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## Technical comparison of domestic hot water system which used in China and Denmark

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### Abstract

Regardless of where they are in the world, people depend on a reliable and sufficient supply of domestic hot water (DHW) for daily use. Some countries, which have district heating infrastructure, combine space heating (SH) and DHW together, with the aim of having a smart, energy efficient and environmentally friendly energy-consumption system, such as Denmark and China. Nevertheless, the development of DHW networks in these two countries differs significantly. This article detailed the comparisons in technical aspect: common preparation methods of DHW through district heating was introduced in China and Denmark with the analysis on temperature level, hygienic situation of DHW system, circular system, flow capacity and heat metering.

*Key words: District Heating(DH); domestic hot water(DHW) ; legionella; circulatory system, flow capacity; low temperature DH.*

### Introduction

Denmark has the state of art of district heating (DH) technologies in the world, the district heating combines space heating and domestic hot water together, and is available for the whole year. In another DH boosting country, China, most of district heating systems are mainly supplied space heating (SH) in winter, preparation of DHW through DH is uncommon for the whole year. Instead of this, central boilers used fossil fuel and individual water heaters are dominant solutions. This paper contrasts Denmark and China's DHW system based on technical level analysis.

### 1. Technical comparison

Three typical DHW generation applications through DH are listed in Figure 1[1], they are applicative for both Denmark and China. Among them, instantaneous DHW preparation with HEX(Figure 1.(a)) is

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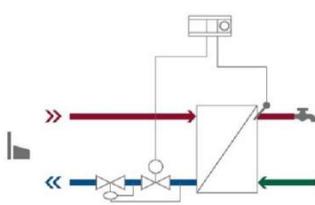


Figure 1.(a). Instantaneous preparation DHW with HEX

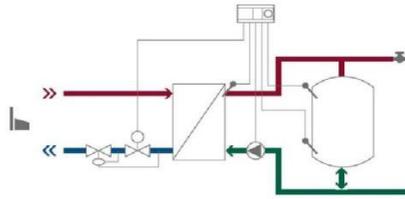


Figure 1.(b). DHW preparation with HEX + tank

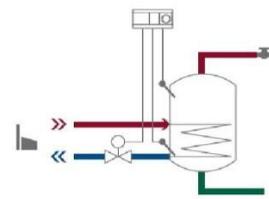


Figure 1.(c). DHW preparation with

highly respected due to multiplex advantages, such as DHW can be generated instantaneously and constantly through the heat exchanger (HEX) with unlimited amount, no regeneration time, reduce the heat loss, save the space required by storage tank, lower total system cost[2], minimize the risk of bacterial growth and so on. In view of the popularity trend for this application in DHW system, technical comparison will be expanded by based on this application. Additionally, in order to ensure a homogeneous comparison, residential multi-storey building will be taken as the example in this paper.

### 1.1 Temperature level in domestic hot water system

Danish standard[3] takes account to the risk of bacterial growth, the water in the heat exchanger could be heated to at least  $60^{\circ}\text{C}$ , and hot water from taps does not drop below  $50^{\circ}\text{C}$  and  $45^{\circ}\text{C}$  at peak. In national standard of China[4], required temperature of water heater should be around  $55\sim 60^{\circ}\text{C}$  by considering the bacteria ( $>55^{\circ}\text{C}$ ) and lime scale issue ( $<60^{\circ}\text{C}$ ), the temperature of DHW at distribution point should be  $50^{\circ}\text{C}$  and not less than  $45^{\circ}\text{C}$  for residential buildings which are supplied by central heating. On the other hand, differ from Denmark, China's temperature requirement of DHW seems to keep on the paper level because of the lack for control and monitoring measures of DHW temperature level, as well as in regulatory aspect, the lack of relevant trainings or educations, guidelines and enough attentions for legionella problem.

