METRUS
Valve Test Bench Excellence

White Paper

Leakage calculation in accrodance with EN 60534 and EN 12266

When it comes to control valve testing, experience shows that the level of knowledge how to properly calculate a leak limit is rather low. An explanation for the lack of knowledge could be found in the testing standard EN 60534-4 itself. It simply does not give a profound explanation on the calculation. It only lists a few examples where the leak limit is miraculously created out of few given Information. Those who follow the hint and take a look at the referenced EN 60534-2-1 will find themselves right in the middle of the control valve design calculation jungle. That is the moment when the tester understandably gives up and decided not to deal with it any more. That is why we did write this white paper. It is supposed bring light into the darkness of standards and to take away the horror of threatening mathematics.

Content

1. Background

As a manufacturer of test benches, both for valve manufacturers and service companies, METRUS GmbH has been familiar with the normative requirements for test procedures for over 40 years. Leakage calculations never played a role until a few years ago. They were simply left to the operators. With the growing popularity of test bench software, however, the expectation grew that leakage could be calculated easily with the software. Today a standard-compliant leakage calculation is part of the software solutions we offer. Consequently, a comprehensive understanding of the interrelationships is mandatory.

2. Basics of EN 60534-4

Before turning to the actual calculation, it is very useful to understand the environment in which the "test standard EN 60534-4" operates and what it says in simple terms about the permissible leakage.

2.1. Location determination

The higher-level framework is provided by the EN 60534 standard entitled "Industrial-process control valves". It summarizes all relevant topics for control valves. Two parts of this standard are particularly important for the leakage calculation:

Part 4 Inspection and routine testing - only applies to testing and includes Table 3 in section 5.5.4 - Maximum permissible seat leakage for each leakage class. Leakage calculation is NOT possible with this part alone!

Teil 2-1 60534-2-1 Flow capacity. Sizing equations for fluid flow under installed conditions. This part is the source of the formulas listed in the example part of 60534-4.

Image 1: Standard EN 60534 the framework for leakage calculation

These two parts of the standard are connected by the term "rated capacity" in table 3 of standard 60534-4.

2.2. What the standard "says" about permissible leakage?

Understanding the calculations is much easier if the underlying context is literally put into words. In the case of leakage calculation of control valves, this can be formulated as follows:

1) A Control valve regulates the flow rate which is controlled by the position of the actuator (plug, ball, butterfly valve, ...)

2) If the actuator is in the nominal opening position (100% open), the resulting flow rate is called "rated capacity".

3) Depending on the leakage class, a closed control valve may still have a very small flow rate as leakage.

4) For leakage classes I to IV-S1, the permissible leakage is calculated as a proportion of the rated capacity.

5) Leakage classes V and VI calculate the leakage directly from the seat diameter (not via the rated capacity).

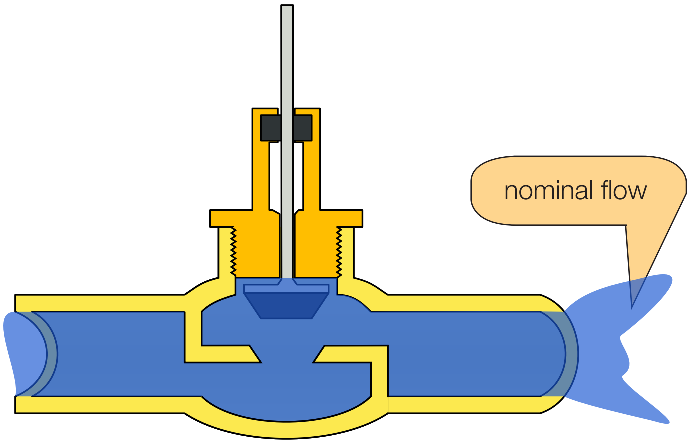

Image 2: Cone in rated travel position >> rated capacity

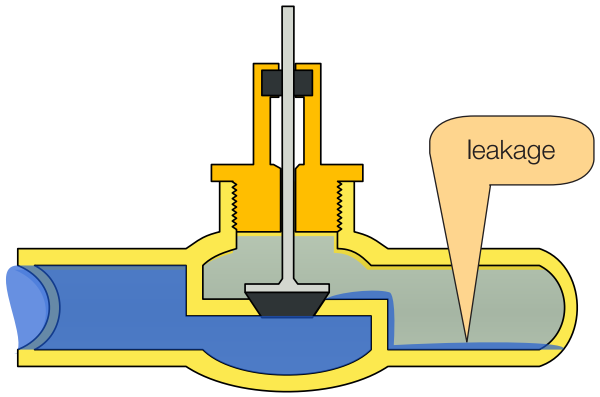

Image 3: Closed valve with leakage

2.3. Facts and errors

The understanding of the calculation is made even easier by the following facts. They should also clear up widespread errors:

- The Cv (or KvS) is NOT the "rated valve capacity" mentioned in 60534-4 Chapter 5.5.4 Table 3 "Maximum seat leakage for each leakage class".
- The Cv - rated flow coefficient – is a characteristic of the valve alike nominal pressure PN, nominal width DN or others.

  Definition: "The value specifies the amount of water (with a temperature between 5 and 40 °C) that flows through the valve at its nominal stroke (100%) and a pressure difference of 1 bar between inlet and outlet." The unit of the Cv value is m^3/h.
- Based on Cv and dedicated EN 60534-2-1 formulars rated valve capacities for water AND for air are calculated.

A simple CONVERSION between water and air leakage does NOT exist.

3. Leakage calculation for classes I to IV-S1

3.1 Calculation in 3 steps

Regardless of the test fluid leakage calculation for classes I to IV-S1 is always done in three steps:

1) Check for flow restriction
2) Calculate the rated capacity Q [m^3/h] according to EN 60534-2-1
3) Multiply the rated capacity Q with the leakage factor as per EN 60534-4

3.2 What is flow restriction?

The flow through a pipe or valve essentially depends on the pressure difference between inlet and outlet. The higher the pressure difference, the stronger the resulting flow. However, this correlation cannot be arbitrarily increased. An infinite pressure difference does not lead to an infinite flow.

In general, the flow velocity of a fluid is limited by the speed of sound (inside the fluid itself). For gas and air the flow velocity can consequently never exceed the speed of sound.

