Application of Outside Casing Water Level Monitoring Tube System in Medium-low Temperature Geothermal Well

FENG Shuyou，RUAN Chuanxia, SU Xiaofei, LUO Li，YANG Zhongyan

Tianjin Geothermal Exploration and Development Designing Institute, Tianjin, 300250

Keywords

Tianjin, geothermal energy, gauge measurement system, geothermal well

ABSTRACT

It realized the geothermal well water level dynamic monitoring by installing a set of water level monitoring tube system outside casing. Based on this achievement, the author carried on reduced pressure test and monitored data of water level in the conditions of outside casing and inside casing. According to the comparison results, the actual error value was between 0 m and 0.02 m, in the range of allowable error, which do demonstrate the water level monitoring tube system outside casing can be competent for observingthe geothermal well water level.

1. Introduction

Water level dynamic monitoring is an important basic work in the development and utilization of geothermal energy. Since 1980s water level dynamic monitoring had begun in Tianjin, the major dynamic monitoring includes water level, water quality, water temperature and reinjection rate, and so on. Based on the arrangement and analysis of dynamic monitoring data, we acknowledge objective and accurate understanding of the development and utilization of geothermal energy and the change trend of thermal reservoirs, which provides scientific basis for the exploration, development and utilization of geothermal energy in Tianjin and provides real-time and accurate information for geothermal energy planning and management decision.

Therestill exist some deficiencies in the water level monitoring equipment development and application at present. For example, water temperature and water quantity monitoring has been basically achieved remote automation in Tianjin dynamic monitoring of geothermal energy, nevertheless, water level monitoring still remain manual measurement. The monitoring line is down to the gaps between the surface casing and pumping pipe (Fig.1), Manual measurement which gaps the line from wellhead into the annual of surface casing and submersible pump pipe is easy to wind with cable affecting the measurement accuracy. Furthermore, the line often broken in the well, the water level cannot be observed, also cause safety hazard of submersible pumps. We use the pump tube observation tube to improve the water level measurement efficiency and authenticity, failed unfortunately. In this paper, we design a relatively independent water level observation tube system, placing outside the casing of the geothermal well. Through studying the construction requirements and materials we gain success in use.

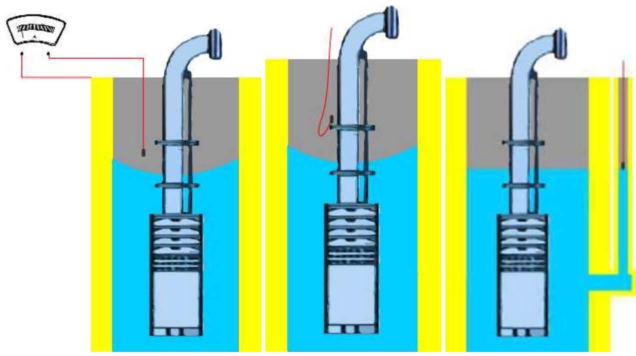

Fig.1 Conventional Observation Illustration Drawing

2. Dynamic monitoring status of Tianjin Geothermal Energy

2.1 Dynamic monitoring status of Tianjin Geothermal Energy

By the end of 2016, 632 geothermal wells are registered 220 of which are main monitoring and are tested twice a month in Tianjin. Besides, there are some problems in geothermal dynamic monitoring in Tianjin at present. The current water level monitoring system is manual monitoring in casing which has been used since 1970s. The dynamic monitoring work of water level is difficult to realize, because of aging wellhead, small pump space, a part of aged geothermal wells having been abandoned.However, the development of automatic water level monitor has achieved initial results. The intelligent network monitoring of geothermal well has been greatly affected because of the pipe corrosion and fracture. Manual dynamic monitoring is still the main method at present.

2.2 Current Status of Water Level Monitoring Pipe in Geothermal Wells

2.2.1Fixed Welding Water Level Monitoring Tube

The black pipe, the same long as the pump pipe, is placed in pre-processing slot of flange and firmly welded. It is installed when water level measuring tube connects the pump pipe. This tube has several shortcomings, as it is difficult to be replaced, the diameter of new and old tube is different, the pump pipe sealant mat probe blockage channel, welding is not firm or rust corrosion cause loss, etc., these factors will affect the water level dynamic monitoring and data collection.

