TECHNICAL INFORMATION

PVDF LINER VENTILATION EXHAUST SYSTEM

General information

Exhaust systems

Exhaust piping systems are mainly used in the area of semi-conductor industry as well as in standard industrial applications for the transport of contaminated process gases.
Different exhaust gases containing chemicals would react together if they are transported in a single exhaust system. For example Ammoniac reacts with the acid parts especially with hydrogen chloride. During this a reaction of extreme fine Aerosols are created which can not be extracted with technically justifiable cost. Therefore, especially in the semi-conductor industry, the exhaust streams for process gases should be separated direct at the machine connection consequently according to their composition direct at the machine connection.
In general 4 different exhaust streams are distinguished.

- General exhaust
- Solvent exhaust
- Acid exhaust
- Caustic exhaust

Material selection for exhaust duct systems

For the selection of the suitable material which should be applied in exhaust systems the following criteria are important:

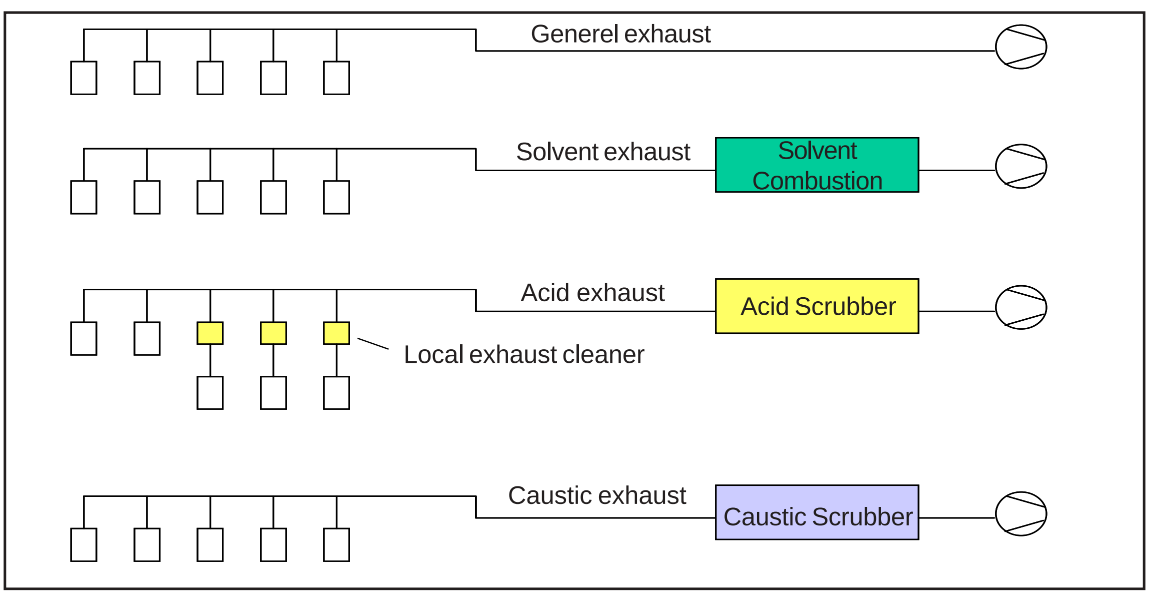
- corrosion resistance
- chemical resistance
- temperature resistance
- fire resistance requirements
- fire behaviour
- installation
- costs

The material PVDF does offer in all criteria excellent performance and is therefore perfectly suitable for the application in exhaust chemical duct systems. Furthermore PVDF exhaust duct offers further advantages as:

- easy and safe connection methods of piping components
- light weight
- very good long term properties
- temperature resistance up to 140 °C

Exhaust stream	Main substance of content	Load
General exhaust	-	none
Solvent exhaust	Isopropanol Aceton etc.	noncritical
Acid exhaust	Hydrogen chloride Hydrogen fluoride	corrosive deposits
Caustic exhaust	Ammoniac	condittionally corrosive (if contaminated)

Table 1: Exhaust gases in comparison



Picture 1: Typical layout of exhaust systems in the industry for the transport of process gases

Material Properties

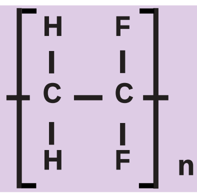
General properties of PVDF

PVDF is an extremly pure polymer and contains in comparison with a lot of other plastics no stabilizers UV-, thermostabilizers, softener, lubricants or flame-retardant additives. It is a unique solution for exhaust corrosive gases in the semiconductor and chemical industry. Due to its chemical inertness, reaction against most media is nearly impossible.

Typical properties of PVDF are:

- Simple processing
- Good weldability
- Good heat formability

PVDF is distinguished in comparison with Stainless Steel by its advantageous price and excellent chemical resistance, even in connection with high temperatures.



Picture 2: Chemical structure of PVDF

Chemical resistance

PVDF has an outstanding resistance to most anorganic and organic acids, oxidising media, aliphatic and aromatic hydrocarbons, alcohol and halogenated solvents.

It is resistant to halogens - in particular bromine - and weak bases. It is degraded by fuming sulphuric acid, some strong basic amines, concentrated and hot alkalis as well as alkaline metals.

PVDF swells in high polar solvents e.g. acetone and ethylacetat and is soluble in polar solvents, e.g. dimethylformamide and dimethylacetamide.

Behaviour at UV-radiation

Solef PVDF contains a high percentage of fluorine. The bond between the highly electronegative fluorid and carbon atom is extremely strong with a dissociation energy of 460 kj/mol. Therefore, PVDF is resistant to environment UV radiation (> 232 nm).

Specific properties of PVDF:

	Properties	Standards	Units	PVDF
Physical properties	Density at 23°C	ISO 1183	g/cm^3	1,78
	Melt flow rate MFR at 230 °C/5 kg	ISO 1133	g/10 min	6 - 24
Mechanical properties	Tensile stress at yield	ISO 527	MPa	50
	Elongation at yield	ISO 527	%	9
	Elongation at break	ISO 527	%	80
	Impact strength unnotched at +23 °C	ISO 179	kJ/m^2	124
	Impact strength notched at + 23 °C	ISO 179	kJ/m^2	11
	Ball indentation hardness acc. Rockwell	ISO 2039-1	MPa	80
	Flexural strength	ISO 178	MPa	80
	Modulus of elasticity	ISO 527	MPa	2000
Thermal properties	Vicat softening point VST/B/50	ISO 306	°C	140
	Heat deflection temperature HDT/B	ISO 75	°C	145
	Linear coefficient of thermal expansion	DIN 53752	$K^{-1} \times 10^{-4}$	1,2
	Thermal conductivity at + 20 °C	DIN 52612	W/(mxK)	0,13
Electrical properties	Volume resistance	VDE 0303	OHM cm	$> 10^{13}$
	Surface resistance	VDE 0303	OHM	$> 10^{12}$
	Relative dielectric constant at 1 MHz	DIN 53483	--	7,25
	Dielectric strength	VDE 0303	kV/mm	22
Physiological properties	Physiologically non-toxic	EEC 90/128	--	Yes
	FDA approved	--	--	Yes
	Colour	--	--	natural

Fire Rating

PVDF is a halogen containing polymer which offers an excellent fire protection without flame-retardant additives. During combustion of PVDF only a slight amount of smoke development arises. With an oxygen index of about 44 %, PVDF is in the best flammability class V0 according to UL 94 (under 21 % oxygen index, plastic material is considered to be flammable).

