Optimal Design and Research on Honeycomb-Like Structure Geothermal Production and Irrigation Well Network

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Abstract. Inspired by the honeycomb shape structure, this structural shape was applied to the design of the geothermal well network, and the CMG simulation software with STARS as the core was used to establish a geothermal resource geological conceptual model of the Liaohe Oilfield Shenyang Oil Production Plant Oilfield. This model applied hydrothermal coupling simulation technology, studied the heat recovery effects of different production and irrigation well networks, conducted comparative analysis, and finally optimized the production and irrigation well network design and chose an inclined seven-point well network. The main advantages of using this honeycomb structure are reduced investment, maximum utilization of space, and larger Covers heat storage area to obtain maximum heat recovery, and it is easy to convert to other good network forms and adjust later.

Keywords: Honeycomb structure; heat storage; sound network layout; hydrothermal coupling simulation; production and irrigation well spacing; geothermal geological model.

1. Introduction

Human beings need to learn from nature, and the scientific philosophy of nature must be carefully explored in this article. In nature, species evolve, the survival of the fittest, and what exists is often the best, and existence is reasonable. The principles need to be explored in depth.



Figure 1-1 Actual fundamental honeycomb diagram

Bees are a symbol of hard work. In addition, bees are also praised as "genius mathematicians and designers" because the nesting technology of bees is called "uncanny." The bee nest consists of a single or several relatively parallel sheets. It is composed of a nest perpendicular to the ground and a series of closely arranged hexahedral nests. The nest is composed of countless hexagonal columnar tiny houses. The bottom of the house is shaped like a hexagonal pyramid containing six triangles.

At the beginning of the 18th century, French scholar Maralchi made careful measurements and found that the angles of the three rhombus-shaped sections at the bottom of each house were equal. The acute angle of the rhombus was 70°32′ and the obtuse angle was 108°28′. It is not 120 and 60 degrees as people usually think, and it is not a regular hexagon. After calculation, it is known that a honeycomb structure composed of such rhombus faces has the largest capacity and requires the least building materials.

The structure of the honeycomb has been a great inspiration to spacecraft designers. They adopted a honeycomb structure during development: first, make a honeycomb out of metal and then sandwich it with two metal plates to form a honeycomb structure. This honeycomb structure is robust, lightweight, and suitable for sound and heat insulation. Today's space shuttles, artificial satellites,

spacecraft companies, and B-2 stealth bombers use many honeycomb structures internally, and the shells of satellites are almost all honeycomb structures.

Another typical application is to simulate the construction of a cellular structure, which is the construction of a communication network, and build a radio coverage area that looks like a honeycomb. This structure has the largest effective coverage area and the most miniature signal towers built to cover the same area, effectively reducing construction investment. Therefore, it is the optimal solution in mobile communications to adopt a cellular-like structure where radio cells are adjacent and cover the entire service area. The regular hexagonal radio coverage area is shaped like a honeycomb, hence the cellular radio cells and cellular mobile phone networks.

