Maintain and enhance production performance from reservoir to refinery

Production capabilities, services and products
The widest choice of technology, the broadest range of expertise

Production challenges  02
- FPSO and deep water  04
- Land operations  06
- Unconventional  08
- Heavy oil  10
- Arctic  12
- North Sea  14

Production chemicals  16
- Overview  16
- Asphaltenes  18
- Commodities, utilities and cleaners  20
- Corrosion inhibitors  22
- Defoamers  24
- Demulsifiers  25
- Hydrates inhibitors  26
- Hydrogen sulfide  28
- Microbiocides  30
- Naphthenates  31
- Paraffin inhibitors  32
- Scale inhibitors  34
- Tracer dyes  36
- Water clarifiers  37

Flow improvers  38
Produced water and sand treatment  40
Descaling, NORM-decontamination and decommissioning  42
Purification solutions  44
Capabilities and resources  46
- Management services  46
- Ecotoxicological testing laboratory  48
- Research and development  50
- Supply chain  52
- Training and career development  54
More answers to your production challenges

Our unique range of chemical, mechanical and data management products and services gives you more ways to maintain and improve production performance—in any environment and on any scale.

**Chemical expertise**
Our production chemicals can be used alone or in combination with mechanical solutions to optimize performance.

**Mechanical expertise**
We have solutions available on a capital purchase or rental basis along with a full maintenance, refurbishment or retrofit service.

**Data management**
We provide analytical data to give you visibility of the complex information needed to manage the technical, commercial and operational performance of your assets.

The best technology for your needs
Because we have a unique range of chemical, mechanical and data management services, we are able to consider both process equipment and chemical consumption for every project. This means we can genuinely offer a solution based on the widest possible choice of technologies available—ensuring that you always achieve the most cost-effective outcome.

From low-rate land wells or high-rate offshore fields to sensitive and remote locations, we help you maintain continuity of production from the reservoir to the refinery.

At every stage of your production operations, M-I SWACO can help to protect asset integrity, improve efficiency, increase production rates and enhance product quality. The results are increased revenues and reduced operating costs with lower NPT.

Applying our expertise
Working with you on-site and using our research laboratories and field support operations, our dedicated teams can analyze any issues across your production operations and then engineer a solution appropriate to your needs. Their knowledge and experience means that your solution will be fully compliant with any prevailing regulations and will safely optimize and protect flow from the reservoir to the refinery.

From individual technologies to fully integrated solutions, the diverse experience and expertise of our multidisciplinary team enables them to engineer and deliver systems and solutions that effectively prevent and meet more production continuity challenges—all delivered safely and in compliance with local regulations.
Offshore Congo, West Africa

**Scale formation prevented in deepwater flowlines**

**The Situation**
The flowlines of a deepwater oilfield in 1400 m of water encountered flow assurance problems including scale deposition. Chemical injection was challenging as the FPSO vessel was 140 km offshore. Any inhibitor needed to withstand severe conditions and not degrade over prolonged residence periods.

**The Solution**
Formulated for deep water use, DS-1618 scale inhibitor was selected. Initial testing ensured it would remain pumpable at high pressures, avoid blocking subsea umbilicals and be fully compatible with the produced water. Compatibility with a wide range of elastomers, plastics and metals was also evaluated.

**The Results**
Since injecting 75-100 ppm of DS-1618 there have been no scale-related flow assurance problems. The deepwater chemical umbilical and injection equipment have remained blockage free.
Production challenges – FPSO and deep water

Build in offshore production continuity

With production from increasingly greater water depths becoming standard practice, deepwater production today constitutes more than 20% of global offshore production – a proportion that will continue to grow.

**FPSO and deep water**

Issues such as paraffin or hydrate formation are familiar concerns; however, providing subsea flow assurance requires a solution that performs reliably across potentially enormous temperature gradients and hundreds of kilometers. In response, M-I SWACO established a deepwater R&D Center in Houston, and provides products and services designed for the uniquely demanding extremes of deepwater deployment and operations.

As a founding member of the Blockage Avoidance in Subsea Injection and Control Systems (BASICS) Joint Industry Project (JIP), which resulted in the API specification 17TR6, our technologists have set the standards for deepwater flow assurance. Beyond the laboratory phase, manufacture and supply chains have to meet stringent quality control over product cleanliness according to NAS and ISO standards. As a company that provides both production and completion fluids technology, we are ideally placed to meet these demands as every location worldwide has filtration packages to ensure the products meet these tight cleanliness specifications.

We will work with you, providing the right combination of people, processes and technology to ensure that you reduce the time to first oil, maximize production efficiency, reduce downtime and maintain safety.

**Flow assurance and asset integrity**

Our chemical products and services give you more ways to protect critical process equipment, maintain pipework integrity and assure production flow. Our specialist deepwater products are engineered to retain their integrity and performance under high pressure, high shear environments and long retention times of the subsea umbilical, safeguarded by our delivery expertise that ensures the precise dose of chemicals is injected at all times. From scale and corrosion management to wax, asphaltene and naphthenate inhibition, we can help you optimize process performance and maintain production—even in the most challenging conditions.

**Maintaining hydrocarbon quality**

Our wide variety of production chemicals and contaminant-removal products and services help maintain optimum hydrocarbon quality. Using tailor-made demulsifiers to swiftly resolve oil-in-water emulsions, we help you achieve excellent dry crude quality and clean water standards required for discharge or re-injection. Combined with our purification solutions fixed bed media and liquid scavengers we remove H₂S, mercury and mercaptans, so that you meet export specifications and maximize gas sales revenues while reducing QHSE risk and protecting asset integrity.

**Maximizing production**

Our decontamination (EXKAL)† and produced water and sand management (PWSM) products and services give you more ways to build in increased production, with purpose-built technology to manage and remove NORM, and tailored chemistry to optimize our PWSM systems—enhancing separation, maximizing throughput and delivering cleaner streams.

**Environmental stewardship**

Offshore environments require specific consideration to the potential impact of applied chemistry, for example, through produced water discharge. Our strength in ecotoxicity testing over 35 years, combined with our strength in produced water and sand process systems, results in a unique offering to assess, manage and deliver excellence in environmental stewardship.

**Increasing offloading efficiency**

Our drag reduction and flow improvers enhance transfer capacity and build in offloading efficiency—shortening loading times and reducing shuttle tanker demurrage to help you increase profitability. Our technologies can also be used to increase flow rates in export pipelines as well as enhance water injection rates to maximize secondary recovery.
Protecting miles of pipelines is a major challenge for oil and gas producers and chemical suppliers.

Land operations
Pipelines from oil and gas fields that transport hydrocarbons and produced water are spread out over thousands of miles across land operations. Comprehensive pipeline monitoring and appropriate treatments are needed to mitigate the risk of catastrophic failures that could affect the environment and the communities that live around these natural resources.

Environmental stewardship
Local, state, and federal agencies require producers to document every drop of liquid and gas that enters their pipelines. Risk mitigation and safety management programs are put in place to ensure adherence to policies, and that the environment and public are protected.

Where you need us, when you need us
M-I SWACO is strategically located worldwide, providing products and services that meet and exceed customers’ expectations for safeguarding production wells and pipelines.

The vast experience gained from treating thousands of wells every day has given M-I SWACO the expertise to solve almost any production issue imaginable.

Corrosion identification, mitigation, spill prevention and risk management are key program offerings in the service portfolio. These services provide a link between producers and environmental agencies, creating a “chain of custody” in analytical data and reporting.

Highly trained technicians equipped with state-of-the-art analytical equipment
M-I SWACO provides fully-trained technicians and state-of-the-art analytical equipment to service and implement mitigation programs in produced water, oil and gas wells and pipelines.

Data collection and reporting
Corrosion testing, biological control testing, and metallurgical analysis form the cornerstones of the mitigation program. These tests provide producers with supporting data for regulatory agencies regarding pipeline permitting and environmental compliance.

Mobile field labs
M-I SWACO has local technical field support for plant/field evaluations, and support of the daily operations for product applications. Our local technical support includes qualified and experienced personnel and fully equipped mobile labs. The mobile lab not only allows for demulsification testing capabilities, but is equipped to perform solids analysis, residuals, chemical compatibility, solvent evaluations, bacteria studies, and several other tests to help ensure data is relevant and of the highest quality. With the increased drilling and fracking in the South Texas Eagle Ford Shale Play, our mobile lab has been instrumental in our ability to design and implement treatment programs that meet and exceed the chemical challenges of today and set the stage for further advancements for tomorrow.
Production challenges – Unconventional

An established approach to unconventional reserves

Beyond “easy oil” today’s focus is on the production of more challenging fluids from difficult environments. Unconventional reserves are becoming a key feature of both maturing and emerging plays.

Bringing unconventional reserves into today’s energy mix

While unconventional hydrocarbons now represent some of the largest remaining sources of oil and gas around the world, the high level of technical complexity and environmental impact involved in their production can threaten the economic viability of projects.

As these developments require significant technical capability to manage and deliver, M-I SWACO has built a team dedicated to managing the flow assurance challenges associated with harsh environments and demanding conditions. We are working with customers to produce reserves such as shale reservoirs, tight gas and oil, and coalbed methane in more cost-effective, more environmentally-acceptable ways.

A common factor in the extraction of these reserves is the need to hydraulically fracture the formations using significant volumes of water—water that must be treated to preserve the quality, transport key additives and prevent the introduction of potentially damaging bacteria. The same water then has to be handled at surface when the well is brought into production.

Challenges with flow-back include:
- Water clarification
- Desalination
- Naturally Occurring Radioactive Materials (NORM)
- Scale control
- Corrosion and integrity management

M-I SWACO provides a full suite of technologies to support these applications. These include chemical additives that enhance flow, mixed oxidant technology to manage bioactivity, as well as coagulant and electrostatic coalescence technology. We also offer unique NORM management and remediation offerings allied to leading expertise in scale and corrosion control technologies and management practice.

Coalbed methane (CBM)

The unique cleated structure and dual gas storage mechanism of coal deposits necessitate specialized technologies for successful production of coalbed methane—an increasing component of global natural gas production. As with other unconventional resources, it is water management—specifically how the water is sourced, treated and disposed or reused—that enables cost-effective productivity and can make or break a project’s economic and regulatory viability.

Eagle Ford Shale, South Texas

Revenues increase thanks to paraffin inhibition

The Situation

Various Eagle Ford Shale wells produce oil containing high concentrations of paraffin that can plug production tubulars and flowlines, as well as creating residues during storage. A treatment program was required to reduce solids deposition during railway car transit.

The Solution

PI-7060® is a comprehensive blend of wax modifiers and dispersants effective across a range of crude oils, including the high-carbon chain paraffins of Eagle Ford Shale. It is formulated to prevent paraffin precipitation and agglomeration.

The Results

Through continuous injection of PI-7060, Eagle Ford Shale operators have maximized their product transport capacity, while reducing the time lost removing paraffin build-up—increasing overall revenues.
Production challenges – Heavy oil

Large reserves of heavy oil, significant investment

Some of the world’s largest reserves are heavy oil reservoirs, with oil in place equal to the largest conventional oilfields in the Middle East.

Heavy oil

While these large reserves are found in more than thirty countries around the globe, relatively few have been developed extensively. The significant operating investment involved requires a high market price to financially justify heavy oil recovery.

Heavy oil recovery challenges

The main challenge in heavy oil is not in finding reserves, but in extracting, recovering, producing, and selling heavy crudes within often changing economic guidelines. Under stable market conditions, heavy oil assets have the potential to generate many years of steady cash flow – typically producing for more than 50 years. However, when the energy ratio needed to produce and upgrade a barrel of heavy oil can be as high as 40%, balancing economics throughout the project is a challenge.

In recent years, M-I SWACO R&D focus has been predominantly dedicated to heavy oil and deepwater practices. We are developing technologies to enable the extraction, separation and transport of heavy oil fractions, while dealing with flow assurance issues such as asphaltenes, napthenates and paraffin deposits.

A number of our patented technologies are now commercialized. They are providing a step change in the cost of managing asphaltenes deposition in North America and the North Sea. They are delivering game-changing wax dispersion performance results during crude production and transportation for operators in the Eagle Ford and Bakken Shale Plays. The unique non- or low-acid napthenate inhibition technologies we pioneered in Asia have been transferred across the globe: most recently in the demanding conditions of offshore Brazil.

Egypt

Demulsifiers reduce backpressure by 80% and ensure crude quality

The Situation

A heavy oil field suffered backpressure at the wellheads due to the highly viscous emulsion being produced. The operator also struggled to attain the specifications required for shipping.