2.2.2 Suspension Pluggable Water Level Monitoring Pipe

This type of tube is wildly used in the most types. It is mainly composed by DN20 galvanized pipe, fixed flake and suspending connection jacket. Firstly, connect the end of the DN20 galvanized pipe to the end of the suspension connection sheath with thread. Then install it to the pump pipe flange. At last, insert each pipe to the holes in the flange. The pipe has some advantages, for example changing welting to suspending, easy to replace and transport, connection of the upper and lower pipe is completed in sheath excluding which solve the different diameter problems of new and old pipe and sealant gasket blocking, the replacement of same model new and old monitoring pipe will not affect the usability. However, the service life of pipe is only six months to one year because of galvanized pipe usually being corrodedseriously. It is necessary to timely maintain and replace the monitoring tube to ensure the water level data collection rate and continuity.

3. Outside Casing Water Level Monitoring System

Outside Casing water level monitoring system is an observation instrument, which can be easily placed and is convenient forwater level monitoring. It is a part of the well structure, connecting the casing to ensure consistent water level inside and outside, but with greatest degree of independence. Its function loss or structural damage should not affect normal work of the geothermal well. In the construction process, without changing the original drilling process, the water level monitoring system does not bring unacceptable difficulties or risks, is easily installed, and is economic and durable.

3.1 Component of Outside Casing Water Level Monitoring System

The outside casing water level monitoring system mainly includes monitoring tube, connecting joints, monitoring tube fixture and monitoring tube connecting base (Fig.2).

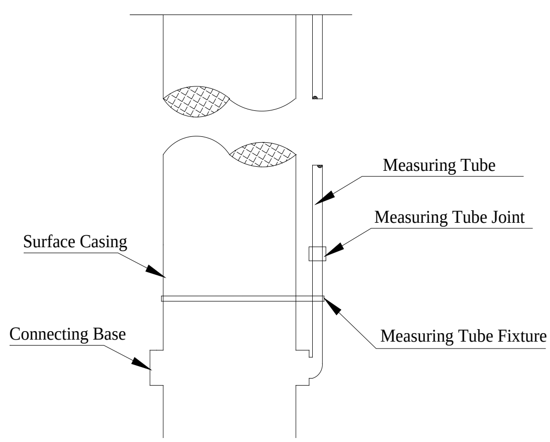

Fig.2 The structure of outside casing water level monitoring system

3.2 Technology Requirement of Outside Casing Water Level Monitoring System

(1) Based on the conventional open hole diameter, the diameter of monitoring tube is 42mm, the maximum radial length of the entire casing structure is 434mm, and open hole diameter 445mm.

(2) Considering the drilling process requirements after tripping the tube, the compression strength of the material and its components should be higher than 10MPa.

(3) Put a single nylon block in the connecting base of casing and tube.

(4) To ensure entire surface string strength, the connecting base is made in surface casing coupling.

(5) Using some special ring to fix the tube to surface casing. Strictly control the cementing quality and make sure to return the cement slurry to the ground.

(6) In order to easily connect the tube and shorten the tripping time, the tube is designed with male and female joint, special lifting tools are made, and a number of pup joints are processed.

3.3 Technology Program of Outside Water Level Monitoring System

3.3.1 Structural Design

Without changing the open hole diameter 444.5mm and surface casing diameter 339.7mm of conventional geothermal well, the tube diameter should be between 35mm and 45mm and is designed as 42mm. The system is attached to the surface casing, which makes the maximum diameter as 434mm and less than 445mm (Fig.3).

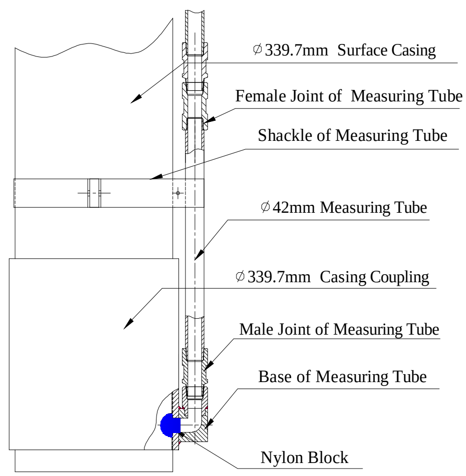

Fig. 3 the Installing Illustration of Outside Water Level Monitoring System

3.3.2 Material Selection

According to the surface casing cementing and subsequent construction technical requirements of conventional geothermal wells, he very material should possess several properties. The internal pressure strength must be greater than 6 MPa and the material ought to be easily connected and highly non-corrosion. Several materials are compared, including of tubing, seamless steel pipe, galvanized pipe, geological drill pipe, PPR pipe and PVC pipe (Table 1).