PVDF is tested according ASTM E 84 (or UL723). This test is to evalualte both the flame spread on the surface of a material and the density of the smoke released by the combustion. The results are flame propagation index: 5; smoke density: 90; classification: class 1.

The PVDF Liner Ventilation exhaust system is tested and certified acc. FM4910.

Advantages:

· Wide temperature range
· High heat deflection temperature
· Very good chemical resistance, even at elevated temperatures
· Good resistance against UV- and Gamma-radiation
· Pure material with no additives
· Very good surface quality
· High ageing resistance
· Low friction coefficient
· Excellent abrasion resistance
· Very good anti-friction properties
· Good mechanical properties
· Excellent insulating characteristics
· Flame retardant
· Physiologically non-toxic
· Good and simple processable

PVDF Exhaust system

For the installation of PVDF duct systems a wide range of products and connection technologies are available. To install the PVDF duc system certain criteria must be followed to ensure the integrity of a system.

General product performance

- permissible vacuum
- maximum pressure
- chemical resistance table

Transport and storage of piping components

General installation guidelines

Support system

Thermal expansion

Connection methods for piping components and semifinished products

Quality assurance during installation and test of installed piping system

Permissible buckling pressures for PVDF liner ventilation exhaust piping systems

In the table stated below, the data apply to air or water. The given values are based on a safety factor of 2,0 (minimum safety coefficient for stability calculations).

OD [mm]	s [mm]	20 °C		40 °C		60 °C		80 °C		100 °C		120 °C	
		10 yrs. [Pa]	25 yrs. [Pa]	10 yrs. [Pa]	25 yrs. [Pa]	10 yrs. [Pa]	25 yrs. [Pa]	10 yrs. [Pa]	25 yrs. [Pa]	10 yrs. [Pa]	25 yrs. [Pa]	10 yrs. [Pa]	25 yrs. [Pa]
63	2,5	62999	60479	47879	45360	33600	31920	23520	21840	19320	17640	16800	15960
110	3,0	19679	18891	14956	14169	10495	9970	7347	6822	6035	5510	5248	4985
140	3,0	9375	9000	7125	6750	5000	4750	3500	3250	2875	2625	2500	2375
160	3,0	6229	5980	4734	4485	3322	3156	2326	2160	1910	1744	1661	1578
200	3,0	3153	3027	2396	2270	1682	1598	1177	1093	967	883	841	799
250	3,0	1600	1536	1216	1152	853	811	597	555	491	448	427	405
315	4,0	1900	1824	1444	1368	1013	963	709	659	583	532	507	481
355	4,0	1321	1269	1004	951	705	670	493	458	405	370	352	335
400	5,0	1811	1738	1376	1304	966	918	676	628	555	507	483	459

Permissible component operating pressure MOP for PVDF liner ventilation exhaust piping systems

The maximum component operating pressure for PVDF liner ventilation exhaust system is 1 bar from 20°C up to 95°C.

For the calculation of the operating pressure in piping systems system a reduction coefficient fs=0,8 for butt welding and fs=0,4 for hot gas welding have to be applied.

These operating pressure have to be also reduced by the corresponding reducing coefficients for every application.

Material Properties
Installation Guidelines
Calculation Guidelines
Connection Systems
Applications
Approvals and Standards

Installation Guidelines

Transport Storage and handling

At the transport Storage and handling of pipes and fittings, the following guidelines have to be observed in order to avoid damages:

- Transport and support pipes on the full length, that means do not bend or deform them. Take pipes/fittings carefully from the transport vehicle. Do not throw items.

- The storage area has to be even and free from waste, stones, screws, nails, moisture and any other conditions which may damage the pipe/ fitting/valve.

- Impact- and bending stresses at temperatures < 0°C have to be avoided.

- Damages of the surface (scratches, marks, ...), as they occur at dragging of pipes, have to be avoided.

- At piling of pipes, storage heights of 1 m may not be exceeded. In order to avoid a rolling away of the pipes, wooden wedges have to be situated at the outside pipes. Smaller and lighter pipes should be stored on top of bigger sizes.

- Cardboard boxes from fittings and/or valves should be removed prior to processing only.

Fitting storage area

Pipe stock

General Installation guidelines

Due to the lower stiffness and rigidity as well as the potential length expansions (caused by changes in temperature) of thermoplastics in comparison with metallic materials, the following requirements for the fixing of piping elements should be met.

On laying of pipes above ground expansion and contractions of pipes in both radial and axial directions must not be hindered - that means, installation with radial clearance, position of compensation facilities, control of changes in length by reasonable arrangement of fixed points.

Pipe supports have to be calculated to avoid pin-point stresses, that means the bearing areas have to be as wide as possible and adapted to the outside diameter (if possible, the enclosing angle has to be chosen > 90°).

The inside surface of the pipe clip have to be designed in that way that no mechanical damage to the pipe surface could happen.

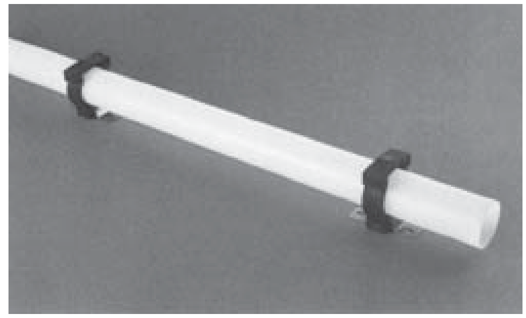
Valves (in certain cases also tees) should basically be installed on a piping system as fixed points.

Installation by means of pipe clips

Pipe supports made of steel or of thermoplastics are available for plastics pipes. Steel clips have at any rate to be lined with tapes made of PE or elastomers, as otherwise the surface of the plastics pipe may be damaged. AGRU plastics pipe clips as well as pipe holders are very good suitable for installation. These may be commonly applied and have especially been adjusted to the tolerances of the plastics pipes.

