DISCUSSING ON THE MINING TECHNIQUE AND THE APPLICATION OF THE BRINE WELLS IN SALT MINE

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Abstract: Based on the geological characteristics of rock salt in Dingyuan salt-mine, the mining process of rock salt and its application are summarized and analyzed in this paper.

Keywords: single well convection, butting of double wells, directionally butted

PREFACE

The Dingyuan Salt Mine of China Salt Dongxing Salt Chemical Co., LTD was found and exploited by the 323 geological brigade of Anhui Geology Bureau in 1972, which located in Dingyuan County, Anhui Province. In 1976 Reserve Broad of Anhui Geology Bureau approved that the reserves of ore, sodium chloride and sodium sulfate is 1.75 billion tons, 1.24 billion tons and, 9.306 million tons, respectively, and the flat spreading area is about 14.4 square kilometers. Therefore, Dingyuan Salt Mine is awarded as high-qualified mine deposit with characteristics of shallow buried depth, high grade, easy exploitation by experts.

GENERAL SITUATION OF GEOLOGY

Production zone of rock salt

Rock salt ore deposit stored in Eocene Series Dingyuan Group Stratum under the Cenozoic Tertiary is sodium sulfate ore deposit. The surface is covered with quaternary sediments, under which is Paleozoic Permian Stratum. Dingyuan Group Stratum is formed by continental deposit, whose lithology is terrigenous riverbed, sandstone and mudstone, gypsum mudstone of lakefront facies or salt lake facies with thick rock salt layer. There is a thin conglomerate layer with the total thickness of 867.07～1812.69 m between the bottom and the upper. According to the content of mineral of lithology, Dingyuan Group Stratum is divided into five sections.

Buried depth and thickness of ore body

The ore layer of rock salts is buried about 218 meters (roof) - 594 (bottom) underground, which is shallowly buried and easy to build wells and exploit. The thickness of ore-bearing layer changes greatly, with the biggest thickness of 198.40 meters and 60～70 meters commonly. The thick thickest part is in the central depressions of the middle by east of the ore body, and it becomes gradually thin and reduces to zero suddenly in marginal part.

The occurrence and changes of salt ore layer structure

With big thickness, the Dingyuan rock salt layer contains many intercalations, about

1～26 layers, many of which are very thin. The biggest thickness of the intercalation is 5.42 meters and generally 0.5-2 meters; the thickness of a single salt layer is generally 1～5 meters; and there can be seen thick layers of salt with the height of over 10 meters in the central of ore body. Therefore, Salt ore layer and intercalation can be considered as a whole, that is, a simple single ore layer from the macroscopic view.

From the whole view, the dip angle of Dingyuan salt ore is gentle, which is about 5°～10°in the two small depression centers in ore-bearing layer. Stretching from center to edges, the dip angle gradually becomes steep , 20 °～ 40 °in the edge and 50 °in certain parts. But in vertical direction, the dip angle of salt layers changes heavily, namely, in the upper and top of stratums the dip angle is very small, but in the bottom the angle increases steeply to 40°～50°.

SELECTION AND APPLICATION OF BRINE EXPLOITATION PROCESS

Production process of single well convection

The salt ore body changes greatly in terms of shape and thickness, has shallow buried depth and interlayer with small thickness, whose structure is mostly thin beds. Therefore, a combinatorial method for brine mining was adopted in the early period, which is single-well convection benching exploitation process supplemented by double-well natural connection. The early stage is also trial stage. The structural dimension of well body is Φ194-114.3-60.3 meters; The well distance is 80 meters, the distance between groups is 200 meters; the width of ore pillar is 120 meters. After years of production , due to the fouling and clogging of pipes, the production of brines is only 4～6 m^3/h, and wells have not been connected yet. In order to create conditions for double-well dissolution natural connection, some adjustments have been made in the 2nd mining area: the distance between groups: 160 m, well distance: 60 m, the width of pillar: 80～100 m, the structure of well body: Φ 219-139.7-73. Although this structure increases the production of brine, the original concentration of brine reduces.

The advantages of single-well convection solution mining method are simple, quick effects and light work load; but many drawbacks are also found in the process of production. Especially the development of rock-salt cavity can not be controlled effectively; the roof is easy to expose in large areas, then it may collapse after destabilization; so the casing tube, central tube may come about bending or deformation. Accordingly, the service life of brine wells will reduce.

Double-well natural connection production process

Along with the development of rock-salt cavity of single well, rock-salt cavities among wells are connected together, with two or three wells connected. To increase the brine production, the central pipe of single well is taken away, then the casing pipe technology is used to realize the inflow and outflow of water: one well for freshwater injection and another well for brine outflow. For example, well groups 21#-22#-23# and 13#-14# both adopted such production process.

