Energy saving in high rise buildings

Optimization of energy consumption in booster systems

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1 Introduction

1.1 Purpose

The purpose of this document is to shed light on the amount of energy consumed to supply drinking water in new and existing residential high rise buildings. This is done by taking a look at the different types of plumbing systems used to supply drinking water to individual apartments, the different configurations offered for high-pressure systems and the impact of high-efficiency motors. This information can be used to give architects, advisers, engineers and end users objective advice on optimizing the amount of energy consumed to supply drinking water.

1.2 Structure

This chapter first describes the different systems that are available and then describes the different booster systems.

2 Energy consumed by the system

2.1 Energy

Energy is needed to transport water at a certain pressure. Single homes generally have enough energy to transport water from the mains to the tap points. high rise buildings on the other hand do not have enough energy to transport water to the top floors. This chapter talks about using a booster system to supply water in high rise buildings based on the assumption that the lowest floors (low pressure) are not connected to the booster system.

There is an energy relationship between the amount of water and the pressure needed for a building. The more tap points and the higher the building, the more energy is needed.

The amount of energy needed is the product of pressure and capacity:

$P\ [W] = Q\ [m^3/s] * p\ [Pa]$

This result enables the amount of energy that is theoretically consumed to be determined providing the number of residents and the height of the building are known.

A number of different plumbing systems can be used, each of which needs a different amount of energy. The below explains the different types of systems and the initial amount of energy needed for each type.

The types are:

- Type 1 Standard
- Type 2 Parallel
- Type 3 Serial

2.1.1 Type 1 Standard

One pressure booster system (A) with a pressure reducer (B) for the medium pressure system (C). The high pressure system (D) comes directly from the booster system.

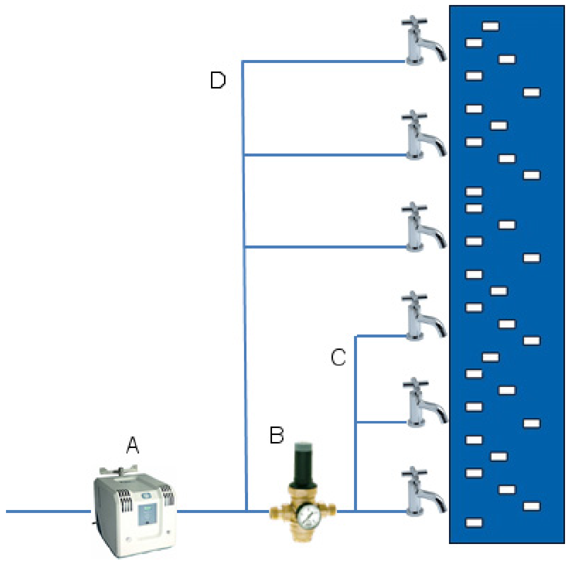


Figure 1: Type 1 Standard

2.1.2 Type 2 Parallel

Two booster systems (A + B) in one room, one for the high pressure system (D) and one for the medium pressure system (C).

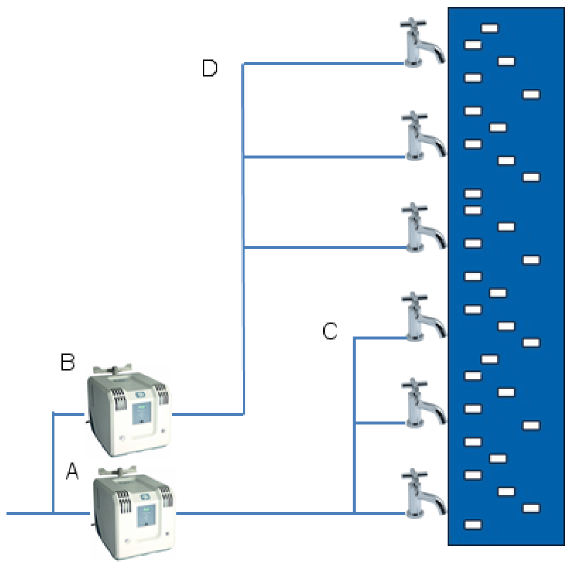


Figure 2: Type 2 Parallel

2.1.3 Type 3 Serial

Two booster systems (A + B) connected in series, one for the medium pressure system (C) and one for the upper floors (D), which are now also being fed with medium pressure. The systems are installed in series.

