USAGE OF THE ENERGY-SAVING TRANSFER RESERVOIR IN A DRAINAGE SYSTEM

Robert MALMUR*

*Dr; Faculty Environmental Protection and Engineering, Czestochowa University of Technology, ul. Brzeźnicka 60a, 42-200 Częstochowa, Poland
E-mail address: *rmalmur@is.pcz.czest.pl*

Received: 1.03.2012; Revised: 20.04.2012; Accepted: 14.05.2012

Abstract
Intensive rainfalls and snow melting often cause floods of protected terrains and overflowing of existing sewage systems. Such situations are burdensome for occupants, and also cause considerable material losses. One of possible technical solutions assuring unfailing outflow of sewages transfer reservoir are draining system to receiver set introduced in paper.
In case when gravitational outflow of sewages is not possible, in the beginning at first suitable volume of sewages are accumulated by transfer reservoir and then are thrown into the water receiver sets. However, gravitational discharge of sewages to water receiver set is realized through the transit chambers of transfer reservoir.

Streszczenie
Intensywne opady deszczu, a także szybkie topnienie śniegu, powodują często podtapianie terenów chronionych i przepełnianie istniejących sieci kanalizacyjnych. Sytuacje takie są uciążliwe dla mieszkańców, a także powodują znaczne straty materialne. Jednym z możliwych rozwiązań technicznych zapewniającym niezawodny odpływ ścieków do odbiornika jest przedstawiony w artykule zbiornik retencyjno-przerzutowy.
Zbiornik retencyjno-przerzutowy ma za zadanie gromadzić odpowiednią ilość ścieków, a następnie przerzucić je do odbiorników wodnych, w przypadku, gdy nie możliwy jest ich odpływ grawitacyjny. Natomiast grawitacyjne odprowadzanie ścieków do odbiornika realizowane jest przez ich tranzytowy przepływ przez komory zbiornika.

Keywords: **Transfer reservoirs; Sewage reservoirs; Sewage transfer; Retention; Drainage system.**

1. INTRODUCTION

Development of our civilization has caused that urban centres have been deprived of natural retention system especially referring to sewages coming out of atmospheric rainfalls. Present sewage systems, in most cases are not able to carry away a great intensity of sewage flow. Therefore, different technical interventions are undertaken in order to catch and keep this surplus of flow temporarily (Figs. 1a, 1b).

In urban agglomerations sewage retention is done indirectly by different kind of sewage reservoirs [10]. In a period of heavy rainfalls or intensive spring melting of snow local flooding of urban terrains may appear because of faulty drainage system or because of faulty culverts, which should carry away sewages coming out of atmospheric rainfalls directly into a water receiver (Fig. 1c) [1, 2, 9].

Figure 1.
a) High intensity rainfall, b) The Flood after rainfalls, c) Example of faulty culverts

Figure 2.
a) Moving sewage pumping stations, b) Outflow collectors with shut-off check valve, c) Safe outflow collectors, d) Insecure outfall sewer

Problem of sewage transfer to receivers is solved in a different way in each of the countries. There are well-known solutions of either stationary or moving sewage pumping stations (Fig. 2a). However, most often outflow of excessive sewages coming out of atmospheric rainfalls is performed gravitationally through outflow collectors linking storm overflows with water receiver. The outlet of these outflow collectors is usually equipped with shut-off check valve in order to protect terrains against flooding (Fig. 2b). However, practically these valves are not always used, whereas they are installed and usually deprived of

