- Initial valve closure achieved when washstring/collet is retrieved through the valve.
- Bi-directional sealing mechanism provides a fully tested downhole barrier.
- Unlike nitrogen pre-charged systems, the fluid spring indexing mechanism eliminates well-specific setup and enhances long-term suspension capability.
- One-time remote activation achieved by the application of pressure cycles, eliminating the need for well intervention.
- Activation piston provides increased opening force (up to 200% increase over previous FS valve designs).
- Improved fluid management helps ensure valve operation in debris.
- Increased differential opening capability.
- Design provides unlimited mechanical opening/closing of valve. Indexing system is unaffected by changes in hydrostatic pressure, making it suitable for use in wells with fluid loss.
- Valve opens on pressure bleed down, minimizing the risk of surging the formation.
- Full bore ID maximizes production and allows access to the formation.
- Design incorporates enhanced debris exclusion features.
- Mechanical shifting profile incorporated within design.
- Sealed actuation mechanism helps prevent control system contamination.
- Cycling mechanism isolated from debris in the wellbore.

Qualification Testing

Each FS2 valve is subjected to extensive qualification testing during prototyping. In addition to rigorous discrete component level testing, a full valve test program designed to help ensure reliable performance in well conditions is carried out. Testing includes:

- Remote opening at maximum rated temperature
- Differential opening capability test
- Collapse testing at maximum rated temperature
- Multiple remote open tests in debris

Qualified in accordance with the requirements of ISO 28781.

Options

- Available to suit 7-in., 7 5/8-in., 9 5/8-in./9 7/8-in., and 10 3/4-in. casing
- Ball differential rating up to 10,000 psi (689.5 bar)
- Collapse rating up to 15,000 psi (1034.2 bar)
- Burst rating up to 12,000 psi (827.4 bar)
- Temperature rating to 350°F (176.7°C)
- Increased differential opening capability

IB Series Mechanical Fluid Loss Isolation Barrier Valve

The IB series mechanically activated fluid loss isolation barrier valve provides a reliable, mechanical solution for fluid loss control during well completion, eliminating potential formation damage. Initially designed for electric submersible pump (ESP) applications, the IB valve provides a means of isolating the formation below the uppermost gravel pack packer before the upper completion has been installed and can be utilized in frac pack, gravel pack, and stand-alone screen applications.

For sand control applications, the IB valve is run into the well (ball open) below the uppermost gravel pack packer as an integral part of the gravel pack assembly. The washpipe, located on the bottom of the gravel pack service tool, is extended through the valve. A collet shifting tool is attached to the end of the washpipe. On washpipe retrieval, the collet shifting tool closes the ball isolating the formation and allowing inflow or positive pressure testing. The lower sandface completion and reservoir is isolated by the closed ball in the IB valve, which permits safe installation of the upper production completion.

The valve is opened mechanically using a collet shifting tool attached to the end of the upper completion. The closure device is a proven, high-performance ball mechanism that provides a positive bi-directional seal in brine and oil-based mud environments. The debris-tolerant, non-translating ball design eliminates unnecessary movement within the mechanism during opening and closing operations.

The IB4 valve can be considered the base design. The collet shifting tool opens the ball mechanism while passing through the valve. This eases space out concerns and provides maximum flexibility.

The IB5 fluid loss device provides the collet shifting profile of the IB4 valve but also includes a secondary larger ID shifting profile. Utilizing the secondary profile allows the valve to be opened and closed while maintaining the ID through the valve. The IB5 valve is ideally suited for use in stacked frac pack completions where a reduced ID may be a concern.

Features and Benefits

- Initial valve closure achieved when washpipe/collet is retrieved through the valve
- Bi-directional sealing mechanism provides a fully tested downhole barrier
- Improved fluid management helps ensure valve operation in debris
- Design provides unlimited mechanical valve opening/closing
- Full bore ID maximizes production and allows access to the formation

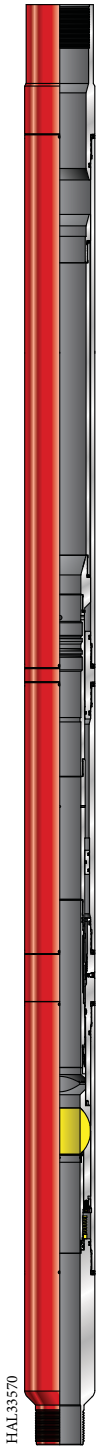
Qualification Testing

Qualified in accordance with the requirements of ISO 28781.

Options

- Available to suit 7-in., 7 5/8-in., 9 5/8-in., 9 7/8-in., and 10 3/4-in. casing
- Ball differential rating up to 10,000 psi (689.5 bar)
- Collapse rating up to 15,000 psi (1034.2 bar)
- Burst rating up to 12,000 psi (827.4 bar)
- Temperature rating to 350°F (176.7°C)

IB4 Fluid Loss Isolation Barrier Valve



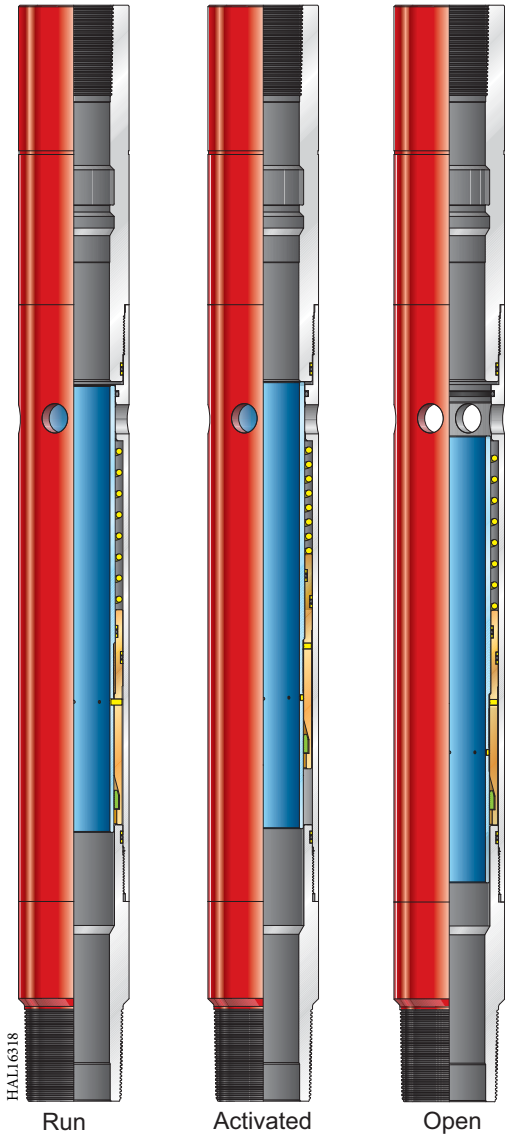
IB5 Fluid Loss Isolation Barrier Valve

Hydraulically Activated Sliding Side-Door® Circulating Device

The hydraulically activated Sliding Side-Door® circulating device provides a means to open a zone to production without intervention when running a releasable or fixed AIS system in underbalanced applications.

Features and Benefits

- Opens via a single pressure cycle; opening occurs after the bleed-off cycle
- Capable of opening numerous valves simultaneously
- Adjustable activation pressure prevents premature actuation when stimulating an upper zone
- Flow area through the ports is equal to or greater than the flow area through the bore of the sleeve for full bore flow circulation



Hydraulically Activated Sliding Side-Door® Circulating Device

Twin-Flow Absolute Isolation System

The Twin-Flow Absolute Isolation System (AIS) system is a sand control fluid loss isolation system designed for use in multizone applications and especially suited to SmartWell® system completions. The Twin-Flow AIS uses a concentric string to isolate the screen interval after the packing operations are completed. Above the concentric string is a mechanical hydraulic sub-assembly that seals off the annular flow and is opened hydraulically after the completion tubing has been installed. This system has proved effective in stacked zone completions.

Where fluid loss and downhole flow between zones presents a problem for fluid loss flappers or chemical fluid loss methods, the Twin-Flow AIS and the original AIS system are proven and reliable solutions.

AIS Features and Benefits

- Provides zone isolation and zone access
- Can be used with SmartWell system completions
- Saves intervention to open a zone to flow
- Isolates a zone until flow is desired
- Provides a secondary mechanical means to open and close the valve
- Incorporates gravel pack washpipe as the isolation string
- Saves time
- Effective in stacked zone completions
- Offers proven and reliable solutions in fluid loss isolation

Currently, there are three types of Twin-Flow AIS:

- Twin-Flow AIS-SH (Shearable)
- Twin-Flow AIS-SC (Single Cycle)
- Twin-Flow AIS-LS (Liquid Spring)

Twin-Flow AIS-SH (Shearable)

The Twin-Flow AIS-SH is a pressure shearable version of the Twin-Flow valve. This version opens when annulus pressure is applied to shear the screws. A shifting profile is incorporated in the ID as a backup opening feature.

Twin-Flow AIS-SC (Single Cycle)

This tool design opens when applied annulus pressure is bled off after reaching activation pressure. It is designed to minimize pressure-related formation shock.

Twin-Flow AIS-LS (Liquid Spring)

The Twin-Flow AIS-LS fluid control device is designed for use in multizone applications and especially suited to SmartWell completions or multizone completions. It protects a zone from fluid loss and allows separate production between the upper and lower zones. The tool is run in the closed position and kept in the closed position until the upper zone is completed and ready for production. The tool works in conjunction with a liquid spring module that responds to tubing pressure and only opens after 10 to 12 pressure cycles—with no time limit for actuation. This provides the option of testing the tubing before the AIS-LS activates and opens.

External differential pressure across the tool has no effect on the indexing mechanism. The system can also be opened manually with tubing pressure applied to a plug or test tool set in the Twin-Flow profile. Some can be closed with a B shifter.

AIS-LS Features and Benefits

- Suited for SmartWell system completions
- Works in conjunction with liquid spring module
- Option of tubing testing before AIS-LS activates and opens
- Protects the zone from fluid loss
- Allows separate production between upper and lower zones
- Can be opened manually

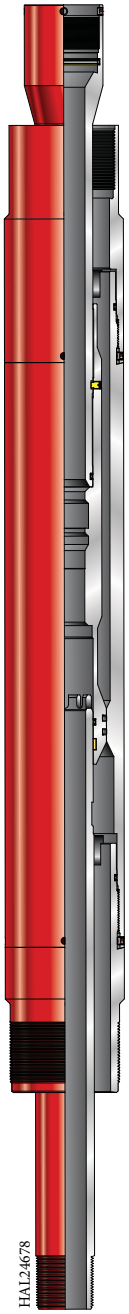
Fixed and Conventional AIS Components

Fixed AIS systems include an internal concentric string attached at the top of the blank with a three-way crossover and a lower set of seals generally stabbed into the sealbore in the lower seal assembly. The washpipe does not move during packing operations and is not retrievable.

A slimline DuraSleeve® Sliding Side-Door® circulation and production device is run in the internal string to take fluid returns during gravel packing operations as well as act as a production sleeve later. An additional DuraSleeve Sliding Side-Door device can be run at the top of the washpipe to provide additional production capability and minimize pressure drop.

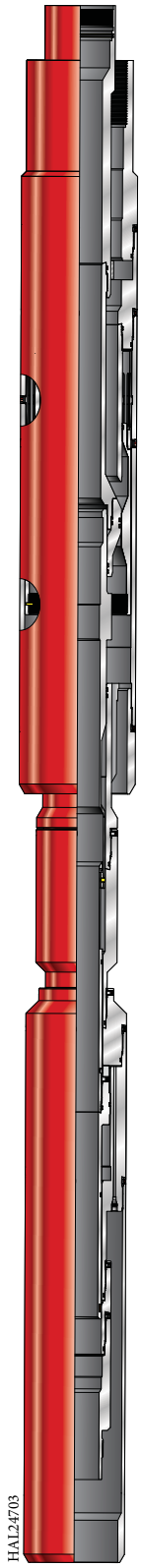
Three-Way Adapter/Crossover

Fixed AIS assemblies use a three-way crossover to connect the inner string, blank pipe, and lower extension.



Twin-Flow AIS-SH
Shearable

Twin-Flow AIS-SC
Single Cycle



Twin-Flow AIS-LS
Liquid Spring Version

Accessory Tools

Indicator Collars and Adapters

Optional indicator collars are assembled to the blank pipe as part of the gravel pack completion assembly. Indicator collars provide a sized restriction in the blank pipe for the MPC indicator collet to engage. The relative position of the multi-position tool service seal unit crossover port, when the collet engages the collar, can be seen on the weight indicator on the rig floor. These collars can be configured to indicate in either tension or compression.

MSJ Shear Joints

MSJ multi-position shear joints are used between the packer assembly and screen/blank assembly. The MSJ shear joint allows retrieval of the packer assembly before washing over and retrieving the screen/blank assembly. Shear value can be adjusted in 10,000-lb (4535-kg) increments with a minimum recommended shear value of 40,000 lb (18 143 kg) for tools used in 7-in. (177.80-mm) and larger casing. The MSJ shear joint, with a stroke of 12 in. (304.80 mm) after shearing, is recommended to allow for settling and compaction forces during and after gravel packing. Shorter shear joint designs exist for use where length is critical. Shear values should be adjusted to suit anticipated heavy completion weights and high drag forces during running.

Compaction Joints

A compaction joint allows for compaction of the gravel pack and shear of the shear joint without allowing fluid flow to bypass the screen. The 12-in. stroke shear joint is the recommended length. If compaction occurs, the screen may move downward, creating large tensile forces between the anchored packer and the gravel packed screen.

O-Ring Subs and Stingers

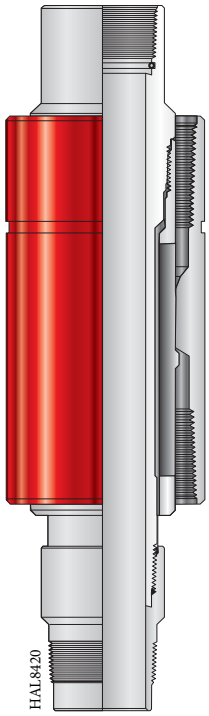
Halliburton o-ring subs and polished stingers are typically used to provide a temporary seal between the end of a washpipe and the sump packer seals below the screen or between two screen sections to provide upper and lower circulating positions. They can be used anywhere a stabbing type seal is required but are not intended for long-term service because of the possibility of the o-rings washing out with flow as it is assembled.

O-ring subs are tubular components that have tubing or casing threads and generally have box × pin threads (without couplings) typically of the same size and same type threads. Internal to the o-ring sub is a controlled ID with one or more o-ring grooves. O-rings are generally installed in these grooves at the time of completion assembly. The polished stinger is typically threaded on the upper end and has an extended length surface along the OD of the part that mates with an o-ring sub of the mating size.

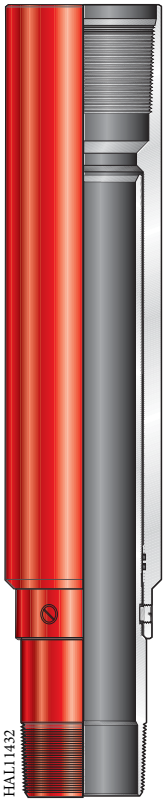
MUS Makeup Sub

The Halliburton makeup sub provides a quick, non-rotational means to make long screen assemblies. It is used to connect two separate pieces of equipment without having to torque through the assemblies. The makeup sub is separated and installed on the desired equipment. When the equipment is assembled, the cap is made up into the coupling and locked into place using set screws. The inner mandrel and bottom sub have locking lugs that enable the makeup sub to be torqued through after it is assembled.

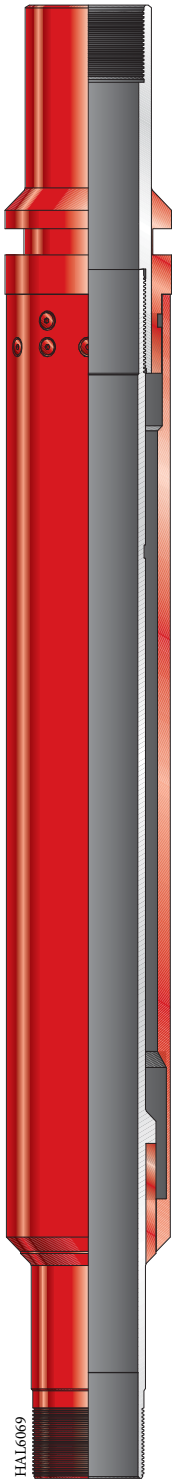
The makeup sub speeds rig assembly and minimizes the risk of washpipe unscrewing during concentric strings make up.



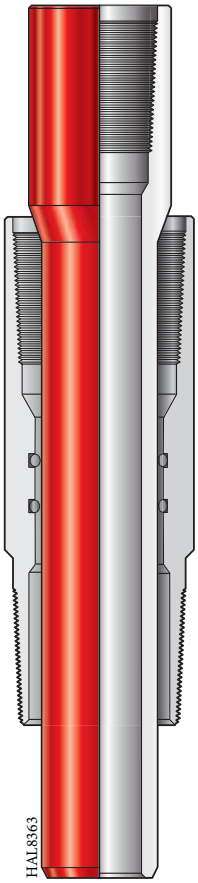
Indicator Collar with Collet



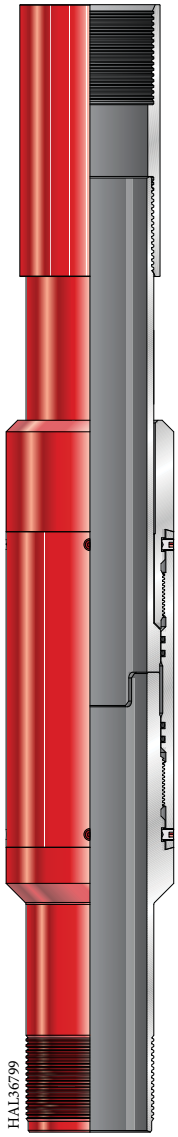
MSJ Shear Joint



Compaction/Shear Joint Assembly



O-ring Sub with Polished Hanger



Makeup Sub

Long Space-Out Travel Joint

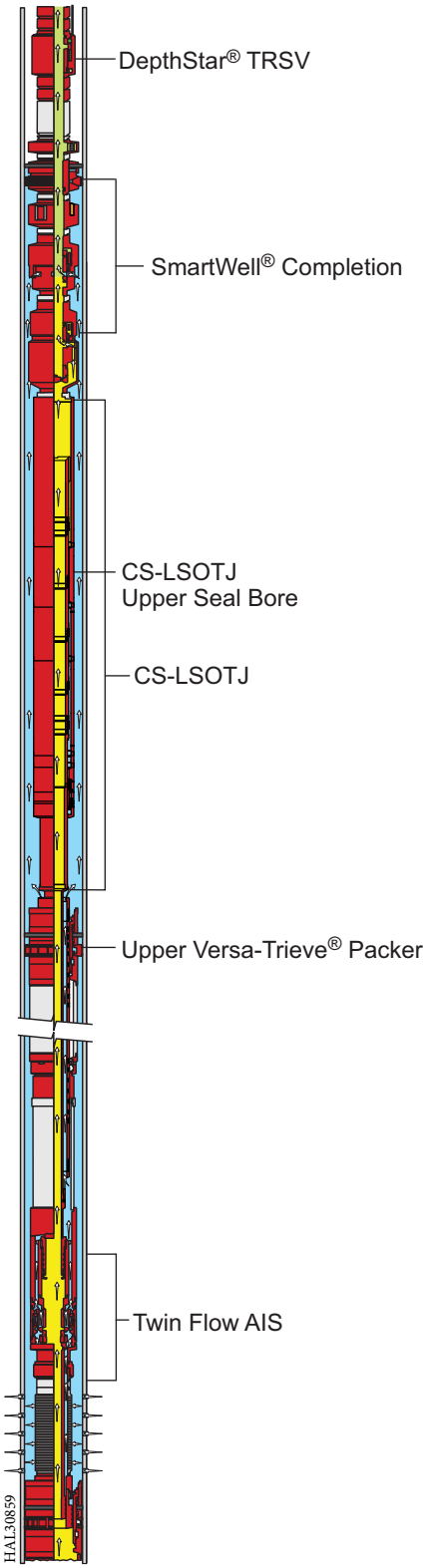
Spacing out production tubing and landing the tubing hanger on subsea completions is very challenging. Variables such as well depth, water depth, deviation, and rig heave add to the complexity of the space-out operation. The extremely high rig rates in deepwater environments make it imperative the first attempt to land the production tubing string be successful. The most efficient means of spacing out in these adverse conditions is essential to job success.

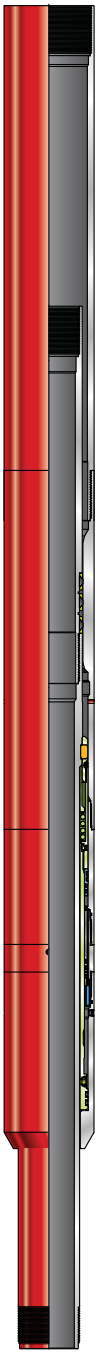
To address these subsea space-out issues, Halliburton has developed the Long Space-Out Travel Joint (LSOTJ). The travel joint is designed to telescope downward in response to a timed application of a compressive load created when the production seal assembly is landed into the sealbore packer. The LSOTJ collapses as the production tubing is lowered, allowing the subsea tubing hanger to land in the wellhead.

There are two versions of the LSOTJ design—Continuous Sealing (CS-LSOTJ) and Non-Continuous Sealing (NCS-LSOTJ). The CS-LSOTJ version is designed for dual-zone selective completions and intelligent well applications. The CS-LSOTJ maintains flow and pressure separation of the zones once the tubing is landed. The NCS-LSOTJ version used for single-zone and multi-zone commingled completions has initial pressure integrity for pressure testing but provides communication to the casing once the travel joint strokes.

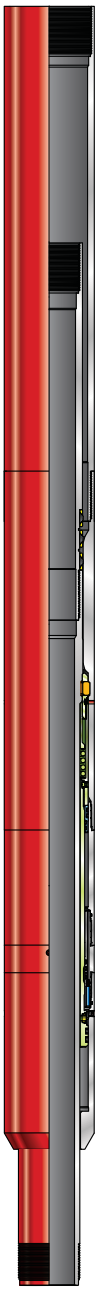
Features and Benefits

- Simplifies space-out calculations required to install production tubing in subsea completions
- Reduces concern over shearable type travel joints, while pushing through blowout preventers (BOP) or liner tops
- Continuous and non-continuous sealing designs
- Collapses after a timed compressive load
- Positioned between production packer and the uppermost gravel-pack packer
- Economical and simple travel length adjustment
- Limitless travel length capability
- Can be locked and unlocked multiple times
- Hydraulic “soft” release without rotation or shearing pins
- Pressure integrity in run position allows downhole testing of equipment
- High load carrying capability
- Includes a safety contingency release
- Compact modular design

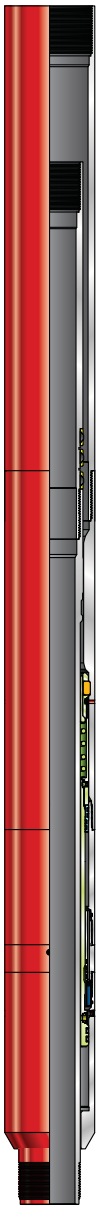




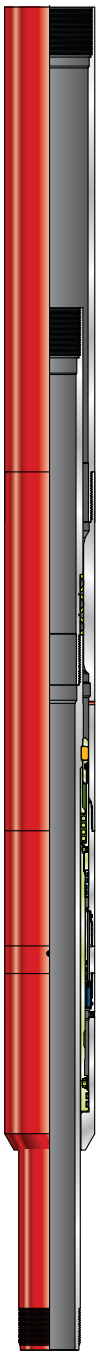
Run In – not landed into GP Packer



Start-to-Release – landed into GP packer, downward travel initiated, subsea hanger not landed



Released/Stroking Downward – travel downward until subsea hanger landed



Re-Latch – pulling production tubing

Seal Assemblies

Halliburton seal assemblies for permanent and retrievable sealbore-type packers act as a seal between the tubing string and the packer. If components will be exposed to corrosive fluids, the seal's standard alloys may be plated for extra protection or manufactured from corrosive resistant alloys.

A Halliburton seal assembly consists of three major components:

- locator
- molded or premium seal units
- muleshoe guide, collet, or production tubing

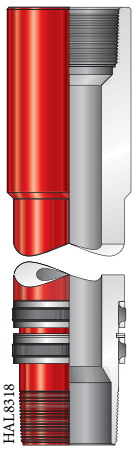
No-Go Locators

No-go locators are used with packers with the short Versa-Latch® type receiving heads. These locators provide a positive locating stop for the tubing at the packer. These locators can be provided with the correct spacing between the no-go and seals because the lower end is machined to accept either molded seals or premium seal units.

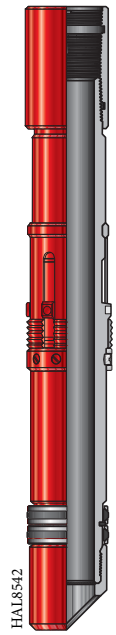
Versa-Latch® Seal Assembly

The Versa-Latch locator is a locating and latching assembly that connects the end of the tubing to a Versa-Trieve® VTA, VCA, and VGP style packer. It is released through rotation. The proprietary latching thread provides excellent debris tolerance and enhances its ability to rotationally or straight-shear release. Locators exist that provide either a rotational release or a combined rotational and straight-shear release. Specialized assemblies exist that protect the threads when run into the well. For more information, see your local Halliburton representative.

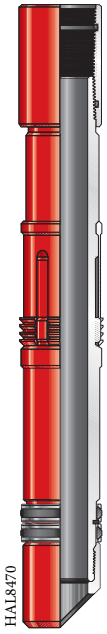
No rotation is necessary to install the Versa-Latch seal assembly. It is a positive latch system that minimizes seal movement in the well. Right-hand tubing rotation is used to disengage the Versa-Latch assembly. It may be relatched or pulled with the tubing for redress operations. The straight-shear Versa-Latch assembly can be disengaged by either rotation or straight pull.



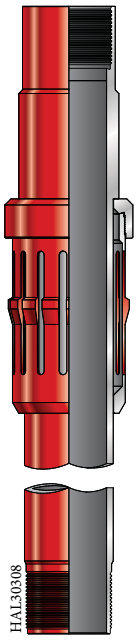
No-Go Locators



Straight-Shear Versa-Latch® Seal Assembly



Versa-Latch® Seal Assembly



Top Snap Locator

Seal Units

Halliburton offers molded, crimp, and premium seal units. Molded and crimp seals are recommended for applications in which the seal will be going in and out of the sealbore. Premium seals are ideal for applications requiring the seal units to remain in the sealbore.

All seal units are designed for easy field redress.

The geometry of the seals enables them to provide more positive seal as they are subjected to higher pressures and temperatures. Many types of seal units are available, and others can be designed to fit specific needs.

The standard MSN or MSF molded seal units are designed with a high-modulus rubber compound (nitrile or Fluorel®* element) bonded to two metal backup shoes. The shoes are designed to pressure-energize the seals, increasing differential pressure so the element seals more tightly. These seal units have proved effective in wells with highly abrasive fluids and in wells when the unit must be set and released many times.

Premium seal units are vee-packing seal systems of either elastomeric or plastic materials with a plastic and metal backup system. The lips of the v-ring are designed to have an initial interference fit with the sealbore. The lips respond to pressure increases by flexing outward. Various backup material combinations can be used with each vee-packing seal to make it suitable for different temperatures and pressures.

Crimp seals, in combination with centering rings and debris barrier rings, can be fitted on very long seal mandrels, which eliminates threaded connections typically used on successive chevron stacks. The crimp seal consists of a rubber seal ring fitted to a groove on the seal mandrel. The seal is retained to the groove by a metal ring crimped over the seal. It is available in various elastomers and can be fitted with anti-extrusion backup rings.

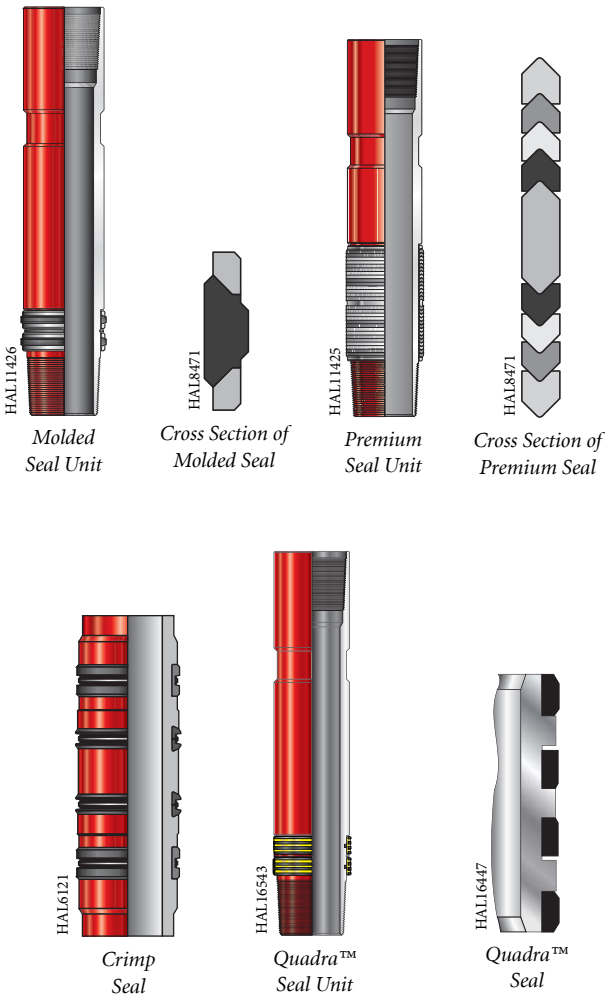
Quadra™ Seal Units

Quadra™ seals exhibit reduced seal friction, improved sealing capabilities, increased temperature ratings, and excellent sand abrasion resistance.

Seal Lubricant

Halliburton seal lubricant is a special-purpose lubricant used to protect sealbore seals and other packer accessory elastomers. It retains much of its room-temperature consistency at a wide range of temperatures, is odorless, and is resistant to many chemicals. Seal lubricant is serviceable from -40° to 500°F (-40° to 260°C), has excellent resistance to water and oil, low volatility, and resistance to melting or hardening with prolonged exposure to high temperatures.

The lubricant is available in an 8-oz container, which is sufficient to protect and lubricate two standard packer sealbore seal units, and in 1-gal quantities.



Molded Seal Unit — *Cross Section of Molded Seal* — *Premium Seal Unit* — *Cross Section of Premium Seal*

Crimp Seal — *Quadra™ Seal Unit* — *Quadra™ Seal*

**Fluorel is a registered trademark of Dyneon, LLC.*

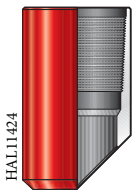
Self-Aligning Muleshoe Guides

Self-aligning muleshoe guides allow the end of the guide to rotate and orient with the liner top without rotation of the tubing. This tool is recommended in wells where tubing rotation is difficult or may damage downhole tubing accessory items. The self-aligning muleshoe guide should be considered in dual-string completions, tubing installations with multiple control lines, and for horizontal completions.

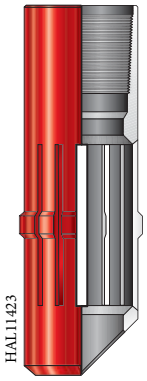
Muleshoe Guides

Muleshoe guides provide a means to guide the end of the tubing away from the casing wall, then enter liner tops or the packer bores. The length of the muleshoe varies with the application from centralization to seal guide and protection to flow isolation sleeve.

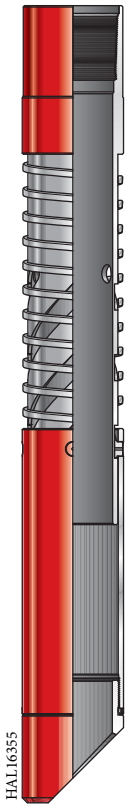
Collet muleshoe guides combine the features of the muleshoe with an indicator collet to provide a surface indication of the packer seals entering or leaving a packer bore. Push-through and no-go type collets are available for indication on the packer or a special ID sub below the packer.



Muleshoe Guide



Collet Muleshoe Guide



Self-Aligning Muleshoe Guide

Downhole Sand Control Service Equipment

Downhole sand control service tools are designed for use with the Versa-Trieve® packer and multi-position tool system.

Sand Control Versa-Trieve® Packer / Multi-Position Tool Systems

Setting Tool System

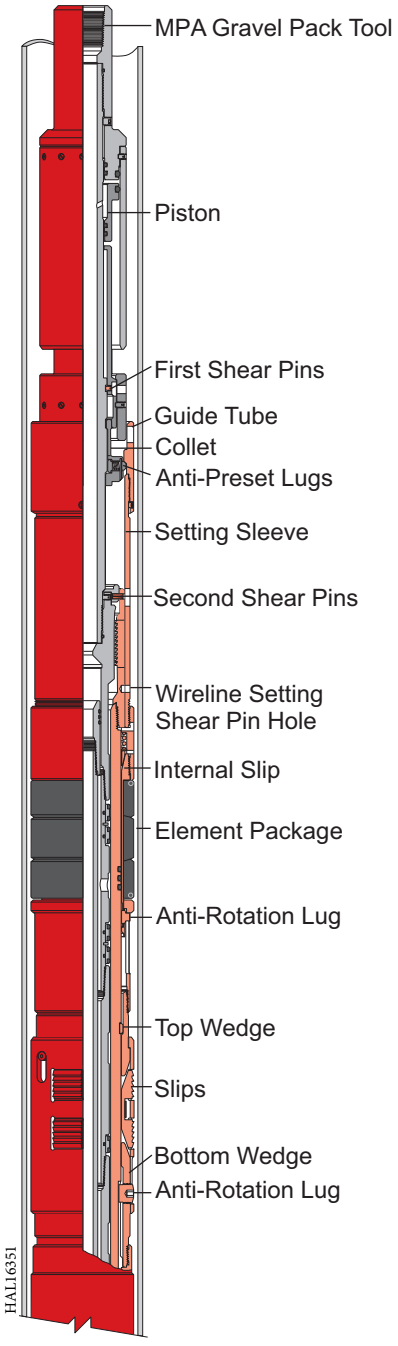
The Halliburton multi-position gravel pack tool is a key component of a number of the sand control tool systems. In the squeeze position, it establishes the flow paths necessary to squeeze fluid into the formation. In upper and lower circulating positions, it circulates fluid across the formation interval, through the screen, then back up the tubing/casing annulus. In the reverse circulating position, it circulates reverse fluids down the annulus and back up the tubing. It can also be used to circulate down the tubing to spot fluid in place. These positions are used during tubing cleaning, acidizing, and sand slurry placement stages and are required to place and circulate fluids to achieve an optimal gravel pack. Raising and lowering the multi-position tool relative to the packer provides these changes of flow path.

Versa-Trieve packers are set with the multi-position tool which has a hydraulic setting mechanism. When the multi-position tool is installed into the packer, the multi-position tool lugs expand to engage the packer-guide tube and act to prevent premature packer setting caused by drag on the outside components of the packer. These lugs transmit tensile forces from the packer to the multi-position tool and retract only after the setting piston has begun to stroke down. The multi-position tool is designed so the shear pins between the packer and multi-position tool (packer setting pins) are not stressed during the running-in of the packer, screen, and blank bottomhole assembly.

Standard Multi-Position Tool Piston Areas*

Bore	Piston Area	
	in.²	*cm²*
2.55	10.89	*70.26*
2.75	10.89	*70.26*
3.25	12.28	*79.22*
3.88	12.28	*79.22*
5.00	21.71	*140.06*
5.500	21.71	*140.06*
6.00	21.71	*140.06*
8.500	40.00	*258.06*

*Double-check the tool engineering data sheet for the correct tool piston area. These numbers are for reference only.



Run-in lugs supporting bottomhole assembly. No loading of shear pins.

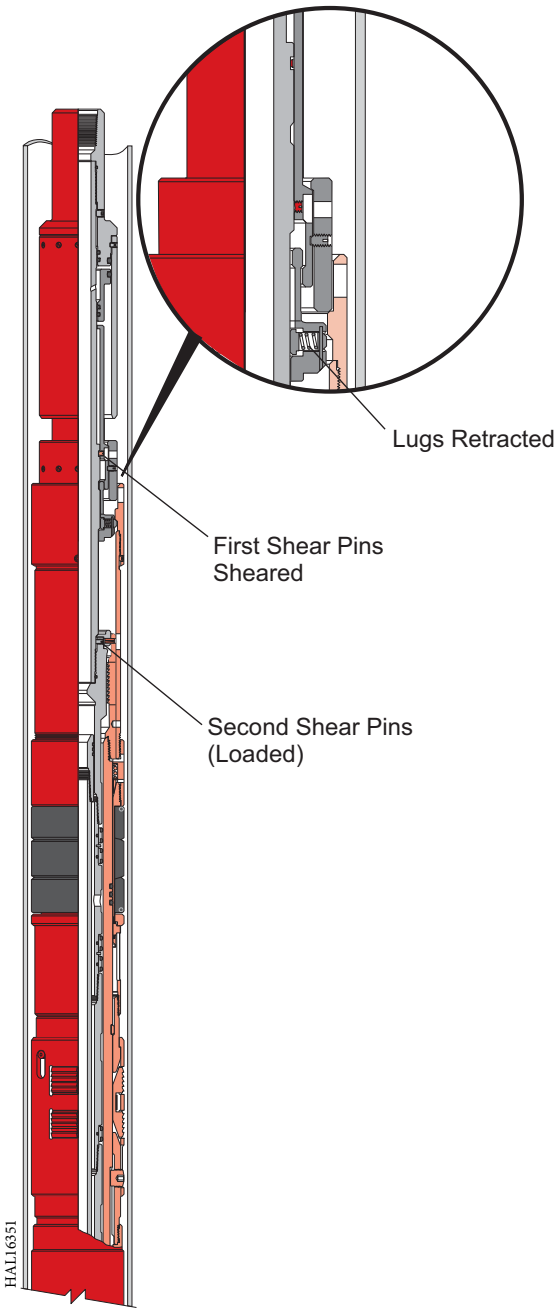
Setting Tool System—Packer Setting Operation

The packer is set by dropping a ball down the workstring after the packer assembly has been run and located at the proper depth. After the ball has gravitated to or has been pumped onto the ball seat, pressure is applied to the workstring. Pressure enters the cylinder of the multi-position tool and forces the piston down, shearing the start-to-set screws in the multi-position tool. Once these screws are sheared, the piston begins to move down, allowing the lugs to retract and the setting load to be transferred to packer setting pins. Further movement forces the packer guide tube downward, causing the packer slips to expand outward, engaging the casing wall and compressing the packer elements. The internal slips of the packer retain this setting movement and related force. The large piston area of the multi-position tool permits adequate setting force to be achieved with low-setting pressures. The packer is fully set when the packer-setting shear pins, holding the multi-position tool to the packer, shear at a pressure above the start-to-set pressure. At this point, the multi-position tool is free from the packer. The ball seat must be expended into the sump of the crossover sub, or the ball must be reversed, for packing to begin.

A non-shearing secondary ball seat is provided in most multi-position tools. It is designed for a larger, low-density aluminum ball and permits the setting procedure to be completed in the unlikely event that the primary seat shears prematurely. The secondary ball must then be reverse-circulated out.

When extremely high running loads are encountered, as occurs in horizontal wells or long intervals, the Acme threaded packer top sub (VTA, VBA, VCA, VGP, or AGP packer) may be run with a threaded multi-position tool locator, or a VGH or VCH packer can be run with an HPT setting tool. This provides additional weight-carrying and setting capabilities since the weight of the assembly is not pulling on setting pins as it sets. Packer and setting tool combinations can be provided for high torque or tension capabilities and in some cases, for both capabilities.

Other setting options include an isolation sleeve for the hydraulic setting ports, a ball reversing option for the FracPac™ system, and variations of the setting procedure for one-trip systems.



Setting lugs disengaged. Setting force acting on the elements and shear pins.

Multi-Position Tools

Halliburton multi-position tools allow the Versa-Trieve® gravel pack assembly to be run and set hydraulically to perform single-trip gravel pack operations. The Halliburton multi-position service tool carries the gravel pack assembly downhole and sets the packer. Once the screen assembly is positioned across the perforated interval, a ball is dropped down the workstring. Pump pressure is applied to set the Versa-Trieve packer and release the multi-position tool. Increased pump pressure expends the ball and seat into the sump of the crossover, opening the flow path below the packer. Two primary tool versions are available to provide for differences in completion objectives, operating location, and downhole conditions. The four-position tool has the following gravel pack positions:

- Squeeze
- Lower circulating
- Upper circulating (above the telltale)
- Reversing (circulating above the packer)

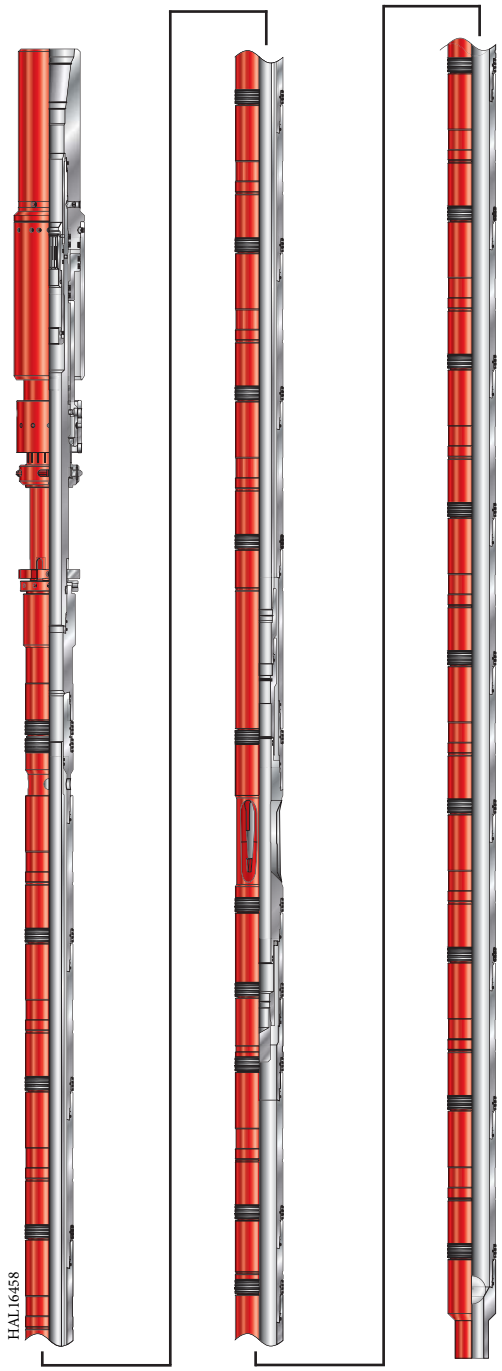
Weight-down positioning is possible in both squeeze and circulate positions.

Halliburton multi-position tools consist of a hydraulic setting piston and service-seal assembly.

Benefits

- No rotation is required.
- Anti-preset lock mechanism prevents premature sets.
- Multi-exit ported flow sub with specially designed port areas allows for more even distribution of pack material, less gravel crushing, and low pump pressure.
- A range of tool designs exist for medium to high flow rate capabilities.
- The large piston area allows for lower setting pressures.
- Modular design allows for conversion to the weight-down, extended length (floating vessel), FracPac™ system operations, washdown, or one-trip perforate/pack configurations.

The multi-position tool used for large volume high-rate FracPac system treatments and water packs has a slightly different design. The ball must be reversed after the packer is set to provide an unobstructed flow path during the high-velocity flow. Larger flow areas in these tools limit erosion, and a specially designed crossover sub withstands long pumping stages at the highest rate.



Multi-Position Tool

HPT Setting Tool

The HPT setting tool is a heavy hang weight setting tool that has a straight pick up to release from the packer once the packer is fully set. It is used with VCH packers which are a special version of the VCA packer. It can also be used with VGH packers which are similar to the VGP packers.

Applications

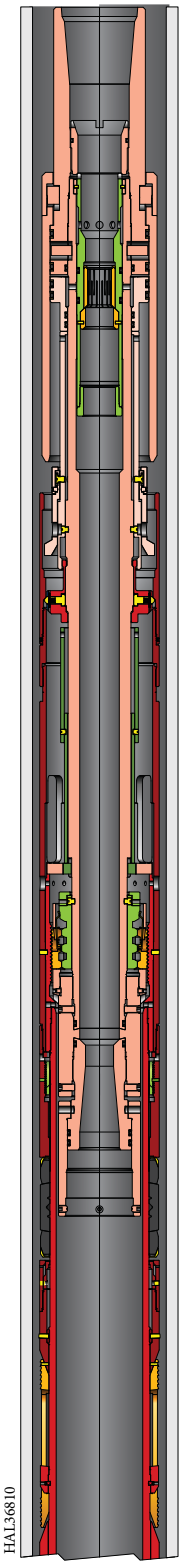
- ESTMZ™ completions
- Can be used to replace the existing hydraulic section

Features

- Hang weight is carried on the setting tool lugs, which thread into the packer top sub for increased tensile load capacity.
- Torque may be applied through the setting tool and packer while running in the well.
- Hang weight is independent of the packer setting pins.
- Straight pull "soft" release from the packer.
- Weight down applied while setting pins shear.
- Two steel shear pins retain the clutch in place. Drill out the two pins and rotate the setting tool out of the packer.
- Currently available in 9 5/8-in. 6.00 bore.

Benefits

- Changes in hang weight will not cause early release from the setting tool and a less than optimum set of the packer
- No need to rotate off the packer to get high load capabilities
- Simpler setting operation
- No "slingshot" action when the packer shears free of the setting tool
- Easy to control operation on a floating vessel
- Easier redress of backup equipment
- Field-proven functionality



HPT
Setting Tool

Reverse Position Indicators

Reverse position indicators are assembled to the lower end of the multi-position tool to provide a positive surface indication of a single downhole tool position. A multi-position shear ring (MSR) positive indicator consists of a snap ring held in place with a shear ring. Once the packer is set, the multi-position tool is raised until the MSR snap ring engages the bottom end of the honed bore below the packer. This normally occurs at the reverse position but may be arranged to indicate other positions. To release the MSR ring, an upward pull on the workstring shears screws to cause the shear ring and snap ring to move downward. The snap ring collapses into a recess, allowing the multi-position tool to be pulled upward through the honed bore.

Reverse Ball Check Valve

Reverse ball check valves control fluid loss from the annulus to the formation when the multi-position tool is in the gravel pack circulating and reverse positions. The slotted seat allows a metered fluid amount to escape past the ball, limiting buildup of pressure differential and preventing a hydraulic lock that swabs the formation as multi-position tool is raised.

Actuated Reverse Ball Check Valve

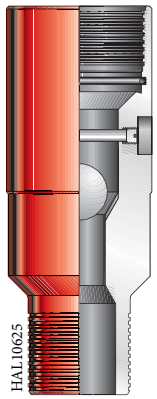
The actuated reverse ball check valve is assembled above or in place of the reverse indicator on the multi-position tool. The ball is held off-seat during running of the gravel pack tools, packer setting, and gravel packing operations. Shearing the reverse indicator pulls the ball onto seat at any time after the packer is set to stop fluid loss during the job. This tool reduces problems of swabbing the formation during tool manipulations and provides a means to monitor screen annulus pressure when in the circulating position. The weep tube provides metered fluid loss control.

MPC Collet Indicators

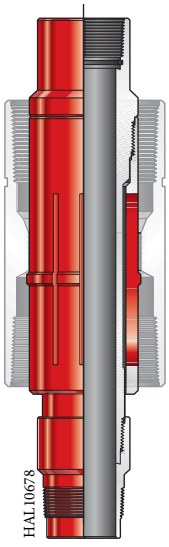
Multi-position collet (MPC) indicators are assembled below the multi-position tool as part of the washpipe assembly. Collet indicator collars are made up as part of the gravel pack blank assembly at predetermined locations to indicate various circulation positions when the multi-position tool is raised and lowered.

Multi-Acting Ball Check

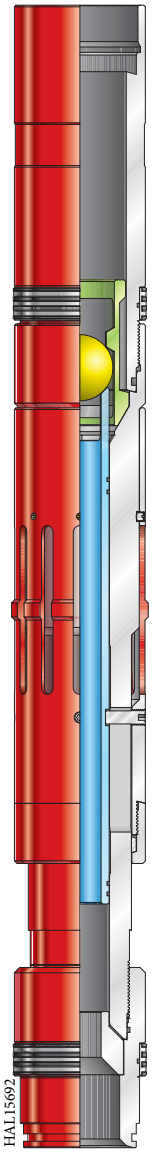
The multi-acting ball check (MABC) allows flow from the annulus to the formation when in the weight-down position and closes when the multi-position tool is raised to allow tubing to be reversed out. This tool provides a reliable means of opening the back side flow path for frac pack operation pressure monitoring. Weep tubes of varying lengths can be provided to minimize swabbing in varied well conditions.



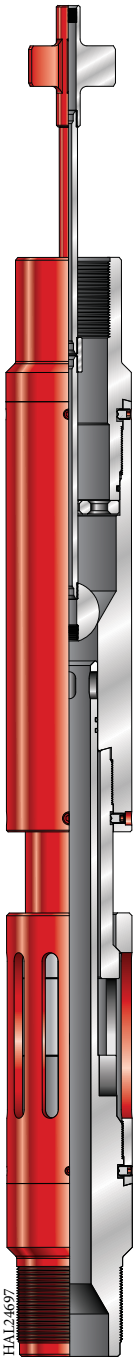
Reverse Ball Check



MPC Collet Indicator



Actuated Reverse Ball Seat (with Weep Tube)



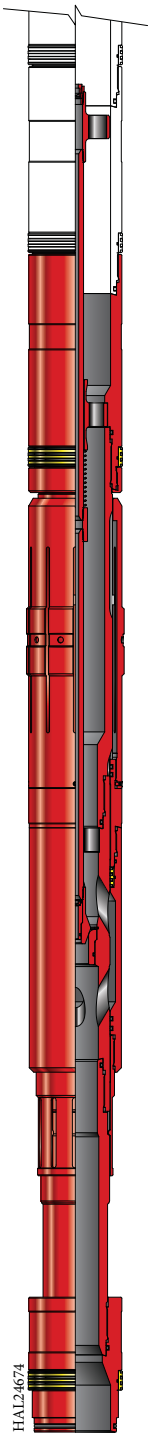
Multi-Acting Ball Check

ROC™ Reverse-Out Check Tool

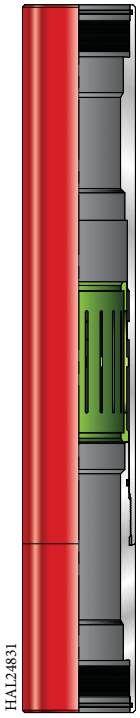
The Halliburton ROC™ reverse-out check tool is attached to the lower end of the multi-position tool and can be used in most gravel packing systems. The ROC tool allows for packer testing, pressure maintenance when closed, and acts as a reverse-out check valve or shifting tool. The ROC tool is designed with large flow ports to minimize pressure drop. The large collet on the ROC tool is a MCS shifting tool and shifts the ROC tool open or closed as it engages the positioning nipples. The collet also provides a high snap load indication when pulled through a positioning nipple.

Features and Benefits

- Can be used in most gravel packing systems
- Collet provides high snap load indication when pulled against positioning nipple
- Allows for packer testing and pressure maintenance
- Acts as a shifting tool
- Large flow ports minimize pressure drop
- Acts as a reverse-out check valve



ROC™ Reverse-Out Check Tool



Positioning Nipple

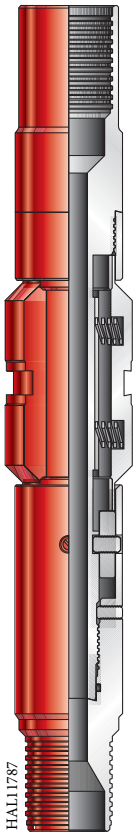
Positioning Tools

MCP Closing Sleeve Positioning Tools

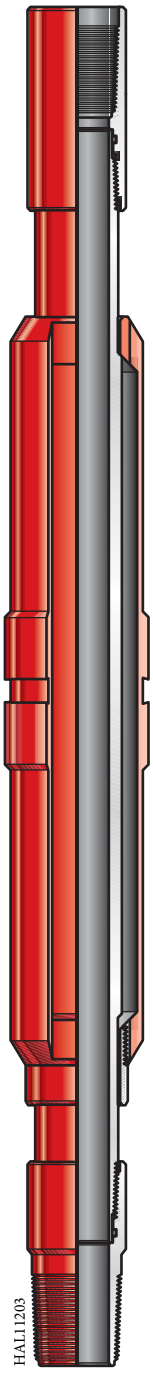
Multi-position collet-type positioning (MCP) tools are self-releasing positioning tools installed below the multi-position tool. The positioning tool uses 90° shoulders to positively engage the inner sleeve of a mating MCS closing sleeve. The fluted release ring on top of the MCS sleeve or the lower honed bore below the MCS sleeve causes the positioning tool to release the inner sleeve only after the sleeve has been fully shifted. If necessary, the closing sleeve may be reopened and closed by simply lowering or raising the positioning tool through the sleeve. These tools can also be used to shift the internal sleeve of the EGF expendable flapper valve to allow the flapper to close.

