ISSN:2309845 7
2018 年 09 月
第 24 期
季刊

中國地熱能

CHINA GEOTHERMAL ENERGY

承印人：泰業印刷有限公司　地址：香港新界大埔工業邨大貴街 11-13 號　售價：人民幣 10 元　港幣 20 元

恒有源科技发展集团有限公司

EVER SOURCE SCIENCE & TECHNOLOGY DEVELOPMENT GROUP CO.,LTD

2000年创建

香港上市号 8128.HK


浅层地能热恒有
Perpetual Heat from Shallow Ground Energy
循环利用暖无忧
Unfailing Warmth with Cyclic Utilization

恒有源科技发展集团有限公司
EVER SOURCE SCIENCE &TECHNOLOGY DEVELOPMENT GROUP CO.,LTD.

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《中国地热能》杂志社
China Geothermal Energy Magazine

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主 办	**Sponsor**
中国地热能出版社有限公司	China Geothermal Energy Press Limited
地址	**Address**
香港中环皇后大道中 99 号中环中心 37 楼 3709–10 室	Units 3709-10,37/F,The Center,99 Queen's Road Central,Central,Hong Kong
协 办	**Co-Sponsor**
北京节能环保促进会浅层地（热）能开发利用专业委员会	Special Committee on Shallow Ground Source (Thermal) Energy Development and Utilization under Beijing Association to Promote Energy Conservation and Environmental
国际标准刊号 :23098457	ISSN:23098457
承印人	**Printed by**
泰业印刷有限公司	Apex Print Limited
地址	**Address**
香港新界大埔工业邨大贵街 11–13 号	11-13 Dai Kwai Street, Tai Po Industrial Estate, Tai Po, Hong Kong
发行部	**Publishing Department**
黄礼玉	Coniah Wong
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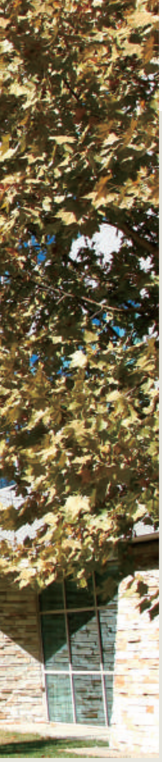
目录

CONTENTS



P52
DEVELOPMENT FORUM
发展论坛

P57
HOTSPOT INFO
热点资讯

P62
KNOWLEDGE SHARING
能源科普

封面 / 目录图片 摄影：孙伟 封面为恒有源集团项目——北京海淀外国语实验学校

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CHINA GEOTHERMAL ENERGY

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地源热泵技术研究新进展

NEW DEVELOPMENTS OF GROUND SOURCE HEAT PUMP RESEARCH

作者：徐生恒　彭涛　王秉忱　武强　张军　毕文明

摘 要：本文简要介绍了十二 . 五期间地源热泵技术的部分研究进展，包括采用分布式光纤测温系统测温、利用柱模型计算测试结果、可得到厚度大于 0.25m 地层热物性参数的新型岩土热物性测试的研发，单井循环换热地能采集井示范研究与技术规范编制；单井循环换热地能采集井模型研究及地温场预测评价；智慧能源管理系统平台软件 (High Efficient 智能能源管理系统) 的研发等。

关键词：地源热泵；岩土热物性测试仪；单井循环换热地能采集井；地温场；智能能源管理系统

前言

目前，国内外地源热泵技术的研究还存在以下几个方面的不足：

（1）岩土热物性参数是土壤源地源热泵设计的重要参数，其准确性、代表性对地源热泵系统设计至关重要，但目前的测试技术没有对地层进行分层测试，得出的岩土热物性参数是一个全孔深的综合参数，既不能将地表变温层对测试的影响剔除，也不能反映地下各地层的分层热物性参数，以至于不能很好的判别地下各层对热泵效率的贡献大小，导致地埋管设计深度缺乏针对性，不能做到既经济又节能。

（2）地下水源地源热泵的回灌技术还不成熟，造成回灌困难，部分用户偷排地下水，以至于部分地区不得不限制地下水源地源热泵的使用。

（3）对于地源热泵的规模化应用产生的地下温度场变化与影响还缺乏深入研究。

（4）对于从地源热泵系统中小规模应用转向大规模应用所需的监测、监管技术还不系统、不完善，对地源热泵系统应用过程中产生的问题难以及时发现和监管。

本文简要介绍了十二五期间我国地源热泵研究的部分成果。

1 新型岩土热物性测试仪器研发

1.1 新型岩土热物性测试仪设计

新型岩土热响应测试仪器由车载式热响应测试仪和分布式光纤测温系统组成，其中，分布式光纤测温系统主要由光纤传感器、通道扩展模块、光纤信号调节仪构成（图 1-1）。测试前，将光纤传感器深入地埋管中，沿纵向空间分布在不同的岩土层内，可测得不同深度的岩土层原始温度和每一层的地埋管内循环温度，通过柱热源模型计算，最终获得不同深度地层的岩土热物性参数（导热系数、体积热比）。

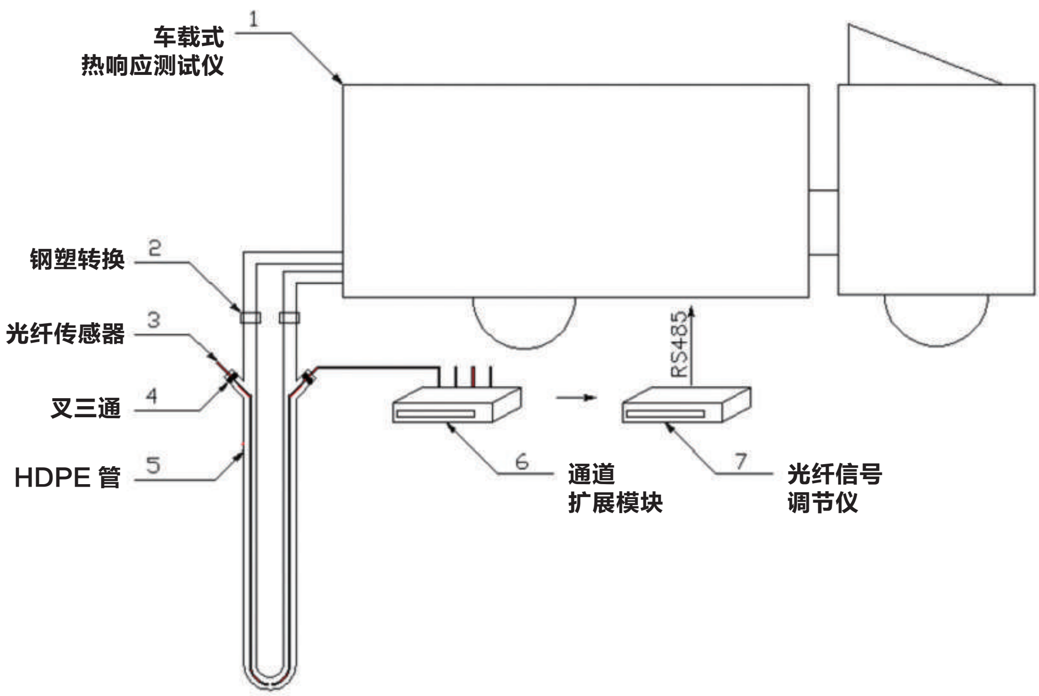

图 1-1 分布式光纤测温系统与车载式热响应测试仪连接示意图

1.2 模型分析及算法

常规的用于稳定热流热响应测试的数据分析模型包括无限长线热源模型、有限长线热源模型和柱热源模型，三个模型都是将地埋管换热器看成一个整体进行分析，若考察对象为每个地层，当某个地层厚度较小时，地埋管换热器管径与长度比值变大，显然不能作为线热源模型考虑，因此只能采用柱热源模型进行分析。分层的稳定热流热响应测试，对于整个换热孔来说，加热功率（热量）是稳定的，但是对于每个地层来说，其热功率（热量）是不稳定的，并且是不规律变化的，因此，必须对柱热源模型进行改进，以适合变热流的热响应测试分析。

（1）模型分析

本课题以柱热源模型为基础，提出分层柱热源模型分析方法，用于分析地下岩土分层（图 1-2）。

分层柱热源模型将岩土中换热的柱体结构沿纵向分解成若干层，每层换热功率可通过该层每根管的进出口水温差及流量计算，然后利用柱热源模型计算公式，将不同时刻多个时间步长的温度响应进行叠加计算。最终可分析出不同地层岩土热物性参数及换热特性。

（2）柱热源模型的改进

Carslaw 在线热源模型的基础上提出了柱热源传热模型。该模型把地下埋管看作是一个具有一定半径的理想圆柱导体，以恒定的放热率向周围无限大、常物性的岩土散发热量，并给出了某时刻 t，距离柱热源轴线 r 处的岩土温度表达式。

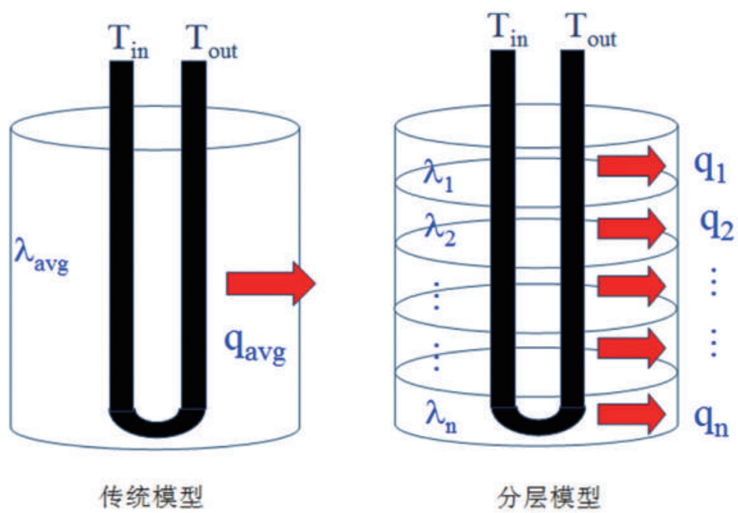

图 1-2 岩土分层模型

1.3 示范应用

示范项目为北京顺义某度假酒店二期工程，设计测试孔孔深 100m，测试成果如下：

1）分层热响应试验可以得到不同深度的岩土导热系数，见图 1-5。

2）地下 30 ~35m，55~60m，85~90m 导热系数较其他区域明显偏高，地下水流经该区域可能性较大。

3）地下 85~90m 段导热系数最高，90m 后导热系数迅速下降。据此可根据地埋管成孔费用的实际情况对设计孔数进行增减，以求达到最优的结果。

新型岩土热物性测试仪已获国家专利局专利授权。

2 单井循环换热地能采集井示范研究与技术规范编制

本课题在以下方面进行了示范研究：

（1）根据水文地质条件、建筑物冷热负荷要求，对采集井的结构优化技术进行研究。

（2）不同地质条件下采集井额定供热功率的确定。

（3）对采集井关键部分如蓄能颗粒、渗透膜等的研究，确定使用范围。

在上述研究的基础上，编制了北京市地方标准《单井循环换热地能采集井工程技术规范》（DB11/T935-2012）。该规范适用于为建筑物供暖、制冷和提供生活热水的单井循环换热地能采集井工程，并对单井循环换热地能采集井的设计、施工、验收等都做了具体要求。

《规范》指出，地能采集井按结构可分为：有蓄能颗粒采集井、单一含水层无蓄能颗粒地能采集井和多含水层无蓄能颗粒地能采集井。另外，该《规范》还规定了关于地能采集井设计应包括的内容：搜集拟建地能采集

井（井群）地区的水文地质资料；确定地能采集井的类别：有蓄能颗粒地能采集井或无蓄能颗粒采集井；地能采集井区的范围、确定地能采集井的数量和位置；确定地能采集井的结构；确定循环水量、供热（冷）功率。

对于地能采集井位置的设计，应根据拟建地能采集井区的地质和水文地质条件确定，同时，还应符合以下要求：靠近机房；地能采集井位与建（构）筑物应保持足够的距离；相邻两口有蓄能颗粒地能采集井与无蓄能颗粒地能采集井的距离分别不宜小于 8m 和 10m；对于地能采集井群，应最大限度地保持地能采集井的中心连线的方向与当地地下水流方向垂直。

《规范》明确了地能采集井结构设计的内容，包括：地能采集井直径和深度；蓄能颗粒材料种类、规格和数量；隔离膜和阻水换热壁的结构、性能；导流板的结构和位置。

对于地能采集井功率，该《规范》指出，夏季运行期间地能采集井循环水的出口最高温度宜低于 33℃；冬季运行期间地能采集井循环水的进口最低温度宜高于 4℃。

工程验收作为从设计到使用的最后一个环节，《规范》要求：隐蔽工程施工记录应齐全，且有全程录像，并已通过相应的质量检验。施工单位应提交包括地能采集井的综合柱状图等资料在内的成井报告。此外，成井后应结合地能采集井内装置和供热（冷）系统，对采集井的供热（冷）功率进行测试，得出采集井的实际供热（冷）功率，采集井的实际供热（冷）功率应不低于设计值。

3 单井循环换热地能采集井模型研究及地温场预测评价

3.1 单井循环换热地能采集井的物理过程

有蓄能颗粒的单井循环换热地能采集井的物理过程为，循环水由绝热井壁内部抽水区的潜水泵抽出排走，送入热泵机组，经过放热或者吸热后，由热泵机组返回，进入地能采集井上部的加压回水区内部。水流在绝热井壁与隔离膜之间有蓄能颗粒的环形空间内流动，大部分进入下部抽水区，一小部分透过孔壁的隔离从加压回水区通过渗透流到土壤介质中，最后从抽水区回流。地能采集井的所有回水透过绝热井壁下部的花管由潜水泵抽走送回热泵机组。

无蓄能颗粒的单井循环换热地能采集井中绝热井壁与隔离膜之间的空间没有蓄能颗粒，充满介质水，其余部分的构造和传质传热物理过程与有蓄能颗粒的单井循环换热地能采集井相同。

3.2 有蓄能颗粒的单井循环换热地能采集井的数学模型

3.2.1 控制方程

由于有蓄能颗粒单井循环地能采集井各部分皆为多孔介质，其中充满的流体是水。水在多孔介质中流速非常缓慢，可按粘性不可压缩的层流模拟计算。多孔介质内水的流动考虑固体骨架，遵循质量守恒方程（9）、动量守恒方程（10）、能量守恒方程（11）：

（1）质量守恒方程

$$\frac{\partial(\gamma\rho)}{\partial t}+\nabla.(\gamma\rho V_i)=0 \qquad (9)$$

式中，γ 为多孔介质的孔隙度，ρ 为流体密度，t 为时间变量，V_i 为流体的速度张量，i=1,2,3。

（2）动量守恒方程

$$\frac{\partial(\gamma\rho v_i)}{\partial t}+\nabla.(\gamma\rho V_i V_i)=-\gamma\nabla p+\nabla.(\gamma\tau_{jk})+\gamma\rho g+S_m \qquad (10)$$

式中，p 为流体静压，$\tau_{j\kappa}$ 为应力张量，$j\kappa=1,2,3$，g 为重力加速度，S_m 为多孔介质的动量源项，γ、ρ、t、v_i 含义同（9）式。

（3）能量守恒方程

$$\frac{\partial}{\partial t}\left(\gamma\rho_f E_f+(1-\gamma)\rho_s E_s\right)+\nabla.\left(v_i\left(\rho_f E_f+p\right)\right)=\nabla.\left(ke\nabla T-\left(\sum_i h_i J_i\right)+\left(\tau_{jk}V_i\right)\right)+S_f^h \quad (11)$$

式中，E_f 为多孔介质中流体总能量，E_s 为多孔介质中固体骨架总能量，h_i 为多孔介质中流体及各种固体骨架的焓，J_i 为多孔介质中流体及各种固体骨架组分 i 相对于质量平均速度每单位面积的质量流量，$i=1, 2, \ldots$，S_f^h 为流体的焓源项，p、γ、ρ、t、τ_{jk}、v_i 含义同（9）式，ke 为多孔介质的有效热传导率，，根据计算区域中流体热传导率和固体骨架热传导率加权求得。显然当孔隙率为 100% 时，上述方程退化为不可压缩流体的层流控制方程。

3.2.2 定解条件

定解条件种类较多，在实际工程中可根据具体情况列写，常见的定解条件如下。

（1）初始条件

计算流场处于静止状态，即初始时刻速度 $V(0)$ 为零，初始时刻压强 $P(0)$ 为外界大气压 P_0，初始时刻温度 $T(0)$ 为常量 T_0，表达式如下

$$V(0)=0 \quad (12)$$

$$P(0)=P_0 \quad (13)$$

$$T(0)=T_0 \quad (14)$$

（2）边界条件

a. 计算域的进口边界

进口流量 Q_{in} 为常量 Q_1，即

$$Q_{in}=Q_1 \quad (15)$$

进口温度 T_{in} 为常量 T_1，即

$$T_{in}=T_1 \quad (16)$$

进口出压强 P_{in} 为常量 P_1，即

$$P_{in}=P_1 \quad (17)$$

b. 计算域的出口边界

进口流量 Q_{out} 为常量 Q_2，即

$$Q_{out}=Q_2 \quad (18)$$

出口温度 T_{out} 未知，不予设定，由已知条件计算得到。

出进口出压强 P_{out} 为常量 P_2，即

$$P_{out}=P_2 \quad (19)$$

c. 计算域的其他边界

土壤等温外边界 Γ_1 及绝热外边界 Γ_2 表达式如下。

$$T|_{\Gamma 1}=t_0 \quad (20)$$

$$q|_{\Gamma_2}=0 \quad (21)$$

定热流密度边界条件如下

$$q|_{\Gamma_2}=c \quad (22)$$

边界上的流场速度 v 为零，即

$$\vec{v}|_{\Gamma_1\cup\Gamma_2}=0 \quad (23)$$

式（20）~(23） 中，T 表示边界 Γ_1 的温度，q 表示边界 Γ_2 的热流密度。

3.3 无蓄能颗粒的单井循环换热地能采集井的数学模型

3.3.1 控制方程

无蓄能颗粒单井循环地能采集井计算区域分为有多孔介质计算区域和无多孔介质计算区域两部分。两部分分别采用不同的控制方程。

（1）有多孔介质计算区域

无蓄能颗粒单井循环地能采集井的土壤多孔介质的流动属于层流，其控制方程与有蓄能颗粒单井循环地能采集井的控制方程

（9）-（12）式完全相同。

（2）无多孔介质计算区域

无蓄能颗粒单井循环地能采集井的进水加压管和抽水回水管部分无多孔介质，全部充满水，采用粘性可压流的紊流流动的标准 K-ε 模型。

K-ε 微分方程的通用形式为下式

$$\frac{\partial}{\partial t}(\rho\phi)+div(\rho v_i\phi)=div(\Gamma_\phi\, grad\ \phi)+S_\phi \qquad (24)$$

