

# Sewage retention reservoirs as elements of rainwater drainage

Zbiorniki retencyjne jako elementy kanalizacji deszczowej

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The paper discusses the current state of knowledge on the design of sewage retention reservoirs understood as very effective components of a modern sewage system that improve its hydraulic efficiency in a process of sewage outflow from a basin, particularly in urban areas. A wide range of types of reservoirs has been presented, differing in the design of the chambers, the method of operation, and the electricity demand. A short description characterizing the basic parameters of each reservoir was supplemented with an indication of the related literature providing details of their designs. The paper aims to familiarize the readers with a wide range of technical solutions for sewage retention reservoirs and, consequently, to encourage them to be widely used in practice.

*Keywords: sewage system, retention, sewage reservoirs*

W artykule przedstawiono aktualny stan osiągnięć z dziedziny różnorodnych rozwiązań kanalizacyjnych zbiorników retencyjnych, które jako elementy nowoczesnych sieci kanalizacyjnych skutecznie wpływają na podnoszenie jej sprawności hydraulicznej w procesie regulowania odpływu ścieków ze zlewni, najczęściej zurbanizowanej. Podział zbiorników wynikający z hydraulicznego sposobu ich działania uzupełniony jest schematem ideowym pokazującym konstrukcyjny układ komór każdego z prezentowanego zbiornika. Krótka charakterystyka każdego zbiornika oprócz sposobu jego działania wskazuje na możliwość uzyskania określonych korzystnych efektów eksploatacyjnych jak również informuje o ograniczeniach ich stosowania wynikających z uwarunkowań terenowych względnie ze zużycia energii elektrycznej. Zaprezentowano również energooszczędne ich rozwiązania w wariacie z pompami próżniowymi oraz pompami ssąco-tłoczącymi. Dokonana prezentacja ma na celu zapoznanie czytelników z szeroką ofertą technicznych rozwiązań kanalizacyjnych zbiorników retencyjnych, a w konsekwencji zachęcenie do ich szerokiego stosowania w praktyce.

*Słowa kluczowe: kanalizacja, retencja, zbiorniki retencyjne*

## Introduction

The oldest paper in the technical literature on sewage retention reservoirs dates back to 1913, in which a rainwater retention reservoir was shown and described for the first time [1]. Since then, progress in this field of science has been generated by a growing body of scientific papers, covering issues related to the technological and structural aspects of using retention reservoirs as components of sewage systems. The advisability of their use was justified not only on economic but, first and foremost, operational grounds.

In modern solutions of sewage systems, retention reservoirs are their basic component that is mainly used in the following cases [2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 20]:

- when the progressive development of urban and industrial areas, reducing natural water retention, causes a sig-

nificant increase in the amount of rainwater discharge, resulting in overloading of the existing sewage system, flooding of streets, basements, etc.;

- when, with insufficient soil permeability, there is a need for the temporary storage of rainwater before further discharge to infiltration facilities;
- protection of receiving waters from the effects of wave discharges of pollutants contained in rainwater runoff;
- connection of new catchment areas to existing sewage systems;
- construction of new sewage systems, in which significant amounts of rainwater runoff is discharged through long collectors in unfavorable geological and topographical conditions (e.g., flat terrain);
- hydraulic relief of wastewater treatment plants by equalizing the intensity of wastewater inflow to the treatment plant facilities.

With the important role played by retention reservoirs that interact with the sewage system, they can be classified as follows [6, 11, 12]:

- relief reservoirs, which are designed to hydraulically relieve the pressure on the sewage system and the facilities that interact with the system, located below these reservoirs. These reservoirs are also used to control the outflow of rainwater to the receiver in situations where the capacity of the channels and the flow in the river are not sufficient to accommodate the wastewater collected during heavy rainfall [15, 16];
- rainwater reservoirs designed to retain the first wave of pollution (averaging), whose function is to intercept and retain the first most polluted rainwater runoff and discharge it back into the system or to the wastewater treatment plant during periods of reduced flow;

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- treatment reservoirs, which act as settling tanks for treating rainwater, combined sewage, and industrial wastewater mixed with rainwater [15, 16]. The outflowing wastewater is considered mechanically treated and is generally discharged directly to the receiving water [15, 16].

Furthermore, reservoirs with special designs and purposes include:

- cascade reservoirs, with their volume divided into several chambers separated by partition walls (cascades), used especially in steep terrain [18];
- damming reservoirs, in which the inflow channel is located at the bottom of the reservoir [18];
- retention reservoirs designed for sewage collection stations [6];
- retention and interceptor reservoirs, which are used when high water levels in the receiving water prevent the gravitational outflow of rainwater [17, 18].

In the last two decades, there has been a marked increase in scientific research related to the problems of wastewater retention methods in sewage systems. Based on the research work, several modern sewage retention reservoir solutions have been developed [17], characterized by high efficiency and operational reliability. The various solutions for sewage retention reservoirs have been developed as a result of meeting specific expectations arising from the needs of their practical application. The main premise that has inspired the progress in the field of new sewage reservoir solutions was the requirements for the operation of modern sewage systems, in which a retention reservoir or a system of such reservoirs is an indispensable element of system operation that ensures effective and reliable control of the process of outflow of wastewater, especially rainwater, from urbanized catchment areas.

