ENGINEERING TOMORROW

Article

Analysis on flat station concept
(Preparing DHW decentralised in flats)

Jan Eric Thorsen, Senior Project Manager, M.Sc.

Jan Eric Thorsen,
Senior Project Manager, M.Sc.
Danfoss District Energy, Nordborg, Denmark

Analysis on flat station concept (Preparing DHW decentralised in flats)

The 12th International Symposium on District Heating and Cooling, September 5th to September 7th, 2010, Tallinn, Estonia

In some countries the flat station concept is becoming a common way of realising heating and domestic hot water (dhw) installation in blocks of flats. Anyhow, in other countries it is at the very beginning. Experience from those countries reveal a number of questions when understanding and evaluating the flat station concept.
A number of parameters can be addressed to and be evaluated to disclose qualities and performance of the flat station concept in relation to traditional concepts for heating and dhw installations.
This paper aims at analysing main parameters regarding quality (comfort) and performance of the flat station concept, covering block distribution system, flat station itself and flat installation. Parameters in focus are: riser system, instantaneous dhw principles, heat losses, comfort of dhw, investments and energy savings, metering and hygienic issues for dhw.

Introduction

Areas of district heating distribution systems, building heating installations and domestic hot water (dhw) installations show a high degree of conservatism and traditions, which are reasonable due to their lifetime. But this also implies a number of questions when new concepts like the flat station concept are to be introduced. Not only questions addressed to the flat station concept but also to existing systems, where detailed knowledge is faded out due to the maturity of concepts.

The parameters adressed

Investments:
- Distribution system
- Basement sub station versus flat stations
- Energy meters

Energy savings:
- Heat loss in primary distribution system
- dhw circulation pump consumption

Comfort:
- dhw temperature stability and variation
- dhw recovery time after idle period

Hygienic issues:
- Considerations on Legionella related to the system's physical layout

Investments

Reference for comparing the flat system concept with a conventional concept is based on modern way of making block pipe distribution systems [1]. In both cases it is a horizontal pipe layout in flats with a vertical pipe tunnel for distribution. Pipe distribution systems are shown in fig. 1. Main differences are to be seen in the number of pipes installed. Since dhw is prepared decentralized in flats, dhw pipe and dhw circulation pipe are eliminated. Centrally located dhw station in the basement is replaced by decentralized flat stations. Balancing valves for heating as well as for dhw distribution is saved for the flat station concept. Regarding metering then the dhw meter is eliminated, since the primary supply to the flat station covers flat heating and dhw as well. According to measurements of more than 2500 dwellings in Denmark, including detached houses as well as multi storey buildings, individual metering, say individual billing, resulted in savings of 15 – 30%, [2]. Therefore, this analysis assumes metering of all thermal energy deliveries to flats.
A recent investment example comparing flat station concept (F) with traditional system (C) is included in fig. 2. Data are based on a Danish case from Århus area where a block, built in 4 levels and a basement level consisting of 24 flats, will generally be modernised. Investments compared are based on concepts presented in fig. 1. Main conclusion is that investment level is approx. break-even for the two systems, for this typical Danish case. For other countries implying other components/costs levels, level could change. In general, the experience is that flat stations are on break-even cost level or slightly higher. This is valid for new buildings as well as for renovation projects.

Energy savings

Main contribution to energy saving is originated from installed hot distribution pipes. To begin with, it is assumed that half the yearly distribution energy loss is net loss (summer time), meaning not contributing to heating up the building. Wintertime temperatures are assumed to be identical for the two concepts, because for this period the heating system defines temperature levels. To quantify losses a room temperature of 20°C is assumed. Danish Technical Insulation Standard [3] requires minimum allowable heat loss constants (W/m), depending on temperatures, annual operation time and pipe diameter. These constants turn out to be quite similar to all pipes in question. To simplify preconditions a heat loss coefficient of 0.20 W/mK has been chosen for all hot pipes. Table 1 shows a comparison of pipe temperatures, heat loss and electrical dhw circulation pump.

Flats in this first case are provided with floor heating in bathrooms; therefore, heating is active all year. Due to floor heating, temperatures for the traditional concept are lower during summer season compared to the flat station concept, since floor heating typically operates at lower temperatures. For the flat station concept a dhw temperature at 45°C is assumed, demanding a primary temperature of 55°C.

Comparing the two systems regarding heat loss, then favour is towards the flat

station concept. For the Århus case it means approximately 4200 kWh/year savings corresponding to 210 Euro/year (ex. pump. costs). This means a saving of approx. 2 kWh/m^2/year. This represents a saving of approx. 2% of the yearly heat demand for a 1970 Danish block building (not including energy for dhw).

Secondly, a situation is analysed where heat loss is not utilised in the building distribution system at all. Winter energy losses for the flat station is assumed to be usable and no floor heating is active during summer.