Two types of demulsifier were therefore required: one to reduce wellhead backpressure and a second to enable continuous fine-tuning of the shipping specifications.

The Solution

M-I SWACO selected, tested and prequalified two demulsifiers. EPT-2699† was injected at the wellheads and into downhole casing where ESP efficiency was threatened by heavy emulsion. Meanwhile EB-8956‡ was injected at the inlet line of the central production facility (CPF).

The Results

Backpressure dropped from 400-500 psi to just 80-150 psi. Water content was maintained below 0.5% and salt content below 25 ptb, which meant the crude met agreed shipping specifications.

PTB = Pounds of salt per thousand barrels of oil
High oil prices have made deepwater extraction increasingly viable even in some of the most hostile environments, but although the financial rewards have increased, so have the technical challenges.

Meeting challenges in the Arctic

The Arctic area has among the most sensitive ecosystems in the world, particularly with respect to birds, mammals and marine organisms. Several large marine ecosystems (LMEs) are found in northern areas, including the Arctic Ocean, and cold climates present particular challenges for mitigating the potential impacts of any materials discharged into the environment. Operators and service suppliers can expect very strong regulatory requirements for operating in the Arctic area, and well-implemented policies addressing environmental concerns and ethics will be key to success. Low impact operations, low energy consuming equipment, safe waste handling, and acceptable chemistry are areas where M-I SWACO is a market leader.

Specially developed products and services

Oilfield chemicals must achieve optimum operational performance and should have low impact on the environment. The AURORA† product line from M-I SWACO is a unique portfolio of chemicals and services specifically designed for use in sensitive ecosystems such as the Arctic. These provide confidence that, should chemicals be discharged, they will make the least possible impact on the environment. The AURORA ultra-sensitive, built-for-purpose product line concept has a place in every part of the life of a field and in every activity where M-I SWACO provides support and services, including: drilling, wellbore productivity, production technologies and environmental solutions. From beginning to end, we help to maximize oilfield productivity, improve operational effectiveness and reduce environmental impact.

Under the AURORA product line, M-I SWACO also provides industry-leading engineering and design services that ensure compliance with specific technical and environmental requirements of operations in particularly sensitive ecosystems. Regulations on the use of oilfield chemicals differ to reflect the variation in local ecosystems that need to be protected. Even small disturbances in the fragile Arctic ecosystem can have devastating consequences.
By contrast, with sensitive coral reefs, toxicity may be of a greater concern than biodegradation, and the products must be tailor-made accordingly.

The M-I SWACO product range includes chemicals tailored to work in harsh climates and with demanding geology, while minimizing potential impact on the environment. Our research scientists have found that, in general, the safest solution is to let nature do the job, which is why AURORA products use nature’s own chemicals: either chemicals approved for the food industry or other readily biodegradable, low-toxicity substances. The AURORA concept has been developed with improved quality to cover all the critical environmental challenges, so the products are not only individually best-in-class, but together create a class of their own.
Partial-processing system helping restore blocked production

The Situation
A mature North Sea field had forecast to produce 212,000 bpd with water cut of 85-90%. Due to pressure depletion and well back-pressuring that severely constrained pipeline fluids, production was significantly reduced.

The Solution
M-I SWACO configured a partial-processing package comprising two 50% CYCLOTECH P20 pre-separation hydrocyclone vessels and three 33% CYCLOTECH B20 deoiling hydrocyclone vessels. The processing program also included recommissioning an existing degassing vessel and developing a comprehensive sand management system.

The Results
Once installed, the partial-processing package successfully de-bottlenecked the export pipeline, allowing production to quickly approach expected levels.
Securing hydrocarbon resources from the North Sea, a long-established oil and gas producing area, still presents significant technical, environmental and logistical challenges today.

North Sea

Whether developing new subsea infrastructure, enhancing mature asset production, or enabling the decommissioning of “end-of-life” facilities, M-I SWACO is an experienced partner on hand to help operators overcome their flow assurance challenges.

Production enhancement

Rapid, efficient extraction of dehydrated crude oil from produced emulsions is critical to optimize the quality of export specification crude, and to minimize oil-in-water overboard discharge to the sea. M-I SWACO offers dehydration, demulsifier, and water treatment technologies that significantly reduce the environmental impact of separation solutions, while maximizing the delivery of export-quality product.

An asset’s hydrocarbon production profiles are affected by the properties of the water it produces, whether connate or injected, leading to production chemistry challenges such as scale, corrosion, separation system efficiency and oil-in-water overboard. These issues can significantly reduce process efficiency, production capacity and NPT.

M-I SWACO offers a full suite of topside and subsea approved technologies that directly mitigate scale, corrosion, emulsions, sand production and other associated production risks to deliver a fully optimized hydrocarbon production system.

Production chemical solutions

At M-I SWACO we acknowledge that exceptional production technology performance must be aligned with industry and government best practice, such as: Step Change in Safety, LOGIC and PILOT initiatives, and CRINE (Cost Reduction in the New Era). In addition, complying with environmental legislation without compromising product performance is the biggest challenge affecting innovation in production technology. Dedicated in-house Good Laboratory Practice (GLP)-approved environmental testing and screening facilities in Bergen, Norway contribute greatly to the success of M-I SWACO in delivering environmentally friendly solutions, particularly in the North Sea.

De-bottlenecked existing infrastructure

As the reservoir matures and the production facility ages, there is an increasing likelihood that the performance of water and sand related topside plants will not match operator expectations. Existing equipment can become capacity constrained, obsolete, blocked with sand, eroded by sand, or it might never have performed satisfactorily in the first place.

They all lead to the same problem: they struggle to maintain performance and availability.

In response to these problems, M-I SWACO provides high-efficiency, compact process solutions to significantly expand the operating envelope of existing equipment in terms of both capacity and performance. These are simple and cost-, time-, and space-efficient upgrades which are superior to standard equipment replacement. These technologies allow excess water and sand to be either:

- Pre-separated upstream with a partial processing system to ensure unimpeded flow.
- Processed by the upgraded plant with new internals to handle these increased phase loadings.

Decommissioning

As North Sea infrastructure matures, it is increasingly critical to be prepared for asset decommissioning. Offering industry-leading technology and experience in descaling, decontamination and decommissioning asset infrastructure, M-I SWACO Production Technologies is more than ready to support operators during this challenging phase of the oilfield lifecycle. In 2008, M-I SWACO won the EI International Platinum Award for technology and service associated with decommissioning of a condeep, concrete structure in the UK CNS.
Production chemicals – Overview

Engineering effective and efficient treatments

Corrosion. Emulsion. Scale. Bacteria. Foam. Wax. Hydrogen sulfide. These are just a few of the myriad of potential problems our clients face every day when producing, processing and transporting petroleum products.

Production chemicals overview

Each problem is different, just as there are differences in each field and, very often, in each well. That’s why we are committed to tailoring solutions to meet all of our customers’ unique, changing needs.

The right chemistry, expertly delivered

Armed with highly knowledgeable and talented personnel, a comprehensive product portfolio that is second to none, and an extensive infrastructure, M-I SWACO brings to every job the resources and commitment to engineer innovative and cost-effective solutions. Whether completely altering a particular chemical formulation to tackle a specific need, or making a minor change, the people of M-I SWACO have one mission: create the most effective and economical solution for each situation.

Enhancing process and mechanical systems performance

In a typical topside separation process, chemicals injected at the crude oil inlet will enhance the system performance. Injection of oil process antifoam agent and demulsifier are just two examples of how chemicals will improve the separation of oil, gas and water.

Managing the precise delivery of chemical treatments

M-I SWACO provides AVOCET PROCHEM®, a production chemical data management software system to help predict, identify and prevent production disruptions, to ensure greater production continuity from reservoir to refinery. The service consists of several tools to help reduce and manage the workflow related to chemical applications, injections and production processes. It includes visualizations of asset status and trends, from simple traffic lights to detailed interactive reports.

Engineered to meet operational and local requirements

Know-how is one thing. Making it work for a client is another. Although other companies in our industry can claim chemical experience and personnel expertise, what really makes the difference is how all that know-how is directed toward addressing specific customer needs. That’s precisely what sets us apart from all the others. At M-I SWACO, our highly skilled and motivated personnel are focused on our customers, listening to them and then engineering fully documented and effectively applied solutions.

For more than 30 years, clients from the North Sea to the Far East, Canada to Latin America, and Russia to West Africa have learned that time and time again, M-I SWACO is dedicated to delivering answers quickly, correctly and professionally. Through our parent company Schlumberger, M-I SWACO people can offer our clients access to the world’s most inclusive reservoir expertise. In addition, our far-reaching and efficient supply chain ensures lower product cost, high quality and ready availability.

Our production chemical portfolio includes:

- Cleaning compounds
- Commodities, utilities and cleaners
- Corrosion inhibitors
- Demulsifiers
- Foamers and defoamers
- Hydrate inhibitors
- Microbiocides
- Napthenate inhibitors
- Oxygen and H₂S scavengers
- Paraffin and asphaltene inhibitors
- Scale inhibitors and dissolvers
- Tracer dyes
- Water clarifiers
Production chemicals – Asphaltenes

Stabilizing and dispersing asphaltenes to prevent plugging and related issues

Asphaltenes are defined as solids that precipitate when in excess of n-heptane or n-pentane.

Chemically, asphaltenes are high-molecular-weight, polynuclear, aromatic polar compounds containing carbon, hydrogen, oxygen, nitrogen, sulfur, and may also contain heavy metals such as vanadium and nickel.

Asphaltenes are soluble in crude oil at reservoir temperatures and pressure conditions. Physical and chemical factors contribute to destabilization of asphaltenes, leading to precipitation and possible flocculation of asphaltenes as the peptide layer is stripped (resins, e.g. maltenes) as a result of loss of aromaticity and increased linear alkane content.

Factors responsible for asphaltene destabilization include:
- Depressurization
- Miscible flooding with CO₂ or natural gas
- Acidization
- Mixing fluids with different densities
- Gas lift

Asphaltenes can deposit in reservoirs, wellbore tubing, flowlines, separators, and other parts of hydrocarbon production systems. These deposits can interrupt and potentially stop production due to the formation of plugs. Other operational issues related to the precipitation of asphaltenes include stable crude oil emulsions, higher emulsion viscosity, and migration of asphaltenes into water phase leading to produced water treatment issues.

Treatment options

A range of mechanical and chemical options is available to treat asphaltene deposition issues. Mechanical cleaning methods include pigging, wireline cutting and coil tubing options, while chemical treatments include the injection of inhibitors, dispersants or solvents.

Asphaltene solvents usually include aromatics or aromatics-based blends, especially those containing bi- and tri-cyclic aromatics and reduced biphenyl content. The solvents work well with pigging and dissolve the asphaltene deposits.

Asphaltene inhibitors are polymeric compounds that stabilize the micelles and prevent the asphaltenes from flocculating.

The inhibitors have very similar properties to those of the resins and interact with the asphaltenes to stabilize the asphaltene micelles in the crude oil. The asphaltene inhibitors possess stronger association with the asphaltenes and are able to stabilize the asphaltenes through greater changes in pressure, temperature, shear and chemical environment. Asphaltene inhibitors can be squeezed into the formation or continuously injected downhole. Squeezing the inhibitor into the reservoir can prevent deposition of asphaltenes in the near-wellbore area.

It is important that the inhibitors are added to the crude oil before the asphaltenes become destabilized and flocculation occurs.

Asphaltene dispersants do not prevent precipitation, but maintain precipitated asphaltene in a dispersed state to prevent flocculation. The advantages of using asphaltene treatment chemicals include:
- Reduction in deposition of solids which helps to maintain production.
- Reduction in equipment plugging leading to reduced NPT.
- Reduction in produced water treatment problems leading to reduced oil-in-water carryover, which in turn results in environmentally safe water disposal.
- Lower pumping pressures due to reduced viscosities.

MI-SWACO provides expertise in designing treatments to meet an operator’s particular asphaltene challenges. Based on specific field information about the issues, laboratory tests are designed and performed to evaluate potential solutions that will deliver the desired results. Factors considered include cost-effectiveness, environmental impact and safety issues.

Product performance can be monitored in the field using various instrumental and chemical assay methods.
Adhi, Pakistan

Mitigating deposits helps filters last up to 45 times longer

The Situation
A major gas condensate field operator began to experience solids deposition—primarily wax and asphaltene—within flowlines and other equipment. Frequent maintenance and cleaning operations became necessary, with production shut down or diverted while hourly filter changes were performed.

The Solution
Following comprehensive sampling and a field trial at actual conditions, PI-7269 low-dose asphaltene inhibitor was selected and injected at the inlet separator and upstream filter.

