Health, Safety, and Environment

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Health, safety, and environment (HSE) continue to be integral parts of all sectors of the oil and gas industry. Individual companies and industry associations strive continually to develop more-effective systems for managing HSE.

In the May 2008 issue, *JPT* editor John Donnelly wrote a column about how safety performance could be strained as worldwide drilling demand continues to grow at unprecedented rates. Nobody in the business wants to see this happen, but the safety (and health and environmental) challenges of operating faster and in more-difficult situations cannot be overlooked.

This year, as the HSE feature coordinator, was far more complicated than in past years. The *JPT* staff sent me more than 350 abstracts from HSE papers presented during the past year. Out of that thick pile, I had to select only a few for featuring here. I have encouraged splitting the three HSE disciplines into three, or at least two, separate features. The first gradual movement in that direction happened this year, as a new feature (CO_2 Applications) was created, which considers carbon-capture and -sequestration papers. In a second small shift, this year's HSE feature offers papers for additional reading separately in each of the three areas. Your input regarding the split of these disciplines into separate features is encouraged, especially in the next reader survey. **JPT**

Health, Safety, and Environment additional reading available at the SPE eLibrary: www.spe.org

Health

SPE 108551 • *"Occupational-Health Aspects of Emergency Preparedness and Response" by D.S. Jones, ExxonMobil*

SPE 111545 • *"The Other Infectious Diseases of Concern" by Jean-Marie Moreau, ConocoPhillips, et al.*

Safety

SPE 111563 • *"Technology and Innovations Contribute to Safety and Efficiency in Storm-Disaster Recovery" by J.F. Mailey, SPE, Chevron*

SPE 111845 • *"Our Sustained Efforts—'Hand and Finger Campaign'" by Rune Hobberstad, Halliburton, et al.*

Environment

SPE 110118 • *"Mercury-Removal Project: Issues and Challenges in Managing and Executing a Technology Project" by Muhamad Rashid Sainal, Petronas, et al.*

SPE 111973 • *"Emerging Issues in Produced-Water Management: Total E&P Norge's Approach" by Pierre Goud, Total, et al.*

SPE 112861 • *"Oil and Gas Producers' E&P Waste-Management Guidelines" by E. Garland, SPE, Total, et al.*

REACH and the HSE Case for Formate Brines

Europe's largest single piece of legislation, Registration, Evaluation, and Authorization of Chemicals (REACH), went into effect on 1 June 2007. REACH requires manufacturers, importers, and users of chemicals to demonstrate that their products are safe to use for humans and the environment. There will be increasing pressure to substitute less-hazardous materials for chemicals perceived as potentially harmful. The legislation is expected to have a significant effect on the management and application of chemicals used by the oil industry in Europe.

Introduction

The new European chemical legislation, REACH, represents a major revision of European chemicals management, replacing some 40 existing European Union (EU) Directives and Regulations. An objective of REACH is to place the responsibility of demonstrating the safety of chemicals on the manufacturers, importers, and users of the chemical. At the same time, the aim is to minimize the use of animal testing and encourage the substitution principle. The legislation encompasses all chemicals or chemical substances, including oilfield chemicals such as drilling and completion fluids. The full-length paper details the effect that REACH will have on management decisions and compliance procedures related to ensuring safe use of chemicals.

This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper IPTC 11222, "REACH and the HSE case for Formate Brines," by ***Ylva Gilbert,*** *SPE, Gaia Consulting;* ***Adrian Nordone,*** *Cabot Corporation;* ***John Downs,*** *Cabot Speciality Fluids; and* ***Anu Vaahtera, Piia Pessala,*** *and* ***Tuomas Raivio,*** *Gaia Consulting, originally prepared for the 2007 International Petroleum Technology Conference, Dubai, UAE, 4–6 December. The paper has not been peer reviewed.*

Methodology

The work presented in the full-length paper is based on a review of the literature and legislation as it applies to oilfield well-construction operations using formate brines as example chemicals throughout the discussion. Where comparisons with traditional brines are made, the data mainly have been sourced from open literature, and there are many gaps. For the formates, the authors also have had access to previously unpublished test results from the manufacturers. The findings from the literature have been complemented with information on the practical challenges of meeting REACH requirements, gleaned from discussions with four major operators.

