ISS-EWATUS

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D2.1 The installation of sensors at urban level

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Consisting of:

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UNIWERSYTET SLASKI	US	Poland
INSTYTUT EKOLOGII TERENOW UPRZEMYSLOWIONYCH	IETU	Poland
Rejonowe Przedsiębiorstwo Wodociągów i Kanalizacji w Sosnowcu Spółka Akcyjna	RPWiK	Poland
LOUGHBOROUGH UNIVERSITY	LU	United Kingdom
BRUNEL UNIVERSITY	BU	United Kingdom
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Executive summary

This deliverable is a part of Work Package **2 (WP2), which is dedicated to data acquisition and structuring**. This Work package is crucial for successful and timely performing of other work packages: **it is a base for both decision support systems at the household (WP3) and urban level (WP4)**. It is also the source of information for the social-media platform (WP5) and of course it is a part of the validation of the whole system (WP7).

The general objective of the report is to summarise the installation of sensors at urban level [page 9 of the Description of Work, DoW]. Execution of this objective is summarised in the following table.

Objective	Task	Reached (Yes/No)	Outcome
Installation of sensors at urban level	Task 2.1 Selection of sensors and their installation within Water Distribution Systems (WDS) [page 8 of the DoW]	YES	In both demonstration sites: Sosnowiec in Poland and Skiathos in Greece, pressure regulation valves (PRV) were successfully installed together with the control system and data collection / transmission systems. The installations of the equipment in Poland and Greece are described in **Sections 1.5 and 2.5** respectively.

The content of the deliverable is organized as follows. In Section 1 the Polish demonstration site is described. Section 2 describes the Greek demonstration site. The installations of the equipment in Poland and Greece are described in **Sections 1.5 and 2.5,** respectively.
The final section of the document summarises all installations at the water distribution systems. Five appendices are included in the report to present details on components of the pressure regulation systems.

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Introduction

This deliverable aims to present the results of the task 2.1 that is: selection of sensors and their installation within the Water Distribution Systems (WDS) in two validation sites. These sites, one in Poland and one in Greece are characterised by two significantly different challenges. The Regional Water Supply and Sanitation Company in Sosnowiec is a modern and developing institution. It operates based on the integrated IT system that collects current data on water flow and pressure within the network and the on the water consumption. The system organizes the maintenance works, failures removal, scheduling of the car fleets, billing etc. Thanks to such a well-developed information system, the water losses decreased recently to about 9%. However, due to very low water losses and the very efficient, automatic monitoring the further optimisation seems to be very difficult to obtain. Therefore, Polish partners together with the water company representatives had to elaborate the solution that gives the chance of the improvement and is the integral part of the existing system. As the result of the consultations, the list of necessary equipment was prepared, it included: the pressure reduction valve (PRV), the electronic driver, the water meter, the Cello recorder and workstation software. The installed equipment will allow for a better management of potable water and an automatic control of pressure within the water network. The installation has been successfully performed in one selected water district without delay.

In turn, the Municipal Company for Water Supply and Sewerage in Skiathos is very old and poorly maintained. The water losses are very high up to 46% and tend to increase. So, theoretically any new monitoring and controlling devices may bring the benefits and reduce the water loses. The selected equipment included: downstream pressure reducing stabilizing valves, an electronic pressure regulation valve controller, a data logging and control software, 3 compact SMS/GPRS pressure and flow data loggers and 3 piezoelectric pressure sensors. It has to be mentioned that the installation of the new equipment in Skiathos was more complex than in Poland, due to many factors, such as the general, bad conditions of the water network, problems with the transportation of the devices, bigger size of the study area etc. Despite

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multiple unpredicted obstacles the equipment has been successfully implemented in April 2015.

State of the Art

Currently, cities have to deal with a series of challenges concerning water and energy resources depletion and following side effects such as the raise of emissions and the effects of climate change. Municipalities suffers a common problem of scarce water resources leading to increasing demand in energy for reaching more and more inaccessible water. Inextricably linked to this issue is the ageing and deteriorating urban water supply infrastructure with increasing bursts and extended leakages (Figure 1). Pressure in water distribution systems (WDS) is usually kept constant and lumped and is not adjusted temporally and spatially according to water demand; this reinforcing even more bursts due to constant unneeded tensile stress and leading to energy overconsumption. Smart pressure management and optimized operation based on smart algorithms, network intelligence and the installation of pressure and flow sensors throughout the network can significantly improve operations, save water and energy and successfully follow the new trends in cities (Laspidou, 2014). A powerful tool for minimizing background leaks through optimal and precise network pressure management is realized through the following: (i) Information and Communications Technologies (ICTs) solutions with flow and pressure sensors in the network providing online visibility and network intelligence, and (ii) remote control of valves based on automatic pressure optimization algorithms. Various research works have investigated the potentials of using pressure reducing valves (PRVs) in combination to real time monitoring and ICTs.

A recent approach (Jalalkamali and Jalalkamali, 2011) for estimating leakage rate in Water Distribution Network Systems (WDNSs) and investigating the complex relation between leakage rate and pressure, involved a hybrid Artificial Neural Network (ANN) – Genetic Algorithm (GA) model aiming to understand the complex concepts related to the field of hydraulic. The GA was used to determine the number of neurons in the hidden layer of the ANNs. The model showed excellent fitting of simulated and measured leakage rates for the case study of the

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WDS in Kerman province, Iran. A 2011 research work by Skworcow and Ulanicki suggested an active identification procedure for unreported pipe burst detection in WDSs. New suitable bursts indicators were proposed considered to be more resilient to modeling errors and to inaccurate reading of the pressure logger elevation.

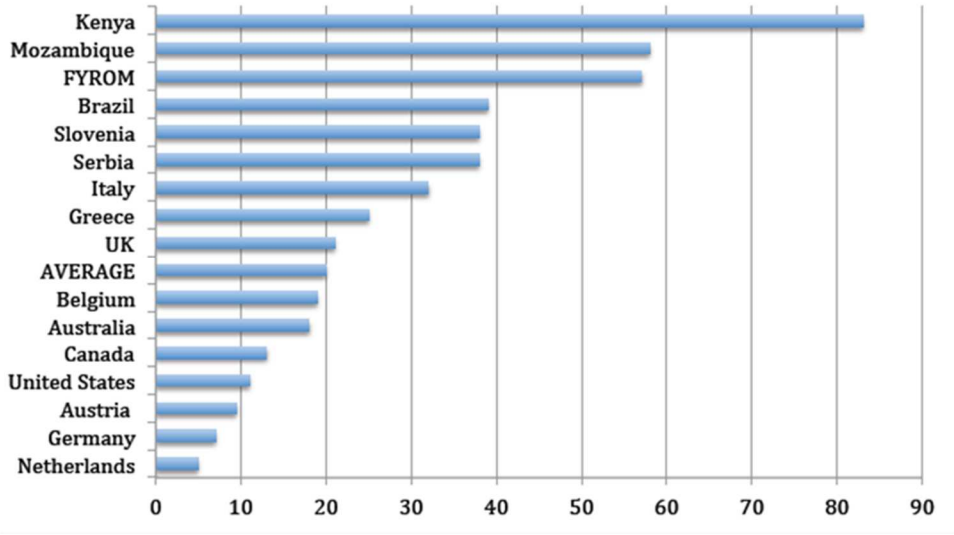

Figure 1. Leakage rate in water distribution networks world-wide. Average based on country-level leakage percentage estimates weighted by water operational expenses spending by country (data from Global Water Intelligence, 2008; available on-line at (www.globalwaterintel.com)

Panu (1990) applied numerical modelling of PRVs in (WDSs) suggesting a procedure for resolving difficulties in representing PRVs in network – analysis models. He achieved a significant reduction in computational effort with the use of modified friction factors. Prescott and Ulanicki (2008) have shown, through three case studies, examples of unwanted interaction between PRVs and transients in water networks such as sustained or slowly decaying oscillation and large pressure overshoot and proposed a proportional-integral-derivative (PID) control mechanism to significantly improve the network response. Abdel Meguid and Ulanicki (2010) used genetic algorithms to derive the optimal coefficients of a second order relationship between the flow and the outlet pressure for a PRV. The results were compared with a time schedule approach using a non-linear programming method (Ulanicki et al., 2008). Both techniques performed equally well indicating that the leakage in that particular case study could be reduced by up to 20%.

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Ulanicki et al. (2000) investigated two online pressure control strategies, predictive control and feedback control with many PRVs and many target points. They justified that the idea of a control model is very powerful and it enables a universal control system to be created that will work for any water network. The simulation studies confirmed that the predictive and feedback control strategies allow for achieving leakage reduction close to that predicted by optimal planning studies, i.e., 50% of the original leakage level. Another research work on reducing leakage via pressure management was conducted by Nazif et al. (2010) concerning a case study of a northwest part of Tehran Metropolitan, Iran. A Genetic Algorithm (GA) was used to optimize hourly water level variations in a storage tank in different seasons so as to minimize leakages. The constraints in the optimization were linked to resiliency and failure indices of the WDS. The proposed methodology resulted in a more than 30% yearly average leakage reduction. Yates and MacDonald (2007) applied pressure management via flow modulation and documented its benefits. Ulanicki et al. (2008) investigated pressure control in District Metering Areas (DMAs) with boundary and internal pressure PRVs, sharing experience from the Process Control-Water Software Systems group which was involved in many pressure control projects and the Neptune project (www.neptune.ac.uk) and presenting a fast and efficient method to calculate the optimal time schedules and flow modulation curves for the boundary and internal PRVs in order to minimize leakages in a WDS. Through this work the benefits of spatial pressure control are highlighted through two DMA case studies, in Yorkshire and in North Yorkshire, UK.

Tricarico et al. (2014) investigated the conflicting targets in WDS, characterized by significant variation in elevation, of pumping water to higher levels and reducing excess pressure. They suggested strategically located in the network Pumps operating As turbines (PATs). They demonstrated their methodology on the trunk mains model of the Sorrento Peninsula, Italy using PATs for energy recovery, resulted in clear economic benefit and leakage reduction.

Laspidou (2014), concluding, points out the potential of making WDS pressure control, leakage detection, leakage rate estimation and other involved modules fully automatic, through a combination of ICTs, developed algorithms, real time monitoring and short-term forecasting. **Providing the reliable and most up-to-date information regarding flow, pressure and water demand can be the key to the efficient water supply management through the**

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data-driven decision support systems. Frequent and detailed monitoring allows for the quick identification of leaks and for the adjustment of pressure to the water demands.

1. The case study in Poland

Study area is situated in Sosnowiec, southern Poland. The city is located in the Upper Silesian Industrial Region and is a part of Upper Silesian metropolitan area populated by about 5,294,000 people. The population of the city is about 220,000 (2012) (CSO, 2012). Sosnowiec is located about 10 km east of Katowice which is the capital city of the Silesian Voivodship.

1.1 Characterisation of the Polish study area

At the beginning of the 20th century, so just after obtaining city rights, potable water supply system did not exist. In 1928 the Ulen&Co company started to construct the water supply system, which was over 32 km long. Ulen&Co was not a random contractor, since 1924, the company began to work on ten water and sewer projects in Polish cities (ePiotrkow, 2008). In 1930, the first water supply and sanitation company in Sosnowiec was launched. After the World War II the length of the water distribution system was 59 km, however water was distributed only to households located in the city centre and to factories. That is why in 1946 new sections providing new districts with water were built. Until 1990 only steel pipes were used, but due to its breakability and inflexibility, the water company decided to exchange them to PVC and PE pipes. It is ongoing process and both the city and the company share the cost of the modernisation. The demonstration site and water distribution system in Sosnowiec is provided in Figure 2.

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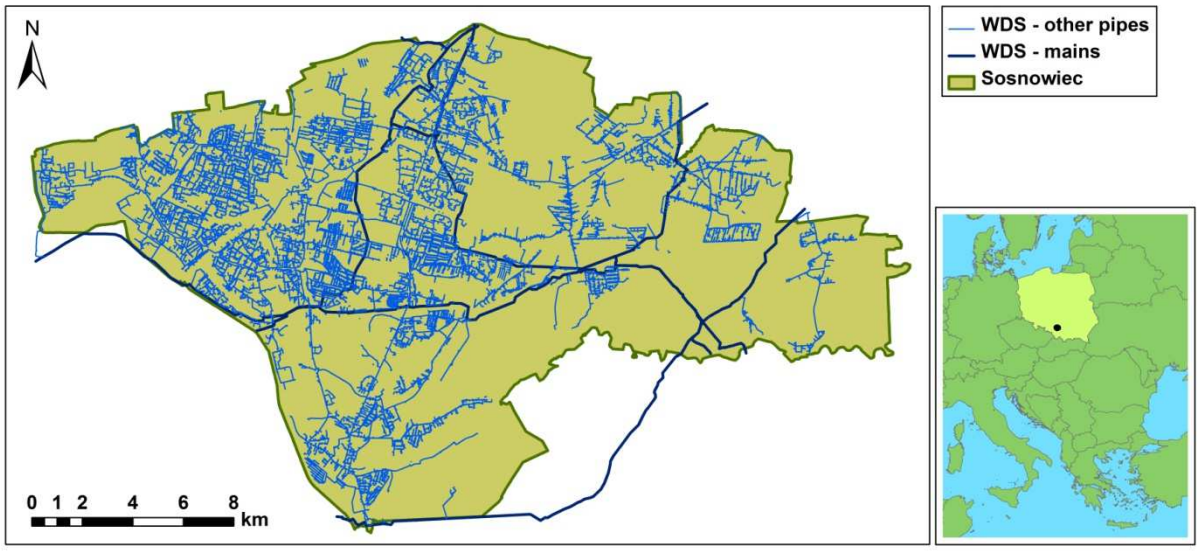

Figure 2. Location of the demonstration site and the present water distribution system in Sosnowiec (source: RPWiK)

1.2 The Regional Water Supply and Sanitation Company in Sosnowiec - basic information

The main task of the Regional Water Supply and Sanitation Company in Sosnowiec is to supply the municipality with water and a collective sewage disposal. The detailed tasks are as follows:

- Recognising and balancing needs regarding drinking water and sewage management;
- Providing continuous water supply (CWS) and sewage disposal;
- Water trading (purchasing and selling);
- Controlling of sewage quality;
- Operating devices that assure continuous water supply and sewage disposal;
- Conservation, modernisation and repairs of the infrastructure;
- Detecting the network's failures and its removal;
- Carrying out services regarding new connections to networks.

