

## The Research Progress of Oil Sand Separation Technology in China

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Received 25 October 2012; accepted 17 December 2012

### Abstract

From 2007 to 2008, Research Institute of Petroleum Exploration & Development, Langfang Branch launched oil sand resource exploration and the study of hot water separation technology in Fengcheng area, Northwest of Junggar Basin, and the recoverable oil-sand oil resource is 54.98 million tons with the oil content in 7.1-10%, which is distributed in Cretaceous and Jurassic with the thickness of 80-140 meters, the cover depth of oil sand is 50-90 meters. Combining with the characteristics of the oil sand in this area and based on the research of hot water separation mechanism in oil sand, the hot water separation reagent for the oil sand in this area has been successfully developed, and its separation rate reaches 90%, provided that the concentrations of the agent is 4% and the separation temperature is 85 °C. Based on series of study, the construction of testing site, which is capable of processing 10,000 tons oil sand in this area, is completed, and the on-site separation tests of oil sand are launched with the recovery rate of 90% in normal operation, and the hot water separation technology and equipment research & development are successful.

**Key words:** Oil sand; Hot water separation technology; Separation reagent; Tests

Fang, C.H., Zheng, D.W., Ge, Z.X., Li, X.L., & Huang, Z.L. (2012). The Research Progress of Oil Sand Separation Technology in China. *Advances in Petroleum Exploration and Development*, 4(2), 63-70. Available from: <http://www.cscanada.net/index.php/aped/article/view/j.aped.1925543820120402.893>  
DOI: <http://dx.doi.org/10.3968/j.aped.1925543820120402.893>

### INTRODUCTION

According to the results of a new round of evaluation of oil and gas resources in China, the geological resources of the oil sand oil equal to 5.97 billion tons, ranking fifth of the world, among which the recoverable resources amount to 2.258 billion tons, the forecast geological resources of oil sand oil within 0-100 meters deep amount to 1.856 billion tons, during which the recoverable resources amount to 1.131 billion tons, the forecast geological resources of oil sand oil within 100-500 meters deep amount to 4.114 billion tons, during which the recoverable resources amount to 1.127 billion tons. The oil sand oil geological resources are mainly distributed in the western of China, Xinjiang, Qinghai and Inner Mongolia. And the oil sand resources in Xinjiang Fengcheng area are the biggest oil sand with the maximum depth and best quality currently discovered in China (Jia, 2007).

The oil sand hot water separation method is currently the most sophisticated extraction technology in ground oil sand industry (Gao & Li, 2006), and moreover, such method has been massively used in commercialized mining industry, typically represented by Syncrude Company and Suncor Company in Canada. After several decades of research and accumulation of on-site mining experience, currently the oil sand industry in Canada develops rapidly, and its development technology skill takes the lead in the world. At present, 26 oil sand projects in total are put into production in Alberta, among which, 7 are strip mines, and 9 mines adopt on-site extraction technique, with the daily production capacity in total of 830,000 barrels, which amounts to 3 percent of the oil production in Canada (Tu *et al.*, 2005; Zhang, 2005).

Research Institute of China Petroleum Exploration & Development, Langfang Branch has been working on the research of oil sand extraction process and the development of extraction apparatus since 2006, and the compounding oil sand extraction agent independently

developed, which is of high efficiency and environment friendly, has the outstanding characteristics of “one-high-two-low” (i.e. high extraction efficiency, low temperature and low concentration), and plays an important roles in energy saving and consumption reducing, and cost reduction. Based on the laboratory technological parameter, it developed vertical bench-scale test device of hot water separation with the capacity of 15 tons per day, and horizontal bench-scale test device of hot water separation with the capacity of 10 tons per day in 2006, respectively, which are successfully applies to on-site extraction experiment. The results of the on-site extraction experiment shows that the bench-scale test device provided reliable and stabilized performance, and its results are consistent with the indoor laboratory experiment results, which complies with the anticipated experimental effect. In 2009, a pilot-scale test device of oil sand extraction with the capacity of 10,000 tons per year was designed on the basis of the on-site bench-scale test device’s operating parameters. The brand new test device adopts continuous process, automated operation, and the sludge processing system is initially equipped; the clay after processed will be reloaded, and the recovered agent will be put into the extraction system for cyclic utilization; the heating system of the device adopts high temperature steam heating, without any polluted gas being released.