To set the scene, the following section introduces the case-study chemicals. This is followed by a brief overview of two means of ranking chemicals on the basis of regulatory data. REACH and its processes as well as the time frame of implementation are then presented, followed by an overview of data requirements to support REACH. The findings then are discussed from a management point of view, as illustrated with formate brines.

Case-Study Chemicals. Well-construction fluids (WCFs) and chemicals provide a good case for reviewing the effects of REACH because large volumes of specialized chemicals with differing health, safety, and environment (HSE) profiles are used. Modern water-based WCFs tend to be based on solutions of salts, either used straight in solids-free mode or with the addition of micronized solids and soluble polymers. The past decade has seen a steady increase in the substitution of traditional halide brines (e.g., sodium chloride, potassium chloride, calcium chloride, calcium bromide, and zinc bromide) with alkali-metal formate brines (potassium formate and cesium formate), particularly in challenging operations.

The REACH assessment process begins with the identification of the degree of hazard posed by a particular chemical, using information obtained from toxicology testing and data gathering. The formate brines were introduced in the 1990s and have been in use as drilling and completion fluids for the past 14 years. They originally were selected for their benign HSE profile and have undergone extensive toxicology testing. The combination of good technical and HSE performance makes the formates a good candidate for "best available technology," supporting the use of formates as a case study for REACH from an oil-company-management point of view.

Chemical Classification

Regulatory chemical-classification and labeling information is a useful source of comparative data on chemicals. Classification and labeling of chemicals are regulated around the world by numerous and varied bodies of legislation and can be dependent on the type of use (e.g., transport or storage) or stage of life cycle. For example, zinc and zinc compounds are classified as hazardous waste in Europe. Today, the clas-

For a limited time, the full-length paper is available free to SPE members at www,spe.org/jpt.

sification and labeling of substances in the EU (other than for transport) mainly are based on criteria defined by the Dangerous Substance Directive (DSD). For example, substances labeled as harmful, irritant, or corrosive. are classified as dangerous. All high-density completion brines except potassium formate are classified as dangerous under DSD. Ordering of the classifications can support comparative HSE profiling. This will be enhanced by the introduction of the United Nations Globally Harmonised System (GHS) of Classification and Labelling of Chemicals, which will attempt to standardize chemical-classification systems around the globe. GHS will supplement REACH in the EU.

Another type of classification was developed following the decision in 2000 by the Oslo Paris Convention to introduce a harmonized and mandatory Control System for Offshore Chemicals. Some parallels can be found with the more complex REACH. The obligatory procedures include chemical registration and testing (by producers and importers) and risk assessment (by oil companies and service companies) before use, as well as the adoption of management procedures to ensure compliance during use. Toxicity testing required is largely unified, although some variation is allowed on species. The country-specific ranking systems are subtly different and use different color or letter codes, which may be confusing for the uninitiated. Nevertheless, the classification has provided a means of ranking chemicals on the basis of the results of acute toxicity tests, among other things.

REACH Registration

REACH will be applied in all the EU countries and Norway. The European Chemicals Agency (ECHA) will manage the technical, scientific, and administrative aspects at the community level, and the national authorities will play a primary role in each country. REACH represents a fundamental shift of responsibility from authorities to manufacturers, importers, and users to ensure that the risks of substances are assessed, acknowledged, communicated, and mitigated with sufficient safety measures. REACH will require that the assessed risks and projected use scenarios for high-volume chemicals, such as drilling- and completion-fluid chemicals, include all foreseen routes of exposure supported by sufficient data. Thus, the REACH assessments will provide comparable data, useful for feeding into existing risk assessments. This will allow better comparisons of chemical alternatives within other regulatory-framework areas.

Because of the number of chemicals affected by REACH, there will be a transitional period for registration that will be both volume- and hazard-dependent. A "preregistration" period will apply to all substances currently listed on the European Inventory of Existing Commercial Chemical Substances.

The chemical uses and associated potential exposure scenarios will need to be communicated to the manufacturer/importer performing the registration well before December 2010. Oil exploration and production companies as end-users must ensure any chemicals used after 1 December 2008 have been either preregistered or fully registered.

The quantity of drilling or completion/workover brines used in a single well-construction operation in Europe typically might be 400 to 600 tonnes. Assuming multiple uses, this places the brines well within the "over 1000 tonnes per annum" range and within the first wave of registrations.