Comparing the two systems regarding heat loss, then favour is again towards the flat station concept. For the Århus case it means approximately 9900 kWh/year savings corresponding to 490 Euro/year (ex. pump. costs). This means a saving of approx. 4 kWh/m^2/year. This represents a saving of approx. 4% of the yearly heat demand for a 1970 Danish block building. Additionally, as for the flat station concept there is no need for dhw circulation pump, thus no need for the electric energy of 260 kwh/year. A part of this saving is anyhow spent for the flat station concept due to additional circulation of primary water. It is assumed that this is approx. half the electric energy for dhw circulation pump of 130 kwh/year.

When looking at annual energy consumption savings in percent, figures might appear rather low and of minor impact. In this respect it has to be remembered that energy saving relates to a typical 1970 building.

Present building codes require energy savings in the order of 50% reduction for 2010 established buildings and another 50% for 2015 established buildings.

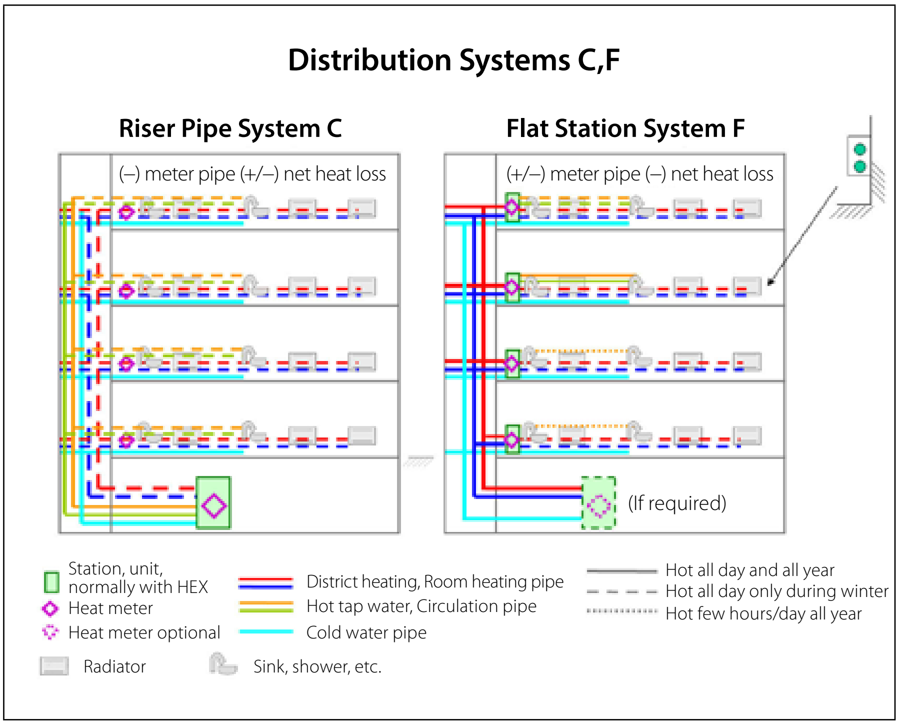

FIGURE 1: Pipe distribution systems in blocks of flats. C: Modern reference principle. F: Flat station principle

This means savings in relative numbers for the flat station concept will triple towards 2015 compared to 1970 building standards. Range of relative savings goes from 2 – 4% to 8 – 16% towards 2015.

Comfort

Comparing the two ways of preparing dhw, i.e. by storage tank and by heat exchanger [4] / [5], it is obvious that dynamics of control tasks is quite different. At continuous tapping from full charged storage tank temperature will be constant and also independent on tapping flow changes until colder layers (cold water) have "refilled" the storage tank. At this point comfort drops drastically. If tappings are made periodically and in shorter duration then temperature will be constant within each tapping, but will vary between tappings due to mixing of temperature layers.
A typical question regarding instantaneous prepared dhw is how stable are temperatures when applying dynamics.

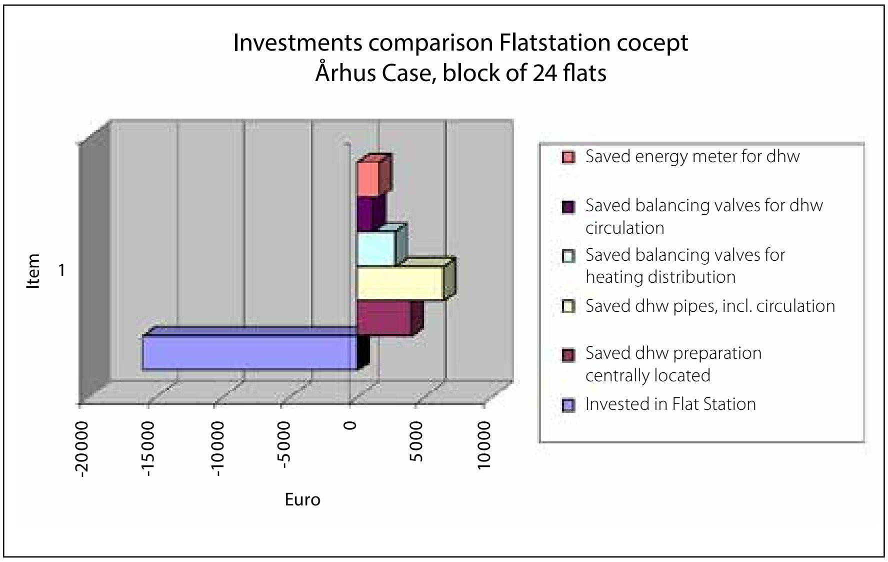

FIGURE 2: Investment balance for traditional system C and flat system F. Block of 24 flats

Regarding dynamic control performance an example is included in fig. 3.