Table 1 Material Comparison Table of outside casing

NO.	Material	tensile strength	Connection	Anti-corrosive	Inner volume
1	tubing	high	conventional	medium	satisfied
2	seamless steel pipe	high	conventional	medium	satisfied
3	galvanized pipe	medium	conventional	weak	satisfied
4	geological drill pipe	high	conventional	medium	satisfied
5	PPR pipe	low	conventional	strong	satisfied
6	PVC pipe	low	conventional	strong	satisfied
Conclusion	Comprehensive strength, price and other factors, we select seamless steel pipe as the tube material.				

(1) All the six material can satisfy the system requirement in diameter and connection.

(2) Both PPR pipe and PVC pipe are good at anticorrosion, weak in tensile strength and yield Strength. They are not suitable for being monitoring tube.

(3) With convenient connection, strong tensile strength and cheap, galvanized pipe is mainly used of monitoring system. However, its anticorrosion is weak with less than 2 years lifetimeand not suitable for casing outside monitoring tube.

(4) Tubing, seamless steel pipe and geological drill pipe can meet the system requirements in tensile strength, connection and anticorrosion, while geological drill pipes are expensive and the 42.2mm diameter tubes are difficultly purchased.

Through the above analysis, seamless steel pipe is designed as monitoring tube because of the properties of cheap price, high tensile strength, easily connected, good corrosion resistance and so on.

3.3.3 Design of Tube and Connecting Joint

The tube is made of the 45# seamless steel pipe of outside diameter 42mm and thickness 6mm and covered anti-rust paint. Both ends of the tube are installed with male and female joints, which are made of 45# seamless steel and sized 54mm × 12 mm. The joints are connected with threads (Fig. 4).

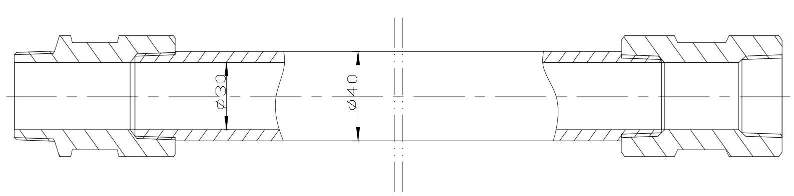

Fig. 4 The Tube Diagram

3.3.4 Tube Fixture

The tube fixture fastens the outside monitoring tube and surface casing through connecting bolt and supports the self-weight of the outside tubes. Through the production of samples and the installation of the experiment, we chose "Uo" type tube fixture for its simple structure, easy processing, conveniently installed (Fig. 5). The tube fixture is made of 40mm diameter, 4mm length with Q235A steel, and coated with anti-rust paint. and not suitable for casing outside monitoring tube.

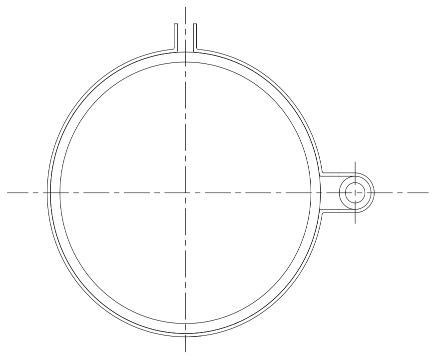

Fig. 5 "Uo" Type Tube Fixture

3.3.5 Design of Connect Base

The connect base of monitoring tube is made of short casing. It is hermetically connected by the surface casing at 200m depth with threads and welding connected with steady of the outside monitoring tube. (Fig.6)

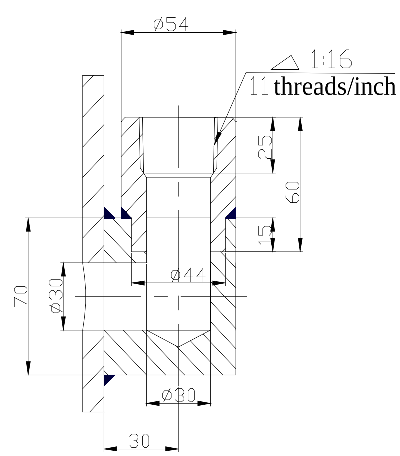

Fig. 6 Sectional View of Steady of the Outside Monitoring Tube

3.3.6 Processing-Production of the Outside Monitoring Tube System

According to the design, we produce the components of the monitoring system of the geothermal well. The tube is made of the seamless steel of diameter 42mm and wall sickness 6mm that both ends are threaded and the surface is coated with antirust paint. Both ends of the tube are installed male and female joint, made of 45# seamless steel and made 100mm length, 54mm diameter and 12mm wall sickness. The joints threads are internal flat thread. The connecting joints are made of the 339.7mm casing of 400mm long extended coupling. The tube fixture is processed to 40mm diameter and 4mm length Q235A steel and coated with anti-rust paint. Considering the risk of cementing pressure leakage, we decided to add a nylon block in case. Its diameter is 40mm and length is 20mm, while the small end diameter is 30mm.