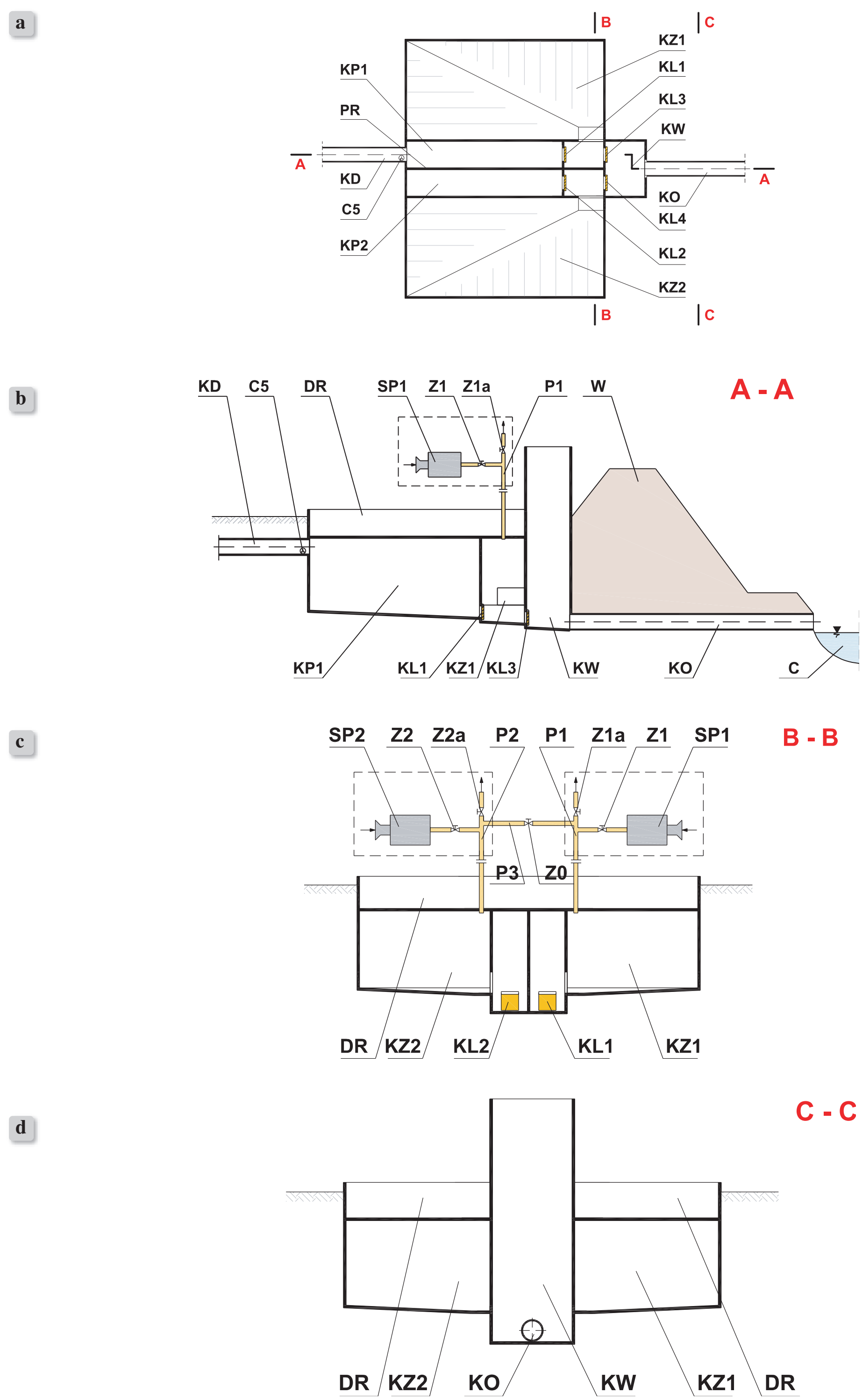

Figure 3.
Example solution transfer reservoir GEMINUS – ET: a) top view, b) cross section A – A, c) cross section B – B, d) cross section C – C; KZ1, KZ2 – storage chambers, KP1 – flow-through chamber, KP2 – overflow chamber, KW – tower chamber, KD – inlet channel, KO – outlet channel, KL1-KL4 – check valves, PR – partition wall with weir, W – fluid levee, C – water receiver, Z1, Z1a, Z2, Z2a, Z0 – shut-off valves, SP1, SP2 – pressure compressor, P1, P2, P3 – air pressure pipe, DR – additional storage chambers

proper care and preservation (Figs. 2c, 2d). Thus, their technical state make for these valves work impossible.

