



SMART 3D Displacement Strategy

**Integrating mechanical, chemical and hydraulic components
for truly engineered displacements**



SMART 3D Displacement Strategy: The single-source solution for a trouble-free displacement the first time.

Improperly preparing a wellbore for completion is the chief cause of reservoir damage and severely restricted production. Failing to adequately design and execute the displacement of the drilling fluid leads to additional rig time to repair damage and recover production. Displacements often have been compromised as different parties focus on their respective segments. The resulting disconnect can leave critical transition elements neglected and the well ill-prepared for completion or production operations.

With our unequaled SMART 3D displacement strategy, M-I SWACO project specialists use their industry-leading expertise and resources to design and deliver a customized approach to protect your producing reservoir while minimizing trips, fluid volumes and interfaces, and reducing waste-disposal costs and other potential problems during completion. This approach adds operational value while controlling overall project costs.

Prepare your well by focusing on the three critical displacement components

Features

- Single-source displacements
- Integrated mechanical, chemical and hydraulic solutions
- Tested and field-proven technologies
- Proprietary VIRTUAL COMPLETION SOLUTIONS[†] (VCS) modeling software
- WellBuilder[†] design software
- New-generation clean-up tools
- Designed to meet all displacement environmental standards
- One-drum, multi-purpose displacement fluid compatible with oil-, synthetic-based muds
- Highly experienced displacement specialists

Benefits

- Provides single-source accountability
- Reduces non-productive time (NPT)
- Minimizes risk of formation damage
- Cuts waste volumes
- Avoids cross-contamination of premium drilling fluids and brines
- Delivers debris-free wellbore
- Minimizes interface
- Clears way for trouble-free completions
- Reduces overall costs
- Enhances production
- Improves HSE performance

The SMART 3D[†] displacement strategy from M-I SWACO, a Schlumberger company, brings all the critical elements together in an integrated package of displacement services with single-source accountability. With the SMART 3D displacement strategy, we combine the latest generation chemical, mechanical and hydraulic technologies into a cohesive displacement solution. By taking complete ownership of the design and execution of the displacement, we ensure all components are appropriately considered to provide efficient, cost-effective delivery of a properly prepared wellbore, one requiring no remediation.

A primary goal of the SMART 3D displacement strategy is to mitigate risks and operational problems from debris or incompatible drilling or completion fluids left in the wellbore. In fact, operators have said that 30 percent of failed completions result directly from poor debris management, or allowing mud or drilling residue to remain in the hole during well construction. The SMART 3D displacement strategy meets that troublesome and profit-draining issue head-on. It is the result of our long-held objective to engineer and execute a consistent, holistic wellbore displacement philosophy, one that meets increasingly stringent environmental standards, particularly offshore where minimizing interface and contaminated fluid volumes are paramount. The SMART 3D displacement strategy clearly reflects our commitment to integrated solutions.

With SMART 3D displacements, we are the only company capable of exploiting the intrinsic interdependency of all the mechanical, chemical and hydraulic components in the seamless design and delivery of an effective displacement – the first time, every time.

1

MECHANICAL

A comprehensive suite of specialized tools and filtration equipment that deliver a clean wellbore ready for the completion process.

2

CHEMICAL

High-performance and environmentally compliant wash pills and spacers formulated to meet the challenges specifically related to displacing and cleaning your well.

3

HYDRAULIC

Powerful software-generated simulations that evaluate downhole fluid dynamics, pressures and equipment limitations to ensure the highest degree of efficiency.



A clear pathway for full production: expect no less from the industry leader

The undisputed leader in deepwater and other technically demanding applications, M-I SWACO knows better than anyone the inherent value of integrating interrelated disciplines. Our track record speaks for itself. As a pioneer in the development of technologies and processes to improve the displacement operation, especially in deepwater, M-I SWACO has long maintained that mechanical, chemical and hydraulic components each play vital roles in the trouble-free transition from a drilling fluid to a completion brine. An exhaustive analysis of more than 40 diverse well operations validated our long-held view that ignoring or failing to properly account for even one element within these interrelated disciplines all too often results in inefficient displacement, additional rig time for remedial work and, at worst, lost production.