### 1.2 Legionella bacteria

Temperature level is a key factor in DHW system, which relates to hygienic and healthy matter. Legionella, a kind of bacteria, can live in all "warm" water systems, no exceptions for DH system. The facts are that legionella will be proliferation boost between  $20^{\circ}\text{C}$  and  $50^{\circ}\text{C}$ , with optimal growth between  $30^{\circ}\text{C}$  and  $40^{\circ}\text{C}$ , inhibited growth around  $50\sim 55^{\circ}\text{C}$  and gradual sterilization between  $55\sim 60^{\circ}\text{C}$ . Above  $60^{\circ}\text{C}$ , legionella cannot survive[5]. That implies the temperature of DHW should remain above  $50^{\circ}\text{C}$  (no growth possible). The only known infection route is that people have inhaled contaminated aerosols, which can cause "pontiatic fever" and "legionnaires diseases" such as chronic lung disease, immunodeficiency, or even died[6]. Since Denmark will be in 4<sup>th</sup> generation DH (4DH) which refers to low temperature DH (LTDH), supplied DH temperature could be as low as  $55^{\circ}\text{C}$ , how to prevent legionella from occurring in DHW system is becoming a hot topic. In accordance with Danish standard, if concentration of legionella in contaminated hot water has reached 1000 cfu/l, the sterilization treatments should be acted. Table 2 lists some alternative disinfection methods to prevent and control legionella bacteria[7]. Apart from this, the system will be safe with temperature below  $50^{\circ}\text{C}$  if the total water volume of the DHW system excluding HEX is less than 3 liter according to Germany standard w551[8].

Table 1. Alternative disinfection methods to prevent and control legionella bacteria

Techniques	Methods.	Description
Thermal techniques	Water re-heating	Water is heated to above 60°C, so that the Legionella bacteria are slain.
	Pasteurization	The systems continuously disinfect the incoming water flow.
Chemical techniques	Use chemicals	A dose of chemicals being added to water, complete disinfection. Such as NaOCl, ClO <sub>2</sub> , ClNH <sub>2</sub> , H <sub>2</sub> O <sub>2</sub>
	Ozone	Ozone readily gives up one atom of oxygen providing a powerful oxidizing agent
Photochemical techniques	UV light	UV light kills bacteria Legionella.
	Photochemical management	Based on the use by low-pressure lamps, ultraviolet light in combination with titanium oxide to generate (-OH) which can destroy the cell wall membrane of micro-organisms so that the cell dies.
Electrochemical management	Copper-silver ionization	Copper-silver ionization brings through electrolytic way, copper and silver ions into the water. These kill the legionella bacteria
	Anodic oxidation	Anodic oxidation converts salts by electrolysis in disinfectants such as free chlorine and kill the legionella bacteria.
Physical techniques	Ultrafiltration	Microfiltration and ultrafiltration to keep out passing bacteria

### 1.3 Circulation system

Danish standard[4] stipulates “To avoid the wastage of water, DHW system should be designed that hot water at flow rate of 0.2l/s reaches the taps within approximately 10 seconds (maximum) with the temperature of never below 50° C”. This will, in many cases cause the system to be carried out with effective circulation system in order to ensure the prescribed temperature maintains in the distribution pipes all the time. According to China’s national standard[4], for centralized DHW system, there are two types to set the circulation pipes of DHW system. 1). Only main pipes and riser pipes have the corresponding circulation pipes, 2). Main pipes, riser pipes and branch pipes to each water use point have the corresponding circulation pipes. For Type 1 implies long waiting time for hot water, low comfort, wastage of hot water and increasing the risk of legionella bacteria in the branch pipes. In addition, this amount of cold water is also charged as hot water fee. However, due to lower initial investment and easier hot water consumption measurement than Type 2, Type 1 is still the main solution for some buildings of China which have general or average level requirements for DHW system.

### 1.4 Determining flow capacity for domestic hot water

When dimensioning the flow demand of DHW in residential buildings, Denmark and China follow the different calculation principle.

$$q_{rh} = \frac{k_n * m * q_r}{T} \quad (1)$$

Reference [9] gives the calculation principle which is in line with the situation of Denmark. Two curves: “Denmark-min and Denmark-max” separately represent the upper and lower flows that are currently used to dimension the flow demand in residential buildings. Closer to “Denmark-min”, better economical and

maintenance results for DHW system. For China case, the flow demand for residential buildings is determined by following the formula (1).  $k_h$  presents the coefficient of variation per hour. Table 3 shows the specific value of  $k_h$  in residential building of China,  $m$  and  $q_r$  respectively stand for the number of occupants, and the quota (For residential buildings, if DHW is 60° C, and quota is 60~100L/day•person). Taking  $m$  as 5 persons per apartment, and  $q_r$  as upper limit of 100L/day•person, the curve “China” is gotten in Figure 2. Figure 2 demonstrates the difference of flow capacity of DHW in residential buildings between Denmark and China.