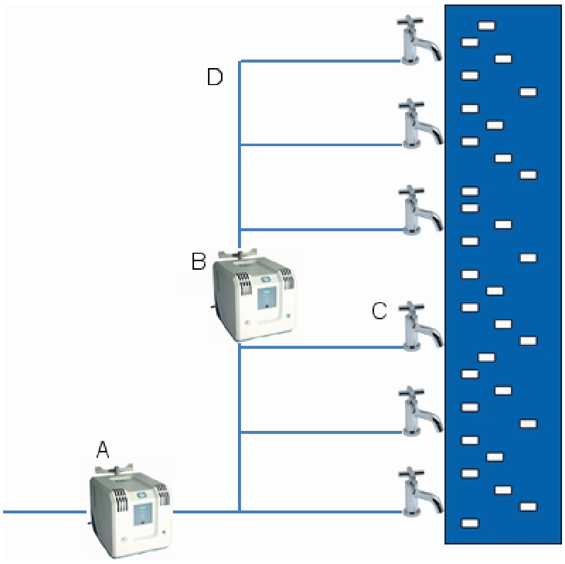


Figure 3: Type 3 Serial

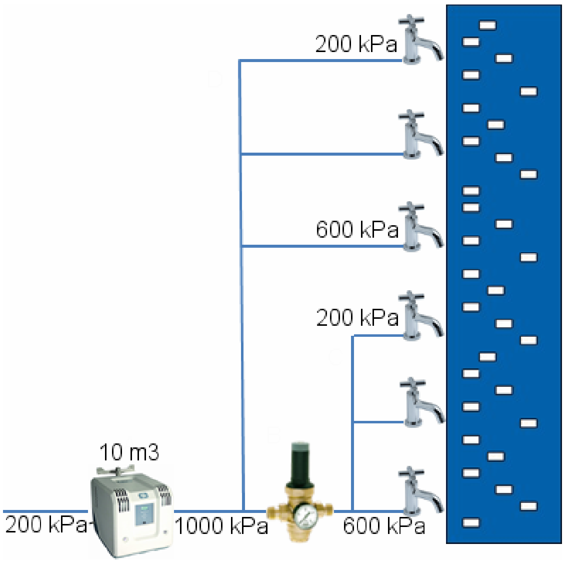
2.2 Energy calculation

The following values are used to calculate the energy that is needed (dimensionless):

Assumptions[1]	
Water consumption	10 m^3 per day
Inlet pressure at the mains:	200 kPa
Minimum pressure at the tap:	200 kPa
Height:	80 m
Medium pressure system:	0 - 40 m
High pressure system:	40 - 80 m

1. Pressure losses in the system are not taken into account

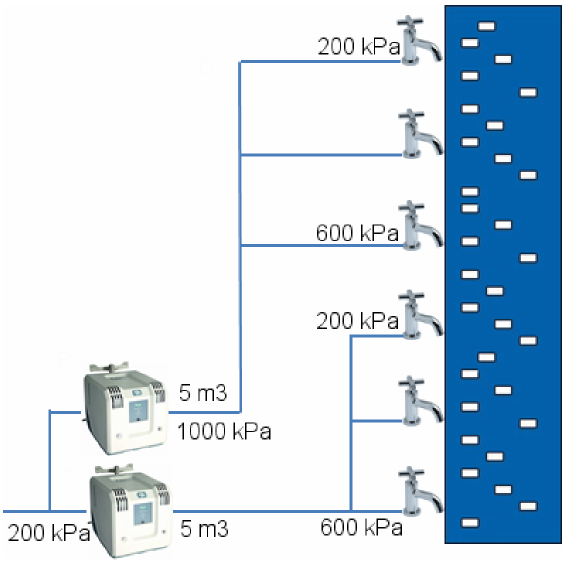
2.2.1 Type 1 Standard



Energy calculation:
Energy = Q * p
Energy = 10 * (1000-200) = 8000

The energy consumed by this system is 8000. This is set at 100% and is used as reference point.

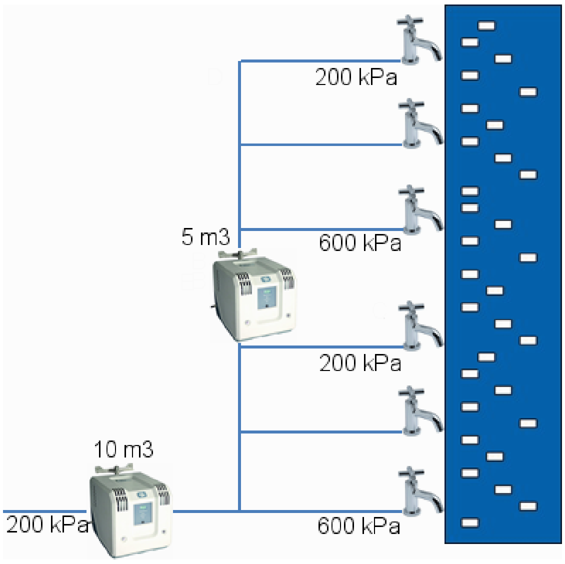
2.2.2 Type 2 Parallel



Energy calculation:
Energy = Q * p
Energy system 1 = 5 * (600-200) = 2000
Energy system 2 = 5 * (1000-200) = 4000

The energy consumed by this system is 2000 + 4000 = 6000, making it 25% more efficient than Type 1.

