Plant design and control valve selection under increasing cost and time pressure - Part II

This is the second and final section of Mr Siemers´ technical paper addressing plant design and control valve selection when working under increased time and cost pressure. The first section (April issue) focused on control valve operating points and provided a case history involving a mismatch before introducing better valve sizing practices. Part two starts by explaining the trends and definitions of inherent valve characteristics before focusing on "quick and dirty" sizing. The paper then addresses cavitation before concluding with the expert software available to help select the optimum valve characteristic form.

By Dipl. Ing. Holger Siemers, SAMSON AG

Part I

1. Plant design under cost and time pressure
2. Control valves today are converting links between budgets!
3. From traditional to modern Development and Engineering Practice (DEP) for plant designers
4. The new DEP for trouble-shooting the mismatched case study in section 2

Part II

5. Trends and definitions of inherent valve characteristics for globe and rotary valves.
6. Detail engineering-sources for plant and valve designers have dried out!
7. Noise reduction and getting the plant power under control.
8. Selecting the optimum valve characteristic form
9. Using software to increase control quality, reduce cost and save time for creativity

5 Trends and definitions of inherent valve characteristics for globe and rotary valves

Gain requirements of valve inherent characteristics are defined in IEC 543 2-4 with a tolerance band of +-10 % within the limits: $0.5 < \Delta cv / \Delta s < 2$. This was a compromise to the former stricter national regulations of VDI 2173 with $0.7 < \Delta cv / \Delta s < 1.3$ and +-10% of the cv100 value. See Figures 7a to 7c.

Because today there are many types of inherent valve characteristics, from the globe control valves to quarter-turn control valves, IEC 534 2-4 has defined basic requirements for the characteristic quality (see Figures 7a to 7e).

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 534 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 (cv x 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 cv values. To be competitive, valves need to be offered mostly with the largest seat diameter (smallest nominal size DN), if not specified otherwise.

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.[4]

Figures 7d and 7e show 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 xFz characteristics versus load cv/cv100. Valves with higher xFz values convert the power [dp x q x const.][1] 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.

Note: given the amount of detail in some of the graphics in this article, readers might like to note that a high resolution PDF version can be viewed at: www.valve-world.net/magazine/controlvalves.asp.

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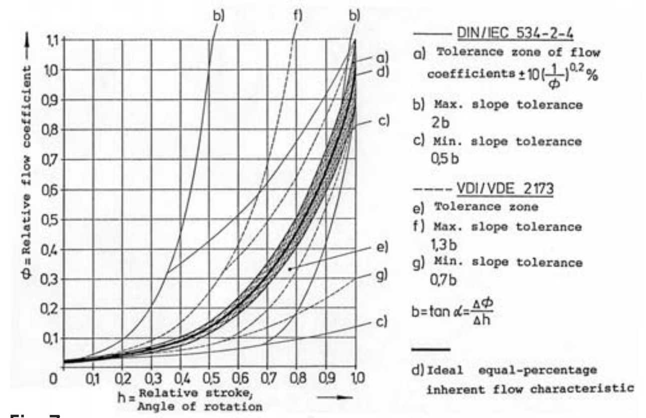