Sewage retention reservoirs intended for use in various types of sewage systems can be divided into gravity, gravity-vacuum, and gravity-pneumatic units. The choice of the type of reservoir for practical application depends both on the expected efficiency of operation and the terrain conditions that may, in the case of gravity reservoirs, limit or eliminate its use.

The sewage retention reservoirs presented in this paper are now one of the integral components of modern sewage systems. Regulating rainwater runoff by temporarily holding peak flows in retention reservoirs can largely prevent catastrophic flooding, and allows for flexible sewer development to be carried out by dividing the construction into stages.

The primary purpose of this paper is to present available and existing sewer retention reservoirs and the division of retention reservoirs according to their function, mode of operation, or conditions of inflow and outflow of wastewater.

### Scientific rationale for the presentation of sewage retention reservoirs

A review of the technical literature on the state of the science in the field of effective methods for regulating surface runoff from urbanized areas has revealed the need for comprehensive solutions to reduce and slow down precipitation runoff. The normalization of the situation, related to the management of rainfall runoff, should be calculated for many years. This is due to a large amount of money required to implement the construction of sewage systems with large cross-sectional sizes, which are underutilized operationally. Therefore, it is necessary to strive for the implementation of such solutions, which, while reducing unnecessary costs, would be optimal in terms of capital expenditures incurred.

An analysis of various ways of regulating wastewater outflow from urbanized catchments has shown that the most effective way of slowing down wastewater outflow is achieved by using retention reservoirs.

Conventional solutions for retention reservoirs require a significant area of land for their construction and the deep laying of the outflow collector.

Multi-chamber gravitational reservoir solutions represent a major advance in the hydraulic performance of this type of reservoir, reducing their necessary retention capacity compared to the classical solution. They also made it possible to maintain an almost constant value of the reduced outflow rate in the process of filling these reservoirs.

The inspiration for a new generation of gravity and vacuum retention reservoirs comes from the limitations of using gravitational-only design in practice. Gravity and vacuum reservoirs allow for partial or complete retention of sewage above its surface in the inflow.

Energy-saving reservoir solutions result from the need to reduce the amount of electricity required to enable vacuum pumps to operate. Their designs do not differ from multi-chamber reservoir solutions, while the separation of the tank's retention capacity into gravity and vacuum parts is related to the volumetric capacity of a small vacuum pump, with its operation predicted during the filling of the gravity chamber.

All reservoir solutions are large-scale concrete underground structures. Their implementation in each case requires the development of specialized projects, while the construction itself is a long-term investment process.

### Gravity sewage retention reservoirs

The basic solution of the gravity retention reservoir is a single-chamber conventional SIMPLEX reservoir (see Fig. 1) [2].

Sewage is supplied through a channel located as high as possible in the upper part of the reservoir, while the outflow is made possible by a throttling discharge pipe, which is located at the lowest point of the building. The reservoir requires ensuring a large retention capacity of the chamber. Consequently, its construction requires a considerable area for the reservoir to be built.

The CANALIS reservoir (Fig. 2) [2, 4] does not differ in its hydraulic operation from the SIMPLEX reservoir (Fig. 1). However, it has a different design as its retention chamber is made up of pipe sections connected in series with an appropriately

Fig. 1. Single-chamber SIMPLEX reservoir [2]  
Rys. 1. Jednokomorowy zbiornik typu SIMPLEX [2]

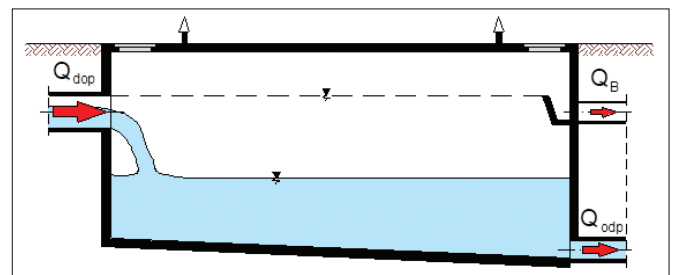
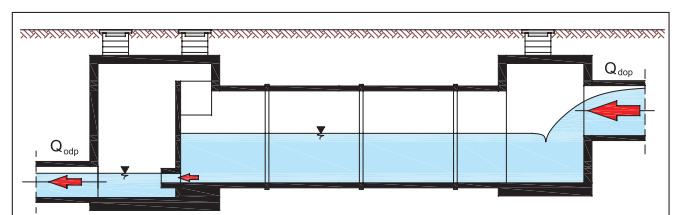


Fig. 2. Single-chamber CANALIS reservoir [2]  
Rys. 2. Jednokomorowy zbiornik typu CANALIS [2]



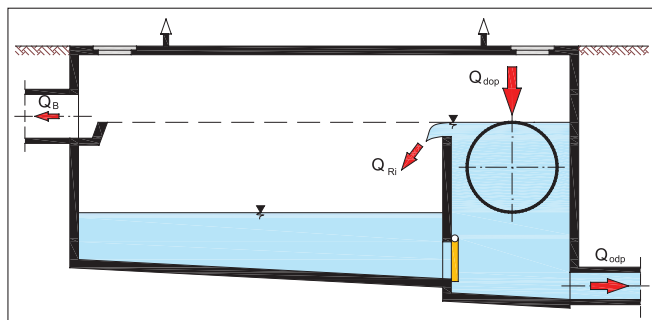
increasing diameter compared to the transit collectors.

