7.5.4.1 Inherent rangeability

Ideally the open-loop gain remains constant independent of the position of the valve in a closed-loop control system. Unfortunately, this condition is only achieved in rare cases. Every user has already experienced a situation where a control valve at higher travel positions is completely stable, yet permanent oscillations occur at small travel positions. This is caused by a higher gain of the valve and a steeper slope of the valve characteristic. In order to simplify the application and the selection of control valves for the control specialist, certain boundary values for the slope of the inherent characteristic have been set.

In this way, the permissible slope tolerance is exceeded if the inclination of the straight line which connects two neighboring measured values (e.g. points 5 % and 10 %), is more than 2:1 or less than 0.5:1. This rule applies for valve characteristics which the control valve manufacturer has specified for the same travel positions in its literature (see Figure 7.5.4.1.-1).

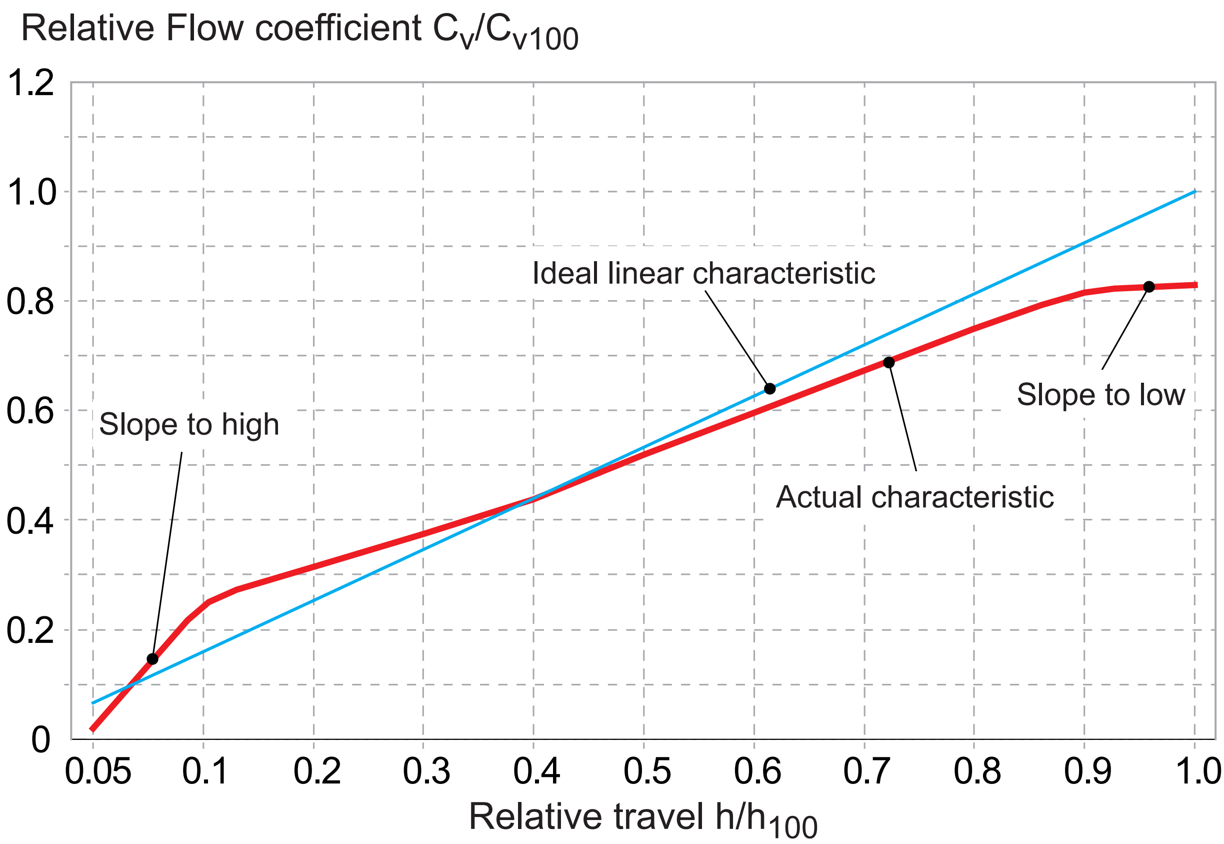


Figure 7.5.4.1.-1: Linear characteristic showing non-permissible deviations

A typical inherent characteristic is shown in Figure 7.5.4.1.-1. At relatively small C_V -values the curve proceeds above the ideal characteristic. In the case of large valve travels, however, it is under it. This is acceptable as long as the characteristic is in accordance with the slope tolerances and the rated flow coefficient (C_{v100}) is within its limit values. The represented characteristic shown in Fig. 7-16 violates the IEC-standard in three different points:

- Between 5 % and 10 % travel the slope of the characteristic is too steep,
- between 90 % and 100 % travel the slope is too flat and
- the rated flow coefficient (C_{v100}) deviates more than 10 % from the stated value.

As already mentioned the valve characteristics depend only on the constructive details - the inherent design factors. Therefore, the manufacturer must analyze whether the constructive assumptions are really given if deviating characteristics or inadequate C_{v100} - value occur. The starting points of such an investigation are the following:

- Seat ring diameter calculated correspondingly?
- Sufficient cross-sectional area available (seat ring / plug)?
- Streamlined valve body employed?
- Correct flow direction chosen?
- Guiding effect of the trim considered?

Trends and definitions of inherent valve characteristic for globe and rotary valves.

Gain requirements of valve inherent characteristics are defined in IEC 60534-2-4 with a tolerance band of ± 10 % within the limits $0.5 < \Delta C_v / \Delta_s < 1.3$ and ± 10 % of the C_{v100} value. See Figure 7.5.4.1.-2 to Figure 7.5.4.1.-5.

Because today there are many types of inherent valve characteristics, from the globe control valves to quarter-turn control valves, IEC 60534-2-4 has defined basic requirements for the characteristic quality (see Figures Figure 7.5.4.1.-2 to Figure 7.5.4.1.-6).

In general, all kinds of characteristics are supported, but they are to be published if they are not of the ideal linear or equal percentage type, i.e. outside the tolerance band defined in IEC 60534-2-4. The ideal equal percentage characteristic of globe valves from former times cannot be achieved with modern economic standard globe valves, which also have to follow general market demands to the highest flow capacity ($C_v \cdot 100$)/DN^2 at lowest initial cost. Today, the inherent characteristics of globe valves are somewhat modified equal percentage in the competitive range of published highest C_v values. To be competitive, valves need to be offered mostly with the largest seat diameter (smallest nominal size DN), if not specified otherwise.