From the beginning, we recognized that all displacements have three core dimensions: fluid hydraulics, mechanical debris removal and chemical debris removal. Consequently, as one element affects the other, often

considerably, a successful displacement requires each of these fundamental components to be considered equally and integrated completely. The resulting philosophy has led to an entirely new dimension – SMART 3D displacement strategy – for mechanical, chemical and hydraulic technologies that consistently improve efficiencies, while reducing the time and costs of deepwater displacements.

With SMART 3D displacements, M-I SWACO designs a cost-effective technology package tailored for your specific requirements and follows up with an engineered approach to integrate and coordinate all the elements to assure they work seamlessly.

The SMART 3D displacement strategy comprises of:

- A comprehensive suite of specialized tools that deliver a clean wellbore ready for the completion process
- High-performance and environmentally compliant wash pills and spacers formulated to meet the challenges specifically related to displacing and cleaning your well
- Powerful software-generated simulations that calculate and evaluate parameters such as downhole fluid dynamics, pressures and equipment limitations to ensure the highest degree of efficiency in the displacement process

What's more, our cross-trained specialists are with you throughout the process to ensure these three cornerstones of a successful displacement work in harmony. This assurance allows you to displace your well cleanly and efficiently, while minimizing waste volumes and rig time, and opening the door to maximized production.



From beginning to end, we have the smart three-dimensional solution

Well before the displacement begins, our project specialists work closely with your key personnel to tailor procedures to meet your specific well requirements, for the very basic to extremely complex completions.

By analyzing and evaluating the three fundamental cornerstones of a successful displacement, M-I SWACO experts engineer a displacement strategy that specifically addresses the identified challenges. Once the job begins, these specialists oversee every aspect of the process, from fluid and rig preparation to displacement execution.

Throughout the process, our specialists incorporate the very latest in field-proven tools, chemicals and hydraulics support in an integrated displacement designed to deliver the results you deserve:

- Zero displacement-related NPT
- Maximum reservoir potential
- Heightened QHSE awareness
- Maximum efficiency throughout the displacement operation

Dimension **1**: New generation mechanical components clear the way

Obviously, the chances of a successful completion are slim if debris is left in the wellbore after displacement. That's why a properly engineered mechanical cleanup, using state-of-the-art tools, is a mandatory precursor and complements the chemical sweeps and washes designed to remove drilling or produced fluids from the wellbore.

M-I SWACO has designed the industry's most comprehensive portfolio of pre-completion mechanical wellbore cleanup technologies. The wide range of specialized tools we have assembled delivers the mechanical forces necessary to remove drilled solids, barite and scale from the casing wall; mill out residual cement from liner jobs and squeezes; jet-wash blowout preventers and risers; and remove scale, drilling and milling debris from the hole. M-I SWACO specially designs a work string for your specific requirements, delivering exactly what you need to get the job done right the first time.

Our wellbore preparation tools include both single-purpose equipment as well as multiple-configuration tools, giving you solutions applicable for any well.

Polished bore receptacle preparation, liner-top testing

SMART 3D displacement strategy includes tools designed for single-trip dressing of the polished bore receptacle and inflow testing the liner top. For example, the unique WELL COMMISSIONER[†] tool allows inflow and negative tests to be conducted on a liner top during the same trip as the wellbore displacement. The integral scraper and mill ring ensures a clean area for setting the packer element and a smooth liner top, respectively. This one-trip approach results in significant savings in rig time compared to other inflow testing methods.

Casing and combo-casing cleanup

The SMART 3D displacement strategy includes the industry's most advanced brushes, magnets and scrapers for capturing and carrying large metal debris out of the wellbore. Cleanup solutions include the modular MULTIBACK[†] tool, comprising an integral magnet section to capture ferrous debris and scrapers to dislodge difficult-to-remove debris, plus brushes to disturb the sheath and any additional fluid build-up on the inner wall of the casing or liner. We also offer a variety of circulating valves that boost annular velocities. Another key component is the WELL PATROLLER[†] validation tool that performs a cleaning action when run in tandem with the MAGNOSTAR[†] magnet tool and non-rotating casing brushes and scrapers.