Insecure outfall sewer with closing, working relatively inefficient check valves have caused numerous flooding of terrains and urbanized districts in many Polish towns for the last few years and of course the material losses which arose as a result of these flooding were considerable.

Problem of reducing causes of drowning resulting from heavy rains or intensive melting of snow on the urban terrains can be carried into effect by building special retention reservoirs on the drainage system, which would accordingly reduce sewage intensity flow. On suburban terrains of housing estates draining of a drainage area can be also realized superficially through the system of drainage ditches. In each case, if sewage falls are carried away directly to the water receiver, applied protection of valves installed behind the dam on the river side must undergo current checking and preservation. But it does not change the fact, that during the water rising in a river the access to these valves is limited, if there is a need.

In case of long duration rainfalls, which are usually accompanied by high states of filling in water receiver, proper working of reversible valve protects sewage system against flowing there water from the receiver and at the same time makes gravitational sewage outflow from protective reservoir impossible. When these states of filling appear, where gravitational outflow is impossible, there is a need to build a proper sewage transfer system from the protective terrain to the water receiver.

A survey of practical ways of transfer sewage from the protected drainage area to the receiver during the periods of high fillings has not brought a universal and unfailing solution, which could have a wide application in practice.

So the problem of working out a solution of hydraulic way of carrying away the sewage coming out of atmospheric rainfalls to the receiver has been taken up that would assure their natural, gravitational outflow during the periods of either low states and medium fillings in the receiver or during the period of high fillings their strained transfer. This kind of solution of transfer sewage rainfalls to the water receiver are transfer reservoirs [3, 4, 6]. A common solving feature of these reservoirs is that they are located on the side of drained terrain. This solution guarantees possible damage repairments even when in the receiver – river high states of filling appears. Transfer reservoirs can be applied in the following cases [5]:

– in separate sewerage system on the outlets of the main collectors of the rainfall system;
– in combined sewerage system on the outlets of a stormy canal;
– in combined sewerage system on the outlets of stormy canals with simultaneous pumping of domestic and industrial wastewater to a wastewater treatment plant;
– in case of collectors carrying away clear sewage from the wastewater treatment plant.

In the present paper there has only been presented the transfer reservoir GEMINUS – ET type in energy-saving version [7]. Transfer of sewage, using this kind of reservoir, is done through applying a system of air-compressors and a proper combination of pressing systems. But the effect work of energy-saving reservoir is gained during the process of balancing of air pressure in both separated from the atmosphere reservoir storage chambers.

2. CONSTRUCTION OF THE TRANSFER RESERVOIR

The transfer reservoir GEMINUS – ET type has the flow-through chamber linked in a top zone with the inlet channel and the overflow chamber (Fig. 3). The flow-through chamber and the overflow chamber are separated by a barrier with overflow (Fig. 3a). The edge of overflow is located lower than top point of the inlet channel outline. The flow-through chamber is linked through the check valve with the gas-proof storage chamber. Both the storage chambers through the following check valve are combined with the tower chamber. The tower chamber, of height greater than ordinate of water level is combined with a water receiver indirectly through the outlet channel. The check valves work automatically as they are opened by hydrostatic pressure.

In a ceiling of the storage chambers there is a pipeline linking together with the shut-off valves this zone with the air-compressors or the atmosphere. One shut-off valve cuts the storage chamber off the line of the air-compressor, whereas the other one cuts this chamber from the atmosphere, and similar thing happens in another storage chamber (Figs. 3b, 3c). Air pipes are joined together with an extra line through the shut-off valve. Air pipes and a special control of the shut-off valves enable to use the pressure of compressed air caught in the previously emptied storage chamber to a partial evacuation of the other chamber without using the air-compressor.

