Pulsation Control

Lau Koop
Thomassen Compression Systems

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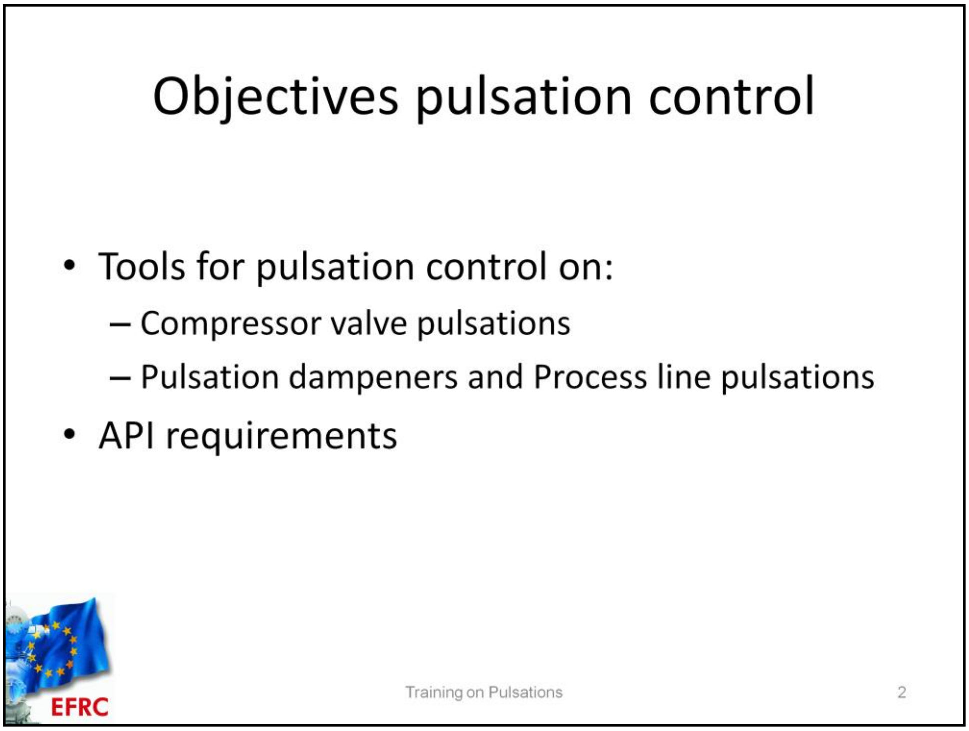

Pulsation control in a compressor cylinder can be more or less divided into two independent sections:

The pulsations in the valve chambers and

The pulsations in the process piping

The API requirements and recommendations on pressure pulsations in both sections have a different approach, and are described in different paragraph’s

Pulsations at cylinder flanges

Paragraph 7.9.4.2.5.2.1

$$Pcf = 3R$$

or $7\%pp$ (whichever is lower)

Pcf = maximum allowable unfiltered peak-to-peak pulsation level as a percentage of static line pressure

R = stage pressure ratio

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The API 618 gives a formula for determining the maximum pulsationlevel at the cylinderflanges.

Pulsation control

Compressor cylinder flange pulsations

- Tools:
  - Pulsation dampers
  - Cylinder – pulsation bottle tuning
  - Damping orifice plates
  - Compressor operation and capacity control

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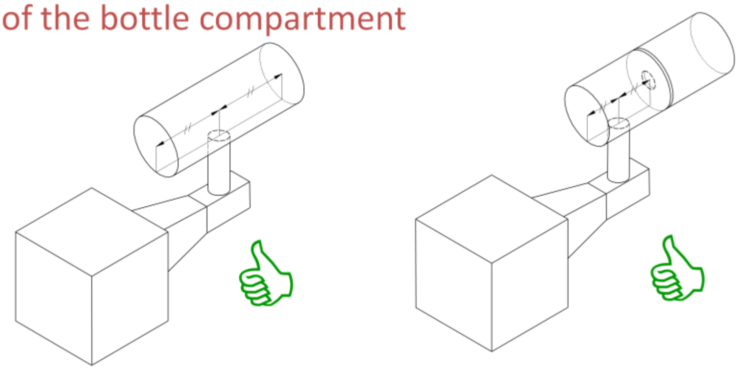
Tools to minimize valve pulsations are mentioned here. All four have their own characteristic and are all of the same importance.

The magnitude of pulsations near the cylinder flange is determined by the geometry of the gas passage volume in the cylinder, the size and length of the cylinder nozzle, and to a certain extend also by the volume of the pulsation damper.

The damper volume is mainly determined by the requirements of the process line. Coincidence of resonances inside the bottle and in the cylinder nozzle can be avoided by the application of baffles and/or the location of the nozzle connection in the centre of the longitudinal length of a compartment.

