

THE SUCCESSFUL APPLICATION OF THE NEW TECHNOLOGY OF TWO WELL DIRECTIONAL AND HORIZONTAL CONNECTION IN BRINE MINING IN XIANGHENG SALT MINE

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Abstract: Based on the technology of two well directional connection in brine mining, Xiangheng salt mine carried on the research of the new technology of two well directional and horizontal connections in brine mining, and succeeded.

Key words: directional and horizontal well; connection ; brine mining

1、 PREFACE

In 1992, Xiangheng salt mine carried on the research of two well directional connection technology in brine mining, its achievement won the gold medal of scientific innovation in Hunan Province, and the second prize of national advance in technology. Compared with the single well convection brine mining, this technology has many advantages: small footprint; more reserves for mining; large capacity of brine mining; high resources recovery; few brine well accident; high brine concentration and etc. In the past decades, the new technology of two well directional connection in brine mining has been applied widely in the domestic mine of the same type. However, in Xiangheng salt mine, with the rapid development of mining demand (the yield increased from 300,000 tons/year to 2,000,000 tons/year), the limitations of the new technology of two well directional connection in brine mining become more and more significant, especially the limitation in the reserves for mining, capacity of brine mining and so on. In order to fully display its superiority and potential, based on the two well direction detection connection of brine mining technology, Xiangheng salt mine

carried on the research of two well directional and horizontal connection brine mining

technology again with thought innovation from 2006 during the third mining area's newly built project of energy conservation environmental for the yearly produce 600,000 tons salt and sodium sulfate project. In September 2007 to December 2008, we successfully completed 4 groups of directional and horizontal connection well's drilling, trough construct and trough expand for mining. At present, these 4 groups of directional and horizontal connection well have entered stably brine-mining phase.

2、 OUTLINE OF THE TECHNOLOGY OF TWO WELL DIRECTIONAL AND HORIZONTAL CONNECTION BRINE MINING

The two well directional and horizontal connection brine mining technology is mainly composed of two parts: one is the directional and horizontal connection well group; the other is the brine mining facility and trough construct, trough expansion and brine mining.

2.1. Directional and horizontal connection well group

The directional well refers to the well which was drilled according to the design of drift angle, the azimuth and the well hole spool thread shape. The directional and horizontal well refers to the drift angle to be

bigger than or to be equal to 86° , and keeps this kind of angle to drill a certain length. According to radius of curvature, the horizontal well can be divided into three types, as shown by following table:

Well types Item	Long radius horizontal well	Medium radius horizontal well	Short radius horizontal well
Rate of angle	$< 6^\circ/30\text{m}$	$6^\circ\text{—}20^\circ/30\text{m}$	$150^\circ\text{—}300^\circ/30\text{m}$
Radius of curvature	304—914m	291—87m	12—6m

The directional and horizontal connection well group which was researched and constructed by Xiangheng salt mine this time, is composed of two medium radius directional horizontal wells through water-soluble, constructs trough. The well under the central tube is the goal well, another one is the connection well. Compared with the

former directional connection well group, this kind of well group has big breakthrough in inner diameter, well spacing, radius of curvature and length of Horizontal well. Its main parameters are shown in the following table

	Technical drive pipe caliber (mm)	Inner diameter (mm)	Length of Horizontal well (m)	Radius of curvature (m)	Well spacing (m)
Directional connection well group	$\Phi 108 \times 4.5$	$\Phi 76$	< 50	> 150	< 300
Directional horizontal connection well group	$\Phi 177.8 \times 8.05$	$\Phi 152$	> 250	< 100	> 700

Just for this kind of breakthrough, it has laid the solid foundation for the directional and horizontal connection well group's "three high" (high mining reserves, high brine mining capacity and high brine concentration).

2.2、construct trough, expansion trough and brine mining

The construct trough, expansion trough and brine mining craft with directional level connection well group is similar with former craft, but the difference still exists.

When the goal well's trough is constructed, due to the large well spacing, the total trough construct quantity should be large. Taking ZK305 for example, it's total trough construct quantity is approximately 4000 m^3 , and this may form a big dissolved cavity in the target area which is advantageous for the connection well's entry.

5 or 6 months must maintained for expansion trough.

The brine flow must be adjusted at the right time during the brine mining period.

3. CONSTRUCTION OF THE DIRECTIONAL AND HORIZONTAL CONNECTION WELL GROUP

At the first stage project of the third mining area, Xiangheng salt mine has arranged 4 groups of directional level connection wells: ZK301—ZK302、ZK303—ZK304、ZK305—ZK306、ZK307—ZK308. The well groups were arranged along the direction tendency (north west), and located at the third mining area's southeast area.