Riser, subsea BOP and wellhead cleanup

A successful deepwater displacement requires the riser, subsea BOP and wellhead be cleaned thoroughly before initiating the completion – an operation requiring specialized tools and proficiency. SMART 3D displacements deliver on that front, too, with specially designed equipment that precisely matches the profile of your well, including our PUP[†] RISER BRUSH tool and RISER MAGNO BUCKET[†] tool.

Filtration

Maintaining completion fluid quality is another critical aspect of a successful completion. Completion brines coming into direct contact with the pay zone or programmed to be left in the wellbore post-completion must be filtered to remove any solids that could compromise the completion assembly or the production zone. Even small or colloidal particles in brine pose the potential for compromising the reservoir. Whether the operation calls for diatomaceous earth (DE) filter presses or a cartridge unit, the M-I SWACO project specialist can optimize the filtration process to ensure fluid-quality specifications while meeting operational requirements and rig limitations. In addition, we also offer our FILTER FLOC[†] fluid filtration agent mixed directly into contaminated fluid to flocculate and precipitate solids, which improves filtration rates and minimizes consumption of filtration consumables – just one more example of the breadth of the SMART 3D displacement strategy.





Dimension **2**: Ground breaking chemical solutions set us apart

Being the first name on the list of innovators in the development and application of drilling, reservoir drill-in, completion fluid systems and associated additives, M-I SWACO has a major advantage in designing chemical displacement solutions. Since fluids have long been our core strength, our industry-leading expertise naturally enhances our SMART 3D displacement strategy. Our expertise in drilling fluid and completion brine chemistries gives us the know-how to design and apply chemical solutions to fully prepare the wellbore for completion. We have developed a wide range of solvent and surfactant chemical spacers that prevent interaction of incompatible synthetic- or oil-based drilling fluids and completion brines and the generation of viscous emulsions that can jeopardize the displacement.

Meanwhile, our chemical approach to debris removal ensures a smooth transition from one fluid to another, leaving the downhole tubulars water-wet and fully prepped for the completion. The project-specific SMART 3D displacement chemical

analysis begins with a thorough laboratory simulation, where cleaning efficiencies and compatibilities are determined. The resulting data is inputted into our knowledge-based X-CLEAN[†] simulator and incorporated into the proprietary VCS hydraulic software simulator. With VCS software, our specialists model the fluid and fluid interfaces to optimize spacer size and rheological properties, and determine the effect of contamination on spacer performance. The results from the VCS simulator also help reduce fluid interfaces and associated waste.

At the heart of SMART 3D displacements is DEEPCLEAN[†] spacer technology, a powerful, multi-purpose cleaning agent that satisfies all the requirements of a multiple-stage displacement wash train with a single product. This efficient combination of powerful solvents, surfactants and water wetting agents not only provides highly effective surface cleaning, but does so with an excellent HSE profile. DEEPCLEAN spacer technology chemistry eliminates the need for multiple chemical spacers, thus reducing rig time

and costs while minimizing fluid waste. Our all-inclusive SMART 3D displacements also extend to tubing-pickling displacements with our SAFE-T-PICKLE[†] pipe dope remover. SAFE-T-PICKLE solvent eliminates the HSE hazards associated with commodity chemicals, while delivering a more effective pipe dope dissolving capacity.

The SMART 3D displacements philosophy also addresses one of the most crucial chemo-mechanical aspects of displacements. For extremely complex wells, invert emulsion drilling fluids provide tremendous lubricity, but clear-brine fluids alone are unable to generate the same level of friction resistance. To mitigate this limitation, we developed the SAFE-LUBE[†] additive to enhance the lubricating qualities of clear brines to a level approaching that of oil- and synthetic-based drilling fluids. The lubricating capacity of SAFE-LUBE additive maintains the low mechanical friction needed to manipulate and move the work string after the displacement is complete.



