AGRUCHEM

INDUSTRIAL PIPING SYSTEMS

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Seit 1948 erfolgreich

AGRU liefert Kunststofftechnik, die Kunden aus unterschiedlichen Industriebereichen weltweit erfolgreich macht. Als zuverlässiger, erfahrener Lieferant bieten wir vom Halbzeug bis zum technologisch optimierten Spritzgussformteil alles aus einer Hand. Wir kennen die Herausforderungen aus tausenden Projekten und entwickeln unsere Produkte und Dienstleistungen laufend weiter. Kompromisslose Qualität, herausragender Kundennutzen und hohe Betriebssicherheit sind dabei unsere Maximen. Maßgeschneiderte Kundenlösungen und anwendungsorientierte Neuentwicklungen realisieren wir mit höchster Flexibilität - präzise und kostengünstig. Unsere engagierten Mitarbeiter mit Kunststoffkompetenz machen AGRU zu einem erfolgreichen Global Player.

Alles aus einer Hand anzubieten, unterscheidet uns von Vielen. Wir verarbeiten ausschließlich hochwertige, thermoplastische Kunststoffe. Und wenn es um Lösungskompetenz bei Materialauswahl und Verlegung geht, sind wir Ihr bester Ansprechpartner.

Successful since 1948

AGRU supplies the plastics technology that makes customers from all over the world successful in their widely differing industries. As a reliable, experienced supplier we offer everything from semi-finished products through to technologically optimised injection mouldings, all from a single source. We handle the challenges from thousands of projects and evolve our products and services on a rolling basis. Uncompromising quality, outstanding customer benefit and high operational dependability are our maxims. We implement custom solutions and application-oriented new developments with the highest flexibility - with precision and economically. Our dedicated employees with plastics expertise make AGRU successful as a global player.

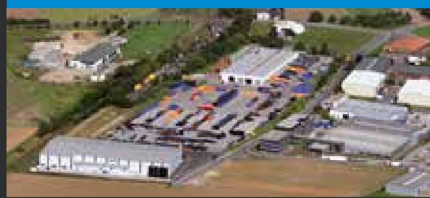
Our ability to supply everything from a single source sets us apart. We use only top-grade thermoplastic polymers as our raw materials. When it comes to application-technical consulting, we are your best partner in the field.

AGRU PLANTS

AGRU KUNSTSTOFFTECHNIK
AUSTRIA

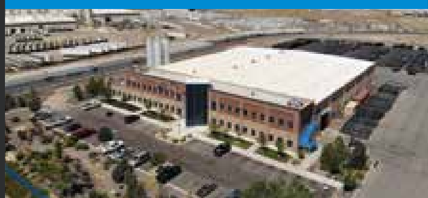
AGRU OBERFLÄCHENTECHNIK
AUSTRIA

AGRU-FRANK
GERMANY

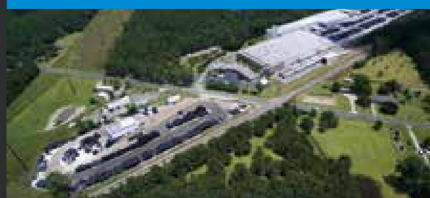


TWS
POLAND

AGRU NEVADA
FERNLEY, NV/USA

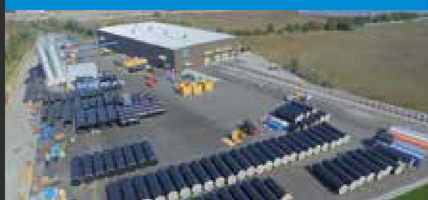


AGRU AMERICA
GEORGETOWN, SC/USA



AGRU AMERICA
ANDREWS, SC/USA

XXL PIPE PRODUCTION FACILITY
CHARLESTON, SC/USA



TAICANG AGRU PLASTICS
CHINA

PRODUCTS

AGRUCHEM INDUSTRIE INDUSTRIAL PIPING SYSTEMS

ROHRSYSTEME / PIPING SYSTEMS

Rohr- und Doppelrohrsysteme aus PP, PE 100-el, PPs, PPs-el, PVDF und ECTFE für industrielle Anwendungen wie den Transport von aggressiven Medien und kontaminiertem Abwasser. Rohrsysteme aus PE 100 blau für diverse Druckluftanwendungen.

Piping systems and double containment piping systems made of PP, PE 100-el, PPs, PPs-el, PVDF and ECTFE for industrial applications such as transport of aggressive media and contaminated sewage water. Piping system made of PE 100 blue for various compressed air applications.

AGRULINE

ROHRSYSTEME / PIPING SYSTEMS

PE 100-RC Rohrsysteme für Gas- und Wasserversorgung sowie Abwasserentsorgung und PE 100-RC Rohrsysteme für grabenlose und sandbettfreie Verlegung erhältlich in Dimensionen bis zu d_a 3500 mm.

PE 100-RC piping systems for gas and potable water distribution as well as sewage water disposal and PE 100-RC piping systems for trenchless and sandbed-free installation available in dimensions up to OD 3500 mm.

PURAD

ROHRSYSTEME / PIPING SYSTEMS

Rohrsysteme in PVDF-UHP, PP-Pure, Polypure und ECTFE für den Transport von hochreinen Medien der Halbleiter- und Pharmaindustrie sowie der Getränke- und Lebensmittelindustrie.

PVDF-UHP, PP-Pure, Polypure and ECTFE piping systems for the distribution of ultra-pure-water in semiconductor, pharmaceutical and food industry.

Zulassungen / Certifications

DIBt · TÜV SÜD · FM Approvals Listed 4910 Cleanroom Material · ÖVGW GEPRÜFT · kiwa Partner for progress · CE · BELGAQUA · HSE

NF · UNI · 012 · LANDES UMWELTAMT NRW 2004 · iiP · PSB Certification

HALBZEUGE
SEMI-FINISHED PRODUCTS

HALBZEUGE / SEMI-FINISHED PRODUCTS

Rundstäbe, Blöcke, Linerrohre, Schweißdrähte, Platten und Formteile aus thermoplastischen Kunststoffen wie PP, PE, PPs, PPs-el, PEHD, PE 100-el, PVDF, ECTFE, FEP und PFA passend für den Apparate- und Behälterbau.

Sheets, bars, blocks, liner pipes welding rods and fittings made of PP, PE, PPs, PPs-el, HDPE, PE 100-el, PVDF, ECTFE, FEP and PFA for the manufacturing of tanks and for use in apparatus engineering.

LINING
SYSTEMS

DICHTUNGSBAHNEN / GEOMEMBRANES

Dichtungsbahnen und Abdichtungen aus PEHD, PE-VLD, PE-LLD und FPP sowie Drainage Systeme aus PE und PP für Deponien, Tunnel und Teiche.

Geomembranes made of HDPE, VLDPE, LLDPE and FPP as well as drainage systems made of PE and PP for the use in landfills, tunnels, ponds, hydraulic engineering.

BETONSCHUTZ
CONCRETE PROTECTION

BETONSCHUTZPLATTEN / CONCRETE PROTECTIVE LINERS

Betonschutzplatten und Profile aus PE, PP, PVDF und ECTFE sind der passende Schutz für Ihr Bauwerk gegen chemische Korrosion.

Concrete protective liners and assembly profiles made of PE, PP, PVDF and ECTFE for the protection of your concrete structures from wear and chemical corrosion.

SCHWEISSEN
WELDING

SCHWEISSTECHNIK / WELDING SYSTEMS

Schweißmaschinen in verschiedensten Dimensionen für die professionelle Infrarot-, Stumpf-, Induktions- und Heizwendelschweißung.

Welding machines in various dimensions for professional infrared-, butt- and induction welding.

Innovation sichert Erfolg

Forschung und Entwicklung haben einen sehr hohen Stellenwert im Unternehmen. Ziel der Forschung ist der absolute Kundennutzen im Sinne kontinuierlicher Verbesserung und neuer Marktanforderungen.

Die Mission erster zu sein.
Europas erster Produzent von Formteilen im Spritzguss. Die weltweit erste Kalandrierung von extrabreiten Dichtungsbahnen. AGRU setzt nun mit einem Reinraumwerk für Reinstmedien-Rohrsysteme neue Maßstäbe.

Innovation - the key to success

AGRU's plastics engineers are focused on the future. Only those who today are dealing with the customer- and target-group-specific requirements of tomorrow will be successful in the future.

We claim to be the first.
Europe's first to produce fittings in injection moulds; the world's first to calender liners many meters wide. Once again the company has set new standards by building a clean-room plant for ultra-pure media piping systems.

GROUND-BREAKING INNOVATIONS HAVE BEEN A HALLMARK OF AGRU SINCE ITS EARLIEST DAYS.

Qualität

Kompromisslose Qualität, herausragender Kundennutzen und hohe Betriebssicherheit sind unsere Maximen. In mehr als 50 Jahren hat AGRU einen Pool an Fachwissen aufgebaut, das in der Branche einmalig ist. Diese „Lebenserfahrung" fließt in anwendungsorientierte Innovation, hochtechnologische Produktion sowie herausragende Service- und Logistikleistungen ein.

Wir sind stolz auf viele nationale und internationale Zertifikate, Zulassungen und unser nach ISO 9001:2015 zertifiziertes Qualitätssystem – im Sinne unserer Kunden für weltweiten Einsatz.

Quality

Operational reliability, on-time delivery and maximum customer benefit are our maxims. Over more than 50 years, the plastics experts have accumulated a wealth of expertise unique in the industry. This lifetime of experience flows into application-oriented innovation, high-tech production and outstanding service and logistics performance.

We are proud of our numerous national and international certificates, approvals and certified quality system ISO 9001:2015 – for our customers and for worldwide application.

AGRU IS KNOWN FOR ITS HIGH QUALITY STANDARDS AROUND THE WORLD

AGRU - A TRUSTED PARTNER

Zuverlässigkeit

Unterschiedliche Werkstoffe, Technologien und Produkte sowie ein weltumspannendes Partnernetzwerk machen AGRU zum zuverlässigen Komplettanbieter. Vor allem für Großprojekte und Sonderlösungen bietet AGRU damit seinen Kunden einen One-Stop-Shop. AGRU ist ein Synonym für Kundennutzen und dafür bekannt, die Kundenwünsche effizient, kostengünstig und mit höchster Flexibilität zu erfüllen. Maßgeschneiderte, kundenorientierte technische Lösungen, „Out-of-the-box-Denken" und jahrzehntelange Kunststofferfahrung sind dafür notwendig.

Reliability

Different materials, technologies and products plus a worldwide network of partners all contribute to making AGRU a single-source supplier. For large-scale projects and special solutions in particular, AGRU is able to offer its customers a one-stop shop. AGRU has built a reputation for satisfying its customers' wishes efficiently, cost-effectively and with superlative flexibility. Customer-oriented technical solutions, the ability to think outside the box and decades of hands-on experience are what it takes.

MAXIMUM CUSTOMER BENEFIT

Service

Die Wirtschaftlichkeit einer technischen Lösung entscheidet sich oft beim eingesetzten Werkstoff. Nur wenn das Ausgangsmaterial perfekt an die Einsatzbedingungen angepasst ist, können Chemikalien- und Temperaturbeständigkeit sowie die physische Belastbarkeit voll erfüllt werden. Die anwendungsspezifische Materialauswahl ist eine Kernkompetenz von AGRU. Als professioneller Ansprechpartner rund ums Thema Kunststoff zeigt AGRU die wirtschaftlichste Lösung für jede noch so große Herausforderung auf.

Service

Very often, the material used turns out to be definitive in terms of the ultimate profitability of an engineering solution. Only if the raw material is perfectly matched to the real-world conditions of use can physical toughness and resistance to chemicals and temperature effects be fully to specification. Application-specific material selection is one of AGRU's core competences. As a professional partner for everything associated with plastics, AGRU can point out the most economical solution for any problem, no matter how big the challenge.

Technologieführerschaft

Am Stand der Technik zu produzieren, Prozesse zu verbessern und die Ergebnisse zu optimieren, ist bei AGRU der Garant für Wettbewerbsfähigkeit. In unseren Werken rund um den Globus beweisen wir Tag für Tag Kosten- und Qualitätsführerschaft. Der technologische Vorsprung bewirkt, dass AGRU-Lösungen stets zu den besten ihrer Branche zählen.

Technology leadership

Producing at the cutting edge of technology, improving processes and optimising results are part and parcel of AGRU's guarantee of competitiveness. Day in, day out, we demonstrate our cost and quality leadership in our plants all over the globe. The technological edge means that AGRU solutions are consistently among the best in their field.

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Material Properties

1 General properties

1.1 Polyethylen (PE)

As a result of the continuous development of PE resins, the efficiency of PE pipes and fittings has been improved significantly. Due to that fact new international standards (ISO 9080, EN 1555, EN 12201) were introduced, which lead to higher permissible operating pressures.

Polyethylene (PE) for pipes and fittings is no longer classified by its density (e.g. PE-LD, PE-MD, PE-HD) but it is now divided into MRS-classes (MRS = minimum required strength).

In comparison to other thermoplastics PE shows an excellent diffusion resistance and has therefore been applied for the safe transport of gases for many years. The new classification is based on the minimum required strength (MRS), which has to be applied for designing long-term loaded PE pipes operating at a temperature of +20 °C for at least 50 years. Thus the first-generation pipes are named PE 32, PE 40 and PE 63 and the second-generation pipes PE 80, the third-generation are named PE 100. The figures stand for the MRS values in bar. Expressed in megapascal the design stresses for PE 80 and PE 100 pipes will consequently be 8,0 and 10,0 MPa.

Other essential advantages of this material are the UV-stability (in case coloured black), and the flexibility of the molding material ("flexible piping system").

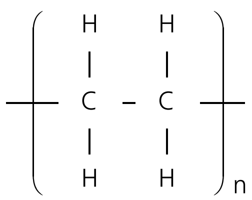


Figure A.1: Chemical structure of polyethylene

1.1.1 Physiological non-toxic

With respect to its composition polyethylene complies with the relevant food stuff regulations (according to EU 10/2011, ÖNORM B 5014, Part 1, BGA, KTW guidelines). PE pipes and fittings are verified and registered regarding potable water suitability according DVGW guideline W270.

1.1.2 Behaviour at radiation strain

Pipes made of polyethylene (PE) can be applied across the range of high energy radiation. PE pipes are well established for drainage of hot radioactive sewage water of laboratories and for cooling water piping systems of the nuclear energy industry. The usual radioactive sewage water contains beta and gamma radiation. PE piping systems do not become radioactive even after many years of use. Also in environments of higher radio activity, pipes made of PE are not affected in case they are not exposed to a higher, regularly spread radiation dose of 10^4 Gray during their complete operation time.

1.1.3 Advantages of PE

- UV-resistance (black PE)
- flexibility
- low specific weight of app. 0,96g/cm³
- convenient transportation
- very good chemical resistance
- weathering resistance
- radiation resistance
- good weldability
- very good abrasion resistance
- no deposits and no overgrowth possible
- due to less frictional resistance less pressure losses in comparison with e. g. metals
- freeze resistance
- resistant to rodents
- resistant to all kinds of microbic corrosion

1.1.4 Polyethylene type PE 100

These materials can also be described as polyethylene types of the third generation (PE-3) or respectively as MRS 10 materials. This further development of PE materials is achieved by a modified polymerisation process resulting in an altered mol mass distribution. Therefore, PE 100 types have a higher density and exhibit improved mechanical properties such as increased stiffness and hardness. Also the tensile creep rupture behaviour and the resistance against rapid crack propagation could be improved. Consequently, this material is suitable for use in larger diameters pressure pipes. In comparison to standard PE pressure pipes, the required pressure rating will be achieved with less wall thickness.

1.1.5 PE 100-RC polyethylene type

The primary difference, compared to standard PE 100 materials, is the high resistance against slow crack growth. This property allows safe sand-bed-free installations as well as the use of alternative installation technologies e.g. burst lining for underground piping systems. During sandbed-free installations the excavated material (soil, gravel, ballast) can be reused in case it is compressible acc. to current standards. Guideline for the grain size of the excavated material (source: ÖVGW/GRIS PW 405/1):

DIM OD ≤ 63 mm up to 22 mm grain size

DIM OD > 63 mm up to 100 mm grain size

PE 100-RC therefore provides extended protection against:

- point loads,
- crack initiation,
- slow crack growth (SCG).

1.1.6 Modified polyethylene PE 100-el (Polyethylene, electro-conductable)

Due to the electro-conductibility, PE 100-el is often used for transportation of highly inflammable media or dust as such piping systems can be fit with an electrical grounding.

1.2 General properties (PP)

According to DIN 8078, three, different types of polypropylene are recognised:

Type 1: PP-H (homopolymere)

Type 2: PP-R (random-polymere)

By copolymerisation with ethylene special properties are achieved for PP type 2: PP-R, which result in improved processability (e.g. lower danger of shrinkage cavitation during injection molding process) and better impact strength of the manufactured products in comparison to PP-H.

AGRU pressure pipes are made of nucleoid PP-H (Beta (β)-PP) since the mid-seventies. Also fittings are produced from PP-R (poly-propylene-random-co-polymer) since the end of the seventies. Both types have been stabilized against high temperatures and are the best suited materials for the production of pressure piping systems. In comparison to other thermoplastics such as PEHD and PVC, PP shows a thermal stability up to 95 °C (short-time up to 120 °C for pressure less systems). PP shows good impact strength in comparison to PVC. The impact strength depends on temperature and increases with rising temperatures and decreases with falling temperatures.

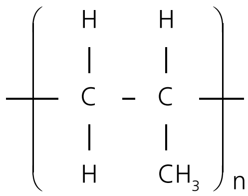


Figure A.2: Chemical structure of PP

1.2.1 PP and copper

Direct contact with copper leads to deterioration of PP, especially at higher temperatures. Due to the accelerated thermal oxidation, the heat ageing proceeds faster.

Recommendation: avoid contact with copper.

1.2.2 Physiological non-toxicity

With respect to its composition, polypropylene complies with the relevant food stuff regulations (according EU 10/2011, ÖNORM B 5014 Part 1, FDA, BGA, KTW guidelines).

An operating temperature of -5 °C for PP-H and -10 °C for PP-R must not be undercut.

1.2.3 Advantages of Polypropylene

- low specific weight of 0.91 g/cm 3
- high creep resistance
- excellent chemical resistance
- high resistance to material ageing
- good weldability
- excellent abrasion resistance
- smooth inside surface of pipes, therefore no deposits and no overgrowth possible
- due to less frictional resistance less pressure loss in comparison with e.g. metals
- non-conductive, therefore the structure is not affected by leak current
- PP is a very easily processable and weldable thermo-plastic (e. g. by deep drawing)
- PP shows very low heat conducting properties - therefore in many cases, no thermal insulation is required for hot water piping systems

1.2.4 Impact of high energy radiation exposure

Polypropylene endures radiation doses of up to of 10^4 Gray without losing its essential physical properties.

Absorption of higher doses than 10^4 Gray may lead to a higher temporary rigidity due to cross-linking of the molecular structure. Ongoing exposure to radiation causes ruptures within the molecular chains resulting in the embrittlement of the material as a result of molecular damage.

1.2.5 Impact of UV-radiation exposure

Grey polypropylene pipes do not contain UV stabilizers and must be protected accordingly therefore. For effective protection against direct sun light, a protection layer (AGRU-Coating) or an insulation is can be applied. It is furthermore possible (according to the DVS standard 2210-1) to compensate the arising surface damage by increasing the wall thickness as the damage only occurs on the surface. The increase in wall thickness must not be less than 2 mm and a maximum expected operating period of 10 years has to be taken into account.

As regular polypropylene does not contain any light-stable colour pigments, long-term weathering might lead to color changes (fading).

1.2.6 General properties of modified PP

Due to various specific requirements arising in the construction of piping systems for the chemical industry and apparatus engineering, flame retardant and electro-conductive special types have been developed. Electrostatic charging for example can occur during transportation of fluids or dust in thermoplastic piping systems. Electrostatic charging of piping systems made of electrically conductive polypropylene types can be eliminated by grounding.

These modified properties can be achieved by adding certain additives. However, compared to the standard type, alterations of the mechanical, thermal and also chemical properties must be taken into account.

It is therefore necessary to clarify all projects with our technical engineering department.

1.2.7 Physiological properties of PP special types

Due to the additives contained modified PP special types (flame-retardant resp. electro-conductible PP) do not comply with relevant food stuff regulations with regards to their composition and shall therefore not be used for contact with food stuff and potable water pipes.

1.2.8 Differences to standard types of PP

PP-R, natural:

Polypropylene-random-copolymere, natural

As PP-R natural contains no colour additives, it is applied mainly for high purity water piping systems. However this material is not UV resistant.

PPs:

Polypropylene-homopolymere, flame-retardant

Due to the higher stiffness of PP-s, it is well suited for ventilation and degassing pipes as well as for flue lining systems. It may not be used for outdoors applications due to the missing UV stabilization.

PPs-el:

Polypropylene-random-copolymere, flame retardant, electro-conductive Polypropylene-random-copolymer, flame retardant, electro-conductive. This material combines the positive properties of flame retardant and electro-conductible PP types. Due to safety reasons it is mostly used for the transport of easily ignitable media and may replace expensive stainless steel ductings.

There is however a reduced impact strength of PPs-el as well as a slightly altered chemical resistance.

1.3 Polyvinylidene fluoride (PVDF)

PVDF is an extremely pure polymer which, compared to many other plastics, does not contain any stabilizers, UV-, thermostabilizers, plasticizers, lubricants or flame retarding additives. Its particular suitable for the transport of highly aggressive media such as e.g. hydrochloric acid or sulphuric acid. The application range of PVDF is up to 120 °C.

Pipes and components made of suitable standard types meet the high demands of the semi-conductor industry; e. g. it allows to maintain a specific resistance of deionized ultra-pure water of more than 18 MΩcm.

Taking into consideration it's properties and considering it's very easy processability and it's advantageous price-performance ratio, PVDF is an excellent solution.

Polyvinylidene fluoride (PVDF), like all other thermoplastics, has the following typical properties:

- easy processing
- good weldability
- good heat formability

PVDF is characterized by it's high mechanical strength and a very good chemical resistance, even if used in high temperature applications in presence of aggressive chemical media.

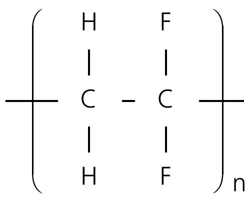


Figure A.3: Chemical structure of PVDF

1.3.1 Advantages of PVDF

- wide temperature range (-20 °C up to 120 °C)
- high heat deformation resistance
- very good chemical resistance, even in connection with high temperatures
- good resistance against UV- and γ-radiation therefore high ageing resistance
- excellent abrasion resistance (low friction coefficient)
- very good anti-friction properties
- good mechanical properties
- excellent insulating characteristics in connection with very good
- electrical values
- flame retarding
- physiologically non-toxic
- good and easy processing

PVDF is a halogen and also offers an excellent PVDF is a halogen compound and offers excellent fire protection even without the addition of flame-retardant additives. During combustion of PVDF only a slight amount of smoke development arises. But like any other organic substance even PVDF is inflammable in case respective temperatures occur.

1.3.2 Solubility

In contact with high polar solvents, e.g. acetone and ethylacetat, the PVDF-homopolymere is susceptible to swelling. Further, PVDF is soluble in certain polar solvents, e.g. dimethylformamide and dimethylacetamide.

1.4 Ethylenechlorotrifluorethylene (ECTFE)

ECTFE is characterized by a unique combination of properties, which is the result of it`s chemical structure - a copolymer with an alternating constitution of ethylene and chlorotrifluorethylene.

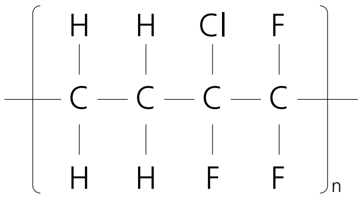


Figure A.4: Chemical structure of ECTFE

1.4.1 Thermal properties

ECTFE has a remarkable resistance against heat decomposition. It resists temperatures up to 140 °C for longer durations.

1.4.2 Resistance against the weathering

ECTFE only shows very little changes in properties or appearance if exposed to weathering in sunlight. Accelerated weathering tests showed a remarkable stability of these polymers particularly the elongation at break, which is a good indicator for the polymer-decomposition. Even after 1000 hours in a "Weather - Ometer" with xenon-light the key properties are hardly influenced.

1.4.3 Radiation resistance

ECTFE shows an excellent resistance against different radiations. Even after irridation with 200 megarad cobalt 60 and it still has good values can be one of the best plastics with a good resistance against radiation.

1.4.4 Mechanical properties

ECTFE is a solid, very impact resistant plastic, which hardly changes its properties over a wide range of temperatures. Besides the good impact strength ECTFE has a good breaking strain and a good abrasion behaviour. Well mentioning is the good behaviour at low temperatures, especially the high impact strength.

1.4.5 Advantages of ECTFE

- wide temperature application range (-30 °C up to 140 °C)
- good resistance against UV- and γ-radiation, therefore excellent ageing resistance
- flame retardant (UL 94-V0-material)
- oxygen index 60
- excellent abrasion resistance
- excellent chemical resistance against most
- technical acids, alkalies and solvents as well as contact with chlorine
- excellent insulating properties in connection
- with very good electrical values
- very good surface slip characteristics

1.4.6 Reproduction of microorganisms on ECTFE

The surface of products made of ECTFE is unfavourable to the proliferation of microorganisms - similar to glass. This conclusion is the result of an examination which has been performed within the framework of a test of the HP-suitability of ECTFE.

2 Material-specific properties

2.1 Material properties PE

The values mentioned are **guidelines** for the particular material.

	Properties	Standard	Unit	PE 100	PE 100-RC	PE 100-el
mechanical / physical	MRS Classification	ISO 9080	N/mm²	10	10	–
	Specific density at 23 °C	ISO 1183	g/cm³	0.96 [2]	0.96 [2]	1.05
	Melt flow rate MFR 190/5	ISO 1133	g/10min	0.3 [1]	0.3 [1]	–
	Melt flow rate MFR 190/21.6			6.4 [1]	6.4 [1]	4
	Tensile stress at yield	ISO 527	MPa	≥23	≥23	≥23
	Elongation at yield	ISO 527	%	≥9	≥9	≥6
	Elongation at break	ISO 527	%	>350 [2]	≥350 [2]	≥100
	Impact strength unnotched (at +23 °C)	ISO 179	kJ/m²	no break	no break	no break
	Impact strength unnotched (at -30 °C)			no break	no break	79
	Impact strength notched (at +23 °C)	ISO 179	kJ/m²	≥13 [3]	≥13 [3]	7
	Impact strength notched (at -30 °C)			10	10	break
	Shore-D hardness (3 sec)	ISO 868	1	60	60	68
	Flexural stress (3.5 % elongation)	ISO 178	MPa	≥21	≥21	≥21
	Modulus of elasticity	ISO 527	MPa	≥1000	≥1000	≥1000
	Stress cracking resistance (FNCT)	ISO 16770 EN 12814-3	h	≥300 [3]	≥8760 [3]	≥300
thermal	Vicat Softening point VST/B/50	ISO 306	°C	74	74	85
	Heat deflection temperature HDT/B	ISO 75	°C	75	75	109
	Linear coefficient of thermal expansion	ISO 11359-2	$K^{-1} \times 10^{-4}$	1.8 [4]	1.8 [4]	1.4
	Thermal conductivity (at 20 °C)	DIN EN 12667	W/(m×K)	~0.4	~0.4	~0.4
	Flammability	UL94 DIN 4102	– –	94-HB B2	94-HB B2	94-HB B2
	Application temperature	–	°C	-40 up to +60 *	-40 up to +60 *	-20 up to +60 *
electric	Specific volume resistance	DIN EN 62631-3-1	Ω × cm	$>10^{16}$	$>10^{16}$	$\leq10^{8}$
	Specific surface resistance	DIN EN 62631-3-2	Ω	$>10^{13}$	$>10^{13}$	$\leq10^{6}$
	Relative dielectric coefficient at1 MHz	DIN 53483	–	2.3	2.3	–
	Dielectric strength	DIN IEC 60243	kV/mm	70	70	–
general	Food contact	EU 10/2011	–	yes	yes	no
	UV stabilized	–	–	carbon black	carbon black	carbon black
	Colour	–	–	black	black	black

Table A.1: Specific material properties of PE 100, PE 100-RC and PE 100-el.

Guidelines from: [1] DVS 2207-1, [2] EN 12201, [3] DVS 2205-1 suppl.1, [4] DVS 2210-1

* depending on the application area and operating time (see chapter 2.1.3)

2.2 Material properties PP

The values mentioned are **guidelines** for the particular material.