The two-chamber CONTRACT reservoir (Fig. 3) has a flow chamber and a gravity retention chamber [9]. It has the ability to maintain an almost constant outflow from the reservoir during the process of filling its gravity retention chamber with sewage. With this property and depending on the minimum degree of flow reduction

ity retention chambers located one over the other. The upper retention chamber of the reservoir is filled with sewage first, and, after it is completely filled, the sewage fills the lower retention chamber during its transit flow. Partial or complete filling of the upper retention chamber allows for (but to a very limited extent) maintaining increased values of sewage outflow from the reservoir, both when the rate of sewage inflow

into the reservoir reaches a value lower than the rate of reduced outflow, and when the process of emptying the reservoir begins. This reservoir is the most effective solution in the case of the accumulation of sewage characterized by high flow variability.

The three-chamber serial-parallel COMPLEX reservoir (Fig. 6) has a flow chamber with two gravity retention chambers adjacent on both sides. The retention chambers are filled by gravity with sewage in series order, which means that the filling of a chamber is possible only after the complete filling of the previous one. The gravity retention chambers are emptied simultaneously after they are completely filled by opening the flap valves located in the bottom zone of the flow chamber in the walls separating it from both retention chambers of the reservoir.



**Fig. 3.** Two-chamber CONTRACT reservoir [6]  
*Rys. 3. Dwukomorowy zbiornik typu CONTRACT [3]*

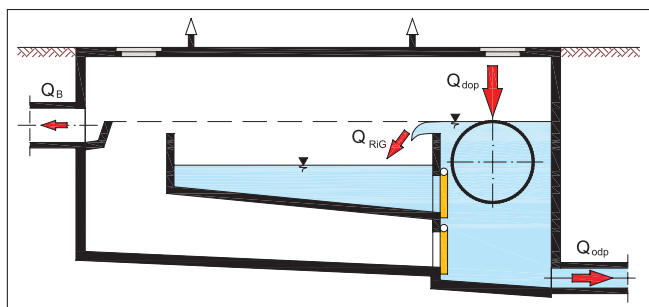
for the reservoir, the total retention capacity of the CONTRACT reservoir is reduced compared to the retention capacity.

The smaller retention capacity of the CONTRACT reservoir allows for faster emptying and a reduced horizontal projection of the reservoir, while making the position of the outflow collector from the reservoir more shallow.

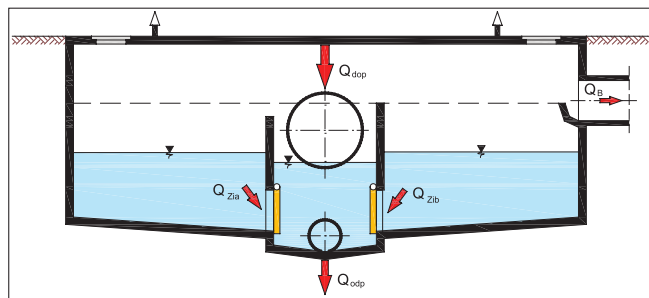
The COMPLEMENT multi-chamber serial reservoir (Fig. 4) [6] has a flow chamber and gravity retention chambers located one after another, with their number justified by the diversity of operational hydrographs of the inflow to the reservoir. Unlike the CONTRACT reservoir (Fig. 4), the COMPLEMENT reservoir is characterized by the fact that its retention capacity is divided into a certain number of chambers. For most operational hydrographs of sewage inflow to the reservoir, partial or complete filling of the next chamber is only possible after the previous one is completely filled. With this type of retention capacity, when the COMPLEMENT reservoir is partially filled, it is emptied faster than the same volume of sewage accumulated in one chamber, such as in a CONTRACT reservoir.

The three-chamber WISKARB reservoir (Fig. 5) has a flow chamber and two grav-

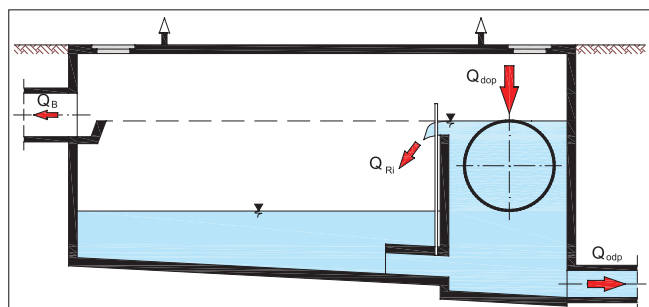
**Fig. 5.** Multi-chamber WISKARB reservoir [9]  
*Rys. 5. Wielokomorowy zbiornik typu WISKARB [9]*