Design rules for valve chamber pulsations

- Pulsation damper
  - Cylinder nozzle in the middle longitudinal length of the bottle compartment



Design rules for valve chamber pulsations

- Length and internal diameter of pipe section between cylinder and bottle
  - Keep the length of the nozzle as short as possible
  - Choose the maximum possible size of the connecting pipe.

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The magnitude of pulsations in this area is determined by the geometry of the gas passage area in the cylinder, the size and length of the cylinder nozzle, and to a certain extend also by the volume of the pulsation damper.

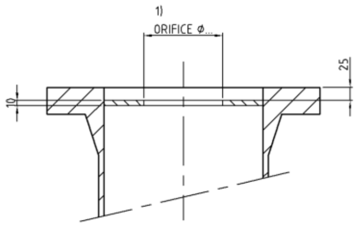
Rules of thumb are:

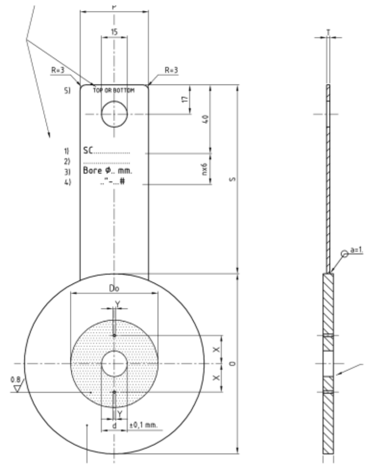
Keep the length of the nozzle as short as possible

Choose the maximum possible size of the connecting pipe.

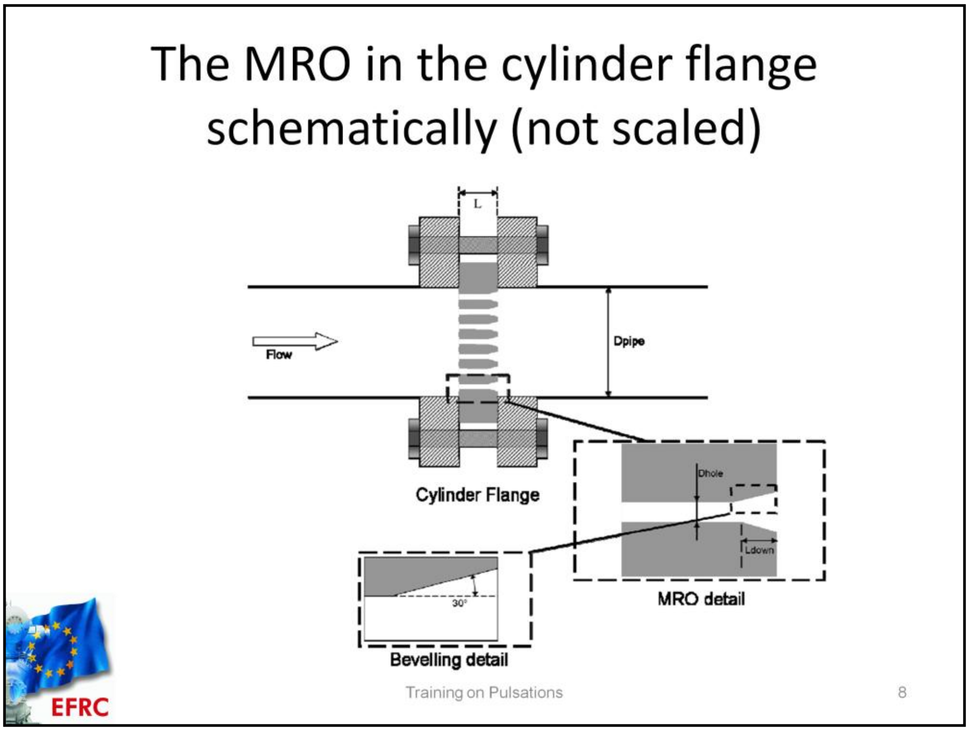
Design rules for valve chamber pulsations

