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Budapest Újpest Szt. István sq. - Thermal energy supply with sewage heat utilization

Design and Customization Guidelines

Thermal energy generation system proposed at the project:

HEAT4COOL

Smart building retrofitting complemented by solar assisted heat pumps integrated within a self-correcting intelligent building energy management system

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1 PROCESS OF THE PROJECT REALISATION OF A WASTEWATER HEAT UTILISING SYSTEM

To realise a wastewater utilising system the following order of tasks to be considered as exemplary:

1. Selection of project site
2. Assessment and investigation of the parameters of the wastewater resource available in acceptable distance
3. Assessment of the thermal demand and other possibilities of thermal supply in the facility to be serviced
4. In cases where the facility to be serviced is a new development there is an opportunity for determining thermal supply temperature levels to be favourable for heat pumping
5. Conducting the energy study, including the analysis of the potential savings and return on investment
6. Researching the economic environment, funding and support possibilities, preparation and submission of application for subsidies
7. Preliminary draft of the plans and designs, drawing up the budget
8. Proposal evaluated by the buyer – on acceptance contracting negotiations and finalisation of the agreement, conclusion of the contract
9. Execution designs
10. Obtaining the necessary authorisations and permits
11. Execution of implementation:
    a. construction of the installations for treating and handling wastewater
    b. construction of the engine houses
    c. building engineering works
    d. electrics and automation works
    e. entry into service and trial operation period
12. Long term operation and maintenance

2 IDENTIFICATION OF THE SUITABILITY OF A POTENTIAL PROJECT SITE

To implement a wastewater heat utilising system installation the following essential conditions need to be met simultaneously:

- A building, building complexes or technology with high enough thermal energy requirement
- A sewer line with appropriate flow of communal sewage (independent of rainfall)
- Sufficiently small distance between the site of thermal energy utilisation and the sewer
- Technical feasibility of the connection to the sewer line in its immediate vicinity
- No availability of any other, competing thermal energy sources, which would be economically or technically preferable at subject project site

3 DESCRIPTION OF DIFFERENT TECHNICAL SOLUTION VARIATIONS

3.1 Available technical solutions

Based on the accessibility of the sewage water the following possibilities of different technical solutions are available:

- Utilisation of raw wastewater from communal or combined main collector anywhere along the pipeline, where the flow size is sufficient
- Utilisation of pre-treated wastewater at a lifting station
- Utilisation of raw wastewater at a wastewater treatment plant (WWTP)
- Utilisation of pre-treated wastewater at a wastewater treatment plant (WWTP)
- Utilisation of treated wastewater at a wastewater treatment plant (WWTP)

In cases when pre-treated wastewater (either at a lifting station or at a WWTP) is chosen to be utilised as heat resource, the necessity of the implementation of a muncher to further reduce the size of the solid contamination is to be decided according to the quality of the existing filtration.

In cases when treated wastewater is available as the heat resource, the mechanical treatment (screening unit) may be entirely left out of the design and there could be a wider range of types of heat exchangers to be considered.

During the designing and configuration of a system it is necessary to specify the essential extent of availability of the new system. In case there is a back-up system to ensure the proper facilitation of the thermal requirements, then it is allowed to the new system to shut down in extraordinary circumstances. If there is no spare system, the new thermal supply system needs to be equipped and designed to handle even extraordinary circumstances. Such extraordinary circumstance could occur when in case of large rainfalls the sewer providing the thermal energy resource becomes overloaded and with this it prevents the gravitational backwashing of sewage water from the system to the sewer pipe that is applied in a normal operation – and this state could last for several hours. If there is a back-up system then during such conditions it can be allowed for the wastewater system to be down, but if there is no back-up then the possibility of flushing back utilised sewage to the sewer under pressure has to be ensured in the designs. This is advised to be planed as a supplementary system given streaming sewage under pressure involves the necessity of operation of pumps thus it will increase energy consumption and cause efficiency degradation.

There could be a necessity for back-streaming the utilised wastewater under pressure also in cases where the sewage applied as thermal source is found in a pipeline that is under pressure in normal operation too.

3.2 Sub-systems

The technology can be divided into the following 3 sub-systems and their place of installation can be adapted to the local conditions and circumstances:

- sewage treatment sub-system (screening – pumping, etc.)
- wastewater – technological water heat exchanger

- heat pumping and the thermal energy transmission towards the end-user

Possibilities for grouping the sub-systems in respect of place of installation:

- all 3 of the sub-systems to be installed in the same, typically underground structure (this establishment can be in the building to be serviced or independently)
- the sewage treatment and the heat exchanging is placed in one underground structure and the heat pumping sub-system is situated in the building to be served
- the sewage treatment is separately installed in close proximity to the sewer pipeline and the other two sub-systems are placed in the end-user facility or close by.

4 DIMENSIONING DIRECTIVES

4.1 Dimensioning directives for the complex system solution

A possible project's situation can be considered ideal if the quantity of the sewage available even in its lowest value reliably exceeds the subject facility's resource requirement. In this case the system to be developed could fully serve its consumer.

In case the minimum values of the sewage flow is lower than the required values corresponding to the system's design performance, the situation has to be managed via a sufficient operation strategy. The possibilities of the strategy to be set are dictated by other disposable options of energy sources on site and inclusion of alternative thermal energy producing capacity.

In case the inclusion of alternative additional energy source is not preferable due to technical or economic reasons, the establishment and usage of a wastewater storage structure of a suitable volume to bridge the low flow periods could be considered as a solution.

It is also possible to consider establishing a system that would provide a base-load supply compliant with the minimum flow of the disposable sewage. This is especially economically viable, if in performance rate it is close the facility's requirements, meaning that it could cover the largest possible proportion of the operational season. In this case to properly service the end-user during peak periods additional heat generating equipment (gas boiler or district heating) shall be involved.