**Fig. 6.** Multi-chamber COMPLEX reservoir [4, 9]  
*Rys. 6. Wielokomorowy zbiornik typu COMPLEX [4, 9]*

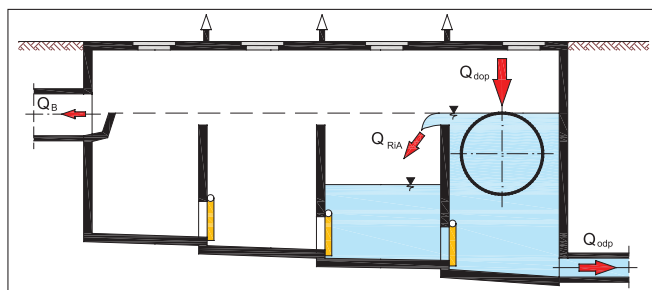


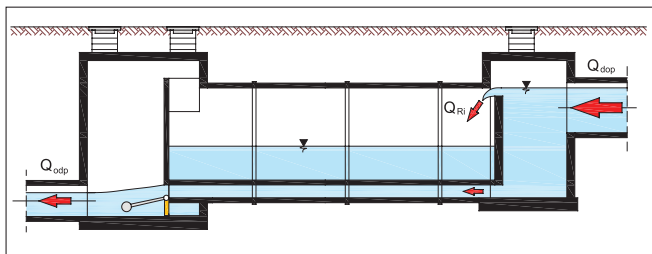
**Fig. 7.** Two-chamber LICET reservoir [4, 9]  
*Rys. 7. Dwukomorowy zbiornik typu LICET [4, 9]*



**Fig. 4.** Multi-chamber COMPLEMENT reservoir [4]  
*Rys. 4. Wielokomorowy zbiornik typu COMPLEMENT [4]*

The two-chamber LICET reservoir (Fig. 7) differs from the two-chamber CONTRACT reservoir (Fig. 3) in that it does not have a flap valve, opened unidirectionally by a difference in hydrostatic pressure, which is generated by the flow of sewage from the retention chamber to the flow chamber. In place of a flap valve, the LICET reservoir has a flow hole with a different flow capacity, larger in the direction of flow





**Fig. 8.**  
**LONGUS pipe reservoir [2]**  
*Rys. 8. Rurowy zbiornik typu LONGUS [2]*

## Gravity and vacuum sewage retention reservoirs

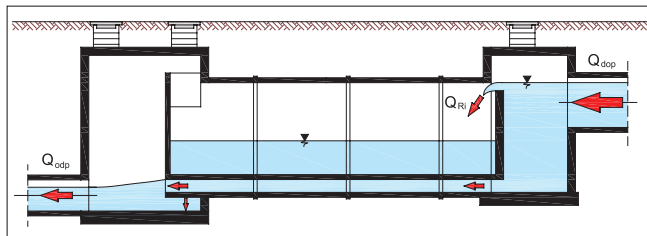
The **COMMODUS – S** reservoir (Fig. 11) is equipped with a gravitational flow chamber and a vacuum retention chamber. Vacuum retention of sewage is achieved using an electric vacuum pump with a reg-

from the gravity retention chamber to the flow chamber.

The **LONGUS** reservoir (Fig. 8) [2] has an additional partition that separates the inflow chamber from the retention chamber, which in the bottom zone, has an inflow to the transit pipe with a smaller diameter, arranged along the entire length of the retention chamber. The outflow from the retention chamber to the outflow chamber is ensured by a drain hole at the lowest point of the reservoir chamber. The intensity of sewage discharge through the drain hole is regulated by a float valve, with its operation depending on the level of sewage in the outflow chamber. The introduced innovation ensures the use of the full retention capacity of the reservoir and hydraulic capacity of the outflow channel.

The concept of the **PROXIMUS** reservoir [2] (Fig. 9) is that the retention chamber, which is also a large-diameter pipe, is arranged with the slope opposite to the

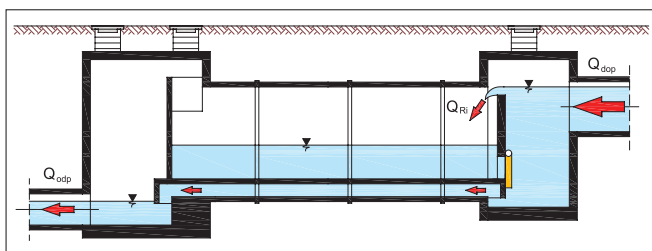
**Fig. 10.**  
**MAGNUS pipe reservoir [2]**  
*Rys. 10. Rurowy zbiornik typu MAGNUS [2]*



its efficiency becoming comparable with other solutions of this type. The reservoir has no mechanical closure to prevent the outflow of the liquid accumulated in the pipe retention chamber. The flow transit pipe located at the bottom of the retention chamber ensures that, with the maximum filling of the inflow chamber, a lower flow rate than the reduced discharge rate is achieved. When the reservoir is completely filled, the short-term outflow from the reservoir, which represents the sum of the transit flow and the free outflow from the retention chamber, is slightly higher than the reduced outflow rate.

ulator that corrects the speed of rising and falling of the sewage surface level in the vacuum chamber. The reservoir is capable of equalizing the sewage outflow both during the process of filling the vacuum chamber and during its emptying. It also compensates for the outflow of sewage from the reservoir in the periods when the inflow rate to the reservoir reaches values lower than the reduced outflow rate.

