2012 International Congress on Informatics, Environment, Energy and Applications-IEEA 2012
IPCSIT vol.38 (2012) © (2012) IACSIT Press, Singapore

Establishing a Hydraulic Model of Pilot Building: Living Lab Environment and Model Description

Jukka-Pekka Skön[a*], Minna M. Keinänen-Toivola[b], Mika Raatikainen[a], Markus Johansson[a] and Mikko Kolehmainen[a]

[a]University of Eastern Finland, FI-70211 Kuopio, Finland
[b]Prizztech Ltd./WANDER NordicWater and Materials Institute, FI-26100 Rauma, Finland

Abstract. World widely, demand for clean and safe potable water consumption is continuously increasing. However, there is a lack of clean potable water in several countries, as the quality of raw water is poor or there is lack of raw water. New legislation is under preparation in EU-level to diminish the used water and energy. Because of that, there is a need for saving water and energy to meet these demands. This will cause a demand of new water saving products and solutions. This further leads to new way of planning and building the whole drinking water solutions in the buildings e.g. limiting the size of pipes and having new hot water concepts. These changes in the potable water systems of buildings will also effect on technical performance, durability and hygienic safety. This paper describes preliminary results of a hydraulic model built in pilot building developed as a part of the Finnish iENV-project. The model will be utilized to research and optimize the different potable water systems; their hygienic, safety and ageing behaviors, especially in low water usage buildings.

Keywords: Hydraulic modelling; Water hammer; Water network

1. Introduction

New material solutions might lead to new innovations on potable water systems. Water and materials are in close interaction with each other. Several aspects (physical, chemical and microbial) affect on the water quality and durability of materials. Operational conditions, such as water quality, flow rate and pressure are greatly dependent on design, construction and installation process, commissioning, and maintenance of the systems. The pattern of water use (draw-off rates and their durations) varies between users and buildings. Users of the water can lower the water demand with their everyday actions. On average, 30 % of energy in a housing building disappears with warm water to drainage in Finland. When new zero-energy building technology is developed, the importance of energy committed to warm water even increases.

Water and its resources is a widely researched topic, because of its manifold effects on people's everyday life. Artificial Neural Networks (ANNs) have been applied several times to predict and forecast water resources variables [1]. Nowadays, increased interest and research on water networks and building potable water pipelines are important, because of for example water quality and leakage of water distribution systems. There has been developed a model for the detection and location of sudden bursts in water distribution networks combining both continuous monitoring of pressure and hydraulic transient computation [2]. As a good example, the durability of pipe networks is affected by water hammer phenomenon. Thus, it is useful to be aware of both historic developments and present day research and practice in the field of hydraulic transients [3]. The hydraulic power capacity and energetically maximum flows in pipes and networks has been determined in a water distribution system, which consists of distribution network and pumping station [4]. To ensure better water quality there has been created a model for optimizing the

* Corresponding author.
E-mail address: jukka-pekka.skon@uef.fi

placement of sensors in municipal water networks to detect injected contaminants [5]. Drinking water might contain residual biodegradable dissolved organic compounds which provide a primary source for the formation of a trophic chain inside the pipes. In addition, there has been proposed a model for the study of the behavior of bacterial biomasses in distribution networks [6]. The model makes use of the data supplied by the hydraulic modeling software, which can provide predictive mapping of the situation of each section of the network.

Hydraulic simulation models of water distribution network are widely and routinely used for operational investigations and network design purposes [7]. A number of simulation software packages are available that allow tailor made simulation models. Popular packages are for example EPANET (US Environmental Protection Agency), Infoworks (Wallingford software) and SynerGEE (Adventiga). These simulation software packages enable the implementation of mathematical models of water distribution networks. These simulation software's are made to simulate water distribution networks and they are not suited for building water network simulation. In this study, simulation was made using Simulink and SimHydraulics which are extensions of Matlab by Mathworks Inc.

Hydraulic modelling is a cost-effective way to research, simulate and optimize water distribution systems. This paper describes a Living lab environment where study was made and preliminary results of a hydraulic modelling in a pilot building. At this phase of research, built model describes the first and essential part of the pilot building potable water network. The modeling started from water meter and income pipeline situated in the technical room.

2. Materials and methods

2.1. Pilot building and water distribution system

Fig. 1. Technology and innovation centre Sytytin (modified from [8]).

Pilot building Sytytin (Figure 1) is a technology and innovation centre located in Rauma, Finland. The water distribution system of the building is designed for full-scale research purposes. It obtains its drinking water from the Rauman vesi, which is a local water utility. Water is surface water and it is chemically purified with a process including sedimentation, flotation, and disinfection [8].