4. Field Test of Outside Water Level Monitoring System

4. 1 the basic condition of test well

The test well (SY-01) is a two open structure vertical and lies in Xiawuqi, WuQing District. The purpose reservoir is Guantao Group of Neogene. The well SY-01 is completed with perforation. It officially started drilling on March 21, 2014 and completed at 2180m depth on April 10, 2014. According to the cuttings and logging data, the SY-01well strata is exposed from new to old that is the Cenozoic Quaternary, Neogene, and Paleogene (Table 2). The well SY-01 is completed with water 61℃ temperature and 150.63m ^{3} / h flow. The well structure and casing procedure are shown in Table 3.

Table 2 Strata Exposed by SY-01

strata		depth	
		Down depth（m）	thickness（m）
Quaternary		380	380
Neogene	Minghuazhen Group	1480	1100
	Guantao Group	2150	670
Paleogene		2180	30

Table 3 SY-01 Well Structure and Casing Procedure

procedure	Bit		Casing and Measuring tube	
	Caliper（mm）	Depth（m）	Diameter（mm）	Length（m）
First	444.5	400	339.7	400
			42	207.73
Second	311.2	2180	244.5	2180

4.2 Filed Experiment of Measuring Tube System

(1) According to the current geothermal drilling process, the surface casing diameter is 339.7mm, wall thickness is 9.65mm, steel grade J-55, and meets API standard oil casing.

(2) The tube should be positioned deeper than 200m outside of the surface casing, the bottom and surface casing is connected by special joint.

(3) Before tripping the tube, we should measure, number and connect the tubes on ground.

(4) When the surface casing is down to 207.73m depth, the tube connect base is tripped and connected by the tube.

(5) According to casing and tube number tripping, using tube fixture to fix the casing and tube.

(6) When the surface casing reaches the end, the tube is 1m higher than the ground, fill the water into the tube and install the nylon block.

(7) Using R32.5 slag Portlandcement to achieve well cementation , slurry returns to the surface, the density is 1.70g / cm^3 that meets the design requirement.

(8) Correct tube length (Fig.7).

$L_T = L_1 + L_J - L_D$ （Equation 1）

where L_T, L_1, L_J, $L_D$aretheoretical tube length, casing length, casing joint length, drilling floor height, respectively.

The surface tube of SY-01well is 212.03m, the casing joint length is 0.2m, the drilling floor high is 4.56m, and the tube length is 207.55m. In fact, the tube length is 207.73m. Finally the tube theoretical and actual length error is 0.06m.

From the calculation results, based on the casing length the tube theoretical calculation length is only 0.06m shorter than actual length. In the actual measurement of water level, the error will be much smaller than 100m. Thus the error can be ignored when processing data.

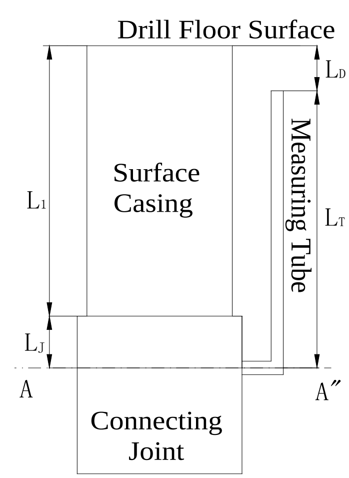

Fig. 7 The Correct tube length diagram

4.3 Experiment of Water Level Monitoring System

4.3.1 Pumping Test

SY-01 well has performed three different pumping test duringApril 25 to 28, 2014, including the large depth down test, middle depth down test and small depth down test. Before the pumping, we should open the nylon block at first. According to the field equipment and connecting parts, we use air compressor to transfer 4MPa pressure and open nylon block. The flow rate of pump is 140m3/h, its head life is 180m, the flow rate is observed by the triangular weir box, and the water level is measured by current water level gauge. The water level values of the wellbore and the tube were measured respectively. All the test data were collected and the length of the survey line was corrected. Besides, the water temperature and temperature were observed by mercury thermometer. The duration of each depth step-down is 2880min, 580min, 550min and the stabilization time is 24h, 8h and 8h, respectively. The test results are shown in Table 4.

