

# FLOW CALCULATOR 2011

## *Design Programs for EBRO Butterfly Valves*

**Author:** Dr.-Ing. G.Ehrhardt, Priv.-Doz. at RWTH Aachen

**Editor:** Dipl.-Ing. D.Lücke, Design Engineering, EBRO-ARMATUREN

**Client:** EBRO-ARMATUREN Gebr. Bröer GmbH, Hagen

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**1 Symbols and Nomenclature**

Symbol	Nomenclature	Unit
D	Inside diameter of the pipe	mm
DN	Nominal Diameter of the butterfly valve	-
DN <sub>Lmin</sub>	Minimum diameter of the pipe	-
F <sub>P</sub>	Pipe geometry factor	-
F <sub>R</sub>	Reynolds number factor	-
κ	adiabatic exponent	-
Kav	Measure for Kavitation, Kav x <sub>F</sub> /z <sub>V</sub>	-
K <sub>V</sub>	Flow coefficient	m <sup>3</sup> /h
L <sub>A</sub>	Sound pressure level at distance of 1m	dB(A)
p <sub>1</sub>	Pressure upstream of butterfly valve	bar <sub>abs</sub>
p <sub>C</sub>	Thermodynamical critical pressure	bar <sub>abs</sub>
p <sub>N</sub>	Normal pressure 1,013 bar <sub>abs</sub>	bar <sub>abs</sub>
PN	Nominal pressure	bar
p <sub>V</sub>	Boiling pressure	bar
Q <sub>1</sub>	Volume flow rate at operating condition p <sub>1</sub> and t <sub>1</sub> upstream of the butterfly valve	m <sup>3</sup> /h
Q <sub>N</sub>	Volume flow rate at normal condition p <sub>1</sub> and t <sub>N</sub>	m <sup>3</sup> /h
Re <sub>V</sub>	Butterfly valve Reynolds number	-
T	Temperature	°C
t <sub>1</sub>	Temperature upstream of the butterfly valve	°C
t <sub>N</sub>	Normal temperature 0°C	°C
V	Velocity in the pipe (with fluids)	m/s
V <sub>κ</sub>	Velocity in the throttling area (with fluids)	m/s
V <sub>1</sub>	Velocity in the pipe upstream of the butterfly valve (with gas/steam)	m/s
V <sub>2</sub>	Velocity in the pipe downstream of the butterfly valve (with gas/steam)	m/s
W	Mass flow rate	kg/h
x <sub>F</sub>	Pressure ratio with fluids	-
Y	Expansion factor	-
z <sub>V</sub>	x <sub>F</sub> -value at start of cavitation (depends on α)	-
α	(Opening-) angle of butterfly valve plate	°
ΔL <sub>F</sub>	Butterfly valve specific correction element with fluids	dB(A)
Δp	Pressure loss of the butterfly valve	bar
Δp <sub>L</sub>	Pressure loss of the pipe	bar
Δp <sub>ges</sub>	Pressure loss of the butterfly valve and the pipe together	bar
η	Dynamic viscosity	Pa s
λ	Coefficient of friction, depends on Reynolds number and roughness of pipe	-
ρ	Density	kg/m <sup>3</sup>
ρ <sub>1</sub>	Density at operating condition p <sub>1</sub> and t <sub>1</sub> upstream of the butterfly valve	kg/m <sup>3</sup>
ρ <sub>N</sub>	Density at normal condition p <sub>N</sub> and t <sub>N</sub>	kg/m <sup>3</sup>

## 2 Summary

The Program is constructed with the Software EXCEL used to calculate flow- and sonically dimensions for compressible and incompressible fluids on the basis of the rules and standards [1] to [5] and on the basis of theoretical analysis [6] and [18]. Butterfly valves and substance-specific data are taken from the sources [7] to [17].

**Important!** This program works with Macros. To use the Macro they have to be allowed in Excel. If the Macros weren't allowed, the program doesn't work!

*(Macros can only be used when the security level is minimum selected:*

*Office 2007: „Deactivate all Macros with message“*

*Office 2003: „Security Level medium/middle“*

*with these settings the Macros have to be activated every time the program will be opened.)*

### 3 Installation

Extract the „FlowCalculator2011.zip“ (e.g. mit Winzip). Memory Location of the program can be selected (for example „c:\“ ). In the file folder folder „Flow Calculator 2011“ is a file named „Flow Calculator.xls“. Opening this file will open the program (Chapter 4.2).

Don't change the structur of the file folder „Flow Calculator 2011“!