DEEPCLEAN

Solvent

Surfactant

Dimension 3: Hydraulic simulations consider all variables

Complementing our industry-leading expertise in oilfield chemistry is our pioneering work in the engineered modeling and monitoring of downhole hydraulics. Our pacesetter VIRTUAL HYDRAULICS⁺ drilling fluids simulation software has long been the industry standard. We bring that same standard to the planning and execution of a SMART 3D displacement strategy. Undoubtedly, with fluids hydraulics reigning as the most complex dimension of a displacement, ensuring all the elements are correct is essential for a successful pre-completion operation.

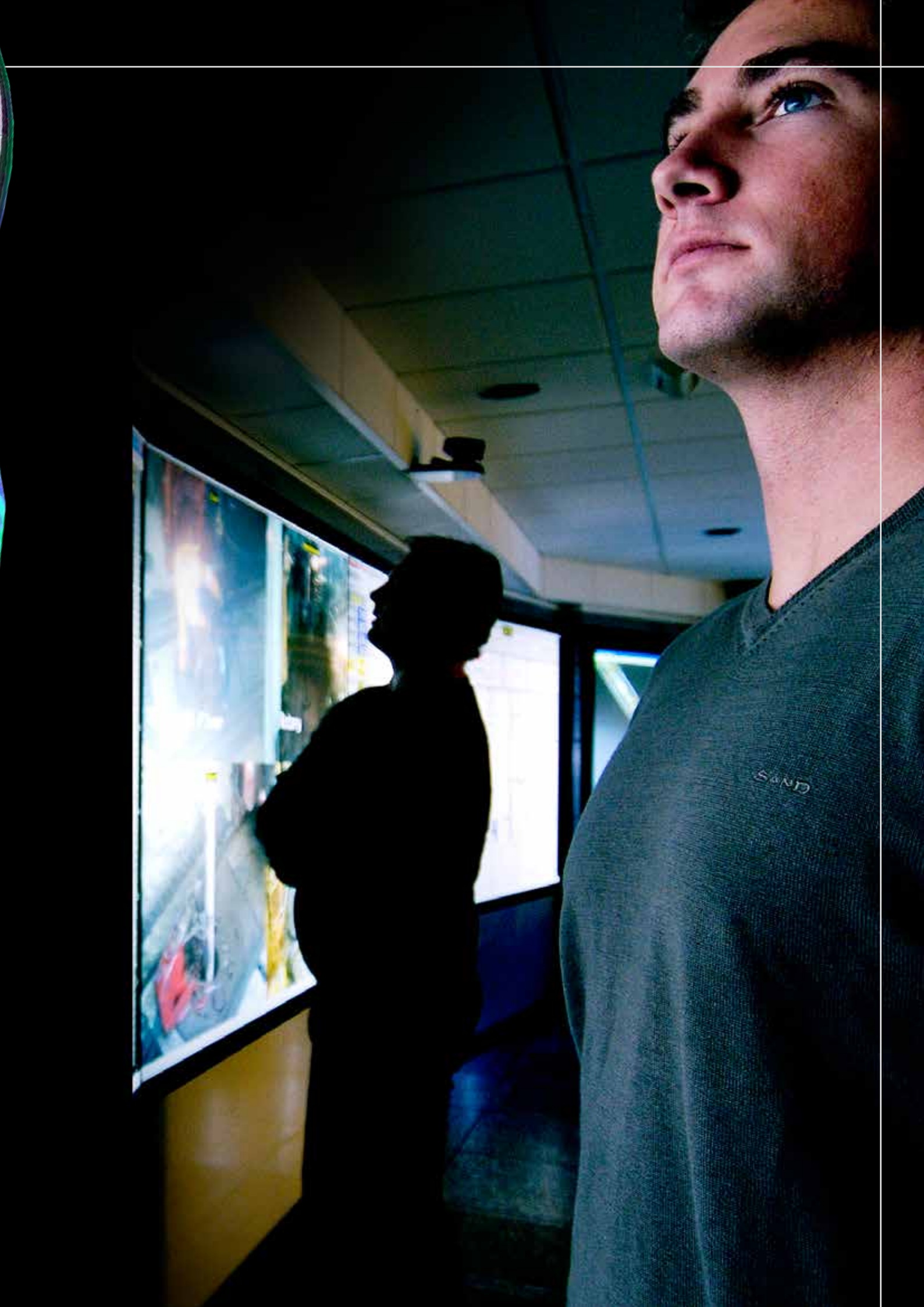
For a given wellbore configuration, every flow-related aspect must be taken into consideration, including pump rate, maximum attainable pump pressures, fluid viscosity and density differences, wellbore temperature, equivalent circulating density at various key points, spacers, and the type of completion fluid to be used. Here, M-I SWACO relies on data from our multi-faceted VCS software engineering package. In the pre-planning stage, we carefully evaluate all the flow-related elements and

