Hot Water Recirculation in High Rise Buildings to Reduce Water Consumption

Dipl. Eng. **Paul FRĂSIE[1],** Assoc. Prof. Dr. Eng. **Adriana TOKAR[2]**

[1] Pinchin Ltd., Canada, paul.frasie@yahoo.com

[2] Politehnica University Timisoara, Faculty of Civil Engineering, adriana.tokar@upt.ro

Abstract: *In present, water save has become essential in all regions, even where water seems abundant. The most effective way to save hot water from buildings plumbing is recirculation systems, but for high rise buildings the things are more complex. The article approaches an analysis of a 27-storey high-rise building with three recirculation pumps and associated heat exchangers. The lower head zone pumps and smaller local heat exchangers are used successfully. By using a low head pump instead of a high head pump it can be saved the operating cost, even though the initial cost of a small double wall plate heat exchanger and low head pump is comparable to the cost of a high head pump*.

Keywords*: Recirculation, Hot Water, High Rise Buildings, Water Consumption*

1. Introduction

Water is very precious resource being considered at the same time a renewable one; however, the percentage of usable water (fresh water) is decreasing while the population are increasing in number [1]. From the total of usable water available on the Earth, more than 68% is embedded in glaciers, and only 3% is usable water (Figure 1) [2, 3, 4].

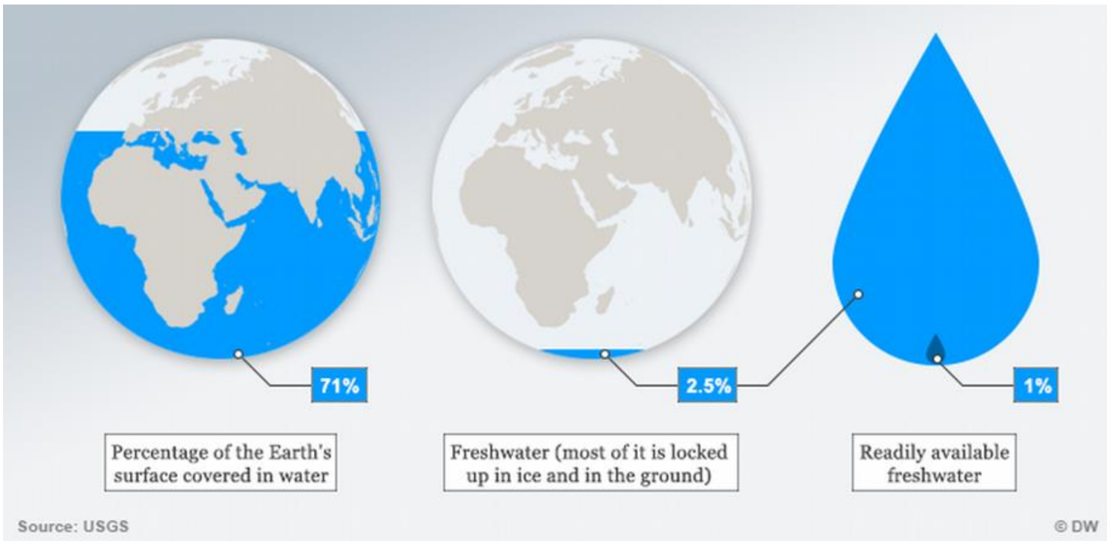
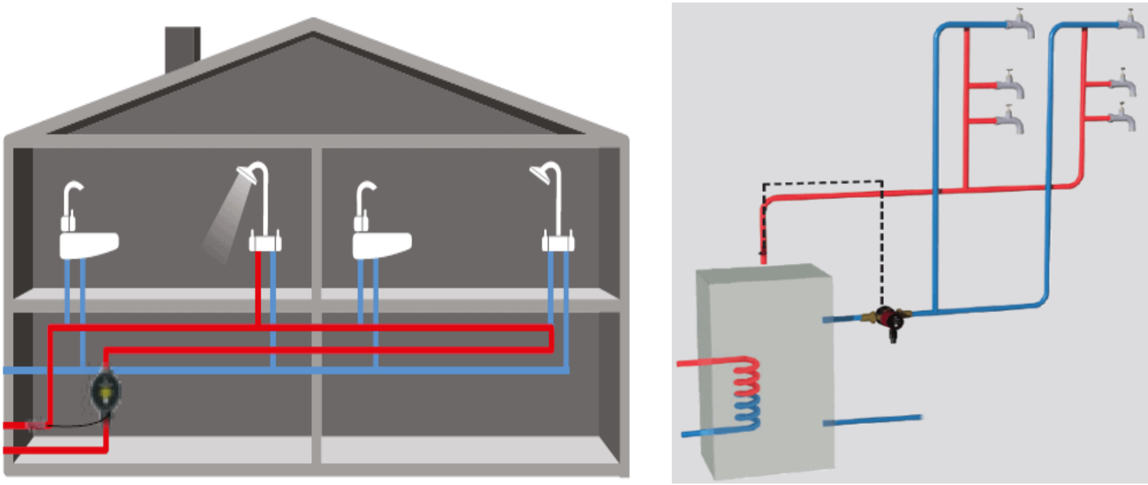