Fig. 7a

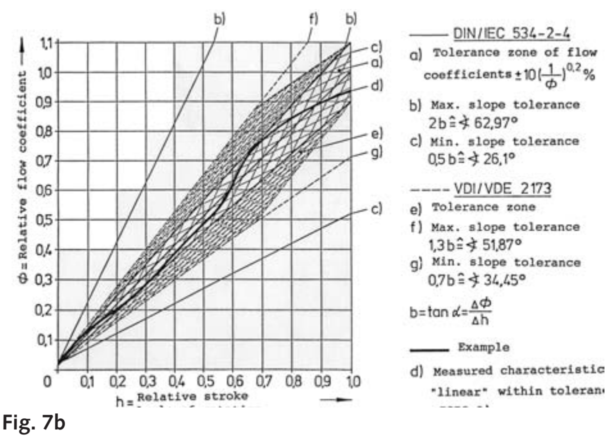

Fig. 7b

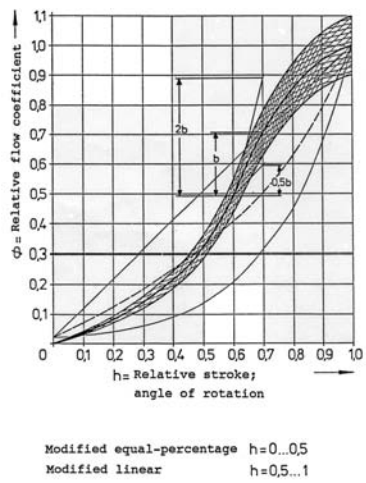

Fig. 7c

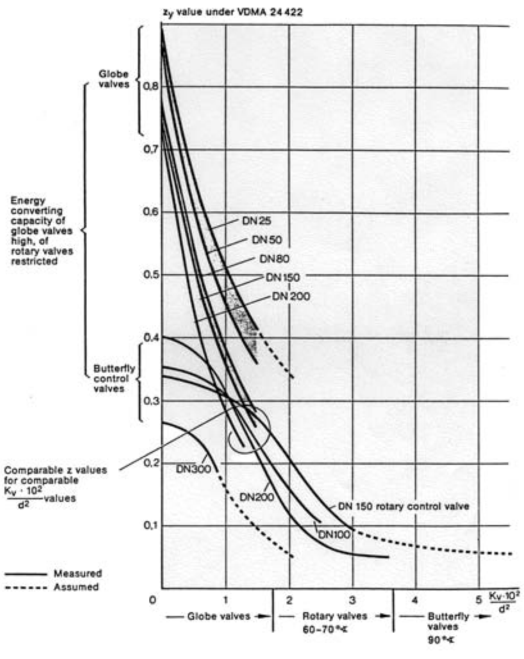

Fig. 7d

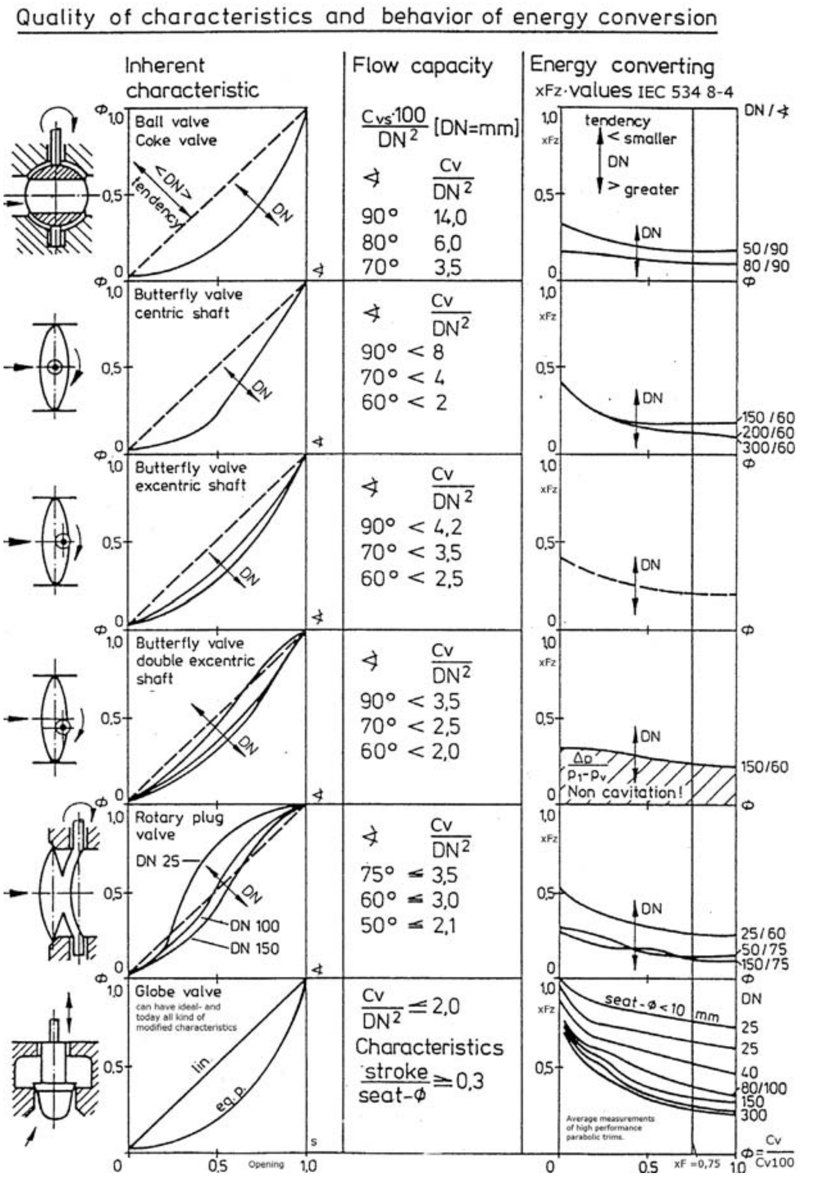

Fig. 7e

Figs 7a to 7e: Inherent valve characteristic versus flow capacity versus power converting capability -xFz f(cv/cv100)-.