develop a plan to optimize hydraulics to ensure that the recommended displacement procedure can be pumped at required flow rates.

Our hydraulic programs prevent the myriad problems that can result from pressure differentials, including mechanical breakdown of the formation or squeezed perforations and/or liner tops. Besides being fundamental to effective casing and BOP cleanups, the hydraulic dimension also plays an important role in open hole completions where filter-cake integrity is critical for wellbore stability, formation protection, and operations efficiency. A poorly optimized profile in the open hole can hydraulically remove or erode a filter cake prematurely, inducing fluid losses. We take this risk into

consideration in the pre-planning stage, where we use VCS software calculations to optimize hydraulic profiles to ensure that only excess filter-cake residue is removed while the integrity of the cake itself remains intact.







WellBuilder Design Software: Advanced engineering, compact design

Ensuring the optimum performance of your wellbore cleanup operation begins in the pre-job planning stage with our proprietary WellBuilder* completion design software module. WellBuilder software gives our engineers a powerful tool for designing the most effective cleanup BHAs to prepare the wellbore for displacement and completion. Used in conjunction with the tool technical database, WellBuilder software is consistently effective in the planning, designing, executing and post-job reporting of debris management operations, all to ensure that your well is properly prepared for running the completion. WellBuilder software includes BHA schematics based on the most up to date technical data and also includes the facility to capture on the job data throughout the process, resulting in a comprehensive end-of-well report to optimize future operations. With WellBuilder software, our engineers can also access a global data base of similar operations in which these innovative tools have been employed. The result of all this is a wellbore cleanup operation that ensures a debris-free well and a trouble-free completion to meet your requirements.

Put the SMART 3D Displacement to work for you

To learn more about the SMART 3D displacement strategy and how it is performing for our other customers worldwide, contact the M-I SWACO representative nearest you.

VIRTUAL COMPLETION SOLUTIONS

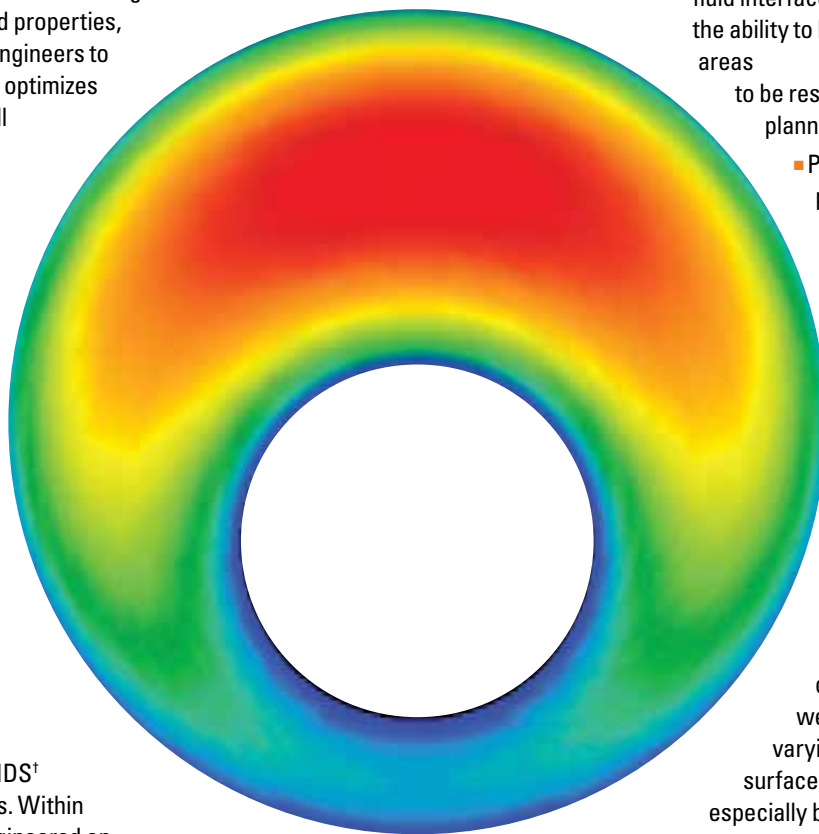
software brings an entirely new dimension to hydraulics modeling

