HOW TO SIZE A PRESSURE REGULATOR

CHOOSING THE CORRECT REGULATOR

In order to choose the correct regulator the following information is needed:
- Function: Pressure reducing or backpressure control?
- Pressure: What are the maximum and minimum inlet and outlet pressure ranges?
- Fluid: Is it a gas or a liquid?
- Temperature: What is the operating temperature?
- Flow: What are the flow requirements?

“Valve sizing” does not refer to the size of the end connections. It means determining how much flow can pass through the pressure regulator.
There is quite a difference in sizing regulators for gas or for liquids, because gases are compressible and liquids are not.

SIZING FOR LIQUIDS

The flow equations used for sizing for liquids have their roots in:
- Bernouilli’s energy equation
- the “continuity” equation

The continuity equation states that the volume flow (Qv) flowing through a pipe cross-section (A) in a unit of time is always constant. Qv = A x V(velocity). This implies that velocity must increase as the cross-section becomes smaller to maintain the same volume flow.

The conclusion is that because liquids are incompressible, their flow rate depends only on the pressure drop. As long as the difference between P1 and P2 is the same, the flow is the same, no matter if the system pressure is high or low.

Important:
It is important to realize that whatever goes through the regulator seat will go though the outletport of the regulator.
However, we want controlled pressure, not pressure drop or noise.

To keep this pressure drop and noise within acceptable limits a rule of thumb says that velocities should not exceed:

1m/sec : suction side of reciprocating pumps
2m/sec : suction side of centrifugal pumps
≤ 1m/sec : return line of pumps
4,5 m/sec: delivery side of pumps

Another rule of thumb says not to exceed a velocity of 4,5 m/sec for pressure above 7 bar.

Calculate a velocity in a pipe:

Formula: $V = 278 \dfrac{Q}{A}$

V = m/sec Q = m^3 / hr A = area in mm^2
As $A = \frac{1}{4} \Pi d^2$, you can also calculate the diameter.

Effects of specific gravity (s.g.)
The significance of s.g. on liquid flow is diminished because it is a square root function. Only if the s.g. is very high or very low will the flow change by more than 10 % from that of water.

Effects of temperature.
As the effects are too small these can be ignored.

SIZING FOR GASES

General information

Because gases are compressible sizing for gases is not as straightforward as sizing for liquids. The density of gases changes with pressure.

Orifices

There are two orifices (holes) in a regulator which need to be looked at:

1. the seat orifice
2. the outlet orifice

<u>The seat orifice</u>.

This is a restriction inside the regulator body. When a flowing fluid (gas or liquid) flows through a restriction into a lower pressure environment the velocity MUST increase as this fluid flows through this restriction. (Conservation of mass). At the same time the pressure decreases.
If the pressure decreases to a point where the P1 = 1.7 - 1.9 x P2 or more, we have a **choked flow** situation, where the velocity through the restriction becomes **sonic**.
This situation is also called **critical flow**.
A choked flow condition is a limiting one, because, even if the downstream pressure increases further (to zero for example), the flow cannot increase. Gas cannot achieve a velocity greater than sonic.

Thus, if the pressure drop is big enough the seatflow depends on the inletpressure and not on the outletpressure.
See “maximum flow”.

If we have a **non-critical flow**, when P2 is more than 0,5 x P1, the flow through the seat is restricted by the high outletpressure.
This is the situation where we need to apply the correction factor (Y).

One can also use the seatsizing formula to calculate the **maximum flow** through any particular regulator.
Example:
The maximum airflow through model RS6, with 10 bar inlet pressure is:
0.33 x 11 x 67 = 243 Nm^3/ hour of air. (Does not apply to regulators with filters.)
This is the flow which a safety valve should be able to pass.

The first thing to do is to calculate the seat orifice area A1.

<u>The outlet orifice</u>

A rule of thumb says that energy cannot be destroyed.
It means that whatever quantity one can feed through a seat will come out of the regulator.
However….. the question is in what form will this energy come out of the regulator. As velocity, noise, temperature or droop?

All we want is: **controlled outlet pressure with as little as possible droop**.

To achieve that we have to look at orifice number 2….. the outlet.
In order to achieve this controlled outlet pressure we have to keep the velocity of the fluid on the P2 side at an acceptable level.
For gases in general this is: 25 - 30 m/sec. and for liquids 4,5 - 5 m/sec.
This of course is a rule of thumb.

Now we calculate the required outlet orifice area while assuming a certain velocity.

The formula tells us that a given flow at a certain pressure requires a certain area in order to flow through that area at the assumed velocity.

ACTUAL SIZING FOR GASES

The following information is required to select the most suitable regulator:
- the maximum and minimum inlet and outlet pressure
- the fluid
- the flow requirement
- the temperature
- materials of construction

The next step is to calculate the:
- seat orifice area (A1) : the flow area between a valve stem and the seat with the valve fully opened.
- outlet port area (A2) : the area of the internal passage in the regulator outlet connection.

