Environment Protection Engineering

Vol. 34 2008 No. 3

TOMASZ SIONKOWSKI*,
RYSZARD ŚLIZOWSKI**

THE PHENOMENON OF SIMULTANEOUS WORK OF PUMPS IN A PRESSURISED SEWERAGE SYSTEM

The occurrence of simultaneous pump operation in pressurized sewage systems was described. This occurrence consists in synchronic pump operation on the common main pipe and is important for the proper operation of the whole system. The analysis was conducted for two different active volumes, characteristic of one separate pumping. This occurrence becomes important especially for large, expanded systems consisting of more than 75 pumping stations. For the systems consisting of 100 domestic pumping stations, simultaneous operation may even represent 12% of the total operating time.

1. INTRODUCTION

In the last several years, pressure piping systems have been used as an alternative to gravity systems. Numerous studies [1]–[6] describe these types of wastewater reposition. Pressurized wastewater systems are composed of tens or hundreds of domestic lift stations operating on a common sewer force main. Uninterrupted simultaneous loading of the main is a result of pumps' successively switching on and off. This method of operation has been defined as simultaneous pump operation. Thus, the term *simultaneous operation of a pressurised sewerage system* applies to the situation in which in a pumped system at any time interval more than two pumps switch on and operate without interruption. The time of simultaneous operation is measured from the moment the first pump switches on to the moment the last pump switches off. This situation is presented in figure 1.

* Veolia Water Systems, sp. z o.o., ul. Wrocławska 53, 30-011 Cracow, Poland. Phone 012 423 38 66. Fax. 012 423 34 82. E-mail: sionkowski@poczta.onet.pl

** Chair of Sanitary Engineering and Water Management, Agricultural University of Cracow, al. Mickiewicza 24/28, 30-059 Cracow, Poland. Phone 012 662 40 57. Fax. +48 012 633 11 70. E-mail: wisig@ar.krakow.pl