Within liquids there is an additional physical effect – cavitation

– in addition to the speed of sound limitation. The faster the liquid velocity, the lower the static pressure inside the liquid will be. If the static pressure falls below its specific vapour pressure, vapour bubbles appear - the liquid begins to foam. However, the speed of sound is considerably lower in foam than it is in the liquid. Meaning the flow velocity falls down to well below the liquid's speed of sound. Cavitation slows down the flow velocity, restricting it to the speed of sound in foam.

As already mentioned, test standard EN 60534-4 calculates the permissible leakage as a proportion of the rated capacity. However, since this rated capacity cannot become arbitrarily high, it makes sense to check in the first step whether flow restriction appears.

For the "test for flow restriction", two valve parameters are required which can be obtained from the manufacturer or taken from the tables in EN 60534-2-1:

- X_T (also called $X_{chocked}$) – The Greek letter "Chi" refers to the "differential pressure ratio for gases at which flow restriction occurs".
- F_L – Pressure recovery factor for liquids

The following table contains examples of XT and FL values for selected valve types. An extended list can be found in EN 60434-2-1.

Valve type	**Flow restrictor**	**F_L**	**X_T**
Single seat - streight-way valve	V-seat cone	0,90	0,70
	parabolic cone	0,90 0,80	0,72 0,55
	perf. cylinder 60 holes	0,90	0,68
	perf. cylinder 120 holes	0,90	0,68
Double seat - streight-way valve	slotted ball	0,90	0,75
	profiled ball	0,85	0,70

Table 1: Examples of X_T and F_L values

3.3. Calculate air leakage in 3 steps

To calculate the permitted leakage for a test with air the following steps shall be performed in sequence:

Step 1 - Check for flow restriction

Calculate: Differential pressure ratio X of the test situation.

$$\chi = \frac{P_{inlet} - P_{outlet}}{P_{outlet} + 1{,}01325}$$

Pressure in [bar]

If the valve outlet is open to environment $P_{outlet} = 0$

Check: If the existing differential pressure ratio X of test is smaller than the critical differential pressure ratio X_T, X is used for the calculation, otherwise use X_T

In mathematical words
$X < X_T \rightarrow X_{SIZING} = X$
$X > X_T \rightarrow X_{SIZING} = X_T$

X_{SIZING} is the selected value that is used for the calculation of Q in the following step.

Step 2 - Calculate rated valve capacity Q [m³/h] in accordance with EN 60534-2-1

The general formula for calculating the air flow through a control valve in accordance with EN 60534-2-1 is:

$$Q = C_V \times N_9 \times F_p \times p_1 \times Y \sqrt{\frac{\chi_{sizing}}{MT_1 Z_1}}$$

Due to the special situation on the test bench, this formula can be significantly simplified:

$$Q = C_V \times 2600 \times p_1 \times Y \sqrt{\frac{\chi_{sizing}}{8343,36}}$$

Using:

Cv The Cv (Kvs) value of the valve in m³/h.

N_9=2600 - Numerical constant No. 9 with the value for the reference temperature 15 °C, pressure in bar and flow rate in m³/h. The standard does not provide further explanations.

F_P=1 pipe geometry factor - the test scenario only considers the valve, not any connected pipes. Therefore always "1".

p1 Absolute pressure at the inlet of the valve. Calculated from test pressure + absolute ambient pressure >> test pressure + 1.01325 bar.

MT_1Z_1=8343,36 - The product of molar mass of air (28.97 kg/kmol) x inlet temperature (288 °K) x real gas factor (1). If you test with nitrogen, the molar mass is 28.013 kg/kmol and the value changes to 8067.74.

$Y = 1 - \frac{\chi_{sizing}}{3 * \chi_T}$ Describes the expansion factor and is calculated from the previously selected X_{sizing} and the valves parameter X_T from step 1. Within the appendix of this document you will find a table to read Y using X_{sizing} and X_T. The value is in any case smaller than 1. The result of this calculation is the rated capacity Q of the valve for the test bench scenario. The dimension of the result is m³/h.

Step 3 - Multiply the rated capacity Q by the leakage factor according to EN 60534-4

The actual EN 60534-4 standard is only applied in the last step of the leakage calculation. Table 3 - "Maximum seat leakage for each leakage class" the following factors are specified for classes I to IV-S1:

Leakage class	Factor
I	as agreed
II	0,005
III	0,001
IV	0,0001
IV-S1	0,000005

Table 2: Factor for each leakage class

Multiply the rated capacity Q by the factor of the leakage class to receive the permissible leakage in m³/h

The leakage is typically not given in m³/h, but in a unit appropriate to the quantity. The necessary conversion factors are to be found within the appendix.

Example calculation of a permissible air leakage:

Cv value: 160 m³/h
X_T: 0,7
Test pressure p1: 3,5 bar air, valve open to the outlet
Leakage class: IV -> factor 0,0001

Step 1 - Check for flow restriction

$$\chi = \frac{3,5}{3,5 + 1,01325} = 0,78 \geq \chi_T = 0,7$$

X is larger than X_T -> X_{sizing} = X_T = 0,7. Pressure restriction occurs. The X_T – value is used for further calculation.

Step 2 - Calculate rated capacity Q

$$Y = 1 - \frac{0{,}7}{3 * 0{,}7} = 0{,}67$$

$$Q = 160 \times 2600 \times 4{,}51325 \times 0{,}67 \sqrt{\frac{0{,}7}{8343{,}36}} = 11453\ m^3/h$$

Step 3 - Multiply leakage factor

Permissible leakage = 11453 m³/h x 0,0001 = **1,145 m³/h** converts to 19,1 l/min

Further conversion factors are to be found in the attachment.

3.4 Calculate water leakage in 3 steps

To calculate the permitted leakage for a test with water the following steps shall be performed in sequence:

Step 1 - Check for flow restriction

Calculate 1: Pressure difference of the test situation

$\Delta p = p1 - p2$

If the valve outlet is open to environment then $\Delta p = p1$ equals the test pressure.

Calculate 2: critical pressure difference for flow restriction $\Delta p_{chocked}$.

Note: Different to testing with gas the comparison parameter for pressure restriction is not given when testing with water. It must be calculated using the valves parameter F_L.