#### Abstract:

Flow Calculator 2011.zip

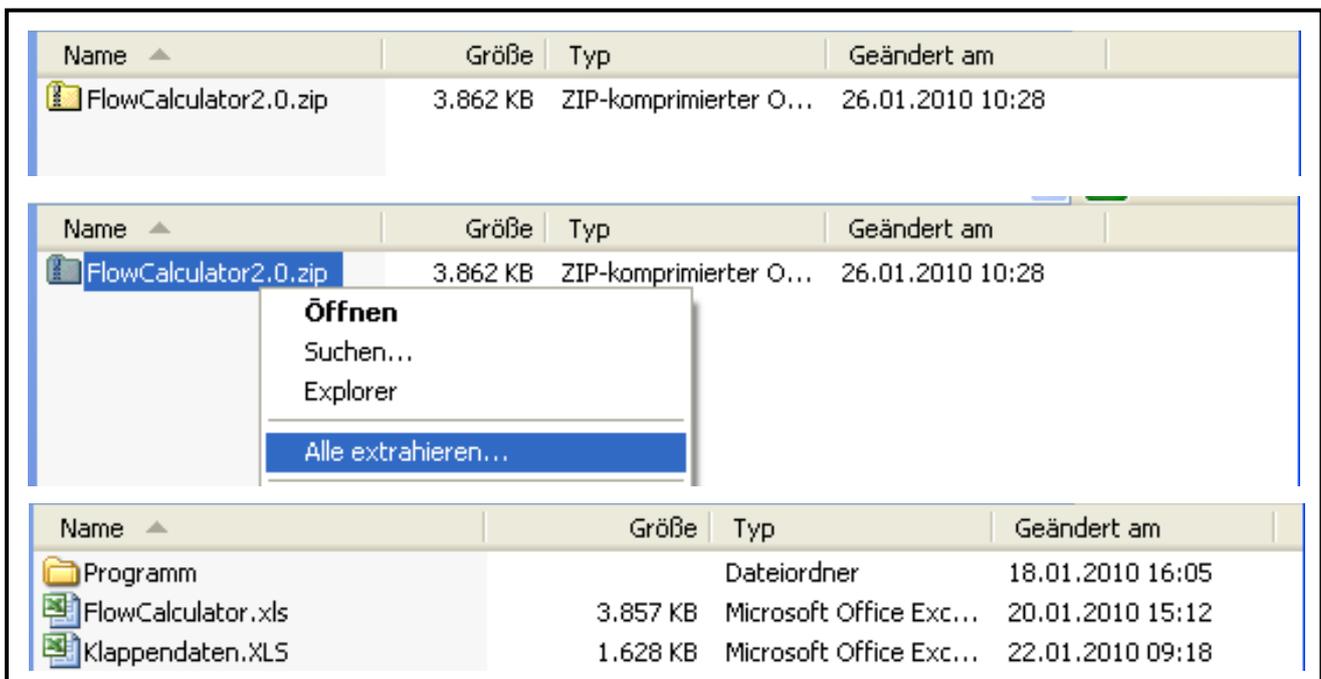


extract

Double-click on Flow Calculator 2011

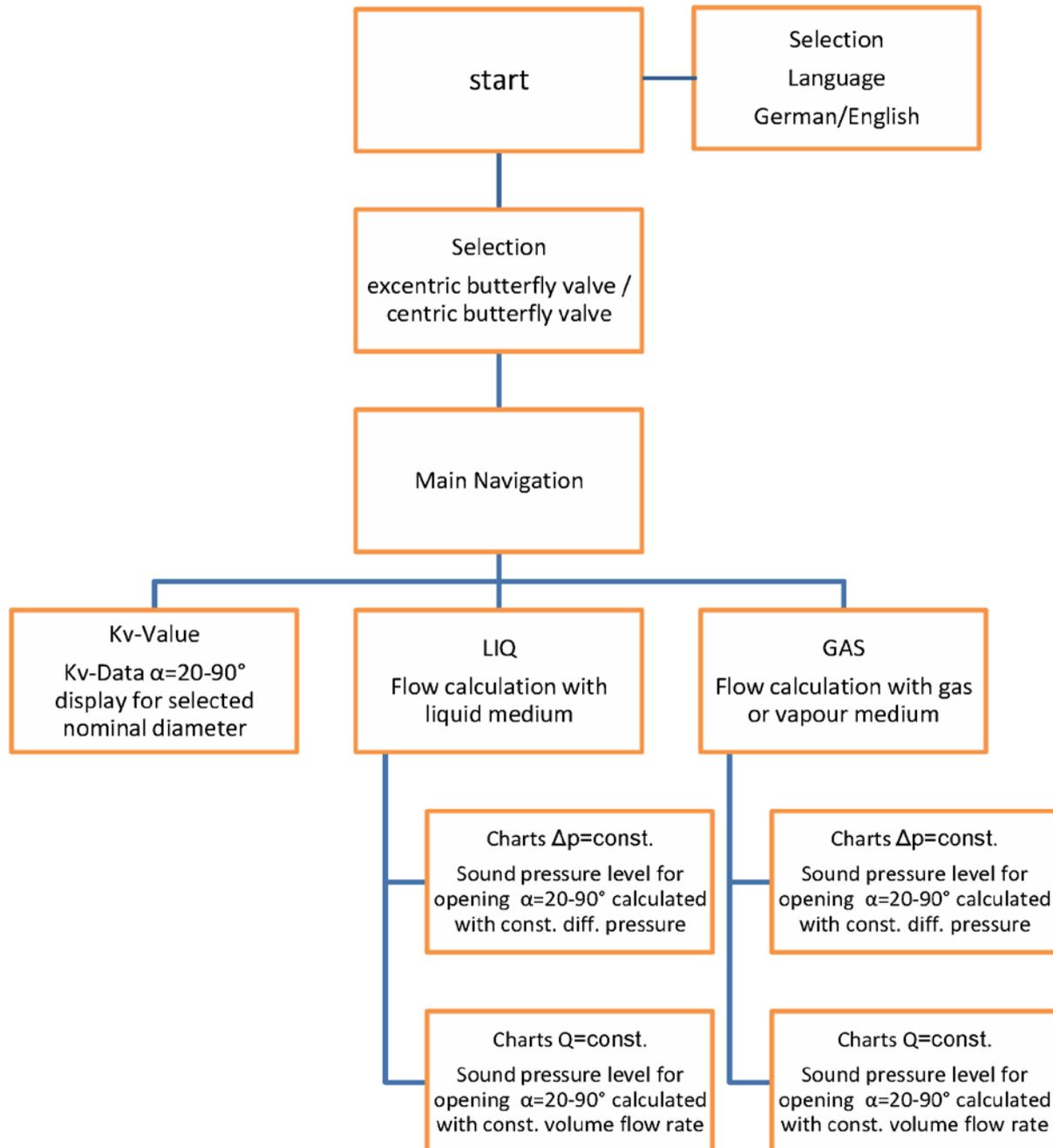


open program



## 4 Program, Menu, Input

### 4.1 Program structure



## 4.2 Start page

### 4.2.1 Scale



This choice box for scale of the excel-sheets will be first on the start page when the macros are activated. The scale of 75% is possible for using the program at laptop (with smaller screen). The display of the flow calculator will be reduced to 75%. With this scale scrolling of the sheets during using the program will be reduced. The scale of 100% is suited for PC's with normal screens.

### 4.2.2 Start page

When you select a scale, you can see the start page:

# Flow Calculator 2.0

Flow Calculation for EBRO Butterfly Valves

**Warning:** These programs are based on standards for control valves as well as on experimental and theoretical research on EBRO butterfly valves. Although we have taken the greatest care in writing these programs, we decline any liability concerning damages by their use.

Programs in English choice: press grey key	Technical Specifications			
	PN	liner type	type	catalog index
centric valves	16	Elastomer	Z011 / Z014 F012 / F012 Z411 / Z414 Z611-A / Z614-A	1.1 / 1.2 1.4 / 1.5 1.6 / 1.7 1.9 / 1.10
		PTFE	T211 / T214 / T212	2.1 / 2.2 / 2.3
excentric valves	16	>DN150 DN50-150	HP 111-E / HP 114-E	3.3 / 3.4
	25		HP 111 / HP 114	3.1 / 3.2
	40		HP 111 / HP 114	
	40		HP 111-C / HP 114-C	

Zoom +/-

close program

Sprache/ Language

Sizing-Programs for EBRO Butterfly Valves  
 Author: Dr.-Ing. G. Ehrhardt, Priv.-Doz. at RWTH Aachen  
 Client: EBRO-ARMATUREN Gebr. Bröer GmbH, Hagen  
 Aachen, March 2005

documentation

EN

At the right side of the page the following program options can be select:

