A Review of Recovery and Utilization of Heat from Wastewater Mixed with Deep Well Aeration Tank

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Abstract. At present, environmental pollution and energy consumption have become one of the major problems in the world. Municipal sewage is a better clean energy source. While treating sewage in deep well aeration tank, sewage source heat pump technology can be used to recover its heat. It can be used for cooling and heat demand of buildings wholly or partially, reduce the consumption of coal and oil, and then reduce the total amount of harmful substances released to the atmosphere by combustion. Sow clean and renewable energy. This is a clean and renewable energy source.

Research Background and Significance

Nowadays, building energy consumption accounts for 30% of the total energy consumption in China, heating and air-conditioning energy consumption has exceeded 1/2 of building energy consumption. According to the current level of building energy consumption, by 2020, China needs to increase 140 million tons of standard coal per year for heating and 400-450 billion kWh/a of electricity consumption[1]. Sustainable energy development and environmental issues have become the focus of attention of all countries in the world. According to the latest survey and analysis by the U.S. Energy Agency in 2013, the total world energy consumption will increase from 524 Btu in 2010 to 630 Btu in 2020. By 2040, it will reach 820 Btu, with an annual growth rate of 1.50%[2,3].

Table 1. Energy Consumption in Industry, Construction and Transportation

<table>
<thead>
<tr>
<th>item</th>
<th>2010</th>
<th>2020</th>
<th>2040</th>
<th>Annual growth rate</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption</td>
<td>524</td>
<td>630</td>
<td>820</td>
<td>1.50%</td>
<td>Btu</td>
</tr>
<tr>
<td>Industrial consumption</td>
<td>200</td>
<td>247</td>
<td>307</td>
<td>1.40%</td>
<td>Btu</td>
</tr>
<tr>
<td>Building consumption</td>
<td>81</td>
<td>95</td>
<td>131</td>
<td>1.50%</td>
<td>Btu</td>
</tr>
<tr>
<td>Traffic consumption</td>
<td>101</td>
<td>112</td>
<td>140</td>
<td>1.10%</td>
<td>Btu</td>
</tr>
<tr>
<td>Other</td>
<td>142</td>
<td>176</td>
<td>242</td>
<td>1.70%</td>
<td>Btu</td>
</tr>
<tr>
<td>Electric energy</td>
<td>20</td>
<td>27</td>
<td>39</td>
<td>2.20%</td>
<td>Trillion kilowatts</td>
</tr>
<tr>
<td>Coal</td>
<td>7954</td>
<td>9499</td>
<td>11500</td>
<td>1.20%</td>
<td>Million tons</td>
</tr>
<tr>
<td>Natural gas</td>
<td>112</td>
<td>133</td>
<td>187</td>
<td>1.70%</td>
<td>Trillions of cubic feet</td>
</tr>
<tr>
<td>Petroleum</td>
<td>87</td>
<td>97</td>
<td>115</td>
<td>0.90%</td>
<td>Million barrels per day</td>
</tr>
</tbody>
</table>

The huge amount of energy consumption not only restricts the development of human society, but also brings about environmental pollution problems. For this reason, people have begun to study low-grade clean energy, such as air, soil, solar energy, urban sewage, industrial waste heat and so on. They are used to replace some high-grade energy, such as coal, oil, electricity and so on, in order to alleviate the energy exhaustion and environmental problems caused by the consumption of mineral energy.

Characteristics of Urban Sewage

Urban sewage is a mixture of domestic sewage and industrial wastewater, which is discharged into sewage treatment plants through the urban sewage drainage system. Urban sewage has high quality and low grade cold and heat sources. It has the following characteristics:
(1) The discharge amount is huge, which is more than 85% of the urban water supply [4]. By 2020, the discharge amount of urban sewage in China will reach 60 billion tons, and the environmental pressure will be enormous [5].

(2) The water temperature of municipal wastewater varies little with the seasons, usually within 10 °C. Temperature can be maintained between 10 and 25 degrees Celsius, water temperature is 3 to 5 degrees Celsius higher than groundwater temperature in air conditioning heating and 10 to 15 degrees Celsius lower than air temperature in refrigeration, which is a good source of cooling and heat [6]. Relevant data show that the average temperature of sewage in Changchun Sewage Treatment Plant is 20-24°C in summer and 10-20°C in winter; the temperature of sewage in Shenyang City is about 21°C in summer and 11°C in winter; the temperature of sewage in Gaobeidian Sewage Treatment Plant in Beijing is within the range of 22-25 °C in summer and 13.5-16°C in winter. The sewage temperature in Harbin is about 22 degrees in summer and 10 degrees in winter.