$\Delta p_{chocked} = F_L^2 \times (p1 + 1{,}01325 - F_F p_v)$ universal formula

$\Delta p_{chocked} = F_L^2 \times (p1 + 0{,}99)$
Applying the parameters for water

Using:

F_L Pressure recovery factor for liquids (valve parameters)

p_1 Test pressure at the inlet of the valve in bar relative

1,01325 - Ambient pressure - this formula uses absolute pressure.

F_F critical pressure ratio factor in liquids (0.9571 for water)

p_v Absolute vapour pressure of the liquid (0.0234 bar absolute for water)

Check: If the pressure difference Δp of the test is smaller than the flow restricted pressure difference $\Delta p_{chocked}$, Δp is used for the calculation, otherwise use $\Delta p_{chocked}$

In mathematical words:
$\Delta p < \Delta p_{chocked} \rightarrow \Delta p_{sizing} = \Delta p$
$\Delta p > \Delta p_{chocked} \rightarrow \Delta p_{sizing} = \Delta p_{chocked}$

Δp_{sizing} is the value used for the calculation of the flow Q in the following step.

Step 2 - Calculate rated capacity Q [m³/h] in accordance with EN 60534-2-1

The general formula for calculating the water flow through a control valve in accordance with EN 60534-2-1 is:

$$Q = C_V \times N_1 \times F_p \times \sqrt{\frac{\Delta p_{sizing}}{\rho_1/\rho_0}}$$

Due to the special situation on the test bench, this formula can be significantly simplified:

$$Q = C_V \times \sqrt{\Delta p_{sizing}}$$

Using:

Cv The Cv value of the valve in m³/h.

$N_1 = 1$ Numerical constant No. 1 for pressure in bar and flow rate in m³/h. The standard does not provide further explanations.

$F_P = 1$ Pipe geometry factor - the test scenario only considers the valve, not any connected pipes. Therefore always "1".

ρ_1 bzw ρ_0 - relative desnity of the fluid at temperature T_1 (inlet) and T_0 (reference condition15 °C). For water at appr. 20 °C the result is $\rho_1/\rho_0 = 1$

The result of this calculation is the rate capacity of the valve for the test bench scenario. The dimension of the result is m^3/h.

Step 3 - Multiply the rated capacity Q by the leakage factor in accordance with EN 60534-4

Step 3 does not differ for classes I to IV-S1 because the factors for water and gas testing are the same:

Leakage class	Factor
I	as agreed
II	0,005
III	0,001
IV	0,0001
IV-S1	0,000005

Table 2: Factor for each leakage class

Multiply the rated capacity Q by the factor of the leakage class to receive the permissible leakage in m^3/h.

As when testing with air when testing with water the leakage is usually converted from m^3/h to a more suitable unit.

Example calculation of a permissible water leakage:

Cv value: 160 m^3/h
F_L: 0,9
Test pres. p1: 100 bar water, valve open to the outlet
Leakage cl.: IV Factor 0,0001

Step 1 - Check for flow restriction

$\Delta p = 100 - 0 = 100$ bar

$\Delta p_{chocked} = 0{,}9^2 \times (100 + 0{,}99) = 81{,}8$ bar

Δp is larger than $\Delta p_{chocked}$ -> $\Delta p_{sizing} = \Delta p_{chocked} = 81{,}8$ bar. Pressure limitation occurs, therefore the $\Delta p_{chocked}$ – value is used for further calculation..

Step 2 - Calculate rated capacity Q

$$\boldsymbol{Q = 160 \times \sqrt{81{,}8} = 1447{,}11\ m^3/h}$$

Step 3 - Leakage - multiply with factor

Permissible leakage = 1447.11 m^3/h x 0.0001 = 0.1447 m^3/h converts to **2,4 l/min**

Further conversion factors can be found in the appendix.

3.5 Accuracy of results

The calculation of the rated capacity Q multiplies very large values (e.g. 2600) by values below 1, e.g. the formula for the value Y in the case of pressure limitation gives the value 2/3, which is a decimal value of 0.66666666666.... By multiplying the large and small values, the number of decimal places used has a visible influence on the result. When using 0.667 instead of 0.67 for Y withing the given example the result of the rated capacity Q will be 11510.23 instead of 11452.96. Consequently, a calculation using a spreadsheet program or the METRUS Leak Calculator, computing 16 decimals, will give a slightly different result than a calculation with a pocket calculator and paper, where fewer decimals are used. However, since "only" a permissible leakage is calculated, this inaccuracy can be tolerated.

4 Leakage calculation for class V

Class V is much easier to calculate, as only the seat diameter or the pressure difference is required. The rated capacity is not calculated via the Cv value.

4.1 Calculation for test fluid air/gas

Important: For leakage class V a **test pressure of 3.5 bar is mandatory** when testing with air. Consequently, the pressure difference is not part of the calculation formula:

Leakage in m³/h = 10,8 x 10^{-6} x D

Using:

$10,8 \times 10^{-6}$ = 0,0000108

D Valve seat diameter [mm]

m³/h = 1000 x 1000 / 60 / 0,15 bubbles/min [conversion in accordance with EN 60534-4]

The formula simplifies to:

Leakage in bubbles/min = 1,2 x D

Calculation example: Valve with seat diameter 80 mm

Perm. leakage = 1.2 x 80 = 96 bubbles/min

At such a limit it is already recommended to work with electronic flow measurement.

4.2 Calculation for test fluid water

The single important aspect when testing class V with water is the general formula delivering already a result in [l/h]:

Leckage in l/h = 1,8 x 10^{-5} x Δp x D

Using:

$1,8 \times 10^{-5}$ = 0,000018

D Valve seat diameter [mm]

Δp Differential pressure inlet-outlet (bar rel.) = p_{inlet} in case p_{outlet} = ambient pressure

l/h = 1000 / 60 ml/min [conversion]

The formula simplifies to:

Leckage in ml/min = 0,0003 x p_{inlet} x D

Calculation example: Valve with seat diameter 80 mm

Test pressure 100 bar

Perm. leakage = 0,0003 x 100 x 80 = 2,4 ml/min

Such flow is easy to be measured with a common fuel measure.