	Properties	Standard	Unit	PP-H	PP-R	PPs	PPs-el
mechanical / physical	Specific density at 23 °C	ISO 1183	g/cm^3	0.91	0.91	0.93	1.17
	Melt flow rate MFR 190/5	ISO 1133	g/10 min	0.5	0.5	0.6	–
	Melt flow rate MFR 230/2.16			0.3	0.3	0.35	–
	Melt flow rate MFR 230/21.6			–	–	–	~40
	Tensile stress at yield	ISO 527	MPa	30	25	30	>20
	Elongation at yield	ISO 527	%	≥8	≥10	≥8	>6
	Elongation at break	ISO 527	%	>300 [1]	>300	>50	≥30
	Impact strength unnotched at +23 °C	ISO 179	kJ/m^2	no break	no break	no break	–
	Impact strength unnotched at -30 °C			no break	no break	28	–
	Impact strength notched at +23 °C	ISO 179	kJ/m^2	8	20	9	9.5
	Impact strength notched at 0 °C			2.8	3.5	2.8	–
	Impact strength notched at -30 °C			2.2	2.0	2.2	2.3
	Shore-D hardness (3 sec)	ISO 868	1	70	62	73	70
	Flexural stress (3,5% elongation)	ISO 178	MPa	28	20	30	–
	Modulus of elasticity	ISO 527	MPa	1300	900	1300	≥1100
thermal	Vicat-Softening point VST/B/50	ISO 306	°C	91	65	85	87
	Heat deflection temperature HDT/B	ISO 75	°C	96	70	85	88
	Linear coefficient of thermal expansion	ISO 11359-2	$K^{-1} \times 10^{-4}$	1.6	1.5	1.6	–
	Thermal conductivity at 20 °C	DIN EN 12667	W/(m*K)	0.22	0.24	0.2	–
	Flammability	UL94	–	94-HB	94-HB	V-0	V-0
		DIN 4102		B2	B2	–	–
	Application temperature	–	°C	-5 up to +95	-10 up to +95	-5 up to +95	-5 up to +95
electric	Specific volume resistance	DIN EN 62631-3-1	$\Omega \times cm$	$>10^{16}$	$>10^{16}$	$>10^{15}$	$<10^{8}$
	Specific surface resistance	DIN EN 62631-3-2	Ω	$>10^{13}$	$>10^{13}$	$>10^{15}$	$<10^{6}$
	relative dielectric constant at 1 MHz	DIN 53483	–	2.3	2.3	–	–
	Dielectric strength	DIN IEC 60243	kV/mm	75	70	30 - 40	–
general	Food contact	EU 10/2011	–	yes	yes	no	no
	UV stabilized	–	–	no	no	no	yes
	Colour	–	–	Ral 7032 grey	Ral 7032 grey	Ral 7037 dark grey	black

Table A.2: Specific material properties of PP.

[1] valid for pipes

*Fire classification B1 only valid for wall thickness of 2-10 mm

2.3 Material properties PVDF und ECTFE

The values mentioned are **guidelines** for the particular material.

	Properties	Standard	Unit	PVDF	ECTFE
mechanical / physical	Specific density at 23 °C	ISO 1183	g/cm³	1.78	1.68
	Melt flow rate MFR 275/2.16	ISO 1133	g/10 min	–	0.8-4
	Melt flow rate MFR 230/5			1-30	–
	Tensile stress at yield	ISO 527	MPa	50	20
	Elongation at yield	ISO 527	%	8	5
	Elongation at break	ISO 527	%	30	150
	Impact strength unnotched at +23 °C	ISO 179	kJ/m²	124	no break
	Impact strength notched at +23 °C	ISO 179	kJ/m²	11	no break
	Shore-D hardness (3 sec)	ISO 868	1	78	72
	Modulus of elasticity	ISO 527	MPa	2000	1690
thermal	Vicat-Softening point VST/B/50	ISO 306	°C	140	111
	Heat deflection temperature HDT/B	ISO 75	°C	145	90
	Linear coefficient of thermal expansion	ISO 11359-2	$K^{-1} \times 10^{-4}$	1.2	0.8
	Thermal conductivity at 20 °C	DIN EN 12667	W/(m*K)	0.20	0.20
	Flammability	UL94	–	V-0	V-0
		FM 4910	–	yes*	–
	Application temperature	–	°C	-10 up to +130	-40 up to +140
electric	Specific volume resistance	DIN EN 62631-3-1	Ω × cm	$>10^{14}$	$>10^{15}$
	Specific surface resistance	DIN EN 62631-3-2	Ω	$>10^{12}$	$>10^{14}$
	relative dielectric constant at 1 MHz	DIN 53483	–	7.25	2.6
	Dielectric strength	DIN IEC 60243	kV/mm	25	15
general	Food contact	EU 10/2011	–	yes	no
	UV stabilized	–	–	yes	yes
	Colour	–	–	natural	natural

Table A.3: Specific material properties of PVDF und ECTFE.

* For details on FM4910 applications, please contact our technical department.

3 Preferred applications

The below mentioned table gives an overview about different application options of our molding materials.

Range of applications	PE100/ PE100-RC	PE 100-el	PP-H	PP-R	PPs	PPs-el	PVDF	ECTFE
Industrial applications								
Pipes for transportation of chemicals	✓	✓	✓	✓	✓	✓	✓	✓
Pipes for cooling water systems	✓	✓	✓	✓	✓			
Pipes for the transport of solids	✓	✓	✓	✓			✓	✓
Piping systems in explosion-proof rooms						✓		
High purity water piping systems	✓			✓			✓	✓
Water extraction and water preparation	✓							
Pipes for swimming pools	✓		✓	✓				
Protective pipes for district heating systems	✓							
Protective pipes for cables	✓							
Apparatus engineering and vessel construction	✓	✓	✓	✓	✓		✓	✓
Ventilation and degassing piping systems	✓	✓	✓	✓	✓	✓		
Lining of containers and tanks	✓	✓	✓	✓	✓	✓	✓	✓
Construction of facilities	✓	✓	✓	✓	✓	✓	✓	✓
Distribution of compressed air	✓							
Applications for environmental protection								
Pipes for drainage systems	✓		✓	✓				
Lining of channels, channel relining	✓			✓				
Dual pipes	✓		✓	✓			✓	✓
Piping systems for sewage treatment plants and lining	✓		✓	✓				
Degassing pipes for waste disposal facilities	✓	✓						
Drainage pipes for landfill sites	✓							
Applications for supply systems								
Pipes for irrigation systems	✓							
Pipes for potable water systems	✓		✓	✓				
Gas pipes	✓							

Table A.4: Applications.

4 Pressure curve and operating pressures

For calculation of a respective operating pressure for above ground installed piping systems we recommend to multiply the operating pressure stated in the table with a system reduction coefficient fs = 0.8 (This value contains installation-related influences such as welding joints, flange or bending loads). The operating pressure has to be reduced by the corresponding reduction coefficients (see page 170-171) for every application.

4.1 Hydrostatic strength curve for PE 100, PE 100-RC and PE 100-el

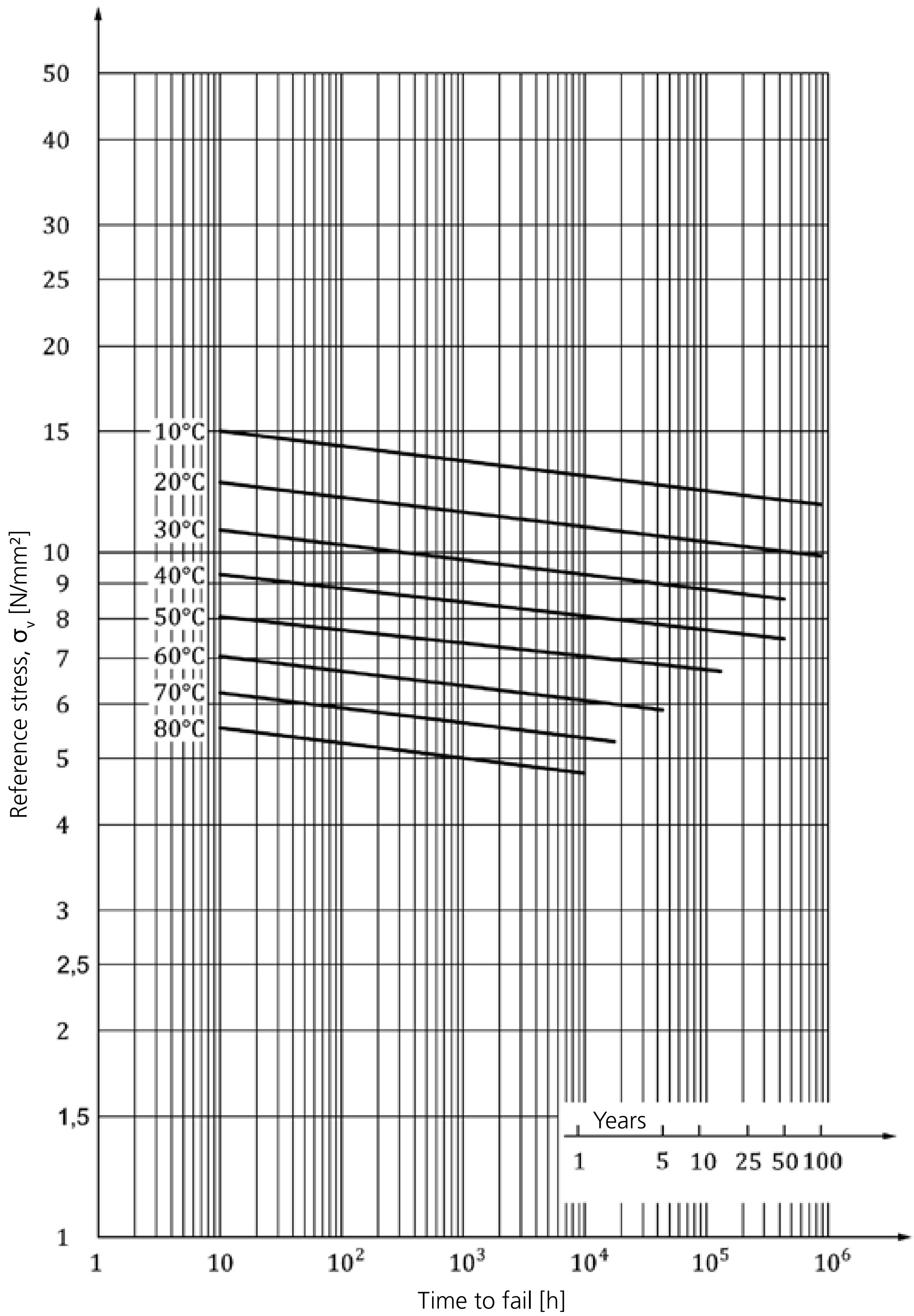


Figure A.5: Hydrostatic long-term strength (hoop stress graph) for PE 100, PE 100-RC and PE 100-el.
(Source: DIN 8075:2018-08, ISO 15494:2015-01)

4.2 Permissible component operating pressures p_B for PE 100, PE 100-RC and PE 100-el depending on temperature and operation period.

Tempe-ratur [°C]	Betriebs-dauer [a]	Zulässiger Bauteilbetriebsüberdruck [bar]									
		Wasser								Gas	
		SDR 41	SDR 33	SDR 26	SDR 21	SDR 17	SDR 11	SDR 9	SDR 7,4	SDR 17	SDR 11
		ISO-S 20	ISO-S 16	ISO-S 12,5	ISO-S 10	ISO-S 8	ISO-S 5	ISO-S 3,2	ISO-S 3,2	ISO-S 8	ISO-S 5
10	5	5,0	6,3	7,9	10,0	12,6	19,9	25,1	31,6	7,9	12,5
	10	4,9	6,2	7,8	9,8	12,4	19,6	24,7	31,1	7,7	12,3
	25	4,8	6,1	7,7	9,6	12,1	19,2	24,2	30,5	7,6	12,0
	50	4,8	6,0	7,5	9,5	12,0	18,9	23,9	30,0	7,5	11,8
20	5	4,2	5,3	6,7	8,4	10,6	16,8	21,1	26,6	6,6	10,5
	10	4,2	5,2	6,6	8,3	10,4	16,5	20,8	26,2	6,5	10,3
	25	4,1	5,1	6,5	8,1	10,2	16,2	20,4	25,7	6,4	10,1
	50	4,0	5,0	6,3	8,0	10,0	16,0	20,0	25,0	6,3	10,0
30	5	3,6	4,5	5,7	7,2	9,0	14,3	18,0	22,7	5,6	8,9
	10	3,5	4,5	5,6	7,1	8,9	14,1	17,7	22,3	5,6	8,8
	25	3,5	4,4	5,5	6,9	8,7	13,8	17,4	21,9	5,4	8,6
	50	3,4	4,3	5,4	6,8	8,6	13,6	17,1	21,6	5,4	8,5
40	5	3,1	3,9	4,9	6,2	7,8	12,3	15,5	19,5	4,9	7,7
	10	3,0	3,8	4,8	6,1	7,6	12,1	15,3	19,2	4,8	7,6
	25	3,0	3,8	4,7	6,0	7,5	11,9	15,0	18,8	4,7	7,4
	50	2,9	3,7	4,7	5,9	7,4	11,7	14,7	18,5	4,6	7,3
45	5	2,9	3,6	4,6	5,7	7,2	11,5	14,4	18,2	4,5	7,2
	10	2,8	3,6	4,5	5,7	7,1	11,3	14,2	17,9	4,5	7,1
	25	2,8	3,5	4,4	5,5	7,0	11,1	13,9	17,5	4,4	6,9
50	5	2,7	3,4	4,3	5,4	6,7	10,7	13,5	16,9	4,2	6,7
	10	2,6	3,3	4,2	5,3	6,6	10,5	13,3	16,7	4,2	6,6
	15	2,6	3,3	4,2	5,2	6,6	10,4	13,1	16,5	4,1	6,5
55	5	2,5	3,2	4,0	5,0	6,3	10,0	12,6	15,8	3,9	6,2
	10	2,5	3,1	3,9	4,9	6,2	9,8	12,4	15,6	3,9	6,2
60	5	2,4	3,0	3,7	4,7	5,9	9,4	11,8	14,8	3,7	5,9

Table A.5: Maximum operating pressure of PE 100, PE 100-RC and PE 100-el (Source: DIN 8075: 2018, ISO 15494: 2015-01).

Figures stated in the above table refer to water. They were calculated by referring the respective creep curves taking into account a safety coefficiant of C=1.25.

4.3 Hydrostatic strength curve for PP-H

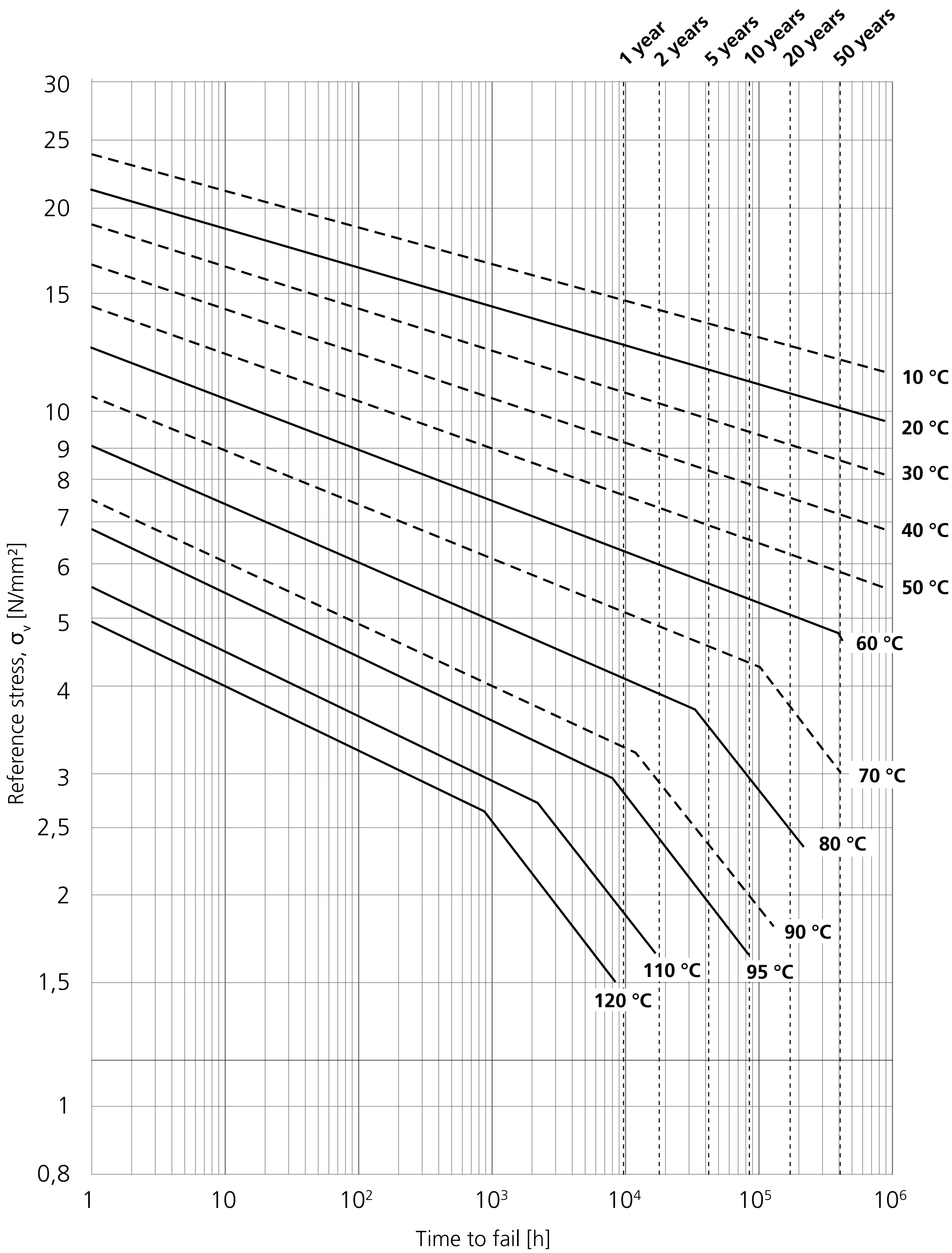


Figure A.6: Minimum required hydrostatic strength curve for PP-H (according to EN ISO 15494 supplement C)

4.4 Permissible component operating pressures p_B for PP-H depending on temperature and operation period

Temperature [°C]	Operating period [years]	Permissible component operating pressure [bar]						
		SDR 41	SDR 33	SDR 26	SDR 17,6	SDR 11	SDR 7.4	SDR 6
		ISO-S 20	ISO-S 16	ISO-S 12.5	ISO-S 8.3	ISO-S 5	ISO-S 3.2	ISO-S 2.5
10	1	4.5	5.7	7.1	10.8	18.0	28.6	36.0
	5	4.1	5.2	6.5	9.9	16.5	26.2	33.0
	10	4.0	5,0	6.3	9.6	15.9	25.3	31.8
	25	3.8	4.8	6.0	9.1	15.2	24.1	30.3
	50	3.6	4.6	5.8	8.8	14.6	23.2	29.2
	100	3.5	4.4	5.6	8.4	14.1	22.3	28.1
20	1	3.9	4.9	6.2	9.3	15.6	24.7	31.1
	5	3.5	4.5	5.6	8.5	14.2	22.5	28.4
	10	3.4	4.3	5.4	8.2	13.6	21.6	27.3
	25	3.2	4.1	5.1	7.8	12.9	20.5	25.9
	50	3.1	3.9	4.9	7.5	12.4	19.7	24.9
	100	3.0	3.7	4.7	7.2	12.0	19.0	23.9
30	1	3.3	4.2	5.3	8.0	13.3	21.1	26.6
	5	3.0	3.8	4.8	7.2	12.1	19.2	24.1
	10	2.9	3.6	4.6	6.9	11.6	18.4	23.1
	25	2.7	3.4	4.3	6.6	10.9	17.4	21.9
	50	2.6	3.3	4.1	6.3	10.5	16.6	21.0
40	1	3.2	4.0	5.1	7.7	12.9	20.5	25.8
	5	2.9	3.6	4.6	7.0	11.6	18.4	23.2
	10	2.8	3.5	4.4	6.7	11.1	17.6	22.2
	25	2.6	3.3	4.1	6.3	10.5	16.6	20.9
	50	2.5	3.1	4.0	6.0	10.0	15.9	20.0
50	1	2.7	3.4	4.3	6.5	10.8	17.2	21.6
	5	2.4	3.0	3.8	5.8	9.7	15.4	19.3
	10	2.3	2.9	3.6	5.5	9.2	14.6	18.4
	25	2.1	2.7	3.4	5.2	8.6	13.7	17.3
	50	2.0	2.6	3.3	4.9	8.2	13.1	16.5
60	1	2.5	3.1	4.0	6.0	10.0	15.9	20.1
	5	2.2	2.8	3.5	5.3	8.9	14.1	17.8
	10	2.1	2.6	3.3	5.1	8.5	13.4	16.9
	25	2.5	2.4	3.1	4.7	7.9	12.6	15.8
	50	1.8	2.3	2.9	4.4	7.4	11.7	14.8
70	1	2.6	2.5	3.2	4.9	8.2	13.0	16.4
	5	1.8	2.2	2.8	4.3	7.2	11.5	14.5
	10	1.7	2.1	2.7	4.1	6.8	10.9	13.7
	25	1.4	1.7	2.2	3.4	5.6	9.0	11.3
	50	1.2	1.5	1.9	2.8	4.8	7.6	9.5
80	1	2.1	2.0	2.6	4.0	6.6	10.5	13.2
	5	1.3	1.7	2.2	3.3	5.5	8.8	11.1
	10	1.1	1.4	1.8	2.8	4.7	7.4	9.3
	25	0.9	1.1	1.4	2.2	3.7	5.9	7.5
95	1	1.1	1.4	1.8	2.7	4.6	7.3	9.2
	5	0.7	0.9	1.2	1.8	3.1	4.9	6.2
	10	0.6	0.8	1.0	1.5	2.6	4.1	5.2

Table A.6: Permissible component operating pressures for PP-H. (source: ÖNORM EN ISO 15494)

Operating pressures do not apply to pipes exposed to UV radiation. Up to 10 years of operation, this influence is compensated or at least significantly reduced by the additives added to the molding material (e.g. carbon black). Figures stated in the above table refer to water. They were calculated by referring the respective creep curves taking into account a safety coefficiant C.

C = 1,6 (10 - <40°C)

C = 1,4 (40 - <60°C)

C = 1,25 (≥ 60°C)

4.5 Hydrostatic strength curve for PP-R

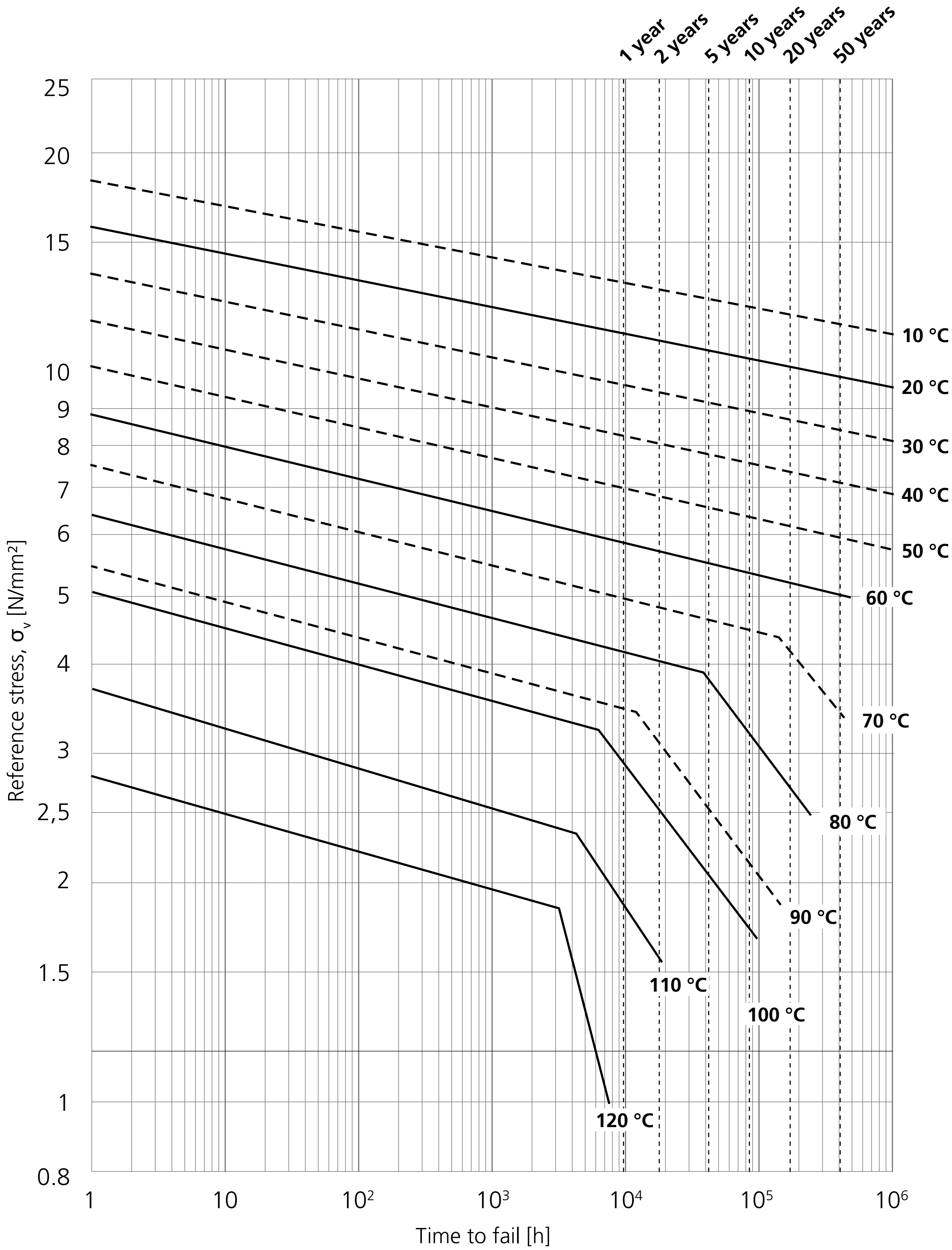


Figure A.7: Minimum required hydrostatic strength curve for PP-R (according to EN ISO 15494 supplement C)

4.6 Permissible component operating pressures p_B for PP-R depending on temperature and operation period

Temperature [°C]	Operating period [years]	Permissible component operating pressure [bar]							
		SDR 41	SDR 33	SDR 26	SDR 17.6	SDR 17	SDR 11	SDR 7.4	SDR 6
		ISO-S 20	ISO-S 16	ISO-S 12.5	ISO-S 8.3	ISO-S 8	ISO-S 5	ISO-S 3.2	ISO-S 2.5
10	1	5.3	6.6	8.4	12.6	13.3	21.1	33.4	42.1
	5	4.9	6.2	7.9	11.9	12.5	19.8	31.5	39.7
	10	4.8	6.1	7.7	11.6	12.2	19.3	30.7	38.6
	25	4.7	5.9	7.4	11.2	11.8	18.7	29.7	37.4
	50	4.5	5.7	7.2	10.9	11.5	18.2	28.9	36.4
	100	4.4	5.6	7.0	10.7	11.2	17.8	28.2	35.5
20	1	4.5	5.6	7.1	10.8	11.3	18.0	28.5	35.9
	5	4.2	5.3	6.7	10.1	10.6	16.9	26.8	33.7
	10	4.1	5.2	6.5	9.9	10.4	16.4	26.1	32.8
	25	3.9	5.0	6.3	9.5	10	15.9	25.2	31.7
	50	3.8	4.8	6.1	9.3	9.7	15.4	24.5	30.9
	100	3.7	4.7	6.0	9.0	9.5	15.0	23.9	30.1
30	1	3.8	4.8	6.1	9.2	9.6	15.3	24.2	30.5
	5	3.6	4.5	5.7	8.6	9.0	14.3	22.7	28.6
	10	3.5	4.4	5.5	8.4	8.8	13.9	22.1	27.8
	25	3.3	4.2	5.3	8.1	8.4	13.4	21.3	26.8
	50	3.2	4.1	5.2	7.8	8.2	13.0	20.7	26.1
40	1	3.2	4.1	5.1	7.8	8.2	13.0	20.6	25.9
	5	3.0	3.8	4.8	7.3	7.6	12.1	19.2	24.2
	10	2.9	3.7	4.7	7.1	7.4	11.8	18.7	23.5
	25	2.8	3.5	4.5	6.8	7.1	11.3	18.0	22.6
	50	2.7	3.4	4.3	6.6	6.9	11.0	17.4	22.0
50	1	2.7	3.4	4.3	6.6	6.9	11.0	17.4	21.9
	5	2.5	3.2	4.0	6.1	6.4	10.2	16.2	20.4
	10	2.5	3.1	3.9	5.9	6.2	9.9	15.7	19.8
	25	2.4	3.0	3.8	5.7	6.0	9.5	15.1	19.0
	50	2.3	2.9	3.6	5.5	5.8	9.2	14.7	18.5
60	1	2.3	2.9	3.6	5.5	5.8	9.2	14.7	18.5
	5	2.1	2.7	3.4	5.1	5.4	8.6	13.6	17.2
	10	2.1	2.6	3.3	5.0	5.2	8.3	13.2	16.6
	25	2.0	2.5	3.1	4.8	5.0	8.0	12.7	16.0
	50	1.9	2.4	3.0	4.6	4.9	7.7	12.3	15.5
70	1	1.9	2.4	3.1	4.6	4.9	7.8	12.3	15.5
	5	1.8	2.2	2.8	4.3	4.5	7.2	11.4	14.4
	10	1.7	2.2	2.7	4.2	4.4	7.0	11.1	13.9
	25	1.5	1.9	2.4	3.6	3.8	6.0	9.6	12.1
	50	1.2	1.6	2.0	3.0	3.2	5.1	8.1	10.2
80	1	1.6	2.0	2.6	3.9	4.1	6.5	10.3	13.0
	5	1.4	1.8	2.3	3.4	3.6	5.7	9.1	11.5
	10	1.2	1.5	1.9	2.9	3.0	4.8	7.7	9.7
	25	0.9	1.2	1.5	2.3	2.4	3.9	6.2	7.8
95	1	1.1	1.4	1.8	2.7	2.9	4.6	7.3	9.2
	5	0.7	0.9	1.2	1.8	1.9	3.1	4.9	6.2
	10	0.6	0.8	1.0	1.5	1.6	2.6	4.1	5.2

Table A.7: Permissible component operating pressures for PP-R (Source: ÖNORM EN ISO 15494).

