ENGINEERING
TOMORROW

Design Guide

# Pressure safety valve in a seawater RO system


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## 1. Introduction

The Pressure Equipment Directive 97/23/EC (PED) of the EU sets out the standards for the design and manufacture of pressure equipment ("pressure equipment" means pressure vessels, piping, safety valves and other components and assemblies subject to pressure loading). It has been mandatory throughout the European Union since 30 May 2002.
The PED enacted in the UK as the Pressure Equipment Regulations (PER).

**The system designer is responsibility to design the equipment according to the local regulations where the equipment is running.**

The information's in this document are based on PED 97/23/EC and ISO 4126 "Safety devices for protection against excessive pressure". ISO 4126 is confirming to Essential Requirements of the new Approach Directive 97/23/EC (PED)

This guideline is giving input to the risk analysis and guiding how to size a Pressure Safety Valve and where to place this valve in a Sea Water Reverse Osmosis (SWRO) system.

## 2. Summary

Local regulations according to Pressure equipment and machinery protection must be followed.

According to PED 97-23-EC a risk assessment must be made to identify and evaluate hazards which apply to his equipment on account of pressure.

Where, under reasonable foreseeable conditions, the allowable limits could be exceeded, the pressure equipment must be fitted with, or provision made for fitting of, suitable protective devises.

Pressure limiting devices must be so designed that the pressure will not permanently exceed the maximum allowable working pressure (Ps); however a short duration the momentary pressure surge must be kept to 10% of Ps for pressure vessels and max 17% of Ps for the pump alone.

Discharge pressure on the pump is generated only by the restrictions in the pipelines, valves and membranes.
The pump can build up pressure that will exceed the mechanical strength of the membrane vessels, pipes and other accessories.
The pressure rise can be fast and may exceed the response time for electrical safety equipment, like pressure switch and control loop.

## 3. Terms and definitions

**Safety device**: Device that serves as the ultimate protection to ensure that the maximum allowable accumulated pressure is not exceeded. Example is a safety valve or bursting disc.

**Harm:** Harm is the physical injury or damage to health of people, or damage to property or to the environment.

**Hazard:** Potential source of harm

**Risk:** Combination of the probability of occurrence of harm and the severity of that harm.*)

**Risk analysis:** Use of available information to identify hazards and to estimate the risk. *)

**Risk evaluation:** Judgement on the basis of risk analysis as to whether a tolerable risk has been achieved. *)

**Risk assessment:** Overall process of risk analysis and risk evaluation. *)

**Maximum allowable pressure (Ps):** Maximum pressure for which the equipment is designed, as specified by the manufacture.

**Accumulated pressure:** Pressure in the equipment to be protected which can exceed maximum allowable pressure for a short duration during the operation of safety devices.

**Maximum allowable accumulated pressure Ps, accum:** Value of the accumulated pressure in the equipment being protected.

**Redundancy:** Provision of more than one device or system such that the necessary function will still be provided in case of failure of one or more of these devices.

*) See ISO/IEC Guide 51

### 3.1 Risk consideration according to PED ISO 4126-9:2008(E)

All service conditions shall be considered when selecting the most appropriate safety concept, in order to ensure safe operation of the pressure equipment. This requires a realistic assessment of risk by means of risk analysis and risk evaluation. Risk analysis involves, for example:

- Determination of boundaries of the pressure equipment, concluding:

  - Maximum quantity of fluid to be disharged
  - Intended use
  - Reasonably foreseeable misuse
  - Influences of sizing and flow of the safety device on operational reliability and performance of the safety system