With its capacity to facilitate evaluation of the hydraulic dimension at various levels of the process, our proprietary VCS software has been a key contributor to the success of the SMART 3D displacement strategy. Utilizing concise and well-specific data on wellbore geometry, casing and drill string dimensions, and active mud properties, VCS software allows our engineers to design a displacement that optimizes vital elements, including pill properties, contact time, flow regime and pump pressures. This design method helps improve displacement efficiency, minimize the volume of chemicals used, and reduce the generated volume of contaminated completion fluid.

VCS software is a totally re-designed, state-of-the-art software, integrating the widely accepted proprietary VIRTUAL COMPLETION FLUIDS[†] (VCF[†]) and VIRTUAL RESERVOIR DRILL-IN FLUIDS[†] (VRDF[†]) software packages. Within VCF software, we have engineered an integrated suite of programs to analyze and design brines, completion fluids, and displacement operations under simulated field conditions. The VRDF software suite of programs is used to select, design and optimize reservoir drill-in fluids. VCS software combines the two software tools with improved engineering models and analyses, as well as synchronized workflows and processes.

The DISPRO[†] (DISPLACEMENT PROFILE) module is a valuable component within VCS software, as it presents a two-dimensional depiction of fluid-flow dynamics. In

designing a displacement for a deepwater well, the M-I SWACO specialist inputs well data, with the output illustrating the well geometry. This displacement representation enables the engineer to visualize in a single graph the effects of



rate, pressure and hydraulic horsepower. With the DISPRO module, fluids are described by volume, density and rheology. Employing the state-of-the-art VCS software package allows M-I SWACO, with an unequalled degree of accuracy, to:

- Minimize rig time for displacements by calculating all critical variables in the wellbore
- Design a displacement that stays within equipment limitations by inputting exact

wellbore geometry, including angle, and calculating such parameters as hydraulic horsepower, flow rate, choke pressures and back pressures

- Model the effect of pipe eccentricity on wellbore cleanup efficiency and fluid/fluid interfaces, dramatically improving the ability to highlight potential problem areas

to be resolved in the pre-planning phase

- Provide flexible operating parameters for critical wells by simulating displacement in either direction, tracking all fluids in the displacement as a function of volume or pump strokes, and displaying position, pressure, rate and other data at any point in the wellbore
- Optimize completion fluid economics by predicting equivalent static and local brine density at any point in the wellbore, accounting for varying temperatures from surface to bottom, which is especially beneficial in the cold environments of deepwater wells.

To complete the loop, different scenarios can be modeled by varying the chemical and mechanical inputs and their relative effects on the hydraulics. When the model is fully optimized for a specific project, the entire hydraulic profile is presented on a single page within the client's wellbore profile to clearly summarize the hydraulic dimension. This key module in the SMART 3D strategy provides clients the precise information they require to address the complex hydraulics dimension of their specific wellbore characteristics.



SMART 3D Displacement Strategy proves itself in the field

Gulf of Mexico: SMART 3D displacement strategy maximizes performance in difficult high-angle well

The Situation

Poor debris management during the displacement left behind unwanted solids that had the potential to plug perforations or prevent the completion assembly from reaching bottom. Insufficient pit space made it difficult to build the necessary spacer train. Previous wells were completed indirectly and unbalanced, displacing from mud to sea water, prior to placing the completion brine. However, pressure limitations required a balanced direct displacement from mud to brine with no intermediary fluid.