3.1. the third mining area

The third mining area located at the west of old mining area and separated by 400 m, the first stage developed area is 0.99 km². The third mining area and the old mining area can run and develop independently. The two areas can coordinate mutually and supply the brine together.

The third mining area's salt mine level reserves in the middle section of Chashan area. from the top downward, it can be divides into:

A. upper sulfate belt (E_{2X}^{1-4}): primarily includes Calcium Sodium Sulfate, associated with anhydrite gypsum and gypsum. The ore bed seam of Calcium Sodium Sulfate's average thickness is 26.65 meters; and the average ore body thickness is 22.76 meters. The average Na₂SO₄ purity of 30.1%, and ore-bearing purity of 85%.

B. chloride belt's main rock salt ore bed seam (E_{2X}^{1-3}): primarily rock salt, including few argillaceous bands, associated with Calcium Sodium Sulfate, anhydrite, average thickness 177.72 meters, average NaCl purity of 46.62%, ore-bearing purity of 86%, associated Na₂SO₄ average purity of 11.27%.

C. chloride belt's rock salt vice-ore bed seam (E_{2X}^{1-3}): The rock salt delivers with the argillaceous band, including few Calcium Sodium Sulfate, anhydrite, average thickness 18.65 meters, ore-bearing purity of 34%, average NaCl purity of 36.2%.

D. under sulfate belt (E_{2X}^{1-2}): primarily anhydrite gypsum, associated with Calcium Sodium Sulfate, rock salt, most holes have not passed through this class, thickness is known to be more than 200 meters.

The third mining area's geologic structure is simple, the salt-bearing red rock has the monoclinical structure, the inclination angle is gentle, generally in the range of 10~20°. In mining area there is no fault cutting.

The third mining area's main water-bearing strata have the fourth section pebble level pore water and the bedrock's decency crevice water of the Xialiushi group, confined water in dissolution pore, brine water of the top salt layer and so on five water-bearing strata. Except those two upper water-bearing strata has the water power relation in their distribution area, other water-bearing strata have no water power relations due to the thickness and stable marl and mudstone for the good aquiclude. Its

hydro geological conditions belong to the simple type.

The main ore bed seams in the third mining area are the mining strata, its characteristic of thin layer, multi-layered and heavy-layered together with the simple structure and the hydro geological conditions in mining area, provided a high quality platform for the drilling, construct trough and mining of the directional horizontal well group.

3.2. Well group building

This article only take ZK305-ZK306 as the examples due to the similar types and technical parameter of the three working area's 4 well groups.

3.2.1 Well group drilling

A. well group types

ZK305 is the directional horizontal target well; ZK306 is the directional horizontal connection well. Two wells arranged along approximately the east and the west. The ZK305 well concurrently be treated as exploration well, after entering the ore bed seam, takes the core sample and records data to determine the target position and the depth.

B. drilling ways

The drilling ways for the two well's straight sections are turntable revolving, which uses roller bit (not take core) and the diamond (takes the core) drill bit.

The drilling ways for directional horizontal well section is screw rod drilling tool revolving, matched with the measuring instrument of wired-drill, which uses PDC and the roller bit. Direction is settled by Hunan Province's 417 team of Geology Investigation Development Bureau and Dongying Tiangeng petroleum technical service company of Shandong Province.

C. well group's geology condition

The ZK305 well has taken the core at the place between 240 m and 701.88 m of the straight section and the data is recorded.

Drilling positions are shown in the following table:

Drilling positions	The fourth stratum	Q	0~18m	Humus soil, yellow clay
	The third stratum	E_{2X}^{1-5}	18~237m	Deep gray mudstone and reddish brown sandy mudstone in the same stratum, clamps the feldspar silicarenite at the middle
		E_{2X}^{1-4}	237~298m	Deep gray mudstone, Clamps the thin layer gypsum and the Calcium Sodium Sulfate stratum
		E_{2X}^{1-3}	298~641m	Mainly rock salt
		E_{2X}^{1-2}	641~701.88m	Deep gray mudstone, anhydrite and Calcium Sodium Sulfate

D. well drilling quality

Error between the two well's depths is smaller than 0.05%.

Two well's inner diameter expansion rate is smaller than 15%.

Ore core's mining rate is larger than 85%.

