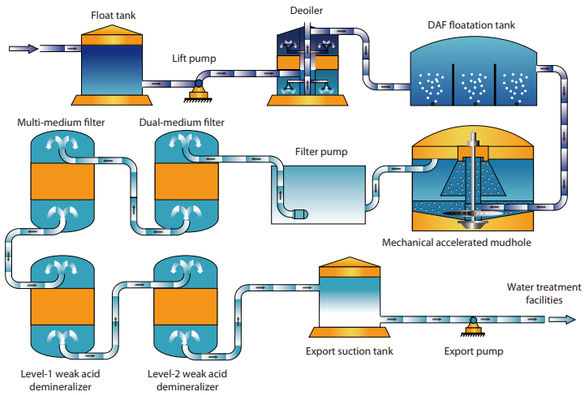
CNPC's superheated steam injection technology is significant for SAGD development of ultra heavy oil and super heavy oil. It can supply high-dryness and even superheated steam necessary for SAGD development without increasing the cost of existing water treatment systems. This is why we say it can much help to increase the production of hard-to-tap heavy oil.

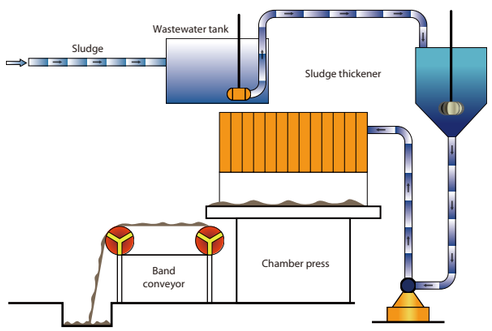
Cyclic utilization of heavy oil wastewater

Extracting heavy oil needs a great deal of clear water, while outputting a large amount of wastewater. In Liaohe Oilfield, heavy oil wastewater is treated and boiled to produce steam, which then is re-injected into heavy oil reservoirs. In this circulatory process, 30 million tons of clear water can be saved each year, energy consumption can be reduced due to higher temperature of water supplied to steam boiler, and more importantly, pollution to the environment is eliminated.

Heavy oil wastewater, after being treated by deoiling, suspended sediment removal, air flotation, silicon removal, filtration and softening, is reused as water source to boil steam for the thermal recovery of heavy oil. In this way, water and heat from the wastewater can be made full use and environmental impact can be reduced.



Wastewater treatment flow



Sludge dewatering flow

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Heavy Oil Thermal Recovery

China National Petroleum Corporation

CNPC has discovered and proved abundant heavy oil resources in the Songliao, Bohai Bay, Junggar, Tuha, and Tarim basins in China. We have built two major heavy oil production bases in the Liaohe and Xinjiang oilfields, producing 12 million metric tons of heavy oil annually, about 10% of CNPC's total crude output.

As a result of years of study and practices, CNPC has developed advanced and applicable heavy oil recovery technologies, enabling the heavy oil with a viscosity up to 100,000 centipoises or buried at a depth of 5,300 meters to be extracted to the ground.

Huff and puff is the major technology CNPC uses to produce heavy oil, which can generally improve the recovery efficiency to over 20%. For mid-deep heavy oil reservoir, steam flood has been applied successfully after multi-cyclic huff and puff, enhancing recovery efficiency by more than 25%. Pilot SAGD with vertical/horizontal wells for extra-heavy oil recovery has achieved success and been put into industrial use, which can potentially raise the ultimate recovery efficiency to 56%.

Major thermal recovery methods:

- Huff and puff
- Steam flood
- Steam assisted gravity drainage

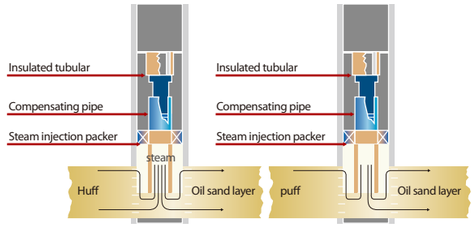

Diagram of huff and puff (injection and recovery)

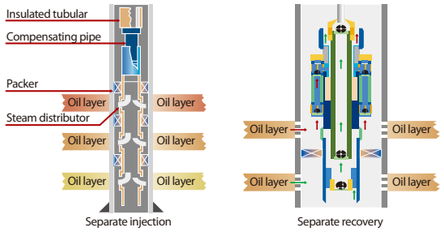

Diagram of separate injection and recovery

Steam flood for mid-deep heavy oil recovery

The steam is injected into the oil layer via injectors to form a saturated steam zone around the wellbore. The front of the steam zone cools down due to heat exchange with reservoir rocks and fluids. The steam condenses (hot water) generated thereby drives the oil to the producers, where it is extracted to the ground. The displacement process is a combined effect of viscosity break, thermal expansion, steam distillation, degasification, dissolved gas drive and miscible flooding.

Case study: Steam flood after Huff and Puff for Mid-deep Heavy Oil Extraction

Lianhua Formation in Block Qi-40 in Liaohe Oilfield has a depth of 1,050m and a viscosity of gas-free surface crude of 3,000mPa·s at 50°C.

Block Qi-40 has been developed by huff and puff since1987. In 1998, CNPC launched a pilot steam-flood with four well groups in mid-deep heavy oil reservoirs. After excellent performance had been seen in the pilot test and the expanding test, commercial steam flood was applied throughout the block, a total of 150 well groups being deployed and the ultimate recovery efficiency is expected to be 55%.

SAGD with vertical-horizontal wells

Drill a horizontal well at the bottom of the reservoir and one or several vertical wells above it. Inject the steam continuously into the drilled or already existed vertical wells to create a steam chamber, which expands and heats the layer of hydrocarbons. The fluidized heavy oil and water condensed from the steam then flow by gravity to the horizontal producer, where they are pumped to the surface.

Advantage

- Higher recovery capability
- Higher oil/steam ratio
- Higher ultimate recovery efficiency
- Minimize interwell interference and avoid premature interwell communication

Features

- Deep burial depth: 600-1000m
- Largely altered original reservoirs: after huff and puff production
- Existing vertical wells

Case study: SAGD after Huff and Puff for Extra-Heavy Oil Extraction

Guantao Formation in Block Du-84 in Liaohe Oilfield is buried at a depth of about 650m, with a crude viscosity of 230,000Pa·s. Since SAGD was conducted years ago, all production indexes have met their targets, owing to dynamic performance tracing, optimization and adjustment. The recovery rate is 5.1% currently, with the oil/steam ratio kept at 0.22 during the period. As the steam chamber expands, output will increase, likely to drive the ultimate recovery efficiency by huff and puff–SAGD to 56%.