Therefore they serve e.g. as sliding bearing at horizontal installed piping systems in order to take up vertical stresses. A further application range of the AGRU pipe clip is the function as guiding bearing which should hinder a lateral buckling of the piping system as it can also absorb transversal stresses.

Pipes should be supported by means of pipe clips, which do not fix the pipe in an axial direction.



AGRU Pipe clip support

Calculation of support distances for pipes (acc. DVS 2210-1)

The support distances from the thermoplastic piping systems should be determined under consideration of the licensed bending stress and the limited deflection of the pipe line. On calculating of the support distances, a maximum deflection of $L_A/500$ to $L_A/750$ has been taken as basis. Under consideration of the previous deflection of a pipe line between the centers of tire impact results a permissible support distance of the pipe system.

$$L_A = f_{LA} \cdot \sqrt[3]{\left(\frac{E_C \cdot J_R}{q}\right)}$$

L_A .... Permissible support distance [mm]

f_{LA} .... Factor for the deflection (0,80 ... 0,92) [-]

E_C .... Creep modulus for t = 25 years [N/mm²]

J_R .... Pipe inactivity moment [mm^4]

q .... Line load out of Pipe-, filling- and additional weight [N/mm]

Remark: The factor f_{LA} is determined depending on the pipe outside diameter. There is the following relation valid:

$$\min \leftarrow OD \rightarrow \max$$
$$0{,}92 \leftarrow f_{LA} \rightarrow 0{,}80$$

Usual Support distances for Liner Ventilation Exhaust Systems can be taken from the following tables.

da OD [mm]	s [mm]	20°C [cm]	30°C [cm]	40°C [cm]	50°C [cm]	60°C [cm]	70°C [cm]	80°C [cm]	100°C [cm]	120°C [cm]
63	2,5	167	163	156	149	146	139	132	118	104
110	3,0	234	228	219	209	204	194	185	165	146
140	3,0	266	260	249	238	232	221	210	188	166
160	3,0	285	278	266	255	249	237	225	201	178
200	3,0	318	311	298	285	278	265	252	225	199
250	3,0	354	346	331	317	310	295	280	251	221
315	4,0	418	409	391	375	366	348	331	296	261
355	4,0	442	432	414	396	387	367	349	313	276
400	5,0	489	478	458	438	428	407	387	346	306

Table 3: Support distances

Calculation of the linear change

Changes in length of a plastic piping systems are caused by changes in the operating or test process. There are the following differences:

- Linear change by temperature
- Linear change by internal pressure load
- Linear change by chemical influence

Linear change by temperature

If the piping system is exposed to different temperatures (operating temperature or ambient temperature) the situation will change corresponding to the moving possibilities of each pipe line. A pipe line is the distance between two anchors.

For the calculation of the linear change use the following formula:

$$\Delta L_T = \alpha \cdot L \cdot \Delta T$$

ΔL_T ..... Linear change due to temperature [mm]

α .... Linear expansion coefficient [mm/(m·°K)]

L .... Pipe length [m]

ΔT ..... Difference in temperature [°K]

The lowest and hightest pipe wall temperature T_R by installation, operation or standstill of the system is basis at the determination of ΔT.

α-average value	mm/(m.K)	1/K
PVDF	0,12	$1{,}2 \times 10^{-4}$

Table 5: Linear expansion coefficient

Linear change by internal pressure load

The by internal pressure caused length expansion of a closed and frictionless layed piping system is:

$$\Delta L_P = \frac{0{,}1 \cdot p \cdot (1 - 2\mu)}{E_c \cdot \left(\frac{da^2}{di^2} - 1\right)} \cdot L$$

ΔL_P ..... Linear change by internal pressure load [mm]

L .... Length of piping system [mm]

p .... Operating pressure [bar]

μ .... Transversal contraction coefficient [-]
(In general 0,4 for thermoplastic materials)

E_C .... Creep modulus for t = 25 years [N/mm²]

da ..... Pipe outside diameter [mm]

di ...... Pipe inside diameter [mm]

Linear change by chemical influence

It may come to a linear change (swelling) of thermoplastic piping system as well as to an increase of the pipe diameter under influence of certain fluids (e. g. solvents). At the same time, it comes to a reduction of the mechanical strength properties. To ensure a undisturbed operation of piping systems out of thermoplastics conveying solvents, it is recommended to take a swelling factor of f_{Ch} = 0,025 ... 0,040 [mm/mm] into consideration at the design of the piping system.

The expected linear change of a pipe line under the influence of solvents can be calculated as follows:

$$\Delta L_{Ch} = f_{Ch} \cdot L$$

ΔL_{Ch} ... Linear change by swelling [mm]

L .... Length of piping system [mm]

f_{Ch} .... Swelling factor [mm/mm]

Remark: For practically orientated calculations of piping systems conveying solvents out of thermoplastic materials, the f_{Ch}-factor has to be determined by specific tests.

Calculation of the minimum straight length

Linear changes are caused by changes in operating or ambient temperatures. On installation of vontilation piping systems, attention must be paid to the fact that the axial movements are sufficiently compensated.

In most cases, changes in direction in the run of the piping may be used for the absorption of the changes in length with the help of the minimum straight lengths. Otherwise, compenstion loops have to be applied.

The minimum straight length is expressed by:

$$L_s = k \cdot \sqrt{(\Delta L \cdot da)}$$

L_S .... Minimum straight length [mm]

ΔL ..... Change in length [mm]

da ..... Pipe outside diameter [mm]

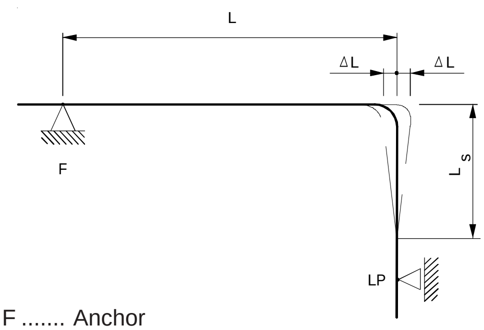
k .... Material specific proportionality factor (Average values: PVDF 15.2)

If this cannot be realised, use compensators of possibly low internal resistance. Depending on the construction, they may be applied as axial, lateral or angular compensators.

Between two anchor loads, a compensator has to be installed. Take care of appropriate guiding of the piping at loose points whereby the resulting reaction forces should be taken into account.

Note: An installation temperature of 20 °C is basis at the calculation of the k-values. At lower temperatures, the impact strength of the material has to be taken into account.