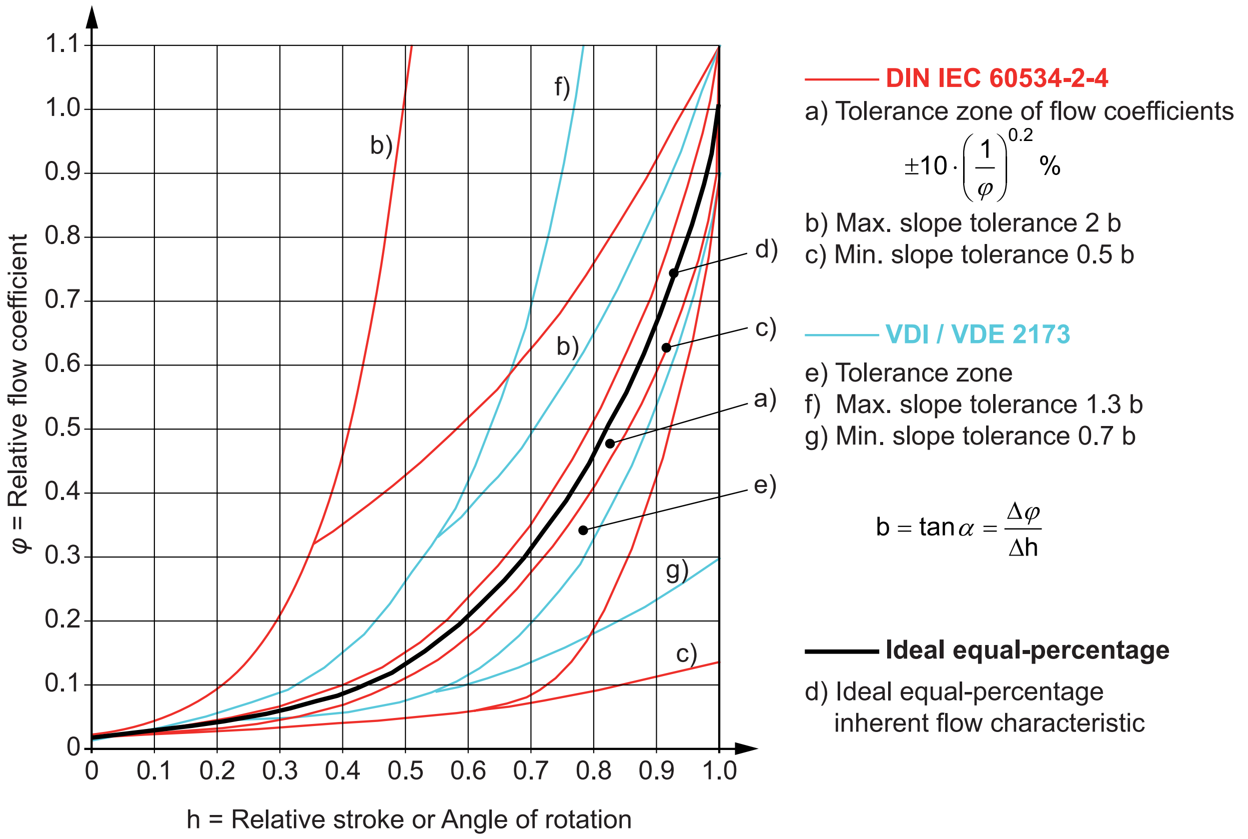