Figures stated in the above table refer to water. They were calculated by referring the respective creep curves taking into account a safety coefficiant C =1.25. **Due to the modified mechanical properties of the material PPs-el the maximum operating pressure has to be reduced to 60 %!**

Operating pressures do not apply to pipes exposed to UV radiation. Up to 10 years of operation, this influence is compensated or at least significantly reduced by the additives added to the molding material (e.g. carbon black).

4.7 Hydrostatic strength curve for PVDF

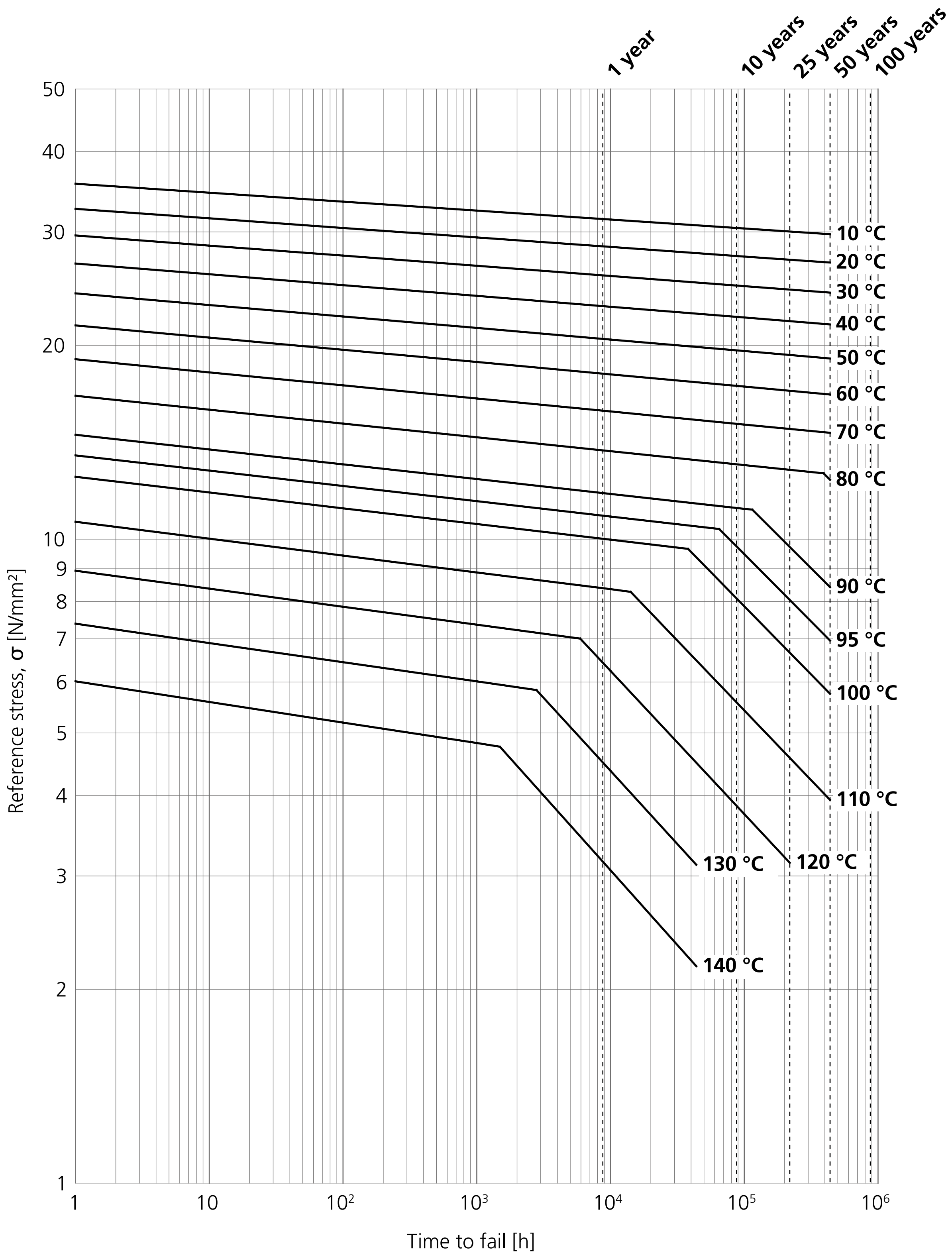


Figure A.8: Minimum required hydrostatic strength curve for PVDF (acc. to EN ISO 10931 supplement A).

4.8 Permissible component operating pressures p_B for PVDF depending on temperature and operation period

Temperature [°C]	Operating period [years]	Permissible component operating pressure [bar]	
		SDR 33	SDR 21
		ISO-S 16	ISO-S 10
10	1	12.2	19.6
	5	12.0	19.1
	10	11.8	19.0
	25	11.7	18.7
	50	11.6	18.5
20	1	11.1	17.8
	5	10.8	17.3
	10	10.7	17.2
	25	10.6	16.9
	50	10.5	16.8
30	1	10.0	16.0
	5	9.7	15.6
	10	9.6	15.4
	25	9.5	15.2
	50	9.4	15.0
40	1	8.9	14.3
	5	8.7	14.0
	10	8.6	13.8
	25	8.5	13.6
	50	8.4	13.4
50	1	8.0	12.7
	5	7.7	12.4
	10	7.6	12.2
	25	7.5	12.0
	50	7.4	11.9
60	1	7.0	11.3
	5	6.8	10.9
	10	6.7	10.8
	25	6.6	10.6
	50	6.5	10.4
70	1	6.1	9.8
	5	5.9	9.5
	10	5.9	9.4
	25	5.7	9.2
	50	5.7	9.1
80	1	5.3	8.5
	5	5.1	8.2
	10	5.1	8.1
	25	5.0	8.0
	50	4.8	7.7

Temperature [°C]	Operating period [years]	Permissible component operating pressure [bar]	
		SDR 33	SDR 21
		ISO-S 16	ISO-S 10
90	1	4.6	7.3
	5	4.4	7.1
	10	4.3	6.9
	25	3.8	6.0
	50	3.2	5.2
95	1	4.2	6.8
	5	4.0	6.5
	10	3.8	6.0
	25	3.1	5.0
	50	2.7	4.3
100	1	3.9	6.2
	5	3.6	5.8
	10	3.1	5.0
	25	2.6	4.1
	50	2.2	3.6
110	1	3.2	5.2
	5	2.5	4.0
	10	2.1	3.4
	25	1.7	2.8
	50	1.5	2.4
120	1	2.5	4.0
	5	1.7	2.8
	10	1.5	2.4
	25	1.2	1.9
130	1	1.7	2.8
	5	1.2	1.9
140	1	1.2	1.9
	5	0.8	1.3

Table A.8: Permissible component operating pressures for PVDF. (source: ISO 10931)

Figures stated in the above table refer to water. They were calculated by referring the respective creep curves taking into account a safety coefficiant C =1.6.

4.9 Hydrostatic strength curve for ECTFE

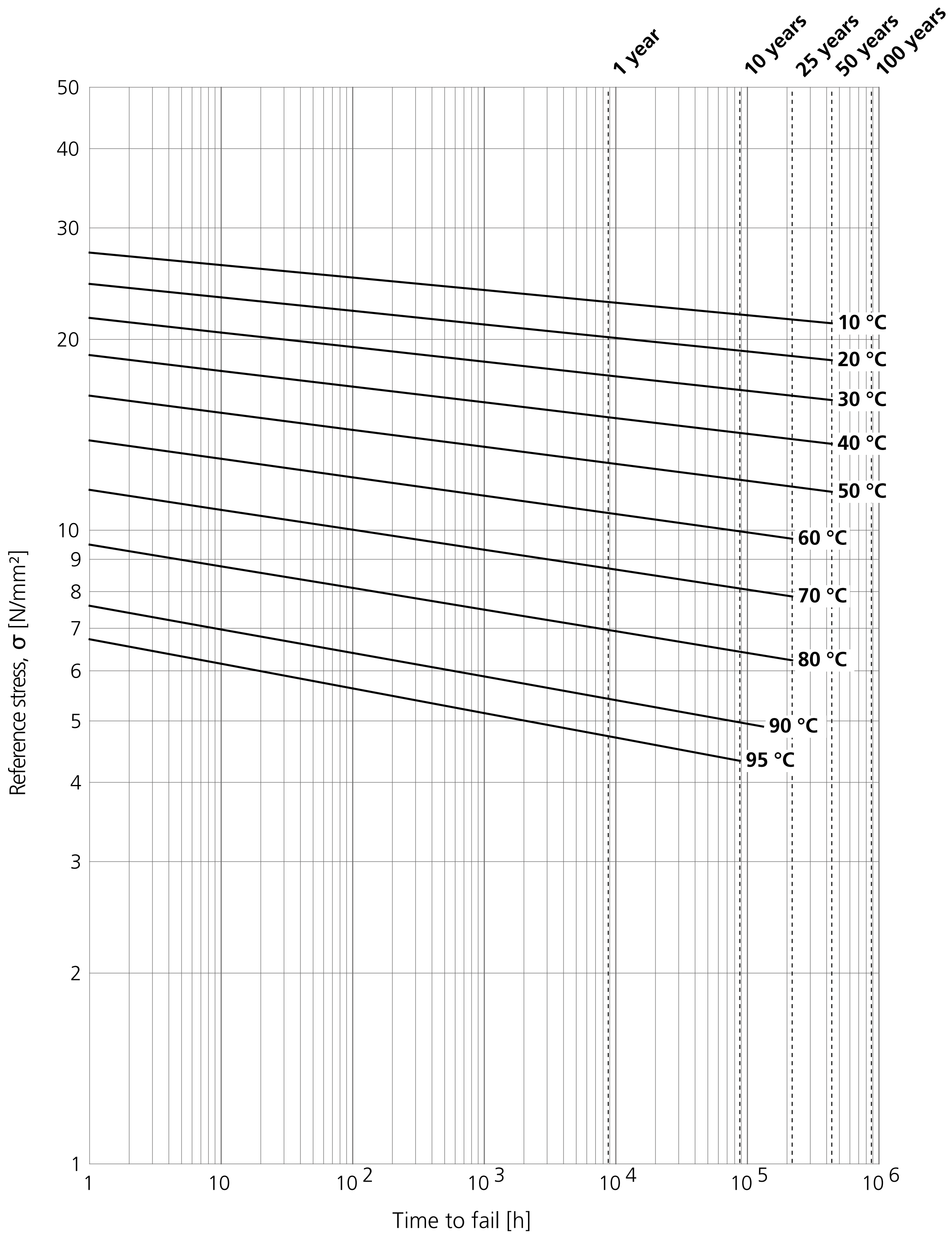


Figure A.9: Minimum required hydrostatic strength curve for ECTFE (according to DVS 2205-1 supplement 4)

4.10 Permissible component operating pressures P_B for ECTFE depending on temperature and operation period

Temperature [°C]	Operatingperiod [years]	Permissible component operating pressure [bar]	
		SDR 33	SDR 21
		ISO-S 16	ISO-S 10
10	1	8.9	14.3
	5	8.6	13.8
	10	8.5	13.6
	25	8.4	13.4
	50	8.2	13.2
20	1	7.8	12.6
	5	7.6	12.1
	10	7.4	12.0
	25	7.3	11.7
	50	7.2	11.6
30	1	6.8	10.9
	5	6.6	10.5
	10	6.5	10.4
	25	6.3	10.1
	50	6.2	10.0
40	1	5.8	9.4
	5	5.6	9.0
	10	5.5	8.9
	25	5.4	8.7
	50	5.3	8.5
50	1	4.9	7.9
	5	4.7	7.6
	10	4.6	7.5
	25	4.5	7.3
	50	4.4	7.1
60	1	4.1	6.6
	5	3.9	6.3
	10	3.8	6.3
	25	3.7	6.0
70	1	3.3	5.4
	5	3.2	5.1
	10	3.1	5.0
	25	3.0	4.9
80	1	2.7	4.3
	5	2.5	4.1
	10	2.5	4.0
	25	2.4	3.9
90	1	2.1	3.3
	5	1.9	3.1
	10	1.9	3.1
	15	1.9	3.0
95	1	1.8	2.9
	5	1.7	2.7
	10	1.6	2.7

Table A.9: Permissible component operating pressures for ECTFE (based on ISO 10931).

Figures stated in the above table refer to water. They were calculated by referring the respective creep curves taking into account a safety coefficiant C =1.6.

5 Creep modulus curves

5.1 Creep modulus curves for PE 100, PE 100-RC and PE 100-el

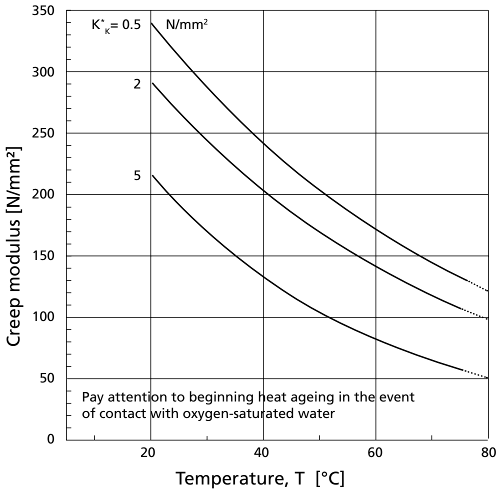


Figure A.10: Creep modulus of PE 100, PE 100-RC and PE 100-el for1 year. (Source: DVS 2205-1)

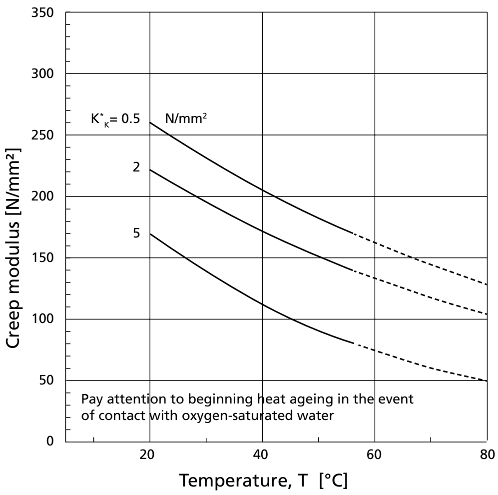


Figure A.11: Creep modulus of PE 100, PE 100-RC and PE 100-el for10 years. (Source: DVS 2205-1)

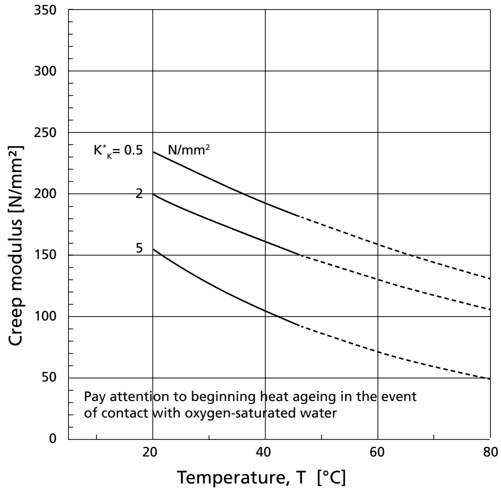


Figure A.12: Creep modulus of PE 100, PE 100-RC and PE 100-el for25 years. (Source: DVS 2205-1)

In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.

Influences by chemical attack or by eccentricity and unroundness have to be taken into account separately.

5.1.1 Isochronous stress/strain diagramm

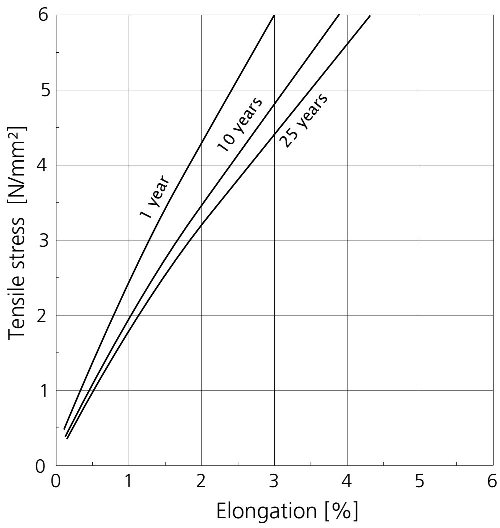


Figure A.13: Isochronous stress/strain diagramm of PE 100 for 23°.

5.2 Creep modulus curves for PP-H

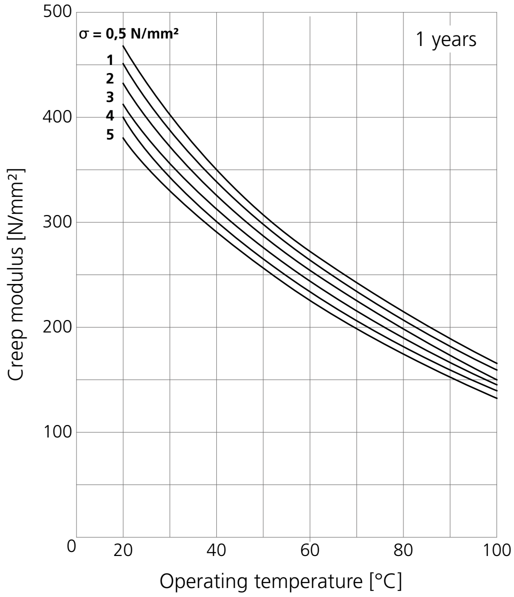


Figure A.14: Creep modulus curves for PP-H for 1 year (acc.to DVS 2205-1).

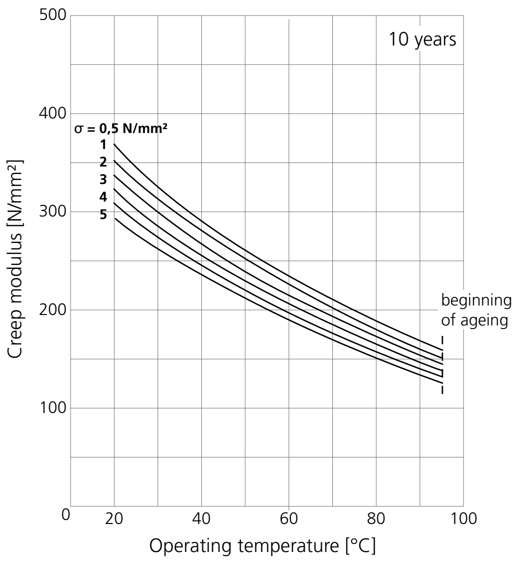


Figure A.15: Creep modulus curves for PP-H for 10 years (acc.to DVS 2205-1).

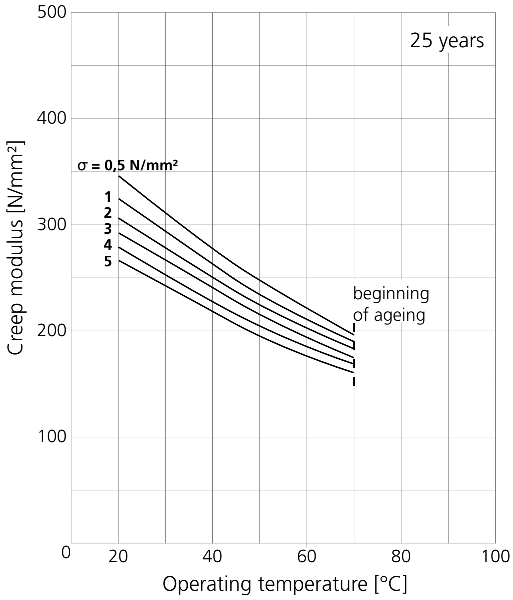


Figure A.16: Creep modulus curves for PP-H for 25 years (acc.to DVS 2205-1).

In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.

Influences by chemical attack or by eccentricity and unroundness have to be taken into account separately.

5.3 Creep modulus curves for PP-R

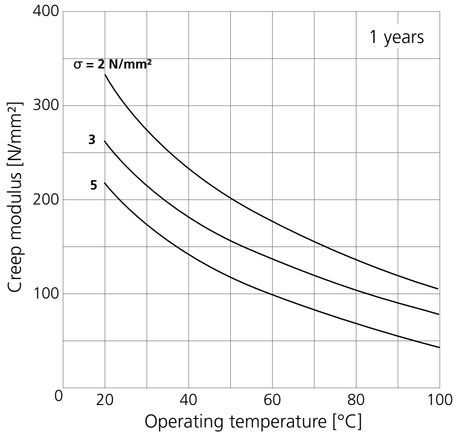


Figure A.17: Creep modulus curves for PP-R for 1 year (acc.to DVS 2205-1).

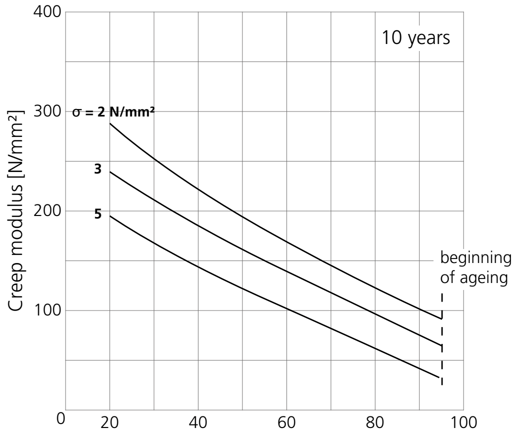


Figure A.18: Creep modulus curves for PP-R for 10 year (acc.to DVS 2205-1).

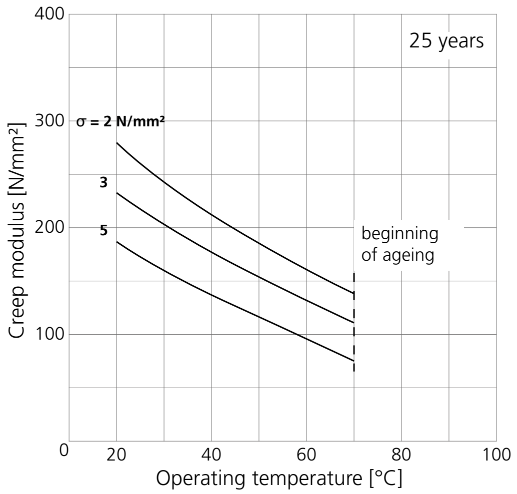


Figure A.19: Creep modulus curves for PP-R for 25 year (acc.to DVS 2205-1).

In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.

Influences by chemical attack or by eccentricity and unroundness have to be taken into account separately.

5.4 Creep modulus curves for PVDF

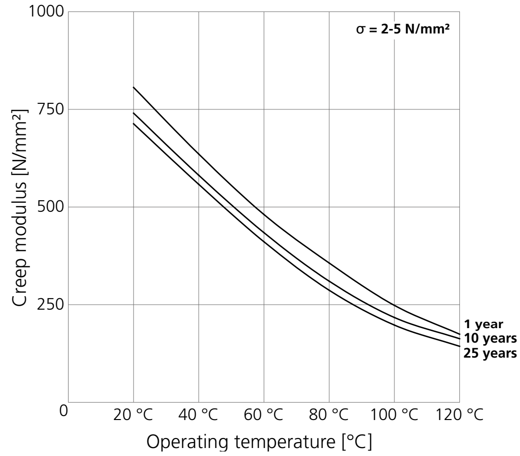


Figure A.20: Creep modulus curves for PVDF (acc.to DVS 2205-1).

In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.

Influences by chemical attack or by eccentricity and unroundness have to be taken into account separately.

5.5 Creep modulus curves for ECTFE

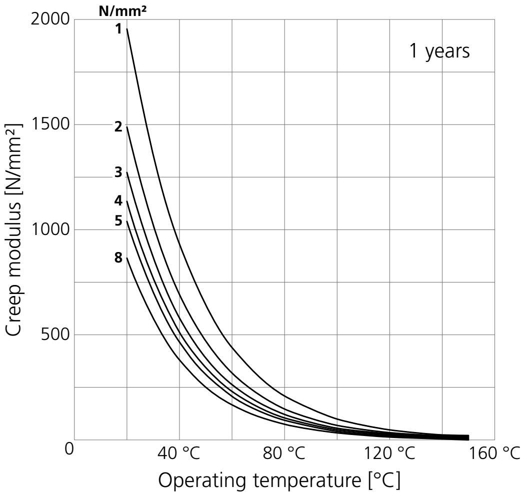


Figure A.21: Creep modulus curves for ECTFE for 1 year (acc.to DVS 2205-1).

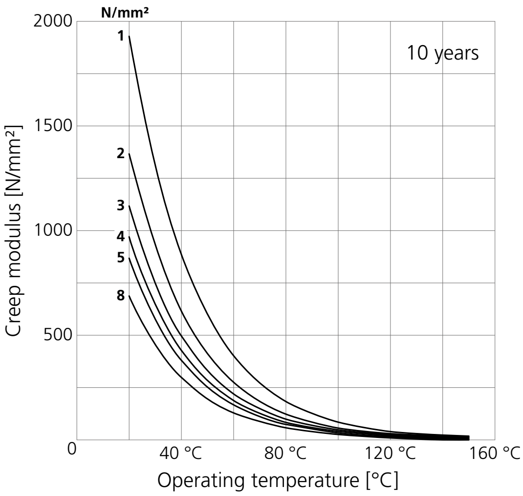


Figure A.22: Creep modulus curves for ECTFE for 10 year (acc.to DVS 2205-1).

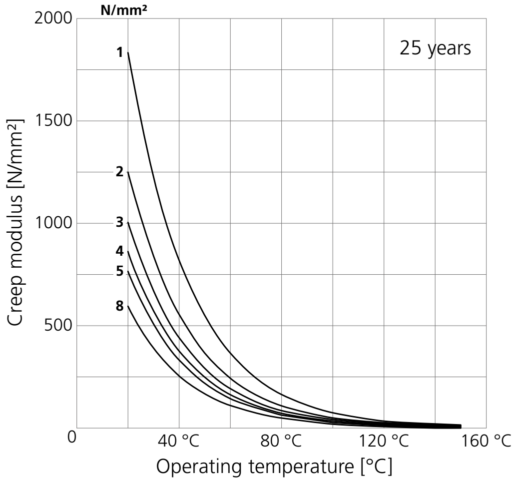


Figure A.23: Creep modulus curves for ECTFE for 25 year (acc.to DVS 2205-1).

In the stated diagrams the calculated creep modulus still has to be reduced by a safety coefficient of ≥ 2 for stability calculations.

Influences by chemical attack or by eccentricity and unroundness have to be taken into account separately.

6 Permissible buckling pressures

The buckling pressures shown in table A.10 to A.13 have been calculated according to the formula stated on page 168 (based on DVS 2210). These buckling pressures have to be decreased by the corresponding reducing factors due to chemical influence or unroundness for every particular application.

6.1 Permissible buckling pressures for PE 100, PE 100-RC and PE 100-el

Tempera-ture	Operating period	Permissible buckling pressure [bar]							
[°C]	[a]	SDR 41	SDR 33	SDR 26	SDR 21	SDR 17	SDR 11	SDR 9	SDR 7.4
20	1	0,054	0,107	0,212	0,429	0,854	3,376	6,719	13,423
	10	0,041	0,081	0,161	0,325	0,648	2,561	5,097	10,183
	25	0,037	0,074	0,146	0,296	0,589	2,328	4,634	9,257
30	1	0,047	0,092	0,183	0,370	0,736	2,910	5,792	11,571
	10	0,036	0,070	0,139	0,281	0,559	2,212	4,402	8,794
	25	0,034	0,066	0,132	0,266	0,530	2,095	4,170	8,331
40	1	0,037	0,074	0,146	0,296	0,589	2,328	4,634	9,257
	10	0,032	0,062	0,124	0,251	0,500	1,979	3,939	7,869
	25	0,030	0,059	0,117	0,237	0,471	1,863	3,707	7,406
50	1	0,032	0,062	0,124	0,251	0,500	1,979	3,939	7,869
	10	0,028	0,055	0,110	0,222	0,442	1,746	3,475	6,943

Table A.10: Permissible buckling pressure for PE 100, PE 100-RC and PE 100-el.

6.2 Permissible buckling pressures for PP-H und PP-R

Temperature [°C]	Operation periods [years]	Permissible buckling pressure [bar]							
		SDR 41		SDR 33		SDR 17.6		SDR 11	
		ISO-S 20		ISO-S 16		ISO-S 8.3		ISO-S 5	
		PP-H	PP-R	PP-H	PP-R	PP-H	PP-R	PP-H	PP-R
20	1	0.080	0.060	0.170	0.125	1.11	0.83	5.15	3.80
	10	0.060	0.050	0.130	0.110	0.86	0.73	3.95	3.35
	25	0.055	0.050	0.120	0.110	0.78	0.70	3.65	3.25
30	1	0.070	0.050	0.150	0.110	0.96	0.71	4.45	3.30
	10	0.055	0.045	0.115	0.100	0.75	0.64	3.50	2.95
	25	0.050	0.045	0.110	0.095	0.71	0.61	3.30	2.85
40	1	0.060	0.045	0.130	0.095	0.83	0.62	3.85	2.85
	10	0.050	0.040	0.105	0.090	0.68	0.57	3.15	2.65
	25	0.045	0.040	0.100	0.085	0.64	0.55	2.95	2.55
50	1	0.050	0.040	0.110	0.080	0.73	0.53	3.40	2.45
	10	0.045	0.035	0.095	0.075	0.61	0.49	2.85	2.30
	25	0.040	0.035	0.090	0.075	0.57	0.48	2.65	2.20
60	1	0.045	0.035	0.100	0.070	0.64	0.47	2.95	2.15
	10	0.040	0.030	0.085	0.065	0.55	0.43	2.55	2.00
	25	0.035	0.030	0.080	0.065	0.52	0.42	2.40	1.95
70	1	0.040	0.030	0,085	0.060	0.57	0.41	2.65	1.90
	10	0.035	0.025	0.075	0.055	0.49	0.37	2.25	1.70
	25	0.030	0.025	0.070	0.055	0.46	0.36	2.15	1.65
80	1	0.035	0.025	0.075	0.050	0.50	0.34	2.30	1.60
	10	0.030	0.020	0.065	0.045	0.44	0.31	2.20	1.45
95	1	0.030	0.020	0.065	0.040	0.41	0.27	1.90	1.25
	10	0.025	0.015	0.055	0.035	0.35	0.23	1.65	1.05

Table A.11: Permissible buckling pressures for PP-H und PP-R.