式中，t 为时间变量，ρ 为流体密度，φ 为所研究的任一因变量，v_i 为流体速度张量，i=1,2,3，在展开式中，v_1= vx， v_2= vy ，v_3= vz，x_1= x ，x_2= y，x_3= z，Γ_ϕ 是扩散系数，S_ϕ 是源项。上述方程中的四项分别是非稳定项、对流项、扩散项及源项，各项表达式见表 1。

表 1 标准 K-ε 湍流模型中各项意义一览

方　程	φ	Γ_ϕ	S_ϕ
连续性方程	0	0	0
x 轴向动量	v_x	μ_{eff}	$-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial v_x}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_{eff}\frac{\partial v_y}{\partial x}\right)+\frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial v_z}{\partial x}\right)-\frac{2}{3}\frac{\partial}{\partial x}(\rho k)$
y 轴向动量	v_x	μ_{eff}	$-\frac{\partial p}{\partial y}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial v_x}{\partial y}\right)+\frac{\partial}{\partial y}\left(\mu_{eff}\frac{\partial v_y}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial v_z}{\partial y}\right)-\frac{2}{3}\frac{\partial}{\partial y}(\rho k)$
z 轴向动量	v_x	μ_{eff}	$-\frac{\partial p}{\partial z}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial v_x}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_{eff}\frac{\partial v_y}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial v_z}{\partial z}\right)-\frac{2}{3}\frac{\partial}{\partial z}(\rho k)$
湍流动能	k	$\frac{\mu_{eff}}{\sigma_k}$	$P_k-\rho\varepsilon$
湍流动能耗散率	ε	$\frac{\mu_{eff}}{\sigma\varepsilon}$	$C_1P_k\frac{\varepsilon}{k}-C_2\rho\frac{\varepsilon^2}{k}$
能　量	T	$\frac{\mu}{\Pr}+\frac{\mu_{eff}}{\sigma\varepsilon}$	源项 S 按实际确定

表中，k 为湍流动能，ε 为湍流动能耗散率，μ_{eff} 为有效粘性系数，μ 为分子粘性系数，μ_t 为湍流粘性系数，C_1、C_2、$C\mu$、$\sigma\varepsilon$ 这四个符号是常数，P_k 是平均速度梯度引起的湍流动能的产生项，能量方程中的 T 采用绝对温标。

$$\mu_{eff}=\mu+\mu_t \qquad (25)$$

$$\mu_T=C_\mu\rho\frac{k^2}{\varepsilon} \qquad (26)$$

$$P_k = \mu_{eff}{}^{2}\left\{\left[\left(\frac{\partial v_x}{\partial x}\right)^2+\left(\frac{\partial v_y}{\partial y}\right)^2+\left(\frac{\partial v_z}{\partial z}\right)^2\right]+\left(\frac{\partial v_x}{\partial y}+\frac{\partial v_y}{\partial x}\right)^2+\left(\frac{\partial v_y}{\partial z}+\frac{\partial v_z}{\partial z}\right)^2+\left(\frac{\partial v_z}{\partial x}+\frac{\partial v_x}{\partial z}\right)^2\right\} \quad (27)$$

3.3.2 定解条件

在初始条件和进口及边界中增加湍流动能 k 和湍流动能耗散率 ε 条件，其它内容与前述中内容相同。

3.4 理想模型及示范工程模拟分析及预测

进行数值模拟计算时，首先建立二维模型结构化网格，计算收敛条件为残差控制在 1×10-3 以下，然后采用在流体力学与传热学广泛应用的有限体积法进行数值模拟求解。采用流体与传热软件 FLUENT6.3 进行模拟计算。

从数值模拟计算结果可以看出：

（1）在一定范围内随着水循环流量的增加，同一单井循环换热地能采集井的热交换量增加。

（2）由于热积累效应，同一地能采集井随着时间的延续换热量逐渐降低。

（3）其他条件不变时，地能采集井的进水与出水温度差值随着水循环流量的降低逐渐提高。

（4）减小土壤的比热容、增加土壤的孔隙度有助于增加单井循环换热地能采集井换热量。

（5）土壤的渗透系数增加会减小粘性阻力，从而对增加地能采集井的换热量具有较明显的效果。

（6）由于土壤的热积累效果会很大程度降低换热效率，对同一区域利用换热器冬季制热、夏季制冷会明显降低热（冷）积累效应。

4 智慧能源管理系统平台软件（High Efficient 智能能源管理系统）研究

4.1 系统功能

针对目前国内地源热泵工程存在无序开发、监管缺失的问题，本课题研发了一套智慧能源管理系统平台软件(High Efficient 智能能源管理系统)。

4.2 系统架构

智能能源管理系统是 3 级结构的集散式系统，即有管理级、监控级和现场控制级构成，如下图所示。

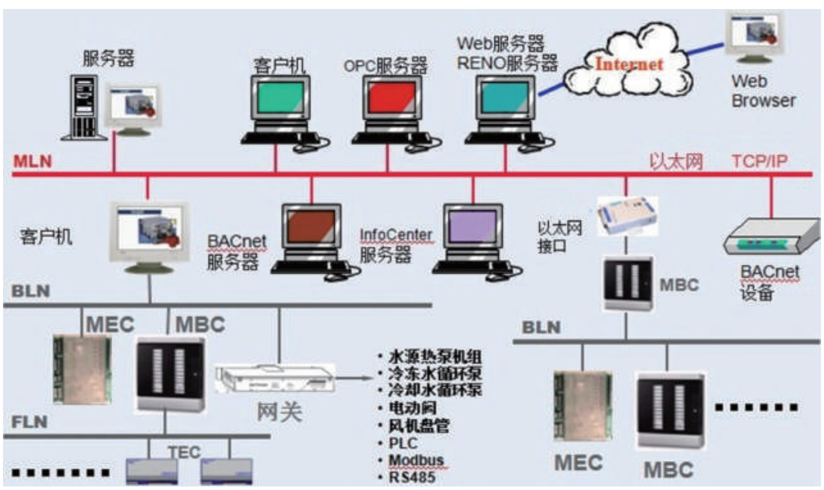

图 4-1 智能能源管理系统是 3 级结构示意图

4.2.1 现场控制级

系统第一级为现场控制级，包括现场控制器、各类传感器和执行器，直接控制现场设备。其主要任务包括：

● 过程数据采集。对被控对象的各个过程变量和状态信息进行实时数据采集，保证数字控制、

设备监测、状态报告等获得所需要的现场信息。

● 直接数字控制。根据控制平台数据库、控制算法模块去实施连续控制、程序控制。

● 设备监测、系统测试与诊断。根据过程变量和状态信息，分析并确定是否对被控对象实施调节，并判断现场控制器硬件的状态和性能，在必要时报警或给出诊断报告。

● 安全、冗余操作。发现系统硬件或控制板有故障时，及时切换到备用部件，以确保整个系统安全运行。

现场控制级是对单个设备的自动控制，具体功能的实现是由安装在被控设备附件的现场控制器去完成的。它是一个可独立运行的计算机监测与控制系统，既能作独立控制其执行控制作用，又有强大的通信能力，可组成网络实现高速实时运算。一般有几路模拟量和数字量的输入、输出，其中有：

● 模拟量输入（AI），如温度、压力、流量等。

● 数字量输入（DI），如接触点闭合、断开等。

● 模拟量输出（AO），如操作调节阀等。

● 数字量输出（DO），如电动机起 / 停控制，2 位通 / 断控制等。

直接数字式控制器还应有数字量累计的接口，可输入低频脉冲信号，作为电量、水量的累积计算。

现场控制器的功能靠软件来实现，现场控制器的软件包括：系统软件、通信软件、输入输出点处理软件、操作命令控制软件、报警处理软件、运算软件、控制软件、时间 / 事件程序（TEP）、能量管理和控制软件、用户化软件和终端仿真软件等。

4.2.2 监控级

系统第二级为监控级。监控级监视地源热泵系统的各单元，并管理系统的所有信息，主要任务包括：

● 优化控制。当现场条件发生变化时，监控级根据优化策略，进行分析计算，产生新的设定值和调节值，交由现场控制级执行。

● 协调控制。根据被控设备情况，以优先准则协调相互的关系等。

● 系统运行监视。监视整个系统的运行参数、状态，指定被控设备记录报表，进行报警显示，故障显示、分析、记录等。

监控级的计算机设置在监控中心，称为中央站，对整个系统实行管理和优化控制。中央站和现场控制器通过通信接口进行数据通信，现场控制器可作为独立控制器执行独立的控制作用，它把数据信息传导至中央计算机，又能接受中央计算机的控制。中央计算机除要求完善的软件功能外，首先要求硬件必须可靠，通常选用高档微机和较高级的配置。

监控级的功能是由中央站的软件来实现的，中央站的软件包括：系统软件（网络操作系统），语言处理软件，数据通信软件，显示格式和表格式软件，操作员接口软件，日程表软件，时间 / 事件诱发程序软件（TEP），报警处理软件，控制软件，数据库软件，能量管理和控制软件等。中央站主要软件功能：

● 访问级别控制。

● 图形操作。

● 适应多种通信协议。

● 用户定义的报警管理。

● 点的分类

● 图形生成工具和库

● 使用程序。

● 设备运行和特殊事件的计划安排

● 历史和动态点趋势选择

● 各种报表和信息记录

● 通用窗口软件

4.2.3 管理级

系统第三级为管理级。管理级计算机位于整

个系统的顶端，具有十分强大的处理能力。

管理级的图形工作站可以进入以太网进行数据管理（TCP/IP），实现区域性数据联网，提高管理水平，速率可达到10/100Mbps。

4.3 硬件配置方案

4.3.1 中央处理单元

采用web access研华工控机。

4.3.2 现场控制单元

（1）信号传输模块

信号传输一般采用有线接入以太网和无线发送的形式;考虑到现场以太网以及现场布线等因素，采用GPRS发射模块

（2）现场控制模块

该部分包括控制模块，以及扩充的I/O模块，采用西门子PXC MODULAR系列的控制模块和I/O扩充模块。

4.3.3 末端元件

包括各类温度传感器、压力传感器、流量传感器、电流传感器、电压传感器。

4.4 软件开发方案

4.4.1 软件规划

High Efficient智能能源管理系统，通过多种数据采集及远程传输手段，对大型建筑进行分类分项能耗计量基础上，采用GIS、组态、自定义等方式实现能耗在线监测、统计分析、节能控制决策和优化。

4.4.2 软件功能

（1）现场控制级的软件功能

1）运算软件:主要对数据进行计算,如平均值、高低值选择、逻辑运算和积算。

2）控制软件：采用直接数字控制，有比例、比例积分、比例积分微分等控制功能。它执行现场要求的操作顺序，用比例、比例积分、比例积分微分算法控制中央空调系统。程序包含DDC操作员程序，例如自适应控制可对环境变化作出响应，自动调整系统的运行。

3）时间/事件程序：按照时间表发出命令，或根据起动停机计划，点报警或点状态变化触发标准的或定制的DDC程序，控制空调设备等。控制器固有的TEP提供与中央站TEP无关的时间顺序制和时间触发程序。

4）能量管理和控制软件：有最佳起动停机程序、趋势记录、周期性负载和最大需求管理。节能和控制程序库可以在控制器内执行，这些程序可以从其他控制器读取共享的输入,以控制自己的输出。这些程序能独立于中央站而运行，以保证系统的可靠性。

5）用户化软件：可简化数据文件的修改，授权的操作员可以增加、修改和删除现场控制器、监测点数据、能量管理数据和用户程序。

6）终端仿真软件：当不需要现场控制器提供图形操作的全部能力的时候，操作员可以用视频显示终端或个人计算机，以合适的终端仿真软件实现对简单的点和设备的操作，例如读取测点数据，发出对该点的命令。

智能能源管理系统中使用各种传感器，检测设备的工作状态。传感器和变送器是将电量或非电量转化为控制设备可以处理的电量的装置，一般用于测量温度、湿度、压力、压差等物理量。

（2）监控级软件功能

1）访问级别控制。系统提供多级操作员访问级别，工作站判断是否允许进入系统，同时鉴别各种操作员访问的级别。操作员只能用密码进入系统，访问所授权的级别。为了减少操作员在进入系统状态下离开工作站时，被别人非法使用的可能性，有一个超时信号自动将该操作员退出系统。自动退出和超时信号的时间长短可按不同操作员定义来决定。

2）图形操作。用色彩来区分正常和不正常的空调设备温度，以电机的动画来确认其运转/停机

和开 / 闭状态。任何现场控制点，可以显示在任意一级的图形上。利用作图软件，操作员可以生成、修改和删除任何图形。为了发出一个命令，操作员首先要选择一个点，直接从图形上控制这些点。系统也可显示出一个对话框，来选择合适的命令。

3）适应多种通信协议。通过总线连接现场控制器，它们都采用同层通信协议，此协议使每个设备都有相等级别的总线访问权。所有设备都有出错恢复和总线初始化能力。在用其他总线通信协议时，或当中央显示器脱离线路时，总线通信便停止。而采用同层通信协议时，只要总线上有 2 台设备在运行，通信就仍然继续进行。

4）用户定义的报警管理。报警信息会自动打印出来，或在操作员控制下显示和打印出来。多点报警按优先级顺序显示。

5）点的分类。按照点的性能类型来分组，以便于数据文件的更新和操作员在显示图形上更快地识别出来。例如，所有的温度传感器可以归类为温度一类，这一类点在示图上使用相同的颜色标识来显示各种数值，并有相同的报警处理点。

6）图形生成工具和库。操作员可以用图形软件来开发图形，为了简化图形的生成过程，系统提供一整套暖通空调和电气符号及标准系统，诸如空调机和冷冻机的图库。系统还规定好设备类别，为它们提供标准的配色、刷新速率、动画、工程单位和预设属性。

7）实用程序。实用程序用于产生现场控制器应用程序和数据库。设计人员可选用暖通空调绘图元件来建立控制顺序。

8）设备运行和特殊事件的计划安排。系统支持下列设备运行和特殊事件的计划安排功能，控制器使用单独的计划安排功能，它不与图形相联系，而是用文本 / 选单引导来驱动。控制器分组使假日和例外程序得以简化，对于控制器，操作员可对空调系统的每日运行，建立一个正常或临时使用的计划表，可以先显示与希望的点有关的图形，然后确定或修改适当的计划表。对于特殊事件，如晚会，操作员可确定动作并安排这些动作，如按时间和日期发生。诸如所有点的报告和报警摘要也是计划安排的事件。全部工作都是用对话框设定的，可以用单击，翻动图面或键盘输入。

9）历史和动态点趋势选择。

10）各种报表和信息记录。报表包含当前的历史的点的数据和信息记录，操作员可以按要求打印屏幕画面，即通过供选用的彩色打印输出，可以打印在纸上或投影仪用的透明软片上。还允许操作员通过选择起始图形和后续图形中的点，可以在所希望的时间安排输出。

11）通过窗口软件。操作员可用一个窗口作为中心图形接口，而其他窗口可用作执行第三方软件专用，例如电子表格软件或文字处理程序。操作员能方便地切换窗口，因此可用提高工作效率。

（3）管理级的软件功能

1）对建筑冷热负荷的各种干扰条件进行采集、统计和分析，确定最经济、有效的供能量，从而实现按需供能。

2）实时控制热源侧和使用侧水系统参数（水温、压力和流量），优化热泵主机的运行工况，监控热泵主机的系统参数（制冷系统压力、温度、电流、能效比），控制主机的 COP 值，使其处于最佳状态。

3）通过水的变流量控制、主机能量调节控制以及供能条件优化控制，以逐渐提升系统 COP 值为目标，从而实现基于数据和专业调控策略的系统优化模式。

4）智能化和自动化的控制减少人为因素对能耗的不利影响，降低各种人为失误带来的损耗。

4.4.3 数据通讯设计

这一部分主要是作为远程客户机与下位机 (PLC) 通信的桥梁，一方面负责采集 PLC 数据，

并将其传送给远程客户机，另一方面，接收远程客户机的控制信息，并将其写入 PLC。一般在应用服务器中安装有 OPC Server（或自己开发的数据采集服务程序），OPC Server 通过串口或以太网方式与设备上的 PLC 连接，进行数据采集，并将采集到的数据缓存在应用服务器中。公司内部局域网通过有线或无线以太网方式与现场 OPC Server 连接来读取数据。

4.4.4 远程客户端软件设计

这一部分主要是实现与上位机的通信以及监控画面的开发，为了便于实现与上位机的通信，将整个应用程序分配给多个服务器，用以提高项目的整体容量结构，并改善系统的性能。服务器的分配可以是基于项目中物理设备结构或不同的功能，用户可以根据系统需要设立专门的 IO 服务器、历史数据服务器、报警服务器、登录服务器和 WEB 服务器等。

在客户监控画面方面采用 ActiveX 控件，并嵌入到网页中。用户只需要在客户端 IE 浏览器的地址栏中输入服务器的 IP 地址，当用户第一次访问服务器的网页时，IE 浏览器会自动把服务器网页上的 ActiveX 控件下载到本地计算机中，并自动注册 ActiveX 控件。这样用户就可以通过 IE 浏览器对现场设备进行实时监控。通过使用 ActiveX 控件，远程客户端可以直接读取服务器上的 OPC 数据并实时更新，并不需要通过数据库来进行中转。

5 结论

(1) 研发的新型岩土热物性测试仪可以测得厚度大于 0.25m 的岩土层的导热系数及不同岩土层的初始温度，而传统稳定热流热响应法只能得到岩土层初始平均温度。由于常规使用的岩土热响应测试采用线热源模型，并且将地下埋管当做一个整体进行计算。与新型岩土热物性测试仪的柱热源相比，在模型选择上存在误差，因此分层热响应法计算所得地下岩土热物性参数更准确。通过分层热响应测试可获得地下岩土导热系数曲线，据此可以判断不同岩土层的渗流情况和一个区域的地下水流状况，从而为地埋管换热器选址、更大限度的利用浅层地热能提供科学依据。

（2）通过室内试验及现场示范研究，将单井循环换热地能采集井技术主要技术要点进行总结、集成与定型，基本解决了地下水源热泵的回灌问题，在此基础上编制了北京市地方标准《单井循环换热地能采集井工程技术规范》（DB11/T935-2012），为将该技术大面积推广奠定了基础。

（3）与单井循环换热地能采集井技术研究相结合，建立了单井循环换热地能采集井技术的理论与数值计算模型，并与示范工程实际数据进行了对比分析，解决了单井循环换热地能采集井技术的理论问题，对推广单井循环换热地能采集井技术具有重要意义。

（4）研发的 High Efficient 智能能源管理系统既可对地源热泵各运行参数及地质环境参数进行监测、监管，也可根据建筑供暖、制冷实际需求，调控地源热泵系统运行状态，实现能源管理的智能化。

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New Developments of Ground Source Heat Pump Research

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Abstract: Some new researches of ground source heat pump (GSHP) are described in the article. A new rock and soil thermal physical property tester has been developed, and it use distributed optical fiber temperature measuring system to measure the temperature of the stratum. The new tester use column model to calculate the parameters of rock and soil thermal physical property. The parameters of rock and soil thermal physical property of the stratum which thickness greater than 0.25m can be measured. The code of the single-well geothermal energy collection with circulation heat exchange has been written. The numerical model of the single-well geothermal energy collection with circulation heat exchange has been researched. The geothermal field of the single-well geothermal energy collection with circulation heat exchange has been predicted using the new numerical model. A high efficient energy management system has been developed too.