The Results
Field data verified the lab results: deposits in the pipeline and other equipment were significantly reduced, while smooth flow was assured. As a result, production of LPG/NGL was optimized. Filter-change frequency was also reduced from hourly to once every 2 days.
Commodities, utilities and cleaners can be as essential to operations as critical applications such as hydrate control, corrosion inhibition and oil-water separation.

Commodities, utilities and cleaners

Commodities—by definition—are products supplied under a generic name, such as MEG, methanol, and ammonium bisulphite. Utilities are those products applied during the general maintenance operations of a facility, such as heat exchanger treatment, re-boiler management, and steam generation. As the term suggests, cleaners ensure each facility remains in a good state and provides a safe working environment. All of these components are vital in maintaining the continuity of production and ongoing operations.

One primary factor in managing the provision of these materials is sourcing a secure supply at the best price. It also demands systems and procedures to manage container and tank fleets, and to ensure that quality and delivery standards are maintained at the highest levels.

MEG regeneration systems are increasingly being installed to manage hydrates where major volumes are required for first-fill applications. These large-scale jobs often require blending to meet key system specifications including water content, admix, pH and viscosity.

M-I SWACO understands these markets and has the global infrastructure to ensure operational excellence in this domain. We have delivered several major first-fill projects utilizing sea bulk, quayside storage and blending, followed by controlled release to site, as required.

Historically, these operations would have involved excessive road transport and demurrage, adding project risk and complexity.

Selecting the right cleaner

While many factors contribute to the positive result of a cleaning operation, the following represent the most important characteristics:

- **Temperature**—a higher temperature always gives a better cleaning result.
- **Solubility-Dispersibility**—if the dirt is soluble or easily dispersible in the cleaning medium, the cleaning effect is greatly enhanced.
- **Mechanical treatment**—scrubbing, high-pressure spraying.
- **Soak time**—also an important factor for good cleaning.

Solvent-based cleaning compounds

Solvent products should be used when the dirt is mainly organic and particularly when temperature cannot be increased to soften the ‘foulant’. They also have advantages when the dirt is mainly composed of water-soluble or dispersible materials and is coated with or “glued” together by hard hydrocarbon substance. Usually a high-aromatic solvent will provide the best cleaning results, but cost, health and environmental concerns may be prohibitive. Alternatives are white spirit-type solvents, low-aromatic naphthas, kerosene or diesel. While these options are less toxic to people and the environment and lower in price, they generally offer reduced effectiveness.

If a basic product consists of a surfactant concentrate diluted with hydrocarbon solvent, care must be taken to apply the correct proportions of concentrate and solvent.

This is because individual products are specifically designed to perform optimally in combination either with high, medium or low-aromatic solvents.

A cleaning compound can also be designed to give either a stable or a self-separating (quick-break) emulsion upon flushing with water.

Aqueous cleaning compounds

Aqueous cleaning compounds have definite advantages over solvent-based products in terms of both handling properties and price. They can also be made more environmentally acceptable, but are not necessarily as efficient. Aqueous products can be used in almost all cases and particularly for solid-particle dirt. They are not particularly suitable for the removal of hard, mechanically-resistant organic dirt when the temperature cannot be raised to soften it. Smaller amounts of organic solvents can be included in aqueous products to increase solvent properties, but aqueous cleaning compounds act by dispersing the dirt into the aqueous phase.

Chemical cleaning

There are six chemical cleaning techniques used by M-I SWACO to accompany our range of solvent-based and aqueous cleaning compounds:

- Fill and soak
- Circulation
- Cascade
- Online cleaning
- Foam cleaning
- Vapor-phase cleaning
Removing corrosion threats to asset integrity

Commonly found in produced fluids, acidic gases such as CO₂ and H₂S are corrosive towards carbon steel tubing, vessels and pipelines. In addition, organic acids can also corrode carbon steel, as can produced solids and bacteria.

Corrosion inhibitors

Corrosion generally takes place where water and corrosive chemicals are present, with the rate affected by variables including CO₂ and H₂S content, temperature, pH, water cut, salinity, pressure, solids levels, and also liquid and gas velocity. To mitigate carbon steel corrosion, corrosion inhibitors, H₂S scavengers, and biocides are applied.

In seawater injection systems, corrosion can also occur due to the presence of oxygen in the injected water. However, the oxygen can be removed from the sea water fairly easily using a combination of chemical or mechanical methods. Chemical oxygen scavengers are used to remove the oxygen, normally applied in conjunction with de-aeration towers. Bacterial corrosion in seawater injection systems is also common, but can be mitigated by the regular application of biocides and/or management of nutrient control to shift the consortia from sulfate-reducing to nitrate-reducing species.

Forms of corrosion

Corrosion can manifest itself in many forms that can result in failures. The most common forms of corrosion can be categorized within seven types:

- Localized pitting corrosion
- Galvanic corrosion
- Under-deposit corrosion
- Stress corrosion
- Erosion corrosion
- Corrosion fatigue
- Uniform corrosion

Impacts of corrosion

The failure to control corrosion rates can have catastrophic consequences, such as equipment failure, which can result in environmentally-damaging leaks. Extensive repair and maintenance operations often require expensive system shutdowns and consequent loss of production. There are also safety implications of failing to control corrosion with the potential to harm personnel.

Corrosion inhibitor options

A corrosion inhibitor is a chemical which, when added in small amounts to a corrosive environment, decreases the rate of corrosion of a metal in that environment. Corrosion inhibitors can be divided into four groups:

- Inorganic anodic inhibitors mitigate corrosion by disrupting or blocking electrochemical reactions at the anodic sites on a metal surface. Commonly used to control corrosion in cooling tower water, heating/cooling mediums, and glycol dehydration, they are not recommended to control corrosion due to CO₂ or H₂S, or in seawater injection systems.

- Inorganic cathodic inhibitors function by forming a protective film at the cathodic sites that polarizes the metal by restricting access by dissolved oxygen to the metal surface. Used with the same applications and restrictions as anodic inhibitors, this group is regarded as less effective.

- Neutralizing/volatile inhibitors are suitable where the aqueous phase is condensed water, and are particularly effective where the main cause of corrosion is CO₂. Increasing system pH reduces corrosion and forms a protective FeCO₃ film on metal surfaces.

- Organic inhibitors work by forming a protective film over the entire metal surface and address corrosion due to CO₂, H₂S and organic acid. They are not effective in preventing corrosion due to oxygen.

In addition to the four inhibitor categories, scavengers can also be used to remove H₂S from oil and gas systems and oxygen from seawater injection systems.
Corrosion inhibitor applications
Corrosion inhibitors can be applied anywhere in a production system: downhole, at the wellhead, production manifold, gathering lines, gas or oil export pipelines, and also in produced water re-injection systems. Corrosion inhibitors are normally applied either continuously or via batch treatment.

For batch treatments in wells, an inhibitor is typically diluted in a carrier solvent (e.g. diesel or condensate) and pumped down the well or pipeline. Batch treatments typically last up to three months. In pipelines, the diluted inhibitor is placed between two pigs. The production fluids are then used to force the pigs and inhibitor solution along the pipeline.

Batch treatments are typically used in systems where continuous injection is not possible or practical, such as in certain oilfield operations. The use of batch treatments allows for the periodic release of inhibitors to maintain a consistent level of protection against corrosion.

Corrosion inhibitor range
M-I SWACO offers an extremely comprehensive portfolio of corrosion inhibitors suitable for application to address a wide range of corrosion challenges including:

- Oxygen corrosion
- Sweet (CO₂) corrosion
- Sour (H₂S) corrosion
- Organic acids corrosion
- Under-deposit corrosion
- Galvanic corrosion
- Erosion corrosion

The corrosion inhibitor product range consists of the following types of products:

- CO₂ corrosion inhibitors
- H₂S corrosion inhibitors
- Hydrotest products
- Cooling water corrosion inhibitors
- Environmentally-acceptable corrosion inhibitors
- Batch corrosion inhibitors
- High-temperature corrosion inhibitors
- Gas corrosion inhibitors
- Multifunctional products (combined scale/corrosion inhibitors)
- Oxygen scavengers
- H₂S scavengers
- Oil/gas pipeline inhibitors
- Subsea/deepwater corrosion inhibitors

Inhibitor treatment considerations
Before deploying an organic corrosion inhibitor, a number of factors need to be considered. Firstly, the method of inhibitor application itself, which depends on several parameters including system conditions, injection location, and the availability of chemical injection equipment.

Solubility is also a consideration. Inhibitors are generally classified as being oil-soluble, water-soluble, or oil-soluble/water-dispersible. Their emulsification and foaming tendencies at the required dose rate are essential properties that must be taken into account, and must be assessed to ensure product stability under typical storage temperatures for prolonged periods, and at injection temperature.

The compatibility of corrosion inhibitors with the metallurgy of the chemical injection system needs to be assessed, as does their compatibility with other production chemicals in the system. Conversely, checks should be performed to ensure that other chemicals present do not affect corrosion inhibitor performance.
Destabilizing foam-related issues

During the complex process of oil and gas production, depressurization of the mixture of hydrocarbons can easily lead to the formation of stable foam. Foams can be found throughout the process, ranging from production separators, through gas dehydration or sweetening processes, and when processing water for injection. Foam can have dire consequences when carryover of liquid occurs in the associated gas stream and when liquid hydrocarbon carryover contaminates dehydration or amine units.

Defoamers

The presence of gas dissolved in the crude oil, especially when viscosity is high, can initially produce a gas dispersion or spherical foam upon depressurization. This can occur in the tubing or separation system. As the bubbles rise through the liquid and come to the surface, they can produce conventional polyhedral foam. Under these conditions, a chemical defoamer is required to perform a dual function: to accelerate the ascent of the gas bubbles and to counteract the formation of the stable polyhedral foam.

The severity of the foam in the production system is dependent on several factors:

- Oil production rate and associated gas
- Pressure and temperature
- Chemical composition of the produced fluids
- System design
- Other chemicals used in the process such as corrosion inhibitors or contaminants such as fines, scales or corrosion by-products.

Defoamer operation

Production systems can be optimized with respect to oil production rate and pressure to reduce the risk of foaming, but this might not be enough—or may impose unacceptable constraints on production—in which case defoamers might be necessary for constant, smooth operation. Defoamers can be highly cost-effective and can work at injection rates of just a few ppm. They act in one of two ways: either by displacing stabilizers from the bubble wall, or by locally rupturing them. Displacement of foam stabilizers occurs after a thin defoamer layer is spread over the bubble surface. Bursting occurs when a defoamer, with a lower surface tension than the oil, causes localized surface-tension depression.

Chemical evaluation

M-I SWACO can provide tailored defoaming solutions to meet specific operational needs. It is important to use live or specially reconstituted crude in experimental testing to ensure similar surface tension effects, as ‘dead’ crude may have a falsely high surface tension. Another significant factor is the temperature and thermal history, both of which must be replicated in laboratory tests.

Tailored defoamer solutions

M-I SWACO offers a range of generic defoamer types for various oilfield applications. Silicones are the most commonly applied in crude oil, glycol units, and water injection systems with non-silicone products available for amine gas treatment units, glycol units for dehydration, and water injection systems where silicone defoamers may be less popular.

Mechanical systems

M-I SWACO can supply a mechanical auger designed to remove up to 80% of the free gas from the wellstream prior to the separator. By preventing the initial formation of foam, an auger has the potential to eliminate the need for a defoamer altogether.
Breaking emulsions to optimize performance

Demulsifier formulations are used to help ensure the residual water and salt content in the crude, and oil-in-water content of the separated water, meet required specifications. The purpose of a demulsifier is to destabilize an emulsion and facilitate separation into oil, water, and also solids.

**Demulsifiers**

To do this, the demulsifier must disrupt the ordered structure of the natural surfactants that stabilize the emulsion, allowing the dispersed droplets to coalesce as they collide to form a larger droplet size. The droplets then move to the oil/water interface by gravity. The important criteria is the demulsifier’s ability to penetrate the emulsifying monolayers to displace the natural surfactant(s) or insoluble(s) that stabilize the emulsion, and allow the film around the droplets to rupture, thus creating the conditions for the emulsion to resolve.

**Tailored solutions**

Each individual hydrocarbon region produces fluids with different characteristics, ranging from light to heavy, paraffinic to asphaltic, sweet to sour, and from high to low total acid number (TAN). Natural gas, water, and solids such as sand and scale are produced alongside crude—each contributing to the characteristics and stability of the emulsions produced.

The diversity of fluids and applications means that effective demulsifiers are almost always field-specific.