MKP Lug-Type Self-Releasing Positioning Tools

Lug-type self-releasing positioning tools function in the same way as the MCP positioning tools to open and close sleeve-shifting devices. They have the advantage of passing through smaller restrictions than the MCP positioner and are recommended for horizontal applications where the tool must be pulled through long sections of pipe and screen. In addition, these tools have a safety shear release to be used if they are unable to shift a sleeve.



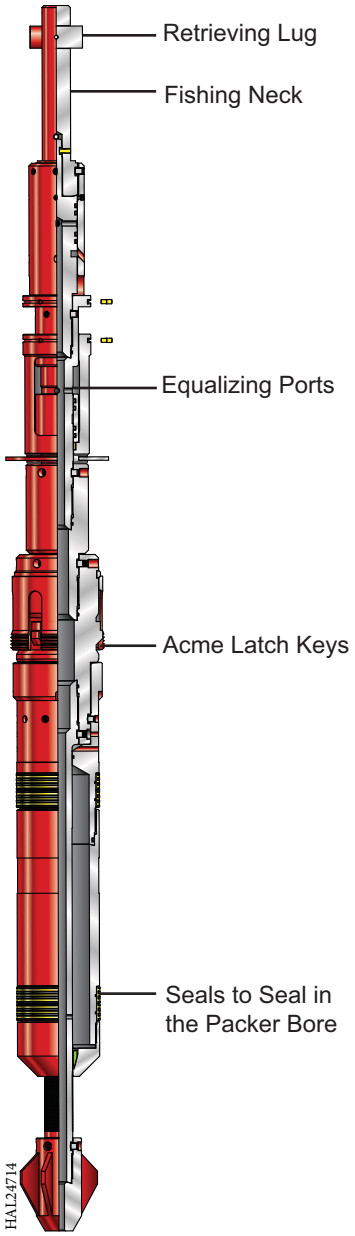
MKP Lug-Type Self-Releasing Positioning Tool



MCP Closing Sleeve

Straight-Shear Packer Plugs

Halliburton straight-shear packer plugs are designed to land and latch into a Versa-Trieve® or Perma-Series® packer top sub, seal from above and below, and be released through tension. The plugs can latch into Versa-Latch® threaded top sub designs. Equalization of the plug occurs as the retrieving overshot engages the plug. An optional rotation release is possible on the Versa-Latch threaded-plug design after equalization. The plug is equalized while stabbing into the packer.



Straight-Shear Packer Plug for a VTA or VBA Packer

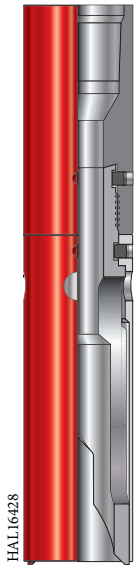
Straight-Shear Plug Running Tools

Straight-shear plug running tools are pinned to the top of the straight-shear plug and can be run on tubing, wireline, or coiled tubing. Once the plug is landed in the packer, the pin is sheared, releasing the plug and closing the bypass to seal off from above and below.

Straight-Shear Plug Retrieving Tool

Straight-shear plug retrieving tools are designed to pull the straight-shear packer plug. Refer to the design specifications of the plug being used for the retrieving tool.

Straight-Shear Plug Running Tool



Straight-Shear Plug Retrieving Tool

ShurMAC™ Collet

The weight-down reciprocating system provides the ability to maintain weight on the packer in both the squeeze and circulating position without closing the blowout preventer (BOP). Most weight-down systems have only a single weight-down position. With the addition of the ShurMAC™ collet to the weight-down tool, weight-down can be maintained in multiple positions.

Optionally this system can incorporate a reverse ball that is on seat in the reverse position but fully open when weight is on the tool in the circulating position for live annulus monitoring.

The proprietary ShurMAC collet allows the tool to be shifted between squeeze and circulating positions multiple times. Tubing set-down weight is supported by the ShurMAC collet in the circulating position.

Features

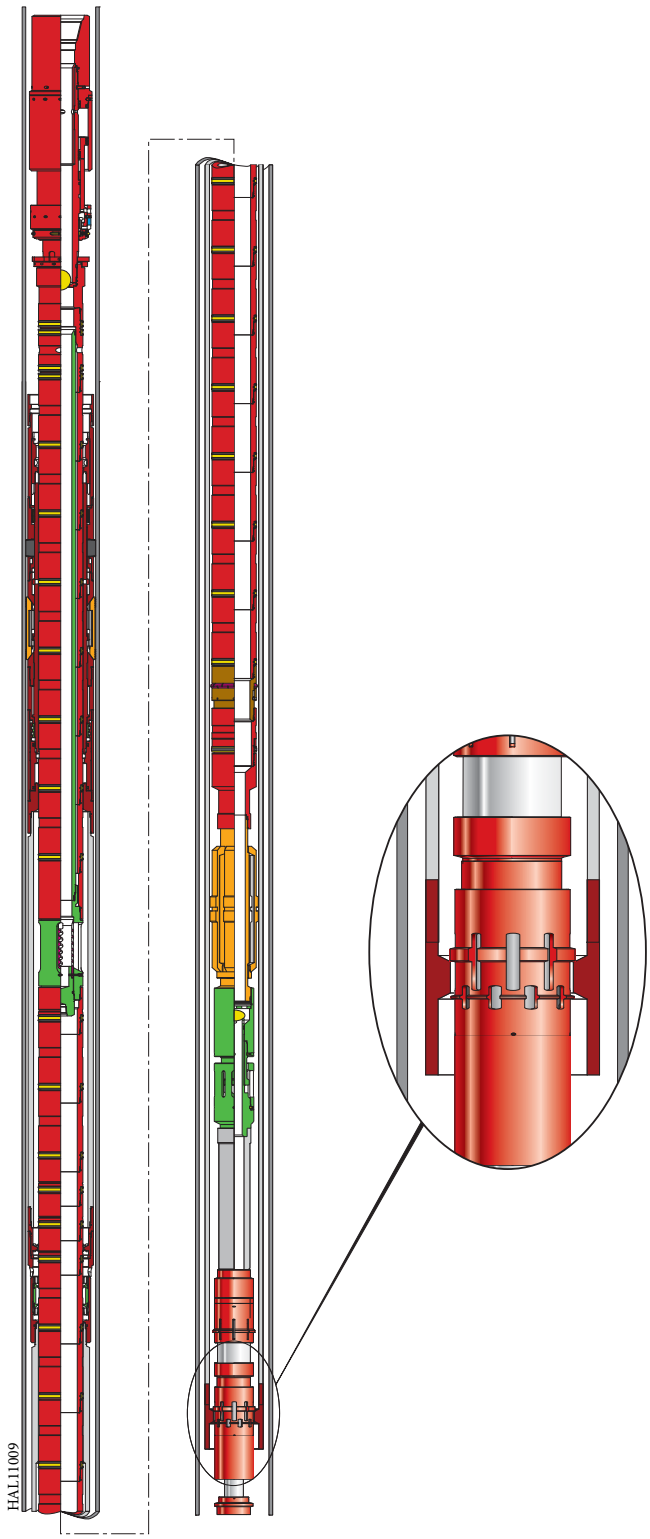
- Able to maintain weight on packer in squeeze and circulating positions without closing the BOP
- Can choose between weight-down circulating and squeeze mode while assembly is in the well

Benefits

- Safety – The ShurMAC collet design improves knowledge of tool position during the job
- FracPac™ system treatment improvement – Having live annulus capability when possible allows for better job placement
- Casing burst prevention – Having the ability to switch to squeeze mode when necessary can prevent casing over-pressure

Monobore ShurMAC Collet

The monobore ShurMAC collet is designed to work in multizone applications where the packer and MCS sealbores are the same ID as the indicator coupling ID.



Weight-Down Tool Featuring ShurMAC™ Collet

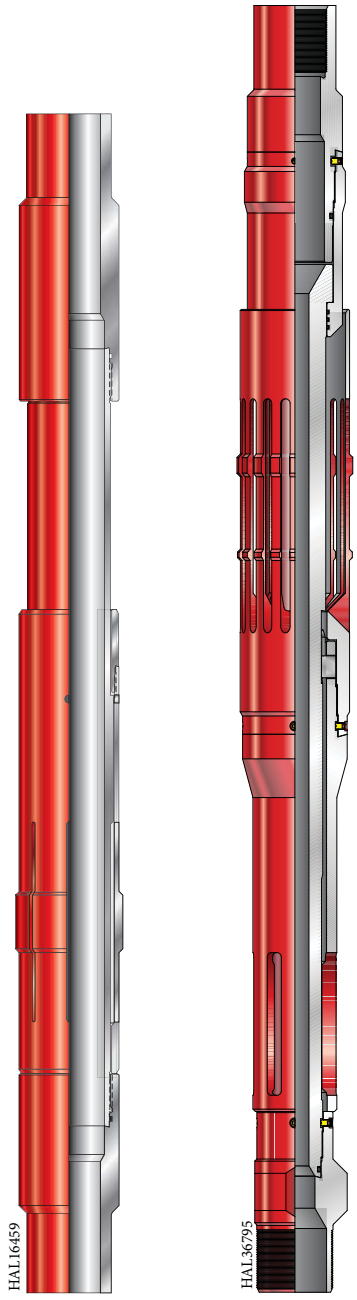
Single-Acting Weight-Down Collet

Single-acting weight-down collets provide a single pass through the restriction into either the squeeze or circulating position for multiple position options. With a single restriction, a multi-acting collet, and a single-acting collet or slip-type stroking device is used. Using collets to locate position in single-zone systems provides the shortest and most reliable way to achieve confidence the tool is in the correct position.

Washpipe

The washpipe is attached to the gravel pack service tool and run inside the screen. The washpipe serves two functions. First, it provides a return fluid circulation path that can be spaced out at the very end of the screen interval. This path forces the proppant slurry to flow to the lowermost screen before bridging in the screen-casing annulus.

The second function of the washpipe is to prevent the proppant carrier fluid from flowing to the outside of the screen. Loss of fluid from a proppant slurry can cause premature and rapid bridging to occur, especially in high-density proppant concentrations. A number of studies have indicated the pipe diameter should be at least 80% of the screen basepipe ID.



Single-Acting Weight-Down Collet

ShurMAC™ Collet

Horizontal Well Completion Components

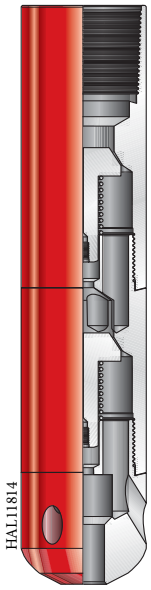
The components discussed below can be used in a wide variety of configurations to meet your horizontal well completion objectives.

All-Metal Down-Jet Shoe

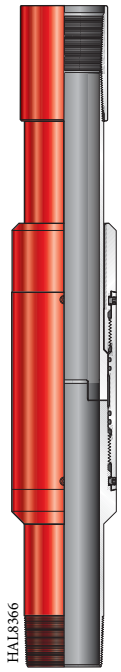
This simple spring-loaded, acid-resistant, check valve design can be made in single or double valve side-port down-jet shoe configurations for washdown and circulating operations. An all-metal design, when made from corrosion resistant alloys, provides additional corrosion resistance where acid attack is a problem and long-term serviceability is important. An open shoe with isolation flapper valve or isolation sleeve can be used for reverse circulation.

Makeup Subs

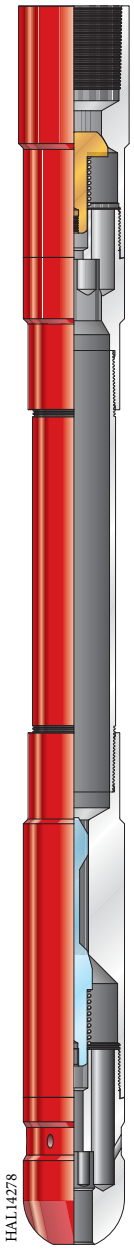
Makeup subs provide a quick, non-rotational means to make up the packer assembly to long screen assemblies. The makeup sub provides full torque capabilities through the tool when assembled with the Acme threaded collar. This tool speeds rig assembly and minimizes the risk of washpipe unscrewing during the makeup of concentric strings or thread galling.



Double Valve Down-Jet Shoe



Makeup Sub



Specialized Washing Shoe

Screen

The screen is a critical part of the success of the horizontal well. Selection of a screen should be based upon the level of filtration required and the mobility of the formation sands. Once well characteristics and objectives are known, a Halliburton representative can help you select an appropriate screen. Reference Section 4 Screens for more information about screens offered by Halliburton.

Packer Test Assembly

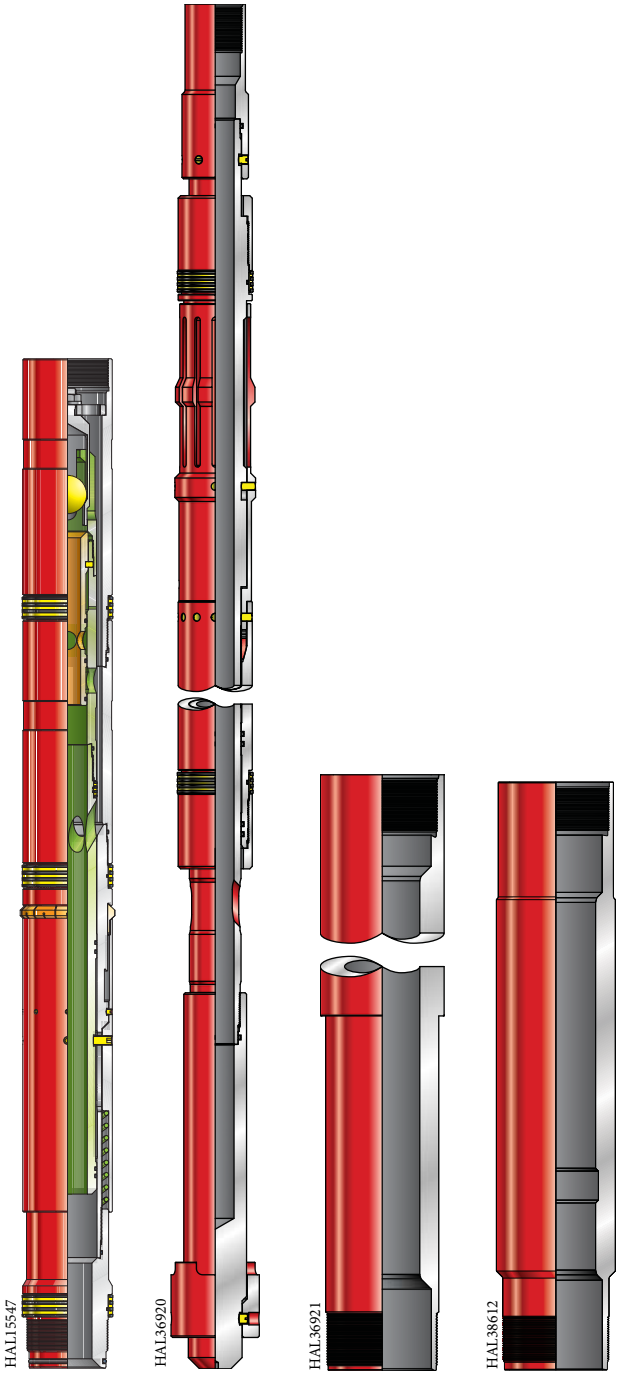
Part of the MPW service tool, the packer test assembly is used to maintain pressure on the formation of an openhole horizontal gravel pack completion while the packer is run, set, tested, and prepared for gravel packing. This assembly prevents isolation of the formation from both tubing and annulus pressure at any time in the completion, addressing the potential problem of pressure loss in the formation which results in losing the filter cake. The pressure maintenance assembly, which is run with ports in the open position, has positions that are open-closed and then opened again to achieve the objectives. Before testing, the service tool is raised and the test assembly is shifted to the closed position, allowing the packer to be tested down the annulus. Pressure is then increased to shear pins and reopen the tool so circulation is again possible. When the packer test assembly is used, the MPW tool will also have a special tapered seat assembly in the bottom of the crossover and will utilize an actuated reverse ball seat below the packer test assembly.

Screen Isolation Device

The screen isolation device is a washpipe-deployed plug used to permanently isolate a lowermost screen and shoe after the gravel pack. When the gravel pack is complete, it is set in a sealbore above the lowermost screen by a straight pull and is locked in place by internal slips. The running tool is released by tension. During initial screen running operations, the plug is placed into a lower sub-assembly with a latch looking upward. Once the screen is in the well, the washpipe is run with a mating Versa-Latch® receiving head on bottom and is stabbed and latched into the plug assembly.

Locator Nipple

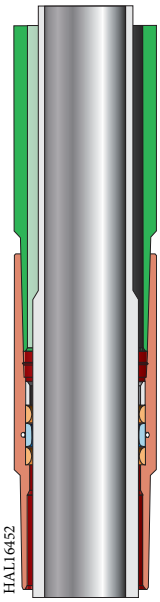
The locator nipple is used to provide a receptacle for the screen plugging device. It is attached to the top of the lowermost screen of a horizontal gravel pack completion.



Packer Test Assembly | *Screen Isolation Device* | *Lower Sealbore* | *Locator Nipple*

Inverted Washpipe Seal System

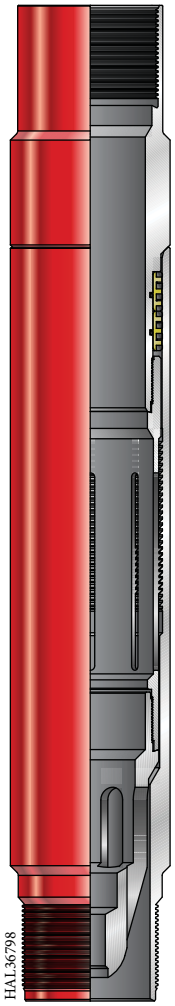
The inverted washpipe sealing system is used with long polished stingers on the washpipe. The seal housings are located at each screen joint or multiple screen joints. The workstring is moved to position, the stingers across two housings, and the treatment is pumped out a ported sub between the stingers.



Washpipe Seal System

Washpipe Latch Assembly

The washpipe latch assembly is generally used to connect two sections of washpipe in a gravel pack system. The lower half of the assembly is made up to an assembly within the well or at the bottom of the screen, such as a cup packer washing assembly. The upper half of the latch assembly is made up to the washpipe. The upper half is run on the washpipe and latched into the lower half. Right-hand rotation will tighten the latch threads. Molded seals on the latch assembly provide a seal between the workstring and the cup packer.



Washpipe Latch Assembly

Horizontal Crossover Reversing Tool

The horizontal crossover reversing tool is part of the 1062C™ horizontal completion system. The tool provides the means to circulate and reverse fluids during the horizontal well completion. Circulation is accomplished by pumping through the annular gap and around the crossover exit ports. This keeps the spring-loaded ball check on seat. Reverse circulation is achieved by pumping down the annulus, through the ports and upward, to force the spring-loaded ball check off its seat to return fluids up the workstring.

Horizontal Packer Running Tool

Multi-position tool-type horizontal packer running tools with isolation sleeve provide the means to run and set Versa-Trieve® packers in a horizontal completion assembly. The hydraulic isolation assembly allows pressure to be applied to wash the completion into place without exposing the hydraulic piston and setting pins to hydraulic pressure. Specialized tools are available for high running loads, and many have torque-through capabilities.

Washpipe Swivels

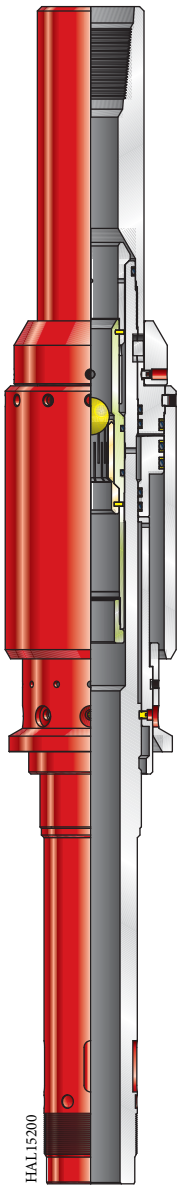
Washpipe swivels expedite makeup and allow for safer operations on the rig floor. Use of the swivel allows the end of the service tool extending from the packer assembly to be made up to the washpipe without rotation of the packer.

Swellpacker® Systems or Inflatable Packer Assemblies

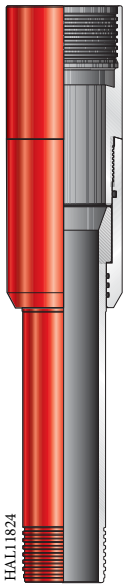
Swellpacker® systems or inflatable packer assemblies may be used to isolate openhole intervals. The inflatable packer can be set after the Versa-Trieve® packer. If more than one inflatable packer is used, each packer can be set and tested individually.

Swellpacker systems will set over time when exposed to well fluids. For a complete description of Swellpacker system options, see Section 4 Swell Technology in the *Completion Solutions* catalog.

Consult your Halliburton representative for assistance in selecting the correct packer for your well application.

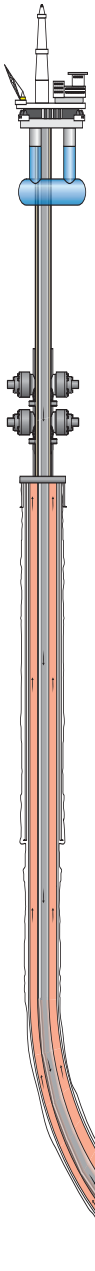


Hydraulic Setting Tool Isolation Sub-Assembly



Washpipe Swivel

Horizontal Crossover Reversing Tool

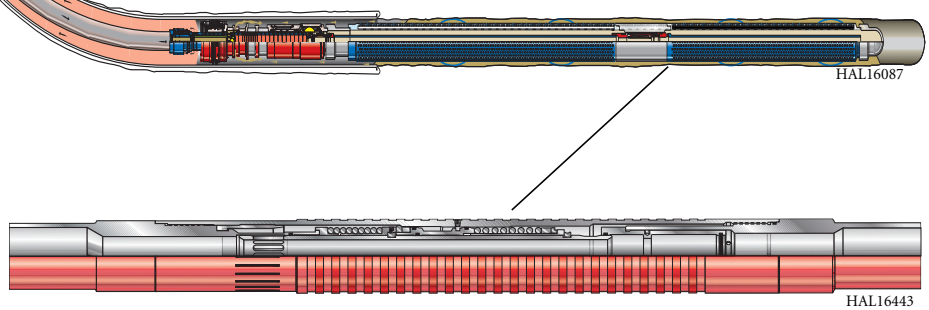


Horizontal Gravel Pack System with Upstream/Downstream Differential (UDD) Valves

The Halliburton upstream/downstream washpipe differential (UDD) valve is run as part of a horizontal openhole gravel pack completion on the washpipe and is spaced within a restriction in the screen. The valve responds to the differential pressure created by fluid friction across the valve length. As the fluid volume that passes within the restriction between the OD of the valve and the ID of the restrictor tube increases, pressure differential increases, and the valve opens. The valve will shift open when the differential pressure exceeds the pressure at which the valve is set to open. When it is opened, the fluid returns are diverted through the valve and up the remaining length of washpipe, through the service tool return path, and back up the annulus to the surface. By shortening the return flow path, the differential pressure across the openhole horizontal interval is reduced, allowing the packing operation to continue to completion without the pressure reaching a critical fracturing pressure (that would terminate the packing operation).

Features and Benefits

- Reduces circulation pressure increases resulting from beta wave formation
- Operates on flowing friction pressure differential
- Upstream to downstream differential
- Not sensitive to hydrostatic
- No seals on the valves or washpipe—close fit only, reduces sticking
- Provides a sleeve check valve to stop fluid pressure from escaping from tubing to annulus
- Adjustable for the expected differential
- Control of differential pressure in the openhole interval
- Enhances normal alpha-beta wave deposition during the packing operation
- No seals external to the valve to stick in sealbores
- Internal to external pressure integrity after opening to allow circulation to bottom for acid washing
- Able to apply internal pressure to set inflatable packers after actuation
- Simple, rugged construction
- Single moving sleeve for operation
- Flow grooves on OD to minimize chances of sticking with sand/fines during retrieval
- Large flow ports to minimize backpressure during gravel packing
- High-pressure check valve to allow single-trip gravel packing and setting inflatable packers



Upstream/Downstream Valve

FracPac™ System Completion Components and Service Tools

High-Rate and High-Volume Tools

Halliburton has a multi-position tool designed to place high volumes of proppant reliably at the high rates and pressures necessary to achieve fracture design parameters. The tools have been extensively tested to verify erosion capabilities and characteristics with varying rates, volumes, and proppant materials. This testing has identified which tools are suited to particular jobs.

Three crossover designs exist:

- Intermediate service tool with large flow areas for gravel packs and lower volume high-rate water packs
- High-rate tool with a carbide erosion sleeve for the most severe conditions
- Ultra high-rate Beyond Red Zone® tool for the most severe jobs

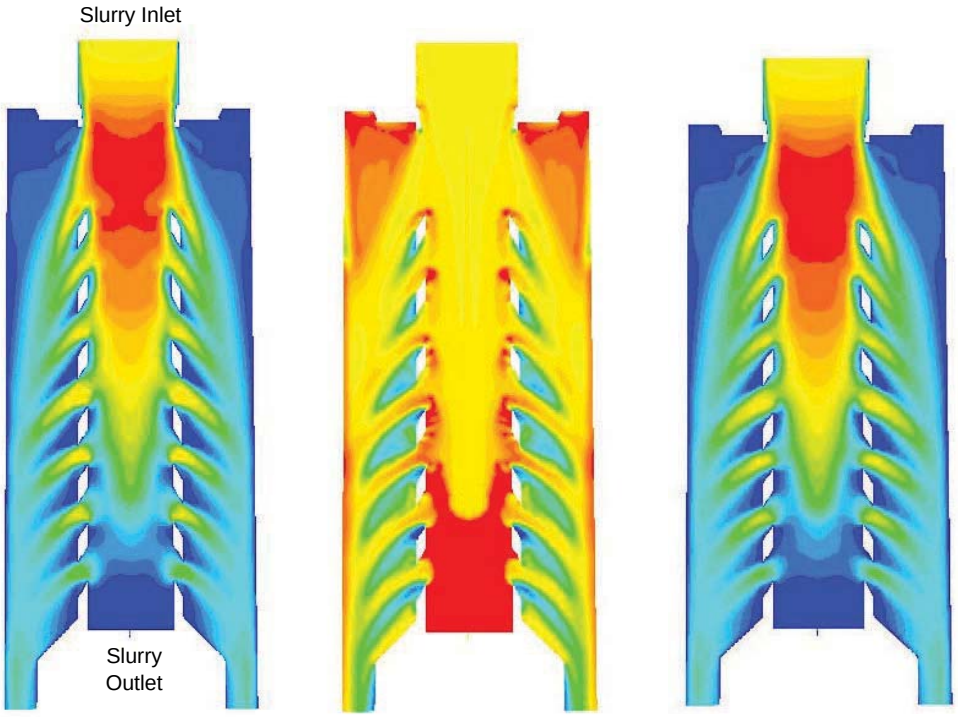
Critical areas of these tools have been analyzed using finite element analysis in conjunction with pressure cycle testing.

These tests were performed above the rated pressure calculations to assure long-term success in FracPac™ system operations.

Flow erosion can also present a problem in the upper extension, flow sub, and casing when extremely large jobs are pumped at very high rates. Halliburton has performed tests to simulate this erosion and has designed tools to survive the job and protect the well casing.

MCS FracPac System Closing Sleeve Assemblies

Halliburton MCS FracPac system closing sleeves provide all the features of the MCS closing sleeves with the additional benefit of high flow rate and volume capabilities. Each sleeve is carefully designed to cause minimum flow erosion to the closing sleeve and production casing while minimizing fines generation at maximum slurry velocity. Special sleeves are required for Beyond Red Zone FracPac system applications.

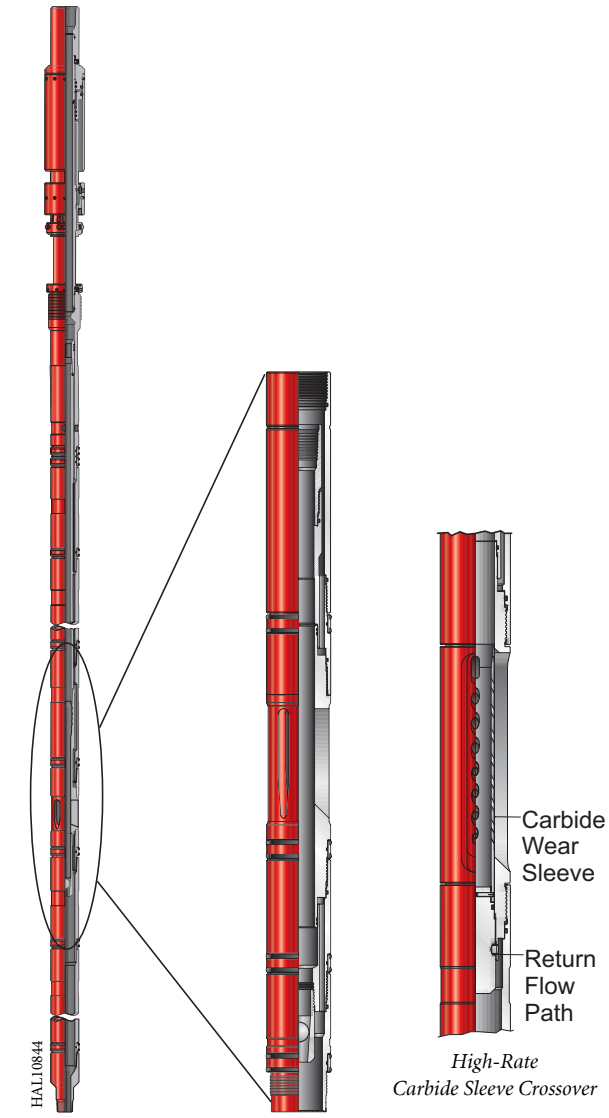


Fluid Velocity Magnitude *Volume Fraction of Proppant* *Proppant Velocity Magnitude*

Distributions of fluid velocity magnitude, volume fraction of proppant, and proppant velocity magnitude in the crossover tool

FracPac℠ Service Casing Extensions and Blank Pipe

In high-rate water pack (HRWP) or FracPac™ system treatments, sufficiently high differential pressures occur during the screenout of the casing/blank annulus to collapse blank pipe made of lightweight, low-strength materials. For this reason, the casing extensions and any other blank pipe located below the closing sleeve or perforated extension of the completion assembly are part of the completion design.



Multi-Position Tool Assembly

Intermediate Rate Crossover with Washdown Ball Seat

High-Rate Carbide Sleeve Crossover

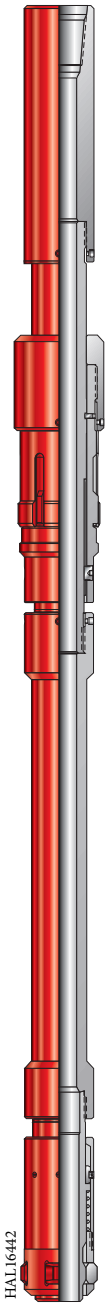
Versa-Trieve® Packer Retrieving Tool

Versa-Trieve® retrieving tools are used to retrieve Versa-Trieve packers. To retrieve the packer, the retrieving tool is run on a workstring, stung into the packer bore, and latched into the Versa-Trieve packer. Once latched, the tool locates the packer's release sleeve and moves it upward, allowing the packer to be released. Additional upward movement of the workstring releases the sleeve and moves the packer mandrel up, which permits the packer slips to retract and the packer to be retrieved.

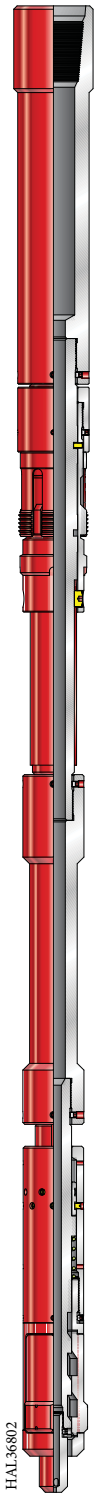
No rotation is necessary in the pulling operation. To release the pulling tool from the packer, only a 1/4 turn to the right is needed on the J-latch-type locators. Additional rotation (six to eight turns) is required to release from the Versa-Latch® locator from the packer top sub.

Benefits

- No rotation required for pulling operation
- Straight-through ID allows washing down to the packer
- Easy to release with 1/4 turn on lug-type tools (VRT type), and six to eight turns on a Versa-Latch tool (VRA or VRB type)
- Rugged lug-type design engages the release sleeve



Versa-Trieve® Packer VRA Retrieving Tool



Versa-Trieve® Packer VRB Retrieving Tool

Schematic 1—Engaging

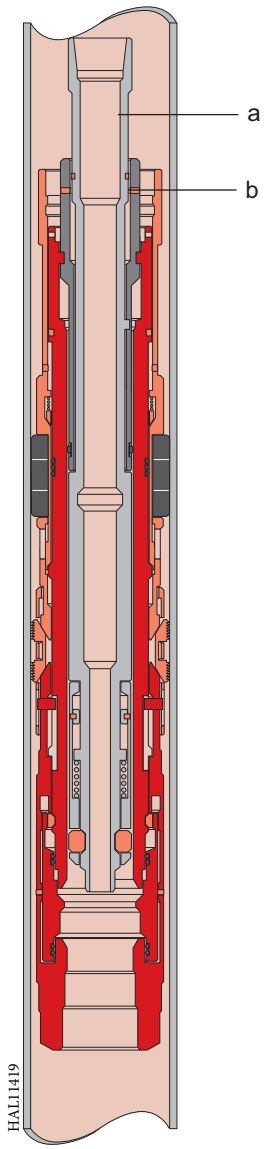
- After the tubing and seal assembly have been removed, a Versa-Trieve® retrieving tool is lowered into the packer until the locator no-goes on the packer top sub. An upstrain on the workstring (a) verifies that the retrieving tool is latched into the packer and shears the locator to the mandrel shear pin (b).

Schematic 2—Releasing

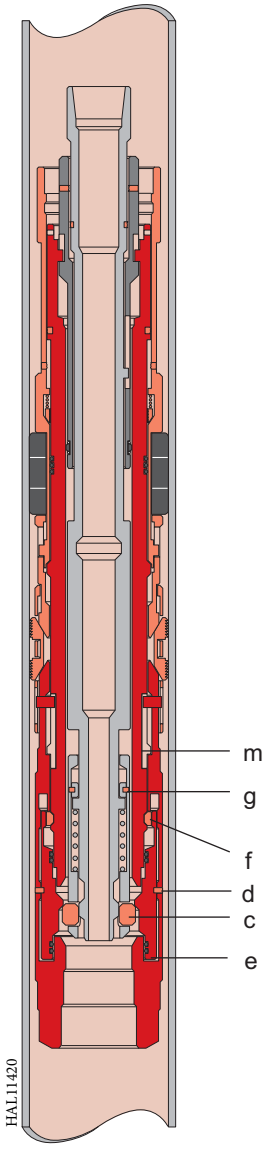
- With the retrieving tool properly latched to the packer, the workstring is slacked off until the retrieving tool begins to take weight. An upstrain applied to the retrieving tool allows the lugs of the retrieving tool (c) to engage the packer release sleeve. Continued upstrain will shear the shear pins (d) in the release sleeve, allowing the release sleeve (e) to move upward and toward the release ring (f).

Schematic 3—Retrieving

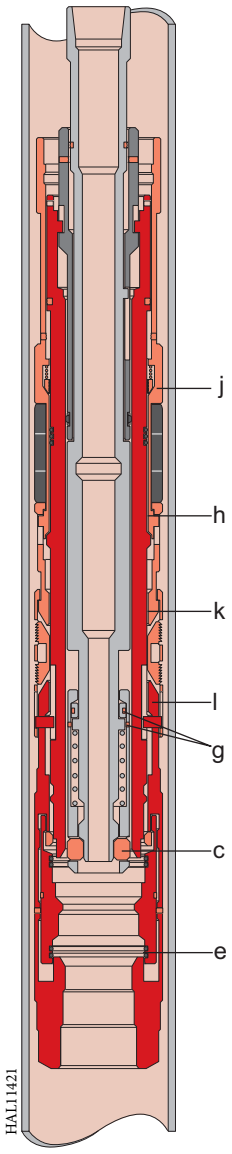
- Additional upstrain shears the pins (g), causing the lugs of the retrieving tool (c) to retract. Upward movement of the packer's mandrel causes the shoulder (h) to raise the element mandrel (j) and top wedge (k). The top wedge is pulled out from under the slips and pulls on the slip carrier, which pulls the slips off of the lower wedge (l). The shoulder (m) catches the lower edge and supports the tailpipe below the packer.



Schematic 1



Schematic 2



Schematic 3

Screens and Inflow Control Technology

Why Halliburton Screens?

Deep water. Unconventionals. Interventions. Mature assets. Solids mitigation. Water/gas breakthrough. Heavy oil.

Whatever your challenge, Halliburton experts stand ready with solutions using the most effective, reliable, value-added sand control screens and inflow control technology in the business—with unequalled customer collaboration every step of the way. Today's sand control needs are far reaching and diverse. Every reservoir has a unique set of attributes and problems that demand a customized sand control solution to maximize productivity and the life of the well. Halliburton prides itself on the ability to solve these problems and provide a reliable solution for any scenario. Halliburton is committed to setting the standards for well screen and inflow control technology design and manufacturing.

Manufacturing and Technology Centers

Carrollton Technology Center

The experience and knowledge of our people, coupled with a commitment to technological innovation, allows Halliburton to deliver technically superior, value-added products and services to our customers. The Carrollton Technology Center in Carrollton, Texas houses state-of-the-art testing and design facilities. This center has developed a steady stream of innovative oil industry products receiving numerous engineering innovation awards. The engineering test facilities provide engineering analysis and support, high-temperature/high-pressure testing, and tool prequalification to API and ISO requirements. The facility also features two working test wells with rig accessories which allow Halliburton to simulate actual well environments before running new tools in a customer's well.

Singapore Technology and Manufacturing Center

To mirror the state-of-the-art testing and design facilities in the eastern hemisphere, Halliburton opened the Completion Technology and Manufacturing Center in Singapore. This facility includes an administration building, technology workshops, high-pressure/high-temperature testing capabilities, deep well simulators, and an 8,750-ft (2667-m) test well with a horizontal section and rig, enabling system integration testing products and services in simulated well conditions.

Lafayette Manufacturing Center

Located in Lafayette, Louisiana, the 200,000 ft² (18 581 m²) Lafayette Manufacturing Center includes 173,000 ft² (16 072 m²) of manufacturing shop floor space and onsite technology capacity. In addition to the manufacturing shop floor built for long parts, the facility includes a metallurgical lab capable of performing physical property tests on incoming raw materials and sample rubber. This state-of-the-art plant features an efficient shop-floor layout, new machines, and streamlined processes, allowing for maximum productivity. The facility's cutting-edge technology and equipment for screen production includes hydraulic stress-relief racks and machines that help improve the screen jacket assembly process.

Malaysia Manufacturing and Technology Center

The Malaysia Manufacturing and Technology Center manufactures an extensive range of products, including swell and screens technology. The more than 300,000 ft² (27 871 m²) facility includes a manufacturing plant, a bulk plant, and an administration building. This site also offers technology capabilities, including high-pressure and physical property tests on location. Halliburton's Malaysia Manufacturing and Technology Center plays a key role in meeting the growing needs of customers in the Eastern Hemisphere and globally.

Malaysia Manufacturing and Technology Center

Mesh Screens

PetroGuard® Mesh DS Screen

For sand control applications where a more efficient filtration media is required, the PetroGuard® Mesh DS (Dual Shroud) screen provides effective solids filtration in a shrouded, non-bonded mesh screen.

Woven mesh often provides better performance than a wire-wrapped screen in unconsolidated formations. This is especially true when it comes to filtering a high percentage of fines and in formations with more poorly sorted sands. The unique construction of the PetroGuard Mesh DS screen optimizes inflow area and filtration efficiency to provide superior sand control completion performance.

The screen consists of a perforated basepipe and a non-bonded mesh filter cartridge. The perforated outer shroud protects the mesh filter during deployment, while the dimples in the shroud lend stability to the mesh and ensure the filter layer remains overlapped, maintaining sand control integrity and reducing potential failure due to erosion.

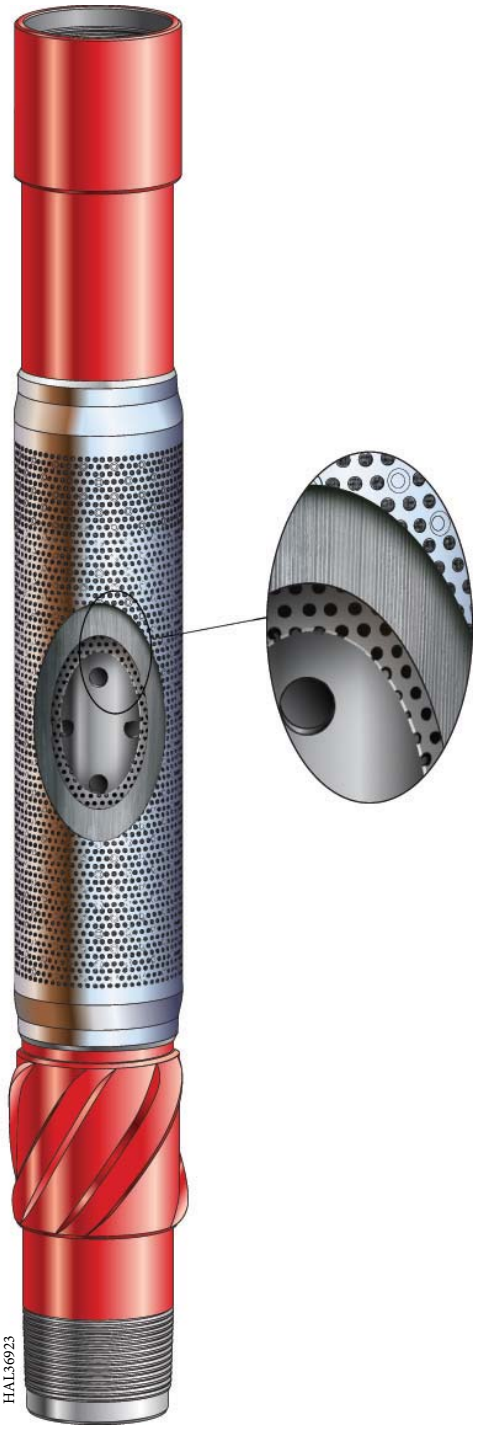
The PetroGuard Mesh DS screen can be used as a standalone system or in conjunction with gravel or frac pack applications, providing a reliable barrier against production of formation sands. When used in conjunction with other technologies, such as EquiFlow® inflow control technology and zonal isolation tools, the PetroGuard Mesh DS screen is the heart of a total sand control solution.

Features

- Multiple filter cloth options (square, plain dutch, reverse dutch twill, etc.)
- Dimpled inner and outer shroud
- Crimped end rings
- Multiple drainage layer designs

Benefits

- Optimizes inflow performance, mesh layer support, and inflow efficiency
- Eliminates crossflow of solids at end of filter cartridge and provides superior cartridge attachment
- Compatible with inflow control devices, sliding sleeves, and provides control-line/fiber-optic deployment
- Improved flow efficiency into basepipe



PetroGuard®
Mesh DS Screen

PetroGuard® Mesh DS Screen

Basepipe OD		Basepipe Holes per ft	Basepipe Hole Size		Open Area of Basepipe Holes		Filter Jacket				Screen Radial Open Area**	
							Maximum Assembly OD		Jacket Weight*			
in.	*mm*	qty	in.	*mm*	in.²/ft	*cm²/m*	in.	*mm*	lb/ft	*kg/m*	in.²/ft	*cm²/m*
2.38	*60.45*	36	0.375	*9.53*	3.98	*84.2*	3.15	*80.03*	5.9	*8.78*	22.6	*477.70*
2.88	*73.15*	44	0.375	*9.53*	4.86	*102.9*	3.66	*92.86*	6.4	*9.52*	26.2	*554.26*
3.5	*88.90*	60	0.375	*9.53*	6.63	*140.3*	4.29	*108.89*	9.2	*13.69*	30.7	*649.97*
4.0	*101.60*	68	0.375	*9.53*	7.51	*159.0*	4.79	*121.72*	9.5	*14.14*	34.3	*726.53*
4.5	*114.30*	76	0.375	*9.53*	8.39	*177.7*	5.30	*134.54*	11.6	*17.26*	37.9	*803.10*
5.0	*127.00*	84	0.375	*9.53*	9.28	*196.4*	5.80	*147.37*	17.0	*25.30*	41.6	*879.66*
5.5	*139.70*	92	0.375	*9.53*	10.16	*215.1*	6.31	*160.20*	18.0	*26.79*	45.2	*956.22*
6.63	*168.40*	108	0.375	*9.53*	11.93	*252.5*	7.44	*189.06*	24.0	*35.72*	53.3	*1128.50*
7.0	*177.80*	116	0.375	*9.53*	12.81	*271.2*	7.82	*198.68*	26.0	*38.69*	56.0	*1185.92*

*Jackets are offered in 5, 10, 16, and 20-ft lengths.
**Based upon shroud/drainage layer not including filter mesh. For mesh screen data, contact your local Halliburton representative.

PetroGuard® Advanced Mesh Screen

PetroGuard® Advanced Mesh Screen brings superior filtration technology to the upstream oil and gas industry. Its multi-layered construction is designed to provide the highest solids retention and plugging resistance possible.

Conceived for fines-prone heavy oil reservoirs, development testing confirmed this breakthrough in oilfield filtration technology is ideal for a wide range of sand control applications. In fact, the more poorly sorted the sand, the better the relative performance of the PetroGuard advanced mesh screen when compared with wire-wrap and metal mesh screen products.

The PetroGuard advanced mesh screen is formed from a series of surface filter layers. This means precise pore size control and no tortuous flow paths, making it possible to backflush to clean the screen.

Features

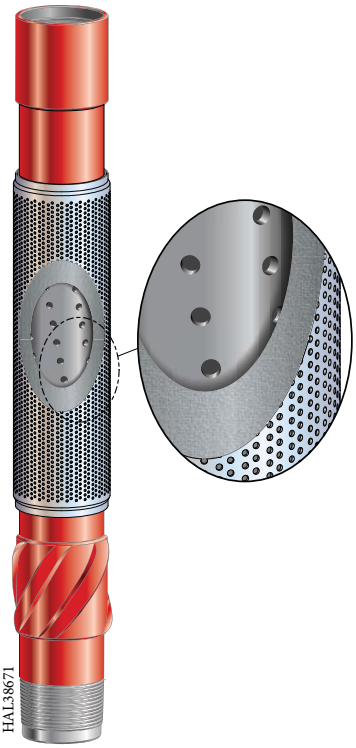
- Custom designed for each project
- Multiple graduated filtration layers
- No tortuous flow path
- Precise pore size control

Benefits

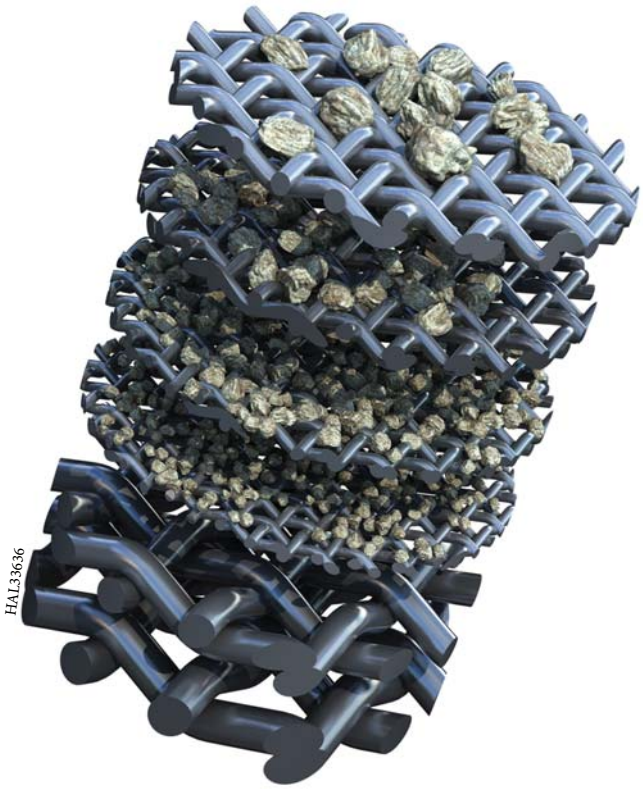
- Optimized filtration for each field
- Higher solids retention
- Improved plugging resistance
- Improved inflow efficiency and backflushing capability
- Reduced need for pumped sand control solution

This technology allows the use of bare screen sand control techniques in completions where typically a pumped sand control solution was required due to poor grain size uniformity. Using graduated filtration layers, the PetroGuard advanced mesh screen filters progressively smaller particles from the production stream as flow moves toward the basepipe, allowing the valuable final filtration layer to be challenged by fewer solid particles.

Each screen is designed specifically for a project's unique sand sample. The result is a custom-designed sand screen—a significant improvement over traditional screen sizing methods.



PetroGuard®
Advanced Mesh Screen



PetroGuard® Advanced Mesh Screen

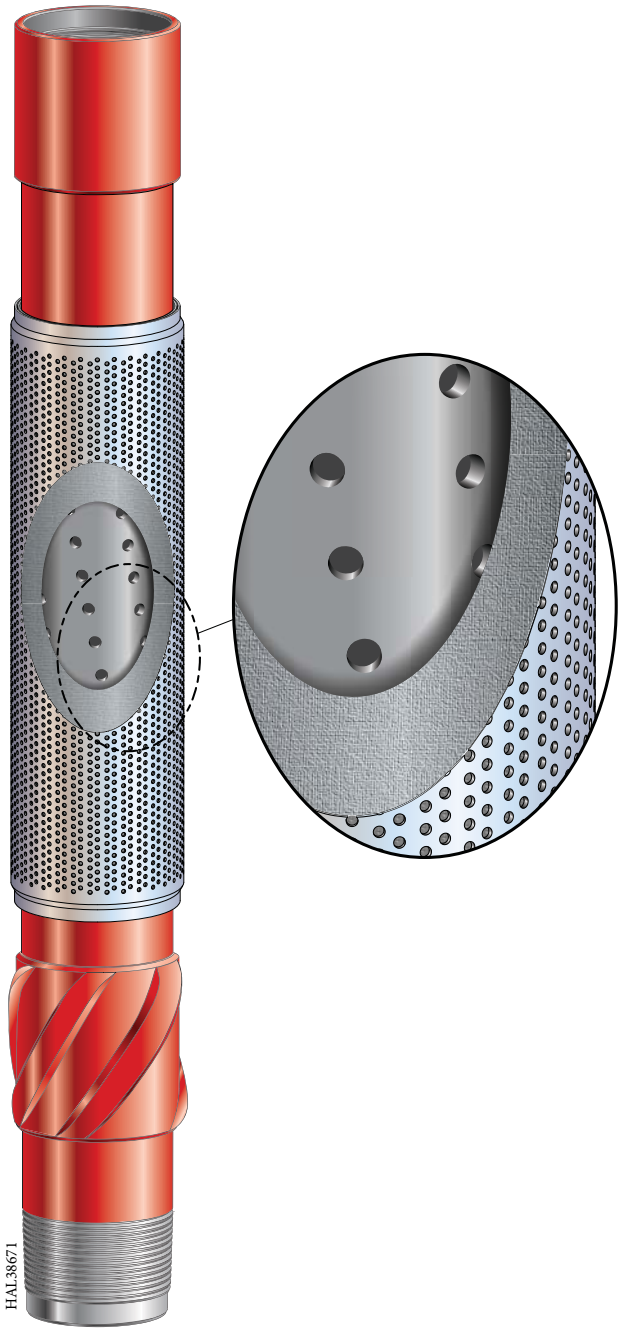
Basepipe OD		Basepipe Holes per ft	Basepipe Hole Size		Open Area of Basepipe Holes		Filter Jacket				Screen Radial Open Area**	
							Maximum Assembly OD		Jacket Weight*			
in.	*mm*	qty	in.	*mm*	in.²/ft	*cm²/m*	in.	*mm*	lb/ft	*kg/m*	in.²/ft	*cm²/m*
2.38	*60.45*	54	.375	*9.53*	6.0	*126.24*	3.03	*79.96*	3.1	*4.60*	26.3	*556.10*
2.88	*73.15*	66	.375	*9.53*	7.3	*154.29*	3.53	*89.66*	3.6	*5.41*	30.6	*647.87*
3.5	*88.90*	78	.375	*9.53*	8.6	*182.35*	4.15	*105.41*	4.2	*6.31*	36.0	*761.66*
4.0	*101.60*	90	.375	*9.53*	9.9	*210.40*	4.65	*118.11*	4.8	*7.09*	40.3	*853.42*
4.5	*114.30*	102	.375	*9.53*	11.3	*238.45*	5.17	*131.32*	5.3	*7.90*	44.8	*948.86*
5.0	*127.00*	114	.375	*9.53*	12.6	*266.51*	5.67	*144.02*	5.8	*8.63*	49.2	*1040.63*
5.5	*139.70*	126	.375	*9.53*	13.9	*294.56*	6.18	*156.97*	6.4	*9.48*	53.6	*1134.23*
6.63	*168.40*	138	.375	*9.53*	15.3	*322.61*	7.31	*185.67*	7.5	*11.16*	63.4	*1341.62*
7.0	*177.80*	150	.375	*9.53*	16.6	*350.67*	7.69	*195.33*	7.9	*11.74*	66.7	*1411.36*

*Jackets are offered in lengths of 54 in., 102 in., 150 in., and 198 in.
**Based upon shroud not including filter mesh. For mesh screen data, contact your local Halliburton representative.