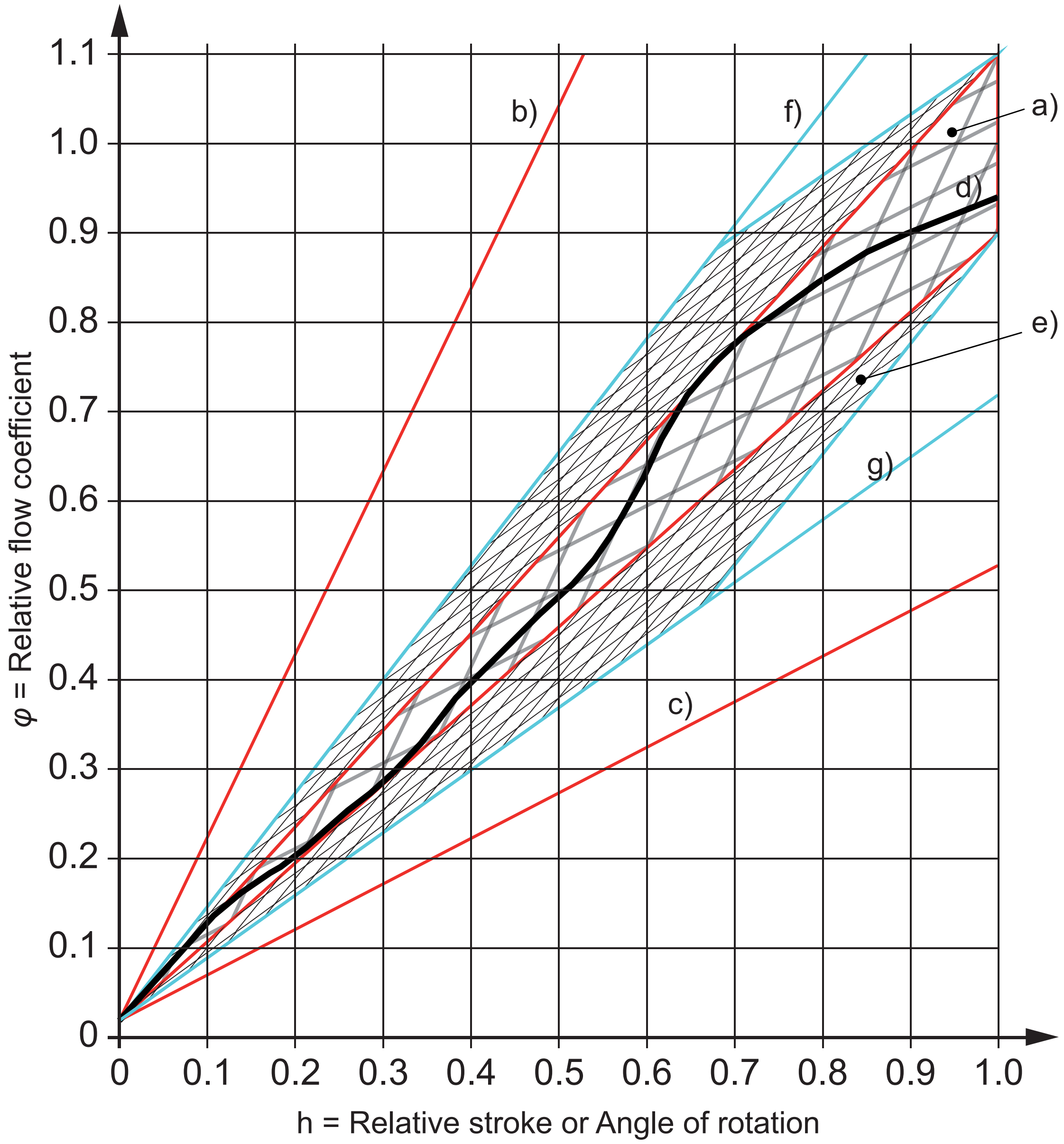