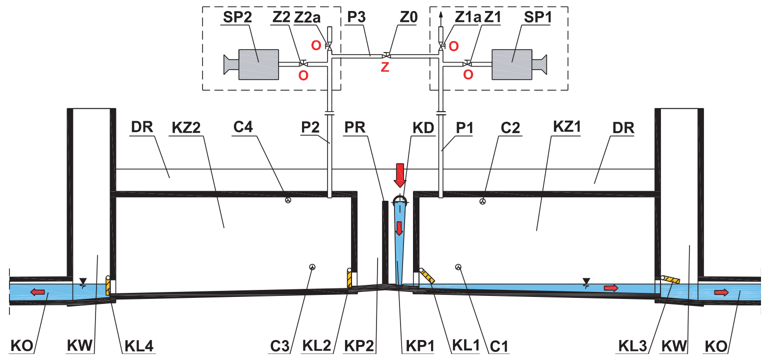

Figure 4.
Schematic diagram of transfer reservoir – gravitional outflow with low states of a water receiver

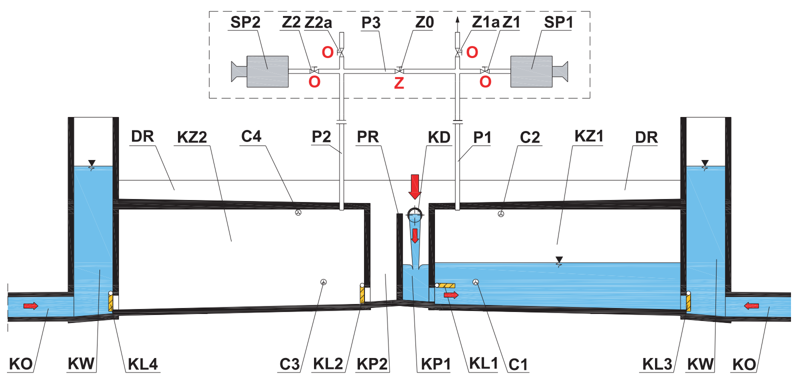

Figure 5.
Schematic diagram of transfer reservoir – filling the first storage chamber and filling the flow-through chamber

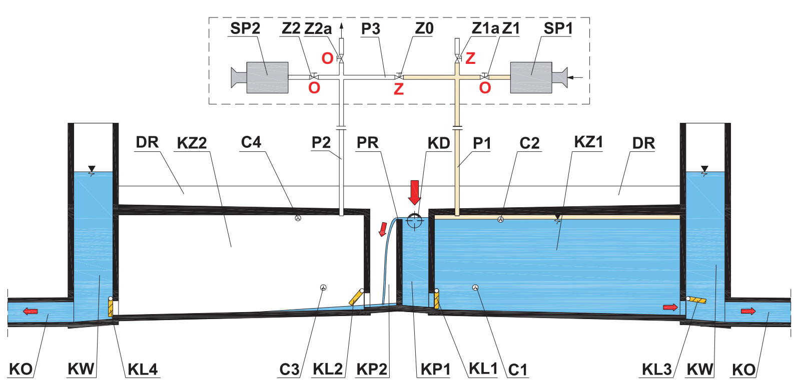

Figure 6.
Schematic diagram of transfer reservoir – the beginning of emptying the first storage chamber and filling the second storage chamber

3. FUNCTIONING OF TRANSFER RESERVOIR

With low and average states of filling a water receiver, there are certain conditions preserved for gravitational outflow of the storm water to the receiver which flows with the help of the inlet channel to the transfer reservoir. In such cases, storm water flows through the flow-through chamber and through opened check valve first to storage chamber and further through next opened check valve to the tower chamber, and from here to the water receiver (Fig. 4).

