

# DISCUSSION ON THE APPLICATION PROSPECT OF HORIZONTALLY BUTTED WELL IN ROCK SALT MINE OF PENGLAI

Yi-kai Wang, Cheng-gang Liao

Penglai Salt Chemical Co., Ltd of Sichuan Jiuda Daying, Sichuan 629300

**Abstract:** Through analyzing the application of horizontally butted well technology in deep well of rock salt mine of Penglai, this paper summarizes the experience and existent problems, and puts forward technologic advices for exploitation of similar mines in the future, which can be the reference in the exploitation and design of rock salt of deep well and production technology management for people of the same profession.

**Keywords:** Horizontally butted well; rock salt in deep well; safety under the well; application analysis

## SUMMARY

The exploitation technology for well and rock salt (rock salt) in China is mainly the water dissolving mining method. That is to form the well eye through carrying out the mine drilling technology, then to inject clear water from well eye in order to dissolve the rock salt mine body in the stratum and push the rock salt brine out the floor after dissolving the rock salt mine body, finally the man-made brines (rock salt brine) can be gained for processing and manufacturing of salt chemical products.

At present, the water dissolving mining technology mainly contains the process methods as follows: single-well convection(single-well positive and negative circulation), oil pad slot connection (single-well oil pad and double-well oil pad

connection), hydraulic fracturing; man-made directional horizontally connection exploitation. Besides, it also includes cavern solution mining and blasting method etc.

In the actual course of application, the former three kinds of process methods contain several disadvantages such as low output of brine, low concentration, high production cost, bad control, short service life of brine well, low recovery ratio, many accidents in the well and high frequency and cost of well repairing, etc. However, horizontally butted well technology basically overcomes these lacks.

APPLICATION SITUATION OF  
HORIZONTALLY BUTTED WELL IN  
ROCK SALT MINE

### **Advantages of horizontally butted well in rock salt mine**

The technology of horizontally butted well is to realize the convection brine exploitation by adopting the man-controlled directional drilling technology and directly drilling through the two wells away from hundreds of meters in the ledge of rock salt, then realizing the connection of two wells or multi-wells in the initial stages of brine exploitation in the salt beds. Compared with other methods, this water dissolving mining technology possesses such advantages as follows: brine with high concentration, high output and recovery ratio; brine well with long service life, long safety period, small accident ratio in the wells, low cost for brine exploitation and good comprehensive benefits.

### **Application of horizontally butted well in rock salt mine**

The directional horizontal well-drilling technology is firstly applied in the field of oil and gas prospection and exploitation, which was used to exploit the oil and gas resources with thin storage stratum and bad connection performance in order to increase the area of oil in single-well and output of the oil well. From the early 1990s, this technology began to be applied in exploiting well and rock salt. With successfully introducing directional horizontal well-drilling technology for the first time for exploring well and rock salt in Hunan Xiangheng, the connection of two rock salt wells is realized. Then Hunan, Hubei, Yunnan, Guangdong, Shaanxi etc. also popularize and apply this technology to explore the rock salt deposit with buried depth of about 1,000 meters, and also all the butted wells are successfully connected for just one time.

In recent years, Sichuan Salt Industry Geological Well-drilling Team applies the horizontally butted well technology to drill out successfully abundant butted well-groups in the well and rock salt mines such as Shaanxi Yulin, Hubei Shalongda, Jiuda Changshan Salt Mine, Yibin Changning and Nanchong etc., and the depth of wells is from 500 meters to 3,000 meters, and the distance between two

wells is from 150 meters to more than 600 meters.

### **Current situation of applying the horizontally butted well technology in rock salt mine**

The first mine which applied the horizontally butted well technology to exploit rock salt of deep well is Chongqing Suote Mine Company. In 2002, Wanyan 1 well and Wanyan 104 well are drilled through at the depth of 3,000 meters in salt bed, and the brine exploitation quantity can achieve 180 m<sup>3</sup>/h, with the content of NaCl reaching 300g/l and the salt for brine of 200,000 tons.

In recent years, the butted well technology has been used widely to explore the deep well rock salt in 2,000 meters to 3,000 meters, and the rock salt mines in Chongqing, Changning, Nanchong etc. apply this technology in brine exploitation. The opposite joint of dissolving cavity of Changning 5 well and Changning 1 well of Yibin Changning Sifeng Salt Chemical Company is the most representative among them, and the technologic parameter of this well group is: the well depth of drilling is 2,960 meters; the upright depth of drilling is 2,517.62 meters; the well depth in the KOP is 2,328 meters; the length of the horizontal level is 338 meters; the length of the salt bed footage is 529 meters; the closed horizontal displacement is 638.53 meters; the closed orientation is 325.85 degrees; the biggest deviation angle is 100.65 degrees; the output of brine is 150-160 m<sup>3</sup>/h; the content of NaCl is 300-310 g/l; the salt consumption for brine exploitation per year is 350,000 tons.