Fig. 3 shows that stability, temperature peaks at load change and total dhw temperature (T22) variation is limited to 3 – 4°C. Regarding oscillations at low tapping flow it should be noted that T22 is measured at heat exchanger outlet. As example a 5 m ø22mm pex pipe reduces peaks and amplitudes additionally, dependent on frequencies, but typically 50%. This example is for very high primary supply conditions. Oscillations appear at tap flow of 100 l/h or below. This level shall be seen in relation to the fact that a typical tapping flow for one tap is 200 – 400 l/h.

Another relevant question is how fast dhw temperature is on desired level if supply is in idle condition. Here dynamics are heavily influenced by idle bypass thermostat setting. Also pump dynamics are influencing, meaning how fast is the primary circulation pump reacting on rapid changes of hydraulic conditions, say opening of primary valve. Fig. 4 shows a flat system with cold heat exchanger. Bypass temperature setting corresponds to primary supply temperature (Tf.dh) of 40°C and primary return temperature (Tr.dh) of 30°C. This setting is in the very "low" end, but in the "high" end regarding energy saving. Available differential pressure is 1 bar, but drops to 0.25 bar at the beginning of the tapping. In this case temperature in circulation (Tsupply) is approx. 67°C. Primary branch pipe from supply to the flat station is 4 m, ø 20 mm. Measurements show that primary supply has a delay of approx. 7 sec. to reach level of 55°C. Additional delay is then caused by heating up the heat exchanger and dhw water, this delay is additional approx. 3 sec. to reach a minimum demanded level of 45°C. After 5 meter of pex pipe of ø 22 mm additional delay is approx. 7 sec. By this the total delay from tapping the start to reach 45° at the tap is approx. 17 sec. In this example a very long idle branch pipe length is used, more realistic would be 0 – 2 m, resulting in a "primary side" delay of not more than a few seconds. Also diameter of secondary dhw pipe is rather big and represents a typical shared pipe dimension, representing one pipe for several taps.

Anyhow, this delay is only relevant for the first tapping, since thermal capacities combined with efficient insulation is maintaining temperature, typically with time constants of 1 – 2 hr.

Comfort level is increased by applying a higher bypass thermostat setting and/or a "hot" heat exchanger during idle. Fig. 5 shows an example of flat station with "hot" heat exchanger and thermostatic controlled heat exchanger [7]. Idle temperature is approx. 50°C corresponding to dhw tapping temperature.

Fig. 5 shows a flat system with "hot" heat exchanger at idle. Bypass temperature setting corresponds to a primary supply temperature (T11) of 58°C and primary return temperature (T12) of 44°C. This setting is the high end, meaning in "high" end regarding comfort. For this system there are no primary delays, and dhw tapping temperature at the flat station is available after approx. 2 sec. Additional delay due to dhw piping towards tap would be similar to previous example.

In many practical matters a compromise between the two examples regarding idle temperature setting fulfils demands for good comfort with reasonable energy consumption.

In the following a general trade off is included between branch pipe length, dhw pipe length, idle condition for heat exchanger and temperature delay on dhw, based on dynamic simulations. Pipes are simplified by simple delay models with no heat loss. Heat exchanger is based on a lumped capacity model described in [5].

For simulations a branch pipe flow (Q1) of 800 l/h is assumed. This represents a situation where the thermostat is fully open until the desired set temperature is reached. Further a step vice flow change from zero to Q1 or zero to Q2 is assumed. Tapping flow is assumed to be on a high level flow for one tap, which is typically applied when opening the dhw. Q2 = 400 l/h for all simulations.

Heat exchanger simulated is Danfoss XB06H-40 [6]. It can be seen from figure 7, that influence on hot or cold heat exchanger is in the range of 2 sec. delay. Branch pipe length (L1) has minor impact on time delay. This is due to the fact that temperature is maintained with a temperature gradient along pipe during idle,