The Regional Water Supply and Sanitation Company doesn't own water intakes/sources, and drinking water is purchased from the another water company - Upper Silesian Water Supply Company GPW. Water is conveyed from three distribution points: treatment stations

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"Maczki" and "Goczałkowice" and emergency treatment station "Łazy", and is distributed by pipelines to the main and distributive networks. There are four main networks from the "Maczki" station (ø 800 and 600) and one main network from the "Goczałkowice" station (ø 1400).

In 2014 the total length of the water distribution system was 580 km, including supply distribution network (ø 50 – 600), network connections (ø 32 – 100) and leased sections.

Pipelines are built of polyethylene (PE) – 54%, steel -24%, cast iron – 20% and polyvinyl chloride (PVC) – 1%. The water distribution network has two pressure zones; urban and the zone of pumping stations. In 2014 the company owned 24 pumping stations that pump water to high-rise blocks of flats (usually higher than 4 floors).

In order to reduce water losses the company continuously monitors conditions within the network by means of devices installed at 44 purchase wells and 47 local water meters. Additionally, the company controls the water distribution to particular recipients, in 2014 there were c.a. 14,000 radio-read water meters installed at households and public use institutions. The very visible effect of the monitoring is a gradual and significant reduction of water losses from nearly 32% in 2002 to 9% in 2012 (Figure 3). In additional, the failure frequency decreased noticeably; the number of breakdowns was reduced from 975 in 2004 to 253 in 2014.

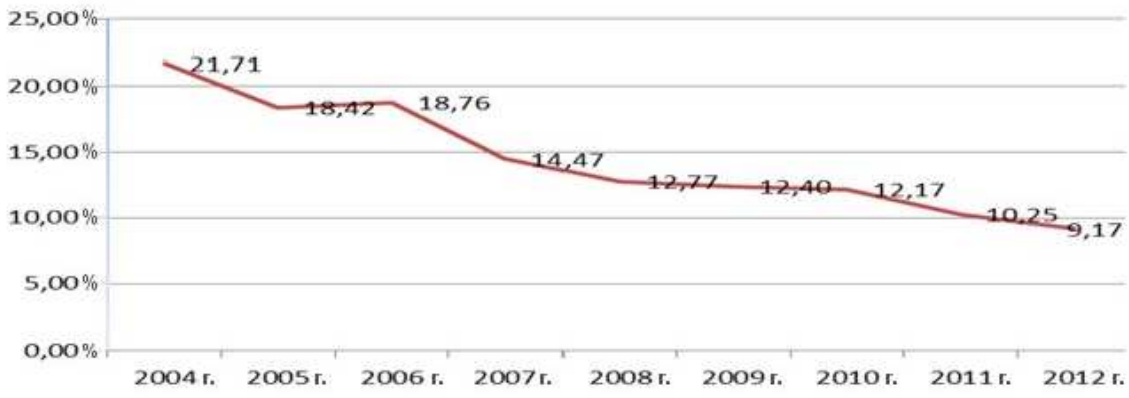

Figure 3. Water losses dynamics in Sosnowiec (source: RPWiK Sosnowiec (Jarek, 2011))

1.3 The Regional Water Supply and Sewerage Company – existing IT solutions

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Automatic monitoring of the network

The Regional Water Supply and Sanitation Company, as it was mentioned in the previous section, purchases drinking water from the Upper Silesian Water Supply Company. There are 44 purchase wells that distribute water to different districts of the city (Figure 4). Thus, each zone/district is usually fed only by one well and only in case of failures in the WDS or accidental water quality deterioration the water is transferred from other zone(s).It is a closed and easy to control system.

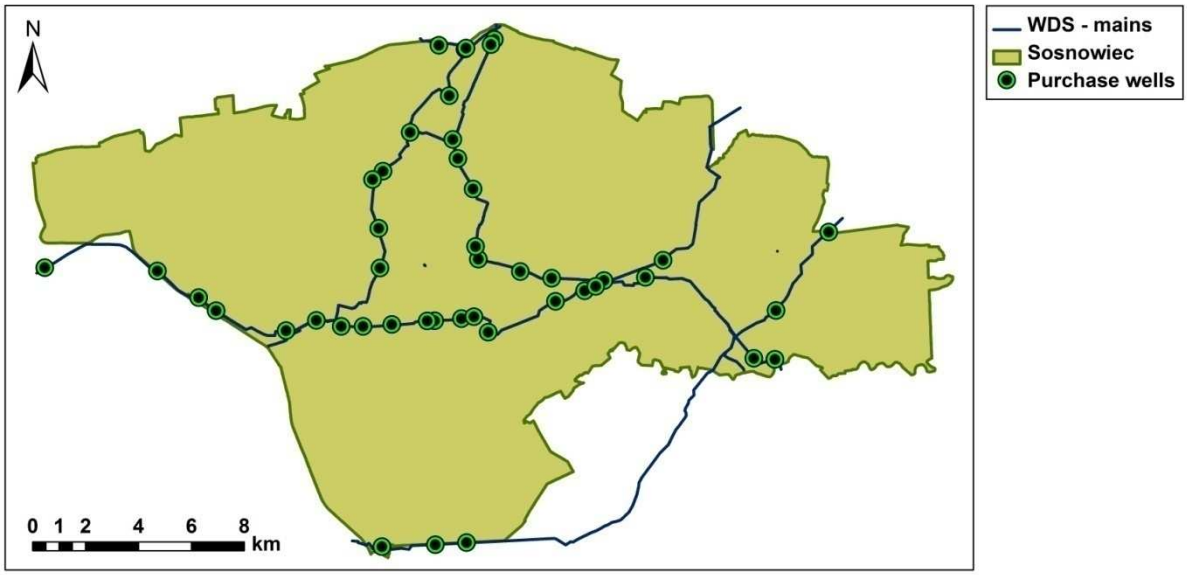

Figure 4. Location of the purchase wells and main pipes (source: RPWiK)

At the beginning of the 21st century the water losses were very high, but thanks to installed monitoring devices it has been gradually decreased. Both, water flow and pressure are continuously monitored by 44 water meters installed at purchase wells and other zonal water meters. By means of this equipment, the identification of leaks is more accurate, and the water company can easily assess the losses. Every water meter is equipped with the CELLO recorder of the TECHNOLOG company. The sensors located at purchase wells monitor pressure and flow, zone water meters measure only flow. The collected data are transmitted by GSM modem to the water company's office, subsequently analysed and archived by means of the PMAC Plus software. The latter is capable of alarming, visualisation of results and mathematical analysis. Currently, the GIS department employees are working on the application aiming

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to display pressure and flow data as GIS layers. Thus, at this moment PMAC software is a stand-alone solution and is not integrated with other IT systems.

Monitoring of pumping stations

In order to control the operation of pumping stations the solution based on GSM technology is applied. It uses short messages service to inform about the recent conditions. Data collectors (INTERA by Satel company) that are installed at the pumping stations continuously check the records, and in case of abnormal values send the alarm message to the SMS receiver which is located in the company's headquarter. The controller uses Network GSM application that is provided by the Abratronik company to check the records. Alarm messages are generated in case of: opening the door or manhole, power cut, too high pressure, too low pressure, the pump breakdown, flooding of the room etc.

Monitoring of the cars fleet

In order to efficiently manage the cars fleet owned by the Regional Water Supply and Sanitation Company, the automated monitoring system has been implemented in 2008. The supplier of the system is the Electronic Institute ATROM. The system consists of two parts: recorders with the additional equipment that are installed in cars and software installed in PCs at head office in Sosnowiec. In all vehicles GPS 6600TXD recorders were installed. Additionally, each vehicle has been equipped with the sensor of fuel level, driver's identifier and GPS satellite receiver that enables the determination of vehicle's position and its speed and route.

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Billing system

The Water Supply and Sanitation Company in Sosnowiec has a very advance monitoring of the municipal water consumption. In 2014 there was c.a. 14000 radio-read water meters. These appliances are designed for the remote reading using the communication Cyble module. The latter uses the two-way data transmission. The supplier of this system is the ITRON company. The system may be also retrofitted with the module Pulse RF and pulse generators Cyble Sensor. The pulse module can be used in places with difficult access wherein the traditional radio module cannot work properly due to insufficient range of a signal or a muffled signal. The module Pulse RF can be used for reading of water meters of other brands. The records from water meters are collected by means of the drive-by method. It means that the readings are carried out by employees equipped with a PSION WorkAbout Pro terminal (Elsaco RMS Mobile software). Data from the terminal are subsequently transferred to the head office and used in Kom-Media system for preparation of water bills.

Resources management system

In order to assure the most efficient management of resources,Kom-Net system of the Asseco company has been implemented. This system is characterised by a modular architecture with three main features: supporting of maintenance staff (planning of works, removal of failures, planning of investments), keeping a full record of network facilities and GIS information system using ESRI tools. The first module enables recording and tracking of orders, works and actions performed as a routine maintenance actions or failures removal. The second part is the inventory of facilities, especially water meters and scheduling of its changes. The numerical map is prepared using ESRI technology and it's embedded in the graphical user interface (GUI) of the Kom-Net system. The map is used for the visualisation of network parts.

1.4 The water company's needs versus project's goals

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As it was stated in previous sections the Regional Water Supply and Sanitation Company in Sosnowiec is very modern and dynamically developing. During the last ten years, water losses were reduced threefold, to the level of 9%. It is very satisfactory level for the water company. The company's CEO is aware that new IT solutions are crucial for the better management of resources and monitoring of water consumption. That is why the new monitoring systems are implemented. Polish partners along with the representatives of the water company needed to elaborate the solution that will be interesting (beneficial) for the company and will facilitate achieving of project's goals. First and foremost, consortium partners kept in mind that the company relies on water supplies from the other business partner. Drinking water in Sosnowiec is distributed from dozens of purchase wells and is delivered under variable pressure settings that has to be changed manually by the employees. This procedure is based on long-term observations of water demands in the particular areas/districts and can be performed on a daily basis. Taking into consideration that the company employs very automated systems, it is the gap that can be filled. At the same time the company employees underlined that the reduction of water losses will be very hard to reach and the risk of leaks is low because the network is well maintained. Thus, as a result of multiple discussions, the decision regarding the purchase of a pressure regulating device controlled in a real-time mode by an electronic driver has been made. The new equipment has to:

- Be the integral part of the existing water distribution system, it means that the equipment "co-operates" with all elements,
- Help to achieve project's goals, i.e. the water distribution system will operate more efficiently and cost-effectively,
- Assure that water demand are met,
- Be accepted by the company's employees,
- Be affordable,
- Be more automatic than existing solutions,
- Have potential of being developed and used by the decision support system (DSS) and the water company,
- Be of high quality and provide good accuracy,
- Be easy to use by non-professionals.

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1.5. Installation of equipment in Sosnowiec

In terms of the water distribution, Sosnowiec is divided into the districts, each is fed by a different purchase well. Accordingly, these sections are usually closed for the inflow of water from other parts of the system and by that the system is more controllable and predictable. Only one district was chosen for the installation of the additional equipment (PRV) and the further implementation of the whole DSS. It was caused by limited funds and the pilot character of the installation. The study area, referred as "Kolonia Cieśle", is a residential area dominated by detached and semidetached houses. This area of Sosnowiec represents rather new part of the network. However, some parts of the infrastructure was not renovated recently and the pipelines might be fraught with failures and leaks that eventually should be detected by the new equipment. In addition, the renovation/maintenance schedule doesn't set the changes within this part of the network in the next few years. It is also worth mentioning that there is no underground infrastructure that may be an obstacle for the installation. To sum up, the area that was chosen for the installation is:

- Technically feasible (absence of underground obstacles and plans of modernisation);
- Fed by the one purchase well;
- Suitable for the prototype installation.

The University of Silesia through consultations prepared a request for proposals for the following equipment:

A. Dual-chamber pressure regulation valve,
B. Electronic driver for the pressure regulation valve,
C. Workstation software,
D. Water meter,
E. Pressure and flow sensor.

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The offer (prepared and administratively confirmed in October 2014) was settled once the company "Zlote Runo" answered for the request. The contract was signed on 4th of December 2014.

A. Dual-chamber pressure regulation valve Ray

The dual-chamber valve is built of a durable and anticorrosive material (brass and anticorrosive steel). It is resistant to cavitation and composed of minimal number of turntable parts vulnerable to damages. The chosen valve is a 'smart' device that can effectively adjust hydraulic conditions to the current demands. It means that it is activated and controlled by the current water pressure and doesn't need any external power source. It is a very cost-effective and optimal solution for the automation of industrial, public and agricultural system of water supply. It can be installed at any point within the water network under one condition of reaching the minimal water pressure. Additionally, the pressure reduction valve can be combined with the electronic drivers that can even more effectively change the pressure, adjusting it to very variable demands.