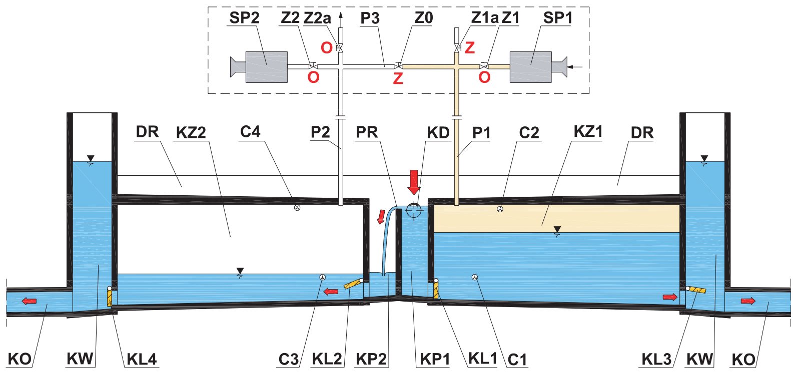

Figure 7.
Schematic diagram of transfer reservoir – the process of emptying the first storage chamber and filling the second storage chamber

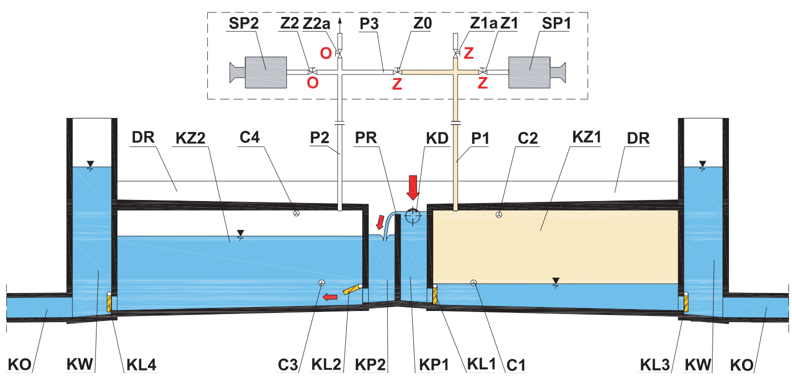

Figure 8.
Schematic diagram of transfer reservoir – complete emptying of the first storage chamber and filling the second storage chamber

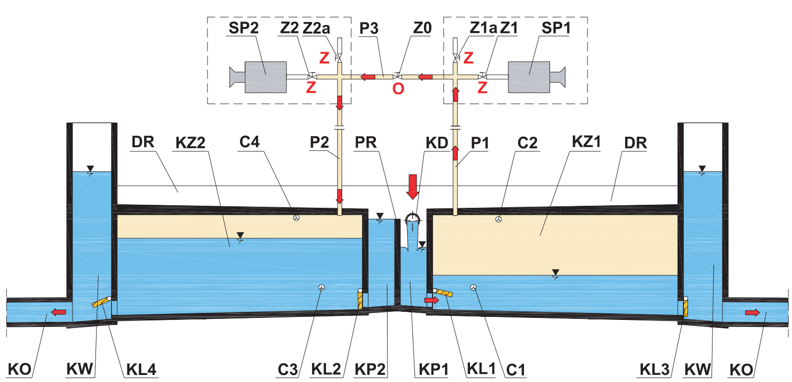

Figure 9.
Schematic diagram of transfer reservoir – the process of partial emptying of the second storage chamber by compressed air and filling the first storage chamber

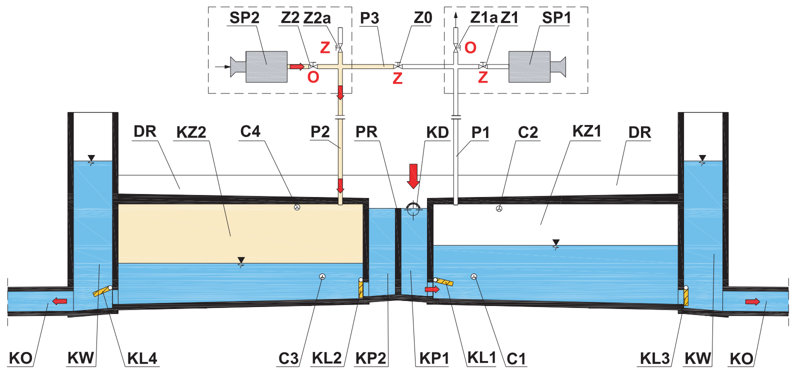

Figure 10.
Schematic diagram of transfer reservoir – continuation of emptying the second storage chamber with participation of the air-compressor and repeated filling the first storage chambering the first storage chamber

