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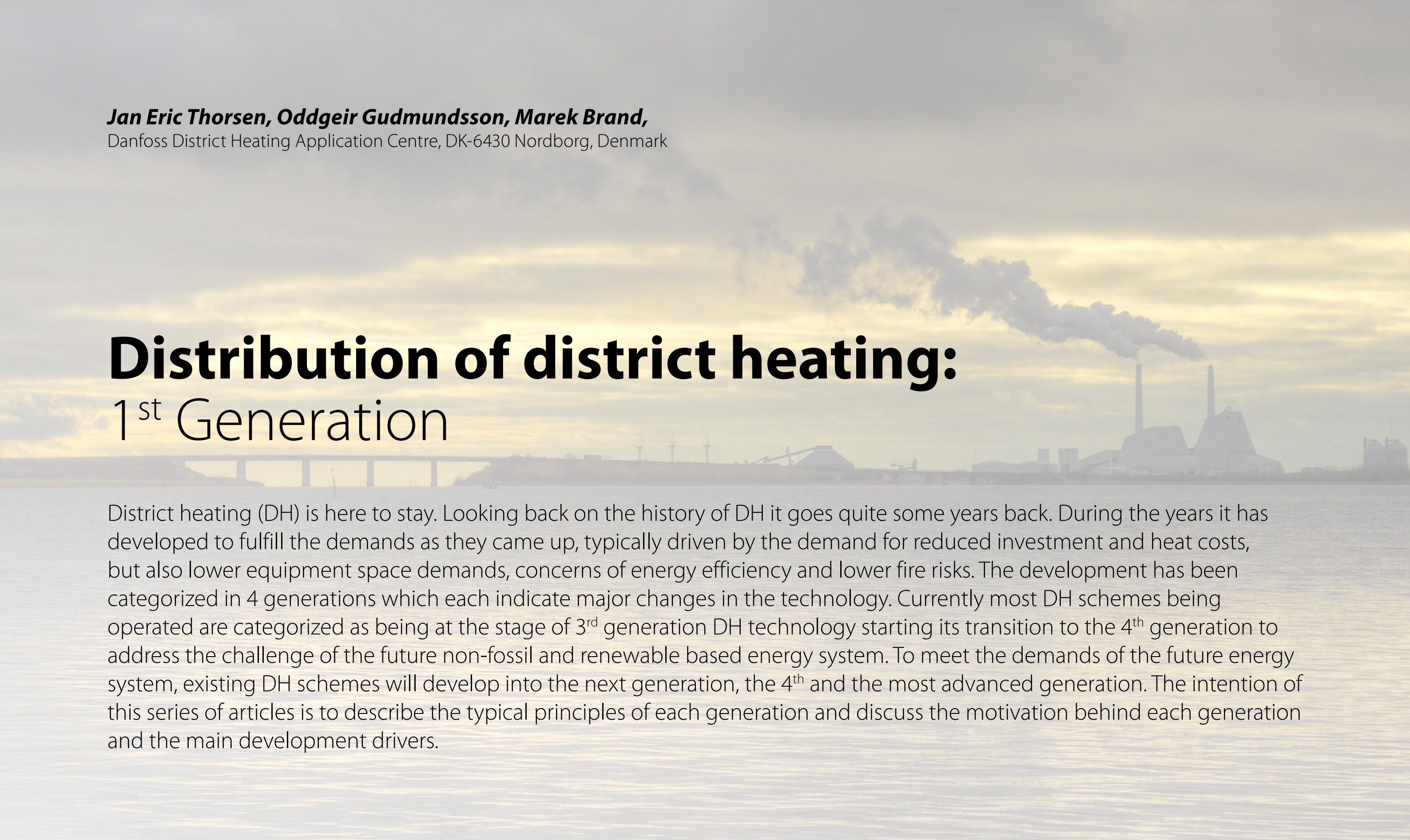

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Distribution of district heating:
1^{st} Generation

District heating (DH) is here to stay. Looking back on the history of DH it goes quite some years back. During the years it has developed to fulfill the demands as they came up, typically driven by the demand for reduced investment and heat costs, but also lower equipment space demands, concerns of energy efficiency and lower fire risks. The development has been categorized in 4 generations which each indicate major changes in the technology. Currently most DH schemes being operated are categorized as being at the stage of 3^{rd} generation DH technology starting its transition to the 4^{th} generation to address the challenge of the future non-fossil and renewable based energy system. To meet the demands of the future energy system, existing DH schemes will develop into the next generation, the 4^{th} and the most advanced generation. The intention of this series of articles is to describe the typical principles of each generation and discuss the motivation behind each generation and the main development drivers.

First generation

The main characteristic of the first generation DH system was that the heat was transported with steam. Steam was obvious to use since electric motors were not yet available for more long-distance hot water distribution. The consumer groups were to some extent small urban industries who used steam in their processes and large heat consumers such as hospitals and big residential building complexes. Additionally steam was considered as a good transportation media due to its high heat content. Further it was available from e.g. boilers or steam power plants which did not run in a condensing mode and hence had high temperature steam available. Basically this was when the concept of CHP was brought into operation. The first steam based systems where built in the USA in the 1880s and basically where the normal way to design new DH systems until 1930.

Still today steam based DH systems are in operation, like e.g. the systems in New-York/Manhattan and Paris. Both cities have tremendous high urban heat densities, reducing the cost for using the old steam distribution technology. Other urban steam systems have ran conversion programmes successfully, e.g. the systems in Salzburg, Hamburg, and Munich. Currently HOFOR, the DH utility for inner Copenhagen is converting the existing steam system into a hot water system. The plan is to have the system fully converted in 2021, and main arguments are that the main users for steam – industry – have moved away from the inner Copenhagen area.