REACH Process and Formate Brines

Registration. Suppliers of high-volume WCFs will be required to register their complete range of uses within the registration dossier in the form of a Chemical Safety Report. This report should contain information on specific applications and user scenarios and cover the life cycle of the product. Recommended controls of exposure hazards to humans and the environment also must be included. It is the responsibility of users to ensure that the application scenarios filed by the manufacturers match the intended applications. Guidance from ECHA is required before undertaking detailed assessments, but the preliminary assessments of data gathered for the formate brines indicate low hazard levels and relatively simple precautionary measures.

Evaluation. The information given to ECHA by manufacturers and importers undergoes a Dossier Evaluation process by the national Competent Authorities. Existing mammalian and ecotoxicology data for the formate brines are reasonably extensive and indicate limited intrinsic hazard. Hence, it is unlikely that there will be a requirement for any extensive additional vertebrate testing. In contrast, where toxicology data are more limited and existing data suggest the possibility of hazard, as would appear to be the case for the bromide brines, further testing may be required.

Substance evaluation will be undertaken whenever a member state or ECHA believes that there may be reasons for suspecting that uses of a chemical may represent a risk to human health and/or to the environment. The formate brines have relatively benign mammalian and ecological toxicity profiles, and it seems unlikely that they will need a substance evaluation. In contrast, the equivalent data for the bromide brines may be a cause for concern, and could trigger an evaluation. The outcome of the dossier and substance evaluations for the bromide brines cannot be predicted by use of publicly available data.

Authorization. Substances considered to be "of very high concern" will be made subject to a mandatory authorization process. For any substances identified as being subject to authorization, the first option would be substitution of a less-hazardous chemical. Where substitution is not viable, adequate risk control must be demonstrated. For example, genotoxic carcinogens are likely to be authorized only for use in closed systems. If the risks are considered to be "unacceptable," the applicant will be required to implement EU-wide risk-reduction measures that make up the restrictions part of the legislation. The formate brines do not fall within these criteria, whereas the case for the halide brines is not so clear-cut.

Restriction. Restrictions will be placed on substances that are determined to pose unacceptable risks. These can relate to how the chemical can be applied, prescription of additional risk-management measures, or, in extreme cases, banishment from the market. The overall process of REACH registration can be expected to progress smoothly for low-hazard chemicals such as the formate brines, even in the high-volume category.

Oil-Company Perspective

The practical aspects of managing REACH have been discussed less widely in public because there is as yet no formal guidance on the exact details required for compliance. However, to give a picture of the practical implications of REACH, the management measures required were discussed with REACH experts and HSE management representatives from four major oilfield operators in the spring of 2007. While the approach to managing REACH indicates subtly different detail on the basis of current differences in management processes, three main themes are recognizable: (1) ensuring supply of vital chemicals, (2) achieving compliance, and (3) using data required by REACH as input to decision criteria.

Ensuring Vital-Chemical Supply. The cost of implementing REACH will lead each chemical manufacturer/importer to view the EU chemical-market potential through an investor's eye. For each chemical, a decision to either continue or discontinue the supply will have to be made, with the decision influenced by the total costs incurred in registration and evaluation vs. the income and profit flow generated by sales in the EU.

An oil company also acting as a chemical manufacturer estimates that the cost of registration fees alone for its portfolio of products will reach USD 60 million. The estimate of actual overall cost to chemical manufacturers and downstream users to implement REACH varies between EUR 2.8 and 5.2 billion.

Whether a manufacturer will go through the expense of complying with REACH and continue to supply oilfield customers in the EU is likely to be dependent on the turnover and profit margins of the chemical in the EU market. Products more likely to pass such financial scrutiny are the well-characterized low-hazard chemicals, such as the formate brines.

To ensure the uninterrupted supply of vital oilfield chemicals, the early identification of essential products that may be at risk of not being registered is a priority action for the oil companies. The number of oilfield chemicals used offshore is significant, and the screening exercise is not trivial. Nevertheless, each of the companies interviewed recognizes the need to design and implement an "at risk" screening program. For oilfield chemicals that are identified as being unlikely to be registered by the manufacturer and are recognized as being vital for operations, the best way forward might be for the operator to carry the registration cost and act as the lead registrar of that chemical. **JPT**

Development of a Security Process

Security risks are some of the most pressing risk-management concerns of oil and gas companies in the Asia Pacific region. There is a strong requirement to develop a standard process that allows oil and gas companies to both manage security risks and meet their business requirements in the various countries in which they operate. The process, once developed, needs to be integrated into all relevant aspects of the business. The security process should be developed as a core feature of the operations-management system, allowing all levels of the organization to understand how security management fits into the business structure.