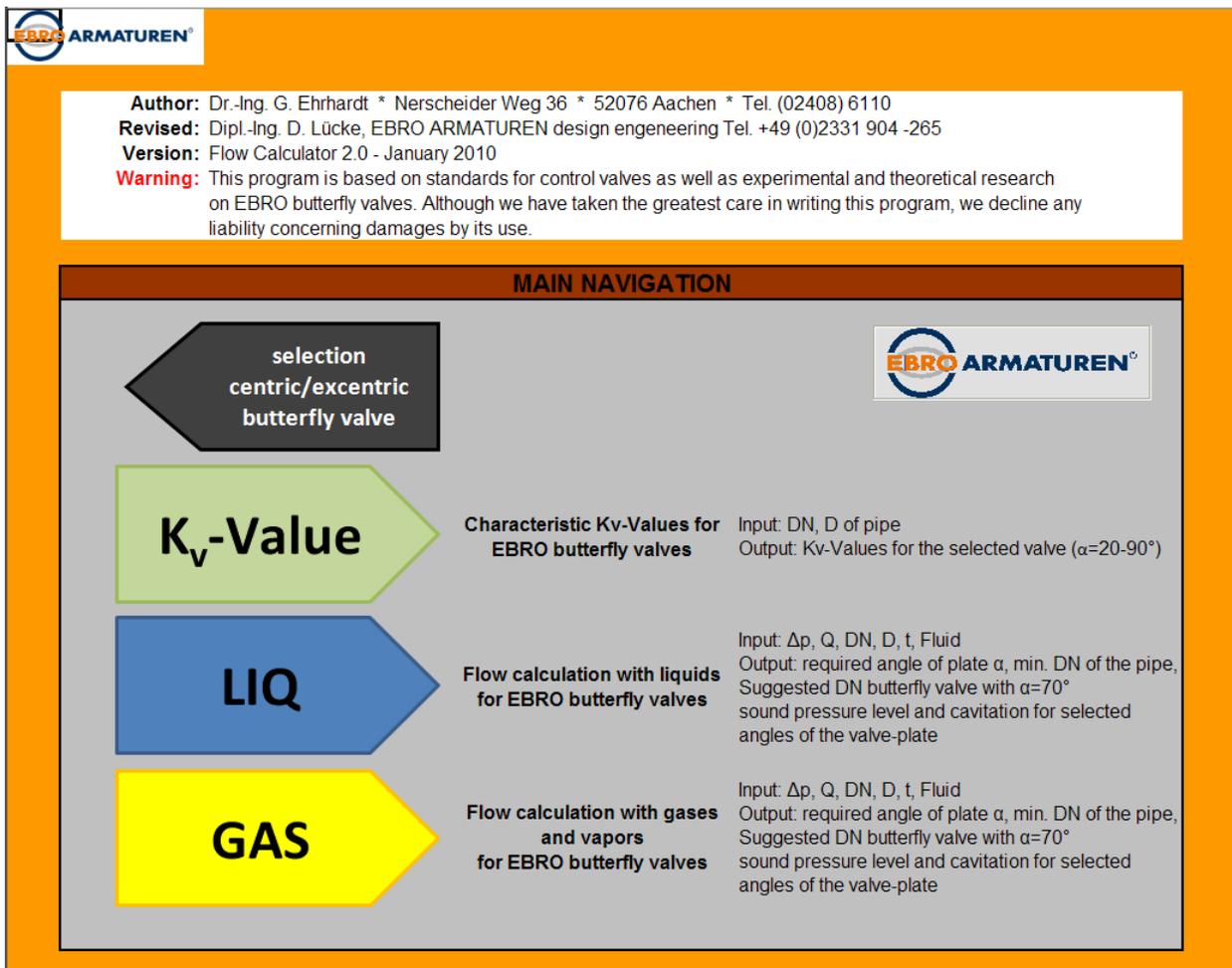
- [Zoom +/-]:                   The scale (Chapter 4.2.1) can be change every time.
- [Close program]:           Closes the program.
- [Sprache/Language]:       The menu navigation switch to English or German by click on the flag.

The type of butterfly valve can be selected on the left side of the page. With the grey buttons the types [centric valves] or [excentric valves] can be selected. The table right beside the grey buttons informs with which types of butterfly valves you can calculate after choosing a butterfly valve type. It also informs which nominal pressure they have, which type of liner they have and in which register of the EBRO-Catalogue the types are.

Below this table is the information of the Author and Client, as well as this documentation of the program which can be opened by a click on the grey button [documentation].

### 4.3 Calculation centric/excentric butterfly valves

This page “Main navigation” follows by selecting a type of butterfly valve (Chapter 4.2). From this page there are labeled arrows which leads you through the program. Generally the left-pointing arrows take you back to the previous page. The right-pointing arrows take you to the next page.



**Author:** Dr.-Ing. G. Ehrhardt \* Nerscheider Weg 36 \* 52076 Aachen \* Tel. (02408) 6110  
**Revised:** Dipl.-Ing. D. Lücke, EBRO ARMATUREN design engineering Tel. +49 (0)2331 904 -265  
**Version:** Flow Calculator 2.0 - January 2010  
**Warning:** This program is based on standards for control valves as well as experimental and theoretical research on EBRO butterfly valves. Although we have taken the greatest care in writing this program, we decline any liability concerning damages by its use.

**MAIN NAVIGATION**

**selection centric/excentric butterfly valve**

**K<sub>v</sub>-Value**  
 Characteristic Kv-Values for EBRO butterfly valves  
 Input: DN, D of pipe  
 Output: Kv-Values for the selected valve ( $\alpha=20-90^\circ$ )

**LIQ**  
 Flow calculation with liquids for EBRO butterfly valves  
 Input:  $\Delta p$ , Q, DN, D, t, Fluid  
 Output: required angle of plate  $\alpha$ , min. DN of the pipe, Suggested DN butterfly valve with  $\alpha=70^\circ$  sound pressure level and cavitation for selected angles of the valve-plate

**GAS**  
 Flow calculation with gases and vapors for EBRO butterfly valves  
 Input:  $\Delta p$ , Q, DN, D, t, Fluid  
 Output: required angle of plate  $\alpha$ , min. DN of the pipe, Suggested DN butterfly valve with  $\alpha=70^\circ$  sound pressure level and cavitation for selected angles of the valve-plate

Left-pointing arrow:

- „selection centric/excentric butterfly valve“:

By a click on this arrow you can get back to the starting page (Chapter 4.2)

Right-pointing arrows:

- K<sub>v</sub>-Value (Chapter 4.4)  
Fluid-independent calculation of K<sub>v</sub>-values for butterfly valve types
- FLÜ (Chapter 4.5)  
Calculation of flow data for butterfly valves for liquid fluids
- GAS (Chapter 4.6)  
Calculation of flow data for butterfly valves for gases and steam

#### 4.4 Calculation Kv-value centric/excentric butterfly valves

The Calculation of the  $K_v$ -Value is Fluid-independent.

The following data have to be entered for Calculation:

1. EBRO Type [Selection]

The EBRO Type can be selected dependent on the selected type at the start page (Chapter 4.2).

→When “centric valve” is selected then the standard EBRO-Type is Z011/014; F012. With the [selection]-Button the valve type can be changed to EBRO-Type T200 and also back to Z011/014; F012. When the type is changed to T200, you must choose between the EBRO-Types T200-A metallic, T200-C metallic, T200-A PTFE (coated disc) and T200-C PTFE (coated disc).

→When “excentric valve“ is selected then the standard EBRO-Type is HP111/114. With the [selection]-Button the valve type can be changed to EBRO-Type HP111/114-E and HP111/114-C and also back to HP111/114.

2. With the buttons on the left side of the page the nominal size DN of the valve type can be selected. There are only the DN's displayed which are available for the selected valve type.
3. The inside Diameter D of the pipe. The inside Diameter of the pipe should not be less than the nominal size of the selected valve. When DN is bigger than D the message “DN>D“is displayed (Chapter 5).

Output data:

When the Input data are complete entered, the  $K_v$ -value of the butterfly valve for an opening angle from  $\alpha=20^\circ-90^\circ$  is displayed graphically (diagram on the left side) and tabular.

If the inside diameter D of the pipe is greater than the DN of the butterfly valve, the  $K_v$ -value will be smaller because of the difference between the pipe and the valve. The factor  $F_p$  shows this influence. The factor is shown in the table and the calculated  $K_v$ -value. The right diagram shows the  $K_v$ -value calculated with the factor  $F_p * K_v$ .