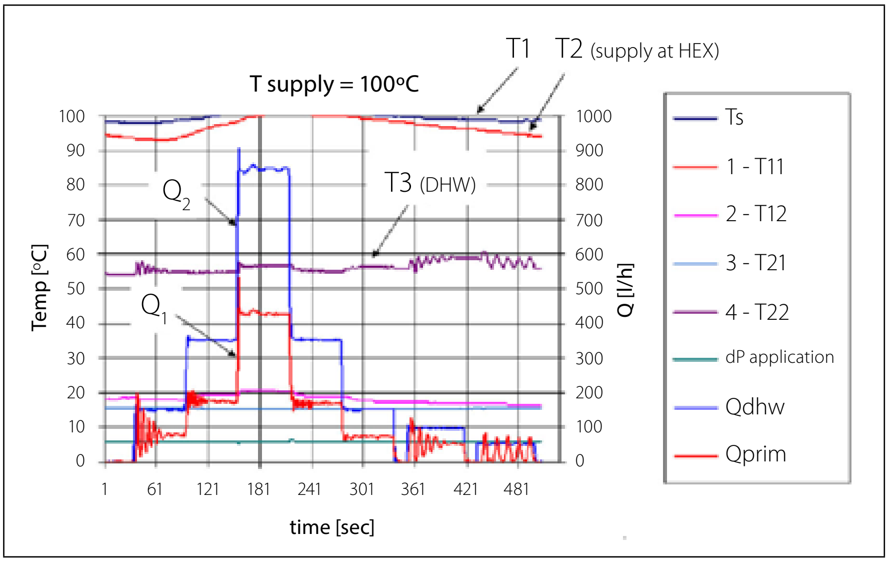

FIGURE 3: Dynamic control performance (step test) for thermostatic and pressure controlled heat exchanger for dhw production [6]

		Heat loss from distribution pipes Electrical pump comsumption, dhw	**Pipe lenght [m]**	**Lambda [W/mK]**	**T pipe [°C]**	**T amb [°C]**	**E loss [W]**	**E loss/y [kWh]**	**Net E loss/y [kWh]**	**E. price [Euro/kWh]**	**E. costs [Euro/year]**
Trad. con.	**C**	Sum. flow	120	0,20	40	20	480	4205	2102	0,05	105
Trad. con.	**C**	Sum. return	120	0,20	25	20	120	1051	526	0,05	26
Flat st. con.	**F**	Sum. flow	120	0,20	55	20	840	7358	3679	0,05	184
Flat st. con.	**F**	Sum. return	120	0,20	30	20	240	2102	1051	0,05	53
Trad. con.	**C**	Unit heat loss	1 pcs.	300	W/unit			2628	1314	0,05	66
Flat st. con.	**F**	Unit heat loss	24 pcs.	25	W/unit			3816	1908	0,05	95
dhw circ.	**C**	Summer	240	0,20	53	20	1584	13876	6938	0,05	347
dhw circ. elec.		Summer + winter	-	-	-	-	(30W elec.)	260	-	0,25	65
Trad. c.	**C**	Total							10880		544
Flat st. c.	**F**	Total							6638		332
Difference	**C-F**	Total							4242		212

TABLE 1: Energy losses for traditional system C, and flat system F based on the Århus case.

		Heat loss from distribution pipes Elec. pump cons., dhw circulation	**Pipe lenght [m]**	**Lambda [W/mK]**	**T pipe [°C]**	**T amb [°C]**	**E loss [W]**	**E loss/y [kWh]**	**Net E loss/y [kWh]**	**E. price [Euro/kWh]**	**E. costs [Euro/year]**
Trad. con.	**C**	Sum. flow	120	0,20	20	20	0	0	0	0,05	0
Trad. con.	**C**	Sum. return	120	0,20	20	20	0	0	0	0,05	0
Flat st. con.	**F**	Sum. flow	120	0,20	55	20	840	7358	3679	0,05	184
Flat st. con.	**F**	Sum. return	120	0,20	30	20	240	2102	1051	0,05	53
Trad. con.	**C**	Winter flow	120	0,20	70	20	1200	10512	5256	0,05	263
Trad. con.	**C**	Winter return	120	0,20	30	20	240	2102	1051	0,05	53
Flat st. con.	**F**	Winter flow	120	0,20	70	20	1200	10512	5256	0,05	263
Flat st. con.	**F**	Winter return	120	0,20	30	20	240	2102	1051	0,05	53
Trad. con.	**C**	Unit heat loss	1 pcs.	300	W/unit			2628	2628	0,05	131
Flat st. con.	**F**	Unit heat loss	24 pcs.	25	W/unit			3816	1908	0,05	95
dhw circ.	**C**	Summer + winter	240	0,20	53	20	1584	13876	13876	0,05	694
dhw circ. elec.		Summer + winter	-	-	-	-	(30W elec.)	260	-	0,25	65
Traditional	**C**	Total							22811		1141
Flat station	**F**	Total							12946		647
Difference	**C-F**	Total	(ex. electrical consumption)						9865		493

TABLE 2: Energy losses for traditional system C, and flat system F based on the Århus case.

