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The Ground Temperature Monitoring Method of Borehole Pipe Heat Exchangers

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ABSTRACT

The stratum temperature measurement and digital transmission systems of distribution and tandem is a core technology to improve marine layer temperature measuring sensor, and overcome many drawbacks of the traditional test, such as more test wires, commissioning difficulties, high cost, hardly reflect the true soil temperature. This technology considered the accuracy of measurement temperature, the stability of the instrument, the feasibility of installation, price and other factors. The experiment showed that, the measured temperature difference between inner and outer PE pipe is 0.05 -0.1 °C, which could reflect the actual formation temperature variation, and the measuring line in PE pipe has several advantages, such as: survey line can be replaced, the measured line is better protected, etc.. This ground temperature monitoring method has been applied in many heat transfer systems, the accuracy and stability can meet needs of subsurface temperature dynamic monitoring in the development and utilization.

With the development of society and economy, the world's attention on environmental issues is increasing. Shallow geothermal energy as a renewable energy, is increasing people's attention. Using it can achieve energy saving, environmental protecting purposes. Shallow geothermal energy has been started in China since 1960s, and has made a large number of achievements. For a better use of the green shallow geothermal energy in economic construction, MLR issued No. 249 document< Notice on vigorously promote the development and utilization of shallow geothermal energy >(MLR issued No. 249 [2008]) deploying to the nation geological exploration units three tasks: investigation and assessment, to identify shallow geothermal resources; preparation of planning, ensure sustainable use of shallow geothermal energy; strengthen monitoring, control the development and utilization dynamics. The document required "Protect in the development and develop under the protection." We should implement standardized management and promote healthy development and utilization of shallow geothermal energy. Because the development and utilization of shallow geothermal energy requires heating the ground and taking heat from it, so the dynamic monitoring should not only record system operating conditions and energy consumption, calculate EER, test project energy savings, but also monitor the ground heat exchanger group and the surrounding areas ground source side geothermal field, water table, ground elevation and other geological environmental factors (Han J.H., Lin L., Zhang X.X., et al. 2011)

1. THE STATUS OF GROUND TEMPERATURE MONITORING

Currently, the buried ground temperature monitoring are mostly adopted in China,. This method has many problems. For example: using more leads and on-site commissioning is difficult. Three leads are needed for three buried temperature sensors. If the measurement accuracy reaches 0.1 °C, each line requires not only temperature calibration, but also the further increase the accuracy of to adjust the length of the wire resistance. So one temperature measurement point needs four leads a total of 48 leads are needed for a 120m borehole, if a temperature point is laid every 10m.

The location of the sensor is in larger range and not smooth, which will form interspace after it down into the monitoring hole, the sensor data will also drift as time goes on. Therefore, it cannot accurately reflect the true rock layer temperature which is mainly related to the physical properties of the sensor;

The accuracy of the measurement data is insufficient. Considering the temperature measurement accuracy of 0.1 °C, the resolution should reach 0.05 °C, the conventional sensor is difficult to meet this requirement.

The collected temperature signal is analog signal, which needs to transform secondary instruments and high-end telemetric module, resulting in higher costs and construction requirements of the sensors; the survival rate is low and can’t be replaced. In some projects, some buried sensors were soon found that it can’t be used, some sensors failed to measured after a period of operation. The main reasons for this phenomenon are improper construction methods, sensors gland structure and waterproof design improper, or processing quality does not meet the requirements.

2. THE NEW GROUND TEMPERATURE MEASUREMENT AND DIGITAL TRANSMISSION SYSTEMS

In order to do long-term monitoring, avoid the shortcoming of direct buried sensors, and create conditions for the ongoing maintenance and replacement, easy sensor calibration and periodic damage sensor replacement. For the development and utilization of shallow geothermal energy, we developed a "Distribution of the tandem formation temperature measurement and transmission fine collection system." This system improved the core technology of regional hydrological wartime naval vessels firing fast wired marine layer temperature measuring sensor, independent research on micro-silicon integrated micro-silicon temperature sensors, temperature transmitters, TCP / IP module, digital to analog conversion, data Output Interface all functional modules and register digital compensation module. The SOC chip can direct output digital temperature under 10MPa pressure, small size, simple cabling, only four wires laying serial number of sensors are needed for the entire system position, temperature depth is up to 600m. Its performance is reliable, the requirements of on-site construction technology are low, it can be made smooth cable. The system will combine temperature measurement components, transmission wires and ground data acquisition systems. This digital measurement system has considered the temperature measurement accuracy, stability of the instrument, the feasibility of installation, price and other factors (Tian G.H., Lin L., Chen W.Q., et al.2011).