Double wells can be connected naturally when the cavity reaches a certain volume in the late period of single well exploitation; and it usually happens in the top of rock-salt cavity. Because connected tunnels are unknown and the connected ore layers are unpredictable, the management and control of rock-salt cavity may face some difficulties. It will take a long time to conduct production by use of dual wells natural connection and the ore layers are unknown after connection.

Rock-salt cavity connection technology between the new and the old

In order to promote the connection between new and old wells, increase the service life of old wells and brine production and improve the brine quality and recovery ratio of the mine, a new method which helps to drive new wells into the rock-salt cavity of old wells is adopted in our company over a period

of time. Namely, the newly-dug well is drilled directly into the edge of old rock-salt cavity, till reaching to the top of rocksalt cavity; and the technology casing pipe is installed to the upper part of cavity, then oil well cement is used for well cementation; after well cementation it doesn't matter whether the central pipe is installed or not, finally, the new well is connected with the old well by butting for production.

Thus, 4#、33#、34# wells built in 1993、1999 have been connected with 3#、1#、7#、8# wells, respectively. From years of production, the effects are good.

Directionally butted well technology

Directional butted technology is a directional drilling technology under the manual control, which drills through directly the two wells whose surface distance is several hundred meters in the rock salt layer of the deep earth to realize the connection of double or multi wells. Then freshwater is injected into a well to dissolve the salt ore layer for producing brines, and then the surplus pressure by injecting water will force brines to return to earth through another well for achieving the convection brine mining.

Directional butted well technology aim to make double wells hundreds of meters apart realize the water-soluble convection brine mining by using screwdrill directional drilling techniques and drilling horizontal well drilling technology. In recent years it has become the main production process, which is an advanced technology with such characteristics of less investment、large ore-controlling area and high mining ratio. From the year 2006 to 2008, our company has built 5 pairs of directionally butted wells with the brine production of about 80 m^3 / h, which is equivalent to about 6-8 single wells. So it greatly saves investment and reduces the worker's labor intensity.

1. Main equipments of directional drilling technology

In my company, the main equipments for directional drilling well technology is: TSJ - 1000 Rotary Drilling Machine, Φ73 mm drilling pipe, Φ95 mm screw drill and PDC bit, Φ105 mm non-magnetism pressure-bearing drilling pipe, logging tool while drilling, gyroscope, logging winch and notebook computer, etc. Well cementing equipment: cementing car.

2. Design of the directionally butted well technology

According to the structure of ore deposit in our mine zone and technology requirements, butted wells are usually designed in the hinterland, namely the place with the thickest salt layer and the deepest floor. The vertical well is located in the centre of basin, which is the deepest place of the floor; the inclined well locates in the upper end of the vertical well, namely the upper syncline. They are arranged along the tendency of salt layer and should carry out connection in the bottom of the vertical well. Vertical well structure: surface casing pipe: Φ219×10 mm, technological casing pipe: Φ139.7×9 mm, installed down to the roof of the mining layer, cementing with oil well cement; the central pipe: Φ73×5.15 mm, installed down to one meter above the floor. Well structure of inclined well 3: surface casing pipe: Φ219×10 mm, technological casing pipe: Φ139.7×9 mm, installed down to 10 meters above whipstocking point, cementing with oil well cement, The central pipe: Φ89×5.15 mm, down to whipstocking section.

Technical requirements: as for vertical well and inclined well, the grade of slope of the straight section is less than 3°, once inclination measurement every 30 meters, ore core of more than 85%, rock core of more than 70%, the error of well depth of less than 0.5%. Average built-up rate is 0.55, rock-salt cavity of the vertical well where target lies in: 640 meters, target range: 1 meter up and down, 5 meters right and left. The horizontal level should be less than 100 meters.

3. The construction of directionally butted wells

The construction of vertical wells is the same as that of single well. There is some difference after the well completion; gyroscope is used to do the well logging (repeated measurements) to determine the orientation of

vertical well , position of salt layers, coordinate, vertical depth, well inclination and visual translation , aiming to change the design of inclined well. After well completion, with wellhead device connected and then water injected by positive circulation, the period of cavity construction is coming. About one month, the cavity is built with certain diameter and height; the scope of the target area is expanded in the bottom of well to improve the docking of inclined well and the probability of the target hitting.

According to the logging data of the vertical well and the horizontal distance between two wells, referencing to the data of the old wells nearby, then the natural inclination direction of formation is analyzed and the depth of straight section of inclined well is determined; finally, design and calculation are made to change the orbits of inclined well and the position of target. The construction of the straight well section of inclined well is the same as that of the vertical well. The quality of the well itself should be ensured at first, that is, the control of the inclination. It needs to be measured one time each 30 meters, preventing the inclination over standard. According to the logging data of vertical well and modified orbit design of the inclined well 3, the construction scheme is determined and then construction is implemented according to the design and construction scheme strictly.