- Damping orifice
  - Orifice between flanges or welded in nozzle

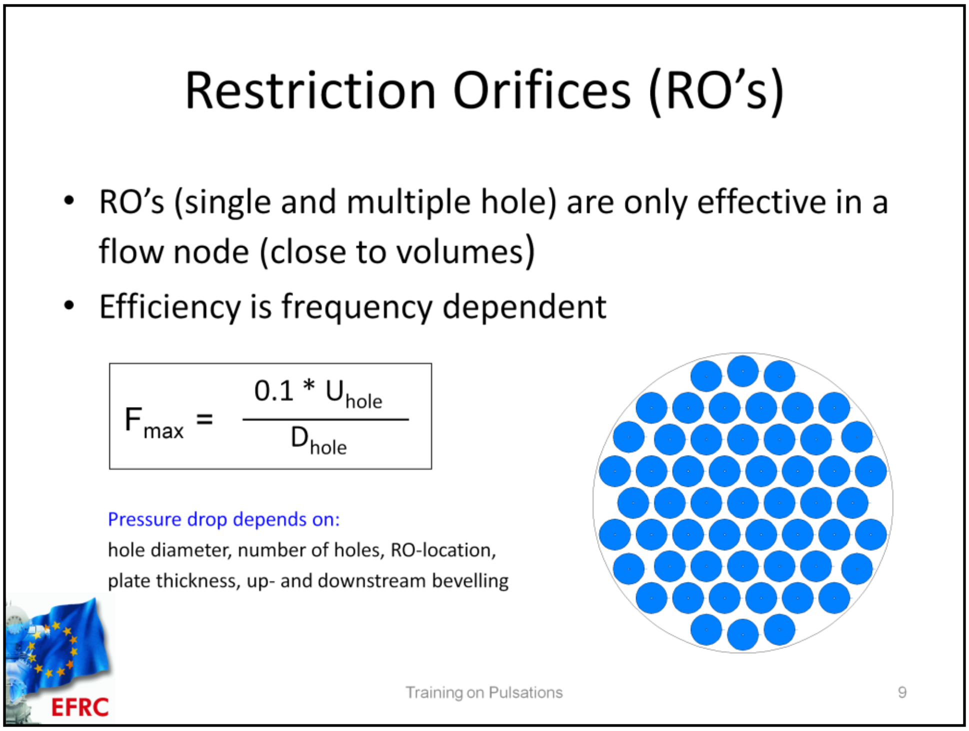




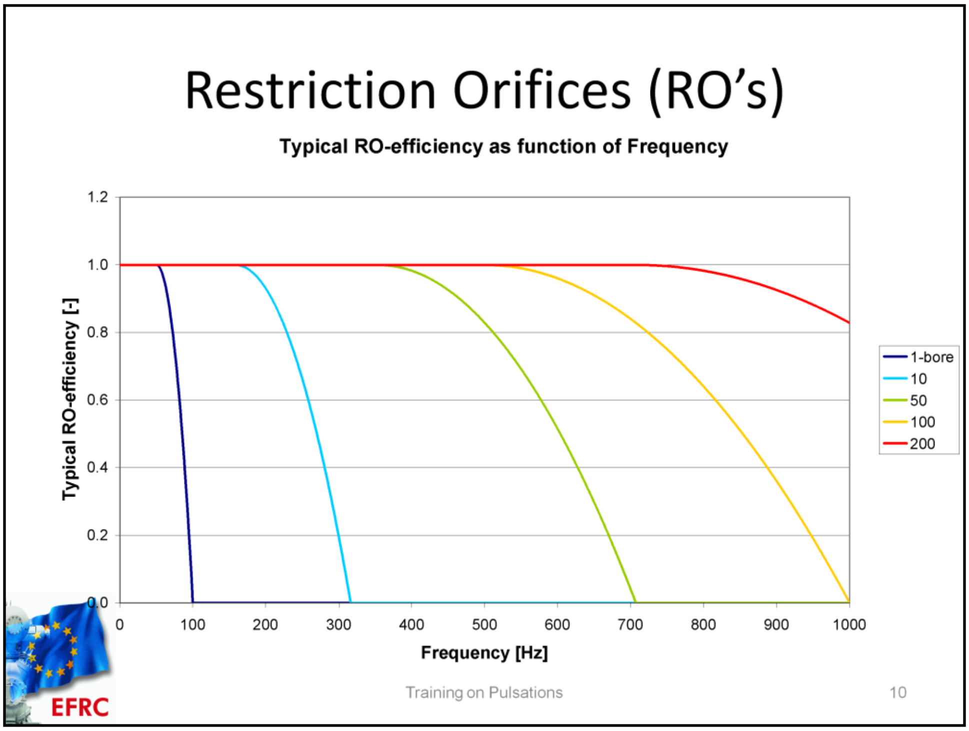
In many cases orifices are required to damp the pulsations in the valve chambers. They are installed between the cylinder and the damper, welded in the nozzle, or supplied as a loose item. A loose item requires two packing's, and can accidently be left out.



A multiple bore orifice must always be clamped between the flanges.