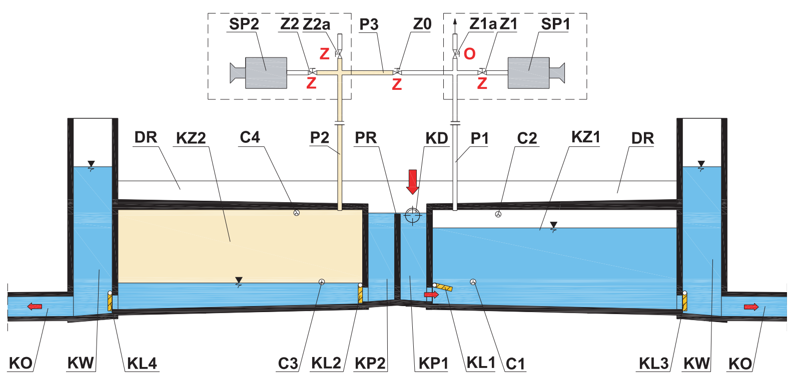

Figure 11.
Schematic diagram of transfer reservoir – complete emptying of the second storage chamber and continuation of filling the first storage chamber

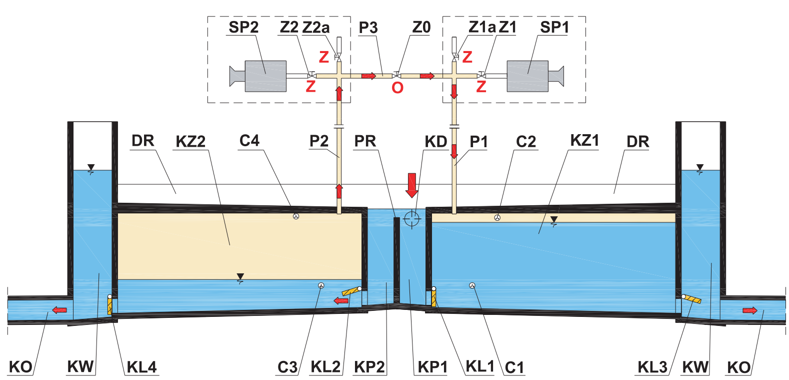

Figure 12.
Schematic diagram of transfer reservoir – the process of the partial emptying of the first storage chamber through the balancing the air pressure in both separated from the atmosphere the storage chambers

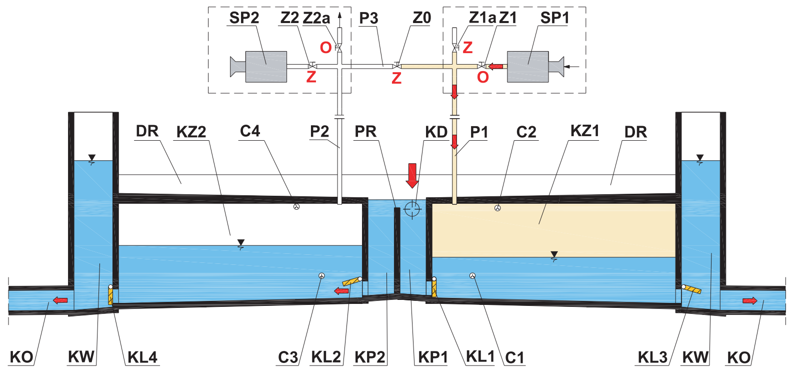

Figure 13.
Schematic diagram of transfer reservoir – continuation of emptying the first storage chamber at the participation the air-compressor and repeated filling the second storage chamber

With high states of filling in a water receiver when gravitational outflow of sewages is not possible, storm water which flow in with the help of the inlet channel to the flow-through chamber of the reservoir through the opened check valve fills the first storage chamber. While filling process, appropriate shut-off valves placed on the air pipe are opened. This way they enable the air outflow from the storage chamber to the atmosphere (Fig. 5).

