## GESTRA Steam Systems

# GESTRA Information A 2.4

## Sizing of Vacuum Breakers

Vacuum breakers (air-inlet valves) are used to protect vessels or heat exchangers against vacuum.

The causes leading to the formation of vacuum depend on the specific plant conditions, but the basic considerations required to determine the size of a vacuum breaker are in many cases similar.

We want to take a feedwater tank with deaerator dome as an example for demonstrating the method of calculating the size of a vacuum breaker.

**Sizing of vacuum breakers for feedwater deaerators**

Vacuum in feedwater deaerators is formed if the heating-steam supply fails and if, at the same time, cold water is added resulting in condensation of the remaining steam.

To prevent the formation of a vacuum an adequate system must be provided to ensure that air can enter the deaerator to provide a pressure balance as soon as vacuum starts to form. A vacuum breaker – for example a GESTRA DISCO non-return valve – fulfils this purpose.

The basis for the calculation may be assumed to be the condition prevailing when the vacuum breaker starts to open. As the exact opening pressure of a non-return valve depends on the installation position, we shall base our calculation on a mean opening pressure of 20 mbar. At an average ambient pressure of 1 bar absolute this corresponds to an opening point of 0.98 bar a.

We furthermore suppose that the cold make-up water is heated to no more than 99 °C (boiling temperature at 0.98 bara).

The following facts are not considered or may be neglected:

- Heat transfer by heating steam to the inflowing air (when vacuum breaker is open)
- Ambient heat loss of the deaerator
- Revaporization (flashing) when pressure drops
- Increase in water volume from condensation of heating steam and added make-up water.

### Method of Calculation

**General**

The heating steam in the deaerator transfers its heat to the cold make-up water.

If the steam supply is interrupted, that part of the steam which is lost by condensation has to be compensated for by the admission of air to prevent the formation of a vacuum.

To be able to determine the air volume that should enter the deaerator in a given time to prevent vacuum formation, i.e. to calculate the nominal size of the vacuum breaker, the following questions have to be answered:

**A** What is the total heat of evaporation (latent heat content) available in the deaerator at the opening point of the vacuum breaker (0.98 bar a)?

**B** What is the maximum amount of heat that can be absorbed by the cold make-up water?

**C** What is the amount of water required to condense the total heating-steam volume, i.e. to absorb the complete heat of evaporation of the heating steam?

**D** What is the time required by the cold make-up water to condense the total heating-steam amount? The corresponding air volume must flow in at the same-time to prevent the formation of vacuum.

**E** What is the volume of the required air flow?

**F** What is the resulting nominal size?

To be able to establish a formula for the calculation of the air volume flow, the calculation is carried out in individual steps.

**A** **Determination of the heat of evaporation available in the deaerator if the steam supply fails at a pressure of 0.98 bar a.**

At 0.98 bara the heat of evaporaton is r = 2259.6 kJ/kg (in acc. with steam tables).

The total amount of heat of evaporation (R) is then

❶ $R = m_1 \cdot r$ [kJ]

and the heating-steam mass ($m_1$)

❷ $m_1 = \frac{V}{V''}$ [kg]

❷ in ❶ = ❸ $R = \frac{V}{V''} \cdot r$ [kJ]