PoroMax® Screen

Combining the global sand control experience of Halliburton with the recognized filtration technology of Purolator Facet, Inc., the PoroMax® screen is a premium shrouded, diffusion-bonded laminate screen product engineered for optimum inflow area. Diffusion bonding not only provides precise pore size control in all load conditions but also provides superior solids filtration and toughness. This makes the PoroMax screen suitable for installations with an extended reach and/or long open hole and for installation through a casing window (such as for multilateral completions) with or without centralization. With improved dirt-holding capacity and pressure drop performance due to its optimized inflow design, PoroMax screens are also suitable for high-flow applications.

PoroMax is a registered trademark of Purolator Facet, Inc.



PoroMax® Screen

PoroMax® Screen

Basepipe OD		Basepipe Holes per ft	Basepipe Hole Size		Open Area of Basepipe Holes		Filter Jacket				Screen Radial Open Area**	
							Maximum Assembly OD		Jacket Weight*			
in.	*mm*	qty	in.	*mm*	in.²/ft	*cm²/m*	in.	*mm*	lb/ft	*kg/m*	in.²/ft	*cm²/m*
1.05	*26.67*	54	5/16	*7.94*	4.1	*86.80*	1.690	*42.93*	1.2	*1.79*	14.7	*310.17*
1.32	*33.53*	66	5/16	*7.94*	5.1	*107.87*	1.950	*49.53*	1.4	*2.08*	16.9	*357.89*
1.66	*42.16*	78	5/16	*7.94*	6.0	*127.02*	2.300	*58.42*	1.7	*2.53*	19.9	*422.12*
1.9	*48.26*	42	3/8	*9.53*	4.6	*97.38*	2.470	*62.74*	1.9	*2.83*	21.4	*453.32*
2.06	*52.32*	42	3/8	*9.53*	4.6	*97.38*	2.720	*69.09*	2.2	*3.27*	23.6	*499.21*
2.38	*60.45*	54	3/8	*9.53*	6.0	*127.02*	3.030	*76.96*	2.5	*3.72*	26.3	*556.10*
2.88	*73.15*	66	3/8	*9.53*	7.3	*154.54*	3.530	*89.66*	3.0	*4.46*	30.6	*647.87*
3.5	*88.90*	78	3/8	*9.53*	8.6	*182.06*	4.150	*105.41*	3.4	*5.06*	36.0	*761.66*
4.0	*101.60*	90	3/8	*9.53*	9.9	*209.58*	4.650	*118.11*	3.8	*5.66*	40.3	*853.42*
4.5	*114.30*	102	3/8	*9.53*	11.3	*239.22*	5.140	*130.56*	4.3	*6.40*	44.6	*943.35*
5.0	*127.00*	114	3/8	*9.53*	12.6	*266.74*	5.650	*143.51*	4.6	*6.85*	49.0	*1036.95*
5.5	*139.70*	126	3/8	*9.53*	13.9	*294.26*	6.160	*156.46*	5.1	*7.59*	53.4	*1130.56*
6.63	*168.40*	138	3/8	*9.53*	15.3	*323.90*	7.310	*185.67*	6.0	*8.93*	63.4	*1341.62*
7.0	*177.80*	150	3/8	*9.53*	16.6	*351.42*	7.690	*195.33*	6.3	*9.38*	66.7	*1411.36*
7.63	*193.80*	162	3/8	*9.53*	17.9	*378.94*	8.330	*211.58*	6.9	*10.27*	72.2	*1528.82*
8.63	*219.20*	186	3/8	*9.53*	20.5	*433.99*	9.350	*237.49*	7.8	*11.61*	81.1	*1716.02*
9.63	*244.60*	210	3/8	*9.53*	23.2	*491.14*	10.370	*263.40*	8.7	*12.95*	89.9	*1903.23*

*Jackets are offered in 55.5-in. to 222-in. lengths.
**Based upon shroud not including filter mesh. For mesh screen data, contact your local Halliburton representative.

Wire-Wrap Screens

Direct-Wrap Screens

Direct-wrap screens, often referred to as wrap-on-pipe, are wire-wrap-type screens featuring a filtration layer made up of shaped wires wrapped over and welded to support or rib wires. The resulting filter uses an interference fit created by wrapping directly onto the basepipe, enhanced by cooling and shrinking of the wire after welding, to create a remarkably strong attachment.

PetroGuard® Wrap Screen

Bringing together the latest machine technology and an optimized wire design results in a screen product with best-in-class performance—the PetroGuard® Wrap Screen. Its wrap-on-pipe design features wire wrapped directly onto the basepipe. Longitudinal ribs support the wrap wire and function as a drainage layer, ensuring an open flow path to the basepipe perforations. Wire is tightly wrapped around the basepipe with additional strength achieved when the wire is welded to the ribs and the cooling process shrinks the wire around the pipe. Basepipe perforations are designed to optimize flow while retaining strength.

Keystone-shaped wire helps reduce the risk of screen plugging associated with particles becoming lodged between wires, providing self-cleaning action and a great reduction in flow friction. The resulting screen provides a robust solids filter for use in both cased and openhole environments.

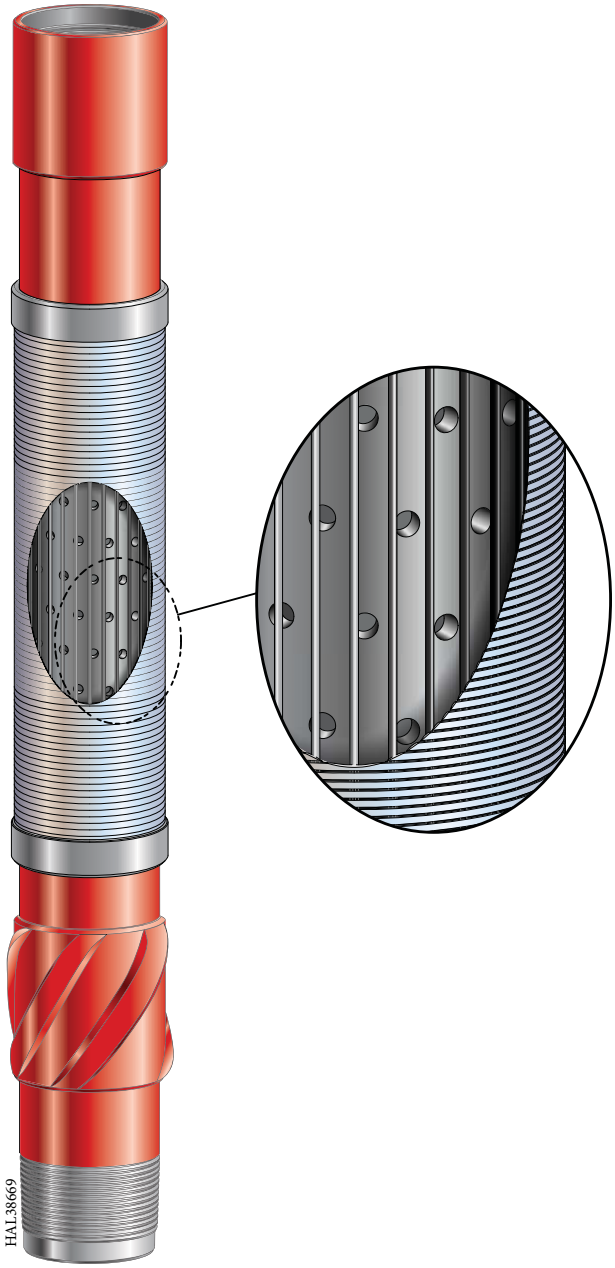
The PetroGuard wrap screen can be used as a standalone system or in conjunction with gravel or frac pack applications, providing a reliable barrier against production of formation sands. When used in conjunction with other technologies, such as EquiFlow® inflow control technology and zonal isolation tools, the PetroGuard Wrap screen forms part of a total sand control solution.

Features

- Available in basepipe sizes ranging from 2 7/8 to 7 in.
- Monitored wire wrapping process
- Optical slot verification
- Wrap wire welded to ribs at every contact point

Benefits

- Consistent gauge for reliable sand control
- Increased strength allows “working” of completion in the hole



PetroGuard® Wrap Screen

PetroGuard® Wrap Screen

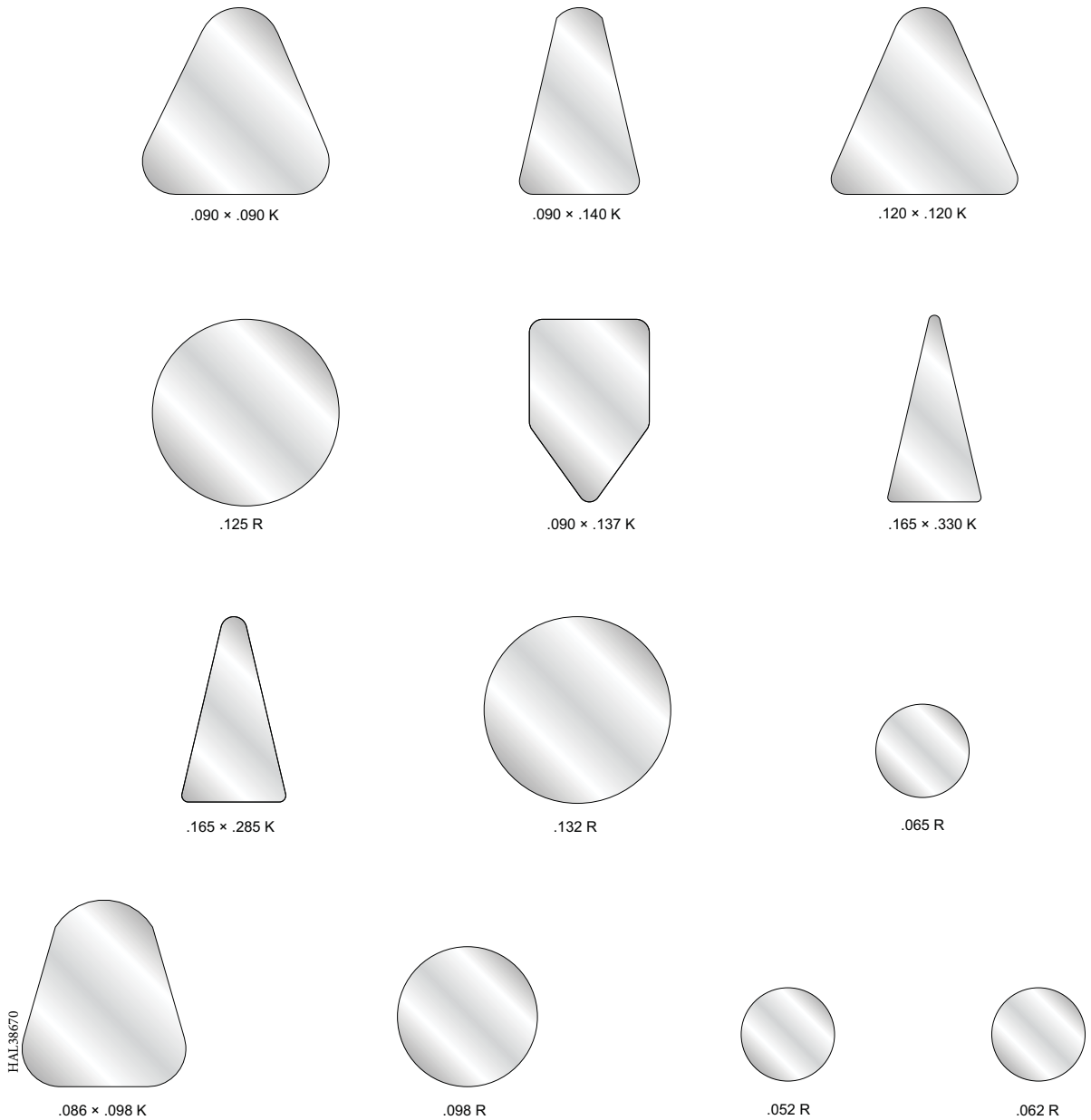
Basepipe OD		Basepipe Holes per ft	Basepipe Hole Size		Open Area of Basepipe Holes		Number of Ribs	Filter Jacket				Screen Radial Open Area**	
								Maximum Assembly OD (End Ring)		Jacket Weight*			
in.	*mm*	qty.	in.	*mm*	in.²/ft	*cm²/m*		in.	*mm*	lb/ft	*kg/m*	in.²/ft	*cm²/m*
2.38	*60.45*	N/A	N/A	*N/A*	N/A	*N/A*	N/A	N/A	*N/A*	N/A	*N/A*	N/A	*N/A*
2.88	*73.15*	20	.375	*9.53*	2.2	*46.76*	20	3.48	*88.39*	3.4	*5.06*	11.3	*239.18*
3.5	*88.90*	26	.375	*9.53*	2.9	*60.78*	26	4.11	*104.39*	4.1	*6.10*	13.4	*283.63*
4.0	*101.60*	28	.375	*9.53*	3.1	*65.46*	28	4.61	*117.09*	4.6	*6.85*	15.2	*321.73*
4.5	*114.30*	30	.375	*9.53*	3.3	*70.13*	30	5.12	*130.05*	5.1	*7.59*	16.9	*357.72*
5.0	*127.00*	32	.375	*9.53*	3.5	*74.81*	32	5.62	*142.75*	5.5	*8.18*	18.6	*393.70*
5.5	*139.70*	32	.375	*9.53*	3.5	*74.81*	32	6.13	*155.70*	5.9	*8.78*	20.3	*429.68*
6.63	*168.40*	40	.375	*9.53*	4.4	*93.51*	40	7.27	*184.66*	6.9	*10.27*	24.1	*510.12*
7.0	*177.80*	44	.375	*9.53*	4.9	*102.86*	44	7.64	*194.06*	7.4	*11.01*	25.4	*537.63*

*Jackets are offered in lengths up to 432 in.
**Based upon 12 gauge screen

PetroGuard® Wrap Screen Gauge Measurement

The PetroGuard® Wrap screen gauge measurement uses state-of-the-art equipment designed to measure a full length of screen on every joint of screen produced. All slots on at least one plane between two ribs are measured to ensure screen gauge is within specified tolerances. The optical measuring system has been calibrated with National Institute of Standards and Technology (NIST) traceable standards and is accurate to 2.5 µm. The camera and manufacturing processes have been optimized to produce highly accurate, repeatable gauging results to 5 µm. All gauge data is traceable to each serialized screen joint and is summarized in a custom formatted output file for quick reference.

Halliburton Wire-Wrap Screen Wire Profiles

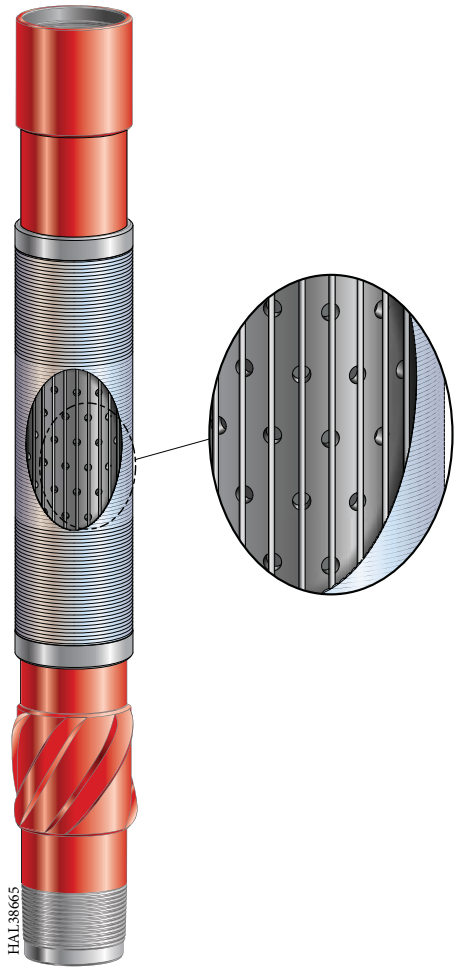


Slip-On Screens

The wire-wrap filter component of slip-on wire wrap screens is fabricated in a separate step before being slipped over the basepipe and attached. This construction style allows low cost and flexibility in manufacturing schedules and locations, while still allowing high gauge accuracy and reliability. The Halliburton All-Weld screen uses this same construction style and has been a high-quality screen product manufactured continuously for more than 40 years. Halliburton prepacked screens also use this construction for one or more of the wire-wrap filter components.

All-Weld (Slip-On) Wire-Wrap Screens

The Halliburton All-Weld wire-wrap screen is field proven with years of reliable oilfield service. The keystone-shaped wire decreases screen plugging associated with particulates lodging between wires. The wire wrap is manufactured separately from the basepipe, and the wire wrapped jacket is then placed over the perforated basepipe and welded to the basepipe at either end.



All-Weld Wire-Wrap Screen

All-Weld Wire-Wrap Screen

Basepipe OD		Basepipe Holes per ft	Basepipe Hole Size		Open Area of Basepipe Holes		Number of Ribs	Filter Jacket				Screen Radial Open Area**	
								Maximum Assembly OD		Jacket Weight*			
in.	*mm*	qty	in.	*mm*	in.²/ft	*cm²/m*	qty	in.	*mm*	lb/ft	*kg/m*	in.²/ft	*cm²/m*
2.38	*60.45*	54	.375	*9.53*	5.96	*126.2*	15	2.86	*72.6*	2.3	*3.42*	12.6	*267.01*
2.88	*73.15*	66	.375	*9.53*	7.29	*154.3*	17	3.36	*85.3*	2.7	*4.02*	14.8	*313.70*
3.5	*88.90*	78	.375	*9.53*	8.61	*182.2*	21	3.99	*101.3*	3.2	*4.76*	17.6	*372.51*
4.0	*101.60*	90	.375	*9.53*	9.94	*210.4*	23	4.49	*114.0*	3.6	*5.36*	19.8	*419.19*
4.5	*114.30*	102	.375	*9.53*	11.27	*238.5*	25	5.00	*127.0*	4.0	*5.95*	22.1	*466.81*
5.0	*127.00*	114	.375	*9.53*	12.59	*266.5*	27	5.51	*139.9*	4.4	*6.55*	24.3	*514.42*
5.5	*139.70*	126	.375	*9.53*	13.92	*294.6*	29	6.01	*152.7*	4.8	*7.14*	26.5	*561.10*
6.63	*168.40*	138	.375	*9.53*	15.24	*322.6*	31	7.15	*181.6*	5.6	*8.33*	31.5	*667.54*
7.0	*177.80*	150	.375	*9.53*	16.57	*350.7*	37	7.53	*191.3*	6.1	*9.08*	33.2	*703.01*

*Jackets are offered in lengths up to 228 in.
**Based upon 12 gauge screen

Inflow Control Technology

EquiFlow® inflow control technology has been designed to improve completion efficiency and longevity by balancing inflow throughout the length of a horizontal completion. Differences in influx from the reservoir can result in premature water/gas breakthrough, leaving valuable reserves in the ground. Typical applications include wells experiencing "heel-toe effects", breakthrough of water/gas, permeability differences, and water challenges in high viscosity reservoirs. By using EquiFlow inflow control technology, the reservoir inflow from low productivity zones is, in effect, stimulated to increase completion efficiency.

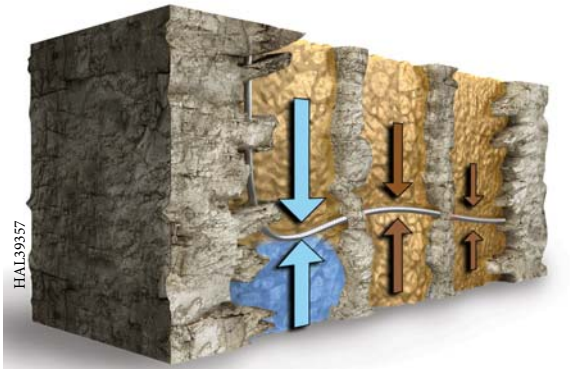
The Halliburton EquiFlow product family increases completion efficiency and well longevity as well as ultimate recovery from the well by delaying breakthrough of unwanted fluid.

The EquiFlow family consists of two main products—passive and autonomous inflow control devices.

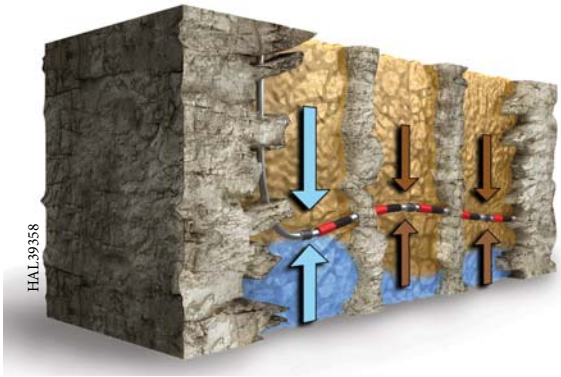
EquiFlow® Inflow Control Device

Standard passive inflow control devices (ICD) are chokes installed in the completion string which create a pressure drop along the interval length. Differences in influx from the reservoir can result in premature water/gas breakthrough, leaving valuable reserves in the ground. EquiFlow® inflow control devices are designed to improve completion performance and efficiency by balancing inflow throughout the length of a completion. The desired placement locations of ICDs are typically determined in the project design phase.

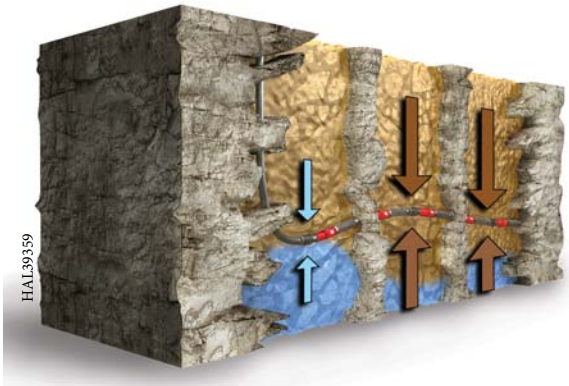
The EquiFlow ICD consists of an annular chamber on a standard oilfield tubular. If a screen is required, the reservoir fluid is produced from the formation, through the sand screen, and into the flow chamber. The flow continues through a set of chokes, which create the pressure drop, and then into the pipe through a set of ports. The number of chokes and their ID are configured to deliver the pressure drop needed for optimum completion efficiency based on wellbore modeling.



Slotted/Pre-Drilled Liner Standalone Screen
Uneven production – early water/gas breakthrough likely, oil production declined



Passive EquiFlow® Inflow Control Device
Balanced influx – delayed water/gas breakthrough, oil production limited



EquiFlow® Autonomous Inflow Control Device
Balanced influx – breakthrough delayed and restricted, oil production stimulated

EquiFlow Adjustable Inflow Control Devices

Today's reservoir challenges call for optimum completion solutions, and because no two reservoirs are alike, having multiple options can be of significant benefit. EquiFlow Adjustable ICDs can be reconfigured, if required, after the equipment has left the manufacturing facility. For applications where design flexibility is needed, this adjustable ICD allows the operator to change settings closer to the time of installation.

The EquiFlow Adjustable ICD helps improve logistics and reduce delivery time because it can be stocked knowing the wide range of configurations will meet most well requirements. This allows for determination of the final ICD profile later in the project, such as when the operator receives updated well data from measurement and logging operations. With this reconfiguration capability, backup devices can be used in other applications or projects.

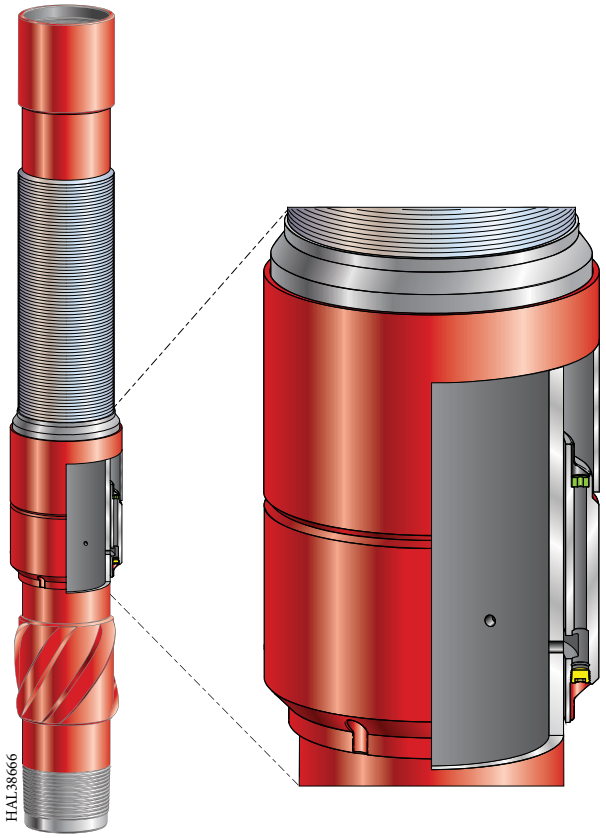
The EquiFlow Adjustable ICD features external access to the chokes. The flow profile is changed by closing or opening a pre-determined set of chokes. This operation is carried out at the surface and can be completed before shipment to the rig or on location.

Features

- Externally adjustable
- No elastomers, all welded construction
- No orientation required
- Built as part of the completion string
- Simple construction
- Robust design
- No moving parts
- Can be used for both producers and injectors

Benefits

- Allows for last-minute changes to the configuration
- No potential leak paths
- Minimizes plugging risk
- Can decide on final flow profile configuration later in the project
- Can be re-configured to fit other applications or projects



EquiFlow® Adjustable Inflow Control Device

EquiFlow® Adjustable Inflow Control Devices

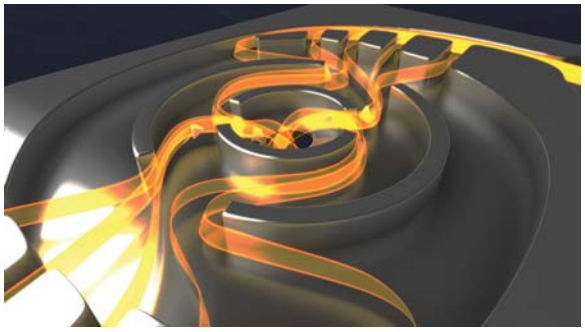
Basepipe OD	EquiFlow Inflow Control Device OD	PetroGuard® Wrap Screen OD	PetroGuard Mesh DS Screen OD	Inflow Control Device Length	Standard Metallurgy	Standard Temperature Range	
in.	in.	in.	in.	in.	Material	°F	*°C*
3 1/2	4.625	3.900	4.286	20.25	316L	325	*160*
4	5.125	4.450	4.796	20.25	316L	325	*160*
4 1/2	5.625	4.900	5.300	20.25	316L	325	*160*
5	6.125	5.450	5.815	20.25	316L	325	*160*
5 1/2	6.625	5.900	6.314	20.25	316L	325	*160*
6 5/8	7.75	7.025	7.446	20.25	316L	325	*160*
7	8.125	7.400	7.825	20.25	316L	325	*160*

EquiFlow® Autonomous Inflow Control Device

Horizontal wellbores are often favored by operators for exploiting narrow, oil-bearing formations to maximize contact with the payzone. However, when production causes unwanted water/gas to migrate to the wellbore or uneven production distribution results due to pressure drop in the tubing, operators turn to the Halliburton EquiFlow® autonomous inflow control device (AICD). The EquiFlow AICD will not only delay breakthrough of unwanted fluids but also upon breakthrough, restricts zones with high water and gas flow.

The EquiFlow AICD uses innovative dynamic fluid technology to differentiate between fluids flowing through the device to maximize oil production. The EquiFlow AICD works like a passive ICD during oil production, balancing inflow, yet restricts the production of water and gas at breakthrough to minimize water and gas cuts dramatically. It uses no moving parts, does not require downhole orientation, and uses the dynamic properties of the fluid to direct flow. This technology employs an engineered system of flow paths and channels to control fluid flow.

Oil, which has high viscosity, has a short, direct path through the EquiFlow AICD which results in a low pressure differential and high total flow rate. Water and gas, which have a low viscosity, spin at a high velocity, wasting energy which results in a high pressure differential and low total flow rate. Viscosity is the primary property to distinguish fluids, although density and rate can also have an impact. EquiFlow AICDs work as a system in a well, first delaying water/gas breakthrough, and when a breakthrough does occur, the local EquiFlow AICD creates a greater restriction allowing other zones to continue high oil production, maximizing recovery and value for an operator.



EquiFlow® Autonomous Inflow Control Device

Description	Oil Range	Fluid Restriction
Range 1	0.6-1.5cP	Gas only
Range 2	1.5-10cP	Gas and Water*
Range 3	3-200cP	Gas and Water
Range 4	150+cP	Gas and Water

*Water restriction for temperatures at or above 150°F (65°C).

Features

- Operates autonomously
- Contains no moving parts, electronics, or connections to the surface
- Requires no intervention
- Requires no downhole orientation
- Will cease flow restriction if unwanted fluid recedes
- Designs available to produce oil and restrict either water or gas
- Uses innovative dynamic fluid technology to direct flow
- Functions as a standard ICD prior to water/gas breakthrough
- Each device functions independently for precise response to the reservoir

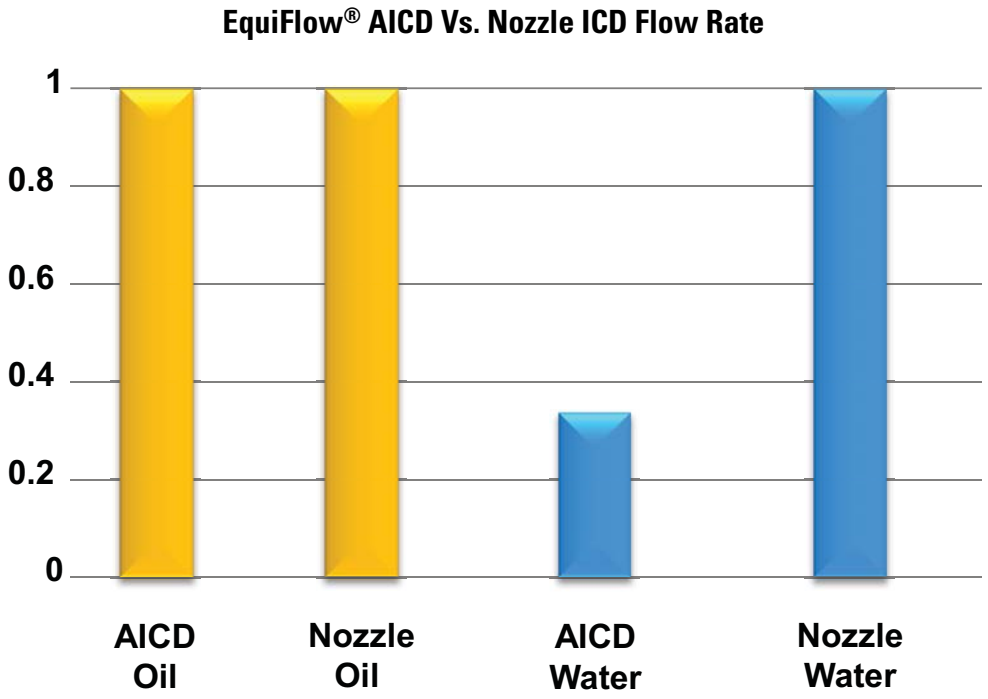
Benefits

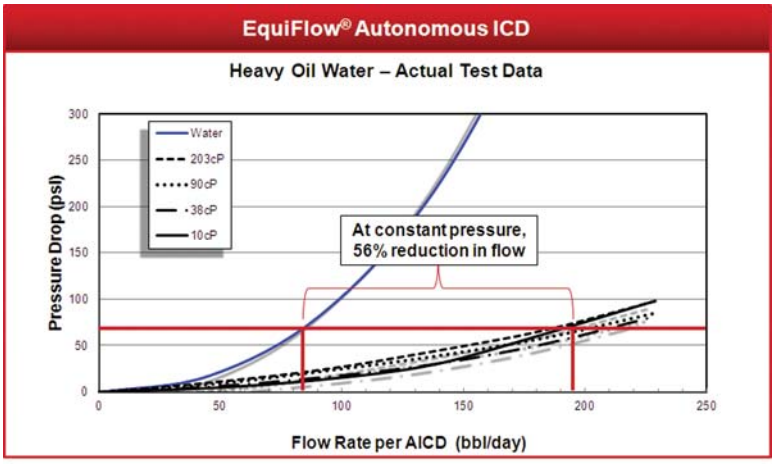
- Maximizes ultimate recovery
- Increases reliability through design simplicity
- Minimizes undesired fluid production, helping reduce associated cost and risk
- Delays onset of unwanted water/gas production

Application and Installation

Both the standard EquiFlow® inflow control device (ICD) and EquiFlow® autonomous inflow control device (AICD) are installed as part of the completion string and require proper configuration for optimal functionality. This requires close collaboration between Halliburton and the operator to determine the well parameters affecting the completion.

Once these criteria are known, Halliburton uses a combination of near-wellbore and full field reservoir simulations to arrive at the most effective completion arrangement. This determines the ideal number of compartments to be created, number of devices per compartment, and the proper pressure.





Note: The performance curves shown are for a three-insert range 3A EquiFlow® autonomous inflow control device. For flow performance specific to your application, contact your local Halliburton Screens representative.

Simulation Software for EquiFlow® ICD Completions

Simulation and modeling is critical to design optimized completions, which leads to greater value delivered by the well, using EquiFlow® inflow control devices (ICD) for injection and/or production. Halliburton has a unique software suite including NETool™ nodal analysis software and QuikLook® service to quantify the benefits and allow near-wellbore and long-term (transient) analysis of an EquiFlow completion.

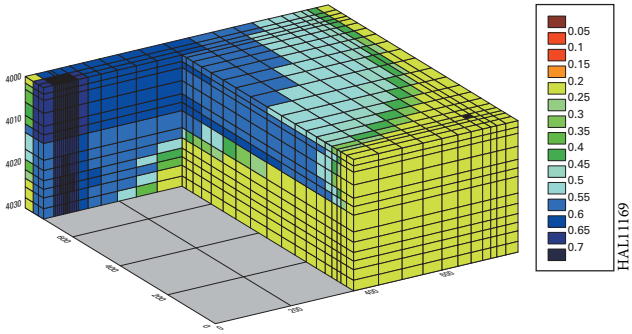
NETool™ Simulation Software

NETool software is a steady-state, network-based simulator for quick calculation of multiphase fluid flow through a well completion and near-wellbore region. The software allows the user to study how production is affected by changes in well placement, length, and equipment selection.

EquiFlow ICD completions can be set up in NETool software to simulate designs varying inflow parameters such as water cut, permeability, skin models, etc. Using NETool software, numerous scenarios can be run quickly in order to compare results and optimize the completion.

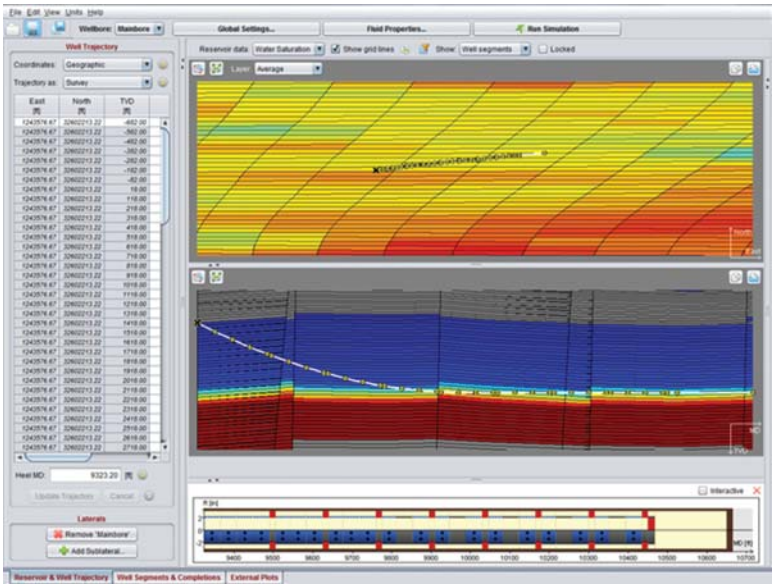
QuikLook® Simulation Software

The QuikLook reservoir simulation tool studies the long-term effects (transient analysis) of an EquiFlow ICD completion on the reservoir. QuikLook simulation software is exceptionally versatile and easy to run with powerful visualization and output report capabilities. Data can be imported from other simulators if needed. It is also possible to switch between sanding prediction and geomechanical models. Designed with the practicing engineer in mind, QuikLook software combines the power of numerical reservoir simulators with a simpler user interface capable of processing a 1,000,000 grid model. Its reservoir fluid management tool has a superior graphic interface to enter complex well data, check data consistency, produce supplemental plots, display interactive graphics, launch and monitor simulation runs, and analyze results.



Time = 200 Days

QuikLook® Simulator Screen Shot



Collaborative Philosophy

To maximize the benefits of an EquiFlow® inflow control device (ICD) completion, Halliburton works closely with clients to model completion and reservoir performance. This collaborative relationship allows both parties to agree on the expected results as well as build a basis for continuous improvement for future completions in the field.

Workflow Overview

Certain well and reservoir parameters must be known to begin the modeling process. The accuracy of the results depends greatly on the accuracy of the input data used by the software. Once input data is gathered, Halliburton Reservoir Engineers will use NETool™ software to model the completion and near-wellbore for up to three basic scenarios in most cases.

- Barefoot completion – Standard completion run in the field and used as a baseline against which all optimized completion scenarios are evaluated.
- Base case EquiFlow ICD completion – Run with an optimized EquiFlow ICD design in conjunction with compartmentalization of the pay interval using one or more zonal isolation devices.
- Optimized EquiFlow ICD completion – Model adjusted typically by increasing the number of compartments in the completion and employing EquiFlow ICDs with varying pressure drops.

The resulting outputs of these three scenarios clearly illustrate the benefits of leveling the production performance throughout the interval and are frequently considered sufficient evidence to move the project forward; however, more detailed reservoir response information is available.

Using a proprietary link between the NETool application and the QuikLook® reservoir simulator can quantify the benefits associated with each successive completion scenario. The result is a clear understanding of wellbore performance over time with regard to cumulative oil production increase, the amount of time unwanted water/gas production should be delayed, and the resulting cumulative reduction in unwanted water/gas production.

Zonal Isolation

Inflow control device (ICD) completions are most effective when compartments are created in the completion. There are two primary means of creating compartments in openhole inflow control completions: ZoneGuard® mechanical packers and Swellpacker® isolation systems.

ZoneGuard® Hydraulic-Set Mechanical Packer

The ZoneGuard packer family provides zonal isolation options for a wide range of openhole wellbore conditions. Applications include, but are not limited to, formation control, selective stimulation, and fracturing applications.

When an immediate seal is required, ZoneGuard packers include a hydraulic-set capability and a multi-durometer element package to deliver unsurpassed sealing performance.

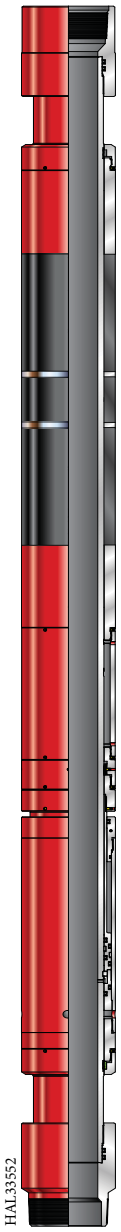
ZoneGuard HE Packer

The ZoneGuard HE packer is designed for situations where a high-expansion sealing element is required and large variations in hole gauge diameter are anticipated. The packer can be used for zonal isolation in formation control, selective stimulation, and fracturing applications.

The ZoneGuard HE packer is run as part of the completion string and can be set hydraulically with plug set below or with an isolation straddle tool when plugging is not possible. The packer contains a hydrostatic assist feature, which helps maintain positive pressure on the packer at all times.

Applications

- Openhole applications (horizontal or vertical)
- Water shutoff
- Gas shutoff
- Stimulation
- Production testing
- Isolation
- Selective production
- Stage cementing



ZoneGuard® HE Packer

Features

- Small running OD
- Large element expansion capabilities
- Multi-piece/multi-durometer element package
- Adjustable setting shear value
- Internal locking system
- Long-term isolation reliability
- Hydraulically set plugged tubing and isolation straddle
- Hydrostatic assist allows positive pressure on element

Benefits

- Selective production management in horizontal wellbores
- Reliably control inflow or injection within selected sections of the wellbore
- Wide range of openhole isolation capabilities with one packer design

ZoneGuard® HE Packer

Maximum Metal OD	Minimum ID	Minimum Bore Hole	Maximum Bore Hole
in.	in.	in.	in.
5.625	3.49	6 1/8	8 1/4
8.000	4.88	8 1/2	11 1/2

ZoneGuard® SR Packer

The ZoneGuard® SR (Short Radius) packer is designed for situations where tight radius well conditions are anticipated. The design features an anti-preset feature to help protect against premature setting of the packer during running operations. The packer can be used for zonal isolation in formation control, selective stimulation, and fracturing applications.

The ZoneGuard SR packer is run as an integral part of the production casing or casing string. The packer is set with hydraulic pressure either by setting a plug beneath the tool, or when plugging the completion string is not possible, by running an isolation straddle tool across the packer.

Applications

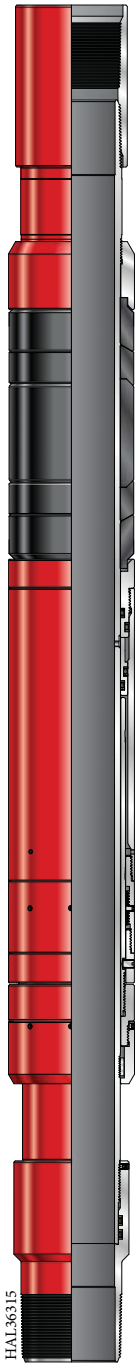
- Horizontal or vertical completions
- Openhole isolation
- Stimulation
- Stage cementing
- Water shutoff
- Gas shutoff
- Production testing
- Selective production

Features

- Long-term isolation reliability
- Small running OD
- Compact length for short radius well conditions
- Anti-preset feature
- Multi-piece/multi-durometer element package
- Adjustable setting shear value
- Internal locking system
- Multiple hydraulic setting methods

Benefits

- Ideally suited for short radius and higher differentials
- Enables selective production management in horizontal wellbores
- Reliably control inflow or injection within selected sections of the wellbore



ZoneGuard® SR Packer

ZoneGuard® SR Packer

Tool Connection	Maximum Metal OD	Minimum ID	Minimum Bore Hole	Maximum Bore Hole	Length	Temperature Rating	Pressure Rating
in.	in.	in.	in.	in.	in.	°F	psi
4 1/2 Blank	5.65	3.850	5 7/8	6 1/4	70.48	325	up to 10,000
4 1/2 13.5 lb API-LC	5.65	3.850	5 7/8	6 1/4	60.01	325	up to 10,000
4 1/2 13.5 lb API-BC	5.65	3.850	5 7/8	6 1/4	63.98	325	up to 10,000
5 1/2 23.0 lb API-LC	7.25	4.670	7 1/2	7 7/8	80.24	325	up to 10,000
5 1/2 23.0 lb API-BC	7.25	4.670	7 1/2	7 7/8	80.24	325	up to 10,000
5 1/2 Blank	7.25	4.670	7 1/2	7 7/8	80.24	325	up to 10,000
5 1/2 20.0 lb API-LC	8.00	4.670	8 1/2	8 3/4	80.36	325	up to 10,000
5 1/2 23.0 lb API-BC	8.00	4.670	8 1/2	8 3/4	80.36	325	up to 10,000
5 1/2 Blank	8.00	4.670	8 1/2	8 3/4	80.36	325	up to 10,000

Swellpacker® Isolation System

The Swellpacker® isolation system is based on the swelling properties of rubber in hydrocarbons or water, or both. The rubber swells up to 200% of its original volume, sealing the annulus around the pipe to achieve effective zonal isolation. Once deployed, the rubber retains its flexibility, allowing the Swellpacker isolation system to adapt to shifts in the formation over time, retaining the integrity of the seal. Its self-healing properties make this a truly innovative technology for all zonal isolation applications. It is a bonded-to-pipe product that can be delivered with any element length depending on the basepipe. Since the rubber is bonded to the basepipe, it is extremely robust and can hold significant differential pressures.

The Swellpacker system can be used in cased or openhole environments. In some openhole applications, operators may be able to avoid cementing and perforating altogether, reducing the expense associated with these operations. By reducing well construction costs, saving rig time, and isolating producing zones, the system helps enable previously unachievable levels of oilfield performance.

Swelling Delay Systems

To ensure the oil or water contained within well fluid does not affect the packer while it is run into the hole, Halliburton has engineered several systems that can delay the swelling process. These systems enable control of the elastomer swelling process so the setting time can be tailored according to customer needs, mitigating the risk of premature setting while optimizing the operating envelope. Swelling delay systems include polymers with built-in slower swelling properties and a variety of applied diffusion barriers. Customizing a design with either of these options, or using in combination, allows for creation of a well-specific engineered product.

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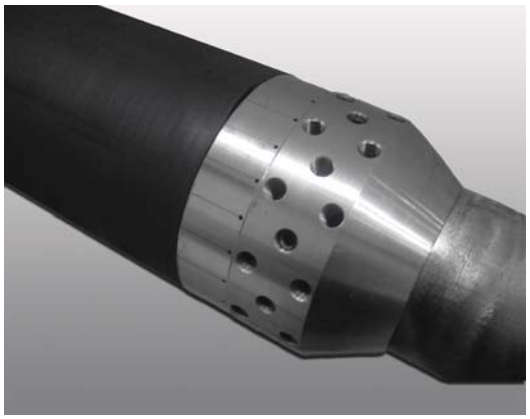
Swellpacker®
Isolation System

End Ring Design

End rings assist in increasing the differential pressure capability and guide the packer when run into the hole. Depending on the application and metallurgy requirements, the design can be anchored using set screws, a crimping process, or welding.

The Halliburton K2 end ring protects the rubber element while running in hole and further eliminates element extrusion once the packer is set. One of the benefits of this unique end ring is the ability to shorten tool length, while maintaining differential pressure. It also increases absolute differential pressure performance of the tools with testing performed to 15,000 psi across the packer.



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K2
End Ring

Swellpacker® Cable System

The Swellpacker® system can be delivered with a unique cable feed-through option that enables passage of single or multiple control lines and flatpacks for downhole monitoring, chemical injection, and SmartWell® completions without cutting the cables or lines. This removes the requirement for cable splices, control-line cuts, and cable stripping, greatly reducing the risk of failure. It provides an annular seal in cased and open hole, and a seal around the control lines or flatpacks capable of holding differential pressure. Installation of the cables through the Swellpacker system is performed on the rig floor at the time of running the completion and requires no extra rig time.

Applications

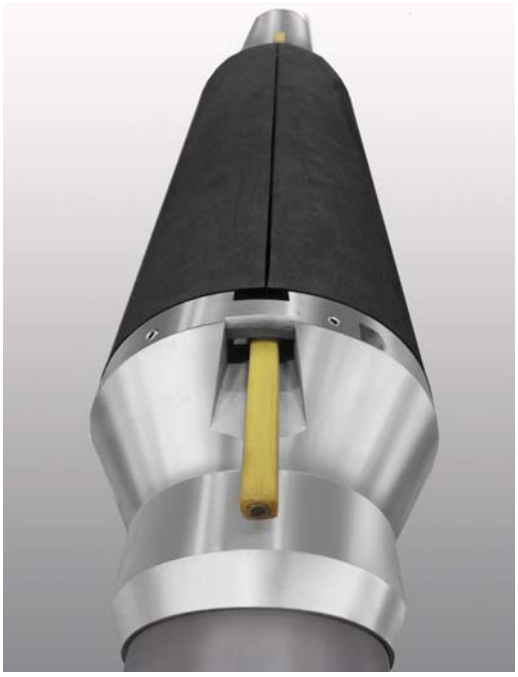
- Open and cased hole isolations
- Stimulation placement
- Open and cased hole straddles
- SmartWell completion systems
- Monitoring and chemical injection
- Water control
- Multilaterals
- Standalone screen sand control
- Compartmentalization for screen/ICD completions
- Gravel pack isolation
- Well construction

Features

- Manufactured on any oilfield tubular
- Suitable for cased and open holes
- Robust construction
- No moving parts
- Spliceless cable feed-through option
- Self-healing, interventionless technology
- Can be run in most all fluid environments
- Multiple polymers available to provide oil swelling, water swelling, and hybrid swelling solutions
- Engineered swelling delay system

Benefits

- No specialist operator required for installation
- Casing integrity is maintained
- Perfect seal for irregular borehole geometry
- Alternative solution to cementing and perforating in certain applications
- Complements cement to resolve well integrity issues
- Helps reduce operational risk
- Isolates producing zones more effectively
- Helps reduce well costs and rig time
- Cable feature increases system reliability by eliminating cable splicing and enables openhole SmartWell completions



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Swellpacker® Cable System

Swellpacker® Slip-On Isolation System

The Swellpacker® slip-on isolation system is another option for effective zonal isolation. This unique slip-on packer retains a full length internal seal against the pipe. Once deployed, the rubber retains its flexibility, allowing the Swellpacker system to adapt to formation shifts over time to maintain seal integrity. Its self-healing properties make it a truly innovative technology for all zonal isolation applications.

The Swellpacker slip-on isolation system does not require basepipe to be supplied up front in the manufacturing process and is installed at the service location or rig site by sliding over the pin end of the casing or tubing joint. This allows storing and stocking of the tools, simplifying logistics, and reducing cost significantly.

The system can be used in cased or openhole environments. In some openhole applications, operators may be able to avoid cementing and perforating altogether, reducing the expense associated with these operations.

Applications

Swellpacker slip-on isolation systems can be key components in gravel packs for isolation and standalone screen completions to reduce fines migration. In reservoirs prone to sand production, the slip-on tool helps enable increased productivity and reduced well construction costs since it can be installed without specialized operating personnel. In completions using inflow control devices, slip-on tools are used to create shorter compartments for improved reservoir management.

One of the main applications for slip-on systems is with hydraulic stimulation operations. Halliburton horizontal completions provide operators with new options for completing horizontal multizone wellbores and enable highly accurate fracture placement with little to no intervention. The service allows operators to selectively access, isolate, and stimulate multiple payzones in a single wellbore with the option to close off one or more zones at a future date. This makes multizone stimulation possible in a shorter time interval, leading to reduced overall well completion costs.