5 Leakage calculation for class VI

Leakage class VI, being the highest class for a control valve, stipulates air or gas as the test fluid. There is no calculation for liquids at all. The calculation is based on the seat diameter, the test pressure and a leakage factor listed in EN 60534-4. The result is directly retrieved as a value in ml/min.

D[mm]	$LF_{ml/min}$	D[mm]	$LF_{ml/min}$	D[mm]	$LF_{ml/min}$
25	0,15	80	0,90	250	11,1
40	0,30	100	1,70	300	16,0
50	0,45	150	4,00	350	21,6
65	0,60	200	6,75	400	28,4

Table 3: LF - Leakage Factor per seat diameter for class VI

Leakage in ml/min = 0,3 x Δp x $LF_{ml/min}$

Using:

Δp Differential pressure inlet-outlet (bar rel.) = p_{inlet} wenn p_{outlet} = Ambient pressure

$LF_{ml/min}$ Leakage factor according to table in ml/min

With the conversion 0.15 ml/min = 1 bubble/min the alternative formula is

Leakage in bubbles/min = 2 x Δp x $LF_{ml/min}$

Calculation example:

Seat diameter	150 mm
Test pressure	6 bar
$LF_{ml/min}$	4,00 ml/min (aus Tabelle)

Leakage [ml/min] = 0,3 x 6 x 4,00 = 7,2 ml/min
or
Leakage [Bubbles/min] = 2 x 6 x 4,00 = 48 Bubbles/min

6 ANSI FCI70-2 and EN 60534-4

In the US and Canada, as well as in all industries related to the oil industry, ANSI FCI-2 is the standard for valve testing. ANSI FCI70-2 and EN 60534-4 calculate the permissible leakage in the exact same way. You can apply the calculation methods shown within this document. There are only two aspects to consider:

1) Leakage class IV-S1 does not exist in ANSI FCI70-2

2) In ANSI the Cv value is given in [liq.gal US/min] instead of [m³/h]

liq.gal US is the abbreviation for "liquid gallon". US refers to the US American unit of measurement. The addition is important because Great Britain also uses a "liquid gallon". However, the British gallon differs from the US gallon. To apply the formulas of EN 60534, the Cv value must be converted in the following way:

Cv [m³/h]= 0,865 x Cv [liq.gal/min]

Note: The conversion also takes into account that the Cv [m³/h] is related to 1 bar pressure differential, the Cv [liq.gal US/min] value to 1 PSI.

7 Appropriate measurement technology

For many decades, the bubble counter has been the instrument of choice when it comes to detecting small gas leaks. With the definition of EN 60534-4 sating: 0.15 ml/min = 1 bubble/min, leakage measurement has become possible using simple tools. A glass of water and a tube are sufficient.

Test bench software with direct data acquisition has created the need for suitable leakage measuring instruments. Influenced by the ubiquitous bubble counter, the call for an "electronic bubble counter" became loud, which most test bench manufacturers, including METRUS GmbH, meet with different product solutions.

If you realise that:

1) EN 60534 calculates permissible leakages as a proportion of the rated capacity,

2) Leakage classes V and VI first calculate a flow rate

3) The conversion from ml/min to bubbles/min is a help to detect leakages in a simple and economic way

it becomes clear that the approach of counting physical bubbles themselves electronically is not in line with the standard. It appears smarter to detect small leakages with a sensitive flow measuring instrument and to convert them in to bubbles for comparison with traditional glass-of-water bubble counters.

There are different suppliers of flow meters and many offer a very sensitive device with a measuring range of 0 - 10 sccm (standard cubic centimetres per minute). By converting 1 sccm = 1 ml/min = 6.66667 bubbles/minute the 0 - 10 sccm sensor becomes a 0 - 67 bubbles/minute sensor. All that is necessary is to set up the display module or the connected software accordingly in order to obtain a correctly determined, electronically measured value.

8 Leakage calculation in accordance with EN 12266

EN 60534 is a set of rules specifically for control valves. Furthermore, there is the industrial valves standard EN 12266 that is mainly used for shut-off valves. Part 1 (EN 12266-1) of this standard contains the requirements for the leakage test.

In general, the following must be observed:

1) The test medium must have room temperature on the outlet side

2) The calculation based on the DN may also be used for diameter-equivalent inch flanges or threads.

3) The calculation is based on the nominal diameter (DN) directly, following the table below.

Fluid	Leak rate A	Leak rate B	Leak rate C	Leak rate D	Leak rate E	Leak rate F	Leak rate G
Liquid	No visually detectable leakage during the test	0,01 x DN	0,03 x DN	0,1 x DN	0,3 x DN	1,0 x DN	2,0 x DN
Gas/Air		0,3 x DN	3,0 x DN	30 x DN	300 x DN	3000 x DN	6000 x DN

Table 4: Leakage calculation via Leak rate, nominal diameter and test fluid

4) The result has the dimension mm^3/s

5) Conversion into EN 60534-4 bubbles/min via:

bubbles/min = 2,5 x mm^3/sek

Calculation example:

DN 200 Valve • test fluid air • Leak rate B

Perm. Leakage = 0,3 x 200
= 60 mm^3/sek
= 24 bubbles/min.

Unlike 60534-4, the requirements of EN 12266 decrease as the letter increases. In EN 60534-4, the requirements increase as the class rises.

9 Appendix

9.1 Flow restriction X_{sizing}

Requirement: Valve outlet open to ambient pressure

1) Search the test pressure in column P_1 (e.g.: 3,5 bar)
2) Column $X = \Delta p / p_{1abs}$ shows the X value of the test situation (e.g.: 0,78)
3) Find the X_T column of the valve in the tables main sector (e.g.: 0,7)
4) Find X_{sizing} to be used for the calculation withing the row of the test pressure P_1 3,5 bar (e.g.: 0,7)

If the background of the cell is blue, flow restrictino appers and you have to use X_T as X_{sizing} for the calculation