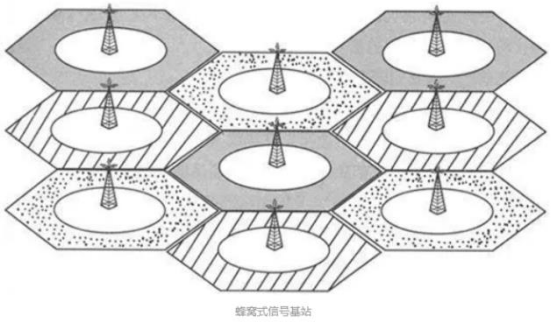


Figure 1-2 Construction diagram of cellular information base station

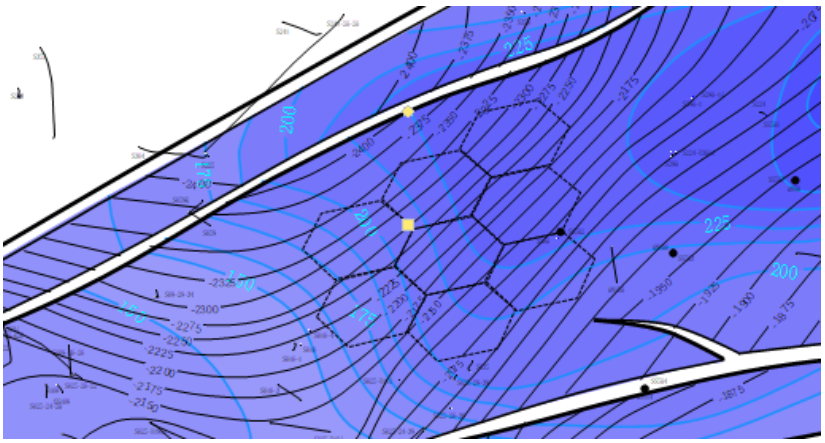


Figure 1-3 Final planning diagram of vertical sound production and irrigation design in the 260-well area of Shenyang Oil Production Plant of Liaohe Oilfield (oblique reverse seven-point blooming pattern)

For the development of geothermal resources in oil fields, the production and irrigation well network is the focus of this study [1] [2]. Compared with the center position of the honeycomb designed by this radio signal tower, it is the water intake well in the production and irrigation well network designed in this article. Each corner has advanced reinjection technology, which is almost consistent with the well pattern designed for geothermal production and irrigation of the Shenyang Oil Production Plant of Liaohe Oilfield [3] [4]. Geothermal Simulation has gradually become a popular research topic. The following article conducts detailed numerical simulation verification. Reinjection technology is the only way to develop hydrothermal geothermal resources. However, cold water reinjection technology may cause thermal breakthroughs, resulting in lower production of well water temperatures and shortened thermal field life. To this end, it is necessary to carry out a reasonable sound pattern layout for the production wells and recharge technology wells in the hot field area to achieve sustainable development and utilization of geothermal resources [5].

2. Research on the development of geothermal resources in oil fields

The Liaohe Depression has an oil and gas sedimentary basin and contains many geothermal resources [6]. Oilfield development has significant inherent advantages in thermal storage. The goals of geothermal development are mainly used for domestic heating, combined stations, oil transportation heat tracing, and pipeline cleaning. etc., saving a lot of fuel, gas and coal, and achieving significant economic and social benefits [7]. The geothermal resources in the Shenyang Oil Production Plant of Liaohe Oilfield are hydrothermal. The geothermal resource project replaces coal-fired boilers to provide clean energy for winter heating of 780,000 square meters in the mining area of the Shenyang Oil Production Plant of Liaohe Oilfield;

2.1. Regional geological background

The mining area number of the Shenyang Oil Production Plant of Liaohe Oilfield is Shen 260 Block. This block is located in the Anfutun Depression. The edge of the block is close to the bedrock and deep faults. The seismic continuity of the upper and middle sections of the Shahejie Formation in the depression is poor in the plane. The upper part is better than the leading oil and gas area.

The thermal reservoir target layer is the third member of Shahejie (S3), a sedimentary system in the fault depression period with obvious cyclicity. According to lithology combination, cycle characteristics, and fossil combination, it is divided into four sub-sections from bottom to top, namely: Sha 34 sub-member (S34), Sha 3 3 sub-member (S33), and Sha 3 2 sub-member (S32), Shasan1 subsection (S31), and the heat storage target sections are S32 subsection and S33 subsection.

Characteristics of thermal reservoir distribution vertically: the thermal reservoir section is buried deep between 800 and 2930m, and the single layer thickness is generally 2 to 10m, with an average of 460m; horizontally: the thickness of the thermal reservoir is controlled by structural sedimentation, with the most considerable thickness in the Shen 260 well area, and the cumulative thickness is more significant than 600m. It is an interlayered high-permeability thermal storage. The thickness of the thermal storage in the Shahe Street section is 450-650m, and the thermal storage temperature is 45-90 degrees.

After low-temperature reinjection technology, water is injected into the thermal storage, and the pressure (water level), temperature, etc., of the reservoir will show complex dynamic changes. If the excellent network layout parameters, such as the production and irrigation volume, the production and irrigation well spacing, etc., are set unreasonably, the thermal storage pressure will occur. A series of problems, such as excessive decline and reduction in production well temperature (thermal breakthrough), affect the life of oilfield geothermal resources. Recharge technology mining is currently recognized as a sustainable mining method for geothermal resources [8] [9]. Hydrothermal coupling simulation is an effective method to understand the response of heat storage during geothermal development. It has been widely used in the planning and management of geothermal resources in oil fields. It is an effective means to study the energy extraction process of geothermal systems and provide data support for determining a reasonable exploitation plan for geothermal resources[10].