If it is possible to set (or reset) the heating and/or cooling water temperature, in favour of economic heat pumping the lowest possible heating and highest possible cooling temperature is to be chosen.

With more heat pumps installed the settings of the equipment's combined operation should be adjusted to the consumer side's temperature differential. In case of larger than 10°C temperature differential (this may occur during heating supply), the heat pumps' condenser sides to be in series connection must be enabled.

4.2 Dimensioning directives for system elements: Heat Pump (HP)

For choosing the appropriate heat pump the basic factor is the required maximal performance capacity of the system. Given this always depends on the operation conditions of any equipment, it has to be borne in mind to comply with the requirements in both operating modes (heating and cooling).

The next important selection criteria is the nature of the heat pump's load, which could either change with different meteorological conditions or provide a so called basic supply with more or less constant load. This latter can be encountered at other, specific applications too. For a weather tracking application such equipment is advised to be selected, that has favourable part load indicators.

Such are primarily the heat pumps equipped with variable frequency drive (VFD) compressors, but also multiple (4-6-8) and multi-stage compressor HPs could mean a good solution. In case of systems with close to constant performance need it is advised to use fix frequency drive compressor HP – in case of certain products the efficiency could be even be higher than that of the VFDs.

In cases where there is a significant difference between the heating and the cooling needs, it could be appropriate to select HPs with different performance which should be adjusted to the magnitude of the load in the different operating modes.

4.3 Dimensioning directives for system elements: Heat Exchangers (HEX)

As per present practice the dimensioning of the heat exchanger system consists of the determination of the number of the HEX units and the number of our uniformly structured HEX elements in a unit, furthermore of the selection of the hydraulic layout of the sewage and technological water circle. One unit of HEXs can be made up of 3, 4 or 6 elements and apart from achieving the necessary performance the main point of the selection and joining of elements is that the adequate functioning of the HEXs can only be obtained in a relatively small flow range.

During the formation of the hydraulic circles each units' balanced requisition (flow-through) should be ensured.

Correct maintenance and cleaning of the service spaces of the HEXs as well as the adequate draining of water splashed on the floor are equally important: floor drains and appropriate floor slope has to be designed.

4.4 Dimensioning directives for system elements: Drum filter and wastewater pump

When dimensioning the wastewater screening station calculating with operational security and effective maintainability is essential. Operational security is guaranteed by the rule of 'n+1' meaning n+1 pieces of unit have to be installed of both screening units as well as lifting pumps. Therefore the smallest number installable of both equipment is 1+1. Particular attention must be paid for the placement of these equipment in order to ensure the accessibility and cleanability of all of the pipeline sections potentially affected by clogging.

The adequately sized load-bearing holding rails to extract the pumps and screening units if needed shall also be placed in the sewage shaft.

4.5 Dimensioning directives for system elements: piping, 2 vs. 4 pipeline systems

According to usage profile the following heating and cooling modes and corresponding system construction can be needed at a project site:

- 2 pipeline system for only heating supply
- 2 pipeline system for only cooling supply
- 2 pipeline system for heating and cooling supply, using a hydraulic switch to change thermal supply mode at each season's ending
- 4 pipeline system for simultaneous heating-cooling supply

Each structure requires their unique optimised hydraulic construction, however designing a 2 pipeline system is a basic engineering task.

When composing the hydraulics of the 4 pipeline system the following aspects should be thoroughly considered:

Whenever possible both thermal supply sides' needs should be met, however the two sides' requirements only randomly ensure operational performance equilibrium for the heat pumps. Consequently ensuring the balance becomes the responsibility of the heating/cooling capacity of the wastewater side. We can meet the requirements and guarantee the balances of the machinery by operating the heat pump as per the control settings of the larger supply need and the resulting surplus on the other side would be forwarded towards the sewage heat exchangers via mixing valves or additional heat exchangers. This process requires necessary automatization with usage of sufficient temperature sensing and motorised valves. The special case when during summer cooling season a relatively low amount of heating need is to be fulfilled (e.g. for domestic hot water production) should be explicitly mentioned. In this situation it is also a possibility to insert a heat pump specifically for this purpose but in any case it has to be ensured that the heat pump responsible for producing the DHW is forced to work on a high condensing temperature and so the other heat pump(s) condensation could be kept on the normal (low) values. Here it cannot be avoided to incorporate a separator heat exchanger.

Towards the consumer side hydraulic transmission or buffer tank need to be included, as appropriate. It is advised that these two functions would be designed to be interchangeable with switch of a valve. However with significant water flow in the district pipelines this is optional.

5 DESIGN AND SIZING GUIDELINES FOR SEWAGE HEAT BASED LARGER SYSTEMS, DISTRICT LIKE HEATING/COOLING STRUCTURES

District heating/cooling systems' efficiency is also essentially influenced by the temperature of the heating/cooling medium forwarded towards the network(s) to be supplied, therefore if it is still a possibility to interfere with the supply temperature, it should be achieved that the lowest possible heating and highest possible cooling water temperature is set in the designs.

The next important element is the selection of the appropriate heat pump(s). The main aspect in this regard is whether the expected level of the load is 90-100% (this can happen in case of the so called base load supply, when the performance of the sewage heat utilising system represents only a relatively small proportion of the full supply) or the partial-load operation is more typical (this is the case if the supply is for the whole or substantially the whole system and the load level follows the prevailing weather conditions). In the case of the former the inclusion of a fix frequency drive compressor HP equipped with an aftercooler is advised, while in the case of the latter the most efficient by all means is a variable frequency drive (VFD) compressor HP.

Analysing given circumstances and requirements the installation of either a 2 or a 4 pipeline system could be found necessary.