# HEAT ENHANCED RECOVERY OF NAVY SPECIAL FUEL OIL

By
John D. Conway. P.G., NAVFAC, Atlantic Division, Norfolk, Virginia
David E. Fulton, P.G., IT Corporation, Trenton, New Jersey

This poster presentation is a case history of an innovative approach to recover highly viscous Navy Special Fuel Oil (NSFO) from the subsurface using a closed-looped indirect steam process in conjunction with a series of recovery trenches and water treatment. The presentation will highlight the application of "indirect" steam heating at the Fleet and Industrial Supply Center, Defense Fuel Supply Point, located in Yorktown, Virginia. This facility served as a bulk storage and fueling operation between 1918 and 1980. Historical losses over the years resulted in an estimated 3 million gallons of NSFO released into the subsurface, covering approximately 13 acres. Construction techniques such as horizontal directional drilling and "one-pass" trenching are highlighted as well as treatment technologies using precipitation, dissolved air floatation, organic clay, filtration, and activated carbon. Recovery rates, system performance data, and cost information for the Yorktown project are also presented that illustrate the benefits of this innovative thermal approach.

## PROJECT BACKGROUND

The Department of the Navy uses a variety of petroleum fuels in support of naval operations, including gasoline, diesel, aviation gas, and navy special fuel oil (NSFO). Specialty fuels such as NSFO are less common; however they have a variety of physical and chemical properties that make remediation of these fuels more difficult. In particular, these heavy fuel oils are highly viscous and possess high specific gravities. Subsequently, the amount of available information about remediation of these fuels is limited due to the lack of spill sites involving this unique fuel. Therefore, innovative remediation methods and technologies are needed to clean up these sites to meet state regulatory criteria.

One such site requiring a unique remediation method is a Naval Fuel Farm located in Southeast Virginia. The site was activated in 1918 with the construction of eight reinforced concrete tanks, each with a holding capacity of 90,000-barrels (3,780,00 gallons). The site comprises 110 acres of generally flat, open field terrain at an elevation of 25 to 50 ft above sea level. The NSFO Tanks were used until 1980 when groundwater was discovered in the tanks and NSFO was found seeping from a low-lying area to the east of the NSFO tank area. Losses over the years resulted in an estimated 3 million gallons of NSFO released into the subsurface, covering approximately 13 acres.

Remedial objectives were established and a Corrective Action Plan was developed and approved by the Virginia Department of Environmental Protection (VDEQ). The remedial action was required to meet a free product clean-up goal of 3 mm (0.01 feet), and a soil total petroleum hydrocarbon (TPH) goal of 25,000 parts per million (PPM).

## CHARACTERISTICS OF NSFO

NSFO is the equivalent of No. 5 (light) fuel oil which is produced by blending No. 6 fuel oil with lighter distillates (Perry, 1984). The physical and chemical properties of NSFO determine how it moves within the subsurface, its recoverability, and its ability to partition into other phases (i.e., vapor and dissolved). Viscosity of NSFO is the primary physical characteristic, which relates to mobility. NSFO has a viscosity of 170 centistokes at ambient temperature, which is 250 times that of gasoline, at 0.68 centistokes. Therefore, when released in a medium such as the site soils, which have an estimated porosity of 35 percent, NSFO is relatively immobile.

## REMEDIAL DESIGN CRITERIA

While the use of direct steam injection proved to be the most successful during the pilot test, several site-specific concerns were identified with this application. Subsequently, the use of “indirect” steam heating was selected as the method for heat enhanced recovery. Indirect steam heating involves generating steam and circulating it through a closed-loop grid system. The grid system consists of piping that is placed just below the NSFO/groundwater interface using horizontal directional drilling techniques. Radiant heat from the steam grid heats the NSFO/groundwater interface directly to reduce NSFO viscosity and enhance mobility. Recovery trenches placed around the site perimeter and between the former tanks will allow for effective groundwater depression and NSFO removal. This innovative modification to steam heating provides the following advantages:

Reduced capital costs associated with multiple boilers

Reduced make-up water requirements and lower costs associated with water pre-treatment

Boiler fuel consumption is significantly reduced

The closed-loop steam grids provide radiant heat directly at the NSFO/groundwater interface without creating an emulsion

The use of closed-loop steam grids eliminates groundwater mounding

The risk of fugitive vapors is eliminated and the capital cost for expensive vapor collection and treatment is eliminated

Indirect steam heating grids that are horizontally drilled address the site constraints associated with the buildings and structures

The use of recovery trenches will transect and normalize local heterogeneity

## REMEDIAL STRATEGY

A stepped approach was developed to gradually and incrementally phase in the different elements of the recovery system. These phases include:

STEP #1: Initiate NSFO skimming only
STEP #2: Initiate hydraulic control
STEP #3: Initiate steam heating
STEP #4: Initiate heated infiltration to recover residual NSFO

**RESULTS**

While direct steam injection has been used in the environmental remediation industry to volatilize contaminants into the vapor phase or heat viscous fluids, this project required an innovative approach to maximize recovery of the highly viscous NSFO while minimizing waste streams and mitigating risks to off-site sensitive receptors. The following innovative technologies were used on this project:

Steam lines installed using the horizontal directional drilling technique
Recovery trenches installed using the “one-pass” trenching technique
Stainless steel and CPVC wells installed in the recovery trenches using vibratory drilling equipment
Pneumatic groundwater extraction and NSFO skimming pumps
Treatment of extracted groundwater using precipitation, dissolved air floatation, organic clay, filtration, and activated carbon
Capability for treated water to be either heated to 60 degrees Celsius for infiltration into select trenches or cooled for discharge to the York River.

Recovery rates, system performance data, and cost information for the Yorktown project are presented to illustrate the economic advantages to “indirect” steam heating.

Prior to the use of indirect steam, approximately 18,049 gallons of NSFO were recovered over a five-year period. Step #1 was implemented between April and July 2000, recovering 10,521 gallons. Step #2 was initiated in August 2000. Between August 2000 and April 2001, approximately 42, 927 gallons have been recovered.

The project was completed within schedule and budget. The recovered NSFO is sold to a recycling company and generates a cash value of $0.12/gallon. Steam Heating was initiated in late May 2001.

The steady and controlled propagation of radiant heat to the NSFO layer using steam in a closed-loop system is an innovative approach to remediating heavy viscous fuel oil.