The project is the first project on oil sand separation through washing process in China, which is significant for the commercial development of oil sand in China. The washing separation reagent is developed based on the characteristics of oil sand in Fengcheng, with the feature of fast speed, high efficiency, reusable and environmental. The experiment on washing process testing unit has also proved to be successful, which can be applied in the commercial development of Fengcheng oil sand.

## 1. OIL SAND RESOURCE EXPLORATION IN THE NORTHWEST MARGIN OF JUNGGAR BASIN-FENGCHENG

Fengcheng Oil Sand Mines is located in Wu-xia fault area on the uplift zone of Junggar Basin, with Ke-bai fault zone on the west part, Wu-xia fault zone on the east, Mafu Depression on the south part, and Hala’alat Mountain on the north part. Fragmentation and small-scale fold developed in the mining area with complex patterns, the main faults include Ulan Linge fault, Xia-hong north fault and secondary fault, which constitute the Wuerhe and Xiazijie fault zones with NE-SW direction. The mining area is 12 km long along East-West direction, 5 km wide along South-North direction, with an area of 35 km<sup>2</sup>.

In the mining area, the oil sand ore body occurrence layer contains J<sub>3q</sub> and K<sub>1t</sub>. From 2006 to 2008, 80 exploratory wells were drilled in this area, and oil sands

with different thickness were discovered. The study found that the oil sands are stratigraphically steady and continuously distributed, and the thickness of a single layer is very large. The oil contents of the oil sand are generally high, with an average rate of 7.1-10%. The thickness of the oil sand is 80-140 meters, and the largest thickness of single layer is 30.3 m, and the buried depth of the top of oil sand is 50-90 meters.

Considering that the oil content and the density of the rock in this area can easily be obtained, the oil sand resource can be calculated through gravimetric method, which is simple and accurate. Outline the effective thickness and effective oil content of the four layers of ore body, at the same time; identify the flat area of the mining area, and then asphalt geologic reserves of the oil-sand oil has been calculated out as 54.98 million tons with the oil content method.

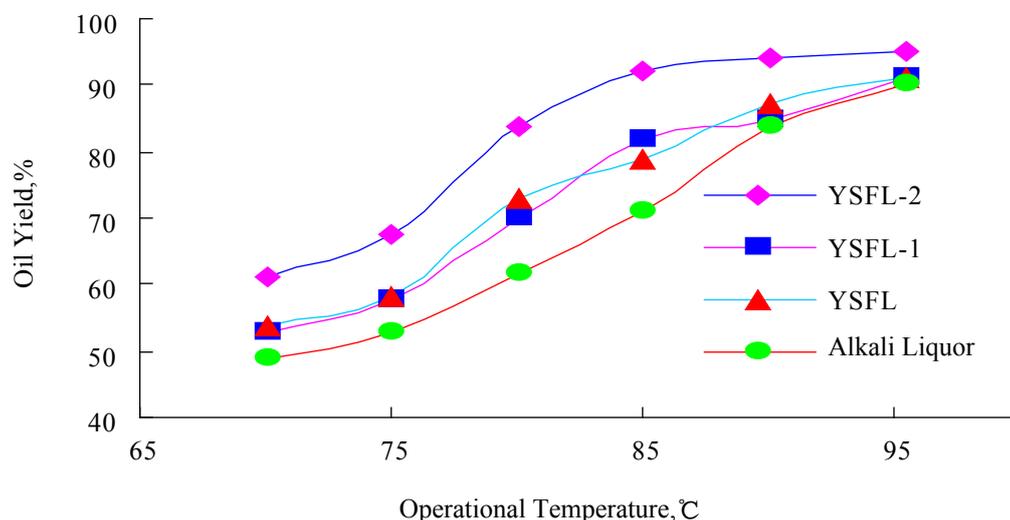
## 2. THE RESEARCH PROGRESS OF YSFL SERIES OF WATER SEPARATION REAGENT FOR OIL SAND

