

# NEW DEVELOPMENTS OF DIRECTIONAL OPPOSITE JOINT TECHNOLOGY IN THE CONNECTED WELLS

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**Abstract:** Directional Opposite Joint Technology in the connected wells has developed into a special technology in recent years in order to make directional drilling technology meet the needs of rapid economic development. It can be used in many sectors of the national economy. So far, it has been widely used in the exploitation of soluble well and rock salt, trona deposit, Glauber's salt (sodium sulfide), and coalbed methane (CMB), etc.

## INTRODUCTION

With using mining characteristics and adopting directional drilling and horizontal drilling technology, Directional Opposite Joint Technology in connected wells aims to have the two-well or multi-well jointed and connected at target exploitation layer at the underground depth of hundreds or thousands of meters, and thus achieve the two-well or multi-well connection mining, which are hundreds of meters away from each other.

## APPLICATION OF DIRECTIONAL OPPOSITE JOINT TECHNOLOGY IN THE CONNECTED WELLS IN THE MINING OF WELL AND ROCK SALT IN CHINA

### Necessity of Technical implementation

At present, single-well convection water-soluble brine extraction, fracturing method, natural solution and communication process and oil padding process are mainly used in the well and rock salt mining, which all

have some different shortcomings. For instance, single-well convection water-soluble brine extraction has low mining rate less than 20%, low brine production capacity, unstable quality, frequent well incidents, and big pollution to the environment as well as high costs of constructing mines. As for the fracturing method, which requires that the roof and floor of salt rock mining layer should be strong; the success rate of connection is usually lower than 50 with serious resource waste and pollution to the earth, and the connection direction and the layer position are difficult to control. In natural solution and communication process, because the connection of wells is realized by solution mining in the late stage of mining, the connection effect of wells is bad, with a waste of resources, high cost of drilling and poor availability. Oil padding process is also not suitable for well and rock salt mining in our country due to the high cost of drilling, long connection period and serious pollution. However, with directional opposite joint well-connecting technology, two-wells or multi-wells are directly oppositely jointed in

the target mining layer, which has many advantages, such as low drilling cost, high yield of brine, good quality, easy control of the opposite joint direction and layer, possibility of preserving safety pillars, big ore-controlling quantity and high availability of resources, as well as simple production management and low pollution to ground and underground, etc.

#### **Conditions of implementing the technology**

In order to implement the opposite joint of two-wells or multi-wells, the space coordinates of each well must be equal or approximate to each other at the target point of the opposite

joint. To this end, some key problems in technology should be solved, including design of connected wells, drilling equipment and technology of connected wells, well drilling measurement and data processing technology, control of well bore trajectory, cleaning and protection of well bores, etc.

#### **Application Effects**

So far, hundreds of oppositely connected brine wells have been completed for salt mines and trona mines at home and abroad. Some technology indexes are presented in the following table.

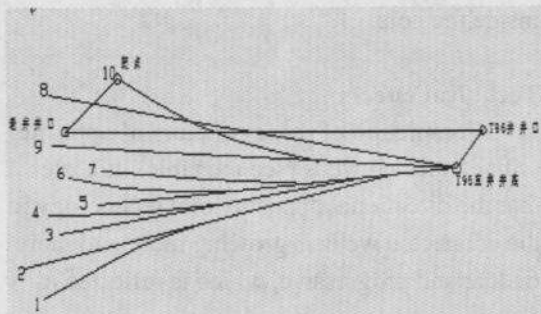
**Main Technology Indexes for some oppositely joint wells**

Name of Mine	Distance between two well(m)	Total depth(m)	Average build-up rate(°/m)	Length of horizontal portion(m)	Opposite connection error(m)	Completion date
Hunan Xiangheng Salt Mine	233.6	626.3	0.40	11.5	0.45	Dec. 92
		610.1	0.41			
	218.6	678.0	0.42	27.0	1.37	Jan. 94
		648.5	0.41			
	227.2	640.4	0.42	21.0	1.07	April 94
		578.6	0.42			
Hengyang Brine Mine	143.0	782.0	New vertical well		0.70	Aug. 94
		810.0	0.40			
Xuzhou Salt and Chemical	153.0	1011.0	Old brine wells		0.55	Jan. 95
		998.0	0.41	41.0		
Yingcheng Salt Plant (Hubei)	221.0	609.9	0.41	51.0	0.65	May 96
		599.8	0.42	43.0		
Xuzhou Salt and Chemical	152.5	1084.0	Old brine wells		1.16	Aug. 97
		1131.6	0.41	39.5		
Jing County Sixiaoqiao Salt (Jiangsu)	177.6	955.0	Existing Brine well		0.84	Oct. 97
		1026.0	0.50	44.0		
Luicheng Salt Plant Shangong	166.7	1243.0	New vertical well		1.07	Aug. 99
		1320.0	0.42	58.0		
Jiangxi Salt Mine	176.4	1093	Existing Brine well		0.86	Jan. 2000
		1069.3	0.45	60.0		
Huai'an Jionghsen Salt Mine	235.7	1293	Existing Brine well		1.12	April 2000
		1411.0	0.58	130.0		
Jiangxi Salt Mine	187.8	1001	Existing Brine well		1.06	July 2000
		1083.6	0.47	65.0		
Jiangxi Salt Mine	183.7	1093	Existing Brine well		1.02	Sept. 2000
		1089.3	0.47	65.0		
Shalongda Salt Mine	490	2605	New vertical well		1.02	Jan. 2003
		2787	0.3	50.0		
Tongbai Trona Mine(5 pairs)	450	672	New vertical well		0.82	Sept. 2005
		1002	0.3	230.0		
Eti Soda Trona of Turkey(31 pairs)	500	452	New vertical well		0.32	Dec. 2006
		730	0.3	250.0		