**Demulsifier bases**

In the formulation of a demulsifier it is rare that single-component chemistry is effective. The following comments are generally directed toward emulsions containing water dispersed in a continuous oil phase:

- **Solvents** play a key role, keeping intermediates and active ingredients in solution and helping deliver them to the emulsion interface. They also help make crude components such as paraffins more soluble.
- **Alcohols** can stabilize a demulsifier where individual components might otherwise separate, and can be used to “winterize” them for cold-climate application. Certain solvents are restricted by environmental legislation or flammable handling concerns.
- **Flocculants** are characterized by non-ionic surfactants that congregate droplets so that they combine when in close proximity.
- **Coalescers** effectively disrupt the stabilized film by causing water droplets to combine on collision.
- **Water droppers** cause coalescing droplets to combine rapidly, forming a continuous phase. They are critical for short residence systems such as offshore applications where weight and space are at a premium.
- **Wetting agents** alter the interfacial tension of fluids so that solids can move into the water phase. These solids include sands, clays, scales, napthenates and carboxylates, bitumens, and other insolubles that collect at the interface.

In the selection of a demulsifier for a particular crude-producing facility, a number of factors must be considered. Factors such as fluid residence times, injection points and temperature all have a role to play.

When recommending a demulsifier, M-I SWACO also investigates application-wide factors including location, nature of the oil, environment, and limitations of the equipment and facilities. Each item is thoroughly evaluated so the facility can operate with minimum disruption and lowest cost.

**North Sea, UK**

**Water quality increased while dosage halved**

**The Situation**

A major operator experienced issues with the produced water quality going overboard from two adjoining platforms while injecting demulsifier. They also required greater onboard emulsion resolution and separation.

**The Solution**

EB-8035 is an emulsion breaker formulated to break water-in-oil emulsions and deliver clean produced water. Supplied for field trial, it does this while leaving minimal residual emulsion in process separation systems.

**The Results**

Demulsifier volumes were reduced by ~ 50%. Water-in-oil results were also significantly improved, averaging 5-15ppm overboard while maintaining zero emulsion at the export pumps. Post-shutdown separator upsets were also handled without water quality reductions. Ongoing data shows oil in water remains at acceptable levels today with no residual emulsion build-up in the separators or carryover to the export pumps.
Modifying fluid properties to prevent hydrate formation

Historically, the formation of gas hydrates in subsea tubulars, production pipelines and process equipment has presented costly problems, especially in deepwater developments and in Arctic regions.

Hydrate Inhibitors

Operators have used a number of preventative methods, including insulation and heating to keep produced fluids hot enough to avoid hydrate formation. Methanol and glycol treatments are commonly used and, while they are effective in many cases, both present drawbacks.

M-I SWACO offers low-dosage hydrate inhibitors as an alternative, technically reliable and economically attractive solution to meet industry demand for more cost-effective and environmentally-acceptable methods of hydrate inhibition.

Understanding hydrate formation

Gas hydrates are mixed solids formed by water and natural gas. Whether a hydrate will form or not is a function of a number of parameters including temperature, pressure, gas composition and the presence of water.

Hydrates can plug flowlines, pipelines and process equipment. Once formed, the hydrate plugs are relatively stable and require a large input of energy over an extended time period to remove them. Plug removal can cause safety issues such as potential pipeline rupture. Hydrates can form at temperatures above that at which ice would be expected and formation at 20°C (68°F) is not unusual. They can easily form at North Sea and deepwater Gulf of Mexico seabed temperatures, plugging pipelines as large as 40 in. diameter. The critical factors for most pipeline operators is pressure and temperature. The occurrence of hydrates is most marked where pipelines are routed along the seabed over considerable distances, allowing the contents to cool.

Low-dosage solutions

As the offshore industry moves into the development of marginal fields in more hostile environments and both deep and ultra-deep waters, M-I SWACO has responded with a new class of treatment chemicals known as low-dosage hydrate inhibitors (LDHIs). LDHI threshold inhibitors interfere with the mechanism of hydrate formation and have two basic modes of action:

- **Kinetic inhibitors** interfere with hydrate crystal growth or nucleation by embedding themselves into the lattice structure, delaying significant growth for longer than the fluid’s residence time.
- **Anti-agglomerants** prevent the agglomeration of hydrate crystals into large masses by dispersing water droplets within the condensate or oil phase.

CO₂ hydrate formation from dissolved gas (i.e. no free-gas phase) under high degree of sub-cooling

Hydrates formed from dissolved gas (Cl-CO₂ system)
In comparison to methanol and MEG-based treatments, the low-toxicity characteristics and smaller treatment levels of LDHIs make them more environmentally desirable over the long-term. Because no recovery stage is required, leakage risks from storage, treatment and transport facilities are reduced.

**Tailored solutions**

The optimal choice of inhibitor is determined by fluid and field characteristics. M-I SWACO provides detailed support to its customers for LDHI applications. System conditions are modeled using an industry-standard phase-equilibrium program. Advanced equipment is used for testing LDHIs at field conditions of pressure, temperature and cooling rate to select the most appropriate treatment. Technical support includes consideration of product physical properties and compatibility with contacted materials.

G = Gas  
L = Aqueous Phase  
H = Hydrate  
Gr = Grain

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**Alberta, Canada**

**KHI reduces operating costs by 50%**

**The Situation**

A gas pipeline transports around 2,430 m³/d of gas to a remote amine plant across difficult terrain. Produced water is introduced into the pipeline, mainly after a compressor station. To prevent hydrates forming, the line is treated with 4,000 L of methanol, yet this is carried into the amine plant, contaminating the reflux water and increasing corrosion risks.

**The Solution**

M-I SWACO introduced a hydrate inhibitor program using the kinetic hydrate inhibitor (KHI) GT-7569. The KHI was initially applied at 1,500 liters per day, approximately 40% of the methanol injection volume. Pig-returns and inlet pipeline pressures were then monitored for hydrate formation indicators.

**The Results**

Injection rates were reduced in incremental stages before being optimized at just 700 liters per day, without hydrate formation. Analysis of reflux water showed no contamination. KHI application saved the operator over 50% in chemical and operational costs.

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Methane hydrates formed in the vapor and gas/water interface
The production of hydrogen sulfide (H₂S) gas along with petroleum fluids is a common occurrence in many areas of the world. Other sulfides that can be present include sodium hydro-sulfide, sodium sulfide, and various lower mercaptans and disulfides.

Hydrogen sulfide

Hydrogen sulfide is corrosive even at low levels and has a toxicity level similar to that of hydrogen cyanide. The occupational exposure limit is set at 10 ppm, and exposure to concentrations above 150 ppm could be fatal. Gas pipeline requirements often specify the maximum permitted levels of H₂S, typically less than 5 ppm.

Corrosion due to hydrogen sulfide can take the form of hydrogen blistering, pitting, cracking and embrittlement (when in contact with high-strength stressed steel). These types of corrosive attacks can lead to catastrophic failures, which may occur without the warnings that might accompany other types of corrosion. Additionally, hydrogen sulfide can form insoluble salts with many different types of metal ions that might be present in the produced water, causing fouling, filter blocking and injection-well damage.

Hydrogen sulfide can be a natural component of some petroleum reservoirs, or it may arise from bacterial reduction of sulfur compounds in the water. Most produced water that contains hydrogen sulfide is disposed at, or near to, the production site, so safety and corrosion concerns must be considered in these systems.

Sulfide generated by bacteria may form at relatively low levels in water, but when liberated and concentrated in the vapor phase, it has been seen to reach levels in excess of 2,000 ppm.

Forms of hydrogen sulfide

Sulfide can exist in water solution in three different forms:

- H₂S, the molecular form of the compound, is soluble in water and oil, but, due to its volatility, may be concentrated in the vapor phase in most systems.
- HS⁻, the hydrosulfide ion, is the result of partial ionization of H₂S as the pH of water is increased. This ion can exist in equilibrium concentrations with H₂S over the approximate pH range of 5 to 9.
- S, the sulfide ion, predominates at very high levels of pH.

Hydrogen sulfide scavengers

M-I SWACO offers a range of sulfide scavengers based on reaction products of amines and aldehydes. These products have been developed for application in gas, water and oil streams, and they react rapidly with sulfide to form tightly-bound organosulfur compounds. They may be applied as a solution in bubble towers for gas treating, or atomized directly into the gas streams. When used in water systems, rapid sulfide removal is possible and, in many cases, insoluble metallic salts of sulfides can be re-dissolved with these products. The products designed for water and gas application form water-soluble, low-toxicity, biodegradable compounds which are non-corrosive and which will not release hydrogen sulfide—even over extremes of pH variation.

Haynesville Shale, North Louisiana

H₂S scavenger also inhibits corrosion and scale

The Situation

A pipeline company’s produced gas averaged 13 ppm of H₂S within a range of 4-30 ppm. A multi-function chemical treatment program was required to scavenge H₂S, reduce pipeline corrosion and inhibit scale deposition. The Solution was to be applied to two fields, each with several wells and a total of six sales points.

The Solution

HR-2636: a unique combination of a triazine H₂S scavenger, a mixed amine corrosion package and a phosphonate scale inhibitor. For high efficiency and maximum gas contact the atomized product was continuously injected into the pipeline.

The Results

Calcium and barium scale were effectively controlled, and average corrosion rate was 0.15 mm/yr. H₂S content was reduced to a maximum of 2 ppm.
Hydrogen sulfide scavengers

Purification Solutions technology from M-I SWACO provides the world’s top-rated fixed-bed H₂S scavenger used in the oil and gas industry today. Please see page 44 for the full range of Purification Solutions provided by M-I SWACO.

A non-hazardous granular material removes H₂S from natural gas streams via a lead-lag-process. Unlike nearly all other scavengers that are liquids, SULFATREAT™ is solid, thereby preventing foaming or carryover. Its reactions are predictable and reliable under a wide range of conditions.

Monitoring and management

The level of H₂S and other sulfur compounds will normally be a part of the export specification for hydrocarbon gases and liquids, and monitored either online or very regularly by operational personnel. The inlet level of H₂S and other sulfur compounds should also be monitored online or on a very regular basis, typically at least once per day. For most systems, the level of H₂S and other sulfur compounds should be measured for individual wells, and this related to individual flow rates to obtain a mass balance on the contribution of H₂S from the various sources. Once the scavenger system is operational and optimized, management will require regular field checks to ensure that further optimization is not required.

Direct injection scavengers

The most common application for H₂S scavengers is direct injection into a wet gas stream, frequently at the outlet to the three-phase separation train. It is normal for the largest proportion of the H₂S to be removed at the high-pressure separator. In most cases, the water present in the wet gas stream from the three-phase separators will be solely condensed water. Where some produced or formation water is present, significant carbonate scale problems should be expected.

Products destined for use in oil systems can be pumped directly into the stream. They are completely soluble and yield soluble, biologically-friendly reaction by-products. In all cases, the reaction by-products are complex organic molecules containing sulfur, nitrogen and carbon. Direct injection scavengers can be very cost-effective in applications where the total mass of H₂S to be treated is comparatively low and where offshore space limitations restrict equipment size.
Wherever water is present there will always be the threat of bacterial activity. Left unmanaged, bacterial colonies grow logarithmically, seriously impacting water injection and production processes.

**Microbiocides**

The best approach is to have an effective preventative program in place from day one—controlling potential activity that may otherwise result in slime formation, microbial influenced corrosion (including pitting/under deposit corrosion), injectivity index impairment, reservoir souring (where seawater is used as the secondary recovery mechanism) and formation of pyrophoric scale within the production train due to the presence of H₂S.

Microbiocides fall into three fundamental categories: those that penetrate the cell and denature the protein (e.g. aldehydes), those that coat the membrane and block the passage of nutrients across the cell wall (e.g. cationic surfactants), and those that lyse the cell wall (e.g. oxidizing biocides).

Microbiocides can be broken down further into two main sub-categories: inorganic and organic. Inorganic microbiocides are cost-effective disinfectants used in all types of industrial systems, while organic microbiocides are a less corrosive option and can be used in combination with inorganic alternatives, or as the sole treatment.

**Microbiocide selection**

When selecting chemistries suitable for industrial application, several factors must be assessed:

- Mammalian and marine and/or freshwater toxicity
- Ease of handling
- Ratio of solubility in oil and water
- Compatibility with construction materials and other process additives
- Ability and requirement to penetrate biofilms and/or solid deposits within the system.
- Economy of use

Compatibility is particularly important since many bactericides that demonstrate good performance in distilled or soft water, for example, can become ineffective in saline or hard water, even at high concentrations.