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. 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.

6 Detail engineering-sources for plant-and valve designers dried out!

Plant and valve designers in the field of severe applications need time to optimize control quality, the sound level and power consumption as well as to handle increasing regulation paperwork and economic aspects. Sizing control valves from a total point of view is a challenge for the project engineer as well as for the valve manufacturer's specialists, even if they use modern powerful in-house sizing programs and tools. Those "valve guys" need long-term experience and high skills in measurement and control, mechanical engineering and thermodynamics. In comparison to the past, the time available for major projects has been more than halved, the specification volume -including the increasing paperwork associated with standards, special regulations and tailored customer requirements have more than doubled.

Negative effects of today are: valve specification sheets are often of low quality, operating points are missing or not logically sorted to qmax, qnorm, qmin, Important property data (like the vapour pressure) may be missing, no information about the worst-case conditions like during start-up, no control loop information etc. No wonder that sources of competence for high-level engineering for valves with higher demands have dried out and the risk of "quick and dirty" sizing is increasing.

Given today's quality standards ISO 9001:2000 and the upcoming SIL (IEC 61508) requirements even for non emergency shut down ESD serial valve products, do we really need SIL for special severe service valves? Also, as products are more often being offered under e-purchasing conditions characterized by an increasing cost and time pressure, the author would like to point out that care needs to be taken in this area, particularly for severe service valves. Proper control valve selection requires detail engineering with competence. We should not save initial costs by cutting back on detailled engineering and shifting higher cost to other after-sales budgets, e.g. troubleshooting, maintenance and, at worst, plant shutdown or accidents.

The CONVAL software looks at plant parameters (pipework, pipe devices, flow meters and valves) from an overall point of view with expert system features to compensate for the negative trends described above. The integrated mighty valve database can store every brand valve function like inherent valve characteristic as well as all defined valve recovery factor functions.

7 Noise reduction and getting the plant power under control is not that easy under time pressure.

Figures 8a to 8d show the interaction of different valve authority parameters with the liquid sound emission and the challenge to select the most economic valve for each unique plant design. Figure 8a shows examples of a pump-generated plant system with total valve authority V=0.3 and a tank level control process with total valve authority V = 0.7.

All possible valve authorities versus valve load cv/cv100 are shown in Figure 8b. The hatched area may include > 80% of all applications. Cost pressure drives the trend towards the bottom line V < 0.1, unfortunately with a negative impact on good control parameters. This sometimes calls for undersizing cv 100 < cv max to avoid excessive gain fluctuations.

Figure 8c shows different standard globe valve qualities with comparison measurements of seven globe valves. Adjusted to the same cv100 value the valves create SPL differences between 65 and 95 dB(A) depending on valve design parameters like top-guided parabolic, top seat-guided contour plug or top seat-guided parabolic AC trim. If no measurements from the valve database are available, valve recovery factors versus valve load cv/cv100 are used in the software for flow and SPL calculation as a first approximation for parabolic plugs (flow to open).

Figure 8e shows a real-time test rig for comparison measurements as demonstrated in Figure 8f with xFz measurements -xFz versus valve load cv/cv100- for different plug guidance principles. In critical cases detailled engineering is necessary to find valves with xFz characteristics Figure 8f overlaying the curves in Figure 8b to avoid cavitation over the entire control range.

In applications with steam or gases, highly sophisticated noise reduction measures also need to be taken, giving priority to the valve outlet velocity, especially in case of flashing, which is not noise sensitive.[1, part 2]

8 Selecting the optimum valve characteristic form

This is the last point to improve control quality but also the most difficult. In case of pressure control from a static point of view, an equal percentage characteristic stands for a more constant gain $\Delta p/ds$; $p=p1$, $p2$, or Δp independent of the valve authority. But anti-surge pressure control mostly calls for a linear characteristic because of dynamic reasons to protect the flow machine as quickly as possible.

The software looks at all loop parameters using questions and answers as illustrated in the table in Figure 10. The recommendation then is the characteristic form with advantages in comparison to others. It does not mean that other characteristics are not practicable. It only means that they will produce higher gain fluctuations, which can be checked separately by the graphical support of the software.

Figure 9 shows the borders of valve authorities where the program shifts to the next better valve characteristic form.