3. Numerical model of geothermal resource development in Shenyang Oil Production Plant of Liaohe Oilfield

Based on the existing geological structure data, the STARS module of CMG software was used to establish the geological model of the Shen 260 area. Formation temperature: The formation temperature is inferred based on the study area's formation thickness and adjacent wells' geothermal gradient data. The geothermal gradient of the hot reservoir in the Shahejie area is 3.0°C/100m, the surface constant temperature zone is 30m, and the temperature is 11.5°C; the geothermal gradient between the caprock and the reservoir is Refer to the regional average data; due to the temperature connection in the thermal reservoir, the formation temperature is estimated based on the mid-depth

position of the reservoir, so the mid-depth temperature of the formation in the study area is estimated to be 68-83°C.

Table 3.3-1 Relevant simulation parameters table

Relevant parameters for simulation of geothermal resources in Shenyang Oil Production Plant of Liaohe Oilfield			
Parameter	Unit	Data	Data
Physical data		S32	S33
Porosity	%	0.198	0.192
Permeability	md	531.1	290.0
Formation thickness	m	175-325	125-225
The land reserve ratio	%	70	46
Formation temperature	℃	64	85
Tail water temperature	℃	30	30
Medium depth	m	1827	2327

Since the geological model of the entire region is too large, this paper uses it as a prediction calculation for the overall plan. It selects an ideal model for optimization research when optimizing simulation calculations for harvesting and irrigation parameters. Establish an ideal model with S33 as the target layer, with a thickness of 200m, a porosity of 0.192, and a permeability of 290md, as shown in Figure 3.3-1

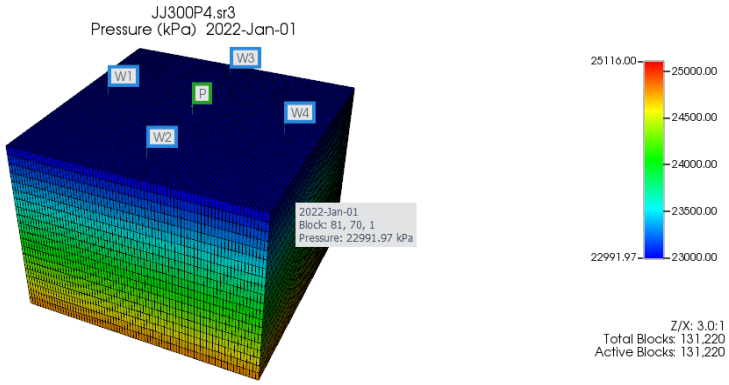


Figure 3.3-1 Ideal model of S33

3.1. Determination of well type

Since the thermal reservoirs in this area are interbedded and the average single layer thickness is less than 4.5m, it is not suitable for developing horizontal wells and highly deviated wells. This study focuses on vertical well production and irrigation development.

3.2. Determination of production and irrigation well spacing

The design adopts a five-point well network, with seven vertical sound production and irrigation well spacings ranging from 300m to 900m. The liquid production volume of a single well is limited to 80m3/h. The oil and water well effect analysis results are obtained, and the hydrothermal coupling simulation is used to calculate the 50-year development cycle—cumulative production heat of the well group.

The analysis of numerical simulation calculation results shows that when the well spacing between production and irrigation is less than 400 meters because the well spacing is too small, it is easy to form a thermal breakthrough and reduce heat production. Of course, the well spacing should be manageable, and it is challenging to balance production and irrigation, which is not conducive to Collaborative pressure reduction between production and irrigation wells. When the well spacing is more significant than 400 meters, the increase in heat produced by the well group becomes

significantly smaller. Simulation studies show that irrigation with a well spacing of about 400 meters can achieve better thermal development results.

Table 3.3-2 Optimization results of vertical well production and irrigation OK spacing

Plan	Ratio of irrigation and production wells	Extraction-irrigation ratio	Liquid volumem^3/h	Liquid production volumem^3/d	Reinjection technology volumem^3/d	Cumulative heat production in 50 yearsJ	Growth ratio%
Five Points300	4	1	80	1920	480	7.63E+15	/
Five Points400	4	1	80	1920	480	8.27E+15	8.45
Five Points500	4	1	80	1920	480	8.45E+15	2.1
Five Points600	4	1	80	1920	480	8.48E+15	0.35
Five Points700	4	1	80	1920	480	8.49E+15	0.12
Five Points800	4	1	80	1920	480	8.53E+15	0.52
Five Points900	4	1	80	1920	480	8.53E+15	0