Features

- Suitable for cased and open holes
- Install on any non-upset basepipe
- Robust construction
- No moving parts
- Self-healing, interventionless technology
- Can be run in most all fluid environments
- Multiple polymers available to provide oil swelling, water swelling, and hybrid swelling solutions
- Engineered swelling delay system

Benefits

- No specialist operator required for installation
- Casing integrity is maintained
- Simplified logistics
- Permits last minute adjustments to placement
- Perfect seal for irregular borehole geometry
- Protect sand screens from plugging
- Alternative solution to cementing and perforating
- Helps reduce operational risk
- Isolates producing zones more effectively
- Helps reduce well costs and rig time

Swellpacker®
Slip-On Isolation System

Specialty Screens

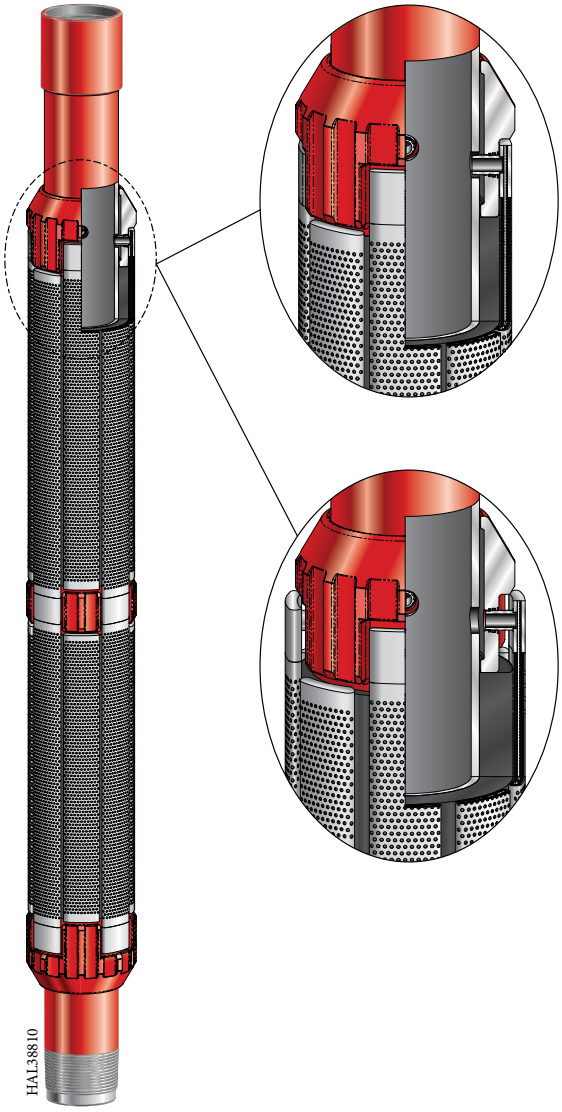
Compliant Screens

PetroGuard® Swell Screen

The PetroGuard® Swell screen provides an alternative to traditional expandable sand control techniques. The design combines Halliburton Swell Technology with bonded mesh filtration media to provide a self-expanding screen which delivers the benefits associated with traditional expandable solutions but with greatly reduced risk.

The system uses basepipe coated with swellable elastomer. Low-profile screen louvers are bonded to the elastomer and feed production into common manifolds via telescoping inflow tubes. The manifolds also act as centralizers to protect the screen when running in hole.

As the elastomer swells, the screens are deployed to the formation face to provide a robust screen solution delivering borehole support without any reduction in the mechanical strength of the completion.



PetroGuard® Swell Screen

Features

- Combines proven swellable properties with mesh screen
- Available with all basepipe metallurgies and threads
- Polymers available to provide oil and water swelling
- Installed like conventional screens
- Easily adapted for zonal isolation between screen joints

Benefits

- No expansion risk
- Places positive stress on the formation to reduce formation damage
- No metallurgy or thread limitations
- No compromise on collapse or thread rating
- No specialized installation/expansion equipment
- Reduced rig time

PetroGuard® Swell Screen

Basepipe OD		Screen OD (Pre-Swell)		Centralizer OD		Screen OD (Post-Swell)		Louver Flow Area (Total Cross Section)	
in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*	in.²	*mm²*
5 1/2	*139.7*	7.850	*199.39*	8.125	*206.38*	9.50 (tested)	*241.3 (Est)*	2.00	*1290*
3 1/2	*88.9*	5.425	*137.80*	5.750	*146.05*	6.80 (Est)	*172.72 (Est)*	1.10	*710*

Alternate Path Screens

PetroGuard® Shunt System

The PetroGuard® Shunt system for sand screens is an improved version of field-proven equipment. It provides an alternate flow path for gravel pack slurry distribution to help ensure a complete gravel (or man-made proppant) pack along the producing interval. The following can be achieved using the PetroGuard Shunt system:

- Resisting fluid leak-off to the reservoir while packing the interval
- Bypassing collapsed hole conditions
- Reducing erosion to the borehole wall/filter cake while pumping

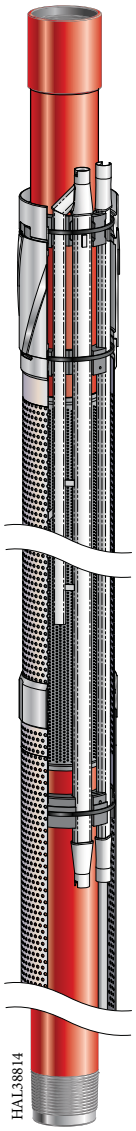
Designed primarily for gravel packing in horizontal wells, the PetroGuard Shunt system is a 2 × 2 design featuring two larger transport tubes and two smaller packing tubes mounted to standard Halliburton PetroGuard or PoroMax® sand screens in an eccentric design. An oriented thread is used to align the eccentric design between joints of sand screen, and a special openhole centralizer is integral to the shunt system. The design allows a pressure rating of 5,000 psi (3,750 psi working) for internal pressure in the shunt tubes.

The round jumper tube system allows for quick, easy assembly and reliable sealing. There are no set screws or other components that require the use of small hand tools on the rig floor while running the system into the well. The shroud covering the connection between joints is an integral component of the design with no bulky clamshell hinges or pins to be assembled at each joint connection. A sturdy, custom-designed centralizer covers and anchors the connection shroud in the run-in-hole position. Operational testing indicates this connection design may be assembled in 60% of the time necessary for assembling competing designs.

Extensive computer flow modeling was used to design for reduced friction in flow transitions at tube connections, providing improved erosion resistance and lower pressure loss. The improved hydraulic connections between transport tubes and packing tubes enable gravel packing at the highest possible rates.

Separate from the sand screen ratings, the PetroGuard Shunt system components are tested to torque, tension, and compression capabilities. The tested and rated values for the torque, tension, and compression of the 5.5-in. basepipe system are 5,000 ft-lb, 60,000 lbf, and 60,000 lbf respectively. All values match or exceed common industry specifications. In addition, the system was tested for dogleg tolerance by running the equivalent of 2,000 ft (61 m) through a 15°/100-ft radius dogleg of varying orientation with no damage to the system.

Variations of the standard 2 × 2 configuration are possible for small wellbore sizes or other geometry constraints.



PetroGuard® Shunt System

CAPS℠ Concentric Annular Pack Screen Service

Halliburton's CAPS℠ concentric annular pack screen service coupled with advanced pumping and fluids technology helps ensure successful sand control completions in unconsolidated sands to achieve optimum well productivity and longevity.

Applications

- In FracPac™ system applications with:
  - Formations with varying permeability
  - Formations with distinct layer separations
  - Deviated wellbores through zone of interest
  - Zones separated by un-perforated casing
  - Requirement for enhanced FracPac system placement reliability
  - Need for complete annular pack
  - Immediate or future recovery of FracPac system bottomhole assembly
- In horizontal gravel pack applications with:
  - Potential for annular blockage
  - Changing hole diameters
  - Hole stability issues
  - Potential for screen damage while running in hole

Features

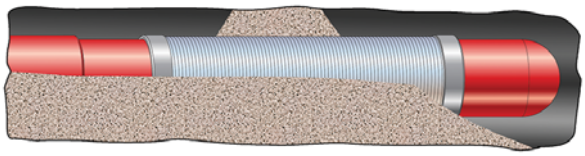
With CAPS service, a perforated shroud surrounds the screen and provides multiple flow paths. The concentric shroud with an engineered hole pattern increases the likelihood of placing a uniform frac pack treatment of complex intervals and complete gravel packing by allowing annular bridges to be bypassed. In addition, the shroud protects the screen, which can be of any type (mesh or direct wrap) while running into the well and resists future subsidence damage.

CAPS Service Adds Value

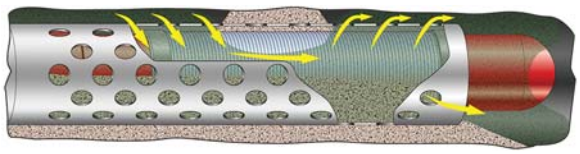
- Improves frac pack and annular gravel packing reliability of long or complex intervals
- Provides more uniform frac pack treatment of multiple sand layers
- Enhances alpha-beta packing for horizontal gravel packs
- Enables bypassing of annular bridges, unstable hole sections, or washouts

CAPS™ System Provides Flexibility for Well Conditions

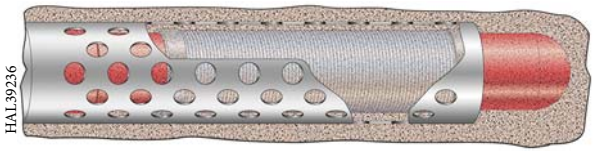
- Fluid losses in excess of 50% can be tolerated without detrimental effects on pack efficiency
- Added strength protects the screen from subsidence damage
- Can pack past annular blockages
- Enhances the proven alpha-beta wave packing method
- Improved frac pack placement
- Time-saving makeup
- Smooth outer profile facilitates retrieval for workovers
- Economical
- Larger screen size in open hole than similar systems
- Lower friction pressure/higher rate capability
- Treatment simulators assist in design



With a conventional gravel pack, premature bridging causes incomplete packing.



CAPS℠ service allows bypassing of bridges.



HAL39236

CAPS™ system enhances annular packing to form a complete pack.

Multizone Screens

PetroGuard® Modular Screen

Modular screens have an annular flow path outside the basepipe which is used to collect flow while gravel or frac packing around the screen or while producing the well and direct it to controlled entry points in the basepipe. This design enables shutoff of flow through some screen sections while others in the same well are open to flow, leaving the bore of all the screens open for service tools to pass through.

Flow from a modular screen enters the basepipe through one or more circulation/production sleeves connected to the modular screen joints. The number of these devices used is determined by the expected flow rates, and usually is less than the number of screens deployed. During packing, only a single sleeve at the bottom of the screen assembly is left open for circulating flow, eliminating the need for washpipe.

Modular screens are used with the ESTMZ™ enhanced single-trip multizone system to shut off some screens while others are being packed to eliminate the need for washpipe and enable screen isolation after packing is finished and the well is being completed.

With PetroGuard® direct-wrap technology, Halliburton has created a screen with an annular flow path under the screen filtration component, yet separate from the flow path inside the basepipe, using only a single pipe. Compared to alternative constructions using multiple pipes for creating a controllable annular flow path, the PetroGuard Modular screen is much more efficient in use of available space, enabling a larger ID or smaller OD.

The annular flow path is created by unique and larger screen rib wires between the non-perforated basepipe and screen filter media (wire-wrap or mesh). With this design, the annular flow path is connected between joints as needed through a communication sleeve installed over the connection after makeup.

This screen can be configured as a PetroGuard Wrap Modular screen or PetroGuard Mesh DS Modular screen.

Dual Basepipe Modular Screen

This screen provides an annular flow path much like a fixed absolute isolation system (AIS) when combined with mid-joint production and frac circulation sleeves. The modular screen is connected as a complete unit across each zone. Annular communication between joints is accomplished with the use of a bulkhead fitting on the inner basepipe. A single sleeve at the bottom of the screen is opened to allow flow, eliminating the need for washpipe seals and enabling the treatment of various zone lengths in the same wellbore.

Modular Screen

Accessories

EquiFlow® Sliding Side-Door® Inflow Control Device

The EquiFlow® Sliding Side-Door® inflow control device (ICD) with PetroGuard® sand screen combines ICD technology with mechanical sliding sleeve functionality. The ICD balances the influx of fluids, and the SSD allows for selective shutoff of sections in the production interval. The combination provides a simple and robust system for controlling and isolating flow while ensuring reliable sand control.

Sliding Side-Door sleeves are a robust and reliable method of isolating the tubing ID from the reservoir for a variety of reasons including fluid loss control, activation of hydraulically set downhole tools, zonal stimulation and production, and ICD shutoff for ultimate production control.

Inflow control devices have proven to be valuable assets in balancing the influx profile in long horizontal wells. Whether it be eliminating the heel-toe effect or mitigating high permeability variances from zone to zone, the ICD is a cost effective solution that reaps large rewards in total oil recovery over the life of the well.

The EquiFlow ICD provides the ability to balance the inflow from high productivity zones with that from low productivity zones. This increases overall productivity and ultimate recovery, delaying unwanted water or gas production.

The adjustability of the EquiFlow ICD allows the operator to change pressure drop settings on the fly with ease and reduces stocking costs and logistics as a single EquiFlow Sliding Side-Door ICD can cover a wide range of production scenarios.

Combining the ICD with a sliding sleeve allows selective intervention with a mechanical shifting tool to shut off and re-open ICDs along the length of the producing interval.

System modularity allows for adding, changing, and removing all aspects of the tool from the Sliding Side-Door sleeve function to the ICD capability to the type of sand screen required. The system as a whole can function with all three or just one of any of the components.

Features

- Sliding Side-Door ICD functionality
- ICD adjustability capability
- Standard Sliding Side-Door sleeve shifting profiles
- Variety of sand control screens available

Benefits

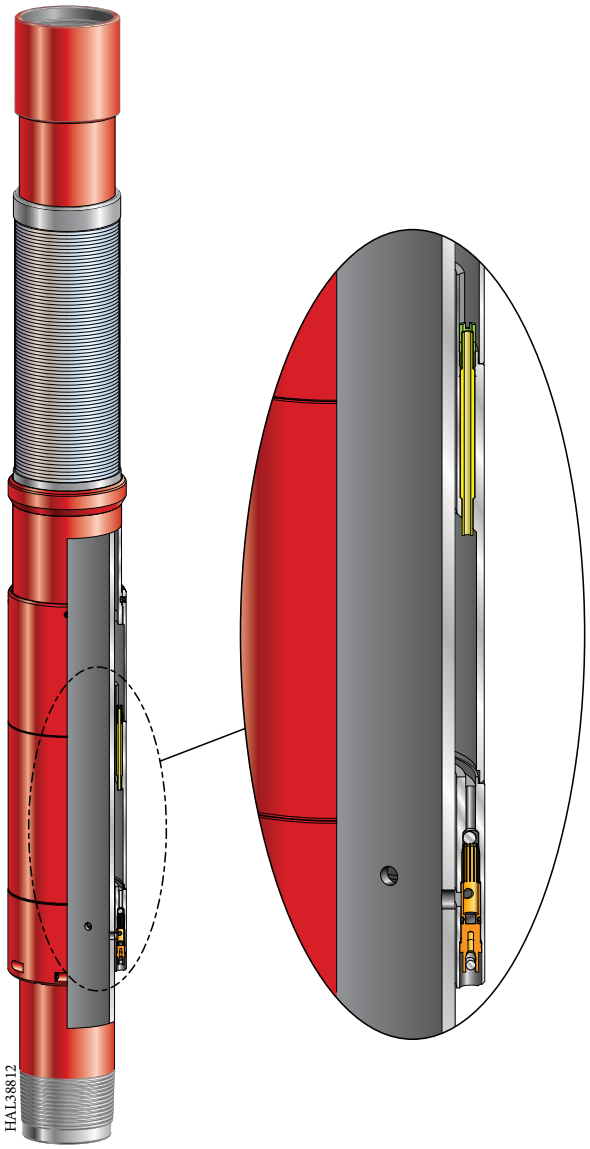
- Balanced production fluid influx
- Delay of water/gas breakthrough
- Fluid loss control
- Full shutoff of ICD

EquiFlow® Sliding Side-Door®
Inflow Control Device
with PetroGuard® Screen

PetroGuard® Screen and EquiFlow® Inflow Control Device with Remote-Open Valve

A remotely opened valve is available for use with PetroGuard® screens and EquiFlow® inflow control devices (ICD) that holds internal pressure when closed but opens the screen to full production flow after sufficient internal pressure is applied and released. This enables pressuring devices during completion operations even when screens are run for sand control. Valves are sealed to internal pressure only, allowing the screens to fill with well fluid when run into the well. When the screens are pressured high enough internally, they seal to prevent tubing-to-annulus flow. After pressure is released, the valves are opened permanently.

Any model of the PetroGuard sand screen compatible with an EquiFlow ICD can be built with the remote-open feature. Compatible screens can be supplied with the remote-open feature even if no ICD is used.

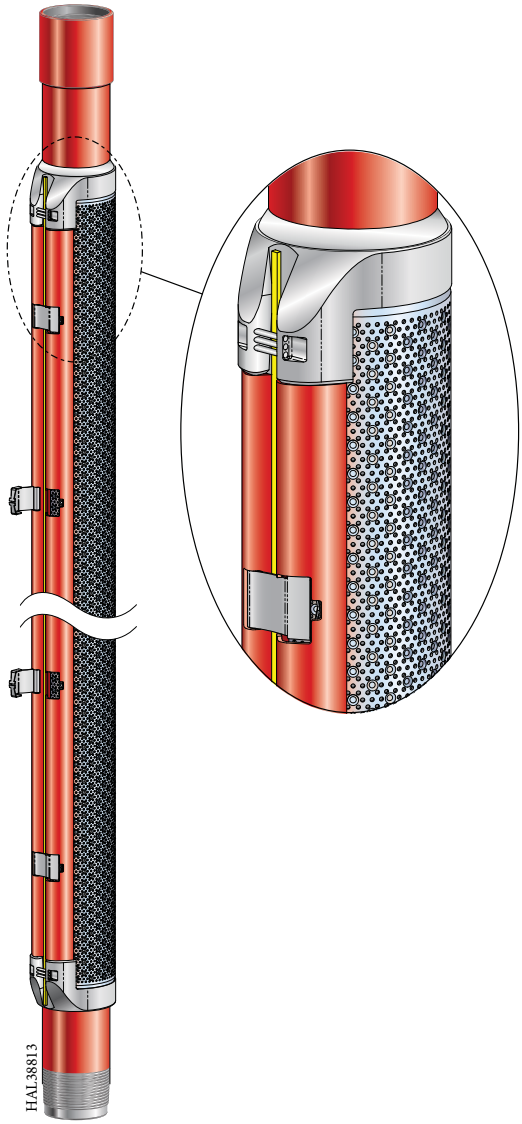


PetroGuard® Screen and EquiFlow® ICD with Remote-Open Valve

PetroGuard® Line and Cable System

The PetroGuard® Line and Cable system (LCS) enables encapsulation and protection of any standard cable or control line used in downhole applications on any standard Halliburton screen. The highly robust system can withstand the anticipated tension, torque, and bending loads that may be encountered while running in hole. Thorough testing has indicated the PetroGuard LCS system has no detrimental effect on screen strength and in fact increases some screen ratings. The system was also tested in burst using standard ISO 17824 procedures exceeding the ISO-rated burst pressure. In crush testing, it protected a standard 11 mm encapsulated fiber optic cable with the cable showing no loss in signal strength despite the screen being crushed flat.

The PetroGuard LCS system is compatible with any standard fiber optic, control, or electric-line configuration. It is fabricated eccentrically on any standard Halliburton sand screen with timed threads aligning the channels between joints. A purpose-built cable protector is used at connections between screen joints.



PetroGuard® Line and Cable System

PetroGuard® Line and Cable System

Basepipe OD		Screen OD (Concentric)		System OD (Eccentric)*		Cable Capacity**	
in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*
4	*101.60*	4.80	*121.92*	5.59	*141.99*	0.43 × 0.43	*11 × 11*
4 1/2	*114.30*	5.31	*134.87*	6.10	*154.94*	0.43 × 0.43	*11 × 11*
5	*127.00*	5.82	*147.83*	6.61	*167.89*	0.43 × 0.43	*11 × 11*
5 1/2	*139.70*	6.32	*160.53*	7.11	*180.59*	0.43 × 0.43	*11 × 11*
6 5/8	*168.28*	7.46	*189.48*	8.25	*209.55*	0.43 × 0.43	*11 × 11*

*Timed threads required
**Other configurations are available, contact your Halliburton representative.

Testing

Halliburton Sand Control Screens are rigorously tested to validate mechanical and hydraulic performance. Screens and inflow control technology products are subjected to the industry's most demanding testing protocol. Halliburton continuously strives to ensure products have been thoroughly proven in all loading scenarios. Burst and collapse testing of the sand screens portfolio is conducted in accordance with ISO 17824 Downhole Equipment Standard for Sand Screens. Contact your local Halliburton representative for more information about particular product ratings.

Screen Tensile Test

This test simulates screens under large tensile loads while running in hole. Screen joint (wire-wrap, shrouded mesh, etc.) is put under tensile load. Load is applied through the basepipe to test the effects on the filter media.

Screen Torque Test

This test simulates screens under large torque loads during make and break as well as running in hole. Screen joint (wire-wrap, shrouded mesh, etc.) is put under torque load. Load is applied through the basepipe to test effects on filter media.

Screen Cement Tensile Test

Filter media (wire-wrap, shrouded mesh, etc.) is cemented inside a length of casing such that there is no cement bond on the basepipe. Cemented casing is fixed and tensile load is applied to the basepipe. This test simulates a screen stuck inside an undersized or collapsed borehole. Load is applied to the filter media and welds, not through the basepipe as in a traditional tensile test.

Screen Cement Torque Test

Filter media (wire-wrap, shrouded mesh, etc.) is cemented inside a length of casings such that there is no cement bond on the basepipe. Cemented casing is fixed and torque is applied to the basepipe. This test simulates a screen stuck inside an undersized or collapsed bore hole. Load is applied to the filter media and welds, not through the basepipe as in a traditional torque test.

Screen Bending Test

This test simulates running the screen joint through doglegs and multilateral tool windows. Screen joint is fixed at both extremes. Two hydraulic rams inside the fixed points deploy radial load to the basepipe, forcing the screen joint to bend upward. Effects on the filter media are recorded at various bend angles.

Screen Crush Test

Screen joint is placed on a solid bed. A 16 × 12-in. steel plate is forced into the filter media applying radial force. Screen joint is crushed until the basepipe deforms. Effects on filter media are recorded at various basepipe deformation levels. This test simulates effects of a collapsed formation on a screen joint.

Screen Burst Test

End caps are placed on screen joint and a pre-sized plugging pill is pumped into the basepipe ID. The plugging pill bridges off on the filter media ID, creating hydraulic burst load. This test simulates maximum burst load a screen joint can withstand without damaging the filter media.

Screen Collapse Test

End caps are placed on screen joint and the entire joint is placed in a pressure vessel. A pre-sized plugging pill is pumped into the pressure vessel. The plugging pill bridges off on filter media OD, creating hydraulic collapse load. This test simulates the maximum collapse load a screen joint can withstand without damaging the filter media.

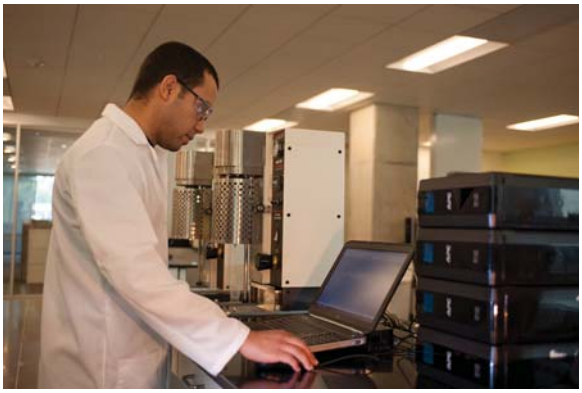
Sand Control Production Enhancement Products and Services

Halliburton Sand Control offers many products and systems to prevent the loss of asset value caused by sand production. The development of these products and systems is based on customer needs as well as comprehensive research in the areas of fluids and pumping technology, resins and coatings, fluids rheology, and formation damage prevention.

As exemplified by the Halliburton Sand Control Value Proposition: providing single-source customized solutions providing integrated sand control tool and pumping technology to improve completion efficiency and maximize reservoir producibility—the key to effective sand control service is the adaptation of these products and systems to the complex array of conditions that exist in oil and gas wells throughout the world.

Thorough knowledge of worldwide sand control procedures and practices helps ensure the service treatments Halliburton recommends and uses will be the most effective available in today's marketplace and the most compatible with the well and reservoir. Professional personnel using dedicated and specialized laboratory equipment, facilities, and computer-enhanced design programs gain insight into the critical role of formation and downhole conditions. Local experience in every part of the world, coupled with a dedicated support team, helps ensure selection of the optimum sand control technique.

Halliburton offers a variety of fluids and chemical systems for gravel pack services, FracPac™ completions, wellbore cleanup, matrix acid stimulation services, completion fluid loss control, fines damage control, and sand consolidation services as well as techniques to accommodate all sand control needs.



HAL37948

A study of rock properties helps researchers decide the correct sand control treatment.

FracPac™ Fluid Systems

Halliburton fracturing fluid systems and services such as SeaQuest® and DeepQuest® service are designed to meet the energy industry's needs for offshore stimulation. These systems are formulated to provide reliable treatments under a wide range of well and reservoir conditions while reducing non-productive time and optimizing stimulation results.

SeaQuest®, SeaQuest HT Service

SeaQuest service features a seawater-based fluid system for stimulating offshore reservoirs up to 300°F with SeaQuest HT service—both consolidated and unconsolidated. This versatile system is appropriate for both offshore fracturing and FracPac℠ service in either shelf or deepwater environments. Specifically designed for seawater mixing, the system does not produce damaging precipitates and provides greater flexibility for job design and delivery.

SeaQuest service features an HPG-based polymer and a proprietary blended crosslinker. This system combined with on-the-fly mixing ability greatly increases the volume of frac fluids an offshore stimulation vessel can deliver without returning to dock. SeaQuest service also has the latest developments in environmental advances for fracturing fluids.

- SeaQuest service:
  - Helps reduce delays due to stimulation vessel scheduling issues inherent with freshwater-based fluid systems
- InstaVis™ mixing system:
  - Helps reduce or eliminate rig operations time required to prepare frac fluid
  - On-the-fly rheology changes are simple
  - On-line quality control helps achieve desired fluid properties

Application Range

- Bottomhole temperature
  80 to 300°F (27 to 149°C)
- Base fluid density
  8.34 lb/gal to 8.7 lb/gal (1.0 to 1.04 specific gravity)

DeepQuest®, DeepQuest HT Service

DeepQuest service enables effective stimulation of ultra-deep reservoirs. This high-density borate crosslinked system provides a typical specific gravity of 1.14 to 1.50, whereas the typical specific gravity for an aqueous fracturing fluid is 1.0 to 1.04. The high density provides extra hydrostatic pressure at the formation to help reduce the pressure requirements on surface equipment. Without this fluid, many ultra-deep wells cannot be fractured due to current surface equipment pressure limitations.

Application Range

- Bottomhole temperature
  80 to 375°F (27 to 191°C)
- Base fluid density
  10.5 lb/gal to 12.5 lb/gal (1.26 to 1.50 specific gravity)

Delta Frac® Service

The classic, reduced-polymer-loading system, Delta Frac® service provides viscosity and proppant transport with up to 30% less polymer than conventional systems. The fluid systems reduced polymer loading helps reduce formation damage and provides superior regained conductivity. The fluid system is compatible with both enzyme and oxidizing breakers.

Application Range

- Bottomhole temperature
  80 to 200°F (27 to 93°C)
- Base fluid density
  8.34 lb/gal to 8.7 lb/gal (1.0 to 1.04 specific gravity)

Hybor™ Fluid Service

Hybor™ fluid is a delayed borate crosslinked fluid using guar or HPG gelling agent. Hybor fluid is recommended for wells with bottomhole static temperatures (BHST) of 125° to 300°F. It is a high viscosity fluid and can be run semi-continuously or batch mixed The crosslinked fluid reheals after shearing. Hybor requires precise pH control and is not compatible with carbon dioxide.

Application Range

- Bottomhole temperature
  125 to 300°F (52 to 149°C)
- Base fluid density
  8.34 lb/gal to 8.7 lb/gal (1.0 to 1.04 specific gravity)

Liquid Sand™ Delivery System

The Liquid Sand™ delivery system is a highly concentrated blend of proppant and carrying fluid. The Liquid Sand system allows proppant to be metered at very precise rates by blending with the dilution stimulation fluid to provide the required proppant concentration. Halliburton's Liquid Sand system can help improve quality control and performance, plus reduce the amount of equipment and personnel on location, the deck space required, and the time required.

Application Range

- Bottomhole temperature
  Depends on dilution stimulation fluid
- Base fluid density
  8.43 lb/gal (1.01 specific gravity)

Gravel Pack Fluid Systems

Exhaustive tests have been performed with numerous gelling agent candidates.

AquaLinear®, Aqualinear HT Gravel Pack Fluid Service

AquaLinear® service is a viscosified fluid service used for gelling a wide range of water-based brines, and treating fluids. Its properties allow simple mixing procedure and rapid viscosity development in water-based fluids including:

- Freshwater
- Organic and hydrochloric acid mixtures
- Potassium chloride brines
- Sodium chloride brines
- Sodium bromide brines
- Calcium chloride brines
- Calcium bromide brines

Applications

AquaLinear® fluid is a viscosified fluid with rheological properties different from those of hydroxyethylcellulose or similar linear gels. It is based on a biopolymer gelling agents. Brines gelled with these advanced biopolymer gelling agents are shear thinning and are uniquely efficient in static sand suspension. AquaLinear fluids allow a substantial amount of design flexibility for varying degrees of sand support for gravel packing, fluid loss control, friction pressure reduction, and other applications benefiting from a shear thinning, low damage fluid system.

This service can be designed so the gelled fluid suspends sand similar to that of a crosslinked gel. At lesser polymer levels, it produces a "slick brine" consistency giving reduced pumping friction pressures. The base polymer can be rapidly dispersed in water without going through a complex mixing protocol or extended time-consuming hydration period and its ease of mixing and rapid hydration applies to most of the brines used in completion operations. The polymer used in AquaLinear service is specially treated during its manufacturing process to enable it to yield consistently high return permeability from treated cores. The gravel pack gels attained with this polymer have another important characteristic. All gels, regardless of the level of polymer selected, possess outstanding fluid loss properties. This feature, in many instances, helps provide better sand packing by allowing tighter grain-to-grain contact than gels that rely more heavily on viscosity for sand support. This combination of features means total sand transport and excellent fluid loss can be attained in the same fluid. Field applications for AquaLinear service include:

- Gravel pack carrier fluid for Ex-tension Pac℠ service
- Gravel pack carrier fluid for Halliburton's CAPS™ concentric annular packing system
- Viscosifying completion fluid or brines for fluid loss control
- Sand washing and coiled tubing cleanout operations
- Viscosifying acid or brine for treatment fluid diversion
- Drill-in fluids rheology control

Application Range

- Bottomhole temperature
  80 to 270°F (27 to 132°C)
- Base fluid density
  8.34 to 14 lb/gal (1.0 to 1.68 specific gravity)

Ex-tension Pac℠ Service

Ex-tension Pac℠ service applies a FracPac℠ service level of quality service techniques to high-rate water packs (HRWP). It combines the technologies of AquaLinear Gravel Pack Fluid Service, Liquid Sand™ delivery system, SandWedge® service, and other service tools and chemicals listed in this catalog. Application of these services is optimized using the latest engineering technology and software, such as Ex-tranalysis™, FracPac-N℠ service, FracProPT®*, or GOHFER™** software.

The main objective of the Ex-tension Pac℠ service process is to maximize the amount of proppant placed (targeting a typical range of 200 to 250 lb/ft) into the formation and reduce overall skin values through a combination of on-site data analysis and Liquid Sand technology. Increased proppant placement plus lower skin values will result in an increase in overall production for the customer. In addition, the proven benefits of SandWedge® technology (SandWedge® OS, SandWedge ABC service) can be combined in the Ex-tension Pac process to further enhance well productivity and sand control reliability.

Hydropac℠ Service

Hydropac℠ service uses a gravel pack technique using high concentrations of packing solids carried in a gelled aqueous fluid. The fluid is gelled with an extremely low-residue hydroxethyl cellulose (HEC) gelling agent. This polymer gelling agent provides maximum gel clarity and viscosity per pound, ease of preparation, and the best possible permeability retention after treatment. Reliable low-corrosion breaker systems, which accommodate both low and high-temperature hole conditions, are available. These breaker systems assure quicker, more thorough polymer removal after the pack is established. As much as 20 lb (9.1 kg) of pack sand can be pumped per gallon in this water-based viscous gel system.

Benefits

- Improved gravel packs – Relatively high leakoff potential and good sand transport enables tighter gravel packs, particularly in packing perforation tunnels.
- Fast cleanup – Recovery of original formation permeability is fast and returned fluids are disposed of easily.
- Versatility in selecting mixing water – Gels may be prepared using a wide variety of filtered brines.
- Versatility in gel break times – The sand transport life of gels can be tailored to well requirements by treating with breaker additives, which influence gel viscosity during a prescribed time.
- Versatility in initial gel texture and strength – Gels meeting a variety of needs can be prepared by increasing or decreasing the polymer concentration.

Application Range

- Bottomhole temperature
  75 to 230°F (24 to 110°C)
- Base fluid density
  8.34 to 12.5 lb/gal (1.00 to 1.5 specific gravity)

HAL11834

Varying viscosities show the versatility of Hydropac℠ service gels

High-Rate Water Pack Systems

The high-rate water pack gravel placing method uses rates higher than a normal water pack treatment (5 to 10 bbl/min) to enhance gravel placement into the perforation tunnels. Due to the higher rates, a friction reducer or small amount of gelling agent is sometimes used to reduce friction pressures.

Water Pack Systems

The water pack gravel placement technique has proven efficient in openhole gravel packs, horizontal, extended reach, and highly deviated wells. Successful completion of cased hole wells (especially extended reach and highly deviated wells) normally includes a gel-sand or acid prepack stage to pack the perforation tunnels. The annular pack is then completed with a low-density water pack.

Benefits

- No temperature limitation
- Excellent annular packing under a variety of conditions

Application Range

- Bottomhole temperature
  No limitations
- Base fluid density
  8.34 to 19.20 lb/gal (1.00 to 2.30 specific gravity)

**FracProPT is a registered trademark of Pinnacle Technologies*
***GOHFER is a trademark of Barree & Associates*

Gravel and Proppants

All Halliburton fracturing sands, gravel pack sand, or synthetic proppants meet or exceed specifications adopted by current ISO / API standards.

A number of fracturing and gravel pack sand sizes are available. The fracturing sand size is chosen to ensure packed fractures with a high-flow capacity and sufficient strength to resist crushing. Gravel pack sand size is chosen to produce packs that will resist plugging by using Saucier's criteria.

Synthetic proppants (i.e., proppants stronger than sand) fall into three different categories: high-strength sintered bauxite, intermediate-strength (and density) sintered bauxite, and ceramics. The size and type proppant is chosen to provide for a highly conductive fracture.

ISO / API Gravel Pack Gravel

ISO / API standard compliant gravel pack sands are available in the following sizes and have a specific gravity of 2.63 and an absolute volume of 0.0456 gal/lb.

- 12/20 US Mesh
- 16/30 US Mesh
- 20/40 US Mesh
- 30/50 US Mesh
- 40/60 US Mesh
- 50/70 US Mesh

Low Density Intermediate-Strength Ceramic Proppants

Ceramic proppants have a specific gravity and bulk density close to sand. The specific gravity ranges from approximately 2.65 to 2.75. These ceramic proppants have greater strength than sand but less strength than the intermediate- and high-strength sintered bauxite proppants.

Intermediate-Strength Proppants

Intermediate-strength sintered proppants have been introduced for closure pressures from about 3,000 psi (206.89 bar) to about 10,000 psi (689.66 bar). These are higher strength materials than sand and because of their specific gravity are more easily transported in the fracture than sintered bauxite.

High-Strength Proppants

High-strength proppants such as sintered bauxite can give higher fracture flow capacity than sand or the intermediate-strength materials under many treating and formation conditions. Sintered bauxite is especially suited for wells with closure pressures in the range of 10,000 to 15,000 psi (689.66 to 1034.50 bar). Field applications have proven its value in many operating areas. Special laboratory fracture flow tests can assist in selecting the propping agent to give maximum fracture flow capacity in a particular formation.

Conductivity Endurance Technology for High-Permeability Reservoirs

Field experience and recent third-party testing have led to a more thorough understanding of key factors about conductivity endurance for high permeability completions that involve fracturing:

- Intrusion of formation material into the pack contributes to decreased production in virtually all formations, even “clean” sands. Formation material entering the pack and plugging pore spaces continually decreases flow area and increases flow path tortuosity. The result: rapid production decline. Some multi-rate buildup tests indicate these effects account for as much as 80% of total skin.
- Stress cycling contributes to reduced effective fracture width. Stress cycling occurs, for example, when flow rates are changed or the well is temporarily shut in. This cycling causes the pack to shift and enables formation material to intrude. The result: rapid production decline.

Conductivity endurance technology helps achieve better long-term conductivity and sustained production through two primary mechanisms:

1. Stabilizes the proppant pack/formation interface which greatly reduces the intrusion of formation material into the pack.
2. Stabilizes the pack so it is resistant to damage during stress cycling. The cohesive nature of the coated grains helps prevent the pack from shifting and allowing formation material to intrude.

Conductivity endurance fracturing incorporates Halliburton's proprietary SandWedge® agent and proppant coating technologies with treatment design and proppant selection based on understanding the formation properties.

SandWedge® ABC Service

SandWedge® conductivity enhancement system is specifically designed to enhance fracture conductivity resulting from treatments with water-based fluids. This technology chemically modifies the surface of the proppant grains, resulting in increased porosity and permeability of the proppant pack and enhanced frac fluid cleanup.

Extensive testing has verified the ability of the SandWedge agent to stabilize the proppant pack/formation interface to greatly reduce intrusion of formation material into the proppant pack. In addition, SandWedge enhancer has been shown to control the effects of diagenesis. It remains active almost indefinitely for long-term pack stability and conductivity to help achieve improved production.

The aqueous-based SandWedge ABC service delivers all the benefits of Halliburton's proprietary conductivity enhancement technology and adds the benefits of being operationally more efficient, versatile, and reliable while providing improved health, safety, and environmental (HSE) performance. SandWedge ABC service also enables important applications in remedial treatments.

Applications

As an aqueous-based system, SandWedge ABC enhancer can be added directly to water-based treating fluids. This means it is now possible to control further damage caused by fines invasion and migration in existing propped fractures and minimize subsequent fines damage. It can also be used as part of the fracturing fluid system.

Features and Benefits

- Helps maintain a high production rate for a longer period of time
- Provides improved HSE performance and reliability
- Enhances frac fluid cleanup (Figure 1)
- Highly effective in both hard rock and unconsolidated formations for primary or remedial applications (Figure 2)
- Enables treatment of existing proppant packs to help prevent further damage caused by fines invasion (Figures 3 and 4)
- Delayed onset of tackiness prevents coating of mixing equipment with sticky material. This eliminates the need for special solvents on location, reducing environmental exposure. The coating process is improved resulting in more uniformly coated proppant.
- Can be used to treat most wells from low temperature to more than 450°F to provide improved and sustained fracture conductivity.

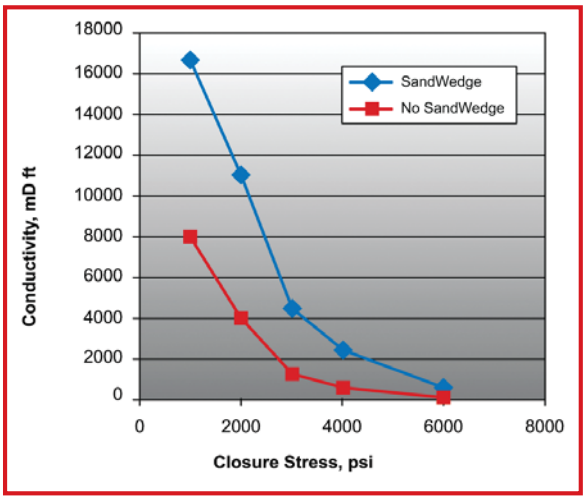


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Figure 1: Coating proppant with SandWedge® enhancer typically results in conductivity enhancement of 20 to 30% when measured with base brines. When conductivity is determined utilizing actual complete fracturing fluid, the enhancement is typically a 100 to 200% improvement. Improved conductivity contributes to better frac fluid cleanup and increased long-term production.

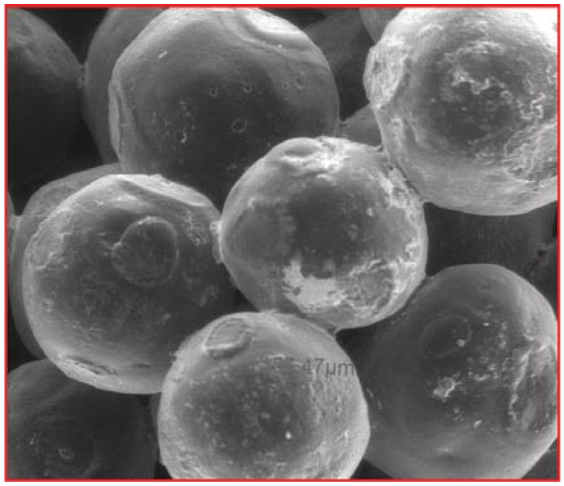

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Figure 2: SandWedge ABC enhancer coats the proppant causing it to become permanently tacky to help control intrusion of formation material (fines) into the proppant pack, reduce proppant settling and help maintain proppant strength-all leading to improved long-term conductivity.

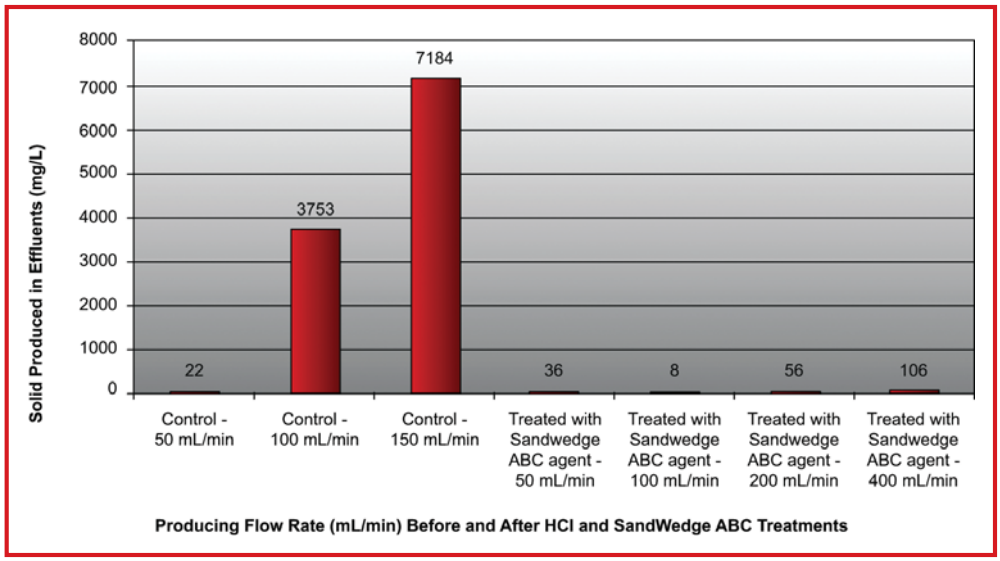

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Figure 3: This graph shows total suspended solids in effluents collected at increasing flow rates before and after treatments of 15% HCl acid and diluted SandWedge® ABC solution. An acid treatment was introduced to the sand pack that was damaged by invaded formation fines, sand, or scale buildup to remove these materials. After the acid treatment, a diluted SandWedge ABC solution was used to treat the sand pack to lock the formation sand and fines in place. Notice that at over twice the flow rate, solids production was virtually negligible after the sand pack was treated with SandWedge ABC agent.

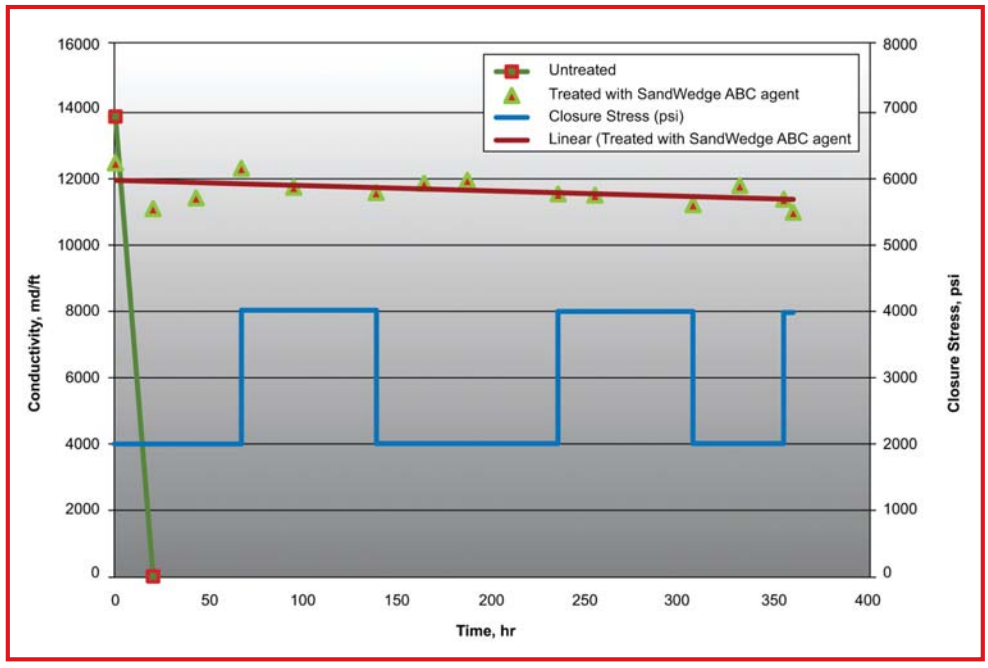

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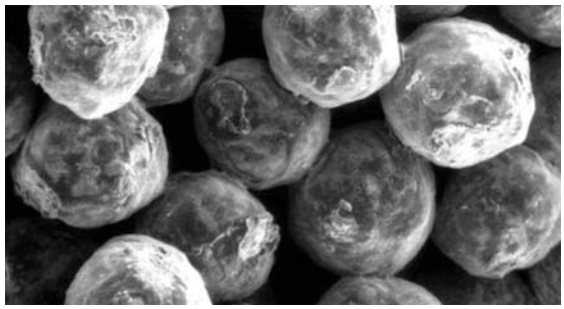
Figure 4: Using a standard API conductivity cell, conductivity was compared between unconsolidated sand packs with and without SandWedge® ABC enhancer. Silica flour was used in simulating the unconsolidated formation. Lightweight ceramic proppant was used as a propping material with loading concentration of 5 lb/ft². Testing was performed at 180°F and closure stresses of 2,000 and 4,000 psi. The stress cycle was repeated several times with the results indicating that the treatments were effectively stabilizing the unconsolidated fines that made up the formation. Note that conductivity declined to zero after only about 20 hours in the untreated sample but remained high throughout the stress cycles in the sample treated with SandWedge ABC agent.

SandWedge® OS Service

SandWedge® OS (offshore) enhancer is a more environmentally acceptable version of SandWedge NT enhancer optimized for dry-coating applications. In addition to having improved dry-proppant coating properties, it does not require a flammable label, and the working viscosity is reduced. This material was formulated for use in the Gulf of Mexico (GOM) offshore environment. It will pass the "Oil and Grease" test in the GOM and is currently used on more than 75% of the frac work.



PropStop® ABC service provides cohesion between grains without damaging permeability or conductivity of proppant pack.

PropStop® ABC Service

The aqueous-based PropStop® ABC service provides proppant flowback control in a safer and easier to use system. PropStop ABC service is essentially noncombustible and safer to handle. It is also highly compatible with many other treatment fluids, enabling simplicity in the field and easier system deployment.

Remedial treatments to apply a resin coating to the proppant pack have proved effective in controlling flowback. PropStop ABC service was developed as an alternative to solvent-based resins. It is able to create a high-strength consolidated pack using a small amount of consolidating material. The reduced material volume needed—in conjunction with the ability to be foamed—makes PropStop ABC service more economical. Since foam is self-diverting, longer intervals can be treated using a simple bullheading process. The foamed fluid also increases capillary forces and provides improved strength development in a proppant pack.

Application

This service is deployed using coiled tubing or bullheading. Enhanced placement is achieved with Pulsonix® TFA service.

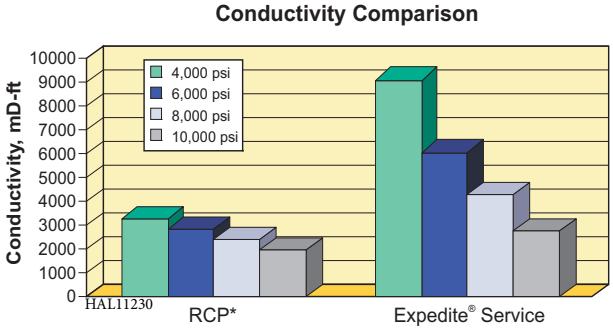
Features and Benefits

- Provides cohesion between proppant grains without damaging permeability or conductivity of proppant pack
- Helps maintain highly conductive fractures and long-term productivity
- High-strength consolidation can be achieved with small amounts of material
- Helps eliminate many health and safety hazards
- High flash point makes system easier to manage
- No special solvents required on location for equipment cleaning
- Can be applied using bullheading or coiled tubing
- Enables treating long intervals; foam acts as a resin extender and is self-diverting

Expedite® Service

In formations where controlling proppant flowback following fracture treatments is a primary consideration, Expedite® service can help improve production and the net present value (NPV) of treatments in several ways:

- Enhances or maintains proppant pack conductivity
- Widely used resin-coated proppants and fibrous flowback control materials placed in the proppant pack matrix often reduce conductivity under high closure stresses
- Applied to proppant on-the-fly so no excess resin or coated proppant is left after treatment



Expedite service uses Halliburton's exclusive direct proppant coating process to apply a proprietary resin mixture to all the proppant used in a fracturing treatment.

- Enables earlier production of hydrocarbons after fracturing than is possible with conventional resin-coated or non-coated proppants
- Promotes cleanup of fracturing fluid
- Eliminates fibrous materials plugging surface equipment
- Helps eliminate damage to coated proppants inherent in handling and storage

An Expedite service formulation is available to help improve fracture treatment results in virtually any formation. Formulated as Expedite Lite, Plus, or Max treatments based on the required coating amount, it is applicable from 80 to 550°F (27 to 288°C).

Formation Stabilization Systems

Sand control by chemical consolidation involves injecting chemicals into the unconsolidated formation to provide grain-to-grain cementation. Cementing the sand grains together at the contact points creates a strong consolidated matrix. Subsequent flushes displace excess resin material further into the formation to clear the pore spaces between grains, allowing the best possible permeability for oil and gas flow. Halliburton chemical consolidation systems help control sand without mechanical screening devices restricting the wellbore or limiting access to lower producing zones. Ideal for dual-zone completions, these systems permit access to a lower zone without disturbing the upper zone. This is accomplished by consolidating the upper zone and gravel packing the lower zone.

The following processes are currently available:

- SandTrap® ABC formation stabilization system
- SandTrap® formation stabilization system
- HYDROFIX℠ service

SandTrap® ABC Formation Consolidation Service

With recent emphasis on recovery of bypassed hydrocarbon reserves and extending mature field production, formation consolidation techniques present viable completion options. Since economics is a key decision criterion, resin consolidation offers a reliable and cost-effective sand control solution.

Applications

SandTrap ABC service can be applied to the following new or existing well completions.

- Cased and perforated
- Supported openhole which includes stand-alone screens or perforated liners
- Screenless through-tubing recompletions for accessing bypassed reserves
- Failed gravel pack or frac pack sand control completions

Contact of the treatment with the annular gravel pack and surrounding formation sand can be enhanced with fluidic oscillator technology provided by Pulsonix® TFA service.

Benefits

SandTrap® ABC service provides benefits that facilitate the use of resin consolidation for oil and gas reservoirs requiring sand control.

- High-strength consolidation can be achieved with small amounts of low-viscosity consolidating material.
- High flash point makes the system easier to manage, especially in offshore environments.
- Large over-displacement of this material is not required to re-establish permeability.
- No special solvents required on location for equipment cleanup.
- Treatments can be bullheaded due to no requirement for isolating the zones to be treated.
- Foam acts as a good diverter, helping to achieve a more effective system in long production intervals by overcoming the effects of variable permeabilities.
- Foam acts as a resin extender by increasing the bottomhole volumes and making it operationally easier to place small-volume consolidation treatments.
- The introduction of a foamed fluid into a proppant pack increases the capillary forces which results in better coating and improved strength development.