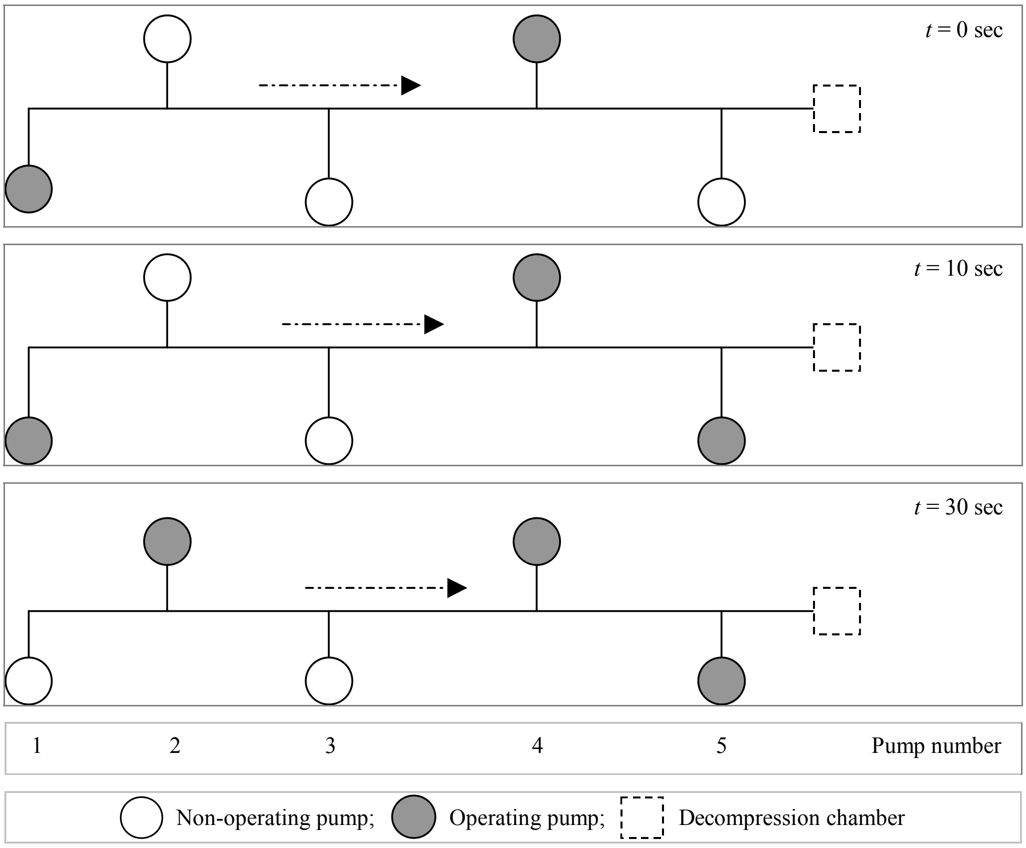

Fig. 1. Simultaneous work of a pressurised sewerage system

At the time $t = 0$ the pumps numbered 1 and 4 switch on. After 10 seconds pumps 1 and 4 are still operating and pump 5 additionally switches on. After 30 seconds, pump 1 switches off, while pumps 4 and 5 continue to operate. In addition, pump 2 is also operating.

Since the pumps switch on at $t = 0$ seconds and switch off at $t = 40$ seconds, one can say that four pumps are engaged in simultaneous work and that the period of their simultaneous operation lasts 40 seconds.

2. RESEARCH METHOD. MODEL ANALYSIS

A computer model has been constructed to permit the study of a pressurised sewerage system. It was developed and tested to meet the requirements of the pressurised sewerage system in Modlinczka in the commune of Wielka Wieś. In a sewerage system, the dynamics of flow to the model's lifting station is characterised by daily changes. Usually the morning and evening peaks are observed. In the simulation (as shown in figure 2), a daily distribution of the flow in sewerage has been assumed which is characterised by two peaks: a lower, morning peak between 7.00 and 10.00 a.m. and a higher, evening peak between 7.00 and 11.00 p.m. During the morning peak, 19% of the total flow of sewage to the system takes place, and during the evening peak 28% occurs. In the model, it is assumed that the total percentage of sewage flow between 11 p.m. and 5 a.m. is only 5.5%.

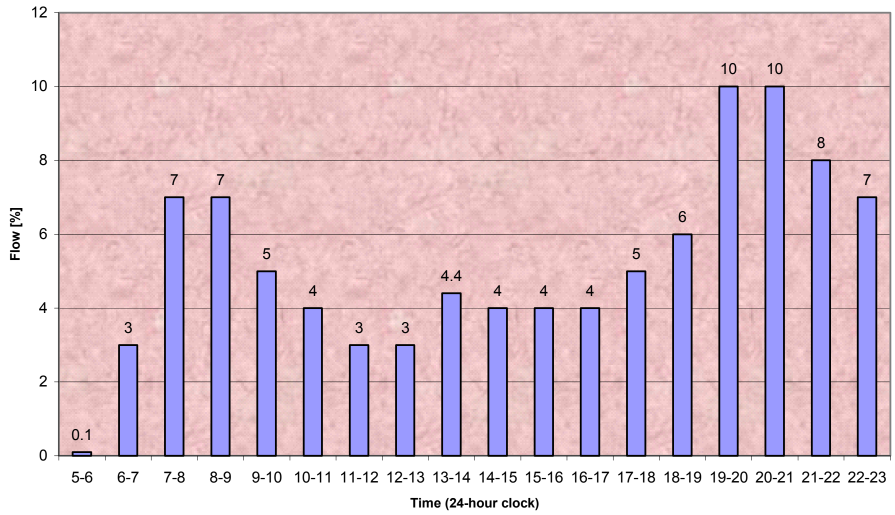

Fig. 2. Hourly distribution of flow of sewage measured as proportions of total

A series of simulations was performed for systems comprising 10, 20, 30, 40, 50, 75 and 100 domestic lift stations for two different levels of switching on and off pumps. The parameters of the lift stations in the two types of simulations were identical (table 1). In simulations for the first group (Simulation 1), the lift stations switched on more often when the active volume of the stations was (at 148.05 dm^3) half the active volume for the Simulation 2 group (296.11 dm^3).

