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# Oil Recovery from Tarmat Reservoirs Using Hot Water and Solvent Flooding

T. M. OKASHA
Saudi Aramco
H.K. MENOUAR, S.A. ABU-KHAMSIN
King Fahd University of Petroleum and Minerals

## Abstract

The existence of tar accumulations (tarmat) beneath the oil zone in some reservoirs creates productivity problems through restricted aquifer support during the primary recovery stage. It also affects the performance of peripheral water injection when the tar/oil boundary is irregular.

The objective of this study was to investigate and evaluate combined solvent and hot water injection beneath the tarmat to improve aquifer support by displacing and dispersing the tar. Displacement runs were conducted in one-foot long Berea sandstone composite cores, simulating a tar zone and an oil zone in series, at injection rates of 1 ml/min. and higher.

The results show that although the oil recovery from hot water displacement is lower than cold water displacement in the absence of tar, the gain in recovery for hot water over cold water is substantial in the presence of tarmat. Driving a slug of solvent with hot water to displace tar increases the hydrocarbon recovery even further. However, for each of the two solvents studied, there is an optimum slug size with which the hydrocarbon recovery is maximum. Moreover, the recovery was found to increase further when the optimal slug is divided into portions separated by small slugs of hot water.

The injection rate had a profound effect on the recovery for all hot-water flooding schemes. The results showed consistently that the recovery increased at lower injection rates.

## Introduction

Many oil reservoirs are characterized by the presence of a highly viscous hydrocarbon layer (tarmat) at the oil/water contact. Such tarmats are found in many major oil reservoirs in the world and, particularly, in the Middle East. They are reported in the literature to vary widely, ranging from highly viscous hydrocarbon fluids to near solid materials[1]. The thickness of the tarmat varies from place to place in the same reservoir and sometimes reaches few hundred feet; while their extent can reach several kilometres. In Ghawar field, for example, the tar zone extends more than 25 km and reaches up to 150 m in thickness[2].

Several geochemical studies presented by various authors attribute tarmat formation to gravity segregation which leads to a compositional grading with depth[3-5]. Depending on reservoir conditions and tar viscosity, field experience shows that some of these tarmats can become mobile under conditions of moderate differential pressure[2].

The presence of tar deposits at the oil/water contact in a tarmat reservoir can have serious adverse effects on the effectiveness of natural water drive as well as secondary recovery projects. When the tarmat completely surrounds the oil zone, the oil reservoir behaves like a finite lens where the pressure decreases rapidly as soon as the first well starts producing. This leads to an alarming increase in gas/oil ratio during the primary stage of depletion which has been the case with Minagish reservoir in Kuwait[2]. Another such example is El Bundug reservoir in Qatar[6].

In other situations where the tar has some mobility or thins out at some location, a breakdown of tarmat may occur as a result of the build up of large pressure differentials across the tar layer leading to severe water conning.

Although publications on recovery of heavy oil from tar sands are numerous, studies done on tar displacement in consolidated matrix are relatively rare. A study on cold waterflooding in a tarmat reservoir laboratory model (composite Berea sandstone core) was carried out by Abu-Khamsin et al.[7] The results showed that oil recovery slightly decreases as the viscosity-thickness product of the tar zone increases. Another study was conducted by Harouaka and Asar[8] on tar properties and methods for improving injectivity in tarmats using naphtha and steam.

The purpose of this study was to investigate some techniques to improve the tar mobility with the aim of tar displacement in a tarmat reservoir and the effect of such techniques on oil recovery in this kind of reservoir. Specifically, the use of a combination of solvent and hot water to displace the tar was evaluated. The effects of temperature, solvent slug size, type of solvent, injection rate, and injection mode on recovery were examined in detail. A reservoir laboratory model representing the tar and oil zones was simulated by a linear composite core.

## Experimental Apparatus and Procedures

### Apparatus

A schematic of the experimental apparatus used in this study is shown in Figure 1. It consists of the fluid injection system, core holder, an oven, a differential pressure instrument, temperature measurement, recording system and a fraction collector. A Hassler type, stainless steel core holder designed for consolidated core samples up to 31 cm in length and 2.54 cm in diameter was used. It can withstand pressures up to 69 MPa. Detailed description of each component of the apparatus as well as configuration of the core holder and end plugs are found elsewhere[9].

A reservoir volume element with sections of the tar and oil zones is simulated by a linear composite core. When a displacement run involves a solvent slug, a piece of core is saturated with the required amount of solvent and placed before the tar core. The configuration of the composite core as it is loaded in the rubber sleeve is shown in Figure 2.

### Materials

In this study, filtered kerosene was used to simulate the oleic