Moreover, the selected model can be controlled by the self-contained remote controller that is fixed on a required pressure value. It means that the pressure reduction valve maintains the constant outlet pressure despite the variable inlet pressure. In case of a high pressure within the network the chances that leaks will occur are also higher so keeping it at fixed value is justified for public safety reasons and at the same time water demands in critical points are also met. More details can be found in Appendix 1.

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B. Electronic driver for PRV Regulo-SMS/GPRS

The driver that cooperates and controls the pressure reduction valve:

- Enables the wireless data transmission by GSM/SMS/GPRS at user-defined time intervals;
- Represents the advance knowledge regarding water flow and pressure regulation;
- Offers different settings regarding pressure regulation;
- Is equipped with sensors that control pressure at the inlet and outlet from the valve;
- Is easy to install;
- Enables the remote regulation of data recordings and pressure;
- Is powered by an internal or external battery;
- Enables setting and configuring of threshold and profile alarms;
- Monitors in real-time the PRV's operation.

From scientific point of view most important requirements were to provide the wireless data transmission and collecting the data in a (near) real-time mode. The appliance proposed by the water company and the supplier operates in several modes and can regulate the water pressure in four different ways:

- Customizing based on user-defined time patterns (daily, weekly, seasonally);
- Regulating based on a current flow, water flow data required for the regulation is collected from a water meter installed in front of the PRV;
- Closed-loop case – outlet pressure is controlled in accordance with current data transmitted from the critical point by a flow and pressure sensor;
- Self-learning case – water pressure value sent from the data recorder is used to automatic generation of a regulation profile.

In case of driver's failure the PRV 'returns' to the basic, fixed settings that are set up by the self-contained remote controller. Thus, the risk that water demands are not met is close to zero. Furthermore, the controller recommended by professionals can detect technical problems at very early stages and alert the maintenance staff if any embedded component operates poorly. The driver/controller settings can be also modified by means of software that is

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delivered with the device. The recommended and selected controller can wirelessly send data to a PC unit by means of the attached software. Subsequently, collected data can be analysed, exported and visualised. More details about the Regulo driver can be found in Appendix 2.

C. Workstation software PMAC Plus by Technolog

Nowadays, all advanced sensors are offered with the software that provide easy-to-read access to collected data. Usually, those solutions can analyse data and visualised them in form of tables, plots or reports. The software dedicated to sensors is almost always protected by the copyright law so it cannot be modified at any stage of data collecting and processing. The protection causes that:

- Prior sending data to the dedicated server, raw data are transmitted to the stand-alone database supported by the licensed software,
- Coupling of licensed software with the newly developed software is rather impossible.

First factor can result in a small delay in obtaining data, thus measurements will be collected in a near real-time mode. The second factor means that the PRV's driver is resistant and unresponsive for any attempts of the outer control by the uncertified software. However, the recommended software (PMAC Plus) can run in the user-defined mode. The latter enables incorporating of the desired pressure patterns based on the long-term observations. The PMAC Plus is Windows-based software, and serves as a data logging system for every type of devices made by the Technolog company. It provides a continuous access to data and many user-friendly functions that help with the data management and as the result with the efficient water supply. PMAC Plus features include:

- User definable, map-based operation;
- Modular expansion;
- Remote communications;
- High-speed graphics,
- Data archiving
- Windows 98 and Windows NT support

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More details about the software can be found in the PMAC Plus manual (PMAC, undated).

D. Water meter Woltex

In order to monitor flow near the Pressure Reduction Valve the water meter has been installed, its features can be found in Appendix 3.

E. Pressure and flow Cello recorder

The Cello device that monitors both flow and pressure has been placed in the critical point (the highest point in the district) to check the pressure range in this point and eventually to have the option to control the PRV in the closed-loop manner. Cello is a family of GSM data logging devices for water applications, which has a custom designed aerial to maximize GSM signal in underground locations. It can be connected to pulse output meters and/or pressure tappings and records data at intervals between 1 second and 1 hour and is user-programmable. Cello has sophisticated alarm regimes for detecting and immediately signalling abnormal conditions. Additionally, profile alarms can be configured to follow daily data profiles. In the event of an alarm, Cello can be programmed to automatically send data more frequently.
More details regarding the installed devices can be found in Appendix 4.

Implementation of the control monitoring system in Sosnowiec

The equipment has been installed on the 25th of February at the Kolonia Ciesle district supplied by the purchasing well "Lesna" (Figures 5 and 6). Prior to the installation, the bypass manhole was prepared, it means that PRV and water meter are not directly connected to the purchase well. In case of any PRV's failure, drinking water will be delivered under pressure fixed at the purchase well. The PRV is the RAY valve 60 DN 80 by the Raphael company. Its dimension has been assessed based on the average and extreme flow condition within the selected area. The driver is the Regulo controller by the Technolog company, the water meter Woltex produced by the Itron company. The flow and pressure sensor is Cello recorder produced by the Technolog company. The software collecting data from the devices is PMAC Plus by Technolog company.

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The final choice regarding devices was double-checked by the supplier and confirmed by the head of the water distribution department in the water supply company to avoid future problems. All devices have a one year warranty. The supplier provides also the after warranty service. The representative of the supplier was present during the installation and provided the technical support for the employees of the water supply company.

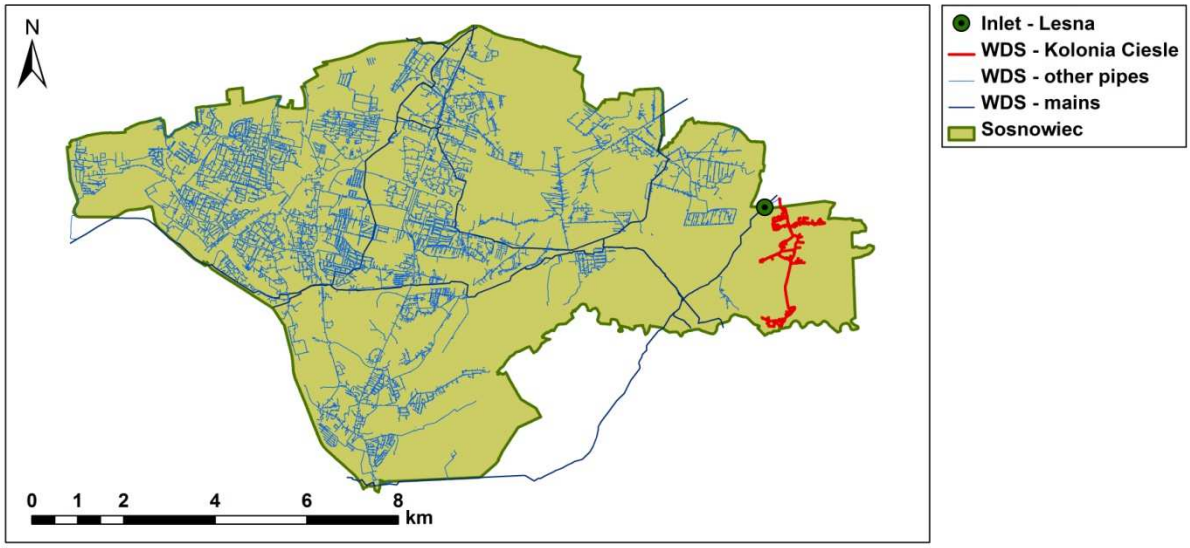

Figure 5. Sosnowiec WDS with the installation point and the urban pilot area "Kolonia Ciesle"

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Figure 6. Equipment (water meter and PRV) installed in the 'Kolonia Cieśle' district

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2. The case study in Greece

The island of Skiathos (Figure 7), which belongs to the complex of North Sporades, occupies an area of 50 km^2 and has 44 km of coastline. The higher parts of the island are located in the north-northeastern part, while the lowest in the east and southeast tip of the island. It has about 5 000 inhabitants living mainly from the tourism and agriculture. Many inhabitants leave the island in the winter and work in mainland Greece. The south side of the island has a large touristic development, while the north remains pristine and unexplored.

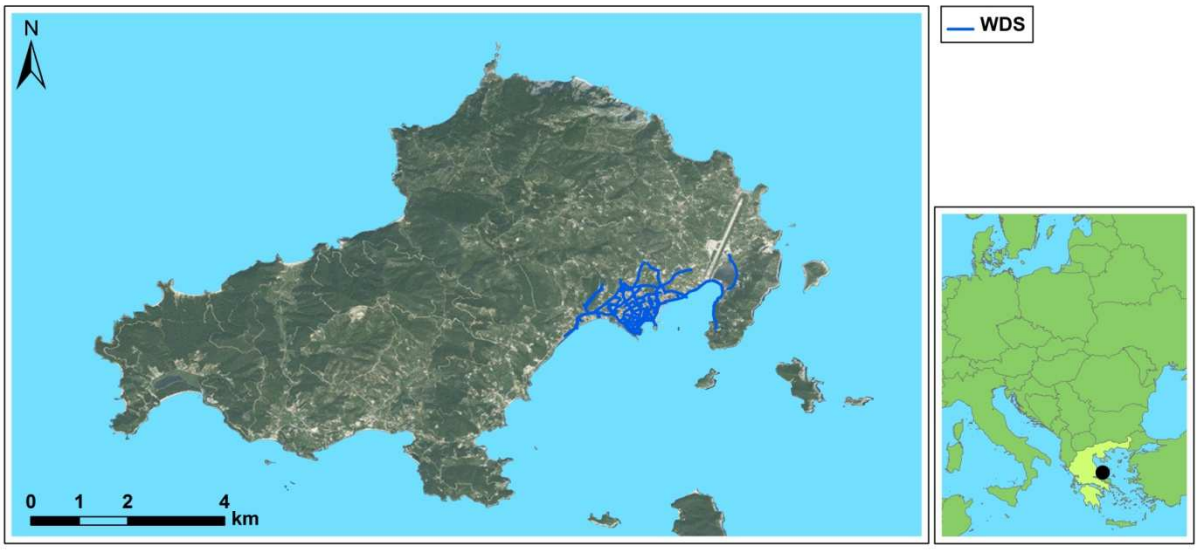

Figure 7. The island of Skiathos and the water distribution system (WDS) network (source: DEYASK)

2.1. The study area in Greece

Administratively, Skiathos consists of a single municipality with twelve settlements. The town of Skiathos, which is the only town and at the same time the capital of the island, is located in the eastern side. The town surrounds a port that has great touristic traffic. It is small, not so picturesque, since it was completely destroyed after bombardment by the Germans at the end of the Second World War and was rebuilt in haste, but with its own character, its own colour and its unique vitality. The island is characterized by relatively smooth gradients in East-northeast part, where is the biggest production area of the island and the town of Skiathos.

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Within the town of Skiathos and the east coast there are smooth slopes near the beach, in general, that become more intense in the upstream portion to the ring road, except for some hilly elevations within the settlement (Kotroni, Plakes, Ag. Nikolaos) where there are stronger slopes and higher elevations. The terrain of the area allows the water supply with gravity in most of the water distribution system. Nowadays, the water distribution system (Figure 8) is antiquated, literally crumbling and falling apart at many places, facing severe water loss problems.

Figure 8. The water network of Skiathos

The construction of the water distribution system of Skiathos and its gradual extensions have been made at different times, without previous planning and without an extensive study, or the use of a hydraulic model. Therefore, the water-supply network in Skiathos has strong non-uniformity in the layout, in the paths and in the construction materials of the main pipelines, while some of the cross sections of the existing pipeline are currently considered as insufficient for easy supply of water in future, given the population growth, which has been observed the last 20 years. Furthermore, it should be noted that there are already problems in the network due to pipeline breakage, concerning either old asbestos pipes or even younger PVC pipes, placed under the main roads that are not adequately protected by supernatant traffic loads. The adequacy of the water distribution system is in marginal levels in order to meet the needs of the summer period, while the biggest problems occur in areas with higher

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altitudes within the settlements (Kotroni, Plakes, Ag. Nikolaos). In order to tackle these severe problems of the existing network, it is being renovated and part by part it is being sealed using new materials to decrease leakages and consequently decrease the required pressure.

2.2. Municipal Enterprise for Water Supply and Sewerage of Skiathos (DEYASK) in Greece - basic information

The Municipal Enterprise for Water Supply and Sewerage of Skiathos was established in 1988 (GG 111 A /3-5-1989) and since 1991 has operated in accordance with the provisions of national law (N. 1069/80). The Company is a private legal entity and a municipal utility (special purpose vehicle according to 3463/2006 law) and is subject to rules of private economy. It is also subject to State control as provided by national law. The Public Water Supply and Sewerage Company of Skiathos is a small one, considering the number of residents (3 700 water meters) that is being serviced. However the company is obliged to operate and maintain water distribution facilities and networks because of the seasonal variation of the number of people being serviced (winter-summer). The Company is responsible of:

- design, construction, repair, maintenance, operation, administration and management of water supply systems, boreholes, reservoirs and pumping stations,
- design, construction, repair, maintenance, operation, administration and management of the drainage network and drainage, sewage pumping stations, as well as wastewater treatment plants,
- billing and bill collection for water supply and sewerage,
- regulating and the implementation of the Regulation of the operation of water distribution facilities and networks,
- surveillance of water distribution facilities and networks and implementation of the regulation of networks.

