Understanding in situ combustion

In situ combustion (ISC) involves the injection of air, enriched-air, or oxygen to enable combustion of oil within the reservoir formation, creating chemical reactions and the release of CO₂. Heat ahead of the combustion front reduces viscosity and some in situ distillation (upgrading) occurs. CO₂ created during combustion can also assist by increasing pressure and mixing with the oil, further reducing viscosity and aiding flow.

The combustion and production zone between injection and production well is typically tens of feet wide. The combustion front is at around 800–1000 degF (430–540 degC). Sand screens and perforated pipe can handle these temperatures. The completions “jewelry” (e.g., packers) are kept in the vertical section, where the produced oil is cooler, typically around 300 degF (150 degC). The primary limitation of the system is that the combustion front is hard to control. However, ISC has several benefits relative to steam injection e.g., steam assisted gravity drainage (SAGD) and cyclic steam stimulation (CSS).

Steam injection requires treatment of water and energy (usually gas) to heat the water, both of which incur significant cost. ISC avoids these heat-related costs, requiring only compressors for the injected air. It should, however, be noted that ISC is not free—the compressors are very powerful and quite expensive. ISC requires very large volumes of air, although not very high pressures, as these might damage the formation.

Steam generation produces CO₂ at the surface, representing a significant environmental impact, and heat is lost during transport to the formation. ISC produces CO₂ downhole, some of which may...
subsequently be produced to surface, but probably less than would be created during steam generation.

Steam injection systems can produce oil economically and operators understand the dynamics of these systems. By contrast, there is a lack of confidence in ISC systems, despite the fact that they have the potential to deliver significantly higher recovery rates. In addition, until recently, software tools and computer power were inadequate to handle the complexities of modeling ISC.

**ISC success stories**

ISC success stories are limited. Although used in the US during the 1950s and 1960s and in Venezuela during the 1970s, ISC has often not been economical due to low oil prices, so there is little worldwide experience. Notable exceptions include Romania and India. ISC in the Romanian Supaluc de Barcău reservoir began in 1964, since then it has maintained a production and a recovery factor of 56%. This and several other successful thermal recovery projects were celebrated at the SPE conference in Bucharest, “150 years of the Romanian Petroleum Industry”, in October 2007. In India, ONGC implemented ISC in its Balol and Santhal heavy oil fields in 1997, where recovery factors using conventional methods had fallen to 6–15%. ISC increased recovery to 30–45%, producing an additional $400 bbl/d. ONGC has developed a special ignition technique for the project to overcome the challenges of high pressures in wells over 3,300 ft (1,000 m). Several new ISC pilot tests are being performed in Canada and elsewhere and, if successful, these could be the catalyst for a rapid expansion of ISC usage worldwide. The technique may not only be applicable for heavy oil. It has also been considered for depleted conventional oil reservoirs.

**ISC requirements**

ISC requirements include high permeability (e.g., 3–5 Darcies), which is common in the shallow depths in which heavy oil bearing formations are usually found. It is most suitable for homogeneous sandstones. Formation thickness is a key factor determining well geometry and production strategy, which must consider gravity effects. The high well density required for ISC and other thermal processes means that it is usually only economical for shallow onshore reservoirs. Effective control of air injection rates requires good up-front experiments plus modeling and simulation based on actual production rates. It is also important to avoid breakthrough of air/oxygen from behind the combustion front.

The ECLIPSE Thermal simulator models the burning and break-up of the hydrocarbon components of the original oil in place (ooip) and the chemical reactions that occur at or near the combustion front during the ISC process. Coke is considered as an intermediate component which will burn so long as the temperature remains high enough. The complex effects that happen ahead of the combustion front are also accurately modeled.

Observations in laboratory combustion tubes indicate very clean rock behind the combustion front, with the clay minerals leached out, which could lead to geomechanical problems. Literature has mentioned the production of heavy metals from the clay minerals mixing with the oil—another consideration that should be tested in any pilot study.

The key to the success of ISC is the will to do it. A lot of reasons can be found by someone wanting to take a more conventional approach. ISC can pay dividends, although it needs comprehensive planning, laboratory experiments, physical and software modeling and simulation. An international oil company (IOC) will generally own production licenses for a finite duration so will need a fast return on investment (ROI). By comparison, a national oil company (NOC) may be more attracted to the improved long-term recovery rates offered by ISC, despite the up-front investment required for studies. For both IOCs and NOCs, partnering with companies that can provide experience, facilities and technology will help to maximize returns.

**Leveraging technology**

Schlumberger has a wide range of technologies applicable to heavy oil, such as specialist proprietary completions and Sensa fiber optic continuous well temperature monitoring systems. It has a global support infrastructure and is rapidly building its heavy oil knowledge base.

The Schlumberger DBR Technology Center in Edmonton, Alberta, houses research and product development activities focused on phase behavior, flow assurance, enhanced oil recovery and heavy oil production. This is part of a global network of research, engineering and development facilities.

Heavy oil prices are increasing and the software and hardware required to effectively model the complexities of heavy oil thermal production have only recently become available. In the future, different production methods will find their own niche, and among these, growing experience and confidence will help to realize the benefits of ISC.