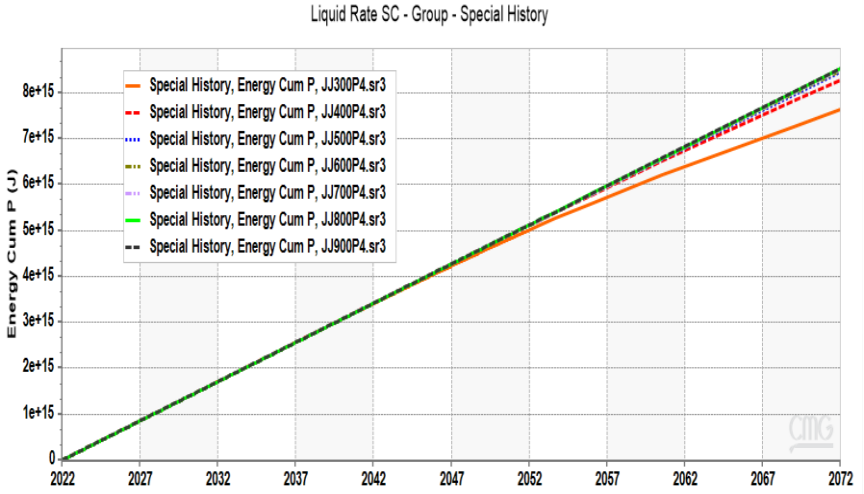


Figure 3.3-2 Comparison curve of heat recovery calculation at different well spacing in the primary layer.

3.3. Research on optimization of production and irrigation well network

Comparing the blooming patterns of oil and water wells in common oilfields, the non-area water injection method is better than area water injection. The characteristics of area water injection are wide adaptability and quick results. It should be adjusted and suitable for various geological conditions. The reservoir distribution is irregular, the extensibility could be better, and the structure needs to be completed in large areas. , fault distribution can be deployed.

Area water injection wells are divided into triangular and square blooming patterns. Here is a comparison table 3.3-2 of common blooming patterns. Geothermal investment must be low. It is not recommended to invest in four wells in one well group (nine points). It is too large. In addition, according to actual statistics, the production and irrigation capacity ratio is between 1 and 2. From the average control area of each well, the triangular well network is slightly lower, so it will not be considered this time. Therefore, the three gray schemes in the simulation table in this article are determinant, inverse five-point, and inverse seven-point-inclined seven-well networks (like honeycomb structure).

Table 3.3-3 Comparison table of expected production and irrigation well network forms

Well pattern system	Well pattern shape	Well number ratio	Well group control area F	Average control area per well S
Determinant	Determinant Square Well Pattern	**1**	**2A*A**	**A*A**
Inverse five points	square well pattern	**1**	**2A*A**	**A*A**
Reverse nine o'clock	square well pattern	3	4A*A	A*A
Reverse seven points-slant seven	square well pattern	**2**	**3A*A**	**A*A**
determinant	triangular well pattern	1	1.732A*A	0.866A*A
Inverse seven points	triangular well pattern	2	2.598A*A	0.866A*A
Oblique reverse nine points	triangular well pattern	3	3.646A*A	0.866A*A