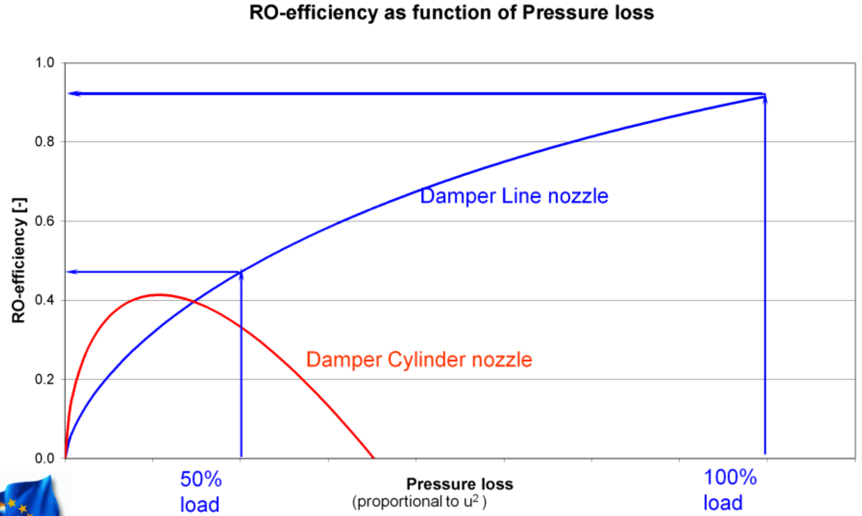


Maximum effective frequency for a MRO is proportional to the square root of the number of holes



This graph shows the damping effect of orifices in the frequency domain. The more holes are used the higher frequencies will be damped. In particular when noise is a topic, the application of multiple bore orifices can be a solution.

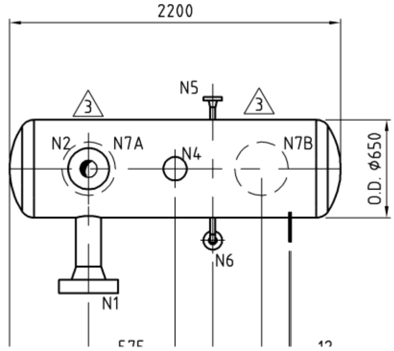
Restriction Orifices (RO's)



The pressure drop in a restriction is proportional to the square of the gas velocity. This means that at low throughput, the effectiveness of the orifice will decrease. The damper nozzle orifice pressure drop is only effective upto about 0.3 %.

Pulsation damper terminology

- Volume bottles
  - No baffles



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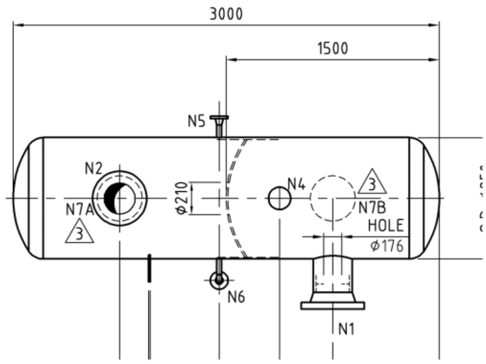
There are different types of damper and their terminology.

Vessels without internals (volume bottles)

Pulsation damper terminology

- Filter type dampers (pulsation damper)
  – Internal volume separated in compartments



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Vessels separated in compartments by baffles and choke tubes (pulsation dampers)

Volume bottles supported on the crosshead guide

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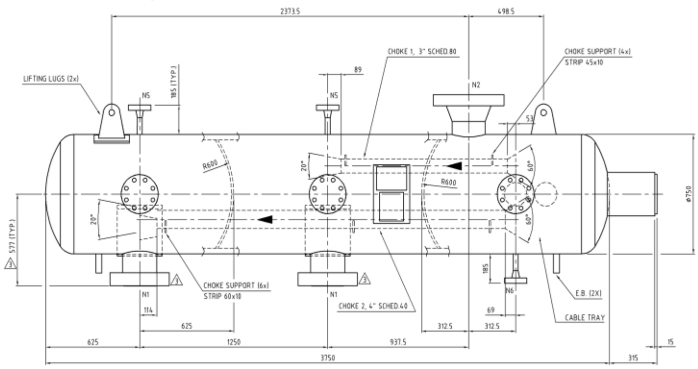
This picture shows an example of volume bottles. The length of the nozzles is extensive. This is caused by the height of the valve unloaders.

Pulsation damper terminology

- Manifolds
  - Two or more cylinders connected to one vessel.



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Three compartment bottle, and two choke tubes. The tuning of the choke tubes cannot be performed by handcalculations. These type of pulsation dampers are only used when the process conditions are very stable.

Manifold pulsation bottle

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One vessel for two or more cylinders (manifolds)

Pulsation control

Process line pulsations

- Pulsation dampers; Parameters
  - Volume
  - Division of compartments
  - Baffles
  - Tubes
  - Pressure drop (orifices)

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The major parameter for the damping efficiency is the volume of the vessel.