The straight well's drift angle in ZK305 is 1.1°; the straight well's drift angle in ZK306 is 2.05°.

The entire well does not have key slot and angle change, no fall things and sinking sands at the well bottom.

The well cementation facilities are the cement well cementation vehicles. The well cementation cement is the G class of medium anti 75° oil-well cement. The well cementation quality meets the well drilling requirement.

After the ZK305 is completed, put the central tube down into the well. The end of the central tube's manufacture and entry meet the requirement.

E. Construction time

The drilling time of ZK305 is on April 2, 2007 - June 10, 2007.

The drilling time of ZK306 is on July 6, 2007 - July 14, 2008.

3.2.2 Well group parameter

A. well coordinate

ZK305

X : 2981779.065 Y :

38368589.645 H: 84.77

ZK306

X : 2981737.735 Y :

38367862.528 H: 106.87

B. Well spacing and line position

The well spacing between ZK305 and ZK306 is about 728m, two well's line position approximately 267°.

C. well body and tube string structure

ZK305

X : 2981779.065 Y :

38368589.645 H: 84.77

ZK306

X : 2981737.735 Y :

38367862.528 H: 106.87

ZK305

Drilling order	Well depth m	Drill bit size mm	Drive pipe size mm	Drive pipe's position	Drive pipe depth m	Well Cement returns to the depth
First drilling	140.66	311.1	244.5×10.03	E _{2X} ¹⁻⁵	140.85	Ground
Second drilling	480.06	215.9	177.8×8.05	E _{2X} ¹⁻³	480.0	Ground
Third drilling for core	701.88	152				
Fourth drilling for angle building	918.87	152	88.9×6.05	E _{2X} ¹⁻³	917.59 (central pipe)	

ZK306

Drilling order	Well depth m	Drill bit size mm	Drive pipe size mm	Drive pipe's position	Drive pipe depth m	Well Cement returns to the depth
First drilling	155.0	311.1	244.5×10.03	E _{2X} ¹⁻⁵	155.91	Ground
Second drilling	484.0	215.9	177.8×8.05	E _{2X} ¹⁻³	485.94	Ground
Third drilling for angle building	992.35	152				

D. target spot

According to the data of the ZK305 exploration section, the target position is about 1 m from the bottom of the rock salt's main seam floor. Compared with ZK305, the target spot's vertical depth is 599.07 m, the drift angle is 88°, azimuth of 271°.

E. radius of curvature

At ZK305's directional drilling period, the well's drift angle increased from 2° to 86°, the length is 140 m; the radius of curvature is

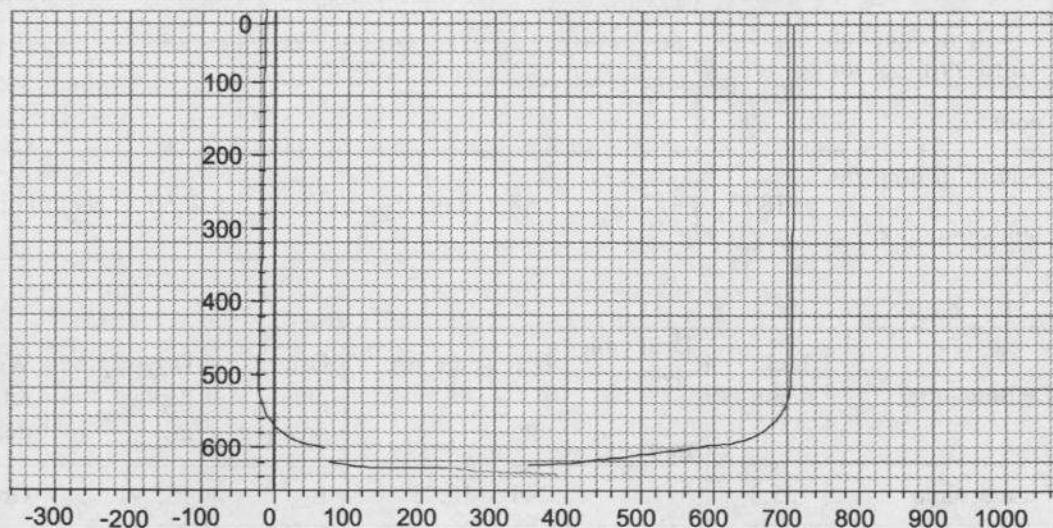
approximately 95 m. The length of the horizontal well section (drift angle keeps about 86°) is 294 m.