Introduction

Because of our dependence on oil, energy security is one of the most important issues facing the world economy today. The most common image of energy security is that of meeting the increasing demand for energy by ensuring a constant supply to consuming nations. However, there is an aspect of energy security that looks at the threats to the energy supply, the protection of the energy- supply systems, and physical protection of the people and assets that make up those systems. This second aspect is very much the subject of attention of security professionals working within the oil industry.

This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper SPE 108621, "Development of a Security Process To Meet the Requirements of Oil and Gas Companies in the Asia Pacific Region," by ***Matthew Quin,*** *Chevron, originally prepared for the 2007 SPE Asia Pacific Health, Safety, Security, and Environment Conference and Exhibition, Bangkok, Thailand, 10–12 September. The paper has not been peer reviewed.*

Security departments traditionally have not been seen as profit generators or business drivers and, therefore, have not justified the close attention of business managers and have not been well understood by them. It was the events of 9/11 that caused a major shift, when major oil companies with operations in the Asia Pacific region started to scrutinize more closely their security preparedness regarding the physical well-being of their personnel and assets. In a short period of time, security departments had to transform themselves from little-known entities into credible and accountable business units.

Security departments of major oil companies working in the Asia Pacific region have had to adapt to best serve the interests of one of the security profession's most challenging industries. The Asia Pacific region has the fastest-growing power sector in the world and is likely to be a growth engine of the world's economy throughout this century. Energy sources in the Asia Pacific region are fast replacing the maturing fields in more traditional regions, making security of the energy sources in this region an important issue. An effective solution is to modernize the role of a security department within the organization by developing a business-related process that enables an oil company to integrate its security function with all relevant aspects of its business operations.

Theory

Traditionally, security management has been defined by physical security, personnel security, investigations, and emergency practices. Security managers in the Asia Pacific region often have come from law-enforcement or military backgrounds, with little or no experience in business management. However, following 9/11, when new security-risk perspectives brought about a requirement for organizations to justify higher operating costs for security, business-management principles have taken on a greater role in defining security management. Security departments now are required to justify increasing costs for personnel and equipment by using good business-planning and accounting principles. Security managers are required to be more accountable, by not only having to justify the expense of modern security systems but also having to explain if security systems are producing their intended results.

The environment for the modern-day security manager is more complex, and the theory and definitions of security management have changed to account for the convergence of security-management principles with business-management principles. Terms used in modern-day security management are fast changing to be more business-focused than before. Higher risks and higher prices are leading business managers to pay closer attention to recommendations from security departments. Security managers are now required to be familiar with business terms like cost/benefit analysis, cash flow, return on investment, and the project-management cycle.

There also have been recent changes in the nature of the threats against which a security department must protect. Obviously, the most prominent threat to emerge has been terrorism in its various forms: global (jihadist), regional, or local (separat-

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ist/issue-based). This threat has been the main motivation behind companies increasing their security preparedness in the Asia Pacific region after 9/11.

In addition to the threat of terrorism, there are other common security-related threats that are high on the list of risk-management concerns among oil companies. These include reputation issues, environmental risk, regulation and legal environment issues, business interruption, explosions and fire, political risks, executive risks (e.g., executive protection), and corporate issues. Each of these factors has a relationship with the roles and responsibilities of security departments, adding to the complexity of defining modern-day security management and its importance to the organization. Protecting a company from internal fraud, from conflicts of interest, and from the legal requirements surrounding support from a host country's security forces are examples of the complex demands being placed on security departments by company managements.

Description and Application

Given the increased importance and expectations placed on oil-company security departments, there is a strong requirement to develop a security process that provides an effective mechanism though which security can be managed effectively. The security process should be developed as a core feature of a company operations-management system to ensure legitimacy and enforceability of the security function throughout the company and to promote its integration with other relevant business aspects, thus providing critical links with other core functions and allowing all levels of the organization to understand how the security management fits into the business structure.