The geothermal monitoring sensor system of ground heat exchanger systems group design is shown in Figure 1 to Figure3. It consists of three core components, namely, the temperature sensor module, relaying reliable digital transmission module and the reliable data acquisition module with SNR of less than 1.

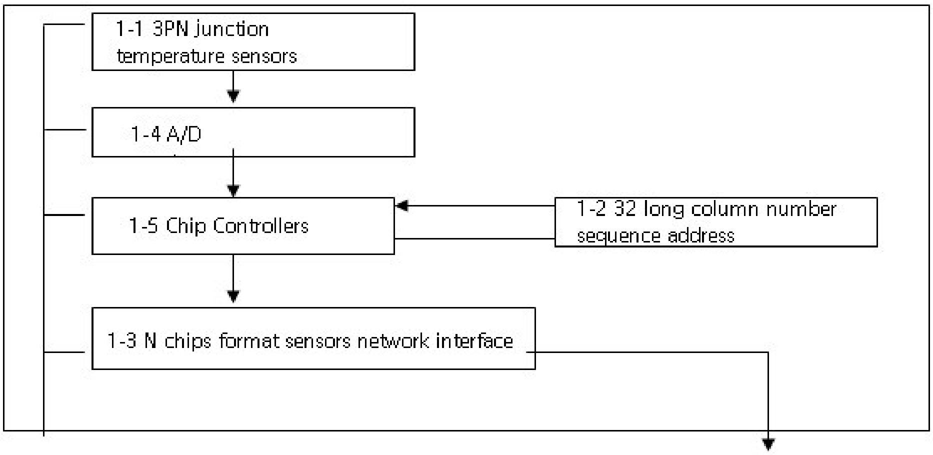

Figure 1: Temperature sensor module

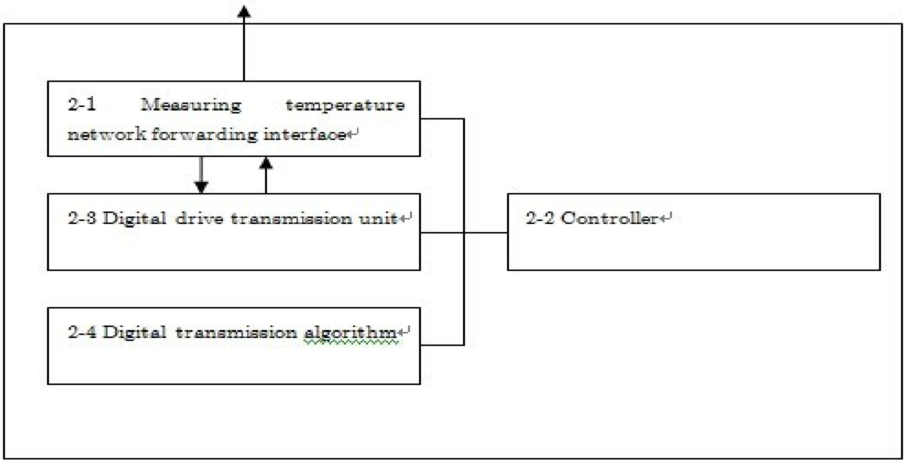

Figure 2: Relaying reliable digital transmission modules

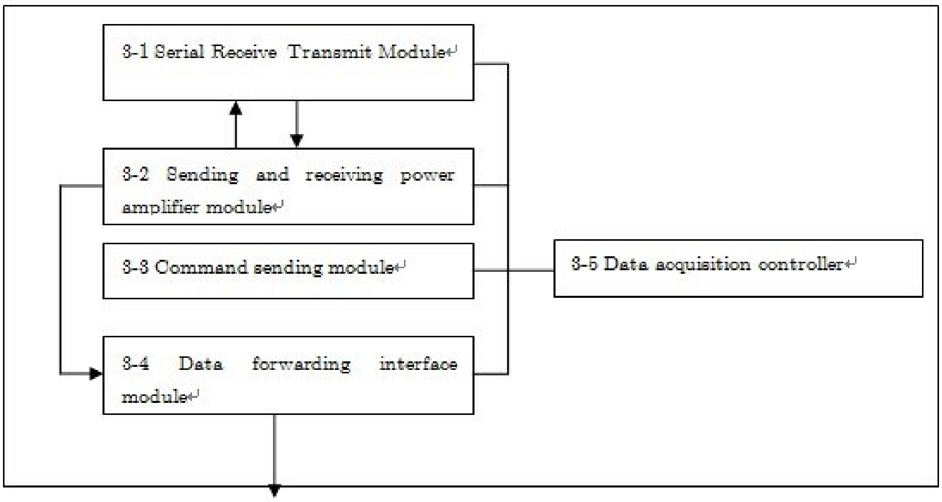

Figure 3: The reliable data acquisition module who's SNR is less than 1

A plurality of temperature sensors may be connected in parallel to a signal line in each of the monitoring hole (1). Interval 5m, 10m, or any custom intervals, each measuring point comprises more than three sensors. We installed in series in the signal line and the signal line ground transmission line one relaying reliable digital transmission module every 30 m(2). In the control room, the signal line connects with the data