A division of the vessel in compartments by baffle plates can decrease the pulsation induced vibration forces.

The application of choke tubes has to be examined thoroughly, as they can even decrease or minimize the damping effect when not well designed. Choke tubes introduce pressure drop.

Orifices will be most effective, when placed near the inlet or outlet of a relative large vessel. When positioned in or very near the line flange of the pulsation damper, they will dampen the amplification effect of possible resonances. They will not lower the bottom level of the pulsations.

Pulsation bottles:
Preliminary sizing volume

- API Formula’s to determine the preliminary dimensions of the pulsation suppression devices
- Only suitable for non-filter design.
- Volume may be altered during pulsation prestudy.

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API 618 specifies formula’s that should be used for the determination of the minimum required volume of the pulsation dampers

Pulsations at line side nozzle

API 618 paragraph 7.9.4.2.5.2.2.2

- *P1 is the maximum allowable peak-to-peak level of individual pulsation components expressed as a percentage of mean absolute line pressure;*
- *c is the speed of sound for the gas in m/s (ft/s);*
- *P_L is the mean absolute line pressure in bar (psia);*
- *D_i is the inside diameter of line pipe in mm (in.);*

$$P_1 = \sqrt{c/350} * \left(\frac{400}{\left(P_L * D_i * f\right)^{1/2}} \right)$$

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Requirement of API 618 for line side pulsations.

API 618 Formula's preliminary sizing Par. 7.9.3.2

- *VS minimum required suction surge volume [m3 (ft3)];*
- *Vd :minimum required discharge surge volume [m3 (ft3)];*
- *K: isentropic compression exponent at average operating gas pressure and temperature;*
- *r : stage pressure ratio at cylinder flanges*
- *TS: absolute suction temperature in [K (°R)];*
- *M: molar mass;*
- *PD : total net displaced volume per revolution of all compressor cylinders to be manifolded in the surge volume* [m3/r (ft3/r)].

$$Vs = 8.1 * PD \left(\frac{k * Ts}{M}\right)^{\frac{1}{4}} \qquad Vd = 1.6 * \left(\frac{Vs}{r^{\frac{1}{k}}}\right)$$

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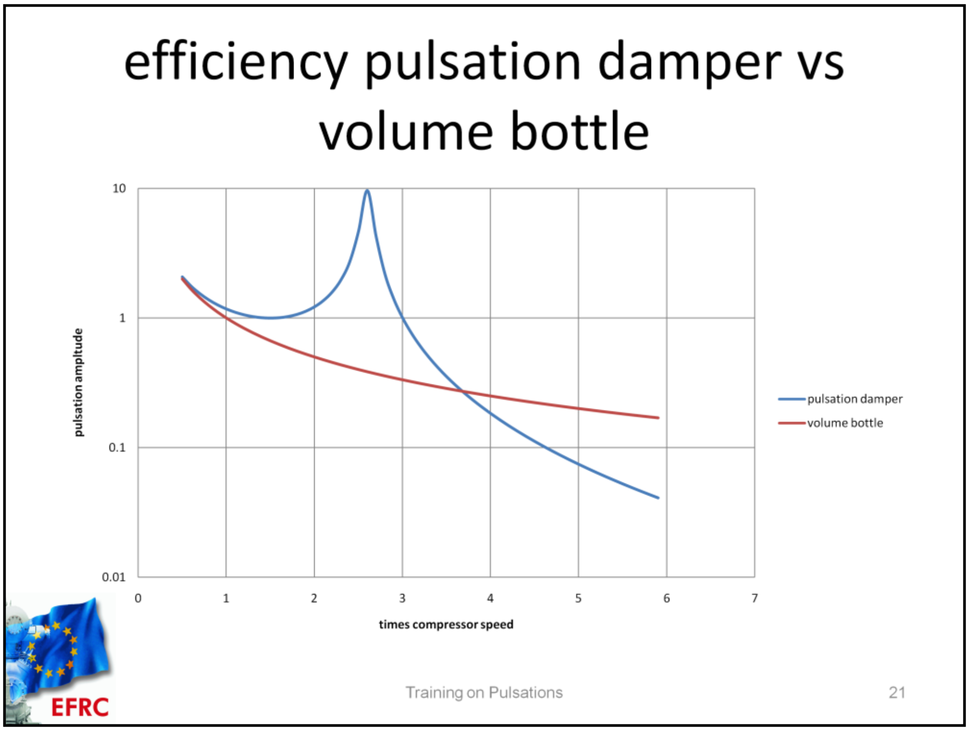
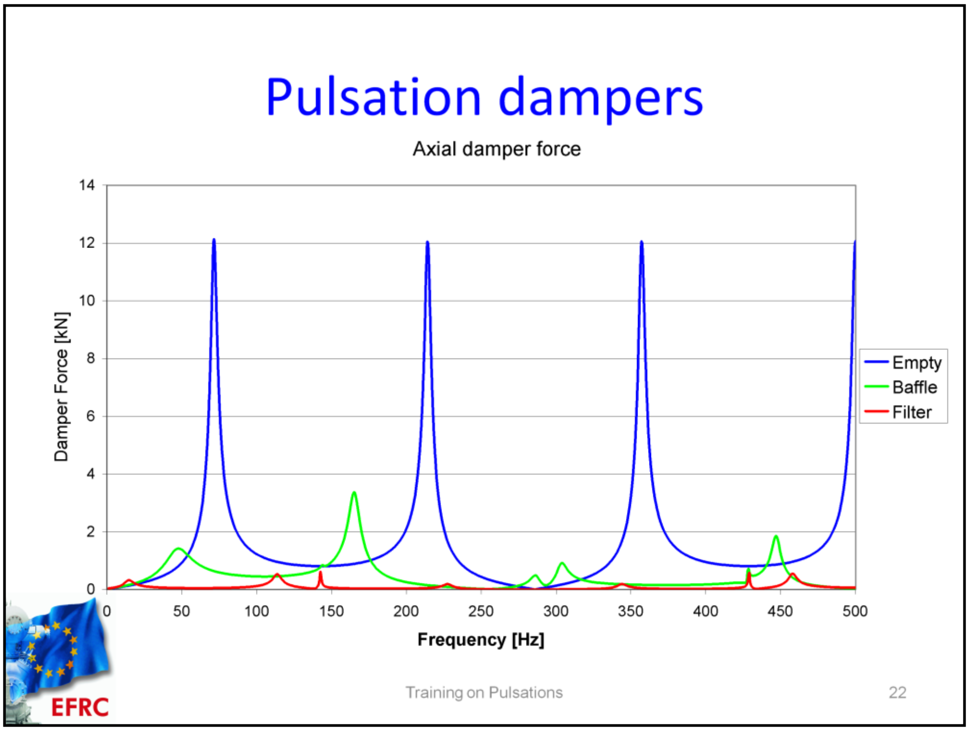
The basis for the determination of the suction surge volume bottle is de net displaced volume the subject compressor cylinder(s), and the process gasproperty at suction conditions. The basis for the discharge surge volume is the suction volume and the pressure ratio. It must be noted that the volumes determined in this way may be altered in the prestudy to a larger volume, but it may also well be possible to apply smaller volumes.



