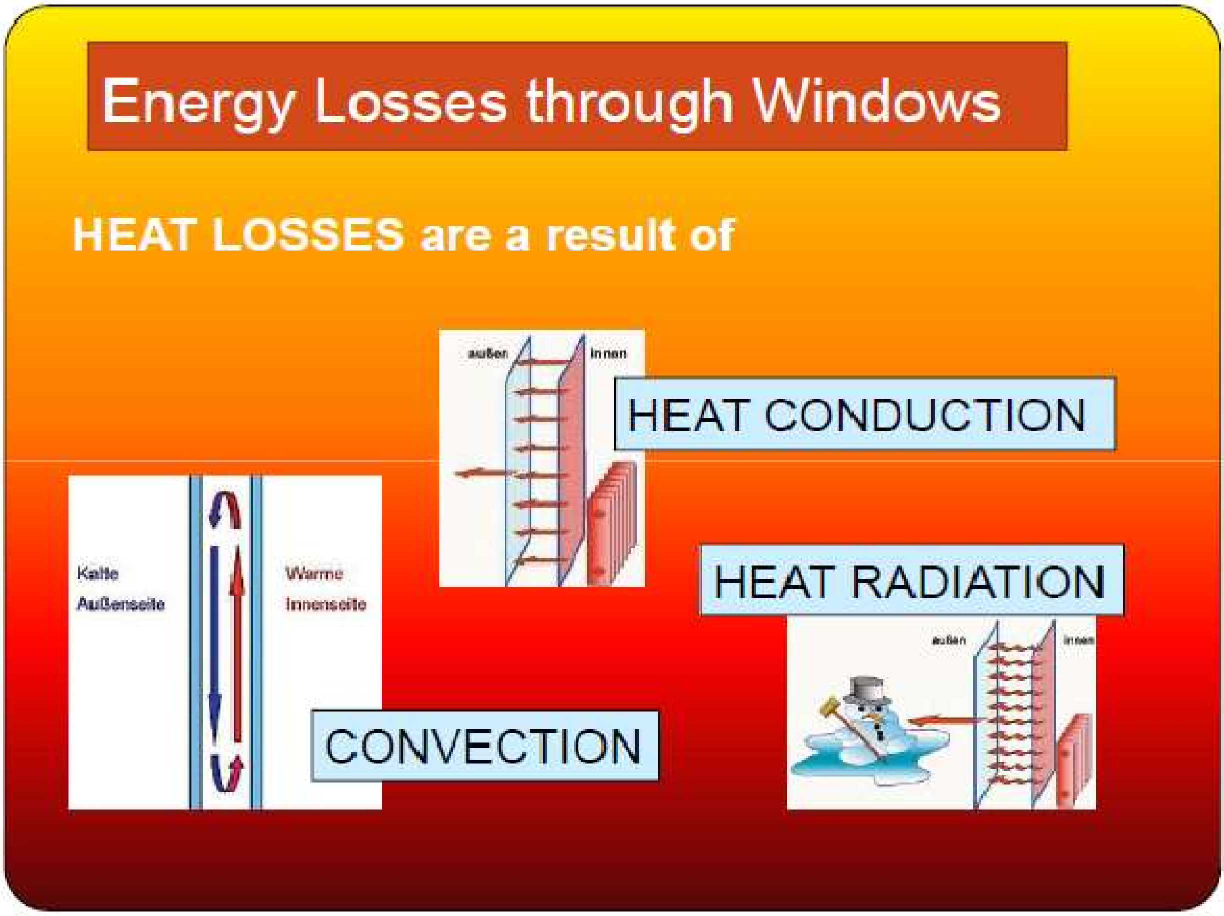
Gas filling of insulating glass units

An effective and ecologically well thought-out generation and use of energy is currently one of the most important tasks of the time. In this context, the glass industry can be proud that the innovations developed and implemented over the last few decades are responsible for an extreme improvement in energy saving in building technology and building culture. In no component of modern architecture has such an improvement in thermal insulation been achieved in recent decades as in modern windows, doors and glass facades. The thermal insulation of these elements could be improved by more than an order of magnitude by combining the most diverse technologies.

