# STUDY OF THE RELATION BETWEEN PUMPING AND STORAGE IN MUNICIPAL WATER SUPPLY

By

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(Received: November 1st, 1976)

## 1. The water supply system

Municipal water supply systems consist of several establishments, *viz.* those serving

— water withdrawal,
— water treatment,
— pumping into the network,
— water conveyance and distribution,
— consumption, and
— storage.

This latter establishment consists of several units itself, the overhead and the deep reservoir.

The scheme of a water supply system in *Fig. 1* consists technically of two subsystems. Change of the condition of an establishment (unit) of one subsystem affects the condition of the other units; this effect becomes directly manifest within the subsystem. For instance, in case of subsystem **B**, change of the volume or areal distribution of the consumption affects the water discharge $Q_p$ of the network pump and the water turnover $Q_T$ in the overhead reservoir.

Again, if the overhead reservoir, subsystem **B**, runs empty — involving pressure decrease in the network — consumption decreases and pump discharge changes.

Similarly, condition changes occurring in subsystem **A** directly affect the condition of other elements in the subsystem.

Within any subsystem, the effect of a state change becomes manifest with little delay, practically at once.

Also the two subsystems may be in interaction, either *indirectly* (e. g. induced by consumption decrease, some wells get disjuncted by an automatism or human intervention) or *directly* (e. g. insufficient water production results in the pumping basin of the water works running dry, thus the network pump discharge will become $Q_p = 0$). Interaction between two subsystems needs some time to become active.

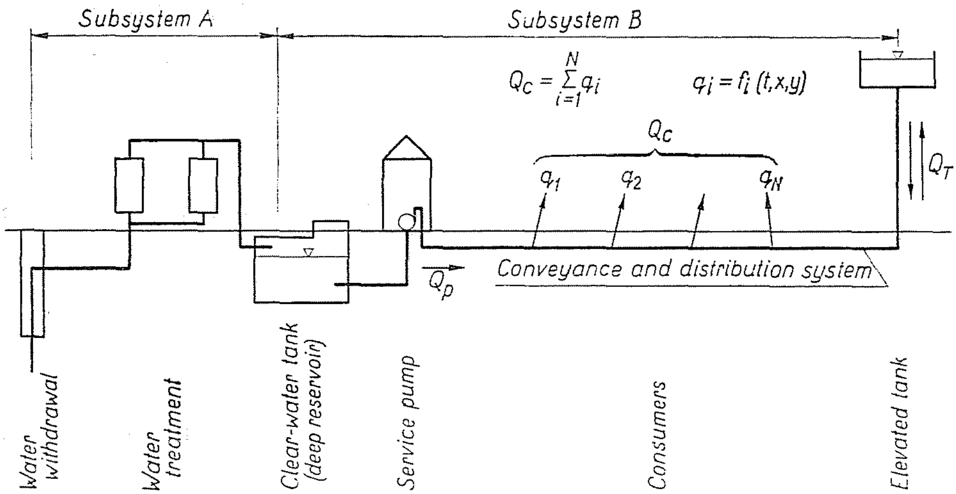


*Fig. 1.*

The two subsystems may undergo a technical-economic assessment either separately or as a whole (as a matter of fact, no pure separation is possible, since the deep reservoir belongs to both). A combined technical-economic examination of both subsystems may be justified by a marked decrease of water consumption on holidays compared to that on work-days (industry of high water consumption, high percentage of working people living off the town). In such cases — especially if water can be exploited at a high cost only — water works may be designed for weekly average consumption rather than for daily maximum, entailing, however, a compulsory increase of storage capacity. In this case, a combined analysis of the two subsystems may result in finding the optimum.

## 2. Analysis of subsystem B

In subsystem **B**, the network pump and the overhead reservoir combine to provide for network pressure and to discharge water meeting the actual consumption:

$$Q_c = Q_p + Q_r \tag{1}$$

where:

$Q_c$ consumption

$Q_p$ pump discharge

$Q_r$ water turnover in the overhead reservoir.

Consumption $Q_c$ is composed of $N$ time-dependent consumptions $q_i$, where the variation schedule differs for each consumer (schedule being not quite correct a term for a random process as this).