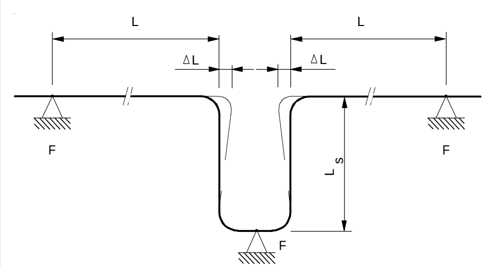
Principle drawing a L-compensation elbow



F .... Anchor
LP ..... Loose point (e.g. pipe clips)

Picture 12: L-compensation

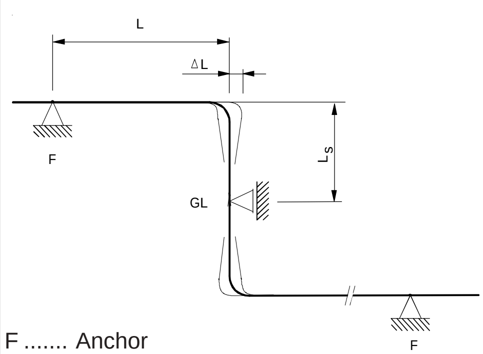
Principle drawing of an U-compensation elbow



F .... Anchor
GL .... Sliding bearing

Picture 13: U-compensation

Principle drawing a Z-compensation elbow



F .... Anchor
GL .... Sliding bearing

Picture 14: Z-compensation

Determination of the pipe cross section

Flowing processes are calculated by means of the continuity equation. For fluids with constant volume flow, the equation is:

$$\dot{V} = 0{,}0036 \cdot A \cdot v$$

$\dot{V}$ ....Volume flow [m³/h]

A ...Free pipe cross section [mm²]

v ....Flow velocity [m/s]

For gases and vapours, the material flow remains constant. There, the following equation results:

$$\dot{m} = 0{,}0036 \cdot A \cdot v \cdot \rho$$

$\dot{m}$ ....Material flow [kg/h]

ρ ....Density of the medium depending on presure and temperature [kg/m³]

If in these equations the constant values are summarized, the formulas used in practice for the calculation of the required pipe cross section result there of:

$$d_i = 18{,}8 \cdot \sqrt{\frac{Q'}{v}}$$

$$d_i = 35{,}7 \cdot \sqrt{\frac{Q''}{v}}$$

d_i ....Inside diameter of pipe [mm]

Q' ....Conveyed quantity [m³/h]

Q'' ....Conveyed quantity [l/s]

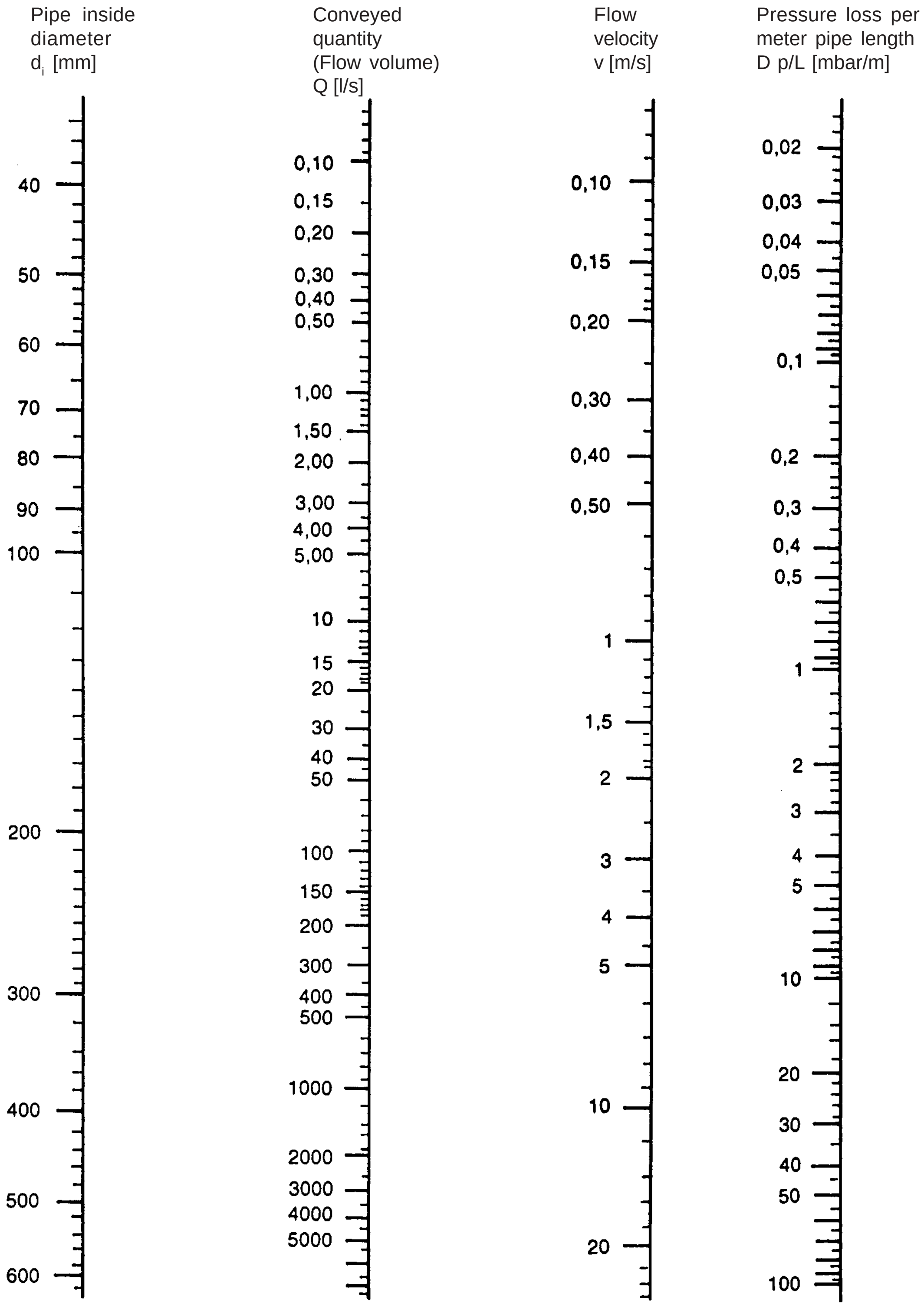
v ....Flow velocity [m/s]

Reference values for the calculation of flow velocities may be for fluids:

Reference values for the calculation of flow velocities for gases
$v \sim 10 \div 30$ m/s

Flow nomogramm

For rough determination of flow velocity, pressure loss and conveying quantity serves the following flow nomogram. At an average flow velocity up to 20m of pipe length are added for each tee, reducer and 90° elbow, about 10m of pipe for each bend r = d and about 5m of pipe length for each bend r = 1,5 x d.