Senior–Management Direction. The critical first step is to obtain clear guidelines from senior management on the expected roles within the organization of the security department. These roles tend to vary from company to company. The security director will need to structure the department according to the direction received, ensuring that an adequate number of qualified corporate security staff are allocated in each of the key areas of operations. Generally, the role of the security department will include process development, asset and loss protection, investigating security incidents, audits and reviews, contingency planning, crisis management, executive protection, travel security, and security-awareness training. Once the roles are agreed upon, a policy statement should be disseminated throughout the company to outline the exact roles and responsibilities of the security department. This policy statement will demonstrate the commitment of senior management to the promotion of security throughout the company.

Operations-Management System. To stipulate the expectations of senior management clearly, the company should ensure that security becomes a unique and separate element within the operations-management system. This also ensures legitimacy of the security function, which then can be tied to a standard, enforceable process with a corresponding allocation of resources and business targets. Tying the security process to the everyday business operations of the company is a good way to gain commitment to security from all levels of management.

Security-Process Guidelines. Once the commitment and support of management have been obtained and a policy statement has been developed, the next step is to develop security-process guidelines, which should be kept as simple as possible, outlining the key elements of the security function and the means through which those elements will be conducted. The process guidelines should stipulate clearly how the operating units within the company are expected to meet the expectations of senior management. Guidelines must be consistent throughout the organization. For example, guidelines on standard security-alert levels and the protective measures expected at each alert level are critical.

Allocate Process. A key aspect of making the security process relevant to all parts of the company is to make an initial business case for allocation of specific elements of the process to the appropriate levels of business. This will depend on the nature and size of the company and the complexity of its financial structure. For an integrated oil company with both upstream and downstream operations, this will be a complicated step, requiring a great deal of thought and planning. The company will need to decide on some important higher-level issues such as standardization of certain security systems, setting up security reporting lines on a functional or geographical basis, and allocating responsibilities on a regional, country, or site-specific basis. There is no standard solution to allocating the various aspects of the security process, and the best fit will vary from company to company. However, in the Asia Pacific region, the allocation of responsibilities will need to consider the unique differences involved in operating in each country. The critical element for success in this step is to aim for cost effectiveness and to ensure that specific elements of the process are allocated to a level with the appropriate financial authority.

Develop Plans and Procedures. There must be a common flow of expectations throughout the security process, so that relevant tasks are managed at an appropriate level. An effective method is to conduct top-down planning followed by bottom-up reviews. For example, if the organization is sufficiently large, there is likely to be the need for a number of regional- or country-level security-management plans linked to associated business plans. In addition, there is a range of national and international security requirements that must be incorporated with a company's own security-management plans (e.g., maritime security regulations). These plans need to be detailed sufficiently to deal with the higher-level tasks and regulatory requirements, while at the same time allowing the all-important site-specific security plans to be as simple and effective as possible. The success of the process can be measured by how effectively the various elements of the security process flow from the day-to-day management at the individual facilities all the way to the top of the organization. A good example to use is security-incident reporting. If this has been well formulated within the security process and integrated effectively with other relevant business and regulatory functions, there will be a streamlined flow of information and coordination of incident-response activities from a particular facility to the top of the organization.

Provide Sponsors. Once the security process has been tied to the relevant business levels, it is important to enable the critical link between the business function and the security process to occur. Appointing sponsors from within the business units who understand their respective levels of business intimately can achieve this. These people should be part of management teams with appropriate financial authority. They should take on the role of mentor to the security adviser or manager responsible for the security process and ensure that the necessary resources are available.

Link Security Risk Assessment With Business-Planning Cycle. Once the guidelines and support mechanisms are in place at the relevant levels, it is time for the security department to demonstrate its skill sets. As with other areas of business operations, a risk assessment is used to begin the security process. There needs to be a realistic and accurate understanding of the security risks facing the company at each relevant level (e.g., in a particular region, country, and location). The more this can be incorporated into the organization's wider risk-assessment methodology, the better. For example, the same risk-matrix scoring system should be used to allow business managers to understand how security risks rate against more-traditional safety and environmental risks. Importantly, annual security risk assessments should be timed to coincide with the business-planning cycle, so that key recommendations can be inserted into the annual business plan and budgeted accordingly. Once inserted into the business plan, security recommendations then can be tracked and reviewed accurately by the relevant levels of management. **JPT**

Tar-Sands Drilling-Waste Management: A Clean Solution

The full-length paper presents novel technology for treatment of tar-sands drilling waste generated from steam-assisted gravity drainage (SAGD) and other tar-sands drilling operations. The continuous treatment process is based on hot-water addition, mixing, and separation techniques to reduce the viscosity and specific gravity of the bitumen to separate it from the sand. Treatment of cuttings with light to heavy bitumen contamination has shown this treatment method to be a simple and effective means of producing clean sand and recovering the bitumen component.