Typical steam temperatures are up to 300°C and pressures up to 20 Bar, the values also depend on the size of the scheme. Based on fossil fuel sources and limited concerns to heat losses in the system, the high temperatures were acceptable. The high heat content resulting in low mass flows was one of the main drivers and will be the argument for maintaining/applying this technology in the future, fulfilling the needs of e.g. the industry, for driving absorption cooling machines, for food preparation, for laundry and dry cleaning or sterilization processes.

The steam pipes were typically placed in concrete ducts, one larger pipe for the steam flow and one smaller for the condensate return. Mostly, condensate return pipes were installed, but many of them have corroded and have been disconnected by the years. In these cases, the condensate is nowadays drained at the customer's location, since installing new condensate pipes has been considered to be too expensive. However the main limitation of avoiding a condensate return line is the significant heat loss. Typically 15% of the heat in the steam and expensive process water is lost. The steam pipes where insulated on site using wooden block insulation and later typical mineral wool, both wrapped to keep the insulation in place.

Due to the high supply temperature the surface temperature of the pipes is high, up to 300°C. In case water from the surface comes into contact with the pipe it will evaporate resulting in steam clouds. At the same time the steam in the pipe might condensate leading to water slug flowing through the pipe. As the water slug, which is basically water in liquid form, moves along the pipe network with the steam at high speeds it becomes a risk that valves and bends will be destroyed, see Figure 1.

Due to the general heat loss from the steam pipes will unavoidably condensate as it moves along the pipe. To separate the condensate, drains are installed with regular intervals the network. Typically the pipes are installed with a longitudinal slope leading the condensate to the drains

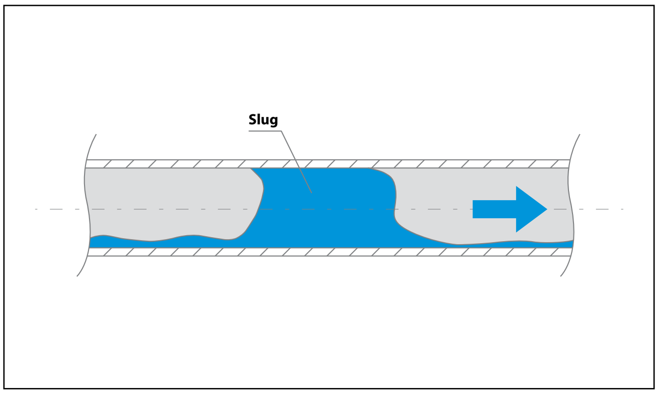

FIGURE 1: Condensate in steam distribution pipe with slug

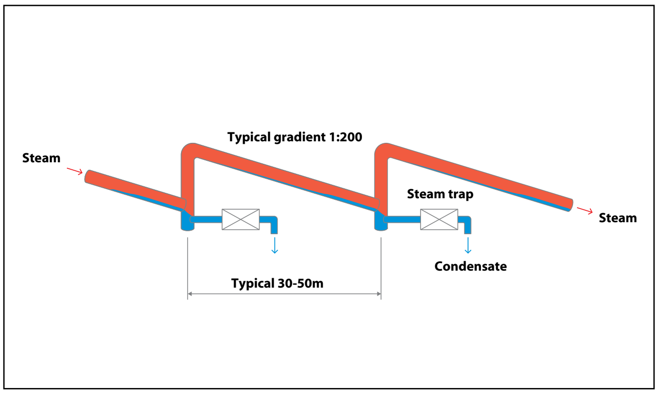

FIGURE 2: Basic principle for steam flow pipes including condensate drains

FIGURE 3: A chimney for dispersion of condensation from the steam distribution network. The condensation can be caused by water coming into contact with the steam pipes being boiled or leakage of the steam pipes.

located at the lower positions, see Figure 2. A number of expansion joints are installed along the pipes to absorb the thermal elongations of the pipes.

At the consumer site a condenser is installed in order to extract the heat, returning the condensate by means of a return pump in case there is a condensate return pipe. Industry steam users might use the steam directly in their processes.

A common challenge for the network is corrosion. The condensate absorbs easily oxygen and carbon dioxide leading to high corrosion levels inside the condensate pipe. Corrosion is also an externally risk if the condensate pipe is exposed by the surroundings. One option – although an expensive one – are stainless steel condensate return pipes. The steam pipe is less exposed to corrosion, both internally and externally. The treated water will limit internal corrosion and the high temperatures will limit external corrosion by keeping moisture away from the outside of the pipe. Several accidents have occurred in both New York and Paris from steam explosions.

Benefits

There are only few benefits using steam in district heating networks. The main benefit is that in addition to space heating the high temperature steam can be used for high temperature demands, as driving heat in local absorption chillers.

Reasons for the steam systems to develop to the second generation

The increased use of district heating, in particular in the 1930s and 1950s, revealed the disadvantage of steam-based systems. The major drawbacks for steam distribution are:

- The high investment and operation costs
- Requirements for complex condensate system
- High heat losses due to high operating temperatures
- Expensive and complex consumer connections in case of expansion
- Reduced plant electrical efficiency due to high DH supply temperatures
- Limited access to low-temperature heat sources

The future of steam based district heating systems is uncertain and most of the steam system is in need of renovation. This gives the perfect opportunity to change the systems to pressurized hot water district heating systems.

FIGURE 4: Cloud of steam, as seen from the 59th floor of the Empire State Building due a leak in the steam system

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