Horizontally butted well technology has currently been popularized and applied widely in rock salt mine and created considerable economic and social benefit for enterprises and society during the production practice; and it is also approved by the mine enterprises and experts. From the developing trend, this technology has been the main technology-developing direction of rock salt exploitation and deep layer exploitation in the future.



## THE CURRENT SITUATION AND EXISTING PROBLEMS OF THE APPLICATION OF HORIZONTALLY BUTTED WELL TECHNOLOGY IN ROCK SALT MINE OF PENG LAI

### The current situation of rock salt mine exploitation and the application of horizontally butted well technology of Penglai

It has been 30 years since Penglai mine started to apply the well drilling water-soluble single-well natural convection method to explore deep rock salt in February 1979. The rock salt bed is buried in  $T_2L^3$  stratum with the depth of 2,900--3,100 meters, and there are many rock salt interbeds with the depth of pure salt of 40--120 meters. According to the analysis and calculation from related information, where the ore deposit of rock salt is big type mine, which is suitable for the well drilling solution exploitation.

From October 2006, Penglai mine began to apply the horizontally butted well technology to explore the deep well rock salt. The design was to connect Yan 12 well and the old Yan 10 well (at that time, the well 10 and well 11 had been connected naturally). Finally the two wells were connected successfully in January 2008, with the distance of 505 m, the length through the salt bed of 420 m, and the well completion depth of Yan 12 well is 3,377.47 meters.

The Yan 14 well and the old Yan 11 well began to be connected in May 2005, and they were connected successfully in May 2008. The distance between them is 579 meters; the length through the salt bed is 450 meters and the well completion depth of Yan 14 is 3451 meters.

Till now, this rock salt mine has drilled 9 rock salt wells, which are 4 pairs and 2 groups of butted wells, including 2 pairs of natural connection wells, 2 groups of horizontally

butted wells, 2 accidental wells and 1 single-well. Among these 6 wells for producing brines, the output of well-group is 1500-3600  $m^3/d$  and the content of NaCl in brine is about 310 g/l. The productive capacity of mine can reach 1,000,000 tons per year.

### Current situation of horizontally butted well production

Yan 12 well was successfully connected with Yan 10 well at the top of second salt bed on 1<sup>st</sup> January 2008. First enlarge the channel by injecting water through drilling slurry pump; then inject water through high pressure brine extraction pump in Yan 10 well to enlarge the channel; then the low pressure brine extraction pump of Yan 10 well was used to inject water on 15<sup>th</sup> January 2008. Finally, the brine was produced from the Yan 12 well, with the brine output of 120  $m^3/h$  and the NaCl content of about 210 g/l. Therefore, the connection of Yan 12 well and Yan 10 well had been completed. At present, injecting water from Yan 10 and 11 well with different facilities, the brine output of Yan 12 well is 120--200  $m^3/h$  and the NaCl content of brine is about 315 g/l.

Yan 14 well was successfully connected with Yan 11 well at the top of second salt bed on 6<sup>th</sup> May 2008. First enlarge the channel by injecting water through drilling slurry pump for 15 days; then continue to inject water through low pressure brine extraction pump in Yan 4 well to enlarge the channel; and then the high pressure brine extraction pump was used to inject water from Yan 11 well to Yan 12 well on 24<sup>th</sup> June 2008. Finally, the brine was produced from the Yan 14 well, with the brine output of 100  $m^3/h$  and the NaCl content of about 310 g/l. At present, in the case of injecting water from Yan 10 and 11 well with different facilities, the brine output of Yan 14 well is 120--170  $m^3/h$  and the NaCl content of brine is about 315 g/l.

At present, Penglai mine applies horizontally butted well technology to explore deep well rock salt; the biggest brine production of the well groups can reach 200  $m^3/h$ ; the NaCl content of brine is 310 g/l and the brine productivity of the well groups is

450,000 tons. Comparing the deep well rock salt exploitation industry in our country, the performance of productivity of well groups has reached the top of the industry in many aspects like well depth, well distance and horizontal length, etc

#### **Existing problems of horizontally butted well in Peng-lai salt mine**

3.3.1. The big difference in temperature between the bottom of the well and the floor and the instability of brine production usually lead to the salt crystallization inside the well canister of brine well and frequent pipe blockage, which bring big pressure for the production organization and technologic management.

3.3.2. Yan 12 and 14 well are both connected with old well, and the exploitation layer is in the upper part of the salt bed, so it will be more difficult to go on exploring the lower part of the salt bed.

3.3.3. The casing pipes of horizontal Yan 12 and 14 wells don't reach the top of the salt bed. With the prolonging of production time, if the top plate collapses, it will influence the concentration of brine in the well.

3.3.4. Without withdrawing the central pipe of old well in time, the quantity of injected water will be influenced, and the cost of brine exploitation will be increased and comprehensive benefit will be reduced.