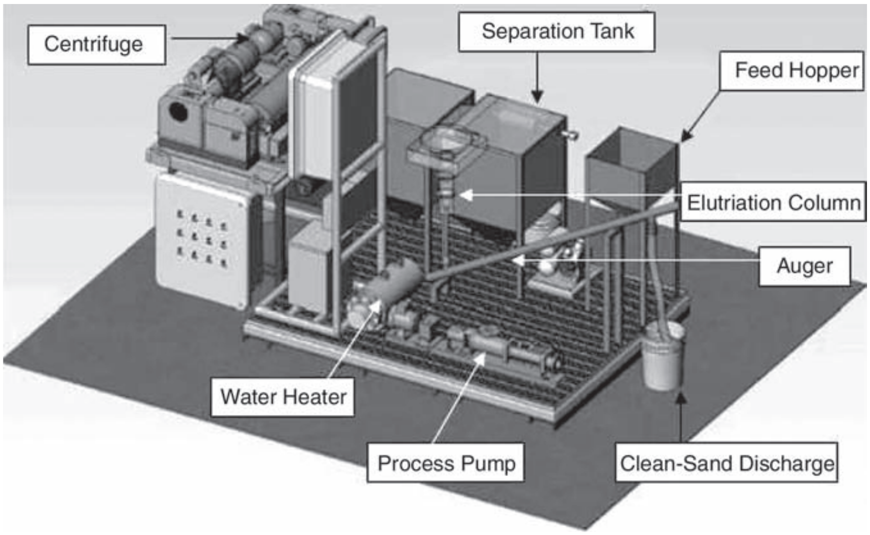

Fig. 1—Tar-sands-cleaning equipment.

Introduction

Tar sands are sandstone formations saturated with bitumen or heavy oil. The sandstone is thought to remain water-wet in the formation and can be unconsolidated, with the sand grains held together mainly by the bitumen. Alternatively, the sandstone can be consolidated, with silica or carbonate cement holding the sand together and bitumen filling the remaining voids. The bitumen deposits were formed in the geological past from crude oil that migrated to the surface of the Earth. Weathering and chemical and biological processes resulted in loss of the light fractions, leaving behind the very-viscous, solid or semisolid heavy fractions. Typically, bitumen has a density greater than 960 kg/m^3. Over the millennia, weather and geologic action covered the semisolid bitumen with layers of soil, and today, most bitumen and heavy-oil production comes from deposits buried more than 400 m below the surface of the Earth. Bitumen deposits are found in more than 70 countries worldwide, but 75% occur in Canada and Venezuela. In Canada, most of the oil sands are located in three major areas in northern Alberta, which hold at least 175 billion bbl of recoverable bitumen.

Where the heavy oil is thin it can be pumped out of the sands with progressing-cavity pumps (PCPs). To increase recovery, cold heavy-oil production with sand also is used in which sand is encouraged to enter the well by aggressive perforation and swabbing strategies. Removal of the sand with the heavy oil increases the formation permeability, expands the high-permeability zone as sand is produced, and prevents plugging of the near-wellbore region by asphaltenes or fines.