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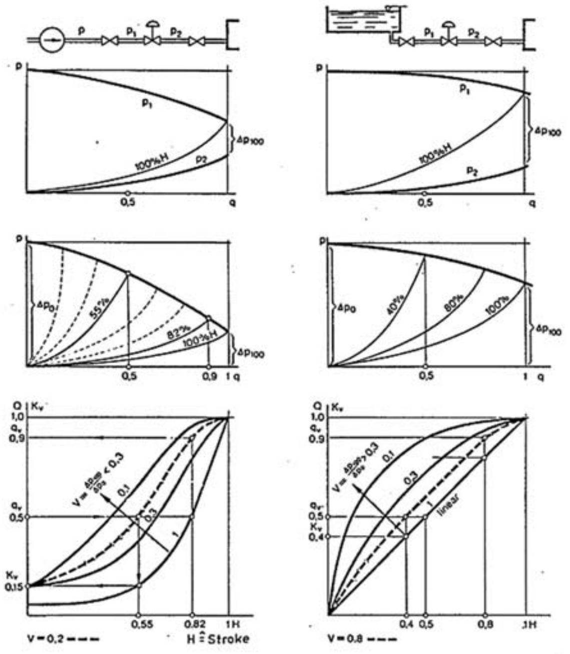
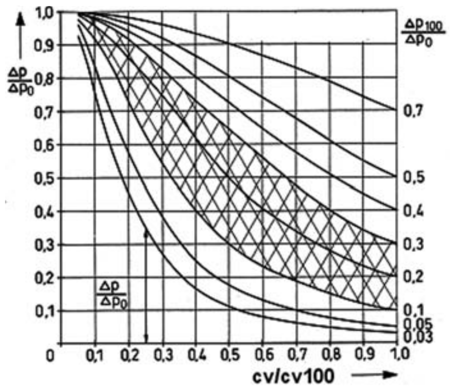


Optimum quality of control with :

$$V_0 = V_R \cdot V_s = \frac{\Delta pBI}{\Delta Q} \cdot \frac{\Delta x}{\Delta pBI} \cdot \frac{\Delta y}{\Delta x} \cdot \frac{\Delta H}{\Delta y} \cdot \boxed{\frac{\Delta Q}{\Delta H}} = \text{const.}$$

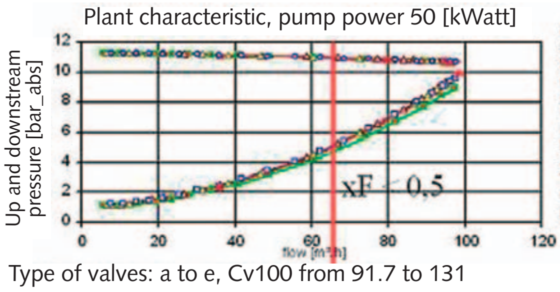
Fig. 8a: The interaction of valve authority parameters to different installed flow characteristic.

Valve authority versus load cv/cv100



The valve authority characteristic is independent from the valve characteristic. The hatched area includes > 80% of all applications.

Fig. 8b: Characteristic of the plant parameter xF as a function of the load cv/cv100 and the valve authority.



Globe valve comparison: If xF > 0.5, risk of high SPL dB(A) and resonating stem for top guided parabolic trims DN > 1.5 inch. Difference > 30 dB(A) between valve Type d) and AC Anti-Cavitation Trim System-Top and seat guides special parabolic trim.

Type of valves: a to e, Cv100 from 91.7 to 131

Plant adjustment: dp_100/dp0 = 0.1 at V713 and direct replacement with a to e.

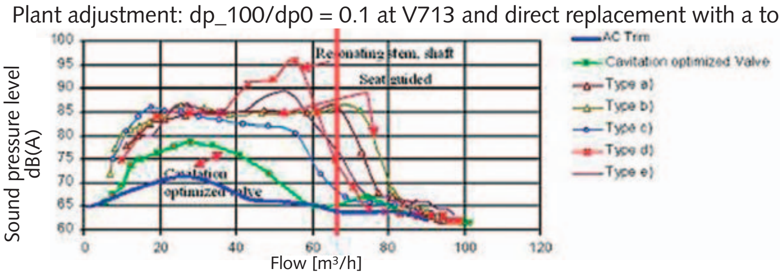


Fig. 8c: The interaction of globe valve design parameters to the liquid sound emission.