Please note that the following formulae are used to determine **the flow of air** through a regulator.
Correction factors for other gases are shown on the next page.

Calculating the seat orifice area (A1)

Use the formula: 0.33 x A1 x P1 = Q1 (does not apply to regulators with filters).

A1 = seat orfice area in mm²
P1 = inletpressure in bar (a)
Q1 = max. flow of **air** in Nm³/hour through the seat orifice area.

Normally the customer gives you the flow (Q1) and the gas. If the gas is not air convert the gasflow to airflow.
The customer should also give you the inletpressure (P1) and the outletpressure (P2).
Knowing these 3 parameters you can calculate the seat orifice area (A1).

Remember!
If you know 3 out of 4 parameters you can always calculate the unknown fourth.

Non-choked flow

A non-choked flowsituation (or non-critical) occurs when the outlet pressure (P2) is more than half the inlet pressure (P1). P2 > 0,5 x P1
Simply said you need a bigger seat orifice area to pass a flow, because of the small pressure differential.
To make sure that the sizing is correct multiply seat area flow Q1 by correction factor Y.

Correction factor Y

P2 (in bar abs.) / P1 (in bar abs.)	Multiplyer Y
0,975	0,1
0,95	0,31
0,925	0,52
0,9	0,6
0,85	0,71
0,8	0,8
0,75	0,86
0,7	0,91
0,65	0,95
0,6	0,98
0,55	0,99
0,5	1

Formula: 0,33 x A1 x P1 x Y =Q1

Maximum flow

To determine the maximum flow through a regulator use either:
- the seat orifice area formula, or
- the nomograph.

As long as there is a choked (critical) flow, (P1 = 2 x P2 at least), the flow which you will find on the nomograph is the maximum flow with the valve wide open.
The nomograph also allows you to find the maximum flows for smaller differential pressures.
The flows which you find for any given pressure differential can be used for **sizing a relief valve**.

Note!
The nomograph does not say anything about accuracy, it just gives you maximum flows.

Calculating the outlet port area (A2)

Use the formula:
0,10 x A2 x P2 = Q2 (assuming a velocity in the downstream piping of 30 M/sec.)
0,18 x A2 x P2 = Q2 (assuming a velocity in the downstream piping of 50 M/sec.)
0,30 x A2 x P2 = Q2 (assuming a velocity in the downstream piping of 75 M/sec.)

A2 = outlet port area in mm^2
P2 = outlet pressure in bar abs
Q2 = flow of air in Nm^3/hour through the outlet port area at the selected velocity.

Remember that Q2 is the flow which the customer has given you.

Correction for other gases

Multiply the maximum airflow through the seat area (Q1) by the following factors to obtain the specific gas flow.

Hydrogen	: 3,81	Nitrogen	: 1,02
Oxygen	: 0,95	Helium	: 2,695
Argon	: 0,85	Neon	: 1,28
Carbon dioxide	: 0,8	Carbon monoxide	: 1,0
Ammonia	: 1,27	Methane	: 1,8
Acetylene	: 1,05	Chlorine	: 0,64
Ethane	: 1,0	Ethylene	: 1,03
Hydrogen sulphide	: 0,93	Nitrous oxide	: 0,83
Propane	: 0,82	Sulphur dioxide	: 0,68
Lpg	: 0,8	Natural gas	: 1,30

USEFULL DATA

1 mbar	= 1 hPa = 10 mm w.c.
1 kPa	= 10 mbar
1 bar	= 100 kPa
1 MPa	= 10 bar
1 mm Hg	= 1,333 mbar
1” Hg	= 33,858 mbar
1 UK gallon	= 4,55 L
1 US gallon	= 3,785 L
1 m^3	= 35,315 ft^3
˚C	= 5/9 (˚F – 32)
˚F	= 9/5 (˚C + 32)
˚K	= ˚C + 273,15

Cv value
Cv value is the flowcoefficient indicating the flow of water in U.S.gallons/min at a ΔP of 1 psi and a watertemperature of 60°F.

Kv value
Kv value is the flowcoefficient indicating the flow of water in m^3/hr at a ΔP of 1 bar and a watertemperature of 5-30°C.

Kv = 0,86 x Cv

Kvs value
Kvs value is the Kv value with the valve fully open. Gives the maximum possible flow through a regulator.

RULE OF THUMB
Size a regulator based on the largest possible flow and the smallest ΔP.
Should you come close to the limit of a regulator take the next larger one.

Note
Our formulas apply to ordinary gases and liquids. They do not apply to gases or vapours near or at the point of liquefaction. Also they do not apply to boiling or very viscous liquids.

Safe Product Selection

When selecting a product, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

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