Table 1

Parameters of the model lifting stations

Parameter	Simulation 1	Simulation 2
Internal diameter of the lifting stations (m)	0.78	0.78
Head of switching on (m)	1.29	0.98
Depth (m)	1.8	1.8
Head of switching off (m)	1.6	1.6
Head of emergency (m)	1.24	0.90

Volume of one lifting station (dm^3)	148.05	296.11

In all the simulations, the time interval dt = del(t) was equal to 10 seconds. The simulations were conducted for a random daily flow of sewage to the lifting stations of between 250 dm^3 and 500 dm^3. Since the amount of sewage flow is a random variable, the volume of sewage flowing into each lifting station was random within the limits of 250 dm^3 and 600 dm^3. After performing a series of simulations for a system composed of k-number lifting stations, where k amounts to 10, 20, 30, 40, 50, 75 and 100 stations, respectively, the daily sewage flow in a single randomly-chosen lifting station was doubled; then a series of simulations was performed for a system composed of k-number lifting stations. The procedure described above for increasing the volume of sewage flow was used in turn for 2, 3, 4, 5, 6, 9 and half the lifting stations in a k-station system. The level of active retention (between $H_{\text{switch on}}$ and $H_{\text{switch off}}$) was also generated randomly for the time t = 0 so as to avoid the unrealistic situation in which at time t = 0 the lifting station holding tanks contain the same amount of sewage.

The Symbol SYM_00 means that pumped systems with varying numbers of lifting stations (20, 30, 40, 40, 75 and 100) were studied with the flow of sewage to none of the lifting stations being doubled. SYM HALF means that pumped systems with varying numbers of lifting stations (20, 30, 40, 40, 75 and 100) were studied with the flow of sewage to half of the lifting stations being doubled. An example is given in figure 3.

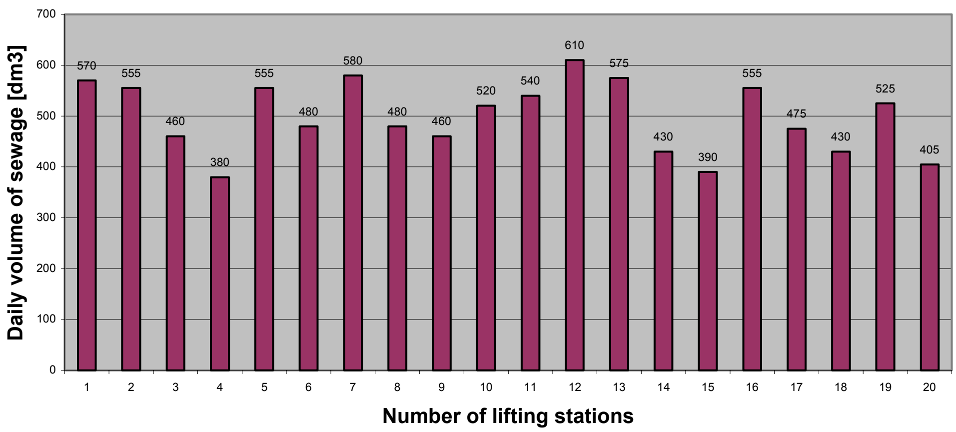

Fig. 3. Daily volume of sewage flow SYM_20 (dm^3)

The major input parameters to the model are:
- the length of particular sectors of the main sewer,
- the length of side drains,
- height of junctions,

• height of lifting station's bases,
• levels at which lifting stations switch on and off,
• diameters of main sewer and side drains,
• diameters of lifting station holding tanks.

On the basis of the above data, losses in pipelines were calculated and pumps selected. Pumps were selected so that the lowest possible number of types of pumps (no more than two or three types) are used in the system as a whole. The pumps selected are presented in figure 4.