According to the oil displacement principle of the oil sand separation, preliminarily select several active agents such as Alkali liquor, reagent GX-p, reagent GX-si, reagent GX-12s, reagent GX-c, reagent GX-ch as inspection objects to carry out the reagent optimization (DAI & CHUNG, 1996; LIU *et al.*, 2005; LI *et al.*, 1995; Yochida *et al.*, 1997; Schramm *et al.*, 2003; Desando & Ripmeester, 2002), through the reagents reaction conditions, characteristics and the cost examination, with the surface active agent, wetting agent, and additives that can significantly change the tension, emulsifying property and wettability of the substances surface as the selected reagents, the oil sand separation contrast test should be carried out with the single Alkali liquor and reagents of YSFL, YSFL-1 and YSFL-2 which can be obtained by the compound of a variety of highly permeable surface active reagents, additives and other with the various ingredients and proportions. In order to compare the test results, the concentration of the Alkali liquor and all the reagents should be 10%, with the reflecting time of 30 min, and please see Figure 1 for the test results.

As you can see from the Figure, in case of a low temperature, the extraction effect of several reagents are unsatisfactory, and once the temperature reach 80-85 °C, the oil yield of the sample adding YSFL-2 reagent is obviously higher than those of the other two samples, around 90%, while the oil yield of the sample adding single alkali liquor is only about 70%. When the temperature reaches 95 °C or higher, the oil yields of those four samples are tend to be close with each other. It is easy to conclude that the extraction effect of YSFL-2 reagent under lower temperature is better than those reagents mixed with other two reagents and the single

alkali liquor. Although those reagents containing a single component have some effects on the oil sand extraction, the mixed reagents containing various components are better choice for purpose of high efficiency and rapid extraction, because those components in the reagent not only play a part on the extraction of oil sand, but also coordinate with each other to increase the extraction

effect. Such as the mixture of surface active agent and alkali liquor has a higher surface activity, and other auxiliaries can reduce the consumption of surface active agent and alkali liquor, meanwhile, the reaction of alkali liquor and calcium ions and magnesium ions can protect the surface active agent and auxiliaries, etc.



**Figure 1**  
**Comparisons of the Effects of Different Reagents**

### 3. INSPECTION OF THE INFLUENCING FACTORS OF OIL SAND

Investigate the impact of different heating temperature on extracting efficiency for oil sand by changing the heating temperature when the mass fraction of the extracting agent is 4%, the extracting time is 20 min and the mass ratio of reagent and sand is 2:1. The test results are shown in Figure 2. the oil yield of the oil sand increases with the rising of temperature, and in a linear fashion before the temperature reaching 80. While after the temperature reaching 80 °C, the oil yield increased slowly. Once the temperature is over 90 °C, the oil yield will reach 95% or above. This is mainly because that: in case of a low temperature, the surfaces of sand-water-oil are ambiguous, with a worse layered effect and a lower oil yield; in case of a high temperature, the mean kinetic energy of oil sand liquor increases, which reduces the viscosity of the oil sand asphalt (oil) film, loosens the molecular arrangement on the surface film. Besides that, the thermal expansion reduces the viscosity ability of asphalt film and the density of oil-water increases when the temperature rises, the oil extracted continuously float upward in small oil globule form which makes itself much easier to separate with the sand and the surface between oil and water is quite clear with a better layered effect. However, higher temperature increases the evaporation velocity of water, which is adverse to the stirring extraction of oil sand, and a higher

temperature means higher energy consumption. Taking all the factors above into consideration, the optimum operational temperature for oil sand extraction is 90 °C.