A well spacing = a row

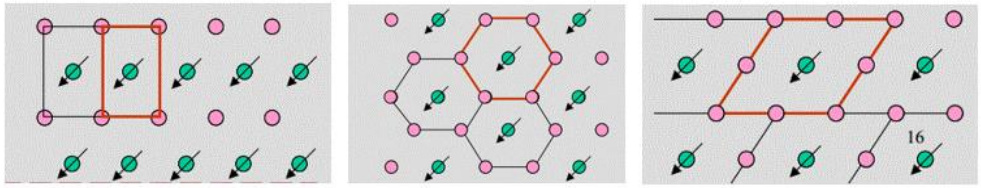


Figure 3.3-3 Schematic diagram of a triangular well network

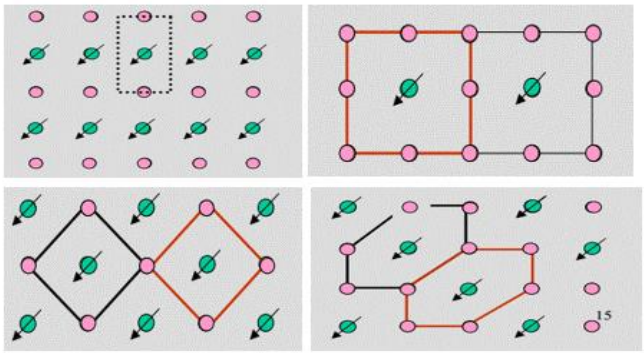


Figure 3.3-4 Schematic diagram of the square well network

Geothermal wells generally adopt the mode of multiple injections and one production under the same production and irrigation with a well spacing of 400m and the same liquid production volume compared with oil wells. That is, there is no inverse word before the name of the well network. Study and compare the row well network and the five-point well network. The thermal development effect of the inclined seven-point square sound pattern.

Table 3.3-4 Comparison table of simulated heat recovery effects of different blooming patterns

Plan	Ratio of irrigation and production wells	Extraction-irrigation ratio	Liquid volumem^3/h	Liquid production volumem^3/d	Reinjection technology volumem^3/d	Cumulative heat production in 50 yearsJ	Growth ratio%
Row well network	1	1	80	1920	1920	7.82E+15	/
Five points 400M	1	1	80	1920	1920	8.27E+15	5.79
Oblique seven points 400M	2	1	80	1920	1920	8.33E+15	0.63

From the calculation results and field diagram analysis, the determinants of the three well patterns are the worst. There is little difference between the five-point and seven-point inclined square well patterns. Both of them can be deployed as well as patterns. However, the number of irrigation and production wells in the five-point well pattern is higher than that of the inclined seven-point well pattern. The seven-point investment is significant which is conducive to reducing the intensity of injection wells and increasing the technical capabilities of reinjection. The operation is more reasonable, and the latter two sound patterns can also be combined.

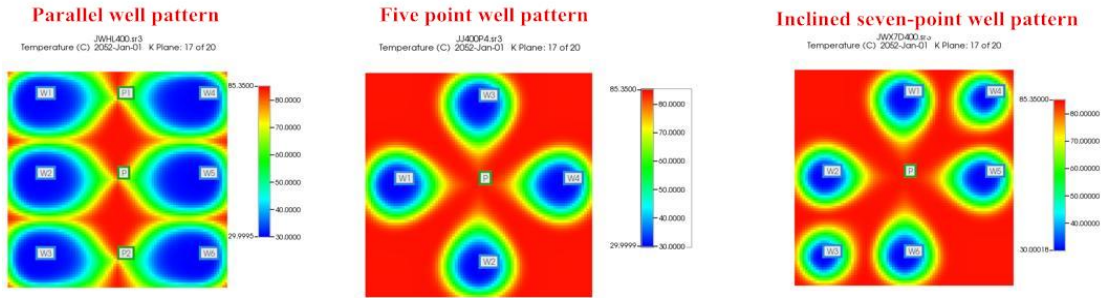


Figure 3.3-5 Comparison of plane temperature fields of different well networks in the same layer during 30 years of development

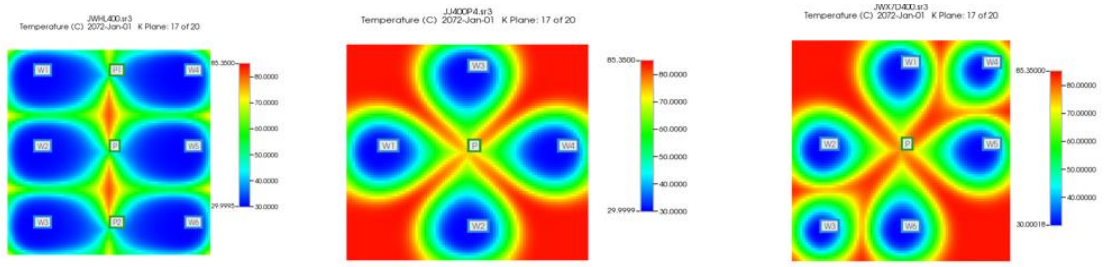


Figure 3.3-6 Comparison of plane temperature fields of different well networks in the same layer during 50 years of development