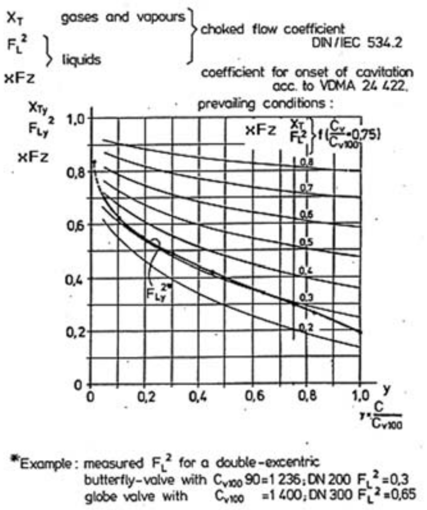
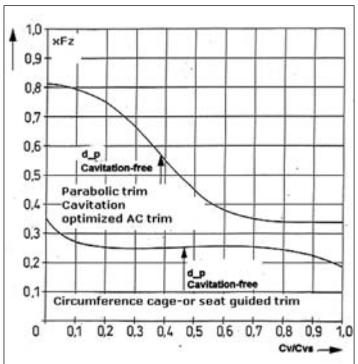


Fig. 8d: Approximation of valve recovery factors for standard valves (flow to open - FTO), if only one value at load cv/cv100 = 0,75 is given.



Typical globe valves xFz-characteristic curves for sound SPL dB(A) prediction regarding IEC 534-8-4

Fig. 8f: Typically measurements of xFz-characteristic for parabolic plug trims (FTO) and circumference guided trims

Fig. 8e: Real-time test rig at SAMSON AG.

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Nevertheless, attention should still be paid to some more specific loop parameters for the final software decision of the best characteristic form. (See Figure 10b.)

After calculating the specific valve authority the software expert system goes through the tables by Questions and Answers and recommends the optimum valve inherent characteristic form (Figure 10a).

9 Using software to increase control quality, reducing cost and saving time for creativity

The CONVAL® 6 software treats the plant and valve sizing parameters from an overall point of view, issuing dynamic graphics with installed characteristics concerning flow, power, gain, and outlet velocity as a function of the valve coefficient cv and the valve travel. The software is a manufacturer-independent optimization tool for pipelines and pipe devices. Including material and property database for more than 3,000 substances like hydrocarbons and chlorine. About 60 industrial fluids are calculated very accurately using equations of state developed by Ruhr University in Bochum, Germany. (See www.conval.de for more details.)

If operating conditions are given with one, two or three operating points the plant system is defined in the standardized differential pressure versus flow diagram.

The inherent cv characteristic of any valve as well as all other valve characteristics xFz, Fl, xT, Fd, etc. are stored in a mighty valve database in form of equations or polynomial coefficients. Every valve installed characteristic like flow, gain, and valve authority, sound, inlet and outlet velocity as well as cavitation, flashing and choked flow areas are presented in graphic form. A dynamic ruler indicates all results including alarms at any valve travel position. The program combines expert valve sizing with powerful plant optimization and troubleshooting. ▶

Recommendations to improve the optimum inherent valve characteristic form. The valve manufacturer cannot influence the valve upstream and downstream pressure characteristic - plant design responsibility. The valve manufacturer can influence the valve authority V if the optimum cv100 valve is chosen. CONVAL recommend five typically characteristics forms of valve families found today.

Total valve authority dp100/dp0	Valve authority dp90/dp0 Qmax = 0.9 q100	Inherent flow characteristic for optimum, installed flow characteristic, which is as linear as possible.
V ≤ 0.1	Vqmax < = 0.27	Equal percentage DIN IEC 534-2-4
0.1 < V ≤ 0.15	0.27 < Vqmax < = 0.31	Equal percentage up to s = 0.8
0.15 < V ≤ 0.3	0.31 < Vqmax < = 0.43	Modified equal percentage
0.3 < V ≤ 0.5	0.43 < Vqmax < = 0.6	Modified linear
0.5 < V ≤ 1	0.6 < Vqmax < = 1	Linear

Example for flow control with measurements dp proportional to flow.

If other characteristics are chosen from other aspects of view, eg, dynamic aspects, the control loop may have more gain variations. (If not out of limits, who cares?)

Fig. 9: Borders of the inherent valve characteristics forms as a function of the valve authority.