**Managing consortia**

To prevent water injection system souring the bacterial colony can be shifted from sulphate-reducing bacteria (SRB) to nitrogen-reducing bacteria (NRB); a practise that is increasingly being adopted across the industry.

M-I SWACO was one of the companies that pioneered this energy-efficient approach, and today manage systems from the Americas to the North Sea, from West Africa to Asia, and Russia to as far as Sakhalin Island.

**Microbiocide products**

M-I SWACO provides a range of specialty chemicals designed to control a broad spectrum of anaerobic and aerobic bacteria, particularly sulfate-reducing bacteria for water injection, produced-water, and cooling-water systems. These products are effective both by their microbiocidal activity and by chemically modifying the environment to prevent harmful bacterial activity.

Typical oilfield applications include water injection systems, process systems, fuel systems, stagnant water masses, and potable water systems. The products are supported in application through monitoring programs, including installation of devices such as Robbins side-stream equipment to develop sessile biofilm colonies on retrievable studs.
Reducing naphthenate and carboxylate formation to protect continuity and quality

Naturally occurring naphthenic acids in crude oil present significant flow assurance challenges during the production and refining process.

The term naphthenic acid is broadly used for all carboxylic acids and includes straight chain fatty acids as well as high-molecular-weight carboxylic acids containing one or more naphthenic rings.

Naphthenates

Naphthenic acids are considered as weak acids and remain soluble in crude oil. As the crude is depressurized, pH changes occur simultaneously, and above pH 5.0 the naphthenic acids start dissociating. In this process these acids react with cations in water such as Ca, Fe, Mg, and Na to form a soap complex.

There are two types of naphthenate soaps/complexes that deserve important consideration from a flow assurance perspective: the metal carboxylate soap emulsions formed by reaction of monocarboxylic naphthenic acids with metal cations, and calcium naphthenate hard scales formed as a result of reaction between high-molecular-weight polycarboxylic acids with calcium.

Flow assurance challenges include:

- Loss of revenue due to higher proportion of dissolved salts in crude oil, which reduces its sale value.
- Accumulation of the carboxylic soap at the oil/water interface, impacting separator level control.
- Hard solid deposits which can reduce vessel residence times and result in interface pad formation, loss of level control and even total production shutdown and consequent loss of revenue.
- Partitioning of naphthenate soaps into the water phase may cause oil in water to exceed discharge regulations.

Treatment options

Mechanical options to clean the deposits are limited and depend on the type of naphthenate formed. Heat does not dissolve the soaps and in certain instances has been demonstrated to make it worse. Chemical treatment options include use of acid demulsifiers, as well as naphthenate inhibitors that are non-acidic in nature.

Organic acids are commonly used for treatment of naphthenate soaps. The acids suppress water pH and prevent the dissociation of naphthenic acids to reduce the naphthenate soap formation. Acetic acid and phosphoric acids are often used, and several other acids have also been evaluated. One of the drawbacks of acid treatment is that large volumes of acids are needed to suppress pH. There are also health, safety and environmental considerations related to the handling of these acids.

Non-acid surfactants have been used successfully when added early in the system. Use of these products may also significantly reduce the requirement for organic acids. These non-acid naphthenate inhibitors can be injected at much lower dose rates compared to acids, and pose less health and safety risks.

The effectiveness of particular naphthenate inhibitors varies greatly from field to field, and the choice of solvent and surfactants needs to be appropriate for specific conditions. M-I SWACO provides recommendations based on its worldwide expertise in naphthenate treatment. Factors that must be considered include field pressure and temperature, and fluid characteristics.

Laboratory test methodologies are designed based on the proposed type of naphthenate treatment able to meet the desired results and field monitoring techniques. Economics, effectiveness, environmental and safety issues are also considered.

M-I SWACO has developed patented technology covering application methodology and high performance non-acid chemistry.
Safeguarding system uptime by controlling paraffin deposition

Petroleum fluids are unique, complex hydrocarbon mixtures containing linear chains from C1 to C100+, asphaltenes, fatty acids, resins and other organic and inorganic elements.

Higher-molecular-weight components begin to precipitate as solids and/or increase the gellation and pour point properties of the fluid.

**Paraffin inhibitors**

The paraffins, also referred to as waxes, can crystallize and cause operational problems throughout the production and transport system as they can solidify in the bulk oil as discrete particles or crystals, and condense onto cooled surfaces such as pipe walls and tubulars. The vast majority of waxes will crystallize in bulk oil, impacting its low temperature flow behavior and potentially resulting in pumping and restart difficulties. Another issue, especially for subsea flowlines, is the build-up of solid waxy layers on pipe walls.

Once system temperatures fall below the cloud-point, wax has the potential to deposit and will require some form of control and removal.

**Paraffin treatment and removal**

Paraffin treatments prevent or inhibit the formation of waxes through the use of dispersants and crystal modifiers. Paraffin removal utilizes mechanical, thermal and chemical means to physically treat waxes after their formation.

Single or combined treatments may use one or more of the following types of paraffin control products:

- **Paraffin solvents** to remove existing deposits and enhance crude solvency.
- **Paraffin dispersants** to assist removal of existing deposits and prevent deposition.
- **Paraffin inhibitors/crystal modifiers** to inhibit paraffin crystallization and deposition.
- **PPD** to reduce the native crude pour-point, viscosity profile and gel characteristics.

Paraffin inhibitors are one of the most widely-used chemical mitigation techniques in treating deposition issues. Acting as crystal modifiers, they are incorporated onto the face of a growing paraffin crystal, interrupting its structure, changing its formation rate and thereby reducing the formation of three-dimensional networks. The paraffin inhibitor must have sufficient compatibility with the host crystal to adsorb onto the surface to disrupt subsequent crystal growth.

Paraffin dispersants are used where crystal modification is not possible due to the presence of extremely-high-molecular-weight paraffins. Dispersants coat the paraffin crystal and metal surfaces, causing paraffin crystals to repel each other and the metal surfaces. This approach to paraffin control does not prevent the growth of crystals, but stops them agglomerating to form a solid deposit and keeps them transported within the crude.

Advantages of using paraffin treatment chemicals include:

- Reduction in crude oil viscosity
- Reduction in heating demands resulting in energy savings.
- Maintained fluid flow through the pipeline.
- Reduction in solids build-up
- Mitigation of lost production

When designing chemical treatments to address an operator’s specific paraffin challenges, M-I SWACO starts with gathering field information about the particular issues then designs and implements appropriate laboratory tests. Factors considered in recommending solutions include: economics and effectiveness, environmental and safety issues, storage issues, and physical specifications such as viscosity and flash point. Based on these considerations, paraffin control products are designed by combining the inhibitors and solvents. Surfactants can then be added to the formulation based on the nature of problem.
Central North Sea

**Wax deposition prevented for more than five years**

**The Situation**
The multiphase flowlines of an offshore field were at risk of wax deposition. Due to the environmentally sensitive area, an inhibitor was needed that combined high performance with low environmental impact, and remained effective within flowlines between 8-12” diameter and up to 32 km long.

**The Solution**
Following laboratory testing and field optimization, PI-7258 was applied continuously into the multiphase production lines at dose rates of 50-500 ppm, depending on conditions.

**The Results**
PI-7258 has successfully mitigated wax deposition for more than five years. It has also been batch injected on shutdown/startup and pigging operations. Improved demulsification has also resulted from the effective long-term prevention of wax formation.
As temperature, pressure, and water chemistry vary through the life of the field, an effective scale management plan is essential. The design should reflect the current status while establishing contingencies to cover forecast and unpredicted events. M-I SWACO conducts more scale-squeeze treatments in the North Sea than any other provider.

**Scale inhibitors**

M-I SWACO has designed an effective scale management strategy that considers:

- Prediction of scale formation and location.
- Evaluation of the various potential inhibitor chemicals.
- Deployment techniques for long-term effectiveness.
- Alternative options for scale removal

**Tailored solutions**

Our all-inclusive portfolio of environmentally-acceptable scale inhibitors and treatment methods is the result of one of the industry’s most extensive laboratory evaluation programs. Products selected from our pre-screening process undergo laboratory evaluation based on a customer’s criteria for deploying chemical treatments. Our technical service scale laboratories have the expertise and tools to carry out all the tests required for qualifying a suitable product package including:

- Static pre-screening for compatibility, efficiency and adsorption
- Dynamic tube-blocking tests at high-temperature, high-pressure (HTHP) and low-temperature, low-pressure (LTLP) for determination of injection dosage or minimum inhibitor (i.e. threshold) concentration.
- Pre-emptive squeezing of reservoirs using non-aqueous base scale inhibitors.
- Tagged and end-capped polymeric scale inhibitors.

**Environmental compliance**

M-I SWACO ecotoxicological laboratories in Norway and the US are good laboratory practice (GLP) compliant to ensure that proposed products comply with each country’s environmental requirements.

Ecotoxicological tests performed include biodegradation (OECD 306), bioaccumulation (OECD 117, 107) and toxicity testing. While most scale inhibitors demonstrate relatively low marine toxicity and tend not to bioaccumulate, their very low biodegradability means these chemicals can exhibit high levels of persistence. To meet demand for continuous improvement in environmental acceptability, M-I SWACO has developed a range of new, biodegradable, polymeric and phosphorus-containing scale inhibitors.

**Innovative technologies for demanding conditions**

The operational demands placed on scale management solutions include increasingly complicated well completions, production from harsh environments such as HTHP and deepwater fields, and stricter environmental regulations. To meet these demands, M-I SWACO has invested heavily in developing new scale-control technology, creating a comprehensive line of scale-inhibitor chemistries that include deployment techniques that focus on three key areas:

- Continuous down hole injection via gas-lift and capillary injection.
- Scale protection prior to a well cutting water.
- Requirement for lower density squeeze packages in depleted reservoirs.
- Protecting water-sensitive reservoirs from formation damage.
Non-aqueous-base scale inhibitors are required for wells where severe scaling is predicted at the onset of water production, or for unmanned platforms where lengthy mobilization time can threaten the asset.

Many operators now consider pre-emptive treatment with a non-aqueous-base scale inhibitor package an essential requirement of their total scale management strategy.

Key features of these non-aqueous-base scale inhibitors are that they:

- Are customizable to any scaling regime
- Eliminate the tendency for emulsion formation.
- Have proven field results
- Stimulate oil production after squeezing

**Green downhole scale inhibition using biopolymers**

M-I SWACO is at the forefront of biopolymer development for downhole scale inhibition. Biopolymers are considered the most environmentally friendly chemistry for topside and subsea scale control. Biopolymer chemistry meets the requirement of no harmful discharge to the sea because the molecules are completely degraded after discharge.

While biopolymers have been used for scale squeeze, they require optimization for temperature stability and adsorption/desorption properties in the reservoir. Technology development has yielded several molecules that are temperature stable above 248°F (120°C) and that show outstanding efficiency for scale inhibition—even better than traditional phosphonate chemistry. Our researchers are also evaluating the in-reservoir adsorption properties of this promising technology.

Traditional phosphonates have been used extensively for scale squeeze, but their geometrically locked backbone and sterically-hindered functional groups prevent bacteria from breaking them down in seawater.

Phosphonates are preferred for scale squeeze applications because of their low minimum inhibitory concentration (MIC), long treatment lifetime, and low level detection monitoring capabilities.

Ongoing research has identified some phosphonates that show significant biological degradation in seawater. These are being evaluated for efficiency, temperature stability, adsorption/desorption properties, detection in produced water, and compatibility.
Knowing where fluids are flowing can be a vital element in protecting the environment, optimizing applications and enhancing production.

**Tracer dyes**

Tracers have been applied in the oil and gas industry since the early ‘60’s for a number of purposes. These have included: leak detection (proactively in hydro-testing and reactively in association with a spill) to monitor near-wellbore and inter-well connectivity to assist in reservoir management and maximize recovery rates, to minimize water injection and water production rates by optimizing flow patterns, and to better optimize inhibitor squeeze programs, amongst others.

Compounds used for this purpose include: radioactive species, stable isotopes, chemicals such as fluorescent dyes, inorganic ions and aromatic acids (e.g.) NSA and FBA. Some of the early chemical tracers were rejected due to adsorption onto the rock and so radioactive species, with a low detection limit, a low reactivity, and a low presence in the environment became widely used. However, their use has become more restricted in response to the radioactive hazards associated with their use, hence a new range of non-radioactive tracers were developed and tested in the ‘90’s based on the aromatic acids.

Perhaps the most commonly used tracer in the oil and gas industry is fluorescein. Not only is it stable in reservoirs as hot as 250°C, it has a detection limit of approximately 10 parts per trillion using conventional spectrofluorometry. In addition, since it fluoresces in the visible spectra, fluorescein can be detected using a simple, inexpensive and easily operated fluorometer.