The buckling pressure figures in [bar] stated in the above table refer to water and were calculated taking into account a safety coefficiant of C =2.0 (minimum safety coefficiant for stability calculations).

6.3 Permissible buckling pressures for PVDF

Temperature [°C]	Operation periods [years]	Permissible buckling pressure [bar]	
		SDR 33 ISO-S 16	SDR 21 ISO-S 10
20	1	0.28	1.18
	10	0.26	1.08
	25	0.20	1.04
30	1	0.26	1.05
	10	0.23	0.95
	25	0.23	0.92
40	1	0.23	0.93
	10	0.21	0.85
	25	0.20	0.85
50	1	0.20	0.82
	10	0.19	0.74
	25	0.17	0.70
60	1	0.17	0.70
	10	0.16	0.63
	25	0.15	0.60
70	1	0.15	0.60
	10	0.13	0.53
	25	0.12	0.50
80	1	0.13	0.52
	10	0.11	0.45
	25	0.10	0.42
90	1	0.11	0.43
	10	0.09	0.37
	25	0.08	0.35
100	1	0.09	0.36
	10	0.08	0.32
	25	0.07	0.29
110	1	0.07	0.30
	10	0.06	0.26
	25	0.06	0.23
120	1	0.06	0.26
	10	0.06	0.24
	25	0.05	0.21

Table A.12: Permissible buckling pressures for PVDF.

The buckling pressure figures in [bar] stated in the above table refer to water and were calculated taking into account a safety coefficiant of C =2.0 (minimum safety coefficiant for stability calculations).

6.4 Permissible buckling pressures for ventilation pipes made of PP-H and PE.

Pipe dimension OD x s [mm]	Material	Permissible buckling pressure [Pa]							
		20 °C		30 °C		40 °C		50 °C	
		10 years	25 years	10 years	25 years	10 years	25 years	10 years	25 years
140 x 3.0	PP-H	4200	3800	3650	3450	3350	3100	3000	2800
160 x 3.0	PP-H	2750	2500	2400	2300	2200	2050	1950	1850
180 x 3.0	PP-H	1900	1750	1700	1600	1550	1400	1350	1250
200 x 3.0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
225 x 3.5	PP-H	1550	1400	1350	1300	1250	1150	1100	1050
250 x 3.5	PP-H	1100	1000	1000	900	900	850	800	750
280 x 4.0	PP-H	1200	1100	1050	1000	950	900	850	800
315 x 5.0	PP-H	1650	1500	1450	1350	1300	1250	1150	1100
355 x 5.0	PP-H	1150	1050	1000	950	900	850	800	750
400 x 6.0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
400 x 8.0	PP-H	3400	3050	2950	2800	2700	2500	2400	2250
400 x 8.0	PE 100 (-RC)	2035	1815	1705	1540	1375	1265	1100	–
450 x 6.0	PP-H	950	900	850	800	750	700	700	650
450 x 8.0	PP-H	2350	2150	2050	1950	1850	1750	1650	1550
450 x 8.0	PE 100 (-RC)	1375	1265	1155	1045	935	880	770	–
500 x 8.0	PP-H	1700	1550	1500	1400	1350	1250	1200	1000
500 x 8.0	PE 100 (-RC)	990	935	825	770	660	605	550	–
500 x 10.0	PP-H	3400	3050	2950	2800	2700	2500	2400	2250
500 x 10.0	PE 100 (-RC)	2035	1815	1705	1540	1375	1265	1100	–
560 x 8.0	PP-H	1200	1100	1050	1000	950	900	850	800
560 x 10.0	PP-H	2400	2150	2100	1950	1900	1750	1700	1600
560 x 10.0	PE 100 (-RC)	1430	1265	1210	1045	990	880	770	–
630 x 10.0	PP-H	1650	1500	1450	1350	1300	1250	1150	1100
630 x 10.0	PE 100 (-RC)	990	880	825	715	660	605	550	–
710 x 12.0	PP-H	2000	1850	1750	1650	1600	1500	1450	1350
710 x 12.0	PE 100 (-RC)	1210	1100	990	880	825	715	660	–
800 x 12.0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
900 x 12.0	PE 100 (-RC)	825	770	660	605	550	495	440	–
900 x 15.0	PP-H	1900	1750	1700	1600	1550	1400	1350	1250
900 x 15.0	PE 100 (-RC)	1155	1045	935	880	770	715	605	–
1000 x 15.0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
1000 x 15.0	PE 100 (-RC)	825	770	660	605	550	495	440	–
1200 x 18.0	PP-H	1400	1250	1200	1150	1100	1050	1000	900
1200 x 18.0	PE 100 (-RC)	825	770	660	605	550	495	440	–
1400 x 20.0	PP-H	1200	1100	1050	1000	950	900	850	800
1400 x 20.0	PE 100 (-RC)	715	660	605	550	495	440	385	–

Table A.13: Permissible buckling pressures for ventilation pipes out of PP-H and PE (100000 Pa = 1bar).

The buckling pressure figures in Pascal stated in the above table were calculated taking into account a safety coefficiant of C =2.0 (minimum safety coefficiant for stability calculations).

7 Comparison pressure ratings

Table A.14 shows the comparison of the SDR, S series and PN pressure ratings

SDR	S	PN-pressure rating		
		PE 100 / PE 100-RC / PE 100-el	PP	PVDF/ECTFE
41	20	4	2.5	–
33	16	5	3.2	10
26	12.5	6.3	4	–
21	10	8	–	16
17.6	8.3	9.6	6	–
17	8	10	6.3	–
11	5	16	10	–
9	4	20	–	–
7.4	3.2	25	16	–
6	2.5	32	20	–

Table A.14: Comparison pressure rating (Source: EN 12201-2, DVGW G400-1, DVGW G472)

8 Behaviour at abrasive fluids

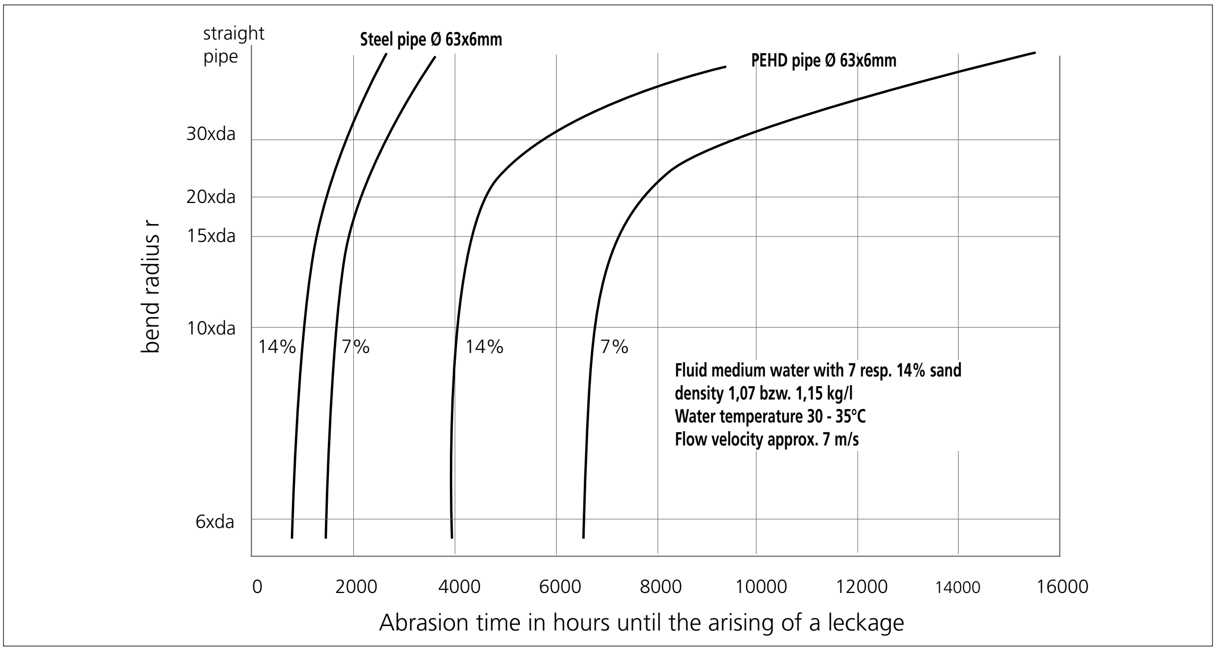


Figure A.24: Abrasion time of HDPE- and Steel elbows of different bending radii in dependance on solid portion

There is one more testing method which is even more related to practice, during which a medium is pumped through pipe samples which are built-in into a piping system. An adequate way to to check the abrasion behaviour of such a system is to determine the time elapsed until leakage is noticed. As indicated in above illustration, thermoplastic pipes (in this particular case PE pipes have been used, whereas PP pipes would show same or even slightly better results) have an essential advantage compared to steel pipes. For conveying dry abrasive acting materials polypropylene is only suitable conditionally. As electrostatic charging might occur only electro-conductible materials (PE 100-el, PPs-el) should be used for such applications.

Each particular application should be checked with our technical engineering department.

Generally speaking, thermoplastic pipes are much better suited for conveying fluid-solid-mixtures than e. g. concrete or steel pipes. We have already experienced many positive results for various applications. A testing method was developed by the "Technische Hochschule Darmstadt", during which a 1 m long half-pipe is tilted with a frequency of 0.18 Hz. The decrease of the wall thickness after a certain testing time can be regarded as adequate measure for abrasion.

The result clearly shows advantage of thermoplastic pipes for the transportation of fluid-soild-mixtures in gravity pipelines.

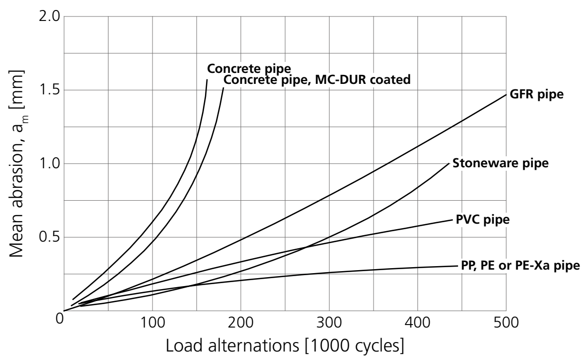


Figure A.25: Abrasion behavior according to method Darmstadt Medium: silica sand-gravel-water mixture 46 Vol.-% silica/gravel, grain size up to 30 mm

9 Chemical properties

9.1 General chemical properties of PE & PP

Compared to metals, which undergo irreversible chemical changes when attacked by chemicals, polymers in most instances are only affected by physical changes which typically only influence the present utilisation value. Such physical changes are e.g. swelling and dissolution processes which can alter the microstructure of polymers and as a result compromise the physical properties. In such cases reducing factors need to be taken into consideration when designing facilities and parts of those.

PE und PP are resistant to diluted solutions of salts, acids and alkalis as long as those are not strong oxidizers. Further they are unaffected by many solvents, such as alcohols, esters and ketones. In contact with solvents, such as aliphatic and aromatic compounds or chlorinated hydroxycarbons, significant swelling, especially at raised temperatures, can be expected.

Actual destruction rarely occurs. Ampholytes (e.g. chromic acid, concentrated sulphuric acid) can drastically reduce the durability through stress cracking corrosion.

9.1.1 Lyes

9.1.1.1 Alkalis

Diluted alkali solutions (e.g. caustic lye), even at higher temperature and at higher concentrations do not react with PP and PE and can therefore be used without problems, unlike PVDF or other fluoroplastics.

9.1.1.2 Bleaching lye

As these lyes contain active chlorine, only a durability is given at room temperature. At higher temperatures and concentrations of active chlorine, PP and PE are rather delimited for pressureless piping systems and tanks.

9.1.1.3 Hydrocarbons

Even at ambient temperature PP is only resistant to hydrocarbons (petrol as well as other fuels) conditionally (swelling > 3 %). PE however can be used for conveying of such media up to temperatures of 40 °C and for the storageof these media up to temperatures of 60 °C. Only at temperatures > 60 °C PE is conditonally resistant (swelling > 3 %).

9.1.2 Acids

9.1.2.1 Sulphuric Acid

Concentrations up to approximately 70 % only slightly change the properties of PP and PE. Concentrations above 80 % can cause oxidation already at ambient temperature. At higher temperatures, oxidation can even lead to carbonization of the surface of the PP semi-finished products.

9.1.2.2 Hydrochloric acid, hydrofluoric acid

PP and PE are chemically resistant to concentrated hydrochloric acid and hydrofluoric acid. At concentrations above 20 % for hydrochloric acid and above 40% for hydrofluoric acid diffusion will occur. Double containment piping systems have proven practical for such applications.

9.1.2.3 Nitric acid

Highly concentrated nitric acid has an oxidizing effect on materials. The mechanical strength can be reduced at higher concentrations.

9.1.2.4 Phosphoric acid

PP and PE are chemically resistant even at higher concentrations and raised temperatures. For more detailed information regarding the chemical resistance of our products, our application engineering department will be at your disposal at any time.

Actual lists of chemical properties are available on www.agru.at.

9.2 Chemical resistance PVDF

PVDF is resistant to a wide range of chemicals.

It has an outstanding resistance to most anorganic and organic acids, oxidising media, aliphatic and aromatic hydrocarbons, alcohols and halogenated solvents. PVDF is also resistant to halogens (chlorine, bromine, iodine), but not fluorine.

Generally PVDF is unsuitable for the following media, because they can lead to decomposition:

- amine, basic media with a pH value ≥ 12
- compounds, which can generate free radicals under certain circumstances
- fuming sulfuric acid
- high polar solvents (acetone, ethyl acetate, dimethyl-formamide, dimethylsulphoxide, ...): PVDF might swell or dissolve
- alkali metals melted or amalgam

Please note the potential risk of stress cracking. This might occur in case PVDF is exposed to a milleu with a pH value ≥ 12 or if PVDF is exposed to a mechanical stress in the presence of free radicals (e.g. elemental chlorine).

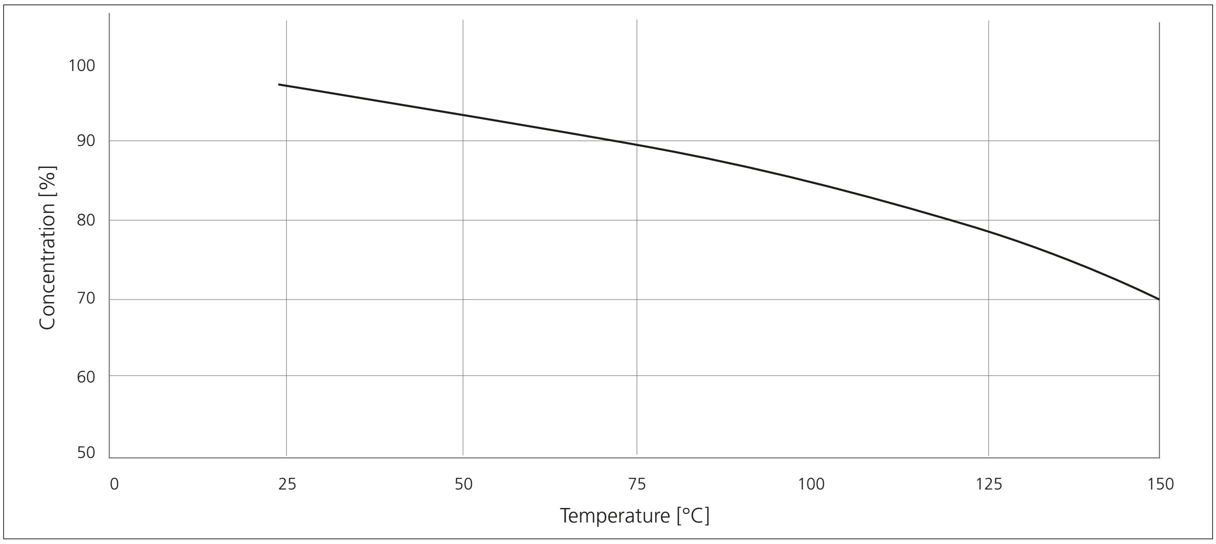


Figure A.26: Maximum permissible H_2SO_4-concentration for PVDF pipes depending on temperature (based on tests with the Dechema Console).

9.2.1 Example: sulfuric acid

Free sulphur trioxide might cause stress cracking in PVDF if in contact with concentrated sulphuric acid in case of simultaneous exposure to mechanical stress. At high temperatures the content of free sulphur trioxide of even highly diluted sulphuric acid can cause stress cracking in PVDF.

In order to determine the permissible pressure in presence of sulphuric acid depending on temperature, the behaviour of PVDF pipes at various pressure and temperature levels was analysed in the DECHEMA-module.

The following essential parameters should be considered for every case:

- Properties of the finished piece made of PVDF
- Chemical structure and physical state of the joint(s), which come in contact with the fitting made of PVDF.
- Concentration
- Temperature
- Time
- Potential diffusion or dissolubility

Updated lists of chemical properties are available on www.agru.at

9.3 Chemical resistance ECTFE

ECTFE is characterized by outstanding chemical resistance and remarkable barrier-properties. It is practically unaffected by most common industrially used corrosive chemicals, e.g. strong mineral and oxidizing acids, alkalines, metal-etching-products, liquid oxygen and all organic solvents, except hot amines (e.g. aniline, dimethylamine).

The stability data for the solvents listed in the following table were tested using undiluted solvents. The intensity of chemical attacks depends on the respective concentration. As a result, the effect of the listed media in the table below can be expected to be smaller at lower concentrations. As with other fluorinated hydrocarbons ECTFE will be attacked by sodium and potassium. The particular impact depends on the exposure time and temperature. Certain halogenated solvents can cause swelling of ECTFE and other fluorinated polymers. This effect normally has no influence on the usability. After removal of the solvent and drying of the surface, the mechanical properties return to their origin values, which shows that no chemical attack has occurred.

Updated lists of chemical properties are available on www.agru.at

Chemical	Temperature [°C]	Weight gain [%]	Influence on tensile modulus	Influence on elongation at break
Mineral acid				
Sulfuric acid 78%	23	< 0.1	U	U
	121	< 0.1	U	U
Hydrochloric acid 37%	23	< 0.1	U	U
	75-105	0.1	U	U
Hydrochloric acid 60%	23	< 0.1	U	U
Chlorosulfonic acid 60%	23	0.1	U	U
Oxidizing acid				
Nitric acid 70%	23	< 0.1	U	U
	121	0.8	A	U
Chromic acid 50%	23	< 0.1	U	U
	111	0.4	U	U
Aqua regia	23	0.1	U	U
	75-105	0.5	U	U
Solvents				
Aliphates	23	0.1	U	U
Hexane	54	1.4	A	U
Isooctane	23	< 0.1	U	U
	116	3.3	A	U
Aromates				
Benzene	23	0.6	U	U
	74	7	C	U
Toluene	23	0.6	U	U
	110	8.5	C	U
Alcoholes				
Methanol	23	0.1	U	U
	60	0.4	A	U
Butanol	23	< 0.1	U	U
	118	2.0	A	U
Classical plastic				
Dimethyl formamide	73	2.0	A	U
Dimethyl sulphoxide	73	0.1	U	U

Table A.15:
Chemical resistance ECTFE

U- Insignificant
A- Reduction by 25-50 %
B- Reduction by 50-75 %
C- Reduction by > 75 %

1 Transport and handling

During transport and handling of pipes and fittings, adhere to the following guidelines in order to avoid damages:

At pipe wall temperatures below 0°C, pipes made of PP special materials (PPs-el, PPs, PE 100-el) and pre-fabricated components (for example segmented bends) must be loaded and transported only with special care.

Impact- and bending stress at temperatures below 0°C must be avoided. Damage of surface (scratches, marks, etc.), which can occur when dragging pipes, have to be avoided.

Figure B.1: PPs-pipes

2 Storage

During storage of pipes and fittings, adhere to the below stated guidelines in order to avoid any dete-rioration of quality:

The storage area has to be even and free from waste, such as stones, screws, nails, etc.

In case pipes are piled up, storage height must not exceed 1m. In order to prevent to inadvertent rolling of pipes, wooden chocks have to be placed under the outer pipes. For pipes > OD 630mm, maximum two rows may be stored on top of one another. Pipes > OD 1000mm have to be stored loosely. Pipes have to be stored flat and avoiding bending stress, if possible in a wooden crate.

Natural coloured and grey coloured products have to be stored protected against UV radiation when kept outdoor. According to standard EN 12007-2, pigmented (orange, blue) pipes may be exposed to a maximum radiation dose of 3.5 GJ/m² (this corre-sponds to an outdoor storage period of 12 months in central Europe). Pipes and fittings made of PPs-el and PE 100-el have to be protected during storage against humidity and UV radiation (no outdoor exposure, use of dry warehouses).

Figure B.2: Horizontal pipe storage

Attention!

As the special types PPs-el and PE 100-el suffer the danger of absorption of humidity at a storage period above 12 months, it is recommended to check the usability of the material by means of a welding test.

3 General installation guidelines

Due to the lower stiffness and rigidity as well as the potential length expansions (caused by tem-pera-ture changes) of thermoplastics in comparison with metallic materials, the following installation require-ments for piping elements have to be con-sidered: for above ground applications expansion and con-traction in both radial as well as axial direc-tion must not be hindered - that means, installation with radial clearance, establishing compensation provisions, allowance of controlled expansion in longitudinal direction by reasonable placements of fixed points.

Fixations have to be configured in such a way so as to avoid pin-point stresses, which 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 surface of the attachments should be of such nature as to avoid mechanical damage of the pipe surface.

Valves (in certain cases also tees) generally should be installed as fixed points within the piping system. Valve constructions with integrated attachment devices within the valve housing are most suitable.

3.1 Fixing by means of pipe clips

Attachments made of steel or thermoplastics are available for plastics pipes. Steel clips have to be lined with tapes made of PE or elastomers in any case, as otherwise the surface of the plastics pipe may be damaged. AGRU plastics pipe clips as well as pipe holders are ideal for installation. These may be commonly applied and have been particularly designed in regards to the tolerances of the plastics pipes.

Figure B.3: PP piping system installed with AGRU pipe clips.

Therefore, they serve e.g. as sliding bearing in hori-zontally installed piping systems allowing to absorb vertical stresses. Another application range of AGRU pipe clips is the use as guiding bearing for the pur-pose of avoiding lateral buckling of piping systems as it can also absorb transversal stress.

For smaller pipe diameters (< 63mm) it is recom-mended to use half-round steel pipes as support for the piping system in order to enlarge the support distances.

3.2 Installation temperature

The minimum installation temperature for each welding method has to be considered.

3.3 Installation guidelines for electro-conductable materials

In principle the general installation guidelines are applicable. When installing earthing clips it has to be taken care that the pipe surface below the clip is scraped. It is absolutely mandatory to remove the potentially present oxide film in order to ensure the required surface resistance of < 106 Ohm.

For flange joints, electro-conductible flanges or steel flanges have to be used.

After completion, the installed and earthed piping system is required to undergo a final evaluation by qualified personnel regarding the bleeder resistance in any case.

Figure B.4: Electrically conductive pipe system with electro-con-ductable flange joints.

4 Minimum bending radius

The flexibility of the pipe ensures that minor deviations due to structural conditions can be absorbed by the pipe without the use of fittings. Reference values for the minimum bending radius of pipes are as follows in table B.1:

$$R = OD \cdot x$$

Formula D.1: Bending radius.

R Bending radius [mm]
OD Outer diameter of the pipe [mm]
x Multiplication factor [-]

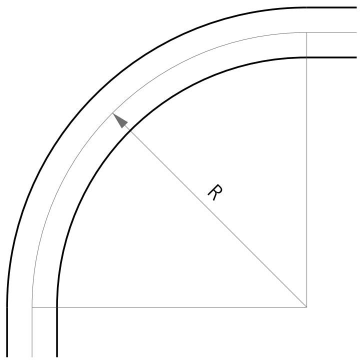


Figure B.5: Bending radius.

Installation temperature [°C]	x: Multiplication factor [-]								
	PE 100 / PE 100-RC / PE 100-el			PP-H	PP-R	PVDF	ECTFE	PolyFlo PE 100-RC	PolyFlo PP-R
	SDR 7.4-17	SDR 21-26	SDR 33-41	SDR 11-17	SDR 11-17	SDR 21	SDR 21	SDR 17/11	SDR 17/11
+30	20	30	50	35	30	60	30	25	35
+20	20	30	50	35	30	60	30	25	35
+10	35	52,5	87,5	50	45	100	52	40	50
0	50	75	125	70	65	150	75	55	70

Tabelle B.1: Multiplication factor bending radius.

Attention: if fittings or flanges are installed in the bending area, a minimum bending radius of da x 100 must not be exceeded.

Example:

1. PE 100-RC; OD = 110 mm; SDR 11; 20°C → R = OD * x = 110 * 20 = 2200 mm
2. PE 100-RC; OD = 110 mm; SDR 33; 20°C → R = OD * x = 110 * 50 = 5500 mm
3. PP-H; OD = 110 mm; SDR 11; 20°C → R = OD * x = 110 * 35 = 3800 mm

4. PP-R; OD = 110 mm; SDR 17; 20°C → R = OD * x = 110 * 30 = 3300 mm

5 Machining

5.1 Machining of PP and PE

(valid for cutting, turning, milling and drilling)

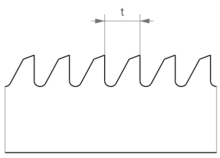
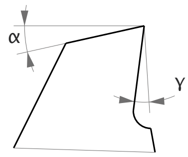
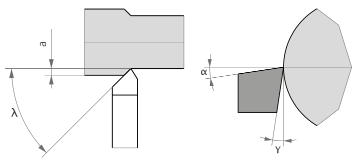
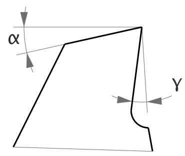
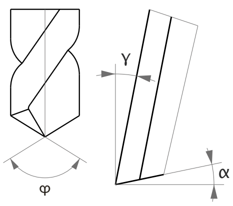
	Cutting			
	Clearance angle α Rake angle γ Pitch t Cutting speed v	[°] [°] [mm] [m/min]	20 - 30 2 - 5 3 - 8 500	Band saws are appropriate for the cutting of pipes, blocks, thick sheets and for round bars
	Cutting			
	Clearance angle α Rake angle γ Pitch t Cutting speed v	[°] [°] [mm] [m/min]	20 - 30 6 - 10 3 - 8 2000	Circular saws can be used for the cutting of pipes, blocks and sheets. HM saws have a considerably longer working life
	Turning			
	Clearance angle α Rake angle γ Tool angle λ Cutting speed v Feed f Cutting depth a	[°] [°] [°] [m/min] $[mm/min^{-1}]$ [mm]	6 - 10 0 - 5 45 - 60 250 - 500 0,1 - 0,5 >0.5	The peak radius (r) should be at least 0,5mm. High surface quality is obtained by means of a cutting tool with a wide finishing blade. Cut-off: Sharpen turning tool like a knife.
	Milling			
	Clearance angle α Rake angle γ Cutting speed v Feed f	[°] [°] [m/min] [mm/Zahn]	10 - 20 5 - 15 250 - 500 0.5	The use of uncoated carbide tools is recommended.
	Drilling			
	Clearance angle α Rake angle γ Centre angle ϕ Cutting speed v Feed f	[°] [°] [°] [m/min] $[mm/min^{-1}]$ [°]	5 - 15 10 - 20 60 - 90 50 - 150 0.1 - 0.3 12 - 16	Spiral angles 12 - 15°. For holes with diameters of 40 - 150mm, hollow drills should be used; for holes < 40mm diameter, use a normal SS-twist drill.

Table B.1: Parameters guide values for machining.

5.2 Machining of PVDF and ECTFE

The machining of PVDF and ECTFE fittings and pipes can be carried out without any particular problems if the following guidelines are observed:

If necessary, remove remaining stresses of larger surfaces by annealing before processing.