Tar sands that do not flow easily at ambient temperatures and pressures can be produced either through surface mining or in-situ methods. Surface mining is used to extract shallow bitumen deposits through open pits using traditional mining equipment such as excavators, conveyors, and dump trucks. Where the overburden exceeds 50 m, in-situ techniques are used. These techniques use steam or solvents to soften and thin the bitumen before recovery and include cyclic steam injection, fracture-assisted steam technology, vapor extraction processes, toe-to-heel air injection, and pressure-pulse technology. One technology developed in the 1980s in Canada for reservoirs where the heavy oil is essentially immobile is SAGD. This technique is becoming increasingly common because of high bitumen recovery rates (60 to 70%) at relatively low cost. In the SAGD process, two horizontal wells are drilled, one at the bottom of the formation and the second approximately 5 m above

This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper SPE 112368, "Tar Sands Drilling Waste Management: A Clean Solution," by ***C. Nilsen,*** *SPE,* ***K. McCosh,*** *SPE, and* ***M. Kapila,*** *SPE, M-I SWACO, originally prepared for the 2008 IADC/SPE Drilling Conference, Orlando, Florida, 4–6 March. The paper has not been peer reviewed.*

the first. Steam is injected into the upper well and moves from the liner slots into the tar sand, where it softens the bitumen and loosens it from the sand. The steam reduces the viscosity to as low as 1 to 10 cp, depending on temperature and initial conditions. The steam and gas rise because of lower density, and the oil and condensed water flow into the lower well where they can be pumped to the surface. The distance the hot bitumen will flow limits the well length, and typically, hundreds of wells are required.

Specialized drilling fluids are used to drill the high-angle and long-reach horizontal sections of SAGD wells. In addition to the traditional roles of drilling fluids in stabilizing the formation, cooling the drill bit, and suspending the drill cuttings/sand, this drilling fluid must also act to prevent bitumen accretion to the drillstring and minimize blinding of shakers, which are typically used to remove the cuttings from the drilling-fluid system. The separated cuttings comprise sand and bitumen with a residual coating of drilling fluid. In most cases, the contaminated sand cuttings are stored in large bins at the rigsite and are blended with material such as sawdust and hauled to centralized disposal facilities. Further blending allows the sand to be disposed of or reused. Blending with soil allows land disposal, and blending with building material enables the sand to be used for construction of roadways and pads.

Treatment of the cuttings to reduce the bitumen content so that the material is no longer classified as hazardous waste will benefit environmental objectives and encourages recycling and reuse. A novel technology for treatment of the tar-sands drilling waste, the system provides a simple and efficient process to produce clean sand that can be disposed of safely in situ. The process also recovers the bitumen component, which can be added back into the production train, increasing recovery efficiency.

Tar-Sands-Cleaning Process Development

One example of a specialized drilling fluid used for SAGD drilling operations is a water-based fluid with solvent emulsified by water-wetting surfactants. These surfactants act to water-wet the tar and other oleophilic surfaces, and the resultant repulsion of surface charges prevents accretion of tar and precipitation of surfactants while drilling. Fluid turbulence can disrupt the emulsion, momentarily allowing the solvent droplets to soften and dissolve bitumen that can become attached to the bottomhole assembly and tool joints. The sand particles recovered over the shakers are encapsulated in the bitumen and are thought to remain in a water-wet state, assisted by the presence of surfactants in the drilling fluid. In this state, a thin water film is present between the oil and the sand surface, which should allow for separation of the bitumen from the sand particles with water, without the need for organic solvents or chemicals.

Separation techniques using water are known and typically are used to treat tar sands recovered from surface-mining operations. In these systems, adequate mixing of the tar sand and water generates air bubbles that attach to the bitumen particles and cause them to float to the surface, where they can be recovered. Heat also can be used to cause bitumen to float on water (see Fig. 2 in the full-length paper). When heat is applied to a substance, the constituent particles move around more vigorously and by doing so generally maintain a greater average separation. This is termed thermal expansion. The coefficient of thermal expansion for bitumen is greater than that of water, and as a result, bitumen has a greater density than water at 77°F (25°C) but a lower density when heated to 158°F (70°C).

On the basis of these observations, a simple, energy-efficient, and continuous treatment system was developed to clean tar-sand cuttings by use of water and heat. In the process, the bitumen-contaminated drill cuttings are mixed with hot water to make slurry that can be conveyed through primary and secondary separation steps easily. The primary step separates the sand from the majority of bitumen through the force created by a hydrocyclone. The secondary separation takes place in an elutriation column to remove any residual contaminants from the sand. The clean sand produced can be disposed of by land spreading or burial, or it can be used for industrial purposes. Disposal on land is possible as long as the oil/bitumen content is controlled. In Alberta, Canada, for example, land spreading will be permitted only if the material has a total petroleum hydrocarbon (TPH) content of less than 0.1wt%. The general practice is to mix the cuttings 1:3 with clean soil before land spreading. This translates to an acceptable oil content of the cleaned sand of 0.4 wt% before blending. This formed the specification against which the cleaning-process performance was gauged. A less stringent treatment criterion of 5% TPH applies if the cuttings are used for industrial applications such as construction of roadways and pads. In this application, the sands also would be blended with building material before use.