acquisition module (3), and the data acquisition module send the collected data through the serial port to a computer. We use computer to compare and analyze the collected temperature data. (Figure 4 to 7).

Figure 4: Temperature measuring cable schematic

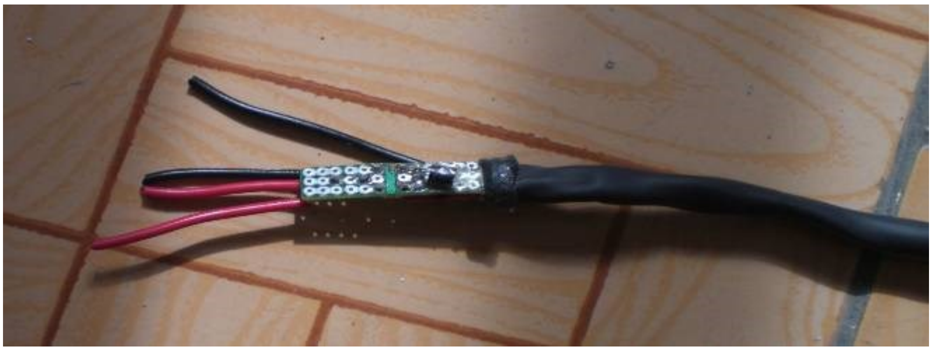

Figure 5: Sensor schematic

Figure 6: Measuring instruments

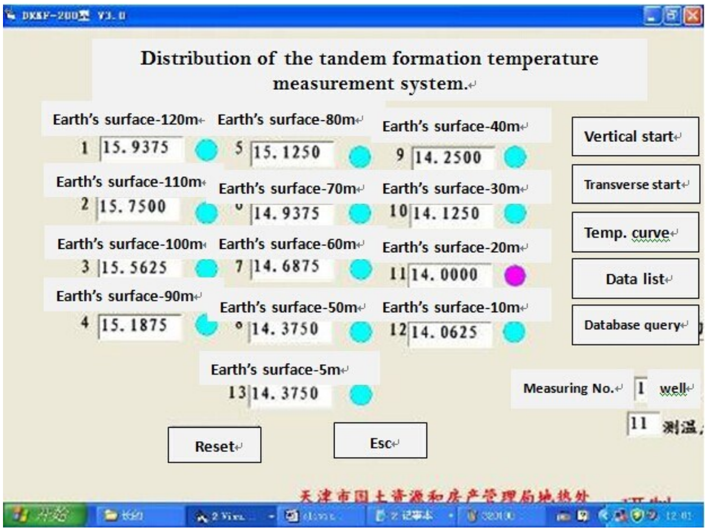

Figure 7: Interface schematic of data acquisition

3. ENGINEERING APPLICATIONS

The Distribution of the tandem formation temperature measurement and transmission fine collection system has been applied in many ground heat exchanger systems engineering project in Tianjin, Beijing and other places[2] and its stable performance were tested (Figure 8to 11). For some project with room construction lagging behind, in order to avoid damage caused by man-made or natural factors, we need to focus on temperature hole and temperature line protected well within the protective device under field conditions before non-networked (Figure 12).