Key words:
Ground source heat pump (GSHP); Rock and soil thermal physical property tester; Geothermal field; Single-well geothermal energy collection with circulation heat exchange; High efficient energy management system

Foreword

At present, there are still some shortages in the research on ground source heat pump technology at home and abroad:

(1) Thermal physical property of rock and soil is an important parameter for design of ground source heat pump of soil source, and its accuracy and representativeness are crucial to the design of ground source heat pump system. However, the current testing technology hasn't conducted layered testing to stratum, and the obtained rock

and soil thermal physical property is a comprehensive parameter of whole hole depth, which cannot get rid of influence of ground surface metalimnion on testing, and cannot reflect layered thermal physical property parameter of each underground stratum, so it is difficult to judge the contribution of each underground stratum to the thermal pump efficiency, and then the design depth of buried pipe is lack of pertinence, so the design cannot achieve the goal of both economic and energy saving.

(2) The reinjection technology of ground source heat pump of underground water source is still immature, thus causing difficult reinjection, and a part of users drain underground water furtively. Therefore, in some regions, the using of underground water source and ground source heat pumps must be restricted.

(3) There is the lack of in-depth research on underground temperature field change and influence generated by large-scale application of ground source heat pump.

(4) The monitoring and supervision technology required by transforming medium and small-scale application to large-scale application of ground source heat pump is still not systematic and complete, and it is difficult to find out and supervise problems generated during the application process of ground source heat pump system in time.

This article briefly introduces some achievements about research on ground source heat pump in our country during the twelfth five-year plan period.

1 Research on New Type of Rock and Soil Thermal Physical Property Tester

1.1 Design of New Type of Rock and Soil Thermal Physical Property Tester

The new type of rock and soil thermal response tester consists of vehicle-mounted thermal response tester and distributed type optical fiber temperature measurement system; wherein, the distributed optical fiber temperature measurement system mainly consists of optical fiber sensor, channel expansion module and optical fiber signal regulator (Figure 1-1). Prior to testing, it is necessary to make the optical fiber sensor go deep into the buried pipes and make it distribute in different rock and soil layers along with longitudinal space, and then original temperatures of rock and soil layers of different depths and circulating temperatures in buried pipes of all layers can be measured. Through calculation of cylindrical heat source model, rock and soil thermal physical properties (heat conductivity coefficient and volume heat ratio) of strata of different depths can be obtained finally.

1.2 Model Analysis and Algorithm

Routine data analysis models for testing thermal response of steady heat flow include infinite line thermal source model, finite line heat source model and cylindrical heat source model. In these three models, the buried pipe heat exchanger is regarded as a whole for analysis. If the observation object is each stratum, when the thickness of some stratum is relatively small, and the ratio of pipe diameter to length of buried pipe heat exchanger

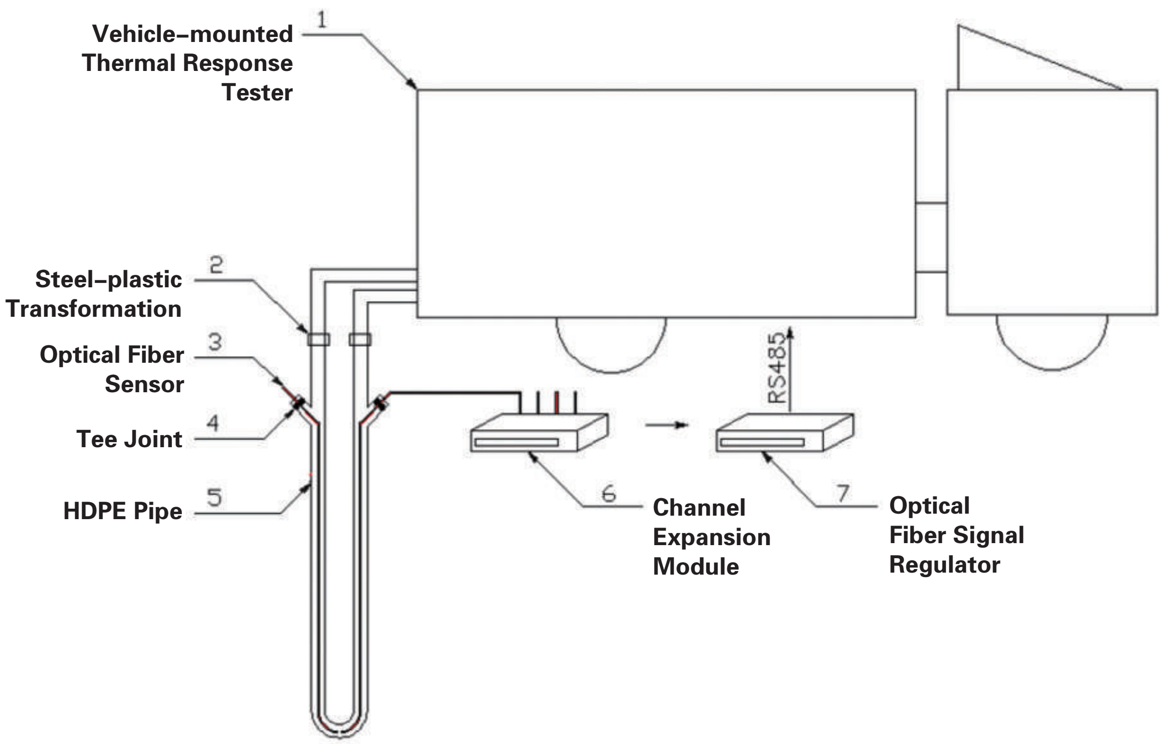

Figure 1-1 Schematic Diagram of Connection between Distributed-type Optical Fiber Temperature Measurement System and Vehicle-mounted Thermal Response Tester

is bigger than original value, it cannot be used as line heat source model obviously. Therefore, only the cylindrical heat source model can be used for analysis. With regard to the testing of thermal response of layered steady heat flow, for the whole heat exchange hole, the heating power (heat quantity) is stable. However, for each stratum, its heat power (heat quantity) is unsteady, and is changed irregularly. Therefore, it is required to improve the cylindrical heat source model, so as to adapt to analysis on thermal response testing of variable heat.

(1) Model Analysis

The subject takes the cylindrical heat source model as foundation, and the analysis method with layered cylindrical heat source model is proposed to analyze underground rock and soil layering (Figure 1-2).

The layered cylindrical heat source model decomposes cylindrical structure of heat exchange in rock and soil into several layers, and the heat exchange power of each layer can be calculated through water temperature difference and flow at inlet and outlet of each piece of pipe. Next, the cylindrical heat source model calculation formula is utilized to conduct superposition calculation of temperature response of multiple time steps at different times. Finally, rock and soil thermal physical

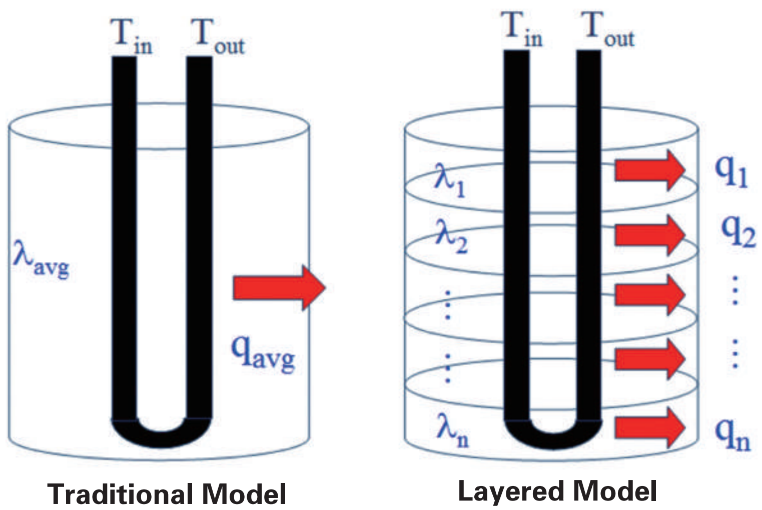

Figure 1–2 Rock and Soil Layering Model

properties and heat exchange characteristics of different strata can be worked out.

(2) Improvement of Cylindrical Heat Source Model

Carslaw proposed cylindrical heat source transfer model based on the line heat source model. In this model, the buried pipe is regarded as an ideal cylindrical conductor with a certain radius, emit heat to infinite and constant property around with constant heat release rate, and give the rock and soil temperature expression in the place r away from the axis of cylindrical heat source at some moment t.

1.3 Demonstration and Application

The demonstration project refers to Phase-II project of some resort hotel in Shunyi District, Beijing, with design testing hole depth of 100m, and testing achievements are shown as below:

1)Through the layered thermal response test, rock and soil heat conductivity coefficients of different depths can be obtained, and see Figure 1-5 for details.

2)Underground 30-35m, 55-60m and 85-90m heat conductivity coefficients are obviously higher than those in other regions, and the underground water may be likely to flow through the region.

3)The heat conductivity coefficient of underground 85-90m section is the highest, and the heat conductivity coefficient after the 90m section will decline rapidly. Based on this, the number of design holes can be increased or decreased according to actual situation of hole forming cost of buried pipe, so as to achieve the best result.

The new type of rock and soil thermal physical property tester has obtained patent authorization of National Patent Office.

2 Research on Demonstration and Preparation of Technical Code for Single-well

Geothermal Energy Collection with Circulation Heat Exchange

The subject has conducted demonstration research in the following aspects:

(1) Research the structural optimization technology of collecting well according to requirements for cooling and heating loads of hydro-geological conditions and buildings.

(2) Determine rated heat supply power of collecting well under different geological conditions.

(3) Research key parts of collecting well, such as energy storage grain and permeable membrane, and determine the using scope.

Based on above research, the local standard Technical Code for Single Well of Geothermal Energy Collection with Circulation Heat Exchange of Beijing local standard (DB11/T935-2012) is prepared. The Code is applicable to the engineering of single-well geothermal energy collection with circulation heat exchange which provides heat, cooling and domestic hot water for buildings, and has made detailed requirements for design, construction, inspection and acceptance of single-well geothermal energy collection with circulation heat exchange.

The Code points out that based on structure, the geothermal energy collection well can be divided into: collecting well with energy storage grain, single- aquifer geothermal energy collection well without energy storage grain and multi-aquifer geothermal energy collection well without energy storage grain. In addition, the Code also rules contents which the design of geothermal energy collection well shall include: search hydro-geological data of geothermal energy collection well (well group) region to be constructed; determine the category of geothermal energy collection well: geothermal energy collection well with energy storage grain or collecting well without energy storage grain; determine the scope, quantity and position of geothermal energy collection well region; determine the structure of geothermal energy collection well; and determine the circulation water amount and heating (cooling) power.

The design of geothermal energy collection well position shall be determined according to geological and hydro-geological conditions of geothermal energy collection region to be constructed. Meanwhile, the design shall also conform to the following requirements: be close to the machine room; there shall be a sufficient distance from the geothermal energy collection well position to the building (structure); the distance between two adjacent geothermal energy collection wells with energy storage grain and between two adjacent geothermal energy collection wells without energy storage grain should not be shorter than 8m and 10m respectively; for geothermal energy collection well group, it is required to keep that the direction of central collection line of geothermal collection well is vertical to the local underground water flow to the greatest extent.

The Code definitely rules contents of

structural design of geothermal energy collection well, including diameter and depth of geothermal energy collection well; category, specification and quantity of energy storage grain material; structure and performance of isolating membrane and water heat exchange wall; structure and position of guide plate.

For the power of geothermal energy collection well, the Code points out that the maximum temperature at the outlet of circulating water of geothermal energy collection well during the running period in summer should be lower than 33℃ ; and the minimum temperature at the inlet of circulating water of geothermal energy collection well during the running period in winter should be higher than 4℃ .

The engineering inspection and acceptance is the last link from design to using. The Code requires that construction records of concealed work shall be complete, and there shall be whole-process recording, and all of them shall have passed corresponding quality inspection. The Construction Unit shall submit well completion report including materials such as comprehensive histogram of geothermal energy collection well. In addition, after well completion, the heating (cooling) power of collection well shall be tested by combining device and heating (cooling) system in the geothermal energy collection well, so as to work out the actual heating (cooling) power of collection well, which shall not be lower than the design value.

3 Research on Model of Single-well Geothermal Energy Collection with Circulation Heat Exchange as well as Forecast and Assessment of Geothermal Field

3.1 Physical Process of Single-well Geothermal Energy Collection with Circulation Heat Exchange

The physical process of single-well geothermal energy collection with circulation heat exchange with energy storage grain is shown as below: the circulating water is pumped out and drained by internal pumping area of heat insulation shaft wall, and then the circulating water is sent into the heat pump unit, after heat release or absorption, it will be sent back by the heat pump unit, and then enter the inner of pressurized backwater area at the upper part of geothermal energy collection well. The water will flow inside the annular space with energy storage grain between the heat insulation shaft wall and the isolating membrane, and most of them will enter the pumping area at the lower part, while a small part of them will flow the soil medium through permeation from the pressurized backwater area, and flow back from the pumping area finally. All backwater of geothermal energy collection well will be pumped out by the submerged pump via floral tube at the lower part of heat insulation shaft wall and then sent back to the heat pump unit.

There is no energy storage grain in the

space between the heat insulation shaft wall and the isolating membrane in single-well geothermal energy collection with circulation heat exchange without energy storage grain, but is filled with medium water, and the structure and the physical process of mass and heat transfer of other parts is the same as that of the single-well geothermal energy collection with circulation heat exchange with energy storage grain.

3.2 Mathematical Model of Single-well Geothermal Energy Collection with Circulation Heat Exchange with Energy Storage Grain

3.2.1 Control Equation

For each part of the single-well geothermal energy collection with circulation heat exchange with energy storage grain generally refers to porous media and is filled with water fully. The flow velocity of water in the porous media is very slow, and it can be of simulation calculation according to viscous and incompressible laminar flow. The flowing of water in the porous media mainly considers solid matrix, complying with the mass conservation equation (9), momentum conservation equation (10), and energy conservation equation (11):

(1) Mass conservation equation

$$\frac{\partial(\gamma\rho)}{\partial t}+\nabla.(\gamma\rho V_i)=0 \qquad (9)$$

In the formula, γ refers to the porosity of porous media, ρ refers to fluid density, t refers to time variable, Vı refers to speed tensor, i=1,2,3….

(2) Momentum conservation equation

$$\frac{\partial(\gamma\rho v_i)}{\partial t}+\nabla.(\gamma\rho V_i V_i)=-\gamma\nabla p+\nabla.(\gamma\tau_{jk})+\gamma\rho g+S_m \qquad (10)$$

In the formula, p refers to static pressure of fluid, $\tau_{j\kappa}$ refers to stress tensor, $j\kappa$=1,2,3, g refers to acceleration of gravity, S_m refers to momentum source term, and meanings of γ, ρ, t and v_ι are the same as that of the formula (9).

(3) Energy conservation equation

$$\frac{\partial}{\partial t}(\gamma\rho_f E_f+(1-\gamma)\rho_s E_s)+\nabla(v_i(\rho_f E_f+p))=\nabla\left(ke\nabla T-\left(\sum_i h_i J_i\right)+(\tau_{jk}V_i)\right)+S_f^h \qquad (11)$$

In the formula, Ef refers to total energy of fluid in porous media, Es refers to total energy of solid matrix in porous media, hi refers to enthalpy of fluid and various solid matrixes in porous media, Ji refers to the mass flow of the fluid and various solid matrixes in porous media ı to the unit area of mass average speed, ı =1, 2 ,…, Sfh refers to enthalpy source term of fluid; meanings of p, γ, ρ, t, τjκ, vı are the same as that of the formula (9), and ke refers to effective thermal conductivity of porous media, which are worked out according to weighting of heat conductivity of fluid and heat conductivity of solid matrix in the calculation region. Obviously, when the porosity is 100%, the above equation will be degenerated to laminar flow control equation of incompressible fluid.

3.2.2 Definite Conditions

There are relatively many categories of definite conditions, which can be listed according to detailed situations in actual engineering, and frequently definite conditions are shown as below.