At ZK306's directional drilling period, the well's drift angle increased from 2° to 86°, the length is 154m; the radius of curvature approximately 105m. The length of the horizontal well section is 328 m.

This well group's curvature radius belongs to the lower limit of the curvature radius scope (291 m-87 m); it can effectively raise the resource's recovery ratio.

i. **ZK305-ZK306 well bore path diagram**

306-305 profile of the well



4. CONSTRUCTION TROUGH, EXPANSION TROUGH AND BRINE MINING OF THE DIRECTIONAL AND HORIZONTAL CONNECTION WELL GROUP

Still take ZK305 - ZK306 for example.

4.1. Trough construction

After the goal well ZK305 is completed, put the central tube down, and the trough construction period begins.

4.1.1. Trough construction facilities

Because ZK305's horizontal section is rather long (approximately 294m) and there are too many clamp stones in the bottom of the main salt deposit, the D85-67×9 multistage centrifugal pump with high lift is selected for the trough construction. Each pump is responsible for two goal wells' trough construction work.

4.1.2. Trough construction procedure

Trough construction method is to enter from the center and out from all around. The process is carried out continuously. Trough construction procedure is: Construct the trough pump - working area's irrigation pipeline - measurement control room - ZK305 central tube - dissolved cavity - ZK305 link spatial - measurement control room - returning brine pipeline in mining area -light brine pond.

4.1.3. Trough construction parameter

When the ZK305's trough is constructed, the capacity maintains approximately 40 m³/h. The brine concentration is approximately 21°Be. NaCl content is approximately 260 g/l. Thus, the rock salt dissolution speed may be guaranteed to be at a relatively high value (23 kg/m²h). The well's dissolved cavity is effectively expanded and at the same time makes the equipment run economically.

The total trough construction of the third mining area's 4 goal wells' is approximately 40000 m³. The brine's NaCL content is approximately 260g/l, and the dissolved cavity

space is approximately 9400 m³. Thus, conditions are created for the connection well to reach the target smoothly.

4.2. Expansion trough

After the well group enters the dissolved cavity of the ZK306 target well, the tentative mining and expansion period begins.

4.2.1. Trough expansion facilities

Still use the trough construction pump and the pipeline.

4.2.2. Trough expansion procedure

The trough expansion method is: feed water in the central tube ZK305, vent brine from the ZK306. If the well is blocked up at the trough expansion time, then back flushing should be adopted which means feed water in ZK306, vent the water from the central tube or the surrounding according to the situation of ZK306. Restore the original procedure after the block up relieved.

4.2.3. Trough expansion parameter

The well group's capacity maintains about 40-50 m³/h at the trough expansion period. The brine concentration is approximately 22-23°Be. NaCl content is approximately 280-290 g/l. The goal to expand the trough mainly is to expand the dissolved cavity of the connection well ZK306, and build foundation for the large-scale brine production of the well group.

4.3. Brine mining

After about 5 to 6 months of continuous trough expansion and tentative mining, the process enters the brine mining period.

4.3.1. Brine mining facilities

After the dissolved cavity's expansion, the dissolved cavity's resistance decreases. Hence, the brine pump should select D280-65/84×8 multistage centrifugal pump with relatively low lift.

4.3.2. Brine mining procedure

The brine mining method is: feed water in ZK305; water comes out from the ZK306. Brine mining procedure is: brine mining pump-mining area's irrigation pipeline-measurement control room- ZK305 irrigation

pipeline - ZK305 central tube + link spatially (on or off according to the situation)- ZK306 dissolved cavity -ZK306 brine returning pipeline - measurement control room - mining area's brine returning pipeline - brine tank.

Regularly reverse the procedure during the brine mining period.

4.3.3. Brine mining parameter

At present, well group's capacity is approximately 100-150 m³/h. NaCl content is approximately 280-298 g/l. The brine concentration is approximately 23°-24° Be. Along with the mining work, their mining ability will be further enhanced.

5. CONCLUDING REMARKS

Since Xiangheng salt mine's third mining area started production in December, 2008, the well group has run normally. Every target of the drilling and brine mining has been achieved or even surpassed. Compared with the two well directional connection well group, its brine concentration is higher (about 298 g/l), brine capacity is higher (100-150 m³/h, formerly about 50-80 m³/h), and the well group's reserves is higher (2 times more than former). The superiority of "three high" is obvious. Meanwhile, the working area's well group number and construction investment is reduced largely. Therefore, Xiangheng salt mine's research on the technology of two well directional and horizontal connections well has been proved to be successful by production practice and worths further promoting.

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