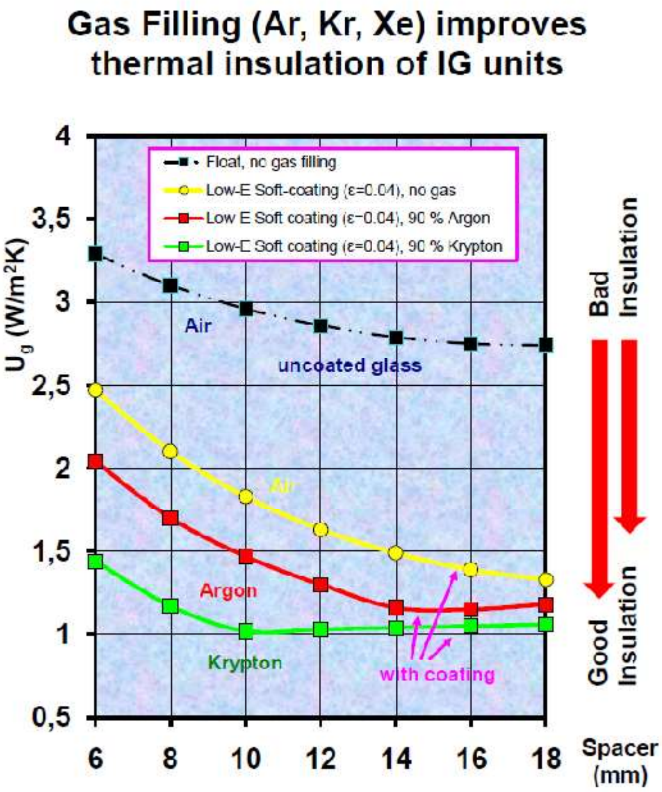
In order to achieve this goal of good thermal insulation, it was necessary to reduce all major forms of energy transport:

- thermal radiation
- Heat conduction
- Material heat transport (e.g. convection)



For this purpose, optimized double or multiple panes of glass have been used in Central Europe for several decades. Equipping the basic glass with coatings of low emissivity (low-ε) leads to an almost complete elimination of the radiation losses through the glass units with the desired thermal insulation.

A few years earlier, in Central and Northern Europe, homogeneous filling of insulating glass units with heat-insulating gases was state-of-the-art in order to also largely limit heat conduction and convection current losses.



For practical reasons, when **filling insulating glass units with gas**, only completely non-toxic, ecologically unproblematic, odorless and tasteless, non-explosive, not easily flammable or combustible, and only colorless and transparent gases without streak formation or birefringence, which are so inert, come into consideration that they do not decompose over time or attack the glass, the sealants or the spacer or promote evaporation from these substances, which could lead to disruptive deposits on the glass in the medium or long term.

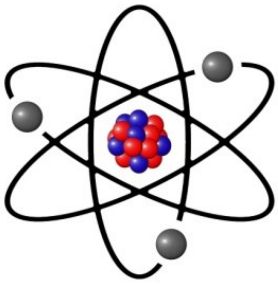
These requirements are met by the noble gases **argon, krypton, xenon** and their mixtures because their thermal conductivity is significantly lower than that of air. The noble gases helium and neon, on the other hand, have better thermal conductivity than air and are therefore not suitable for thermal insulation applications. The noble gas radon is extremely rare, expensive and radioactive, so that it cannot be used for this application either. At room temperature and ambient pressure, these 3 elements are atomic and gaseous and only condense at very low temperatures or high pressure