(1) Initial conditions

The calculation fluid field is in the static status, i.e. the velocity $V(0)$ at the initial moment is zero, and the intensity of pressure $P(0)$ at the initial moment refers to ambient pressure P_0, and the temperature $T(0)$ at the initial moment refers to constant T_0, and the expression is shown as below:

$$V(0)=0 \quad (12)$$

$$P(0)=P_0 \quad (13)$$

$$T(0)=T_0 \quad (14)$$

(2) Boundary conditions

a. Inlet boundary of computational domain

The inlet flow Q_{in} refers to constant Q_1, i.e.:

$$Q_{in}=Q_1 \quad (15)$$

The inlet temperature T_{in} refers to constant T_1, i.e.:

$$T_{in}=T_1 \quad (16)$$

The intensity of pressure at the inlet P_{in} refers to constant P_1, i.e.:

$$P_{in}=P_1 \quad (17)$$

b. Outlet boundary of computational domain

The inlet flow Q_{out} refers to constant Q_2, i.e.:

$$Q_{out}=Q_2 \quad (18)$$

The outlet temperature Tout is unknown and is not set, but is worked out via known conditions.

The intensity of pressure at the outlet P_{out} refers to constant P_2, i.e.:

$$P_{out}=P_2 \quad (19)$$

c. Other boundaries of computational domain

Isothermal external boundary Γ1 and heat insulation external boundary Γ2 expressions of soil are shown as below:

$$T|_{\Gamma 1}=t_0 \quad (20)$$

$$q|_{\Gamma_2}=0 \quad (21)$$

Boundary conditions of constant heat flux are shown as below:

$$q|_{\Gamma_2}=c \quad (22)$$

Fluid field velocity v on the boundary is zero, i.e.:

$$\vec{v}|_{\Gamma_1 \cup \Gamma_2}=0 \quad (23)$$

In formulas from (20) to (23), T means the temperature of boundary Γ_1, and q means the density of heat flow of boundary Γ_2.

3.3 Mathematical Model of Single-well Geothermal Energy Collection with Circulation Heat Exchange without Energy Storage Grain

3.3.1 Control Equation

The computational domain of single-well geothermal energy collection with circulation heat exchange without energy storage grain is divided into computational domain with porous media and computational domain without porous media. Two parts adopt different control equations respectively.

(1) Computational domain with porous media

The flowing of soil porous media of single-well geothermal energy collection with circulation heat exchange without energy storage grain belongs to laminar flow, and its control equation is completely the same as that of control equations (9) – (12) of single-well geothermal energy collection with circulation heat exchange with energy storage grain.

(2) Computational domain without porous media

The air intake pressurization pipe and pumped backwater pipe of single-well geothermal energy collection with circulation heat exchange without energy storage grain has no porous media, and is filled with water fully, and the standard K-ε model of turbulent flow of viscous and compressible flow.

The universal form of K-ε differential equation is shown as below:

$$\frac{\partial}{\partial t}(\rho\phi) + div(\rho v_i \phi) = div(\Gamma_\phi \, grad \, \phi) + S_\phi \quad (24)$$

In the formula, t refers to time variable, ρ refers to fluid density, φ refers to any dependent variable, v_i refers to fluid velocity tensor, i=1,2,3, and in the expansion, v_1= vx, v_2= vy, v_3= vz, x_1= x, x_2= y and x_3= z, Γ_ϕ refers to diffusion coefficient and S_ϕ refers to source term. Four terms in above equation refer to unsteady term, convective term, diffusion term and source term respectively, and see Table 1 for various expressions.

In the Table, k refers to turbulent kinetic energy, ε refers to turbulent kinetic energy dissipation rate, μ_{eff} refers to effective viscosity coefficient, μ refers to molecular viscosity coefficient, μ_t refers to turbulent viscosity coefficient, and the four symbols C_1, C_2, $C\mu$ and $\sigma\varepsilon$ are constants, P_k refers to the generation term of turbulence kinetic energy caused by average velocity gradient, and the T in the energy equation adopts absolute temperature scale.

$$\mu_{eff} = \mu + \mu_t \quad (25)$$

$$\mu_T = C_\mu \rho \frac{k^2}{\varepsilon} \quad (26)$$

Table 1 List of Various Meanings in Standard K– ε Turbulence Model

Equation	φ	Γ_ϕ	S_ϕ
Continuity equation	0	0	0
X−axis momentum	v_x	μ_{eff}	$-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial v_x}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_{eff}\frac{\partial v_y}{\partial x}\right)+\frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial v_z}{\partial x}\right)-\frac{2}{3}\frac{\partial}{\partial x}(\rho k)$
Y−axis momentum	v_x	μ_{eff}	$-\frac{\partial p}{\partial y}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial v_x}{\partial y}\right)+\frac{\partial}{\partial y}\left(\mu_{eff}\frac{\partial v_y}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial v_z}{\partial y}\right)-\frac{2}{3}\frac{\partial}{\partial y}(\rho k)$

Z−axis momentum	v_x	μ_{eff}	$-\frac{\partial p}{\partial z}+\frac{\partial}{\partial x}\left(\mu_{eff}\frac{\partial v_x}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_{eff}\frac{\partial v_y}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial v_z}{\partial z}\right)-\frac{2}{3}\frac{\partial}{\partial z}(\rho k)$
Turbulent kinetic energy	k	$\frac{\mu_{eff}}{\sigma_k}$	$P_k-\rho\varepsilon$
Turbulent kinetic energy dissipation rate	ε	$\frac{\mu_{eff}}{\sigma\varepsilon}$	$C_1P_k\frac{\varepsilon}{k}-C_2\rho\frac{\varepsilon^2}{k}$
Energy	T	$\frac{\mu}{\Pr}+\frac{\mu_{eff}}{\sigma\varepsilon}$	The source term S is determined according to actual situation

$$P_k=\mu_{eff}{}^2\left\{\left[\left(\frac{\partial v_x}{\partial x}\right)^2+\left(\frac{\partial v_y}{\partial y}\right)^2+\left(\frac{\partial v_z}{\partial z}\right)^2\right]+\left(\frac{\partial v_x}{\partial y}+\frac{\partial v_y}{\partial x}\right)^2+\left(\frac{\partial v_y}{\partial z}+\frac{\partial v_z}{\partial z}\right)^2+\left(\frac{\partial v_z}{\partial x}+\frac{\partial v_x}{\partial z}\right)^2\right\} \quad (27)$$

3.3.2 Definite Conditions

Add the turbulent kinetic energy k and turbulent kinetic energy dissipation rate ε conditions in initial conditions as well as inlet and boundary, and other contents are the same as those mentioned above.

3.4 Simulation Analysis and Forecast of Ideal Model and Demonstration Project

During the numerical simulation calculation, it is necessary to firstly establish 2D model structural network, and the computational convergence condition is that the residual error shall be controlled below 1×10-3, and then adopt the finite volume method which is widely applied by fluid mechanics and heat transfer theory for simulation solution. The fluid and heat transfer software FLUENT6.3 is adopted for simulation calculation.

From the result of numerical simulation calculation, it can be known that:

(1) Within a certain scope, along with the increasing of water circulation flow, the heat exchange amount of single-well geothermal energy collection with circulation heat exchange will also increase.

(2) Due to heat accumulation effect, the heat exchange amount of the same geothermal energy collection well will gradually reduce as time goes by.

(3) When other conditions are not changed, the temperature difference value between incoming water and outgoing water of geothermal energy collection well will increase gradually along with the reduction of water circulation flow.

(4) Reducing the specific heat capacity of soil and increasing porosity of soil will be in favor of increasing the heat exchange amount of single-well geothermal energy collection with circulation heat exchange.

(5) The increasing of soil permeability coefficient will reduce viscous resistance, thus obviously increasing the heat exchange amount of geothermal energy collection well.

(6) For the heat accumulation effect of soil will greatly reduce the heat exchange efficiency, utilizing heat exchanger to the same region for heating in winter and cooling in summer will obviously reduce the heat (cold) accumulation effect.

4 Research on Platform Software of High Efficient Smart Energy Management System

4.1 System Functions

Targeting problems such as disorder development and absence of supervision of ground source heat pump engineering at home at present, the subject has researched and developed a set of platform software of High Efficient smart energy management system.

4.2 System Architecture

The smart energy management system is a distributed system of 3-level structure, i.e. it consists of management level, monitoring level and on-site control level, as shown in the Figure below.

4.2.1 On-site Control Level

The first level of the system refers to on-site control level, including on-site controller, various sensor and actuator, which directly control on-site equipment. Its main tasks are shown as below:

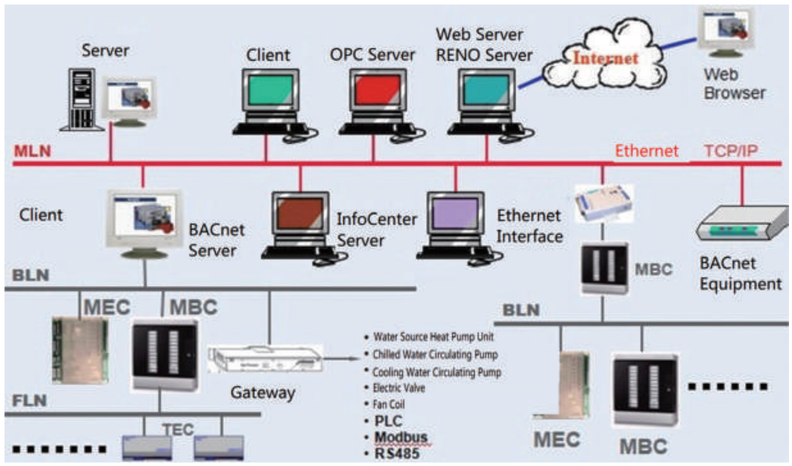

Figure 4–1 Schematic Diagram of 3–level Structure of Smart Energy Management System

● Process data collection. Collect real-time data of various process variables and status information of the controlled object, and guarantee that the digital control, equipment monitoring and status report obtain required on-site information.

● Direct digital control. Implement continuous control and program control according to control platform database and control algorithm module.

● Equipment monitoring, system testing and diagnosis. Analyze and determine whether the controlled object is to be adjusted according to process variables as status information, judge status and performance of hardware of on-site controller, and sent out alarm or give diagnosis report if necessary.

● Safe and redundant operation. In case of finding that the system hardware or control plate has any fault, it is necessary to switch to standby parts in time, so as to guarantee the safe running of the whole system.

The on-site control level refers to automatic control to single equipment, and detailed functions are completed by the on-site controller which is installed on the accessories of the controlled equipment. It is a computer monitoring and control system which can run independently, which not only can control its execution and control function independently, but has powerful communication capability, able to form a network to realize high-speed real-time computation. Generally, there are input and output of several channels of analog and digital quantity, including:

● Analog input (AI), such as temperature, pressure and flow.

● Digital input (DI), such as contact closing and breaking.

● Analog output (AO), such as operation and regulation valve.

● Digital output (DO), such as motor startup/shutdown control, 2-digit on/off control, etc.

The direct digital controller shall also have interface of digital quantity accumulation, which can input low-frequency pulse signal as accumulative calculation of electric quantity and water quantity.

Functions of on-site controller are realized via software, and the on-site controller software includes: system software, communication software, input and output contact processing software, operation command control software, alarm treatment software, computation software, control software, time/event program (TEP), energy management and control software, customized software and terminal simulation software.

4.2.2 Monitoring Level

The second level of the system refers to monitoring level. The monitoring level is to monitor various units of ground source heat pump system, and management all information of the system, with its main tasks including:

● Optimization control. In case that the on-site conditions have any change, the monitoring level can conduct analysis and calculation according to optimization strategy, so as to generate new set value and regulated value and hand over them to the on-site control level for execution.

● Coordination control. Coordinate mutual relationship with the priority criteria according to situation of the controlled equipment.

● System running monitoring. Monitor running parameters and states of the whole system, appoint record and statement of the controlled equipment, and conduct alarm display, fault display, analysis and record.

The computer of monitoring level is set in the monitoring center, and it is called central station, which is used to conduct management and optimization control to the whole system. The central station and on-site controller conduct data communication via communication interface; the on-site controller can execute independent control function as an independent controller, and it can not only transmit data information to the central computer, but accept the control of central computer. Besides software functions which are required to be completed, the central computer shall have reliable hardware, and usually, the top-grade microcomputer and relatively high configuration are to be selected.

The function of monitoring level is realized via software of central station, and software of central station includes: system software (network operation system), language processing software, data communication software, display format and tabular software, operator interface software, schedule software, time/event triggering program (TEP), alarm treatment software, control software, database software, energy management and control software. Functions of main software of central station are shown as below:

● Visit level control

● Graphic operation

● Adapting to multiple communication protocols

● Customized alarm management

● Point classification

● Graph generation tool and library

● Utility program

● Scheduling of equipment running and special event

● Selection of trend of historical and dynamic points

● Various statements and information records

● Passing window software

4.2.3 Management Level

The third level of the system is management level. The management level computer is at the top of the whole system, and it has very powerful processing capability.

The graphic work station at the management level can enter the Ethernet for data management (TCP/IP), so as to realize regional data networking and enhance management level, with the rate reaching 10/100Mbps.

4.3 Hardware Configuration Scheme

4.3.1 Central Processing Unit

Adopt web access Advantech Industrial Control Computer.

4.3.2 On-site Control Unit

(1) Signal transmission module

The signal transmission generally adopts wired access to Ethernet and wireless transmission; considering factors such as on-site Ethernet and on-site wiring, the GPRS transmission module is to be adopted.

(2) On-site control module

This part includes control module and expanded I/O module; and Siemens PXC MODULAR series control modules and I/O expansion modules are to be adopted.

4.3.3 Terminal Element

It includes various temperature sensors, pressure sensors, flow sensors, current sensors and voltage sensors.

4.4 Software Development Scheme

4.4.1 Software Planning

The High Efficient smart energy management system adopts GIS, configuration and self-definition to realize on-line monitoring and statistical analysis of energy consumption, as well as decision making and optimization of energy saving control based on classified and itemized energy consumption metering of large-sized buildings by adopting multiple data collection and remote transmission manners.

4.4.2 Software Functions

(1) Functions of On-site Control Level Software

1) Computation software: it mainly used to conduct calculation of data, such as mean value and high/low value selection, logic computation and integration.

2) Control software: it adopts direct digital control, and has control functions such as proportion, proportional integral and proportional integral differentiation. It executes operation sequence required by the site, and adopts proportion, proportion integral and proportional integral differentiation algorithm to control the central air conditioning system. The program includes DDC operator program, e.g. the self-adaptation control can make response to the environmental change and automatically adjust the system running.

3) Time/event program: send out command according to schedule, or trigger standard or customized DDC program according to startup and shutdown plans, point alarm or point status change, and control the air conditioning equipment. The inherent TEP of controller provides time sequence system and time trigger program irrelevant with the central station TEP.

4) Energy management and control software: it has the best startup and shutdown program, trend record, periodic load and maximum demand management. The energy saving and control program library can be executed in the controller, and the programs can read shared input from other controllers, so as to control their own output. The programs can run independently without relying on the central station, so as to guarantee the system reliability.

5) Customized software: it can simplify modification of data document, and the authorized operator can add, modify and delete on-site controller, monitoring point data, energy management data and user program.

6) Terminal simulation software: In case that the on-site controller is not required to be adopted to provide all capabilities of graphic operation, the operator can use video to display terminal or personal computer, realize operation to simple point and equipment via suitable terminal simulation software, such as reading measuring point data and issuing command to the point.

The smart energy management system adopts various sensors to detect working status of equipment. The sensor and transmitter are devices which transform electric quantity or non-electric quantity into electric quantity which can be processed by control equipment, and they are generally used to measure physical quantities such as temperature, humidity, pressure and differential pressure.

(2) Functions of Monitoring Level Software

1) Visit level control. The system will provide multiple operator visit levels, and the work station will judge whether the operator is allowed to access to the system, and will identify various operator visit levels. The operator can only access to the system via password and visit the authorized level. To reduce the possibility of illegal using by others in case that the operator leaves the work station in the status of access to system, there is a time-out signal which will automatically make the operator log out. The duration of automatic logout or timeout signal can be decided according to different operator definitions.

2) Graphic operation. Adopt colors to distinguish normal and abnormal air conditioning equipment temperatures, and confirm the running/shutdown and opening/closing status of motor via animation. Any control point on the site can be displayed on the graph at any level. Through mapping software, the operator can generate, modify and delete any graph. To send out a command, the operator shall firstly select a point, and then direct the points from graph. The system also can display a dialog box to select a suitable command.

3) Adapting to multiple communication protocols. The bus is adopted for connection with on-site controller. They all adopt peer-to-peer communication protocol, and the protocol makes each set of equipment have bus visit right of the same level. All equipment has the capabilities of error recovery and bus initialization, and in case of using other bus communication protocols, or when the central display breaks away from circuit, the bus communication will stop. However, in case of adopting peer-to-peer communication protocol, as long as 2 sets of equipment on the bus are running, the communication will continue.

4) Customized alarm management. The alarm information will be printed out automatically or displayed and printed out under the control of the operator. The multi-point alarm will be displayed according to priority.

5) Point classification. Points are grouped according to their performances. In this case, the data documents can be updated conveniently, and points can be identified by the operator on the displayed graph more rapidly. For example, all temperature sensors can be classified into the category of temperature, and this type of points can be marked with the same color on the graph, so as to display various values, and they have the same alarm treatment point.

6) Graphic generation tool and library. The operator can adopt graphic software to develop graphs, and to simplify the generation process of graph, the system will provide a set of HVAC and electrical symbol and standard system, such as drawing library of air conditioner and refrigerator. The system also rules equipment categories, and provides standard color matching, refresh rate, animation, engineering unit and default

property for them.

7) Utility program. The utility program is used to produce on-site controller application program and database. The design personnel can select HVAC mapping element to establish control sequence.

8) Scheduling of equipment running and special event. The system supports scheduling function of the following equipment running and special events, and the controller uses independent scheduling function, and is not associated with graph, but is driven through text/menu-driven guide. The controller grouping makes the holiday and exception program simplified, and for controller, the operator can establish a normal or temporarily used schedule for daily running of air conditioning system, and can display graphs related to expected points, and then determine or modify appropriate schedule. For special events, such as evening party, the operator can determine actions and arrange the actions to make them occur as per time and date. For example, the report and alarm abstract of all points are also scheduled events. All work is set with dialogue box, which can be entered via single click, picture turning or keyboard input.

9) Selection of trend of historical and dynamic points

10) Various statements and information records. Statements include data and information records of current historical points, and the operator can print screen picture as required, i.e. print and output the screen picture with colors for selection, and the picture can be printed on the paper or the transparent film for projector. In addition, the operator is allowed to arrange the output within the expected time period through selecting points in the initial graph and subsequent graph.