Figure 7.5.4.1.-2: Inherent valve equal-percentage characteristic



DIN IEC 60534-2-4	VDI / VDE 2173
a) Tolerance zone of flow coefficients $\pm 10 \cdot \left(\frac{1}{\varphi}\right)^{0.2}$ % b) Max. slope tolerance 2 b ≙ Angle of 62.97 degrees c) Min. slope tolerance 0.5 b ≙ Angle of 26.10 degrees	e) Tolerance zone f) Max. slope tolerance 1.3 b ≙ Angle of 51.87 degrees g) Min. slope tolerance 0.7 b ≙ Angle of 34.45 degrees $b = \tan\alpha = \frac{\Delta\varphi}{\Delta h}$
Example	d) Measured characteristic linear within tolerance zone a)

Figure 7.5.4.1.-3: Inherent valve linear characteristic

Cam and positioner signal technology used to linearize any mismatching is not the “door to heaven”; rather, advantages and disadvantages need to be discussed separately.

Figure 7.5.4.1.-5 and Figure 7.5.4.1.-6 shows that there is an interaction between the valve characteristic form, the flow capacity and the power consumption. This is shown here with liquid measurements of x_{Fz} characteristics versus load C_v/C_{v100}. Valves with higher x_{Fz} values convert the power ($\Delta p \cdot q \cdot$ const.) better to heat by flow friction than high flow capacity valves, which convert more to flow velocity and therefore cavitation occurs at smaller pressure drops. Modern control valves are designed for specific marked segments like chemicals, food & beverage and pharmaceuticals. On a higher price level they are used for the downstream hydrocarbon processing industries and oil and gas market.