2.2.3 Type 3 Serial



Energy calculation:
Energy = Q * p
Energy system 1 = 10 * (600-200) = 4000
Energy system 2 = 5 * (600-200) = 2000

The energy consumed by this system is 4000 + 2000 = 6000. This is also 25% more efficient than Type 1 and equal to Type 2.

2.3 Conclusion

Savings of at least 25% can be achieved by dividing a building into two pressure zones and using two systems instead of one. Adding more zones would reduce the amount of energy consumed even further.

3 Savings on the booster system

3.1 Introduction

There are several types of pressure boosting systems that differ mainly in terms of their controls. The control intelligence affects the amount of energy consumed. In order to compare the different types of systems objectively, the different pump systems were tested at one specific location during a fixed period of time.

The systems were measured during a period of six months at Piet Heyn Staete in Amstelveen, a residential building with nine floors and ground floor and a total of 54 apartments.

Four types of booster systems were installed:

- One with on/off control without sophisticated controls (conventional)
- One with on/off control with optimized minimum run time
- One with speed control
- One with on/off control and effective overrun time by means of buffering

The first group consists of an outdated system that is still in use and is still delivered by some suppliers but not DP Pumps. Energy measurements were already done on these installations during earlier tests. The values measured during these tests are used in this document.

Group 2 and 3 consist of different configurations (different controls). The result is the average amount of energy consumed by each group.

Each system was measured over a period of 14 days. The pressure, volume and the amount of energy the system consumed were recorded and logged using a calibrated data logger.

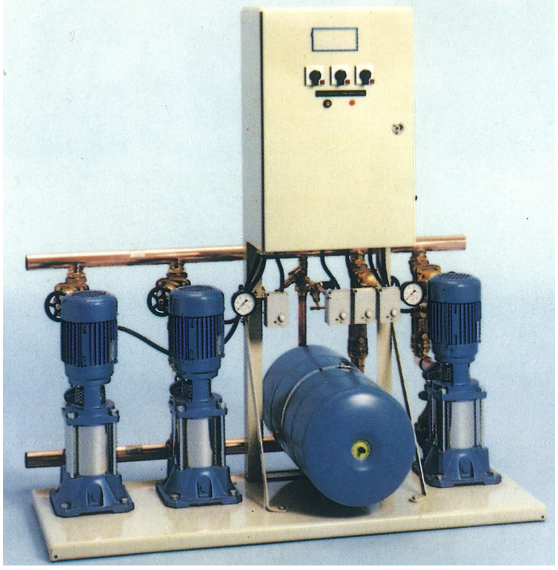
The results are presented in groups and explained in the following sections. For each group, an average is calculated that represents the amount of energy the respective type of system consumes.

The unit of measure on which this report is based is the amount of electricity consumed per unit of water or kWh/ m^3. The absolute energy consumption in kWh provides little information about the aforementioned indicator because it only applies to the period in question and a specific building. Other parameters (such as pressures, duty cycle, etc.) are used to make sure the system is functioning properly and to explain the consumption. The amount of energy consumed is displayed for each group as an absolute number and a percentage at the end of each section. The percentages for the groups are shown in relation to the current standard system (Group 2: Systems with on/off control with optimized overrun).

3.2 Group 1 - Systems with on/off control without sophisticated controls

3.2.1 Description of the system

This conventional system is pressure-based and is equipped with pumps with a fixed speed and forced overrun. Once the cut-off pressure has been reached, the pumps continue running for a few minutes without moving any water in order to limit the number of changeovers per time unit (VEWIN requirement).



3.2.2 Result

Because DP Pumps no longer supplies this type of system, the only measurements that are available are from 1999. The measurements for the Type 2 system produced similar results in 1999 and 2007. This enables us to say that the results for Group 1 have not changed and explains why the results from the 1999 report are used for this type of system. The difference produced by changes in the demand pattern is negligible.

The energy consumed by system Type 1 is 0.92 kWh/m^3 (133% compared with Type 2).

