

**Numerical tool:
Deltares water hammer program Wanda**

In order to perform a water hammer analysis, Deltares utilizes and sells its in-house water hammer program Wanda. The program has about 250 external users, which range from operators and consultants to universities.

Wanda is a powerful and user-friendly program for the hydraulic design and optimization of pipeline systems. Both engineers and operators use Wanda to study the steady and dynamic behavior of liquid, heat, gas and slurry flows in arbitrarily configured pipeline networks. The software can be easily linked to other applications, e.g. for operator training systems or advanced real-time control. Wanda has been extensively tested, validated and designed for engineers by engineers.

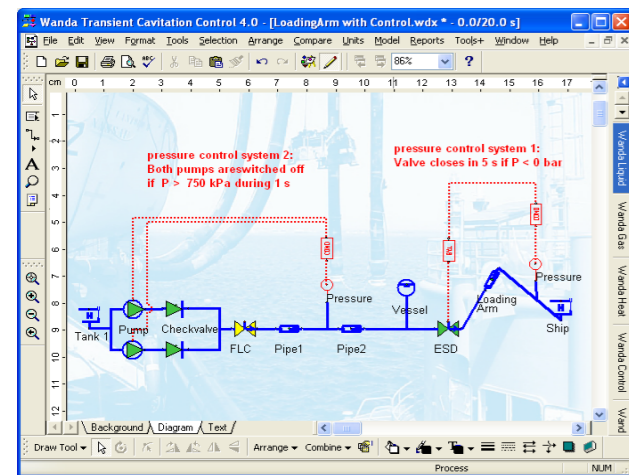


Figure 8: An example of Wanda control which allows the hydraulic system to be linked to a control system.

In addition to its ability to model hydraulic components, Wanda has the following control capabilities which are of importance for the control system in a desalination plant:

- Advanced pumping station controllers including parameters for ramp-up time, minimum speed etc.
- Activation of valves, pumps, etc
- Controlling of boundary conditions
- Sensors and generators
- Conditional block (IF-statements and switches)
- Boolean operators (AND, OR, exclusive OR, NOT)
- Numerical operators (add, multiply, functions, etc.)
- Continuous controllers (PID incl. start/stop and ramp)

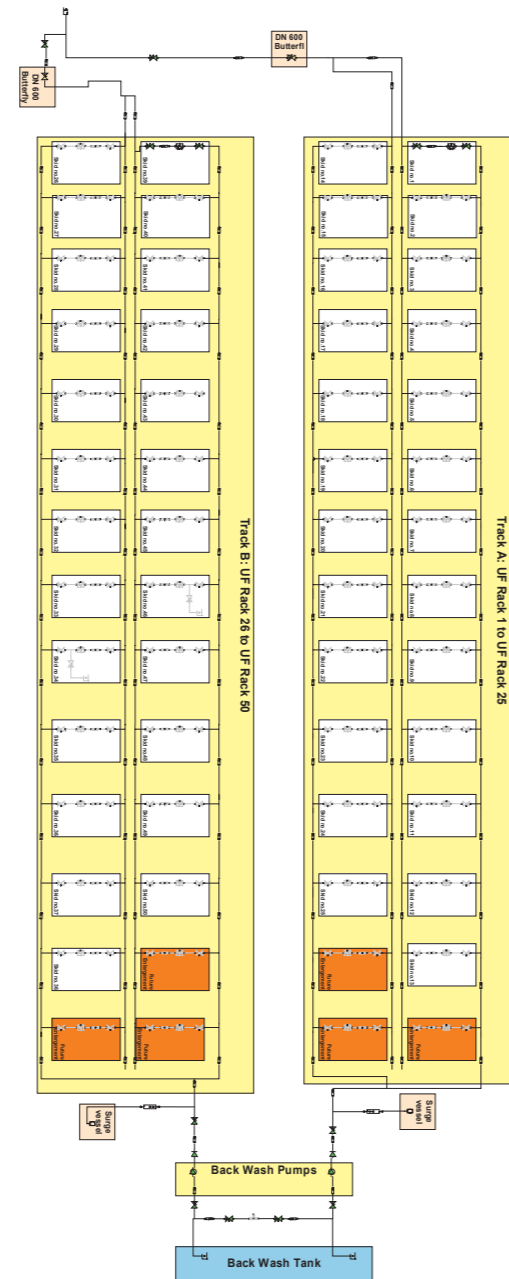
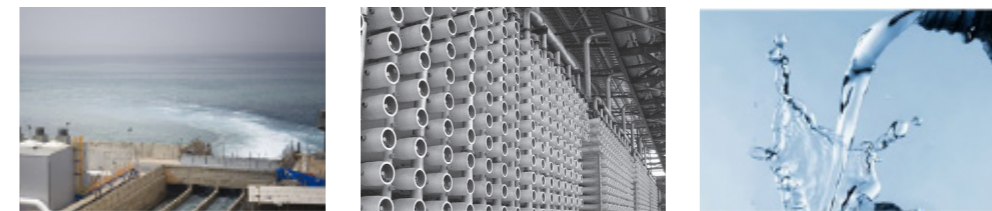


Figure 9: Numerical model of a backwash system of a desalination plant built in the water hammer program Wanda 4.1. The cascade approach as presented in Figure 3 is used within this model.