Connection Methodes for piping components

Connection systems have to be designed to avoid any kind of stresses. Stresses which may arise from differences in temperature between installation and operation conditions must be kept as low as possible by taking appropriate measures.

Depending on pipe dimension, following conneciton systems are applicable:

Dimension	Flange connection	Heating element butt welding - HS	Hot gas welding	Sanitary connection
OD 63 - 200 mm	■	■	■	■
OD 250 - 315 mm	■	■	■	
OD 355 - 400 mm		■	■	

Tabel 7: Connection Systems

Flange connections of piping systems

Before applying of the screw initial stress, the sealing faces have to be aligned plane parallel to each other and fit tight to the sealing. The drawing near of the flange connection with the thereby occuring tensile stress has to be avoided under any circumstances. The length of the screws has to be chosen this way that the screw thread possibly flushes with the nut. There have to be placed washers at the screw head and also at the nut. The connecting screws have to be screwed by means of a torque key (torque values see supply program).

It is recommendable to brush over the thread, e.g. with molybdenum sulphide, so that the thread stays also at longer operation time easy-running.

Unions

To avoid unpermissible loads at the installation, unions with round sealing rings should be applied. The union nut should be screwed manually or by means of a pipe band wrench (common pipe wrenches should not be used). Prevent the application of unions at areas with bending stresses in the piping systems.

Welded joint

Welding is a very reliable and proven connection method. In case of PVDF Liner Ventilation Exhaust Piping Systems, Heating Element - and Hot Gas Welding are the preferred welding technology.

Welding personnel

The quality of the welded joints depends on the qualification of the welder, the suitability of the machines and appliances as well as the compliance of the welding guidelines. The welding joint can be checked through non destructive and/or destructive methods.

The welding process should be supervised. Method and size of the supervision must be agreed from the parties. It is recommended to document the method data in welding protocols or on data medium.

Each welder must be qualified and must have a valid proof of qualification. The intended field of application can be determined for a type of qualification. For the heating element butt welding method for sheets as well as for industrial piping system construction, DVS 2212 part 1 is valid. For pipes OD > 250 mm an additional proof of qualification is necessary.

Welding machines

Utilize proven welding techniques for the joining of components, only approved welding machines should be used. The application of non approved welding techniques can result in reduced joint quality in both strength and purity. In addition, welding parameters should have been recorded for every performed welding. A print-out label with significant welding information is required to identify and evaluate every welding joint.

The utilized welding machines and appliances must correspond to the guidelines of the DVS 2208.

In general, following facts should be considered of welding PVDF Ventilation piping systems:

- Application of suitable and approved welding machines
- Application of trained and certified personnel
- Consideration of the prescribed welding guidelines (parameters)
- Performance of the welding process in the cleanroom area
- Complete control and documentation of the performed welding operations

The design of a system should consider installation conditions such as space and environment conditions. Based on the above criteria the choice of welding technique is crucial for a successful installation. The installation should be planned to fabricate assemblies and subassamblies to reduce the amount of welds conducted in restricted (confined) locations.

Welding joint evaluation

The control of the welding joint quality on site should be performed only by certified personnel with proper knowledge of the welding technique. Different tests acc. DVS guidelines may be performed:

- Tensile test for the determination of the short time welding factor (DVS 2203 part 1)
- Bending test for the determination of the bending angle (DVS 2203 part 5)
- Optical assessment of the welding joint (DVS 2202)
- Pressure test on the installed pipeline acc. DVS 2210 part 1, Supplement 2 (DIN 4279)
- Spark testing

Measures before the welding operation

The welding area has to be protected from bad weather conditions (e.g. moisture, wind, UV-radiation, temperatures < 0 °C). If appropriate measures (e.g. preheating, tent-covering) secure that the required pipe wall temperature will be maintained, welding operations may be performed at any outside temperatures, provided, that it does not interfere with the welder's manual skill. If necessary, the weldability has to be proved by performing sample welding joints under the given conditions.

If the welding product should be disproportionately warmed up as a consequence of UV-radiation, it is necessary to take care for the equalization of temperature by covering the welding area.

The pipe ends should be closed during the welding process.

The joining areas of the parts to be welded must be clean (free from dirt, oil, shavings or other residues) and in a straight cutted planed surface condition before start the welding process.

On applying any of these methods, keep the welding area clear of flexural stresses (e.g. careful storage, use of pipe supports, etc.).

Heating element butt welding (following to DVS 2207, Part 15)

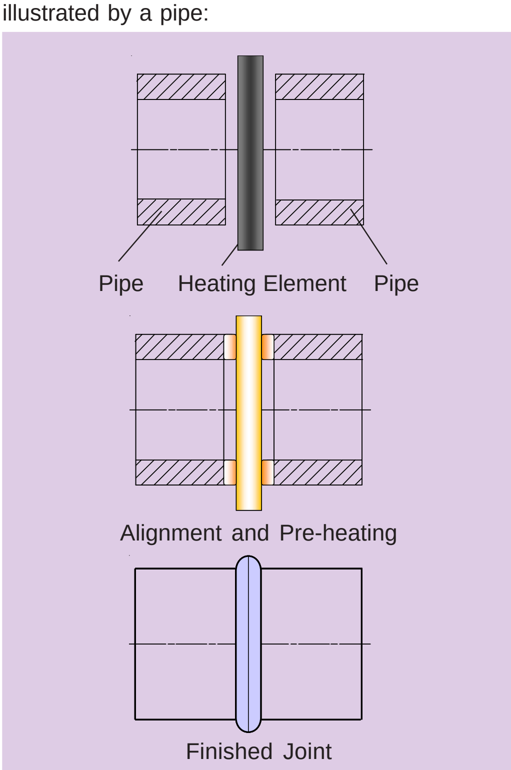
Butt fusion (HS) has been utilized for the past 20 years and has been proven to be a reliable and a efficient joining method.

Butt fusion maintains the advantage; it can be done in a variety of environments. Wind or a strong breeze can make IR welding troublesome, for these cases butt fusion is preferred. If welds are to be made in an outside area, butt fusion should be used. Field welds in place can also be accomplished with butt fusion. A variety of different types of butt fusion equipment is available.

Welding method discription

The welding faces of the parts to be joined are aligned under pressure onto the heating element (alignment). Then, the parts are heated up to the welding temperature under reduced pressure (pre-heating) and joined under pressure after the heating element has been removed (joining). During cooling, the joining pressure has to be maintained.