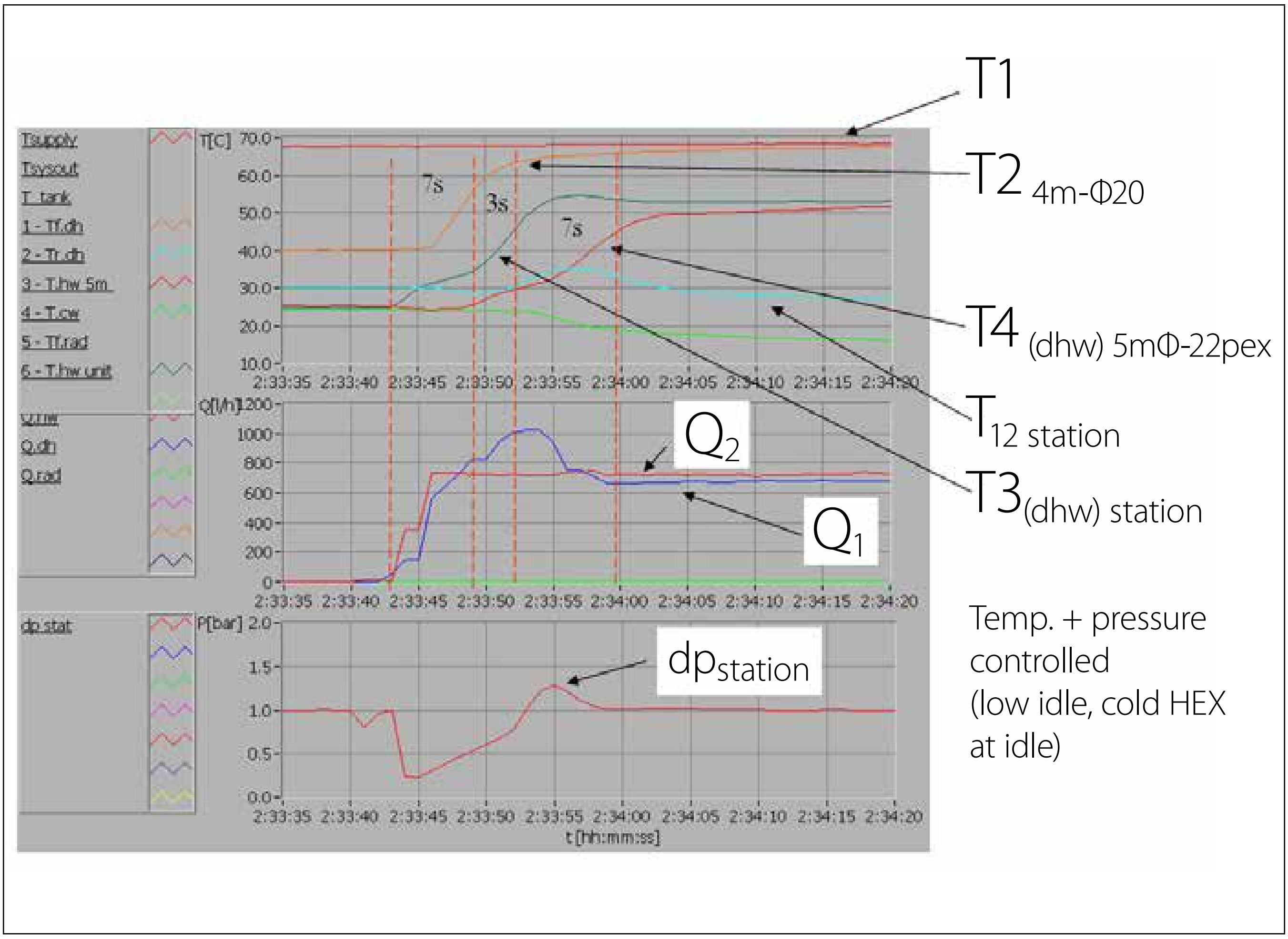

FIGURE 4: Space heating application above and DHW application below. Both applications are controlled by a motorized control valve and a dP controller