The Municipal Enterprise for Water Supply and Sewerage for Skiathos is the operator of the whole water distribution network of Skiathos. The central abstraction well is located north of Megali Ammos, at 16 m above sea level (a.s.l.) and has a total depth of approximately 16 m; that is, the bottom of the well is approximately at sea level. In the borehole, two submersible

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pumps are located with a capacity of 110 m^3/h and 70 m^3/h with manometric head of approximately 100 m. The pumps feed directly the town network through PVC pipe F225 and only any excess amount of water is transferred to the tank which offers no possibility of regulating the fluctuation of water supply, because of its small volume. In order to avoid high pressure inside the network, a pressure regulating valve has been installed on the central pipe at the output of the pump, which is adjusted manually at operating pressure of 4,8 atm in the winter and 5,2-5,5 atm during summer, due to greater water consumption. In case of malfunction or incorrect setting of that valve at higher pressures (something that has been observed in the past) severe damage on central network pipes has been caused. Additionally, the water distribution network currently faces severe problems of water losses, since the network is too old (with frequent breakages and leakages) and the pressure of the system is not rationally controlled in order to meet marginally the fluctuating water needs throughout the day. In the figure below (Figure 9) the annual water losses of the water distribution network are presented:

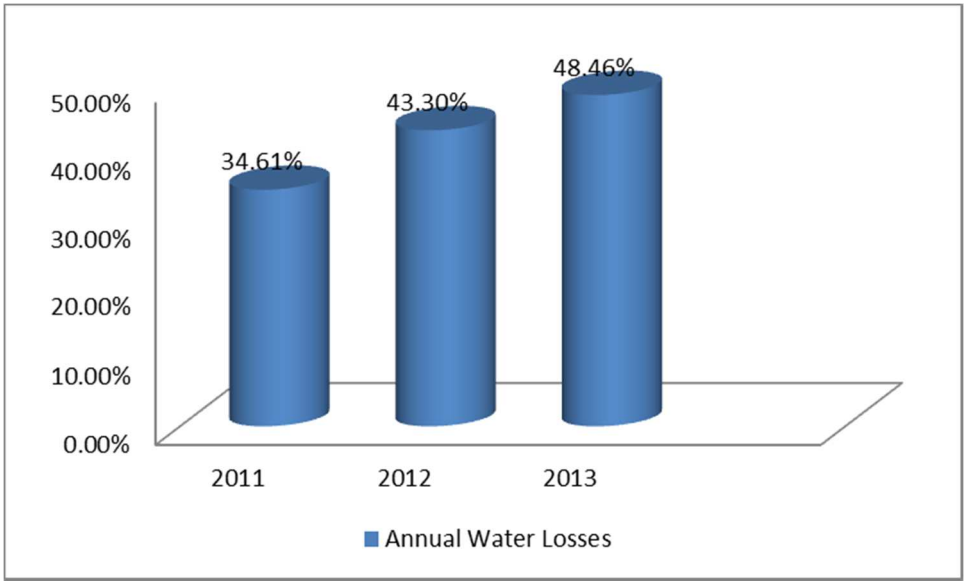

Figure 9. Annual water losses of the water distribution network.

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2.3. The Municipal Enterprise for Water Supply and Sewerage of Skiathos (DEYASK)—existing control systems

Central control/monitoring system

A central control system is installed in the building of DEYASK and ensures the continuous monitoring of all operating parameters of the water distribution system, such as:

- Tanks water levels,
- Network pressure,
- Residual chlorine,
- Instantaneous flow,
- Total flow,
- Well water level (for drillings),
- Pump operating hours.

Automatic Water disinfection

For water disinfection a chlorination device is installed with sodium hypochloride. Two dosing chlorine pumps feed the tanks with chlorine, to ensure the disinfection of water. In the pumping station of Ftelia, an automated chlorine residual measuring system is installed, upstream of the water distribution system. Chlorine residual control is being conducted on a daily basis in four other locations also, within the town agglomeration.

There is also a power generator installed, which through a switch panel can be automatically activated during power outages. Recently, in the pumping station a new electrical panel and an automation panel for the operation of pumps has been installed, in order to better automate their operation.

Control System – Setting Network Pressures

In the pumping station of Ftelia a network pressure regulator is established, as well as a system of continuous inlet pressure recording on the network. Correspondingly, continuous pressure

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recording systems are installed in the building of DEYASK, in Kotroni and Panagia. The recording system in DEYASK was installed in order to ensure the minimum pressure in the network of the town. In Kotroni (an area with strong slopes and high altitude) and in Panagia (a remote area), it was deemed necessary to install a pressure recording system, aiming at adjusting the pressure regulator of the pumping station of Ftelia, in order to continuously supply the area with the minimum water pressure.

2.4. The Company's needs vs project goals

It is obvious that DEYASK has to deal with an aged and inadequate water distribution system. The monitoring of water consumption and the management of water resources is not based on modern and 'smart' methods, such as IT solutions. Water losses, which range at high levels (48,46 % in 2013), increase over the years and significant amount of water is lost in an area with severe water scarcity issues. Renewed network infrastructures combined with IT solutions can be a powerful solution to tackle these problems. The goal of the ISS-EWATUS is the optimisation of the operation of the water distribution system, through the development of DSS at urban level.

In order to address problems of the internal water distribution system of Skiathos, while for the full modernization and renovation of the network, a number of interventions are required, while most of them are consistent with the goals of ISS-EWATUS, as it is shown below:

- Ensure sufficient network pressure on the high points of the central zone and high distant parts of the network in peak summer conditions for the next 40 years.
- Installation of remote control system of the whole aqueduct (external and internal) for easier monitoring of the functioning and the anticipation of operating problems (partially constructed).
- Automation of the operation of the central pressure regulator which adjusts pressure on the town's network, depending on the operating conditions (winter-summer, supply peaks, etc.) to avoid low or high pressures.
- Installation of adequate hydraulic components for easier operation and maintenance of the network.

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The overall design of the proposed project aims to the full satisfaction of the aforementioned needs for the next 20-40 years. At the same time, both new projects and the entire network have to be sufficient for the conditions of 40 years, although these needs cannot be satisfied by the existing abstraction source, which already shows finite potential power. Thus, additional complementary abstraction sources have to be explored and exploited for the town of Skiathos.

2.5. Installation of equipment in Skiathos water distribution system

The water distribution system in Skiathos is monitored mainly manually, the infrastructures are very old and there is absence of sensors and automated monitoring in order to manage the system in an effective way, optimize the whole system and achieve the goal of a robust water network oriented in meeting the consumers' water demands and save water at the same time. The project is very challenging because of these peculiarities; however, there is considerable scope for decreasing the networks' water losses and for protecting these valuable assets from further breakage and leakage for life. Even more importantly, ISS-EWATUS will also play an important role in saving water-resources and in alleviating the stress in this water-scarce region. Pressure control is of high priority and with the installation of automatic control valves, the water supply company will be able to manage the system pressure remotely and in an effective way. It was decided to install the necessary equipment to establish all needed conditions for a dynamic pressure management in the network of DEYASK.

The detailed offer for the equipment included:

A. Downstream pressure reducing stabilizing valves (CSA XLC 410), required to cover the full range of pressure control in the network.
B. An electronic pressure regulation valve controller (Regulo-SMS/GPRS)
C. A data logging and control software (PMAC and GSM software)
D. 3 compact SMS/GPRS pressure and flow data loggers (Cello)
E. 3 piezoelectric pressure sensors (ATM.ECO)

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A. Downstream pressure reducing stabilizing valve (CSA XLC 410)

According to the water supply measurements in the pumping station for the year 2013, the maximum and minimum historical water supply were defined, and they were 34.7 l/s (August) and 13.07 l/s (February) respectively. The following figure (Figure 10) shows the average daily flow rate in the pumping station for the year 2013.

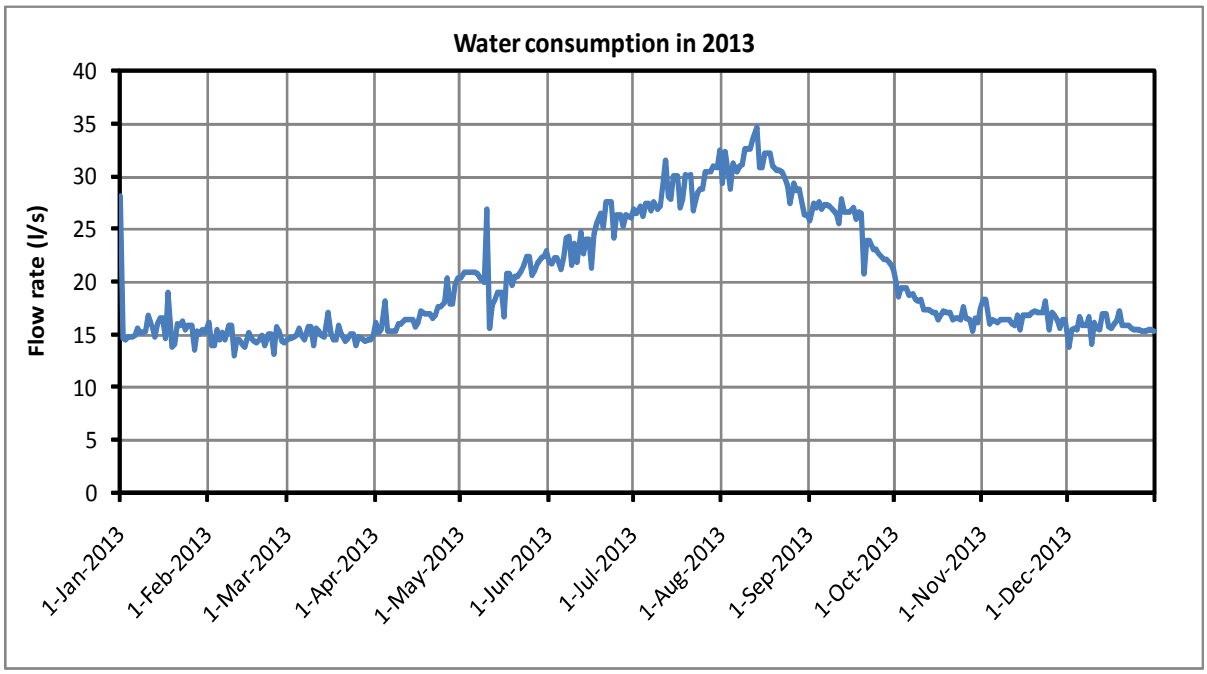

Figure 10. Average daily flow rate in the pumping station for the year 2013

However, the observed trend over the last three years is an increasing one, so it is reasonable to expect an increase in water demand over the coming years in Skiathos, which has a great potential for expansion. Skiathos Island is becoming an increasingly popular touristic and summer destination in general for Greeks and foreigners alike. In the following graph (Figure 11), the historical demand over the last 3 years indicating an upward trend can be seen. This has also been documented in demand modelling studies conducted in the framework of ISS-EWATUS, already published (Kofinas et al., 2014).

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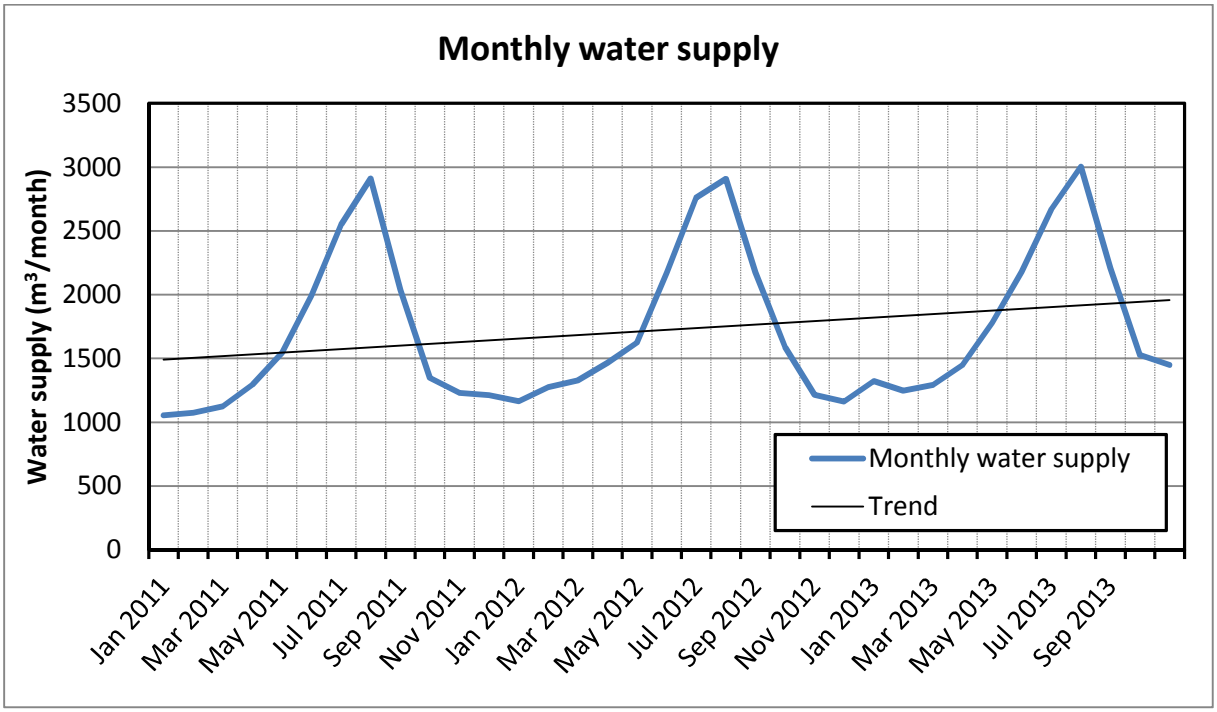

Figure 11. Historical demand over the last 3 years in Skiathos

Therefore, three main factors were taken into consideration in the PRV selection process: 1) the existing water demand with high seasonal variations, 2) increasing water demand trends and 3) anticipated reduction in leakage and flow rates resulting from the ongoing WDS modernisation and application of pressure control.