SandTrap® Formation Consolidation Service

Formation consolidation is not a new concept and in many applications has proved to be a successful means of providing sand control. SandTrap service provides features that facilitate the successful use of resin consolidation for oil and gas sands requiring sand control including:

- Operational simplicity with brine and solvent preflush stages, two-component consolidation fluid, and brine post-flush
- Low-viscosity fluids for more effective placement into reservoirs with variable permeability
- Good consolidation performance in sands with clay mineral content
- Post-flush displaces the consolidation fluid to retain pay sand permeability

This system incorporates a solvent/resin mixture with very unique properties that cause the resin to be deposited as a thin film on the formation and clay surfaces.

The solvent package is used to provide a very low-viscosity treating fluid and to provide a means to get the resin in contact with the formation. The resin is internally catalyzed so that no post-flush treatments are required to initiate the curing process. The resulting treatment procedure involves only five stages:

- Brine pre-flush treatment
- Solvent pre-flush
- Formation consolidation system
- Oil spacer
- Brine post-flush over-displacement

The absence of any severe contrasts in fluid rheology provides much more uniform, consistent resin placement.

Applications

SandTrap® service can be applied to new or existing sand completions. The treatment can be placed several ways:

- Down production tubing
- With jointed pipe and service packer
- With coiled tubing

New perforations can be treated down production tubing for zone changes or recompletions to access additional reserves.

Coiled tubing and SandTrap service can put existing zones back on production without the expense of a rig-based workover.

For wells with failed gravel packs, SandTrap service can be used to consolidate the existing gravel pack and reservoir sand in the problem area to put a shut-in well back on line. Sand consolidation treatment fluids commingled with nitrogen have proved to be an effective solution for gravel pack repair. Contact of the treatment with the gravel pack and surrounding sand can be enhanced with fluidic oscillator technology provided by Pulsonix® service.

Operation

Preflushes to condition the formation sand for a high-strength consolidation and improved permeability retention. The preflush allows the mineral surfaces to attract the consolidation fluid so that a thin, uniform coating of consolidation fluid coats the formation matrix grains.

Connate water is displaced from the pore spaces to improve treatment penetration into the pores and subsequent displacement by the post-flush to enhance consolidation strength and permeability retention.

The solvent-based resin systems include two epoxy systems: the SandTrap 225 service high temperature version and the SandTrap 350 service low temperature version as well as a furan-based system which can be catalyzed in different ways.

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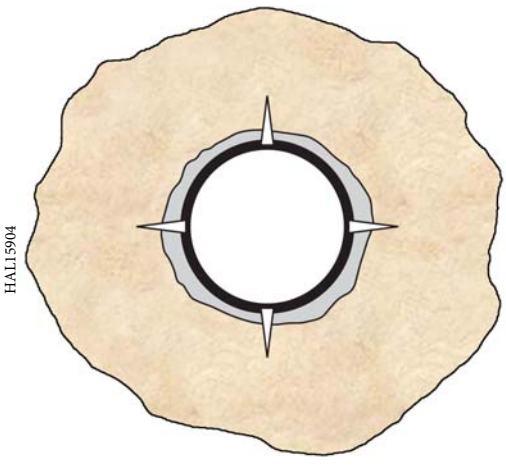

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SandTrap® service uses resin technology to consolidate the near-wellbore area to help prevent sand production. The consolidated area maintains almost 100% of initial permeability.

Pulsonix® TFA Service

Pulsonix® TFA service incorporates Halliburton's coiled tubing expertise with proven fluidic oscillator technology. Tuned frequency amplitude (TFA) enables fine tuning rates and frequencies based on the requirements of the application.

Applications

Pulsonix TFA service is excellent for a wide variety of vertical and horizontal wells, both openhole and cased hole, including oil, gas, injection, geothermal, CO_2, water, disposal, monitoring, and solution mining. It provides proven performance for these operations:

- Removing deposits from the near-wellbore area, perforations, and screens
- Perforating damage
- Mud and cement damage
- Scales of all types
- Emulsions
- Formation fines
- Drilling damage
- Paraffins and asphaltenes
- Water and gas blocks
- Enhancing treatment fluid placement and effectiveness
- Stimulating high permeability formations
- Treating perforations and wellbore to improve the effectiveness of subsequent stimulation treatments including gravel packing and frac packing
- Removing fill from openhole or casing
- Optimizing injection profiles

Features

- Wide range of rates enables matching the bottomhole assembly and achieving the benefits of flow capacity
- Strong amplitude provides effective near wellbore action
- Side and bottom ports enable direct impingement on perforations
- Functions at low flow rates

Benefits

- Breaks up many types of near-wellbore damage.
- Helps remove debris from the perforations
- Enhances the permeability of the near-wellbore area
- Waves can penetrate deeply into the formation for more effective cleaning and stimulation
- Cleans out fill and stimulates the well in one trip resulting in fast operations
- Eliminates the stand off requirements of jetting nozzles
- Can be run in conjunction with other tools

HYDROFIX℠ Service

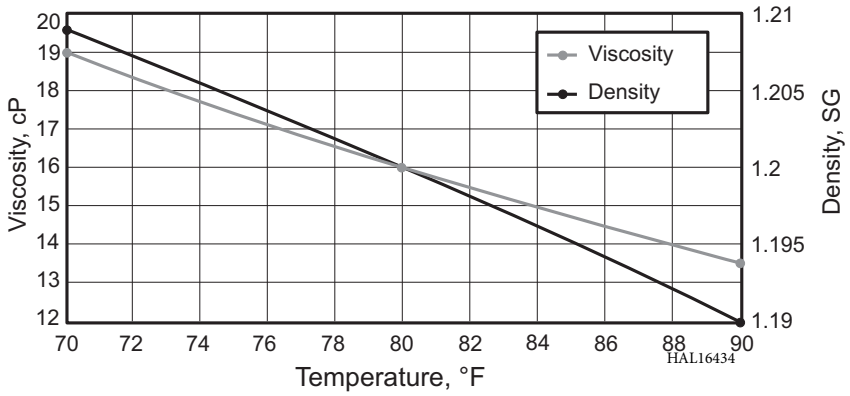
HYDROFIX℠ service is specifically designed to consolidate sandstone. The resin has an affinity for quartz. The furan resin becomes attached to the sand grains. A spacer is pumped followed by an HCl acid catalyst which overflushes the resin from the pore spaces and catalyses the residual resin coating. Nitrification of the resin and other phases of HYDROFIX service have allowed successful treatments of even long intervals [150 ft (45.72 m)].

Applications

- Gravel pack screen repair
- Stringer gas sands that would be uneconomical to gravel pack
- Through-tubing sand control
- Free pack proppant and formation flowback prevention

Application Ranges

- Bottomhole temperature
  80 to 225°F (27 to 107°C)
- Base fluid density
  9.20 lb/gal (1.10 specific gravity)



HYDROFIX℠ Service Resin Properties

In-Situ Resin Consolidation Services with Overflush Hardener Systems

Product Name	Type Resin	Temperature Range		Base Fluid	Perforated Interval		Hardener	Shut In Time Required	Minimum Permeability for Placement
		°F	°C		ft	*m*		Hours	
SandTrap® ABC	Epoxy	70 to 230	21 to 110	3-7% KCl	0 to 25*	0 to 7.62	Internal	24 to 72	100 mD
PropStop® ABC	Epoxy	70 to 250	21 to 121	3% KCl	0 to 25*	0 to 7.62	Internal	24 to 72	N/A
SandTrap® 225	Epoxy	70 to 225	21 to 107	5% NH_4Cl	0 to 25*	0 to 7.62	Internal	4 to 24	<50 mD
SandTrap 350	Epoxy	200 to 350	93 to 177	5% NH_4Cl	0 to 25*	0 to 7.62	Internal	4 to 24	<50 mD
SandTrap 550	Furan	300 to 550	148 to 288	5% NH_4Cl	0 to 25*	0 to 7.62	None	4 to 24	<50 mD
HYDROFIX™	Furan	80 to 225	30 to 107	15% NaCl	0 to 25*	0 to 7.62	HCl Acid	4 to 24	35 mD

*With nitrification, the zone length can be extended much beyond the stated length utilizing foam diversion.

Wellbore Cleaning Products

DuraKleen® Service

DuraKleen® service uses an environmentally enhanced water/aromatic solvent emulsion system that represents an important advancement in maintaining long-term production rates.

- Cleans and dissolves asphaltene deposits
- High solvency power is enhanced by the dispersing effects of the surfactant
- Strips asphaltenes and waxes from tubulars as well as the formation
- Provides a longer-lasting treatment
- Leaves the formation in a water-wet state which delays deposition of asphaltene deposits
- Improved environmental and safety footprint as compared to traditional asphaltene removal systems
- No BETX (benzene, ethyl benzene, toluene, or xylene)
- Flash point greater than 145°F (63°C)
- Requires less transport of chemical components due to high water content
- All components are fully miscible
- May be batch mixed or easily mixed on-the-fly
- Can be applied wherever heavy oils are produced

Paragon™ Solvent

The Paragon™ family of hydrocarbon solvent blends can dissolve solid or semi-solid paraffin and asphaltene deposits that form or collect near the formation face and on tubular goods. Various versions of Paragon solvent are available:

- Paragon 100E+™
- Paragon EA™

Applications

- Helps remove paraffin deposits in wellbore and production tubing
- Helps remove excess pipe dope and thread lubricants from tubing and casing
- As a preflush, helps remove oil residues before scale removal or matrix acidizing operations
- Functions as a component in emulsified stimulation systems, such as PAD™ Paragon acid dispersion system and HV-60™ high-viscosity emulsified acid
- Can either be circulated or spotted and allowed to soak depending on the application

N-Ver-Sperse™ Invert Oil-Based Mud Cleaning System

N-Ver-Sperse O™ and N-Ver-Sperse A™ Fluids

Two perforating and breakdown fluids have been developed for cleanup of invert oil-based muds. N-Ver-Sperse O™ and N-Ver-Sperse A™ dispersant fluids were specifically designed to help remove invert emulsion-type drilling muds which can greatly hinder stimulation treatments. N-Ver-Sperse O fluid is a hydrocarbon-based fluid, and N-Ver-Sperse A fluid, containing wetting agents and dispersants, is an aqueous-based fluid. Need for a hydrocarbon-based or an aqueous-based fluid, economic factors, hydrostatic pressures, and other conditions determine choice of fluid. Both fluids can be used either for removal of mud from the wellbore or as formation breakdown fluids. When used as mud cleanout fluids, they are circulated at fairly high rates to prevent the solids in the mud from settling out. As a perforating fluid, N-Ver-Sperse O fluid would be superior to an acid or common aqueous perforating solution due to the adverse effects these fluids have on the invert muds. In instances where large volumes of whole mud are lost into the producing formation during drilling, N-Ver-Sperse flush solutions can be used very effectively in a series of flushing and back flowing or swabbing stages to pull the mud solids toward the wellbore and clean them out.

Wellbore Cleaning Products and Services Reference Chart

Chemical or System	Purpose	Oil-Based/ Aqueous-Based	Flash Point	Comments
Paragon EA™	Remove paraffin/pipe dope/crude oil residue	Oil-Based	155°F (68°C)	Intended for use in Europe/Africa
Paragon 100E+™	Remove paraffin/pipe dope; degrease producing wells in waterfloods	Oil-Based	150°F (66°C)	Contains no BETX- 100% aromatic
N-Ver-Sperse A™	Disperse/remove invert emulsion-type drilling fluids	Aqueous-Based	N/A	
N-Ver-Sperse O™	Disperse/remove invert emulsion-type drilling fluids	Oil-Based	N/A	

Formation Damage Removal Systems

Sandstone 2000™ Acid System

In the 1980s, Halliburton analyzed fluid returns from an HF acidizing treatment. The results of the analysis were completely unexpected and defied chemical theory of the time. From these studies and subsequent research projects, Halliburton can now better provide an HF acid job with preferred effects. The changes in HF acidizing were primarily made to avoid precipitation products from secondary reactions occurring between spent HF fluids and aluminosilicate minerals in the formation. Previously, these reactions formed scales, partially or completely obstructing gravel pack screens. The precipitation of fluosilicate formation minerals was also discovered in wells that contained sodium feldspar and potassium feldspar. Halliburton can now provide help in finding solutions to improve wells. Through research and testing, we learned how to tailor treatments to deal with formation minerals like potassium feldspar, sodium feldspar, illite clay, zeolites, carbonates, etc. New procedures and additives minimize problems with ion exchange, acid-unstable clays, high temperatures, and more. The Sandstone 2000™ system is the product of exhaustive research and field testing. New discoveries led us to lay aside old HF acidizing theories and develop better ways to avoid problems and remove damage in sandstone formations. Sandstone 2000 acidizing system can be divided into damage removal systems and formation conditioning systems.

Sandstone 2000 Damage Removal Fluid Systems

Sandstone Completion™ Acid

Sandstone Completion™ acid promises to be the new standard for treating most sandstone formations and the safest system when mineralogy and nature of damage are uncertain. It provides maximum HF dissolving power without secondary precipitation. In addition, it prevents aluminum precipitation better than acetic acid and helps maintain formation compatibility.

Fines Control™ Acid

Conventional matrix acidizing with HF acid is only effective for removing shallow clay damage 2 to 4 in. from the wellbore at most. Halliburton Fines Control™ acid is a retarded HF system used for treating sandstone formations damaged by the migration and/or swelling of silica, feldspars, and clays. This retarded acid process penetrates to remove deep damage caused by fines and swelling clays.

Very few sandstone formations are sensitive to this system. There is far less tendency for it to unconsolidate formations than conventional HF systems.

K-Spar™ Acid

K-Spar™ acid is the treatment of choice in formations high in potassium feldspar and illite. It increases production by reducing fines migration and near-wellbore damage over a wide range of temperatures.

Volcanic™ Acid

This organic-HF acid system replaces acetic and formic-HF fluids which produce severe secondary precipitation. It protects formations too sensitive to HCl acid. Compatible with HCl-sensitive minerals such as chlorite and zeolite, it can also be used at higher temperatures. In addition, this acid system helps avoid sludging of crude.

Silica Scale™ Acid

The Silica Scale™ acid system is designed especially to remove silica scale from geothermal wells.

Guardian™ Acid Enhancement System

This system introduces a new concept in formation protection beyond the limitations of conventional acidizing additives. Even properly designed additive blends have been known to have caused sludging and formation damage with certain crude oils. Guardian™ enhancer provides excellent sludge and emulsion control even with problem crudes. In addition, the Guardian enhancer system outperforms conventional acid inhibitors.

The Guardian system minimizes adsorption of additives on the formation. The advantages of the Guardian enhancer package include:

- Acid blends are greatly simplified.
- Generally, the additive loading is significantly reduced.
- Less mutual solvent and dispersants are required.
- Enhanced corrosion protection is attained, even during flowback.

Consider the Guardian enhancer system whenever:

- Sludging crude oils are present.
- The acid blend requires an anionic surfactant.
- Acid blend stability is required.

Formation Conditioning Systems

In addition to choosing the optimum HF fluid, selecting pretreatment and preflushes is very important and can determine the ultimate success of a treatment. Halliburton calls these fluids formation conditioning systems. These fluids prepare the formation for the damage removal fluid systems.

N-Ver-Sperse™ O System

N-Ver-Sperse™ O is required when oil-based whole mud is lost to the formation. Acid mixing with oil-based mud will cause emulsions resulting in severe damage. Whole mud must be removed before sandstone acidizing.

Mud-Flush™ System

The Mud-Flush™ system is the fluid system of choice for removing water-based whole mud.

MCA™ Blend

The MCA™ mixture is a blend of Morflo® III surfactant and dilute HCl. This mixture helps eliminate water and emulsion blocks, cement filtrate damage, and shrink natural clay minerals.

Organic Solvents

Organic solvents are required to remove any oily deposits such as heavy oil, pipe dope, paraffins, and asphaltenes from the formation face. If the aqueous HF fluid cannot contact the damaged formation, it will be unable to improve the well performance.

HCl for Pickling Tubing

It is very important to remove iron scales from coiled tubing, wellbore tubing, and casing prior to treatment with acid fluids. HCl is the recommended acid for this process, while organic acids such as acetic acid are not effective in dissolving the iron scales at any temperature. The fluid should be circulated and recovered without allowing the spent acid to enter the formation. Performing a pickling treatment (tubing cleanout) causes the acid preflush and HF stages to remove formation damage more effectively.

Gidley's CO_2 Conditioner

In this process, carbon dioxide (CO_2) is used to improve the performance of HF acidizing treatments in oil wells. The system involves the use of about 100 to 200 gpf of CO_2 under miscible conditions to displace the oil from the matrix in the near-wellbore area. CO_2 is also used throughout the acid stages to provide enhanced energy for cleanup as well.

Benefits

- Reduction in terminal upsets due to emulsions created during the acidizing treatment.
- A tendency to prevent preferential acidizing of water zones: The xylene, CO_2 preflush conditions the formation in the critical wellbore area, leaving the matrix with a relative permeability to acid (water) which is fairly even across the entire zone. Due to the removal of the oil by the preflush, this occurs regardless of whether the matrix initially contained oil or water. While use of CO_2 does not prevent water production, the CO_2 treatments have resulted in less enhancement of water production than previous treatments for some operators.
- Improved treatment response attributed to two factors: better invasion of the matrix due to the removal of the oil and prevention of immobile matrix emulsions stabilized by oil wet particles.

CLAYFIX™ 5 Conditioner

CLAYFIX™ 5 conditioner is necessary for ion exchange and for moving formation fluids away from the wellbore to avoid incompatibilities with the acid fluids. Typical ion-exchanging minerals include Smectite, mixed layer clays, and zeolites.

HCl Conditioners

HCl is the most common preflush prior to the HF stage. Typical concentrations are 5 to 15%. The purpose of an acid preflush is to stimulate ion exchange, to prevent mixing of formation fluids with the HF stage, and to remove carbonates. In addition, HCl very effectively removes polymers, such as HEC, xanthan, and K-Max™ material used during completion operations.

Clay-Safe™ H Blend

Clay-Safe™ H blend is a special blend of an organic acid, Clayfix™ salt for ion exchange, and 5% HCl. It can be used safely ahead of HF acid blends. However, this blend has been optimized for safe removal of polymer damage and other applications where unprotected breaker acid mixtures could damage HCl-sensitive formations.

Clay-Safe F Blend

Clay-Safe F blend is a special blend of two organic acids, Clayfix salt for ion exchange, and no HCl. It can be used safely ahead of HF acid blends because of the inclusion of Clayfix salt. At temperatures above 180°F (82.22°C) this blend of organic acids has been shown to act synergistically to remove certain polymer damage. It has been optimized for safe use in formations with clay instability ratings of 25 or greater.

KelaStim℠ Service

KelaStim℠ service is a simpler, more environmentally-friendly service to chemically stimulate carbonate or mixed carbonate/sandstone formations. The fluid system reduces the complexity of the treatment by eliminating some of the flush stages.

SandStim℠ Service

A chelant-based acidizing fluid for sandstone formations, SandStim℠ fluid has less risk of damaging the formation than traditional acid blends.

Chart of Formation Conditioning Systems

Fluid System	When/Why Use This System
Mud Cleanout	
Mud-Flush™	Whole water-based mud losses
N-Ver-Sperse O™	Whole oil-based mud losses
Wellbore Conditioning	
PARAGON™ or other organic solvents	Asphaltene/paraffin problems, heavy oils, pipe dope
HCl for pickling	Removal of iron scales, preventing them from entering the formation
Oil Well Conditioning	
Gidley's CO_2 Conditioner	Emulsion problems, terminal upsets, improves acid penetration into oil zones
Matrix Conditioning	
Clayfix™ 5 Conditioner	Preflush ahead of Sandstone acids to allow for ion exchange
5-15% HCl	Carbonate removal, ion exchange, removal of polymer damage
Clay-Safe™ 5 Conditioner	HCl-sensitive mineralogy
Clay-Safe H Conditioner	HCl-sensitive mineralogy, where removal of polymer damage (K-MAX™, HEC) or high carbonate levels with acid fluids is required
Clay-Safe F Conditioner	HCl-sensitive mineralogy

Sandstone 2000™ Damage Removal Systems

Name	Advantages
Silica Scale™ Acid	Contains a high HF concentration to remove silica scale from geothermal wells
Sandstone Completion™ Acid	Provides maximum dissolving power without secondary precipitation, prevents aluminum precipitation, and is the fluid of choice when mineralogy is unknown
Fines Control Acid	Is a retarded system, removes deep damage caused by fines and swelling clays, and prevents fines migration.
K-Spar™ Acid	Is compatible with formations high in feldspars and illite and prevents fines migration
Volcanic™ Acid I and II	Contains an organic acid system, is compatible with HCl-sensitive minerals, and can be used in higher temperature applications

Filter Cake Breaker Systems

N-FLOW℠ Stimulation Service

Drill-in fluid (DIF) filter cake deposits are a major cause of restricted flow from the producing formation. N-FLOW℠ stimulation service effectively removes drill-in fluid filter cake residue and near-wellbore formation damage in conventional or gravel packed openhole completions.

N-FLOW service has proved effective in both carbonate and sandstone reservoirs for the following applications:

- Long treatment intervals of horizontal wells
- Gravel packed wells
- Water-based drill-in fluid cleanup
- Synthetic- or oil-based drill-in fluid cleanup
- Stimulation of dolomite and limestone formations in new and mature wells

Benefits

- In-situ acid production delivers acid to wherever the fluid has been placed. The treatment fluid contains a precursor of an acid (which is not acidic itself) that provides time-controlled downhole organic acid release for carbonate removal.
- Avoids placement problems associated with using a reactive acid
- Helps achieve excellent zonal coverage. The controlled reaction N-FLOW™ chemicals dissolve DIF filter cake components along the entire pay section and do not cause hot spots resulting in premature loss of treating fluids
- More environmentally acceptable, less damaging and less hazardous than comparable HCl-based systems. Unlike cleanup materials containing hydrochloric acid and corrosion inhibitors, the initial non-acidic nature of the agents used in the service lowers the safety risk to personnel and the environment, and avoids corroding downhole hardware, including screens, packers, and tubulars
- Effective in a wide range of completion fluids
- N-FLOW service is available for both water-based and synthetic oil-based DIFs

Fluid Loss Control Systems

One of the major problems encountered in the wellbore prior to gravel packing is excessive fluid loss to the formation. When the service tool is being tripped out of the well after a gravel packing job, fluid loss is again a concern. Workovers and completions require non-damaging products and systems to control fluid loss and keep fluids in balance.

LO-Gard® Service

LO-Gard® service helps control fluid loss (leak off) in perforating/gravel pack completions and horizontal gravel pack applications where fluid loss through the filter cake could cause problems with placing the gravel. For openhole completions, the service provides important benefits:

- Solids-free, low-viscosity, lost-circulation control system
- Decreases formation permeability to aqueous fluids thus limiting leakoff into the following:
  - High permeability streaks
  - Leaky, thinned or eroded drill-in fluid wall cake
  - Breached or fractured wall cake
  - Natural or hydraulic fracture networks
- Results in no significant permeability loss to oil or gas, > 95% retention is typical with 100 md core material
- Applicable over a broad range of temperatures and permeabilities
- Effective in both sandstone and carbonate lithology
- Shut-in time not required
- Requires no breaker
- Easier mixing than with conventional viscous gel systems
- Can be formulated for a wide range of pill densities in specific brines
- Reduces water inflow during production
- Polymer can be removed if required
- Environmental performance – passes Gulf of Mexico oil and grease test for overboard discharge

The highest fluid loss level controllable with the LO-Gard system is unknown; however, in one example, an attempt to kill a 300°F well with 10-lb/gal brine was unsuccessful because the formation was taking fluid at 18 bbl/hr. Pumping 80 bbl of LO-Gard service agent reduced fluid loss to 0 bbl/hr, and the operation was completed successfully.

K-Max Plus℠ Service

K-Max Plus℠ service batch-mixed, non-damaging blocking material provides abrupt fluid loss control and helps control wellbore sloughing in open hole. In cased holes, it helps prevent sand sloughing, especially in highly deviated completions.

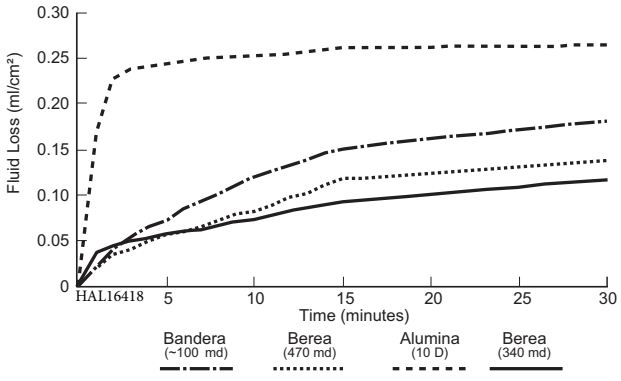
K-Max Plus service provides an HEC-based, high viscosity, crosslinked gel pill that requires no heavy-metal crosslinker. Its crosslink is pH controlled and completely reversible. The service provides clean breaks with both internal and external breaker systems. Break back times can be designed for a variety of applications. Reversible crosslinking technology has been shown to yield regain permeability of 90 to 100% with an external breaker in Berea sandstone. K-Max Plus service uses a liquid gel dispersion system, designated WG-33™ gelling agent, for easy preparation.

K-Max Plus™ material does not require shearing or filtering. Gel remains flowable in the wellbore while controlling fluid loss and sloughing at the formation face. It can also be circulated out without loss of fluid control. When time comes to remove the pill, lowering the pH of surrounding fluid reverses the crosslink state and converts the pill to a flowable fluid easily circulated or produced from the wellbore. This service has been used to control fluid loss into 10 darcy permeability sand with minimal damage. The semi-rigid pill can also be used for the following applications:

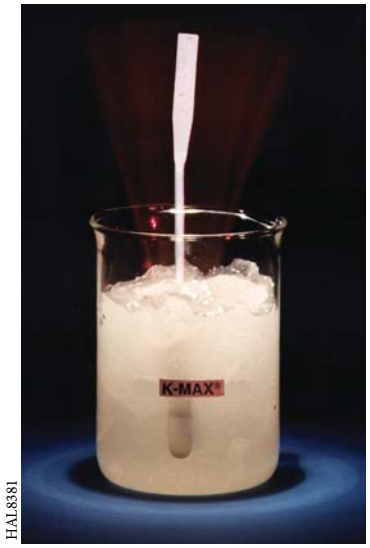
- Help support poorly consolidated formations
- Isolate zones for temporary diverting during stimulation
- Aid in other operations in multizone completions

Application Ranges

- Bottomhole temperature
  75 to 300°F (24 to 149°C)
- Base fluid density
  8.34 to 14.00 lb/gal (1.00 to 1.68 specific gravity)



K-Max Plus™ Fluid Loss



K-Max Plus™ Material

Max Seal® Fluid Loss Control Additive

Max Seal® additive is a unique fluid loss control additive that is supplied ready-to-use and is easily dispersed into most brines with minimal mixing energy. The particles in Max Seal additive that help stop fluid loss are essentially highly crosslinked gel ready to disperse in wellbore fluids. The Max Seal additive crosslinking chemistry is the same as that in K-Max Plus℠ service. Reduction of pH readily causes the polymer to uncrosslink and eventually revert to a water-thin fluid when workover activities are complete.

Applications

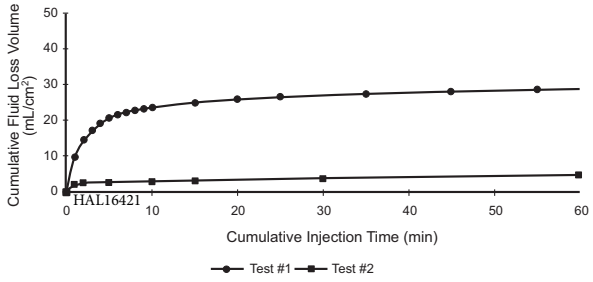
- After perforating
- After gravel packing or performing a frac pack
- During and after horizontal hole cleanup of drilling fluid filter cake
- Completion and workover operations
- Pill to enhance hole stability to reduce or prevent formation sloughing

Application Ranges

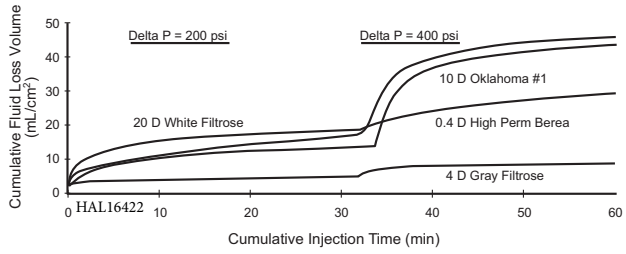
- Bottomhole temperature
  75 to 275°F (24 to 135°C)
- Base fluid density
  8.34 to 11.60 lb/gal (1.00 to 1.39 specific gravity)

Benefits

- Ready-to-use product requires no on-location gel preparation
- Readily disperses in most completion fluids
- Low friction pressure allows it to be placed through small diameter tubing
- Provides effective fluid loss control
- Easily removed with acid
- Little or no lost well productivity
- No special storage (will not freeze and is not damaged by summer storage)



Max Seal®
Static Fluid Loss Test



Max Seal®
Dynamic Fluid Loss Test

Z-Max℠ Service

Z-Max℠ service non-particulate gel system combats fluid losses in wells where zinc bromide or other high-weight brines are being used as completion or workover fluids. Z-Max service is similar to the K-Max℠ service crosslinkable HEC system. However, Z-Max service is specially formulated to gel $ZnBr_2$ brines. Like the K-Max system, superficial application of a mineral acid solution causes Z-Max service to break back to a water-thin texture, allowing it to be reversed out of the wellbore or produced back from perforation tunnels and the formation matrix.

Application Ranges

- Bottomhole temperature
  75 to 225°F (24 to 107°C)
- Base fluid density
  14.5 to 18.5 lb/gal (1.74 to 2.22 specific gravity)

High Viscosity Linear Gels

For controlling fluid losses in situations where permeabilities are low and overbalance pressure is not high, Halliburton offers viscous linear gels. The normal gelling agent is processed HEC used at high concentrations. Other systems, such as AquaLinear® gravel pack service gels, have seen some use due to their uniquely applicable rheology. But all these systems depend upon building up a bank of viscous fluid in the formation pore spaces away from the wellbore. For highly permeable formations or high overbalance situations, the linear gels will typically require numerous applications and ultimately may not work at all. The preferred temperature range is below 230°F (110°C) for HEC and other linear gels typically degrade at elevated temperatures.

Application Ranges

- Bottomhole temperature
  80 to 230°F (27 to 110°C)
- Base fluid density
  8.34 to 19.20 lb/gal (1.02 to 2.30 specific gravity)

Breaker Agents

- Enzymes
- Oxidizers
- Acids

Fluid System Additives

Breaker Systems

HT Breaker

HT breaker is a strong oxidizing breaker used at temperatures from 75 to 200°F (23.8 to 93.3°C). It is typically used for breaking K-Max Plus™ pills and AquaLinear® service gels.

GBW-30™ Breaker

GBW-30™ breaker is a water-soluble enzyme breaker for aqueous-based gelling agents at temperatures below 120°F (48.8°C). Its reactive strength is approximately 10 times that of the original GBW-3 breaker.

SP™ Breaker

SP™ water soluble oxidizing breaker for aqueous-based gelling agents is used at temperatures above 120°F (48.8°C).

Oxol II™ Breaker

Oxol II™ breaker is a delayed release oxidizing breaker for low-temperature applications where enzyme breakers may not function. It is effective in the 70 to 140°F (21 to 60°C) temperature range. Combined with CAT®-3 activator, it can be used in high concentrations to give performance profiles superior to those of a persulfate breaker.

ViCon NF™ Breaker

ViCon NF™ breaker is an aqueous form of a strong oxidizer breaker shown to be effective in breaking a variety of oilfield polymer gels. Breaker concentration is determined by downhole temperature, stabilizer concentration, and required break time. Gels containing this breaker retain viscosity and break slowly. It can be added to batch-mixed gels or run on-the-fly throughout the entire job, including the pad volume.

CAT®-OS-1 and CAT®-OS-2 Activators

CAT®-OS-1 and CAT®-OS-2 activators are catalysts for the ViCon NF internal breaker used with SeaQuest® service and Delta Frac®Pac system. CAT-OS-1 activators can effectively activate the ViCon breaker above 170°F. At lower temperatures, a combination of CAT-OS-1 and CAT-OS-2 activators with ViCon NF breaker will provide an accelerated break time.

CAT®-3 and CAT®-4 Activators

CAT-3 and CAT®-4 activators are proprietary mixtures of chemicals that enhance the activity of many oxidizer breakers. They can be used separately or together with most fracturing fluids and traditional persulfate breakers.

CAT-3 activator can be used at bottomhole surface temperatures of 85°F (29°C) and above. It allows the use of less Oxol II breaker at temperatures higher than 120°F (48.8°C). CAT-4 activator can be used at bottomhole surface temperatures of 140 to 200°F (60 to 93°C). CAT-3 and CAT-4 activators can be either added to fracturing fluids on-the fly or added to K-38 crosslinker to form a crosslinker/activator solution. These activators are beneficial because they are solutions instead of mixtures of solids. Their break times can be tailored to specific job times.

Surfactants

LoSurf-259™ Surfactant

LoSurf-259™ surfactant is a nonionic, nonemulsifier blend specifically designed for acidizing limestone and dolomite formations. It has also been effective in sandstone acidizing and fracturing treatments.

LoSurf-300™ Surfactant

LoSurf-300™ surfactant is a liquid, broad-spectrum, nonionic nonemulsifier for application in acids and other aqueous fluids. It can be used in stimulation fluids for treatments of either sandstone or limestone formations. Because it is nonionic, it should be compatible with most other acid additives, including Cla-Sta® agents. However, it is advisable to perform emulsification tests before including LoSurf surfactant in any treatment regime.

LoSurf-357™ Surfactant

LoSurf-357™ nonionic surfactant can be used with aqueous fluids, such as fresh water, brines, KCl solutions, and acids. It can be used in treating any type of formation rock. Since it is nonionic, it has low adsorption properties and is compatible with most other additives.

LoSurf-360™ Surfactant

LoSurf-360™ nonionic surfactant is for use in stimulation fluids (fracturing) to lower surface tension of the treating fluid. It has shown to be an effective non-emulsifier for a variety of crude oils and can be used in sandstone, carbonate, and shale formations and applications where LoSurf-300M non-ionic surfactant would normally be used.

LoSurf-396™ Surfactant

LoSurf-396™ surfactant is a nonionic blend of demulsifiers, dispersants, and solvents specifically designed for use in areas where health, safety, and environmental concerns are prevalent. The surfactant is effective at bottomhole temperatures greater than 300°F (149°C).

LoSurf-400™ Surfactant

LoSurf-400™ surfactant is a nonemulsifier for acidizing and fracturing operations and can be added to preflushes in general, acid preflushes, HF/HCl main flushes, and fracturing fluids crosslinked with either metal ions (neutral to moderate basic pH) or borate crosslinked fluids (high pH).

LoSurf-2000S™ Surfactant

LoSurf-2000S™ solid, powder surfactant is a blend of anionic nonemulsifier and an anionic hydrotrope. It can be used as a surface-tension reducer and nonemulsifier in fracturing and acidizing applications. LoSurf-2000S surfactant can be added to stimulation fluids as a solid or premixed in water and metered into the treatment for on-the-fly application. It can prevent and/or remove emulsion or water blocks during stimulation treatments, and can also be used in water-based mud dispersants, preflushes, acids, HF acid, and overflushes. It is compatible with Delta Frac® and Delta Frac®Pac service and Hybor Frac™ systems.

LoSurf-2000L™ Surfactant

LoSurf-2000L™ liquid surfactant is a blend of anionic nonemulsifier and an anionic hydrotrope. It can be used as a surface-tension reducer and nonemulsifier in fracturing and acidizing applications. LoSurf-2000L surfactant is compatible with the following fracturing/acidizing fluids:

- Delta Frac, Delta FracPac, and Delta Frac 275 service
- Hybor Gel™ system
- Pur-Gel III℠ service
- Thermagel℠ service
- Sirocco® service
- My-T-Gel™ fluid
- Sandstone 2000℠ service
- Hydrochloric acid (HCl)
- MOD™ acids
- HTA-710 acid containing HAI-81M™ or HAI-GE™ inhibitors
- SGA-II™ and SGA-HT® gelling agents
- SWIC II™ system

NEA-96M™ Surfactant

NEA-96M™ surfactant is a general surfactant and non-emulsifier for preflushes, acid preflushes, HCl and HF acid systems, overflushes, and fracturing fluids. When added to water-based fluids, it helps remove water blocks and aqueous external emulsion blocks. When added to water-based preflushes, it can lower breakdown pressure. NEA-96M surfactant can also be used to help clean up kill fluids, packer fluids, completion fluids, or any fluid that might invade the formation. It can be used with Musol® A or Musol® E agents if solvents are needed, and in acid systems containing either HAI-81M™ or HAI-85M™ corrosion inhibitors. Because it is an anionic blend, it is compatible with other anionics, nonionics, and anionic/nonionic blends. NEA-96M surfactant provides the following benefits:

- Helps prevent the creation of emulsions between injected fluid and formation fluid
- Helps break emulsion blocks and water blocks
- More effective in smaller amounts than many other surfactants (0.1 to 1.0% concentrations)

Clay Stabilizers

Cla-Sta® Compounds

Cla-Sta® compounds are permanent clay stabilization materials that may be used with brine systems common to sand control and fracturing processes. Cla-Sta compounds are organic polymeric materials which do not alter the water-wet condition of a sandstone formation. They are not corrosive to tubular goods. The chemical structure of these compounds is key to their effectiveness. When absorbed on a water-sensitive clay surface, the compounds are not easily replaced or desorbed as individual ions but rather act as ions linked by a chain-like structure. When formation brines flow past the treated clays, Cla-Sta compounds are not easily replaced by cations from the brine. The compounds can also effectively resist acidizing and other formation treatments.

Cla-Sta® FS Additive

Cla-Sta® FS additive was specifically developed for stabilizing mineral fines and clays in hydrocarbon-bearing formations. The Cla-Sta FS chemical is readily absorbed on formation surfaces. This alters the surface properties of the formation fine particles, reducing their interaction with flowing fluids (water, brines, oil, and gas) within the rock capillaries. Because the drag forces exerted on the fine particles by flowing fluids are decreased, fines migration is reduced even in the presence of very high rates of fluid flow. Stabilizing mineral fine particles significantly reduces solids production and permeability impairment.

Cla-Sta® FS additive effectively stabilizes a variety of mineral fines that do not respond to conventional stabilizers. Examples are:

- Silica
- Kaolinite
- Carbonates
- Hematite
- Magnetite
- Siderite

Cla-Sta FS additive may be applied in brine or acid solutions. Once treated, fines remain stabilized in the presence of acids, brines, oils, and even fresh water. Cla-Sta FS additive is often included in small percentages of filtered completion fluid as a perforating medium. When fluid is lost to the formation, it is instantly protected from later contact with incompatible fluids.

Cla-Sta® XP Stabilizer

Cla-Sta® XP stabilizer is the clay and fines stabilizer of choice for formations with permeabilities of approximately 30 md or less. It can be placed in almost all treating fluid, including FracPac™ system and gravel pack gels, acids, and brines. More information on how the Cla-Sta XP polymer controls clays in tight formations can be found in SPE paper 18881, "Clay Stabilization in Low-Permeability Formations." This chemically resistant clay stabilizer provides superior penetration in tight formations and is compatible with most fracturing and gravel packing gel systems including crosslinked systems. A water-soluble cationic material, it is designed to surface-absorb very rapidly upon contact with clays and fines. Cla-Sta XP stabilizer helps prevent clay swelling and migration during and following fracturing, gravel packing, and acidizing treatments.

Cla-Sta® O Additive

Cla-Sta® O additive is an oil-soluble version of either Cla-Sta FS or Cla-Sta XP additive.

Scalechek® HT Scale Inhibitor

Scalechek® HT inhibitor is a solid phosphonate scale inhibitor designed to be placed in a fracturing treatment.

Applications

Scalechek HT inhibitor can help control calcite (calcium carbonate), gypsum (calcium sulfate), and barite (barium sulfate) scales. It can also help prevent naturally occurring radioactive material (NORM) scale that is often associated with barium sulfate scale formations.

- Effective at temperatures of 100°F (38°C) and above.
- Compatible with all of Halliburton's current aqueous fracturing fluids.
- Incompatible with low-pH fluids, strong oxidizers, and strong acids.

Benefits

- Coated to prevent interference with crosslinked fracturing fluids. Compared with squeezed inhibitors, a higher percentage of Scalechek HT inhibitor remains in the formation to control scale.
- Designed to be placed in the fracturing fluid along with the proppant, eliminating the need for a separate treatment for placement.
- Placement with a planned fracturing treatment can provide up to 2 years of scale inhibition.

Friction Reducers

Friction reducers are primarily used for coiled tubing cleanout jobs where fluid losses to the formation are not expected. Friction reducers are not recommended for fluids injected into sandstone formations.

FR-66™ Friction Reducer

FR-66™ liquid friction reducer is used for light brines. It consists of an oil-external emulsion easily inverted and/or broken and dispersed with shear in aqueous fluids. It can tolerate more dissolved solids in the water than previous friction reducers.

- It is effective at low concentrations (0.25 to 0.5 gal per 1,000 gal) in fresh water.
- Higher concentrations of FR-66 friction reducer may be required in KCl or NaCl water.
- Easier to mix than powdered materials.

In addition, the concentrated liquid friction reducer can be mixed on-the-fly and does not cause the lumping problems associated with powdered friction reducers.

FR-56™ Friction Reducer

FR-56™ liquid friction reducer is used for fresh water and light brines. It consists of an oil-external emulsion that is easily inverted and/or broken and dispersed with shear in aqueous fluids. FR-56 friction reducer can be used at temperatures above 40°F (4°C). It is used to reduce pipe friction pressure while pumping water during hydraulic fracturing treatments. Because it is a highly anionic material, FR-56 friction reducer is particularly effective in light brines, such as KCl brines. In addition, because it is a concentrated liquid, FR-56 friction reducer can be mixed on-the-fly and does not cause the lumping problems associated with powdered friction reducers.

FR-48W Friction Reducer

FR-48W friction reducer is a cationic liquid reducer designed to perform over a wide range of surface fluid temperatures. FR-48W friction reducer contains a new aqueous carrier fluid for delivery of the polymer, rather than a typical hydrocarbon carrier fluid. Laboratory data indicates FR-48W friction reducer is compatible with freshwater, 2% KCl, 10% NaCl, 2% $CaCl_2$, 11.0 lb/gal $CaCl_2$ brine, and acids.

FR-38 Friction Reducer

FR-38 cationic, liquid friction reducer is designed to perform over a wide range of surface fluid temperatures. FR-38 friction reducer does not contain a hydrocarbon carrier fluid for delivery of the polymer. FR-38 friction reducer contains a new aqueous carrier fluid that is environmentally evaluated.

FR-5™ Friction Reducer

FR-5™ liquid additive is used to reduce friction pressure when pumping hydrocarbon base fluids such as kerosene, crude oil, and refined fracturing oils in turbulent flow through pipe. FR-5 friction reducer is a high molecular weight, synthetic polymer. The base fluid must be pumped in turbulent flow for this additive to be effective. Field experience has demonstrated the effectiveness of FR-5 friction reducer to produce friction reduction. For example, FR-5 friction reducer was added to a lease crude (43° API gravity) at 5 gal per 1,000 gal and injected at 10 bbl/min down a common manifold of 5 1/2-in. casing and 2 3/8-in. tubing. Calculated friction reduction was 56%.

FR-98™ Friction Reducer

FR-98™ cationic, liquid friction reducer is recommended for use when the total dissolved solids of the source water is above 200,000 mpL and where fresh-water sources are not available for dilution or water-treatment equipment is not available. It is an oil-external emulsion easily inverted and/or broken and dispersed in water with a minimal amount of shear. It is effective at low concentrations (0.25 to 1.0 gal per 1,000 gal) in clay-control brines and produced and flowback water sources. This system is suitable for harsh, cold-weather environments because of its low pour-point temperature.

FR-88™ Friction Reducer

FR-88™ cationic, liquid friction reducer is recommended for use when the total dissolved solids of the source water is in the range of 100,000 to 200,000 mpL, and where fresh-water sources are not available for dilution or water-treatment equipment is not available. It is an oil-external emulsion easily inverted and/or broken and dispersed in water with a minimal amount of shear. It is effective at low concentrations (0.25 to 1.0 gal per 1,000 gal) in clay-control brines and produced and flowback water sources. This system is suitable for harsh, cold-weather environments because of its low pour-point temperature.

FR-78™ Friction Reducer

FR-78™ cationic, liquid friction-reducer additive is recommended for use when the total dissolved solids of the source water is up to 100,000 mpL, and where fresh-water sources are not available for dilution or water-treatment equipment is not available. It is an oil-external emulsion that is easily inverted and/or broken and dispersed in water with a minimal amount of shear. It is effective at low concentrations (0.25 to 1.0 gal per 1,000 gal) in clay-control brines and produced and flowback water sources. This system is suitable for harsh, cold-weather environments because of its low pour-point temperature.

Stimulation Equipment and Services

Halliburton Sand Control offers a complete line of reliable mixing and pumping equipment and quality filtration services that are vital to successful sand control operations. Solids such as cement, scale, and rust in mixing and pumping equipment can damage the formation and the gravel pack permeability. Halliburton's wide range of dedicated mixing and pumping equipment helps ensure a safe, reliable, clean operation. Filtration of completion brines and sand control fluids is as important to a successful sand control completion as selecting the proper pack-sand size, carrier fluid, or placement technique. Halliburton offers a wide range of equipment for filtration of completion brines, perforating fluids, acids, and gravel pack fluids.

Pumping Capabilities

Backed by the experience and skill of Halliburton sand control specialists and research groups, Halliburton sand control surface equipment provides the technology and service to meet today's industry demands.

Whatever the requirements, Halliburton has a pumping skid or truck-mounted unit to do the job. The core of our pumping capabilities lies with the positive displacement pumps designed and manufactured by Halliburton. These include the HT-400™ and the HQ-2000™ pumps.

A large variety of pumping/blending skids/trucks for sand control operations are available:

- HT-400 pump skids with V-8, V-12, or V-16 engine
- CPS-MS single HT-400 pumping unit
- Panther pumping skid
- One-piece Grizzly™ skid with HQ-2000 pump
- Two-piece Grizzly skid with HQ-2000 pump
- Acid single pump truck with CLAM™ blender
- Euro-Trailer™ unit

Pumping Equipment

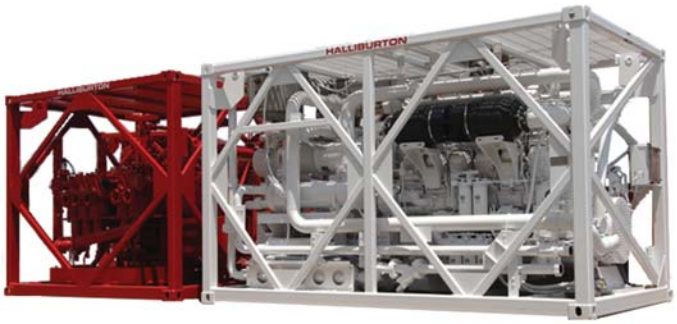
Pump Name	Pump Type	HHP Rating		Weight				L × W × H	
				Pump Section		Power Section		Pump Section	Power Section
		bhp	*kW*	lb	*kg*	lb	*kg*	ft	ft
HT-400™ Single Skid Pumping Unit	HT-400	800	*596.5*	18,078	*8200*	N/A	*N/A*	19.4 × 6.1 × 9.3	N/A
V-16 (PSL-3) Twin Skid (Skid SK11608)	HT-400	800	*596.5*	32,209	*14 610*	16,535	*7500*	16.1 × 7.9 × 8.9	9.7× 7.9 × 8.7
CPS-MS Single HT-400 Pumping Unit	HT-400	800	*596.5*	10,500	*4762*	12,000	*5443*	7.8 × 5.2	13.1 × 5.2
Single-Piece Marine Panther Pumping Skid	HT-400	800	*596.5*	26,000	*11 793*	N/A	*N/A*	19, 10 in. × 6 × 8.5	N/A
Two-Piece Marine Panther Pumping Skid	HT-400	800	*596.5*	12,000	*5443*	17,000	*7711*	9.81× 6 × 8.5	12.08 × 6 × 8.5
Two-Piece, Self-Contained Panther Pumping Skid	HT-400	800	*596.5*	12,200	*5534*	21,100	*9571*	9.81 × 8 × 8.5	14 × 8 × 8.5
Single-Piece Grizzly™ Skid	HQ-2000™ Quintuplex	2,250	*1678*	49,000	*22 226*	N/A	*N/A*	20 × 8 × 8.5	N/A
Two-Piece Marine Grizzly Pumping Skid	HQ-2000 Quintuplex	2,250	*1678*	16,000	*7257*	33,000	*14 969*	9.81× 8 × 8.5	14 × 8 × 8.5
Two-Piece, Self-Contained Grizzly Pumping Skid	HQ-2000 Quintuplex	2,250	*1678*	17,000	*7712*	35,000	*15 876*	19 × 8 × 8.5	19 × 8 × 8.5

HAL11862

V-16
Twin Skid

HAL15936

CPS-MS
Single Skid



Two-Piece Grizzly™
Pumping Unit

Blending Capabilities

A variety of blending skids for sand control operations are available depending on job requirements.

- Single-skid FracPac™ blender
- Two-skid FracPac blender
- CLAM™ Constant level additive mixing systems
- SMS-30D™ blender
- SMS-40D™ blender
- SC-50™ blender

Single-Skid FracPac™ Blender

This unit consists of a 25-bbl blender skid and an auxiliary additive skid. The blender skid contains all the mixing and pumping equipment. The additive skid contains all of the storage and metering pumps/feeders for both liquid and dry additives. The additive skid stacks on top of the blender skid during operation. Both skid frames have the dimensions of ISO freight containers. Consequently, shipping and handling of the unit is easy and inexpensive. The skid frames also provide considerable protection against handling damage. Skids are not ISO-certified.

The blender skid contains a proppant system that consists of a hydraulically driven 12-in. (305-mm) screw with an operating range of:

- 12-in. full flight screw, 4 to 105 ft^3/min
- 12-in. cut-down screw, 3 to 88 ft^3/min

The sand is fed into a 5-bbl (0.8-m^3) capacity cylindrical tub where it is agitated by a hydraulically driven turbine agitator.

The blender skid contains a Liquid Additive System and a Dry Additive System.

Liquid Additive System

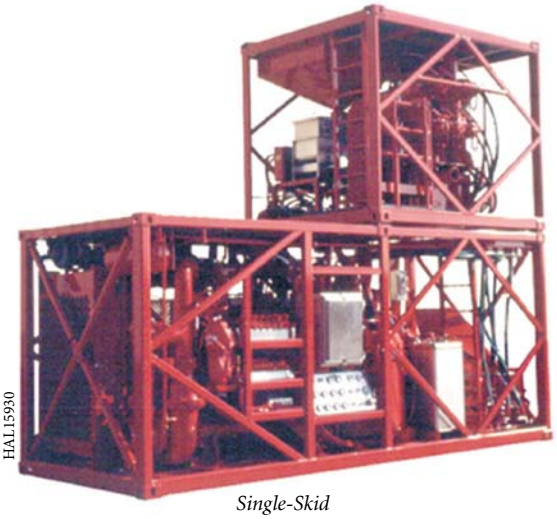
- (1) Roper 71205 liquid additive pump, 2 to 40 gal/min (plumbed to sand hopper and slurry tub)
- (1) Viking L-32 liquid additive pump, 10 to 120 gal/min (plumbed to slurry tub)
- (1) Hastelloy CMF200 (1 1/2-in. Elite) Micro Motion flowmeter, 0.4 to 190 gal/min

Dry Additive System

- (1) Acrison size H (2 3/4 in.), 0.89 ft^3/min at 180 rpm
- (1) Acrison size M (3 7/8 in.), 2.80 ft^3/min at 180 rpm

The auxiliary skid contains:

- (3) Roper 733025 liquid additive pump, 0.2 to 3.1 gal/min
- (2) Roper 71202 liquid additive pump, 0.8 to 16 gal/min
- (5) Hastelloy CMF100 (1-in. Elite) Micro Motion flowmeters, 0.1 to 60 gal/min
- (5) 75-gal HalTank™ containers
- (5) Orberdorfer chemical transfer pumps, 50 gpm



Single-Skid FracPac™ Blender

Blender Skid Specifications

Length		Width		Height		Total Weight	
ft	*m*	ft	*m*	ft	*m*	lb	*kg*
22	*6.71*	8.00	*2.44*	10	*3.05*	32,000	*14 515*

Auxiliary Skid Specifications

Length		Width		Height		Total Weight	
ft	*m*	ft	*m*	ft	*m*	lb	*kg*
10.00	*3.05*	8.00	*2.44*	8.00	*2.44*	15,500	*7031*

Two-Skid FracPac™ ARC Blender

For large FracPac™ operations, Halliburton has developed the two-skid FracPac automatic remote control (ARC) blender. It is a Halliburton-designed twin centrifugal blender powered by a single engine on each skid. One skid contains the mixing equipment, and one skid contains the pumping equipment. Each skid is an ISO-standard 668 designation ICC freight container. Shipping and handling for the skid is easier and less expensive than for a standard skid. The frame provides considerable protection of the blending equipment. The 10-in. suction pump is hydraulically driven. The discharge pump is a hydraulically driven rubber-lined horizontal centrifugal pump. The control system is the Halliburton-designed ARC unit controller and operator interface panel (OIP). Blending range is 2.5 to 50 bbl/min (0.4 to 8 m^3/min). The proppant system can deliver 160 to 20,000 lb/min (73 to 9072 kg/min).