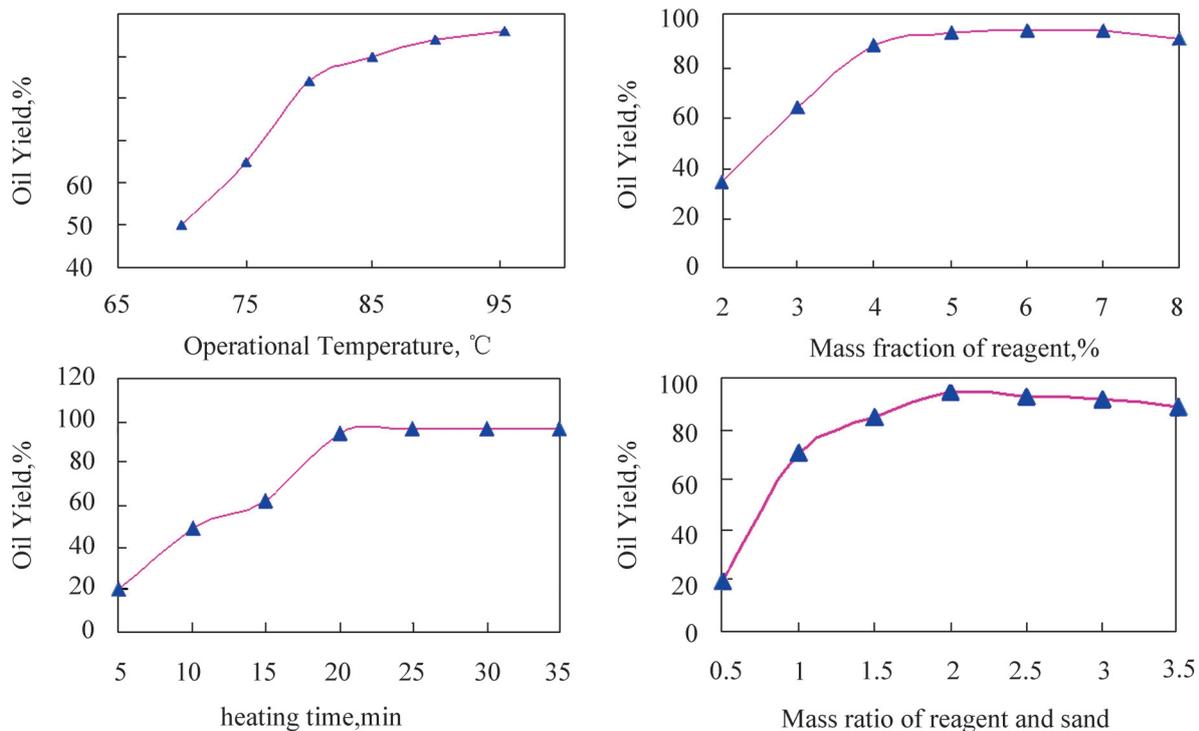
Investigate the impact of different mass fraction of extracting agent on extracting efficiency for oil sand by changing the mass fraction of extracting agent when the heating temperature is 90 °C, the extracting time is 20 min and the mass ratio of reagent and sand is 2:1. The test results are shown in Figure 2. the oil yield of the oil sand rises with the increasing of mass fraction and in a linear fashion before the mass fraction reaching 4%. When the mass fraction of extraction reagent is within the range of 4%-5% °C the oil yield increased slowly. Once the mass fraction reaches 5%, the oil yield reaches the highest, and decreases after that. The oil yield is closely related to whether the oil sand has fully reacted with the effective components in the reagents. When the reagent mass fraction is low, the hydrocarbon components are still exist in the oil sand because of the difficult separation due to the inadequate reaction, so the oil yield of the oil sand increases with the increase of the mass fraction; while when the reagent mass fraction is too high, though the reaction is adequate and the oil sand almost is completely stripped from the sand, yet the products of the separation will be serious emulsified under the action of the surface active agent in the excess reagent, leading to the difficult oil-water separation, which causes decline of the oil yield. Therefore, under the considerations of separation

efficiency and cost, the appropriate mass fraction of the oil sand water separation reagent is around 4%.