The water distribution system has been planned and installed according to current legislation and protocols in Finland. In addition, system is a research complex consisting of pipe collectors, sampling faucets and water meter with remote and continuous water quality monitoring. These enable comparison of different pipe materials and sampling of water. The study water network system incorporates both cold and hot water pipelines. More detailed information on water distribution system can be found at Table 1.

There are different pipeline materials in different parts of the building (Figure 2). Materials used are plastic cross-linked polyethylene i.e. PEX manufactured by Uponor Ltd. and metal i.e. copper manufactured by Cupori Ltd. In addition, there are two heat exchangers in the building so the warm water within PEX and copper pipes do not mix. In the basement, there is also a multilayer pipeline for cold water.

Table 1. Details of the water distribution system.

Measuring device	**Location and number of units**	**Other details**
Pipe collector	-11 units in different parts of the building -One unit contains 5 collectors	It is a short piece of pipe connected with couplings to the system
Water meter	-Main water meter -11 before collector units -4 before sampling taps on the 2nd floor	-Equipped with remote and continuous reading
Sampling faucet	-22 before and after collector units in basement and floors 1 and 3 -4 after water meters on the 2nd floor	
Leak detector		Leakomatic Ltd.
Water treatment device		Bauer Watertechnology Ltd.

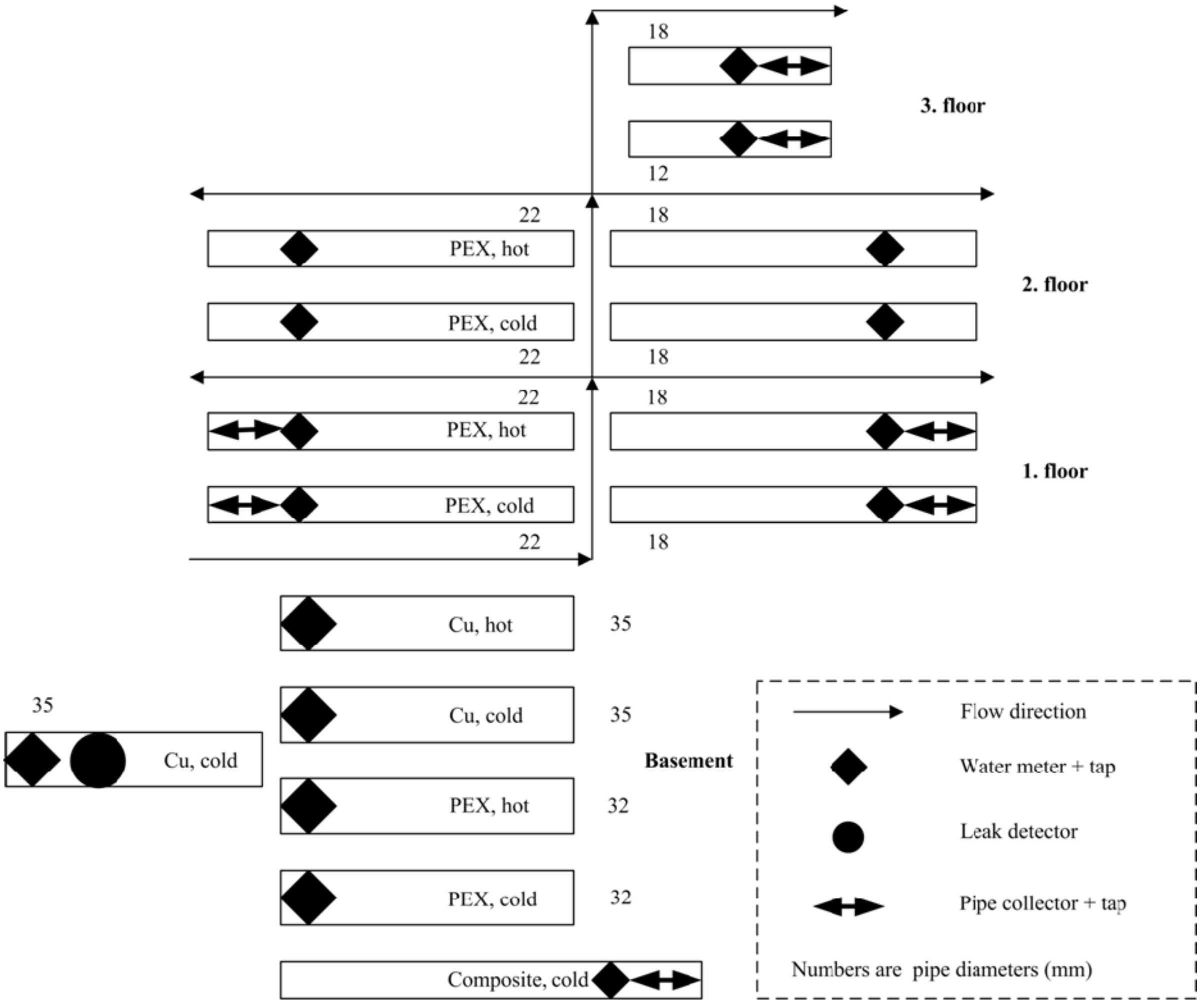

Fig. 2. Schematic diagram of the building water delivery system (modified from [8]). Three different materials have been used to construct the pipeline network; plastic cross-linked polyethene (PEX), copper (Cu) and multilayer composite.