1 System of units

Size	Technical system of units	SI - unit (MKS-system) Legal unit	ASTM - unit
Length	m	m 1 m = 10 dm = 100 cm = 1000 mm 1000 m = 1 km	ft 1 Meile (naut.) = 1.852 km 0.9144 m = 1 yd = 3 ft 25.4 mm = 1 inch
Area	m^2	m^2 1 m^2 = 100 dm^2 = 10000 cm^2	yd^2 0.836 m^2 = 1 yd^2 1 yd^2 = 9 ft^2
Volume	m^3	m^3 1 m^3 = 10^3 dm^3 = 10^6 cm^3	yd^3 0.765 m^3 = 1 yd^3 1 yd^3 = 27 ft^3
Force	kp 1 N = 0.102 kp 1 kp = 9.81 N	N 1 N = 1 kgm/s^2 = 10^5 dyn	lb 1 lb = 4.447 N = 32 poundals
Pressure	kp/m^2 1 N/cm^2 = 0.102 kp/cm^2 0.1 bar = 1 m WS 1 bar = 750 Torr 1 bar = 750 mm Hg 1 bar = 0.99 atm	bar 1 bar = 10^5 Pa = 0,1 N/mm^2 10^6 Pa = 1 MPa = 1 N/mm^2	psi 1 bar = 14.5 psi = 14.5 lb/sq in
Mechanical stress	kp/mm^2 1 N/mm^2 = 0.102 kp/mm^2	N/mm^2	psi 1 N/mm^2 = 145.04 psi = 145.04 lb/sq in
Velocity	m/s	m/s	ft/sec. 1 m/s = 3.2808 ft/sec.
Density	g/cm^3	g/cm^3	psi 1 g/cm^3 = 14.22 x 10^{-3} psi
Volume	m^3	m^3	cu ft 1 m^3 = 35.3147 cu ft = 1.3080 cu yd 1 cm^3 = 0.061 cu in
Temperature	°C	°C 1 °C = 1 [°C+273.15] °K	°F °F = 1.8 x °C + 32

Table C.1: System of units

2 SDR - Standard Dimension Ratio

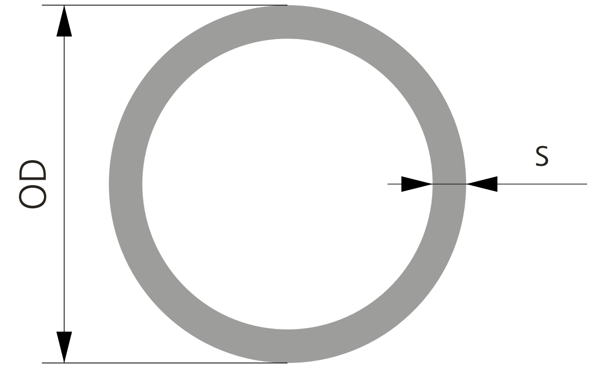


Figure C.1: Dimensions of a pipe.

$$SDR = \frac{OD}{s}$$

Formula C.1: SDR.

OD outer diameter [mm]
s wall thickness [mm]
SDR outer diameter to wall thickness-ratio

$$SDR = \frac{d_a}{s} = \frac{110}{10} = 11$$

Formula C.2: Example: OD = 110 mm, s = 10 mm

2.1 S-Series

$$S = \frac{SDR - 1}{2}$$

Formula C.3: S-Series.

S ISO S-Series
SDR standard dimension ratio

$$S = \frac{SDR - 1}{2} = \frac{11 - 1}{2} = 5$$

Formula C.4: Example: SDR11.

3 Component operating pressure

$$p_B = \frac{20 \cdot \sigma_v}{c \cdot (SDR - 1)}$$

Formel C.1: Component operating pressure.

c_{min} minimum safety factor
p_B component operating pressure [bar]
SDR standard dimension ratio
σ hoop stress [N/mm²]

$$p_B = \frac{20 \cdot \sigma_v}{c_{min} \cdot (SDR - 1)} = \frac{20 \cdot 10}{1.25 \cdot (11 - 1)} = 16$$

Formula C.5: Example: PE 100, 20 °C, 50 years, water (d.h. σ_v=10) SDR 11
C_{min} = 1.25

Material	Temperature		
	10 - <40°C	40 - <60°C	≥ 60°C
PE 100, PE 100-RC	1.25		
PP-H	1.6	1.4	1.25
PP-R	1.25		
PVDF	1.6		
ECTFE	1.6		

Table C.2: Minimum safety factor acc. to EN ISO 12162:2009

3.1 Operating pressure for water-dangerous media

For calculation of the maximum respective permissible operating pressure for conveying of water-dangerous fluids, the operating pressure p to be used as default value can be looked up in the relevant table for permissible system operating pressures (valid for water). Thereafter, this operating pressure has to be reduced by the relevant reduction coefficients. The overall safety coefficient is thereby in any case 2.0 at the minimum, for impact sensitive modified materials it will be higher (for PE 100-el 2.4, for PPs and PPs-el 3.0).

$$p_A = \frac{p_B}{f_{AP} \cdot f_{CR} \cdot A_Z}$$

Formula C.6: Component operating pressure.

p_A Operating pressure of the relevant application [bar]
p_B Component operating pressure, valid for water [bar]
f_{AP} application factor is an additional reducing factor which results a total safety coefficient of 2,0 at a minimum by multiplication with the C-factors according to DIN (see folowing table).
f_{CR} Chemical resistance factor according to DVS
A_Z Reducing factor for the specific tenacity

$$p_B = \frac{20 \cdot \sigma_v}{c_{min} \cdot (SDR-1)} = \frac{20 \cdot 10}{1.25 \cdot (11-1)} = 16\,bar$$

$$p_A = \frac{p_B}{f_{AP} \cdot f_{CR} \cdot A_Z} = \frac{16}{1.6 \cdot 1.4 \cdot 1} = 7.1\,bar$$

Formula C.7: Example: PE 100, 20 °C, 50 years, water (d.h. σ_v=10) SDR 11 C_{min}=1.25
Chemicals: HF (Hydrofluoric acid), Concentration ≤ 75%, i.e. f_{CR} = 1,4 (acc. to DVS 2205-1 supplement 5)

Material	Application factor f_{AP}	C - factor (acc. ISO 12162)	Total safety factor by 20 °C (f_{AP} x C)
PE 100, PE 100-RC	1.6	1.25	2.0
PE 100-el	1.9	1.25	2.4
PP-H	1.25	1.6	2.0
PP-R	1.6	1.25	2.0
PPs	2.4	1.25	3.0
PPs-el	2.4	1.25	3.0
PVDF	1.25	1.6	2.0
ECTFE	1.25	1.6	2.0

Table C.3: Application factors f_{AP} for water-dangerous media

Material	Reducing factor	
	-10°C	+20°C
PE 100, PE 100-RC	1.2	1.0
PE 100-el	1.6	1.4
PP-H	1.8	1.3
PP-R	1.5	1.1
PPs	*)	1.7
PPs-el	*)	1.7
PVDF	1.6	1.4

Table C.4: Reducing factor A_Z for the specific tenacity by low temperatures

*) ... Not applicable

4 Wall thickness

Strength calculations of thermoplastic plastic pipelines are generally based on long-term values. These strength values, which depend on the temperature, are derived from the hydrostatic long-term strength curve (see chapter A).

After the calculation of the arithmetical wall thickness the operating wall thickness is specified by using the nominal pressure or the SDR-class.

Safety margins for the wall thickness have to be taken into account (e.g. for the outdoor operation of the PE pipeline without UV protection or for the transport of abrasive substances).

$$s_{min} = \frac{p \cdot OD}{20 \cdot \sigma_s + p}$$

Formula C.8: Minimum wall thickness.

$$\sigma_s = \frac{\sigma_v}{C_{min}}$$

Formula C.9: Permissible design stress.

c_{min} minimum safety factor
OD outer diameter [mm]
p operating pressure [bar]
s_{min} minimum wall thickness [mm]
σ_v hoop stress [N/mm²]
σ_S design stress [N/mm²]

For the hoop stress see chapter A "Hydrostatic long-term strength".

$$\sigma_s = \frac{\sigma_v}{c_{min}} = \frac{10}{1.25} = 8\,N/mm^2$$

$$s_{min} = \frac{p \cdot OD}{20 \cdot \sigma_s + p} = \frac{16 \cdot 110}{20 \cdot 8 + 16} = 10\,mm$$

Formula C.10: Example:
PE 100, 20 °C, 50 years, water (i.e. σ_v = 10)
Operating pressure 16 bar Outside diameter OD = 110mm

If required, the formula can be used to calculate the hoop stress σ or the operating pressure p.

$$\sigma_s = \frac{p \cdot (OD - s_{min})}{20 \cdot s_{min}}$$

$$p = \frac{20 \cdot \sigma_s \cdot s_{min}}{OD - s_{min}}$$

Formula C.11: Reference stress.

$$\sigma_s = \frac{p \cdot (OD - s_{min})}{20 \cdot s_{min}} = \frac{16 \cdot (110-10)}{20 \cdot 10} = 8\,N/mm^2$$

$$\sigma_v = \sigma_s \cdot c_{min} = 8 \cdot 1.25 = 10\,N/mm^2$$

Formula C.12: Example: Reference stress.

5 Buckling pressure (low pressure)

In certain cases, piping systems are exposed to external pressure:

- Installation in water or buried below ground-water table
- Systems for vacuum. e.g. suction pipes

$$p_K = \frac{10 \cdot E_C}{8 \cdot (1-\mu^2)} \cdot \left(\frac{s}{r_m}\right)^3$$

Formula C.13: Buckling pressure (safety factor 2).

$$r_m = \frac{OD - s}{2}$$

Formula C.14: Mean radius.

E_C creep modulus for 25 years [N/mm²]
p_K critical buckling pressure [bar]
r_m mean pipe radius [mm]
s wall thickness [mm]
μ Transversal contraction factor 0.38
σ_K critical buckling stress [N/mm²]

$$p_K = \frac{10 \cdot E_C}{8 \cdot (1-\mu^2)} \cdot \left(\frac{s}{r_m}\right)^3 = \frac{10 \cdot 220}{8 \cdot (1-0.38^2)} \left(\frac{3.4}{53.3}\right)^3 = 0.085$$

Formula C.15: Example PP-R pipe SDR 33, 40 °C, 25 years
E_C = 220 N/mm² (creep modulus curve - page 150)
outside diameter OD = 110
Wall thickness = 3.4 mm
Additional safety factor 2.0 (Minimum security factor for stability calculation).

The buckling stress can be calculated using the following formula:

$$\sigma_K = p_K \cdot \frac{r_m}{s}$$

$$\sigma_K = p_K \cdot \frac{r_m}{s} = 0.085 \cdot \frac{53.3}{3.4} = 1.33$$

Formula C.16: Buckling stress.

6 Stiffening for pipes with buckling strain

At higher buckling strains, it is common practise to apply a stiffening by means of welded-on ribs due to economic reasons in order to enable the use of essentially thinner pipe wall thicknesses. Basis for this is a slightly modified form of the formulas for buckling pressure calculation of smooth walled pipes. It is necessary to know the present critical buckling pressure for this calculation and to choose the desired pipe wall thickness. Consequently, the maximum distance of the stiffening ribs can be calculated by help of the formula.

$$p_K = \frac{10 \cdot E_C}{8 \cdot (1-\mu^2)} \cdot \left(\frac{s}{r_m}\right)^3 \cdot \left[1 + 50 \cdot \left(\frac{r_m}{L}\right)^2\right]$$

Formula C.17: Calculation of the necessary stiffening for pipes with buckling strain

p_K critical buckling pressure [bar]
E_C creep modulus for 25 years [N/mm²]
r_m mean pipe radius [mm]
s wall thickness [mm]
μ Transversal contraction factor 0.38
L Distance of stiffening ribs [mm]

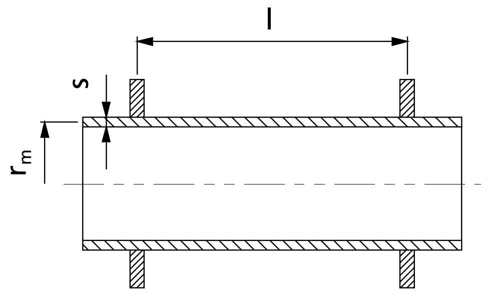


Figure C.2: Distance of stiffening ribs

By means of the stiffening rib distance, the required moment of inertia of the welded-on ribs can be determined.

Afterwards the height or width of the stiffening ribs can be calculated (one of these two parameter has to be chosen).

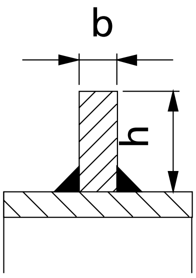


Figure C.3: stiffening rib

$$J = 3.35 \cdot \frac{r_m^{2} \cdot s^3}{L}$$

$$J = \frac{b \cdot h^3}{12}$$

Formula C.18: moment of inertia

J	moment of inertia [mm^4]
r_m	medium pipe radius [mm]
s	wall thickness [mm]
h	height of stiffening rib [mm]
b	width of stiffening rib [mm]

There is naturally the possibility to fix the desired stiffening ribs in their measurements at first and then to calculate the maximum permissible critical buckling pressure for the desired pipe wall thickness and dimension.

7 Pipe cross-section

Flow processes are calculated by means of the continuity equation. For fluids with constant volume flow, following equation is used.

$$\dot{V} = 0.0036 \cdot A \cdot v$$

Formula C.19: Volume flow.

For gases and vapours, the material flow remains constant. Therefore, the following equation can be used for the calculation.

$$\dot{m} = 0.0036 \cdot A \cdot v \cdot \rho$$

Formula C.20: Mass flow.

If the constants used in the above-mentioned equations are combined, formulas for the required pipe cross section as usual in practice are obtained.

$$d_i = 18.8 \cdot \sqrt{\frac{Q_1}{v}}$$

Formula C.21: Inner pipe diameter - m^3/h.

$$d_i = 35.7 \cdot \sqrt{\frac{Q_2}{v}}$$

Formula C.22: Inner pipe diameter - l/s.

A	free pipe cross-section [mm^2]
ID	inner pipe diameter [mm]
$\dot{m}$	mass flow [kg/h]
Q_1	flow rate [m^3/h]
Q_2	flow rate [l/s]
$\dot{V}$	volume flow [m^3/h]
v	flow velocity [m/s]
ρ	medium density depending on pressure and temperature [kg/m^3]

Reference values for flow velocities:

- Fluids:
  - Suction side: v ≈ 0.5 up to 1.0 m/s
  - Pressure side: v ≈ 1.0 up to 3.0 m/s
- Gases:
  - v ≈ 10 up to 30 m/s

8 Hydraulic pressure losses

Flowing media will experience pressure losses and therefore energy losses within the conveying system. The main factors for the losses are:

- Length of the piping system
- Pipe cross section
- Roughness of the pipe surface
- Geometry of fittings, mountings and finished joints or couplings
- Viscosity and density of the fluid

The whole pressure loss results from the sum of the following individual losses:

$$\Delta p_{ges} = \Delta p_R + \Delta p_{RF} + \Delta p_{RA} + \Delta p_{RV}$$

Formula C.23: Total pressure loss.

Δp_{ges}	total pressure loss [bar]
Δp_R	pressure loss in straight pipes [bar]
Δp_{RA}	pressure loss in mountings [bar]
Δp_{RF}	pressure loss in fittings [bar]
Δp_{RV}	pressure loss in finished joints or couplings [bar]

8.1 Pressure loss in straight pipes

The pressure loss in the straight pipes is inversely proportional to the pipe cross section.

$$\Delta p_R = \lambda \cdot \frac{L}{ID} \cdot \frac{\rho}{2 \cdot 10^2} \cdot v^2$$

Formula C.24: Pressure loss in straight pipes.

ID	inside diameter of pipe [mm]
L	length of piping system [m]
Δp_R	pressure loss in straight pipes [bar]
λ	pipe frictional index 0.02 (sufficient in most cases)
v	flow velocity [m/s]
ρ	medium density [kg/m³]

Pressure loss in pipes can also be calculated with the empirical Hazen-Williams equation (source: NFPA 13). Please note, that the equation is only valid for water.

$$p_m = 6.05 \cdot \left(\frac{Q_m^{1.85}}{c^{1,85} \cdot d_m^{4.87}} \right) 10^5$$

p_m	frictional resistance [bar/m pipe]
C	design coefficient (PEHD = 150)
Q_m	flow rate [L/min]
d_m	actual internal diameter [mm]

8.2 Pressure loss in fittings

Inside the fittings friction, deflection and detachment cause considerable pressure losses

The resistance coefficients, used for the calculation can be taken from the following chapter or from the technical literature.

$$\Delta p_{RF} = \zeta \cdot \frac{\rho}{2 \cdot 10^5} \cdot v^2$$

Formula C.25: Pressure loss in fittings.

Δp_{RF}	pressure loss in fittings [bar]
ζ	resistance coefficient for fittings
v	flow velocity [m/s]
ρ	medium density [kg/m³]

8.2.1 Resistance coefficients for the fittings

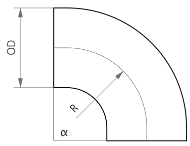
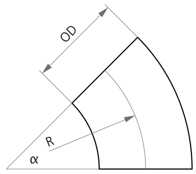
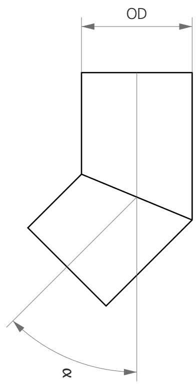
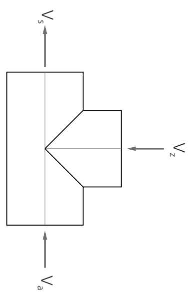
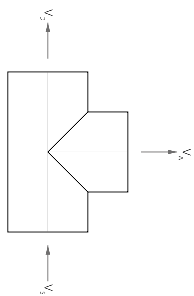
Fitting	Parameter	Resistance coefficient [1]		Flow
Bend 90°	R	ζ		
	1.0 × OD 1.5 × OD 2.0 × OD 4.0 × OD	0.51 0.41 0.34 0.23		
Bend 45°	R	ζ		
	1.0 × OD 1.5 × OD 2.0 × OD 4.0 × OD	0.34 0.27 0.20 0.15		
Elbow	α	ζ		
	90° 45° 30° 20° 15° 10°	~ 1.20 0.30 0.14 0.05 0.05 0.04		
Tee 90°	V_Z / V_S	ζ_Z	ζ_S	
(confluence)	0.0 0.2 0.4 0.6 0.8 1.0	-1.20 -0.40 0.10 0.50 0.70 0.90	0.06 0.20 0.30 0.40 0.50 0.60	
Tee 90°	V_A / V_S	ζ_A	ζ_S	
(bifurcation)	0.0 0.2 0.4 0.6 0.8 1.0	0.97 0.90 0.90 0.97 1.10 1.30	0.10 -0.10 -0.05 0.10 0.20 0.35	

Table C.5: Resistance coefficient for fittings - part 1 (Source: DVS 2210-1).

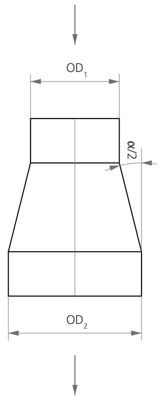
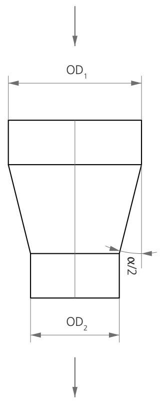
Fitting	Parameter	Resistance coefficient [1]			Flow
Reduction	OD_2 / OD_1	4° – 8°	16°	24°	
(pipe expansion)	1.2 1.4 1.6 1.8 2.0	0.10 0.20 0.50 1.20 1.90	0.15 0.30 0.80 1.80 3.10	0.20 0.50 1.50 3.00 5.30	
Reduction	OD_1 / OD_2	4°	8°	20°	
(pipe construction)	1.2 1.4 1.6 1.8 2.0	0.046 0.067 0.076 0.031 0.034	0.023 0.033 0.038 0.041 0.042	0.010 0.013 0.015 0.016 0.017	

Table C.6: Resistance coefficient for fittings - part 2 (Source: DVS 2210-1).

Positive ζ-values represent a pressure drop, whereas negative ζ-values represent a pressure increase.

V_A outgoing volume flow
V_D continuous volume flow
V_S total volume flow
V_Z additional volume flow

8.3 Pressure loss in valves

The resistance coefficients, used for the calculation can be taken from the following chapter or from the technical literature.

Δp_{RA} pressure loss in valves [bar]
ζ resistance coefficient for mountings
v flow velocity [m/s]
ρ density of medium [kg/m³]

$$\Delta p_{RA} = \zeta \cdot \frac{\rho}{2 \cdot 10^5} \cdot v^2$$

Formula C.26: Pressure loss in mountings.

8.3.1 Resistance coefficients for the valves

Nominal diameter DN	Resistance coefficient ζ [1]							
	Diaphragm valve	Straight valve	Angle seat valve	Gate valve	ball valve	Butterfly valve	Check valve	Swing type check valve
25	4.0	2.1	3.0	0.1 - 0.3	0.1 - 0.15	0.3 - 0.6	2.5	1.9
32	4.2	2.2	3.0				2.4	1.6
40	4.4	2.3	3.0				2.3	1.5
50	4.5	2.3	2.9				2.0	1.4
65	4.7	2.4	2.9				2.0	1.4
80	4.8	2.5	2.8				2.0	1.3
100	4.8	2.4	2.7				1.6	1.2
125	4.5	2.3	2.3				1.6	1.0
150	4.1	2.1	2.0				2.0	0.9
200	3.6	2.0	1.4				2.5	0.8

Table C.7: Resistance coefficients for the valves (Source: DVS 2210-1).

Annotation: The hydraulic resistance coefficients mentioned are reference values and are suitable for rough calculation of pressure loss. For material-related calculations use the values of the particular manufacturer.

8.3.2 Selection criteria for the valves

Selection criteria	Assessment					
	Diaphragm valve, straight valve, angle seat valve	Gate valve	ball valve	Butterfly valve	Check valve	Swing type check valve
Flow resistance	big	low	moderate	moderate	big	moderate
Aperture and closing time	medium	medium	short	short	short	short
Operation moment	low	low	big	moderate	-	-
Wear	moderate	low	low	moderate	moderate	moderate
Flow regulation	suitable	less suitable	less suitable	less suitable	-	-

Table C.8: Selection criteria for the valves (Source: DVS 2210-1).



8.4 Pressure loss in finished joints or couplings

An exact calculation of the pressure loss is not possible, because the types and the qualities of the joints (welding joints, unions and flange joints) may vary.

It is recommended to use a resistance coefficient of ζ_{RV} = 0.1 for the consideration of the joints (butt and socket welding) and flanges in the pressure loss calculation.

$$\Delta p_{RV} = \zeta \cdot \frac{\rho}{2 \cdot 10^5} \cdot v^2$$

Formula C.27: Pressure loss in finished joints or couplings.

Δp_{RV} Pressure loss in finished joints or couplings [bar]
ζ resistance coefficient for the mountings
v flow velocity [m/s]
ρ density of the medium [kg/m³]

9 Flow characteristics (Nomogram)

For rough determination of flow velocity, pressure loss and conveying quantity serves the following flow nomogram. At an average flow velocity up to 20 m of pipe length are added for each tee, reducer and 90° elbow, about 10 m of pipe for each bend r = d and about 5 m of pipe length for each bend r = 1.5 x d.

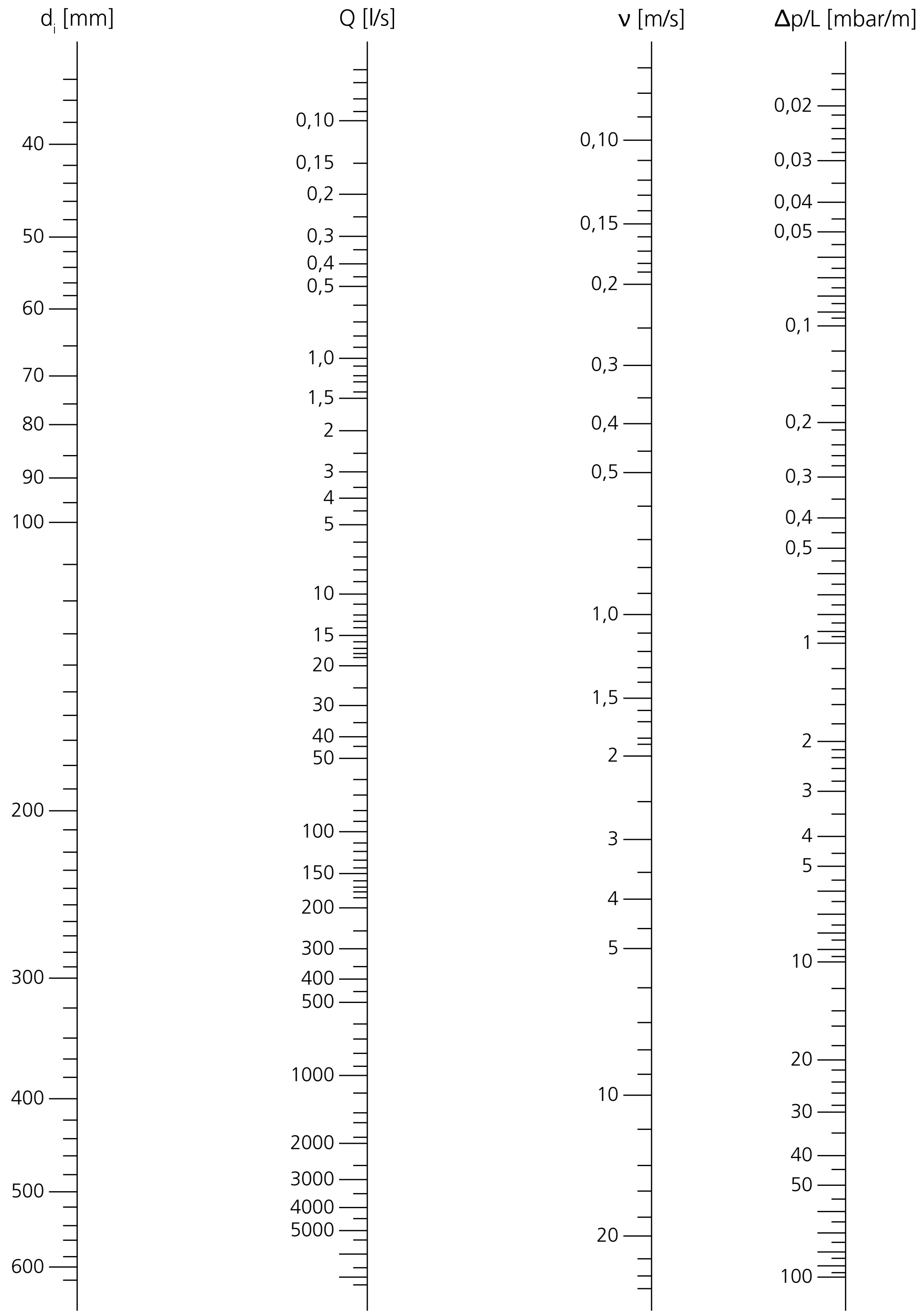


Figure C.4: Flow characteristics (Nomogram)

ID	inside diameter of the pipe [mm]
Q_2	flow rate [l/s]
ν	flow velocity [m/s]
Δp/L	pressure loss per meter pipe length [mbar/m]

Material Properties

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10 Pipe spans

When calculating the pipe spans of a thermoplastic piping system the permissible bending stress as well a limited deflection of the pipeline have to be taken into account. For the maximum deflection a guidance value of $L_A/500$ is normally assumed.

Using the above mentioned deflection value the permissible pipe span can be calculated with the following equation.

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

Formula C.28: Pipe spans for installations above ground.

E_C creep modulus for 25 years [N/mm²]
f_{LA} deflection factor (0.80 - 0.92)
J_R moment of inertia of the pipe [mm^4]
L_A permissible pipe span [mm]
q line load (pipe, filling and additional weight) [N/mm]

The factor f_{LA} is determined depending on the pipe outside diameter. The relation between both parameters is as follows:

min ← OD → max

$0.92 \leftarrow f_{LA} \rightarrow 0.80$

10.1 Usual Support distances

10.1.1 PE 100, PE 100-RC and PE 100-el

OD [mm]	SDR	Support distance L_A [mm]				
		20 °C	30 °C	40 °C	50 °C	60 °C
20	11	600	600	550	450	400
25	11	700	650	600	600	550
32	11	800	800	700	700	600
40	11	950	900	800	800	700
50	11	1150	1100	950	900	800
63	11	1300	1250	1150	1100	950
75	11	1450	1400	1300	1200	1100
90	11	1650	1550	1450	1350	1250
110	11	1800	1750	1650	1550	1400
125	11	1900	1850	1750	1700	1500
140	11	2050	2000	1900	1800	1650
160	11	2250	2100	2000	1900	1750
180	11	2350	2250	2100	2000	1900
200	11	2500	2400	2300	2200	2050
225	11	2650	2550	2450	2350	2250
250	11	2850	2750	2600	2500	2300
280	11	3000	2900	2800	2600	2400
315	11	3150	3050	2950	2800	2550
355	11	3400	3300	3150	3000	2800
400	11	3600	3450	3350	3150	2950
450	11	4000	3850	3600	3550	3350
500	11	4250	4100	3850	3800	3600
560	11	4550	4400	4150	4100	3850
630	11	4900	4700	4500	4400	4150
710	11	5300	5050	4850	4750	4550
800	11	5750	5500	5250	5150	4900
900	11	6200	5950	5700	5600	5300
1000	11	6650	6350	6100	6000	5700

OD [mm]	SDR	Support distance L_A [mm]				
		20 °C	30 °C	40 °C	50 °C	60 °C
1200	11	7500	7200	6900	6800	6400
1400	11	8300	8000	7650	7550	7200
1600	11	9100	8700	8400	8200	7800
1800	17	8800	8400	8100	7950	7500
2000	17	9450	9150	8700	8500	8100
2250	17	10200	9900	9400	9200	8800
2500	17	10950	10650	10100	9900	9400

Table C.9: Guidelines for pipe spans (dim 20-400 mm from DVS 2210-1, dim 450-630 calculated with f_{LA}=0.86), rounded up in 50 mm steps.