Investigate the impact of different heating time on extracting efficiency for oil sand by changing the heating time when the operating temperature is 90 °C, the mass fraction of the extracting agent is 4% and the mass ratio of reagent sand is 2:1. The test results are shown in Figure 2. the oil yield of the oil sand rises with the extending of the heating time, and in a linear fashion before 20 minutes. While after 20 minutes, the oil yield stops to increase. This is because that: the separation of oil sand oil and the oil sand begins when the oil sand separation reagents are mixed into oil sand mortar, and the separation time depends on the heat transfer and mixing effect. The oil sand mortar cannot be fully heated within the short time, so the oil sand asphalt film is attached on the grain of sand closely, while with the separation time extending, the oil sand asphalt is fully heated and the sticky degrees of the emulsifier in the separation reagents reduces, which makes it is easier for the oil sand asphalt split from the grain of sand. Under the conditions of operation temperature of 90°C and adequate mixing, the oil sand oil can be fully evicted from the sand surface for about 20min or within a shorter time. During the industrial production, the heating separation time needs to be determined through the experiment in the field due to the difference of the oil sand preprocessing, mixing conditions and the laboratory.

Investigate the impact of different mass ratio of reagent sand on extracting efficiency for oil sand by changing the

mass ratio of reagent sand when the operating temperature is 90 °C, the mass fraction of the extracting agent is 4% and the heating time is 20 min. The test results are shown in Figure 2, the changes of the mass ratio of reagent and sand have certain effect on the extraction of oil sand, but it does not means that the oil yield increases with the rising of mass ratio of reagent and sand. In case that the mass ratio of reagent and sand is lower than 2:1, the oil yield increases with the rising of mass ratio of reagent and sand; in case that the mass ratio of reagent and sand is higher than 2: 1, the oil yield decreases. This is because the amount of the reagents is too small and the reagents and oil sand can not contact with each other, leading to the inadequate reaction between the reagents and the oil sand, which is not conducive to the separation of oil and sand, at the same time, the oil sand mortar fluidization in the preprocessing phase cannot be realized due to the too small amount of the reagents. While if too many reagents are added, the water consumption, the chemical to be used and the treatment amount of the final circulating water will increase. Also, when the amount of the separation reagents is excessive, the oil sand will settle to the bottom of the water, causing no contact or insufficient contact with the air, almost without the air floating process, so the oil sand oil from separation will contains many small sand grains and debris which will cause a great impact on the later processing and refining. A large number of experiments show that it is appropriate the reagents and the sand ratio is about 2:1.



**Figure 2**  
**Relation Between Oil Yield and Temperature, Mass Fraction of Extracting Agent, Heating Time, Mass Ratio of Reagent Sand**

The test result above further indicates that the best extraction operating parameters for oil sand in Fengcheng, Xinjiang is in the situation that the temperature is 90 °C, the mass fraction of extracting agent is 4%, the extraction time is 20 min and the reagent sand ratio is 2:1. and the oil yield for that may reach 94% or more.

#### 4. THE RESEARCH PROGRESS OF HOT WATER SEPARATION TECHNOLOGY

According to the results and experience of laboratory study in recent years, and through the selective comparison with a variety of methods for the technologies, it is feasible for the oil sand resources buried in the depth of 15 meters with the oil content of more than 6% and small clay content in Xinjiang to extract the oil sand oil with the method of thermochemistry hot water separation, which is confirmed by Research Institute of China Petroleum Exploration & Development, Langfang Branch.

In order to verify the effect of hot water separation technology, Research Institute of China Petroleum Exploration & Development, Langfang Branch established the test base using hot water washing method in Hongshanzui area of Xinjiang Junggar Basin and manufactured two sets of hot water separation devices to launch hot water separation test on site for the oil sand in Hongshanzui area from 2006 to 2008. Among the two sets of devices, one is the vertical extraction device with the capacity of 15 tons of oil sand per day and the other is the horizontal extraction device for oil sand with the capacity of 10 tons per day. The field test indicates that, the oil yielding effect of the oil sand is very good with the extracting temperature of about 85 °C and the extracting efficiency up to over 90%. The processing capacity of two sets of devices basically meets the design requirements and proves that it is feasible for the hot water separation technology and the devices.

##### 4.1 Study and Field Test of 15 t/d Vertical Hot Water Separation for Oil Sand

Using the mode of intermittent operation, the main tank is the agitator tank with charging in upper way and discharging

in lower way, four meters' high. The steam coil in the tank provides the heat supply for the test. There are multi-stage setting basins beside the main tank whose diameter is 2 meters. The devices on site are shown in Figure 3.

