ABSTRACT

This article describes the feasibility of adopting the new concept of Downhole Steam Generation (DHSG) in a known Arctic heavy oil accumulation: the Ugnu field in the North Slope of Alaska. The frozen permafrost zone which overlays the heavy oil zone presents a challenge in adopting surface steam generation as is typically done in similar accumulations in Canada using horizontal injector and producer well pairs known as Steam Assisted Gravity Drainage (SAGD). In addition to retaining integrity of the permafrost, the DHSG concept shows promise to provide higher thermal efficiency, produce high quality CO2 for reuse, and effectively leverages surplus oxygen for superior recovery efficiency in an economically feasible solution.

KEY WORDS: Downhole steam generation; heavy oil; CO2 EOR; SAGD; in-situ combustion; permafrost; CHOPS.

NOMENCLATURE

Bbl: Barrels, US
cf: cubic feet (gas, standard conditions)
CHOPS: Cold Heavy Oil Production with Sand
Cp: Centipoise, viscosity unit
Ft: Feet, length
M[unit]: Thousands (Mcf, Thousand cubic feet)
MM[unit]: Millions (MMcf, millions cubic feet)
mD: miliDarcy, permeability unit
SAGD: Steam Assisted Gravity Drainage, refers to a heavy oil extraction method which employs stacked and parallel pairs of horizontal wells, the producer (bottom) and the steam injector (top).

INTRODUCTION

As discussed more extensively in recent articles (JPT 2012 and Capper et al. 2011), heavy oil production is less than 7% of the world’s oil production and this percentage is not expected to increase dramatically without significant changes in exploitation planning and reservoir management processes (Bonnie et. al. 2005). Not accounting for downstream limitations (which relate to existing refinery capacities and feedstock allowances), heavy oil recovery efficiency is generally low and at a relatively high unit cost, unless enhanced oil recovery methods are used. Steam or CO2 injection methods account for most of the oil recovered worldwide using Enhanced Oil Recovery (EOR) methods. Since the early 1960s, steam and CO2 injection have been used successfully – with CO2 being applied primarily to pressurized light oil fields, as well as some heavy oil fields; and steam applied to viscous heavy oil fields. Reservoir depth and high pressure are limiting factors, among others, for wider application of steam injection in particular. Although there is some overlap in fields that could benefit from either CO2 application or steam, there are relatively few recorded attempts to implement both methods simultaneously. Air injection, first tried as an EOR method, has not been widely implemented because in-situ combustion can be difficult to control in shallow reservoirs and can be especially challenging without water co-injection.

Benefits from effective downhole heat generation have been known to the industry for decades, but to date practical application to heavy oil exploitation has yet to be realized. A recent conceptual design (Castrogianni et. Al. 2011) for Downhole Steam Generation (DHSG), which combines thermal EOR together with CO2 or nitrogen injection, is yet to be field tested, but shows promise to overcome technological barriers, provide improved thermal efficiency and enable exploitation of deeper formations. Such a system includes a novel burner design having fuel, water, and EOR gases delivered to the burner via a fit for purpose umbilical, with burner effluents that include high quality steam and flue gases in an advanced EOR process which is delivered directly to the reservoir face, without steam quality losses. Although the implementation of such DHSG technology is still in the design stage, application of DHSG technology in arctic heavy oil deposits and particularly the Ugnu field in Alaska has been studied in detail and presents a viable exploitation alternative. The implementation is designed around the concept of Steam Assisted Gravity Drainage (SAGD), using horizontal well patterns which include alternating Drive wells. Infrastructure scoping and economic