10.1.2 PP-H, SDR11

OD [mm]	Support distance L_A [mm]						
	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C
16	650	625	600	575	550	525	500
20	700	675	650	625	600	575	550
25	800	775	750	725	700	675	650
32	950	925	900	875	850	800	750
40	1100	1075	1050	1000	950	925	875
50	1250	1225	1200	1150	1100	1050	1000
63	1450	1425	1400	1350	1300	1250	1200
75	1550	1500	1450	1400	1350	1300	1250
90	1650	1600	1550	1500	1450	1400	1350
110	1850	1800	1750	1700	1600	1500	1400
125	2000	1950	1900	1800	1700	1600	1500
140	2100	2050	2000	1900	1800	1700	1600
160	2250	2200	2100	2000	1900	1800	1700
180	2350	2300	2200	2100	2000	1900	1800
200	2500	2400	2300	2200	2100	2000	1900
225	2650	2550	2450	2350	2250	2150	2000
250	2800	2700	2600	2500	2400	2300	2150
280	2950	2850	2750	2650	2550	2450	2300
315	3150	3050	2950	2850	2700	2600	2450
355	3350	3250	3150	3000	2850	2750	2600
400	3550	3450	3350	3200	3050	2900	2750
450	3800	3700	3600	3450	3300	3100	2950
500	4100	4000	3850	3700	3500	3350	3150
560	4400	4300	4150	4000	3800	3600	3400
630	4800	4650	4500	4300	4100	3900	3700

Table C.10: PP-H, SDR 11 (acc. DVS 2210, Tab.14)

10.1.3 PVDF

OD [mm]	Support distance L_A [mm]								
	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	100 °C	120 °C
16	725	700	650	600	575	550	500	450	400
20	850	800	750	750	700	650	600	500	450
25	950	900	850	800	750	700	675	600	500
32	1100	1050	1000	950	900	850	800	700	600
40	1200	1150	1100	1050	1000	950	900	750	650
50	1400	1350	1300	1200	1150	1100	1000	900	750
63	1400	1350	1300	1250	1200	1150	1100	950	800
75	1500	1450	1400	1350	1300	1250	1200	1050	850
90	1600	1550	1500	1450	1400	1350	1300	1100	950
110	1800	1750	1700	1650	1550	1500	1450	1250	1100
125	1900	1850	1800	1700	1650	1600	1500	1350	1200
140	2000	1950	1900	1800	1750	1700	1600	1450	1250
160	2150	2100	2050	1950	1850	1800	1700	1550	1350
180	2300	2200	2150	2050	1950	1900	1800	1600	1400
200	2400	2350	2250	2150	2100	2000	1900	1700	1500
225	2550	2500	2400	2300	2200	2100	2000	1800	1600
250	2650	2600	2500	2400	2300	2200	2100	1900	1700
280	2850	2750	2650	2550	2450	2350	2250	2000	1800
315	3000	2950	2850	2750	2600	2500	2400	2150	1900
355	3200	3100	3000	2850	2750	2650	2500	2250	2000
400	3400	3300	3200	3050	2950	2800	2650	2400	2100

Table C.11: PVDF Ø 16-50 SDR 21, Ø 63-400 SDR 33 (angelehnt an DVS 2210, Tab.17)

10.1.4 ECTFE

OD [mm]	S [mm]	SDR	Support distance L_A [mm]								
			20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C
20	1.9	21	530	510	490	470	450	430	410	380	340
25	1.9	21	580	560	540	520	500	470	450	420	380
32	2.4	21	680	660	640	610	580	560	530	490	440
50	3.0	21	870	840	810	780	740	710	680	620	560
63	3.0	21	950	910	880	850	810	770	740	680	610
90	4.3	21	1200	1160	1120	1080	1030	980	940	870	780
90	2.8	33	1060	1020	990	950	910	860	830	760	790
110	5.3	21	1380	1330	1290	1240	1180	1120	1080	990	890
110	3.0	Liner	1170	1120	1090	1040	1000	950	910	840	750
160	3.0	Liner	1330	1290	1240	1190	1140	1080	1040	960	860

Table C.12: ECTFE Ø 20-160 (acc. DVS 2210, Tab. 17)

10.2 Conversion factors for support distances

For other SDR-series, materials and fluids, the conversion factors of below table can be applied. (new support distance $L = L_A \times f_1 \times f_2$)

L_A = Permissible support distance according tables Page 180-182

Material	SDR-series	Wall thickness	Fluid			
			Gases	Water	others	
			Density [g/cm³]			
			< 0.01	1.00	1.25	1.50
Conversion factor		f_2	f_1			
PE100	33	0.75	1.65	1.0	0.96	0.92
	17.6 / 17	0.91	1.47			
	11	1.00	1.30			
	7.4	1.07	1.21			
PP-H	33	0.75	1.65	1.0	0.96	0.92
	17.6 / 17	0.91	1.47			
	11	1.00	1.30			
	7.4	1,07	1.21			
PP-R	33	0.55	1.65	1.0	0.96	0.92
	17.6 / 17	0.70	1.47			
	11	0.75	1.30			
	7.4	0.80	1.21			
PVDF	33	1.00	1.48	1.0	0.96	0.92
	21	1.08	1.36			
ECTFE	Liner	–	1.75	1.0	0.96	0.92
	SDR 21	–	1.26	–	–	–

Table C.13: Conversion factors for support distances (acc. DVS 2210, table 18)

11 Elongation

Elongations of plastic piping systems can be caused by operating or test processes. These are the influencing factors:

- Elongation due to temperature change
- Elongation due to internal pressure
- Elongation due to chemical influence

11.1 Elongation caused by temperature change

If a piping system is exposed to different temperatures (operating or ambient temperatures) its position changes depending on the possibilities of motion of each pipeline. A pipeline is assumed as the distance between two restraints.

The elongation is calculated as follows:

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

Formula C.29: Elongation due to temperature change.

L	pipe length [m]
α	coefficient of linear expansion [mm/(m×K)]
ΔL_T	elongation due to temperature change [mm]
ΔT	temperature difference [K]

For the determination of ΔT the lowest and the highest possible pipe wall temperature T_R during the installation, operation or standstill has to be considered.

α-average value	mm/(m×K)	1/K
PE	0.18	1.8×10^{-4}
PP	0.16	1.6×10^{-4}
PVDF	0.13	1.3×10^{-4}
ECTFE	0.08	0.8×10^{-4}

Table C.14: Linear expansion coefficient.

11.2 Elongation caused by internal pressure

The elongation due to internal pressure of a closed and friction-free installed piping system is:

$$\Delta L_P = \frac{0.1 \cdot p \cdot (1-2\cdot\mu)}{E_C \cdot \left(\frac{OD^2}{d_i^2}-1\right)} \cdot L$$

Formula C.30: Elongation due to internal pressure.

$E_{C\_100\,min}$ creep modulus [N/mm²]
ID pipe inside diameter [mm]
L length of piping system [mm]
OD pipe outside diameter [mm]
p operating pressure [bar]
ΔL_P elongation by internal pressure [mm]
μ Poisson ratio 0.38

11.3 Elongation caused by chemical influence

In thermoplastic piping systems the influence of certain fluids (e.g. solvents) may lead to a change in length (swelling) and an increase of the pipe diameter. At the same time, a reduction of the mechanical strength properties can occur. To ensure an undisturbed operation of piping thermoplastics systems for conveying solvents, it is recommended to apply a swelling factor of when designing piping systems:

f_{Ch} = 0.025 ... 0.040 [mm/mm]

into consideration at the design of the piping system.

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

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

Formula C.31: Change in length by swelling.

ΔL_{Ch} Change in length by swelling [mm]
L Length of piping system [mm]
f_{Ch} Swelling factor

Remark: For practically orientated calculations of thermoplastic piping systems conveying solvents the factor fch has to be determined by specific tests.

12 Restraint load

Restraints (fixed points) are used to prevent sliding or movement of a piping system in every direction. Furthermore restraints serve as compensation for the reaction forces when using compensators (sliding sockets and push-fit fittings). A restraint has to be dimensioned for all possible forces:

- Stress through restrained thermal expansion
- Weight of the vertical piping systems
- Specific weight of the fluid
- Operating pressure
- Inherent resistance of the compensators

Non defined restraints should be positioned in a way that direction changes in the pipeline are used for the absorption of the elongations.

Possible restraints are the edges of the fitting sockets or special restraint fittings.

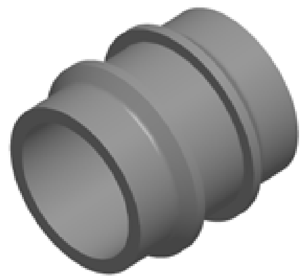


Figure C.5: Restraint fitting.

Swinging clips or the clamping of the pipes are not suitable as restraints.

12.1 Fixed point loads with compensation for the change in length

If the result cannot be realised, compensators with minimal friction coefficient have to be used. Depending on the construction, they may be applied as axial, lateral or angular compensators.

Figure C.6: U-shaped expansion bend

Figure C.7: compensator

In most cases, changes of direction of the pipe sections can be used for the absorption of the elongations. Otherwise, expansion bends have to be installed.

The minimum length of the expansion bend is calculated as follows:

$$L_S = k \cdot \sqrt{\Delta L \cdot OD}$$

Formula C.32: Minimum length of expansion bends.

L_S	min. length of the expansion bend [mm]
k	material specific proportionality factor
ΔL	system length of the expansion bend [mm]
OD	pipe outside diameter [mm]

k-value	0 °C	10 °C	30 °C	40 °C	60°C
	multiple temperature changes				
PE	16	17	23	28	-
PP	23	25	29	31	40
	single temperature change				
PE	12	12	16	17	-
PP	18	18	20	20	24

Note: for the calculation of the k-values an installation temperature of 20 °C was taken into account. At lower temperatures the impact strength of the material has to be considered.

The k-values can be reduced by 30% for pressureless pipes (e.g. ventilation).

Between two restraints, a compensator has to be installed. An appropriate guiding of the piping at the loose points has to be ensured. For that matter the resulting reaction forces have to be taken into account.

For the L-shaped expansion bend, the fixed point loads can be approximately determined for the bend deformation without any friction in the slide bearing as follows.

$$FP = \frac{12 \cdot \Delta F \cdot E_{C100} \cdot J_R}{(L_s)^3}$$

Formula C.33: fixed point load on L-shaped expansion

FP	fixed points loads on the L-shaped expansion bend [N]
L_S	length of the bending leg [mm]
ΔL	change in length [mm]
E_{C100}	creep modulus fot t=100min [N/mm²]
J_R	pipe moment of inertia [mm⁴]

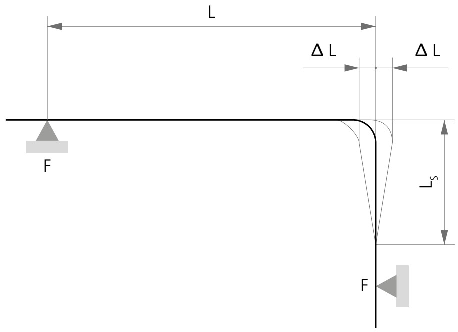


Figure C.8: L-shaped expansion bend

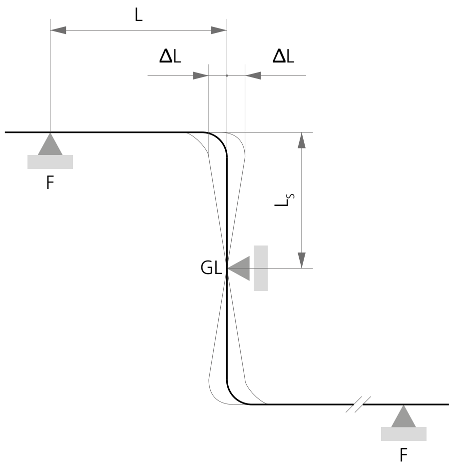


Figure C.9: Z-shaped expansion bend

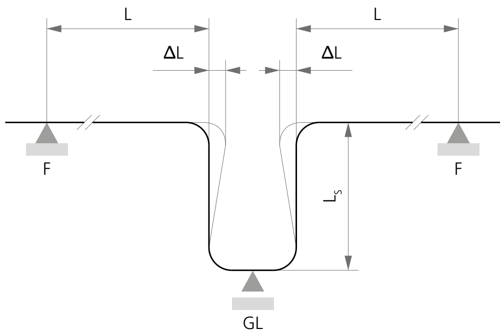


Figure C.10: U-shaped expansion bend

A	restraints
SB	slide bearing

12.1.1 Required length of expansion bends

OD	change in length ΔL [mm]								
[mm]	50	100	150	200	250	300	350	400	500
16	850	1200	1500	1700	1900	2100	2250	2400	2700
20	950	1350	1650	1900	2150	2350	2550	2700	3000
25	1100	1500	1850	2150	2400	2600	2850	3000	3400
32	1200	1700	2100	2400	2700	2950	3200	3400	3800
40	1350	1900	2350	2700	3000	3300	3550	3800	4250
50	1500	2150	2600	3000	3400	3700	4000	4250	4750
63	1700	2400	2950	3400	3800	4150	4500	4800	5350
75	1850	2600	3200	3700	4150	4500	4900	5200	5850
90	2050	2850	3500	4050	4500	4950	5350	5700	6400
110	2250	3150	3900	4450	5000	5450	5900	6300	7050
125	2400	3400	4150	4750	5350	5850	6300	6750	7500
140	2550	3550	4350	5050	5650	6150	6650	7100	7950
160	2700	3800	4650	5400	6000	6600	7100	7600	8500
180	2850	4050	4950	5700	6400	7000	7550	8050	9000
200	3000	4250	5200	6000	6750	7350	7950	8500	9500
225	3200	4500	5550	6400	7150	7800	8450	9000	10100
250	3400	4750	5850	6750	7500	8250	8900	9500	10650
280	3550	5050	6150	7100	7950	8700	9400	10050	11250
315	3800	5350	6550	7550	8450	9250	10000	10650	11950
355	4000	5700	6950	8000	8950	9800	10600	11350	12650
400	4250	6000	7350	8500	9500	10400	11250	12000	13450
450	4500	6400	7800	9000	10100	11050	11950	12750	14250
500	4750	6750	8250	9500	10650	11650	12550	13450	15000
560	5050	7100	8700	10050	11250	12300	13300	14200	15900
630	5350	7550	9250	10650	11950	13050	14100	15100	16850

Table C.15: Straight lenghts for Polypropylen pipes (rounded up in 50 mm steps).

Due to the low material specific proportional factor k of HDPE (k = 26) in comparison to PP (k = 30), the minimum straight lengths stated in the table can be reduced by 13 %.

The minimum straight length for PE is therefore calculated as follows:

$$L_{s(HDPE)} = 0.87 \cdot L_{s(PP)}$$

Formula C.34: Straight length for PE.

12.2 Fixed point loads without any compensation for the change in length

Restraining the elongation of a piping system leads to a fixed system.

Rigid or fixed piping length has no compensation elements and has to be treated as a special case during the dimensioning.

Following parameters have to be calculated:

- Restraint load
- Permissible guiding element distance in consideration of the critical buckling length
- Occuring tensile and compressive stresses

The highest restraint loads occur at straight, axially fixed pipe sections. In general it is calculated using the following formula:

$$F_{FP} = A_R \cdot E_C \cdot \varepsilon$$

Formula C.35: Dog bone load.

A_R annular surface of the pipe wall [mm²]
E_C creep modulus for t = 100 min [N/mm²]
F_{FP} restraint loads in the fixed pipe section [N]
ε prevented longitudinal expansion (by heat expansion, internal pressure)

Considering the possible load types, ε must be determined as follows:

- Load by thermal expansion

$$\varepsilon = \alpha \cdot \Delta T$$

Formula C.36: Thermal expansion.

α coefficient of linear expansion [1/K]
ΔT max. temperature difference [K]
ε prevented longitudinal extension [1]

- Load by internal pressure

$$\varepsilon = \frac{0.1 \cdot p \cdot (1-2 \cdot \mu)}{E_c \cdot \left(\frac{OD^2}{ID^2} -1\right)}$$

Formula C.37: Extension due to the internal pressure.

p operating pressure [bar]
μ Poisson's ratio 0.38 [1]
E_C creep modulus for t = 100 min [N/mm²]
OD pipe outside diameter [mm]
ID pipe inside diameter [mm]
ε prevented longitudinal extension by internal pressure

- Load by swelling

$$\varepsilon = 0.025...0.040$$

Formula C.38: swelling.

Caution: a fixed system where a material swelling is possible, should be generally avoided. Reason: the swelling causes a material weakening.

12.2.1 Determination of guiding distances in the case of axially clamped pipe sections

If piping systems are installed in such a way, that axial movements are not possible, the critical buckling length has to be considered for the safe operation. The distances to be determined must provide a safety factor of minimum 2.0.

Is the necessary support distance L_F smaller than the calculated support distance L_A, then L_A must be reduced to L_F.

If fixed piping systems are aperated at raised temperatures, the calculated support distance has to be reduced by 20 %. The raised operating temperatures are summarized in the table below.

Material	PE	PP	PVDF
Temperature	> 45 °C	> 60 °C	> 100 °C

L_F is calculated as follows for a minimum safety of 2.0:

$$erfL_F = 3.17 \cdot \sqrt{\frac{J_R}{\varepsilon \cdot A_R}} \geq L_A$$

Formula C.39: Support distance.

L_F Required support distance [mm]
J_R Moment of inertia [mm^4]
ε Prevented heat expansion
A_R Pipe wall ring area [mm^2]

The following table can be used as simplified way for the determination of the support distances:

OD [mm]	Simplified support distance L_F [mm] depending on the hindered length expansion ε								
	0.001	0.002	0.004	0.006	0.008	0.01	0.012	0.015	0.02
16	505	355	250	205	175	160	145	130	110
20	645	455	320	260	225	200	185	165	140
25	805	570	400	330	285	255	230	205	180
32	1030	730	515	420	365	325	295	265	230
40	1290	910	645	525	455	405	370	330	285
50	1615	1140	805	660	570	510	465	415	360
63	2035	1440	1015	830	720	640	585	525	455
75	2425	1715	1210	990	855	765	700	625	540
90	2910	2060	1455	1185	1030	920	840	750	650
110	3560	2515	1780	1450	1255	1125	1025	915	795
125	4045	2860	2020	1650	1430	1275	1165	1040	900
140	4530	3200	2265	1845	1600	1430	1305	1165	1010
160	5175	3660	2585	2110	1830	1635	1495	1335	1155
180	5825	4120	2910	2375	2060	1840	1680	1500	1300
200	6475	4575	3235	2640	2285	2045	1865	1670	1445
225	7280	5150	3640	2970	2575	2300	2100	1880	1625
250	8090	5720	4045	3300	2860	2555	2335	2085	1805
280	9065	6405	4530	3700	3200	2865	2615	2340	2025
315	10195	7210	5095	4160	3605	3220	2940	2630	2280
355	11495	8125	5745	4690	4060	3635	3315	2965	2570
400	12950	9155	6475	5285	4575	4095	3735	3340	2895

13 Calculation of buried piping systems

A stress and deformation proof according to ATV-DVWK-A 127, AWWA M55, has to be furnished for buried piping systems (e.g. drainage channels). Other basic principles or results of research projects may be applied as well.

There is a software for the surcharge calculation according to ATV-DVWK-A 127 is available at our technical engineering department in order to furnish such proof if required. Please fill in the following questionnaire as thoroughly as possible. We will promptly prepare a respective structural analysis after receipt of the questionnaire.

Comments to some points of the questionnaire.

- Generally:
  These general statements are necessary to enable an assignment of the different projects.
- Details regarding pipe:
- Pipe material (polyethylene or polypropylene) and pipe dimensions must be specified here.
- Soil / Installation:
  There are four different groups of soil.

Group		Specific gravity γ_B [kN/m³]	gravity of internal friction ϕ'	Deformation modulus E_B in [N/mm²] at degree of compaction D_{Pr} in %					
				D_{Pr}					
				85	90	92	95	97	100
G1	non-cohesive soils (e.g. sand, gravel-/ sand-mixtures)	20	35	2.0	6	9	16	23	40
G2	slightly cohesive soils (e.g. silts / silty sand and gravel mixtures)	20	30	1.2	3	4	8	11	20
G3	cohesive mixed soils, coarse clay (e.g. silty sand and gravel, cohesive stony residual soil)	20	25	0.8	2	3	5	8	13
G4	cohesive soils (e.g. clay)	20	20	0.6	1,5	2	4	6	10

Table C.16: Information soil types.

The deformation modulus of the soil which are used for calculation can be discriminated according to the following zones:

E_1 Surcharge above pipe summit

E_2 Pipe (embedment) zone around the pipe (min. 10 cm)

E_3 Native soil aside the pipe zone

E_4 Native soil below the pipe

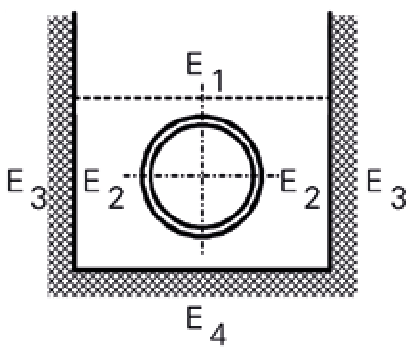


Figure C.11: Trench embedding condition

- Surcharge:
  The surcharge height for trench embedding provisions is equivalent to the installation depth of the pipe (referring to the pipe summit) and for dam embedding provisions equivalent to the waste surcharge.
- Operating conditions of the pipe:
  You only have to fill in the corresponding operating parameter for each application.

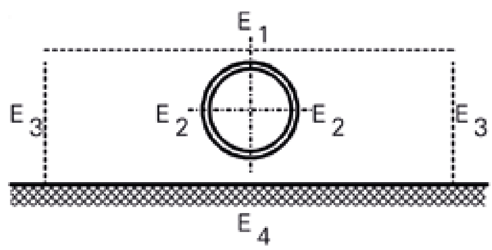


Figure C.12: Dam embedding condition

1. Generally	Project:			
	Site:			
	Principal:			
2. Details for pipe	Pipe material:		Pipe inside diameter:	mm
	Pipe outside diameter:	mm	Wall thickness:	mm
	Nominal width:	mm		
3. Soil		Zone		
	Group	G (1,2,3,4)		
	Specific gravity	[kN/m³]		
	Proctor density	[%]		
	E-Modulus of the soil E_B	[N/mm²]		
4. Installation	Method of laying: Trench ☐ Dam ☐			
			Trench width in pipe crown height	b= [m]
	Cover height (installation depth) from pipe crown to finished floor	h= [m]	Gradient of slope	β = [°]
5. Surcharge	Traffic load: without ☐ LKW12 ☐ SLW30 ☐ SLW60 ☐			
	Additional weight on surface		F=	[kN/m²]
	Minimum ground water level above pipe sole			m
	Maximum ground water level above pipe sole (m)			m
6. Operating conditions of the pipe	Operating temperature		T=	[°C]
	Operating pressure short time (24h)		p=	[bar]
	Operating pressure long time (50 years)		p=	[bar]

Table C.17: Calculation of buried piping systems

1 General Standards

The welding work must be monitored. Type and range of supervision has to be agreed between the contract partners. It is recommended to record the welding data in welding protocols or on data carriers.

Each welder must be qualified and must have a valid certificate. The intended field of application may require different types of qualification. For heating element butt welding of sheets as well as for piping system construction DVS 2215 part 1 is applicable. For pipes > 225 mm outside diameter an additional proof of qualification is necessary.

The machines and appliances used must correspond to the standards of the DVS 2208 part 1.

1.1 Measures before the welding operation

The welding area has to be protected from unfavourable weather conditions (e.g. moisture, wind, intensive UV-radiation, temperatures below +5 °C). If appropriate measures (e.g. preheating, tent-covering, heating) ensure that the required pipe wall temperature will be maintained, welding operations may be performed at any outside temperatures, provided, that the welder is not hindered in his handling.

If necessary, the weldability has to be proven by performing sample welds under the given conditions and tested by destructive tests. If the pipe should be disproportionately warmed up as a consequence of intensive sunlight, it is necessary to take care for the equalization of temperature by covering the welding area in time. Cooling during the welding process by air draught should be avoided. In addition the pipe ends should be closed during the welding process.

PE- and PP-pipes from coils are oval directly after unrolling. Prior welding the pipe ends have to be adjusted, for example by heating using a hot-air blower and usage of a suitable cut pressure or round pressure installation. The joining areas of the parts to be welded must not be damaged or contaminated. Immediately before starting the welding procedure, the joining areas have to be cleaned and must be free from e.g. dirt, oil, shaving chips.

An additional proof must be provided by carrying out sample welds under the mentioned conditions.

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

Before welding the joining areas have to be cleaned with a special cleaning agent (PE cleaning agent consisting of isopropanol, acetone or ethanol acc. to DVGW VP 603)

Caution: Pipes and fittings contaminated with silicone grease cannot be cleaned with most of the common cleaning agents. In such cases brake cleaner fluid can be used. However the suitability has to be checked with the manufacturer and additional sample welds have to be carried out.

The described AGRU welding instructions apply to the welding of semi-finished products, pipes and fittings material montioned in table D1.

Material with MFR values, which do not comply with the values in table D1, have to be checked by carrying out sample welds.

Material designation	Weldability
PE 100, PE 100-RC	MFR (190/5)= 0.3 - 1.7 g/10 min
PP-H, PP-R	MFR (190/5) = 0.4 - 1.5 g/10 min
PE 100-el PPs PPs-el	mit PE 100, PE 100-RC mit PP-H und PP-R mit PP-H und PP-R

Table D.1: Thermoplasts for the welding (Source: DVS 2207-1)

Note: Welding of PE 100 with PE 100-RC as well as PP-H with PP-R is permitted.

2 Heating element butt welding

(following to DVS 2207, part 1 for HDPE and part 11 for PP and part 15 for PVDF)

2.1 Welding method description

With the heated tool butt welding process, the joining zones of the components to be welded are aligned under pressure on the heated tool (alignment), heated up to the welding temperature with reduced pressure (heating up) and joined under pressure (joining) after removal of the heated tool (change-over).

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

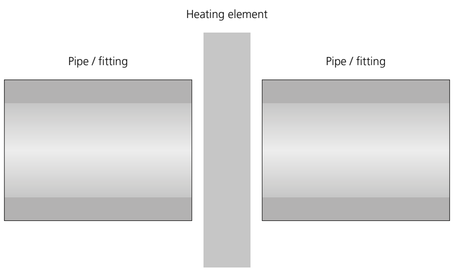


Figure D.1: Preparation of the welding.

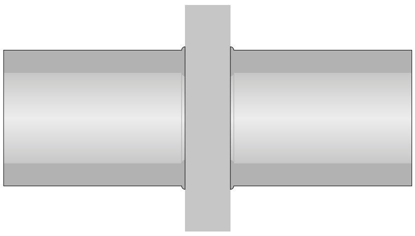


Figure D.2: Alignment and heating.

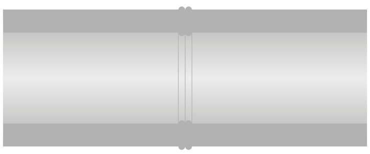


Figure D.3: Joining and cooling.

All welds must be performed with machines and devices which correspond to the guidelines of the DVS 2208 part 1.

2.2 Preparation before welding

Prior to the start of each welding process, the welding temperature of the heated tool has to be checked with an external thermometer. The control measurement must happen within the area of the heating element which corresponds to the pipe areas to be welded. To reach a thermal balance the heating element should be checked only 10 minutes after reaching the required temperature.

To ensure an optimum welding connection the heated tool has to be cleaned with clean lint-free cloth before every welding operation. The non-stick coating of the heating element must be undamaged in the working area.

The particular joining pressure or joining power must be given for the machines used. The values can refer to e.g. construction information, calculated or measured values. In addition, the movement pressure or movement power caused by the slow movement of the work pieces, which can be seen on the indicator of the welding machine, needs to be added to the before determined joining power or joining pressure.

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

Align the pipes and fittings in the axial direction in the welding machine before clamping. The easy axial movement of the parts to be welded-on can be ensured e.g. by means of dollies or swinging suspension.

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

Pipe outside diameter [mm]	**die gap width [mm]**
≤ 355	0.5
400 ... < 630	1.0
630 ... < 800	1.3
800 ... ≤ 1000	1.5
> 1000	2.0

Table D.2: alignment pressure

After removing the planing tool the gap width and the misalignment have to be controlled. The misalignment of the joining areas on the pipe outside may not exceed the permissible size of 0.1 x wall thickness.

Worked welding areas shouldn´t be dirty or touched by hands otherwise a new treatment is necessary. Shavings which are fallen in the pipe should be removed.

2.3 Performing of the welding procedure

During butt welding the areas to be joined are heated up to the required welding temperature by contact with the heating elements, after removal of the heating elements those areas are joined together by applying pressure.

The heating element temperatures are listed in below table. The basic concept is to aim for the upper limits for lower wall thicknesses and for the lower limits for higher wall thicknesses.