**EBRO ARMATUREN** 15.06.2010 14:29

Identifier:  **EBRO Type**

Project:  **selection**

Item-No:

EBRO Type: **Z011/014;F012**

PN = 16 Nominal pressure

DN = 250 Suggested DN butterfly valve

D[mm]= 500,0 Inside-Ø of the pipe

Comments

$\alpha$ °	$K_V$ m <sup>3</sup> /h	$F_P$ -	$F_P * K_V$ m <sup>3</sup> /h	$F_P * K_V$ %
20	176	1,00	176	7
25	216	1,00	215	9
30	290	0,99	289	12
35	404	0,99	400	16
40	562	0,98	550	23
45	766	0,96	737	30
50	1.021	0,94	956	39
55	1.331	0,90	1.196	49
60	1.699	0,85	1.441	59
65	2.129	0,79	1.677	69
70	2.626	0,72	1.890	78
75	3.192	0,65	2.071	85
80	3.832	0,58	2.219	91
85	4.549	0,51	2.336	96
90	5.348	0,45	2.426	100

data export

data import

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NAVIGATION

main navigation

**$K_V$  [m<sup>3</sup>/h]**

$\alpha$  [°]

**$F_P * K_V$  [%]**

$\alpha$  [°]

#### 4.5 Calculation of flow data for butterfly valves for liquid fluids

The following data have to be entered for Calculation:

1. EBRO Type [selection] (Description see Chapter 4.4)
2. With the buttons on the left side of the page the nominal size DN of the valve type can be selected. There are only the DN's displayed which are available for the selected valve type.
3. The pressure  $p_1$  in bar abs upstream the butterfly valve.
4. The temperature  $t$  of the fluid.
5. The fluid. Here a Fluid No. has to be entered. The Fluid-No. for the fluids can be selected from the table of the right side. The material data  $\rho$ ,  $\eta$ ,  $p_v$  and  $p_c$  of the fluids No. 1 to 3 will be calculated after the input of the temperature  $t$ . For other fluids the material data of the fluids have to be entered in the table (possible in the grey areas).
6. The volume flow rate  $Q$  in  $m^3/h$  – when a mass flow rate in  $kg/h$  is given, the volume flow rate can be calculated with the “Help for Conversion from  $W$  to  $Q$ ”. For this calculation the temperature and the Fluid-No. have to be entered.
7. The pressure loss of the butterfly valve  $\Delta p = p_2 - p_1$ .
8. The inside Diameter  $D$  of the pipe. The inside Diameter of the pipe should not be less than the nominal size of the selected valve. When DN is bigger than  $D$  the message „DN > D“ is displayed (Chapter 5).

Output data:

- „Input  $\Delta p$ , DN and  $D$ “  
DN<sub>min</sub>: The minimum nominal size of the pipe depending on the input data.  
 $\alpha = 70^\circ$ : DN: nominal size of the butterfly valve with an opening angle of  $\alpha = 70^\circ$  depending on the input data  
DN: selected nominal size of the butterfly valve  
 $\alpha [^\circ]$ : Required opening angle for the selected butterfly valve depending on the input data.
- „Calculation with const.  $Q$ “  
Calculation of  $\Delta p$ ,  $K_v$ ,  $V$ ,  $V_k$ ,  $Re_v$ ,  $F_R$ ,  $F_p$  and the sound pressure level with the cavitation factor  $x_F/z_y$  depending on the input volume flow rate  $Q$ . The pressure loss of the butterfly valve depends on the selected opening angle  $\alpha$  (which you can enter in the grey area or select by scroll bar).
- „Calculation with const.  $\Delta p$ “  
Calculation of  $Q$ ,  $K_v$ ,  $V$ ,  $V_k$ ,  $Re_v$ ,  $F_R$ ,  $F_p$  and the sound pressure level with the cavitation factor  $x_F/z_y$  depending on the input pressure loss of the butterfly valve  $\Delta p$ . The Volume flow rate  $Q$  depends on the selected opening angle  $\alpha$  (which you can enter in the grey area or select by scroll bar).

16.06.2010 07:36

Identifier: -  
Project: -  
Item-No: -  
EBRO-Type: **Z011/014;F012**  
PN= 16      Nominal pressure

**EBRO Type selection**

**Input fluid data**

$p_1$ [bar abs] = 0,600      Pressure upstream butterfly valve  
 $t$ [°C] = 40,0      Temperature  
Fluid no. 1      water  
 $Q$ [m³/h] = 200,0      Volume flow rate  
 $W$ [kg/h] = 199,632      Mass flow rate

**Help for Conversion from W to Q**

$Q$ [m³/h] = 0,000  
 $W$ [kg/h] =

**Input  $\Delta p$ , D and DN**

$\Delta p$ [bar] = 0,200      Pressure loss butterfly valve  
 $DN_{min}$  = 125      Minimum DN of the pipe  
 $D$ [mm] = 300,0      Inside-Ø of the pipe  
 $\alpha = 70^\circ$ : DN = 125      Suggested DN butterfly valve  
DN = 250      Selected DN butterfly valve  
 $\alpha$ [°] = 37      Required Opening angle of plate

**Output**

**Calculation with const. Q = 200 m³/h**  
Table and graph see navigation

$\alpha$ [°] = 43      Opening angle of plate  
 $\Delta p$ [bar] = 0,0878      Pressure loss butterfly valve  
 $K_v$ [m³/h] = 678      Flow coefficient butterfly valve  
 $V$ [m/s] = 0,8      Velocity in the pipe  
 $V_k$ [m/s] = 5,3      Velocity in the throttling area  
 $Re_v = 4,2E+5$       Butterfly valve Reynolds-No.  
 $F_R = 1,000$       Reynolds number factor  
 $F_P = 0,995$       Pipe geometry factor  
 $\Delta L_F$ [dB(A)] = -      spezific correction element  
 $L_A$ [dB(A)] = 51      Sound pressure level at 1m  
 $x_F / z_F = 0,58$       Cavitation if  $x_F/z_F > 1$

**Calculation with const.  $\Delta p = 0,200$  bar**  
Table and graph see navigation

$\alpha$ [°] = 20      Opening angle of plate  
 $Q$ [m³/h] = 79      Volume flow rate butterfly valve  
 $K_v$ [m³/h] = 176      Flow coefficient butterfly valve  
 $V$ [m/s] = 0,3      Velocity in the pipe  
 $V_k$ [m/s] = 6,8      Velocity in the throttling area  
 $Re_v = 3,0E+5$       Butterfly valve Reynolds-No.  
 $F_R = 0,999$       Reynolds number factor  
 $F_P = 1,000$       Pipe geometry factor  
 $\Delta L_F$ [dB(A)] = -      spezific correction element  
 $L_A$ [dB(A)] = 22      Sound pressure level at 1m  
 $x_F / z_F = 0,89$       Cavitation if  $x_F/z_F > 1$

print with charts

**Material parameters of liquid fluids**

$t$ [°C]=Temperature  
 $\rho$ [kg/m³]=Density  
 $\eta$ [Ns/m²]=dynamic viscosity  
 $p_v$ [bar abs]=Boiling pressure  
 $p_c$ [bar abs]=thermodynamically critical pressure  
 $c_L$ [m/s]=Sound speed level

No	Name	t	$\rho$	$\eta$	$p_v$	$p_c$	$C_L$
1	water	40	998	1,02E-03	0,023	220,6	1400
2	Diesel oil	40	837	4,16E-03	0,017	40,0	1250
3	Thermal oil A	40	890	1,52E-02	0,000	2,0	1190
4		40					
5		40					
6		40					
7		40					
8		40					

**Sound pressure level standard**

IEC 60534 (2005) - aktual standard

VDMA 24422 (1979) - old standard

**data export**

**data import**

**NAVIGATION**

**main navigation**

**CHARTS**

**$\Delta p = \text{constant}$**

**$Q = \text{constant}$**

Navigation menu at the right side of the page:

Click on the orange left-pointing arrow to get back to the “main navigation“(Chapter 4.3) where you can select the calculation method:  $K_v$ -value, FLÜ and GAS.

The two right-pointing arrows lead you to the pages with tables and diagrams.

