CRI aims to reduce reinjection risk, liability

RC Minton, F.E. Fragachán
and Q Guo, M-I SWACO

A UNIQUE SUBSURFACE cuttings reinjection (CRI) assurance service, comprising a team of geomechanics and petroleum engineering specialists, is successfully providing premium integrated solid and liquid waste injection services for operators worldwide.

Services contained within the integrated package include front-end engineering and feasibility studies, project-specific injection procedures, custom-designed subsurface injection equipment, specifically trained subsurface injection engineers, monitoring and evaluation of ongoing operations.

A key objective of the integrated group is mitigating the risks and potential long-term liabilities associated with subsurface waste injection and disposal. The all-inclusive and one-of-a-kind service has been employed in high-profile projects off Sakhalin Island, Mexico's Bay of Campeche, the Caspian Sea and elsewhere.

THE CRI PROCESS

When oil-based drilling fluids are utilized in the drilling operation, the cuttings are covered with a residual layer of the oily fluid and have to be disposed of in such a way as to avoid environmental damage. In offshore CRI operations, these cuttings are most commonly mixed with sea water and energized via some form of mixing energy, such that the mixture forms stable viscous slurries that are pumped into a dedicated disposal well, or through the annulus between casing strings.

In most cases, the injection program proceeds without serious mishap. However, there are many instances of the annuli or casings becoming blocked and of blockages of the injection perforations. Additionally, there are reported cases of slurry migrating through natural fractures, or poorly cemented sections of the well, back to the surface and, cases of the fractures propagating back to the sea bed with consequential release of the slurry.

These failures have resulted in significant environmental damage and have been costly in terms of remediation of the injection well, clean-up programs and, in some cases, have necessitated the drilling of new injection wells. Operators have been fined for their failure to control the CRI process, and, on occasion, injection permits have been revoked, impacting the whole drilling program.

It is evident that a more thorough engineering and assurance approach is required. Inherent risks in the process need to be identified and pro-actively managed. Additionally, continuous monitoring of the CRI process needs to be improved such that any developing failures can be identified at an early stage and mitigation steps taken.

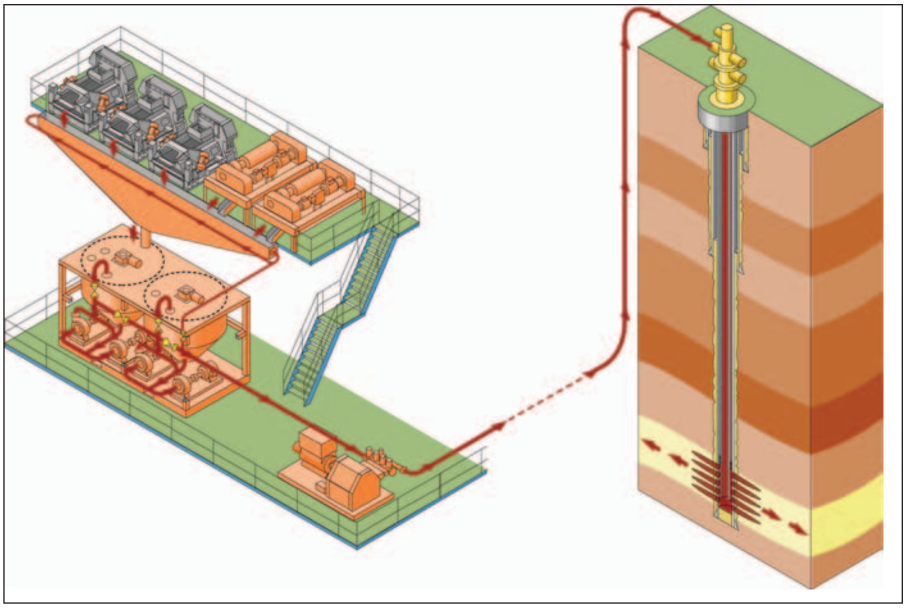
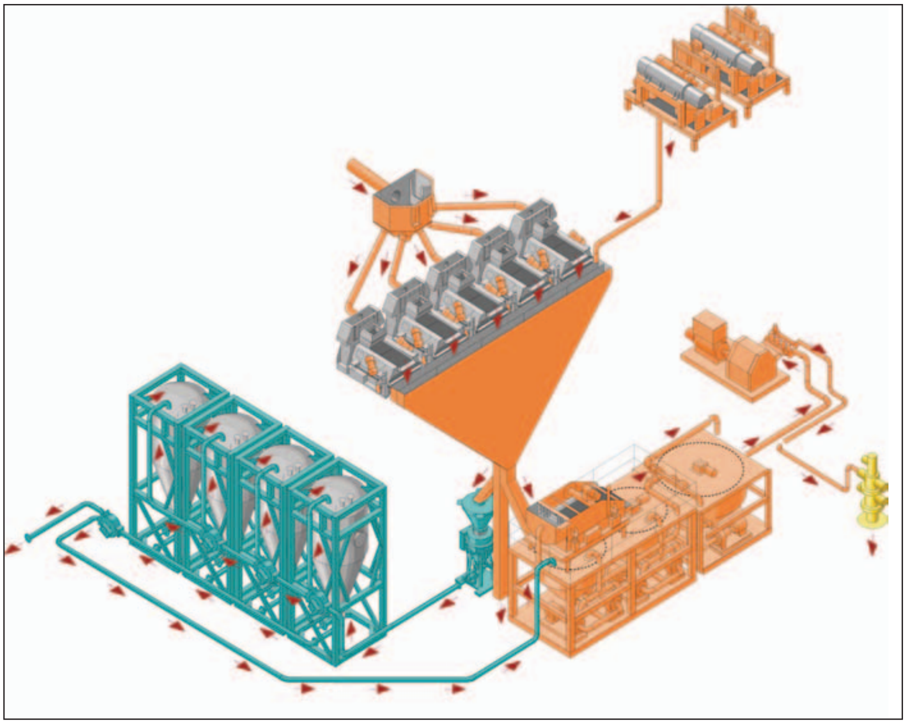