Fig. 1. Percentage of the water on the Earth [3]

Fresh water sources such as aquifers, lakes, and rivers are affected by the increased population, since are used to water supply to the communities. On the other hand, hydrotechnical construction and dams affected the rivers everywhere in the world. World river systems in percent of approximatively 60% were broken by the dams and other constructions, and just a small part of the big rivers in the world are flow freely.

From the above-mentioned reasons, and to reduce the water and energy consumption, it is important that engineers, designers, contractors involved in plumbing systems for residential and nonresidential sector, to optimize the hot water recirculation systems; this specially applies to high rise buildings. Hot water recirculation systems provide comfort and help to reduce the water consumption, ate the same time. In the modern world the human comfort and preservation of the

natural resources, such as water, go hand in hand; these imply the engineers and designers to find solutions.
Technical solution of the domestic hot water recirculation line (Figure2) implies a pipe which is installed parallel with the domestic hot water line which provides a continuous flow of hot water though the pipes and help to maintain warm water in the entire system [5].



a) b)

Fig. 2. Domestic hot water classical recirculation systems [5]
a) water horizontal distribution, b) water vertical distribution

2. Building Statistics

As building owners evolve, and as building code officials may or may not become more stringent on energy use for new buildings, the actual performance of the base building system will mater more than ever. The performance of the building systems has a direct relationship with the overall operating cost. Operating costs tend to reoccur every month over the life of the building and must align with the owner’s portfolio performance expectations.
For example, pumping systems are contributing to the success of performance of the base building system using alternative applications including variable frequency drives or water heaters with minimal or no storage.
On the other hand, pumping systems account for nearly 20% of the world’s electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations [6].
In the World Energy Usage & Consumption (Figure 3):

- 70% of pumps electric motor power is used for pumps, fans, and compressors;
- 20% of the world’s electricity is used in pumping;
- 50% of pumping energy is wasted.
-