Tar-Sands-Cleaning Equipment Development

Initial laboratory studies were conducted on tar-sand cuttings from Alberta to investigate the feasibility of the process. Simple jar tests involved mixing the tar sand with hot water, agitating, and then observing the degree of bitumen separation. If sufficient shear was provided, the hot water caused the bitumen to separate from the sand and float to the surface where it could be recovered. The cleaned sand settled to the base of the test jar. Testing showed the importance of breaking up and heating the bitumen thoroughly to ensure cleaning efficiency.

The tar-sands-cleaning equipment is illustrated in **Fig. 1,** and the process flow is illustrated in Fig. 4 in the full-length paper. Tar sand is introduced into a feed tank and hopper and diluted 1:1 with hot water to preheat and soften the bitumen to increase flowability. The hopper is connected to an eductor that provides adequate shear, good mixing of tar sand and hot water, and a method of transporting the cuttings as slurry. A PCP operates the eductor system to maintain a cuttings-feed and processing rate. Hot water is pumped through the eductor, and a vacuum is created that causes suction of the tar-sand cuttings into the body of the eductor. At this point, the two streams are mixed, providing sufficient shear force to break the agglomerated bitumen and sufficient heat to soften the bitumen. The mixed phase is discharged against backpressure and feeds a hydrocyclone, which uses centrifugal force to separate the sand from the water. The underflow contains the sand and some residual bitumen that enters a secondary cleaning-and-separation process. The overflow contains the process water and the separated bitumen. The hydrocyclone underflow discharges into an elutriation column, which acts as a secondary separation step. The use of a funnel to feed the elutriation column effectively allows the hydrocyclone overflow to enter the column at the correct velocity. An upward flow of hot water from the base of the column heats the bitumen and causes it to float to the surface of the column. The clean sand will flow down the elutriation tube by passing down the outer boundary, where the upward water flow is negligible. The design of the elutriation column is critical to the success of this stage to prevent significant quantities of fine sand and clays from being carried over into the water overflow. Stokes' law states that the settling or terminal velocity of a particle is governed by the acceleration, particle size, density difference between solids and liquid phase, and the viscosity of the media.

If the upward water flow in the elutriation column causes a particle to rise at a velocity greater than the terminal velocity, then the particle will not settle in the column. By selecting the correctly sized column, the upward-water-flow rate can be controlled. Prior testing indicated that approximately 90% of the solids contained in the drill cuttings were 32 µm or larger in diameter, and, therefore, the column was designed so the terminal velocity of the 32-µm particle was greater than the water-rise velocity. The clean sand then can be eluted from the bottom of the column and conveyed from the treatment unit by use of an auger or other solids-conveyance system.

The hydrocyclone overflow and water/tar from the elutriation column are discharged into a separation tank. A baffle plate divides the tank. On one side, a polyethylene drum that has an affinity for bitumen rotates to collect the bitumen from the surface of the water, with a scraper removing the bitumen as the drum rotates. On the other side of the baffle is a weir plate. The cleaned water flows under the baffle plate and through the weir plate to a hot-process water-storage tank. Any fine suspended solids and residual bitumen are removed by polymer treatment and centrifugation if necessary. The water tanks are small because this water is recycled to feed the eductor. For the unit described, the volume of water that can be circulated is 400 L. Because the system is a closed loop, energy will be conserved and waste minimized.

The tar-sands cleaner, designed to treat small batches of cuttings, will be developed further to accommodate larger processing rates so this technology can be used on a commercial scale. With ever increasing environmental regulations, this technology is very important for tar-sand drilling operations. The tar-sand-recovery process is already under criticism for its energy consumption, greenhouse-gas emissions, and environmental impact on the surroundings. Some estimate that the Athabasca oil sands will soon be Canada's biggest contributor to global warming, and the tailings ponds containing the byproducts from the extraction process are even visible from space. With increasing focus on the SAGD method, the market demand for this technology is potentially large. **JPT**