Figure 1 (above) shows a schematic of the CRI process. **Figure 2** (below) shows a simplified schematic of an installed system designed to allow continued drilling during periods of equipment repair and to provide buffer storage during fast drilling operations.



MITIGATING SURFACE RISKS

Delays to the drilling operation can be caused by mechanical failures of the CRI equipment or because of undercapacity. To obviate these risks, it is important to de-couple the drilling and CRI operations. This can be achieved through the installation of additional processing capacity. However, with space at a premium offshore, this is often impractical. While preventative maintenance reduces the risk of failure, it does not address the undercapacity issue during rapid drilling phases. However, recent advances in the pneumatic collection, transportation and storage of oily cuttings mean that equipment failure issues and undercapacity limitations can now be overcome.

Cuttings and the solids from the centrifuges can feed directly to the CRI unit, as usual. In the event of failure or excess cuttings production, part or all of the volume can be pneumatically transferred to the storage tanks. Once the repair is complete or the cuttings generation rate slows down, cuttings can then be transferred from the storage tanks back to the CRI unit for processing. This effectively de-couples the drilling activity from the CRI process, allowing for optimum drilling performance.

REDUCING THE RISKS

A CRI disposal solution must be supported by a sound engineering assessment. Simulating different "what if" scenarios provides a probability window of results, that, if adequately managed, will minimize the risks of failure.

For instance, continuous monitoring of slurry quality and, more importantly, formation pressure response to injection, in conjunction with special diagnostic plots, has proven to be invaluable tools to mitigate the associated risk.

The "know how" infused in these pressure responses is not trivial and requires a continuous analysis to every batch injected. In fact, from well to well, each set of conditions represents a new set of "in-situ" domain parameters requiring characterization and engineering evaluation. Extrapolations of local best practices without specific understanding in-situ geomechanics and reservoir conditions have major ingredients of environmental and financial fiascos.

It must be noted that these evaluations are performed based on data gathered, which is as good and sound as its quality. The high visibility of legislations worldwide has driven the need to enhance the quality of these data. In fact, currently it is common to encounter projects with bottomhole pressures, opening up for a huge understanding and interpretation in pressure decline "anomaly" — behaviors that have been so labeled because a sound engineering understanding of its behavior is pending.

This is the challenge to the engineering risk assessment. The evaluation and interpretation of these pressure analysis signatures, reflecting information regarding not only the geometry, spatial distribution of the injected waste, and containment, but of the effectiveness of the injection and, even more important, about its endurance.

ALLEVIATING PLUGGING

Plugging of the tubing, annulus or perforations is a result of solids settling from the slurry, normally during shut-in periods when the slurry is static. The rate of settlement is a function of particle size, the low shear rate viscosity of the fluid and time. When an injection well becomes plugged from particle settling, attempts have to be made to clear the blockage, re-perforate the tubing at a shallower depth or move to another injection well. All of these steps are time–consuming and costly, often impacting the normal drilling operation. In the worst case, where an alternative injection well is not available, this may even entail the drilling of a completely new well, resulting in a delay to the overall project and adding significant costs.

Quality control of the slurry is normally achieved through measurement of the fluid density and funnel viscosity. However, the slurry is thixotropic, or shear thinning. Hence, funnel viscosity is only relative, not one that can be used to model the suspension characteristics of the fluid.

In order to fully characterize the slurry's viscosity, a viscosity profile at various shear rates and temperatures is required. That can be used, within a solids transport model, to predict the rate at which the particles will settle. This in turn will dictate the safe period for the slurry to remain static and, hence, the point at which displacement of the slurry out of the tubing or annulus has to be done.

Such data can be used to develop a slurry design specification and a pumping procedure aimed at minimizing the risk of plugging. In the optimum case, a bottomhole pressure sensor is installed. The changing pressure readings, under static conditions, give direct indications of developing settling problems, which can then be pro-actively managed.