A pipe collector is a short piece of pipe connected with couplings to the system. For studies, the pipe collector can be detached from the system and replaced with a new collector. As presented in Table 1, there are 11 pipe collector units in different parts of the building. One pipe collector unit contains 5 collectors (Figure 3). This enables to study the water quality, pipeline material dissolution and corrode for example after 1 or 2 years usage. The formation of biofilms and interaction phenomena between materials and water can be studied using pipe collectors.

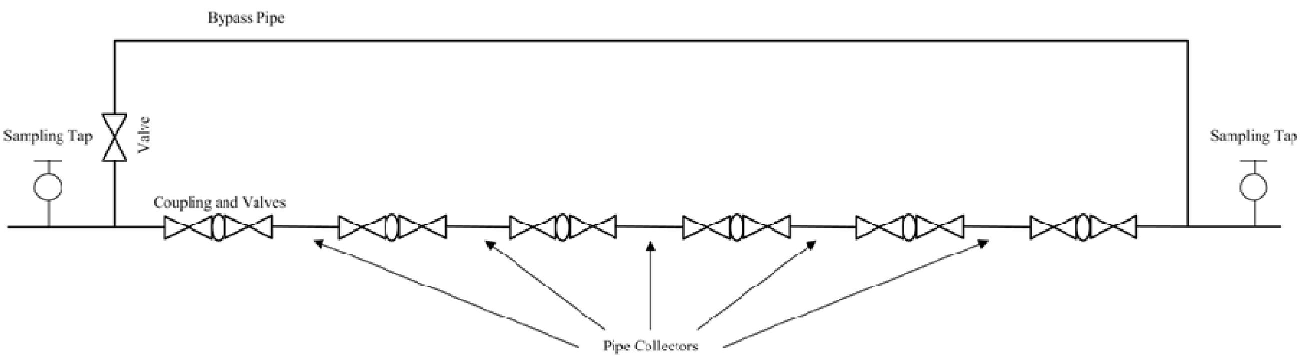

Fig. 3. A diagram of a pipe collector unit (modified from [8]). Pipe collectors enable to study water quality, pipeline material dissolution and corrode.

2.2. Hydraulic model

At this phase of research we have tested a few simulation programs. Simulation of building water network is challenging and we decided to made simulations using Simulink and SimHydraulics. Preliminary results show, that at least simple simulations can be done reliably. We have simulated water hammer caused by the usage of water tap (Figure 4). The measurement was made in Sytytin close to water tap in room 136 with Dataq Instruments, DI-718B Series.