11) Passing window software. The operator can take one window as the central graphical interface, while other windows can be used for execution of the third party software specially, such as Excel or word processing program. The operator can switch windows conveniently, thus enhancing working efficiency.

(3) Functions of management level software

1) Conduct acquisition, statistic and analysis to various disturbance conditions of cold and thermal loads of building, so as to determine the most economic and effective energy supply amount, thus realizing energy supply according to demand.

2) Control parameters of water system (water temperature, pressure and flow) on the heat source side and using side in a real-time way, optimize running conditions of main engine of heat pump, monitor system parameters (cooling system pressure, temperature, current and energy efficiency ratio) of main engine of heat pump, and control COP value of main engine to make it in the best status.

3) Conduct variable flow control of water, adjustment control of main engine energy and optimization control of energy supply conditions, and take enhancing COP value of the system as the target, so as to realize system optimization mode based on data and professional control strategy.

4) The intelligent and automatic control can reduce adverse impact of human factors on energy consumption, and reduce the loss brought by various human errors.

4.4.3 Design of Data Communication

This part is mainly used as the bridge for communication between remote client and lower computer (PLC). On the one hand, it is responsible for collecting PLC data, and on the other hand, it is responsible for receiving control information of remote client, and writing it into PLC. Generally, the application server is installed with OPC Server (or data collection service program developed by ourselves), and the OPC Server is connected with PLC on the equipment via serial port or Ethernet for data collection, and then cache the collected data in the application server. The internal LAN of the Company is connected with the on-site OPC Server via wired or wireless Ethernet for data reading.

4.4.4 Design of Remote Client Software

This part is mainly to realize the communication with upper computer and the development of monitoring picture. To facilitate communication with the upper computer, the whole application program is distributed to multiple servers to enhance the overall capacity structure of the Project and improve the system performance. The distribution of servers can be based on physical equipment structure or different functions in the Project, and the User can set up special IO server, historical data server, alarm server, login server and WEB server according to system demand.

In the aspect of client monitoring picture, the ActiveX control is adopted and embedded into webpage. The User is only necessary to input the IP address of the server in the address field of IE browser at the client end, and when the User visits the webpage of server for the first time, the IE browser will automatically download the ActiveX control on the webpage of server into local computer, and the ActiveX control will be registered automatically. In this case, the User can conduct real-time monitoring to the on-site equipment through IE browser. Through using the ActiveX control, the remote client can directly read OPC data on the server and conduct real-time updating, without transferring via database.

5 Conclusions

(1) The researched and developed new type of rock and soil thermal physical property tester can measure heat conductivity coefficients of rock and soil layers with respective thickness greater than 0.25m and initial temperatures of different rock and soil layers, while the thermal response method of traditional steady heat flow can only obtain the initial average temperature of rock and soil layer. For rock and soil thermal response testing which is used conventionally adopts line heat source model, and the buried pipes are regarded as a whole for calculation, compared with

cylindrical heat source of the new type of rock and soil thermal physical property tester, there is error in model selection. Therefore, the underground rock and soil thermal physical property calculated through layered thermal response method is more accurate. Through layered thermal response testing, the curve of heat conductivity coefficient of underground rock and soil can be obtained, thus judging seepage situations of different rock and soil layers and underground water flow conditions of one region, thus providing scientific basis for site selection of buried pipe heat exchanger and utilizing shallow geothermal energy to a greater extent.

(2) Through indoor test and on-site demonstration research, key technical points of single-well geothermal energy collection with circulation heat exchange have been summarized, integrated and finalized, which basically solves reinjection of underground water source heat pump. Based on this, Technical Code for Single Well of Geothermal Energy Collection with Circulation Heat Exchange of Beijing local standard (DB11/T935-2012) has been prepared, which lays a foundation for large-area promotion of the technology.

(3) Theoretical and numerical calculation models of single-well geothermal energy collection with circulation heat exchange has been established by combining with the research on such technology, and the comparison and analysis also have been conducted between models and actual data of the demonstration project, which solves theoretical problems of the technology of single-well geothermal energy collection with circulation heat exchange, and has significance to the promotion of such technology.

(4) The developed and researched High Efficient smart energy management system can not only monitor and supervise various running parameters and geological environment of ground source heat pump, but can regulate running status of ground source heat pump system according to actual demands of heating and cooling of building, thus realizing intelligence of energy management.

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2018-2019 采暖季 北京各区因地制宜 采取多样化清洁取暖

HEATING SEASON FOR 2018-2019 ALL DISTRICTS IN BEIJING SUIT CLEANING HEATING METHODS TO THEIR LOCAL SITUATION

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今年 6 月 13 日，国务院总理李克强主持召开国务院常务会议，在部署实施蓝天保卫战三年行动计划时指出，要科学合理、循序渐进有效治理污染。坚持从实际出发，宜电则电、宜气则气、宜煤则煤、宜热则热，确保北方地区群众安全取暖过冬。

7 月 3 日，国务院正式印发《打赢蓝天保卫战三年行动计划》(以下简称《三年行动计划》)，对未来三年国家大气污染防治工作进行部署。生态环境部环境规划院院长、中国工程院院士王金南解读称，《三年行动计划》对北方地区冬季清洁取暖工作实现环境效益、社会效益双丰收作了细致安排部署。在技术路线上，提出坚持从实际出发，各地因地制宜选择采取多样化清洁取暖方式，不局限于“煤改气”，减轻气源保障压力。

如今，2018-2019 采暖季如期而至。北京市的“煤改清洁能源”工作进度如何？哪些采暖政策值得关注？补贴方面有无变化？

城镇集中供热实现清洁取暖

4 月 14 日，北京市人民政府办公厅印发《2018 年北京市农村地区村庄冬季清洁取暖工作方案》，提出科学选择技术路线，以“煤改电”为主，完成 450 个村委会和村民公共活动场所、5.38 万平方米籽种农业设施“煤改清洁能源”工作。

截至目前，北京市城镇集中供热已经基本实现清洁能源取暖，且北京“十三五”期间“煤改电”改造任务也已提前两年完成，全市平原地区基本实现“无煤化”。

上个采暖季，北京市已经有 98% 的集中供热采用了清洁能源，仅剩下延庆城东、城南锅炉房，平谷滨河、兴谷和夏各庄锅炉房、密云太师

屯锅炉房等 6 座大型燃煤供暖锅炉房尚未完成改造。10 月 29 日，随着平谷区供热厂锅炉房清洁能源改造项目正式进入设备调试，北京市年内完成了如上 6 座燃煤锅炉房的清洁能源改造任务。至此，北京市城镇集中供热已基本告别燃煤，实现了清洁取暖。

11 月 1 日，国家电网北京电力公司发布了北京市 2018 年“煤改电”工程全面完工的消息。2018 年以来，该公司已完成北京市政府下达的 312 个村、12.26 万户“煤改电”任务，并超额完成山区 163 个村、5.74 万户配套电网改造。至此，北京平原地区基本实现“无煤化”。同时，这也标志着北京“十三五”期间“煤改电”改造任务提前两年完成，全市平原地区基本实现“无煤化”。

与此同时，北京市针对 100 个老旧小区进行了供热管网的改造，自 2008 年至今已经累计改造老旧小区供热管网 1950 个，管线长达 4200 公里，受益者超过 190 万户。排除安全隐患、提高节能效率、提升供热质量之外，也解决了老旧小区常年温度不达标的问题。

农村供暖制定科学路线

根据《北京市 2018 年农村地区村庄冬季清洁取暖工作推进指导意见》(以下简称《指导意见》)，北京市各区将进一步规范各区“煤改清洁能源”和“减煤换煤”相关工作。

《指导意见》在做好确村确户工作方面明确提出，根据当地电力、燃气的现状与资源条件，在确保能源供应安全可靠的基础上，以“煤改电”优先，科学引导农民选择适宜的改造方式。

在科学确定技术路线方面则提出，根据本地住户冬季的用能结构、取暖习惯和清洁能源取暖设备特性，按照“安全、环保、节能、高效、经济”的要求，科学确定技术路线与清洁取暖设备，确保农村住户取暖系统更合理、更优化、更节能，切实降低运行费用，实现清洁取暖系统的最优效果。

《关于完善北京城镇居民“煤改电”、“煤改气”相关政策的意见》相关事项补充规定则显示，实

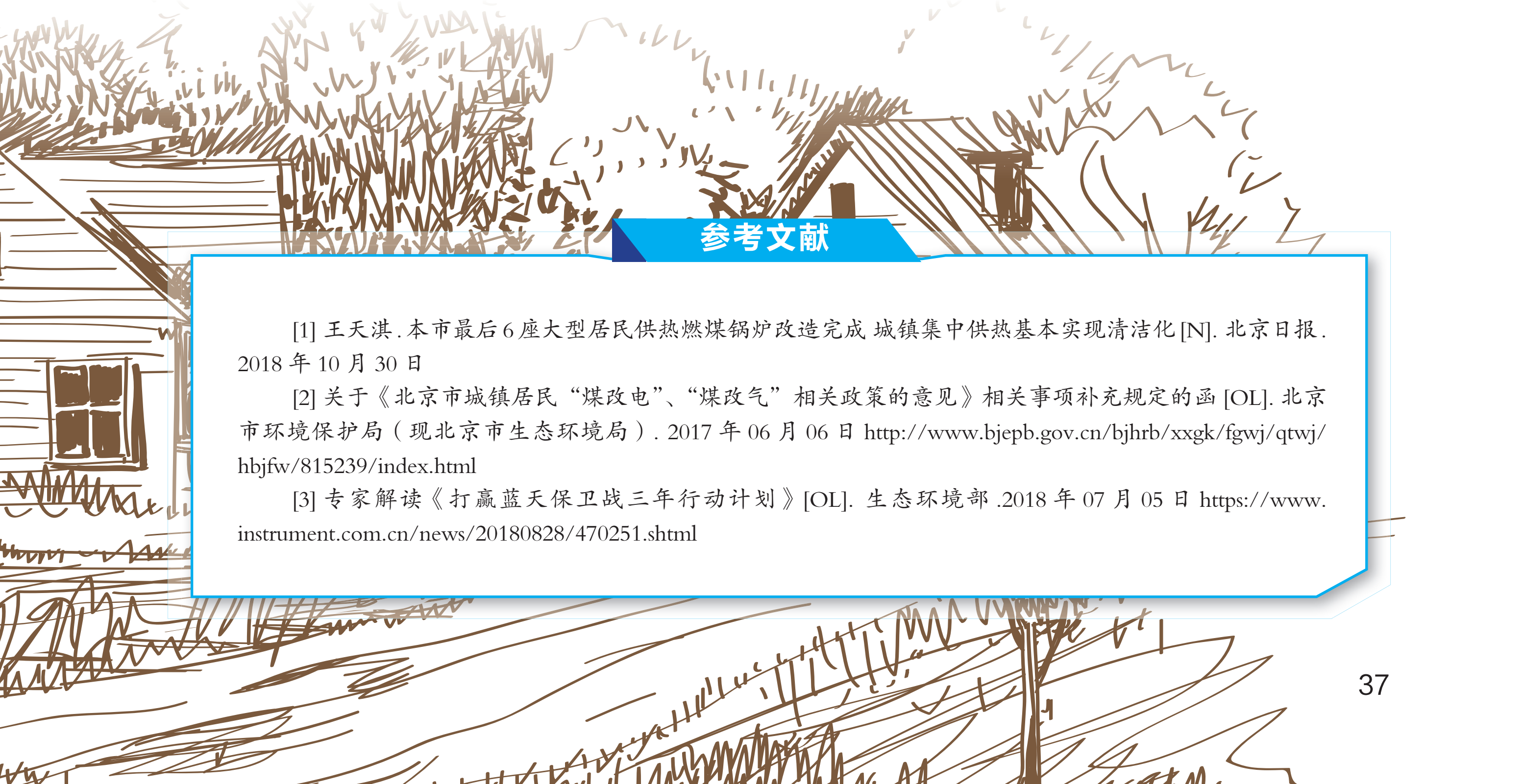
施“煤改电”项目，可根据实际需要选择蓄能式电采暖器、空气源热泵、地源热泵、电加热水储能、太阳能加电辅等清洁能源取暖设备；实施“煤改气”项目，可选择使用市政管道天然气、LNG 等清洁能源，改造方式可以选择单户改造或集中改造。

据了解，从技术成熟情况和实践应用情况来看，空气源热泵（含热水型热泵和热风性热泵）、地源热泵和高能效低排放的燃气取暖设备，是农村地区村庄住户可使用的能效比（COP）较高的取暖新方式。其中，空气源热泵因在零下 30 摄氏度环境温度中可正常运行，且能够通过增加“多能联动、多测符合、多源合一”的新技术，以及“太阳能 + 辅助加热”设备，增加适用性，因而被广泛推广使用。地源热泵，对地质条件有一定要求，推广使用需要因地制宜。不过，“直热式”电取暖设备则因不利于节能及减少运行费用，不建议推广使用。

各区延续以往补贴政策

“煤改清洁能源”后的取暖费用，也是居民最为关心的。据了解，对使用空气源热泵、非整社区安装地源热泵取暖的，市财政按照取暖面积每平方米 100 元的标准进行补贴，对使用其他清洁能源设备取暖的，市财政按照设备购置费用的 1/3 进行补贴，市财政对各类清洁能源取暖设备的补贴金额每户最高不超过 1.2 万元。

2018 年各区农村地区冬季清洁取暖工作方案，均明确对“煤改清洁能源”后的供暖费用给予一定补贴。其中，“煤改电”补贴延续峰谷电价，农村地区采暖季期间平（峰）段电价为 0.4883 元 / 度，谷段电价为 0.3 元 / 度。低谷时段，市区两级政府各补贴 0.1 元 / 度，改电户实缴 0.1 元 / 度，补贴电限额为 1 万度，且该电费补贴实时补贴到用户电表。“煤改气”在执行市级天然气价格（每户 0.38 元 / 立方米补贴）支持政策基础上，区财政再按 0.6 元 / 立方米进行补贴，每个取暖季每户补贴金额最高不超过 1000 元。针对供暖费用的补贴，没有过多变化，基本上延续了以往的补贴政策。



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Heating Season for 2018-2019: All Districts in Beijing Suit Cleaning Heating Methods to Their Local Situation

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On June 13, Premier Li Keqiang chaired a State Council executive meeting and, when deciding at three-year action plan for the Blue Sky Defense War, pointed out that pollution should be treated scientifically, rationally and effectively step by step. He also required adherence to the actual situation and preferred use of electricity, gas, coal or thermal energy whenever appropriate to ensure that the people in the northern region spend a warm winter safely.

On July 3, the State Council officially issued the Three-Year Action Plan to Win the Blue Sky Defense War (hereinafter referred to as "Three-Year Action Plan") which describes the tasks of air pollution prevention and control in the next three years. Wang Jinnan, director of the Chinese Academy for Environmental Planning of the Ministry of Ecology and Environment and academician of the Chinese Academy of Engineering, interpreted the Three-Year Action Plan as detailed blueprint for environmental benefits and social benefits of clean heating in the northern region during winter. The technical route is defined with the actual situation considered, and all districts adopt a variety of clean heating methods according to local conditions without clinging only to "coal to gas". This measure can reduce the pressure of guaranteed gas source.

Now, as the heating season for 2018-2019 is around the corner, how is the "transition from coal to clean energies" going on in Beijing? What are the heating policies worthy of attention? Is there any change in subsidies?

Centralized Heating Realized Clean Heating in Towns

On April 14, the General Office of the Beijing Municipal People's Government issued the Work Plan for Clean Heating in Rural Villages in Beijing during Winter in 2018. The document included a scientifically selected technical route and required realizing the transition from "coal to clean energies", especially "coal to electricity", in 450 village committees and public spaces for villagers as well as seed agricultural facilities of 53,800 square meters.

So far clear energies have basically become dominant in centralized heating in towns in Beijing. Moreover, the "coal to electricity" transformation task during the "13th Five-Year Plan" period in Beijing has been completed two years ahead of schedule. The plain areas in the city are basically "coal-free".

During the last heating season, 98% of centralized heating in Beijing used clean energies, except six large coal-fueled heating boiler rooms in the east and south of Yanqing, Binhe, Xinggu and Xiagezhuang in Pinggu District, and Taishitun in Miyun, which had not been transformed. On October 29, as the clean energy transformation project of the boiler room of the heating plant in Pinggu District was officially put into equipment commissioning, Beijing completed the clean energy transformation task with those six coal-fired boiler rooms this year. So far the centralized heating of urban areas in Beijing has basically got rid of coal to rely on clean energies instead.

On November 1, State Grid Beijing Electric Power Company announced that the "coal-to-electricity" project of Beijing starting from 2018 had been fully completed. Since 2018, the company has completed the transition from "coal to electricity" in 312 villages and 122,600 households, a task assigned by the Beijing Municipal Government. It also overfulfilled the renovation of power grids in 163 villages and 57,400 households in mountainous areas. So far, the plain areas in Beijing are basically "coal free". At the same time, this marks the completion of the "coal to electricity" transformation task during the "13th Five-Year Plan" period in Beijing two years ahead of schedule, and the plain areas in the city are basically "coal free".

Meanwhile, the heating pipe networks in 100 old residential communities in Beijing were renovated. Since 2008, 1,950 old residential communities have seen their heating pipe networks which had a total length of 4,200km rebuilt, and more than 1.9 million households benefited from this change. This project not only eliminated safety hazards, increased energy efficiency, and improved heating quality, but also solved the lasting problem of non-conforming temperatures in those old communities.

A scientific Route for Rural Heating

According to the Guiding Opinions on Promoting Clean Heating in Rural Areas of Beijing during Winter in 2018 (hereinafter referred to as "Guiding Opinions"), all districts in Beijing will further standardize the work related to "coal to clean energies" and "coal reduction and substitution".

As for understanding the situations in the villages and households concerned, the Guiding Opinions clearly gives priority to the transition from "coal to electricity" during which scientific guidance is offered for farmers to select appropriate transformation methods according to the local electricity and gas conditions, provided that the energy supply is safe and reliable.