Flow restriction X_{SIZING} when testing with air/gas • EN 60534-4 Leakage class I, II, III, IV, IV-S1									
$P_2 = 0$		X_T value of the valve							
P_1 rel	$X = \Delta p / p_{1abs}$	0,84	0,75	0,72	0,7	0,68	0,65	0,6	0,55
1	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
2	0,66	0,66	0,66	0,66	0,66	0,66	0,65	0,60	0,55
3	0,75	0,75	0,75	0,72	0,70	0,68	0,65	0,60	0,55
3,5	0,78	0,78	0,75	0,72	0,70	0,68	0,65	0,60	0,55
4	0,80	0,80	0,75	0,72	0,70	0,68	0,65	0,60	0,55
5	0,83	0,83	0,75	0,72	0,70	0,68	0,65	0,60	0,55
5,5	0,84	0,84	0,75	0,72	0,70	0,68	0,65	0,60	0,55
6	0,86	0,84	0,75	0,72	0,70	0,68	0,65	0,60	0,55
7	0,87	0,84	0,75	0,72	0,70	0,68	0,65	0,60	0,55
8	0,89	0,84	0,75	0,72	0,70	0,68	0,65	0,60	0,55
9	0,90	0,84	0,75	0,72	0,70	0,68	0,65	0,60	0,55
10	0,91	0,84	0,75	0,72	0,70	0,68	0,65	0,60	0,55

Flow restriction appears

9.2 Expansion factor Y

Entry values to that table are X_{sizing} as found in the table of 9.1 and the X_T value of the valve.

1) Choose the column as per X_T value of the valve (e.g. 0,7)
2) Find the row of X_{sizing} as retrieved from the table in chapter 9.1 (e.g. 0,70)
3) Find the restult for Y (e.g. 0,67)

Expansionsfaktor **Y** bei Gasprüfung EN 60534-4 Leckageklasse I, II, III, IV, IV-S1								
	X_T Wert der Armatur							
X_{SIZING}	0,84	0,75	0,72	0,7	0,68	0,65	0,6	0,55
0,50	0,80	0,78	0,77	0,76	0,76	0,75	0,72	0,70
0,55	0,78	0,76	0,75	0,74	0,73	0,72	0,69	0,67
0,60	0,76	0,73	0,72	0,71	0,71	0,69	0,67	0,64
0,65	0,74	0,71	0,70	0,69	0,68	0,67	0,64	0,61
0,66	0,74	0,71	0,69	0,69	0,68	0,66	0,63	0,60
0,68	0,73	0,70	0,69	0,68	0,67	0,65	0,62	0,59
0,70	0,72	0,69	0,68	0,67	0,66	0,64	0,61	0,58
0,72	0,71	0,68	0,67	0,66	0,65	0,63	0,60	0,56
0,75	0,70	0,67	0,65	0,64	0,63	0,62	0,58	0,55
0,80	0,68	0,64	0,63	0,62	0,61	0,59	0,56	0,52
0,83	0,67	0,63	0,62	0,60	0,59	0,57	0,54	0,50
0,84	0,67	0,63	0,61	0,60	0,59	0,57	0,53	0,49

9.3 ΔPsizing Differential pressure to be used for the calculation

Requirement: Valve outlet open to ambient pressure

Calculated via the test pressure (bar relative) and the FL value of the valve.

Δp_{sizing} flow restriction when testing with water in accordacne with EN 60534-4 leakage class I, II, III, IV, IV-S1										
	F_L value of the valve									
P_1 rel	0,98	0,95	0,9	0,85	0,8	0,79	0,77	0,74	0,72	0,7
1	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,98
2	2,00	2,00	2,00	2,00	1,91	1,87	1,77	1,64	1,55	1,47
3	3,00	3,00	3,00	2,88	2,55	2,49	2,37	2,18	2,07	1,96
3,5	3,50	3,50	3,50	3,24	2,87	2,80	2,66	2,46	2,33	2,20
4	4,00	4,00	4,00	3,61	3,19	3,11	2,96	2,73	2,59	2,45
5	5,00	5,00	4,85	4,33	3,83	3,74	3,55	3,28	3,11	2,94
5,5	5,50	5,50	5,26	4,69	4,15	4,05	3,85	3,55	3,36	3,18
6	6,00	6,00	5,66	5,05	4,47	4,36	4,14	3,83	3,62	3,43
7	7,00	7,00	6,47	5,77	5,11	4,99	4,74	4,38	4,14	3,92
8	8,00	8,00	7,28	6,50	5,75	5,61	5,33	4,92	4,66	4,41
9	9,00	9,00	8,09	7,22	6,39	6,23	5,92	5,47	5,18	4,90
10	10,00	9,92	8,90	7,94	7,03	6,86	6,52	6,02	5,70	5,39
20	20,00	18,94	17,00	15,17	13,43	13,10	12,44	11,49	10,88	10,29
30	29,76	27,97	25,10	22,39	19,83	19,34	18,37	16,97	16,07	15,19
40	39,37	36,99	33,20	29,62	26,23	25,58	24,30	22,45	21,25	20,09
50	48,97	46,02	41,30	36,84	32,63	31,82	30,23	27,92	26,43	24,99
60	58,57	55,04	49,40	44,07	39,03	38,06	36,16	33,40	31,62	29,89
70	68,18	64,07	57,50	51,29	45,43	44,30	42,09	38,87	36,80	34,79
80	77,78	73,09	65,60	58,52	51,83	50,55	48,02	44,35	41,99	39,69
90	87,39	82,12	73,70	65,74	58,23	56,79	53,95	49,83	47,17	44,59
100	96,99	91,14	81,80	72,97	64,63	63,03	59,88	55,30	52,35	49,49
120	116,20	109,19	98,00	87,42	77,43	75,51	71,73	66,25	62,72	59,29
140	135,41	127,24	114,20	101,87	90,23	87,99	83,59	77,21	73,09	69,09
160	154,61	145,29	130,40	116,32	103,03	100,47	95,45	88,16	83,46	78,89
180	173,82	163,34	146,60	130,77	115,83	112,96	107,31	99,11	93,83	88,69
200	193,03	181,39	162,80	145,22	128,63	125,44	119,17	110,06	104,19	98,49

Flow restriction appears

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Umrechnungsfaktoren Durchfluss / Conversion factors

Ausgangsgröße / tabel entry value "1 xxx = ..."