#### **SEVERAL PIECES OF COGNITION**

Through the application practice of horizontally butted well technology in Penglai rock salt mine, several points of cognition in respect of production and technologic management are gained as follows:

##### **The problem of pipe blockage by salt crystallization**

Pipe blockage by salt crystallization is a usual problem and difficult problem in our mine. The main reason for the brine salt crystallization and pipe blockage is: the brine well is reused for production after stopping production for the long time; the temperature

of the earth's surface is too low; horizontal level of salt bed is too long; salt bed is too deep; the temperature of the bottom of the well and solution cavity of brine well is too high; the velocity of flow of brine and output of brine are small; when the supersaturated brine with high concentration return to the mouth from the bottom of the well, with the temperature gradually declining the precipitation of salt by crystallization happens; moreover, as time goes on, the crystallization and salt precipitation become aggravated, and finally the tunnel of brines is blocked.

The technology measures for preventing the salt crystallization and pipe blockage: the first is to inject water into the well quantificationally before stopping production; the second is to inject water into the well regularly during the period of stopping production; the third is to monitor the output and concentration of brine closely during the period of production and also inject clear water to dissolve the crystallized salt in the dissolving tunnel in time according to the brine concentration and change of output; the fourth is to prevent the leaking of gate valve for outpouring brine to block the brine tunnel during the period of stop production; the fifth is to scientifically and rationally design brine exploitation process in order to reduce the elbow, changeable diameter joint and gate valve, etc. in the outflow system of brine.

##### **The problem of sand plugging**

Before putting the horizontally butted well into production formally, the well drilling facilities (slurry pump) should be employed to inject water for enlarging the channel and building the groove. When the channel and groove is enlarged enough for the requirement of production, the brine exploitation pump still ought to be used to inject water from brine well in fixed quantity and flow speed to further enlarge the sand-storage space of the bottom of brine well and the channel of brine flowage, in order that the sand plugging doesn't happen in the horizontal channel in the course of production. In the case of brine recirculation because of well stopping, power cut or



machine halt, the bottom of the brine well can not be blocked by the sand plugging.

### **Collapse of the top plate**

At the beginning of successfully butting, when using well drilling slurry pump and brine exploitation pump to inject water in fixed quantity and flow speed to enlarge the sand-storage space in the bottom of brine well and the tunnel of brine flowout, the clear water can't be excessive, otherwise, it's easy to lead the collapse of top plate of the butted brine well.

### **CONSIDERATION OF THE APPLICATION OF HORIZONTALLY BUTTED WELL TECHNOLOGY IN ROCK SALT MINE OF PENGLAI**

The horizontally butted well exploitation technology possesses the advantages which the processes like single-convection, natural connection, oil pad and hydraulic fracturing etc. don't have. Therefore, it's the main technology for exploring our rock salt mine in the future.

### **Butted style**

Considering the initial investment, if the new well is connected with the old well, nonrecurring investment expense can be saved. However, in the long term, comparing to the butting between new wells, which one is more economic still needs be further explored.

### **Well patterns**

Due to the safety period of horizontally butted well is relevantly long, which well pattern for different salt mines should be adopted such as parallel well pattern, linear well pattern, round well pattern or other patterns still need to be explored. According to the characteristics rock salt mine of Penglai, such as gentle inclined occurrence, big thickness of pure salt bed, high grade of ores and being in the fringe or inside of city, the newly-drilled brine wells may consider both linear and round well pattern according to different zones.

### **Distance between wells**

According to the buried depth, thickness and structural characteristics of the top plate lithology, it should be better if the surface well distance in our mine is controlled in the range of 500 to 700 meters and the horizontal section of salt bed under the well is in the range of 350 to 450 meters for well pattern. For example, as for the connection of Yan 12 well and Yan 10 well, the well distance is 505 meters and the distance through salt bed is 420 meters; as for the connection of Yan 14 well and Yan 11 well, the well distance is 570 meters and the distance through salt bed is 450 meters. According to the actual production, the effect for production is very good.

### **Safety management of brine wells**

The safety of horizontally butted well production can be safeguarded better than single-well method, but new unsafe factors have also appeared accordingly, such as the high concentration of brine and the channel blockage by salt crystallization. It requires the technical staff and workers for brine exploitation to strengthen working responsibility, operate strictly according to working specifications and technical specifications. Wrong operations must be forbidden.

### **CONCLUSION**

The application of horizontally butted well exploitation technology in deep well rock salt mine of Penglai has been used for more than one year, whose effect for production is very good. The output of brines is 150--180 m<sup>3</sup>/h; the salt content of brine is about 310 g/l and the output of solid salt in brine is more than 400,000 tons per year. The economic benefit is good. This advanced technology will become the main technology of exploring deep well rock salt of our mine in the future.