Among them, ten branch-directional wells have been drilled in the same direction because of some considerations in Jiangsu Xuzhou Salt

and Chemical Co., Ltd (see the following Fig 1.).





**Fig1. Plane Projection Schema of T96 opposite connection well in Jiangsu Xuzhou Slat and Chemical Co., Ltd**

During the period from 2005 to 2006, 31 pairs of oppositely jointed wells had been completed ahead of time by 35 days in Turkey. Since the employer required that all wells should be oppositely connected in just one-step, this construction had faced many challenges due to the difficulty in cavity building, small thickness of layers (only 1 m or so), the requirement that the 250 m horizontal portions must travel through the entire mine layer, and small cavity with the diameter of about 0.5 m.

#### **Economic and social benefits**

Mining by using directional opposite joint technology in the connected wells brings about obvious economic and social benefits. For example, the mining ratio doubles than singlewell brine mining method, up to 40%; resource utilization is improved greatly by changing one mine into two; one pair of wells is 4 times the output per hour of 4 single-wells with high brine concentration and stability. Building a slat mine with 300,000 ton capacity will occupy 15 hm<sup>2</sup> land and need to drill more than 40 single-wells with the single-well method; while the connected-well method only need 5 hm<sup>2</sup> land and 4 pairs of connected wells, which reduces cost in surface pipelines investment by 50%, brine production cost by 40%, and increases the brine concentration by 10 g/L -15 g/L. In case of not adding any extra investments, the salt production cost decreases by 5% with the energy consumption increasing

by 10% -15%, and the salt output increases by more than 5%; meanwhile, the mine can get a direct profit of RMB 30,000 yuan per day from this method. Furthermore, the opposite joint wells possess many advantages, including fewer well incidents, less maintenance and surface pollution cost as well as pollution treatment cost, and longer service life of over 20 years.

#### **NEW DEVELOPMENTS OF THE DIRECTIONAL OPPOSITE JOINT TECHNOLOGY IN THE CONNECTED WELLS**

##### **Improved whipstocking tools**

The screw drills with big torque, long service life and low rotating speed such as YL65 and YL-78 have been developed; stator hanging rubber and rotator Chromium plating technology of the screw drills with small diameter are solved; Alloy and diamond have been employed to make the radial and longitudinal structure of drill bearings. As a whole, the unprogressive status of screw drill rubbers and ball bearings has been changed, and service life of the screw drills is up to more than 100 hrs.

##### **Structure of drilling tools**

Through analyzing angle-building, angleholding and angle-dropping characteristics of different drilling tools, the optimum configuration of the drilling tools has been mastered, with various bent subs, bent housings and accessories improved.

##### **Trajectory design and controlling technology**

The designs of opposite joint connected wells and construction control software have been developed. According to geological and drilling data, a lot of logging and borehole data are input to the computer in time to track the design, facilitating on-site construction, meeting the drilling accuracy requirement,

increasing design and drilling efficiency, alleviating labor intensity of technical personnel at site and reducing working errors.

#### **Sidewalls stabilization and wellbore cleaning**

With the increase of the horizontal distance of opposite joint connected wells and drilling depth, sidewall stabilization and stone dust emission are limited more and more strictly. Research demonstrates that oil-based mud should be used as much as possible to control the stabilization of sidewalls. Oil-based mud can provide good lubrication, increase service life of the drill tools and inhibit the expansion of shale, which has the low water loss of slurry less than 8 ml, good emulsification performance, low shear force with high viscosity and qualified mud cake. The density of mud should be controlled within some limit. If density is too high, sidewall collapse and pumping effect of the drilling string may be brought about; on the contrary, it is difficult to keep ground layer balance, with rock falling incidents taking place, and poor ability to carry stone dust.