In terms of determining a scientific technical route, the document urges the determination of a scientific technical route and clean heating equipment that meet the requirements of "safety, environmental protection, energy saving, high efficiency and economy" according to the energy consumption structure, heating habits and characteristics of clean energy heating equipment used by local households in winter. The purpose is to ensure more reasonable, more optimized, and more energy efficient heating system for rural households, to effectively reduce operating costs, and to achieve the best results of clean heating systems.

According to the supplementary provisions on matters concerning the Opinions on Improving Policies of "Coal to Electricity" and "Coal to Gas" in Urban Residents in Beijing, clean energy heating equipment such as energy storage electric heaters, air source heat pumps, ground source heat pumps, electrically heated water storage, and solar power plus electric auxiliary power may be used according to actual needs in implementing the "coal to electricity" project. In implementing the "coal to gas" project, clean energies such as municipal pipeline natural gas and LNG may be used through single-household transformation or collective transformation.

It is understood that air source heat pumps (including hot water heat pumps and hot air heat pumps), ground source heat pumps, and energy-efficient low-emission gas heating equipment are new heating means that deliver higher coefficients of performance (COP) in rural villages and households, judging from technical maturity and practical application. Among them, air source heat pumps are extensively applied because they can operate normally even under an ambient temperature of minus 30 degrees Celsius and become more applicable when the new technology of "multi-energy linkage, multiple measurements compliance, and multi-source integration" is used and the "solar + auxiliary heating" equipment is added. Ground source heat pumps need to suit local conditions if they are to be used widely because they raise certain requirements for geological conditions. However, electric heating equipment capable of "direct heating" is not recommended because it is not conducive to energy saving and reduction of operating costs.

All Districts Continue the Original Subsidy Policy

The heating cost after the transition from "coal to clean energies" is the utmost concern for residents. It is understood that users of air source heat pumps and ground source heat pumps that are not installed collectively in the whole community can receive a subsidy of RMB 100/m2 of heating area from the municipal finance. Users of other clean energy equipment can receive a subsidy equal to 1/3 of the cost of the equipment. The maximum subsidy for each household that uses a different type of clean energy heating equipment is not more than RMB 12,000.

In 2018, all districts made it clear to subsidize heating with clean energies instead of coal in their respective program on clean heating during winter in rural areas. The subsidy for transition from “coal to electricity” continues to keep track of the peak-valley prices. The level (peak) electricity price during the heating season in rural areas is RMB 0.4883/kWh and the valley electricity price is RMB 0.3/kwh. During the valley period, the municipal and district governments each grant a subsidy of RMB 0.1/kwh. Then, the electricity charge for households that change coal to electricity is RMB 0.1/kwh. The quota for subsidy is 10,000kwh of electricity, and the subsidies are put into the electricity meters of the users in real time. As for the transition from “coal to natural gas”, while the favorable municipal natural gas price (with a subsidy of RMB 0.38/m3) is charged, another subsidy of RMB 0.6/m3 will also be given from the district finance. The maximum subsidy per household in each heating season will not exceed RMB 1,000. There is little change in the subsidies for heating costs, and the original subsidy polices are basically maintained.

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简述地热能的类型特征及应用

BRIEFING ON TYPE, CHARACTERISTICS AND APPLICATION OF GEOTHERMAL ENERGY

作者：骥文

地球是一个巨大的能源宝库，地心是高温炽热的物体，向地下进入的越深就可以得到越高的温度，计算表明，每天由地球内部向地球表面传递的热量相当于全世界每天使用能量的两倍还多。储存于地球内部的这种能源远比煤、石油和天然气等化石燃料更丰富。我们把这种能源称之为地热能，即指以热能为主要形式储存于地球内部的热量。特别有意义的是地热能是一种清洁能源，地热能的使用不会带来全球环境恶化和大气污染。

一、地热能的类型

由于地热资源种类繁多分类形式也多样。如按温度可分为高温、中温和低温地热资源；按形态可分为干蒸汽型、湿蒸汽型、热水型和干热岩型；按热流体成分有碳酸盐型、硅酸盐型、盐水型、卤水型；通常按其属性可分为以下4种类型：

1 浅层地热能

地面以下一定深度内的土壤和岩石中具有与年平均气温相差不大的温度，这个区域通常叫做恒温区。这些低温能量可以依靠热泵技术提取其中的热量用于建筑物供暖，这部分低温能量被称为浅层地热能。一般指0~100米深度内储存的温度在25℃以下的地热能。

2 常规（水热型）地热能

即地球浅处（地下100~4500m）所见到的热水或水蒸气；世界迄今逾百年的地热开发利用的主体是水热型地热能，所以也称为常规地热能。这类资源就是热水和/或蒸汽储存在地下的“热储”中，构成地热田。

3 干热岩地热能

即由于特殊地质构造条件造成高温但水少或无水的干热岩体，需用人工注水的方法才能将其热能取出。我国将3~10KM深度内储存的地热资源称为干热岩地热能。干热岩具有较高的温度但通常不含水。

4 非常规地热能

除上述三种地热能之外还有两种称之为非常规地热能：

（1）地压地热能：即在某些大型含油气盆地深处（3~6km）存在着的高温高压热流体，其中含有大量甲烷气体；

（2）岩浆热能：即储存在高温（700~1200℃）熔融岩浆体中的巨大热能。

在上述4类地热能中，在浅层地热能开发利用以前，只有第2类常规（水热型）地热能已达到大规模商业性开发利用阶段。又可分为高温（>150℃）、中低温（中温90~150℃，低温<90℃）地热能。高温地热能因其分布具有地区局限性，一般出现在火山、地震活动频繁的构造带、板块边缘及其内部，所以主要用于地热发电。而中低温地热能因其分布广泛获得了较多应用，如：供暖、工农业用热和旅游疗养等。

二、地热能的特征

地热能做为可再生能源，是广泛存在、取之不尽、用之不竭的，最终可依赖的初级能源。直至近二三百年化石能源得以大规模开发利用以前，一直是人类赖以生存与发展的主要能源来源。

地热能的应用前景广阔，虽然目前世界地热发电的总量仅占世界总发电量的1%，但是，连同前瞻性的干热岩开发逐趋成熟，美国已规划出至2050年地热电力将占全美用电的10%。

在新能源和可再生能源大家族中，地热能是目前最现实和最具竞争力的一种能源。据国际地热协会统计，无论是全球地热的总装机容量还是其年产能目前均居其他新能源利用之前。地热发电或地热直接利用的成本，目前也远比其他新能源低，在某些情况下，甚至相当于或略低于传统能源发电或直接利用的价格。因此地热在各类新能源和可再生能源中应具有很强的市场竞争力。

高温地热能最大特点之一就是受控于区域地质构造，资源分布具有地域性，不能远程运输，只能就地就近开发利用，所以在一定程度上制约了其发展。但中低温地热资源特别是浅层地热能分布的地域限制却要少得多，尤其是近十几年来快速发展起来的热泵技术，已能将与常温一样的普通地下水看做地热资源来加以利用。从这个意义上来说，地热资源已没有地域限制，可以说无处不在。

近年来由于采集技术的优化，第1类“浅层地热能”的开发和利用异军突起，发展迅速。

浅层地热能蕴藏在地层中温度比较恒定的区域。其温度在冬季比外界空气温度高很多，在夏季又低很多。浅层地热能的温度更接近于使人舒适的室温。当用热泵为建筑物供暖时，用热泵提温或降温的幅度较小，使热泵机组运行工况更经济、合理。当提供同样的热量或冷量时需要的电能较少。浅层地热能所赋存的空间有较大的热容量，且有较强的恢复能力，浅层地热能可在一个使用季节中通过地下局部的暂时降低温度持续不断地输出热能，而在非使用期得到恢复。

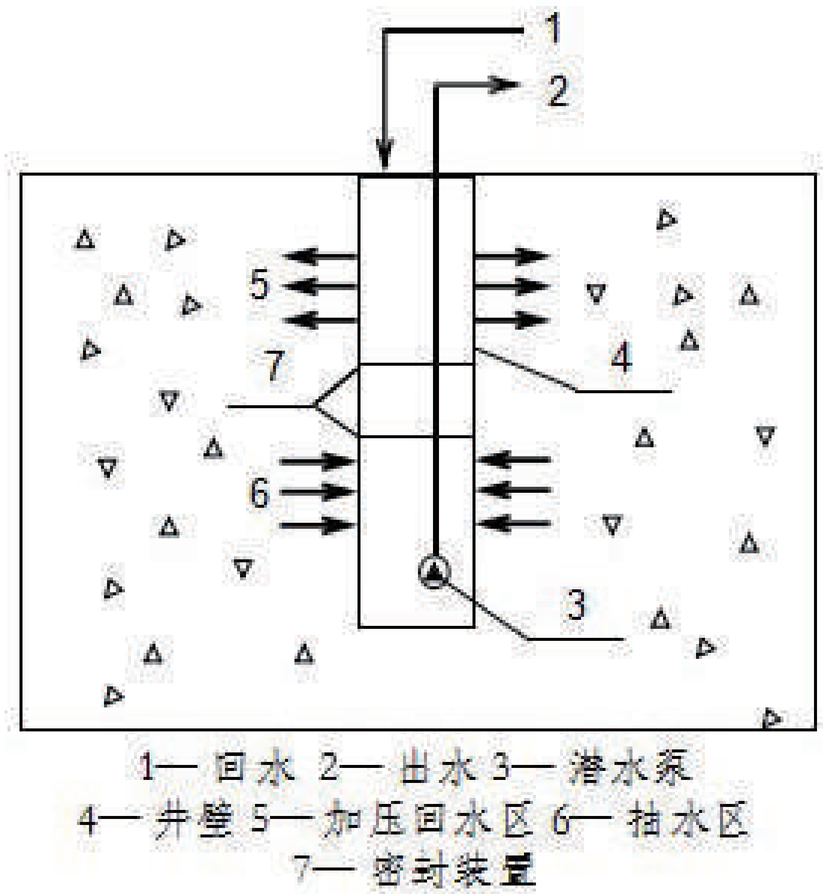
由于我国地域辽阔，南、北方处于不同的气候区，对采暖的需求不同，中纬度地区四季的温差最大，最大达到30℃以上，北方地区以供暖为主，南方地区以制冷为主。在冬冷夏热地区，可以既供暖又制冷，双向使用。由于地层具有一定的蓄热能力，不同季节的反向使用有利于地层温度的恢复。

三、浅层地能的应用

在单井循环换热地能采集技术出现以前，浅层地能的采集系统主要有：1抽水井+回灌井系统；2 地埋管系统。

抽水井+回灌井系统由相隔一定距离的两口井组成。一口为抽水井，与普通供水管井相同；另一口为回灌井。工作时，潜水泵将井水从抽水井抽出进入机组换热，换热后的井水进入回灌井渗入大地。它的优点是结构简单成本低。缺点是只有在地下水很丰富的地区才可以使用，并且有回灌难，移砂和地质沉降等问题。

地埋管系统的典型结构是由垂直埋入地下



▲ 单井循环换热地能采集井物理模型

100米左右深度的单U型或双U型换热管组成。换热管内的介质通过管壁与周围的岩土体换热。它的优点是适应多种地质条件，缺点是换热能力差，占地面积大。

浅层地能采集技术进步过程始终围绕提高采集效率和采集安全性的目标进行。我国经过多年研究，在2000年推出了新的采集技术，即具有国际领先水平的单井循环换热地热能采集技术。单井循环地能采集系统由单井循环换热地能采集换热井（简称采集井），井内换热装置和潜水泵组成。典型的采集井结构如图1。

单井循环换热地能采集井以井水为介质与浅层地下岩土体进行热交换，不消耗也不污染地下水。单井循环换热地能采集井与地埋管相比，虽然同属土壤换热装置，但是单井循环换热的机理比地埋管复杂。地埋管是一种“间壁式”换热装置，管内的循环水与管外岩土体经过管壁传热。单井循环换热地能采集井的换热方式除上面的“间壁式”换热之外，还有井内外水的质量交换，即传质引起的传热。经验和理论计算都显示，这一部分的传热量在单井循环换热地能采集井换热过程中起到重要作用。

单井循环换热地能采集井的深度应能达到浅层地下的恒温区，井底最深处通常在地下80米以内。井内的换热装置设有上下两组密封将井内空间分隔成上部加压回水区，中部密封区和下部抽水区。密封装置内的压力可以调节。调节密封的压力可以改变水的流动速度以得到最好的换热性能。

潜水泵置于井的底部。潜水泵从“恒温区”抽取温度一定（例如15℃）的水进入机组换热，换热以后的水流回井内上部的加压回水区。在重力和压差的作用下，井水最终流入抽水区。循环水在自上而下的运动过程中与井周围岩土体换热。与此同时，随着技术的发展，研发了适用不同渗透条件地层的传热回填颗粒，在井管和井壁之间填充传热回填颗粒，局部改变地层，增大渗透系数。加装蓄能颗粒的单井循环换热采集井大大提高了循环的能力和速度。解决了渗透性弱、单位涌水量小的地层高效采集浅层地能的瓶颈。

四、浅层地能采集技术对比

相较其他浅层地能采集技术，单井循环换热采集技术零污染、零排放、适应性广。由于井水就地原位回灌，所以既不消耗水也不污染水，没有水的流失，不破坏地下水的自然分布，不会造成潜在的地质灾害等问题，并可以应用在不同地质进行地能采集。与此同时，单井循环换热采集技术具有占地面积小、能效比高等优点。能效比是地埋管的20-100倍。不论何种地能采集系统，系统的计划使用时间都在10年以上，所以，稳定高效无污染的地能采集系统都是日后技术发展的目标。

如表1给出以上三种地能采集方式的对比。

五、结论

“取之不尽，用之不竭”可再生的浅层地能作为一种清洁的新能源，随着开发利用力度的加大，将逐渐替代北方供暖能源，加速北方供暖能源的转型。而浅层地能采集技术的不断提高，新技术的不断涌现，将推进地能热冷一体化新兴产业发展，在满足居民供热需求的同时，实现新时代供暖产业的革命。

表 1 三种地能采集方式对比

序号	采集方式	技术来源	对地下水体环境质量的影响				占地面积	能效比	适应性
			地下水流失	污染	潜在地质危害	回灌状况			
1	抽水井 回灌井	国外引进	有	有	有	难	较大	高	局限
2	地理管	国外引进	无	无	无		大	低	广
3	单井循环换热	原始创新	无	无	无	易	小	高（是地理管的 20-100 倍）	广

Briefing on Type, Characteristics and Application of Geothermal Energy

Author: Ji Wen

Earth is a huge treasure of energy, and the earth's core is a red-hot object; the deeper into underground, the higher the temperature it will be. The calculation suggests that, the quantity of heat transferred from the earth's interior to the earth's surface each day is equivalent to more than 2 times of the energy used each day across the whole world. Such energy stored in the earth's interior is far richer than coal, oil and natural gas and other fossil fuels. We call such energy as geothermal energy, namely the heat stored in the earth's interior mainly in the form of heat energy. In particular, the geothermal energy is a clean energy, whose use will not bring about environmental deterioration and atmospheric pollution to the world.

1. Type of Geothermal Energy

Their classification also varies as there are a wide range of geothermal resources. These geothermal energy can be divided into high-temperature, intermediate-temperature and low-temperature geothermal resource by temperature; dry steam type, wet steam type, hydrothermal type and hot dry rock (HDR) type by form; carbonate-type, silicate-type, brine-type and bittern-type by thermal fluid components; in general, they can be divided into the following 4 types by its property:

1. Shallow geothermal energy

The soil and rock within a certain depth below the ground has been endowed with such temperature that differs slightly with annual average temperature, and this area is known as constant-temperature zone. The low-temperature energy, whose heat can be extracted by heat-pump technology for heating the buildings, was known as shallow geothermal energy. In general, it refers to the geothermal energy stored at the temperature below 25℃ and at the depth of 0~100 meters.

2. Conventional (Hydrothermal type) geothermal energy

It refers to the common hot water or water steam at the shallow place of the earth (100 ~ 4,500 meters underground); the subject of geothermal energy that has been exploited and utilized for more than a century is the geothermal energy of hydrothermal type; therefore, it is also known as conventional geothermal energy. Such type of resource is the "geothermal reservoir" stored underground by hot water and/or steam, thus constituting geothermal field.

3. HDR geothermal energy

However, the high-temperature HDR with little or without water due to particular geological structure conditions can only be extracted for heat by injecting water artificially. We name the geothermal resource stored at the depth of 3~10kg as HDR geothermal energy. The HDR has a high temperature, but usually does not contain water.

4 Non-conventional geothermal energy

In addition to the above three types of geothermal energy, there are also two types of non-conventional geothermal energy:

(1) Geopressured geothermal resource: it refers to the high-temperature high-pressure (HTHP) thermal fluid existing in the depth of large-scale oil and gas-bearing basin (3~6km), which contains a great deal of methane gas;

(2) Magma-type geothermal resource: it refers to the considerable heat stored in the high-temperature (700~1200°C) molten magma.

Of the above-mentioned four types of geothermal energy, only the second type, namely the conventional (hydrothermal type) geothermal energy, has reached the stage of large-scale commercial exploitation and utilization prior to the development and utilization of shallow geothermal energy. It can be divided into high-temperature (>150°C), medium- and low-temperature (with the medium-temperature of 90~150℃, and low temperature of <90°C) geothermal energy. Due to the regional limitations of high-temperature geothermal energy in its distribution, it occurs at the tectonic zone with frequent volcano and seismic activities, plate margin and its interior in general; therefore, it is mainly used for geothermal power generation. While the medium- and low-temperature geothermal energy has been widely applied due to its extensive distribution, such as heating, heat for industrial and agricultural purpose as well as tourism and wellness, etc.

II. Characteristics of Geothermal Energy

As a renewable source of energy, the geothermal energy exists extensively and is inexhaustible, and will become a primary energy that can be relied on ultimately. Before the fossil energy was exploited and utilized in a large scale in recent nearly 200 ~ 300 years, it has always been the primary source of energy that human survive on and develop on.

The geothermal energy has broad prospects for application, although the total geothermal power generated in the world only accounts for 1% of the gross power generation in the world at present, and the development of forward-looking HDR tends to be mature, the United States has planned that by 2050, the geothermal power will account for 10% of power consumed throughout the United States.