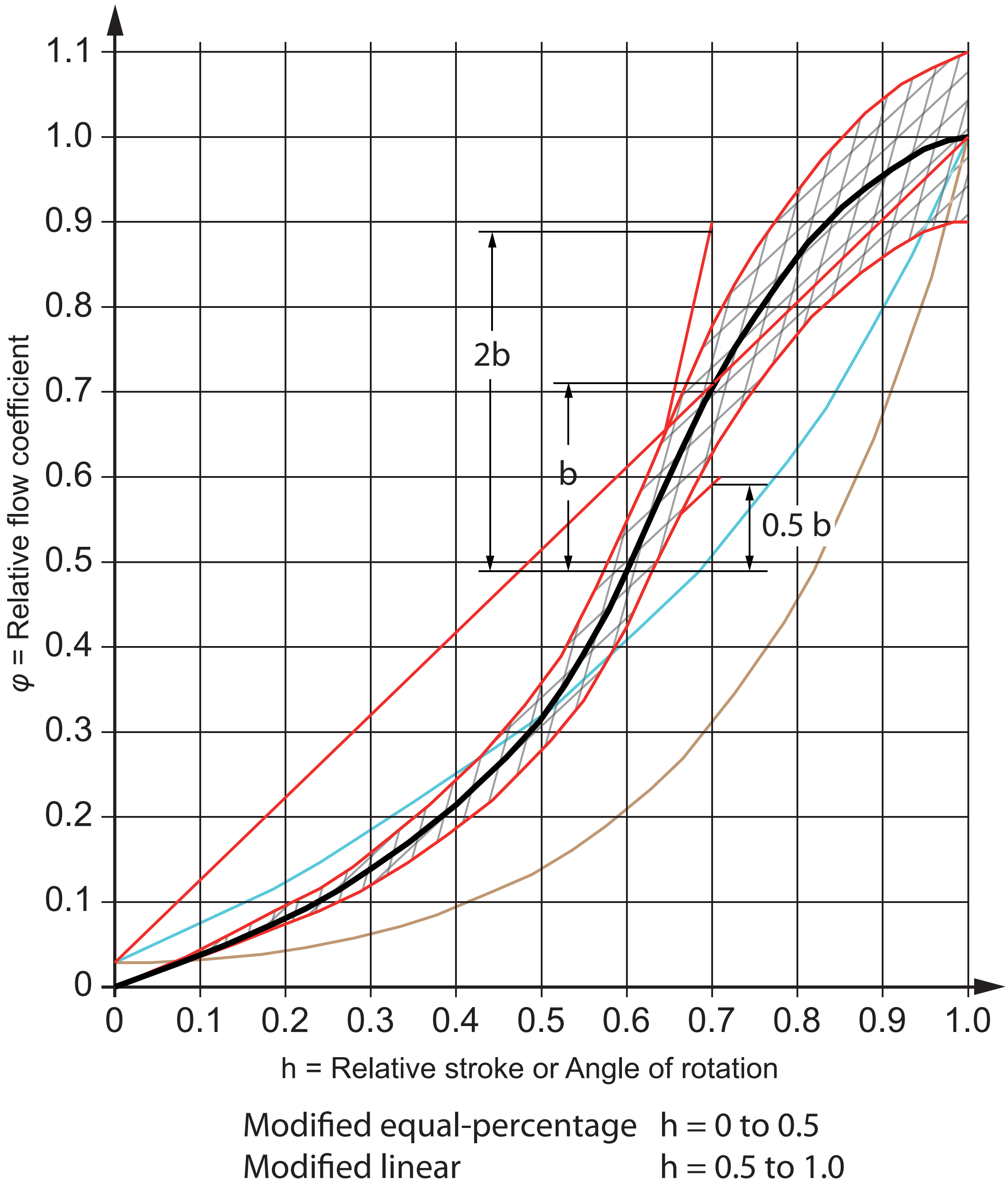


Figure 7.5.4.1.-4: Inherent valve modified equal-percentage and modified linear characteristic