The selected downstream pressure reducing stabilizing valve type (details in Appendix 5) is the CSA XLC 410 control valve, which reduces and stabilizes the downstream pressure to a pre-set value, regardless of variations in demand and upstream pressure fluctuations. Some of the technical features and benefits are:

- Body in ductile cast iron, PN 25 bar rated, full bore globe pattern design.
- Supplied with fixed flanges according to EN 1092/2, that can be changed to suit different pressure conditions.
- Designed to reduce head loss and minimize turbulence and noise during working conditions.
- Diaphragm with reinforced nylon fabric.

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- Internal manufactured in stainless steel, obturator in ductile cast iron for large diameters.
- Maintenance can be easily performed from the top, without removing the valve from the pipe.
- Large expansion chamber to tolerate high pressure ratio.

The valve is operated by the pressurized fluid of the line and controlled by a two ways adjustable pilot in order to maintain a downstream pressure to a determined value. When the downstream pressure increase the pilot acts to reduce the passage allowing for the closure of the main valve. On the contrary, if the downstream pressure reduces, the pilot will automatically increase the passage, allowing the opening phase of the main valve, thanks to which all the perturbations are corrected without delay and the apparatus maintains the downstream pressure to a constant pre-set value.

The following table (Table 1) shows the proposed flow rates for the correct sizing of XLC 410 downstream pressure reducing stabilizing valve.

Table 1. The recommended flow rates for the correct sizing of XLC 410

Recommended flow rate

The following chart shows the recommended flow rate for the proper sizing of XLC 400 control valves.

DN (mm)	Flow rate (l/s)				
	Low head loss (0,1-0,15 bar)		Recommended		Pressure relief
	Min.	Max.	Min.	Max.	Max.
50	0,6	3,9	1,0	8,8	13
65	1,0	6,6	1,8	15	23
80	1,5	10	2,7	22	35
100	2,3	16	4,3	35	54
125	2,5	16	4,6	37	60
150	5,2	35	9,5	80	123
200	9,4	63	17	141	219
250	14	98	27	220	343
300	21	140	39	317	494
400	37	250	70	565	879

To ensure existing and expected water demand, the pressure reduction valves most appropriate to be used in Skiathos have been selected (DN125-150). The installation of PRV has been

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designed according to the required connectivity for the network (Figure 12), whereas the current setup of the pressure reduction is shown in Figure 13.

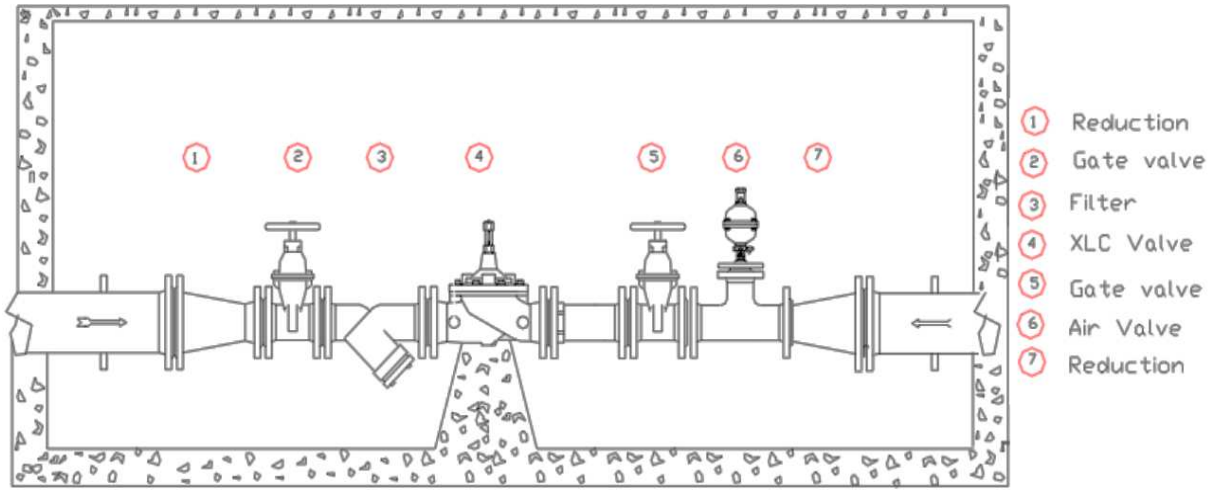

Figure 12. Required PRV connectivity for the network in Skiathos

Figure 13. Example of the current setup of the pressure reduction in Skiathos

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B. Electronic pressure regulation valve controller (Regulo-SMS/GPRS)

The description of the driver might be found in the section 1.5, part B.

C. Data logging and control software (PMAC and GSM software)

It was decided to purchase the PMAC Plus software, which is a program developed as part of a Pressure Monitoring and Control System. PMAC Plus covers a wide range of applications, from pressure control through to flow and temperature logging (see section 1.5, part C). A similarly wide range of communication systems are supported, including PSTN, GSM, Paknet and CDPD.

D. Compact SMS/GPRS pressure and flow data logger

The detailed description of this device might be found in section 1.5, part E, and Appendix 4.

E. Piezoelectric pressure control

Pressure regulation will be achieved by obtaining measurements at several critical points in the network: it is plan to use initially 3 critical points and extend it to 4 points along with the modernisation of the network (Figure 14). The points that were chosen were either the most remote ones, or the one at the highest altitude of the network (Kotroni). The director of DEYASK, Mr. Giannis Sarris, and his assistants have identified these 3 points as the most problematic ones in the network, ones that either have the lowest pressure in the network, or always have trouble maintaining the desired pressure standard for good customer service.

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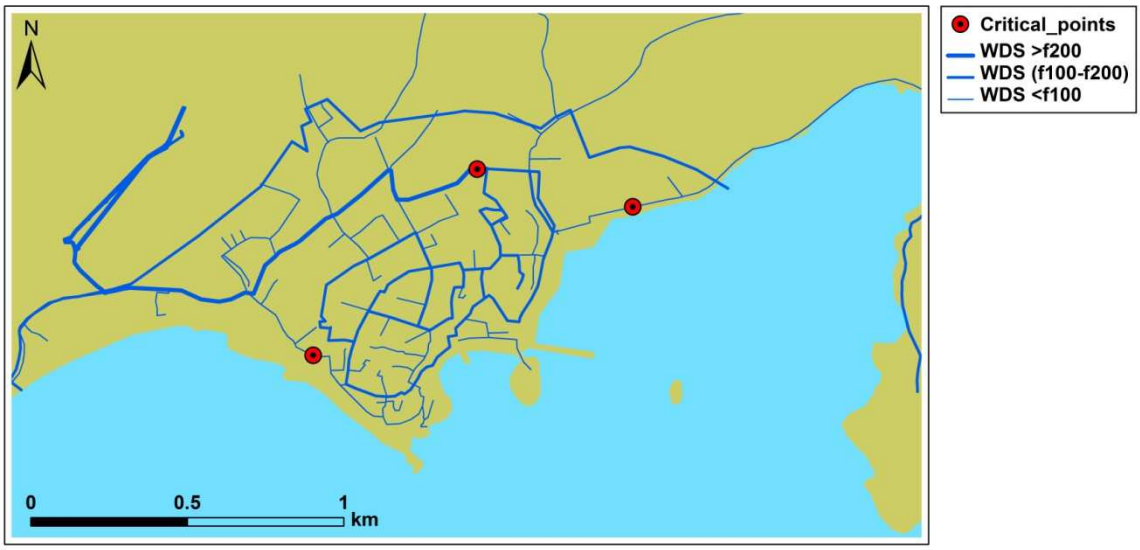

Figure 14. The 3 critical points (circled in red) where piezoelectric pressure sensors are installed

It was decided to purchase the ATM.ECO pressure transmitters for this purpose. Below (Table 2) the technical characteristics of the device are presented:

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Table 2. The technical characteristics of ATM.ECO devices

Pressure measuring range (bar)

	0.1 ... 0.5, (1)	> 0.5 ... 2	> 2 ... 100
Overpressure	3 bar	3 x FS (≥ 3 bar)	3 x FS
Burst pressure	> 200 bar	> 200 bar	> 850 bar
Accuracy, (3), (± % FS)	≤ 0.25	≤ 0.25	≤ 0.25
Total Error, (4), (± % FS)			
0...70 °C, (typ. / max.)	≤ 1.0 / 1.5	≤ 0.7 / 1.0	≤ 0.7 / 1.0
-25...100 °C, (typ. / max.)	≤ 2.0 / 2.5	≤ 1.0 / 1.5	≤ 1.0 / 1.5
Response time, (typ.)	< 1ms / 10...90% FS	< 1ms / 10...90% FS	< 1ms / 10...90% FS
Long term stability, (5)	< 0.5% FS / < 4 mbar	< 0.2% FS / < 4 mbar	< 0.1% FS / < 0.2% FS

	> 100 ... 600, (2), (3)	> 600 ... 1000
Overpressure	3 x FS (≤ 850 / ≤ 1500 bar)	1500 bar
Burst pressure	> 850 / ≤ 1500 bar	> 1500 bar
Accuracy, (3), (± % FS)	≤ 0.25	≤ 0.25
Total Error, (4), (± % FS)		
0...70 °C, (typ. / max.)	≤ 0.7 / 1.0	≤ 0.7 / 1.0
-25...100 °C, (typ. / max.)	≤ 1.0 / 1.5	≤ 1.0 / 1.5
Response time, (typ.)	< 1ms / 10...90% FS	< 1ms / 10...90% FS
Long term stability, (5)	< 0.1% FS / < 0.2% FS	< 0.1% FS / < 0.2% FS

(1) 50 mbar on request
(2) Process connection frontal and flush diaphragm available ≤ 600 bar
(3) Overpressure and burst pressure 1500 bar (stainless steel) optional
(4) Zero based accuracy according to DIN16086, incl. hysteresis and repeatability at ambient temperature
(5) Total error including accuracy and temperature influences at maximum signal span (16 mA / 10 V DC)
(6) 1 year (typ. / max.), the long term stability can be improved by aging (burn-in) the sensor

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Implementation in Skiathos

The installation of equipment has been completed by the 5th of April, with the presence and cooperation of all relative partners. The PRV (DN 150) (Appendix 5) was connected to the network at the point of its drilling (Ftelia), downstream of the tank, as it was planned and the electronic pressure regulation valve controller (Regulo-SMS/GPRS) (Appendix 2) as well. The three compact SMS/GPRS pressure and flow data loggers (Cello) (Apendix 4) and three piezoelectric pressure sensors (ATM.ECO) have been also installed at the three different critical points of the network chosen, two hilly points and one in the village, according to the instructions of the municipal water supply company of Skiathos (DEYASK) and the consultancy of Technolog and CERTH. The relative software that monitors the whole system and includes the data logging and the control software (PMAC and GSM software), is also installed. The DEYASK personnel familiarized themselves both with the equipment and the software. Furthermore dedicated to the task DEYASK-personnel have been specifically appointed to monitor constantly the system and update the relevant partners (DEYASK, CERTH) in terms of the overall functionality of the system and therefore, assuring its proper use. The installation of the equipment is presented in Figure 15. In Figure 15, it is easy to see the functioning of controller of the pressure regulation valve, the flow data loggers, the piezoelectric pressure sensors and the corresponding SMS/GPRS transmitters.

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Figure 15. Installation of pressure control and pressure monitoring equipment in 3 critical points system at Skiathos Island.

In Figure 16 a picture of the PRV installed in Skiathos is presented.

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Figure 16. The PRV installed in Skiathos, completing the installation of urban-level equipment for both case studies.

In Figure 17 a screenshot of the software that accommodates the Cello data logger is presented.

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Figure 17. A screenshot of the provided software by the Cello data logger.

The system:

- Provides administration of multiple login accounts.
- Has the functionality that, specified users are presented with a personalised Dash-board which provides immediate visualisation of sites, status, communications and performance.
- Includes the module "Analysis Viewer" which provides both tabular and geographical interfaces to display site communication status and data verification.
- Allows the creation of user definable pressure control groups.
- Provides easy graphing of sites, with options to totalise data and compare profiles.
- Gives the user the ability to do fluid and intuitive graph navigation.
- Accommodates multiple sites or channels which can be viewed on a single graph using a simple 'drag and drop' e.g. to compare minimum night flows or the effect of flow against multiple pressure points within a distribution network.
- Gives the ability to do "Automated Meter Reading" (AMR) where data can be displayed in an easy to read table.
- Modification of Cello and Regulo settings are based on user log-in permissions, includ-ing communication and transmission frequency, alarm profiles, thresholds, logging rate and scale factors.

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- Regulo advanced PRV and pump controllers may be remotely configured with new profiles or switched between different control modes i.e. Time, Flow or Closed Loop (real-time peer to peer control).
- Site data may be manually or automatically exported into other formats, including CSV, for further manipulation in spreadsheet packages.
- Fully compliant OPC Server with OPC AE (Alarm and Event) and OPC HDA (Historical Data) protocol components, recorded data and alarms can be sent to other client machines also supporting OPC AE and HDA
- Facilitates export of meter indices for billing and offline meter read analysis.

A sample of data **c**ollected by the newly installed system is presented in Figure 18.