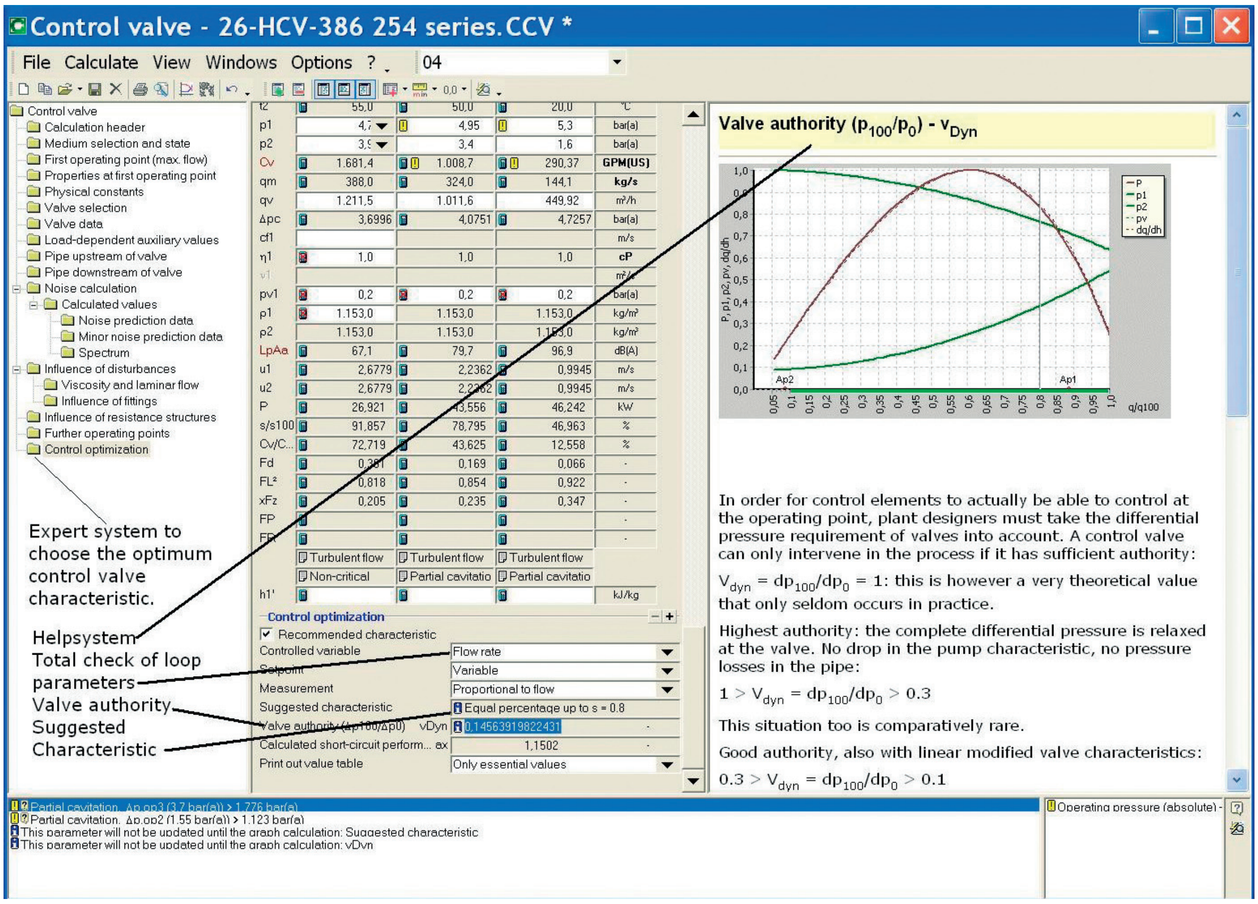


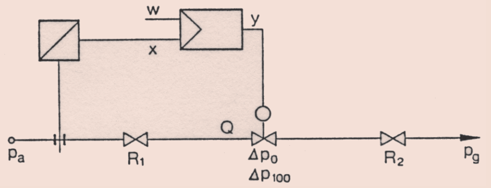
Fig. 10a: Questions and answers in CONVAL to select the best characteristic form for the control variable flow, level, temperature and pressure. See also Fig. 10b.

Recommendations for improving the basic characteristic form

It is assumed that only one of the disturbance quantities acts as the main disturbance quantity.
The symbol "=" in front of the characteristic means that the control loop parameters remain constant; "≈" before the characteristic means that the parameters change in the event of a disturbance or setpoint change.

1. Flow control
Fluid parameters:
υ = Temperature
ν = Viscosity
ρ = Density

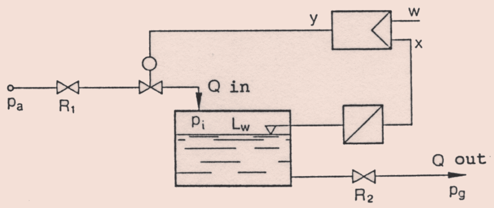
$V = \Delta P100 / \Delta P0$



Setpoint w	Measurement	V	Main disturbance quantity	Basic characteristic form
Constant	x ~ Q x ~ Q^2	1	p_a, p_g, υ, ν, ρ,	= Equal percentage Linear if $W_1 \neq W_2$
	x ~ Q x ~ Q^2	< 1	p_a, p_g, R1, R2, υ, ν, ρ,	≈ Equal percentage
Variable	x ~ Q	1	Disturbance negligible with regard to setpoint	= Linear
	With square-root	V > 0.3		≈ Linear
	extraction	V ≤ 0.3		≈ Equal percentage
	x ~ Q^2	V = 1		≈ linear
	Without	V < 1		