And at the top price level they are mainly applied in the onshore and offshore upstream market, in oil and gas exploration, separation, storing and transport, or they are tailored for special demands. In the HPI market, control valves are more often “power converting machines” up to 300 MW used as flare valves, blow down or anti-surge control valves and for other special demands. Those valves in the severe service area in all nominal sizes and pressure ratings are on average approximately four times more expensive -including more detail engineering- than valves of non critical standard applications in chemical plants in the range of DN ≤ 6 inch and PN ≤ Class 300.

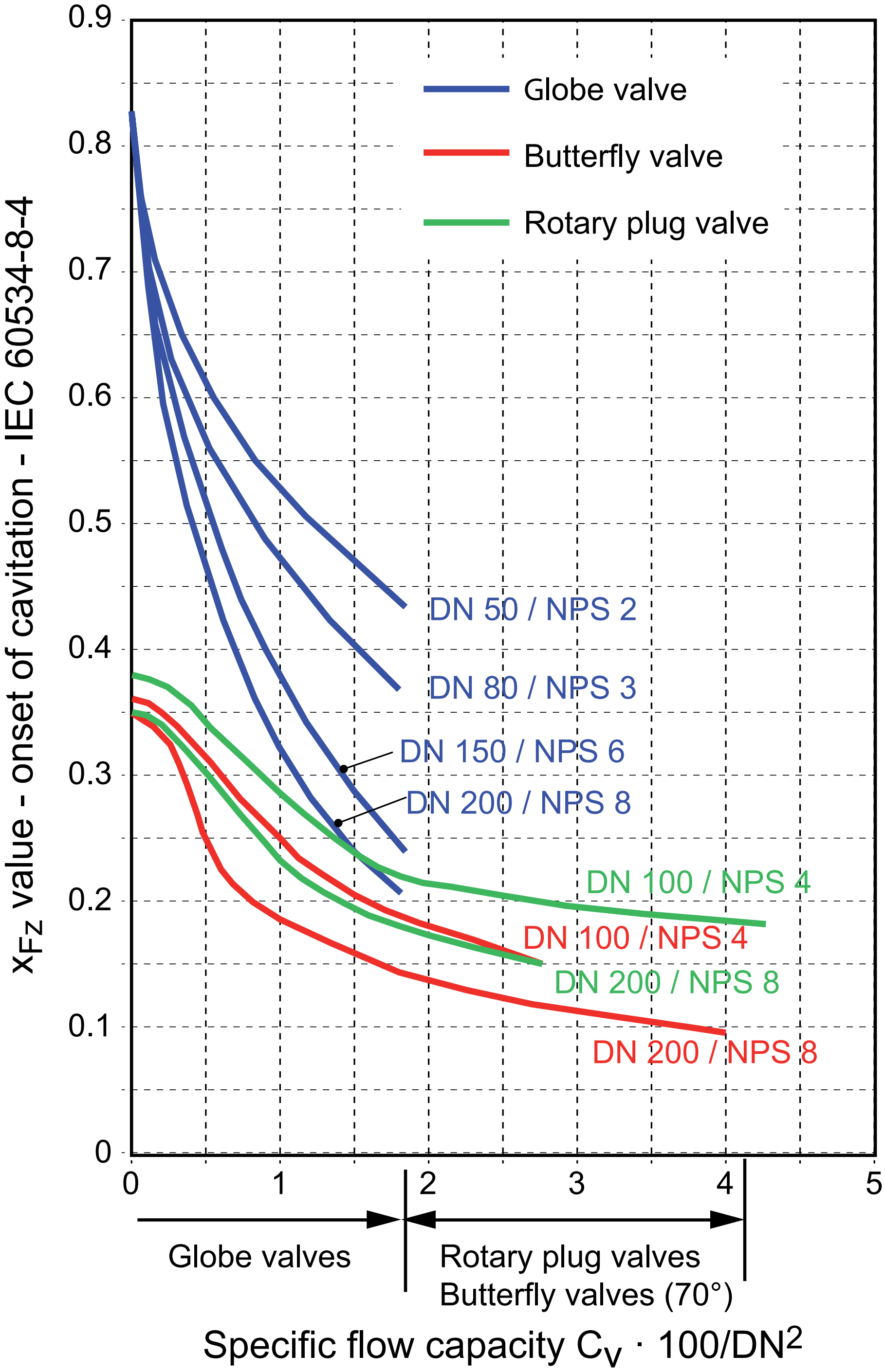


Figure 7.5.4.1.-5: Energy converting capacity of Globe and Rotary valves

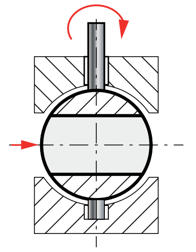
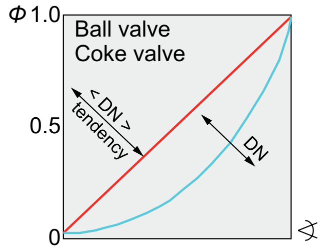
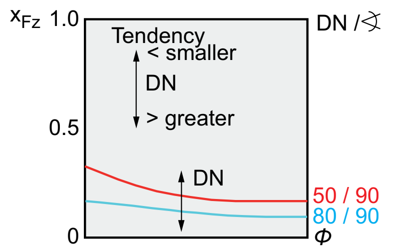
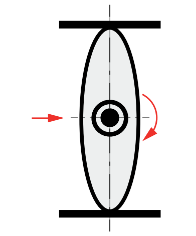
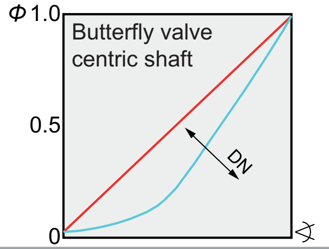
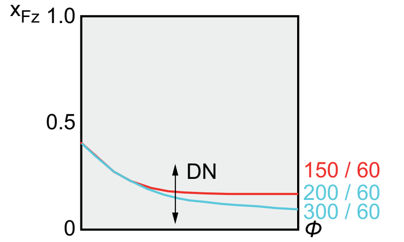