Arrow labeled “ $\Delta p = \text{constant}$ “: A sheet where you can see a table with flow data calculated depending on the input data for the selected valve and opening angle from  $\alpha = 20^\circ$  to  $90^\circ$ . The calculation depends on the pressure loss of the valve  $\Delta p$  from the input data, the volume flow rate  $Q$  is changing depending on the opening angle  $\alpha$ . The last row shows the optimal opening angle for the specified  $\Delta p$ .

Arrow labeled “ $Q = \text{constant}$ “: The same like the “ $\Delta p = \text{constant}$ ” but the calculation depends on the given volume flow rate with the pressure loss of the valve  $\Delta p$  depends on the opening angle  $\alpha$ .

The last row shows the optimal opening angle for the specified  $Q$ .

### Sheet with "Δp = constant":

EBRO ARMATUREN		16.06.2010 07:36														NAVIGATION	
Identifier: -				α	Q	Q	K <sub>V</sub>	V	V <sub>K</sub>	Re <sub>v</sub>	F <sub>R</sub>	F <sub>P</sub>	X <sub>F</sub> / z <sub>y</sub>	L <sub>A</sub>	ΔL <sub>F</sub>		
Project: -				°	%	m <sup>3</sup> /h	m <sup>3</sup> /h	m/s	m/s	-	-	-	-	dB(A)	dB(A)		
Item-No: -				20	39	79	176	0,3	6,8	3,0E+5	0,999	1,000	0,89	38	-		
EBRO-Type: Z011/014;F012				25	48	96	216	0,4	6,9	3,3E+5	1,000	0,999	0,97	41	-		
PN= 16		Nominal pressure		30	65	130	290	0,5	7,1	3,9E+5	1,000	0,999	1,06	48	-		
DN= 250		Selected DN butterfly valve		35	90	181	404	0,7	7,3	4,7E+5	1,000	0,998	1,15	57	-		
D[mm] = 300,0		Inside-Ø of pipe		40	125	250	562	1,0	7,7	5,7E+5	1,000	0,996	1,26	63	-		
p <sub>1</sub> [bar abs] = 0,600		Pressure upstream butterfly v.		45	170	340	766	1,3	8,2	6,9E+5	1,000	0,993	1,37	68	-		
t[°C] = 40,0		Temperature		50	226	452	1021	1,8	8,8	8,2E+5	1,000	0,989	1,50	72	-		
Fluid = water				55	292	584	1331	2,3	9,5	9,7E+5	1,000	0,981	1,66	76	-		
ρ[kg/m <sup>3</sup> ] = 998		Density		60	363	725	1699	2,9	10,1	1,1E+6	1,000	0,989	1,84	79	-		
η[Ns/m <sup>2</sup> ] = 0,001021		dynamic viscosity		65	410	821	2129	3,2	10,1	1,2E+6	1,000	0,953	2,06	81	-		
p <sub>v</sub> [bar abs] = 0,023		Boiling pressure		70	455	910	2626	3,6	10,0	1,2E+6	1,000	0,931	2,35	83	-		
p <sub>c</sub> [bar abs] = 220,6		thermodyn. critical pressure		75	496	991	3192	3,9	10,0	1,3E+6	1,000	0,902	2,75	85	-		
Q[m <sup>3</sup> /h] = 200,0		100% volume flow rate		80	534	1067	3832	4,2	10,0	1,3E+6	1,000	0,867	3,35	88	-		
W[kg/h] = 199,632		100% mass flow rate		85	571	1142	4549	4,5	10,0	1,4E+6	1,000	0,827	4,37	92	-		
Δp[bar] = 0,2000		Pressure loss butterfly valve		90	610	1220	5348	4,8	10,1	1,4E+6	1,000	0,781	6,50	98	-		
				37	103	206	462	0,8	7,5	5,1E+5	1,000	0,998	1,19	60	-		

dotted line: L<sub>A</sub>[dB(A)]      acceptable: X<sub>F</sub>/z<sub>y</sub> < 1,5

Sound pressure level calculated according to IEC 60534-8-4 (2005)

← Input Data

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CHARTS

---

→ Q = constant

### Sheet with "Q = constant":

EBRO ARMATUREN		16.06.2010 07:36														NAVIGATION	
Identifier: -				α	Δp	Δp	K <sub>V</sub>	V	V <sub>K</sub>	Re <sub>v</sub>	F <sub>R</sub>	F <sub>P</sub>	X <sub>F</sub> / z <sub>y</sub>	L <sub>A</sub>	ΔL <sub>F</sub>		
Project: -				°	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV	#NV		
Item-No: -				20	#NV	#NV	176	#NV	#NV	#NV	#NV	1,000	#NV	#NV	#NV		
EBRO-Type: Z011/014;F012				25	#NV	#NV	216	#NV	#NV	#NV	#NV	0,999	#NV	#NV	#NV		
PN= 16		Nominal pressure		30	#NV	#NV	290	#NV	#NV	#NV	#NV	0,999	#NV	#NV	#NV		
DN= 250		Selected DN butterfly valve		35	123	0,245	404	0,8	8,1	5,2E+5	1,000	0,998	1,41	71	-		
D[mm] = 300,0		Inside-Ø of the pipe		40	64	0,128	562	0,8	6,2	4,6E+5	1,000	0,996	0,80	54	-		
p <sub>1</sub> [bar abs] = 0,600		Pressure upstream butterfly v.		45	35	0,069	766	0,8	4,8	4,0E+5	1,000	0,993	0,47	50	-		
t[°C] = 40,0		Temperature		50	20	0,039	1021	0,8	3,9	3,6E+5	1,000	0,989	0,30	47	-		
Fluid = water				55	12	0,023	1331	0,8	3,3	3,3E+5	1,000	0,981	0,19	44	-		
ρ[kg/m <sup>3</sup> ] = 998		density		60	7	0,015	1699	0,8	2,8	3,1E+5	0,999	0,969	0,14	41	-		
η[Ns/m <sup>2</sup> ] = 0,001021		dynamic viscosity		65	5	0,010	2129	0,8	2,5	2,9E+5	0,999	0,953	0,10	39	-		
p <sub>v</sub> [bar abs] = 0,023		Boiling pressure		70	3	0,007	2626	0,8	2,2	2,7E+5	0,999	0,931	0,08	37	-		
p <sub>c</sub> [bar abs] = 220,6		thermodyn. critical pressure		75	2	0,005	3192	0,8	2,0	2,6E+5	0,999	0,902	0,07	36	-		
Q[m <sup>3</sup> /h] = 200,0		Volume flow rate		80	2	0,004	3832	0,8	1,9	2,5E+5	0,999	0,867	0,06	34	-		
W[kg/h] = 199,632		Mass flow rate		85	1	0,003	4549	0,8	1,8	2,4E+5	0,999	0,827	0,06	34	-		
Δp[bar] = 0,2000		100% Pressure loss butterfly v.		90	1	0,002	5348	0,8	1,7	2,4E+5	0,999	0,781	0,07	33	-		
				37	94	0,188	462	0,8	7,3	5,0E+5	1,000	0,998	1,12	61	-		

dotted line: L<sub>A</sub>[dB(A)]      acceptable: X<sub>F</sub>/z<sub>y</sub> < 1,5

Sound pressure level calculated according to IEC 60534-8-4 (2005)

← Input Data

---

CHARTS

---

→ Δp = constant

#### 4.6 Calculation of flow data for butterfly valves for gas and vapor

The following data have to be entered for Calculation:

1. EBRO Type [selection] (Description see Chapter 4.4)
2. With the buttons on the left side of the page the nominal size DN of the valve type can be selected. There are only the DN's displayed which are available for the selected valve type.
3. The pressure  $p_1$  in bar abs upstream the butterfly valve.
4. The temperature  $t_1$  of the fluid. ( $t_1 < 180^\circ\text{C}$ )
5. The fluid. Here a Fluid No. has to be entered. The Fluid-No. for the fluids can be selected from the table of the right side. The material data  $\rho_N$ ,  $\kappa$ , and the molar mass  $M$  of the gas/vapor No. 1 to 35 are given.