Agreement between the left-hand-side $Q_c$ in Eq. (1) and the actual *justified* water demand requires to determine volume $V$ and level of the overhead reservoir and to select the proper pump. Intensity and schedule of pumping influences the storage capcity and head, and maybe also the pipe diameter, involving thus economic problems beside the technical ones, these former will here not be discussed.

In conformity with general practice, determination of capacity $V$ of the overhead reservoir is seen in *Fig. 2*. In general, pump discharge $Q_p$ is considered independent of consumption. In fact, however, pump discharge is function of consumption (of its variation in time and space), a relation demonstrated in *Fig. 3*. In addition to consumption, pump discharge is also affected

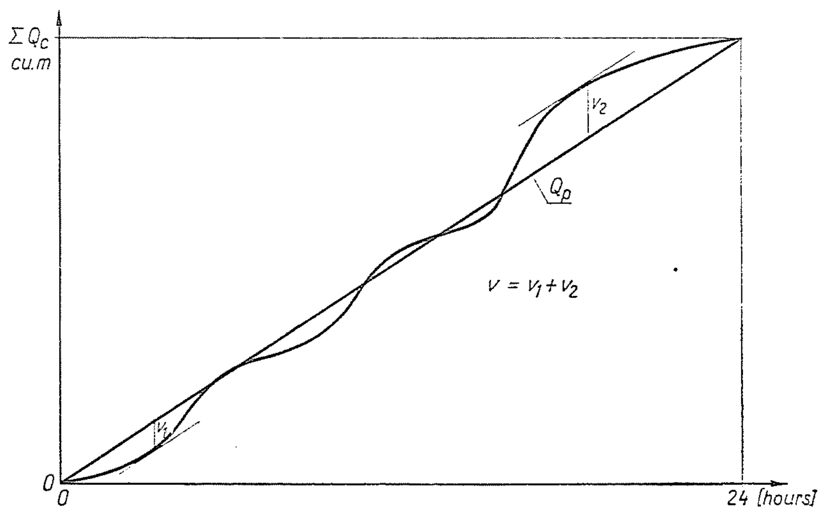


*Fig. 2*

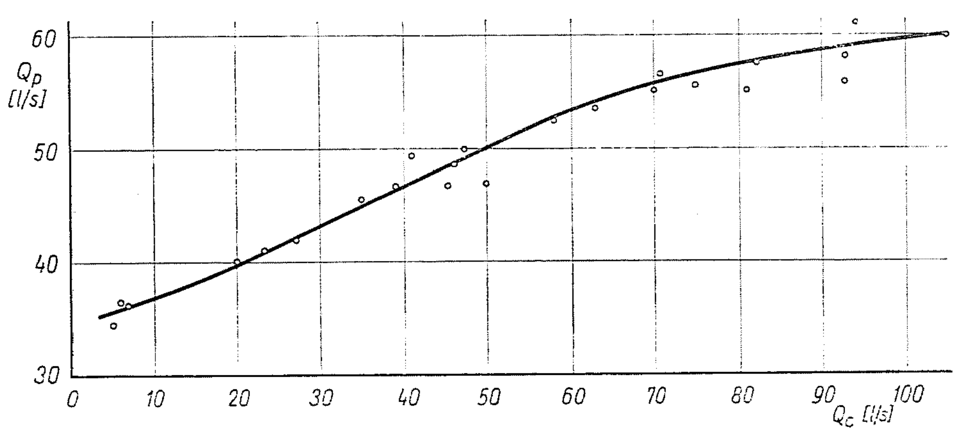


*Fig. 3*

by water level in the overhead and deep reservoirs. (The diagram shows a marked deviation between pertinent couples of values due to the areal variations of consumption and to water level changes in the reservoir.)

Reservoir capacity has to meet the condition

$$\int_{t=0}^{l} Q_p(t)\, dt = \int_{t=0}^{l} Q_c(t)\, dt = Q_k l \tag{2}$$

where $Q_k$ is water production discharge, and $l$ the period of reservoir filling and depletion. Another condition

$$\int_{t=0}^{l} Q_r(t)\, dt = 0 \tag{3}$$

means that within the period $l$, the overall water balance in the reservoir is zero, hence, at times 0 and $l$, water level in the reservoir is the same.