Noble gases	Density [g/L]		Boiling [°C]	Heat conductivity [$Wm^{-1}K^{-1}$]	
	at 20 °C	at 0°C	at 1 bar	at 300 K	at 0°C
Helium	0.17	0.178	-268.93	0.1567	0.141
Neon	0.84	0.899	-246.08	0.0541	0.0488
Argon	1.66	1.784	-185.8	0.0179	0.0162
Krypton ()	3.43	3.749	-153.22	0.00949	0.0086
Xenon	5.49	5.897	-108.0	0.00569	0.0051

Air	1.161	1.292	Gemisch	0.0262	0.0241

Argon, krypton and xenon are found in the earth's atmosphere in quantities that make their extraction through air liquefaction plants economically possible. Argon in particular is not an exotic or even threatening substance, but a gas that we are surrounded by every day in a concentration of around a percentage.

Composition of dry air in the troposphere	Vol. - %
Nitrogen	78,08
Oxygen	20,95
Argon	0,934
Neon	0,0018
Helium	0,0005
Krypton	0,0001
Xenon	0,000009



Natural argon and xenon from air separation plants contain only the slightest traces of added, rare radioactive isotopes. The radioactivity of krypton is - depending on the type of accumulation - usually so low that the radiation emanating from gas cylinders and batteries or from gas-filled insulating glass units or resulting from filling losses is significantly below the natural background radiation and is therefore also classified as harmless by environmental organizations .

The precise regulations on radiation protection differ slightly in each country and, for example, a detailed compilation of the storage regulations is beyond the scope of this overview. For the sake of order, please contact the office responsible for you (employer's liability insurance association, trade inspectorate, etc.) in order to obtain the regulations that apply to you on the handling, storage and transport of krypton, even though the result of your research will then probably show exemption limits of handling krypton without the need for a license or notification, which is considerably higher than the typical amount that is used or stored in insulating glass companies. As a rule, the all-clear can be given with certainty to both customers and the trade association.

A socio-political or industrial-political assessment of the ecological footprint and other evaluation methods of gas-filled insulating glass units when using krypton and xenon also goes beyond the scope of this compilation. While the insulating benefit of the products filled with these gases is undisputed, ecological aspects of the sometimes energy-intensive extraction of these gases can change the positive assessment of these products in the architectural glass sector. Insulating glass manufacturers and their associations have made statements on this subject in the past with very different results, with the marketing-technical and commercial aspects very obviously overriding the environmentally-oriented statements.

However, the very positive assessment from an ecological point of view and worldwide promotion of filling insulating glass units with argon is currently no longer considered controversial by any relevant interest group.

Although noble gases are not toxic, it should be noted that reduced oxygen concentrations can lead to unconsciousness or death within a short period of time. High concentrations of these gases should therefore be avoided in closed rooms::

Oxygen (Vol.-%)	Symptoms
< 18	Often unnoticed, but nevertheless significant decrease in physical and mental performance
< 10	Rapid loss of consciousness, even without warning signs
< 6	Almost instantaneous loss of consciousness with possible death

The deliberately induced, pitch-changing effect after inhaling heavy gases such as krypton and xenon, or otherwise light helium, may be amusing and entertaining, but can be very dangerous or deadly because these gases are immediately suffocating if not fully recovered can be exhaled from the lungs. In the case of heavy or very light gases, depending on the location, there is a very realistic danger. Krypton and xenon are about 3 and 5 times heavier than air and therefore remain in the lungs for a dangerously long time if the upper body is not bent down again to exhale.

Dangers also result from the possible falling over of gas cylinders, so that there are general rules for handling gases that are compiled on the respective safety data sheets for these gases and that must be observed at all costs.

These safety data sheets can be obtained free of charge from the gas supplier on request and, according to the regulations of the professional associations, should always be posted up near the workplace.

Particular attention should be paid to the fact that, especially in the event of a fire, the fire brigade must be informed immediately where which types of gases are stored or used. Your company safety officer will be happy to explain more to you on request. The gas suppliers and professional associations also provide comprehensive advice on handling and storing pressure vessels.