Zielgröße / Result value

	m³/h	cm³/h	cm³/min	cm³/sec	l/h	l/min	l/sec	cl/h	cl/min	cl/sec	ml/h	ml/min	ml/sec	Bl/min	gal/min [US]
m³/h	1	0,000001	0,00006	0,0036	0,001	0,06	3,60	0,00001	0,0006	0,036	0,000001	0,00006	0,0036	0,000009	0,23
cm³/h	1.000.000,00	1	60,00	3.600,00	1.000,00	60.000,00	3.600.000,00	10,00	600,00	36.000,00	1,00	60,00	3.600,00	9,00	227.124,71
cm³/min	16.666,67	0,017	1	60,00	16,67	1.000,00	60.000,00	0,17	10,00	600,00	0,017	1,00	60,00	0,15	3.785,41
cm³/sec	277,78	0,00028	0,017	1	0,28	16,67	1.000,00	0,0028	0,17	10,00	0,00028	0,017	1,00	0,003	63,09
l/h	1.000,00	0,001	0,06	3,60	1	60,000	3.600,00	0,01	0,60	36,00	0,001	0,060	3,60	0,009	227,12
l/min	16,67	0,000017	0,001	0,06	0,017	1	60,00	0,00017	0,01	0,60	0,000017	0,001	0,06	0,00015	3,79
l/sec	0,28	0,00000028	0,000017	0,001	0,00028	0,017	1	0,0000028	0,00017	0,01	0,00000028	0,000017	0,001	0,0000025	0,06
cl/h	100.000,00	0,10	6,00	360,00	100,00	6.000,00	360.000,00	1	60,00	3.600,00	0,10	6,00	360,00	0,9	22.712,47
cl/min	1.666,67	0,0017	0,10	6,00	1,67	100,00	6.000,00	0,017	1	60,00	0,0017	0,10	6,00	0,015	378,54
cl/sec	27,78	0,000028	0,0017	0,10	0,028	1,67	100,00	0,00028	0,017	1	0,000028	0,0017	0,10	0,0003	6,31
ml/h	1.000.000,00	1,00	60,00	3.600,00	1.000,00	60.000,00	3.600.000,00	10,00	600,00	36.000,00	1	60,00	3.600,00	9,00	227.124,71
ml/min	16.666,67	0,017	1,00	60,00	16,67	1.000,00	60.000,00	0,17	10,00	600,00	0,02	1	60,00	0,15	3.785,41
ml/sec	277,78	0,00028	0,017	1,00	0,28	16,67	1.000,00	0,0028	0,17	10,00	0,00028	0,02	1	0,0025	63,09
Bl/min	111.111,11	0,11	6,67	400,00	111,11	6.666,67	400.000,00	1,11	66,67	4.000,00	0,11	6,67	400,00	1	25.236,08
gal/min [US]	4,40	0,0000044	0,00026	0,016	0,0044	0,26	15,85	0,000044	0,0026	0,16	0,0000044	0,00026	0,016	0,00004	1

Umrechnung von Volumeneinheiten / Converting volume

Ausgangsgröße / tabel entry value "1 xxx = ..."

	m³	dm³	cm³	mm³	liter	cl	ml	Blasen	liq. gal. [US]
m³	1	/ 1000	/ 1000 / 1000	/ 1000 / 1000 / 1000	/ 1000	/ 100 / 1000	/ 1000 / 1000	/ 1000 / 1000 x 0,15	
dm³	x 1000	1	/ 1000	/ 1000 / 1000	x 1	/ 100	/ 1000	/ 1000 x 0,15	
cm³	x 1000 x 1000	x 1000	1	/ 1000	x 1000	x 10	x 1	x 0,15	
mm³	x 1000 x 1000 x 1000	x 1000 x 1000	x 1000	1	x 1000 x 1000	x 10 x 1000	x 1000	x 1000 x 0,15	
Liter	x 1000	x 1	/ 1000	/ 1000 / 1000	1	/ 100	/ 1000	/ 1000 x 0,15	x 3,785411784
cl	x 1000 x 100	x 100	/ 10	/ 1000 / 10	x 100	1	/ 10	/ 10 x 0,15	
ml	x 1000 x 1000	x 1000	x 1	/ 1000	x 1000	x 10	1	x 0,15	
Blasen bubbles	x 1000 x 1000 / 0,15	x 1000 /0,15	/ 0,15	/ 1000 / 0,15	x 1000 / 0,15	x 10 / 0,15	/ 0,15	1	
liq. gal					/ 3,785411784				1

10 METRUS Leak Calculator

We do hope this white paper does contribute to a better understanding of the leakage calculation in accordance with the EN standards. However, even though you are now an expert you do not fancy doing these calculations ad hoc at the test bench.

To ease your work, we casted all those formulas described within this white paper into a free of charge desktop app. The METRUS Leak Calculator. Feel free to download it from our web page:

https://www.metrus.de/de/weitere-produkte/software-fuer-pruefstaende/metrus-app

10.1 Application flow

The application has a very simple flow:

1) Choose standard

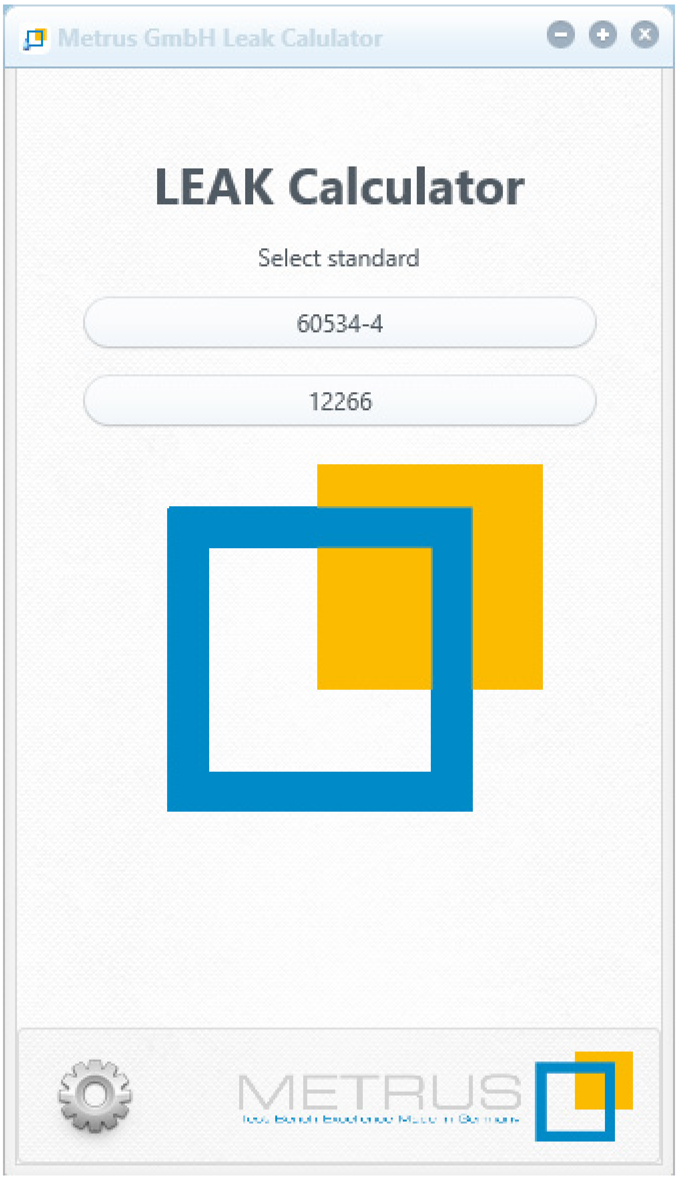
2) Choose test fluid and leak class
   Proceed with the ">" button