Among the big family of new and renewable energy, the geothermal energy is the most realistic and most competitive energy at present. According to the statistics of

International Geothermal Association, no matter the total installed capacity of geothermal energy in the world or its annual production capacity, both of them rank ahead of the utilization of other new energy. Currently, the cost of geothermal power generation or of direct use of geothermal energy is far less than other new energy, so under some cases, it is even equivalent to or slightly lower than the price of power generated by conventional energy or used directly. The geothermal energy, therefore, has very strong market competitiveness among all kinds of new and renewable sources of energy.

One of the largest characteristics of the high-temperature geothermal energy is subject to the regional tectonics, and due to the regional distribution of resources, the energy cannot be transported for a long distance, and can only be exploited and utilized locally, so its development is constrained to a certain extent. However, there are much fewer regional limitations on medium- and low-temperature geothermal resources, in particular the shallow geothermal energy; especially, the heat-pump technology, which has gained rapid development in recent 10 years, can view the geothermal resources as the common underground water with room temperature for utilization. In this sense, there are no geographical restrictions on geothermal resource, so it can be said that such resource is everywhere.

In recent years, the development and utilization of the first type energy - "shallow geothermal energy" sprung up everywhere, with a rapid development.

The shallow geothermal energy reserves in the region of formation with relative constant temperature. Its temperature in winter is much higher than the outside air temperature, but much lower in summer. The temperature of shallow geothermal temperature is close to comfortable room temperature. When using heat pump to heat the buildings, the amplitude of temperature increase or reduction by heat pump is relatively small, so that the heat-pump unit operates more cost-effectively and properly. When providing same amount of heat or cold, it consumes less power energy. The space where the shallow geothermal energy occurs has a large heat capacity as well as strong recovery capacity; the shallow geothermal energy can output heat continuously by reducing the temperature temporarily and locally underground in one using season, while recover during non-using period.

As our country has a vast territory, the south and the north are located at different climate zones, with different demands for heating, and the temperature differences at mid-latitude region are the largest during the four seasons, with the maximum differences of up to more than 30°C, so the northern region is dominated by heating, and the southern region is dominated by cooling. The regions with cold winter and hot summer require heating and cooling, with bi-directional use. As the formation has a certain heat storage capacity, the reverse use at different seasons is conducive to the recovery of formation temperature.

III. Application of Shallow Geothermal Energy

Before the appearance single-well heat exchange circulation for ground source energy collection technology, the collection system of shallow geothermal energy mainly includes: 1 pumping wells + inverted wells system; 2. buried pipe system.

The pumping wells + inverted wells system consists of two wells separating each other from a certain distance. One well is a pumping well, which is the same

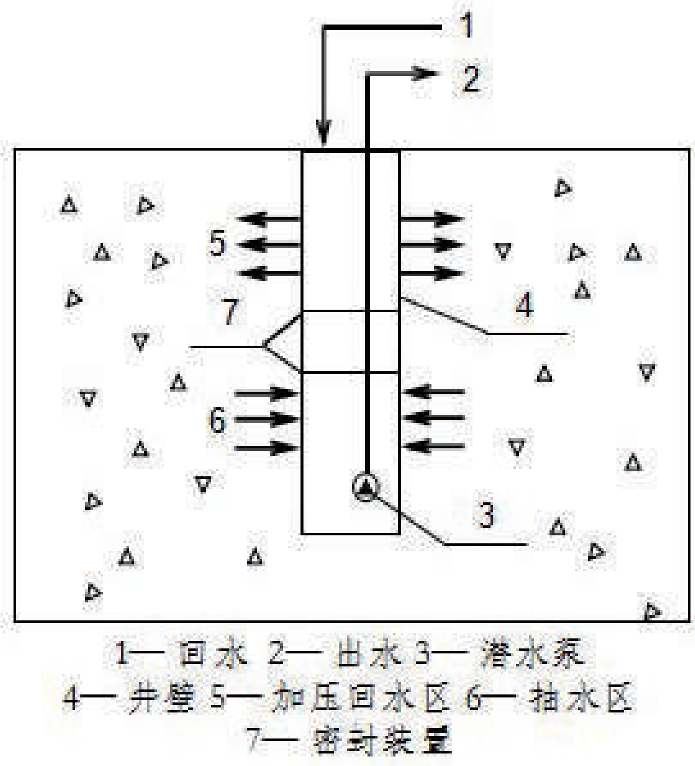


Figure 1 Physical Model for Collection Well of Single–well Circulating Heat Transfer Geothermal Energy

as common water supply pipe well; the other one is an inverted well. When working, the submerged pump will pump the well water from the pumping well into the unit for heat transfer, after which the well water enters into the inverted well and penetrates into the earth.It has the advantages of simple structure and low cost. Its disadvantage lies in that it can only be used at the region with rich underground water, with difficulty in recharge, sand relocation and geological sedimentation, etc.

The typical structure of buried pipe system consists of single U-shaped or double U-shaped heat exchange tubes that are buried vertically into the ground of about 100 meters. The media within the heat exchange tubes exchange heat via the pipe walls and surrounding rocks. It can adapt to a variety of geological conditions, but has poor capacity of heat exchange, and covering a huge area.

The collection technology progress of shallow geothermal energy is oriented to improving collection efficiency and collection safety. Through years of research, our country launched a new collection technology in 2000, namely the single-well heat exchange circulation for ground source energy collection technology, which has reached the international leading level. The single-well heat exchange circulation for ground source energy collection system consists of collection well of single-well heat exchange circulation for ground source energy collection (collection well for short), heat exchanger within well and submerged pump. The typical structure of collection well is shown in Figure 1.

The single-well heat exchange circulation for ground source energy collection technology takes well water as medium, and exchanges heat with the rock-earth mass below the shallow layer, which will not consume or pollute underground water. Comparing the collection well with buried pipe, although both of them are soil-type heat exchanger, the mechanism of single-well heat exchange circulation is more complicated than buried pipe. The buried pipe is a "dividing wall type" heat exchanger, and the circulating water within pipe transfers heat with the rock-earth mass outside the pipe via the pipe walls. In addition to the above-mentioned "dividing wall type" heat exchange, the collection well can exchange heat by mass exchange of external water within well, namely the heat exchange caused by mass transfer. As indicated by experience and theoretical calculation, such part of heat transfer plays an important role in the heat exchange process of collection well.

The collection well shall reach the constant temperature zone of shallow underground, and the deepest place at the well bottom is located within 80 meters underground in general. The heat exchanger within the well is set with two groups of seal, upper and lower seal, which separate the well space into the upper pressurized backwater area, medium sealing area and lower pumping area. The pressure within the sealing device can be adjusted. Adjusting the pressure of seal can change the flow velocity of water in order to get the best heat exchange performance.

The submerged pump is placed at the bottom of well. The submerged pump extracts the water with constant temperature (such as, 15°C) from the "constant temperature zone" into the unit for heat exchange, after which the water flows back into the upper pressurized backwater area within the well. Under the act of gravity and differential pressure, the well water flows into the pumping area finally. The circulating water exchanges heat with the rock-earth mass surround the well during the movement from top to bottom. Meanwhile, with the advancement of technology, the heat exchange backfill particles applicable to the formation with different percolation conditions, were developed to fill between the well casing and well walls, so as to change the formation and increase the permeability coefficient. The collection well filled with energy stored particles has significantly increased its capacity and speed. In this case, it solves the problem in weak permeability and breaks through the bottleneck in efficient collection of shallow geothermal energy from the formation with small specific capacity.

IV. Comparison on Collection Technology for Shallow Geothermal Energy

Compared with collection technologies of other shallow geothermal energy, the single-well heat exchange circulation for ground source energy collection technology is characterized as zero pollution, zero emissions and wide adaptability. As the well water is recharged locally in situ, so such technology will not consume water or pollute water, with no water loss, or destroy the natural distribution of groundwater, or cause any potential geological disasters, etc., and can be applied in different geological conditions for collection of geothermal energy. Meanwhile, the single well of geothermal energy collection technology has the advantages like small coverage of area, high energy efficiency ratio (EER), etc. Its EER is 20-100 times of the buried pipe. No matter what geothermal energy collection system, the service life of the system is planned to be more than 10 years; therefore, stable, efficient and pollution-free geothermal collection systems are the development target of technology in the future.

The table below illustrates the comparison on three collection modes of geothermal energy.

V. Conclusions

The "inexhaustible" renewable shallow geothermal energy, as a new clean energy, will replace the heating energy gradually in the north, and accelerate the transformation of heating energy in the north with the enlargement of development and utilization intensity. With the constant improvement in the collection technology of shallow geothermal energy, new technologies spring up constantly, further advance the development of heat and cold integrated new emerging industry, and meet the heating demands of residents, thus realizing the revolution of heating industry in new era.

Table 1 Comparison on Three Collection Modes of Geothermal Energy

No.	Collection Mode	Technical Source	Impact on Environmental Quality of Underground Water				Area Covered	EER	Adaptability
			Underground Water Loss	Pollution	Potential Geological Disaster	Recharge			
1	Pumping well Inverted well	Introduced from abroad	Yes	Yes	Yes	Difficult	Larger	High	Limited
2	Buried pipe	Introduced from abroad	Non	Non	Non		Large	Low	Broad
3	Single-well circulating heat transfer	Innovated originally	Non	Non	Non	Easy	Small	High (20-100 times of buried pipe)	Broad

2018年亚太低碳技术高峰论坛会议成果丰硕

2018 ASIA-PACIFIC FORUM ON LOW CARBON TECHNOLOGY HAS YIELDED FRUITFUL RESULTS

10月底的长沙，秋意盎然。继前两届峰会的成功举办之后，2018年10月24日上午，第三届2018年亚太低碳技术高峰论坛在远大城第五车间正式开幕。论坛以“共享低碳技术，共保美丽蓝天“为主题，主要目的是支持、促进高科技投资和低碳城市发展方面的实质性合作，并通过平行会议、双边会谈和技术路演鼓励与会者开展深入讨论。本次论坛约400余名国内外嘉宾到场参会，恒有源科技发展集团有限公司受邀参会。

湖南省人民政府副秘书长黎咸兴、亚洲开发银行可持续发展和气候变化局局长严友钟、国家生态环境部应对气候变化司副司长孙桢、远大集团创始人、联席董事长张跃出席开幕式并致辞。在湖南省环境保护厅总工程师张在峰等行业专家的演讲后，北京大学新结构经济研究院、国际发展合作部部长于佳为2018亚洲新能源领创者颁奖。本次论坛的高潮源自于亚洲各地新能源专家进行的高端对话环节。各新能源专家妙语连珠，尤其是国家发展和改革委员会国际合作中心国际能源研究所所长王进提出的“从欧美低价引进高端技术、降低能源成本“的论点引得现场讨论纷纷。

经过上午精彩纷呈的会议演讲，下午4点，模式新颖的“火锅派对“正式开始。“火锅派对”的模式为各低碳技术企业搭建展示自己的技

术，提供开拓市场的机会。恒有源集团副总裁何天悦受邀作为恒有源集团的主推广人进行演讲，主要为亚洲各地政府机构、企业、投资者详细讲解恒有源集团的技术，并解答相关问题。经过5轮不同的客户介绍，该环节完美收官。

次日，本论坛第六平行分会议—清洁供暖与炊事在远大环境哲学院金色大厅举行，分会议根据中国和其他发展中国家的经验，重点研讨清洁的供暖主流化中存在的挑战和机遇。恒有源集团董事长徐生恒受邀进行演讲。在其他代表的精彩发言之后，徐生恒董事长为听众进行了题为“首选浅层地热能作为北方供暖的替代能源，发展热冷一体化新兴产业，保护环境，解决环境问题”的主题演讲。徐总提出，浅层地热能是“冰冻三尺”，在25℃以下的热能，遍地都有。把浅层地热能与供暖热泵结合起来，就可以物理变化的为建筑物供暖，能够一年四季在房间任意调节18到26度之间的温度，实现供暖，制冷和生活热水的供应。徐总同时指出，供暖是中国北方的必需品，制冷是奢侈品，国计民生是雪中送炭，制冷是锦上添花。由于改革开放以后，生活水平提高，建筑物密度加大，大量的雾霾促使整个北方地区能源结构发生重大变化。利用浅层地热能供暖，就是用1/4电直热的配电量和耗电量，来转化成机械能驱动热泵系统，干预低品位低温的可再生浅层地热能，来给建筑物供暖。浅层地热能在设计合理、施工质量保证的前提下，不受外界环境的干扰、不额外增加建筑物的配电，并可达到可再生能源占建筑物供暖总能耗60%的目标。徐总介绍，恒有源集团在京津冀农村地区做了大量的分间供暖实验，采用恒有源集团地能热宝系统的农户，每间房投资8000块钱以内，一个冬季耗电800度，成本优于燃煤，相当于土暖气价格的30~90%。所以首选浅层地热能跟热泵技术结合来为建筑物供暖适合北方地区实际情况。徐总相信，未来中国最好最清洁的供暖能源网是用电网来支撑可再生浅层地热能的热网，是未来中国北方供暖的出路。最后，徐生恒董事长盛情邀请与会代表去北京进行参观指导。发言结束后，听众反响强烈。最后，会议在各参会企业代表、专家的答疑解惑中圆满落幕。

（陈思）

2018 Asia-Pacific Forum On Low Carbon Technology Has Yielded Fruitful Results

The fall was evident in Changsha in the end of October. Following the previous two successful summits, the third Asia-Pacific Forum on Low Carbon Technology was unveiled in the No. 5 Workshop of Broad Town in the morning of October 24, 2018. With the theme of “Sharing Low-Carbon Technology for a Blue and Beautiful Sky”, the main purpose of the Forum was to support and promote substantive cooperation in high-technology investment and low-carbon city development while encouraging deep discussion among participants through parallel sessions, bilateral meetings, and technology roadshows. About 400 domestic and foreign guests attended the Forum, and a delegation from Ever Source Science and Technology Development Group Co., Ltd. (“Ever Source”) was present at the Forum upon invitation.

Li Xianxing, deputy secretary general of the Hunan Provincial People’s Government, Woochong Um, director of the Bureau of Sustainable Development and Climate Change of the Asian Development Bank, Sun Zhen, deputy director of the Department of Climate Change of the Ministry of Ecology and Environment, and Zhang Yue, founder and co-chairman of Broad Group, attended the opening ceremony and delivered speeches. Following the speeches of industry experts including Zhang Zaifeng, chief engineer of the Hunan Provincial Department of Environmental Protection, Yu Jia, director of the Institute of New Structural Economics and the International Development and Cooperation Department at Peking University, presented the award to the New Energy Leaders 2018. The first small climax of this Forum came when new energy experts across Asia held a high-end dialogue which was full of witty remarks. In particular, Wang Jin, director of the International Energy Research Institute of the International Cooperation Center of the National Development and Reform Commission, triggered a hot debate when he suggested “importing high-end technologies at low prices from Europe and America to reduce our energy costs”.

After a number of wonderful speeches in the morning, a fresh “Hot Pot Session” was started at 4:00 PM. It was thrown to provide a platform for low-carbon technology companies to showcase their own technologies and opportunities to open up markets. He Tianyue, vice president of Ever Source, was invited to speak as the main promoter of Ever Source. He mainly explained their technologies to government agencies, enterprises and investors in Asia and answered interested questions. After 5 rounds of pitches, the promotion ended in perfection.

The next day, the sixth parallel session of the Forum, themed “Clean Heating and Cooking”, was held in the Golden Hall of the Environment Philosophy Institute of Broad Group. The session highlighted challenges and opportunities for mainstreaming clean heating and cooking systems. Xu Shengheng, chairman of Ever Source, was invited to give a speech. Following the wonderful speeches of other speakers, Chairman Xu Shengheng gave a speech titled “Preferred Shallow Geothermal Energy as An Alternative Energy Source for Heating in the North, Develop the Emerging Industry of Heating-Cooling Integration, Protect the Environment, and Solve Environmental Problems”. Xu Shengheng suggested that the shallow geothermal energy is “frozen underneath the earth” and heat energy below 25°C is everywhere. Combining shallow geothermal energy with a heating pump can physically heat a building and maintain a temperature between 18 and 26 degrees in rooms throughout the year. It also supports supply of heating, cooling and domestic hot water. Xu Shengheng also pointed out that heating is a necessity in northern China while cooling is a luxury and that providing heating is beneficial to people’s livelihood while providing cooling is the icing on the cake. Since the reform and opening up, improved living standards, denser buildings, and serious haze have caused major changes in the energy structure of the entire Beijing/Northern region. The use of shallow geothermal energy for heating is to convert 1/4 power distribution and consumption to mechanical power that drives the heat pump system. Low-grade and low-temperature renewable shallow geothermal energy is intervened to heat buildings. Under the premise of reasonable design and construction quality assurance, shallow geothermal energy is not affected by the external environment, does not require extra power distribution in buildings, and is able to achieve the goal of making renewable energy account for 60% of the total energy used to heat buildings. According to Xu Shengheng, Ever Source has built a large number of individual heating experiments in the rural areas of Beijing, Tianjin and Hebei. The farmers who use the geothermal energy heating system invest RMB 8,000 for each room and consume 800kwh in winter. The cost is better than that of coal and is equivalent to 30-90% of the prices of traditional heating methods. Therefore, the combination of shallow geothermal energy with heat pump technology is the preferred method to heat buildings and this choice suits the actual situation in the northern region. Xu Shengheng believed that the best and cleanest heating energy network in China in the future would be the one that uses power grid to support renewable shallow geothermal energy, which is the way out for heating in northern China. Finally, Chairman Xu Shengheng extended a warm invitation to the delegates to visit his base in Beijing. After the speech ended, he received tremendous responses from the audience. Subsequently, the session ended successfully with a Q&A part led by representatives of the participating companies and experts. (Chen Si)