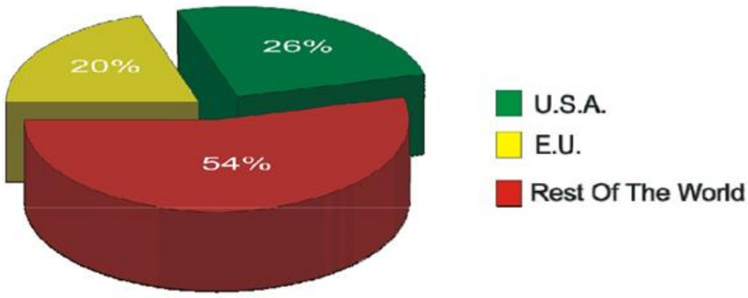
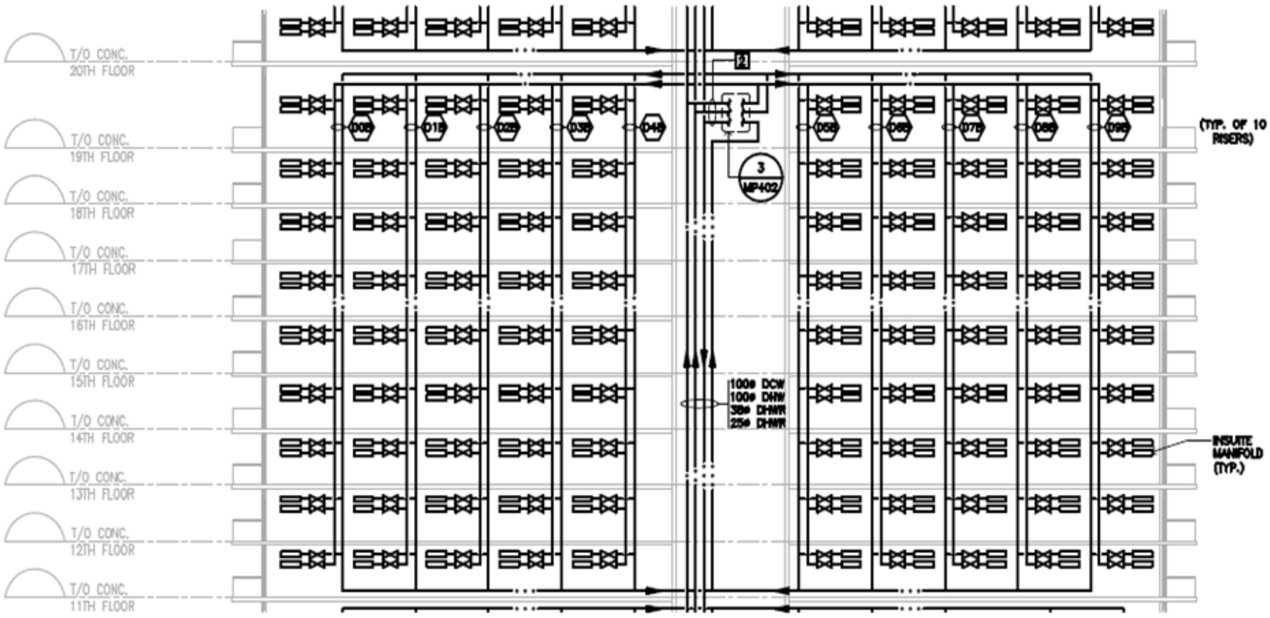


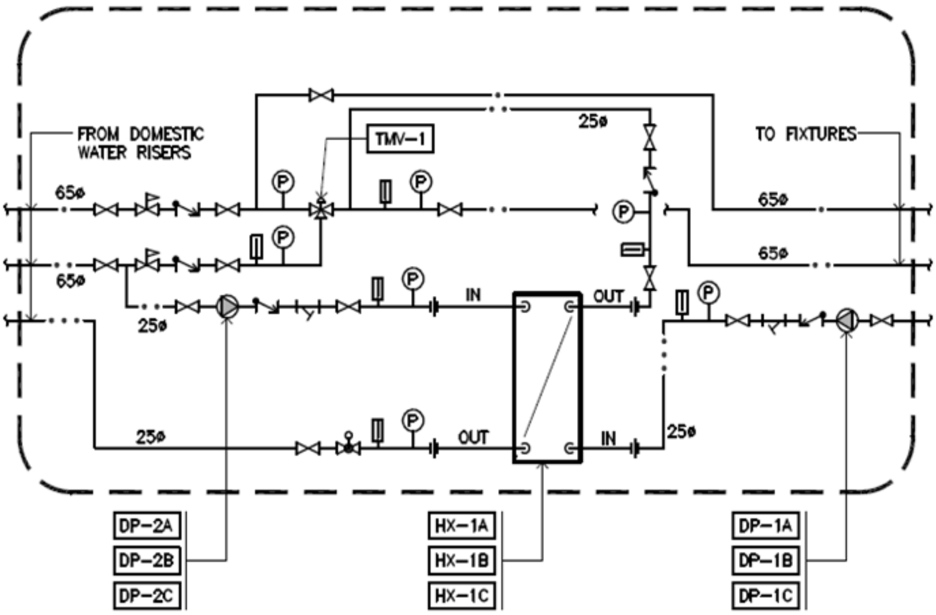
Fig. 3. World Energy Usage & Consumption [6]