The Europe-wide standardization of labeling in accordance with EN 1089 Part 3, which stipulates color coding in addition to clear labeling on the shoulder area of the bottle, is helpful when classifying gas bottles. Industrial noble gases and their mixtures with each other and with compressed air can therefore be recognized by the gray color of the bottle itself with a bright green shoulder, with especially pure argon having a dark green shoulder. In the case of specially tested gas bottles with a particularly high level of gas purity for medical use, on the other hand, the body of the bottle is white. There are no binding legal requirements outside of Europe.

Unlike the type of gas, the degree of purity of the gas qualities offered is largely irrelevant for the insulating glass manufacturer, who is usually concerned with a gas filling level of 88 - 96%. All Argon, Krypton or Xenon purity levels available on the market are of sufficient purity and dryness to be well suited for gas fillings of up to 97%. Availability and price (incl. transport and rental) should therefore be decisive when making your selection.

Products and their Declaration	Purity (Vol. %)
Argon 3.0	> 99.9
Argon 4.0	> 99.99
Technical Argon 4.6	> 99.996
Argon 4.8	> 99.998
Argon 5.0	> 99.999

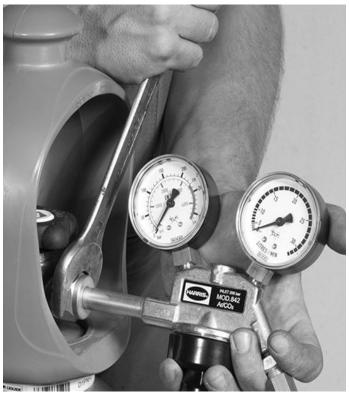
There have been a number of mergers among the globally active manufacturers of industrial gases in the last 10 years, after which only 4 groups remained, the LINDE/BOC/Praxair Group, the Mitsubishi/Taiyo Nippon Sanso Group, Air Liquide/Messer/Airgas Group and the AirProducts/Tyczka Group now share 80% of the world market for technical gases between themselves. As a result, pricing and the ability to deliver krypton and xenon, as well as argon, are not very transparent and are subject to strong, but rationally implausible fluctuations both regionally and in the medium term.

For example, the purchase prices for krypton in the German insulating glass industry have fluctuated regularly by a factor of 20 over the past 10 years; Even if argon is always readily available, the range of fluctuation in gas costs including handling fees and rents is quantity-dependent, but above all regionally different, also at a factor of more than 10, which is very surprising for a product that is so easily available.

It is therefore advisable to obtain several offers when purchasing gas - especially for expensive products such as krypton or xenon - and, if necessary, to consider delivery from nearby countries in order not to be completely at the mercy of the sometimes monopoly-like delivery structures.

Depending on consumption, gas can be delivered in 10 l, 20 l or 50 l bottles or in bundles. The filling pressure of these pressure vessels is usually 200 bar, although there are also 300 bar bottles. This high compression makes it possible to transport large amounts of gas in a space-saving manner, even if our gas filling devices get by with a significantly lower inlet pressure.

Since the handling of gas hoses in this high pressure range is not unproblematic, the pressure directly at the outlet of the gas cylinder is significantly reduced by using a suitable pressure reducer. **Based on the varied experience of the past decades, we strongly recommend the use of the pressure reducer that we have supplied free of charge in order to rule out malfunctions and misunderstandings.**



Unfortunately, the type of screw connection on the gas cylinder is subject to different national standards, although internationalization of the usual standards here is not likely in the foreseeable future. The following summary shows a rough overview of these screw connections, although in many countries it is by no means regulated which standard can or must apply. Especially in Eastern Europe or Asia, depending on the gas supplier, Italian, French, British, Spanish, Central European or completely different standards are used. Worldwide, only the right-handed thread is uniform for non-flammable gases.