A compound closely related to fluorescein is rhodamine. While rhodamine does not possess the same level of thermal stability, where temperature is not a key factor, such as surface or pipeline applications, it is another option. For higher temperature applications it can still be a useful tool, if used in combination with more thermally-stable fluorescent compounds as a reactive tracer to measure the effective temperature along an injection-production pathway. Where colorimetric dyes are not preferred, for example in or near rivers or near shore applications, UV reactive dyes are an effective alternative.
Meeting water injection, reuse or disposal requirements

Water clarifiers, or ‘reverse demulsifiers’, work on emulsions and dispersions where water is the continuous phase and oil the dispersed phase.

In production systems normal and reverse types of emulsions and dispersions can be present. Water clarifiers work on the water, helping to remove oil and other insoluble matter.

**Water clarifiers**

As a field matures, more water is produced that can limit production, particularly when this water must meet purity specifications before injection, reuse, or disposal. As an industry, we produce six times more water than oil—a trend that is only increasing.

As water is ionic while oil is not, clarification generally employs charged chemistries with specific solubility depending on the ionic strength of the water. Generally, fresher waters present a greater challenge in water clarification than higher-density, more-mineral-laden brines. This is because the emulsion or droplets are more readily disrupted by the higher charge densities present in brines allied to the higher differential density between the brine and oil.

Water clarifiers come in three basic types: non-ionic, cationic, and anionic. They are generally classified as polymeric flocculants and metal salts. The salts are inorganic and are excellent in gross treatments; however, they can produce loose flocs (precipitated flakes), and are often unsuitable for some separation systems (e.g. hydrocyclones). In those situations polymers prove more effective.

Polymers vary in chemistry, molecular weight and physical form, may require special handling and can exhibit relatively short shelf lives. The easiest to work with are the solution polymers, which can be applied neat or as a dilution. These are generally low-solids-solutions due to the high molecular weight and are generally used as filtration aids in mixed-media filters.

More concentrated polymers are delivered in different forms of emulsions, whereby polymers in water droplets are then emulsified in oil. This technology is widely used; however, the treatment requires an initial residence in the system for the polymer to invert and yield. Similarly, solid product has been dispersed in a non-toxic, organic carrier. These organic dispersions have become commonplace, with the solids levels of these products achieving up to 50%, but again require residence in the system. Recent developments have led to brine dispersions of high-molecular-weight-polymers that are ready for use.

Handling characteristics and method of use must be considered when designing the field application. In ARCTIC and cold weather conditions, water clarifiers must be winterized or applied in a climate-controlled environment to avoid separation or freeze/thaw issues. Each system should be evaluated individually because, like demulsification, fluids and conditions vary, and the system of oil separation varies from case to case.

When recommending a water clarifier solution, M-I SWACO considers important factors including location, environment, and the limitations of the equipment and facilities. Each item is thoroughly evaluated to minimize facility disruption and lower costs.

Our water clarification range covers all product types, and our procedures enable us to test any variation of separation equipment on site to optimize a solution for each application.
Flow improvers

Quickly increase flow rates and reduce costs

Drag reducer agents (DRAs) are chemicals used to reduce frictional pressure losses in a pipeline. This is an effective way of increasing flow-rate potentials, decreasing operational pressures, and reducing operational costs by saving energy or even by-passing or suppressing one or more pump stations in a pipeline system.

Drag reducer agents

Oil DRA chemicals are generally composed of two phases: solid and liquid. Solid phases are commonly long-chain polymers of very high molecular weight. Liquid phases vary and can be vegetable oils, water, or even some alcohol blends. M-I SWACO Production Technologies’ NECADD™ series (447, 477, 479, 271) uses vegetable oils in its products that are compatible with crude oil and refined products and ensure low environmental impact.

Applications

DRAs are applied in pipelines where the Reynolds number (the ratio of inertial to viscous forces) is higher than the transitional flow regime, resulting in turbulent flow. This means there is a wide range of applications from the semi-heavy to the lightest of crude oils, and also in refined products such as gasoline and diesel. Objectives of DRA applications typically include one or more of the following:

■ Decrease discharge pressure while maintaining flow rate.
■ Increase flow rate while maintaining operational pressure.
■ Increase flow rate while decreasing operational pressure.
■ Reduce energy and operational costs by shutting down pumps.
■ Faster transfer of crude or refined products through pipelines.
■ Accommodate additional stock for new producing wells.
■ Provides for peak flow while minimizing CAPEX.

M-I SWACO is a leading global supplier of DRA products. Our manufacturing facility in Finland provides sufficient production capacity to ensure fast, reliable delivery even for high-consumption projects. The company has researched and implemented the best technology in DRA injection skids suitable for any metrological or operational conditions. Our specialist technical support experts analyze each customer’s specific operational requirements and use performance predictions and software simulations to help develop tailored recommendations for DRA solutions that will deliver the best results.
DRA is not restricted to hydrocarbon application: flow improvement in water injection facilities can also benefit from the application of water-based drag reducers. These products are typically water-soluble polymers and amphoteric surfactants. The former presents the most cost-effective solution; however, for produced water re-injection, surfactant technology mitigates the risk of oil flocculation and provides secondary benefits in terms of acid gas corrosion inhibition.

**Drag reduced in subsea multiphase pipeline by 30.5%**

**The Situation**
An operator in offshore Indonesia needed to reduce operational pressure at a platform to increase oil production through a multiphase pipeline. Three-phase flow within the subsea pipeline segment made it considerably more difficult to dissolve a conventional drag reducing agent.

**The Solution**
Based on an evaluation of operational conditions at that time, NECADD 271 was chosen and injected during a five-day period at a dosage of 250 ppm—the optimal concentration to initiate effective drag reduction.

**The Results**
NECADD 271 reduced drag by 30.5% in the multiphase pipeline, leading to a 13.4% increase in flow rate while reducing discharge pressure by 12.7%. Neither the balance of the system nor the integrity of the pipeline was affected by the treatment levels, with no residual emulsion build-up in the separators or carryover to the export pumps.
Produced water and sand management

Increase production with superior separation

Produced water is the largest volume waste stream in oil and gas production, with an estimated 240m bbl/day worldwide requiring treatment and disposal.

Combined with increasing quantities of produced sand, it threatens production capacity, flow assurance and environmental compliance.

Produced water and sand management

M-I SWACO provides dynamic systems for the optimized treatment of produced sand and water to increase production-process efficiency. Our compact, proven and reliable systems remove produced water and sand at the earliest opportunity in the process, maximizing production capacity and safeguarding assets.

Compact Water Management Systems

Our robustly engineered systems are based on elegant designs without moving parts to ensure reliability and constant availability. With instantaneous turndown you can optimize system performance to deal with variations in flow over the life of your field. Integrated systems help reduce operational requirements, with fully-automated, self-tuning capabilities that enable systems to be installed in more remote locations and platforms to be de-manned.

Our range includes:

- **CYCLOTECH PECT-F**
  Pre-coalescer for improving separation efficiency of a deoiling hydrocyclone

- **EPCON CFU® Technology**
  All-inclusive field-proven technology for treating produced water.

Compact Sand and Solids Management Systems

Designed to accommodate a wide operating envelope rather than a fixed point, our dynamic systems increase your ability to manage the uncertainty of produced sand. Managing the concentrations of sand within the process enables a continuous conveyor state to be achieved in minutes—avoiding blockages and downtime.

Rely on our vast experience and the lessons we’ve learned to create solutions that meet your requirements and provide the highest levels of flexibility to deal with the unpredicted.

Our range includes:

- **CYCLOTECH Sand Receiving and Cleaning Systems**
  Efficient, compact and robust post-separation treatment technology.

- **CYCLOTECH SCARPA Separators Continuous and Batch Sand**
  Proprietary sand removal technology effective in continuous and batch modes.

- **CYCLOTECH WDC Series Wellhead Desanding Cyclones**
  Customized new-generation solids separation technology.

De-bottlenecking and performance enhancement

We provide technologies that enhance the capacity and performance of existing equipment as water and sand production increases, or as current equipment ages. The cost, time and space efficient upgrade options are superior to conventional replacement solutions.

Forties, North Sea, UK

Retrofit delivers results for less than 7% of the cost of replacement

The Situation

An ageing deoiling hydrocyclone liner system operating across four vessels was underperforming. The operator faced having to remove the existing system for total replacement, which would incur significant costs and system downtime.

The Solution

As an alternative to total replacement, the M-I SWACO team carried out a retrofit of new high-efficiency equipment. Working within one shift per vessel, the retrofit was performed without any hot work and without modifications to pipework, valves or instrumentation.

The Results

The new equipment increased flow capacity by 80%, and improved oil-water separation by 35%, enabling production to quickly approach expected levels. The retrofit cost just 1/15th of equipment replacement.
Process equipment rental
We can help de-bottleneck your production operations with long or short-term lease contracts and fast response to process problems. The equipment is available and supported globally at a local level, which ensures we can assist in the design and integration of these temporary systems.

Our range includes:
- Full production-scale produced water treatment
- Small-scale produced water treatment
- Full production-scale sand management

Aftermarket services
We offer an inventory of services for the management of critical spares for any produced water and sand management system. In addition, we provide remote and on-site support to investigate and assist with separation issues, process de-bottlenecking, condition monitoring and equipment maintenance.

Flexible and dynamic
Optimize performance to continuously varying process conditions with minimal operator intervention. Because our systems are self-reliant, self-monitoring, and self-tuning can be fully automated to dynamically optimize performance while minimizing environmental impact.

For example, the EPCON LOGIC automated control system continually monitors the EPCON Compact Flotation Unit (CFU) to reduce oily discharges during process upsets offshore. Its advanced algorithms remove the need for manual tuning, while its real-time process diagnostics reduce personnel risks by making laboratory sampling unnecessary.

Fit-for-purpose
Meet your process requirements for the life of the field. Our expertise enables us to design and engineer bespoke solutions that meet the demands of the application by drawing upon our portfolio of class-leading processing technologies and over 15 years global experience delivering successful produced water and sand management solutions.

North Sea, UK
80% of produced water eliminated at source
Our partial-processing system recently eliminated 80% of produced water at source, enabling a client to open up production and achieve a return on investment in just 53 days.

Compact and reliable
Take advantage of smaller-footprint, lighter-weight engineering without compromising on efficiency or reliability.
Unlock revenue

Mineral scale deposition can seal the most permeable reservoir, requiring operators to find or create pathways to maximize production. Regardless of scale type and location, deposition must be dealt with quickly, effectively and safely.

**Descaling, NORM-decontamination and decommissioning**

Scale deposition restricts production, and increases the costs and risks associated with decommissioning and NORM (naturally-occurring radioactive material)-decontamination. Our all-inclusive EXKAL service gives operators a project specific, single-source solution for their most challenging scale problems:

- Integrates scale, production chemistry and waste management technologies
- Comprehensive suite of cost-effective scale dissolvers
- Mobile, on-site NORM-decontamination
- Downhole, topsides and midstream scale treatment
- Pre-project analytical services
- Decommissioning technologies and services

**A comprehensive service package**

A comprehensive service package effectively removes the obstacles that restrict production, while reducing the costs and hazards of decommissioning and decontamination.

The benefits of EXKAL include:

- Compliant with strict environmental regulations, including North Sea legislation
- Removes scale-related production restrictions
- Reduces personnel risks
- Operates effectively in remote, constrained locations
- Minimizes environmental impact
- Recovers valuable hydrocarbons during decommissioning
- Delivers safe, cost-effective decommissioning
- Maximizes value of producing asset
- Reduces treatment and waste management costs

The all-inclusive EXKAL service package removes the continual requirement to combat downhole or topsides scale deposition. M-I SWACO provides scale deposition remediation specialists, together with comprehensive, safe and cost-effective chemical and mechanical solutions.

Along with advanced and site-specific analytical methodologies, M-I SWACO provides an extensive portfolio of new-generation scale dissolvers that are non-corrosive and environmentally acceptable. Supplied as concentrated blends, EXKAL scale dissolvers effectively reduce chemical volumes to help manage overall treatment costs.

Our ability to deliver mobile on-site solutions makes the EXKAL service package ideal for remote locations, or projects where access is difficult with restricted water and energy consumption.

**Integrated solutions**

Specialists within the M-I SWACO team analyze your particular situation and customize a treatment strategy that incorporates our portfolio of safe and non-damaging scale dissolvers and related services.