3. WHY Recirculation?

The purpose of the domestic hot water recirculation lines is to maintain a minimum flow through the hot water risers at all times. This ensures that hot water is quickly available to all suites, even at times of low hot water use, like late at night.
On the other hand, hot water recirculation pumps are used in order to decrease the unnecessary throwing of cold water, which results in water and energy savings, and more convenience for the owner. Normally, recirculation pumps typically have fractional horsepower motors and run constantly.
For instance, in low rise building cases the recirculation works properly, because the circulators have to overcome friction as closed loop pumps.
In a high-rise building, the things are more complicated and complex. For example, a 27 – story high rise building will have three recirculation pumps and associated heat exchangers. (Note: A double wall plate heat exchanger is a special plate heat exchanger used for heating domestic hot water. It is virtually impossible for boiler water to contaminate the potable water because the plates are separated by air passages leading to the atmosphere. If a plate leaks for any reason, the liquid leaks out of the heat exchanger).
Water is boosted from the basement to the top of the building, and in the illustration shown in Figure 4 a, residual pressure of 275.7KPa (40psi) must be maintained; the total static pressure is 482.6KPa (76psi). This forces the water through the pressure reducing valves (PRVs) in each lower zone in order to avoid excessive pressure at the plumbing fixtures. For instance, the domestic hot water recirculation zone pumps DP-1A&1B&1C would be sized for 9GPM la 117.2KPa (17PSI), and the domestic hot water recirculation zone heat exchanger pumps DP-2A&2B&2C would be sized for 0.57L/S (9GPM) at 48.2 KPa (7PSI); the zone heat exchangers HX-1A&1B&1C is sized for a flow of 0.57L/S (9GPM) at Entering Temperature = 60°C (140°F) and Leaving Temperature = 48.8°C (120°F) (Figure 4 b).



a)



b)
Fig. 4. Proposed recirculation system
a) Capture of Domestic Water Riser Schematic, b) DHWR Zone Heat Exchanger Schematic

4. Design Phase Selection and Calculation

Bellow there is a short presentation of domestic cold water (DCW) and domestic hot water (DHW) systems design including the booster pumps [7, 8, 9, 10]:

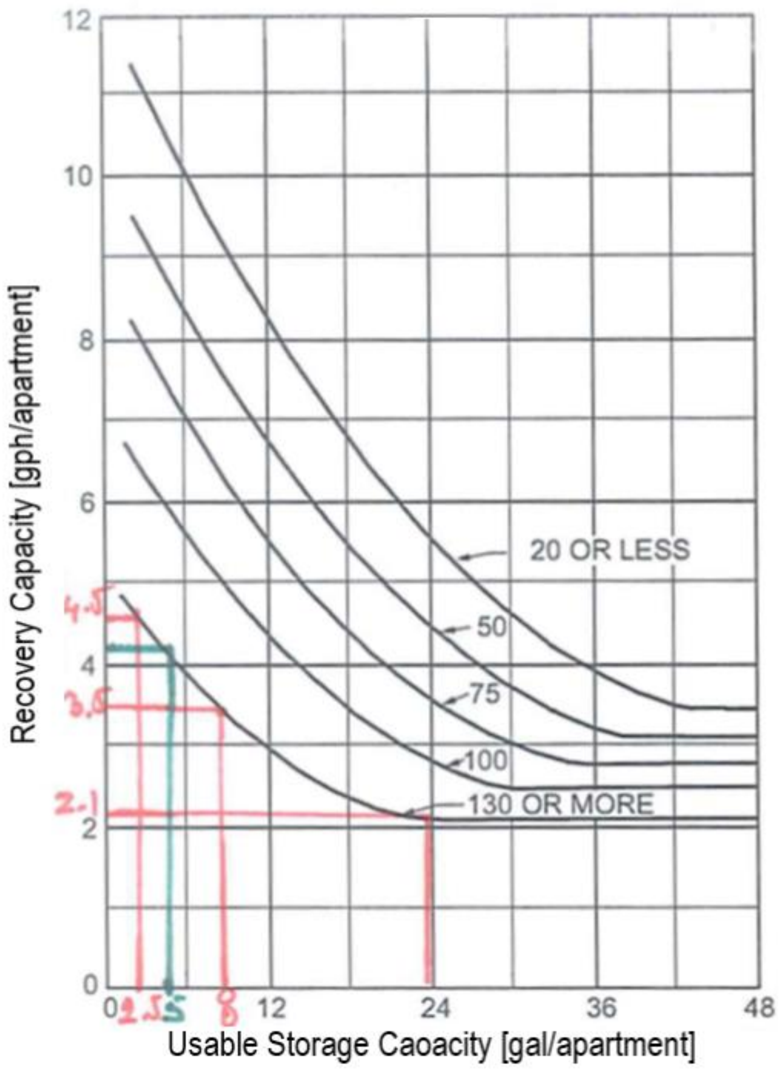
- First it was found out what specific engineering codes, standards, and regulations are applicable
- In order to determine the size for the main water entry line it was calculated the domestic water load (both hot and cold water) based on the total number of the fixture units. Having the total fixture units and using the codes and standards it can be determined the total water demand in gallons per minute (GPM) and sized the main entry domestic line.
- Being a high-rise building (i.e., 27 floors) both DCW and DHW required booster pumps. It was calculated booster pumps capacity and head loss. For DCW calculation: First, it was determined the total pressure loss, which is based on total static height of the building, residual pressure at the most remote point (i.e., 275.7KPa (40psi), piping and fitting head losses (e.g., backflow preventer head loss = 89kpa (30ft)) and the received city water pressure (i.e., 241KPa (35psi). It was sized the pipes for a velocity less than 2.4 m/s (8 fps). Next, it was calculated the flow rate: Being a building with multiple apartments (i.e., 242 apartments), the diversity factor plays an important role in determining the total flow rate. For this calculation it was used three different sources: the method Frenkel Conversion [8], and Armstrong Pressure Booster System Chart for 242 suits [9]. For DHW booster pump calculation, it was followed the same procedure. It was designed pumps complete with variable frequency drives (VFDs). The design package for both cold and hot water consisted of two pumps connected in parallel that alternate on a weekly basis (i.e., LEAD and LAG system). The system was complete with hydropneumatic pressure tanks. The tanks were located in the mechanical penthouse and their role is to keep booster pumps off during very low demand at night time.
- Because the building has 27 stories (92.96-meter height (305 feet height) the static pressure is high and the Code states that maximum static pressure at the fixtures cannot exceed 550kPa~79,77PSI (1psi=2.31ft).

In this case the building was separated in three different zones for both cold and hot water:

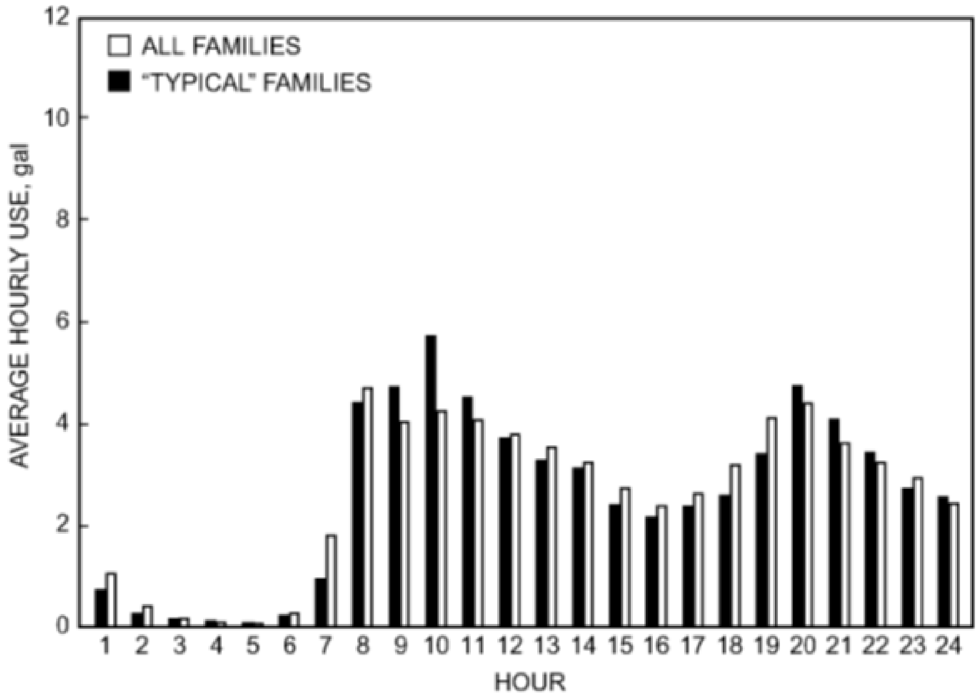
- *Zone 1*: Ground Floor to 10^{th} Floor- residual pressure 241.3 KPa (35 psi) and total static pressure 528.68 KPa (76.68psi);