	PE	PP	PVDF	ECTFE
Heating element temperature [°C]	210 up to 230	200 up to 220	232 up to 248	275 up to 285

Table D.3: Heating element temperature according to DVS

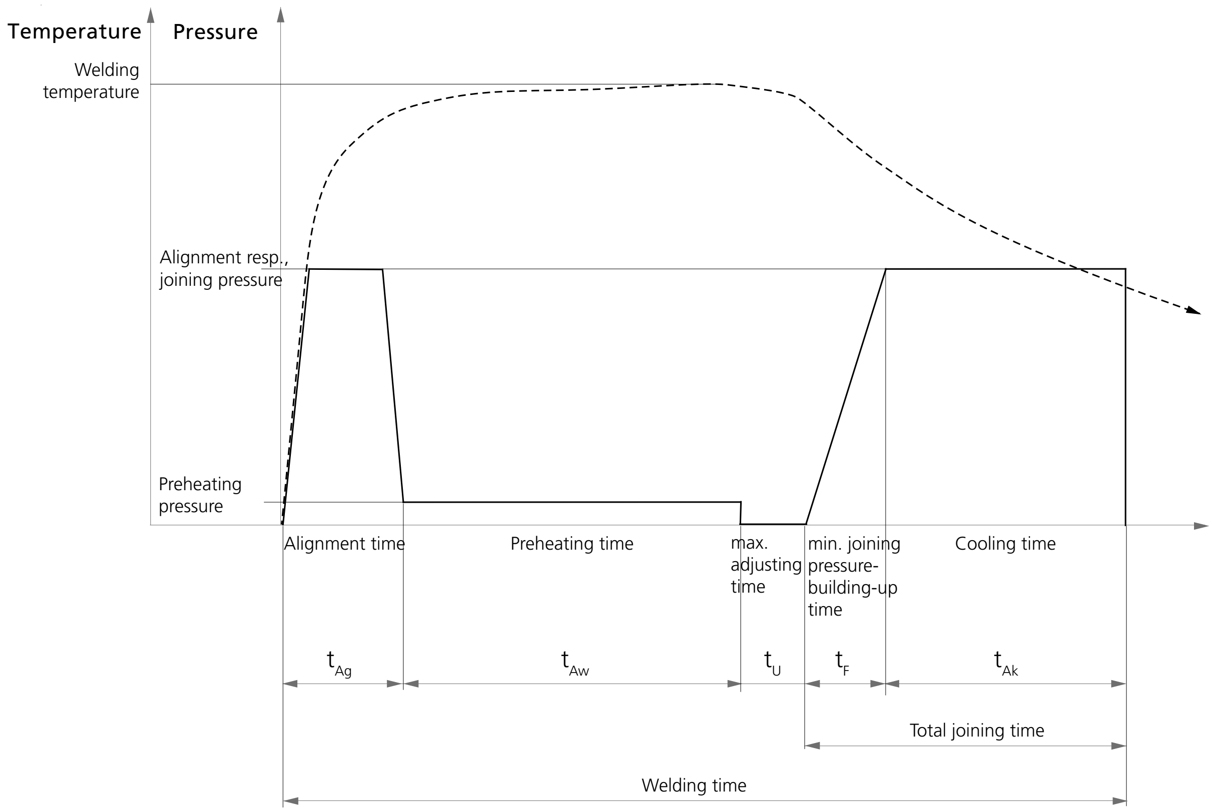


Figure D.4: The gradually sequences of the welding process

2.4 Welding parameters

Reference values for heating element butt welding of PP, PE, PVDF and ECTFE pipes and fittings at outside temperatures of about 20 °C and low air-speed rates.

Type of material	Wall thickness [mm]	Bead height [mm]	Preheating time t_{AW} [s]	max. adjusting time t_U [s]	min. joining pressure build-up time t_F [s]	Cooling time t_{AK} [min]
PE 100, PE 100-RC, PE 100-el		P = 0.15 N/mm²	P ≤ 0.02 N/mm²		P = 0.15 N/mm²	
	up to 4.5	0.5	up to 45	5	5	5
	4.5 – 7	1.0	45 – 70	5 – 6	5 – 6	5 – 7.5
	7 – 12	1.5	70 – 120	6 – 8	6 – 8	7.5 – 12
	12 – 19	2.0	120 – 190	8 – 10	8 – 11	12 – 18
	19 – 26	2.5	190 – 260	10 – 12	11 – 14	18 – 24
	26 – 37	3.0	260 – 370	12 – 16	14 – 19	24 – 34
	37 – 50	3.5	370 – 500	16 – 20	19 – 25	34 – 46
	50 – 70	4.0	500 – 700	20 – 25	25 – 35	46 – 64
	70 – 90	4.5	700 – 900	25 – 30	35	64 – 82
	90 – 110	5.0	900 – 1100	30 – 35	35	82 – 100
DVS 2207-1	110 – 130	5.5	1100 – 1300	max. 35	35	100 – 118
PP-H, PP-R, PPs, PPs-el		P = 0.10 N/mm²	P ≤ 0.01 N/mm²		P = 0.10 N/mm²	
	up to 4.5	0.5	up to 53	5	6	5
	4.5 – 7	0.5	53 – 81	5 – 6	6 – 7	5 – 7.5
	7 – 12	1.0	81 – 135	6 – 7	7 – 11	7.5 – 12
	12 – 19	1.0	135 – 206	7 – 9	11 – 17	12 – 18
	19 – 26	1.5	206 – 271	9 – 11	17 – 22	18 – 24
	26 – 37	2.0	271 – 362	11 – 14	22 – 32	24 – 34
	37 – 50	2.5	362 – 450	14 – 17	32 – 43	34 – 46
DVS 2202-11	50 – 70	3,0	450 – 546	17 – 22	43	46 – 64
PVDF		P = 0.10 N/mm²	P ≤ 0.01 N/mm²		P = 0.10 N/mm²	
	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
DVS 2207-15	20.0 – 25.0	1.7 – 2.0	240 – 290	5	11 – 13	25.0 – 32.0
ECTFE		P = 0.085 N/mm²	P ≤ 0.01 N/mm²		P = 0.085 N/mm²	
	1.9 – 3.0	0.5	12 – 25	4	5	3 – 5
	3.0 – 5.3	0.5	25 – 40	4	5	5 – 7
	5.3 – 7.7	1.0	40 – 50	4	5	7 – 10

Table D.4: Heated tool butt welding parameters.

2.5 Specific heating pressure

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

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

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

$$\approx d_m \cdot \pi \cdot s$$

Formula D.1: Calculation of the welding area

$$F = p_{spez} \cdot A_{pipe}$$

Formula D.2: Calculation of the welding force

2.6 Equalizing

The joint surfaces that are to be welded are pressed against the heating element until all the surfaces lie plane-parallel to the heating element. This can be seen from the shape of the bead. Equalising is complete when the heights of the beads around the entire circumference of the pipe reach the required values. These bead heights indicate that the entire joint surfaces are lying flush against the heating element. Before the welding process of pipes with a larger diameter (> 630 mm) a sufficient bead development also inside the pipe must be controlled with a test seam. The alignment pressure is applied during the whole alignment process.

	PE	PP	PVDF	ECTFE
Specific heating pressure [N/mm²]	0.15	0.10	0.10	0.08 up to 0.09

Table D.5: Eualizing and pre-heating

2.7 Pre-Heating

During preheating, the surfaces must rest against the heating element with very little pressure. The pressure is reduced to practically zero (< 0.01 N/mm²). The warmth generated during the preheating process penetrates the surfaces to be welded and raises their temperature to the welding temperature.

2.8 Changeover

After preheating, the joint surfaces are detached from the heating element. Take care when removing the heating element so as not to damage or contaminate the heated joint surfaces, which should then be brought together quickly or just before they touch. The changeover time is to be kept as short as possible as otherwise the plasticised surfaces will cool down. This would have an adverse effect on the quality of the weld seam.

2.9 Joining

The areas to be welded should be brought together with a speed of close to zero. The required joining pressure is applied, if possible, in an increasing linear manner. During cooling down the joining pressure must be maintained. De-clamping is permitted only after the required cooling time. Rough handling with full mechanical load of the joint (e.g. pressure test or operation) is allowed only after extended complete cooling time. Under factory conditions and insignificant mechanical use, the cooling times may be undercut. This especially applies to parts with thick walls during the clamp removal and storage. Assembly or mechanical manipulation is allowed after complete cool down only. After joining, a double bead, surrounding the whole circumference, must have been emerged. The bead development can be used as parameter for the regularity of the welding. Possible deviations in the formation of the beads might be caused by different flow behaviour of the joined materials. From experience with commercially available semi-finished products having values within the indicated MFR-range, adequate weldability can be assumed, even if asymmetrical beads occur. The bead height K however must be above 0.

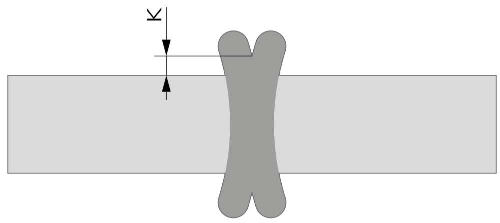


Figure D.5: Bead height K.

2.10 Requirements

(following to DVS 2208, part 1)

2.10.1 Clamping facilities

In order to avoid increased local stresses and deformations of the pipe, the clamping devices should surround the pipe as parallel as possible to the welding plane. The clamping facilities must be designed in such a way that the parts to be welded are clamped in a precise, quick and safe way and the forces necessary for the welding are transferred without changing the positions of the workpieces. For fittings, such as stub flanges and full faced flanges, special clamping devices which prevent deformations of the work pieces have to be used. The pipe clamped at the moveable machine side has to be supported and exactly adjusted if required by means of easy-running dollies, so that the working pressures and conditions required for welding can be maintained. It is recommendable to use clamping elements adjustable in side and height to allow an optimal alignment of the work pieces.

2.10.2 Guide elements

Together with the clamping facilities, the guiding elements have to ensure that the maximum values for the gap width (measured on cold joining surfaces) are not exceeded due to bending or buckling, even at the least favourable point within the respective working area of the machine at max. operating pressure and also with large diameters pipes.

The gap width is measured by inserting a spacer to be positioned opposite to the guide sided while the plane-worked pipes are clamped. Sliding surfaces of the guiding elements have to be protected against corrosion, e. g. by means of hard chrome plating.

2.10.3 Heating elements

The heating element has to be plane-parallel with its effective area. Permissible deviations from plane-parallelism (measured at room temperature after heating the elements to maximum operating temperature at least once):

Pipe outside Ø resp. edge length	permissible deviation
≤ 250	≤ 0.2
> 250 - ≤ 500	≤ 0.4
> 500 - ≤ 800	≤ 0.8
> 800 - ≤ 1200	≤ 1.2
> 1200	≤ 1.5

Table D.6: Permissible deviations from plane-parallelism

For processing in a workshop, the heating element is in general permanently mounted to the device. In case of a not permanently attached heating element, adequate devices have to be provided for its insertion (e.g. handles, hocks, links). If the size and nature of the heating elements requires its machine-driven removal from the joining surfaces, adequate equipment has to be provided too. The power supply has to be protected against thermal damage within the range of the heating elements. Likewise, the effective surface of the heating element has to be protected against damage. Protecting devices are to be used for keeping the heating elements undamaged during the intervals between the welding processes.

2.10.4 Devices for welding seam preparation

An adequate cutting tool has to be used so that the joining surfaces of the clamped pipe can be machined in a plane-parallel way.

Pipe outside Ø OD [mm]	deviation [mm]
≤ 355	≤ 0.5
400 up to < 630 mm	≤ 1.0
630 up to < 800 mm	≤ 1.3
800 up to < 1000 mm	≤ 1.5
> 1000 mm	≤ 2.0

Table D.7: Maximum permissible deviations from plane-parallelity at the joining surfaces

In order to be able to machine parallel joining faces while the pipes are in the clamped condition, provision must be made for a corresponding chip-producing tool.

The surfaces may be worked with devices which are mounted on or which can be introduced easily (e.g. saws, planes, milling cutters).

2.10.5 Control devices for pressure, time and temperature

The force range of the machine must be designed in such a way that there is a pressure reserve of more than 20 % which is required for the maximum welding cross-section and in order to overcome the friction forces of the machine. Time is manually controlled as a rule. In order to ensure reproducibility, a heating element with electronic temperature control is preferred. The characteristic performance and tolerance values have to be ensured.

2.10.6 Machine design and safety in use

In addition to meet the above requirements, machines used for site work should be of light-weight construction. Adequate devices for transportation and introduction into the trench have be available (e. g. handles, links). Especially if voltages above 42 V are applied, the relevant safety regulations of VDE and UVV have to be observed during the construction and operation of the machines.

Machines used in workshops have to meet the following requirements:

- Stable construction
- Universal basic construction (swivelling or retractable auxiliary tools and clamps)
- Quick-clamping device
- Maximum degree of mechanization
- Indication of pressure transmission (hydraulic/welding pressure) on the rating plate
- Possibility to fix working diagrams in the operating area
- In case of big machines, an undercarriage with locking device (stable, adjustable in height, built-in level) is recommended.

3 Non-contact heating element butt welding for PE, PP, PVDF, ECTFE und PFA (IR-welding)

3.1 Welding method

The method is in accordance with approved standard butt fusion, where the components are not in contact with the heat source. The heating of the pipe ends is performed by radiant heat. The advantages of the non-contact method are the minimal bead sizes and the elimination of possible contamination from the heating element (for further detailed information refer to our technical brochure "SP Series").

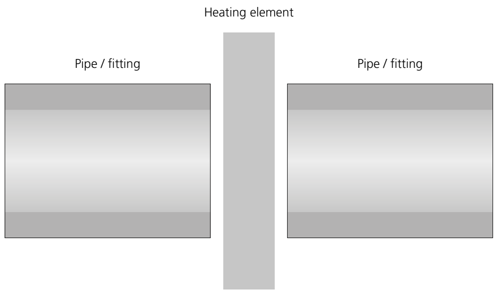


Figure D.6: Preparation of the welding.

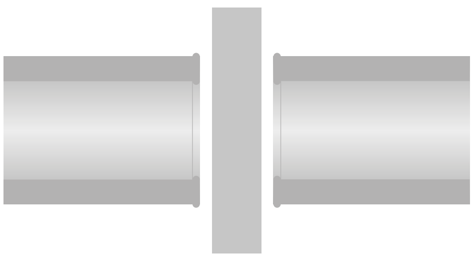


Figure D.7: Pre-heating.

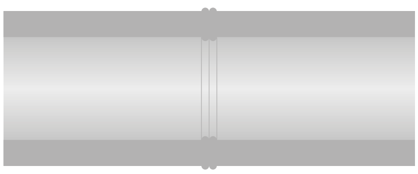


Figure D.8: Joining and cooling.

3.2 Welding parameters

Reference values of welding parameters for the non-contact butt welding of PE- PVDF- PP- PFA- and ECTFE- pipes and fittings need not to be stated separately as this data is stored in the machine for the relevant material and of the dimensions to be welded.

With AGRU IR-welding machines 70 % lower welding times can be reached in comparison to standard butt welding machines.

3.3 SP-welding equipment

This newly developed welding equipment operates fully automated and can be used for different material (PE, PP, PVDF, ECTFE and PFA).

There are the following sizes of welding equipment available:

- SP 63 mobile (OD 20 mm up to OD 63 mm)
- SP 110-S (OD 20 mm up to OD 110 mm)
- SP 250-S (OD 110 mm up to OD 250 mm)
- SP 315-S (OD 110 mm up to OD 315 mm)

Figure D.9: SP 110-S V3

4 Heated tool socket welding

Heating element socket welding (following DVS 2207, part 1 for HDPE, part 11 for PP and part 15 for PVDF)

4.1 Welding method

Heated tool socket welding (see Figure 6) is the overlapping welding of pipe and fitting. The pipe end and fitting socket are heated up to welding temperature by means of a socket-like and spigot-like heating element after which they are joined. The dimensions of the heating elements and fittings are calibrated to each other so that a joining pressure is built up during joining. (see schematic sketch). Heated tool socket welding may be performed manually up to pipe outside diameters of 40 mm. Above that, the use of a welding device is recommended because of increasing joining forces.

The guidelines of the DVS are to be adhered to during the whole welding process!

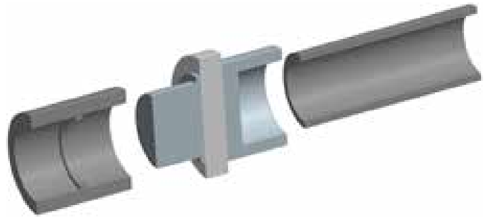


Figure D.10: Preparation of the welding.

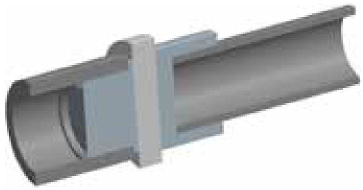


Figure D.11: Alignment and pre-heating.

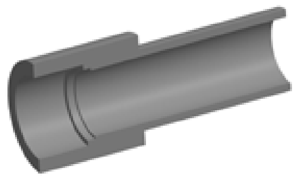


Figure D.12: Joining and cooling.

4.2 Welding temperature (T)

PP-H, PP-R	250 - 270 °C
HDPE	250 - 270 °C
PVDF	250 - 270 °C

Table D.8: Welding temperature

4.3 Welding parameters

Reference values for the heated tool socket welding of PP, PVDF and HDPE pipes and fittings at an outside temperature of about 20 °C and low air-speed rates.

Material type	Pipe outside diameter OD [mm]	heating up		changeover	cooling down	
		heating time [s]		changeover time [s]	fastened [s]	total [min]
		SDR 11, SDR 7.4 SDR 6	SDR 17 SDR 17.6			
PE 100 PE 100-RC PP-H PP-R	16	5	1) Welding not recommended	4	6	2
	20	5		4	6	2
	25	7		4	10	2
	32	8		6	10	4
	40	12		6	20	4
	50	18		6	20	4
	63	24	PE1); 10 (PP)	8	30	6
	75	30	18 (PE); 15 (PP)	8	30	6
	90	40	26 (PE); 22 (PP)	8	40	6
	110	50	36 (PE); 30 (PP)	10	50	8
	125	60	46 (PE); 35 (PP)	10	60	8

Material type	Pipe ouatside diameter OD [mm]	Pipe wall thickness [mm]	heating time [s]	changeover	cooling down	
				changeover time [s]	fastened [s]	total [min]
PVDF	16	1.5	4	4	6	2
	20	1.9	6	4	6	2
	25	1.9	8	4	6	2
	32	2.4	10	4	12	4
	40	2.4	12	4	12	4
	50	3.0	18	4	12	4
	63	3.0	20	6	18	6
	75	3.0	22	6	18	6
	90	3.0	25	6	18	6
	110	3.0	30	6	24	8

Table D.9: Welding parameters heated tool socket welding (Source: DVS 2207-1)

4.4 Processing guidelines

4.4.1 Preparation of welding place

- Assemble welding equipment (prepare tools and machinery)
- Check welding devices
- Set up welding tent if required

4.4.2 Preparation of welding seam

(immediately before starting the welding process)

Cut off pipe faces perpendicularly and deburr inside with a knife. The pipe-ends should be chamfered according to DVS 2207; part 1 and the opposite table.

Work the pipe faces with a scraper until the blades of the scraper flush with the pipe face. Thoroughly clean welding area of pipe and fitting with fluff-less paper and cleaning agents (ethanol or similar).

If peeling is not necessary, work the pipe surface with a scraper knife and mark the depth on pipe.

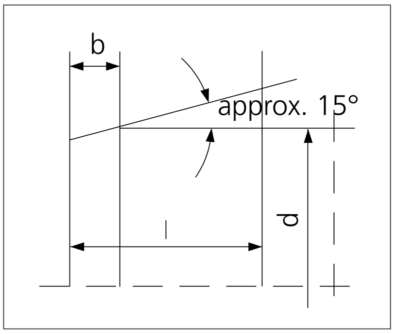


Figure D.13: Bevelling of the pipe end

pipe OD d [mm]	pipe chamfer b [mm]	insertion depth l [mm]
16	2	13
20		14
25		16
32		18
40		20
50		23
63	3	27
75		31
90		35
110		41
125*		46

Table D.10: Required pipe chamfer and insertion depth for PE, PP and PVDF pipes and fittings
*only for PE and PP

4.4.3 Preparations before welding

Check temperature of heating element (on heating spigot and on heating socket). Thoroughly clean heating spigot and heating socket immediately before each welding process (with fluff-less paper). At any rate, be sure to remove clogging melt residues if present.

4.4.4 Performing of welding process

Quickly push fitting and pipe in axial direction onto the heating spigot or into the heating socket until the set limit stop (or marking). Let pass by pre-heating time according to the values stated in tables. Once the preheating time has elapsed, employ a jerking action to remove the fitting and pipe from the heated tools and immediately push them together as far as they will go/to the marking without twisting. Let the joint cool down, then remove clamps. Only once the cooling time has been observed the connection can be placed under stress during the remaining installation work. For manual welding: Align the parts and push them together by applying pressure for at least one minute. (see table: page 205: fixed cooling time)

4.4.5 Visual welding seam control

Check out bead of welding seam. It must be visible along the whole circumference of the pipes.

4.5 Requirements

(following to DVS® 2210-1)

Requirements on the welding device used for heating element socket welding (following to DVS 2208, part 1). Devices for heating element socket welding are used in workshops as well as at building sites. As single purpose machines they should allow for a maximum degree of mechanization of the welding process.

4.5.1 Clamping devices

Marks on workpiece surface caused by special clamping devices for pipe components must not affect the mechanical properties of the finished connection.

4.5.2 Guide elements

Together with clamping devices and heating element, the guiding elements have to ensure that the joining parts are guided centrically to the heating element and to each other. If necessary, an adjusting mechanism has to be used.

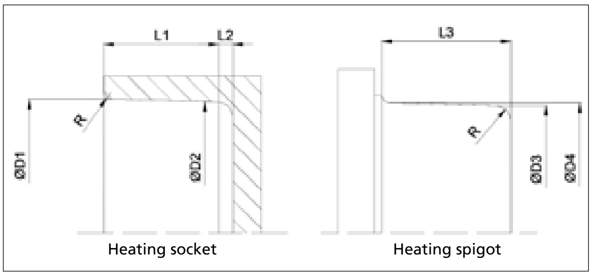
4.5.3 Machine design and safety in use

In addition to meeting the above requirements regarding construction and design, the following points should be considered for the machine design:

- stable construction
- universal basic construction (swivelling or re-tractable auxiliary tools and clamps)
- quick clamping device
- maximum degree of mechanization (reproducible welding process)

4.5.4 Heating elements

The values contained in below table (corresponding to the draft of ISO TC 138 GAH 2/4draft, document 172 E) apply to the dimensions of the heating tool.



Formula D.3: Dimensions of the heating elements

Pipe diameter [mm]	OD 1 [mm]	OD 2 [mm]	OD 3 [mm]	OD 4 [mm]	L 1 [mm]	L 2 [mm]	L 3 [mm]	R [mm]
16	15.9	15.76	15.37	15.5	14	4	13	2.5
20	19.85	19.7	19.31	19.45	15	4	14	2.5
25	24.85	24.68	24.24	24.4	17	4	16	2.5
32	31.85	31.65	31.17	31.35	19.5	5	18	3.0
40	39.8	39.58	39.1	39.3	21.5	5	20	3.0
50	49.8	49.55	49.07	49.3	24.5	5	23	3.0
63	62.75	62.46	61.93	62.2	29	6	27	4.0
75	74.75	74.42	73.84	74.15	33	6	31	4.0
90	89.75	89.38	88.75	89.1	37	6	35	4.0
110	109.7	109.27	108.59	109	43	6	41	4.0
125	124.7	124.22	123.49	123.95	48	6	46	4.0

Tabelle D.1: Dimensions (are valid at 260 - 270 °C) of heating elements for heating element socket welding fittings Type B (with mechanical pipe working)

Tabelle D.2: Dimensional tolerances:
≤ 40 mm ± 0.04 mm
≤ 50 mm ± 0.06 mm

4.5.5 Tools for welding seam preparation

For heating element socket welding with mechanical pipe working (method type B), a scraper is required for calibrating and chamfering the joining surfaces of the pipe. This has to correspond to the heating element and to the fitting socket. The scraper is adjusted with a plug gauge.

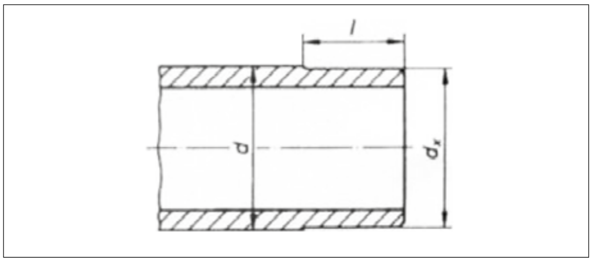


Figure D.14: For the socket welding prepared pipe end (dimensions see table)

Pipe outside diameter [mm]	Calibration diameter d_x [mm]	Calibration length l [mm]
20	19.9 ± 0.05	14
25	24.9 ± 0.05	16
32	31.9 ± 0.05	18
40	39.85 ± 0.10	20
50	49.85 ± 0.10	23
63	62.8 ± 0.15	27
75	74.8 ± 0.15	31
90	89.8 ± 0.15	35
110	109.75 ± 0.20	41
125	124.75 ± 0.20	44

Tabelle D.3: Calibration diameter and length for the machining of pipe ends with method, type B

5 Electrofusion welding

according to DVS ® 2207 part 1 for PE, part 11 for PP)

5.1 Welding method

In case of electrofusion welding, pipes and fittings are overlapped and welded by means of resistance wires which are located inside the electrofusion fitting. A transformer for welding purposes supplies the required electric power.

The expansion of the plasticised melt and the welding pressure which is built up during the shrinking process, caused by cooling, ensure an optimal welding. The method is characterized by low safety voltage as well as by high degree of automation.

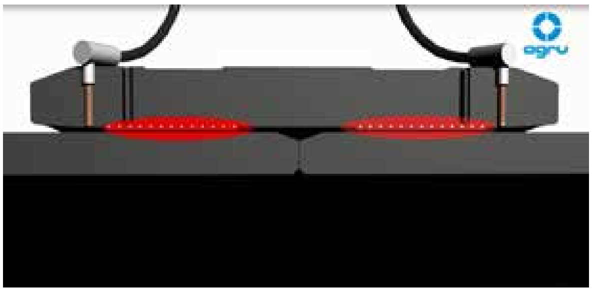


Figure D.15: Principle of the monofilar welding technique

5.2 Welding systems

For welding of AGRU-E-fittings a universal welding machine should be used. This welding device is a machine with bar code identification, it monitors all functions fully automatically during the welding process and files them.

After feeding a code for universal welding machines with magnetic code reading function, the code is deleted thereafter which means that the card can only be used once.

5.3 Suitable welding machines

For welding of electrofusion AGRU-fittings the following universal welding devices with bar code reader are suitable:

- Polycontrol plus
- HST 300 junior plus
- HST 300 print plus
- TINY M
- TINY DATA M
- PF-Frank
- Acuster

5.4 General welding suitability

Only parts made of the same material may be joined with one another. The MFR-value of the E-fittings made of PE is in the range of 0.3 - 1.3 g/10 min. They can be joined with pipes and fittings made of PE 80 and PE 100 with a MFR-value between 0.3 and 1.7 g/10 min.

The weldable SDR-series and the maximum ovality are listed in the following table. The welding area has to be protected against unfavourable weather conditions (e. g. rain, snow, intensive sun-radiation or wind). Pipes and fittings must reach an ambient temperature before welding. Processing temperatures between -10 °C and + 45 °C are approved. National guidelines must also be considered.

5.5 Welding parameters

A bar code label containing the welding parameters is directly affixed on the fitting.

Figure D.16: Agru bar code label

5.6 Weldability for PE electro fusion fittings

EF-fitting	OD [mm]	weldable pipes/fittings							
		SDR 33	SDR 26	SDR 17.6	SDR 17	SDR 13,6	SDR 11	SDR 9	SDR 7.4
SDR 11 (EF-fitting)	20	x	x	x	x	x	✓	✓	✓
	25	x	x	x	x	x	✓	✓	✓
	32	x	x	x	x	x	✓	✓	✓
	40	x	x	✓	✓	✓	✓	✓	✓
	50	x	x	✓	✓	✓	✓	✓	✓
	63	x	x	✓	✓	✓	✓	✓	✓
	75	x	x	✓	✓	✓	✓	✓	✓
	90	x	x	✓	✓	✓	✓	✓	✓
	110	x	x	✓	✓	✓	✓	✓	✓
	125	x	x	✓	✓	✓	✓	✓	✓
	140	x	x	✓	✓	✓	✓	✓	✓
	160	x	x	✓	✓	✓	✓	✓	✓
	180	x	x	✓	✓	✓	✓	✓	✓
	200	x	x	✓	✓	✓	✓	✓	✓
	225	x	x	✓	✓	✓	✓	✓	✓
	250	x	✓	✓	✓	✓	✓	✓	✓
	280	x	✓	✓	✓	✓	✓	✓	✓
	315	x	✓	✓	✓	✓	✓	✓	✓
	355	x	✓	✓	✓	✓	✓	✓	✓
	400	x	✓	✓	✓	✓	✓	✓	✓
	450	x	x	✓	✓	✓	✓	✓	✓
	500	x	x	✓	✓	✓	✓	✓	✓
SDR 17 (EF-fitting)	90	x	✓	✓	✓	x	x	x	x
	110	✓	✓	✓	✓	x	x	x	x
	160	✓	✓	✓	✓	x	x	x	x
	200	✓	✓	✓	✓	x	x	x	x
	225	✓	✓	✓	✓	x	x	x	x
	250	✓	✓	✓	✓	x	x	x	x
	280	✓	✓	✓	✓	x	x	x	x
	315	✓	✓	✓	✓	x	x	x	x
	355	✓	✓	✓	✓	x	x	x	x
	400	✓	✓	✓	✓	x	x	x	x
	450	✓	✓	✓	✓	x	x	x	x
	500	✓	✓	✓	✓	x	x	x	x

*thin-walled pipes must be welded using tubular stiffeners.