The selection of the pump type (head-discharge curve) and pumping schedule (showing daily hours of pump operation, or the hours when individual pumps have to operate), as well as the assumed plan area of the elevated tank permit to determine the water level of the same at time 0, and its stage fluctuation range (defining, together with the plan area, the capacity) so as to meet relationships (2) and (3). Of course, results may lead to inadequate network pressure and an irreal stage fluctuation range. In this case, an adequate solution may be obtained by changing either the pump type and the pumping schedule or the plan area of the reservoir, or both.

For this analysis, two computer programs have been developed at the Section of Water Supply and Sewerage, Institute of Water Management and Hydraulic Engineering, Technical University, Budapest.

Program *SYS.AN.* assumes the overhead tank water level to be constant and reckons with the variation of consumption in time and space to determine the storage capacity for the given pumping and consumption schedule, and the overall water balance in the reservoir: if this latter fails to meet Eq. (3), initial conditions have to be altered.

Program *DIN* checks outputs by Program *SYS.AN.*, taking also time dependence of reservoir water level and turnover into consideration.

## 2.1 *Analysis of a network fed by a pumping plant and a reservoir*

The above programs have been applied by Péter Darabos, graduate student, in his diploma thesis (involving an original system analysis). Thence an illustrative example will be given.

Maximum daily water demand in a little town is 4207 cu·m/day. In the actual case pumping is continuous, storage period is 24 hrs.

The conventional method (if neglecting the effect of the variations of consumption and reservoir water level on the service pump discharge) yielded an elevated tank capacity $V = 855$ cu · m.

Programs *SYS.AN.* and *DIN* resulted in $V = 672{,}2$ cu · m and $V = 672{,}0$ cu·m, respectively (this latter is shown in *Fig. 4)*.

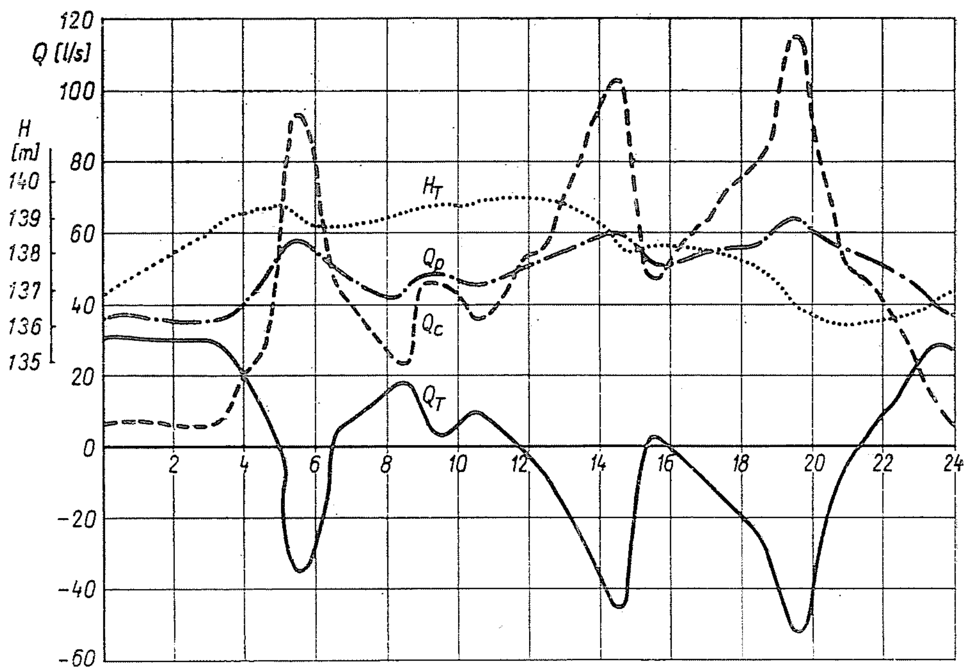


*Fig. 4*

In practice, the computed reservoir capacity is usually augmented, partly for safety's sake, and partly for special water demands (such as fire-fighting, network flushing etc.).