The three-chamber **MIRUS – S** reservoir (Fig. 12) is a special combination of the **COMMODUS – S** (Fig. 11) and **CONTRACT** reservoirs (Fig. 3). It can operate in two variants: in the first one, the gravity chamber is filled after the complete filling of the vacuum retention chamber; in the second, both retention chambers are filled simultaneously. It has the same capability of equalizing sewage outflow from the reservoir as **COMMODUS – S**, provided that there is accumulated sewage in the vacuum chamber.



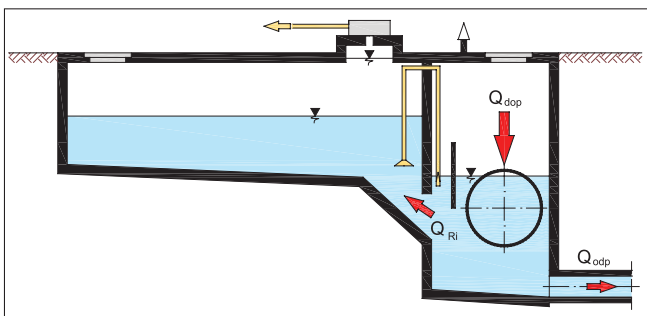
**Fig. 9.**  
**PROXIMUS pipe reservoir [2]**  
*Rys. 9. Rurowy zbiornik typu PROXIMUS [2]*

flow direction. This makes it possible to design the flap closure in the reservoir inflow chamber. The flow transit pipe is also located here on the bottom of the retention chamber. It is therefore placed with the same opposite slope as in the case of the retention chamber pipe.

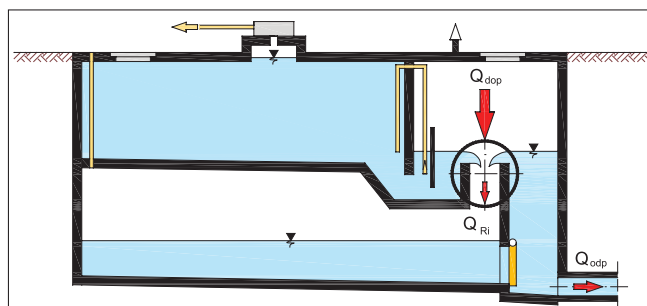
Pollutants carried with rainwater, mainly suspended matter, will cause the formation of sludge at the inflow to the transit channel. Therefore the inflow chamber of the **PROXIMUS** reservoir should also serve as a settling tank, additionally treating the sewage, or function as a kind of absorbent well, if the soil and water conditions are sufficient.

The **MAGNUS** reservoir (Fig. 10) represents a redesign of the basic version of the **CANALIS** reservoir (Fig. 2) aimed to increase the efficiency of their hydraulic operation. It is equipped with additional chambers, thus considered a multi-chamber reservoir, with

**Fig. 11.**  
**Multi-chamber COMMODUS – S gravity and vacuum reservoir [5]**  
*Rys. 11. Wielokomorowy zbiornik grawitacyjno – podciśnieniowy typu COMMODUS – S [5]*



**Fig. 12.**  
**Multi-chamber MIRUS – S gravity and vacuum reservoir [7, 8]**  
*Rys. 12. Wielokomorowy zbiornik grawitacyjno – podciśnieniowy typu MIRUS – S [7, 8]*



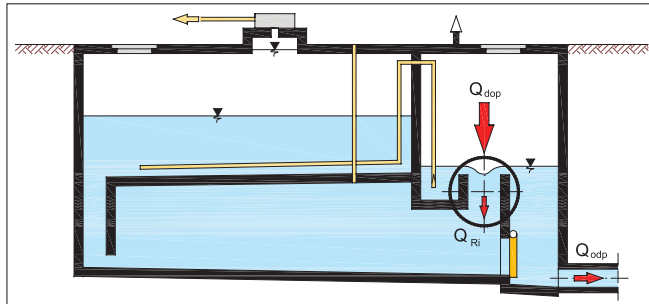
The three-chamber CONSES – S reservoir (Fig. 13) differs from the MIRUS – S reservoir (Fig. 12) in that the filling with sewage from the vacuum retention chamber is performed with a vertical pipe from the gravity retention chamber.

It reaches its efficiency and effectiveness only when both gravity and vacuum retention chambers are fully filled. Its use in prac-

formance vacuum pump or a built-in air jet pump [9]. The basic vacuum pump with a volume capacity as in the MIRUS – S reservoir is only switched on after the complete filling of the gravity retention chamber and partial filling of the vacuum retention chamber if it is necessary to continue the accumulation of sewage in the reservoir. The capacity of the vacuum chamber is

has the same design as the CONSES – S reservoir (Fig. 13). However, it differs in the hydraulic mode of operation and it is equipped with a low-capacity vacuum pump or has an air jet pump installed in the out-flow hole.