FRACTURE PROPAGATIONS

In almost all cases, a CRI program is preceded by a fracture-modeling study using numerical predictive models of various degrees of sophistication. These indicate the likely propagation behavior of the fracture relative to the injected volume. However, even the most sophisticated 3-D model predictions are inaccurate because of the assumptions made in creating the model.

At the planning stage, the rock properties are seldom well understood; the exact lithological sequence is not known, and assumptions have to be made for a wide variety of the input parameters. This is particularly true with respect to physical rock properties. In order to overcome these limitations, a probabilistic approach needs to be taken, where multiple models run is conducted using the range of values for each variable.

Once the injection well has been drilled and logged, the measured rock properties and an exact lithology sequence can be input into the model, thus improving its accuracy. Then, the first injection sequence, with its information regarding the cycle of injection pressure for particular pumping rates, slurry densities and viscosities, validates the model. This cycle of monitoring, model update and validation then needs to be repeated at intervals during the slurry injection project, so that the model can be continually refined and the projected ranges of capacity, fracture growth and pressure development, narrowed. This provides the assurance that the formation pressure response is developing as predicted.

Deviations from the modeled pressure trends during the injection phases then provide early warning signals of unexpected fracture development. Both pressure responses during injection and during decline analysis must provide an insight to evaluate the likely causes of the pressure "anomalies" and steps be taken to mitigate the consequences of the unintended development and/or provide the engineering needs to get back on track.

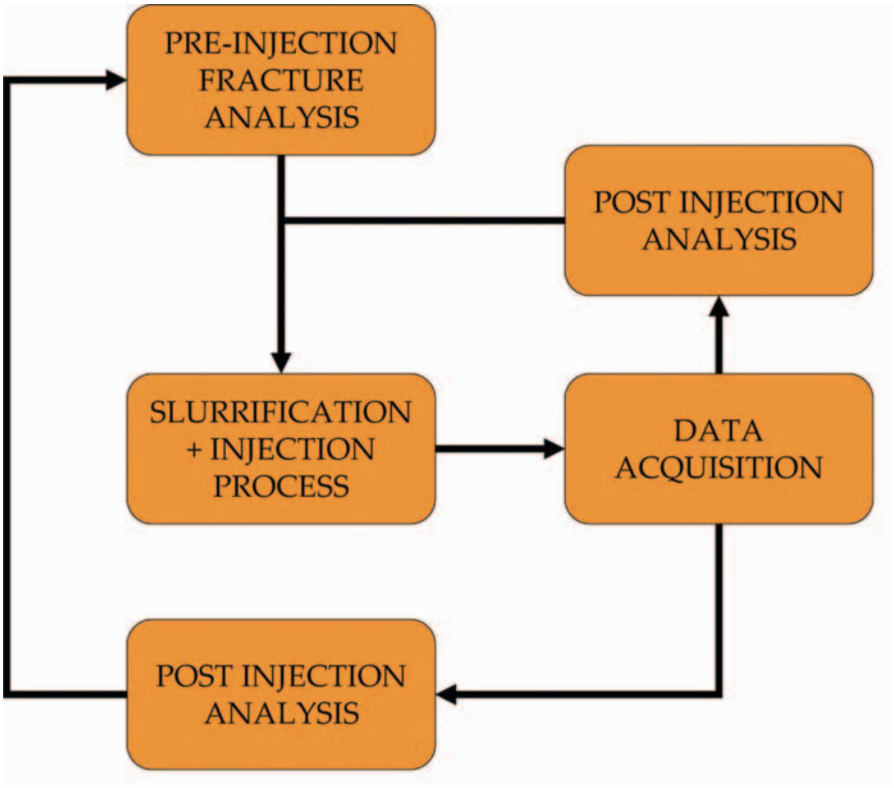


Figure 4: Cycle of monitoring, model update and validation.

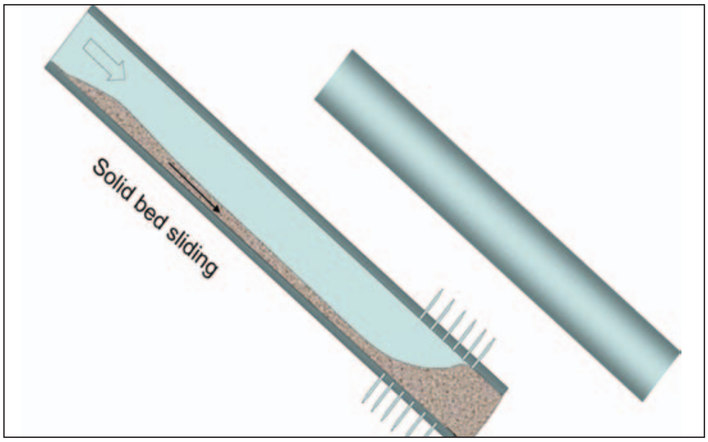


Figure 3: When cuttings settle on the low side of the wellbore, they form a bed that ultimately becomes unstable and slides downhole.