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Hydraulic study for desalination plants

Necessity of water hammer analysis for a reliable and efficient operation

Introduction

Due to the growth of the world population, there is an increasing demand for drinking water. From all water on earth, over 97 % is salt water and only 0.5% can be used for drinking purposes. For this reason, desalination techniques become more and more important and are deployed all over the world. They provide a good alternative for supplying drinking water in vulnerable regions, especially where groundwater resources are depleted.

In a desalination plant, several filtration steps (e.g. Ultrafiltration and Reverse Osmosis) take place to clean the water. Inside these desalination plants, large network of pipes are present which have different functions and purposes. To operate such a system efficiently and safely, it is of utmost importance to carry out a hydraulic investigation. In such a study, the optimal settings are determined for the operation of hydraulic components in order to increase the plant efficiency and to eliminate the risk of failure of the system.

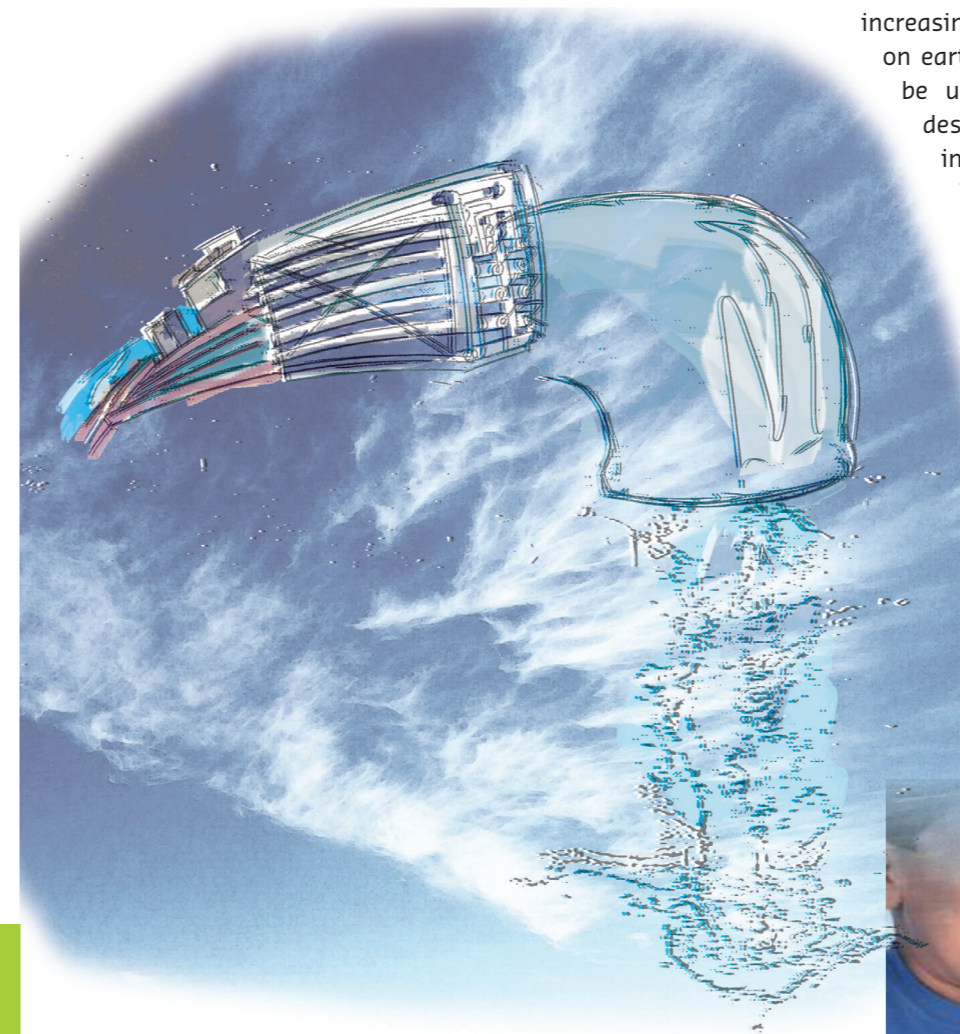


Figure 1: Desalination: a necessary tool to generate drinking water from sea water.