3.3 Group 2 - Systems with on/off control with optimized minimum run time

3.3.1 Description of the system

This type of system is equipped with fixed-speed pumps and advanced control technology (DP-Control from DP Pumps). The control system optimizes the minimum run time by taking the actual number of switches and the maximum number of changeovers allowed per time unit into account.

Measurements were performed on the following systems:

- HU 3 DPV 4-40 DPC I[1] with accumulator tank [2] 18 litres
- HU 3 DPVE 4-40 DPC II[3] - 8 litre expansion vessel

The differences between the above systems are mainly in the controls, the pumps and the expansion vessels.

3.3.2 Result

The result of this group is the average of system 1 and 2 because the purpose of this report is to create a general overview of the types of systems that are available on the market. System 1 actually consumes 0.72 kWh/m^3 (104% compared with the group average) and System 2 consumes 0.33 kWh/m^3 (96% compared with the group average). The positive difference measured for the system in 2007 can be almost entirely attributed to the optimization of the DP-Control. The control of the minimum run time has been further optimized.

The energy consumed by this type of system is 0.69 kWh/m^3 (100%).

1. DP-Control Type 1
2. Small membrane accumulator tank to improve the system's changeover behaviour
3. DP-Control Type 2, introduced in 2007

3.4 Group 3 - Systems with speed control

3.4.1 Description of the system

This type of system is equipped with pumps with variable frequency drives. The controls optimize the minimum run time, which is also necessary for this type of system.

DP Pumps sells this system under the name Hydro-Unit FR.

Measurements were performed on the following systems:

1 HU 3 DPVE 4-40 MCF-III[4] 8 litre expansion vessel
2 HU 3 DPVE 4-40 MCMF-III[5] 8 litre expansion vessel
3 HU 3 DPVE 4-40 MCF-III; 100-litre buffer vessel, no accumulator tank
4 Booster system 3 5-5 3FO; 33-litre accumulator tank

Systems 1 to 3 are made by DP Pumps. System 4 is a speed-controlled system by a different manufacturer. Each pump in this system has an integrated frequency converter instead of speed controls in the control panel.

3.4.2 Result

Frequency control saves energy because the required motor power is cubical to the speed.

ATTENTION
A small reduction in speed can save a large amount of energy.

4. Megacontrol Type 3, introduced in 2007; one central converter
5. Megacontrol Type 3, one converter for each pump

System 3 is equipped with a buffer vessel that was connected to get an impression of the effect it would have on a speed-controlled system. Because the system does not belong to this group, it was not included in the average. System 3 provides an indication of the energy benefits that apply to a 100-litre accumulator tank compared with an 8-litre expansion vessel. The study did not produce any indication that systems with only one converter per system are more energy efficient. Theoretically, they should be more efficient because a frequency converter also consumes energy (some 10% under normal load). The detailed consumption per system is displayed below. The percentage relates to standard Group 2:

System	kWh/m^3
HU3 DPVE4-40 MCF, 8-litre expansion vessel	0.48 (70%)
HU3 DPVE4-40 MCMF, 8-litre expansion vessel	0.52 (75%)
HU3 DPVE4-40 MCF, 100-litre buffer vessel	0.35 (51%)
DVH C3 5-5 3FO, 33-litre accumulator tank	0.57 (83%)

3.4.3 Dynamic control compared with step wise speed control

The relatively poor consumption of the system by a different manufacturer is entirely attributed to the dynamic control. The frequency converters for this system are controlled dynamically: The speed of several pumps is adjusted at the same time. The advantage of this control is that it is fast, stable and shock free. The disadvantage is that more pumps are running than with stepwise control.

With step wise control, the first pump is utilized from 0 to 100%. The second pump is not switched on until the first one reaches 100%. Even if several pumps are running, the system is controlled by only one pump. The advantage is that a pump is fairly quickly switched off. DP Pumps believes that step wise control is the most efficient for residential buildings. Dynamic control is more suitable for industrial processes or situations with a quickly changing flow rate and in which a constant working pressure is desired or even required.

Another important feature is that the system made by DP Pumps switches off when there is no demand rather than at a specific time as other makes do.

The energy consumed by this type of system is 0.52 kWh/m^3 (76%).

3.5 Group 4 - Systems with on/off control and effective overrun control through buffering

3.5.1 Description of the system

This type of system is equipped with pumps with a fixed speed and a 100-litre buffer vessel. The buffer vessel is filled with water during the forced overrun time. DP Pumps sells this system under the name Hydro-Unit HR. The following system was measured:

1 HU 3 DPVE 4-40 DPC-II equipped with 100-litre buffer vessel and WSD

The hysteresis was increased from 30 kPa to 50 kPa. This does not have any energy benefits but it does enable a smaller buffer vessel to be used because the useful content of the tank is increased.