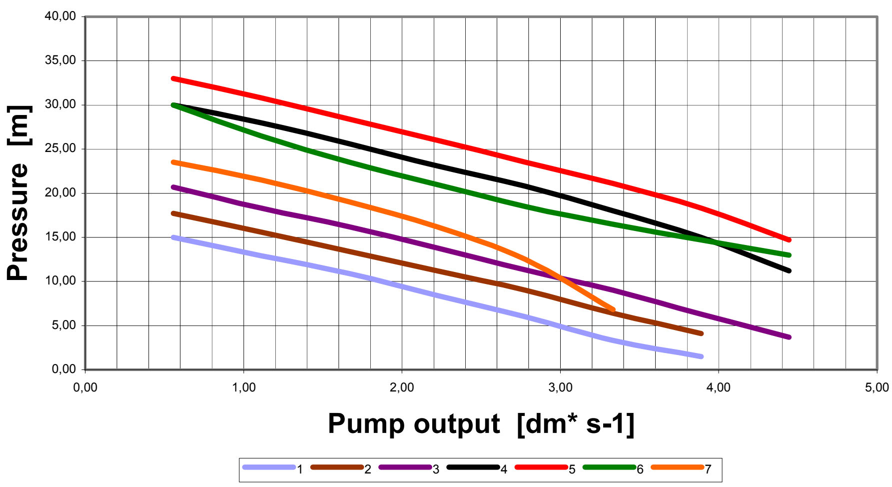

Fig. 4. The features of TP40s/MTS pumps fitted with a cutting knife system

Output parameters obtained from the model are:

• the pump's operating point (a product of the pump and the pipeline characteristics),
• speed at particular tranches of the pipeline,
• the time for which pumps operate,
• the number of pumps operating simultaneously.

For all the simulations, matter density is assumed to be 1.1 kg/dm^3, its temperature 20 °C and the suspended solids' content 500 mg/dm^3. These assumptions relate to the structure of sewage after its passage through a pump fitted with a cutting knife. They allow simulations to be performed under reproducible conditions.

3. RESEARCH RESULTS

Tables 2 and 3 present the major statistics arising from the observation of simultaneous operation under two different active volumes. The results of the observations

cover a period of 30 days. It was noted that the number of occurrences of simultaneous operation rise along with an increase in the number of pumps in the system. Also, the number of such occurrences are higher in the case of lifting stations with a smaller active volume than in that of stations with an active volume of 296 dm^3. In addition, the maximum and average periods of simultaneous operation generally become longer together with a rise in the number of pumps in the system.

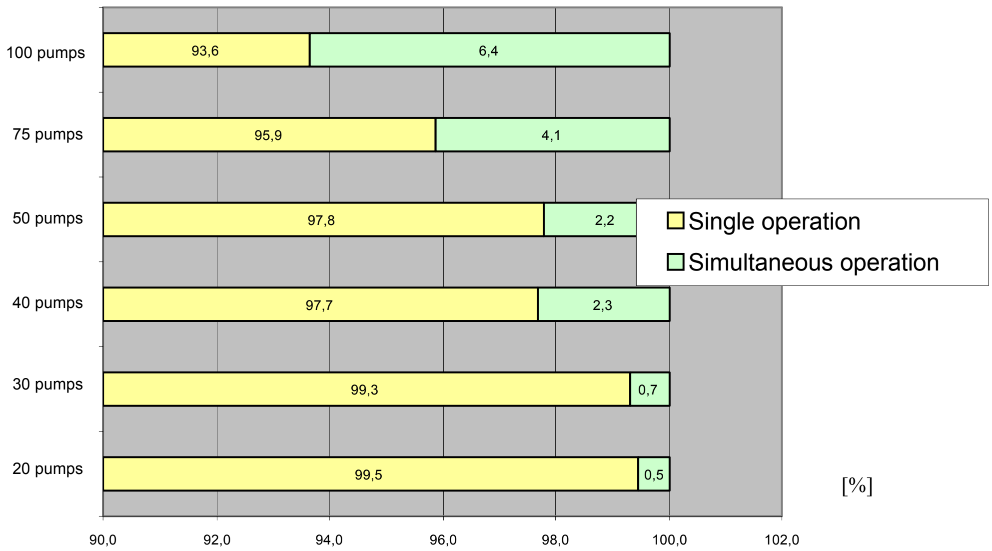

Fig. 5. Proportion of simultaneous operation in total operation of pumped systems composed of *n* pumps with active volume $V = 148$ dm^3 and average sewage flows to lifting stations as specified for SYM_00 simulations