Principle of the heating element butt welding illustrated by a pipe:



Picture 15: Scheme of heating element butt welding

Preparations before welding

Control the necessary heating element temperature before each welding process. That happens e.g. with a high speed temperature probe for surface measurements. The control measurement must happen within the effective joining area of the heating element. To reach a thermal balance, the heating element has to maintain the required temperature for at least 10 minutes.

For a best possible welding, clean the heating element with clean, fluffless paper before each welding process. The non-stick coating of the heating element must be undamaged in the effective joining area.

For the utilized machines, the particular joining pressure or joining force must be given. They can refer to e.g. construction information, calculated or measured values. In addition during the pipe welding process by slow movement of the workpieces occurs a movement pressure or movement force (drag force) which can be seen on the indicator of the welding machine and shall be added to the first determined joining force or joining pressure.

The nominal wall thickness of the parts to be welded must correspond to the joining area and welding parameters.

Before clamping the pipes and fittings in the welding machine they must be axial aligned. The light longitudinal movement of the parts to be welded is to ensure for exsample through adjustable supports or swinging hangers.

The areas to be welded should be cleand immediately before the welding process with a clean, fat-free cleaning agent, so that they are plane parallel in this clamped position. Permissible gap width under adapting pressure see following table.

Pipe outside diameter [mm]	Die gap width [mm]
≤ 355	0.5
400 ... < 630	1.0

Table 8: Permissible die gap

Together with the control of the gap width, also the disalignment should be checked. The disalignment of the joining faces to one another should not exceed the permissible figure of 0.1 x wall thickness.

Finished planed welding areas shall not be dirty or touched by hands otherwise a further planing process is necessary. Shavings which are fallen into the pipe must be removed.

Heat temperatures

The heating element temperatures are listed in the following table. Generally the aim is to use higher temperatures for smaller wall thicknesses and the lower temperatures for larger wall thicknesses.

	Heating element temperature [°C]
PVDF	240 ± 8 °C

Table 9: Heating element temperature

Specific heat pressure

In most cases, the heat pressure [bar] or the heating force [N], which has to be adjusted, may be taken from the tables on the welding machines. For checking purposes or if the table with pressure data are missing, the required heating pressure has to be calculated according to the following formula:

$$A_{Pipe} = \frac{(OD^2 - di^2) \cdot \pi}{4}$$

$$A_{Pipe} \sim d_m \cdot \pi \cdot s$$

$$F = p_{spec} \cdot A_{Pipe}$$

When using hydraulic equipment, the calculated welding force [N] has to be converted into the necessary adjustable hydraulic pressure.

Welding procedure:

Alignment (Bead height)

The welding surfaces are pressed onto the heating element until the whole area is placed plane parallel all over the circumference. This is seen by the development of the bead. The alignment is finished when the bead height has reached the requested values on the whole pipe circumference. The bead height indicates that the joining area completely locate on the heating element.

	Specific heating pressure [N/mm²]
PVDF	0.10

Table 10: Specific heating pressure

Pre-heating

During the pre-heating process the areas must contact the heating element with low pressure. The pressure shall be nearly to zero (< 0.01 N/mm²). On pre-heating the heat infiltrate the parts to be welded (plasticizing) and heat up to the required welding temperature.

Change over time (Adjustment)

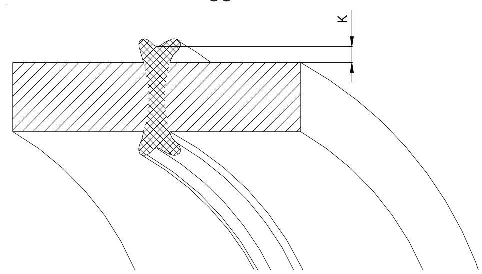
After the pre-heating the weld surfaces shall be removed from the heating element. It shall be taken away (change over) from the weld surfaces without damage and contamination. After that the weld surfaces must close very quickly until prior to contact. The change over time should be kept as short as possible, otherwise the plasticised area will cool down and the welding seam quality would be influenced in a negative way.

Joining and Cooling

The area to be welded shall coincide by contact with a velocity of nearly zero. The required joining pressure will rise linear if possible to the required joining pressure.

During cooling time the joining pressure must be maintained. A higher mechanical load is only after prolongation of the cooling time permissible. Assembly or mechanical treatment is allowed after the whole cooling time.

After joining, a double bead over the whole circumference must have been created. The bead development gives an orientation about the regularity of the welds among each other. Possible differences in the formation of the beads may be justified by different flow behaviour of the joined materials. K must be bigger than 0.

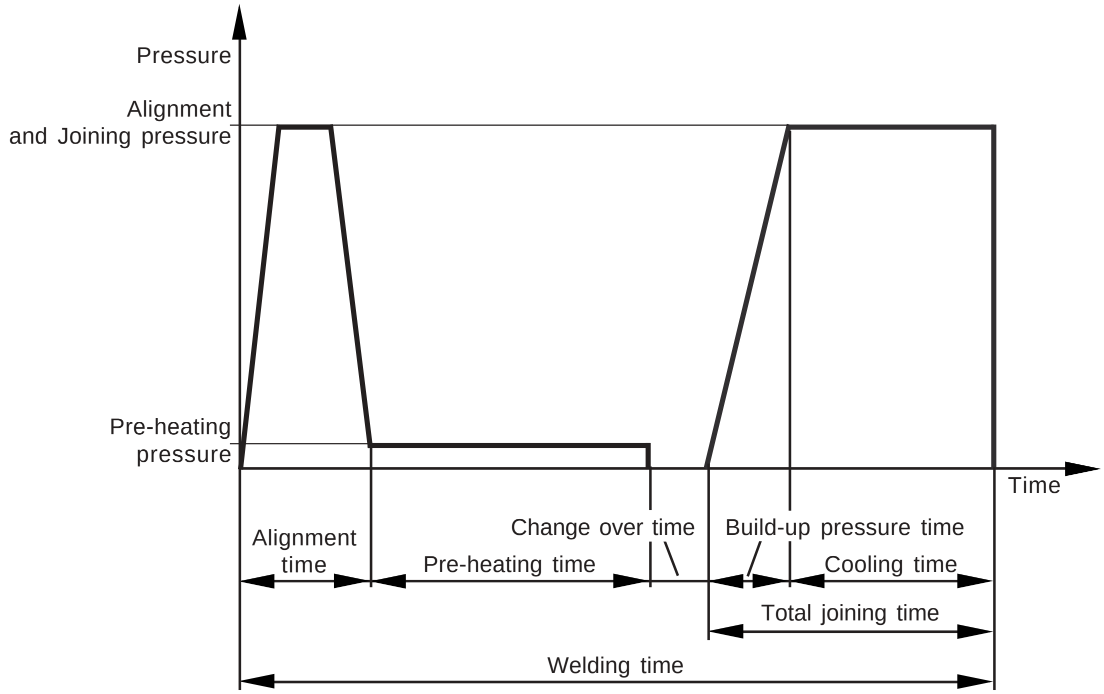


Picture 16: K-value of bead hight

Pressure test

Before pressure testing, all welding joints have to be completely cooled down (as a rule, 1 hour after the last welding process). The pressure test has to be performed according to the relevant standard regulations available (e.g. DVS 2210 Part 1, Supplement 2, DIN 4279).