2. Tank level control

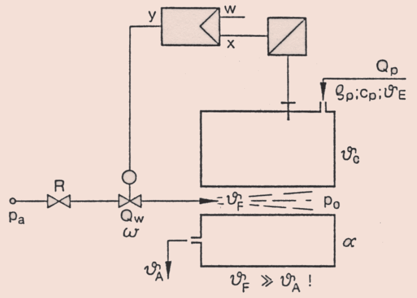
$V_s = \Delta L_W / \Delta Q$ = Constant
$V = \Delta P100 / p_a - p_i$
V = 1
R1 = 0



Setpoint	V	Main disturbance quantity	Basic characteristic form
Constant	1	Q in p_a, p_i, υ	= Equal percentage
Variable	< 1	p_a, R1, p_i, υ	≈ Equal percentage
Constant	1	Q out p_g, R2, ... (p_i)	= Linear
variable	V > 0.3	p_g, (pi), R2	≈ Linear
	V ≤ 0.3		≈ Equal percentage

3. Temperature control

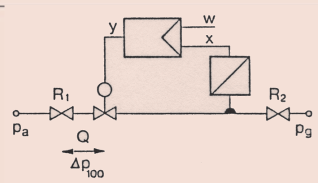
τ = Time constant
υ_{AE} = Product temperature
α = Heat transfer coefficient
υ_F = Flame temperature
υ_0 = Nominal temperature
Q_W = Heating fluid flow
Q_P = Product
ω = Heat content Kcal/m^3
ρ = Density
c = Spec. heat
$V = \Delta P100/ p_a - p_o = 1$; R1 = 0



Setpoint	V	Main disturbance quantity	Static	Dynamic
Constant	1	p_a, R1, ω, ρ_p, C_p	= Equal percentage	Optimum rise rate and control quality
	< 1	Heating fluid Q_W	≈ Equal percentage	τ Controlled system
				τ Control equipment
	V ≤ 0.3	Qp	-	≈ Equal percentage
	V > 0.3	Product	-	≈ Linear
Constant or variable	1	υ_E, υ_0 W	= Linear	-
	V ≤ 0.3	υ_E, υ_0 W	≈ Equal percentage	-
	V > 0.3		≈ Linear	-
Characteristic always equal-percentage for heat exchangers				

4. Pressure control always equal percentage

Reduction and overflow
Parameter: ΔP_L100 = System resistance
$\Delta P100$ = Control valve resistance



Setpoint	ΔP_L100	Main disturbance quantity	Basic characteristic form
Constant	0	p_a, R2, p_g	= Equal percentage
Constant	≠ 0	p_a, R1, R2, p_g	≈ Equal percentage
Variable	0, ≠ 0	-	≈ Equal percentage

▶

Fig. 10b: CONVAL question and answers Table to select flow control, level control, temperature control and pressure control.