While filling the gravity retention chamber of the CONSES – ES reservoir, a simultaneous accumulation of sewage is observed in the vacuum retention chamber due to the operation of a vacuum pump with a low volume capacity. In most operational cases, complete filling of the gravity retention chamber and partial filling of the vacuum chamber ends the filling process. If further sewage accumulation is required, a vacuum pump with a higher volume capacity is switched on and the vacuum chamber is filled with sewage. As in the MIRUS – ES reservoir (Fig. 15), there is



**Fig. 13.** Multi-chamber CONSES – S gravity and vacuum reservoir [6]

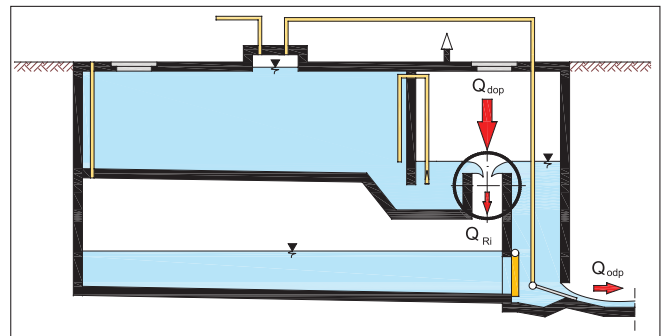
*Rys. 13. Wielokomorowy zbiornik grawitacyjno – podciśnieniowy typu CONSES – S [6]*

tice will therefore be justified only for the cases which guarantee its complete filling.

Three-chamber PARKUS – S reservoir (Fig. 14) also represents a combination of CONTRACT reservoir (Fig. 3) with COMMODUS – S reservoir (Fig. 11) with the difference that the vacuum retention chamber is not separated by the ceiling from the gravity retention chamber, as in the case of MIRUS – S reservoir (Fig. 12). The PARKUS – S reservoir is filled in the same way as the

**Fig. 15.** Multi-chamber energy-efficient MIRUS – ES gravity and vacuum reservoir [7]

*Rys. 15. Wielokomorowy, energooszczędny zbiornik grawitacyjno – podciśnieniowy typu MIRUS – ES [7]*



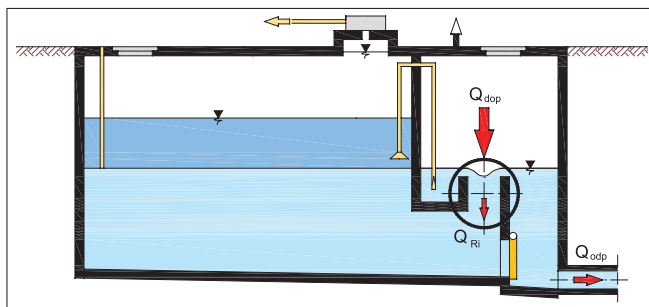
**Fig. 14.** Multi-chamber PARKUS – S gravity and vacuum reservoir [6]

*Rys. 14. Wielokomorowy zbiornik grawitacyjno – podciśnieniowy typu PARKUS – S [6]*

a relationship between the installed lower performance vacuum pump and the vacuum chamber capacity.

### Energy-efficient multi-chamber reservoirs with a system of suction and discharge pumps

The three-chamber COMMODUS – EP reservoir (Fig. 17) has the same design of



**Fig. 16.** Multi-chamber energy-efficient CONSES – ES gravity and vacuum reservoir [9]

*Rys. 16. Wielokomorowy, energooszczędny zbiornik grawitacyjno – podciśnieniowy typu ONSES – ES [9]*

CONTRACT reservoir until the gravity retention chamber is completely filled. When further retention is required, a vacuum pump is switched on and the sewage is vacuum-accumulated in a closed space above the gravity retention chamber. This solution does not require the separation of the two retention chambers with the ceiling and is therefore considered economical in construction. This allows for an easy adaptation of current reservoirs to vacuum accumulation.

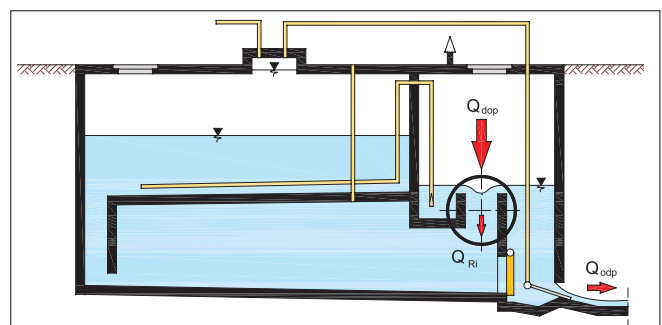
### Energy-efficient multi-chamber reservoirs with a vacuum pump system

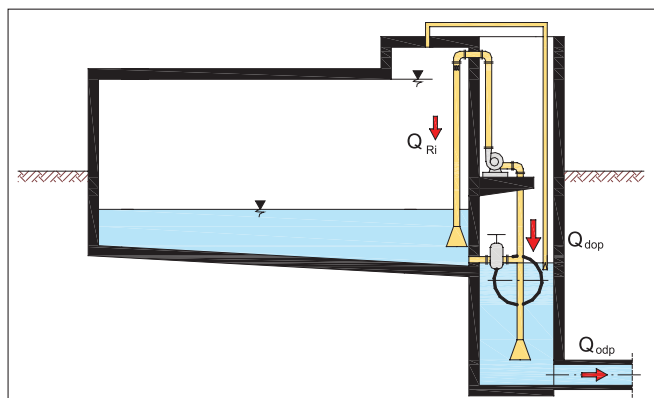
Three-chamber energy-efficient MIRUS – ES reservoir (Fig. 15) [7, 8] has the same design as the MIRUS – S reservoir (Fig. 12). The reservoir is equipped with a low-per-

strictly dependent on the low-performance vacuum pump installed and vice versa. In most operational cases of the inflow of sewage to the reservoir, retention capacity is not completely filled and it is not necessary to switch on the high-performance pump.