##### ➔ DETAILS FOR ENTERING A NEW GAS

For other fluids the material data of the fluids have to be entered in the table (possible in the grey areas). For this case you have to take care about these things:

- The molar mass  $M$  which is important for the calculation of the sound pressure level. When you can't find out the molar mass from the new gas, then you can change the calculation of the sound pressure level from IEC 60534 to VDMA 24422 (Chapter 7). The calculation with the VDMA doesn't need the molar mass to calculate the sound pressure level.
  - The density  $\rho_N$  at normal condition isn't given; you can calculate it by using the operating conditions  $p_1$  and  $t_1$ . Enter the pressure  $p_1$  and temperature  $t_1$  at operating condition and then enter  $p_1$  in the grey area of the "Help for conversion from  $p_1$  to  $p_N$ " and the density  $\rho_N$  at normal condition will be calculated. These density can now be entered for the new gas in the table for Fluids and the calculation of the other parameters can be done. (Apply in case of doubt, particularly in case of a high pressure  $p_1$  and a low temperature  $t_1$ .)
  - If the adiabatic exponent  $\kappa$  of the gas isn't given, an adiabatic exponent of  $\kappa = 1,3$  is applicable for the most cases.
6. The volume flow rate for normal condition  $Q_N$  in  $\text{m}^3/\text{h}$ . When a mass flow rate in  $\text{kg}/\text{h}$  is given, the volume flow rate can be calculated with the "Help for Conversion from  $W$  to  $Q$ " in the volume flow rate. In this "Help for Conversion from  $W$  to  $Q$ " you also can convert a Volume flow rate  $Q_1$  or mass flow rate  $W$  at operating condition in a volume flow rate  $Q_N$  at normal condition. For this calculation the temperature  $t_1$  and the Fluid-No. have to be entered before.
  7. The pressure loss of the butterfly valve  $\Delta p = p_2 - p_1$ .
  8. The inside Diameter  $D$  of the pipe. The inside Diameter of the pipe should not be less than the nominal size of the selected valve. When DN is bigger than  $D$  the message „DN > D“ is displayed (Chapter 5).

### Output data:

- „Input  $\Delta p$ , DN and D“

$DN_{\min}$ : The minimum nominal size of the pipe depending on the input data.

$\alpha = 70^\circ$ : DN: nominal size of the butterfly valve with an opening angle of  $\alpha = 70^\circ$  depending on the input data

DN: selected nominal size of the butterfly valve

$\alpha[^\circ]$ : Required opening angle for the selected butterfly valve depending on the input data.

- „Calculation with const. Q“

Calculation of  $\Delta p$ , V1, V2,  $K_v$ ,  $\psi$ ,  $F_p$  and the sound pressure level  $L_A$  depending on the input volume flow rate Q. The pressure loss of the butterfly valve depends on the selected opening angle  $\alpha$  (which you can enter in the grey area or select by scroll bar).

- „Calculation with const.  $\Delta p$ “

Calculation of Q, V1, V2,  $K_v$ ,  $\psi$ ,  $F_p$  and the sound pressure level  $L_A$  depending the input pressure loss of the butterfly valve  $\Delta p$ . The Volume flow rate Q depends on the selected opening angle  $\alpha$  (which you can enter in the grey area or select by scroll bar).

The screenshot shows the EBRO FLOW CALCULATOR 2011 software interface. The top left corner displays the EBRO ARMATUREN logo and the date 16.06.2010 07:38. The interface is divided into several sections:

- selection DN:** A vertical list of pipe sizes from 20 to 500.
- Input fluid data:** Fields for pressure upstream ( $p_1$ ), temperature upstream ( $t_1$ ), fluid number (Air), volume flow rate ( $Q_v$ ), and mass flow rate ( $W$ ).
- Input  $\Delta p$ , D and DN:** Fields for pressure loss ( $\Delta p$ ), minimum DN ( $DN_{\min}$ ), pipe diameter ( $D$ ), and opening angle ( $\alpha$ ).
- Output:** Fields for opening angle ( $\alpha$ ), pressure loss ( $\Delta p$ ), volume flow rate upstream ( $V_1$ ), volume flow rate downstream ( $V_2$ ), flow coefficient ( $K_v$ ), expansion factor ( $\psi$ ), pipe geometry factor ( $F_p$ ), and sound pressure level ( $L_A$ ).
- Calculation with const. Q = 6.000 m³/h:** Fields for opening angle ( $\alpha$ ), volume flow rate ( $Q_v$ ), percentages of flow rates ( $Q_1, Q_2$ ), volume flow rate upstream ( $V_1$ ), volume flow rate downstream ( $V_2$ ), flow coefficient ( $K_v$ ), expansion factor ( $\psi$ ), pipe geometry factor ( $F_p$ ), and sound pressure level ( $L_A$ ).
- Calculation with const.  $\Delta p = 0.009$  bar:** Fields for opening angle ( $\alpha$ ), volume flow rate ( $Q_v$ ), percentages of flow rates ( $Q_1, Q_2$ ), volume flow rate upstream ( $V_1$ ), volume flow rate downstream ( $V_2$ ), flow coefficient ( $K_v$ ), expansion factor ( $\psi$ ), pipe geometry factor ( $F_p$ ), and sound pressure level ( $L_A$ ).
- Fluids (Gases resp. Vapors) in Normal Condition:** A table with columns for No., Name, Formula,  $\rho_N$ ,  $\kappa$ , and M. It lists various substances like Acetylene, Air, Ammonia, Argon, Benzole, Butane-i, Butane-n, Butylene, Carbon dioxide, Carbon disulfide, Carbon monox. sulf., Carbon monoxide, Chlorine, Dicyanogene, Ethane, Ethylene, Helium, Hydrochlorine, Hydrocyanogene, Hydrogen sulfide, Hydrogene, Methane, Methylchlorine, Neon, Nitric dioxide, Nitric oxide, Nitrogen (pure), Nitrogen of air, Oxygen, Propane, Propylene, Steam, Sulfur dioxide, Toluene, and Xylene.
- Sound pressure level standard:** A section with a red checkmark indicating 'IEC 60534 (2005) - actual standard' is selected, and 'VDMA 24422 (1979) - old standard' is unselected.
- Navigation:** Buttons for 'data export', 'data import', 'main navigation', and 'CHARTS'.

Navigation menu at the right side of the page:

Click on the orange left-pointing arrow to get back to the "main navigation"(Chapter 4.3) where you can select the calculation methods:  $K_v$ -value, FLÜ and GAS.

The two right-pointing arrows lead you to the pages with tables and diagrams.

Arrow labeled " $\Delta p = \text{constant}$ ": A sheet where you can see a table with flow data calculated depending the input data for the selected valve and opening angle from  $\alpha = 20^\circ$  to  $90^\circ$ . The calculation depends on the pressure loss of the valve  $\Delta p$  from the input data, the volume flow rate  $Q$  is changing depending on the opening angle  $\alpha$ . The last row shows the optimal opening angle for the specified  $\Delta p$ .