Figure 8: Ground temperature monitoring hole construction and vertical measuring line down into the ground scene graph

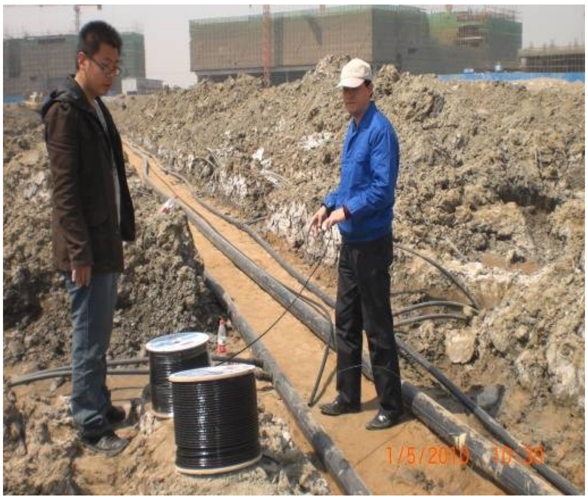

Figure 9: Horizontal measuring line laying scene graph

Figure 10: Ground temperature measurement systems on-site commissioning

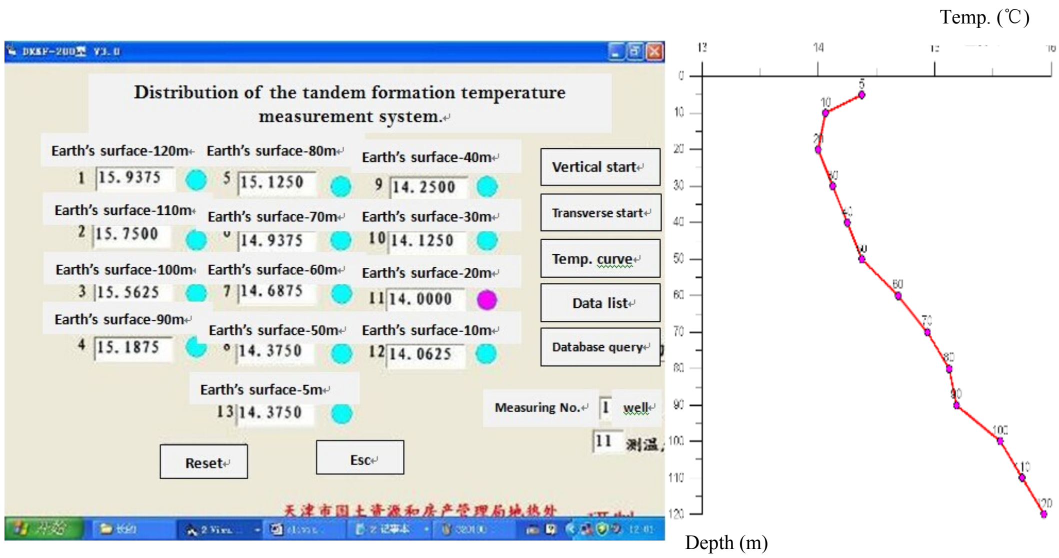

Figure 11: Monitoring hole temperature measurements Schematic

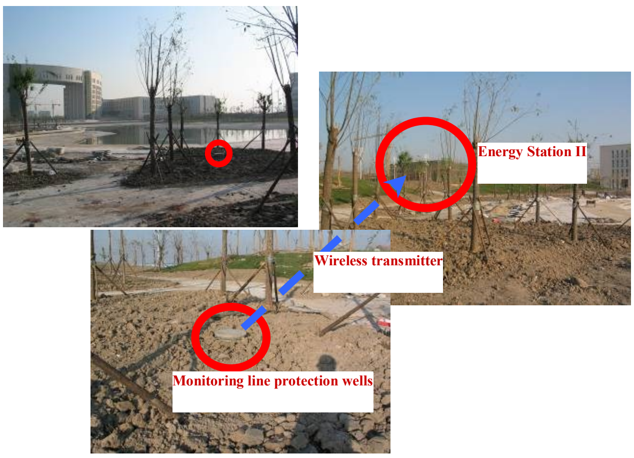

Figure 12: Well head protection equipment of monitoring borehole and networking schematic

4. COMPARISON OF THE DATA MEASURED UNDER DIFFERENT FORMS OF THE LINE DOWN INTO GROUND

In the ground heat exchanger temperature monitoring system of well group, currently geothermal survey lines are mostly outside of the PE pipe, although they can fully contact the soil, , they can't be replaced if there is any problems. If the measured lines are placed inside the PE pipe, they can be replaced as needed, thus ensure the sate continuity and stability. The problem is that the whether the data of outer tube, an inner tube into the ground temperature monitoring can reflect the actual situation of the underground temperature field, and how much error exists of them. To solve this problem, the in-site experiment was carried out in Tianjin.