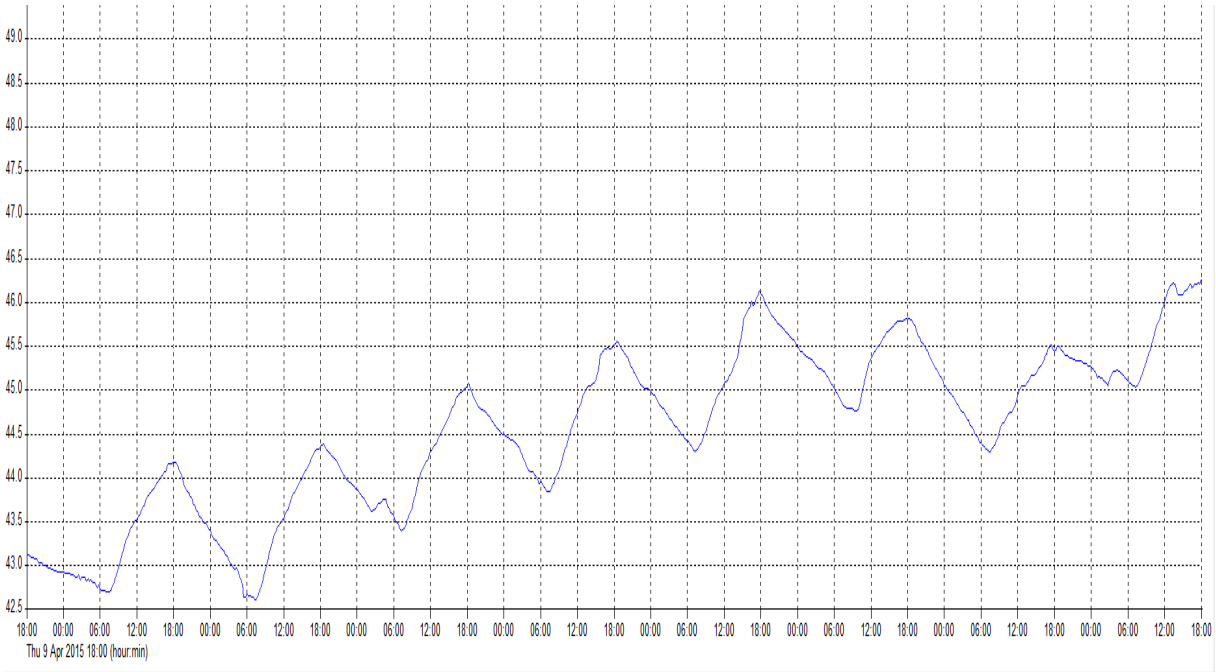

Figure 18. One-day measured pressure (m) output of an installed pressure sensor (Cello) at one of the three critical points of the WDSN of Skiathos, in Ammoudia area.

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Summary

The objectives of task reported in a form of this report have been fully reached. The new equipment for monitoring and controlling the water pressure in both water distribution systems (one in Greece, Skiathos and one in Poland, Sosnowiec) have been purchased, installed and tested.

In case of Poland the most important insights are:

- One district of the city, "Kolonia Ciesle" was chosen for the demonstration. It was imposed by the division of the water network on areas fed by particular purchase wells. Moreover, one, fully controllable area is suitable for the demonstration of the prototypic system.
- All sensors have been selected and ordered in 2014.
- Equipment was successfully installed in February 2015.
- The real-time data gathering from installed sensors have been tested just after the installation.

In case of Skiathos Island, Greece the most important insights are:

- Components of the pressure reduction and monitoring system have been selected and ordered in the end of 2014.
- The pressure control system is applied to the whole town of Skiathos, three critical points for pressure monitoring were selected.
- Equipment has been successfully installed and tested in April, 2015.

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References

Abdel Meguid, H. and B. Ulanicki, 2011, Pressure and leakage management in water distribution systems via flow modulation PRVs, Water Distribution Systems Analysis 2010: pp. 1124-113.

CSO, 2012, Size and structure of population and vital statistics in Poland by territorial division in 2012 as of December 31. Central Statistical Office.

ePiortkow. 2008, From Brasilian Forests to Piotrkow and Athens (in Polish), ePiotrkow information portal: http://www.epiotrkow.pl/artykul/Z-brazylijskiej-dzungli-do-Piotrkowa-i-Aten,853

Jalalkamali, A. and N. Jalalkamali, 2011, Application of hybrid neural modeling and radial basis function neural network to estimate leakage rate in water distribution network, World Applied Sciences Journal, 15 (3): 407-141.

Jarek R., 2011. It support for the water and wastewater management. MSc thesis, University of Silesia, 111 p.

Laspidou, C. S., 2014, ICT and stakeholder participation for improved urban water management in the cities of the future, Water Utility Journal 8: 79-85.

Nazif, S., M. Karamouz, M. Tabesh and A. Moridi, 2010, Pressure management model for urban water distribution networks, Water Resource Management, 24: 437-458.

Panu, U. S., 1990, Numerical monitoring of pressure-reducing valves in water distribution network systems, Can. J. Civ. Eng., 17: 547-557.

PMAC, undated, PMAC Plus installation and operating manual, Technolog, UGZ19000 Issue 2, 176 p.

Prescott, S. L. and B. Ulanicki, 2008, Improved control of pressure reducing valves in water distribution networks, Journal of Hydraylic Engineering, 134: 1 (56).

Skworcow, P. and B. Ulanicki, 2011. Burst detection in water distribution systems via active identification procedure, In: Proceedings of the international CCWI20 conference, 5-7 September 2011, Exeter, UK.

This project has received funding from the European Union's Seventh Framework
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Tricarico, C., M. S. Morley, R. Gargano, Z. Kapelan, G. de Marinis, D. Savic and F. Granata, 2014, Optimal water supply system management by leakage reduction and energy recovery, Procedia Engineering, 89: 573-580.

Ulanicki, B., H. AbdelMeguid, P. Bounds and R. Patel, 2008, Pressure control in district metering areas with boundary and interval pressure reducing valves, Proceedings of the 10th Annual Water Distribution Systems Analysis Conference WDSA2008.

Ulanicki, B., P. L. M. Bounds, J. P. Rance and L. Reynolds, 2000, Open and closed loop pressure control for leakage reduction, URBWAT Journal, 62: 1-10.

Yates, C. D. and MacDonald, G. D. 2007Advanced pressure management via flow modulation; the Dartmouth Central PMA,Water loss 2007, Bucharest, Romania.

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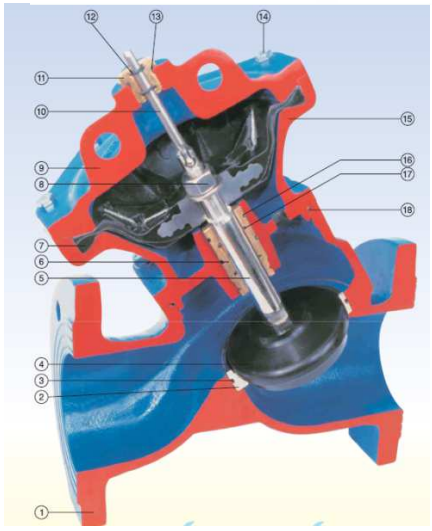
Appendix 1. PRV Ray valve 60 DN 80

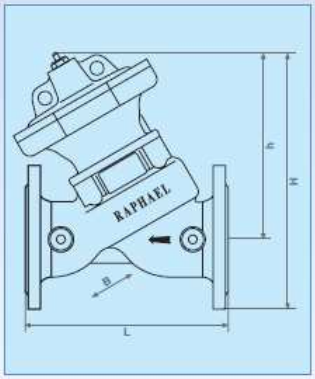


Technical Specifications

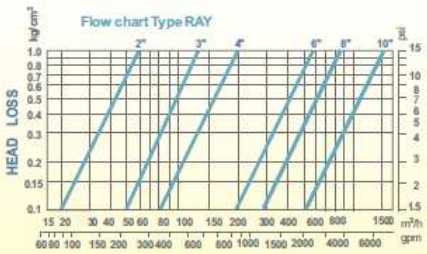
RAY - Part list & Materials

No.	Item	Material
1.	Body	Cast Iron
2.	Seat	Stainless Steel
3.	"O" Ring	Nitrile Rubber
4.	Plug	Nutural Rubber+Cast Iron
5.	Stem	Stainless Steel
6.	Bearing	Bronze
7.	Diaphragm	Nylon Reinforced Natural Rubber
8.	Nut	Stainless Steel
9.	Cover	Cast Iron
10.	Indicator rod	Stainless Steel
11.	Guide Plug	Brass
12.	"O" Ring	Nitrile Rubber
13.	"O" Ring	Nitrile Rubber
14.	Bolt	Stainless Steel
15.	Lower Cover	Cast Iron
16.	"O" Ring	Nitrile Rubber
17.	"O" Ring	Nitrile Rubber
18.	"O" Ring	Nitrile Rubber

* Other materials and coatings available on request



Nom. Dia.		L	H	B	h	Weight kg.	Connections
mm	inch	mm					
50	2	203	260	125	223	9.7	Threaded
50	2	203	298	165	223	13	Flange
80	3	254	350	200	258	22	Flange
100	4	305	380	230	278	33	Flange
150	6	406	470	280	350	71	Flange
200	8	521	650	380	490	122	Flange
250	10	635	780	460	580	212	Flange



MAX PRESSURE = 16 BAR

Flow Factor

Size	2"	3"	4"	6"	8"	10"
Cv	70	160	255	570	990	1760
Kv	60	140	200	570	840	1500

$Cv \text{ or } Kv = \frac{Q}{\sqrt{\Delta P}}$

Kv = 0.856 Cv

Cv = Flow factor: gpm at 1psi drop

Kv = Flow factor: m³/h at 1kg/cm² drop

Q = Flow: gpm – m³/h

ΔP = Pressure drop: psi – kg/cm²

Control Volume

Size	2"	3"	4"	6"	8"	10"
Gallon	0.044	0.105	0.180	0.670	1.240	2.040
Liter	0.17	0.40	0.70	3.30	4.70	7.70

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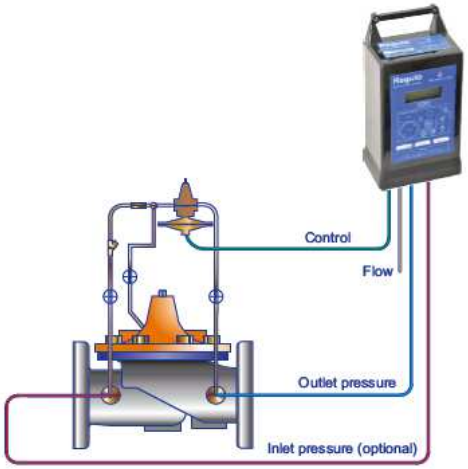
Appendix 2. Regulo driver

Regulo is an Advanced Pressure Controller. It controls the output of a Pressure Regulating Valve (PRV) according to a preset control method. Regulo incorporates Technolog's proven Cello GSM technology, which allows remote data transmission and 'over the air' control parameter configuration.

Regulo modulates the outlet pressure of a PRV. It controls the PRV in one of four methods:

- **Time Control:** outlet of PRV adjusted according to a preset daily or weekly time profile
- **Flow Control:** outlet pressure modulated according to demand
- **Closed Loop:** outlet pressure adjusted according to real time feedback from Cello at the critical point
- **Self-Learning:** critical point pressure from Cello is used to automatically generate a control profile. In the event that the CP pressure falls outside preset limits, alarm messages from the CP Cello are used to correct the PRV outlet pressure



Regulo uses Technolog's patented method of control. In the event of loss of control pressure, the PRV reverts to its preset fail safeoutlet pressure.

Regulo has sophisticated alarm regimes for detecting and immediately signaling abnormal conditions. Regulo records the performance of its internal components (valves, battery etc) and is able to transmit alarms should any of these go out of the normal operating range. Regulo also supports more traditional alarms, such as high flow, low pressure etc.

Data sent by the Regulo can be collected via several methods, including:

- Technolog's proprietary software installed onto a local host PC
- Technolog's resilient twin data centre
- Technolog's WaterCore web based software

Alarms from the Regulo in the field can be forwarded to the relevant field support staff by text message or emails.

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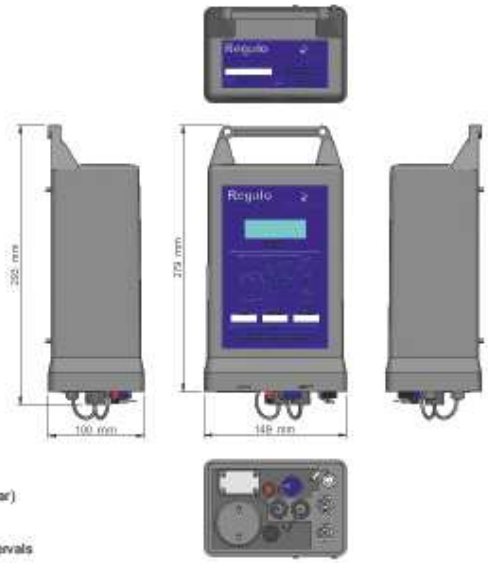
Technical Specifications



Operating Modes	Fixed Pressure
	Time Profile
	Flow Modulation
	Closed Loop
	Closed Loop, Self-Learning
Pressure Inputs	Input range: 0-100m (0-10bar) or 0-200m (0-20bar)
	+/- 0.5% accuracy / resolution
Digital Inputs	Pulses counted over, and recorded at, preset intervals
GSM Modem	Quad band: 900MHz, 1800 MHz / 850MHz, 1900MHz
	Integral antenna. Optional external antenna
Data transmission	SMS or GPRS. Half hourly, hourly, daily, weekly or monthly at programmable time and date
Serial Port	Type: Full duplex, asynchronous
	Data rate: 1200, 2400, 4800, 9600, 19200, 38400 bps
Memory	Size: 128K, allocatable between channels as required (max 64k per channel)
	Type: Solid state, non-volatile
Clock	Type: Crystal controlled calendar clock with leap year adjustment
	Accuracy: 100 seconds per monthly maximum error over operating temperature range
	Synchronisation: Option to synchronise clock to GSM network
Supply Type	User replaceable internal battery pack, up to 2 year life
	User replaceable external battery pack, up to 6 year life
	External 4.5-14V supply
Recording	Recording interval: programmable between 1 second and 1 hour
	Data storage: Rotating store or store until full
	Max/min statistical recording of outlet pressure
Alarm Dial-Out	High/low threshold and profile alarms
	Option to update data more frequently after an alarm
Environmental	Operating ambient temperature: -20°C to +50°C
	Protection classification: IP68 (submersion at 1m depth for > 24 hours)

Regulo – SMS/GPRS Electronic PRV Controller

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Appendix 3. Water meter

Itron

Woltex M

Horizontal Woltmann meter with extended accuracy range for water distribution applications

Woltex M is a horizontal Woltmann meter available in sizes from DN 50 to 500. With its extended accuracy range it is dedicated to all applications around water distribution where high reliability and accuracy is requested.