Arrow labeled " $Q = \text{constant}$ ": The same like the " $\Delta p = \text{constant}$ " but the calculation depends on the given volume flow rate with the pressure loss of the valve  $\Delta p$  depending on the opening angle  $\alpha$ .

The last row shows the optimal opening angle for the specified  $Q$ .

Sheet with " $\Delta p = \text{constant}$ ":

16.06.2010 07:36

Identifier: -  
Project: -  
Item-No: -  
EBRO-Type: **Z011/014;F012**

PN= 16 Nominal pressure  
DN = 250 Selected DN butterfly valve  
D[mm] = 250,0 Inside-Ø of pipe  
 $p_1$ [bar abs] = 5,00 Pressure upstream butterfly v.  
 $t_1$ [°C] = 60 Temperature upstream butterfly v.  
Fluid = Air  
 $\rho_1$ [kg/m³] = 5,23 Density upstream butterfly v.  
 $\rho_n$ [kg/m³] = 1,29 Density in normal condition  
 $\kappa = 1,40$  Isentropic exponent  
 $Q_n$ [m³/h] = 6.000 100% Volume flow rate "norman"  
 $Q_o$ [m³/h] = 1.483 100% Volume flow rate "operating"  
 $W$ [kg/h] = 7.757 100% Mass flow rate  
 $\Delta p$ [bar] = 0,05000 Pressure loss butterfly valve

$\alpha$ °	$Q_n$ m³/h	$Q_n$ $Q_1$ $W$ %	$K_v$ m³/h	$V_1$ m/s	$V_2$ m/s	$\psi$ -	$F_p$ -	$L_A$ dB(A)
20	2.190	36	176	3,1	3,1	0,992	1,000	59
25	2.675	45	216	3,7	3,8	0,992	1,000	60
30	3.601	60	290	5,0	5,1	0,992	1,000	62
35	5.014	84	404	7,0	7,1	0,992	1,000	64
40	6.961	116	562	9,7	9,8	0,991	1,000	65
45	9.487	158	766	13,3	13,4	0,991	1,000	66
50	12.637	211	1.021	17,7	17,9	0,990	1,000	67
55	16.456	274	1.331	23,0	23,2	0,989	1,000	69
60	20.986	350	1.699	29,3	29,6	0,988	1,000	71
65	26.269	438	2.129	36,7	37,1	0,987	1,000	74
70	32.348	539	2.626	45,2	45,7	0,986	1,000	77
75	39.260	654	3.192	54,9	55,5	0,984	1,000	80
80	47.103	785	3.832	65,9	66,5	0,983	1,000	81
85	55.921	932	4.549	78,2	79,0	0,983	1,000	81
90	65.738	1.096	5.348	91,9	92,8	0,983	1,000	81
38	6.115	102	493	8,6	8,6	0,992	1,000	64

**NAVIGATION**

← data input

---

**CHARTS**

Q = constant →

$Q_n$ [m³/h]

$Q_n$ [%]  $Q_1$ [%]  $W$ [%]

$V_1$ [m/s]  $V_2$ [m/s]

If  $V_2 > 110$  m/s sound pressure level is invalid.

Sound pressure level calculated according to IEC 60534-8-3 (2000)

Sheet with "Q = constant":

EBRO ARMATUREN		16.06.2010 07:36	$\alpha$	$\Delta p$	$\Delta p$	$K_v$	$V_1$	$V_2$	$\psi$	$F_P$	$L_A$
			°	bar	%	$m^3/h$	m/s	m/s	-	-	dB(A)
20	0,422	843,9	176	8,4	9,2	0,936	1,000	85			
25	0,270	539,2	216	8,4	8,9	0,959	1,000	80			
30	0,143	286,1	290	8,4	8,6	0,977	1,000	75			
35	0,072	144,3	404	8,4	8,5	0,988	1,000	69			
40	0,037	74,0	562	8,4	8,5	0,994	1,000	57			
45	0,020	39,6	766	8,4	8,4	0,996	1,000	46			
50	0,011	22,2	1021	8,4	8,4	0,998	1,000	37			
55	0,007	13,0	1331	8,4	8,4	0,999	1,000	28			
60	0,004	8,0	1699	8,4	8,4	0,999	1,000	21			
65	0,003	5,1	2129	8,4	8,4	0,999	1,000	15			
70	0,002	3,3	2626	8,4	8,4	1,000	1,000	9			
75	0,001	2,3	3192	8,4	8,4	1,000	1,000	4			
80	0,001	1,6	3832	8,4	8,4	1,000	1,000	0			
85	0,001	1,1	4549	8,4	8,4	1,000	1,000	0			
90	0,000	0,8	5348	8,4	8,4	1,000	1,000	0			
38	0,048	96,2	493	8,4	8,5	0,992	1,000	62			

Identifier: - Project: - Item-No: - EBRO-Type: <b>Z011/014;F012</b> PN= 16 DN = 250 D[mm] = 250,0 p <sub>1</sub> [bar abs] = 5,00 t <sub>1</sub> [°C] = 60 Fluid = Air ρ <sub>1</sub> [kg/m <sup>3</sup> ] = 5,23 ρ <sub>N</sub> [kg/m <sup>3</sup> ] = 1,29 κ = 1,40 Q <sub>N</sub> [m <sup>3</sup> /h] = 6.000 Q <sub>1</sub> [m <sup>3</sup> /h] = 1.483 W[kg/h] = 7.757 Δp[bar] = 0,050000	Nominal pressure selected DN butterfly valve Inside-Ø of pipe Pressure upstream butterfly valve Temperature upstream butterfly v. Density upstream butterfly valve Density in normal condition Isentropic exponent Volume flow rate "normal" Volume flow rate "operating" Mass flow rate 100% pressure loss butterfly valve
------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Comments  
If V2[m/s] > 110 m/s sound pressure level is invalid.

Sound pressure level calculated according to IEC 60534-8-3 (2000)

dotted line: L<sub>A</sub>[dB(A)]

dotted line: V<sub>2</sub>[m/s]

**NAVIGATION**

← data input

**CHARTS**

Δp = constant →

### 4.7 Abstract Flow Calculation Input and Output data

Input	Output
<b>K<sub>v</sub>-value</b>	
DN, D, EBRO-Type	K <sub>v</sub> , F <sub>p</sub> , F <sub>p</sub> *K <sub>v</sub>
<b>FLÜ</b>	
p <sub>1</sub> , t, Fluid Nr., Q, Δp, D, DN, EBRO-Type	ρ, η, ρ <sub>v</sub> , p <sub>c</sub> , DN <sub>Lmin</sub> , DN-suggested, opening angle α
new Fluid: Name, ρ, η, ρ <sub>v</sub> , p <sub>c</sub> , (c <sub>L</sub> )	Diagrams and Tables for Q = constant Diagrams and Tables for Δp = constant
<b>GAS</b>	
p <sub>1</sub> , t <sub>1</sub> , Fluid-Nr., Q <sub>N</sub> , Δp, D, DN, EBRO-Type	Q <sub>L</sub> , W, DN <sub>Lmin</sub> , DN-suggested, opening angle α
new Fluid: Name, ρ <sub>N</sub> , κ, (M)	Diagrams and Tables for Q = constant Diagrams and Tables for Δp = constant

### 5 Messages

Messages are displayed when entered data or results are out of range.