Furthermore, the three-chamber energy-efficient CONSES – ES reservoir (Fig. 16)

chambers as the COMMODUS – S reservoir (Fig. 11). However, the two reservoirs are fundamentally different in terms of how the vacuum chamber is filled. In this case, the vacuum chamber is filled using a system of pumps, which are actuated consecutively by sensors as the flow of sewage into the reservoir increases. The air from the filled vacuum





**Fig. 17.** Multi-chamber energy-efficient COMMODUS – EP gravity and vacuum reservoir with a system of suction and discharge pumps [9]

*Rys. 17. Wielokomorowy, energooszczędny zbiornik grawitacyjno – podciśnieniowy z układem pomp ssąco – tłoczących typu COMMODUS – EP [9]*

chamber is discharged into the atmosphere by the regulator that controls the process of its emptying after the pumps are switched off and the drain pipe is opened.

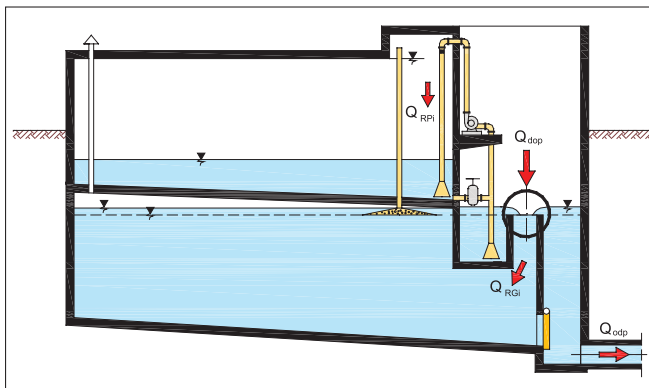
The vacuum retention chamber is only emptied when the reservoir is completely filled or the inflow to the reservoir is stopped. For most of the operational inflows to this reservoir, the method of its filling brings measurable savings in electricity consumption compared to its necessary consumption for a similar inflow in the case of filling the COMMODUS – S reservoir.

The two-chamber MIRUS – EP reservoir (Fig. 18) has three chambers identically located as in the MIRUS – S reservoir (Fig. 12). The vacuum chamber is filled through the system of suction and discharge pumps, with its operation controlled by chamber filling level sensors. The air is discharged from the vacuum chamber filled with sewage into the atmosphere through the regulator's pipe, which in turn controls the sewage outflow rate from the chamber during the emptying process. When filling the vacuum chamber, the drain pipe is closed, and, with switching off the pumps, this closure opens and the process of emptying the vacuum chamber begins simultaneously. Both chambers are filled simultaneously, with the vacuum chamber being filled by a low-performance suction and discharge pump. The choice of a low-performance pump is also related to the accumulation capacity of the vacuum chamber, whereas the principle of operation of the reservoir is identical to that of MIRUS – ES (Fig. 15).

The energy-efficient CONSES – EP reservoir has three chambers with the design and layout of chambers similar to that of MIRUS – S (Fig. 12). However, its operation is typical of the CONSES – S reservoir (Fig. 13), because the filling and emptying of the vacuum chamber are carried out through the gravity retention chamber. The operation of the system of suction and discharge pumps is also controlled by the chamber filling level sensors. The inflow to the regulator is

**Fig. 18.** Multi-chamber energy-efficient MIRUS – EP gravity and vacuum reservoir with a system of suction and discharge pumps [7, 8]

*Rys. 18. Wielokomorowy, energooszczędny zbiornik grawitacyjno – podciśnieniowy z układem pomp ssąco – tłoczących typu MIRUS – EP [7, 8]*



located in the ceiling zone of the gravity retention chamber, while its outflow is located in the ceiling zone of the vacuum retention chamber.

The OPTIMUS – EP reservoir has an identical design as the MIRUS – S reservoir (Fig. 12). It has three chambers: two retention chambers (gravity and vacuum chambers) and a gravity flow chamber. It is equipped with a system of suction and discharge pumps whose suction pipe is located in a gravity retention chamber.

In this reservoir, the gravitational retention chamber is first filled with liquid and, after it is completely filled, the process of vacuum accumulation of the retention chamber is started

### Advantages and disadvantages of sewage retention reservoirs

#### – Gravity sewage retention reservoirs

Conventional gravity reservoirs have many disadvantages [1, 6]. They are generally shaped as very flat cuboids. This particularly applies to single-chamber solutions. The exception to the rectangular shapes of retention reservoirs is their pipe-based solutions. The single-chamber retention reservoirs designed in sewage systems are characterized as highly inefficient solutions, both hydraulically and in terms of the necessary investments for their implementation. All types of single-chamber sewage retention reservoirs operated based on the gravity effect are characterized by limited

filling levels. The need for their deep foundation also requires a deep location of the outflow collector.