Field test mainly investigates the mixing effect, extraction time, heating temperature, rate of charge, concentration of YSFL-2 oil sand extraction reagent and other contents.



**Figure 3**  
**On Site Small-Size Vertical Hot Water Separation Devices for Oil Sand**

The mixing effect of the device is better, and the oil obtained from the device meets the design requirements with the rapid heating rate of about every 10 minutes as well the temperature of 90 °C. The separation time is fundamentally consistent with the laboratory results before and the influence of the rate of charge to the oil sand extraction efficiency is rather distinct. The corresponding extraction effects in different reagent sand ratios show significant differences. The test results are shown as in Table 1.

**Table 1**  
**Investigation of Rate of Charge to Oil Sand Separation Efficiency**

| Serial number | Reagent sand ratio | (Oil content-oil yield) / Oil content×100% |
|---------------|--------------------|--|
| 1             | 1:1                | 47%  |
| 2             | 2:1                | 14%  |
| 3             | 3:1                | 8%   |
| 4             | 4:1                | 5%   |

From the table above, it is clear that with the increase of the reagent sand ratio, the residual quantity of oil sand reduces gradually and the sand discharged is relatively clean. However, the field test shows that the oil sand oil could be extracted from the sand thoroughly only in the

case of the high reagent sand ratio (4:1), which has a large difference from the result of the laboratory study that the optimal reagent sand ratio is 2:1 and this is related with the wave of the agitator and lower efficiency of the test device on site. As for the hot water separation technology,

the reagent sand ratio should not be high because the larger liquid dosage may indirectly result in the higher cost of the subsequent water treatment and the waste of water since it should pay more attention to the saving of the valuable water in Kayamay which is drought and rainless to launch the hot water separation technology.

Concentration of YSFL-2 oil sand extraction reagent is the significant step in the field test for the technology. Because the consumption of reagent is one of the important cost compositions during the whole

technological operation, it is very important to choose reasonable concentration of reagent. According to the result of field test (indicated in Table 2), the extraction for the oil sand is better when the concentration of the formula used at present is higher than 4% and when lower than 4%, the efficiency for the oil sand extraction technology drops obviously, which is consistent with the result of the laboratory test. The concentration therefore shall be not lower than 4% when conducting the technological operation with YSFL-2 oil sand extraction reagent.

**Table 2**  
**Influence of Extracting Agent Concentration to Extracting Effect**

| Serial | Mass fraction/% | (Oil content-oil yield) / Oil content × 100% |
|--------|-----------------|--|
| 1      | 2.5             | 57%  |
| 2      | 3               | 37%  |
| 3      | 3.5             | 20%  |
| 4      | 4               | 7%   |

**4.2 Study and Field Test of 10 t/d Horizontal Hot Water Separation for Oil Sand**

The interior of the horizontal hot water separation device for oil sand is 6 meters’ long, with the width of 0.8 meters and the height of 2 meters. The result in the hot water separation test indicates that this device could extracted the oil from the oil sand conveniently with the fine efficiency and the sand discharged from the device does not include any oil. The devices on site are shown in Figure 4.

The result from several tests indicates that the concentration of the extracting agent is advisable at around 4%. It causes waste and serious emulsification if the concentration is too high, which will bring difficulty for breaking the emulsion while if the concentration is

too low it could not guarantee the extracting efficiency. Generally, the utilizing times of sewage recycling is more than three times, while in case of the supplement of fresh extracting reagent, it could be used continuously for over 5 times. It is difficult to process the stalling settlement of the sliming sewage. At present the device for sewage treatment is not designed into the extraction device, so in the next step, the device for pressure and filtration will be taken into consideration to dehydrate and solidify the sliming sewage. Field test shows that the operation parameters of the hot water separation technology are close to the extracting parameters obtained in the laboratory, which could be amplified after the improvement.