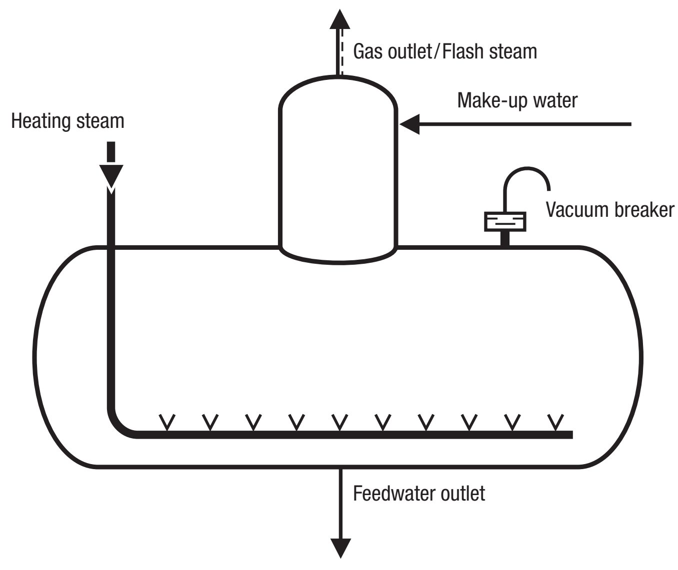


**Fig. 1** *Feedwater tank with deaerator*

**B** **Determination of the maximum amount of heat that can be absorbed by the cold make-up water (Q)**

As the cold make-up water can be heated to no more than 99 °C (boiling temperature at 0.98 bara), the amount of heat absorbed (Q) is the difference between the enthalpy of the cold make-up water ($h_E$) and the maximum possible enthalpy ($h_{max}$) of the make-up water heated by heat transfer from the heating steam.

**4** $$Q = h_{max}\ h_E \quad \left[\frac{kJ}{kg}\right]$$

**C** **Determination of the amount of water required to condense the total heating-steam amount ($m_2$)**

For this purpose the complete heat of evaporation available in the deaerator (at p = 0.98 bar a) is divided by the maximum amount of heat that can be absorbed by the cold make-up water.

**5** $$m_2 = \frac{R}{Q} \quad [kg]$$

**3** and **4** in **5** = **6** $$m_2 = \frac{V \cdot r}{v'' (h_{max}\ h_E)} \quad [kg]$$

**D** **Determination of the time required to condense the total heating-steam amount (t)**

If the amount of water (mass) required for condensing the total heating-steam amount is divided by the cold make-up water amount (mass flow), the time is obtained.

**7** $$t = \frac{m_2}{\dot{m}} \quad [h]$$

**6** in **7** = **8** $$t = \frac{V \cdot r}{v'' (h_{max}\ h_E) \cdot \dot{m}} \quad [h]$$

**E** **Determination of the air flow required to prevent the formation of vacuum ($\dot{V}$)**

If the volume of the heating steam (at 0.98 bar a) is divided by the time required for the total heating-steam amount to condense, the volume of the air that must flow into the deaerator in the same period to prevent the formation of vacuum is obtained.

**9** $$\dot{V}_L = \frac{V}{T} \quad \left[\frac{m^3}{h}\right]$$

**8** in **9** = **10** $$\dot{V}_L = \frac{V \cdot v'' (h_{max}\ h_E) \cdot \dot{m}}{V \cdot r} \quad \left[\frac{m^3}{h}\right]$$

As V can be cancelled from the equation, the result is:

**11** $$\dot{V}_L = \frac{v'' (h_{max}\ h_E) \cdot \dot{m}}{r} \quad \left[\frac{m^3}{h}\right]$$

**F** **Determination of the nominal size of the vacuum breaker**

The pressure drop charts of the GESTRA DISCO non-return valves are based on water as the flow medium. To determine the nominal size of the vacuum breaker the air volume flow has therefore to be converted to the equivalent water volume flow.

The equivalent water volume flow is calculated as follows:

**12** $$\dot{V}_w = \dot{V}_L \cdot \sqrt{\frac{\rho_L}{1000}} \quad \left[\frac{m^3}{h}\right]$$

Refer to the pressure drop chart of the RK valve and choose the size whose pressure-drop curve is intersected by the equivalent water volume flow in the linear range.