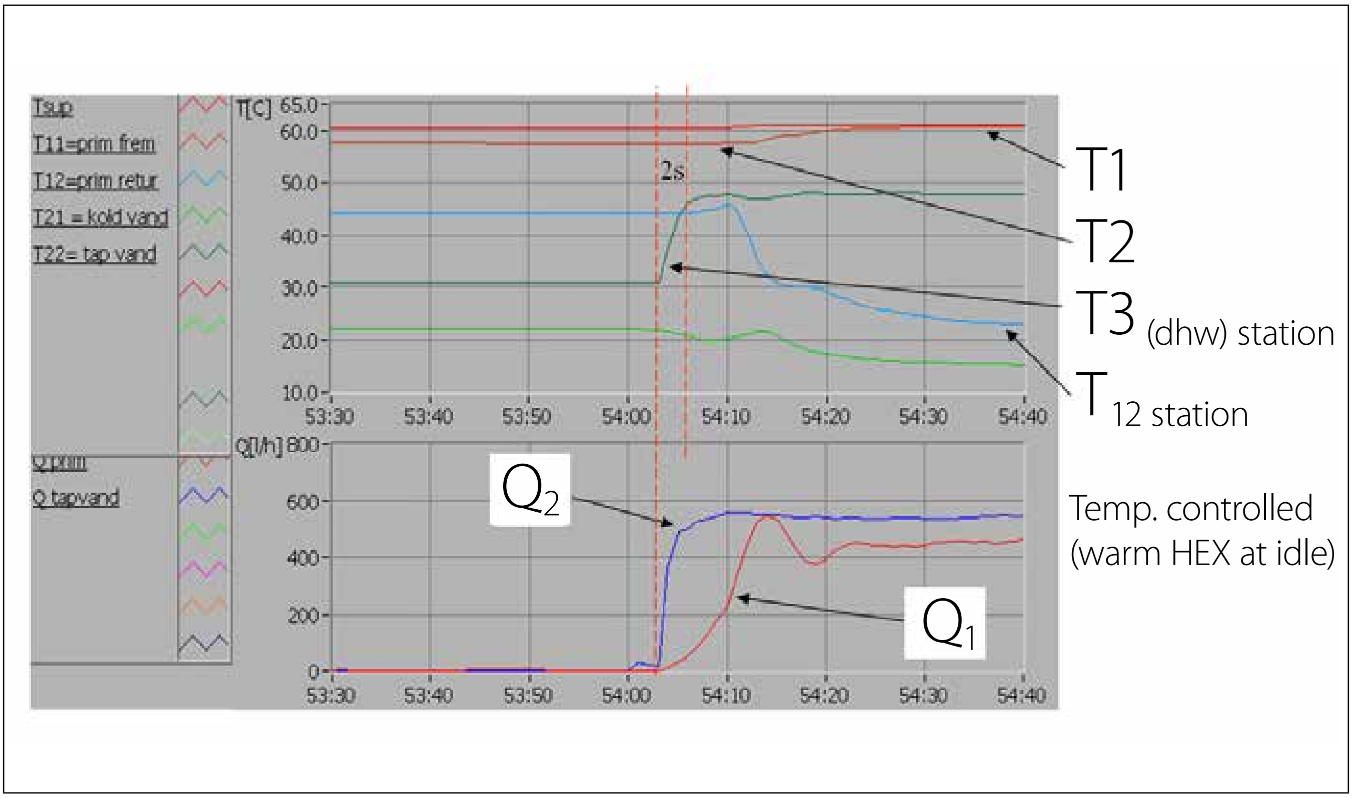

FIGURE 5: Dynamic control performance (idle recovery) for thermostatic controlled heat exchanger for dhw production. Heat exchanger is warm during idle. [7]

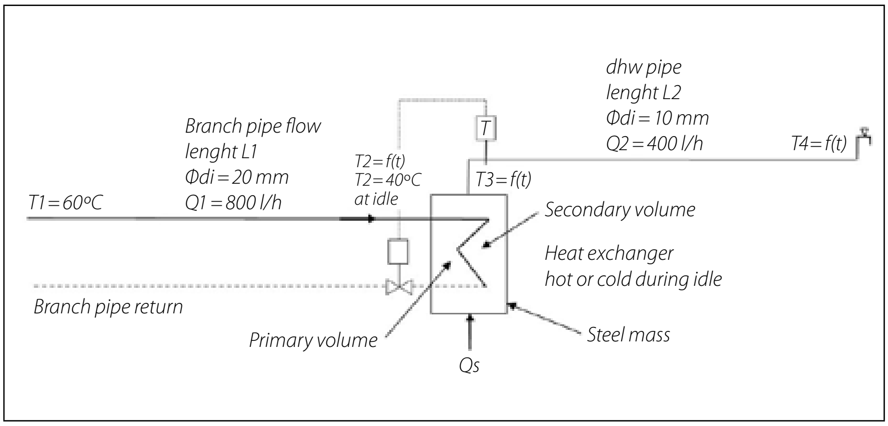

FIGURE 6: Basic application for flat station, including boundary conditions for dynamic simulations