**Figure 4**  
**On Site Small-Size Horizontal Hot Water Separation Devices for Oil Sand**

**4.3 New Extraction Technological Device with the Capacity of 10,000 Tons of Oil Sand per Year**

The processing capacity of this device is 10,000 tons of oil sand per year. If the producing time is calculated as 10 months every year, then it is designed to process the oil sand of 35 tons every day. This process adopts

the hot water separation technology for oil sand, which mainly includes two stages: the first stage is for primary extraction: the crushed oil sand is fully mixed with the oil sand extracting agent in the agitation reaction equipment. Under the condition of certain temperature, reaction time and mechanical power, the oil sand asphalt is peeled off

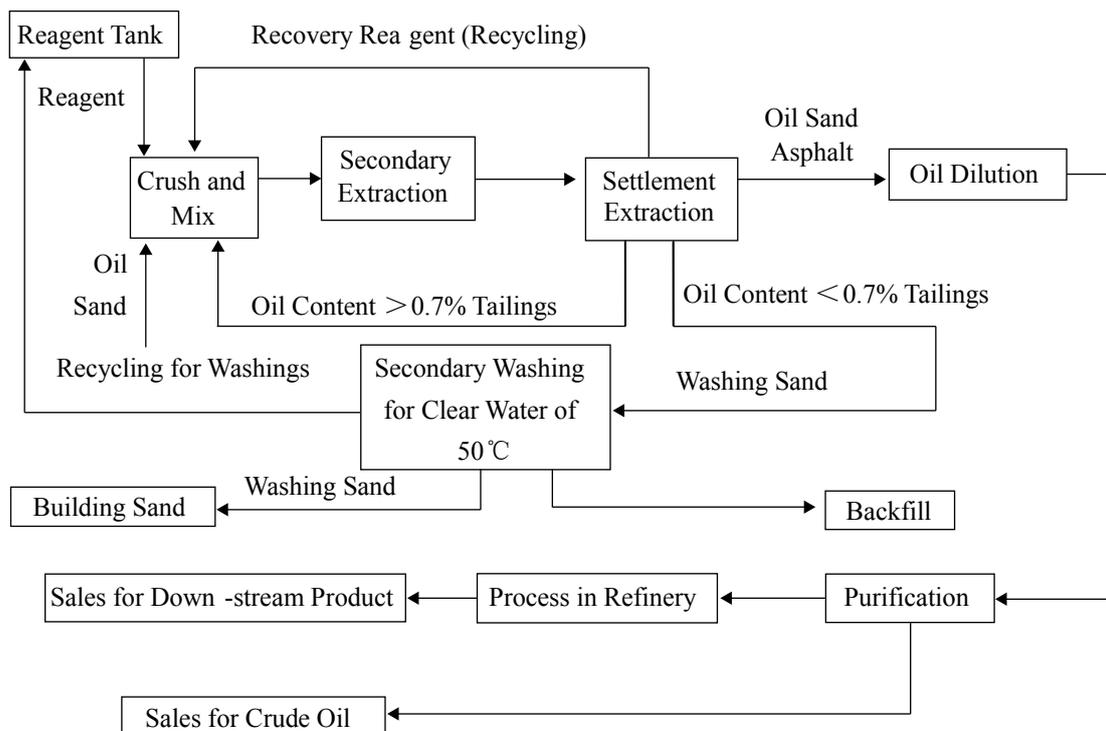
from the solid sand and enters into liquid phase. The second stage is for extraction and flotation, basing on the hydrophobic property of the medium pH solution and oil sand asphalt, certain amount of air is led into the flotation pool to make the droplets of oil sand asphalt with bubbles float from the bottom to the upper, so that most of the sand keeps down to the bottom while the floating oil sand asphalt overflows to the oil recovery system. Extraction technological device is shown in Figure 5 and flow diagram of oil sand extraction is shown in Figure 6.

Through the field test, the evaluation for the largest

throughput and feedstock adaptability of the device is completed and the device stability of automatic control system and information collection system is examined. The test results show that: the biggest logistics speed of the whole system is 4 tons per hour, and the diameter of the max particle size of raw materials is less than 2 cm. The accumulative operation period of the device is 56 days with no mechanical faults. The oil yield is 90% in normal running, and the emission of environmental protection reaches the standard.



**Figure 5**  
**New Extraction Technological Device with Annual Processing of 10,000 tons of Oil Sand**



**Figure 6**  
**Flow Diagram of Oil Sand Extraction**

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