(3) Sewage has great potential for heat energy and is a good heat-carrying fluid. Compared with ground source heat pump and air source heat pump heating system, the heat transfer efficiency is better, and the heating coefficient can reach more than 4.5. Urban sewage accounts for a large part of waste heat in urban areas. According to literature statistics, Tokyo, Japan accounts for about 40% of waste heat and the available heat energy is about 37.68×10^16 J/d, while major cities in China account for between 10-16% and 9.42 ×10^16 J/d-15.07×10^16 J/d, which is the most potential part of urban waste heat recovery [7,8].

(4) Urban sewage volume is increasing year by year. Sewage treatment plants are located in the suburbs of the city. The area is vast. They can be used in small-scale construction or large-scale heat exchanger stations with installed capacity of more than 2000KW [9]. At present, heat pump technology has developed from the thermal energy utilization of secondary treatment water of urban sewage to the thermal energy stage of direct recovery and utilization of untreated urban sewage. Therefore, it is not limited by the location of sewage treatment plants, and can be flexibly utilized according to the situation of urban sewage pipe network and the needs of users, thus expanding the area used in cities.

(5) People's life and production produce sewage at any time, so the distribution of sewage is extensive. Whether in the southwest of China where water resources account for 70% or in the northwest of China where water resources are scarce, with the modernization of industrial production and living, sewage, as a new energy source, can not only optimize the energy structure and improve energy utilization, but also alleviate the problem of uneven distribution of water resources and energy.

(6) Improve the comprehensive utilization of water resources. The recycling of sewage heat energy is mainly recycled industrial circulating cooling water. This part of water can directly use heat pump system to take away heat and save the process of sewage treatment. The discharge of sewage in our country is increasing year by year. If we can effectively use sewage heat energy, it will be a good way to save water resources and solve the problem of water resources in our country. Path.

Research Status of Sewage Source Heat Pump at Home and Abroad

Research Status Abroad

Wastewater thermal energy utilization technology is widely used in Europe and Japan. Low Heat, a research team supported by the European Union, has developed a thermal energy recovery system that can recover low-temperature domestic waste hot water. At present, the main energy-saving policies of the EU include the Energy Efficiency Improvement Policy (SAVE); the development of new energy technologies, especially renewable energy, which will account for 50% of the energy supply structure by 2050; the Intelligent Energy Program (IEE), which mainly focuses on the utilization, innovation and improvement of renewable energy; and the EU Building Energy Efficiency Guidance Policy (EPBD). New buildings should meet the standard of low energy...
consumption, and existing buildings with high energy consumption should be reformed for energy conservation. At the same time, tax system should be used to encourage the use of new energy and improve energy efficiency, so that the potential of building energy conservation can reach 27% by 2020[10].

Americans invented heat pumps in the 1960s. In 1978, Yantuvsky of the former Soviet Union took the lead in exploring the thermal energy of river water, lake water and sewage, explaining its application value and prospects from a macro perspective, which attracted the attention of European countries. Then Norway, Sweden, Japan and other countries have invested in heat pump research. In 1983, the Sprinkling Evaporator Sewage Source Heat Pump (SE-SSHHP) system was developed in Norway and Sweden, and the shell-tube Sewage Source Heat Pump (ST-SSHHP) system in Japan[11].Norway's ASKER Sewage Treatment Plant, which was put into operation in 1983, transfers untreated sewage to the heating station of the new development zone outside the plant, realizing the air-conditioning use of 28 commercial and office buildings with an area of 155,000 m²[12]. RAY Sewage Treatment Plant in Sweden has set up a district central heating station outside the sewage treatment plant. By utilizing the heat energy of secondary treatment water of the sewage treatment plant, the air conditioning load of 5170 buildings has been realized[13,14].In 1984, experimental data from the University of Stuttgart in Germany showed that the energy saving potential of sewage and sludge recovered from sewage treatment plants could reach 30%[15,16]. In 1987, the sewage source heat pump system of Tokyo Tongdao Sewage Pumping Station was built. The heat recovered was used for air conditioning system and hot water supply in the office area of the sewage plant. The heat transfer tube was made of aluminized tubes. The COP value of the heat pump system was 3.2 for heating and 3.6 for refrigeration. Titanium heat transfer tubes are used in the sewage heat energy utilization system of Houle Pumping Station. The cooling coefficient is 3.8 in a building with a floor area of 170,000 m² in 21.6 hectares. In 1999, a sewage heat recovery and utilization heat pump system with a capacity of 1 *9.5 MW was built in Moscow. The compressed heat pump system uses urban sewage as a low-temperature heat source to heat Uhtomski residential area after purification. The COP is 3.3 when heating, and the effect is very good. In Stockholm, Sweden, 40% of buildings use heat pump technology for heating, of which 10% use effluent from sewage treatment plants.