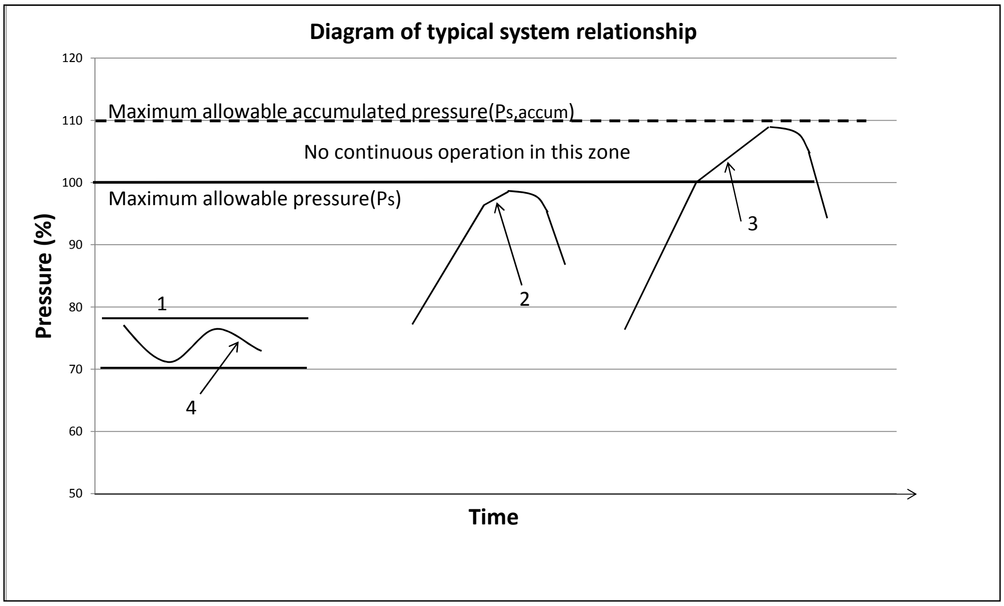
- Identification of potential hazards and estimation of the risk.

In particular, the risk analysis shall take in consideration the following:

- Equipment connected together by piping of adequate capacity, which is free from potential blockage and does not contain any valve that can isolate any part, may be considered as a system of pressurized components for application of pressure relief.
- Where a component failure during operation is forseen and would cause the pressure of fluid in the vessel to exceed the maximum allowable pressure, the pressure equipment shall be protected by means of at least one safety device of adequate capacity of safety device(s).

Where, under reasonably foreseeable service conditions, the internal pressure can exceed the maximum allowable pressure, the pressure equipment shall be protected by means of at least one safety device of adequate capacity and capability.

A safety device is the final element to protect pressure equipment from exceeding its allowable limits. Regulating and/or monitoring devices are not ultimate safety devices in the meaning of ISO 4126-9. They become active in advance of an ultimate safety device (see figure below)




1 Reaction of regulating control system
2 Reaction of monitoring system
3 Reaction of safety system
4 Normal operating range

## 4. Pressure limitation

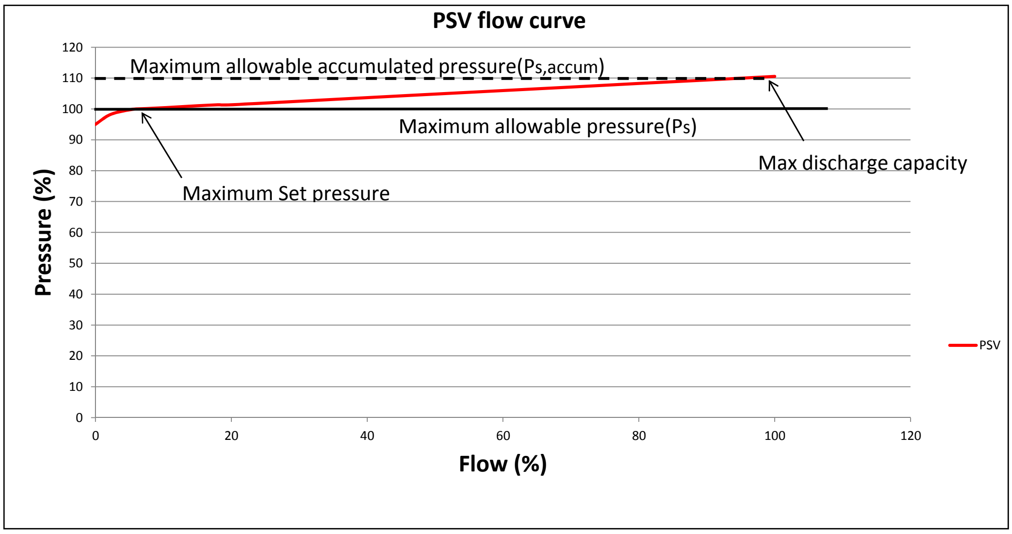
- Safety devices shall have a set pressure not exceeding the maximum allowable pressure (Ps)
- If capacity is provided by more than one safety device, only one of the devices needs to be set at a pressure not exceeding (Ps). The other device(s) may be set at a pressure not more than 5% in excess of (Ps).
- The safety device(s) shall be sized to have the required discharge capacity at a pressure not higher than maximum allowable accumulated pressure (Ps, accum).