These solutions include:

- Deployment of waste injection technology with EXKAL service
- Production chemistry expertise
- M-I SWACO drilling and production waste management capabilities
- Chemical recycling and reuse
- Modifying waste streams to meet local regulatory requirements
- Solids reinjection
- Integration with EPCON CFU technology to separate and treat waste materials prior to discharge or injection
- Integration with Schlumberger coiled-tubing services, flow assurance processes, Jet Blaster™ and related services
Understanding scale types

The performance of scale dissolvers is defined by the treatment design that implements them. First, our specialists determine the location of scale accumulation, whether it is reducing reservoir permeability downhole, or restricting fluid flow in surface process equipment. The next key step is to then identify the precise nature of the mineral scale.

Examples are:

- Sulfate, which is the result of mixing brines such as barium-rich formation water and sulfate-rich seawater for reservoir pressure maintenance. This mixture leads to the deposition of barium sulfate scale.

- Carbonate is the most common oilfield scale and occurs when CO₂ comes out of solution during production, resulting in calcium carbonate deposition.

- Sulfide scales form in the presence of sour waters. H₂S can occur naturally or as a result of sulfate-reducing bacteria (SRB) that produce H₂S gas as a by-product of their respiratory process. In the presence of ferrous iron, this gas can form pyrophoric iron sulfide deposits. Other metal sulfides may also occur such as zinc or mercury.

- Elemental radioactivity is the result of electrochemical processes in wells and process streams that can lead to the radioactive plating of surfaces and contaminate equipment with Lead-210 and other isotopes.

Experts analyze scale deposit samples to determine factors such as dissolution rate and sequestering capacities, which are used as input data for treatment designs. For downhole applications, the deposit thickness, the specific intervals where scale has accumulated, and the candidate dissolver performance are evaluated to calculate the treatment volumes, placement procedure and contact times. If the build-up is concentrated on the topside, scale removal and NORM-decontamination operations are executed with a simple soak or monitored closed-loop treatment.

Post-treatment analysis

As a routine part of its descaling operation, the EXKAL team relies on the proprietary D-SCAL™ diagnostic software package to provide post-treatment analysis. With this tool we are able to determine the efficiency of the treatment by separating the complex mixture of returning fluids into spearhead, dissolver, formation water, and seawater.

The known chemical compositions of each of the component fluids then allows the mineralogy of the removed scale species to be identified as either CaCO₃, CaSO₄, Fe₂O₃, FeCO₃, FeS, BaSO₄ and SrSO₄.

Combining chemical and mechanical solutions

Every component within the EXKAL product line has been tested extensively and demonstrates the best possible environmental performance and elastomer compatibility, while posing little to no corrosion threat when in contact with any of the standard metallurgies used in the oilfield.

Complementing our wide range of chemical offerings are the very latest in mechanical solutions, including ultra-high pressure water jetting and proprietary plasma-cutting technologies.
M-I SWACO is a world-leader in the removal of contaminants from gaseous and liquid hydrocarbon streams, setting the standard for H₂S removal for over 25 years. Our products, which include mercury removal, treat nearly 3 trillion cubic feet of gas annually in more than 1,500 applications in over 20 countries.

Purification solutions
M-I SWACO purification products are used in fixed-bed processes that are simple, easy to operate, with minimal operator attention. Product consumption is dependent only on the amount of contaminant passing through the bed. The flexibility of the fixed-bed process allows the system to adapt to variations in process conditions that may result from changes in operating preferences or tighter regulations, often without additional capital equipment or system retrofitting.

Predictable pressure drops, long bed-life, easy and safe handling, and a simple, reliable operation are a few of the features of the M-I SWACO fixed-bed process.

Purification products
M-I SWACO offers two primary product lines: SULFATREAT® and SELECT.

SULFATREAT products utilize proprietary iron chemistry to selectively remove H₂S and light mercaptans from water-saturated gas. The breadth of application includes: CO₂ streams, light hydrocarbons, water, air, geothermal vapors, landfill gas, and biogas. The products are non-pyrophoric and environmentally safe in unreacted and ready-for-disposal forms.

SELECT products utilize mixed metal oxide chemistry to selectively remove H₂S, light mercaptans, mercury and other contaminants from gaseous and liquid hydrocarbons at low temperatures. The products are suitable for use in both dry and wet gas applications. SELECT products are high capacity, fast-reacting absorbents with patented technology for enhanced porosity and improved activity. This allows for smaller vessels and smaller product volumes in a given process application, providing flexibility in system design.

In addition to the fixed-bed systems, we also offer a range of liquid-based H₂S removal scavengers. Customer requirements for each application are assessed independently to identify the most cost-effective treatment solution, which may be a fixed-bed system, a consolidated solution, or bulk removal with liquids followed by fixed-bed polishing. This flexibility is particularly beneficial when plot space or footprint is a concern, for example, on an offshore installation.

Purification applications
While gas processing is the primary market for M-I SWACO purification products, the range of absorbents will work effectively in most gaseous streams. The diverse range of operating applications includes:

- Gas processing plants
- Offshore platforms
- FPSOs
- Early production systems
- Gas storage
- Vent gas treatment
- Waste water treatment
- Landfill gas
- Biogas
- Food grade CO₂
- Odor control
- Petrochemical plants
- Refineries
Purification equipment

Years of experience across diverse applications and markets give us the unrivalled resources and expertise to design a treatment solution to suit any operator’s specific requirements. Proprietary software modeling is used to deliver system designs that are technically robust, reliable, effective and fit-for-purpose.

The most basic single vessel design requires a temporary bypass or interruption to the gas flow to replace spent media. Conversely, a lead/lag configuration provides the greatest operating flexibility, enabling operations to continue while media is replaced. A parallel design is also possible, generally where pressure drop is a critical process parameter.

To prevent excess free liquids from adversely affecting system performance, an inlet separator is placed upstream to remove them from the gas stream, irrespective of vessel configuration.

Monitoring

The outlet level of H₂S or mercury rises gradually at the end of the bed’s life, indicating the need for replacement. Incorporating this ‘early warning’ period into routine monitoring allows for planned, convenient product change-out. Computer modeling provides information on predicted performance parameters, with bed loading determined by flow and contaminant levels. Optional monitoring around the treatment system envelope can include gas temperature and pressure differential measurement. These measurements are used to confirm anticipated design operating conditions and the impact of changes over time.

Engineered technical solutions

We design treatment systems that address specific process conditions and defined operating philosophies. Our tailored support ranges from basic media provision through to a fully-engineered technical solution comprising:

- Basic system design
- Media supply
- Detailed engineering
- Fabrication package
- Equipment supply
- Spent-media handling

M-I SWACO is also uniquely positioned to offer effective alternative solutions to existing fixed-bed scavenger systems. We assess incumbent applications and provide comparative performance outcomes for review.

Change-outs and disposal

It is recommended that change-outs are handled by catalyst handling specialists. Assistance is available in determining the best option for the recycling/disposal of spent material. Disposal routes are well established and personnel are available for on-site installation and removal support, as needed.

Quality assurance and technical support

SULFATREAT and SELECT products are manufactured to stringent quality specifications. Bespoke software modeling and computerized predictability allows the development of best-fit system design and operations for each site. To ensure a successful process, highly trained personnel support the application through every step.

Global expertise and support

M-I SWACO has several dedicated specialist laboratories for the research, development and testing of fixed-bed absorbent media and alternative purification systems. As part of a global network of advanced oilfield R&D laboratories, these world-class facilities offer customers fast access to new product developments. A comprehensive network of industry specialists, engineering organizations, and experienced personnel supports our portfolio. They are focused on delivering tailored solutions and fast, effective and safe on-site services around the world.
Flow assurance, scale and integrity management

Increasingly remote and complex operations require greater alignment between operator and service provider to deliver excellence in execution and maximum value in operation.

Management services

With all the easy oil found, the race to keep up with market demand is driving the industry deeper and further, to produce from ever-more complex reserves. This dynamic is why today’s oil and gas industry attracts some of the greatest engineers and chemists. And it’s also why M-I SWACO remains focused on needs, delivery, people, technology and value—not simply on products and unit price.

Today, providing a product, solution or service is not enough: as a service provider we must step up and meet the increasing and exacting needs of the industry. We must build the technology pathway and develop smarter methods of working to ensure projects deliver on time, on budget and provide continuous value improvement throughout, from first-oil to end-of-field-life.

Integrated production chemicals engineering

M-I SWACO has held this vision for many years and invested in it’s people, processes, infrastructure and also supports services by locating technical facilities close to clients’ operating centers. We have invested in management programs and software systems that allow our technologists and field engineers to model, monitor and visualize system conditions to anticipate changes.

This enables operators to:

- Mitigate non-productive time
- Maximize production rates
- Minimize the total cost of operations

This is what we call Integrated Production Chemicals Engineering (IPCE), which is managed and supported with software led by the AVOCET PROCHEM platform.

The management program is built upon eight key elements and 11 key stages:

- **HSE**
  - Aligned guiding principles
- **Roles and responsibilities**
  - Clear and simple
- **Processes and practices**
  - Consistent and effective
- **KPI**
  - Measuring what is important
- **Data acquisition, collation and reporting**
  - Knowledge management
- **Problem solving**
  - Central to success
- **Application risk evaluation**
  - Driving the process
- **Project management**
  - (Balanced scorecards)
  - Professional, effective, aligned
- **Best practice**
  - Providing access to the market
- **Environmental stewardship**
  - Improving impact, preserving reputation
- **Commercial structures/contracts**
  - Performance driven
- **Peer review & audit**
  - Nothing better than a fresh pair of (competent) eyes

- **Training and competency**
  - Underpins continuous improvement
- **Interactive business performance review**
  - Measure, share, improve
- **AVOCET PROCHEM production chemical data management software**

The AVOCET PROCHEM platform is a leading-edge production data management and flow assurance system integrated with market-proven tools such as Pipesim, Olga, Scalechem, ScalesoftPizer, Squeeze VI, Norsok, BP Cassandra, MultiFlash, DBRHydrate, and more.

AVOCET PROCHEM platform enables reliable, real-time production performance monitoring and analysis for more accurate decision-making.

The system also acts as a central repository and information exchange platform for all data relating to:

- Flow assurance and integrity management
- Production and product performance
- Inventory management and commercial performance
- Lab data and trend analysis
Technology delivery and support

IPCE and AOV CET PROCHEM are the foundation and guiding principles that enable the process to be managed and accurately monitored—now the technology can deliver its value. To ensure our clients receive the best support industry can offer, we have established technology groups led by discipline leaders that are recognized across our industry in the field they represent; their role is to ensure that specific applications are correctly assessed, effective and fit-for-purpose products are selected, and the success in application is accurately measured. The results drive actions to ensure continuous improvement.

The key technology groups are:

- **Separation Solutions**
  Water clarification, filtration and demulsification

- **Organic Flow Assurance**
  Wax, asphaltene and napthenate

- **Inorganic Flow Assurance**
  Scale and hydrate

- **Integrity Management**
  Corrosion, microbiology and deepwater

- **Flow Improvement**
  DRA

- **Gas Purification**
  H₂S, mercury and compact solutions

- **Solid/Liquid Separation**
  Compact cyclonic separation solutions

The technology groups are the product line custodians. As specialist advisory groups, they manage commercialization of new technology and support the global service organization that provides the direct application and support services to the field.

Technology centers are located in:

- Houston, St. Louis, Aberdeen,
- Basingstoke, Stavanger, Oslo, Porvoo,
- Dubai and Perth.

Technical service centers are additionally located in:

- Nisku-Canada, Broussard-Louisiana,
- Bogota-Colombia, Bergen-Norway.
- Volski-Russia and Bangkok-Thailand.

These are supplemented by local facilities in all countries where we operate.

SLB complementary services

Today, M-I SWACO, as a wholly owned Schlumberger Company, brings even greater access and opportunity to deliver a total service offering to our clients. Key segments within Schlumberger can support the delivery of field performance. The Production Technology Group is closely aligned with:

- **Flow Assurance Consulting**
  Flow assurance consultancy

- **Well Services**
  Pressure pumping, coil tubing, caliper surveys, rigless intervention

- **Wireline and Testing**
  Well logging, production testing and early production facilities

- **Reservoir and Analytical Services**
  PVT, wet chemistry, lithology and geochemical analysis.

- **Reservoir Fluid Analysis**
  Leading-edge fluid analysis and application assessment.

- **Production Management**
  Full field management and field development
M-I SWACO has laboratories in Bergen, Norway and Houston, Texas, dedicated to testing the environmental performance of oilfield chemistry.

Ecotoxicological testing laboratories

Understanding how chemistry drives environmental performance enables continuous improvement to be delivered. Using standard test methods, lab personnel have developed or implemented a range of analytical services designed to protect the environment, including testing for biodegradation, bioaccumulation and acute toxicity to marine organisms such as algae, crustaceans and fish.