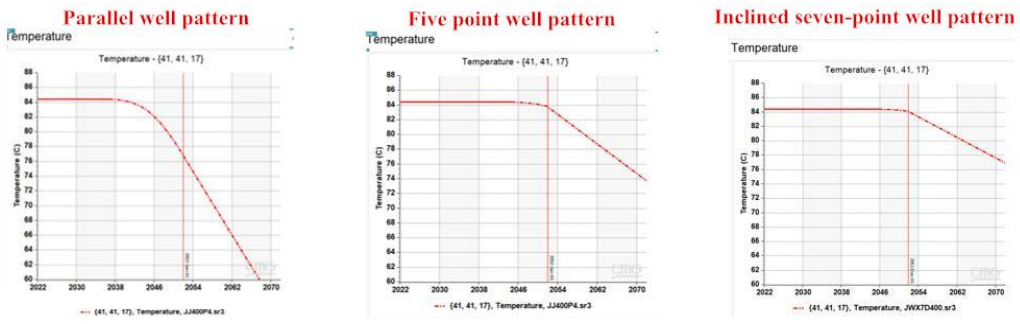


Figure 3.3-7 Temperature variation curve with time at the exact location in heat extraction wells in different sound patterns

Judging from the temperature of the produced fluid at the bottom of the thermal reservoir, in the row well pattern, the temperature maintained at 85 degrees for 16 years has a rapid decline, with a decline of 25 degrees at the end, while the five-point and seven-slant sound patterns have a slow decline, which can reach 24 years at high temperatures. By the end of development, the reduction was less than 10 degrees, among which the inclined seven-well network was better.

Finally, an inclined seven-point honeycomb-type sound form was adopted for unified planning in the whole area, achieving 8 honeycomb structure well groups, 8 heat production wells and 22 recharge technology wells, see Figure 3.3-7

4. Advantages of honeycomb structure inclined seven well network

This kind of blooming pattern has different angles from the standard honeycomb. First, the internal angles are 90 degrees and 135 degrees instead of 120 and 60 degrees. Secondly, the length of the hypotenuse of the blooming pattern is 1.414 times that of the right-angled side. This kind of honeycomb well pattern is very suitable for Geothermal development and has the following advantages

(1) The most significant single well control area suitable for geothermal production and irrigation

In developing geothermal wells, the amount of pressureless reinjection technology is low. How to improve the amount of reinjection technology is a common problem. There are six production and irrigation wells around each heat production well, and the corresponding single well can be dynamically allocated. Recharge technical volume.

(2) Flexible well pattern conversion

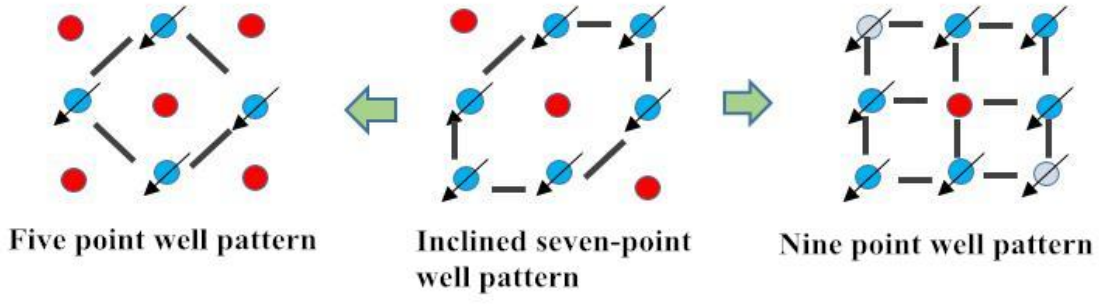


Figure 4-1 Conversion of an inclined seven-point well pattern

As shown in the figure, it can be flexibly converted into a five-point well network and a nine-point well network. The irrigation and production ratio in the area changes between 1 and 3. Dynamic balance in different periods of geothermal development can be achieved by adjusting the irrigation and production wells. (3) Adapt to the geological sedimentation characteristics of oilfield geothermal resources

Adjust the rotation angle of the well network to ensure that the long axis direction of the well network is consistent with the direction of the sedimentary channel, that is, the direction of the source with good physical properties, and achieve a balanced irrigation and production volume of the geothermal well network.

5. Conclusion

Study the heat extraction effects of different production and irrigation well networks, conduct a comparative analysis, optimize the production and irrigation well network design and choose an inclined seven-point well network. This honeycomb-like structure is used, which is mainly suitable for geothermal mining. The advantages are reducing investment, maximizing space utilization, Covering a larger heat storage area to obtain maximum heat recovery, and at the same time, it is easy to convert to other well network forms and flexible for later adjustments.

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