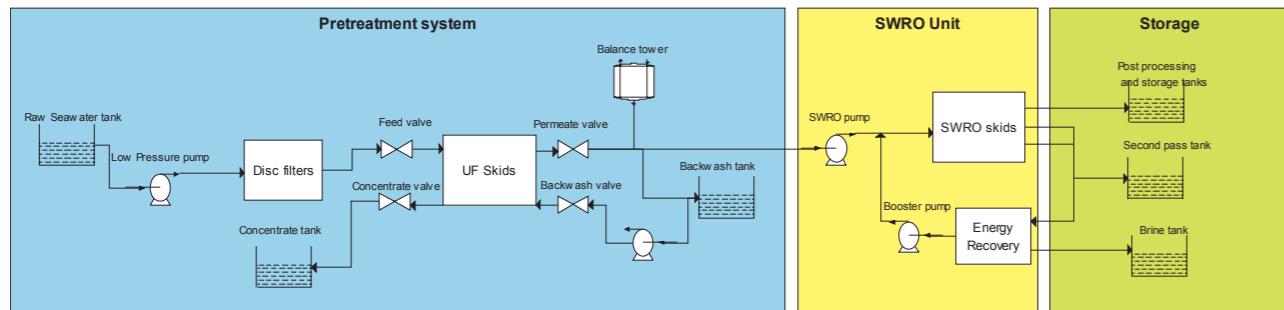


Figure 2: Schematic view of numerical model of a desalination plant.

Expertise

Deltares has a long experience with hydraulic studies for desalination plants including but not limited to seawater recirculation (brine, thermal), intake and outfall structure design as well as the plant pipeline system. We have assisted our clients in preliminary layout selection and detailed design verification for some of the biggest desalination plants in the Middle East region such as Az Zour North Power & Desalination plant in Kuwait, Ashdod Seawater Desalination Plant in Israel, ESI RO plant in UAE and etc.

Within such studies, Deltares utilises various numerical tools and experimental facilities in order to carry out these hydraulic studies. This ranges from water hammer software (Wanda), CFD commercial software to large basins where scaled model of pumping stations are built and tested. Numerical approaches are found to be the most accurate and cost efficient for studying hydraulic properties of desalination plants and are therefore extensively deployed to perform hydraulic studies. A typical example for a numerical model of a UF system is presented in Figure 2.

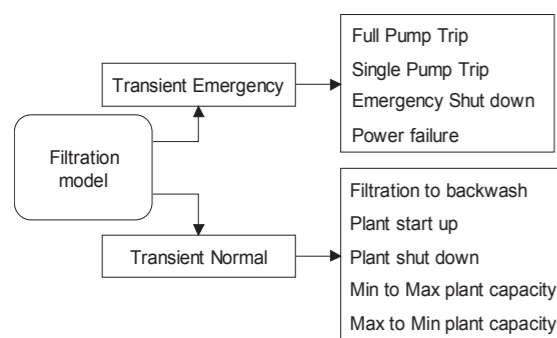


Figure 3: Critical flow scenarios for a filtration model.

Hydraulic investigation

In these investigations for e.g. UF and RO plants, two types of analysis are generally considered: capacity analysis, which is determined by steady state simulations and transient analysis, which describes the dynamic behaviour of a system. In these types of simulations, a safe operation can be verified.

In a transient analysis, all flow scenarios which put the safety of the plant in danger or influence the plant

efficiency should be considered. Depending on the size of the plant and the stages which are designed for the treatment of the water, the scope of investigation differs. Figure 3 shows some of the critical scenarios which can lead to critical situations. Therefore, these scenarios have to be considered in the hydraulic study.

Numerical approach: cascade of models

To perform a hydraulic study, a numerical model has to be built in which all relevant hydraulic components of the plant such as pumps, valves, pipes etc. are included. Due to the complexity of the hydraulic components in a desalination plant (see e.g. Figure 4), an extremely large numerical model is required, which is computationally expensive.



Figure 4: Pipe networks inside a RO plant (image: James Grellier).

To overcome this, Deltares has introduced a cascade approach which starts with the smallest sub-systems in a plant. The hydraulic properties of these sub-systems are calculated and their properties (for example accurate resistance and water hammer storage) are incorporated in the larger models in a fit-for-purpose schematized way. This results in a correct representation of the hydraulic system by the construction of a couple of simple models which

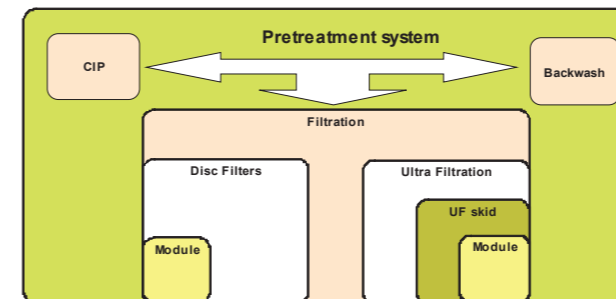


Figure 5: Pre-treatment system of a desalination plant represented by the cascade approach.

include hydraulic details of all sub-systems. Figure 5 shows such a cascade approach schematically.