The cylinder pressure regulators often have a union nut, such as in Germany:

W 21.8 x 1/14" EXT RH (Germany, DIN 477-6) for argon, krypton and xenon,
W 21.7 x 1/14" EXT RH (Spain, ITC EP-6 Tipo C) for argon, krypton and xenon,,
W 21.8 x 1/14" EXT RH (NL NEN 3268, RU 1) for krypton and xenon,
W 24.32 x 1/14" EXT RH (NL NEN 3268, RU 3) for argon, krypton and xenon,
SI 21.7 x 1.814 EXT RH (France, AFNOR / NF - C) for argon, krypton and xenon.

In many countries, on the other hand, the pressure regulators have an external thread as standard:

SI 21.7 x 1.814 INT RH (Italy UNI 11144-5 / 4409) for krypton and xenon,
W 24.51 - 1/14" INT RH (Italy UNI 11144-8 / 4412-1) for argon,
G 5/8" INT RH (Great Britain, BSI 341-3 and Australia, AS 2473.2),
BSP 5/8" INT RH (Argentina, IRAM 2539 No. 3),
NGO 0.960"-14 INT RH (Brazil, ABNT 245-1)
NGO 0.965"-14 INT RH (USA, CGA 580)

At an international level, attempts are being made with ISO 5145-4 to agree on the W 24 x 2 13.3 - 14.7 EXT RH thread for argon and krypton, while for xenon it could be with ISO 5145-1 in the future give a thread W 24 x 2 11.2 - 16.8 EXT RH.

This variety of standards is very annoying in our case. Recreational divers are also familiar with this annoying problem with the fittings of their gas cylinders, because gas suppliers do not always follow the national standards either. We regret that when the appropriate pressure regulator is delivered, in individual cases the gas cylinders procured by the customer do not match the nationally prescribed regulator supplied. To be on the safe side, we therefore ask our customers to put us in touch with the gas supplier to ensure delivery of the right pressure regulator.

On the other hand, there are often problems with cylinder pressure regulators from local gas suppliers, in that they only very rarely actually offer pressure regulators, but instead the flow regulators that are customary in argon welding, with gas flow rates that are far too low. However, with such regulators, our gas filling devices are too severely limited in the gas supply and indicate with a continuous tone alarm that the gas supply is only insufficient.

The difference between a pressure regulator and a flow regulator is easy to see on the second pressure gauge: In both systems, the first pressure gauge on the bottle side is used to check the bottle pressure and thus the filling level of the bottle. With a pressure regulator, the pressure gauge on the outlet side shows the outlet pressure set with the rotary knob at the bottom in the printed unit bar or psi.

With a flow controller, on the other hand, the second instrument shows the maximum flow in the printed unit l/min (argon).

The unit psi, which is mainly used in Anglo-American countries, is converted into the bar unit, which is still often used in Germany and was actually replaced by the SI unit Pa, as follows:

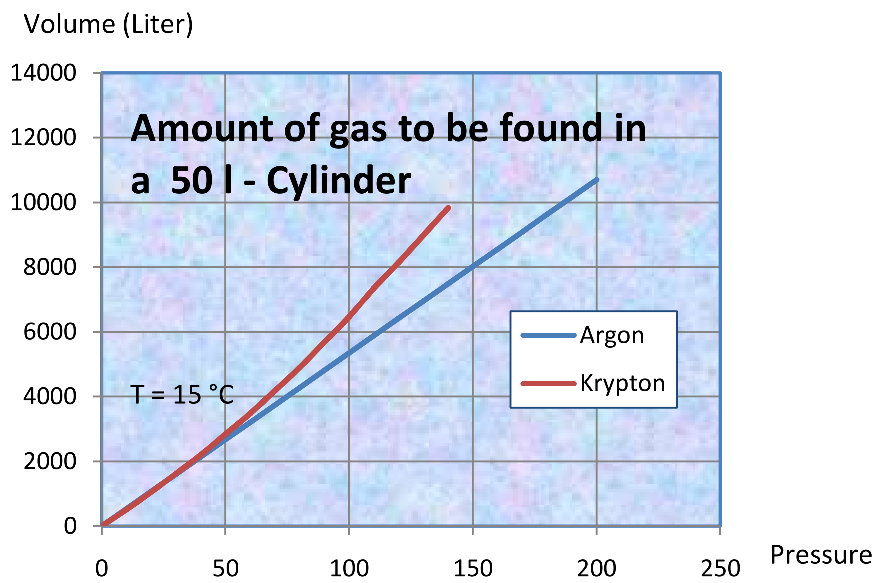
1 bar = 1000 mbar = 1000 hPa = 100,000 Pa = 14.5 psi (pounds/square inch)