The Solution

After evaluating the well characteristics, operator requirements and rig limitations the M-I SWACO team tailored a SMART 3D displacement strategy that comprised:

Mechanical:

The Heavy-Duty BRISTLE BACK brush and Heavy-Duty RAZOR BACK scraper to prepare all packer-setting areas as well as remove drilling fluid and cement debris. The MAGNOSTAR magnet was used to capture ferrous material and transport it to surface. The WELL PATROLLER validation

tool confirmed the effectiveness of the displacement. A twin-press DE package was utilized to maintain fluid quality during the completion process.

Chemical:

The transition spacer was sized to remove the whole mud from the well and for compatibility with the mud that was being displaced.

DEEPCLEAN additive was utilized in the cleaning spacer to remove oily mud film residue and water wet the casing and tubulars. The cleaning spacer was designed in the lab for optimum mud film removal and appropriate contact time. Flow regimes were accurately modeled to provide sufficient contact time for the cleaning spacer.

Hydraulic:

VIRTUAL COMPLETION SOLUTIONS software was used to calculate the size of the transition spacer to account for whole mud removal. VCS software hydraulic profiles verified flow rates and contact time were within specification while providing a cleaning profile to ensure well cleanliness. Hydraulic displacement scenarios were

run in VCS software to make sure we were working within the limitations of the rig's pump pressure, to account for ECD/ESD, and to maintain a balanced displacement.

The Results

Pit space was no longer a problem due to the use of DEEPCLEAN additive which performed the role of a solvent cleaning spacer as well as a water-wetting surfactant spacer in a single pill. The transition spacer was prepared at the brine plant and sent to the rig in marine portable tanks to further save valuable pit space. The engineered clean-up BHA took care of the mud film and debris and the WELL PATROLLER validation tool was empty upon arriving at surface which validated the effectiveness of the displacement. Interface volumes were well below target and the NTU specification set by the operator was reached within one circulation. With SMART 3D displacement strategy, the operator was able to maximize performance from all three critical aspects of an effective displacement.



California: SMART 3D displacement strategy delivers a sixfold increase in production

The Situation

Typically, the operator of a California field followed a completion strategy that entailed drilling the lower sections with oil-based mud, followed by running the liner and displacing cement with lease water. After perforating and acidizing, the production packer would be set, the production string run, and the lease water displaced with nitrogen prior to stinging into the packer and beginning production. All of the pertinent parties concurred that the incomplete removal of cement, residue from the oil-based mud, and the lease water combined to restrict production.

The Solution

On subsequent wells, M-I SWACO responded by designing a fully integrated SMART 3D displacement strategy aimed at increasing production by optimizing the three critical elements into a seamless approach that included:

Mechanical:

- The BRISTLE BACK brush and RAZOR BACK scraper to effectively remove drilling fluid and cement debris in one trip
- Filtration equipment to remove solids from the lease brine
- Removing solids from both the wellbore and completion fluid

Chemical:

- Chemical spacers to remove oil-based mud residue in just over one circulation while leaving the tubulars water-wet
- Properly engineered transition spacer to push the whole mud out of the well

Hydraulic:

- VCS software modeling optimized spacer sizes
- Viscous spacer to provide an effective barrier between oil-based mud and lease brine
- Clear interface to reduce the contaminated fluid volume

The Results

The specially selected cleanup tools removed drilling fluid solids and cement in one trip. The spacer chemistry removed the oil-based mud residue and water-wet the tubulars in just over one circulation. Specialized software modeled the hydraulics to size the spacers and ensure effective cleaning. Filtration equipment removed solids from the lease brine. The bottoms-up fluid sample contained only 10 percent solids and oil residue. The lease water cleaned up 50 bbl (7.95 m³) after the viscous spacer returned with no solids or traces of oil. This was the third well the operator cleaned using the SMART 3D displacement strategy best practices and design. Each of these three wells exceeded the operator's production expectations sixfold.



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