Domestic Research Status
In 1990, the Institute of Thermal Energy of Tianjin University established the first small heat pump station in Hengshui, Hebei Province. Thermal energy utilization technology of urban sewage is developing continuously in China. In 2000, Beijing Drainage Group put into operation a sewage source heat pump test project in Gaobeidian Sewage Treatment Plant. The heat pump was used to heat a 300 M² workshop and a 600 M² engine room in winter and cool in summer. After three years of operation, the effect was good[17]. In 2004, the first domestic project using sewage as energy for heating and refrigeration started trial operation in Beijing Miyun Sewage Treatment Plant, which can save 30% to 40% of the operating cost of heating and refrigeration on average. The original sewage source heat pump developed by Harbin Youqier Heat Pump Air Conditioning Research Institute has passed the national appraisal, which lays a foundation for the research of sewage heat pump in China. Yao Yang, Zhao Liying, Ma Zuiliang and others took the sewage discharge situation of a pharmaceutical factory in Harbin as an example. Under different operating conditions in heating season, they could basically meet the heating demand of 4000m² buildings in winter. The heating coefficient COP of heat pump unit was 3.9[18]. Professor Cui Fuyi of Harbin University of Technology carried out the technical and economic analysis of sewage source heat pump heating and air conditioning, pointing out that compared with traditional air conditioning, sewage source heat pump has the advantages of high refrigeration and heating coefficient, energy saving and environmental protection; at the same time, sewage source heat pump can be used in one machine instead of traditional boiler-air conditioning. Two sets of air conditioning system, saving initial investment, occupied area and operation cost, etc.[19]. In 2008, Professors Sun Dexing and Zhang Chenghu of Harbin University of Technology recently carried out research work on urban raw
sewage as the cold (heat) source of HVAC. They pointed out that although some sewage heat transfer has been applied ahead of time, the theoretical part of heat transfer and sewage flow has not yet been fully supported by clear data[20]. Professor Ding Guoliang of Shanghai Jiaotong University has been using computer simulation to simulate and optimize the structure since the early 1990s. The refrigeration system he proposed has been continuously applied, developed and optimized by heat pump researchers from components to whole modeling and solving methods. In 2008, Professor Bai Li of Jilin Jian Zhu University established the first domestic experimental platform for sewage heat energy recovery and utilization. This work was transferred from theoretical research to applied technology research field, and achieved breakthrough results in indirect sewage heat energy recovery. The research results were identified as reaching the international advanced level for me. The technical foundation is laid for the implementation of thermal energy recovery and utilization of municipal sewage in China. In 2010, Zhu'an and Zhao Qiming of Guizhou Normal University made use of the Clean Development Mechanism (CDM) to study the relationship between the utilization of sewage heat energy and the development of CDM in Guiyang City. The research shows that sewage heat energy can completely replace coal-fired boilers, which has low cost and low pollution.

The thermal energy recovery and utilization of sewage from deep well aeration tank is a new way to recover the thermal energy of sewage based on the thermal energy recovery and utilization of common sewage in recent years. Because the depth of deep well aeration tank is 50-150 meters, the diameter of wellhead is 1.0-6.0 meters, and the velocity of circulating liquid in the well is 1.2-1.5 m/s, it has high oxygen-filling performance that other biological methods can not achieve. The operation modes of deep well sewage are mainly compressed air-powered air lift cycle and pump-powered mechanical cycle. In deep well aeration tank with gas lift cycle, compressed air supplied by riser and downcomer can be used as circulating power of deep well aeration tank as well as provide enough dissolved oxygen for microorganisms in the tank. Therefore, the aeration tank with gas cycle as the main component is widely used. The sewage heat transfer in deep well aeration tank has the following advantages than that in common aeration tank, such as: deep well aeration tank is located 50-150 meters underground, less affected by the external environment temperature; deep well aeration tank is vertical to the ground, with a diameter of 1.0-6.0 meters, occupying a small area; well sewage flow rate of 1.2-1.5 m/s, in turbulent state, and the heat transfer effect is better; After treatment, the water quality is better, the problems of rusting and scaling are not serious when using direct heat transfer; because the opening ratio of air intake is 1/20, because the amount of odor affecting the environment is greatly reduced.

Expectation

Sewage heat transfer has become a kind of high-quality low-grade energy. If we take scientific methods to make good use of it, it will certainly reduce environmental pollution and energy consumption.

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