Table 4 SY-01 Pumping Test Result

Drawdown / program	Large drawdown (S_3)	Middle drawdown (S_2)	Small drawdown (S_1)
Water Temperature（℃）	61	60	59
Water level in tube（m）	91.86	80.25	62.20
Water level in casing（m）	92.08	80.35	61.80
Flow rate（m^3/h）	150.63	112.78	49.65

4.3.2 Data Processing

We can get the stable dynamic water level difference of casing (hC) and tube (hT) through cumulative time and three times drawdown measuring the corrected dynamic water level of casing and tube. Make the curve of hE and flow rate Q, then regress the curve. We get the empirical formula (Figure 8).

Table 5 SY-01 Calculated Data Results

Program	Large drawdown (S3)	Middle drawdown (S2)	Small drawdown (S1)
Flow rate（m^3/h）	150.63	112.78	49.65
Water level in casingh_C（m）	92.08	79.96	61.08
Water level in tubeh_T（m)	91.86	79.86	61.48
Corrected Water level Error h_E（m）	0.22	0.10	-0.40

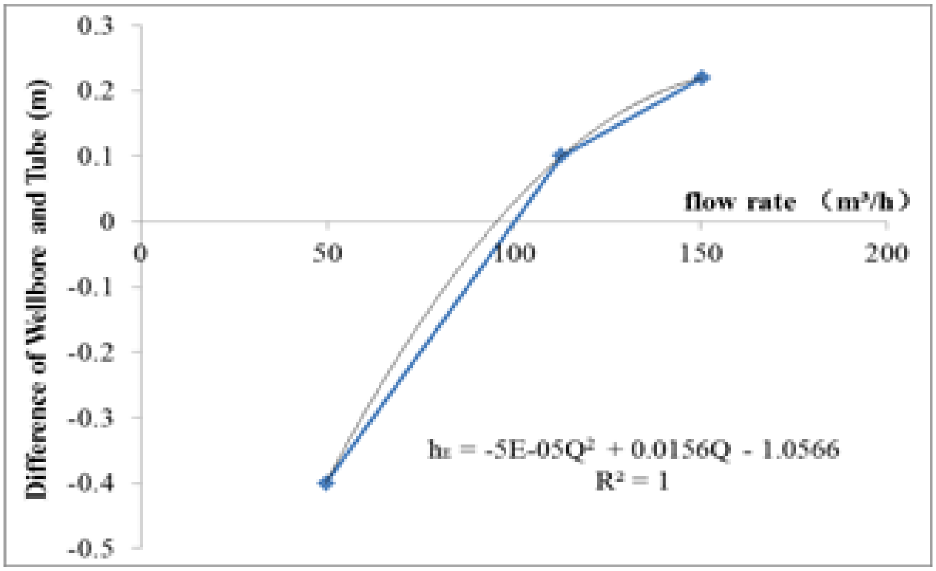

Fig. 8 h_E-Q difference curve data

Through the quadratic curve regression of the data, the curve fitting degree reaches 100% and get the empirical equation is obtained.

$h_E = h_C - h_T = -5 \times 10^{-5} * Q + 1.6 * 10^{-2} * Q - 1.05$ (Equation 2)

where h_E, h_C, h_T, Q are corrected dynamic water levelerror of casing and tube, corrected dynamic water levelerror of casing and tube, corrected dynamic water level in tube, flow rate, respectively.

In order to verify the accuracy of the formula, we verified the formula 2 and carried out error analysis with equation 3. The results are shown in Table 6.

$H_{E2} = h_{E1} - h_E$ (Equation 3)

where h_{E2}, h_{E1}, h_{E2} are error, calculated water level difference, actual water level difference, respectively.

Table 6 Error Analysis Data Table

Water Capacity（m^3/h）	Calculated water level difference h_{E1}（m）	Actual water level differenceh$_E$（m）	Error h_{E2}（m）
150.63	0.23	0.22	0.01
112.78	0.12	0.10	0.02
49.65	-0.38	-0.40	0.02
92	0		

It can be seen that the actual error value is between 0 and 0.02m through calculation. Generally, the calculated water level difference is bigger than the actual water level difference, but within the error allowable range .We can conclude that the water level monitoring tube system outside casing can be competent for observingthe geothermal well water level.

5. Conclusion and Suggestion

5.1 Conclusion

(1) Compared the installation and construction, the process is added 2 hours tripping time and the process are compact, worked easily. The monitoring system is feasible without adding difficulty and risk of drilling construction.

(2) It can be seen from the calculation that the actual error value is between 0 and 0.02m. Generally, the calculated water level difference is bigger than the actual water level difference, but within the error allowable range. We can conclude that the monitoring system can realize the water level observation work of the geothermal well.

5.2 Suggestion

(1) The conclusion is limited because it is just tested by one geothermal well. We still need to do a large number of buck test analysis in the future.

(2) In the future work, we still need to further the theoretical research and establish relevant models.

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