Based on the analysis of the parameters for simultaneous operation, it may be stated that the number of occurrences are significantly greater in the case of studies conducted for an active volume of 148 dm^3. The proportion of simultaneous operation in relation to total operation of the system is presented in figures 5–8. It may be noted that the proportion of simultaneous operation grows significantly for systems of 75 and 100 lifting stations. The proportion of simultaneous operation in the total operating time of a pressurised sewerage system is also greater in the case of larger average flows of sewage into the system.

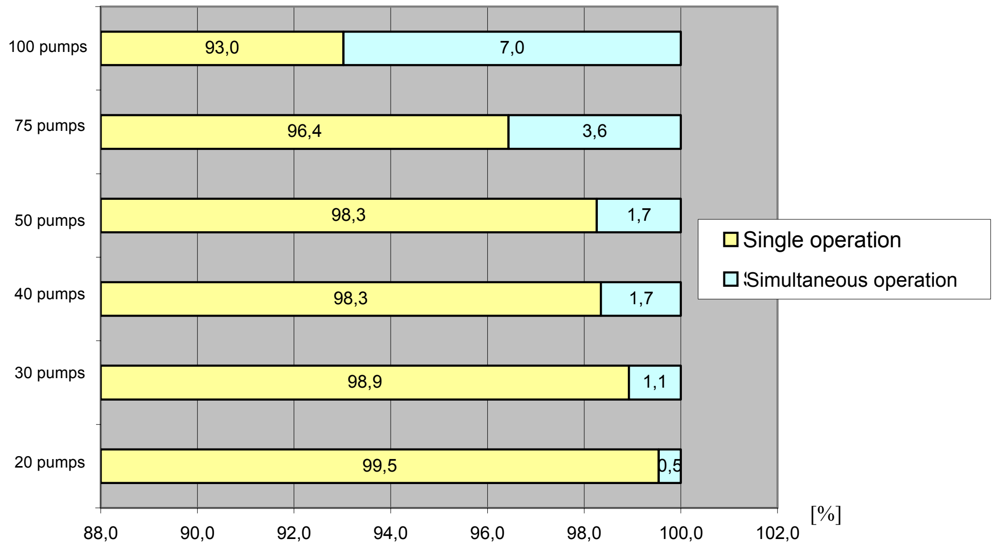

Fig. 6. Proportion of simultaneous operation in total operation of pumped systems composed of *n* pumps with active volume $V = 296$ dm^3 and average sewage flows to lifting stations as specified for SYM_00 simulations