### 4.1 What is a Pressure Safety Valve (PSV)

A PSV is a valve which automatically, without the assistance of any energy other than that of the fluid concerned, discharges a quantity of the fluid so as to prevent a predetermined safe pressure being exceeded, and which is designed to re-close and prevent further flow of fluid after normal pressure conditions of service have been restored.

The allowable tolerances on the operating characteristics are as follows:

- Set pressure ± 3% of set pressure.
- Overpressure: The value stated by the manufacturer but not exceeding 10% of set pressure
- Blowdown: Not greater than the value stated by the manufacture and minimum 2,5% of set pressure




### 4.2 What is a Pressure Relief Valve (PRV)

In contrast to a safety valve a Pressure Relief Valve is designed to guarantee trouble-free operation of a pressurized system or a component. The job of the relief valve is mainly:

- Protect the pressurized system or a component.
- Discharge excessive flow rates within certain pressure limits.
- Protection of the downstream PSV. If both a PRV and PSV are installed, the PRV operation range must be below the set pressure of the PSV

The function of a PRV is equal to the function of the PSV – BUT no demands are made on the opening and blowdown characteristics

## 5. Input to the risk analysis

### 5.1 How does a pump make pressure?

Whatever a pump is of type positive displacement (PD) or a rotary Centrifugal (CF), the pump can only build up pressure corresponding to the total hydraulic resistance in the downstream line including pipelines, valves, and membranes etc. If there is no hydraulic resistance, the pump cannot create any pressure.

#### 5.2.1 Max. discharge pressure from a Centrifugal pump

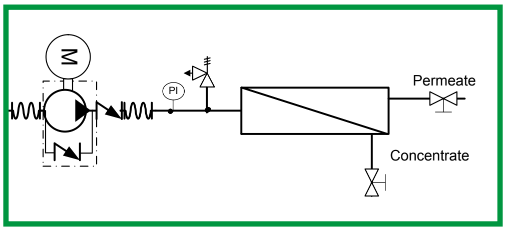
Maximum hydraulic discharge pressure from a CF pump is often called "shut-off pressure" or "dead-end pressure". This pressure is well known from the pump curve on a specific pump. Therefore a CF pump may be started up against a dead-end without risk for over-pressurizing the system.

#### 5.2.2 Max. discharge pressure from a Positive Displacement pump

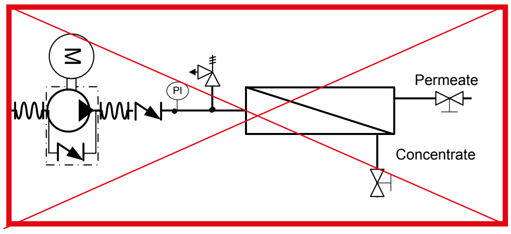
Maximum hydraulic discharge pressure from a PD pump is unpredictable. If the motor driving the PD pump can supply sufficient power the pump will raise the pressure until ALL flow from the pump can escape the pump. Alternative the pump will break internally or the weakest component in the pump discharge line will break. **The pressure rise can be fast and may exceed the response time for electrical safety equipment, like pressure switch and control loop.**