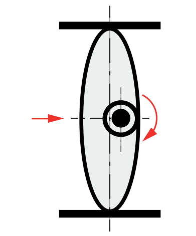
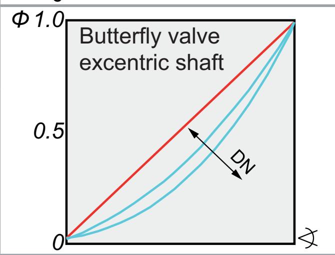
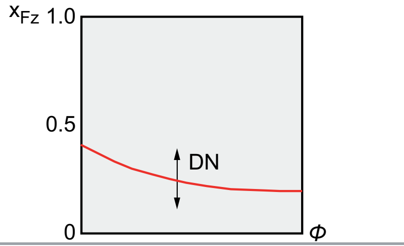
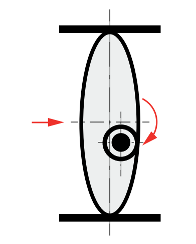
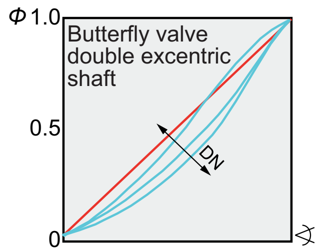
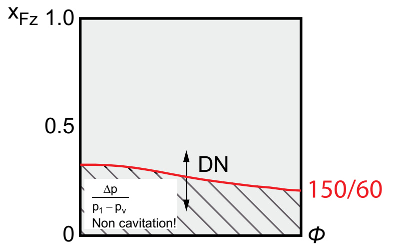
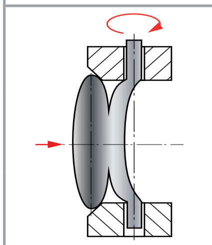
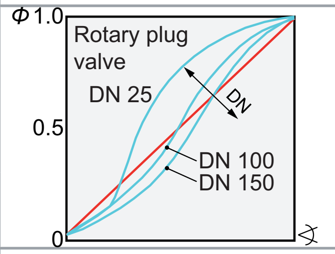
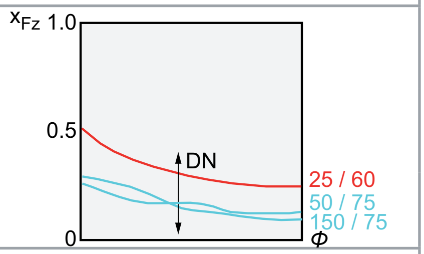
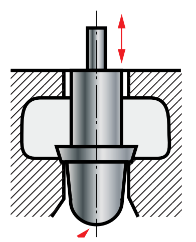
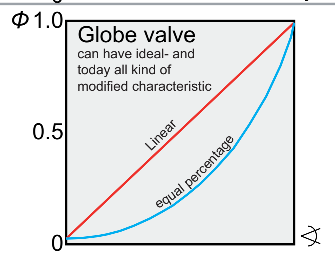
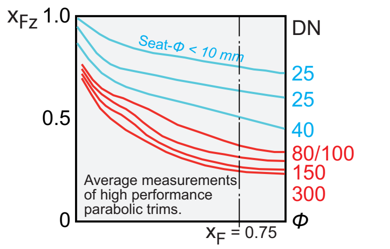
<table>
<tr><th colspan="5">Quality of characteristics and behavior of energy conversion</th></tr>
<tr><th>$\phi = \frac{C_v}{C_{v100}}$</th><th>Inherent characteristic</th><th colspan="2">Flow capacity
$\frac{C_{vs} \cdot 100}{DN^2}$ (DN = mm)</th><th>Energy converting x_{Fz} values
IEC 60534-8-4</th></tr>
<tr><th>Symbol</th><th></th><th>Angle</th><th>C_v/DN^2</th><th></th></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td>90°</td><td>14.0</td><td rowspan="3"></td></tr>
<tr><td>80°</td><td>6.0</td></tr>
<tr><td>70°</td><td>3.5</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td>90°</td><td>< 8</td><td rowspan="3"></td></tr>
<tr><td>70°</td><td>< 4</td></tr>
<tr><td>60°</td><td>< 2</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td>90°</td><td>< 4.2</td><td rowspan="3"></td></tr>
<tr><td>70°</td><td>< 3.5</td></tr>
<tr><td>60°</td><td>< 2.5</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td>90°</td><td>< 3.5</td><td rowspan="3"></td></tr>
<tr><td>70°</td><td>< 2.5</td></tr>
<tr><td>60°</td><td>2.0</td></tr>
<tr><td rowspan="3"></td><td rowspan="3"></td><td>75°</td><td>≤ 3.5</td><td rowspan="3"></td></tr>
<tr><td>60°</td><td>≤ 3.0</td></tr>
<tr><td>50°</td><td>≤ 2.1</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td colspan="2">$\frac{C_v}{DN^2} \leq 2.0$</td><td rowspan="2"></td></tr>
<tr><td colspan="2">Characteristics
$\frac{\text{stroke}}{\text{seat } \phi} \leq 0.3$</td></tr>
</table>

Figure 7.5.4.1.-6: Quality of characteristics and behavior of energy conversion