FEATURES AND BENEFITS

- Hermetically sealed register (copper can/mineral glass envelope)
- Extended range approval
- Interchangeable approved mechanisms without re-calibration
- Pre-equipped through Cyble as a standard

Extended Approved Range

Variable Qn EEC/ISO approval of Woltex M ensures an unmatched approved range of 107:1 (from Qmin to Qmax) instead of 66:1 for standard class B meters. This is ensuring accurate and reliable data collection in a large scope of flow-rates typical of water network applications. Leakage detection as far as peak demands are accurately monitored initially and over time.

Endurance & Peak Flow Resistance

This extended approval is the result of more than twenty years experience in Horizontal Woltmann design, from the first hydrodynamically balanced helix patent in 1985 still resulting in unmatched endurance capabilities to the use of high quality materials.

Ease of Installation, Read and Maintenance

Woltex M range is available in various lengths and connections to minimize installation costs. Interchangeable approved mechanisms allows easy maintenance without re-calibration. Ease of read in the toughest environments (ie: flooded pits) is secured by orientable hermetically sealed register (copper can/ mineral glass envelope).

Communication Device

Pre-equipped for future communication through Cyble.

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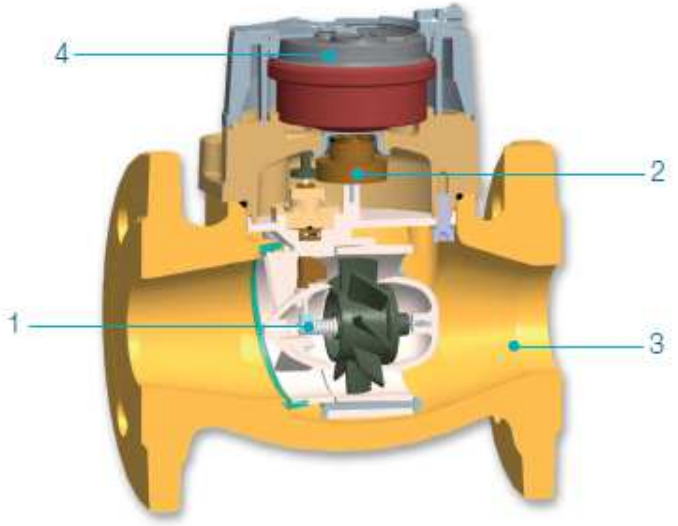
Hydrodynamic balance of helix

WORKING PRINCIPLE

The water velocity is rotating the horizontal axis propeller. Special shape of its inlet and outlet bearing 1 is counteracting the natural hydraulic thrust applied on the propeller then preventing any downstream pivot wear.

This hydrodynamic balance was firstly patented on Woltex range in 1985 and still features Woltex with unmatched enduring capacities. This results in a meter able to withstand sustained high flows without impacting low flow accuracy.

This allows Woltex to be approved according the provisions of EEC/ISO with variable Qn extended range. The propeller rotation is transmitted by a protected transmission and direct magnetic coupling 2 to the register. The cast iron body 3 is durably protected against the effects of corrosion by epoxy powder coating. The hermetically sealed copper can/mineral glass register 4 is safeguarding the read and integrity of the indicator in the toughest environments (flooded pits, mechanical tampering attempts, …).



COMMUNICATION

Woltex M is supplied pre-equipped withCyble Target

Allows communication and remote reading through:

- Pulse output (Cyble Sensor)
- M-Bus protocol (Cyble M-Bus)
- Radio frequency wireless link (Cyble RF)

Compatible with Itron complete offer for Metering Point Management (Automated Remote Reading, Metering Point Analyser, Automated Meter Data Collection):

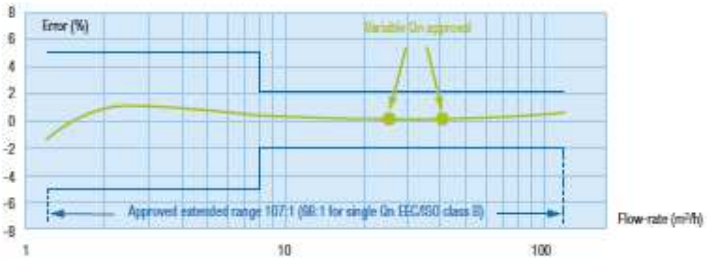
- AnyQuest
- EverBlu
- WaterMind

These Cyble modules allow the Woltex M meter to be connected with various associated systems if and when desired.

They are particularly adapted to commercial and industrial applications where a need for frequent meter monitoring is expressed especially in hard-to-read locations.

Cyble RF fitted on Woltex M with specific lid

VARIABLE QN APPROVED RANGE



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METROLOGICAL CHARACTERISTICS

Typical Performance

Nominal diameter (DN)	mm	50	65	80	100	125	150	200	250	300	400	500
	inches	2"	2" ½	3"	4"	5"	6"	8"	10"	12"	16"	20"
Starting flowrate*	m³/h	0.19	0.22	0.3	0.38	0.4	1	1.6	3	10	15	20
Accuracy ± 2% from*	m³/h	0.4	0.6	1.2	1.5	1.5	3	3.5	5	15	30	40
Accuracy ± 5% from*	m³/h	0.35	0.5	0.75	0.9	1.2	1.5	2.5	3.5	12	25	30
Admissible peak flow (10' max)	m³/h	90	200	250	300	300	700	1000	1500	2500	4500	7000
Max. admissible flowrate (continuous)	m³/h	50	80	120	200	200	500	800	1200	2000	3000	5000
Head loss at Qmax	bar	0.2	0.5	0.55	0.23	0.23	0.15	0.12	0.12	0.2	0.17	0.3
Max. admissible temperature	°C						50					
Max. admissible pressure	bar						20					
Min. scale interval	L			0.2				2			20	
Indicating range	m³			999999.99				9999999.9			99999999	
Cyble HF pulse weight	L			10				100			1000	

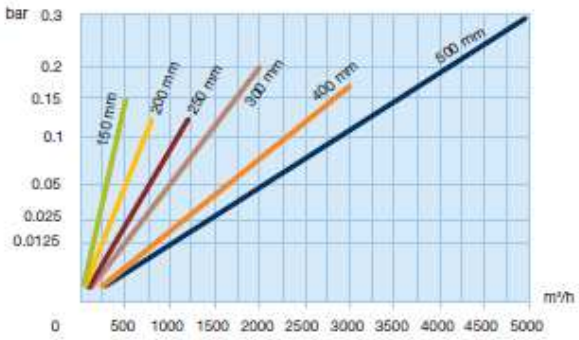
* Average values.

EEC Approval Values

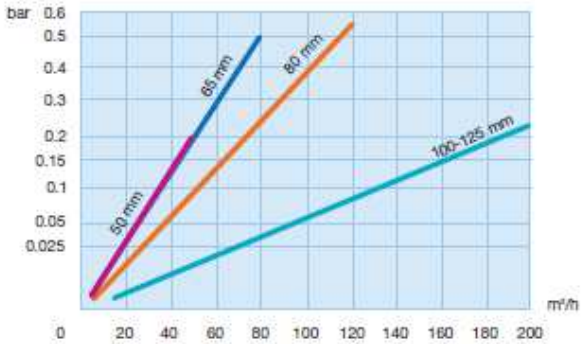
Nominal diameter (DN)	mm	50	65	80	100	125	150	200	250	300	400	500
	inches	2"	2" ½	3"	4"	5"	6"	8"	10"	12"	16"	20"
EEC/ISO class approval						Class B all positions						
Nominal flow rate Qn (variable)	m³/h	25 15	25 40	40 60	60 100	100* -	150 250	250 400	400 600	600 1000	1000 1500	1500 2500
Max. flow rate Qmax	m³/h	50	80	120	200	200	500	800	1200	2000	3000	5000
Accuracy ± 2% class B: Qt from	m³/h	3	5	8	12	20	30	50	80	120	200	300
Accuracy ± 5% class B: Qmin from	m³/h	0.45	0.75	1.2	1.8	3	4.5	7.5	12	18	30	45
Max. working pressure	bar						20					
Max. temperature	°C						30					
EEC approval certificate							F-02-G071					

* DN 125 single Qn approval only.

HEAD LOSS



Woltex M DN100



Woltex M DN500 with Everblu module

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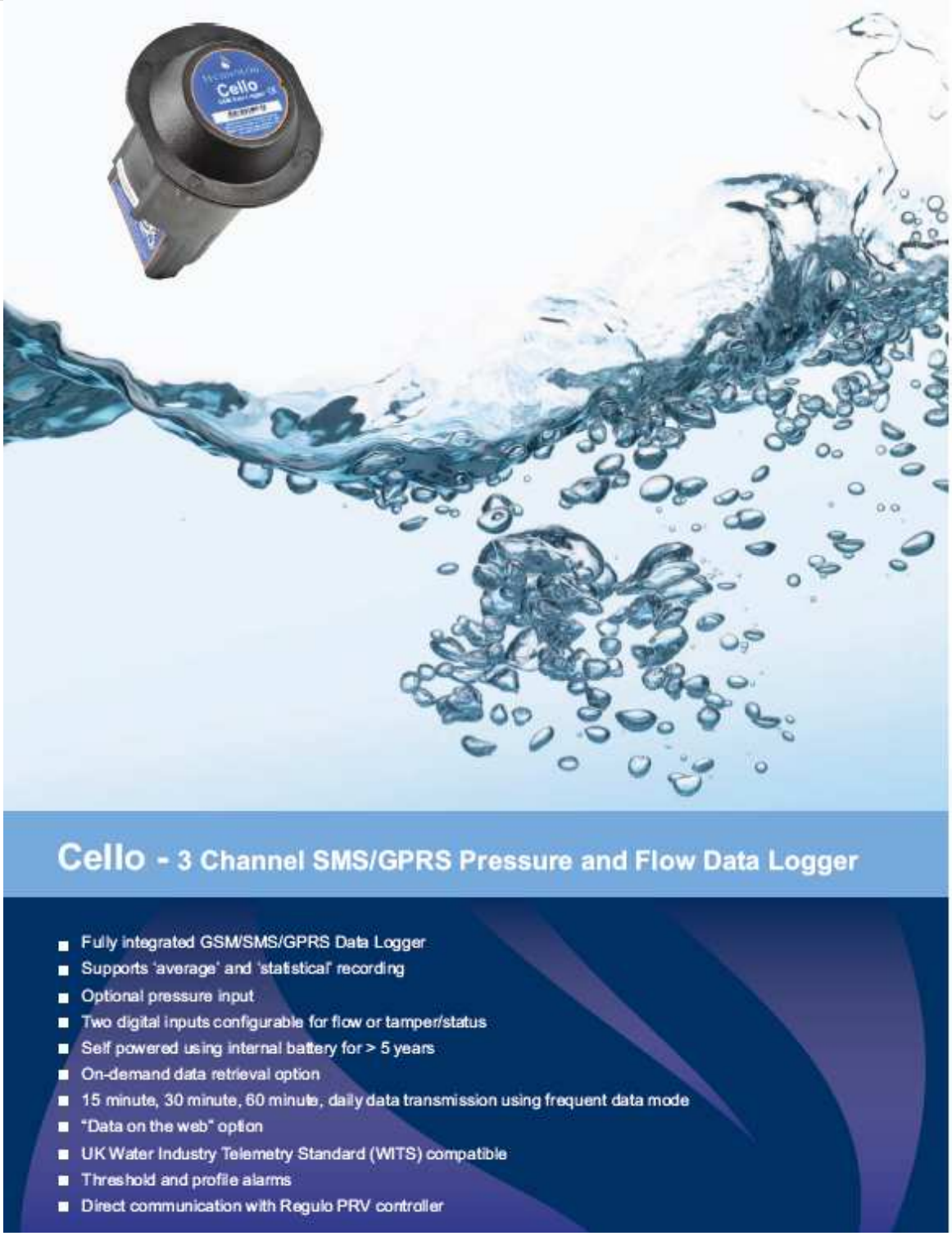
Appendix 4. Cello recorder



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Cello is a family of GSM data logging devices for water, gasand electricity applications. over 250,000 of Cellos havebeen installed throughout the world and Cello has become an industry standard for remote monitoring.

Cello has a custom designed aerial to maximise GSM signal in underground locations. Cello can be connected to pulse output meters and/or pressure tappings and records data at intervals between 1 second and 1 hour (user-programmable).

Cello has sophisticated alarm regimes for detecting and immediately signalling abnormal conditions. Cello supports high and low alarms on each channel. Additionally, profile alarms can be configured to follow daily data profiles. In the event of an alarm, Cello can be programmed to automatically send data more frequently.