### 5.3 Design considerations

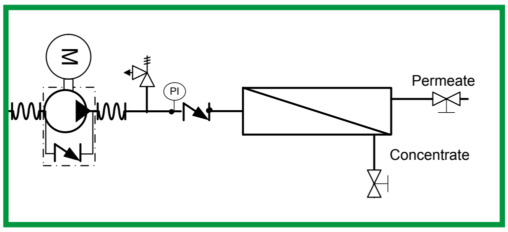
#### 5.3.1 Where to position the PRV or PSV




The flanged NRV on APP cannot be assembled with wrong flow direction.
The PRV or PSV must be placed between the pump and the first valve or component that can generate to high pressure.




The inline NRV can be assembled with wrong flow direction. The PRV or PSV must be placed between the pump and the NRV.




The inline NRV can be assembled with wrong flow direction. The PRV or PSV must be placed between the pump and the NRV.

Always follow the instalation guideline from the PSV or PRV manufacturer.

### 5.4 Examples of risk considerations

1. A valve that can be closed or partly closed in the pump discharge line may be a high risk component together with a PD pump.
   - If the valve by purpose or by accident can be closed faster than the response time for electrical monitoring system, the PRV or PSV must be able to take full flow from the pump.
   - If the valve by purpose or by accident can NOT be closed faster than the response time for electrical monitoring system, the PRV or PSV must be able to take excess flow that eventually causes a pressure peak.
   - A permeate back-pressure controlvalve can raise the pressure both on LP permeate line and the HP line.
2. The flow on a PD pump is proportional to the speed. If the PD pump is started by ramping up the speed from 0 to set-point over a period of time, the flow will also wary from zero to set-flow over the same time period. If the Pump is started up against a dead-end the pressure will rises rapidly but the flow will be small. With respect to the response time of the electrical monitoring system, the PSV must be able to take flow that eventually causes a pressure peak. Example:
   - Total response time for electrical monitoring system to cut main power to electrical motor is 1 seconds.
   - A 78 $m^3$/h pump is ramping up from 0 to 1500 rpm over 20 seconds.
   - After 1 second the pump is giving 3.9 $m^3$/h.
   - The PRV or PSV must be able to take a minimum of 3.9 $m^3$/h.
3. If the pump is started direct online (DOL) against a closed valve the pressure will rise rapidly and exceed the response time for electrical monitoring system, the PRV or PSV must be able to take full flow.
4. The membrane in a RO plant is generating the main hydraulic pressure in the HP line. Fouling/ Scaling over time come slowly and the pressure rise is slower than the response time for electrical monitoring system. If the response time of the electrical system is not fast enough the PRV or PSV must be able to take excess flow that eventually causes a pressure peak. PRV  or PSV flow capacity can be calculated at max allowable working pressure.
   $\mathbf{Q_{PSV} = Q_{HP\text{-}Pump} - Q_{Concentrate} - Q_{Membrane}}$
5. In a RO plant with an Isobaric energy Recovery Device (ERD) all flow from the HP pump will escape through the RO membrane even if the ERD is stopped. With the ERD stopped the membranes will run with a 100% recovery rate and the membrane fouling will cause a pressure raise that may not exceed the response time of the electrical monitoring system.
6. In a RO plant with a backpressure valve on the HP concentrate line a part of the flow from the HP pump will escape through the RO membrane the rest goes through the backpressure valve. With the backpressure valve totally closed the membranes will run with a 100% recovery rate and the membrane may not be able to take all flow from the HP pump. The pressure raise may exceed the response time of the electrical monitoring system and the PRV or PSV must be able to take the same amount of flow as the backpressure flow.
7. As the electrical monitoring system can fail a redundancy electrical monitoring system is necessary.

## 6. Disclaimer

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**Danfoss A/S**
High Pressure Pumps
DK-6430 Nordborg
Denmark