This graph shows the difference in damping efficiency of a volume bottle and a pulsation damper which have the same total volume. The graph shows clearly that the application of pulsation bottles will not always result in lower pulsations.



Pulsation induced vibration force reduction in different type of dampers

Maximum all. Pressure drop

Paragraph 7.9.4.2.5.3.1

Allowable pressure drop across the device

$$\Delta P = 1.67 * \left(\frac{R-1}{R} \right)$$

or 0.25% whichever is higher

Based on the steady flow

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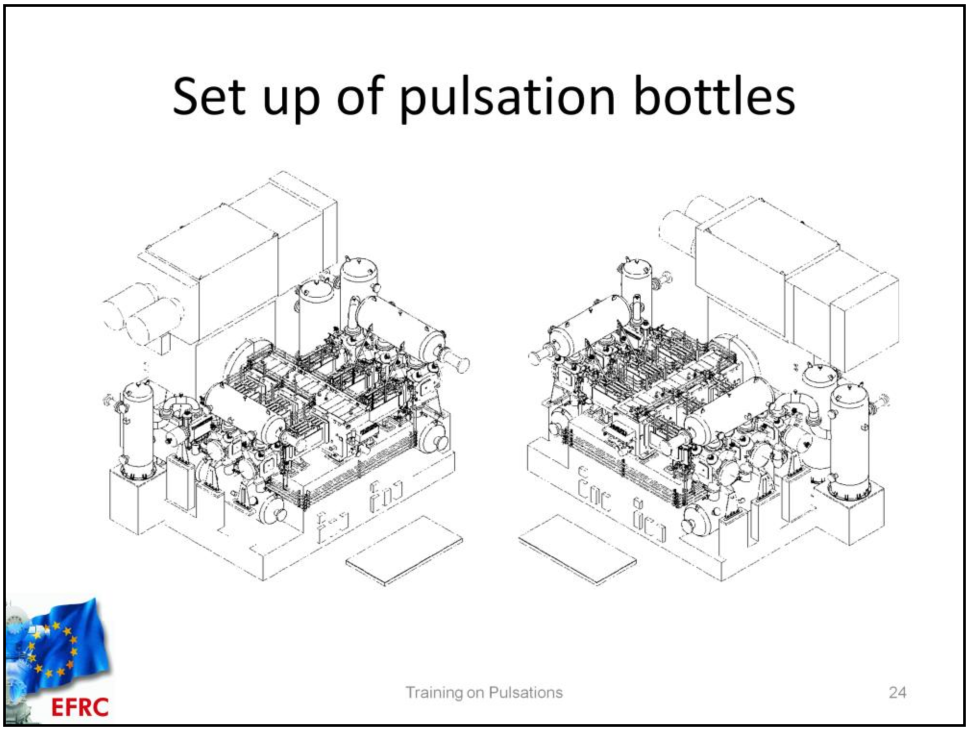
The API formula allows a pressure drop based on the pressure ratio (R) of the subject cylinder. The background here is that when the pressure ratio is low, the cylinder performance is affected by the pressure drop.