Obviously, the conventional computation method invariably results in a bigger elevated-tank capacity than that taking the effect of consumption upon the pump discharge into account. Application of the conventional method seems to be more expedient, since

— it is less cumbersome,
— it results in an overdimensioned storage capacity, being thus on the safe side.

From among the two computing methods, the conventional one can be carried out manually, hence it is less cumbersome than the other, practically not feasible without a computer.

As a matter of fact, however, the conventional method is safer but to an unknown degree. An overhead reservoir of excessive safety, especially if water inlet and outlet are hydraulically objectionable, water stagnation may come about (a possibility even to occur with insufficient overhead reservoir capacities), involving poor water quality.

*2.2 Analysis of networks supplied from several reservoirs*

The scheme of water supply for a small town is shown in *Fig. 5*. This town is in a valley, and reservoirs **A**, **B** and **C** on hillsides near the town are supplied from springs. Some minor settlements are seen to be supplied from basins A and **C**.

Conventional determination of storage capacity, taking time-dependent variation of consumption into consideration, resulted in an overall capacity of 4100 cu·m, showing thus roughly 10% safety of reserve capacity against the existing 4500 cu·m.

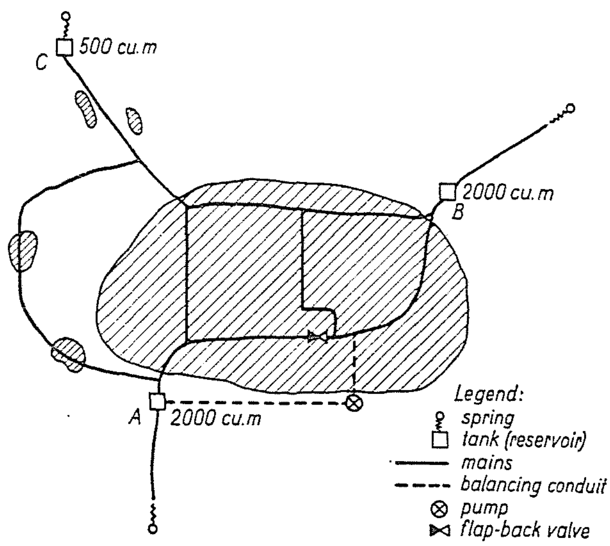


*Fig. 5*

Hydraulic analysis based on periods of minimum hourly consumption showed disproportions between yield of the springs and discharges fed from the reservoirs to the network.

Program *SYS.AN.* reckoning with a storage period of 24 hrs showed reservoir **A** to discharge more water in 24 hrs than to receive from the springs, while reservoir **B** to work in the opposite sense, hence reservoir **A** will often be empty, and **B** overflows at the same time.

When examining the operation of the network and the reservoirs by means of program *DIN* it was found that there was little interaction between water level and water turnover in the reservoirs and thus interaction failed to offset incorrect operation of the reservoirs.

Several means offer themselves to co-ordinate reservoir operations:

*a)* construction of a large-diameter pipeline starting from reservoir **B**, a solution injustified from the aspect of pressure conditions; it is also costly, and water would flow at a low rate in the conduit (stagnation),

*b)* throttling of the flow in the pipeline from reservoir **A**, likely to impair pressure conditions about the reservoir,

*c)* large-diameter conduit to interconnect directly reservoirs **A** and **B**: analysis by means of program *DIN* discarded this solution, subject to improvement, however, by inserting a pump,

*d)* connection of reservoirs **A** and **B** through the network as seen in *Fig. 5*, inserting a pump.

The pump would operate in the night period of low consumption, hence it would not impair pressure conditions around reservoir **B** in daytime, but at night, it would act favourably, by reducing the sometimes excessive night-time pressure near the pumping plant.

This solution requires the insertion of a flap-back valve into the existing conduit in order to avoid suction from reservoir **A**.

The drawback of this solution lies with its requiring another basin of about 1000 cu·m. beside reservoir **A** while leaving the capacity of reservoir **B** unexploited (a direct connection between them would permit continuous lifting and make a new basin superfluous, but daytime pumping is costlier than nighttime one, and would require an excess conduit length of about 3 km).

## Summary

Examples have been presented to illustrate errors likely to arise from the neglection of the variation of consumption in time and space, and of the interaction between elements of the water supply system.

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