The process of filling the first storage chamber is finished when its completely filled with storm water and the flow chamber is filled to the level of overflow. Accomplishing such filling states cause switching the first compressor on and cutting off appropriate shut-off valves placed on air pipe. That contributes to the storage chamber's cutting off which is filled with storm water from the atmosphere. That's how the process of making the storage chamber empty is started (Fig. 6).

The increase of air pressure forced in to the empty chamber by means of compressor causes the storm water outflow to the tower chamber (Fig. 7). After the process of making the first chamber empty the compressor is switched off and appropriate shut-off valves are closed. Because of this process compressed air is kept in empty chamber (Fig. 8).

The process of making the first storage chamber empty as well as the process of filling the second storage chamber starts simultaneously. Because at this stage of chamber's functioning the check valve closes the inlet to the first storage chamber, the storm water which flows into the reservoir through overflow fills the overflow chamber and then fills the second storage chamber. While the second storage chamber is filled, appropriate shut-off valves placed on air pipe are opened. This way they enable the air outflow from the storage chamber to the atmosphere. Filling the second chamber and the overflow chamber takes place simultaneously (Fig. 7).

Completing the second storage chamber with liquid is possible thanks to maintaining compressed air left in the first storage chamber after making it empty (Fig. 8).

The complete filling of the second storage chamber will make the shut-off valves close and this chamber cut off the atmosphere. Simultaneously opening of the shut-off valve on the line which links both air pipes will enable compressed air-flow from the first storage chamber (which was stopped after it had been emptied) to the second chamber. The process of partial emptying of the storage chamber by compressed air is started. The pressure of compressed air is balanced in both storage chambers cut off from the atmosphere (Fig. 9).

The increase of air pressure in the second storage chamber causes the storm water flow from this chamber to the tower chamber (Fig. 9). The equalizing of air pressure in both cut off atmosphere storage chambers leads to partial emptying of the second chamber.

In the next part, for complete emptying of this chamber from the storm water, it is necessary to switch off the second air-compressor with simultaneous opening and closing certain the shut-off valves (Fig. 10).

After complete emptying of the second storage chamber the air-compressor is switched off and simultaneously proper the shut-off valve is closed, so the compressed air is preserved in this chamber (Fig. 11).

While pneumatic emptying of the second storage chamber the storm water that flows up to the receiver fills the first storage chamber again, which is always opened into the atmosphere while the air-compressor is working. This rule is compulsory in the opposite situation, that is, when the pneumatic emptying of the first storage chamber appears through the air-compressor.

Accomplishment of the complete level of filling in the first storage chamber will cause its cut off from the atmosphere. Simultaneously the proper shut-off valve will open which enables the flow of compressed air from the second storage chamber to the first chamber. This is the way of beginning a repeated process of the partial emptying of the storage chamber through the balancing air pressure in both storage chambers separated from the atmosphere (Fig. 12).

The increase of the air pressure in the first storage chamber will cause the flow of the storm water from this chamber to the tower chamber (Fig. 13).

After finishing of the air pressure process the first air-compressor is switched on again and the proper shut-off valves are opened and closed. The air-compressor empties only partially filled storage chamber till its complete emptying. In the meantime the storm water in-flowing to the receiver is taken off by the second storage chamber. Such alternate filling and emptying of the chambers of the reservoir allows to transfer the storm water flowing into it to the water receiver regardless of the fact if it is full or not.

Should the flowing of the storm water to the reservoir stop, two variants of completing the process of its transfer to the receiver are to be considered:

– in the first variant the sensor placed in the inlet to the reservoir will turn on both of the compressors and empty the two storage chambers,
– in the second variant the storage chambers partly filled-in with the storm water will be emptied gravitationally only after lowering the level of filling in the water receiver.