Two-Skid
FracPac™ ARC Blender

Halliburton ARC Blender Specifications

	Length		Width		Height		Weight	
	ft	*m*	ft	*m*	ft	*m*	lb	*kg*
Mix Skid	20.0	*6.10*	8.0	*2.44*	8.5	*2.59*	28,000	*12 701*
Pump Skid	20.0	*6.10*	8.0	*2.44*	8.5	*2.59*	30,000	*13 608*

CLAM™ Mixing System

The CLAM™ constant level additive mixing blender is a continuous mix blender. Halliburton's CLAM blender is ideal for water pacs, Ex-tension Pac™ service, and openhole gravel pack slurry blending. The CLAM blender eliminates the necessity of batch-mixing large volumes of low sand concentration slurries while allowing the sand concentration to be ramped as necessary. The unit's liquid additive system and automatic tub leveling system make it ideal for large volume matrix stimulation treatments that are run ahead of sand control treatments.

Control of CLAM blenders does not require constant operator involvement. Once the predetermined setting is made, only normal job monitoring is required. An operator sets the gate for the sand concentration and pump rate design. The tub level automatically (mechanically) controls fluid flow into the blender. The fluid level remains constant without operator manipulation.

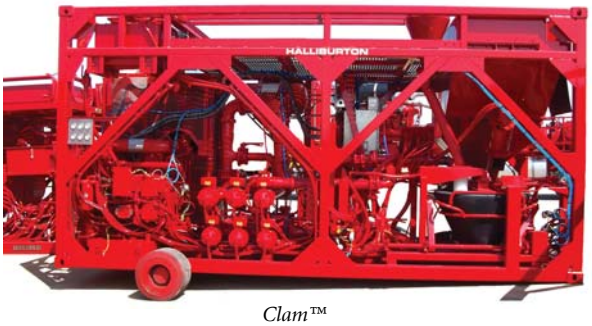
The CLAM blender system comes in a variety of configurations to allow set up of a system that meets the specific requirements of the local operations. In its basic configuration, the CLAM system consists of a 1.5-bbl mixing tub with fluid recirculation, a mechanical agitator, and a single centrifugal pump.

When combined with the 30-ft^3 (9-m^3) sand holding tank and calibrated sand gate, the blender accomplishes excellent uniformity of sand concentration when the acid prepacks or the low sand concentration slurry packs are run.

The CLAM blender is also supplied as a modular system for connecting to separate tanks and pumps. The UNIPRO™ II digital panel meter provides instrumentation and uses a 4-in. or 6-in. flow meter to monitor sand slurry flow or discharge flow rate and tub recirculation rate.

The CLAM mixing system capacity depends on the capacity of the centrifugal pump being used. A downhole flow rate of 10 bbl/min (1.6 m^3/min) can be obtained with a Halliburton 6 × 5 centrifugal pump, and a downhole rate of 20 bbl/min (3.2 m^3/min) can be obtained with a Halliburton 8 × 6 centrifugal pump.

The standard CLAM mixing system, combined with the 30 ft^3 (0.85 m^3) sand holding tank, has a capacity of 2,100 lb (953 kg) sand per minute.



HAL16030

Clam™ Blender

AMS CLAM™ Acid Mixing Skid Specifications

Length		Width		Height		Total Weight	
ft	*m*	ft	*m*	ft	*m*	lb	*kg*
6.0	1.83	2.5	0.76	3.33	1.02	800	363

The basic configuration of the CLAM™ mixing skid consists of a 1.5-bbl polyethylene mixing tank, an automatic mechanical tub leveling device, a manually operated calibrated sand gate (0 to 10.5-sacks/min), and an air-actuated tub assist to adapt to changes in fluid density. The tub assist is controlled by a valve which is mounted on the skid.

Fluid is supplied to the CLAM mixing skid by any 18-bbl/min (2.9-m^3/min) centrifugal pump. Jet action from the recirculating fluid provides agitation in the tub. The output from the tub is 10-bbl/min (1.6-m^3/min) with 8-bbl/min (1.3-m^3/min) recirculation rate.

AMS-15 Acid/Gravel Pack CLAM™ Skid

The AMS-15 acid/gravel pack CLAM™ skid is powered by a Caterpillar C7 engine or an equivalent hydraulic power package. The mixing tank is a 1.5-bbl (0.2-m^3) polyethylene tub with vertical turbine agitator and recirculation for agitation.

Fluid is supplied to the tub by a centrifugal pump blending system with two 6 × 5 Halliburton pump. The output from the mixing tank is 20-bbl/min (3.2-m^3/min) with 20-bbl/min tub recirculation rate.

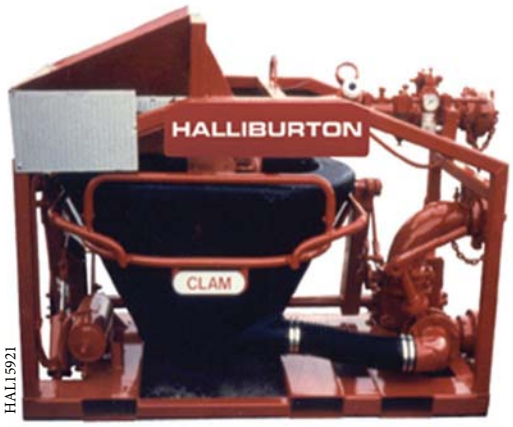
- 15-lb sand/gal gel at 3 bbl/min (1.8 kg/L at 0.5 m^3/min)
- 10-lb sand/gal gel at 5 bbl/min (1.2-kg/L at 0.8-m^3/min)
- 5-lb sand/gal gel at 5 bbl/min (0.6-kg/L at 2.4-m^3/min)

An automatic mechanical fluid leveling with hydraulic tub assist is standard.

The sand rate is determined by a hydraulic-powered 2 × 8-in. (51 × 203-mm) calibrated sand gate (10 sk/min) and is monitored by a UNIPRO™ computer system. A 4-in. (102-mm) Halliburton turbine flowmeter is mounted in the recirculation line to monitor tub recirculation flow rate and a 6-in. (152-mm) Halliburton turbine flowmeter is mounted in the suction line.

An automatic match-meter system is used to control liquid additives and a TDRAD is used to display density of discharge fluid, rate display of recirculation flow rate, and clean flow rate.

A 100-ft^3 (2.83 m^3) sand holding tank is available.



CLAM™ Skid

AMS-15 Acid/Gravel Pack CLAM™ Skid

Length		Width		Height		Weight	
ft	*m*	ft	*m*	ft	*m*	lb	*kg*
20	*6.10*	8.0	*2.44*	10.2	*3.10*	24,000	*10 886*

SC-50™ Blenders

Halliburton SC-50™ blenders are portable mixing units specifically designed for sand control slurry preparations. These blenders are intended for larger sand control jobs, such as gravel packing, and are built to DNV specifications. The SC-50 blender consists of two 25-bbl (4-m^3), 316 stainless steel mixing tanks, and two Halliburton 6 × 5-in. centrifugal pumps driven by hydraulic motors. The hydraulic motors can be run independently at speeds from 0 to 1,500 rpm. Each 25-bbl (4-m^3) tank has a vertical mixing shaft with two rows of four mixing turbine blades manufactured from 316 stainless steel. These turbine mixers are connected to the output shaft of a right angle, speed-reducing gear box and driven by hydraulic motors at controllable speeds from 0 to 90 rpm.

The pumps are manifolded so that fluids can be drawn off either tank by either pump and discharged to either tank or drawn from and pumped to an external location. Suction lines have a 5-in. (127 mm) diameter, and the recirculating lines have a 4-in. (102 mm) diameter.

SC-50™
Control Panel

SC-50™
Batch Blender

Halliburton SC-50™ Blender Specifications

Length		Width		Height		Weight	
ft	*m*	ft	*m*	ft	*m*	lb	*kg*
14.50	*4.42*	8.00	*2.44*	12.00	*3.66*	15,000	*6804*

SMS-30D™ and SMS-40D™ Slurry Blenders

Halliburton's SMS-30D™ and SMS-40D™ slurry blenders are designed to mix gelled fluids and sand-laden slurries for gravel packing. The SMS-30D unit consists of twin, 15-bbl (2.4-m^3) vertical tanks of crosslinked polyethylene or stainless steel construction with hydraulically driven turbine agitators. For flexibility, the SMS-30D is fitted with two 6 × 5 centrifugal pumps, one pump for each tank. Stainless steel manifolding between the tanks and pumps allows maximum versatility in mixing and pumping procedures. A diesel engine provides power for the hydraulically driven turbine agitators and centrifugal pumps. As required, 3-in. (76.20-mm) and 4-in. (102-mm) hoses are available in varying lengths. SMS-40D 40-bbl (6.4 m^3) units are also available with twin 20-bbl (3.2 m^3) vertical tanks. To extend its capabilities and to lessen the equipment footprint on location, the SMS-30 blender can be retrofitted with a CLAM™ blender on applications needing water pac services.

Slurry Blender

Displacement Tanks

A 20-bbl (3.2-m^3) side-mounted displacement tank is available for use with pump skids that do not have a built-in displacement tank. The side-mounted, high-density, crosslinked polyethylene or stainless steel 20-bbl (3.2-m^3) measuring tanks are sump-type with butterfly valve to control fluid low.

Displacement Tanks

Centrifugal Pumps

The standard Halliburton centrifugal pumps, used for water, chemical, and acid transfer and mixing, include the following:

- Halliburton 6 × 5 – Used for mixing and pumping gelled fluids
- Halliburton 4 × 4 – Used for pumping water only

Centrifugal Pump

SMS-30D™ and SMS 40D™ Blender

	Length		Width		Height		Weight	
	ft	*m*	ft	*m*	ft	*m*	lb	*kg*
SMS-30D™	14.50	*4.42*	8.00	*2.44*	10.00	*3.05*	14,700	*6668*
SMS-40D™	14.50	*4.42*	8.00	*2.44*	12.00	*3.66*	15,300	*6940*

Sand Control Pump Trailers

Halliburton sand control pump trailers provide mobile pumping and blending capabilities for gravel pack systems, acid stimulation treatments, and plastic consolidation systems.

Acid/Water Pac Trailer with CLAM™ Blender

The full-service acid/water pac trailer is capable of carrying 2,000 gal (7570 L) of acid or suctioning from onsite acid tanks, blending on-the-fly, utilizing a CLAM™ blender at 10 bbl/min (1.6 m^3/min), and pumping to the wellhead with a maximum pressure of 14,000 psi (984 bar) at 1.7 bbl/min (0.27 m^3/min) utilizing an HT-400™ pump. Data is recorded on a CompuPac™ data acquisition system. Rate and pressure data is initially captured on UNIPRO™ II units.

Features

- Booster pump – Halliburton 6 × 5 powered by a 25-bhp (93-kW) diesel engine
- CLAM system – Single centrifugal pump blender with mechanical automatic tub fluid control, 2-bbl polyethylene tub, turbine agitation for on-the-fly mixing of dry and nonfoaming liquid additives
  - 10-bbl/min (1.6-m^3/min) discharge rate
  - 10-bbl/min (1.6-m^3/min) recirculation rate
  - 20+ psi (138 kPa) boost pressure with 6 × 5 centrifugal pump

Sand Control Acid/Water Pac Truck with CLAM™ Blender

Acid/Water Pac Trailer Specifications

Dimensions						Weights (empty)					
Length (kingpin to rear)		Width		Height		Kingpin		Rear		Total	
ft	*m*	ft/in.	*m*	ft/in.	*m*	lb	*kg*	lb	*kg*	lb	*kg*
36.67	*11.18*	8.00	*2.44*	11.17	*3.40*	17,600	*7983*	25,100	*11 385*	42,700	*19 368*

Acid/Water Pac Trailer Capacity

Fluid End	At Rated Pressure				At Maximum Rate			
in.	bbl/min	*m^3/min*	psi	*MPa*	psi	*mPa*	bbl/min	*m^3/min*
4	1.7	*0.27*	14,000	*96.5*	3,390	*23.4*	7.7	*1.2*
4.5	2.1	*0.33*	11,200	*77.2*	2,571	*17.7*	9.8	*1.6*
5	2.6	*0.41*	9,000	*62.1*	2,160	*14.9*	12.1	*1.9*
6	3.8	*0.60*	6,250	*43.1*	1,500	*10.3*	17.4	*2.8*

Euro-Trailer™ Unit

The Euro-Trailer™ unit is a self-contained unit designed by Halliburton specifically for sand control. The Mercedes Tractor drives all mixing and pumping equipment via two hydraulic pumps.

It provides a complex, soundproof, flexible system suitable for all forms of sand control operations, from water packs with 0.5-lb/gal (59.91 kg/m^3) sand concentrations to high-density gravel packs with up to 15-lb/gal (1797.40-kg/m^3) sand concentrations. Once on the wellsite, this unit is easily and quickly rigged up to the wellhead via a high pressure pump which is provided separately.

The following equipment is fixed in place and optimally interconnected with stainless steel piping to provide all possible required flow paths throughout the Euro-Trailer unit:

- Stainless steel precoat filter unit - 3,000 L/min
- Stainless steel dual cartridge filter unit - 1,500 L/min
- Two 32 bbl (5.2 m^3) stainless steel batch mix blenders
- CLAM™ blender - 2 bbl/min mixing tub, 15 ppg maximum sand concentration, 2,100 lb/min maximum sand delivery rate.
- Two each 5,100 L stainless steel paddle tanks
- 5M centrifugal pump - 1,500 L/min - 15 bar pressure
- 44L centrifugal pump - 1,500 L/min - 3 bar pressure
- CompuPac™ data acquisition system

The Mercedes tractor unit drives two hydraulic pumps to power this equipment. Each piece of equipment on the trailer is controlled individually from the control room at the front of the trailer. The rate at which brine is filtered can be continuously monitored, the fluid volume in each blender is continuously and digitally displayed, the required fluid flow path can be selected through 43 pneumatically actuated valves, and the pump rate and pressure are also continuously displayed.

Euro-Trailer™ Unit

Euro-Trailer™ Unit

Length		Width		Height		Weight	
ft	*m*	ft	*m*	ft	*m*	lb	*kg*
50.86	*15.5*	8.2	*2.5*	13.12	*4*	55,116	*25 000*

Halliburton Marine Vessels

Halliburton operates a large fleet of marine vessels in various locations around the world. Each vessel is set up to handle a specific job or a variety of jobs. The table on the following page provides detailed information on the vessels that handle sand control-related operations.

Marine Vessel Information

High-Pressure Flexible Line Hose Support System

Halliburton's hose support system provides significant advantages:

- Versatile to use offshore with 3-in. (76.2-mm) or 4-in. (102-mm) hoses
- Easy to install with chains or ISO locks (International Standards Organization 1161 locking assembly 350)
- Reduces exposure of safety-related issues in rig-up, rig-down, and emergency disconnect procedures
- Can be attached to the facility in the same way as the gooseneck
- Opportunity to ISO lock FHPH to the deck of the rig for an even safer operation
- No purchase of a mounted hanger support required
- Saves rig time in hose support installation and removal
- Requires a one-time installation of four deck sockets
- Minimal per job charge

The system was designed by Halliburton to increase quality of service to customers and is built to specifications. The system meets all industry standards and provides a safe and efficient way to install a high-pressure flexible line at an offshore facility to help reduce the risks involved.

High-Pressure Flexible Line Hose Support

HOS Saylor

Stim Star III Stimulation Vessel

Stim Star Borneo

Stim Star Angola

Stim Star Arabian Gulf

Marine Vessels

		Stim Star Arabian Gulf	Halliburton 301	HOS Beaufort	HOS Hawke	HOS Saylor	Falcon Tide	Stim Star Angola	Stim Star	Stim Star II	Stim Star III	Stim Star Borneo
Region of Operation	Gulf of Mexico									•	•	
	Bay of Campeche			•	•	•	•					
	North Sea											
	West Africa							•	•			
	South America											
	Middle East	•	•									
	Southeast Asia											•
Statistics	Total Length (ft)	234	210	200	200	243	258	241	274	240	260	200
	Total Beam (ft)	56	42	56	56	54	49	54	56	56	56	66
	Main Engine hp	4,000	2,450	4,200	4,200	7,845	3,000	6,570	3,420	3,420	5,400	2,000
	Cruising Speed (kts)	11.5	11	12	12	12	9	14	14.2	14.2	14.2	7
Above Deck	Acid (gal)	100,000	129,000*	14,800	67,288*	31,000	250,000*	25,000	60,000*	**	**	8,400
	Additive (gal or lb)	12,800	4,400	10,980	15,000	16,720	10,000	21,300	12,100	8,000	10,000	7,437
	Gel/Completion Fluid (bbl)	None	None	None	None	1,628	None	100	None	None	None	None
	Gas (gal)	N/A	12,000	21,600	64,800	32,400	N/A	N/A	N/A	***	***	1,100
	Bulk (ft^3)	N/A	N/A	N/A	N/A	11,087	N/A	N/A	N/A	N/A	N/A	N/A
	Proppant (lb)	N/A	N/A	150,000	N/A	N/A	240,000	450,000	668,000	668,000	835,000	350,000
Below Deck	Additives (gal)	N/A	N/A	N/A	54,228	50,000	N/A	N/A	N/A	N/A	N/A	N/A
	Gel/Completion Fluid (bbl)	9,000	1,570	None	None	1,628	2,450	8,051	4,850	6,040	10,230	4,000
	Proppant (ft^3 or lb)	6,000	N/A	200,000	N/A	N/A	N/A	9,005 ft^3	8,075 ft^3	8,075 ft^3	10,500 ft^3	N/A
Tankage	Frac (bbl)	9,000	N/A	3,988	2,200	1,628	2,450	8,051	4,850	5,465	8,870	4,000
	Water (bbl)	5,800	2,625	5,085	5,085	1,770	2,588	5,661 + Watermaker	4,850	10,486	6,740	5,100
	Filter Capability (bbl/min)	50	N/A	N/A	N/A	N/A	N/A	75	75	75	75	10
Mixing Equipment	Gel on the Fly Capability	Yes	Yes	N/A	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes
	Blender (bbl/min)	70	70	25	35	40	50	70	50	50	75	30
	Batch (bbl)	50	N/A	50	N/A	50	N/A	50	200	N/A	N/A	100
	Acid (bbl/min)	50	70	15	35	40	50	40	30	N/A	N/A	15
	Proppant (lb/min)	N/A	N/A		N/A	N/A	20,000	20,000	20,000	20,000	20,000	20,000
	Frac (bbl/min)	N/A	N/A	18	35	40	50	60	50	50	60	30
	Frac on the Fly Capability	N/A	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Navigational Equipment	Thrusters (hp)	2×750/350	650	1,200	1,200	770/770	1,800	2 × 800/ 2 × 800	1,200/1,000	1,000/400	2-1,000/ 1-1,200	1,000
	Dynamic Positioning	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Dynamic Positioning Type	Beier Radio IVCS 2002 DPS-2	N/A	Simrad SDP01, DPS-1	Simrad SDP01, DPS-1	DPS-1	Nautronics ATS11 402, XDPS-1	Simrad/ Konesberg DPS-2	Simrad/ Kongsberg SDP21, DPS-2	Bridgemate II, DPS-2	Simrad/ Konesberg SDP21, DPS-2	L-3 Joy Stick Control
Safety Equipment	Hose Reel Quick Disconnect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	One Button Operation Shutdown	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Quick Disconnect Work w/ Power Loss	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	QA/QC Lab on Vessel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Treatment Line Size (in.)	3	3	3	3	3	3	3, 4	3, 4	3, 4	3, 4	3
Pumping Equipment	Treatment Line Length (ft)	200	320	200	400	400	400	400	450	400	400	350
	Line Pressure Capability (psi)	15,000	10,000	15,000	15,000	15,000	10,000	15,000	15,000	15,000	15,000	15,000
	Number of Pumps	5	8	8	4	4	5	6	7	6	8	8
	Total hhp	5,000	4,800	7,200	6,750	6,750	7,500	8,250	10,150	17,500	21,500	8,250
	Max. Rate (bbl/min)	45	70	35	35	40	50	62	75	64	64	25
	Max. Pressure (psi)	15,000	11,200	15,000	15,000	15,000	11,500	15,000	15,000	15,000	15,000	15,000
	Below Deck Pump Capability (gpm)	2×2,100	2,100	2 ea 1,150	2,940	3 ea 2,500	2,940	5 ea 2,500	7 ea 2,500	7 ea 2,500	7 ea 3,100	3 ea 1,260
Total Operating Pump Capability	Frac Pumps (hhp)	5,000	4,800	7,000	6,750	6,750	7,500	8,250	10,150	17,500	21,500	8,250

*Acid storage below deck

**Pump "Number" includes all pumps available

***Pump "Maximum Rate" includes all pumps available

Storage Tanks and Trailers

Sand Storage Tanks

Sand storage tanks are available either separately or combined with the CLAM™ blender.

Sand
Storage Tanks

Acid Transport Trailers

Halliburton acid transport trailers are applicable for inland and barge operations. These 4,200-gal capacity tanks have a high-density, crosslinked polyethylene tank within a steel outer tank.

HalTank™ Chemical Containers

HalTank™ chemical containers store and transport acid additives. These Department of Transportation approved tanks are stainless steel, stackable, and available in various capacities:

- HalTank 75 to 150-gal (284 to 568-L) capacity— twin 75 gal (284 L) tanks
- HalTank 160 to 160 gal (606 L) capacity
- HalTank 345 to 345 gal (1306 L) capacity
- HalTank 549 to 549 gal (2078 L) capacity
- HalTank 375 to 375 gal (1419 L) capacity for viscous fluids

HalTank™
Chemical Containers

Acid
Transport Trailer

Marine Portable Tanks

Halliburton marine portable tanks store flammables, corrosives, and combustibles. Tanks are available in 500-gal (1893-L), 1,000-gal (3785-L), 1,500-gal (5678-L), 2,000-gal (7570-L), and 4,000-gal (15 140-L) capacities. The skid-mounted tanks are applicable for offshore oilwell service work only. Construction features include a remolded high-density, crosslinked polyethylene tank within a steel tank shell. Polyethylene tanks provide excellent damage tolerance because of thickness and excellent resistance to most chemicals transported in acid and sand-control services. Tanks can be used at temperatures up to 150°F (66°C).

HAL8369

Marine Portable Tanks

Marine Portable Tanks Specifications

Unit	Capacity	Tank Diameter		Unit Height		Skid Length		Skid Width		Empty Weight	
	gal	in.	*m*	in.	*m*	in.	*m*	in.	*m*	lb	*kg*
W481	500	46.75	*1.19*	68.50	*1.74*	96.00	*2.44*	48.00	*1.22*	3,130	*1420*
W482	1,000	66.00	*1.68*	95.00	*2.41*	96.00	*2.44*	68.00	*1.73*	4,475	*2030*
W483	1,500	72.00	*1.83*	96.00	*2.44*	110.00	*2.79*	74.00	*1.88*	6,260	*2839*
W484	2,000	72.00	*1.83*	98.50	*2.50*	147.00	*3.73*	74.00	*1.88*	7,695	*3490*
W485	4,000	96.00	*2.44*	120.00	*3.05*	156.00	*3.96*	96.00	*2.44*	9,250	*4196*
W491	5,400	91.00	*2.31*	102.00	*2.59*	238.50	*6.06*	96.00	*2.44*	13,030	*5910*

Model ATS-5400 Intermodal Tank with ISO Frame

The model ATS-5400 intermodal tank is intended for HCl use where a top outlet is required. Intermodal tanks are approved for highway, rail, and vessel storage/transportation of flammable, corrosive, or combustible liquids.

Tank volume is 5,400 gal (20.4 m^3). The tanks have no bottom outlets and are air-unloaded. The tank is rated at 4-bar [58-psig (400-kPa)] working pressure at -20° to 200°F (-29° to 94°C). The tank is suitable for low-temperature service at -50°F (-46°C).

HAL15928

Intermodal Tank with ISO Frame

Intermodal Tank

Tank Diameter		Skid Height		Skid Length		Skid Width		Tare Weight	
ft	*m*	ft	*m*	ft	*m*	ft	*m*	lb	*kg*
7.58	*2.31*	8.5	*2.59*	19.875	*6.06*	8	*2.44*	13,030	*5910*

Data Acquisition Services

Halliburton provides a wide variety of data acquisition systems to meet the requirements of various sand control applications. These systems range from the CompuPac™ system with UNIPRO™ unit (or InSite® for Stimulation SITEPac™ system) and HalWin™ data acquisition software (or InSite for Stimulation software) for sand control/ stimulation operations, to the various style TechCommand® centers with automatic remote control (ARC) and automatic controlled equipment (ACE) for FracPac™ system operations.

Real-time access to well data is available using Halliburton's InSite Anywhere® service.

InSite Anywhere® Service

Halliburton InSite Anywhere service allows quick, easy, and secure access to real-time well information across all aspects of well construction to the completion process, providing the freedom to move around and still be connected to operations using a computer or smart phone.

With well data stored in the InSite® database and distributed through the InSite Anywhere interface, users can collaborate with team members in real time no matter what the location and manage well site situations as they arise. The system works with all Halliburton and third-party data. Data can be hosted on a secure website at Halliburton facilities or a designated location. Access via the Internet or smart phone device enables real-time information to flow seamlessly to the right people in real time to enhance collaboration, decision making, and to optimize assets.

- InSite Anywhere Web Client Service – Access well logs from anywhere in the world using any standard Internet connection and Java-enabled browser. As data moves from the rig site to a secure website operated by Halliburton, asset teams can review the results in real time and make informed, collaborative decisions.
- InSite Anywhere Direct Service – This next-generation stand-alone data delivery system provides the flexibility of the industry's most robust database structures—with no need to install any application. Simply download InSite Anywhere Direct software to your computer to start managing your data.
- InSite Anywhere Mobile Service – For maximum convenience and fast, secure access to real-time well information, the InSite Anywhere Mobile service makes it possible to view well data on any smart phone device including Blackberry®, iPhone™, Android™ and Windows® Mobile.

Features

- Real-time 2D or 3D views of data
- Customizable charts and real-time displays
- Access to historical well data on demand
- Can automatically direct data to third-party software to optimize well operations
- Provides custom-configured timeline display for a 24-hour snapshot of rig activity
- Helps identify the source of lost time and improves operational efficiency with the MaxActivity™ rig floor activity monitoring software
- Enables remote viewing of StrataSteer® 3D geosteering service models for optimal wellbore placement

Benefits

- Collaborate with team members and experts in real time
- Optimize well assets and decision making
- Transfer real-time data from multiple data providers into a single source
- Proactively manage well site situations as they arise
- Make faster, smarter decisions
- Control multiple operations at a single well site, or operations at multiple projects — all from one location
- Better utilization of personnel time by remote interface with operations
- Significant travel-related cost savings

InSite® for Stimulation System

InSite® for Stimulation sand control/stimulation-specific software system is the interface to the InSite core software. The InSite for Stimulation system takes into consideration the special sensor packages, data acquisition systems, and networks needed for the well completion applications. The InSite software handles all database operations that take place between the ADI database and the specific software. Additionally, InSite software handles transferring of real-time and historical data between computers, networks, and locations.

Predefined Job Types for InSite for Stimulation

A different set of screens and processes applies for each job type. Current job types include:

- Gel frac
- Gel frac with CO_2
- Gel frac with N_2
- Gel frac with CO_2 and N_2
- Gel and oil frac
- Acid
- N_2 foam acid
- CO_2 foam acid
- Pure N_2 gas (new with version 2.2.0)

InSite for Stimulation Hardware Configurations

- Existing equipment
  - CompuPac™ portable system
  - ACID van (CompuPac™/ SITEPac™ systems)
  - FracVan II™ vehicle
  - 26 ft TechCommand® center / pumping services workstation
  - 40 ft TechCommand center / pumping services workstation
- InSite based equipment
  - SITEPac system
  - TechCommand center 1000
  - TechCommand center 3000
  - TechCommand center 5000

HAL9285

HAL15697

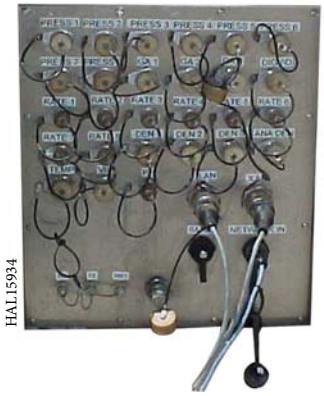
Halliburton's stimulation vessels, which include the Stim Star III are equipped with the same job control and monitoring capabilities as land-based operations like the TechCommand® center 5000.

Data Acquisition Skid

The data acquisition skid (available in the Gulf of Mexico) is a single unit which houses Halliburton data acquisition equipment. Included in this system are electronic equipment, sensors, cables, remote UNIPRO™ II display, and an uninterrupted power supply with battery backup.

Sensors include 2-in. or 3-in. turbine flow meters, electronic pressure transducers, and radioactive densometer for accurate measurement of all rates, volumes, pressures, sand concentrations, and densities for all discharge and returned fluids.

The uninterrupted power supply with battery backup will allow the system to continue monitoring and storing data in the event of a power outage or power surges.


HAL15934

HAL15933

InSite® Skid Unit

Length		Width		Height		Weight	
ft	*m*	ft	*m*	ft	*m*	lb	*kg*
8	*2.44*	14.58	*4.44*	10.67	*3.25*	10,000	*4536*

Appendix

Conversion Factors Applying to Oil Country Calculations

Acre	=	43,560	sq ft	Ft per second	=	0.68182	mile per hour	Part per million	=	0.05835	grain per gallon
Acre	=	4.047	sq m	Ft pound	=	0.001286	British Thermal Unit	Part per million	=	8.345	lb per million gal
Acre foot	=	7,758	barrels	Ft lb per second	=	0.001818	horsepower	Pascal (Pa)	=	0.00015	lb per sq in.
Atmosphere	=	33.94	ft of water	Gallon (US)	=	0.02381	barrel	lb	=	7000	grains
Atmosphere	=	29.92	in. of mercury	Gallon (US)	=	0.1337	cubic ft	lb	=	0.4536	kg
Atmosphere	=	760	mm of mercury	Gallon (US)	=	231.000	cubic in.	lb	=	0.4448	Decanewton (daN)
Atmosphere	=	14.70	lb per sq in.	Gallon (US)	=	3.785	liters	lb per sq in.	=	2.309	ft of water @ 60°F
Bar	=	14.504	lb per sq in.	Gallon (US)	=	0.83267	gallon (Imperial)	lb per sq in.	=	2.0353	in. of mercury
Barrel	=	5.6146	cubic ft	Gallon (US)	=	0.003785	cubic m	lb per sq in.	=	51.697	mm of mercury
Barrel	=	42	gallons	Gallon (Imperial)	=	1.20095	gallons (US)	lb per sq in.	=	0.0703	kg per sq. cm
Barrel of water @60°F	=	0.1588	metric ton	Gallon (Imperial)	=	277.274	cubic in.	lb per sq in.	=	0.0689	bar
Barrel (36° API)	=	0.1342	metric ton	Gallon per minute	=	1.429	barrels per hour	lb per sq in.	=	0.0069	Megapascal (MPa)
Barrel per hour	=	0.0936	cubic ft per minute	Gallon per minute	=	0.1337	cubic ft per minute	lb per sq in.	=	6.895	Kilopascal (KPa)
Barrel per hour	=	0.700	gallon per minute	Gallon per minute	=	34.286	barrels per day	lb per sq in.	=	6895	Pascal (Pa)
Barrel per hour	=	2.695	cubic in. per second	Gram	=	0.03527	ounce	lb per million gals.	=	0.00700	grain per gallon
Barrel per day	=	0.0292	gallon per minute	Horsepower	=	42.44	BTUs per minute	lb per million gals.	=	0.11982	parts per million
British Thermal Unit	=	0.2520	kg calorie	Horsepower	=	33	ft-lb per minute	Quart (Liquid)	=	0.946	liter
British Thermal Unit	=	0.2928	watt hour	Horsepower	=	550	ft-lb per second	Sack cement (set)	=	1.1	cubic ft
BTU per minute	=	0.0236	horsepower	Horsepower	=	1.014	horsepower (metric)	Sq cm	=	0.1550	sq in.
Cm	=	0.3937	in.	Horsepower	=	0.7457	kilowatt	Sq ft	=	0.0929	sq meter
Cm of mercury	=	0.1934	lb per sq in.	Horsepower hour	=	2.547	British Thermal Units	Sq in.	=	6.452	sq cm
Cubic cm	=	0.061	cubic in.	In.	=	2.540	cm	Sq km	=	0.3861	sq mile
Cubic ft	=	0.1781	barrel	In. of mercury	=	1.134	ft of water	Sq meter	=	10.76	sq ft
Cubic ft	=	7.4805	gallons (US)	In. of mercury	=	0.4912	lb per sq in.	Square mile	=	2.590	sq km
Cubic ft	=	0.0283	cubic m	In. of water @60°F	=	0.0361	lb per sq. in.	Temp. Centigrade	=	5/9 (Temp. °F - 32)	
Cubic ft	=	0.9091	sacks cement (set)	Kg	=	2.2046	lb	Temp. Fahrenheit	=	9/5 (Temp. °C) + 32	
Cubic ft per minute	=	10.686	barrels per hour	Kg Calorie	=	3.968	British Thermal Units	Temp. Absolute (Kelvin)	=	Temp. °C + 273	
Cubic ft per minute	=	28.80	cubic in. per second	Kg per sq cm	=	14.223	lb per sq in.	Temp. Absolute (Rankine)	=	Temp. °F + 460	
Cubic ft per minute	=	7.481	gallons per minute	Km	=	3,281	ft	Ton (Long)	=	2.24	lb
Cubic in.	=	16.387	cubic cm	Km	=	0.6214	mile	Ton (Metric)	=	2.205	lb
Cubic meter	=	6.2897	barrels	Kilopascal (KPa)	=	0.145	lb per sq in.	Ton (Short or Net)	=	2,000	lb
Cubic meter	=	35.314	cubic ft	Kilowatt	=	1.341	horsepower	Ton (Metric)	=	1.102	tons (short or net)
Cubic meter	=	1.308	cubic yards	Liter	=	0.2642	gallon	Ton (Metric)	=	1,000	kg
Cubic meter	=	264.20	gallon US	Liter	=	1.0567	quarts	Ton (Metric)	=	6.297	barrels of water @ 60°F
Cubic yard	=	4.8089	barrels	Megapascal (MPa)	=	145.03	lb per sq in.	Ton (Short or Net)	=	7.454	barrels (36° API)
Cubic yard	=	46,656	cubic in.	Meter	=	3.281	ft	Watt-hour	=	0.907	ton (metric)
Cubic yard	=	0.7646	cubic m	Meter	=	39.37	in.	Watt-hour	=	3.415	British Thermal Units
Decanewton (daN)	=	2.2481	lb	Mile	=	5,280	ft	Yard	=	0.9144	meter
Ft	=	30.48	cm	Mile	=	1.609	km				
Ft	=	0.3048	m	Mile per hour	=	1.4667	ft per second				
Ft of water @ 60°F	=	0.4331	lb per sq in.	Ounce (Avoirdupois)	=	28.3495	grams				

Casing Data

Size		Weight	ID		Drift		Capacity	Minimum ID		Coupling OD (API-LTC)	
in.	*mm*	lb/ft	in.	*mm*	in.	*mm*	bbl/100ft	in.	*mm*	in.	*mm*
4 1/2	*114.30*	9.50	4.090	*103.89*	3.965	*100.71*	1.63	4.036	*102.514*	5.05	*128.27*
		10.50	4.052	*102.92*	3.927	*99.75*	1.59	3.995	*101.473*		
		11.60	4.000	*101.60*	3.875	*98.43*	1.55	3.939	*100.051*		
		12.60	3.958	*100.53*	3.833	*97.36*	1.52	3.894	*98.908*		
		13.50	3.920	*99.57*	3.795	*96.39*	1.49	3.852	*97.841*		
		15.10	3.826	*97.18*	3.701	*94.01*	1.42	3.750	*95.250*		
		16.60	3.754	*95.35*	3.629	*92.18*	1.37	3.672	*93.269*		
		16.90	3.740	*95.00*	3.615	*91.82*	1.36	3.657	*92.888*		
		18.80	3.640	*92.46*	3.515	*89.28*	1.29	3.547	*90.094*		
		21.60	3.500	*88.90*	3.375	*85.73*	1.19	3.394	*86.208*		
		24.60	3.380	*85.85*	3.255	*82.68*	1.11	3.261	*82.829*		
		26.50	3.240	*82.30*	3.115	*79.12*	1.02	3.106	*78.892*		
5	*127.00*	11.50	4.560	*115.82*	4.435	*112.65*	2.02	4.502	*114.351*	5.619	*142.723*
		13.00	4.494	*114.15*	4.369	*110.97*	1.96	4.430	*112.522*		
		15.00	4.408	*111.96*	4.283	*108.79*	1.89	4.337	*110.160*		
		18.00	4.276	*108.61*	4.151	*105.44*	1.78	4.194	*106.528*		
		20.30	4.184	*106.27*	4.059	*103.10*	1.70	4.094	*103.988*		
		20.80	4.156	*105.56*	4.031	*102.39*	1.68	4.063	*117.602*		
		21.40	4.126	*104.80*	4.001	*101.63*	1.65	4.031	*102.387*		
		23.20	4.044	*102.72*	3.919	*99.54*	1.59	3.941	*100.101*		
		24.20	4.000	*101.60*	3.875	*98.43*	1.55	3.893	*98.882*		
		26.70	3.876	*98.45*	3.751	*95.28*	1.46	3.757	*95.428*		
5 1/2	*139.70*	14.00	5.012	*127.30*	4.887	*124.13*	2.44	4.948	*125.679*	6.111	*155.194*
		15.50	4.950	*125.73*	4.825	*122.56*	2.38	4.881	*123.977*		
		17.00	4.892	*124.26*	4.767	*121.08*	2.32	4.818	*122.377*		
		20.00	4.778	*121.36*	4.653	*118.19*	2.22	4.694	*119.228*		
		23.00	4.670	*118.62*	4.545	*115.44*	2.12	4.577	*116.256*		
		26.80	4.548	*115.52*	4.375	*111.13*	2.01	4.391	*111.531*		
		28.40	4.440	*112.78*	4.315	*109.60*	1.91	4.326	*109.880*		
		29.70	4.376	*111.15*	4.251	*107.98*	1.86	4.256	*108.102*		
		32.60	4.276	*108.61*	4.125	*104.78*	1.78	4.113	*104.470*		
		36.40	4.090	*103.89*	3.965	*100.71*	1.62	3.941	*100.101*		
6	*152.40*	18.00	5.424	*137.77*	5.299	*134.59*	2.86	5.350	*135.890*	6.680	*169.672*
		20.00	5.352	*135.94*	5.227	*132.77*	2.78	5.272	*133.909*		
		23.00	5.240	*133.10*	5.115	*129.92*	2.67	5.151	*130.835*		
		26.00	5.132	*130.35*	5.007	*127.18*	2.56	5.034	*127.864*		
6 5/8	*168.28*	20.00	6.049	*153.64*	5.924	*150.47*	3.55	5.972	*151.689*	7.464	*189.586*
		24.00	5.921	*150.39*	5.796	*147.22*	3.41	5.834	*148.184*		
		28.00	5.791	*147.09*	5.666	*143.92*	3.26	5.693	*144.602*		
		32.00	5.675	*144.15*	5.550	*140.97*	3.13	5.567	*141.402*		
		34.50	5.575	*141.61*	5.450	*138.43*	3.02	5.458	*138.633*		
		40.20	5.375	*136.53*	5.250	*133.35*	2.81	5.240	*133.096*		
		65.80	4.375	*111.13*	4.250	*107.95*	1.86	4.130	*104.902*		

Casing Data

Size		Weight	ID		Drift		Capacity	Minimum ID		Coupling OD (API-LTC)	
in.	*mm*	lb/ft	in.	*mm*	in.	*mm*	bbl/100ft	in.	*mm*	in.	*mm*
7	*177.80*	17.00	6.538	*166.07*	6.413	*162.89*	4.15	6.469	*164.313*	7.733	*196.418*
		20.00	6.456	*163.98*	6.331	*160.81*	4.05	6.380	*162.052*		
		23.00	6.366	*161.70*	6.241	*158.52*	3.94	6.283	*159.588*		
		26.00	6.276	*159.41*	6.151	*156.24*	3.83	6.186	*157.124*		
		29.00	6.184	*157.07*	6.059	*153.90*	3.71	6.086	*154.584*		
		32.00	6.094	*154.79*	5.969	*151.61*	3.61	5.988	*152.095*		
		35.00	6.004	*152.50*	5.879	*149.33*	3.50	5.891	*149.631*		
		38.00	5.920	*150.37*	5.795	*147.19*	3.40	5.799	*147.295*		
		41.00	5.820	*147.83*	5.695	*144.65*	3.29	5.690	*144.526*		
		42.70	5.750	*146.05*	5.625	*142.88*	3.21	5.614	*142.596*		
		44.00	5.720	*145.29*	5.595	*142.11*	3.18	5.581	*141.757*		
		45.40	5.660	*143.76*	5.535	*140.59*	3.11	5.516	*140.106*		
		49.50	5.540	*140.72*	5.415	*137.54*	2.98	5.384	*136.754*		
		53.60	5.376	*136.55*	5.251	*133.38*	2.81	5.204	*132.182*		
7 5/8	*193.68*	24.00	7.025	*178.44*	6.900	*175.26*	4.79	6.942	*176.327*	8.585	*218.059*
		26.40	6.969	*177.01*	6.844	*173.84*	4.72	6.881	*174.777*		
		29.70	6.875	*174.63*	6.750	*171.45*	4.59	6.780	*172.212*		
		33.70	6.765	*171.83*	6.640	*168.66*	4.45	6.661	*169.189*		
		39.00	6.625	*168.28*	6.500	*165.10*	4.26	6.509	*165.329*		
		42.80	6.501	*165.13*	6.376	*161.95*	4.11	6.374	*161.900*		
		45.30	6.435	*163.45*	6.310	*160.27*	4.02	6.302	*160.071*		
		47.10	6.375	*161.93*	6.250	*158.75*	3.95	6.237	*158.420*		
		51.20	6.126	*155.60*	6.126	*155.58*	3.80	6.102	*154.991*		
		52.80	6.076	*154.33*	6.076	*152.40*	3.74	6.047	*153.594*		
7 3/4	*196.85*	46.10	6.560	*166.62*	6.500	*165.10*	4.18	6.427	*163246*		
8 5/8	*219.08*	24.00	8.097	*205.66*	7.972	*202.49*	6.37	8.015	*203.581*	9.721	*246.913*
		28.00	8.017	*203.63*	7.892	*200.46*	6.24	7.928	*201.371*		
		32.00	7.921	*201.19*	7.796	*198.02*	6.09	7.825	*198.755*		
		36.00	7.825	*198.76*	7.700	*195.58*	5.95	7.721	*196.113*		
		40.00	7.725	*196.22*	7.6	*193.04*	5.8	7.613	*193.370*		
		44.00	7.625	*193.68*	7.500	*190.50*	5.65	7.505	*190.627*		
		49.00	7.511	*190.78*	7.386	*187.60*	5.48	7.381	*187.477*		
		52.00	7.435	*188.85*	7.310	*185.67*	5.37	7.299	*185.395*		
8 3/4	*222.25*	49.70	7.636	*193.95*	7.500	*190.50*	5.66	7.506	*190.652*		
9 5/8	*244.48*	32.30	9.001	*228.63*	8.845	*224.66*	7.87	8.906	*226.212*	10.731	*272.567*
		36.00	8.921	*226.59*	8.765	*222.63*	7.73	8.820	*224.028*		
		40.00	8.835	*224.41*	8.679	*220.45*	7.58	8.727	*221.666*		
		43.50	8.755	*222.38*	8.599	*218.41*	7.45	8.641	*219.481*		
		47.00	8.681	*220.50*	8.525	*216.54*	7.32	8.561	*217.449*		
		53.50	8.535	*216.79*	8.379	*212.83*	7.08	8.403	*213.436*		
		58.40	8.435	*214.25*	8.279	*210.29*	6.91	8.295	*210.693*		
		59.40	8.407	*213.54*	8.251	*209.58*	6.87	8.264	*209.906*		
		61.10	8.375	*212.73*	8.219	*208.76*	6.81	8.229	*209.017*		
		64.90	8.281	*210.34*	8.125	*206.38*	6.66	8.127	*206.426*		
		70.30	8.157	*207.19*	8.001	*203.23*	6.46	7.993	*203.022*		
		71.80	8.125	*206.38*	7.969	*202.41*	6.41	7.958	*202.133*		

Casing Data

Size		Weight	ID		Drift		Capacity	Minimum ID	
in.	*mm*	lb/ft	in.	*mm*	in.	*mm*	bbl/100ft	in.	*mm*
9 3/4	*247.65*	59.20	8.560	*217.42*	8.500	*215.90*	7.12	8.419	*213.843*
9 7/8	*250.83*	62.80	8.625	*219.08*	8.500	*215.90*	7.23	8.478	*215.341*
10 3/4	*273.05*	32.75	10.192	*258.88*	10.036	*254.91*	10.09	10.097	*256.464*
		40.50	10.050	*255.27*	9.894	*251.31*	9.81	9.944	*252.578*
		45.50	9.950	*252.73*	9.794	*248.77*	9.62	9.836	*249.834*
		51.00	9.850	*250.19*	9.694	*246.23*	9.42	9.728	*247.091*
		55.50	9.760	*247.90*	9.604	*243.94*	9.25	9.631	*244.627*
		60.70	9.660	*245.36*	9.504	*241.40*	9.06	9.523	*241.884*
		65.70	9.560	*242.82*	9.404	*238.86*	8.88	9.415	*239.141*
		71.10	9.450	*240.03*	9.294	*236.07*	8.67	9.296	*236.118*
		73.20	9.406	*238.91*	9.250	*234.95*	8.59	9.248	*234.899*
		79.20	9.282	*235.76*	9.126	*231.80*	8.37	9.113	*231.470*
11 3/4	*298.45*	42.00	11.084	*281.53*	10.928	*277.57*	11.93	10.976	*278.790*
		47.00	11.000	*279.40*	10.844	*275.44*	11.75	10.885	*276.479*
		54.00	10.880	*276.35*	10.724	*272.39*	11.50	10.756	*273.202*
		60.00	10.772	*273.61*	10.616	*269.65*	11.27	10.639	*270.231*
		65.00	10.682	*271.32*	10.526	*267.36*	11.08	10.542	*267.767*
		66.70	10.656	*270.66*	10.500	*266.70*	11.03	10.514	*267.056*
		71.00	10.586	*268.88*	10.430	*264.92*	10.89	10.438	*265.125*
		73.60	10.532	*267.51*	10.376	*263.55*	10.78	10.380	*263.652*
		75.00	10.514	*267.06*	10.358	*263.09*	10.74	10.361	*263.169*
		79.00	10.438	*265.13*	10.282	*261.16*	10.58	10.278	*261.061*
		80.50	10.406	*264.31*	10.25	*260.35*	10.52	10.244	*260.198*
		83.00	10.368	*263.35*	10.212	*259.38*	10.44	10.202	*259.131*
		87.20	10.282	*261.16*	10.126	*257.20*	10.27	10.109	*256.769*
11 7/8	*301.63*	71.80	10.711	*272.06*	10.625	*269.88*	11.14	10.563	*268.300*
13 3/8	*339.73*	48.00	12.715	*322.96*	12.559	*319.00*	15.71	12.599	*320.015*
		54.50	12.615	*320.42*	12.459	*316.46*	15.46	12.492	*317.297*
		61.00	12.515	*317.88*	12.359	*313.92*	15.21	12.384	*314.554*
		68.00	12.415	*315.34*	12.259	*311.38*	14.97	12.276	*311.810*
		72.00	12.347	*313.61*	12.191	*309.65*	14.81	12.203	*309.956*
		77.00	12.275	*311.79*	12.119	*307.82*	14.64	12.125	*307.975*
		80.70	12.215	*310.26*	12.059	*306.30*	14.49	12.060	*306.324*
		85.00	12.159	*308.84*	12.003	*304.88*	14.36	12.000	*304.800*
		86.00	12.125	*307.98*	11.969	*304.01*	14.28	11.963	*303.860*
		92.00	12.031	*305.59*	11.875	*301.63*	14.06	11.861	*301.269*
		98.00	11.937	*303.20*	11.781	*299.24*	13.84	11.760	*298.704*
		100.30	11.907	*302.44*	11.751	*298.48*	13.77	11.727	*297.866*
13 1/2	*342.90*	81.40	12.340	*313.44*	12.250	*311.15*	14.79	12.185	*309.499*
13 5/8	*346.08*	88.20	12.375	*314.33*	12.250	*311.15*	14.88	12.212	*310.185*

API Tubing Table

Tubing Size		Nominal Weight		Grade	Wall Thickness in.	ID in.	Threaded Coupling				Collapse Resistance psi	Internal Yield Pressure psi	Joint Yield Strength		Capacity Table	
Nom. in.	OD in.	T & C Non-Upset lb/ft	T & C Upset lb/ft				Drift Dia. in.	Coupling OD Non-Upset in.	Upset Reg. in.	Upset Spec. in.			T & C Non-Upset lb	T & C Upset lb	bbl/LF	LF/bbl
3/4	1.05	1.14	1.20	H-40	0.113	0.824	0.730	1.313	1.660		7,200	7,530	6,360	13,300	0.0007	1516.13
				J-55							9,370	10,360	8,740	18,290		
				C-75							12,250	14,120	11,920	24,940		
				N-80							12,710	15,070	12,710	26,610		
1	1.315	1.700	1.800	H-40	0.113	1.049	0.950	1.660	1.900		6,820	7,080	10,960	19,760	0.0011	935.49
				J-55							8,860	9,730	15,060	27,160		
				C-75							11,590	13,270	20,540	37,040		
				N-80							12,270	14,160	21,910	39,510		
1 1/4	1.660	2.300	2.400	H-40	0.125	1.410	1.286	2.054	2.200		5,220	5,270	15,530	26,740	0.0019	517.79
				H-40	0.140	1.380					5,790	5,900			0.0018	540.55
				J-55	0.125	1.410					6,790	7,250	21,360	36,770	0.0019	517.79
					0.140	1.380					7,530	8,120			0.0018	540.55
				C-75	0.140	1.380					9,840	11,070	29,120	50,140	0.0018	540.55
				N-80	0.140	1.380					10,420	11,810	31,060	53,480	0.0018	540.55
1 1/2	1.900	2.750	2.900	H-40	0.125	1.650	1.516	2.200	2.500		4,450		19,090	31,980	0.0026	378.11
				H-40	0.145	1.610					5,290				0.0025	397.14
				J-55	0.125	1.650					5,790		26,250	43,970	0.0026	378.11
					0.145	1.610					6,870				0.0025	397.14
				C-75	0.145	1.610					8,990	10,020	35,800	59,960	0.0025	397.14
				N-80	0.145	1.610					9,520	10,680	38,180	63,960	0.0025	397.14
2 1/16	2.063			H-40	0.156	1.751	1.626				5,240	5,290		0.0030	335.75	
				J-55							6,820	7,280				
				C-75							8,910	9,920				
				N-80							9,440	10,590				
2 3/8	2.375	4.00	4.70	H-40	0.167	2.041	1.947	2.875	3.063	2.910	4,880	4,920	30,130	52,170	0.0040	247.12
		4.60		H-40	0.190	1.995	1.901				5,520	5,600	35,960		0.0039	258.65
		4.00		J-55	0.167	2.041	1.947				6,340	6,770	41,430		0.0040	247.12
		4.60	4.70	J-55	0.190	1.995	1.901				7,180	7,700	49,450	71,730	0.0039	258.65
		4.00			0.167	2.041	1.947				8,150	9,230	56,500		0.0040	247.12
		4.60	4.70	C-75	0.190	1.995	1.901				9,380	10,500	67,430	97,820	0.0039	258.65
		5.80	5.95	C-75	0.254	1.867	1.773				12,180	14,040	96,560	126,940	0.0034	295.33
		4.00		N-80	0.167	2.041	1.947				8,660	9,840	60,260		0.0040	247.12
		4.60	4.70	N-80	0.190	1.995	1.901				9,940	11,200	71,930	104,340	0.0039	258.65
		5.80	5.95	N-80	0.254	1.867	1.773				12,890	14,970	102,990	135,400	0.0034	295.33
		4.60	4.70	P-105	0.190	1.995	1.901				13,250	14,700	94,410	136,940	0.0039	258.65
		5.80	5.95	P-105	0.254	1.867	1.773				17,190	19,650	135,180	177,710	0.0034	295.33
2 7/8	2.875	6.40	6.50	H-40	0.217	2.441	2.347	3.500	3.668	3.460	5,230	5,280	52,780	72,480	0.0058	172.76
		6.40	6.50	J-55	0.217	2.441	2.347				6,800	7,260	72,580	99,660	0.0058	172.76
		6.40	6.50	C-75	0.217	2.441	2.347				8,900	9,910	98,970	135,900	0.0058	172.76
		8.60	8.70	C-75	0.308	2.259	2.165				12,200	14,060	149,360	185,290	0.0050	201.72
		6.40	6.50	N-80	0.217	2.441	2.347				9,420	10,570	105,570	144,960	0.0058	172.76
		8.60	8.70	N-80	0.308	2.259	2.165				12,920	15,000	159,310	198,710	0.0050	201.72
		6.40	6.50	P-105	0.217	2.441	2.347				12,560	13,870	138,560	190,260	0.0058	172.76
		8.60	8.70	P-105	0.308	2.259	2.165				17,220	19,690	209,100	260,810	0.0050	201.72

API Tubing Table

Tubing Size		Nominal Weight		Grade	Wall Thickness in.	ID in.	Threaded Coupling				Collapse Resistance psi	Internal Yield Pressure psi	Joint Yield Strength		Capacity Table	
Nom. in.	OD in.	T & C Non-Upset lb/ft	T & C Upset lb/ft				Drift Dia. in.	Coupling OD Non-Upset in.	Upset Reg. in.	Upset Spec. in.			T & C Non-Upset lb	T & C Upset lb	bbl/LF	LF/bbl
3 1/2	3.500	7.70		H-40	0.216	3.068	2.943	4.250	4.500	4.180	4,070	4,320	65,070		0.0091	109.37
		9.20	9.30	H-40	0.254	2.992	2.867				5,050	5,080	79,540	103,610	0.0087	114.99
		10.20		H-40	0.289	2.922	2.797				5,680	5,780	92,550		0.0083	120.57
		7.70		J-55	0.216	3.068	2.943				5,290	5,940	89,470		0.0091	109.37
		9.20	9.30	J-55	0.254	2.992	2.867				6,560	6,980	109,370	142,460	0.0087	114.99
		10.20		J-55	0.289	2.922	2.797				7,390	7,950	127,250		0.0083	120.57
		7.70		C-75	0.216	3.068	2.943				6,690	8,100	122,010		0.0091	109.37
		9.20	9.30	C-75	0.254	2.992	2.867				8,530	9,520	149,140	194,260	0.0087	114.99
		10.20														
					0.289	2.922	2.797				9,660	10,840	173,530		0.0083	120.57
		12.70	12.95	C-75	0.375	2.750	2.625				12,200	14,060	230,990	276,120	0.0073	136.12
		7.70		N-80	0.216	3.068	2.943				7,080	8,640	130,140		0.0091	109.37
		9.20	9.30	N-80	0.254	2.992	2.867				9,080	10,160	159,090	207,220	0.0087	114.99
		10.20		N-80	0.289	2.922	2.797				10,230	11,560	185,100		0.0083	120.57
		12.70	12.95	N-80	0.375	2.750	2.625				12,920	15,000	246,390	294,530	0.0073	136.12
		9.20	9.30	P-105	0.254	2.992	2.867				12,110	13,330	208,800	271,970	0.0087	114.99
		12.70	12.95	P-105	0.375	2.750	2.625				17,200	19,690	323,390	386,570	0.0073	136.12
4	4.000	9.500	11.000	H-40	0.226	3.548	3.423	4.750	5.000		3,580	3,960	72,000		0.0122	81.78
				H-40	0.262	3.476	3.351				4,420	4,580		123,070	0.0117	85.20
				J-55	0.226	3.548	3.423				4,650	5,440	99,010		0.0122	81.78
				J-55	0.262	3.476	3.351				5,750	6,300	135,010	169,220	0.0117	85.20
				C-75	0.226	3.548	3.423				5,800	7,420			0.0122	81.78
				C-75	0.262	3.476	3.351				7,330	8,600		230,750	0.0117	85.20
				N-80	0.226	3.548	3.423				6,120	7,910	144,010		0.0122	81.78
				N-80	0.262	3.476	3.351				7,780	9,170		246,140	0.0117	85.20
4 1/2	4.500	12.600	12.75	H-40							3,930	4,220	104,360	144,020		
				J-55	0.271	3.958	3.833	5.200	5.563		5,100	5,800	143,500	198,030	0.0152	65.71
				C-75							6,430	7,900	195,680	270,240		
				N-80							6,810	8,430	208,730	288,040		

Recommended API Criteria

Property	API RP 58	API RP 56	API RP 60
Proppant Size	A minimum of 96% of the tested sand sample should pass the designated coarse sieve	A minimum of 90% of the tested sand sample should fall between the designated sieve sizes; i.e., 12/20, 20/40, etc.	A minimum of 90% of the tested sand sample should fall between the designated sieve sizes; i.e., 20/40, 40/70. etc.
	Not over 0.1% by weight of the total tested sand sample should be larger than the first sieve size	Not over 0.1% of the total tested sample should be larger than the first sieve size	Not over 0.1% of the total tested sample should be larger than the first sieve size
	Not over 2%* by weight can be smaller than the last designated sieve size	Not over 1%* of the sand sample should be smaller than the last sieve size	Not over 1% of the sand sample should be smaller than the last sieve size
Sphericity	≥ 0.6	≥ 0.6	≥ 0.7
Roundness	≥ 0.6	≥ 0.6	≥ 0.7
Acid Soluble Material	≤ 1% by weight	6/12 - 30/50 → 2% 40/70 - 70/140 → 3%	N/A
Turbidity	≤ 250 Formazin Turbidity Units	≤ 250 Formazin Turbidity Units	N/A
Clay and Soft Particle Content	≤1% by volume	≤1% by volume	N/A

*The frac sand sieve stacks typically have one smaller sieve just before the pan.