3) Choose the parameters or type them into the specific fields.

4) Start the calculation via the button "Calculate results"

5) Choose a unit different to m^3/h to convert the result as per your needs.

Done



Choose the sandard

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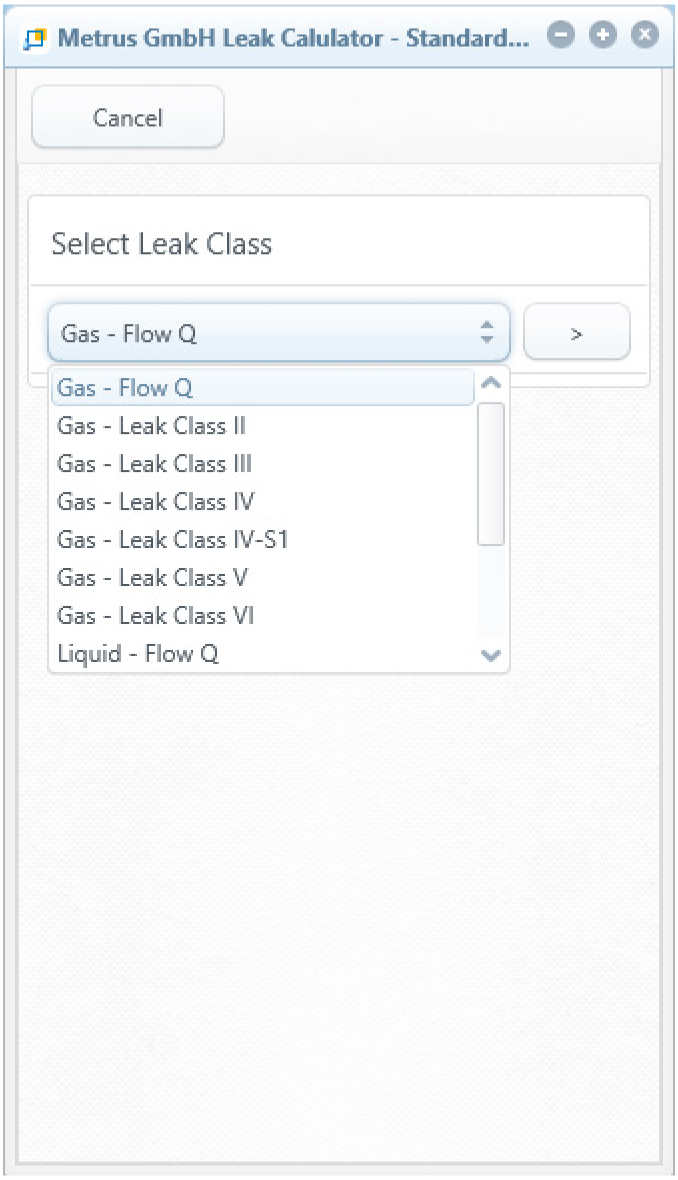
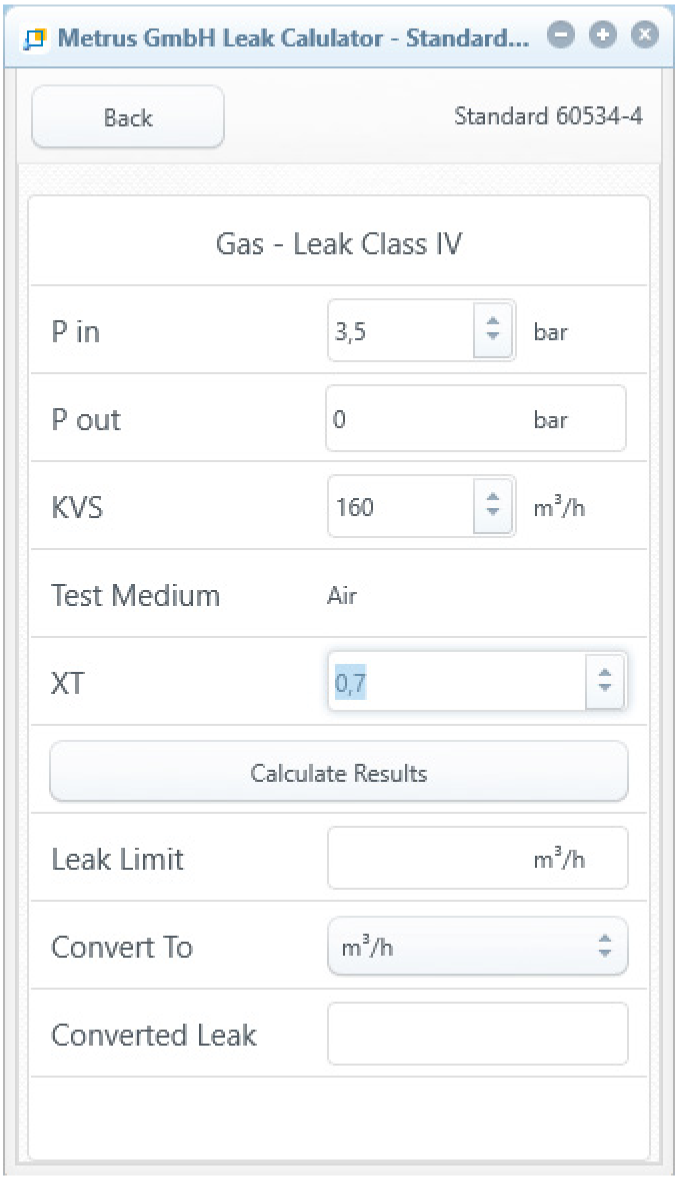
Leakage calculation in accordance with EN 60534 and EN 12266





