Pilot Testing of a Walnut Shell Filter for Heavy Oil Removal at High Temperature

Introduction

Pilot testing is an effective way to determine the performance of produced water treatment products and solutions prior to building full-scale systems. In this case, pilot testing was performed to determine the ability of a walnut shell filter to remove heavy oil (API 13.3) at high temperature (~90° C) – conditions commonly found in heavy oil production operations.

Background

Oil production can result in two to ten barrels of produced water per barrel of oil. This produced water requires further treatment prior to disposal/reinjection, discharge or reuse. Treatment steps for produced water typically include primary (API Separators/Hydrocyclones), secondary (Gas Flotation) and tertiary treatment (Media Filtration).

Walnut shell filters are a proven technology in tertiary treatment applications. However, their applicability in heavy oil operations has not been widely accepted for a variety of reasons, including ineffective removal of heavy oil, the potential for media degradation, and the volume of backwash water needed to effectively regenerate the media.
The Study

In the spring of 2014, a walnut shell filter was pilot tested to determine its effectiveness in the removal of heavy oil (API 13.3) from produced water at high temperature (~90° C).

In this bench scale pilot study, a synthetic produced water was created. Two heating systems were used in series to heat the water to 90° C. Fresh tap water flowed through the first electric heater, and then into a 1,000 gallon tank, in which three heating elements were installed. The tank was used to control the temperature. A pump was used to draw water from the tank and send it through the walnut shell filter pilot unit. A high-viscosity oil pump was used to pump heavy crude oil into the feed line at a desired rate. The oil/water mixture then passed through a static mixer and globe valve to promote mixing and shearing of the oil droplets. A diagram of the test setup is shown below in Figure 1.

Figure 1 – Pilot Test Oil Flow Scheme

The pilot test set-up was designed to create feed water with up to 500 mg/L oil that was at a temperature of 90°C. The high-viscosity pump drew the oil from a reservoir that enabled measurement of the level of the oil before and after each test condition, to determine the amount of oil added to the system. The system was also designed to automatically backwash after 24 hours of continuous operation, and the system was backwashed one time after each completed test condition, unless otherwise noted.

Conditions tested at 90° C included:

- 13.5 gpm/ft² flux, 25 mg/L feed oil concentration
- 20.25 gpm/ft² flux, 50 mg/L feed oil concentration
- 13.5 gpm/ft² flux, 100 mg/L feed oil concentration
- 13.5 gpm/ft² flux, 50 mg/L feed oil concentration, 25 mg/L solids
- 13.5 gpm/ft² flux, 100 mg/L feed oil concentration, 25 mg/L solids
The performance of the walnut shell filter is determined by analyzing how much oil remains in the effluent. All Hexane Extractable Material (HEM) and Total Suspended Solids (TSS) results were analyzed by an in-house laboratory. Many of the effluent HEM samples were non-detect, however, in the graphs following, the non-detect samples are listed at the detection limit (1.51 mg/L).

Another measure of determining the performance of the walnut shell filter is to monitor how much oil the media is able to load. This is done by calculating the grams of oil that are loaded onto the media per cubic inch of media (g/in³).

The pilot unit was backwashed every 24 hours or if oil breakthrough in the effluent occurred (>5 mg/L oil concentration). The pilot unit was backwashed with the synthetic produced water.

The backwash procedure was:

- Media Roll (4 Min)
- Vessel Flush (3 Min)
- Media Roll (3 Min)
- Vessel Flush (3 Min)
- Media Roll (2 Min)
- Vessel Flush (3 Min)
- Bed Settle (1 Min)
- Purge (5 Min)
- Total Backwash Time = 23 Minutes

Suspended solids were added to the feed in later tests. This was done by pumping a concentrated slurry of baby powder (magnesium silicate) to the feed, and averaged 25 mg/L throughout all testing.
Test Conditions

13.5 gpm/ft², 25 mg/L Feed Oil (Test 13-14)

Two consecutive runs were completed at this test condition. All of the effluent HEM samples were non-detect (<1.51 mg/L). The media was able to load 0.20 g oil/in³ of media before being backwashed after 24 hours.
Three consecutive runs were completed at this test condition. All but one of the effluent HEM samples were non-detect (<1.51 mg/L). The media was able to load 0.39 g oil/in³ of media before being backwashed after 24 hours of continuous operation.
Effluent quality diminished when the flux was increased to 20.25 gpm/ft², and the vessel needed to be backwashed after approximately eight hours. The media was only able to load 0.21 g oil/in³ of media on average.
This condition had five consecutive runs. During this time, 22 of the 25 effluent HEM samples collected were non-detect (<1.51 mg/L). The media was able to load 0.79 g oil/in³ of media before being backwashed after 24 hours of continuous operation.
13.5 gpm/ft², 50 mg/L Feed Oil, 25 mg/L Solids (Test 28-31)

The first run with solids addition was successful, and continued for 24 hours with all effluent HEM concentrations <1.5 mg/L. However, the next two runs were unable to produce the same performance. It was determined that with the addition of the suspended solids an extended backwash was required to fully clean the media in between test conditions.
13.5 gpm/ft², 100 mg/L Feed Oil, 25 mg/L Solids (Test 32)

A single run was conducted at 13.5 gpm/ft², with 25 mg/L suspended solids addition. It took four hours for the estimated oil effluent concentration to get to <10 mg/L, and it only remained there for three hours. The estimated oil effluent concentration was >10 mg/L for the remainder of the test.

Conclusions

As a result of this testing, the following conclusions were drawn:

- The walnut shell filter is able to operate for 24 hours at high flux rates of 13.5 gpm/ft² with an inlet feed concentration of as much as 100 mg/L, and is able to produce a constant effluent of <1.5 mg/L.
- The original backwash program was effective at cleaning the media when the synthetic produced water consisted of only tap water and heavy crude oil.
- When additional suspended solids were supplemented into the synthetic produced water, an extended backwash program with additional media roll/flush steps is required to fully clean the media.

Therefore, this pilot test showed that a walnut shell filter does have the ability to remove heavy oil (API 13.3) at high temperature (~90° C). In these types of conditions, which are commonly found in heavy oil production operations, the walnut shell filter is able to effectively remove heavy oil from high temperature produced water without significant media degradation. Additionally, the walnut shell filter does not require a high volume of backwash water to effectively regenerate the media.

The Monosep™ high-flow walnut shell filter from Siemens has proven to be an effective tertiary treatment step in heavy oil/high temperature produced water conditions. The Monosep filter’s proprietary design requires no moving parts to perform backwashes, and greatly reduces the volume of backwash water produced when compared to other walnut shell filter designs. This simplifies the design of the filter, reduces the weight and footprint, and lowers the cost of multiple filter systems.