For 6-cylinder compressors a lot of trying and fitting is required to obtain a proper position the pulsation dampers. Design rules cannot always be followed in such cases. Vertical positioning of vessels has the advantage that they can be supported on a skirt on the concrete, but the length of the cylinder nozzle will be longer than desired. In case of Hydrogen compression this may be acceptable.

When compressors are designed for a large range of pressures and capacities, as sometimes will the case for natural gas compressors, the dampers should be designed for the most severe duty for pulsations. This will result in relatively large volumes. Also in this case positioning the vessels will be quite a braintwister.

Compressor operation and pulsations

- Cylinder capacity control:
  - Standard full load
  - Clearance pocket
  - Valve lifting
  - Reversed flow control
  - Speed control
  - Suction throttling

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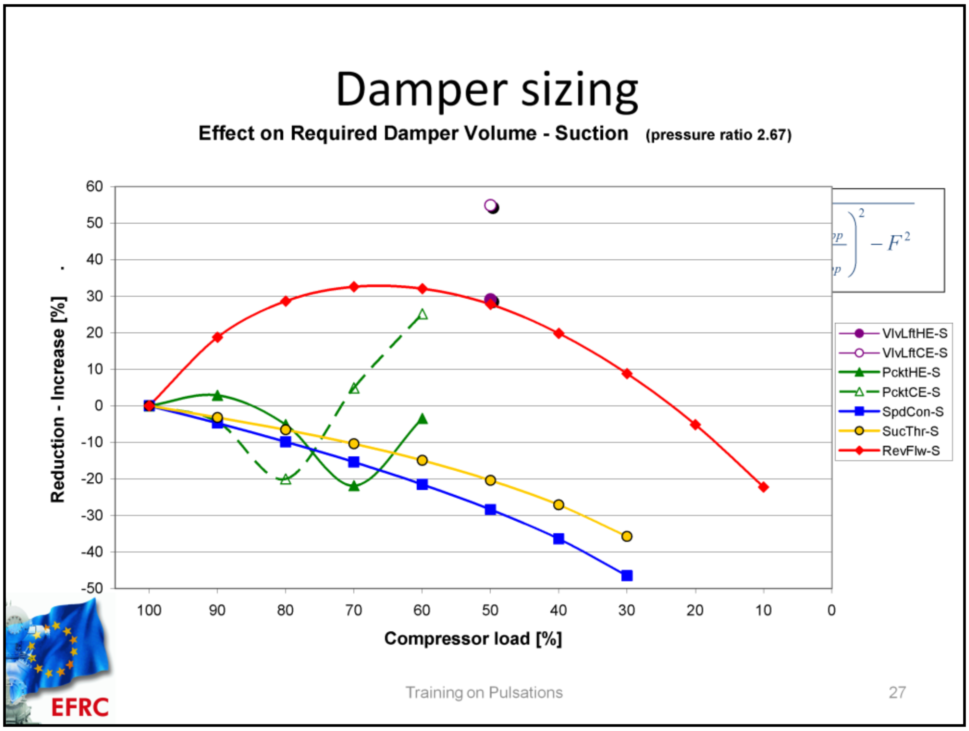
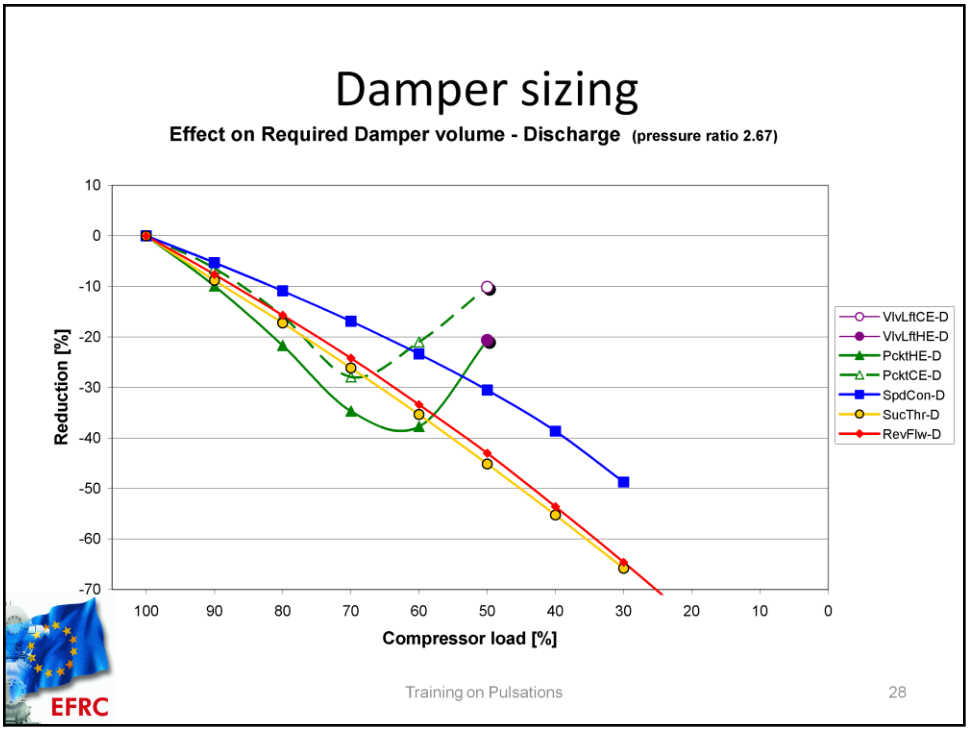
The operating duty of the cylinder determines the pulsation level in the cylinder and the process system.