The gradually sequences of the welding process (welding curve):



Picture 17: Welding curve of butt welding

Welding parameters

Reference values for heating element butt welding PVDF pipes and fittings at outside temperatures of about 20 °C and low air-speed rates (acc. DVS 2207 Part 15).

Material	Wall thickness [mm]	Alignment Bead height min. [mm]	Pre-heating time [sec]	Adjusting time max. [sec]	Build-up pressure time [sec]	Cooling time min. [min]
Spec. welding pressure	--	0.10 N/mm^2	0.01 N/mm^2	--	0.10 N/mm^2	
PVDF	1.9 - 3.5	0.5	59 - 75	3	3 - 4	5.0 - 6.0
	3.5 - 5.5	0.5	75 - 95	3	4 - 5	6.0 - 8.5
	5.5 - 10.0	0.5 - 1.0	95 - 140	4	5 - 7	8.5 - 14.0
	10.0 - 15.0	1.0 - 1.3	140 - 190	4	7 - 9	14.0 - 19.0
	15.0 - 20.0	1.3 - 1.7	190 - 240	5	9 - 11	19.0 - 25.0
	20.0 - 25.0	1.7 - 2.0	240 - 290	5	11 - 13	25.0 - 32.0

Table 11: Welding parameters of butt welding

Material	da (OD) [mm]	Wall thickness [mm]	Alignment Bead height min. [mm]	Pre-heating time [sec]	Adjusting time max. [sec]	welding pressure [kg]	Build-up pressure time [sec]	Cooling time min. [min]
Spec. welding pressure	--	--	0.10 N/mm^2	0.01 N/mm^2	--	--	0.10 N/mm^2	
PVDF	63	2,5	0.5	65	3	5	3 - 4	5.0
	110	3,0	0.5	70	3	10	3 - 4	6.0
	140	3,0	0.5	70	3	13	3 - 4	6.0
	160	3,0	0.5	70	3	15	3 - 4	6.0
	200	3,0	0.5	70	3	19	3 - 4	6.0
	250	3,0	0.5	70	3	24	3 - 4	6.0
	315	4,0	0.5	80	3	40	4 - 5	7.0
	355	4,0	0.5	80	3	45	4 - 5	7.0
	400	5,0	0.5	90	3	63	4 - 5	8.0

Hot gas welding
(following to DVS 2207, Part 3 for PVDF)

Welding method description

At hot gas welding, the edge areas and outer zones of the welding fillers are transformed into plastic condition - as a rule by means of heated air - and joined under low pressure. The hot gas must be free of water, dust and oil.

This guideline applies to hot gas welding of pipes and sheets out of thermoplastics. In general, material thickness of the semi-finished products to be welded ranges from 1 mm to 10 mm.

Fields of application of this welding method are: apparatus engineering, construction of vessels and piping systems.

Weldability of base material and welding fillers according to guideline DVS 2201, part 1, is taken for granted.

Another requirement for high quality welding processes is that the welding fillers are of the same kind and same type as far as possible. Condition and requirement of the welding fillers have to comply with the guideline DVS 2211.

The most common welding fillers are round rods with diameters of 3 mm and 4 mm. There are also used special profiles, such as oval, triangular and trefoil rods, as well as bands. In the following, the term "welding rods" is applied for the different welding fillers.

Welding parameter

Reference values at outside temperatures of about 20 °C (acc. to DVS 2207)

Material	Welding force [N]		Hot air temp.[1] [°C]	Air quantity [l/min]
	Ø 3 mm	Ø 4 mm		
PVDF	12 - 17	25 - 35	350 - 400	40 - 60

[1] measured in hot air stream approximately 5 mm in the nozzle.

Table 12: Hot Gas Welding Parameters

Qualification of welder and requirement on welding devices

The plastics welder must have obtained the knowledge and skill required for the performing of welding processes. As a rule, this would mean that he is a qualified plastics worker and welder continuously practising or displaying of long-time experience. Hot gas welding machines have to comply with the requirements according to guideline DVS 2208, Part 2.

Safety precaution

The recommended load limit acc. to TWA for HCl is 5ppm, for HF 3ppm.

At breathing contact with such vapours, the person should be brought out in the fresh air and medical aid should be summoned without delay (danger of polymer-fever!).

The following safety measures should be considered:

- Please consider for good ventilating of the working place
- Please use eye protections
- Please use hand protections

Drawing nozzle

The drawing nozzle has to correspond with the respective cross section of the welding rod. In order to apply the required heating pressure on welding with welding rods of larger cross sections, an additional press handle may be required with this kind of nozzle. Special slotted nozzles enable the welding of bands.

Processing guidelines - Hot gas welding

Preparation of welding place

Assemble welding equipment (prepare tools and machinery), control welding devices.

Install welding tent or similar device.

Preparation of welding seam (at any rate immediately before starting the welding process)

The adjusting surfaces and the adjacent areas have to be prepared adequately before welding (e. g. by scrapping). Furthermore, it is also recommendable to scrape the welding rods. Parts that have been damaged by influences of weather conditions or chemicals have to be machined until an undamaged area appears.

The forms of the welding seams on plastics components generally correspond with the forms of welding seams on metal parts.The guideline DVS 2205, Parts 3 and 5, are valid with respect to the choice of welding seam forms on containers and apparatus. In particular, pay attention to the general principles for the formation of welding seams. The most important welding seam forms are:

V-weld, double V-weld, HB-weld and K-weld.

With welding areas accessible from both sides, it is recommendable to make double-V-welds (sheet thickness of 4 mm and more). Generally do so when the thickness is 6 mm and more. The displacement of sheets may be minimized by changing the sides of welding.

Preparations for welding

Before starting the welding process, check the heated air temperature adjusted on the welding machine. Measurement is performed by means of a control thermocouple, inserted approximately 5 mm into the nozzle, and with rod-drawing nozzles in the opening of main nozzle. The diameter of the thermocouple must not exceed 1 mm. Air quantity is measured by means of a flow control instrument before the air stream enters into the welding machine.