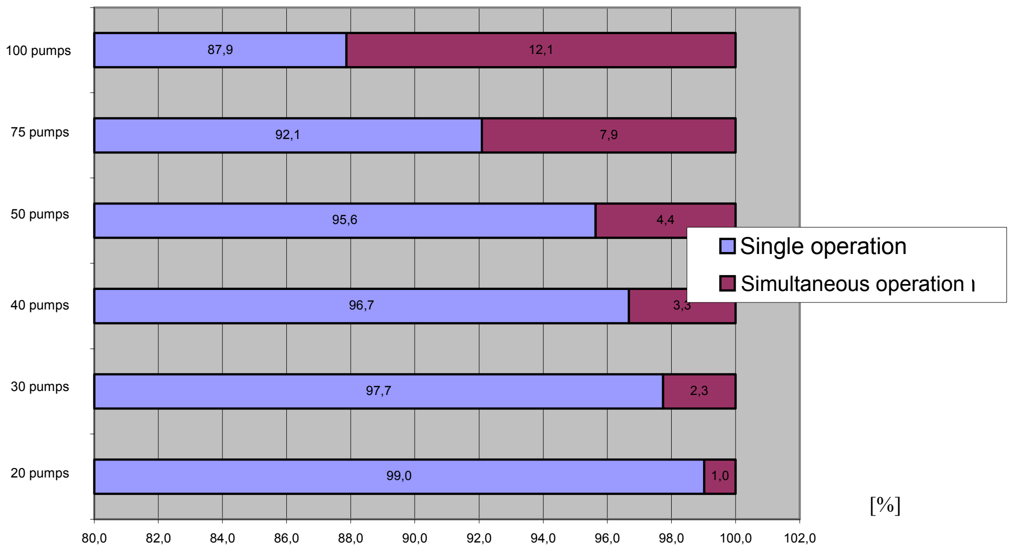

Fig. 7. Proportion of simultaneous operation in total operation of pumped systems composed of *n* pumps with active volume $V = 148$ dm^3 and average sewage flows to lifting stations as specified for SYM_HALF simulations

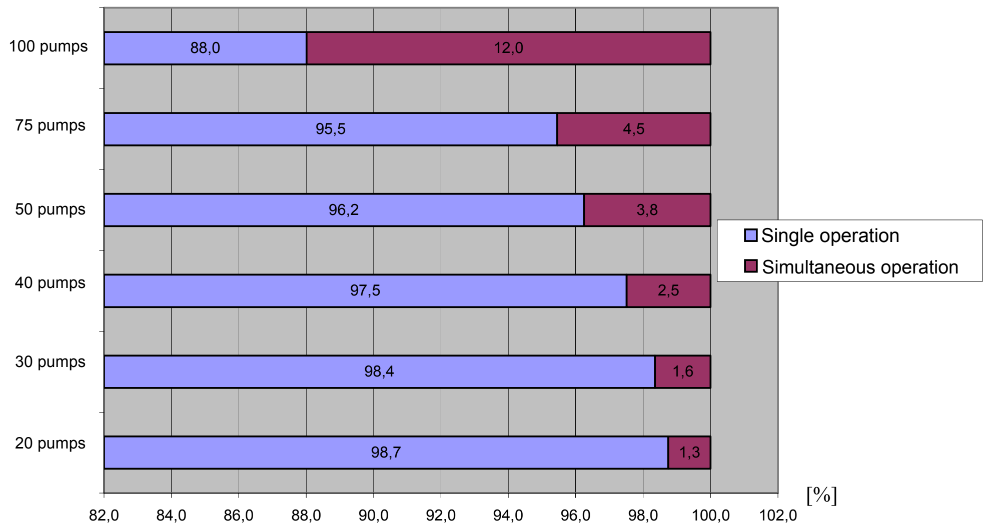

Fig. 8. Proportion of simultaneous operation in total operation of pumped systems composed of n pumps with active volume $V = 296$ dm^3 and average sewage flows to lifting stations as specified for SYM_HALF simulations

In SYM_00 simulations for active volumes of 148 dm^3 and 296 dm^3 in pumped systems consisting of 20 and 30 pumps, the proportion of simultaneous operation in the total operations of the system was low, amounting to 0.5–1.1%. For an analogous group of SYM_ HALF simulations, this share in pumped systems constructed of 20 and 30 pumps was in the range of 1.0–2.3% of the systems' total operating time.

For 40 and 50 pumps, the proportion of simultaneous operation in total system operating time rises and for simulation SYM_00 amounts to 1.7%–2.3%. In the case of studies assuming a higher flow (SYM_HALF), this value lies between 2.5% and 4.3%.

In systems with a larger number of pumps, 75 or 100, the time of simultaneous operation was in a significant proportion to the total operating time of the lifting stations studied. For simulation SYM_00, this amounted to 3.6%–7.0%, while for simulation SYM_HALF the value was between 4.5% and 7.9% for a 75-pump system and between 12.0% and 12.1% for 100 lifting stations.