The indicated trends are directly related to the differences in the flow pulse shapes.

Note that the mutual relation between the different control systems depend on the actual pressure ratio (in this case 2.67)



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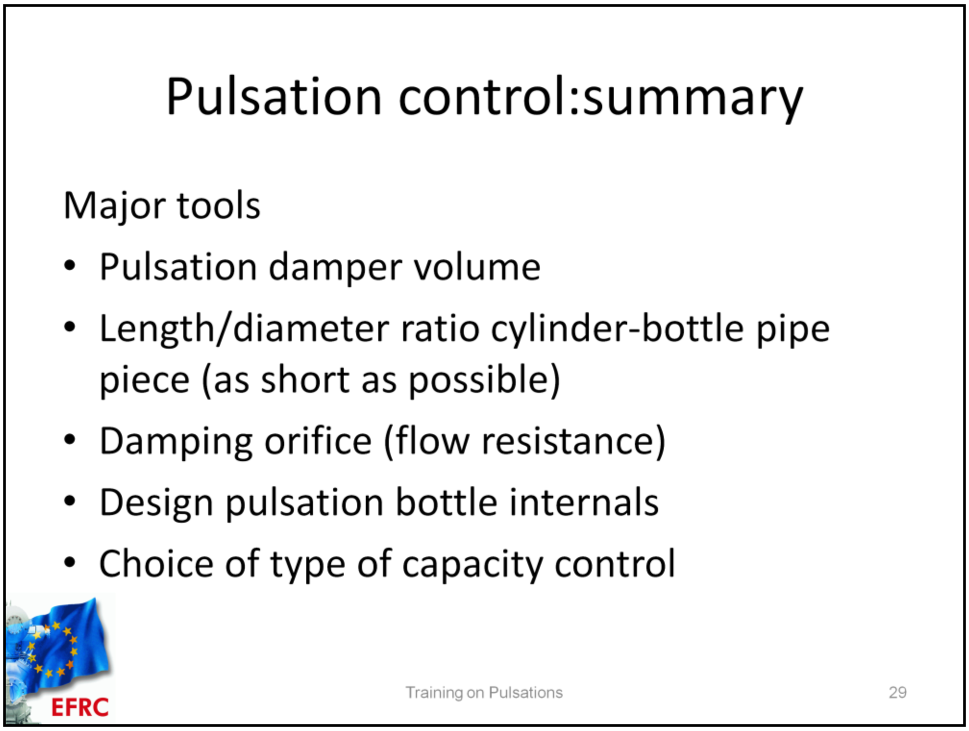

All these parameters can only be optimized and adapted in the design stage of the compressor/process systems. The damping orifice is the only part which could be replaced without major economical impact.

Economics:

Sequence of pulsation damper design

1. Determine the volume in an early stage of the project by a prestudy, or analytical methods.
2. Position the vessels on or near the compressor, taking into account the design rules for the cylinder nozzles.
3. In the prestudy the position of baffles, when required, can be determined
4. Take measures to allow for orifice plates. The size can be determined later.

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