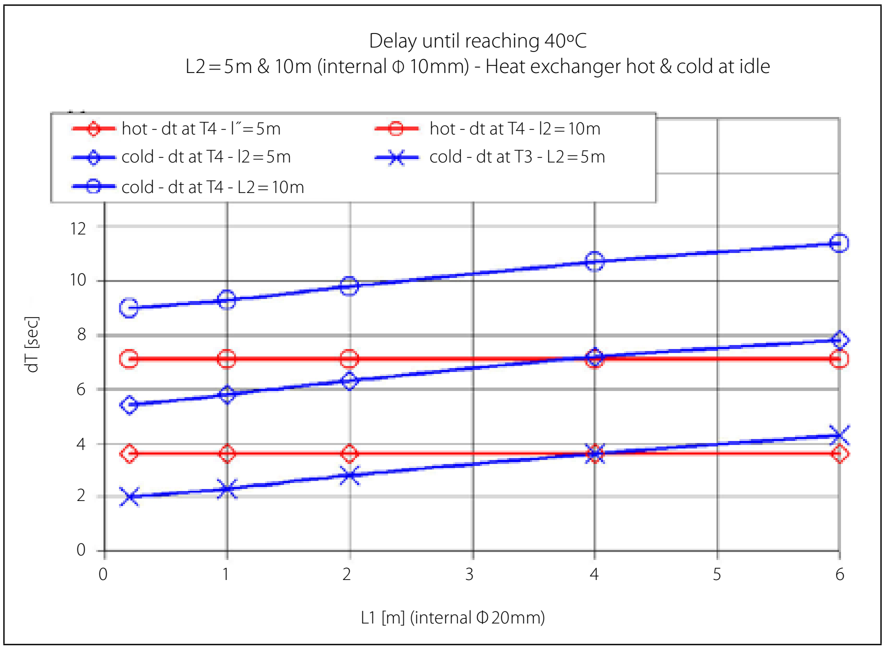

FIGURE 7: Dynamic simulation results for hot and cold heat exchanger during idle. Delay (dt) for dhw temp. of 40°C

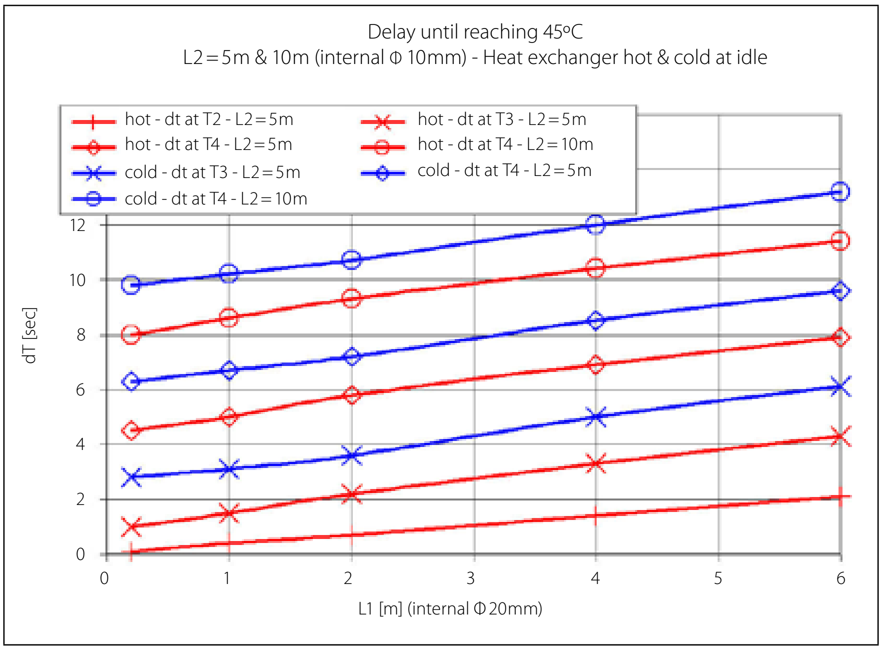

FIGURE 8: Dynamic simulation for hot and cold heat exchanger during idle. Delay (dt) for dhw temp. of 45°C

reflecting T1 to T2. Basically water in branch pipe is heated to a certain level already before tapping. Anyhow, due to energy loss and return temperature, idle bypass temperature is lower than dhw tapping temperature in this case.

Main influence on time delay is dhw pipe diameter and length (L2). Connection in flats shall be of "star coupling" principle where every tap has its own supply pipe with a small inner diameter. Temperature in dhw pipe water is assumed to be room temperature prior to tapping. In general, additional delays of typically 3 to 6 seconds shall be expected due to thermal interaction with thermal capacities along the way to tap and hydraulic dynamics on branch pipe side and hydraulic dynamics on dhw side.

Simulated waiting time for a dhw temperature of 40°C is included in figure 7.

First of all it can be seen that time delay for reaching 40°C at tap is only a bit shorter than reaching 45°C. This is due to the fact that the T4 temperature profile has an almost step vice nature, i.e. if temperature goes up after the dhw pipe is flushed through, it goes almost like a step.

Different dhw controllers have different performance regarding time delay. In case of pure proportional control for dhw system, time delay is longer at part load. This is because primary flow is proportional to secondary flow, and the lower the flow the longer the waiting time. Looking at the example for Q1 = 800 l/h, Q2 = 400 l/h, L1 = 4 m, L2 = 5 m then time delay (dt) at T4 is 6.9 sec to reach 45°C dhw temperature. In case of proportional controller with parameters Q1 = 400 l/h, Q2 = 400 l/h, L1 = 4 m, L2 = 5 m then dt = 11.0 sec to reach 45°C. This has considerable effect on time delay as L1 gets longer. In case of a thermostatically controlled dhw system or a combination of a thermostatically and proportionally controlled dhw system, time delay is shorter because no matter how small tapping is, as long as the desired set point temperature is not reached, the primary valve will be fully or almost fully open resulting in high primary flow. Regarding delay to reach a dhw temperature of 40°C this is only related to dhw pipe dimension since 40°C is the bypass temperature if heat exchanger is hot during idle. In case the heat exchanger is cold during idle, then this introduces an additional time delay as described above. In all cases, time delay is dependent on dhw flow, resulting in delay in the dhw pipe.