Results

The results of the simulations give information about hydraulic properties of the system such as pressure, discharge, flow velocities and etc. during transient events. Moreover, it provides information about the hydraulically related properties of the mechanical components such as pump speed, check valve opening, opening angle of control valve and etc. This helps to a better understanding of the dynamic behavior of the system during transient events. For example, Figure 6 shows the time series of pressure at the highest elevated module in a skid of UF unit after

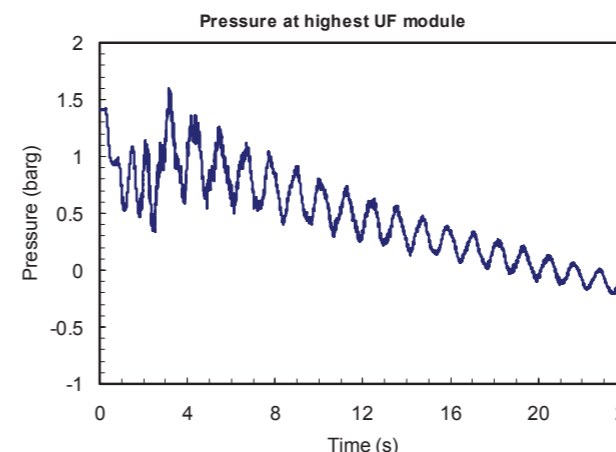
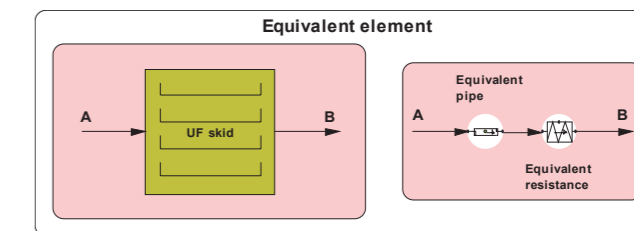


Figure 6: Pressure at highest module in UF skid.

power failure. As it is seen in the figure, the pressure initially drops after the power failure due to the trip of pumps in UF unit. In the downstream SWRO unit, pumps also trip due to the power failure and their downstream check valves close. This leads to an upsurge in the pressure which interacts with the initial pressure drop in the UF unit, resulting locally in higher pressures (see Figure 6).

This provides a good insight to the dynamic behavior of the system and determines the minimum and the maximum transient pressures which may occur during the power failure. Based on such results, the safety of the system can be evaluated.



Added value

To show the importance of the optimization of the hydraulic settings of a system, we assume a simple and schematic model which is typical for desalination plants.

We have a backwash system where the water is flowing from the left to the right through a skid with a flow rate of 2,500 m³/h (see Figure 7). After backwashing, the backwash procedure stops and the filtration starts again. This results in a closure of both backwash and the concentrate valves. Let's assume that the closure of the backwash and the concentrate valves takes place in 12 seconds. By optimization of the closure times in a hydraulic study, it turns out that this time can be reduced to 10 seconds without occurrence of negative pressures. By optimizing this valve closure time, 300 m³ water per skid could be saved in a year. This means that for a plant with 50 UF skids 15,000 m³ of permeate water is saved each year. Moreover, by reduction of the backwash cycle, the production time will increase which leads to an additional production of 3,500m³ permeate water per year.

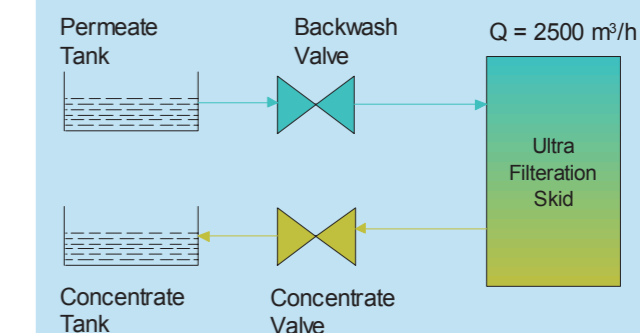


Figure 7: Schematic view of a backwash system in a UF unit of a desalination plant.

It is important to note that there is a limit to the fast closure of the valves, as this would result in negative pressures which would lead to massive fibre breakage in the modules of the skid.

However, with a simple optimization, a lot of permeate water could be saved taking the system integrity into account.