3.5.2 Result

At 0.26 kWh/m^3, this system consumes the lowest amount of energy of all four systems. The measurements show that the system only runs one-third of the time compared with the standard group (Group 2) because of buffering during the overrun time.

ATTENTION
Tax benefits and the energy savings achieved by of this type of system incited SenterNovem, the Dutch government agency for sustainability and innovation, to include buffer vessels on the list of energy investment deductions (EIA). This means that the purchase price of the buffer vessel can be deducted from the profit.

The energy consumed by this type of system is 0.26 kWh/m^3 (38%).

3.6 Savings

The measurements, combined with national water demand averages and the composition of households, make it possible to estimate the energy consumption in high rise buildings with different configurations. The calculation is based on a standard inlet pressure of 200 kPa. The inlet pressure will have a negative effect on the energy savings in high rise buildings with a limited number of residential layers but a positive effect in high rise buildings with many residential levels. The measurements can be used to estimate the energy savings for Group 4 (Hydro-Unit HR). The data are displayed in the below table.

Table 1: Annual savings

Annual energy savings Hydro-Unit HR in compared with the standard system								
		>> Number of apartments						
		20	**40**	**60**	**80**	**100**	**120**	**140**
>> Number of residential floors	18	345	690	1,034	1,379	1,724	2,069	2,414
	16	303	605	908	1,210	1,513	1,816	2,118
	14	260	521	781	1,042	1,302	1,562	1,823
	12	218	436	654	873	1,091	1,309	1,527
	10	176	352	528	704	880	1,056	1,232
	8	134	267	401	535	669	802	936
	6	91	183	274	366	457	549	640

3.7 Conclusion

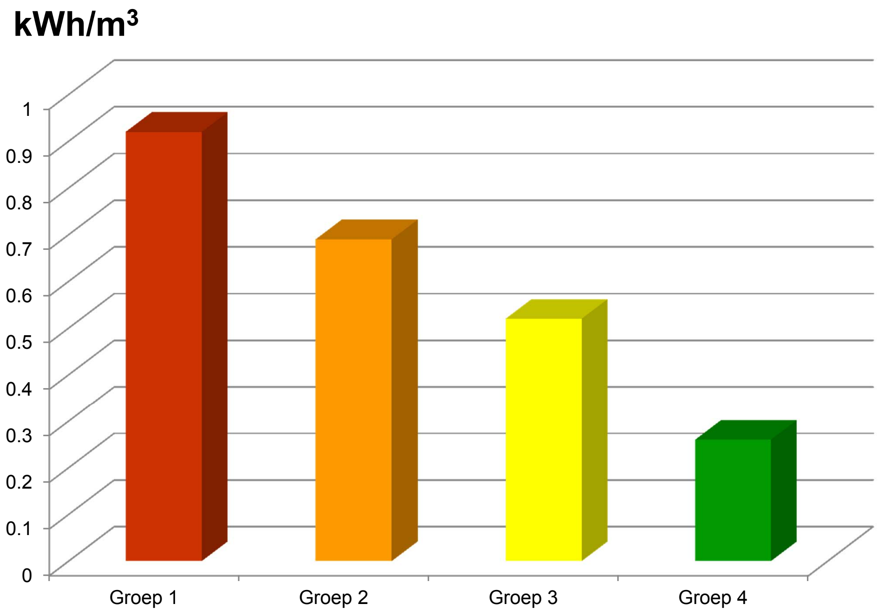


Figure 4: Energy consumed by the different groups

The above figure shows that the Hydro-Unit HR (Group 4) is the most energy efficient system for a residential building.

The explanation is pretty simple and follows from a further examination of the measurements. Systems with buffering have the smallest number of running hours per period of 24 hours by far. Buffering always moves water when a pump is running, in contrast to all other types of systems that are switched on although there is no (substantial) demand for water. In this building, the run time per period of 24 hours for systems in Group 2 and 3 is some 18-20 hours per day, and only 6 hours for systems in Group 4.

Using a speed-controlled system (Group 3) can save a lot of energy but not as much as a system with buffering (Group 4). A speed-controlled system with buffer vessel is also less efficient than a fixed-speed system with buffer vessel. This is because a speed-controlled system keeps the pressure at a constant level, does not switch off when demand is low and therefore doesn't have any buffering (except when switching off). This means that the system has a higher number of running hours.

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