As for wellbore cleaning technology, based on the properties of drilling fluids, the optimum pumping rate can be determined through modeling MTV values of different wellbore sections (Keeping the minimum up-hole velocity of annular cuttings in suspension); meanwhile, footage can not be pursued aimlessly. After drilling is carried to some depth, the well bore should be trimmed and flushed with mud replaced to ensure that the content of solids doesn't exceed the limits. Besides, the equivalent circulation density should be reduced to prevent stratum collapse due to high annular back pressure.

#### **Whipstocking drill bit**

The new generation whipstocking drill bit has longer service life. Production tests show that a single drill bit can have a drill depth of 200 m (in Grade 3 and 4 stratum). Therefore, the blind spot at the center of the drilling bit is avoided, preventing bit burning because the bit

enters the rock core and reducing incidents inside the hole.

#### **Technical effects**

Completion of scores of pairs of opposite joint connected wells (see the table) indicates that the directional opposite joint technology in the connected wells is growing more and more mature and progressive, which is reflected as follows:

(1)Well depth: The deepest opposite joint connected well has reached the depth of 3000 m. With the increase of well depth, the requirements on the equipment bearing capacity, sidewall stabilization, wellbore cleaning, design and control of drilling trajectories will become higher.

(2)Length of horizontal section: At preset, the length of the horizontal section of the opposite joint connected well has reached 500 m, which is only less than 30 m at the early stage of the technology. The increase in the length of the horizontal section reflects the level of horizontal directional drilling technology in some way.

(3)Build-up rate: At present, the build-up rate ranges from 0.4 to 0.6°/m with 0.5°/m commonly used. Occasionally, 0.7 to 0.9°/m is used over some sections of build-up wells. The increase in the build-up rate cuts short the length of build-up sections, which leads to the longer distance of traveling through ore formation in the case of keeping well-and-well ground distance. Therefore, the waste of resources is decreased and mining efficiency is increased.

(4)Well Diameter: With full use of the potential capacity of geological drilling equipment, to enlarge the diameter of wells can increase the circulation passage and mining output. At present, the well diameter can be drilled up to more than 300 mm.

### **PROSPECT OF DIRECTIONAL OPPOSITE JOINT TECHNOLOGY IN CONNECTED WELLS**

#### **Technique Trend**



At present, intelligent directional drilling technology has become a tendency of directional drilling technology at home and abroad, which realizes the horizontal displacement of wells up to over 10,000 m. Also, multi-lateral directional wells and random horizontal wells have been put into use and research on continuous coiled tube drilling technology is identified; however, directional opposite joint connection technology has not been reported. Since the Sixth Five-year Program, a great progress has been achieved in directional drilling technology. Various advanced technologies such as down-hole screw drilling motors, MWD and accessories, diamond and PDC whipstocking drilling bits, and relevant orientation and control prediction softwares, etc have been developed. But compared with the counterparts abroad, there are still some big gaps in terms of techniques, equipments or tools and also limited application range. In the Midwest of China, exploration and mining still face many unexpected technical challenges due to complex surface and underground situation. To adapt the need of resource exploitation in the Midwest of China, it is necessary to promote and improve directional opposite joint technology in connected wells. The main tasks at present concerns research and development of down-hole drilling motors with long service life and high power, variable bending sub and bent outside pipe, variable stabilizer, and the stepwise realization of intelligent directional drilling technology; research and development of multifunctional MWD and realization of geological steerable drilling; completion of analysis, orientation and control software of drilling tools; development of prediction method and software for wellbore cleaning and stabilization in directional opposite joint technology; development of opposite joint control instruments with high precision.

#### **Potential Application Extension**

In the Midwest of China, there stored abundant underground resources for human use, such as petroleum, natural gas, raw coal, thermal energy, water, etc. With the

implementation of the National Midwest Development Program, directional drilling technology is able to fulfill many special applications owing to the geographical and economy-technology characteristics of the Midwest of China; For example, pipeline can be laid in urban and special zones without excavating ground surface; long-range directional horizontal well drilling technology can be used to cross the layer rich in gas and water to increase the mining ratio in water well, geothermal well and gas wells with longer service life; methane can be discharged from the layer rich in methane to protect the mining safety; radioactive horizontal wells can be implemented in a main well among those near-exhaustion water or gas wells to increase recovery rate and service life of wells. In addition, it can also be used to various special projects such as downward vertical holes, upward vertical holes, tunnel blast holes, multi-lateral wells, etc.

Furthermore, it can be used for exploration and recovery of deep buried minerals, extinguishing of burning coal bed, heat extraction from hot-rock, etc.

#### **SUMMARY**

5.1 Directional opposite joint technology in connected wells is used to meet the need of the economy development, which still need further improvement.

5.2 It takes time to understand a new technique, and promotion of the technique should be intensified so that it can be used in various fields of the national economy.

5.3 With the development of directional opposite joint technology in connected wells, the mineral exploration and exploitation level of our country is bound to be improved. It is useful for China to catch up with the advanced countries in exploration and exploitation technology.