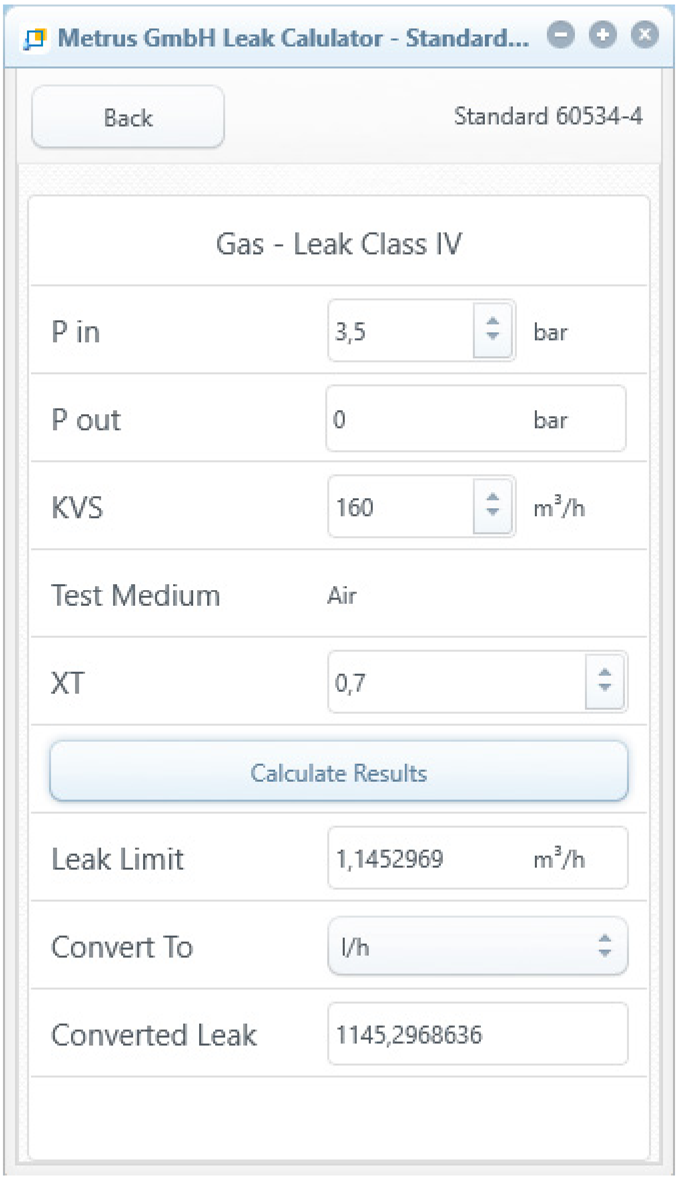
Select test fluid and leak class

Proceed with ">" button

Note: "Flow Q" calculates the ratet valve capacity

Enter the values of your test or type them into the specific fields.

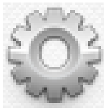
Proceed with "Calculate Results"



Choose a unit from the list "convert to" and choose the unit that suits your needs.

The conversion executes right after you chose a unit

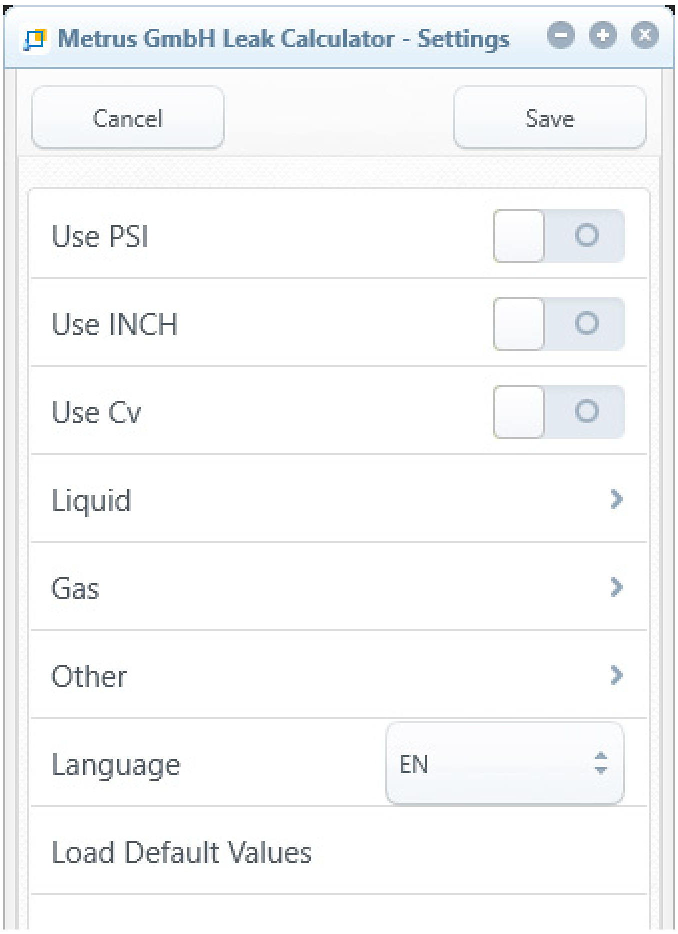
10.2 App settings



The apps default settings contain the physical properties of water and air as well as the unit bar for pressure and m³/h for the Cv ("KvS") values.

Experts who intent to test with other test fluids or who need to use Cv in liq.gal/min or pressure in PSI have full access to all those parameters via the settings.

Changes will only become active after clicking on the button "Save". To return to the default settings, simply click on the button "Load default values".



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