Data sent by the Cello can be collected via several methods, including:

- Technolog's proprietary software installed onto a local host PC
- Technolog's resilient twin data centre
- Technolog's WaterCore web based software

Alarms from the Cello in the field can be forwarded to the relevant field support staff by text message or emails.

Cello - 3 Channel SMS/GPRS Pressure and Flow Data Logger

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Technical Specifications



Pressure Inputs	Input range: 0 - 100m (0 - 10 bar) or 0 - 200m (0 - 20 bar)
	+/- 0.5% accuracy
	+/- 0.5% resolution (optional +/-0.1%)
Digital Inputs	Up to 2: Pulses counted over, and recorded at, preset levels. Tamper/status and event recorded supported
GSM Modem	Quad band: 900MHz, 1800 MHz / 850MHz, 1900MHz
	Integral antenna. Optional external antenna
Data transmission	SMS or GPRS. 15mins, 30mins, 1 hour, 1 day, 1 week or monthly at programmable date and time
Serial Port	Type: Full duplex, asynchronous
	Data rate: 1200, 2400, 4800, 9600 bps
Memory	Size: 128K, allocatable between channels as required (max 64K per channel)
	Type: Solid state, non-volatile
Clock	Type: Crystal controlled calendar clock with leap year adjustment
	Accuracy: 100 seconds per monthly maximum error over operating temperature range
	Synchronisation: Option to synchronise clock to GSM network
Supply	Type: Internally powered by a replaceable lithium cell. Internal back up cell maintains logging and local communications when main battery pack is discharged
	Life: Typical battery life > 5 years depending on mode of use
Recording	Recording interval: programmable between 1 second and 1 hour
	Data storage: Rotating store or store until full
	Supports average and statistical recording (min, max., mean, standard deviation) over a defined logging interval
Alarm dial-Out	High/low threshold and profile alarms independently configurable on each channel
	Option to update data on alarm and more frequently thereafter
Environmental	Operating ambient temperature: -20°C to +50°C
	Protection classification: IP68 (submersion at 1m depth for > 24 hours)
Dimensions	Dimensions: 191mm x 140mm x 150mm
	Weight: 1 kg

Cello - 3 Channel SMS/GPRS Pressure and Flow Data Logger

For further information contact:

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Appendix 5. Pressure Reducing Stabilizing Valves (CSA XLC 410)

Automatic control valves XLC 400 series

The CSA range of automatic control valve consist of a globe pattern hydraulically operated valve, entirely produced in ductile cast iron with internal components in stainless steel. This valve, diaphragm actuated PN 25 class, is also called XLC 400 and represent the basic valve needed to perform a tremendous range of applications, that include pressure reduction, relief, sustain, flow control, level control and many more. Each function is obtained simply by changing the circuitry and pilots that can be combined together.

Technical features and benefits

- Body in ductile cast iron, PN 25 bar rated, full bore globe pattern design.
- Supplied with fixed flanges according to EN 1092/2, that can be changed to suit different pressure
- conditions.
- Designed to reduce head loss and minimize turbulence and noise during working conditions.
- Diaphragm with reinforced nylon fabric.
- Internal manufactured in stainless steel, obturator in ductile cast iron for large diameters.
- Maintenance can be easily performed from the top, without removing the valve from the pipe.
- Large expansion chamber to tolerate high pressure ratio.

Applications

- Main transmission lines.
- Water distribution networks.
- Buildings.
- Industrial plants.

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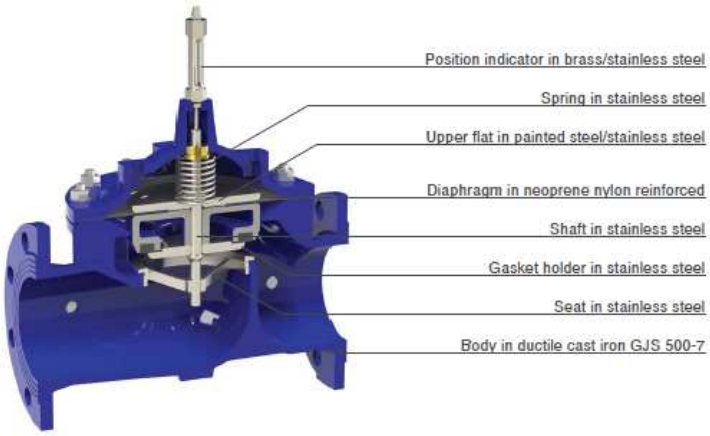
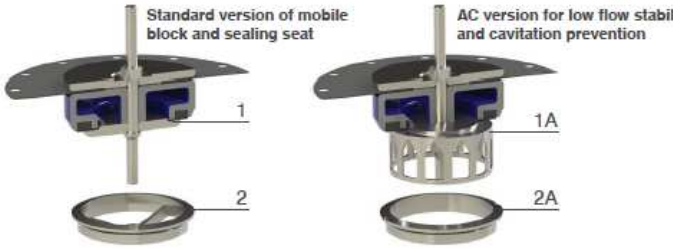


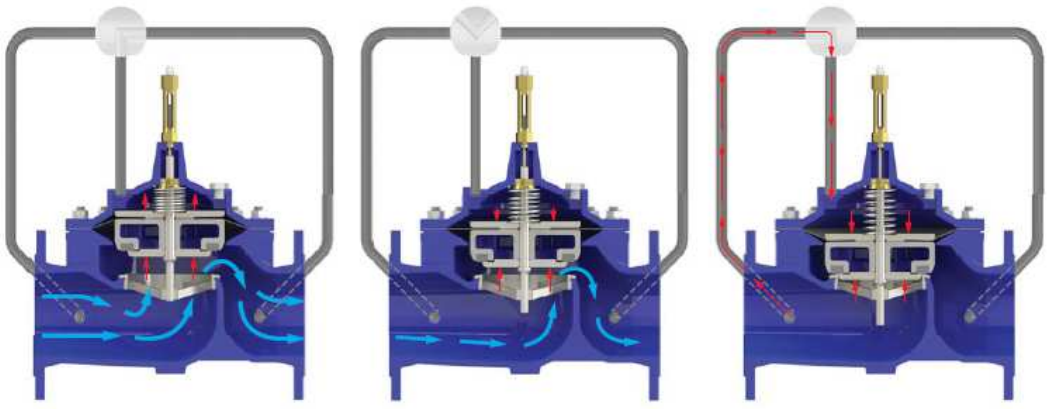


1. Gasket holder in stainless steel
2. Seat in stainless steel

1. Anti-cavitation V-port
2. Seat in stainless steel for anti-cavitation system

The standard version of mobile block and sealing seat, depicted above, includes the obturator, diaphragm and a special gasket holder designed to guarantee the maximum accuracy also during the low opening of the valve. The mobile block with this version is guided in two points, on the cap and on the seat. The AC system is obtained by means of a special seat and device which improves the guiding of the entire block, yet increasing the allowable pressure ratio and valve's performances, also in case of low flow rate avoiding vibrations and noise.

Operating principle on-off mode



Valve opening

If the pressure inside the control chamber is put in communication with the atmosphere the entire upstream pressure will act on the obturator, pushing it upwards allowing the complete opening of the valve.

Valve modulating

During working conditions if the control chamber is isolated from the upstream pressure the valve will remain in the same position, therefore producing the head loss corresponding to such opening percentage.

Valve closing

If the control chamber is put in communication with the upstream pressure, thanks to the difference in area between the upper flat with diaphragm, larger that the obturator underneath, the valve will close completely.

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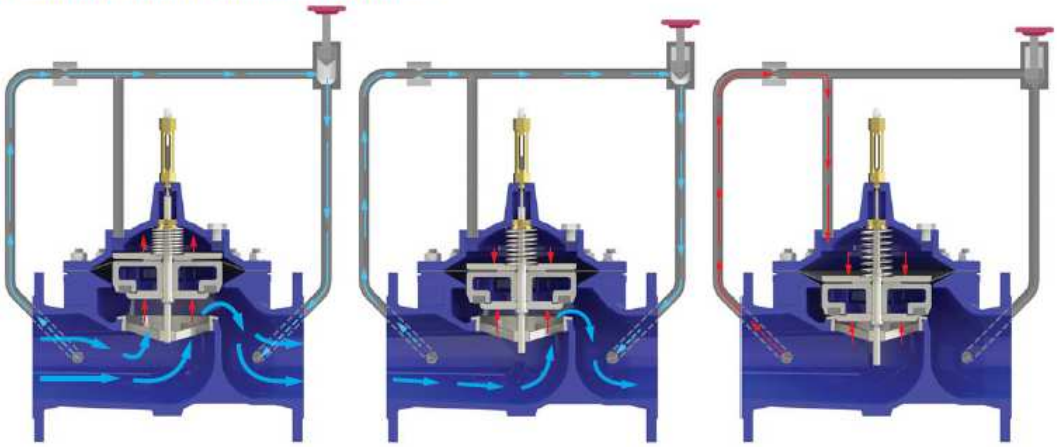
Operating principle modulating mode



Valve opening

When the valve is set to modulate a restriction is required between the upstream pressure and control chamber, in addition to a modulating device as shown in the picture. If the latter is entirely open the pressure inside the control chamber will be relieved, allowing for the complete opening of the valve.

Valve modulating

During working conditions if the modulating device is throttled, reducing the flow passage through it, pressure will be applied inside the control chamber making the valve's mobile block reacting accordingly on the main valve XLC 400.

Valve closing

If the modulating device is completely closed, all the upstream pressure will be diverted into the control chamber. The mobile block will therefore be pushed down on the obturator, producing the interruption of flow through the XLC 400.

GR.I.F.O. 3/8G PN 25

The unit flow control "GR.I.F.O." is a device, designed for modulation, that includes all the necessary functions required for the proper operation of CSA control valves. Entirely built in stainless steel, its compact design makes the circuit easy to be maintained and at the same time allows for a tremendous range of regulations.
GR.I.F.O. is composed of the following:
- a filter, with fine mesh in stainless steel AISI 316, to protect the hydraulic circuitry from possible dirt;
- three needles in stainless steel with check valves, responsible for the regulation of the main valve's response time, opening and closing speed independently from each other;
- filtered and unfiltered pressure ports.

1. Closing speed regulation
2. Opening speed regulation
3. Adjustable orifice regulation
4. Unfiltered 1/8 G port
5. 3/8 G port
6. 3/8 G port
7. 3/8 G port
8. Filtered 1/8 G port
9. Filter

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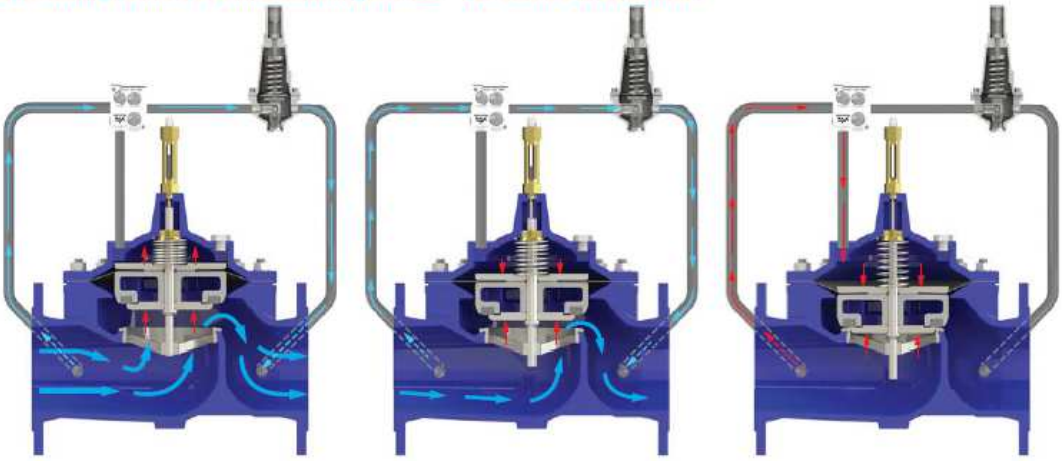
Operating principle modulating mode - pressure reduction



Valve opening

If the downstream pressure value becomes lower than the pilot's set point the passage through the latter will increase, thus relieving pressure out of the main valve chamber XLC 400 with consequent opening as shown in the picture above.

Valve modulating

As a consequence of gradual change and variation in demands the pilot will keep adjusting, this is to regulate the flow in and out of the main chamber. The XLC 400 will then follow the movements of the pilot producing the necessary head-loss required for the downstream pressure reduction.

Valve closing

If the downstream pressure value becomes higher than the pilot's set point the passage through the pilot will decrease, thus conveying flow and pressure to the main chamber of the XLC 400 valve with consequent closure as shown in the picture above.

Downstream pressure reducing stabilizing valve **Mod. XLC 410**

The CSA XLC 410 control valve will reduce and stabilize the downstream pressure to a preset value, regardless of variations in demand and upstream pressure fluctuations.

Most popular configurations	
XLC 410-FR	downstream pressure reducing with back-flow prevention
XLC 410-ND	downstream pressure reducing stabilizing valve with programmer and two set points
XLC 412	downstream pressure reducing and up-stream pressure sustaining valve
XLC 415	downstream pressure reducing stabilizing valve with solenoid control

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Installation layout

The picture depicted below shows the recommended installation layout of the CSA XLC 410.
The sectioning devices and by-pass are very important for maintenance operations, as well as the filter to prevent dirt from reaching the control valve. The direct acting pressure reducer CSA Mod. VRCD is the best choice on the by-pass due to long periods of inactivity. A pressure relief, CSA model VSM or XLC 420, must be present to prevent under any circumstances rise in pressure on the downstream line.