- *Zone 2*: 11th Floor to 19th Floor- residual pressure 241.3 KPa (35 psi) and total static pressure 503.3KPa (73psi);
- *Zone 3*: 20th Floor to 27th Floor residual pressure 275.7KPa (40psi) and total static pressure 524KPa (76psi).

Each zone was complete with pressure reducing valves (PRVs) to avoid excessive pressures at plumbing fixtures.
The domestic hot water (DHW) was supplied by the two storage tanks via booster pumps. The domestic water storage tanks were fed from the main loop via a heat exchanger. From domestic storage water tanks, the DHW at 60°C (140ºF) is sent to the thermostatic mixing valve (TMV). The thermostatic mixing valve mixed domestic hot water (140ºF) from storage tank, with cold water 4.4°C (40ºF) from the City, and with recirculation water ~43.3 °C (~110ºF) from the building; the resulting domestic hot water that goes to the fixtures is 48.8°C (120ºF). (The send out temperature is low enough to help prevent accidental scalding; for public safety controlling temperature is very important). For DHW storage tanks calculation it was used two sources: ASHRAE Handbook - Service Water Heating - for 200 or more apartments, (Figure 5) [10], considering usable storage capacity per apartment = 30 liters/apartment (8 gallons/apartment) and recovery capacity = 13.2 liter/hour/apartment (3.5 gallons/hour/apartment) and Alfred Steel, hot water required per person= 75 liters/day (20 gal/day) [8, 9, 10].



a)



b)

Fig. 5. Diagram for DHW calculation

a) Calculation nomograms (Source: ASHRAE Handbook -Service Water Heating), b) Domestic Hot Water Profile (Source: ASHRAE Application Handbook)

6. Conclusion

As it can be seen, lower head zone pumps and smaller local heat exchangers can be used successfully. By using a low head pump instead of a high head pump it can be saved the operating cost, even though the initial cost of a small double wall plate heat exchanger and low head pump is comparable to the cost of a high head pump.

As technology advanced, we should be focusing on both efficiency and energy conservation. De-coupled recirculation provides benefits for both mentioned above.

References

[1] Tokar, A., D. Foriș, D. Tokar, and S. Popa-Albu. "Solutions for the Reuse of Rainwater in Indoor Plumbing." *Hidraulica Magazine*, no. 4 (2020): 51-58.

[2] Pantsios, A. "8 Shocking facts about water consumption", 2014. Accessed December 18, 2020. https://www.ecowatch.com.

[3] U.S. Geological Survey (USGS). "Summary of the Water Cycle." Accessed December 18, 2020. https://water.usgs.gov.

[4] World Wildlife Fund (WWF). "Freshwater: What's at stake, what we're missing, what we're losing, what it's worth." Accessed December 18, 2020. http://wwf.panda.org.

[5] Avram, N. "Hot water immediately after opening the tap by recirculating the hot water." Accessed December 17, 2020. https://www.trust-expert.ro.

[6] U.S. Department of Energy (U.S.DOE). "World Energy Usage and Consumption." Accessed December 17, 2020. https://www.energy.gov.

[7] The Authoritative Source for Plumbing, Hydronics, Fire Protection and PVF. *Plumbing Engineer* 2010 Edition, p. 60.

[8] Steele, A. *Engineered Plumbing Design 2 - Frenkel Conversion-Table - Maximum Probable Flow and Armstrong Pressure Booster System*. Miramar Publishing Company, p. 381, 1977.

[9] ***. *Armstrong Ltd. Installation and operating instructions*. Accessed December 18, 2020. https://www.pumpexpress.com.

[10] American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *ASHRAE Handbook – Fundamentals*, 2017.