API RP 58 Recognized Gravel Packing Sand Sizes

Sieve Opening Sizes, µm	2360/1180	1700/850	1180/600	850/425	600/300	425/250
Sand Size Designations	8/16	12/20	16/30	20/40	30/50	40/60
Nest of USA Sieves Recommended for Testing	6	8	12	16	20	30
	8	12	16	20	30	40
	10	14	18	25	35	45
	12	16	20	30	40	50
	14	18	25	35	45	60
	16	20	30	40	50	70
	Pan	Pan	Pan	Pan	Pan	Pan

API RP 58 Crush Resistance Test Criteria

US Mesh Size	Load on Cell, lb force	Stress on Sand, psi	Suggested Maximum Fines % by Weight
8/16	6,283	2,000	8%
12/20	6,283	2,000	4%
16/30	6,283	2,000	2%
20/40	6,283	2,000	2%
30/50	6,283	2,000	2%
40/60	6,283	2,000	2%

API RP 56 Recognized Frac Sand Sizes

Sieve Opening Sizes, µm	3350/1700	2360/1180	1700/850	1180/600	850/425	600/300	425/212	212/106
Sand Size Designations	6/12	8/16	12/20	16/30	20/40	30/50	40/70	70/140
Nest of USA Sieves Recommended for Testing	4	6	8	12	16	20	30	50
	6	8	12	16	20	30	40	70
	8	12	16	20	30	40	50	100
	10	14	18	25	35	45	60	120
	12	16	20	30	40	50	70	140
	16	20	30	40	50	70	100	200
	Pan	Pan	Pan	Pan	Pan	Pan	Pan	Pan

API RP 56 Crush Resistance Test Criteria

US Mesh Size	Load on Cell, lb force	Stress on Sand, psi	Suggested Maximum Fines % by Weight
6/12	6,283	2,000	20
8/16	6,283	2,000	18
12/20	9,425	3,000	16
16/30	9,425	3,000	14
20/40	12,566	4,000	14
30/50	12,566	4,000	10
40/70	15,708	5,000	8
70/140	15,708	5,000	6

API RP 60 Crush Resistance Test Criteria

US Mesh Size	Suggested Maximum Fines % by Weight
12/20	25
16/20	25
20/40	10
40/70	8

The table above shows the acceptable amount of fines allowed for each man-made proppant size. API RP 60 suggests stress levels at which the crush test should be performed (7,500, 10,000, 12,500, and 15,000 psi). Other stress levels can be used. When the amount of fines exceeds the suggested maximum, the upper stress limit for the proppant has been identified.

Buoyancy Factors for Steel Pipe in Various Weight Fluids

Fluid Density								
lb/gal	*kg/m³*	Buoyancy Factor	lb/gal	*kg/m³*	Buoyancy Factor	lb/gal	*kg/m³*	Buoyancy Factor
6.0	*718.96*	0.9083	11.0	*1318.09*	0.8319	16.0	*1917.22*	0.7555
6.1	*730.94*	0.9068	11.1	*1330.07*	0.8304	16.1	*1929.21*	0.7540
6.2	*742.92*	0.9053	11.2	*1342.06*	0.8289	16.2	*1941.19*	0.7524
6.3	*754.91*	0.9037	11.3	*1354.04*	0.8273	16.3	*1953.17*	0.7509
6.4	*766.89*	0.9022	11.4	*1366.02*	0.8258	16.4	*1965.15*	0.7494
6.5	*778.87*	0.9007	11.5	*1378.00*	0.8243	16.5	*1977.14*	0.7479
6.6	*790.85*	0.8991	11.6	*1389.99*	0.8227	16.6	*1989.12*	0.7463
6.7	*802.84*	0.8976	11.7	*1401.97*	0.8212	16.7	*2001.10*	0.7448
6.8	*814.82*	0.8961	11.8	*1413.95*	0.8197	16.8	*2013.08*	0.7433
6.9	*826.80*	0.8946	11.9	*1425.93*	0.8182	16.9	*2025.07*	0.7417
7.0	*838.78*	0.8930	12.0	*1437.92*	0.8166	17.0	*2037.05*	0.7402
7.1	*850.77*	0.8915	12.1	*1449.90*	0.8151	17.1	*2049.03*	0.7387
7.2	*862.75*	0.8900	12.2	*1461.88*	0.8136	17.2	*2061.01*	0.7372
7.3	*874.73*	0.8884	12.3	*1473.86*	0.8120	17.3	*2073.00*	0.7356
7.4	*886.72*	0.8869	12.4	*1485.85*	0.8105	17.4	*2084.98*	0.7341
7.5	*898.70*	0.8854	12.5	*1497.83*	0.8090	17.5	*2096.96*	0.7326
7.6	*910.68*	0.8839	12.6	*1509.81*	0.8075	17.6	*2108.94*	0.7311
7.7	*922.66*	0.8823	12.7	*1521.80*	0.8059	17.7	*2120.93*	0.7295
7.8	*934.65*	0.8808	12.8	*1533.78*	0.8044	17.8	*2132.91*	0.7280
7.9	*946.63*	0.8793	12.9	*1545.76*	0.8029	17.9	*2144.89*	0.7265
8.0	*958.61*	0.8778	13.0	*1557.74*	0.8013	18.0	*2156.88*	0.7249
8.1	*970.59*	0.8762	13.1	*1569.73*	0.7998	18.1	*2168.86*	0.7234
8.2	*982.58*	0.8747	13.2	*1581.71*	0.7983	18.2	*2180.84*	0.7219
8.3	*994.56*	0.8732	13.3	*1593.69*	0.7968	18.3	*2192.82*	0.7204
8.33*	*998.15*	0.8727	13.4	*1605.67*	0.7952	18.4	*2204.81*	0.7188
8.4	*1006.54*	0.8716	13.5	*1617.66*	0.7937	18.5	*2216.79*	0.7173
8.5	*1018.52*	0.8701	13.6	*1629.64*	0.7922	18.6	*2228.77*	0.7158
8.6	*1030.51*	0.8686	13.7	*1641.62*	0.7906	18.7	*2240.75*	0.7142
8.7	*1042.49*	0.8671	13.8	*1653.60*	0.7891	18.8	*2252.74*	0.7127
8.8	*1054.47*	0.8655	13.9	*1665.59*	0.7876	18.9	*2264.72*	0.7112
8.9	*1066.45*	0.8640	14.0	*1677.57*	0.7861	19.0	*2276.70*	0.7097
9.0	*1078.44*	0.8625	14.1	*1689.55*	0.7845	19.1	*2288.68*	0.7081
9.1	*1090.42*	0.8609	14.2	*1701.53*	0.7830	19.2	*2300.67*	0.7066
9.2	*1102.40*	0.8594	14.3	*1713.52*	0.7815	19.3	*2312.65*	0.7051
9.3	*1114.39*	0.8579	14.4	*1725.50*	0.7800	19.4	*2324.63*	0.7035
9.4	*1126.37*	0.8564	14.5	*1737.48*	0.7784	19.5	*2336.61*	0.7020
9.5	*1138.35*	0.8548	14.6	*1749.47*	0.7769	19.6	*2348.60*	0.7005
9.6	*1150.33*	0.8533	14.7	*1761.45*	0.7754	19.7	*2360.58*	0.6990
9.7	*1162.32*	0.8518	14.8	*1773.43*	0.7738	19.8	*2372.56*	0.6974
9.8	*1174.30*	0.8502	14.9	*1785.41*	0.7723	19.9	*2384.55*	0.6960
9.9	*1186.28*	0.8487	15.0	*1797.40*	0.7708	20.0	*2396.53*	0.6944
10.0	*1198.26*	0.8472	15.1	*1809.38*	0.7693			
10.1	*1210.25*	0.8457	15.2	*1821.36*	0.7677			
10.2	*1222.23*	0.8441	15.3	*1833.34*	0.7662			
10.3	*1234.21*	0.8426	15.4	*1845.33*	0.7647			
10.4	*1246.19*	0.8411	15.5	*1857.31*	0.7631			
10.5	*1258.18*	0.8395	15.6	*1869.29*	0.7616			
10.6	*1270.16*	0.8380	15.7	*1881.27*	0.7601			
10.7	*1282.14*	0.8365	15.8	*1893.26*	0.7586			
10.8	*1294.13*	0.8350	15.9	*1905.24*	0.7570			
10.9	*1306.11*	0.8334						

*Weight of water at 68°F (20°C)
For open-ended pipe:
Pipe Weight (in fluid) = Pipe Weight (in air) × Buoyancy Factor

Typical Proppants

Trade Name	Supplier	Ceramics, Intermediate Strength, High Strength	Sizes Available	Specific Gravity	Absolute Volume (gal/lb)
CARBO*ECONOPROP*®	CARBO Ceramics, Inc.	Ceramics	20/40, 30/50, 40/70	2.70	0.044
CARBO*LITE*®	CARBO Ceramics	Ceramics	12/18, 16/20, 20/40	2.71	0.044
CARBO*PROP*®	CARBO Ceramics	Intermediate Strength	16/30, 20/40, 30/60, 40/70	3.27	0.037
CARBO*HSP*™	CARBO Ceramics	High Strength	12/18, 16/30, 20/40, 30/60	3.56	0.034
UltraProp™	Saint Gobain Proppants	High Strength	12/18, 16/20, 16/30, 20/40, 30/50	3.50	0.0347
InterProp®	Saint Gobain Proppants	Intermediate Strength	12/18, 16/30, 20/40, 30/50	3.20	0.0374
VersaProp®	Saint Gobain Proppants	Ceramic	One size, more broad than API 20/40 mesh distribution	3.20	0.0374
Sintered Bauxite	Saint Gobain Proppants	High Strength	16/30, 20/40, 30/50	3.50	0.0347
SinterBall®	Sintex Minerals and Services, Inc.	High Strength	14/20, 16/30, 18/30, 20/40, 30/50	3.5-3.58	0.033-0.034
SinterLite®	Sintex Minerals and Services, Inc.	Intermediate Strength	8/16, 12/20, 16/30, 20/40	1.72-1.75	0.038

For the latest product information, refer to the supplier's specifications.

Slack-Off Data for Tubing and Drillpipe

Size of Tubing or Drillpipe	Slack-Off Factor
1.900 OD EUE Tubing	0.68
2 3/8 OD EUE Tubing	0.39
2 7/8 OD EUE Tubing	0.26
3 1/2 OD EUE Tubing	0.17
2 7/8 OD 10.40 lb/ft DP	0.16
3 1/2 OD 13.30 lb/ft DP	0.12
4 1/2 OD 16.60 lb/ft DP	0.10

$$\text{Required Slack (in.)} = \frac{\text{Desired Force (lb)}}{1{,}000} \times \frac{\text{Packer Depth (ft)}}{1{,}000} \times \text{Factor}$$

For 3 1/2 OD Tubing

$$\text{Required Slack (in.)} = \frac{10{,}000 \text{ lb}}{1{,}000} \times \frac{12{,}000 \text{ ft}}{1{,}000} \times 0.17 = 20.4$$

Stretch Data for Drillpipe, Tubing, and Casing

Size of Tubing Length of Pipe	Drillpipe or Casing Suspended in Well		Stretch/1,000 lb Pull Above Weight of Pipe in Water		Pull Above Weight of Pipeline Stretch of Pipe		Stretch Caused by Own Weight Suspended	
in. (*mm*)	ft	*m*	in. (Factor C)	*mm (Factor C)*	lb	*kg*	in.	*mm*
3.5 *(88.90)* Drillpipe 13.30 lb/ft *(19.79 kg/m)*	0.5000	*0.1524*	0.055	*1.40*	18,200	*8,255*	0.14	*3.56*
	1.0000	*0.3048*	0.110	*2.79*	9,100	*4,128*	0.56	*14.22*
	2.0000	*0.6096*	0.220	*5.59*	4,550	*2,064*	2.22	*56.39*
	3.0000	*0.9144*	0.330	*8.38*	3,033	*1,376*	5.00	*127.00*
	4.0000	*1.2192*	0.440	*11.18*	2,275	*1,032*	8.88	*225.55*
	5.0000	*1.5240*	0.550	*13.97*	1,820	*826*	13.88	*352.55*
	10.0000	*3.0480*	1.100	*27.94*	910	*413*	55.51	*1409.95*
4.5 *(114.30)* Drillpipe 16.60 lb/ft *(24.70 kg/m)*	0.5000	*0.1524*	0.045	*1.14*	22,200	*10,070*	0.14	*3.56*
	1.0000	*0.3048*	0.090	*2.29*	11,110	*5,039*	0.56	*14.22*
	2.0000	*0.6096*	0.180	*4.57*	5,550	*2,517*	2.22	*56.39*
	3.0000	*0.9144*	0.270	*6.86*	3,700	*1,678*	5.00	*127.00*
	4.0000	*1.2192*	0.360	*9.14*	2,775	*1,259*	8.88	*225.55*
	5.0000	*1.5240*	0.450	*11.43*	2,220	*1,007*	13.88	*352.55*
	10.0000	*3.0480*	0.900	*22.86*	1,110	*503*	55.51	*1409.95*
5.5 *(139.70)* Casing 17 lb/ft *(25.30 kg/m)*	0.5000	*0.1524*	0.040	*1.02*	24,800	*11,249*	0.14	*3.56*
	1.0000	*0.3048*	0.080	*2.04*	12,400	*5,625*	0.56	*14.22*
	2.0000	*0.6096*	0.160	*4.06*	6,230	*2,826*	2.22	*56.39*
	3.0000	*0.9144*	0.240	*6.10*	4,133	*1,875*	5.00	*127.00*
	4.0000	*1.2192*	0.320	*8.13*	3,100	*1,406*	8.88	*225.55*
	5.0000	*1.5240*	0.402	*10.21*	2,480	*1,125*	13.88	*352.55*
	10.0000	*3.0480*	0.804	*20.42*	1,240	*562*	55.51	*1409.95*
7 *(117.80)* Casing 23 lb/ft *(34.23 kg/m)*	0.5000	*0.1524*	0.030	*0.76*	33,220	*15,068*	0.14	*3.56*
	1.0000	*0.3048*	0.060	*1.53*	16,610	*7,534*	0.56	*14.22*
	2.0000	*0.6096*	0.120	*3.05*	8,305	*3,767*	2.22	*56.39*
	3.0000	*0.9144*	0.181	*4.60*	5,537	*2,512*	5.00	*127.00*
	4.0000	*1.2192*	0.241	*6.12*	4,152	*1,883*	8.88	*225.55*
	5.0000	*1.5240*	0.301	*7.65*	3,322	*1,507*	13.88	*352.55*
	10.0000	*3.0480*	0.602	*15.29*	1,661	*753*	55.51	*1409.95*

When using the above table:

$$L = \frac{S \times 1000 \times 1000}{P \times C}$$

L = length of free pipe, ft

S = stretch of pipe, in.

P = pull on pipe to get stretch, lb

C =constant for the given pipe size and weight being stretched
For this equation, use C factor at pipe length of 1,000 ft.

To calculate tubing stretch under an applied load use:

Stretch (in.) = 5.09 × 10-7 [(T×L) / (POD2-PID2)]

T = applied tension at surface (lb)

L = length of workstring (ft)

POD = pipe outside diameter (in.)

PID = pipe inside diameter (in.)

Elongation of Pipe in Inches Due to Change in Temperature

Length of Pipe	Elongation of Pipe Due to Temperature Difference in °F of									
	25	50	75	100	125	150	175	200	225	250
ft	in.									
1000	2.07	4.14	6.21	8.28	10.35	12.42	14.49	16.56	18.63	20.70
2000	4.14	8.28	12.42	16.56	20.70	24.84	28.98	33.12	37.26	41.40
3000	6.21	12.42	18.36	24.84	31.05	37.26	43.47	49.68	55.89	62.10
4000	8.28	16.56	24.84	33.12	41.40	49.68	57.96	66.24	74.52	82.80
5000	10.35	20.70	31.05	41.40	51.75	62.10	72.45	82.80	93.15	103.50
6000	12.42	24.84	37.26	49.68	62.10	74.52	86.94	99.36	111.78	124.20
7000	14.49	28.98	43.47	57.96	72.45	86.94	101.43	115.92	130.41	144.90
8000	16.56	33.12	49.68	66.24	82.80	99.36	115.92	132.48	149.04	165.60
9000	18.63	37.26	55.89	74.52	93.15	111.78	130.41	149.04	167.67	186.30
10000	20.70	41.40	62.10	82.80	103.50	124.20	144.90	165.60	186.30	207.00
11000	22.77	45.54	68.31	91.08	113.85	136.62	159.39	182.16	204.93	227.70
12000	24.84	49.68	74.52	99.36	124.20	149.04	173.88	198.72	223.56	248.40
13000	26.91	53.82	80.73	107.64	134.55	161.46	188.37	215.28	242.19	269.10
14000	28.98	57.96	86.94	115.92	144.90	173.88	202.86	231.84	260.82	289.80
15000	31.05	62.10	93.15	124.20	155.25	186.30	217.35	248.40	279.45	310.50
16000	33.12	66.24	99.36	132.48	165.60	198.72	231.84	264.96	298.08	331.20
17000	35.19	70.38	105.57	140.76	175.95	211.14	246.33	281.52	316.71	351.90
18000	37.26	74.52	111.78	149.04	186.30	223.56	260.82	298.08	335.34	372.60
19000	39.33	78.66	117.99	157.32	196.65	235.98	275.31	314.64	353.97	393.30
20000	41.40	82.80	124.20	165.60	207.00	248.40	289.80	331.20	372.60	414.00

Note: Temperature difference is the difference between atmospheric temperature and well temperature. Ordinarily, well temperature is the average of atmospheric and bottomhole temperature.

Example: For 100°F surface temperature and 200°F BHT at 10,000 ft
$T_{Average}$= 200 - 100 = 150°F
$T_{Difference}$= 150 - 100 = 50°F From chart: At 10,000 ft and $T_{Difference}$ = 50°F Elongation = 41.40 in.

Minimum Radial Clearances Using Halliburton's Standard Centralizers Sizes - 4 Blades

			Basepipe in.	2.375	2.875	3.500	4.000	4.500	5.000
			Wrap Wire in.	090 × .090	090 × .090	090 × .090	090 × .090	090 × .090	090 × .090
			Jacket OD in.	2.861	3.361	3.986	4.486	5	5.505
Casing Size in.	Weight ppf	Drift in.	ID in.	Stand-off	Stand-off	Stand-off	Stand-off	Stand-off	Stand-off
5.000	15.0	4.283	4.408	0.417	0.167	N/A	N/A	N/A	N/A
	18.0	4.151	4.276	0.436	0.186	N/A	N/A	N/A	N/A
	20.3	4.031	4.184	0.450	0.200	N/A	N/A	N/A	N/A
	23.2	3.875	4.044	0.474	0.224	N/A	N/A	N/A	N/A
5.500	17.0	4.767	4.892	0.667	0.417	0.186	N/A	N/A	N/A
	20.0	4.653	4.778	0.684	0.434	0.204	N/A	N/A	N/A
	23.0	4.545	4.670	0.702	0.452	0.223	N/A	N/A	N/A
	26.0	4.423	4.548	0.723	0.473	N/A	N/A	N/A	N/A
6.625	24.0	5.796	5.921	1.160	0.910	0.679	0.429	N/A	N/A
	28.0	5.666	5.791	1.180	0.930	0.701	0.451	N/A	N/A
	32.0	5.550	5.675	1.200	0.950	0.722	0.472	N/A	N/A
7.000	23.0	6.241	6.366	1.417	1.167	0.938	0.688	0.431	0.178
	26.0	6.151	6.276	1.432	1.182	0.953	0.703	0.446	0.194
	29.0	6.059	6.184	1.448	1.198	0.970	0.720	0.463	0.211
	32.0	5.969	6.094	1.464	1.214	0.652	0.402	0.145	N/A
	35.0	5.879	6.004	1.481	1.231	0.666	0.416	0.159	N/A
	38.0	5.795	5.920	1.160	0.910	0.679	0.429	0.172	N/A
7.625	26.4	6.844	6.969	1.650	1.400	1.170	0.920	0.663	0.410
	29.7	6.750	6.875	1.665	1.415	1.186	0.936	0.679	0.426
	33.7	6.640	6.765	1.683	1.433	1.205	0.955	0.698	0.445
	39.0	6.500	6.625	1.708	1.458	1.231	0.981	0.724	0.472
	42.8	6.376	6.501	1.731	1.481	0.915	0.665	0.408	0.156
	45.3	6.310	6.435	1.406	1.156	0.926	0.676	0.419	0.167
	47.1	6.250	6.375	1.416	1.166	0.936	0.686	0.429	0.177
7.750	46.1	6.500	6.560	1.720	1.470	1.244	0.994	0.737	0.485
8.625	54.0	7.250	7.375	1.914	1.664	1.435	1.185	0.928	0.676
	63.5	7.000	7.125	1.958	1.708	1.481	1.231	0.974	0.722
9.625	40.0	8.679	8.835	2.669	2.419	2.191	1.941	1.684	1.432
	43.5	8.599	8.755	2.683	2.433	2.206	1.956	1.699	1.446
	47.0	8.525	8.681	2.696	2.446	2.220	1.970	1.713	1.460
	53.5	8.379	8.535	2.724	2.474	1.907	1.657	1.400	1.147
	71.8	7.969	8.125	2.457	2.207	1.643	3.636	1.136	0.883

Note: Table stand-off values do not take into account affect on stand-off resulting from pipe sag or buckling due to deviation or compression.

Minimum Radial Clearances Using Halliburton's Standard Centralizers Sizes - 6 Blades

			Basepipe in.	2.375	2.875	3.500	4.000	4.500	5.000
			Wrap Wire in.	090 × .090	090 × .090	090 × .090	090 × .090	090 × .090	090 × .090
			Jacket OD in.	2.861	3.361	3.986	4.486	5	5.505
Casing Size in.	Weight ppf	Drift in.	ID in.	Stand-off	Stand-off	Stand-off	Stand-off	Stand-off	Stand-off
5.000	15.0	4.283	4.408	0.472	0.222	N/A	N/A	N/A	N/A
	18.0	4.151	4.276	0.479	0.229	N/A	N/A	N/A	N/A
	20.3	4.031	4.184	0.485	0.235	N/A	N/A	N/A	N/A
	23.2	3.875	4.044	0.495	0.245	N/A	N/A	N/A	N/A
5.500	17.0	4.767	4.892	0.722	0.472	0.230	N/A	N/A	N/A
	20.0	4.653	4.778	0.729	0.479	0.237	N/A	N/A	N/A
	23.0	4.545	4.670	0.736	0.486	0.244	N/A	N/A	N/A
	26.0	4.423	4.548	0.744	0.494	N/A	N/A	N/A	N/A
6.625	24.0	5.796	5.921	1.219	0.969	0.727	0.477	N/A	N/A
	28.0	5.666	5.791	1.228	0.978	0.736	0.486	N/A	N/A
	32.0	5.550	5.675	1.235	0.985	0.744	0.494	N/A	N/A
7.000	23.0	6.241	6.366	1.473	1.223	0.981	0.731	0.474	0.221
	26.0	6.151	6.276	1.478	1.228	0.987	2.980	0.480	0.227
	29.0	6.059	6.184	1.484	1.234	0.993	0.743	0.486	0.234
	32.0	5.969	6.094	1.491	1.241	0.716	0.466	0.209	N/A
	35.0	5.879	6.004	1.497	1.247	0.722	0.472	0.215	N/A
	38.0	5.795	5.920	1.219	0.969	0.727	0.477	0.220	N/A
7.625	26.4	6.844	6.969	1.716	1.466	1.224	0.974	0.717	0.464
	29.7	6.750	6.875	1.722	1.472	1.230	0.980	0.723	0.470
	33.7	6.640	6.765	1.729	1.479	1.237	0.987	0.730	0.478
	39.0	6.500	6.625	1.738	1.488	1.247	0.997	0.740	0.488
	42.8	6.376	6.501	1.747	1.497	0.972	0.722	0.465	0.212
	45.3	6.310	6.435	1.468	1.218	0.976	0.726	0.469	0.217
	47.1	6.250	6.375	1.472	1.222	0.980	0.730	0.473	0.221
7.750	46.1	6.500	6.560	1.743	1.493	1.252	1.002	0.745	0.493
8.625	54.0	7.250	7.375	1.971	1.721	1.480	1.230	0.973	0.720
	63.5	7.000	7.125	1.988	1.738	1.497	1.247	0.990	0.738
9.625	40.0	8.679	8.835	2.724	2.474	2.232	1.982	1.725	1.473
	43.5	8.599	8.755	2.729	2.479	2.238	1.988	1.731	1.478
	47.0	8.525	8.681	2.734	2.484	2.243	1.993	1.736	1.484
	53.5	8.379	8.535	2.745	2.495	1.969	1.719	1.462	1.209
	71.8	7.969	8.125	2.488	2.238	1.713	3.706	1.206	0.954

Note: Table stand-off values do not take into account affect on stand-off resulting from pipe sag or buckling due to deviation or compression.

Comparison Table of Standard Sieve Series

US Mesh		Sieve Opening		Phi Units	Tyler Mesh	Canadian		British Nominal Aperture	British Nominal	French Opening	French	German Opening	Fall Rate In Water	
Std	Intl					Std	Intl							
5.0000 in.	*125.00 mm*					5.000 in.	*127.00 mm*							
4.2400 in.	*106.00 mm*					4.240 in.	*107.70 mm*							
4.0000 in.	*100.00 mm*					4.000 in.	*101.60 mm*							
3.5000 in.	*90.00 mm*					3.500 in.	*88.90 mm*							
3.0000 in.	*75.00 mm*					3.000 in.	*76.20 mm*							
2.5000 in.	*63.00 mm*					2.500 in.	*63.50 mm*							
2.1200 in.	*53.00 mm*					2.120 in.	*53.85 mm*							
2.0000 in.	*50.00 mm*					2.000 in.	*50.80 mm*							
1.7500 in.	*45.00 mm*					1.750 in.	*44.45 mm*							
1.5000 in.	*37.50 mm*					1.500 in.	*38.10 mm*							
1.2500 in.	*31.50 mm*					1.250 in.	*31.75 mm*							
1.0600 in.	*26.50 mm*				1.050	1.060 in.	*26.92 mm*							
1.0000 in.	*25.00 mm*					1.000 in.	*25.40 mm*					*25.00 mm*		
0.8750 in.	*22.40 mm*				0.883	0.875 in.	*22.23 mm*							
0.7500 in.	*19.00 mm*				0.742	0.750 in.	*19.05 mm*					*20.00 mm*		
												18.00 mm		
0.6250 in.	*16.00 mm*				0.624	0.625 in.	*15.88 mm*					*16.00 mm*		
0.5300 in.	*13.20 mm*				0.525	0.530 in.	*13.46 mm*							
0.5000 in.	*12.50 mm*					0.050 in.	*12.70 mm*					*12.50 mm*		
0.4375 in.	*11.20 mm*				0.441	0.438 in.	*11.13 mm*							
												10.00 mm		
0.3750 in.	*9.50 mm*				0.371	0.375 in.	*9.50 mm*							
0.1875 in.	*8.00 mm*				2.5	0.188 in.	*8.00 mm*					*8.00 mm*		
0.2650 in.	*6.70 mm*				3	0.265 in.	*6.70 mm*							
0.2500 in.	*6.30 mm*					0.250 in.	*6.30 mm*					*6.30 mm*		
No. 2.5		0.3150 in.	*8.000 mm*	-3.00ϕ		No. 2.5								
No. 3		0.2650 in.	*6.730 mm*	-2.75ϕ		No. 3								
No. 3.5	*5.60 mm*	0.2230 in.	*5.660 mm*	-2.50ϕ	3.5	No. 3.5	*5.60 mm*							
										5.000 mm	No. 38	*5.00 mm*		
		0.2210 in.	*5.613 mm*		3.5									
No. 4	*4.75 mm*	0.1870 in.	*4.760 mm*	-2.25ϕ		No. 4	*4.75 mm*							
		0.1850 in.	*4.699 mm*		4									
No. 5	*4.00 mm*	0.1570 in.	*4.000 mm*	-2.00ϕ		No. 5	*4.00 mm*			4.000 mm	No. 37	*4.00 mm*		
		0.1560 in.	*3.962 mm*		5									
No. 6	*3.35 mm*	0.1320 in.	*3.360 mm*	-1.75ϕ		No. 6	*3.35 mm*	3.35 mm	5					
										3.150 mm	No. 36	*3.15 mm*		
		0.1310 in.	*3.327 mm*		6									
No. 7	*2.80 mm*	0.1110 in.	*2.830 mm*	-1.50ϕ		No. 7	*2.80 mm*	2.80 mm	6					
		0.1100 in.	*2.794 mm*		7									
No. 8	*2.36 mm*	0.0937 in.	*2.380 mm*	-1.25ϕ		No. 8	*2.36 mm*	2.40 mm	7	2.500 mm	No. 35	*2.50 mm*		
		0.0930 in.	*2.362 mm*		8									
No. 10	*2.00 mm*	0.0787 in.	*2.000 mm*	-1.00ϕ		No. 10	*2.00 mm*	2.00 mm	8	2.000 mm	No. 34	*2.00 mm*	35.8 to 49.2 ft/min	*10.91 to 15.00 m/min*
		0.0780 in.	*1.981 mm*		9									
No. 12	*1.70 mm*	0.0661 in.	*1.680 mm*	-0.75ϕ		No. 12	*1.70 mm*	1.68 mm	10	1.600 mm	No. 33	*1.60 mm*	32.7 to 44.5 ft/min	*9.97 to 13.56 m/min*
		0.0650 in.	*1.651 mm*		10							*1.25 mm*		
No. 14	*1.40 mm*	0.0555 in.	*1.410 mm*	-0.50ϕ		No. 14	*1.40 mm*	1.40 mm	12				29.5 to 39.8 ft/min	*8.99 to 12.13 m/min*
										1.250 mm	No. 32	*1.25 mm*		
		0.0550 in.	*1.397 mm*		12									
No. 16	*1.18 mm*	0.0469 in.	*1.190 mm*	-0.25ϕ		No. 16	*1.18 mm*	1.20 mm	14				26.4 to 35.0 ft/min	*8.05 to 10.67 m/min*
		0.0460 in.	*1.168 mm*		14									

Comparison Table of Standard Sieve Series

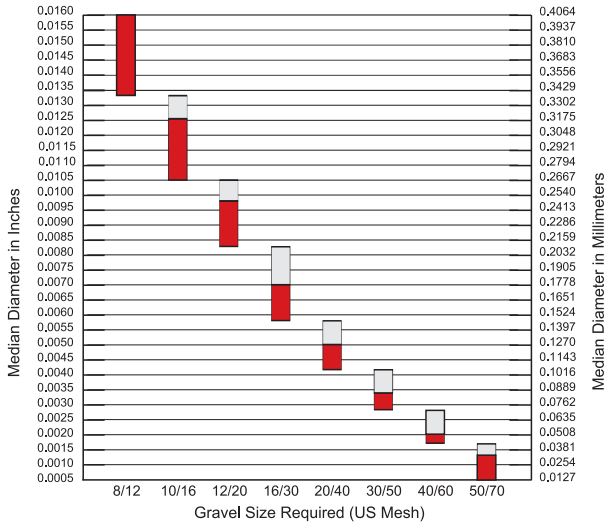
US Mesh		Sieve Opening		Phi Units	Tyler Mesh	Canadian		British Nominal Aperture	British Nominal Mesh No.	French Opening	French	German Opening	Fall Rate In Water	
Std	Intl					Std	Intl							
No. 18	*1.00 mm*	0.0394 in.	*1.000 mm*	0.00ϕ		No. 18	*1.00 mm*	*1.00 mm*	16	*1.000 mm*	No.31	*1.00 mm*	23.2 to 30.7 ft/min	*7.07 to 9.36 m/min*
		0.0390 in.	*0.991 mm*		16									
No. 20	*850 µ m*	0.0331 in.	*0.841 mm*	0.25ϕ		No. 20	*850 µ m*	*850 µ m*	18				20.5 to 26.4 ft/min	*6.25 to 8.05 m/min*
		0.0328 in.	*0.833 mm*		20									
										0.800 mm		*800 µ m*		
No. 25	*710 µ m*	0.0280 in.	*0.707 mm*	0.50ϕ		No. 25	*710 µ m*	*710 µ m*	22				17.7 to 22.0 ft/min	*5.39 to 6.71 m/min*
										0.630 mm	No. 29	*630 µ m*		
		0.0276 in.	*0.701 mm*		24									
No. 30	*600 µ m*	0.0232 in.	*0.589 mm*	0.75ϕ	28	No. 30	*600 µ m*	*600 µ m*	25				15.2 to 18.7 ft/min	*4.63 to 5.70 m/min*
No. 35	*500 µ m*	0.0197 in.	*0.500 mm*	1.00ϕ		No. 35	*500 µ m*	*500 µ m*	30	*0.500 mm*	No. 28	*500 µ m*	12.6 to 15.5 ft/min	*3.84 to 4.72 m/min*
		0.0195 in.	*0.495 mm*		32									
No. 40	*425 µ m*	0.0165 in.	*0.420 mm*	1.25ϕ		No. 40	*425 µ m*	*420 µ m*	36				10.4 to 12.8 ft/min	*3.17 to 3.90 m/min*
										0.400 mm	No. 27	*400 µ m*		
		0.0164 in.	*0.417 mm*		35									
No. 45	*355 µ m*	0.0138 in.	*0.351 mm*	1.50ϕ	42	No. 45	*355 µ m*	*355 µ m*	44				8.7 to 10.4 ft/ min	*2.65 to 3.17 m/min*
										0.315 mm	No. 26	*315 µ m*		
No. 50	*300 µ m*	0.0117 in.	*0.297 mm*	1.75ϕ		No. 50	*300 µ m*	*300 µ m*	52				7.1 to 8.7 ft/ min	*2.16 to 2.65 m/min*
		0.0116 in.	*0.295 mm*		48									
No. 60	*250 µ m*	0.0098 in.	*0.250 mm*	2.00ϕ		No. 60	*250 µ m*	*250 µ m*	60	*0.250 mm*	No. 25	*250 µ m*	5.7 to 6.9 ft/ min	*1.74 to 2.10 m/min*
		0.0097 in.	*0.246 mm*		60									
No. 70	*212 µ m*	0.0083 in.	*0.210 mm*	2.25ϕ		No. 70	*212 µ m*	*210 µ m*	72				4.4 to 5.5 ft/ min	*1.34 to 1.68 m/min*
	212 µ m	0.0082 in.	*0.208 mm*		65									
										0.200 mm	No. 24	*200 µ m*		
No. 80	*180 µ m*	0.0070 in.	*0.177 mm*	2.50ϕ		No. 80	*180 µ m*	*180 µ m*	85				3.5 to 4.3 ft/ min	*1.07 to 1.31 m/min*
	180 µ m	0.0069 in.	*0.175 mm*		80									
										0.160 mm	No. 23	*160 µ m*		
No. 100	*150 µ m*	0.0059 in.	*0.149 mm*	2.75ϕ		No. 100	*150 µ m*	*150 µ m*	100				2.8 to 3.3 ft/ min	*0.85 to 1.01 m/min*
		0.0058 in.	*0.147 mm*		100									
No. 120	*125 µ m*	0.0049 in.	*0.124 mm*	3.00ϕ	115	No. 120	*125 µ m*	*125 µ m*	120	*0.125 mm*	No. 22	*125 µ m*	2.2 to 2.4 ft/ min	*0.67 to 0.73 m/min*
No. 140	*106 µ m*	0.0041 in.	*0.104 mm*	3.25ϕ	150	No. 140	*106 µ m*	*105 µ m*	150					
										0.100 mm	No. 21	*100 µ m*		
No. 170	*90 µ m*	0.0035 in.	*0.088 mm*	3.50ϕ	170	No. 170	*90 µ m*	*90 µ m*	170			*90 µ m*		
										0.080 mm	No. 20	*80 µ m*		
No. 200	*75 µ m*	0.0029 in.	*0.074 mm*	3.75ϕ	200	No. 200	*75 µ m*	*75 µ m*	200					
												71 µ m		
No. 230	*63 µ m*	0.0024 in.	*0.061 mm*	4.00ϕ	250	No. 230	63 *µ m*	*63 µ m*	240	*0.063 mm*	No. 19	*63 µ m*		
												56 µ m		
No. 270	*53 µ m*	0.0021 in.	*0.053 mm*	4.25ϕ	270	No. 270	53 *µ m*	*53 µ m*	300					
										0.050 mm	No. 18	*50 µ m*		
No. 325	*45 µ m*	0.0017 in.	*0.044 mm*	4.50ϕ	325	No. 325	45 *µ m*	*45 µ m*	350			*45 µ m*		
										0.040 mm	No. 17	*40 µ m*		
No. 400	*38 µ m*	0.0015 in.	*0.037 mm*	4.75ϕ	400	No. 400	38 *µ m*	*38 µ m*						

Gravel Pack Sand Sizing Design

Gravel (US Mesh)	Gravel D50		Gravel Pore Throat Diameter*		Formation D50 Range (D50G/6 < D50F < D50G/5)			
					D50G/6		D50G/5	
	in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*
50/70	0.010	*.2540*	0.0015	*.0381*	0.0017	*.0432*	0.0020	*.0508*
40/60	0.014	*.3556*	0.0022	*.0559*	0.0023	*.0584*	0.0028	*.0711*
30/50	0.017	*.4318*	0.0026	*.0660*	0.0028	*.0711*	0.0034	*.0864*
20/40	0.025	*.6350*	0.0039	*.0991*	0.0042	*.1067*	0.0050	*.1270*
16/30	0.035	*.8890*	0.0054	*.1372*	0.0058	*.1473*	0.0070	*.1778*
12/20	0.049	*1.2446*	0.0076	*.1930*	0.0082	*.2083*	0.0098	*.2489*
10/16	0.063	*1.6002*	0.0098	*.2489*	0.0105	*.2667*	0.0126	*.3200*
8/12	0.080	*2.0320*	0.0124	*.3150*	0.0133	*.3378*	0.0160	*.4064*

* Based on Hexagonal Packing where D=6.46*d

Median Diameter of the Formation Grain Sand



Gravel Mesh Size (US Mesh)	Reference Screen Gauge*		PoroMax® Screen Sizing*
	in.	*mm*	microns
8/12	0.055	*1.397*	250
10/16	0.040	*1.016*	250
10/20	0.025	*0.635*	250
12/20	0.025	*0.635*	250
16/30	0.016	*0.406*	250
20/40	0.012	*0.305*	250
30/50	0.008	*0.203*	175
40/60	0.006	*0.152*	125
50/70	0.005	*0.127*	125

*This sizing is based on gravel retention only. For applications where the screen is designed to retain formation sand, see your Halliburton representative.
PoroMax is a registered trademark of Purolator Facet, Inc.

Screen Basepipe/Washpipe Clearance

Screen				Washpipe				
Pipe Base OD		Pipe Base ID		Size OD		Screen ID/Washpipe OD		
						Radial Clearance		Ratio
in.	*mm*	in.	*mm*	in.	*mm*	in.	*mm*	
2 3/8	*60.33*	1.995	*50.67*	1.66	*31.75*	0.168	*4.27*	0.830
2 7/8	*73.03*	2.441	*62.00*	1.90	*48.26*	0.271	*6.88*	0.700
3 1/2	*88.90*	2.992	*76.00*	2 1/16	*52.39*	0.465	*11.81*	0.689
				2 3/8	*60.33*	0.309	*7.85*	0.794
4	*101.60*	3.548	*90.12*	2 7/8	*73.03*	0.337	*8.56*	0.810
4 1/2	*114.30*	3.920	*99.57*	2 7/8 to 3 1/2	*73.03 to 88.90*	0.562 to 0.250	*14.27 to 6.35*	0.733 to 0.892
5 1/2	*139.70*	5.012	*127.30*	3 1/2 to 4	*88.90 to 101.60*	0.725 to 0.475	*18.42 to 12.07*	0.698 to 0.798
6 5/8	*168.28*	5.921	*150.39*	4 1/2 to 5	*114.30 to 127.00*	0.710 to 0.460	*18.03 to 11.68*	0.760 to 0.844
7	*177.80*	6.184	*157.07*	4 1/2 to 5	*114.30 to 127.00*	0.842 to 0.592	*21.39 to 15.04*	0.727 to 0.808

Halliburton recommends a screen ID/washpipe OD ratio of 0.8 or greater.