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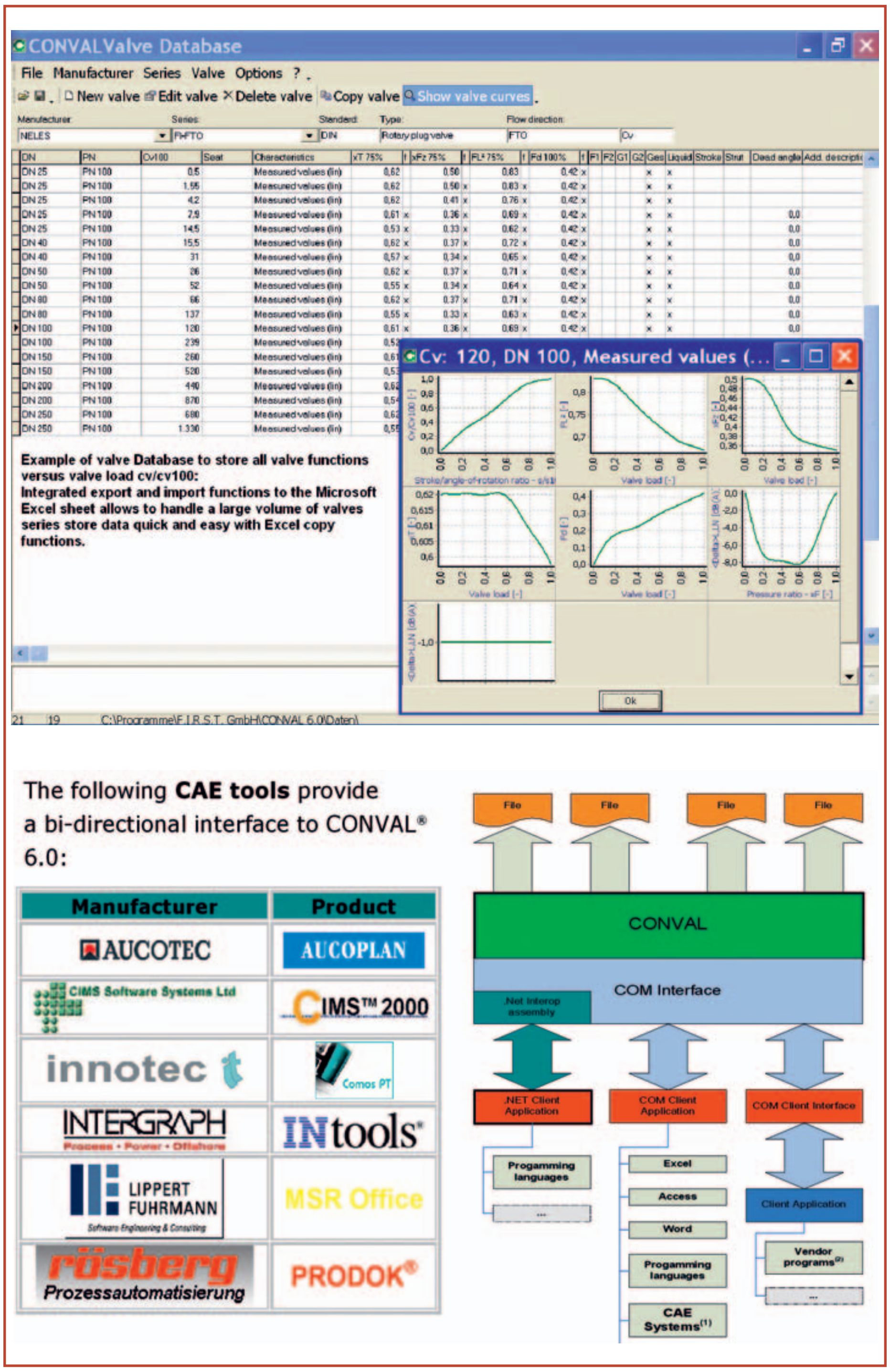

Fig. 11: Valve database for sizing, calculation and optimization of all kinds of valves and common plant components and the bi-directional interface structure.

The software successfully detected valve sizing mistakes in several of the 1,200 control valves installed in a German refinery before the regular plant shutdown after five years' operation. With the software "troubleshooting features" the refinery therefore ordered spare parts in time and started up without any delays.

The software provides a bi-directional COM link to spreadsheets and CAE systems as well as in-house valve sizing programs which companies can use to store valve data e.g. sound measurements, administration of inquiry and quotation systems as well as pricing and drawings. (See Figure 11.) ■

References:

[1] Siemers: Control Valve Design Aspects for critical applications in petrochemical plants. Part I. Valve World Magazine June 2004.

[2] Siemers: Selecting Valves by choosing the optimum flow characteristic, chapter 9, Fig. 9. 3rd International Conference 27-29 March 1990 Developments in valves and actuators for fluid control Bournemouth UK BHR Group.

[3] Dr. Kiesbauer: Control Valves for Critical Applications, Hydrocarbon Processing, June 2001.

[4] H.D. Baumann : Valve Primer, A User`s Guide Chapter 7 ISA Edition.

About the author

Mr Holger Siemers, who gained a Dipl. Ing. Degree from the University of Furtwangen, started his career with ECKARDT AG company. He was former head of the Control Valve Sales Department in ECKARDT; ECKARDT-FOXBORO; SIEBE_INVENSYS. He was one of the founder members of VDMA 24422 79 and 89 which becomes worldwide Standard IEC 534 8-4 - Sound Prediction Methods for liquids.

He was also chairman in the VDI Working Group: Valve Characteristics, gave support and copyright of CONVAL (the plant- and valve optimization tool) and was involved in the R&D of SILENCER Technology - Multi-hole orifices with deliveries of 2500 silencers in the past twenty years.

He has trouble-shooting experience with sound, loop stability, life cycle and plant performance problems and been involved in valve optimization for demanding applications in petrochemicals and refineries (hydro-carbon-processing, HPI, LNG, PTA, ...).

Publications, Training and Support: Application and plant design, control loop optimization, selecting and sizing control valves.

After 30 years' plant design with control valves he joined SAMSON AG in 1999. Now he is SAMSON's Severe Service Control Valves Marketing Manager in the International Sales & Marketing Department.