Considering the operation of a pressurised sewerage system not through the analysis of an individual lifting station, but rather by examining the sewerage system as a whole appears to be innovative. In order to understand the issue, the concept of simultaneous operation of the system has been introduced and basic statistics presented. From the point of view of the system, what is important is not how long an individual pump operates, but rather what the load is on the system as a whole. It has been shown that the period of simultaneous operation is extended along with an increase in active volume. The total time for which this occurs depends on the volume of sewage flowing into lifting stations and on the size of the system itself.

4. CONCLUSIONS

The number of occurrences of simultaneous operation for lifting station holding tanks with an active volume of 148 dm^3 are greater than in the case of lifting stations with a larger retention volume of 296 dm^3. With the same amount of sewage flow, a lifting station with a smaller active volume is emptied more often.

For systems which consist of 100 pump units with an active volume of V_{act} = 148 dm^3, modification of the daily volume of inlet wastewater from 468 dm^3 to 705 dm^3 caused a 231% increase in simultaneous occurrences. Furthermore, the maximum time of a single occurrence was extended from 270 sec. to 330 sec.

For systems which consist of 100 pump units with an active volume of V_{act} = 296 dm^3, modification of daily volume of inlet wastewater from 468 dm^3 to 705 dm^3 caused a 252% increase in simultaneous occurrences. The maximum time of one occurrence was pro longed from 430 sec. to 770 sec.

The concept of simultaneous operation of lifting stations has been introduced. It has been shown that this phenomenon has a significant effect on large systems consisting of 75 or more lifting stations. For 100-pump systems, simultaneous operation may amount to as much as 12% of total operating time.

A detailed analysis of the number of occurrences of simultaneous operation in 10-second time intervals for 75 and 100 lifting stations has shown that the form of uneven distribution depends on the active volume of individual lifting stations. In addition, the number of occurrences increase together with an increase in the size of the system.

REFERENCES

[1] WAYS M., *Zasady projektowania kanalizacji ciśnieniowej*, Materiały techniczne z konferencji „Kanalizacja na terenach wiejskich jako element ochrony środowiska”, Koszalin, 1987.

[2] WIERZBICKI K., *Możliwości stosowania nowoczesnych systemów kanalizacyjnych na terenach wiejskich*, Instytut Budownictwa Mechanizacji i Elektryfikacji Rolnictwa, Warszawa, 1997.

[3] MYCZKA J., *Dimensioning of Pressure Drainage Systems*, Korrespondenz Abwasser, 1999, No. 5.

[4] BIEŃ J., CHOLEWIŃSKA M., *Systemy kanalizacji podciśnieniowej i ciśnieniowej*, Wydawnictwo Politechniki Częstochowskiej, 2001.

[5] DAWIDOWICZ J., SZEROKI A., *Poradnik – Kanalizacja ciśnieniowa w systemie WILO EMU*, wydanie II poprawione, Janki, 2008.

[6] SIONKOWSKI T., ŚLIZOWSKI R., *Współpraca pomp wirowych w systemie kanalizacji ciśnieniowej*, Gaz, Woda i Technika Sanitarna, 2007, 7–8.

PRACA SYMULTANICZNA SYSTEMU POMPOWEGO W KANALIZACJI CIŚNIENIOWEJ

Przedstawiono symultaniczną pracę pomp w kanalizacji ciśnieniowej. Zjawisko to polega na równoczesnej pracy pomp dla wspólnego rurociągu i jest niezwykle istotne dla poprawnej pracy systemu. Analizę prowadzono dla dwóch różnych objętości czynnych charakterystycznych dla jednego pompowania. Zjawisko to staje się ważne w dużych, rozbudowanych systemach składających się z ponad 75 pompowni. W systemach składający się ze 100 pompowni przydomowych praca symultaniczna może stanowić nawet 12% całkowitego czasu pracy.