In order to obtain the formation temperature monitoring data in two different ways that survey line in the PE pipe (water) and out of the pipe (in contact with the soil), and for data validation and comparative analysis, temperature sensors are placed both inner and outer of a single U-pipe with the depth of 150m. As shown in Figure 13, the red curve represents the measured data in PE pipe; other colors represent the measured data outside of the PE pipe. By comparison, the formation measured temperature difference between inner and outer PE pipe is small (Figure 14), generally 0.05 -0.1 °C. Both of them can reflect the actual formation temperature variation, and the measuring line in PE pipe has some advantages, such as the replaced survey line and better protected measured line. This provides a basis for the future scientific and rational layout measuring line. Based on this test, we may consider putting measuring line into the PE pipe in the future, which will not only protect the measuring line, but also replace the measuring line which has problems.

Figure 13: The measuring line in and outside of the PE pipe

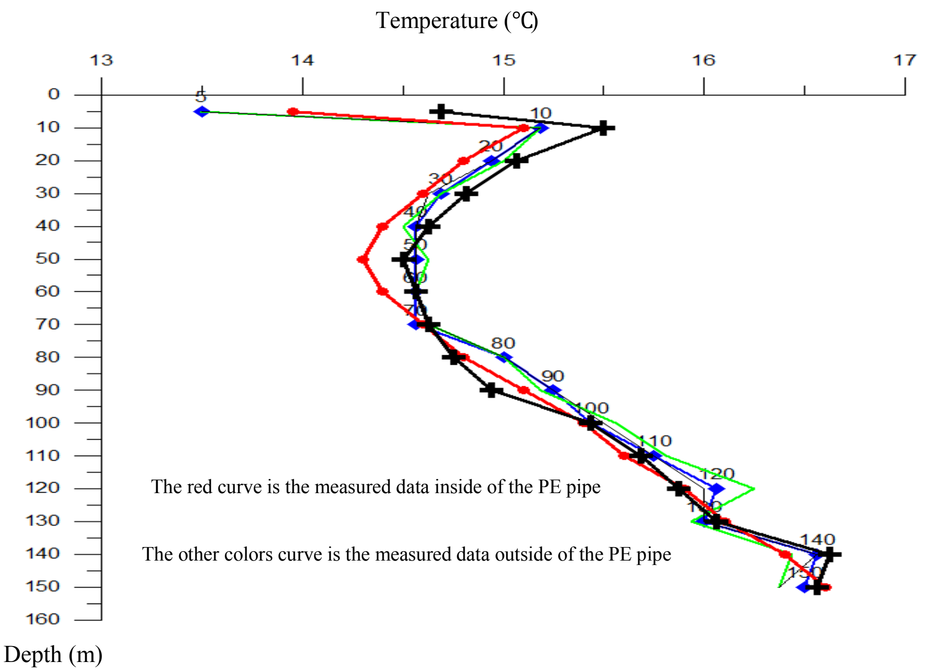

Figure 14: Monitored ground temperature data graphs in and outside of the PE pipe

5. CONCLUSIONS

Ground temperature monitoring of underground group is the major work in the dynamic monitoring of shallow geothermal energy development and utilization (Han Z.S.， Ran W.Y., Tong H.B., et al.2009). Scientific monitoring equipment and advanced technology are the basis of real stable data collection. Th distribution of the tandem formation temperature measurement and transmission fine collection system for the development and utilization of shallow geothermal energy development can digitally monitor the dynamic changes of geothermal field. It has overcome many shortcomings of traditional directly buried sensor and combined the monitoring, collection with transmission. Meanwhile, we experimentally confirmed the monitoring data in and out of the PE pipe can reflect the actual formation temperature variation. We use the method of putting the measuring line in the PE pipe in the practical project. The monitoring system could provide advanced monitoring techniques for the scientific and rational development and utilization of shallow geothermal energy resources, and has wide application prospect.

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