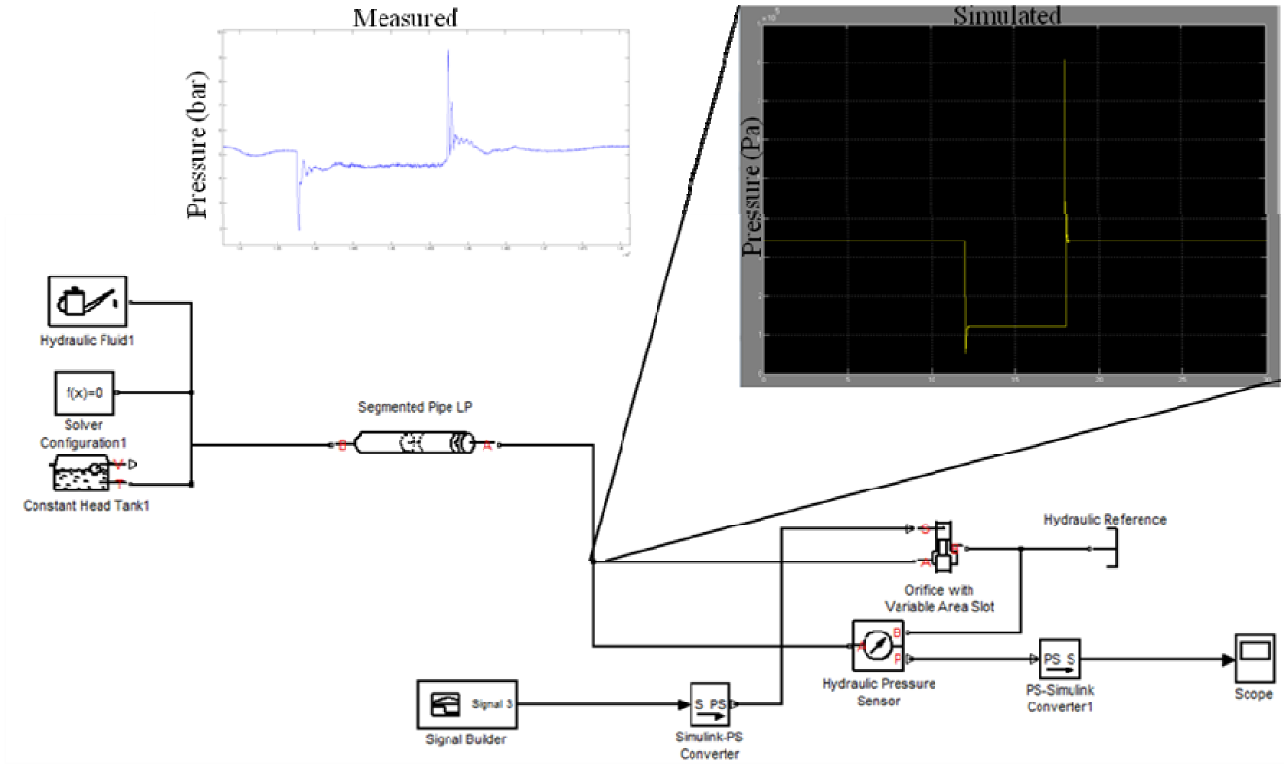

Fig. 4. An example of simulation water tap usage. Segmented Pipe LP is a copper pipe, length of 1,75 m and inner diameter 15 mm. Hydraulic fluid is 15 C water. Water network pressure is set to 5 bar. Orifice with variable area slot describes water tap and its inner diameter is set to 10 mm.

3. Preliminary results and future work

As presented in Figure 4, simulated water hammer seems to be similar to the measured values. When opening the water tap, water pressure drops to 0,5 bar and when closing the tap, water pressure rose up to 8 bars. The information generated by the model can be used for example in water tap designing.

In near future, we are going to research how decreased flow rates and water volumes effect on the potable water systems. In addition, combining information from literature and scientific results to find out the critical parameters on water quality and building technology processes in zero-energy buildings is important. Therefore, utilization of simulation models can lead to create a new computer program as a practical tool for optimizing the building water network systems.

4. Discussion

We have reached promising results with this preliminary work and at this point of research is time to make progress and model the whole water network system of the study building. Hydraulic modelling of building water network is challenging, because there is no tailor made software available and there are many open question and problems to solve. Therefore, more research and model developing are needed for further results to research and develop pipeline materials, durability and impacts of high flow rates and water hammers in different diameters and lengths of pipelines.

5. Acknowledgements

This research was done as a part of the Finnish iENV-project (USER-CENTRIC INDOOR ENVIRONMENT). For financial support, the authors would like to thank the Finnish Funding Agency for

Technology and Innovation (Tekes), and all the companies that have been involved in the iENV-project task 4: Oras Oy, Uponor Oy and Cupori Group Oy.

6. References

[1] Maier HR, Dandy GC. Neural networks for the prediction and forecasting of water resources variables: a review of modelling issues and applications. Environmental Modelling & Software 2000;Vol. 15:101-124.

[2] Misiunas D, Lambert MF, Simpson AR, Olsson, G. Burst detection and location in water distribution systems. Water Science and Technology:Water Supply, Vol. 5:71–80.

[3] Gridaoui MS, Zhao M, McInnis DA, Axworthy DH. A Review of Water Hammer Theory and Practice. Applied Mechanics Reviews 2005;Vol. 58:49-76.

[4] Vaabel J, Ainola L, Koppel T. Hydraulic Power Analysis for Determination of Characteristics of a Water Distribution System. Proceedings of the 8th Annual Water Distribution Systems Analysis Symposium 2006.

[5] Berry JW, Fleicher L, Hart WE, Phillips CA, Watson J-P. Sensor Placement in Municipal Water Networks. Journal of Water Resources Planning and Management 2005;Vol. 131:237-243.

[6] Dukan S, Levi Y, Piriou P, Guyon F, Villon P. Dynamic Modelling of Bacterial Growth in Drinking Water Networks. Wat. Res. 1996;Vol. 30:1991-2002.

[7] Machell J, Mounce SR, Boxall JB. Online modelling of water distribution systems: a UK case study. Drinking Water Engineering and Science 2010; 3:21-27.

[8] WANDER Nordic Water and Material Institute. Web page. Can be found at: www.prizz.fi/wanderwater.