Algae and crustaceans are particularly useful for the acute toxicity testing of fluids because they are fast-growing and sensitive to adverse conditions. Bioaccumulation is a measure of the risk that a substance will concentrate in the food chain, which makes it possible to identify chronic effects. Biodegradation is a beneficial process that results when microorganisms break down a substance.

The Bergen lab uses Good Laboratory Practice (GLP) principles approved by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention). The facilities can perform organism toxicity, biodegradability and bioaccumulation tests on existing products, synthesizing their components and chemistry during R&D activity. The initial environmental evaluation performed by the lab is used to select candidates for further testing and to develop new commercial products.

Government lawmakers are responding with stringent new regulations designed to safeguard the environment. At the same time, operators and suppliers are facing intense public scrutiny for their environmental practices. In some territories, oil and gas companies must submit an annual report publicly disclosing the nature of their discharges into the environment, and companies compete with each other to adopt green strategies. Companies also compete to put together environmentally-friendly chemical portfolios.

Improving environmental performance does not necessarily mean additional cost. In many cases, damaging chemicals can be replaced by alternatives that perform more efficiently and are more cost-effective. Biocides are chemical agents with the capability to destroy living organisms and are a good example. In some applications, biocides can be replaced with natural nutrients and sources of nitrate.

Environmental resources in the company have developed a comprehensive database of chemical properties. This means that, when
studying new molecules and trying to predict how they will behave, analysts can quickly screen out many things based on previous results. Supporting Schlumberger in the eastern hemisphere, the Bergen ecotoxicological testing facility is becoming internationally renowned for balancing scientific thoroughness with the public safety concerns of regulatory authorities. This capability puts it at the leading-edge of what may become a global revolution in green chemistry. These efforts are supported by the Houston lab, which includes both marine and freshwater testing, as well as terrestrial testing. The combined efforts are coordinated to provide routine testing and evaluation of new and existing products. In addition to product testing these resources are involved in developing new tests, and coordinating with other regional toxicity labs to create a global network of testing and evaluation that supports continued progress.

As companies and countries adopt greater standards of environmental stewardship, the demand for greener chemistry is growing worldwide. For over 30 years, M-I SWACO has pioneered and led the field in green chemistry. Today our global database of chemistry and associated environmental information represents a game-changer in the industry and is a rate-enabler when looking at new challenges.

All Schlumberger products, whether for well services, pressure pumping, cementing, drilling fluids or production, are managed under the same process and their data stored in a central server network—building and sharing our knowledge and driving advancement in the field of green and alternative chemistry solutions.

As oil companies explore ever deeper water, unconventional formations, and in increasingly hostile environments that require a more sophisticated portfolio of mechanical and chemical technologies, Schlumberger and M-I SWACO are the partners of choice to support these developments. As the environmental leaders in the market, they add value throughout the licensing, exploration, development and production-process chain.
Developing products for evolving requirements

The M-I SWACO production chemical research and development (R&D) group comprises MSc and PhD level personnel in the UK, Norway and USA who have expertise in organic chemistry and in-depth knowledge of chemistry, synthesis, structure-activity relationships and scale-up.

Research and development

The team develops active molecules that are then formulated by the company’s technology group and packaged for the intended application. The R&D group works closely with M-I SWACO commercial and technical groups and its clients to identify and develop new products where there is an un-met market need, or a gap in the product range. M-I SWACO also works closely with the chemical industry, leveraging innovation from their research as well as developing molecules in-house that may be produced commercially under a toll manufacturing arrangement. When working with supply companies, the goal is to identify exclusive joint projects where there is a good fit for both companies.

It is important to have a close understanding of the chemistry involved in delivering the desired effect (e.g. corrosion inhibition, scale inhibition, emulsion breaking) down to the specific molecular level to provide:

- Ability to understand the total cost of goods, including raw materials, and hence maximize value
- Structure-property correlations can be determined to ensure the optimum solution is developed
- Requires less empirical testing (i.e. it replaces a trial and error approach)

Project selection
Review technical and commercial requirements

Molecule design concept
QHSE, cost, IP landscape

In-house or joint project?

Initial lab and field screening

Project review
Commercialize product or continue process
The product development process
The R&D group applies a structured process for its development of new products:

1. **Project selection**
   The first stage is to identify and review technical and commercial requirements in order to prioritize projects. An internal global steering team meets to review project submissions and determine which projects will be worked on during the following year. Multi-functional teams are assembled to agree project aims and develop plans. Regular meetings take place to review progress as well as formal global half-yearly reviews with management.

2. **Molecule design concept**
   Once a project has been selected, the R&D team meets to review molecule design in terms of molecular architecture. This activity takes into account QHSE requirements, cost, and a review of the intellectual property (IP) landscape.

3. **In-house or joint development project?**
   When the desired molecular architecture has been identified to meet the project requirements then a review is undertaken to decide whether the synthesis program should be conducted in-house or in combination with a supplier as a joint development project. This decision involves a number of factors, including whether a particular chemistry fits with a suppliers’ core competence and the willingness of a supplier to partner for an exclusive joint development project. If joint development is selected, appropriate agreements are put in place.

4. **Initial laboratory and field screening**
   Statistical design will also be employed to help with the synthesis program and to help identify structure-property correlations.

5. **Project review**
   Formal project reviews take place to determine whether the developments have met the objectives, or if further synthesis work is required. If further synthesis work is required, a new program is developed taking into account experience and knowledge gained from the initial phase. If the project aims, including cost-efficiency, have been met, novel work will be protected by IP and the new molecule/s will be formulated by the technology group. The boundaries of performance will then be established, including compatibility with key materials of construction including various metallurgies and elastomers. The new product will then be commercialized through the PAF process and taken to market by the Technology and Regional Tech Services groups.

4. **Initial laboratory and field screening**
   Once the initial set of products has been synthesised, they undergo appropriate laboratory and/or field screening in conjunction with the technology group. Laboratory tests are based on industry-standard and/or clients’ specific methods. Performance results are then put into the statistical model to identify significant trends.

5. **Project review**
   The new product introduction process is expedited using a formalized product approval form (PAF)—an electronic system that guides the introduction through its various stages, including pre-field trial preparation, field trial preparation, field trials, commercialization, and launch. There is also an “Express” version that supports rapid introduction of a new product to meet an urgent client demand.

Examples of recent developments include:
- Environmentally-friendly corrosion inhibitors
- Environmentally-friendly demulsifiers
- Low-dose kinetic hydrate inhibitors
- Pour-point depressants for heavy crude oils
- Pour-point depressants for deepwater applications
- Asphaltene dispersants for heavy crude oils.

The current focus for the R&D group lies with the development of custom molecules for heavy oil and deepwater applications, where technological advances in recent years have enabled strong growth and resulted in opportunities for new product development. The development of environmentally-friendly products is also viewed as a particular strength of the M-I SWACO Production Chemicals R&D group, supported by its in-house GLP environmental testing facilities.
**Procurement**
- Local
- High competence
- Wide network
- Preferred customer agreements

**Production**
- Local
- High quality
- Cost-effective
- Minimum waste

**Transport**
- Effective
- Reliable
- Low CO₂ emissions

**Storage and Base Handling**
- High competence
- Quality control
- Optimized storage
- Reduced waste
- Pod management

**Delivery 24/7**
Capabilities and resources – Supply chain

Global blending and logistics

The comprehensive range of production technology products and services from M-I SWACO is supported by a supply chain organization designed to meet the requirements of the most responsive service company in the oilfield.

Supply chain

The supply chain system leverages years of global experience in M-I SWACO and Schlumberger, and benefits from a shared infrastructure covering every worldwide location where oilfield services are required. Being part of the world’s largest oilfield service company provides M-I SWACO with strong purchasing power and helps minimize the costs of raw materials. Schlumberger has built a worldwide network of verified, approved, suppliers and service providers, resulting in improved quality assurance and optimized cost. Procurement departments in multiple locations are continuously monitoring the market for alternative and more cost-effective raw materials. The strategy in general is to have more than one approved supplier for each raw material in order to maintain cost control and maximize supply security.

A worldwide supply network also supports efforts to encourage local sourcing, when this is a customer priority. Production Technologies operate an integrated strategy over product manufacture. We manufacture where it makes sense and source and toll where it does not. The question we ask is: do we want to sell what we make, or make what we sell? The answer: in many cases is we want to make what we sell. By adopting a make-to-sell strategy, our field operations and technical teams can deliver the best solution in each and every case, as opposed to limiting the selection for a given application based on what we choose to manufacture. This provides agility in approach and where production quantities become significant, our in-house manufacture ensures the lowest cost of goods sold, while not limiting the choice in application.

To deliver this strategy, we have established a global network that starts with our manufacturing facility in Norway, supplemented by qualified toll manufacturers at key locations across the globe, and in-house blending facilities located close to our clients. Wherever possible, and especially where it is deemed contractually important, our aim is to maximize local content. To manage this, our systems are designed to ensure that whatever we make, wherever we make it, the finished product meets the exacting demands and consistent quality expected of a global market-leader.

Quality is central to our success. We operate according to ISO 9001 throughout our organization, and in the majority of cases the systems are accredited against the standard. For deepwater operations, quality control becomes even more critical and requires specific criteria to ensure continuity of operation and mitigation of risk in application. All deepwater products are developed and tested against the strict requirements of our deepwater program. This assures retained performance following extreme testing under conditions of cycling pressure, temperature and shear as experienced during deployment via small-bore umbilical cores.

The products are assessed for viscosity, compatibility with fluids and exposed materials of construction, as well as cleanliness according to the prescribed NAS standards. Details can be provided upon request and the deepwater facility, located at our HQ facility in Houston, is available for inspection. Having qualified a product, the supply chain aspect becomes the next critical path. Specific procedures are established for our DS-rated products and include NAS cleanliness checks, vessel inspection routines and base filtration prior to loading for dispatch offshore. Selective couplings and routine field checks provide the final line of assurance that the deepwater products will meet the demanding challenges in application.

For critical applications (i.e. those where physical property measures cannot necessarily assure product performance), application tests supplement the routine checks (e.g. low-dose hydrate inhibitors).
Before people work for M-I SWACO, they are screened not only for their current skills and experience, but also for their willingness to learn, solve problems, and help others.

**Training and career development**

Once they join the organization, employees benefit from a learning management system that provides: global access to learning resources; in-house and custom e-learning solutions; talent, competency and performance management.

Starting with the basic building blocks for the job at hand, M-I SWACO instructors quickly bring new Production Technologies specialists up-to-speed in the disciplines required for them to deliver maximum value from our products and services for the clients we serve. Standardized global training courses ensure that customers around the world receive the highest level of consistent service. M-I SWACO trainers are also equipped to prepare field personnel for specialized practices to meet particular local requirements.

Basic training is just the beginning of a successful career with M-I SWACO: structured learning continues while people are working in the field, helping them attain their personal goals.

M-I SWACO has developed a range of tools to support its learning management system. It has made a sizeable investment in computer-based training courses and materials that allow employees to progress at their own pace. As an organization, we are developing career paths, checkpoint criteria, and progress measurement methods to keep our people at the forefront of the industry.

The career development program provides a structured plan including technical, business, and personal skills training, and customized development programs linked to required job competencies. Learning is supported by the M-I SWACO Career Advisor Program, which provides employees with access to experienced personnel for mentoring and coaching.

**LEAP training program**

M-I SWACO developed the LEAP training program to acknowledge the unique commitment to safety, the environment, and service quality on which our customers depend. The primary goal of the program is to help each employee Learn, Excel, Apply, and Perform to their maximum potential.

Candidates develop their core technical competencies via a number of activities including mandatory instructor-led technical training, soft skills training, and on-the-job experience. They must also demonstrate they meet the required competency levels of knowledge and key skills, with performance validated on-the-job by a qualified lead-hand designated by local management.

**PROACT training program**

The M-I SWACO Program for Accelerated Career Training (PROACT) provides advanced career development through a corporate funded, 30-month series of programs for all the Production Technologies disciplines. Specially-selected people are put through an intensive technical training program and then deployed as interns to various operations around the world for three-to-six-month assignments, combined with periods of formal instruction. During the program they are required to complete a range of specific tasks that are certified by their supervisor’s manager. After successful completion of the program, they are equipped for deployment in any operation. The combination of hands-on counseling and self-directed training has proved to provide the ideal circumstances for developing highly competent employees and a strong technical company.

M-I SWACO also provides customers with seminars and training programs tailored to their specific requirements, covering topics including production technologies, chemical handling, and environmental management.
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