Hygienic considerations

Legionella is a well-known bacterial risk for dhw systems. Normally it is not the question whether Legionella is present in the dhw system or not, but rather Legionella bacteria concentration in the dhw. Facts influencing on potential for Legionella concentration growth are dhw temperature, exchange rate of hot water in distribution pipes, and volume of dhw water in the entire hot system. Also other factors are influencing, e.g. systematic cleaning of shower outlets, but this will be not addressed to here, since the effect is similar for concepts compared.

Comparing volumes of dhw in pipes for concepts, the flats station solution has significantly lower volume compared to the traditional system. Furthermore dhw pipes should be "star" connected, meaning one small (diameter) pipe from the flat station to each individual hot tap. This eliminates problematic dead end or low flow areas.

Typically volume of heat exchanger is 0.25 to 0.50 litre. Typical dhw pipe volume is 0.10 l/m, equal to 1.0 litre for 10 m pipe. In total this is a volume of 1.5 to 2 litre pr. flat. The comparable centrally placed dhw system with dhw distribution will have a volume of 5 – 7 litre pr. flat. By installing a dhw storage tank this will increase significantly. The German DVGW regulations states that heating dhw up to 60°C, due to e.g. Legionella, is not required if volumes of heat exchanger or volume of dhw pipes is less than 3 litres [8]. Based on those physical concept differences Legionella bacteria risk is reduced for the flat station concept.

Future energy supply/ demand perspective

One important challenge for DH is to convert to 4th generation DH systems. Intention is to realise efficient DH systems for urban areas where heat demands will decrease due to modernisation and new building energy saving codes. In this context one way to go is to reduce temperatures in DH networks [9]/[10]. This allows for cost effective geothermal sources as well as other renewable low temperature sources. For dhw, normal temperature level is 45 to 60°, where higher temperatures typically are based on considerations towards Legionella. A way to reduce temperature levels in DH networks is to set dhw temperature at 45°C. By this a primary temperature at sub station of 50 to 55°C will be sufficient. A precondition for this is to use heat exchangers for dhw production, like the flat station concept.

Conclusion

The two pipe flat station concepts, consisting of decentralised instantaneous dhw production, open the possibility of reducing general DH net work temperature, which for the future will be even more relevant due to decreasing building heat demand and increased availability of renewable energy. For building owners, the investigated case shows that the flat station concept is on brake-even investment level compared to traditional systems. The flat station concept has a net energy saving due to less installed hot pipes. Energy savings are in the range of 2 to 4 kWh/m^2/y for the investigated cases. Comfort level has been investigated, revealing well acceptable dynamic control performance. dhw temperature recovery after an idle period for the instantaneous preparation of dhw is, however, a trade-off between comfort and energy saving. Related to Legionella, then risk can be reduced when installing flat stations as presented in this paper.

ENGINEERING
TOMORROW

References

[1] *Comparing Distributions Systems in Blocks of Flats*, by Kristjansson H., SDDE 2009, Slovenia

[2] *The Installation of Meters Leads to Permanent Changes in Consumer Behaviour*, by Gullev L., Poulsen M., "News from DBDH", #3/2006

[3] DS 452, *Code of practise for thermal insulation of technical service and supply systems in buildings*, 2. revision, Dansk Standard, 1999

[4] *Cost considerations on Storage Tank versus Heat exchanger for htw preparation*, by Thorsen J.E., The 10th International Symposium on District Heating and Cooling 2006

[5] *Control Concepts for DH Compact Stations Investigated by Simulations*, by Thorsen J. E., The 9th International Symposium on District Heating and Cooling 2004

[6] http://www.danfoss.com/Products/Categories/List/HE/Temperature-Controllers/Temperature-controllers/IHPT-and-XB-06/b1c8a73c-59f1-4fef-8b52-49c97b6019b.html

[7] http://www.danfoss.com/Products/Categories/Group/HE/District-Heating-Substations/Substations-Direct-Heating/Flat-Stations/8f81605b-bab9-4644-961b-51a3f0503f05.html

[8] DVGW regulations, Germany, Arbeitsblatt W551, April 2004

[9] *A new Low-Temperature District Heating System for Low-Energy Buildings,* by Olsen P.K., Lambertsen H., Hummelshøj R., Bøhm B., Christiansen C.H., Svendsen S., Larsen C.T., Worm J., The 11th International Symposium on District Heating and Cooling 2008

[10] *Consumer Unit for Low Energy District Heating Net Works,* by Paulsen O., Jianhua F., Furbo S., Thorsen J. E., The 11th International Symposium on District Heating and Cooling 2008

More information

Find more information on Danfoss Heating products and applications on our homepage: **www.heating.danfoss.com**

Danfoss A/S

DK-6430 Nordborg
Denmark
Tel.: +45 74 88 22 22
Telefax: +45 74 49 09 49
E-mail: danfoss@danfoss.com