= 1019.73 mm water = 750.06 mm Hg

= 401.47 inches water = 29.53 inches Hg

By the way, when operating the pressure regulator, please do not forget to fully open the small black outlet valve of the cylinder pressure regulator so as not to unnecessarily reduce the maximum gas flow. Our gas filling devices also indicate this limitation in the gas supply with a continuous tone alarm if the gas supply is insufficient.

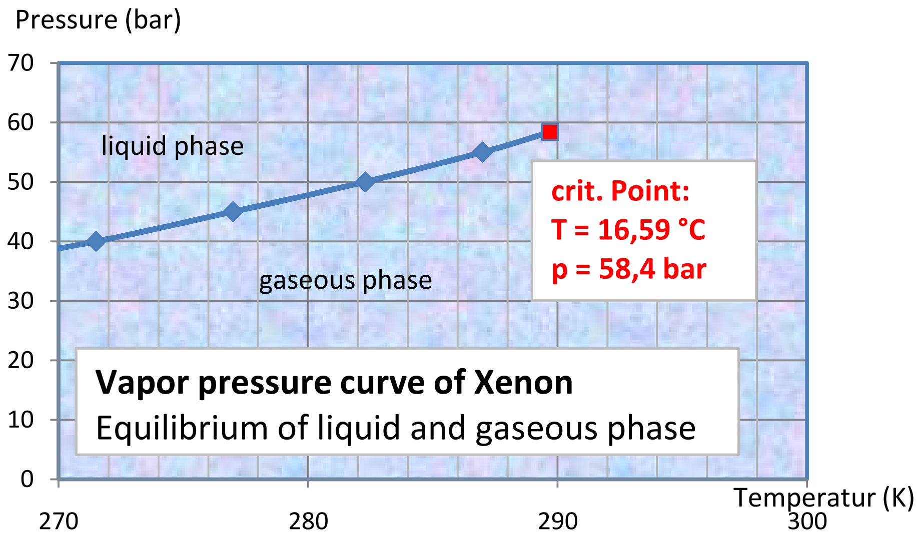
But how can the level of the gases in the bottle be read from the pressure at the outlet of the bottle? A relatively simple physical consideration helps here: In a rough approximation, the volume of gas in the bottle - applying the ideal gas law p*V = const. - in the case of argon and krypton, greater than the internal volume of the gas cylinder by the factor indicated in bar by the cylinder manometer. With a 50 l gas cylinder with a filling indicator of 200 bar, you can assume a usable gas quantity of 200 x 50 l = 10,000 l, which corresponds to the internal volume of 700 insulating glass units of 1 square meter and a 14 mm spacer.



In the case of argon, this simple estimate underestimates the amount of gas actually present in the bottle by up to 7%, and in the case of krypton by almost 30%, since both gases in the bottle are gaseous at room temperature, but only approximately the above-mentioned ideal gas law p* V = const. correspond to.

The deviation is even greater for xenon, for which this calculation can only provide a rough estimate well below around 40 bar.

With xenon - due to its special vapor pressure curve - below its critical point at 58.4 bar and 16.59 °C only the upper part of the bottle contents is gaseous, the rest at the bottom of the bottle is xenon in a liquid state.