4. SUMMARY

Transfer reservoir [6] described in this paper the makes the alternative solution to the sewage pumping station [8]. It ensures a desirable efficiency and reliability. It is a simple solution that fits nicely into the natural environment. It allows to transfer the rain water to the water receiver regardless of its level of filling in. Such solution may also be used in a transfer of waste to the drainage area of a higher elevation, or to be a storage reservoir placed in front of a sewage treatment plant whose waste will be transferred to the technological process of its purification.

The efficient value of a partial emptying of a filled-in with storm water storage chamber, obtained during the process of compensation of the air pressure in the two cut off from the atmosphere chambers, depends on the possibility of the simultaneous filling in with storm water of a chamber that has been emptied before. The research has shown two ways of the air pressure compensation when the storage chambers are cut off from the atmosphere:

– when the inflow of the storm water to the storage chamber emptied before if will not be possible,
– when the inflow of the storm water to the storage chamber will take place.

Energy-saving operation of this transfer reservoir depends on the actual state of filling-in of the water receiver (river), which is equal to the level of the storm water in the tower chamber. Independently from this or this is the reservoir in the basic version or in the energy-saving version, the waste of energy grows up together with from the level of filling up the tower chamber.

The proper function of the transfer reservoir requires the sequence of action when the complete emptying of one storage chamber is first, and just only after that total filling up of second chamber takes place.

ACKNOWLEDGEMENT

This work was supported by the university internal grant BG 401-406/10

REFERENCES

[1] *Geiger W., Dreiseitl H.*; Nowe sposoby odprowadzania wód deszczowych (New methods of draining storm water), Warszawa, 1999 (in Polish)

[2] *Imhoff K.*; Kanalizacja miast i oczyszczanie ścieków (Urban sewage and wastewater treatment), Poradnik, Arkady 1982 (in Polish)

[3] *Kisiel A.*; Zbiornik przerzutowy ścieków opadowych – GEMINUS – T (Transfer reservoir in a drainage system – Geminus-T), Biuletyn Urzędu Patentowego UP P 331776, Warszawa, 3 marzec 1999 (in Polish)

[4] *Kisiel A.*; Zbiornik przerzutowy ścieków opadowych – PLUVIUS – P (Transfer reservoir in a drainage system – Pluvius-P), UP RP 190004, Warszawa, 14 październik 2005 (in Polish)

[5] *Kisiel A., Mrowiec M.*; Zbiornik przerzutowy ścieków deszczowych (Transfer reservoir in a drainage system), Gospodarka Wodna, 12/2001 (s. 511-514) (in Polish)

[6] *Malmur R., Kisiel A.*; Energooszczędny zbiornik przerzutowy ścieków opadowych GEMINUS – ET (The energy saving transfer reservoir in a drainage system Geminus-ET), Biuletyn Urzędu Patentowego UP P 373875, Warszawa, 23 marzec 2005 (in Polish)

[7] *Malmur R.*; Rozprawa doktorska pt: Teoretyczno-eksperymentalna analiza hydraulicznego działania zbiorników retencyjno-przerzutowych (Theoretical and experimental analysis of the hydraulic operation of transfer reservoirs), Częstochowa, 19.06.2006

[8] *Mrowiec M., Kamizela T., Kowalczyk M.*; Occurrence of first flush phenomenon in drainage system of Czestochowa, Environment Protection Engineering, Vol.35 Is.2 p.73-80

[9] *Mrowiec M.*; The application of improved flow diverter for first flush management, Water Science and Technology, Vol.62 Is.9 p.2167-2174

[10] *Mrowiec M., Kisiel A., Malmur R., Kisiel J.*; Hydrodynamic Modeling of Tubular Detention Reservoirs Using SWMM5, Polish Journal of Environmental Studies, Vol.16, No.2A, part III, 2007