Median Diameter, Permeability, and Porosity of Common Gravels

Pack Sand Size		US Mesh Size	Approximate Pack Sand Median Diameter D_{50}		Approximate Permeability of Gravel		
in.	*mm*		in.	*mm*	darcy	resieved	w/resin
0.265 to 0.187	*6.731 to 4.750*	3/4	0.226	*5.740*	8,100		
0.187 to 0.132	*4.750 to 3.353*	4/6	0.160	*4.064*	3,700		
0.132 to 0.094	*3.353 to 2.388*	6/8	0.113	*2.870*	1,900		
0.132 to 0.079	*3.353 to 2.007*	6/10	0.106	*2.692*			
0.094 to 0.079	*2.388 to 2.007*	8/10	0.087	*2.210*	1,150		
0.094 to 0.066	*2.388 to 1.676*	8/12	0.080	*2.032*			
0.079 to 0.056	*2.007 to 1.422*	10/14	0.068	*1.727*	800		
0.079 to 0.047	*2.007 to 1.194*	10/16	0.063	*1.600*			
0.079 to 0.033	*2.007 to 0.838*	10/20	0.056	*1.422*	325		
0.079 to 0.023	*2.007 to 0.584*	10/30	0.051	*1.295*	191		
0.066 to 0.033	*1.676 to 0.838*	12/20	0.049	*1.245*		233/257	250/280
0.047 to 0.023	*1.194 to 0.584*	16/30	0.035	*0.889*		190/210	180/200
0.033 to 0.017	*0.838 to 0.432*	20/40	0.025	*0.635*	121	133/147	125/135
0.023 to 0.017	*0.584 to 0.432*	30/40	0.020	*0.508*	110		
0.023 to 0.011	*0.584 to 0.279*	30/50	0.017	*0.432*		85/95	80/90
0.017 to 0.011	*0.432 to 0.279*	40/50	0.014	*0.356*	66		
0.017 to 0.010	*0.432 to 0.254*	40/60	0.014	*0.356*	45	49/55	55/60
0.012 to 0.010	*0.305 to 0.254*	50/60	0.011	*0.279*	43		
0.012 to 0.008	*0.305 to 0.203*	50/70	0.010	*0.254*	19.23	36/40	41/47
		100 Mesh Sand / Okla. No. 1			7 to 12		

Sand Slurry Volume Data

Sand Concentration Fluid		Sand Volume in Slurry	Fill-Up Volume (ϕ 39%)	Sand in Slurry	
lb/gal	*kg/m³*	%	%	lb/bbl	*kg/m³*
0.5	*59.91*	2.21	3.65	20.50	*58.49*
1	*119.83*	4.33	7.16	40.20	*114.69*
2	*239.65*	8.29	13.70	76.90	*219.40*
3	*359.48*	11.95	19.75	111.00	*316.68*
4	*479.31*	15.32	25.32	142.00	*405.13*
5	*599.13*	18.44	30.48	171.00	*487.86*
6	*718.96*	21.34	35.27	198.00	*564.90*
7	*838.78*	24.04	39.74	223.00	*636.22*
8	*958.61*	26.56	43.90	246.00	*701.84*
9	*1078.44*	28.92	47.80	268.00	*764.61*
10	*1198.26*	31.14	51.47	289.00	*824.52*
11	*1318.09*	33.22	54.91	308.00	*878.73*
12	*1437.92*	35.17	58.13	326.00	*930.08*
13	*1557.74*	37.02	61.19	343.00	*978.58*
14	*1677.57*	38.76	64.07	356.00	*1015.67*
15	*1797.40*	40.41	66.79	374.00	*1067.03*
16	*1917.22*	41.98	69.39	388.00	*1106.97*
17	*2037.05*	43.46	71.83	402.00	*1146.91*
18	*2156.88*	44.87	74.17	415.00	*1184.00*
19	*2276.70*	46.21	76.38	428.00	*1221.09*
20	*2396.53*	47.49	78.50	439.00	*1252.47*

Sand and Gel Required for One Barrel of Slurry

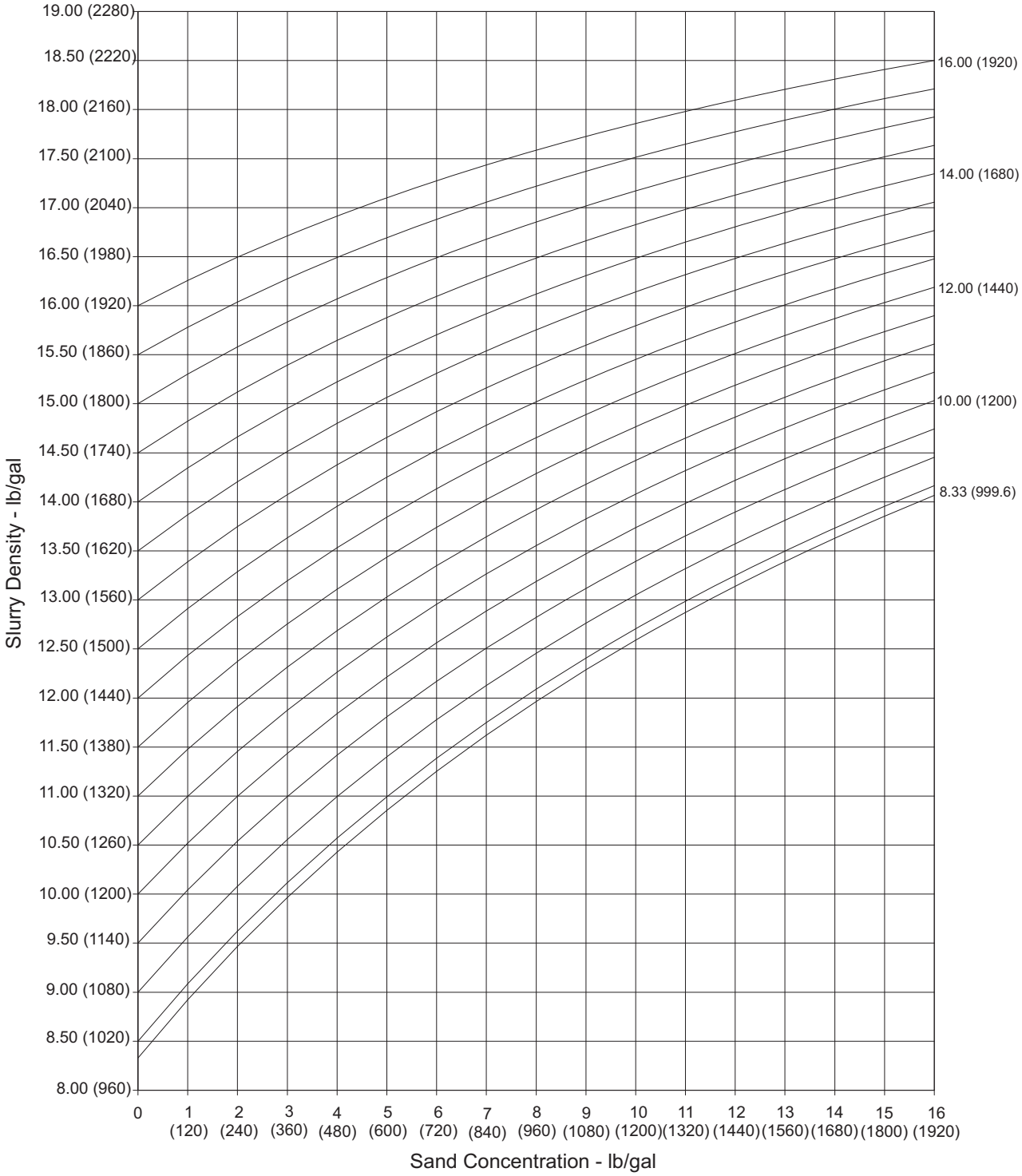
English Units

Sand Concentration	Gel Required	Sand Required	Slurry Volume	
lb/gal	gal	lb	gal	bbl
1	40	40	41.82	0.99
2	38	76	41.47	0.99
3	37	111	42.06	1.00
4	36	144	42.57	1.01
5	34	170	41.75	0.99
6	33	198	42.03	1.00
7	32	231	42.21	1.01
8	31	248	42.31	1.01
9	30	270	42.31	1.01
10	29	290	42.22	1.01
11	28	308	42.05	1.00
12	27	324	41.77	0.99
13	26	338	41.41	0.98
14	26	364	42.59	1.01
15	25	375	42.10	1.00

Metric Units

Sand Concentration g/L	m^3 Sand per m^3 of Gel	m^3 of Gel/m^3 of Slurry	kg Sand/m^3 of Slurry	Slurry Requirement to Place 1 m^3 of Sand	Gradient bar/m
120	*0.046*	*0.956*	*114.76*	*13.96*	*0.107*
240	*0.091*	*0.916*	*219.93*	*7.28*	*0.114*
360	*0.137*	*0.880*	*316.66*	*5.06*	*0.120*
480	*0.183*	*0.846*	*405.92*	*3.95*	*0.125*
600	*0.228*	*0.814*	*488.54*	*3.28*	*0.130*
720	*0.274*	*0.785*	*565.25*	*2.83*	*0.135*
840	*0.319*	*0.758*	*636.66*	*2.52*	*0.139*
960	*0.365*	*0.733*	*703.29*	*2.28*	*0.144*
1080	*0.411*	*0.709*	*765.61*	*2.09*	*0.147*
1200	*0.456*	*0.687*	*824.02*	*1.94*	*0.151*
1320	*0.502*	*0.666*	*878.89*	*1.82*	*0.154*
1440	*0.548*	*0.646*	*930.52*	*1.72*	*0.158*
1560	*0.593*	*0.628*	*979.19*	*1.64*	*0.161*
1680	*0.639*	*0.610*	*1025.15*	*1.56*	*0.164*
1800	*0.684*	*0.594*	*1068.62*	*1.50*	*0.166*
1920	*0.730*	*0.578*	*1109.80*	*1.44*	*0.169*
2040	*0.776*	*0.563*	*1148.87*	*1.39*	*0.171*
2160	*0.821*	*0.549*	*1185.97*	*1.35*	*0.174*
2280	*0.867*	*0.536*	*1221.26*	*1.31*	*0.176*
2400	*0.913*	*0.523*	*1254.87*	*1.28*	*0.178*

Sand Concentration vs Slurry Density for Various Fluid Carrier Fluid Densities



Ammonium Chloride Solution Properties

%NH_4Cl per Weight of		Density		Specific Gravity	Pounds of NH_4Cl		NH_4Cl	Solution Volume		Freezing Point	
Solution	Water	lb/gal	*kg/m³*	*at 20°C*	per gal water	per bbl water	g/L	bbl	*m³*	°F	*°C*
0				*0.998*							
1	1.01	8.36	*1003.00*	*1.003*	0.084	3.522	10.000	1.007	*0.1601*	30.853	*-0.637*
2	2.04	8.39	*1006.00*	*1.006*	0.168	7.044	20.100	1.014	*0.1612*	29.714	*-1.270*
3	3.09	8.42	*1009.00*	*1.009*	0.252	10.584	30.200	1.021	*0.1623*	28.557	*-1.913*
4	4.17	8.44	*1013.00*	*1.013*	0.337	14.158	40.400	1.028	*0.1634*	27.372	*-2.571*
6	6.38	8.49	*1019.00*	*1.019*	0.509	21.377	61.000	1.043	*0.1658*	26.157	*-3.246*
8	8.70	8.54	*1025.00*	*1.025*	0.683	28.667	81.800	1.057	*0.1680*	24.906	*-3.941*
10	11.11	8.59	*1030.00*	*1.030*	0.859	36.061	102.900	1.073	*0.1706*	22.280	*-1.250*
12	13.64	8.64	*1036.00*	*1.036*	1.035	43.491	124.100	1.088	*0.1730*	19.490	*-6.950*
14	16.28	8.69	*1042.00*	*1.042*	1.215	51.025	145.600	1.104	*0.1755*	16.520	*-8.600*
16	19.05	8.73	*1048.00*	*1.048*	1.396	58.630	167.300	1.120	*0.1781*		
18	21.95	8.78	*1053.00*	*1.053*	1.579	66.305	189.200	1.136	*0.1806*		
20	25.00	8.83	*1059.00*	*1.059*	1.763	74.050	211.300	1.153	*0.1833*		
22	28.21	8.87	*1064.00*	*1.064*	1.950	81.900	233.700	1.170	*0.1860*		
24	31.58	8.92	*1069.00*	*1.069*	2.138	89.785	256.200	1.187	*0.1887*		

Potassium Chloride Solution Properties

%KCl per Weight of		Density		Specific Gravity	Pounds of KCl		KCl	Solution Volume		Freezing Point	
Solution	Water	lb/gal	*kg/m³*	*at 20°C*	per gal water	per bbl water	g/L	bbl	*m³*	°F	*°C*
0		8.34	*998.00*	*0.998*							
1	1.01	8.38	*1005.00*	*1.005*	0.08	3.54	10.050	1.004	*0.1596*	31.2	*-0.44*
2	2.04	8.43	*1011.00*	*1.011*	0.17	7.15	20.200	1.007	*0.1601*	30.3	*-0.94*
3	3.09	8.48	*1017.00*	*1.017*	0.26	10.82	30.500	1.011	*0.1607*	29.5	*-1.39*
4	4.17	8.54	*1024.00*	*1.024*	0.35	14.61	41.000	1.015	*0.1614*	28.7	*-1.83*
6	6.38	8.65	*1037.00*	*1.037*	0.53	22.35	62.200	1.024	*0.1628*	27.0	*-2.78*
8	8.70	8.75	*1050.00*	*1.050*	0.73	30.47	83.800	1.032	*0.1640*	25.2	*-3.78*
10	11.11	8.87	*1063.00*	*1.063*	0.93	38.92	106.300	1.041	*0.1655*	23.3	*-4.83*
12	13.64	8.98	*1077.00*	*1.077*	1.14	47.78	129.200	1.051	*0.1671*	21.4	*-5.890*
14	16.28	9.10	*1091.00*	*1.091*	1.36	57.03	152.500	1.060	*0.1685*	19.3	*-7.06*
16	19.05	9.21	*1104.00*	*1.104*	1.59	66.73	176.700	1.071	*0.1703*	17.4	*-8.11*
18	21.95	9.33	*1119.00*	*1.119*	1.83	76.89	200.900	1.082	*0.1720*	14.9	*-9.50*
20	25.00	9.45	*1133.00*	*1.133*	2.09	87.57	226.600	1.092	*0.1736*	15.0	*-9.44*
22	28.21	9.57	*1147.00*	*1.147*	2.35	98.81	251.900	1.103	*0.1754*	32.6	*10.33*
24	31.58	9.69	*1162.00*	*1.162*	2.63	110.62	278.900	1.115	*0.1773*	52*	*11.11**
26.5	36.05	9.82	*1178.00*	*1.178*	3.01	126.28	312.200	1.130	*0.1797*	78.3*	*25.72**

*Precipitates

Sodium Chloride Solution Properties

% NaCl per Weight of		Weight of Solution		Specific Gravity	Pounds of NaCl		NaCl	Solution Volume		Freezing Point	
Solution	Water	lb/gal	*kg/m³*	*at 20°C*	per gal water	per bbl water	g/L	bbl	*m³*	°F	*°C*
0		8.34	*998*	*0.998*				1.000	*0.1590*		
1	1.01	8.38	*1005*	*1.005*	0.08	3.54	10.050	1.005	*0.1598*	30.9	*-0.6*
2	2.04	8.45	*1013*	*1.013*	0.17	7.15	20.250	1.008	*0.1603*	29.9	*-1.2*
3	3.09	8.51	*1020*	*1.020*	0.26	10.82	30.600	1.011	*0.1607*	28.8	*-1.8*
4	4.17	8.57	*1027*	*1.027*	0.35	14.61	41.100	1.015	*0.1614*	27.7	*-2.4*
5	5.26	8.62	*1034.00*	*1.034*	0.44	18.42	51.700	1.018	*0.1618*	26.2	*-3.0*
6	6.38	8.68	*1041*	*1.041*	0.53	22.35	52.500	1.022	*0.1625*	25.3	*-3.7*
8	8.70	8.81	*1056*	*1.056*	0.73	30.47	84.500	1.029	*0.1636*	22.9	*-5.1*
10	11.11	8.93	*1071*	*1.071*	0.93	38.92	107.100	1.038	*0.1650*	20.2	*-6.6*
12	13.64	9.06	*1086*	*1.086*	1.14	47.78	130.300	1.047	*0.1665*	17.3	*-8.2*
14	16.28	9.18	*1101*	*1.101*	1.36	57.03	155.400	1.056	*0.1679*	14.1	*-9.9*
16	19.05	9.31	*1116*	*1.116*	1.59	66.73	178.600	1.067	*0.1696*	10.6	*-11.9*
18	21.95	9.44	*1132*	*1.132*	1.83	76.89	203.700	1.077	*0.1712*	6.7	*-14.0*
20	25.00	9.57	*1148*	*1.148*	2.09	87.57	229.600	1.089	*0.1731*	2.4	*-16.5*
22	28.21	9.71	*1164*	*1.164*	2.35	98.81	256.100	1.101	*0.1750*	-2.5	*-19.2*
24	31.58	9.84	*1180*	*1.180*	2.63	110.62	283.300	1.115	*0.1773*	1.4	*-17.0**
26	35.14	9.98	*1197*	*1.197*	2.93	123.09	311.300	1.129	*0.1795*	27.9	*-2.3***

*Precipitates at -17°C or 1.4°F
**Precipitates at -2.3°C or 27.9°F

Calcium Chloride Solution Properties

%Ca Cl_2 per Weight of	Density		Specific Gravity	Pounds of Anhydrous Calcium Chloride		$CaCl_2$	Solution Volume		Freezing Point	
Solution	lb/gal	*kg/m³*	*at 20°C*	per gal water	per bbl water	g/L	bbl	*m³*	°F	*°C*
0	8.34	*998*	*0.998*				1.000	*0.15899*	32.0	*0.0*
1	8.41	*1008*	*1.008*	0.08	3.54	10.100	1.002	*0.15931*	31.1	*-0.5*
2	8.47	*1015*	*1.015*	0.17	7.15	20.300	1.004	*0.15962*	30.2	*-1.0*
3	8.54	*1024*	*1.024*	0.26	10.82	30.700	1.006	*0.15994*	29.7	*-1.3*
4	8.61	*1032*	*1.032*	0.35	14.61	41.300	1.008	*0.16026*	28.4	*-2.0*
5	8.69	*1042*	*1.042*	0.44	18.42	52.100	1.012	*0.16090*	27.7	*-2.4*
10	9.04	*1084*	*1.084*	0.93	38.92	108.400	1.024	*0.16280*	22.3	*-5.4*
15	9.44	*1132*	*1.132*	1.47	61.74	169.800	1.040	*0.16535*	13.5	*-10.3*
20	9.82	*1178*	*1.178*	2.09	87.57	235.600	1.060	*0.16853*	-0.4	*-18.0*
25	10.24	*1228*	*1.228*	2.78	116.76	307.000	1.090	*0.17330*	-20.6	*-29.2*
30	10.69	*1282*	*1.282*	3.57	149.94	384.600	1.114	*0.17711*	-49.0	*-45.0*
35	11.15	*1337*	*1.337*	4.49	188.58	468.000	1.151	*0.18299*		
40	11.72	*1405*	*1.405*	5.56	233.52	562.000	1.186	*0.18856*		

Sodium Bromide Solution Requirements to Make 1 Barrel (42 gal)

Using Sacked NaBr (95%)		Brine Density at 70°F (21°C), lb/gal	Specific Gravity	Crystallization Point (CP) (LCTD) °F (°C)
Freshwater, bbl	95% NaBr, lb			
0.999	2.1	8.4	1.01	31 (-0.6)
0.996	7.6	8.5	1.02	30 (-1.1)
0.992	13.7	8.6	1.03	29 (-1.7)
0.989	19.2	8.7	1.04	29 (-1.7)
0.984	25.0	8.8	1.05	28 (-2.2)
0.979	31.0	8.9	1.07	26 (-3.3)
0.975	36.7	9.0	1.08	25 (-3.9)
0.970	42.6	9.1	1.09	24 (-4.4)
0.966	48.3	9.2	1.10	23 (-5.0)
0.961	54.2	9.3	1.11	22 (-5.6)
0.956	60.2	9.4	1.13	21 (-6.1)
0.950	66.4	9.5	1.14	20 (-6.7)
0.946	72.0	9.6	1.15	19 (-7.2)
0.941	77.9	9.7	1.16	18 (-7.8)
0.937	83.6	9.8	1.17	16 (-8.9)
0.933	89.2	9.9	1.19	15 (-9.4)
0.927	95.4	10.0	1.20	14 (-10.0)
0.923	101.1	10.1	1.21	12 (-11.1)
0.918	107.1	10.2	1.22	11 (-11.7)
0.914	112.6	10.3	1.23	10 (-12.2)
0.910	118.2	10.4	1.25	8 (-13.3)
0.905	124.1	10.5	1.26	6 (-14.4)
0.900	130.2	10.6	1.27	5 (-15.0)
0.895	136.0	10.7	1.28	4 (-15.6)
0.891	141.7	10.8	1.29	2 (-16.7)
0.886	147.6	10.9	1.31	0 (-17.8)
0.882	153.3	11.0	1.32	-2 (-18.8)
0.877	159.2	11.1	1.33	-3 (-19.4)
0.872	165.1	11.2	1.34	-5 (-20.6)
0.867	171.1	11.3	1.35	-7 (-21.7)
0.862	177.0	11.4	1.37	-9 (-22.8)
0.857	183.0	11.5	1.38	-11 (-23.9)
0.853	188.6	11.6	1.39	-14 (-25.6)
0.847	194.8	11.7	1.40-	16 (-26.7)
0.844	200.2	11.8	1.41	-19 (-28.3)
0.839	206.2	11.9	1.43	-10 (-23.3)
0.834	212.0	12.0	1.44	6 (-14.4)
0.831	217.3	12.1	1.45	14 (-10.0)
0.825	223.6	12.2	1.46	27 (-2.8)
0.823	228.5	12.3	1.47	34 (1.1)
0.816	235.1	12.4	1.49	43 (6.1)
0.812	240.7	12.5	1.50	50 (10.0)
0.807	246.7	12.6	1.51	57 (13.9)
0.804	252.0	12.7	1.52	63 (17.2)

Sodium bromide solution requirements. Dry sodium bromide can be used to produce the required crystallization point (CP).

Maximum Density of Common Completion Brines

Brine Type	Maximum Density	Maximum Density	
	Specific Gravity	lb/gal	*kg/m³*
Ammonium Chloride	1.080	9.000	*1080.00*
Potassium Chloride	1.160	9.700	*1160.00*
Sodium Chloride	1.200	10.000	*1200.00*
Calcium Chloride	1.390	11.600	*1390.00*
Sodium Bromide	1.520	12.700	*1520.00*
Calcium Bromide	1.840	15.300	*1840.00*
Zinc Bromide	2.300	19.200	*2300.00*
Cesium Formate	2.370	19.800	*2370.00*
Potassium Formate	1.560	13.000	*1560.00*
Sodium Formate	1.460	12.200	*1460.00*
Calcium Formate	1.100	9.163	*1100.00*

API Conversion Table

API Gravity	Specific Gravity*	Density*		Pressure Gradient		
		lb/gal	*kg/m³*	psi/ft	*bar/m*	*kPa/m*
15% HCl	1.0750	8.962	*1075.00*	0.4654	*0.1055*	*10.547*
10 (water)	1.0000	8.337	*1000.00*	0.4330	*0.0981*	*9.807*
12	0.9861	8.221	*986.10*	0.4270	*0.0967*	*9.670*
15	0.9659	8.053	*965.90*	0.4182	*0.0947*	*9.472*
18	0.9465	7.891	*946.50*	0.4098	*0.0928*	*9.282*
20	0.9340	7.787	*934.00*	0.4044	*0.0916*	*9.159*
22	0.9218	7.685	*921.80*	0.3991	*0.0944*	*9.044*
24	0.9100	7.587	*910.00*	0.3940	*0.0892*	*8.924*
26	0.8984	7.490	*898.40*	0.3890	*0.0881*	*8.810*
28	0.8871	7.396	*887.10*	0.3841	*0.0870*	*8.700*
30	0.8762	7.305	*876.20*	0.3794	*0.0859*	*8.592*
31	0.8708	7.260	*870.80*	0.3771	*0.0854*	*8.539*
32	0.8654	7.215	*865.40*	0.3747	*0.0849*	*8.487*
33	0.8602	7.171	*860.20*	0.3725	*0.0844*	*8.436*
34	0.8550	7.128	*855.00*	0.3702	*0.0836*	*8.385*
35	0.8498	7.085	*849.80*	0.3680	*0.0833*	*8.334*
36	0.8448	7.043	*844.80*	0.3658	*0.0828*	*8.284*
37	0.8398	7.001	*839.80*	0.3638	*0.0824*	*8.235*
38	0.8348	6.960	*834.80*	0.3615	*0.0819*	*8.187*
39	0.8299	6.919	*829.90*	0.3593	*0.0814*	*8.139*
40	0.8251	6.879	*825.10*	0.3573	*0.0809*	*8.091*
41	0.8203	6.839	*820.30*	0.3552	*0.0804*	*8.044*
42 (diesel)	0.8156	6.800	*815.60*	0.3532	*0.0800*	*7.998*
43	0.8109	6.760	*810.90*	0.3511	*0.0795*	*7.952*
44	0.8063	6.722	*806.30*	0.3491	*0.0791*	*7.907*
46	0.7972	6.646	*797.20*	0.3452	*0.0782*	*7.818*
48	0.7883	6.572	*788.30*	0.3413	*0.0773*	*7.731*
50	0.7796	6.500	*779.60*	0.3376	*0.0765*	*7.645*
55	0.7587	6.325	*758.70*	0.3285	*0.0744*	*7.440*
60	0.7389	6.160	*738.90*	0.3200	*0.0725*	*7.246*

*For heavier fluid weights, pressure gradient in psi/ft = 0.05195 × density (lb/gal) or pressure gradient in kPa/m = 22.626 × density (kg/m³), 1 lb/gal = 119.841 kg/m³

Instruments Used to Measure Viscosity

The Fann® Model 35 and the Chan 35 instruments are direct indicating viscometers used to measure the rheological properties of drilling mud, cements, and gravel packing fluids according to testing procedures established by API, Spec. 10 RP 13B and RP 39. Both instruments use a Couette-type coaxial cylinder sensor system. They are designed so that the absolute dynamic viscosity in centipoise or milliPascal-seconds is indicated on the instrument dials when used at 300 rpm. The Chan 35 instrument is a 12-speed instrument, whereas the Fann Model 35 instrument can be operated at only eight speeds. Both are suitable for laboratory and field use.

How To Compute Viscosity

Viscosity is usually computed in poise (P) or centipoise (cP) where 1 poise = 100 centipoise. Viscosity is shear stress divided by shear rate.

For the Chan 35 instrument viscosity is computed as follows:

viscosity in centipoise (cP) = dial reading × 300/rpm or

viscosity in centipoise (cP)= dial reading × factor (see table below)

For example, if the dial reading is 25 when using an rpm of 300, then:

viscosity = 25 × 300/300 = 25 cP

Shear Stress

Shear stress is a function of the bob surface area and the spring strength. The units for shear stress are dynes/cm² when the viscosity is in poise or centipoise (SPE prefers Pa where 1 dyne/cm^2 =1 Pa × 10-1). The shear stress equals 5.11 × dial reading for the Chan 35 or Fann Model 35 viscometers.

Shear Rate

Shear rate is a function of the test speed in rpm. The units for shear rate are sec^{-1}. Shear rate = 1.70 × rpm for the Chan 35 and Fann Model 35 viscometers.

n' and K'

The following calculations can be made to obtain n' and K'.

Flow behavior index (n') = slope of the flow curve

Note: n' measures the degree to which the fluid is Newtonian. The closer to a reading of 1, the more Newtonian the fluid.

Consistency index (K'_v) = intercept of the flow curve at unity rate of shear where K' is lb-sec^{-1}/ft²

Note: K'v is a measure of the viscosity of the fluid.

If only the field model Fann viscometer is available rather than Model 35 or a Chan 35, then the 600 rpm and 300 rpm readings are the only ones that can be made, and the following formulas can be used to calculate n' and K'.

$$n' = 3.32 \times [\log10 (600 \text{ rpm reading}/300 \text{ rpm reading})]$$

$$K'_v = \frac{[N \times (300 \text{ rpm reading}) \times 1.066]}{(100 \times (511)n')}$$

For calculations where plastic viscosity and yield point are known:

$$n' = 3.32 (\log10 ((2PV + YP) / (PV + YP))$$

$$K'_v = \frac{N \times (PV + YP) \times 1.066^*}{(100 \times (511)n')}$$

where PV = plastic viscosity, cps

YP = yield point, lbf/100 ft² (SPE prefers Pa where 1 lb/100 ft² = 0.04788 Pa)

*This multiplier is obtained from the dial readings of the Fann Model 35.

For Newtonian fluids n' = 1.0 and K' = viscosity in cP/47880.

Users of rheological data often prefer to express all K' values as a function of cP viscosity. These numbers are large compared to the K'_v values. To attain K' as cP multiply the K'_v times the factor 47880.

Instrument Dial Readings to Viscosity

	rev/min	Shear Rate Sec	Factor
Traditional Speeds for API Viscosity	600	1022.00	0.5
	300	511.00	1.0
	200	340.00	1.5
	100	170.00	3.0
	60	102.00	5.0
	30	51.10	10.0
	20	34.10	15.0
	10	17.00	30.0
Traditional Speeds for API Gels	6	10.20	50.0
	3	5.11	100.0
	2	3.40	150.0
	1	1.70	300.0

Acid Loading Guidelines for 1,000 Gallons (15% HCl Acid and Water)

HCl%	Specific Gravity	gal 15% HCl Acid and Water		Solution Weight		Hydrostatic Pressure	
		Acid	Water	lb/gal	*kg/m³*	psi/ft	*kPa/m depth*
1	1.005	66.7	933.3	8.38	*1002.95*	0.435	*9.84*
2	1.010	133.3	866.7	8.42	*1008.94*	0.437	*9.89*
3	1.015	200.0	800.0	8.46	*1013.73*	0.439	*9.93*
4	1.020	266.7	733.3	8.50	*1018.52*	0.442	*10.00*
5	1.025	333.3	666.7	8.55	*1023.32*	0.444	*10.04*
6	1.030	400.0	600.0	8.59	*1029.31*	0.446	*10.09*
7	1.035	466.7	533.3	8.63	*1034.10*	0.448	*10.13*
8	1.040	533.3	466.7	8.67	*1038.98*	0.450	*10.18*
9	1.045	600.0	400.0	8.71	*1043.69*	0.452	*10.22*
10	1.050	666.7	333.3	8.75	*1048.48*	0.454	*10.27*
11	1.055	733.3	266.7	8.79	*1053.27*	0.457	*10.34*
12	1.060	800	200.0	8.84	*1059.27*	0.459	*10.38*
13	1.065	866.7	133.3	8.88	*1064.06*	0.461	*10.43*
14	1.070	933.3	66.7	8.92	*1068.86*	0.463	*10.47*
15	1.075	1000.0	0.0	8.96	*1075.64*	0.465	*10.52*

Based on temperature of 60°F (15.6°C)
Note: Refer to and follow recommended practices in the Halliburton Management System processes as well as MSDS and safety procedures for the materials.

Acid Loading Guidelines for 1,000 Gallons (20° Bé Acid)

HCl%	Specific Gravity	gal 20° Bé Acid and Water		Solution Weight		Hydrostatic Pressure	
		Acid	Water	lb/gal	*kg/m³*	psi/ft depth	*kPa/m depth*
1	1.005	28	972	8.37	*1002.95*	9.84	
2	1.010	55	945	8.42	*1008.94*	0.437	*9.89*
3	1.015	83	917	8.46	*1013.73*	0.439	*9.93*
4	1.020	112	888	8.50	*1018.52*	0.442	*10.00*
5	1.025	140	860	8.54	*1023.32*	0.444	*10.04*
6	1.030	169	831	8.59	*1029.31*	0.446	*10.09*
7	1.035	199	801	8.63	*1034.10*	0.448	*10.13*
8	1.040	228	772	8.67	*1038.89*	0.450	*10.18*
9	1.045	258	742	8.71	*1043.69*	0.452	*10.22*
10	1.050	288	712	8.75	*1048.48*	0.454	*10.27*
11	1.055	318	682	8.79	*1053.27*	0.457	*10.34*
12	1.060	349	651	8.84	*1059.27*	0.459	*10.38*
13	1.065	379	621	8.88	*1064.06*	0.461	*10.43*
14	1.070	410	590	8.92	*1068.85*	0.463	*10.47*
15	1.075	442	558	8.96	*1073.64*	0.465	*10.52*
16	1.080	473	527	9.00	*1078.44*	0.468	*10.59*
17	1.085	505	495	9.05	*1084.43*	0.470	*10.63*
18	1.090	538	462	9.08	*1088.02*	0.472	*10.68*
19	1.095	570	430	9.13	*1094.02*	0.474	*10.72*
20	1.100	603	397	9.17	*1098.81*	0.476	*10.77*
21	1.105	636	364	9.21	*1103.60*	0.478	*10.81*
22	1.110	669	331	9.25	*1108.39*	0.481	*10.88*
23	1.116	703	297	9.30	*1114.39*	0.484	*10.95*
24	1.122	738	262	9.35	*1120.38*	0.486	*10.99*
25	1.127	772	228	9.39	*1125.17*	0.488	*11.04*
26	1.132	806	194	9.43	*1129.96*	0.490	*11.08*
27	1.136	840	160	9.46	*1133.56*	0.492	*11.13*
28	1.141	875	125	9.50	*1138.35*	0.494	*11.17*
29	1.146	910	90	9.55	*1144.34*	0.497	*11.24*
30	1.153	948	52	9.60	*1150.33*	0.499	*11.29*
31	1.158	983	17	9.65	*1156.32*	0.502	*11.36*
31.45	1.160	1000	0	9.66	*1157.52*	0.503	*11.38*
32	1.163			9.69	*1161.12*	0.504	*11.40*
33	1.168			9.74	*1167.11*	0.506	*11.45*
34	1.173			9.78	*1171.90*	0.508	*11.49*
35	1.178			9.82	*1176.70*	0.510	*11.54*
35.2	1.179			9.83	*1177.89*	0.510	*11.54*

Based on temperature of 60°F (15.6°C)
Note: Refer to and follow recommended practices in the Halliburton Management System processes as well as MSDS and safety procedures for the materials.

Acid Loading Guidelines for 1,000 Gallons (22° HCl Acid and Water)

HCl%	Specific Gravity	gal 22° Bé Acid and Water to make 1000 gal Acid		Solution Weight		Hydrostatic Pressure	
		Acid	Water	lb/gal	*kg/m³*	psi/ft depth	*kPa/m depth*
1	1.005	24	976	8.37	*1002.95*	0.435	*9.84*
2	1.010	49	951	8.42	*1008.94*	0.437	*9.89*
3	1.015	73	927	8.46	*1013.73*	0.439	*9.93*
4	1.020	98	902	8.50	*1018.52*	0.442	*10.00*
5	1.025	124	876	8.54	*1023.32*	0.444	*10.04*
6	1.030	149	851	8.59	*1029.31*	0.446	*10.09*
7	1.035	175	825	8.63	*1034.10*	0.448	*10.13*
8	1.040	201	799	8.67	*1038.89*	0.450	*10.18*
9	1.045	227	773	8.71	*1043.69*	0.452	*10.22*
10	1.050	253	747	8.75	*1048.48*	0.454	*10.27*
11	1.055	280	720	8.79	*1053.27*	0.457	*10.34*
12	1.060	307	693	8.84	*1059.27*	0.459	*10.38*
13	1.065	334	666	8.88	*1064.06*	0.461	*10.43*
14	1.070	362	638	8.92	*1068.85*	0.463	*10.47*
15	1.075	389	611	8.96	*1073.64*	0.465	*10.52*
16	1.080	417	583	9.00	*1078.44*	0.468	*10.59*
17	1.085	445	555	9.05	*1084.43*	0.470	*10.63*
18	1.090	473	527	9.08	*1088.02*	0.472	*10.68*
19	1.095	502	498	9.13	*1094.02*	0.474	*10.72*
20	1.100	531	469	9.17	*1098.81*	0.476	*10.77*
21	1.105	560	440	9.21	*1103.60*	0.478	*10.81*
22	1.110	589	411	9.25	*1108.39*	0.481	*10.88*
23	1.116	619	381	9.30	*1114.39*	0.484	*10.95*
24	1.122	650	350	9.35	*1120.38*	0.486	*10.99*
25	1.127	680	320	9.39	*1125.17*	0.488	*11.04*
26	1.132	710	290	9.43	*1129.96*	0.490	*11.08*
27	1.136	740	260	9.46	*1133.56*	0.492	*11.13*
28	1.141	771	229	9.50	*1138.35*	0.494	*11.17*
29	1.146	802	198	9.55	*1144.34*	0.497	*11.24*
30	1.153	835	165	9.60	*1150.33*	0.499	*11.29*
31	1.158	866	134	9.65	*1156.32*	0.502	*11.36*
31.45	1.160	880	120	9.66	*1157.52*	0.503	*11.38*
32	1.163	898	102	9.69	*1161.12*	0.504	*11.40*
33	1.168	930	70	9.74	*1167.11*	0.506	*11.45*
34	1.173	962	38	9.78	*1171.90*	0.508	*11.49*
35	1.178	990	10	9.82	*1176.70*	0.510	*11.54*
35.2	1.179	1000	-	9.83	*1177.89*	0.510	*11.54*

Based on temperature of 60°F (15.6°C)
Note: Refer to and follow recommended practices in the Halliburton Management System processes as well as MSDS and safety procedures for the materials.

Darcy's Law Equations

Linear Form

$$Q = \frac{1.1271 \times k \times A \times \Delta P}{\mu \times L}$$

where

Q	=	bbl/day
k	=	permeability in darcies
A	=	ft^2
ΔP	=	psi
L	=	length in ft
μ	=	viscosity in cP

Radial Form (Oil and Water)

$$Q = \frac{7.08 \times k \times h \times \Delta P}{B_o \times \mu \times \ln (r_e/r_w)}$$

r_w	=	wellbore radius (ft)
r_e	=	drainage radius (ft)
Q	=	flow rate [reservoir bbl (bbl/day)]
k	=	permeability (darcies)
h	=	height or thickness of formation (ft)
ΔP	=	pressure across the formation (psi)
μ	=	viscosity (cP)
B_o	=	formation volume factor

Frictional Pressure Drop

$$\Delta P_f = \frac{0.039 \times L\rho \, V^2 f}{D}$$

where

ΔP_f	=	frictional pressure drop (psi)
L	=	length of pipe (ft)
rρ	=	slurry density (lb/gal)
V	=	velocity (ft/sec)
f	=	friction factor, dimensionless
D	=	inside diameter of pipe (in.)

For annulus,

D	=	$D_o - D_I$

Horsepower (English and Metric)

$$hhp = \frac{P_w \times Q}{40.8}$$

where

hhp	=	hydraulic horsepower
Q	=	rate (bbl/min)
P_w	=	wellhead pressure ($lb/in.^2$)

Displacement Velocity

$$V = \frac{17.15 \, Q_b}{D^2} \quad \frac{= 3.057 \, Q_{cf}}{D^2}$$

where

V	=	velocity (ft/sec)
Q_b	=	pumping rate (bbl/min)
Q_{cf}	=	pumping rate (ft^3/min)
D	=	inside diameter of pipe (in.)

For annulus

D^2	=	$D_o^2 - D_I^2$

where

D_o	=	outer pipe inside diameter or hole size (in.)
D_I	=	inner pipe outside diameter (in.)

Value of pH

pH	Fluid	% by Weight
0.00	HCl Acid	4.3
0.10	HCl Acid	3.6
0.36	HCl Acid	1.8
1.00	HCl Acid	0.44
2.00	HCl Acid	0.036
3.00	HCl Acid	0.0036
4.00	HCl Acid	0.00036
5.00	HCl Acid	0.000036
6.00	HCl Acid	0.0000036
7.00	Neutral	Pure Water
8.00	NaOH	0.000004
9.00	NaOH	0.00004
10.00	NaOH	0.0004
11.00	NaOH	0.004
12.00	NaOH	0.04
13.00	NaOH	0.48
13.60	NaOH	2
13.90	NaOH	3.8
14.00	NaOH	4.6

Sand (20/40 Mesh) Fill-Up in Casing

Size		Weight		ID		Capacity		Capacity		lb Sand/LF	kg Sand/m	LF/lb Sand	m/kg Sand
in.	*mm*	lb/ft	*kg/m*	in.	*mm*	ft³/ft	*m³/m*	ft/ft³	*m/m³*				
4 1/2	*114.30*	9.50	*14.14*	4.090	*103.89*	0.0912	*0.0085*	10.9604	*117.98*	9.7259	*14.47*	0.1028	*0.0691*
		10.50	*15.63*	4.052	*102.92*	0.0896	*0.0083*	11.1669	*120.20*	9.5460	*14.21*	0.1048	*0.0704*
		11.60	*17.26*	4.000	*101.60*	0.0873	*0.0081*	11.4592	*123.35*	9.3026	*13.84*	0.1075	*0.0723*
		13.50	*20.09*	3.920	*99.57*	0.0838	*0.0078*	11.9316	*128.43*	8.9342	*13.30*	0.1119	*0.0752*
5	*127.00*	11.50	*17.11*	4.560	*115.82*	0.1134	*0.0105*	8.8174	*94.91*	12.0897	*17.99*	0.0827	*0.0556*
		13.00	*19.35*	4.494	*114.15*	0.1102	*0.0102*	9.0783	*97.72*	11.7422	*17.47*	0.0852	*0.0572*
		15.00	*22.32*	4.408	*111.96*	0.1060	*0.0098*	9.4360	*101.57*	11.2971	*16.81*	0.0885	*0.0595*
		18.00	*26.79*	4.276	*108.61*	0.0997	*0.0093*	10.0276	*107.94*	10.6307	*15.82*	0.0941	*0.0632*
		21.00	*31.25*	4.154	*105.51*	0.0941	*0.0087*	10.6253	*114.37*	10.0327	*14.93*	0.0997	*0.0670*
5 1/2	*139.70*	13.00	*19.35*	5.044	*128.12*	0.1388	*0.0129*	7.2065	*77.57*	14.7923	*22.01*	0.0676	*0.0454*
		14.00	*20.83*	5.012	*127.31*	0.1370	*0.0127*	7.2988	*78.56*	14.6052	*21.73*	0.0685	*0.0460*
		15.00	*22.32*	4.974	*126.34*	0.1349	*0.0125*	7.4107	*79.77*	14.3845	*21.41*	0.0695	*0.0467*
		15.50	*23.07*	4.950	*125.73*	0.1336	*0.0124*	7.4828	*80.54*	14.2461	*21.20*	0.0702	*0.0471*
		17.00	*25.30*	4.892	*124.26*	0.1305	*0.0121*	7.6613	*82.47*	13.9142	*20.71*	0.0719	*0.0483*
		20.00	*29.76*	4.778	*121.36*	0.1245	*0.0116*	8.0312	*86.45*	13.2732	*19.75*	0.0753	*0.0506*
		23.00	*34.23*	4.670	*118.62*	0.1189	*0.0110*	8.4070	*90.49*	12.6800	*18.87*	0.0789	*0.0530*
7	*177.80*	17.00	*25.30*	6.538	*166.07*	0.2331	*0.0217*	4.2893	*46.17*	24.8527	*36.98*	0.0402	*0.0270*
		20.00	*29.76*	6.456	*163.98*	0.2273	*0.0211*	4.3989	*47.35*	24.2332	*36.06*	0.0413	*0.0277*
		22.00	*32.74*	6.398	*162.51*	0.2233	*0.0207*	4.4790	*48.21*	23.7998	*35.42*	0.0420	*0.0282*
		23.00	*34.23*	6.366	*161.70*	0.2210	*0.0205*	4.5242	*48.70*	23.5623	*35.06*	0.0424	*0.0285*
		24.00	*35.72*	6.336	*160.93*	0.2190	*0.0203*	4.5671	*49.16*	23.3408	*34.73*	0.0428	*0.0288*
		26.00	*38.69*	6.276	*159.41*	0.2148	*0.0200*	4.6549	*50.10*	22.9008	*34.08*	0.0437	*0.0293*
		28.00	*41.67*	6.214	*157.84*	0.2106	*0.0196*	4.7482	*51.11*	22.4506	*33.41*	0.0445	*0.0299*
		29.00	*43.16*	6.184	*157.07*	0.2086	*0.0194*	4.7944	*51.61*	22.2343	*33.09*	0.0450	*0.0302*
		30.00	*44.64*	6.154	*156.31*	0.2066	*0.0192*	4.8413	*52.11*	22.0191	*32.77*	0.0454	*0.0305*
		32.00	*47.62*	6.094	*154.79*	0.2026	*0.0188*	4.9371	*53.14*	21.5918	*32.13*	0.0463	*0.0311*
		34.00	*50.60*	6.040	*153.42*	0.1990	*0.0185*	5.0257	*54.10*	21.2109	*31.57*	0.0471	*0.0317*
		35.00	*52.09*	6.004	*152.50*	0.1966	*0.0183*	5.0862	*54.75*	20.9588	*31.19*	0.0477	*0.0320*
		38.00	*56.55*	5.920	*150.37*	0.1911	*0.0178*	5.2315	*56.31*	20.3764	*30.32*	0.0491	*0.0330*
		40.00	*59.53*	5.836	*148.23*	0.1858	*0.0173*	5.3832	*57.94*	19.8023	*29.47*	0.0505	*0.0340*
7 5/8	*193.68*	20.00	*29.76*	7.125	*180.98*	0.2769	*0.0257*	3.6116	*38.87*	29.5158	*43.92*	0.0339	*0.0228*
		24.00	*35.72*	7.025	*178.44*	0.2692	*0.0250*	3.7152	*39.99*	28.6931	*42.70*	0.0349	*0.0234*
		26.40	*39.29*	6.969	*177.01*	0.2649	*0.0246*	3.7751	*40.63*	28.2375	*42.02*	0.0354	*0.0237*
		29.70	*44.20*	6.875	*174.63*	0.2578	*0.0240*	3.8791	*41.75*	27.4808	*40.90*	0.0364	*0.0244*
		33.70	*50.15*	6.765	*171.83*	0.2496	*0.0232*	4.0062	*43.12*	26.6085	*39.60*	0.0376	*0.0253*
		39.00	*58.04*	6.625	*168.28*	0.2394	*0.0222*	4.1773	*44.96*	25.5186	*37.98*	0.0392	*0.0263*
		43.50	*64.74*	6.435	*163.45*	0.2259	*0.0210*	4.4277	*47.66*	24.0759	*35.83*	0.0415	*0.0280*
8 5/8	*219.08*	24.00	*35.72*	8.097	*205.66*	0.3576	*0.0332*	2.7966	*30.10*	38.1182	*56.73*	0.0262	*0.0176*
		28.00	*41.67*	8.017	*203.63*	0.3506	*0.0326*	2.8527	*30.71*	37.3687	*55.61*	0.0268	*0.0180*
		32.00	*47.62*	7.921	*201.19*	0.3422	*0.0318*	2.9222	*31.45*	36.4791	*54.29*	0.0274	*0.0184*
		36.00	*53.57*	7.825	*198.76*	0.3340	*0.0310*	2.9944	*32.23*	35.6003	*52.98*	0.0281	*0.0189*
		38.00	*56.55*	7.775	*197.49*	0.3297	*0.0306*	3.0330	*32.65*	35.1468	*52.30*	0.0285	*0.0191*
		40.00	*59.53*	7.725	*196.22*	0.3255	*0.0302*	3.0724	*33.07*	34.6962	*51.63*	0.0288	*0.0194*
		43.00	*63.99*	7.651	*194.34*	0.3193	*0.0297*	3.1321	*33.70*	34.0346	*50.65*	0.0294	*0.0197*
		44.00	*65.48*	7.625	*193.68*	0.3171	*0.0295*	3.1535	*33.94*	33.8037	*50.31*	0.0296	*0.0199*
		49.00	*72.92*	7.511	*190.78*	0.3077	*0.0286*	3.2500	*34.98*	32.8005	*48.81*	0.0305	*0.0204*
9 5/8	*244.48*	29.30	*43.60*	9.063	*230.20*	0.4480	*0.0416*	2.2322	*24.03*	47.7561	*71.07*	0.0209	*0.0140*
		32.30	*48.07*	9.001	*228.63*	0.4419	*0.0411*	2.2630	*24.36*	47.1049	*70.10*	0.0212	*0.0143*
		36.00	*53.57*	8.921	*226.59*	0.4341	*0.0403*	2.3038	*24.80*	46.2713	*68.86*	0.0216	*0.0145*
		38.00	*56.55*	8.885	*225.68*	0.4306	*0.0400*	2.3225	*25.00*	45.8986	*68.30*	0.0218	*0.0146*
		40.00	*59.53*	8.835	*224.41*	0.4257	*0.0395*	2.3489	*25.28*	45.3835	*67.54*	0.0220	*0.0148*
		43.50	*64.74*	8.755	*222.38*	0.4181	*0.0388*	2.3920	*25.75*	44.5653	*66.32*	0.0224	*0.0150*
		47.00	*69.94*	8.681	*220.50*	0.4110	*0.0382*	2.4329	*26.19*	43.8151	*65.20*	0.0228	*0.0153*
		53.50	*79.62*	8.535	*216.79*	0.3973	*0.0369*	2.5169	*27.09*	42.3537	*63.03*	0.0236	*0.0159*
		58.40	*86.91*	8.435	*214.25*	0.3881	*0.0361*	2.5769	*27.74*	41.3671	*61.56*	0.0242	*0.0162*
		61.10	*90.93*	8.375	*212.73*	0.3826	*0.0355*	2.6140	*28.14*	40.7807	*60.69*	0.0245	*0.0165*
		71.80	*106.85*	8.125	*206.38*	0.3601	*0.0335*	2.7773	*29.89*	38.3823	*57.12*	0.0261	*0.0175*

The above table is based on sand having bulk density of 14.25 lb/gal (1.71 specific gravity). Absolute Volume of Sand = 0.0456 gal/lb; Bulk Volume of Sand = 14.25 lb/gal = 0.0702 gal/lb/0.0456 = 21.93 lb/gal = 106.6 lb/ft³ = 0.0702 gal/lb assuming that the porosity of 20/40 sand is 35% 106.6 lb.ft^3 × 0.0912 lb³/ft of fill in 4 1/2 in. 9.5 ppf casing.

Gas Table

Well Depth		Correction Factor		
ft	*m*	0.6 Gravity	0.7 Gravity	0.8 Gravity
4,500	*1371.60*	1.099	1.116	1.132
5,000	*1524.00*	1.110	1.130	1.149
5,500	*1676.40*	1.120	1.141	1.163
6,000	*1828.80*	1.320	1.155	1.181
6,500	*1981.20*	1.143	1.175	1.195
7,000	*2133.60*	1.155	1.184	1.211
7,500	*2286.00*	1.171	1.195	1.227
8,000	*2438.40*	1.181	1.210	1.241
8,500	*2590.80*	1.190	1.230	1.260
9,000	*2743.20*	1.202	1.240	1.273
9,500	*2895.60*	1.215	1.250	1.280
10,000	*3048.00*	1.225	1.265	1.305

Example: for a gas of 0.7 gravity at 8,000 ft depth and 3,000 psi surface pressure
$P_{Bottomhole} = P_{Surface} \times$ Correction Factor = 3,000 (1.210) = 3,600 psi

Filtration

Three types of filter rating systems are currently used to predict the actual performance of filters under field operating conditions.

- Nominal rating – the National Fluid Power Association definition for nominal rating is "an arbitrary value assigned to the manufacturer." The nominal rating is based on weight percent removal above a given particle size.
- Absolute rating – The National Fluid Power Association defines the absolute rating as "the largest hard spherical particle which will pass a microporous membrane under specified test conditions. This is an indication of the largest pore in the microporous medium." The absolute rating will not predict the reduction in particle load at all particle sizes below the absolute rating because two legitimately rated 10 µm can have different pore size distributions resulting in different removal efficiencies at all particle sizes smaller than 10 µm.
- Beta rating system – The beta rating system is simple in concept and can be used to measure and predict the performance of a wide variety of filter cartridges under specified test conditions. Oklahoma State University has participated in fluid-power filtration research for several years and defines "absolute" incorporating a beta value or a rating of inlet to outlet particles. OSU acknowledges that a beta of 75 (98.67% efficiency) is recognized by its department as "absolute."

Filtration or Beta Ratio

(βx) – The ratio of the number of particles greater than a specified size (x) in the effluent fluid as compared to the influent fluid, usually expressed as follows:

$$b = \frac{\text{Upstream particle count} > \text{particle size (x)}}{\text{Downstream particle count} > \text{particle size (x)}}$$

A better understanding of beta ratios and their relationships to particle-removal efficiencies can be gained from the following table and formulas.

Filtration Ratio (ß)	Removal Efficiency (%)
1	0.000
2	50.000
4	75.000
5	80.000
10	90.000
20	95.000
50	98.000
75	98.670
100	99.000
1,000	99.900
10,000	99.990
100,000	99.999

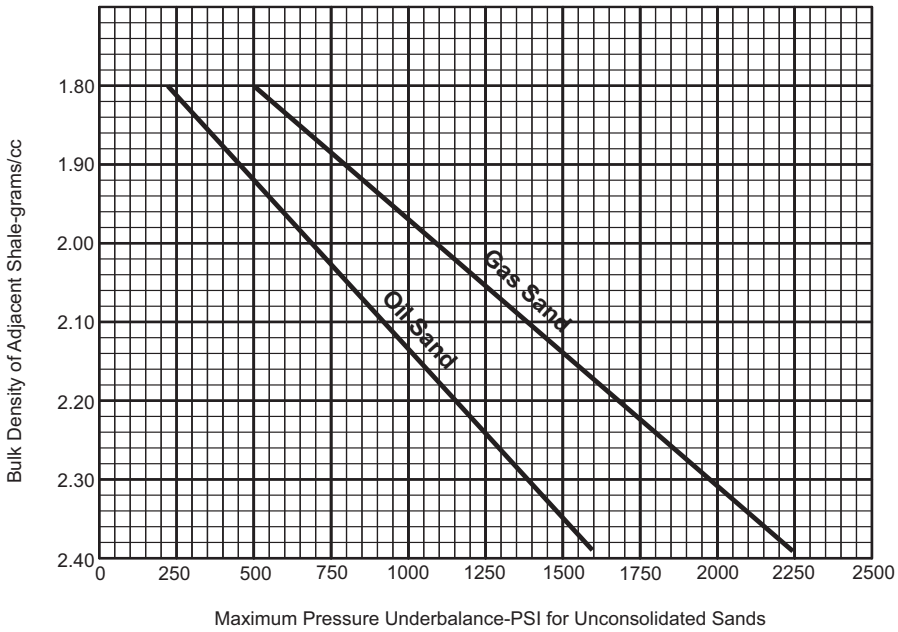
Filtration Ratio and Removal Efficiency (%)

To calculate beta ratio with known removal efficiency (96%), use the following formulas:

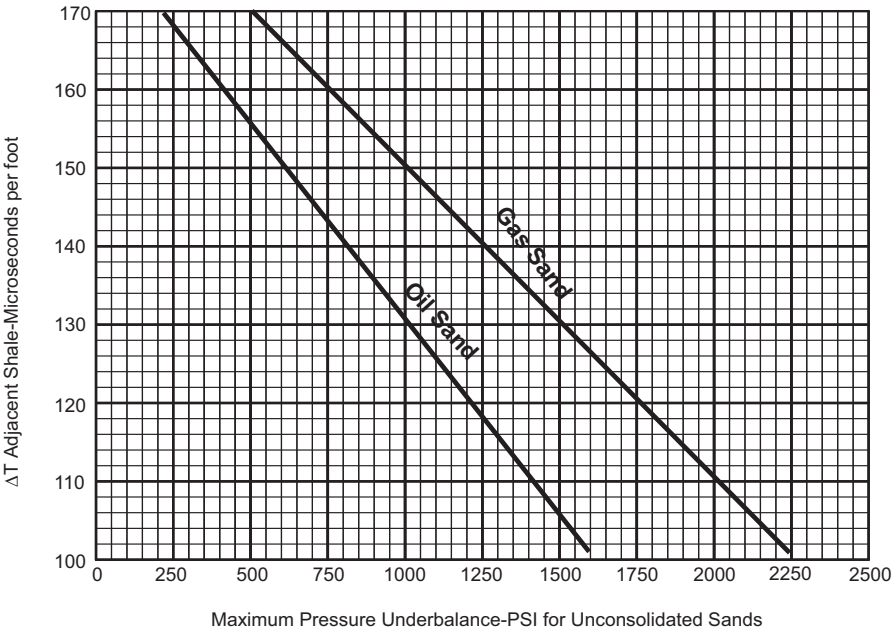
$$b = \frac{100}{100 - \text{removal efficiency}} = 100 - 96 = \frac{100}{4} = \frac{100}{25}$$

$$\text{Removal efficiency} \quad \frac{(b - 1)}{25} = \times 100 \quad \frac{(25 - 1)}{b} \times 100 = 96\%$$

Perforating Underbalance Pressure Using Density Data



Perforating Underbalance Pressure Using Acoustic Data



Unconsolidated Formations

Determine Minimum Underbalance to Overcome Total Skin

1. Find Minimum ΔP Underbalance

For Oil Wells	For Gas Wells
U = 3500/K0.37	U = 2500/K0.17

Legend: U is Underbalance in psi
K is Permeability in md

Examples of Minimum Underbalance

Permeability md	Minimum Underbalance psi	
	Oil Well	Gas Well
1	3500	2500
5	1930	1902
10	1493	1690
20	1155	1502
100	637	1143
500	351	869
1000	272	773
1000	272	773

Find Maximum Safe Underbalance

2. If Formation Compressive Strength is known, Maximum Underbalance

= Actual Formation Pressure - Minimum Pore

= Formation Pressure - (Overburden - 1.7 × Compressive Strength)

3. If Compressive Strength is not known, find Maximum Safe Underbalance.
4. Find Midpoint between Minimum and Maximum ΔP.

Underbalance to Use

A. Shallow Invasion or Low Water Loss Cement – use Minimum to Midpoint ΔP.

B. Deep Invasion or High Water Loss Cement – use Midpoint to Maximum ΔP.

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