*The input data of the flow calculation should not be out of range! When the input data are out of range the calculation can be incorrect!*

Samples for Messages		
Input	Message	Help
t [°C] = 181	t > 180 °C	Choose a temperature below or equal to 180°C
DN = 250; D = 300	DN < D ; D > DN	Choose a smaller DN or a greater D

## 6 Details

### 6.1 Velocity

For velocity in pipes the following details will be applicable:

Fluid flow:  $V$  to ca. 3 m/s

Gas/vapor flow:  $V$  to ca. 30 m/s

Exceptions were e.g.:

- Short pipes with  $V > 5$  m/s at fluid flow (close slowly, pressure surge!)
- Relief pipes with  $V > 200$  m/s at gas and vapor flow

### 6.2 Cavitation

Cavitation should always be avoided. Cavitation starts when the cavitation factor is  $x_F/z_y > 1$ .

A cavitation factor up to  $x_F/z_y = 2$  should be allowed only temporary.

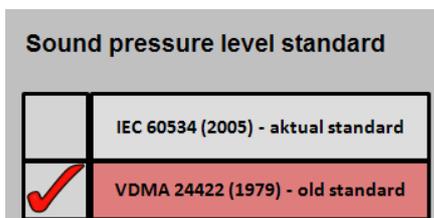
Exception: A cavitation factor up to  $x_F/z_y = 3$  during opening or closing of the butterfly valve.

## 7 Calculation of sound pressure level $L_A$

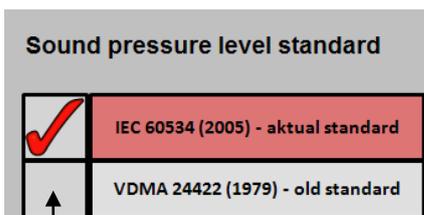
The calculation of the sound pressure level is possible in two ways:

1. Calculation according to VDMA 24422 (1989)

This is an elder, but not an invalid standard. You can calculate the sound pressure level with this standard when you have no sound speed level of a fluid (FLÜ-Calculation Chapter 4.5) or no molar mass of a gas (GAS-Calculation 4.6).



2. Calculation according to IEC 60534-8-4 (2005) for liquids or IEC 60534-8-3 (2000) for gases and vapors



↑ The standard for calculation can be changed by a click on the squares.

## 8 Export and Import of calculation

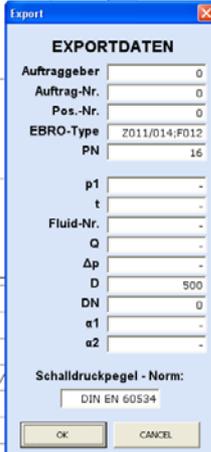
To save the calculation data you can export the data. When you need it again, you can import the data and can go on with the flow calculation. The export-box (only available in German language – but can also be used for the English version of the flow calculator) shows the entered data.

data export

---

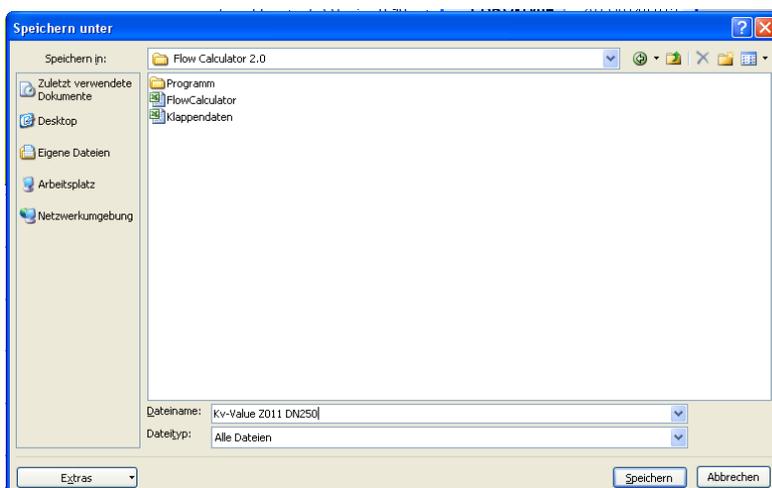
data import

Item-No.:	25	216	1,00
EBRO Type: <b>Z011/014:F012</b>	30	290	0,99
PN = 16 Nominal pressure	35	404	0,99
DN = 250 Suggested DN butterfly valve	40	562	0,98
D[mm]= 500.0 Inside-Ø of the pipe	45	768	0,98
Comments	50	1.021	0,94
	55	1.331	0,90
	60	1.699	0,85
	65	2.129	0,79
	70	2.626	0,72
	75	3.192	0,66
	80	3.832	0,58
	85	4.549	0,51
	90	5.348	0,45

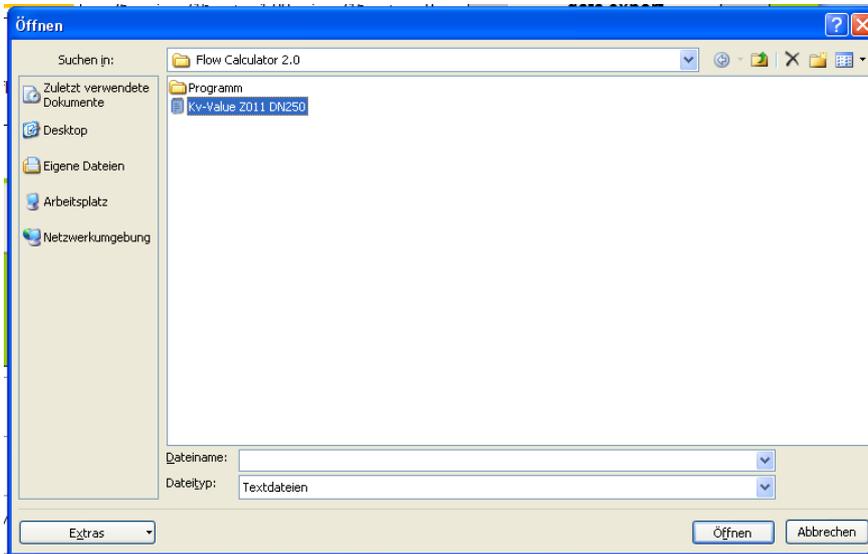




When you click on “OK” the next window for memory location opens. Now you have to select any file folder where you want to save the file. For example you might choose the “Flow Calculator 2.0” folder. Enter a filename without a type of file. It will be saved as a “txt”-file automatically (It isn’t critically if you enter a type of file – the file will also be a “txt”-file). By a click on the “save” button the data were saved.

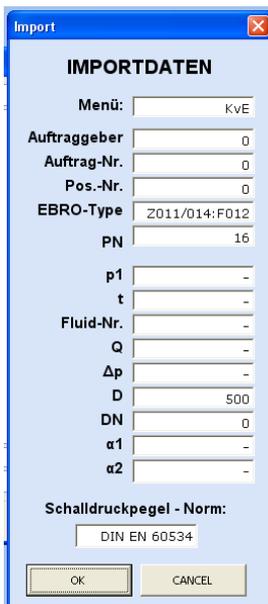


By a click of import you can import the saved data. Search the exported file, and open it.



The import-box opens and show the data which were saved. By a click on “OK” you can import them finally.

By a click on “cancel” you can abort the import.



## 9 References

- [1] DIN EN 60534-2-1: Control valves for Process Control: Part 2: Flow Capacity. Main Section 1: Design Equations for Incompressible Fluids under Installation Conditions. January 1995.
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