第十二届中国新能源国际高峰论坛在京举办

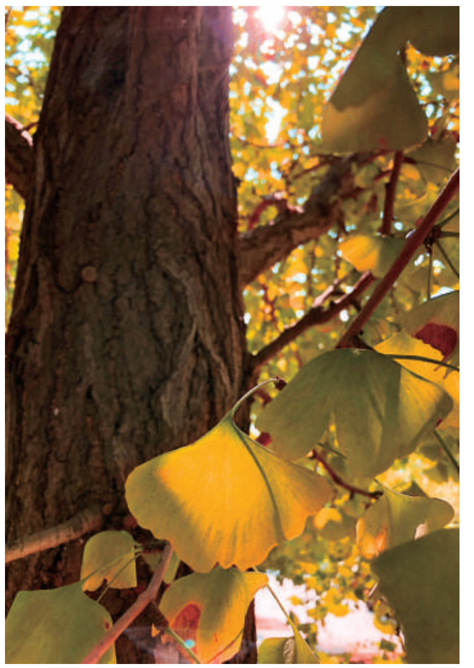
THE 12TH INTERNATIONAL SUMMIT FOR CHINA'S NEW ENERGY WAS HELD IN BEIJING

2018年10月30日，在由全国工商联新能源商会与山西省大同市人民政府共同主办、以“多能互补”为主题的第十二届中国新能源国际高峰论坛在北京国家会议中心隆重开幕。本次论坛大约500名政府官员、行业专家、相关企业代表到场参会，恒有源科技发展集团受邀参会，并在论坛展厅参展。与会者围绕我国能源结构转型，各类新能源“多能互补”协调发展、以及未来发现趋势展开交流。

在开幕式主题论坛上，全国工商联新能源商会会长、隆基绿能科技股份有限公司董事长钟宝申提出，“多品类清洁能源的整体发展，多能互补，将成为我国推进能源现代化转型，建设清洁低碳、安全高效能源体系的重要突破口。”在各业界专家和企业家的精彩发言之后，主办方发布了2017-2018年《中国新能源产业年度报告》。“报告”中对我国不同能源行业2017的发展概况进行了分析，并表明随着各国重视、技术创新、应用拓展等，全球能源资源不论是供给主体还是能源品种均呈现出多元化的发展态势。同时，“报告”还提出，我国在“一带一路”沿线开展可再生能源合作的重点领域集中在地热能、风能、太阳能、生物质能等能源。未来可根据不同区域的可再生能源先天优势、发展规划等，因地制宜、继续有针对性地展开布局。

经过上午精彩纷呈的主题报告，下午1时，分论坛—新能源建筑专业论坛正式开始。本分论坛重点讨论的议题是新能源与绿色建筑的有机结合与应用。在其他代表的精彩发言后，恒有源集团总工程师孙骥受邀进行了题为“开启北方供暖能源3.0时代”的演讲，并在随后的对话环节中，孙总与建筑专家及其他的企业代表人就新能源在绿色建筑上的应用展开座谈。与会代表各抒己见、妙语连珠，引起现场观众强烈共鸣。

（陈思）



山东省人民政府印发
山东省冬季清洁取暖规划(2018—2022 年)

PEOPLE'S GOVERNMENT OF SHANGDONG PROVINCE ISSUED THE NOTICE OF CLEANING ENERGY HEATING PLAN IN WINTER IN SHANDONG PROVINCE2018-2022

近日，山东省人民政府为深入贯彻落实习近平总书记在中央财经领导小组第 14 次会议上的重要指示精神和关于清洁取暖的一系列重要批示精神，依据《国家发展改革委等 10 部委关于印发北方地区冬季清洁取暖规划（2017—2021 年）的通知》（发改能源〔2017〕2100 号）要求，更好地指导和推动全省冬季清洁取暖工作科学有序开展，编制《山东省冬季清洁取暖规划 (2018—2022 年)》。本规划编制的基准年为 2017 年，规划期限为 2018-2022 年。

规划以习近平新时代中国特色社会主义思想为指导，全面贯彻党的十九大和十九届二中、三中全会精神，统筹推进“五位一体”总体布局，协调推进“四个全面”战略布局，牢固树立新发展理念，以保障城乡群众温暖过冬、减少大气污染为立足点，按照企业为主、政府推动、居民可承受的方针，宜气则气、宜电则电、宜煤则煤、宜可再生能源则可再生能源，加快提高清洁取暖比重，构建安全、绿色、节约、高效、适用的清洁取暖体系，为加快推进新旧动能转换重大工程、提升群众获得感幸福感、打造乡村振兴齐鲁样板做出积极贡献。

规划中指出，山东省在加快煤炭等传统能源清洁化利用的同时，积极推进天然气、电能、可再生能源等清洁能源替代，大力发展清洁取暖。总体来看，冬季清洁取暖发展快速。但在工作过程中还存在清洁取暖缺少统筹规划、供应保障能力不足、取暖成本偏高、取暖安全、建筑节能水平有待提高、清洁取暖体制机制亟待完善等一系列问题。目标力争在 5 年左右时间内，全省清洁取暖保障能力显著增强；用能结构优化，清洁取暖率达到 70%；提升能效水平；到 2022 年，继续完成国家下达的减排任务。

规划中同时提出科学合理选择清洁取暖方式，发展可再生能源取暖。因山东省地热资源相对丰富，应因地制宜、规范有序推广使用集中与分散式地热能取暖，大力开发浅层地热能取暖。按照“因地制宜，集约开发，加强监管，注重环保”的原则，采用热泵技术为主，开发利用浅层地热能取暖（制冷），经济高效的替代散煤取暖。与此同时，规划中强调，强化安全应急体系建设、强化制度保障落实工作机制，研究制定规划和实施方案，细化分解任务，明确完成时限，有计划有步骤地组织实施。

甘肃省人民政府办公厅印发《甘肃省清洁能源产业发展专项行动计划》

甘肃省人民政府与2018年6月7日印发了《甘肃省清洁能源产业发展专项规划》，规划中指出甘肃省在有效解决新能源消纳问题的基础上，因地制宜发展热发电、地热等新能源，重点鼓励分散式、分布式可再生能源开发。同时，甘肃省需要有序发展地热能。在中东部地区开展浅层地热能资源勘探评价，加大浅层地热能开发利用的推广力度，开工建设通渭县、张家川县等地浅层地热供热项目并在资源优势地区创建一批以地热供暖为主的示范小区。

河南省开展地热能清洁供暖规模化利用试点

8月24日，河南省发改委、河南省国土厅、河南省环保厅、河南省住建厅联合下发了《关于开展地热能清洁供暖规模化利用试点工作的通知》，今冬供暖季前，河南省将优先选择在地热资源较为富集的地区，启动“取热不取水”的地热能清洁供暖规模化利用试点工作，确保群众采暖需求的同时实现治污减霾。

地热资源是一种可再生的清洁能源，储量大、分布广，具有清洁环保、用途广泛、稳定性好、可循环利用等特点。结合全省地热资源禀赋和开发利用情况，河南省计划用2~3年时间，以县为单元采取特许经营模式，通过整县推进的方式，选择将地热能清洁供暖利用较好的县（区）作为首批启动的试点区域。

目前，河南省首个地热资源开发利用项目已在偃师市首阳山镇开工建设，冬季供暖的地下水经过取热后再由回灌井将冷水重新注回地下水层，如此循环往复，达到“取热不取水”的目的。建成后，每万平方米供热面积可减少标煤燃烧76.38吨。

（摘自《河南日报》）

黑龙江校地企协同探寻地热能开发新路径

9 月 12 日，寒区地温（热）能开发利用科技论坛，在东北石油大学举行。国内众多专家齐聚大庆，探讨地热能开发与利用新途径。

早在 1998 年，在东北石油大学等科研机构的支持下，在林甸县境内的林热一井钻井成功，日产地热水 2000 多立方米，温度达到 50 摄氏度以上，开启了大庆地热勘探开发的历史。

地热的应用十分广泛，可用于日常生活中的供热、制冷、医疗保健、旅游休闲；工业中的发电、烘干、漂洗染;农业中的良种培育、种植养殖、温室农业等方面。东北石油大学地热研究中心主任朱焕来说：“大庆成功应用的有地热供暖。就是利用热水供暖，还有地热的养殖地，地热的种植。上个世纪末林甸地热开发应用之后，利用林三井这样一些井，做了一些温室的养殖，养了一些温带的鱼类，获得很大成功。”

深入研究地热能需要充分发挥高校的人才优势。东北石油大学地球科学学院院长博士生导师张云峰说：“建立这么一个平台，发挥人才优势，充分研究地热的开发和利用，将来肯定会对大庆的经济发展转型起到非常好的作用。”

（摘自《中国科技日报》）

湖北省省地质局与咸宁市拟共同推进地热资源合作勘查开发方案

9 月 7 日，湖北省地质局与咸宁市人民政府签订共同推进咸宁市地热资源合作勘查开发意向书，双方将共同推进咸宁市地热资源勘查开发利用工作。

双方本着“科学规划、统一勘查、优化结构、整体开发、统筹资源、循环利用、做大做强、服务社会”的基本原则，合作开展咸宁市地热资源勘查，全面摸清咸宁市地热资源家底，为咸宁市委市政府科学持续开发利用地热资源提供科学决策依据，高质量打造“香城泉都”品牌效应，积极助推咸宁经济社会可持续发展。

据悉，双方主要在咸宁市全域地热资源专项调查评价、地热资源深度勘查、地热开发利用等方面开展合作，共同推进咸宁地热资源全方位、高品质、多功能的开发与利用，形成旅游开发、养生治疗、生态种植和养殖等新型经济社会发展产业链条。

（摘自湖北省人民政府网）

三维空间大数据助力雄安新区构建地热能“海底世界”

在成立“雄安新区”之后，中国地质调查局就全面评价了整个雄安新区浅层地热资源潜力，认为雄安新区是浅层地热最适宜开发利用的一个地区之一。

周锦明（潜能恒信能源技术有限公司董事长）表示，地下三维空间大数据的重要性主要体现在三个方面：一是城市地下跟地上的统筹规划需要，二是空间布局合理性的需要，三是能源的需要。在构建大数据实现路径方面，前期要数据采集，要考虑城市的运维，之后建模，结合浅层的工程地质、钻井资料，还要建立各种标准，为城市的规划建设提供依据，包括地热能的一些规模进行计算。接着就是平台建设，通过人工智能、大数据、云计算及移动技术，依托数据模型，建立可视化、网联化、共享化的平台。最后，通过打井，深井浅井兼顾，检测它温度的变化、压力的变化、地壳的一些变化，通过现有成熟的技术实施采集、运维，帮助城市进行安全预警、实时管控等。”

中国石化集团新星石油有限责任公司副总地质师国殿斌表示：“经过九年的建设，整个雄县建成供暖面积达到 530 万平方米，实现我国第一个无烟城的目标。”

最后周锦明呼吁，“雄安一定要在近两年完成这个工作（三维数据采集），如果再不完成，后面（建设工程）一开工，采集工作就不方便了，不能留下千年遗憾。”　　（摘自《中国工业报》）

Susan Petty: 需要扩大地热能源的探勘范围

Susan Petty on Expanding the Reach of Geothermal Energy

近日，美国普林斯顿大学地质学学士，夏威夷大学地下水水文硕士苏珊佩蒂在一次访问中提到,地热利用发展需要扩大地热能探勘范围。她所在的位于西雅图的Alta Rock Energy公司计划在位于俄勒冈州本德县以南约32公里的Newberry火山附近钻井，以更好的开发利用地热能源。

苏珊佩蒂在地热行业工作了近四十年，从事过评估油井性能、优化发电厂等相关研究工作。2006年，她被能源部委任参加麻省理工学院举办的影响力的研究论坛。研究论坛提出，地热能在原则上可以满足美国所有的能源需求。但她承认，完全用地热能替代美国现有能源是不现实的。目前，她致力于推进提取和储存技术，以便地热能在满足美国能源需求方面发挥更大的作用。

她预测，地热能在加利福尼亚州的利用率将会从7%升至约25%。与此同时，从不到1%，到25%甚至30%的可再生清洁地热能源占有率也应该是整个美国的发展目标。

(https://physicstoday.scitation.org)

美国能源部宣布 1140 万美元用于推进地热能高效钻探的新项目

US Department of Energy Announces USD 11.4 Million for New Projects to Advance Efficient Drilling for Geothermal Energy

美国能源部（DOE）宣布在7个优选项目中总计投入近1140万美元，以推动地热能开发。这些项目将侧重于加速美国地热能源新技术的研发（R&D）“地热能源是一种清洁高效的基础负荷能源，是我国多元化能源组合的重要组成部分，”美国能源部长里克佩里说，“开发新的高效钻井技术将降低成本并提高地热能源的可用性。”

目前，美国的地热发电项目仅位于西部各州，现有地热项目可在电网上提供约3.8千兆瓦（GW）的电力。通过增强地热扩展系统，可以开发100 GW的潜在地热资源，并消除地理资源壁垒。通过技术创新将地热能源转化为具有成本效益的能源资源是极为必要的：7个优选项目将关注早期研发项目，探索钻探地热井的创新技术，这些技术能够减少非钻井时间，提高渗透率，加速地热钻井改造并将实验室中的先进技术应用至地热能源市场。

(https://www.energy.gov)

全球典型地热田简介

BRIEFING ON GLOBAL TYPICAL GEOTHERMAL FIELD

1. 我国西藏羊八井地热田

羊八井地热田位于拉萨市西北约 90km，热田自 1976 年开始勘察，1977 年 9 月开始 1MW 试验机组发电，此后装机容量逐渐增大，1991 年完成羊八井地热电站装机容量 25.18MW，是我国最早开发的，也是唯一仍然发电运行的高温地热田。

热田的面积为 14.6km2 ，分为南、北两区，以中尼公路为界。南区以第四系砂砾层等构成孔隙热储，有黏土和含砾黏土等构成盖层，热储温度最高 161℃。北区以基岩裂隙热储为主，薄层的第四系为盖层，热储温度 172~202℃。

2. 我国台湾清水地热田

台湾地处环太平洋火环的西端，也是欧亚板块与菲律宾海板块的汇聚边界。强烈的地壳活动造就了丰富的地热资源。已经发现的火山与温泉出露点达到百个。

大屯火山区的地热田有较大的地热发电潜力。其中清水热田的热储温度达到 225℃。该热田在 1977 年建立了 1.5MW 的地热电站。1981 年达到 3MW 的发电能力。但是，第一年实际出力仅为 1.18MW。到第三年下降至 0.52MW。到 1993 年下降至 0.18MW，从而被迫关闭。据后来研究，矿物沉淀结垢是导致出力急剧下降的主要原因。但也有人认为是由于酸性地热流体(热储中含有大量 H_2S 气体导致 pH 小于 2) 使地热电站的设备 (井、管、发电机组等) 受到严重腐蚀问题无法解决而很难加以开发利用。

3. 哥斯达黎加典型地热田

MIRAVALLES 热田是中美洲最大的热田。热田位于哥斯达黎加西北部的 Guanacaste 省，离哥国首都圣侯赛约 150 公里。地热田出露于 Miravalles 火山的西南部。可可斯板块俯冲到加勒比海板块之下形成了安山岩岛弧火山链。热储为安山岩，是一个典型的以水为主的地热田。1994 年热田开始发电，装机容量为 55MW。1998 年第两套 55MW 机组投入运行。到 2000 年，该热田总装机达到 140MW。目前，该热田的主要问题是热储压力持续下降，给可持续开发利用造成威胁。

4. 菲律宾典型地热田

TONGONANG 地热田位于菲律宾中东部莱特岛，在吕宋岛同棉兰老岛之间。1983 年，

112.5MW 电站投入运行，结束了该地区缺电少能的“黑暗时代”。目前，该地热田的装机容量已经达到 723MW，是菲律宾的主干地热田。

5. 墨西哥典型地热田

CERRO PRIETO 地热田位于距墨、美边境 30km 的墨西哥一侧。它是迄今仍然处于商业运行的最大的液体主导的地热田（Lippmann et al.，2004）。它是一个巨大的，高温（大于 300℃）的地热田。它形成于索尔顿地槽南端。热储层为沉积岩和准沉积岩。它是一个典型的液体主导的地热田。

据估算，该地热田的发电潜力为 780 到 800MW，并且可以维持 30 年。到 2000 年，该地热田的装机容量已经达到 720MW.

6. 印度尼西亚典型地热田

KAMOJIANG 地热田是印度尼西亚第一个投入商业性运行的地热田。热田位于西爪哇省首府班顿东南约 40km。1983 年即开始发电。1987 年达到目前的装机容量 140MW。该热田是干蒸气型的火山区高温地热田。不凝气体占蒸气总量不到 2%。热储岩石为安山岩。热田的勘探最早由荷兰火山调查局在 1926 到 1929 年间开展，并且施工了小孔径钻孔。1971 年起印度尼西亚和新西兰政府共同组织了新一轮的勘探。到 1975 年在该热田共施工了 5 口勘探井，深度达 700m。其中两口井在 600m 层段产出 232℃的蒸气。到目前为止，在该热田已经施工了 77 口井，有 33 口生产井。尽管地热田产出的基本上是干蒸气，但是，结垢现象已经有所发现。

7. 新西兰典型地热田

WAIRAKEI 热田是位于新西兰北岛的陶波湖北岸的陶波安山岩火山带的一部分。热田的天然放热量为 300 到 600MW。质量产出为 34560t/d。深部主通道地热流体温度为 260 到 300℃。该热田是世界上第一个投入发电的以水为主导的地热田。1958 年开始发电，迄今已经有近 50 年的历史。目前的装机容量为 220MW。长期开发造成减压和水汽两相带的出现。关于这个热田的数值模拟做过很多。最近的模拟结果表面，未来开发中应减少地热田内部的回灌量。因为回灌太多会影响深部流体的补充而导致热储温度下降。

选自：《中国电气工程大典》第七卷第七篇。
主编：汪集暘、吴治坚、李颂哲、马伟斌、庞忠和等。

敬告读者

TO INFORM THE READER

《中国地能》从 2018 年起更名为《中国地热能》。

《中国地热能》是由中国地热能出版社主办，北京节能环保促进会浅层地（热）能开发利用专业委员会协办的科技期刊，于香港公开发行，双语季刊。我们的办刊宗旨是为政府制定能源政策提供参考建议，为地能开发企业提供宣传平台；为设计者、大众提供交流空间；推广浅层地热能利用经验，展示应用实例。

2018 年，我们始终不忘读者的期待，用心用力办好期刊。毫无疑问，优化空气、节能减排、治理雾霾是当前摆在全体中国人民面前一个重大课题，我们期望《中国地热能》这本小小的期刊能够为攻克这一难题贡献微薄之力。

立足长远，着眼当前，在继承中创新，在变革中发展。自创刊以来，期刊一直得到了业内专家学者和广大读者的热情支持，在此致以我们的衷心感谢。大家的关注是我们的追求，大家的支持是我们的动力。让我们携手共进，在新的一年里共同打造《中国地热能》的美好明天。

《中国地热能》编辑部

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