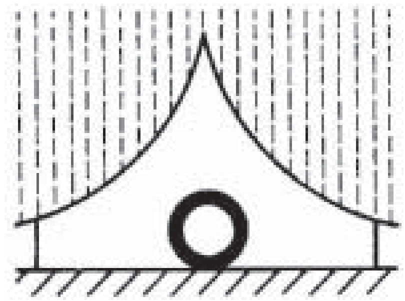
Performing of welding process

The welder has to acquire the feeling for the speed and force he needs for welding by practising. The welding power may be determined by test welding on a weighing machine.

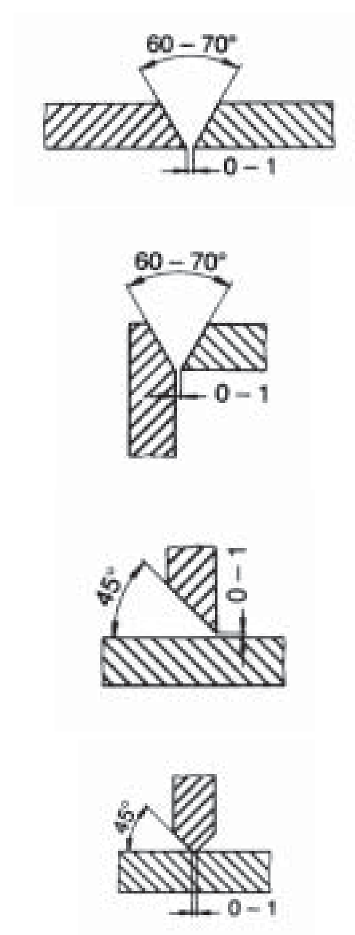
The welding rod is heated within the rod-drawing nozzle and pushed into the welding groove with its break-like extension mounted on the lower part of the nozzle. As a consequence of the forward movements of the nozzle, the welding rod is automatically being pushed on as a rule.
If necessary, the welding rod has to be pushed on manually in order to avoid stretching caused by friction within the nozzle.

Structure of welding seam

The first layer of the welding seam is welded with filler rod, diameter 3 mm (except for material thickness of 2 mm). Afterwards, the welding seam may be built up with welding rods of larger diameters until it will have completely been filled. Before welding with the next welding rod, the welding seam which has been formed with the preceeding welding rod, has to be adequately scrapped.



Picture 18: Protection of Weld Area



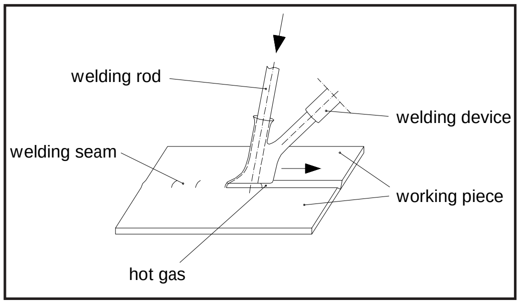
Picture 19: Hot Gas Bead Form

Additional machining of welding seam

Usually welding seams need no reworking however, if necessary, pay atten-tion to the fact that the thickness of the base material must be maintained.

Visual control of welding seam

Welding seams are visually checked with a view to weld filling, surface conditions, thorough welding of welding root and displacement of joining parts.



Picture 20: Schematic of Hot Gas Welding with Rod

Welding devices

Manual welding devices (with external air supply)

The devices comprise handle, heating, nozzle, air supply hose and electrical connecting cable.

Due to their construction properties, they are particularly suitable for longer lasting welding processes.

Requirements on design

- As light as possible
- Favourable position of the gravity center
- Functionally formed handle
- Indefinitely variable power consumption
- If possible, handle with built-in control system
- Operating elements arranged in a way preventing unintentional changes
- Material of handle: break-proof, thermoresistant, thermoinsulating, non-conducting
- Corrosion-proof hot gas supply pipes of low scaling
- Light and flexible hoses without permanent changes after squeezing

Safety requirements

The devices have to be safe with a view of all kind of personal injuries. In particular, the following requirements apply:

- Areas endangering the risk of burning are to be kept as small as possible.
- Parts next to hands should not be heated to temperatures above 40 °C, even after longer use.
- Protection against overheating (e. g. due to lack of air) of the device has to be present.
- Electrical equipment has to conform with the VDE regulations.

Air supply

At hot gas welding, air is normally used which is supplied by a compressed air network, a compressor, a pressure gas bottle or a ventilator. The air supplied has to clean, free of water and oil, as otherwise not only the quality of the welding seam but also the lifetime of the welding devices decreases. Therefore, adequate oil and water separators have to be used.

The air volume supplied to the device has to be adjustable and has to be maintained constant, as it is a main factor influencing the temperature control of the device.

Welding devices with built-in ventilator

The devices comprise handle, built-in ventilator, heating, nozzle and electrical connecting cable. Due to their constructional features, they can be used at sites where external air supply is not available.
On account of their dimensions and their weight, they are less suitable for longer lasting welding processe

Requirements on design

- The ventilator has to supply the quantity of air required for welding various types of plastics to all nozzles (see DIN 16 960, part 1).
- The electrical circuit has to ensure that the heating is only turned on when the ventilator is operating.
- The noise level of the ventilator has to comply with the relevant stipulations.

Safety requirements

- The nozzles used for the particular devices have to be securely fastened and easily exchangeable even when heated.
- The material must be corrosion-proof and of low scaling.
- In order to prevent heat from dissipating, the surface of the nozzle has to be as smooth as possible, e. g. polished.
- For reducing friction, the inner surface of the slide rail of the drawing nozzles have to be polished. The same applies to the sliding surfaces of tacking nozzles.
- In order to avoid strong air vortexes at the outlet of the nozzle, the round nozzles have to be straight for at least 5 x d (d = outlet diameter of the nozzle) in front of the outlet.

Application references

Qualtiy Assured

Due to our extensive quality assurance programmes through internal and external control by state-authorized testing institutes such as TÜV, LKT-TGM, IIP, etc. the continuous high quality standard of AGRU's products is ensured. Strict quality control from the incoming raw material to the final control of the products allows the issue of works certificates according to EN 10 204:1991

FM Approvals

SPECIFICATION TEST REPORT

SPECIFICATION TESTED EXAMINATION OF AGRU PVDF SHEET, PIPES AND FITTINGS FOR USE AS CLEAN ROOM MATERIALS IN ACCORDANCE WITH FM APPROVALS TEST STANDARD 4910

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