Strictly controlling the track of wellbore is a key technology of the directionally butted well technology. In the process of construction, it is required to adjust the drilling trajectory in time according to the test results of logging tool while drilling (usually a measuring point every five meters) and the design trajectory, so that the actual track of drill hole is in accordance with the designed track as much as possible to ensure the realization of connection of the cavity of vertical well. In the process of drilling, it was necessary to analyze and judge the stone dusts from drilling process or returning from the holes. Comparing the stratum of drilling process with the core-taking data of vertical well drilling, whether the stratum of the two wells is consistent can help to adjust the drilling orbit.

4. The use of directionally butted wells

Slot-building period

When the two wells were just connected, the initial dissolving channel is basically the drilling well bore, with the dimension of Φ118 mm and small dissolution plane. Therefore, after the two wells were connected, the slot should be built at once with injecting the water from the inclined well and outflow from the vertical well, and the dissolution channel diameter and dissolution plane should be increased in order to prevent the wellbore blockage by the salt crystals and water insoluble residuals. At beginning the flow rate of brine is very small; it can be gradually increased in case that the water insoluble residuals return to the ground.

Production period

After the butted wells are put into production, the content of NaCl in the brine is up to 300 g/l; the average brine production is $80m^3/h$; the maximum yield is $120m^3/h$. Because of high concentration of brine, in order to prevent the pipe blockage by salt crystallization and make the underground dissolving channel expand out regularly, the water-injecting wells and brine-producing wells should be regularly exchanged, usually once every 3-6 months; in this way, the production process can be ensured to proceed normally.

SEVERAL PIECES OF SUGGESTIONS

Reduce the number of well open and shutdown; insist the principle of production in stable pressure

To improve the yield and quality of brine wells and extend their life span, brine wells must be used normally for production. That is to say, the amount of water injected, the output of brine, the pressure of water-injection is relatively stable, and the entire brine well is in a dynamic equilibrium which is relatively stable. Once this balance is broken, the

accident under the wells may increase (Such as 1-33#). So the number of well opening and shutdown should be reduced as much as possible and operating procedures should be conformed strictly.

Develop the maintenance plan for production wells

The mine as well as the management of brine wells in our mine is always neglected in the daily time. Only when the problem happens, will it be repaired passively; so the difficulty of repairing mines is increased and even sometimes some serious consequence is caused. Under the normal circumstance, a plan of inspection and maintenance should be worked out. The central tube should be inspected and repaired at least once a year normally; in this way, the intact rate and attendance rate of the brine wells can be improved.

Mining and production of brine wells &Technical Reform

There are too much sick mines which lack of maintenance timely; some of them have been shut for over one year, such as 30 #, 31 #. And also, some new wells have not been put into use yet, since they were built, such as 35 #, 36 # which have not been installed. If these sick wells are repaired and new wells are put into use as soon as possible, the production of brine in our mine will be greatly increased. In addition, in order to enhance the output of brine extraction, prolong their service life, and maximize the rational utilization of mineral resources, the old brine wells should be made technical reform to be connected with new wells, and the problem of old wells should be treated in time.

Do the work of subsidence observation well

Because our mine has been exploited for over ten years, the cavity underground is becoming bigger and bigger. As for the connectivity tendency, on one hand, double-well connectivity used now significantly enhances the brine production and increases salinity; on the other hand, it speed up the connectivity of wells. In order to reduce losses in future caused by ground subsidence, the observation of ground subsidence should be done well as soon as possible and a comprehensive observation should be regularly conducted; prevention first.

CONCLUSION

Single well convection mining method had always been used before the year 2006 since this mine was constructed in our company, which has a long history of two decade years. There are totally 70 single wells, among which there are four well groups naturally connected. Labor intensity of workers is heavy and every worker walked more than ten kilometers per day on average. The average production of single well method was only $10m^3/h$; the general content of NaCl is 280g/l or so.

Ever sine 2006, in our company five pairs of butted wells have been successfully implemented, which have become the main force of our mine. Accounting for about 60% of the total production, it increases labor productivity. The connectivity position of directional butted wells is in the bottom of ore layer which is mined and the mining is carried out from bottom to top. So the recovery ratio of ore and generation capacity of well group are enhanced, and the brine has high concentration. The output of a well group (one straight and one inclined well) keeps the range of $70\text{-}90m^3/h$, which is equivalent to that of 6-8 single-wells, with the content of sodium chloride in brine over 300g/l. Meanwhile, the well group has more recoverable reserves, longer security period, and fewer underground accidents; with low cost of mining and longer service life.

Practice proves that directional butted well technology is feasible in our company. It not only break the former situation that single single-well convection manufacturing was the only process , but also shorten the construction period and improve the productive capacity of the mine. It provides a reliable technology safeguard for the rapid development of our mine.