Table 1. coefficient of variation per hour for DHW system in residential building of China

Number of occupants	≤100	150	200	250	300	500	1000	3000	≥6000
$k_h$	5,12	4,49	4,13	3,88	3,70	3,28	2,86	2,48	2,34

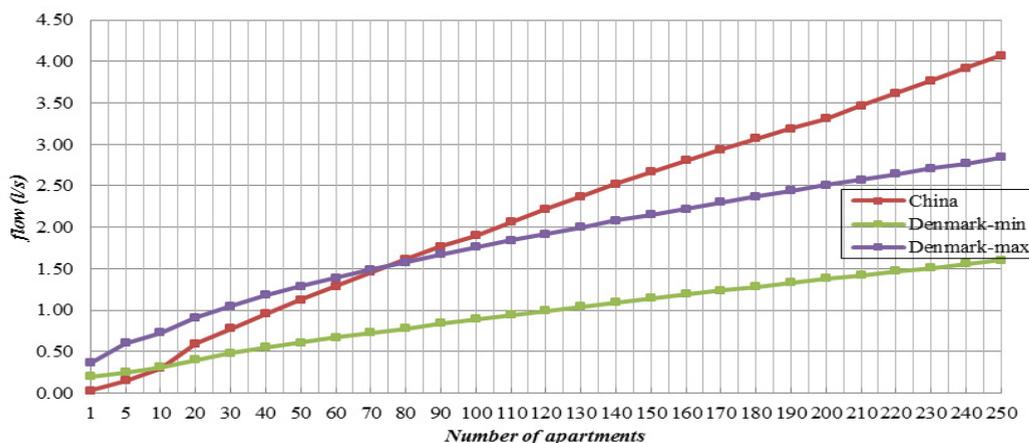


Figure 3. Comparison of flow capacity of DHW in residential buildings between Denmark and China

### 1.5 DHW metering and billing

Heat metering and billing is an effective incentive way to encourage the behavior of energy saving. Currently, the Danish laws and regulations determined that “in each dwelling unit or commercial unit prepared installation of meters for individually measuring the use of hot water [3],” it implies DHW individually measuring is not implemented. For Denmark, the heating fee (both SH and DHW) are charged in the end of each year. DHW cost is apportioned by all apartments of the building according to the use habit of SH. But the new EU energy directive (EED, nr. 2012/27/EU) came into force on 4 December 2012, and initiated “All heating consumption must be paid for on the basis of individual meters; Hot water consumption must be paid for on the basis of meters if this is technically possible and financially viable” (Article 9 (3)). For Denmark, the coming LTDH will also push hot water to be separately measured. LTDH will shift temperature level of DH from current 70/40° C to next 50/25° C, it implies quite big proportion energy is saved in the SH part, in that case, SH and DHW will account for nearly equal proportion in the heating bill for each apartment. Implementing independent DHW metering and billing will be significant for Denmark to practice LTDH. The situation may be relatively simple for

China, the consumed DHW is charged by cubic meter for each apartment, e.g. in Beijing, it is 2.8€/m<sup>3</sup> for DHW which is supplied through municipal DH.

## 2. Flat station solution for preparation of DHW

Based on the above analysis, it could be known China still has great potential to improve DHW system in technical level. On the other hand, even though Denmark has higher level DHW system than China, it is not absolutely. Denmark also has space to improve the DHW system, like DHW measurement.

Flat station is the spreading application in Denmark, and could also be an interesting solution for China's DHW preparation. Excepting the advantages of Figure 1.(a), flat station can be mounted in each flat by combing SH and DHW together with compact design and flexible installation space. In addition, for the coming LTDH in Denmark, flat station concept assumes the DHW temperature at 45°C and demanding a primary temperature of 55°C[10](<90°C for high temperature DH system). Due to heating expense can be measured as each household, it is easily to achieve the individual metering. Whereas for China, lower district heating temperature means less fuel consumption and heat loss of DH network, higher efficiency. Furthermore, DHW system needn't set separate pressure partition for high-rise building in the secondary side, it is safe and no danger because each apartment has own individual hydraulic system. Shorter internal pipes for each apartment will provide a good circulatory system for DHW, thus avoid the undue waiting time and save the water under the condition of favor comfort temperature.

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### Biography

Lipeng Zhang is an industrial PhD student, salaried by Danfoss and currently study in DTU. April 2005 joined Danfoss China and worked in District Energy Division for 7years, May 2012 started industrial PhD study, research work focused on "Techno-Environmental-Economical Evaluation of Implementation High Efficient DH System in China".