Compared to the single-chamber classical SIMPLEX-type design, multi-chamber reservoirs with gravitational operation brought a significant reduction in the required capacity of the retention chambers and made it possible to make the outflow collector arrangement shallower while increasing the utilization of its cross-sectional area. The smaller retention capacity of the reservoir allows it to be

emptied more quickly and reduces its horizontal projection. With the use of a low-volume flow chamber, it is possible to maintain an almost constant outflow from the reservoir, corresponding to the value of the reduced flow rate, during the process of filling its accumulation chamber.

The disadvantage of multi-chamber gravity reservoirs is the increased number of flap valves, which, due to maintenance and repair requirements, reduce the reliability of operation of this type of reservoir and increase the cost of its implementation and operation.

Multi-chamber gravity pipe reservoirs [2, 3, 13] are distinguished by their extremely uncomplicated design, simple and timely construction, and the maximally limited area occupied for the construction works.

The unquestionable advantage of all gravity reservoirs is that their operation is carried out without the use of additional electricity.

#### – Gravity and vacuum sewage retention reservoirs

Gravity and vacuum reservoirs [4, 5, 6, 7, 8] have significantly increased the applicability of retention reservoirs in sewage systems. The advantage of gravity and vacuum reservoirs is that the maximum outflow rate can be maintained while the vacuum section is being emptied, allowing the reservoir's retention capacity to recover more quickly. They allow full or partial retention of wastewater above the level of its water table in the inflow, thus limiting

the horizontal projection of the reservoir and allowing the outflow collector alignment to be significantly shallower.

– **Energy-efficient multi-chamber reservoirs with a vacuum pump system and a system of suction and discharge pumps**

Energy-efficient multi-chamber reservoirs [8, 9] are identical in design to gravity reservoirs but differ in their hydraulic mode of operation and in that they have a low-capacity vacuum pump or a jet air pump built into the discharge opening. Newer designs often have suction and discharge pumps. In these solutions, the necessary operating time of electrical equipment has been minimized. This, however, came at the cost of a slight reduction in the reservoir's hydraulic efficiency. The use of a system of pumps requires a suitable system and a method of controlling them, which is important for the proper operation of the reservoir.

The disadvantage of all vacuum and energy-saving reservoirs is the need for external electricity.

**Accepted designations:**

$Q_{dop}$  – instantaneous rainwater inflow to the retention reservoir,  $[m^3/s]$ ;

$Q_{odp}$  – instantaneous rainwater runoff from the retention reservoir,  $[m^3/s]$ ;

$Q_B$  – instantaneous emergency runoff of rainwater from the retention reservoir,  $[m^3/s]$ ;

$Q_{Ri}$ ,  $Q_{RIA}$  – instantaneous flow through the overflow edge from the retention chamber to the reservoir inlet chamber  $[m^3/s]$ ;

$Q_{RiG}$  – instantaneous gravity flow  $[m^3/s]$ ;

$Q_{RPI}$  – instantaneous pneumatic flow  $[m^3/s]$ ;

$Q_{Zia}$ ,  $Q_{Zib}$  – instantaneous flow in the reservoir chambers  $[m^3/s]$ ;

**Conclusion**

Sewage retention reservoirs are one of the essential and inseparable elements of modern sewerage systems. Control of rainwater run-off from the protected catchment area by temporarily holding peak flows in retention reservoirs largely prevents local flooding and the related risks.

Compared to modern multi-chamber reservoirs, those with conventional design, despite low efficiency of operation, are distinguished by high construction costs.

Multi-chamber gravity reservoirs and gravity and vacuum reservoirs are a new generation of high-performance sewerage facilities in terms of control of the sewage discharge from the catchment area. Their unique and efficient hydraulic system, which makes optimal use of the capacity of the discharge channel, allows for a reduction in

the required reservoir capacity, thus making it possible to shape the reservoir body and to flatten the level of the discharge collector. The significant economic benefits of operating these reservoirs are decisive for their wide range of applications.

The latest solutions of multi-chamber sewage reservoirs indicate that simple designs are being sought, as in the case of channel designs of gravity reservoirs (such as CANALIS, LONGUS, PROXIMUS, and MANGUS), or energy-saving gravity and vacuum solutions (MIRUS-E, CONSES-E). These tendencies are also likely to encourage designers to use such solutions in practice [2, 3, 4, 5, 6, 7, 8, 9, 14].

The use of a retention reservoir in a sewage system should be always preceded by a full technical and economic analysis. Functionality and operation are intended to guide the right solutions. Calculation procedures for sizing reservoirs make it possible to determine the rain parameters for design purposes and, consequently, the necessary capacity of retention reservoirs.

Among the benefits of using a retention reservoir are:

- reduction in the diameter of the collector in a rainwater sewage system used when the cost of running a large-diameter sewer is greater than the cost of building a reservoir,
- no need to rebuild a collector that is overloaded when connecting new parts of the system,
- reducing the peak capacity of pumps by using a reservoir before rainwater pumping stations,
- connection to the receiver if the calculated rainwater inflow from the catchment area is higher than the value allowed for a particular receiver,
- protecting the catchment area and stormwater drainage system from flooding as a result of the backflow from the receiver (river) and possible flooding.

At present, retention reservoirs are the primary solution for modern drainage systems in urbanized areas. They provide an opportunity to control the operation of the system in qualitative and quantitative terms.

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