If **11** is inserted in **12**, the result is

**13** $$\dot{V}_w = \frac{v'' (h_{max}\ h_E) \cdot \dot{m}}{r} \cdot \sqrt{\frac{\rho_L}{1000}} \quad \left[\frac{m^3}{h}\right]$$

If, in addition, the values already known are inserted, there results

$$\dot{V}_w = \frac{1.7272\ (h_{max}\ h_E) \cdot \dot{m}}{2259.6} \cdot \sqrt{\frac{1.19}{1000}} \quad \left[\frac{m^3}{h}\right]$$

$$\dot{V}_w = 2.63 \cdot 10^{-5} \cdot \dot{m} \cdot (h_{max}\ h_E) \quad \left[\frac{m^3}{h}\right]$$

Dimensional analysis for **13**

$$\dot{V}_w = \frac{\frac{m^3}{kg}\left(\frac{kJ}{kg} - \frac{kJ}{kg}\right) \cdot \frac{kg}{h}}{\frac{kJ}{kg}} \cdot \sqrt{\frac{kg/m^3}{kg/m^3}} \quad \left[\frac{m^3}{h}\right]$$

| | | |
|---|---|---|
| R | – | Complete heat of evaporation available in deaerator at a pressure of 0.98 bar a [kJ] |
| $m_1$ | – | Heating-steam amount available in deaerator at 0.98 bar a [kg] |
| V | – | Volume of heating steam at 0.98 bar a [m³] |
| v'' | – | Specific volume of heating steam at 0.98 bar a [m³/kg] (= 1.7272 m³/kg) |
| Q | – | Max. amount of heat that can be absorbed by the cold make-up water [kJ/kg] |
| $h_E$ | – | Heat content (enthalpy) of cold make-up water [kJ/kg] |
| $h_{max}$ | – | Max. heat content (enthalpy) of heated make-up water [kJ/kg] |
| $m_2$ | – | Amount of water required for condensing the total heating-steam amount [kg] |
| t | – | Time required for condensing the total heating-steam amount [h] |
| $\dot{V}_L$ | – | Air flow required to prevent a vacuum [m³/h] |
| $\dot{m}$ | – | Cold make-up water [kg/h] |
| $\dot{V}_w$ | – | Equivalent water volume flow [m³/h] |
| $\rho_L$ | – | Density of air at 1 bar a and 20 °C (ambient values) (= 1.19) [kg/m³] |
| 1000 | – | Densitiy of water [kg/m³] |
| r | – | Heat of evaporaton of heating steam at 0.98 bar a (2259.6 kJ/kg) |

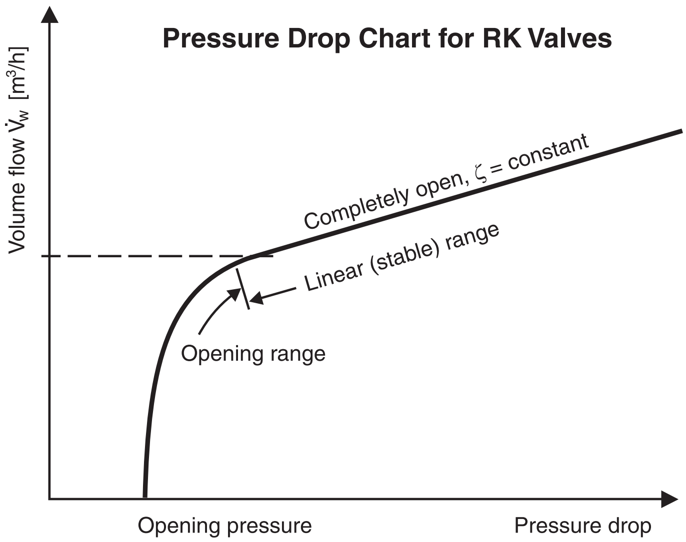


**Fig. 2**


**GESTRA AG**

P. O. Box 10 54 60, D-28054 Bremen
Münchener Str. 77, D-28215 Bremen
Telephone +49 (0) 421 35 03 - 0, Fax +49 (0) 421 35 03-393
E-Mail gestra.ag@flowserve.com, Internet www.gestra.de


FLOWSERVE GESTRA


810670-02/906cm · 1981 GESTRA AG · Bremen · Printed in Germany