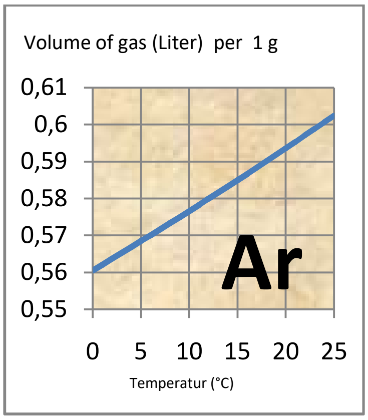
When removing (note: only from standing bottles, from above, i.e. from the gas phase!), part of the liquid xenon evaporates, but the bottle pressure remains almost unchanged - until the entire liquid part has evaporated.

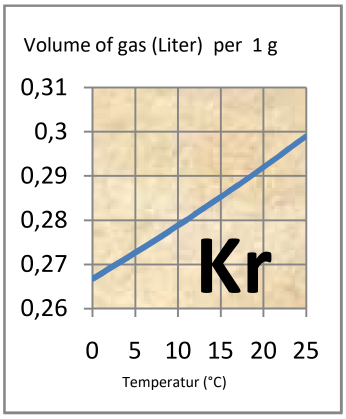
With a pressure display of more than 50 bar, it can therefore only be roughly estimated that more than 50 times the bottle volume is still in the bottle. With xenon, exact values cannot be derived from a cylinder pressure measurement.

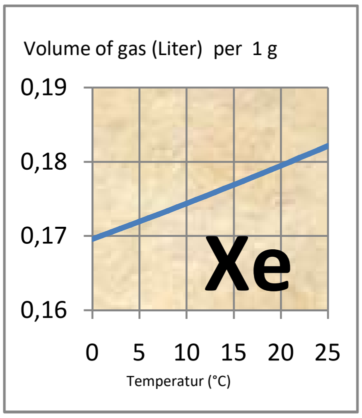
The filling quantity in the bottle or the quantity of inert gases effectively used to fill a disc can be determined more precisely with our SENSOLINE cryptometer (a special scale), which we are happy to offer you as a useful special accessory for monitoring gas losses during gas filling.

The achievable measurement accuracy of a volume consumption measurement by weighing (accurate to 1 g) is in the range of 0.6 liters for argon, around 0.3 liters for krypton and around 0.2 liters for xenon, so that significantly more precise gas loss measurements than are possible with all commercially available flow meters with a connected totalizer by weighing the gas bottle.

Particular attention should be paid to the temperature dependency of the gas density:







Incidentally, the above comments also apply to the 300 bar gas cylinders that are also sometimes offered in Germany, although it is unfortunately not surprising that these gas cylinders in Germany again have their own screw connection standard, which has not yet been imitated anywhere in the world.

An alternative to supplying gas cylinders or containers, especially for argon, is to use tanks that are supplied with liquid argon. The capacity of these tanks is typically 2,500,000 - 50,000,000 liters of gas, whereby the contents of at least 1 - 10 typical 50 l gas cylinders are vaporized and then either used or released into the open air.

Argon tanks are therefore only economically suitable for insulating glass manufacturers with a regular and average production of well over 500 square meters of argon-filled double panes or 250 square meters of argon-filled triple panes.

At the gas extraction points of the tank-based pipe systems there are normal pressure reducers - analogous to the gas cylinders and cylinder batteries - in order to lower the gas pressure at the outlet of the tank to the appropriate, lowest possible operating pressure of our gas filling systems.

Please expressly inform us about the use of gas pipeline systems in your production, since when using gas directly from gas cylinders we have no need to use foreign matter filters, which can also be a source of leaks. In the case of pipe systems, on the other hand, the use of particle filters upstream of the gas filling device is urgently recommended, since experience has shown that normal repair or expansion work on the pipe system introduces metal chip or sealant residues into the entire pipe system. Mechanical filtering of the gases from such systems has proven to be unavoidable in practice.