5.7 Welding procedure electro-socket welding

Installation animation electrofusion couplers

5.7.1 Processing guidelines

- Assemble welding equipment (prepare tools and machinery), check welding devices.
- Install welding tent or similar device.
- Depending on the environmental
- Refer to page 193 for settings depending on environmental conditions and temperature

5.7.2 Preparation of the welding seam

- Cut off pipe perpendicularly using a suitable cutting tool and mark the insertion length.
- Insertion length= socket length/2
- Clean the insertion area of the pipe with a dry cloth and carefully machine the pipe by using a suitable peeling tool or scraper knife in axial direction (cutting depth min. 0.2 mm). Remove chips inside and outside of pipe ends.
- If a fitting is being welded instead of a pipe, the welding area of the fitting has to be cleaned and scrapped accordingly too.

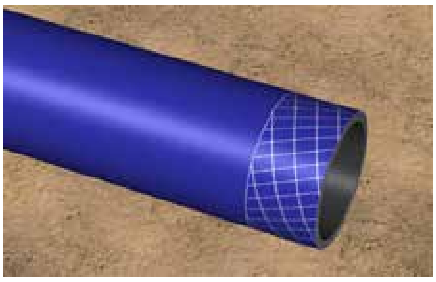


Figure D.17: Mark the insertion length

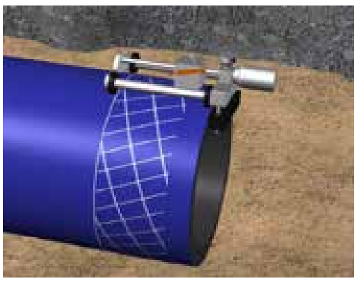


Figure D.18: Scraping the pipe

5.7.3 Preparations before welding

- Unpack the E- fitting only immediately before welding.
- Never touch the inside of the socket and the scrapped pipe end.
- The welding areas have to be cleaned with PP- or PE-cleaner (or similar) and fluffless paper.
- The faces to be welded have to be dry before the socket is slided on the pipe. At any rate, re-move residues of clean-sing agents or conden-sation water with fluffless, absorbent paper.
- Slide the socket onto the prepared pipe end up to the to its center stop until the marking is reached.

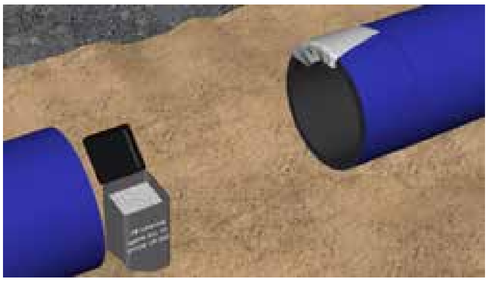


Figure D.19: Cleaning of the welding area

Figure D.20: Fixed welding components

- The second part which has to be welded with the socket (pipe or fitting) should be prepared too. Insert the second pipe end (or fitting) into the socket and clamp both pipes into the clamping device, so that no forces can develop between welding area and the pipe (fitting) and that the socket can be rotated smoothly.
- Check if any marking does not flush with a socket end. In that case the pipe has not been inserted fully.
- The clamping device has to be loosened and the pipe ends must be inserted until the mark-ings are flush with the socket ends.

5.7.4 Performing the welding process

- Refer to the instruction manual for the welding device. Only the most important steps of the welding procedure are described as follows.
- Both plugs of the socket should be facing upwards (however the axial position of the socket must not be altered) and connected with the welding cables. Position the welding cables so as to prevent the socket from twisting due to the weight of the cables.

Figure D.21: Connecting the welding machine

- After the welding equipment has been properly connected, this is indicated on the display.
- The welding parameters are fed in by means of a reading pencil or a scanner. An audio signal will acknowledge the data input.
- After the welding parameters have been fed in, the brand, dimension and outside temperature are shown on the display. These values now have to be acknowledged. Then, for control purposes, one will be asked, whether the pipe has been processed.
- Welding without clamping device:
  EF-fittings might be welded without using a clamping device too if it is allowed by national regulations. Adhere to the working instructions of DVS® 2207 part 1 and to the AGRU welding guidelines. Keep in mind that the installation situation must be tension free. If a tension free situation not possible clamping devices must be used.
- Optionally a traceability barcode label is attached on the fitting, so it is easy to feed the code into the welding machine. The usage of the traceability code is not mandatory. That means, if the code is not needed one still can proceed with the work procedure using a standard welding machine.
- The welding process is started by pressing the green start key. The display now shows the desired welding time as well as the actual welding time and the welding voltage.
- During the whole welding process (including cooling time) the clamping device shall remain installed. The end of the welding process is indicated by an audio signal.
- After completion of the cooling time, the clamping device may be removed. The recommended cooling time must be observed! If a welding process is interrupted (e.g. in case of a power failure), it is possible to re-weld the socket after cooling down to ambient temperature (< 35 °C).

5.7.5 Visual control and documentation

- Welding indicators on the socket can be used as visual control for the welding process. Moreover, all welding parameters are filed internally by the device and can be printed out in order to obtain a welding protocol.

Figure D.22: Welding machine for electro-socket welding

6 Pressure test

Prior pressure testing, all welding joints have to be cooled down completely (as a thumb rule, 1 hour after the last welding process). The pressure test has to be performed according to the relevant standard regulations (e.g. DVS ® 2210 Part 1 - see table page 198). The piping system has to be protected against changes of ambient temperature (direct sunlight).

The internal pressure has to be performed on completed pipelines. The test conditions should be kept above the operating conditions and confirm the reliability of the piping system. A pressure test below the nominal pressure of the piping system should be performed only exceptionally.

6.1 Types of the internal pressure test

- pre-test
- main-test
- short-test

Results of the pressure test including the test conditions have to be recorded. A continuous pressure and temperature record should be kept.

6.1.1 Pre-test

The purpose of a pre-test is to prepare the piping system for the main-test. A stress-strain equilibrium, generated by the internal pressure loads, arises during the preliminary test. Depending on the material used, this will cause a decrease in pressure which needs to be re-adjusted to the test pressure frequently. Often, the flange bolts flanges have to be re-tightened as well.

6.1.2 Main-test

The main test is conducted directly after the pre-test. During the main test, when the pipe wall temperatures are constant, a much lower decrease in pressure can be expected. Therefore, a re-adjustment of pressure is normally not required. Checking will mainly focus on leak tightness of flange connections and eventual dislocations of the piping system.

6.1.3 Short-test

This kind of test should be regarded as special case, because the time required for the pipe to adjusts to the stress-strain balance is too short. Eventually, irregularities can't be identified and the significance of the test result might be quite limited.

Topic and explanation		Pre-test	Main-test	short-test
Test Pressure p_P	depends on the wall temperature and on the max. pressure of components	≤ $p_{P(zul)}$	≤ 0.85 . $p_{P(zul)}$	≤ 1.1 . $p_{P(zul)}$
Test Period	Pipes with or without branches and a total length of L ≤ 100 m [1]	≥ 3 h	≥ 3 h	≥ 1 h
	Pipes with or without branches with a total length of 100 m < L ≤ 500 m	≥ 6 h	≥ 6 h	≥ 3 h
	Pipes with or without branches with a total length of L > 500 m	The respective piping system has to be tested in sections, the testing length of L_P ≤ 500 m must be strictly adhered to.		
		≥ 6 h	≥ 6 h	≥ 3 h
Checks during the test	The test results, test pressure and the temperature profile have to be recorded.	≥ 3 checks (adjusting (increase) the pressure to the testing pressure again)	≥ 2 checks (no adjusting (increase) to the testing pressure)	≥ 1 check (keep the testing pressure constant)
Material specific drecrease in pressure	Depends on the creep modul of the specific plastics material	PE ≤ 1.0 bar/h	PE ≤ 0.5 bar/h	For short term test, no data regarding decrease in pressure is available.
		PP [2]	PP [2]	
		PVDF, ECTFE [2]	PVDF, ECTFE [2]	
		Usually used		Special case (acceptance of the operator or the principal is necessary)

[1] In case the total test length does not exceed the length limit by more than 10 %, the described test conditions can still be maintained. The limitation of test length is due to reactions caused by change in test pressure and temperature. The longer the piping length to be tested, the more difficult the assessment of pressure tolerances is. At test temperatures of 20 °C +/- 5 °C even testing lengths > 500m might give robust results. The decision has to be made by the responsible person in charge.

[2] The DVS working group AG W 4.3a has decided to provide guideline values for all pressure drop rates for various thermoplastics based on research results. One concrete results are available they will be published in relevant journals.

6.2 Details for the internal pressure test

6.2.1 Prior to the pre-test

The air inside the pipe has to be removed. Therefore de-aeration points have to be set on the highest point of the pipe which have to be in open position when filling the pipe.The flush fluid velocity should be 1m/s at least.

6.2.2 Filling of the pipe

The medium for filling is water. The filling should be started at the lowest point of the pipe. When setting the filling speed, it has to be ensured that trapped air can escape at the de-aeration points safely. If a piping system has more than one lowest point, it may be necessary to fill the pipe in sections. The time gap between filling and testing of the pipe has to be long enough as to make sure that trapped air can escape from the de-aeration points (approximate time > 6 … 12h; it depends on the dimension of the pipe). For piping systems larger than DN 150 which do not have a distinct highest point or just have a very low gradient it may be necessary to use a pipeline pig to remove the remaining air in the pipe.

DN	V [l/s]
≤ 80	0.15
100	0.3
150	0.7
200	1.5
250	2.0
300	3.0
400	6.0
500	9.0

Table D.11: Reference values for filling the line

6.2.3 Applying the testing pressure

When applying the test pressure it has to be considered that the increase of the pressure does not causes any water hammers.

The following chart contains guide values:

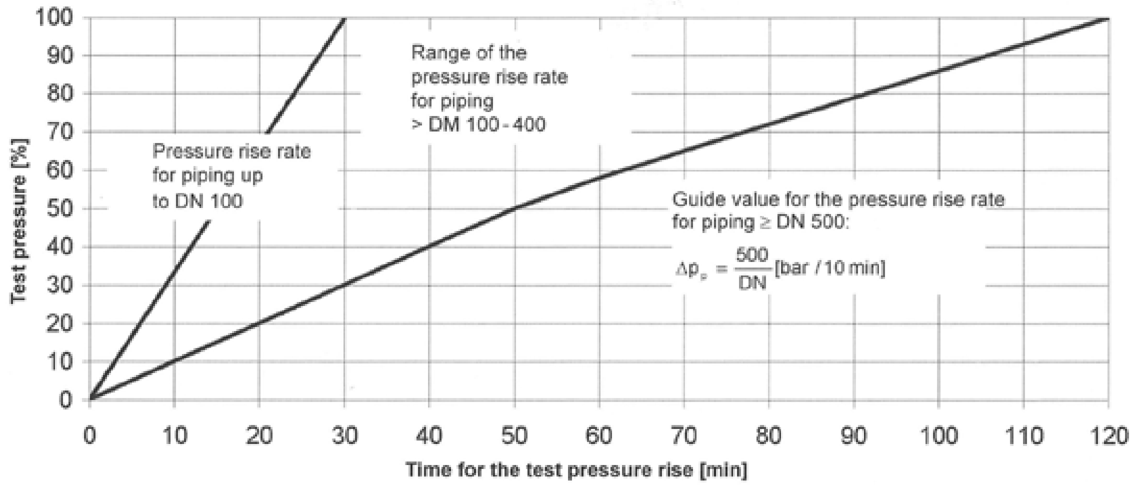


Figure D.23: Pressure increase time

6.3 Testing pressure and temperature

6.3.1 Evaluation of the testing pressure

The allowable testing pressure $p_{P(zul)}$ is calculated according to the following formula:

$$p_{P(zul)} = \frac{1}{\frac{OD}{s}} \cdot \frac{20 \cdot \sigma_{v(T,100h)}}{S_p \cdot A_G} \text{ [bar]}$$

Formula D.4: Allowable testing pressure

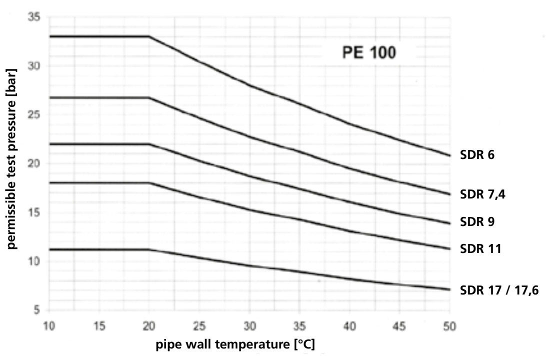
OD	Outside Diameter [mm]
s	wall thickness [mm]
$\sigma_{v\ (T,\ 100h)}$	Reference stress for a wall temperature T_R at t = 100 h [N/mm²]
s_P	Minimum safety distance to the creep strength
A_G	Manufacturing and design specific factor which reduces the allowable test pressure (A_G > 1,0)
d_a / s	~ SDR
p_B	Operating pressure [bar]

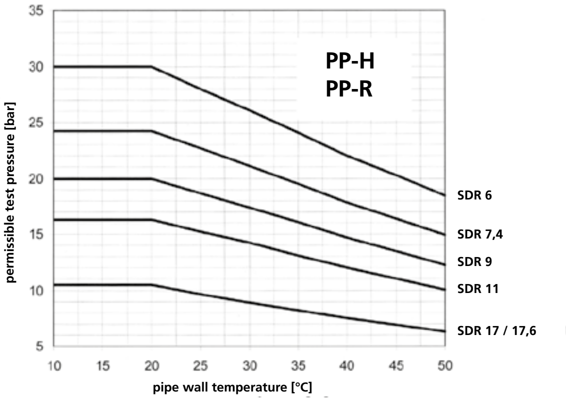
Determining a bigger safety distance as stated in the following table is possible and depends on the user.

Material	PE	PP-H	PP-R	PVDF
S_P	1.25	1.8	1.4	1.4

The allowable test pressure $p_{P(zul)}$ depending on the wall temperature can be extracted from the following chart:

If test pressures are used which are lower than the test pressure determined according to formula, the minimum value for p_P = 1.3 × p_B must be assumed.





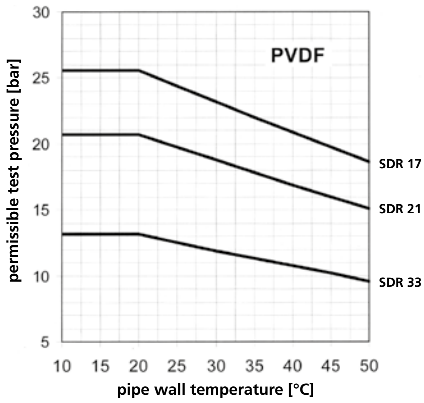


Figure D.24: Testing pressure and temperature

6.3.2 Testing temperature

(advices for walltemperature)

If it is assumed that the wall temperature will change during the test period, the test pressure has to be adjusted according to the maximum expected temperature.

If temperature measurements on the pipe surface shows a higher temperature than expected during testing, the test pressure has to be adjusted immediately according to the chart or the calculation.

The wall temperature can be assumed as the arithmetic mean of T_i and T_{Ra}.

$$T_R = \frac{T_i + T_{Ra}}{2}$$

Formula D.5: Average wall temperature

T_i	Temperature of the medium inside the pipe [°C]
T_{Ra}	Temperature on the surface of the pipe [°C]
T_R	Average wall temperature [°C]

Beside the influence of the temperature on the test pressure, especially for inside pressure tests following the contraction method, high attention has to be paid on constant pipe wall temperature. When testing above ground installed pipelines it is difficult to keep the wall temperature constant which can influence the testing method. To keep the informational value of the test it is absolutely necessary to keep temperatures records.

In case the average wall temperature is supposed to be higher than calculated (or extracted from the table) due to direct sun radiation, the test pressure has to be adjusted accordingly.

The measuring respectively the recording of the temperature inside the pipeline (temperature of the test medium) demands the assembly of a gauge connection at the most disadvantageous point of the piping system. In case it is ensured by proper arrangements, that the temperature of the pipe wall is never exceeding a pre-defined maximum value, the temperature measurement of the medium inside pipe can be left out.

For pipelines made out of thermoplastic materials with low impact strength (e.g. PP-H) the inside pressure test shall never be done at temperatures lower than 10 °C.

7 Hot-gas welding

(following to DVS 2207, part 3 for PP, HDPE, PVDF and ECTFE)

It is recommended to record the welding data in welding protocols or on data carriers.

7.1 Welding method

During hot gas welding the joint areas of the base material and filler material are plasticised by means of hot 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 made of thermoplastics, such as PP and HDPE. In general, material thickness of the semi-finished products to be welded ranges from 2 mm to 10 mm. Fields of application of this welding method are: apparatus engineering, construction of vessels and piping systems.

Piping systems for gas supply and water supply must not be joined by hot gas welding!

7.1.1 Weldability of base material and welding filler

As a precondition, base material and welding fillers must be weldable according to guideline DVS 2201, part 1. Another requirement for a high quality welding process is that the welding fillers are of the same kind and same type as much as possible.

Welding fillers have to comply with the guideline DVS 2211 in terms of specifications and properties. The most common welding fillers are round rods with diameters of 3 mm and 4 mm. Special profiles, such as oval, triangular and trefoil rods, as well as bands are also commonly used. In the following, the term "welding rods" is applied for the different welding fillers.

7.1.2 Welding parameter

Material	Welding force [N]		Hot air temperature [°C] 1)	Air quantity [l/min]
	Rod Ø 3 mm	Rod Ø 4 mm		
PEHD, PE 100-el	15 - 20	25 - 35	300 - 340	45 - 55
PP-H, PP-R, PPs, PPs-el	15 - 20	25 - 35	300 - 340	45 - 55
PVDF	20 - 25	30 - 35	365 - 385	45 - 60
ECTFE	10 - 15	15 - 25	350 - 380	50 - 60

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

Table D.12: Reference values at outside temperatures of about 20 °C (acc. to DVS 2207-3)

7.2 Welder qualification and requirements on welding devices

The plastics welder must have the required skills and knowledge for performing welding procedures. Normally this means that the welder is a qualified plastics worker and welder, continuously practising or with long-time experience. Hot gas welding machines have to comply with the requirements of the guideline DVS 2208-1.

7.3 Welding of ECTFE

The choice of gas is a very important factor in ECTFE welding. It is not necessary to use nitrogen in ECTFE welding; good quality ECTFE welds can be obtained when a clean, oil-free and dry source of air is used, it is important to use appropriate filters. Welding in nitrogen is recommended only when the welding facility lacks a clean and dry source of air.

7.4 Safety precaution

Melting temperatures of PVDF and ECTFE are above 300 °C and hydrogen chloride and hydrogen fluoride are released during welding. They can exhibit toxic effects at higher concentrations and should not be inhaled.

The recommended exposure limit acc. to TWA is 5ppm for hydrochloric acid and 3ppm for hydrofluoric acid. In case of inhalation of PVDF- or ECTFE-vapours the respective person should be brought to fresh air and a medical doctor should be consulted without delay (risk of polymer-fever!).

The following safety measures should be considered:

- Ensure good ventilation of the working place (otherwise please use breathing protections)
- Use eye protections
- Use hand protections

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

7.5 Processing guidelines

7.5.1 Preparation of welding place

- Assemble welding equipment (prepare tools and machinery), check welding devices.
- Install welding tent or similar device.

7.5.2 Preparation of welding seam

(categorically only immediately before starting the welding procedure)

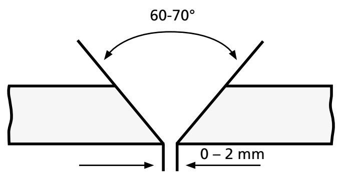
The joining areas and adjacent areas have to be prepared adequately before welding (e.g. by scrapping). Furthermore, it is also recommended to scrape the welding rods. It is, however, a must, when welding PP material. Parts that have been damaged by influences of weather conditions or chemicals have to be machined as much that an undamaged surface appears. The shapes of welding seams of polymer components generally are similar to the forms of welding seams of metal parts. The guideline DVS 2205, parts 3 and 5, are applicable 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 shapes are:

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

For welding areas accessible from both sides (sheet thickness of 4 mm and more), it is recommended to opt for double-V-welds. Double-V-welds should be chosen generally in case the sheet thickness is 6 mm and more. Warping of sheets can be minimized by changing the sides when welding.

7.5.3 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, for round nozzles in the centre of 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.



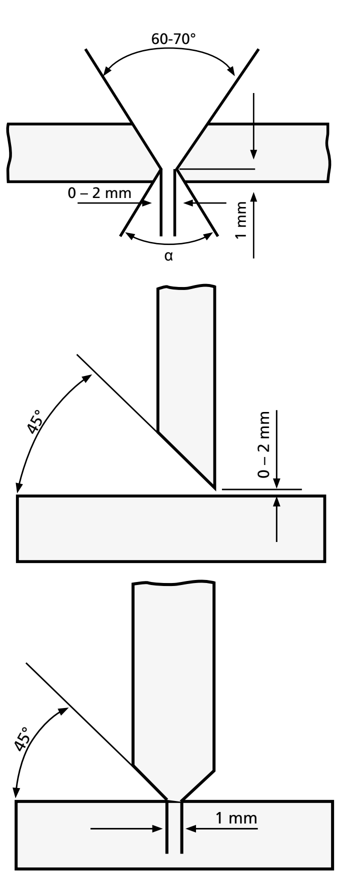


Figure D.25: Welding groove preparation

7.5.4 Performing of welding process

The welder has to acquire the required feeling for the speed and force he needs for welding by practising. The welding force 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 beak shaped attachment mounted on the lower part of the nozzle. As a consequence of the forward movement of the nozzle, the welding rod is automatically being pushed into the welding groove. If necessary, the welding rod has to be fed in manually in order to avoid stretching caused by friction within the nozzle.

7.5.5 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 using welding rods of larger diameters until it is completely filled. Before welding with the next welding rod, the welding seam which has been formed with the preceding welding rod, has to be adequately scrapped.

7.5.6 Additional reworking of welding seam

Usually welding seams do not require reworking. However, if necessary, pay attention to the fact that the thickness of the base material must be maintained.

7.5.7 Visual control of welding seam

Welding seams are visually checked with regards to weld shape, that the surface and edge areas are free from grooves, optimal weld filling and complete fusion on the root side of the joining parts.

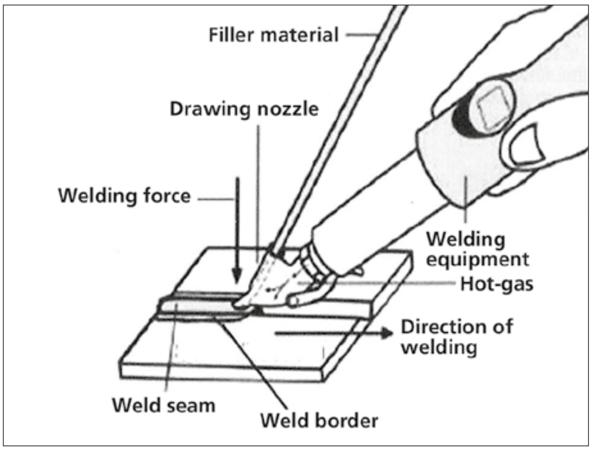


Abbildung D.1: Hot-gas welding

7.6 Requirements on the welding device

(following to DVS 2207-3)

7.6.1 Manual welding devices

(with external air supply)

The devices comprise a handle, heating, nozzle, air supply hose and electrical connection cable. Due to their construction design, they are particularly suitable for lengthy welding procedures.

7.6.2 General requirements

- Safe and reliable operation within temperature range of - 10 to + 60 °C
- Storage within a temperature range of - 20 to + 60 °C does not cause any damage
- Sufficient protection against corrosion from externally-acting humidity
- As light as possible
- Convenient centre of gravity
- Functionally formed handle together with the leads being bi-directional, the nozzle can be fixed in any position
- The functional elements are easily accessible
- Supply hoses and cables are flexible and cause no great exertion for the welder, neither do they kink or twist during correct use
- Welding equipment can be stored safely when the welding work is finished or interrupted
- The nozzles used can be easily replaced and safely fastened into position, even when hot
- Continuously adjustable power regulator
- If possible, handle with built-in control system
- The control elements are protected against accidental manipulation
- Material of handle: break-proof, thermo-resistant, thermo-insulating, electrically non-conducting
- Corrosion-proof hot gas supply pipes of low scaling
- Constant welding temperature to be reached after a maximum of 15 minutes

7.6.3 Safety requirements

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

- Parts in proximity to the user must not exceed an operational temperature of + 40°C, even during periods of extended use.
- Equipment surfaces that pose a risk of burns must be kept as small as possible or isolated and indicated accordingly where necessary.
- An over-temperature protection device must be fitted to prevent overheating or destruction of the equipment or individual components (e.g. due to lack of air).
- Sharp edges on equipment and accessories are to be avoided.

7.6.4 Air supply

Normally the required air is supplied by a compressed air network, a compressor, a pressure gas bottle or a ventilator. The air supplied has to be clean, free of water and oil, as otherwise not only the quality of the welding seam but also the lifetime of the welding device 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.

7.6.5 Welding devices

(with built-in ventilator)

These devices comprise a handle, built-in ventilator, heating, nozzle and electrical connection cable. Due to their design, 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 procedures.

7.6.6 Requirements on design

The ventilator has to supply the required quantity of air for welding various types of plastics using all types of 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.

7.6.6.1 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.

8 Extrusion welding

(following to DVS 2207, part 4)

8.1 Welding method

Extrusion welding is used for joining thick-walled parts (construction of containers, apparatus engineering, piping systems), for joining of liners (for buildings, linings for ground work sites) and for special tasks.

This welding technique is characterized as follows:

- Welding process is performed with welding filler being pressed out of a compounding unit.
- The welding filler is homogenous and completely plastified.
- The joining surfaces have been heated up to welding temperature.
- Joining is performed under pressure.

8.2 Weldability of base material and welding filler

Semi-finished products and welding fillers have to be suitable for extrusion welding. Weldability of base material and welding fillers have to be in perfect processing condition. Assure weldability of parts to be welded according to DVS 2207, part 4.

The welding filler has to be suitable for processing with the particular extrusion welding device and the type of material used as semi-finished product. The welding filler is being processed in form of pellets or rods. Pellets and welding rods of uncontrolled composition and unknown origin must not be processed. Do not use regenerated material for welding. The welding filler has to be dry and clean (prevent moisture from falling upon cold pellets).

8.3 Qualification of welder and requirement on welding devices

The plastics welder must have obtained the knowledge and skills required for performing of welding processes. Generally, this means, that he is a qualified plastics welder continuously practising or having long-time experience.

For extrusion welding, several kinds of devices may be used (see DVS 2207, part 4). The most common device is a portable welding device consisting of a small extruder and a device for generating hot air. The welding pressure is applied onto a Teflon nozzle, directly fastened to the extruder, which corresponds to the welding seam shape. Depending on the type of device, the maximum capacity of the welding fillers is about 4.5 kg/h.

Material	Abbreviation	Compound temperature [°C]	Hot-gas temperature [°C]	Hot-gas volume [l/min]
Polyethylen high density	HDPE	210 - 230	250 - 300	300
Polypropylen Typ 1, 2	PP-H; PP-R	210 - 240	250 - 300	300
Polyvinylidenfluorid	PVDF	240 - 260	280 - 350	300

Table D.13: Welding parameter reference values

8.4 Processing guidelines

8.4.1 Preparation of welding place

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

8.4.2 Preparation of welding seam

(categorically only immediately before starting the welding process)

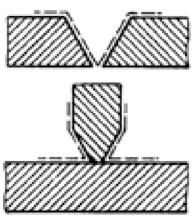
The joining surfaces and the adjacent areas have to be prepared adequately before welding (e.g. by scrapping). Parts that have been affected by influence of weather conditions or chemicals have to be machined until an unspoilt area appears. This has to be considered especially for performing repair works. Do not use cleansing agents affecting plastics which would cause swelling. In order to equalize excessive temperature differences between the different work pieces, the work pieces have to be stored sufficiently long under the same conditions at the working place.

8.4.2.1 Welding seam shapes

For choosing welding seam shapes for containers and apparatus, follow the guideline DVS 2205, part 3 and 5. In particular, observe the general technical welding principles. In general, single-layer seams are suitable for extrusion welding. In case of welding thicker semi-finished products where it is not possible to perform DV-welds, also multilayer welding seams can be applied. The welding seam should laterally protrude by about 3 mm over the prepared welding groove.

8.4.2.2 Lap joint

In order to ensure sufficient heating and thorough welding, it is necessary to provide an air gap depending on wall thickness (width of air gap should be 1 mm minimum).



Welding seam forms for extrusion welding

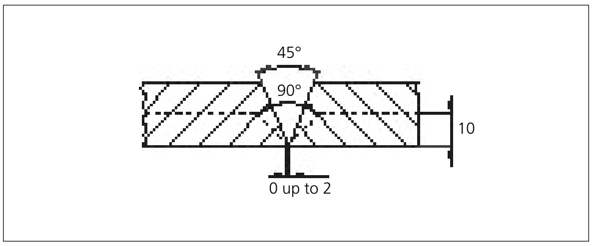


Figure D.26: Prepared welding groove

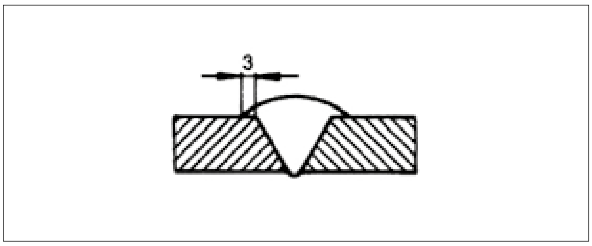


Figure D.27: V-weld without sealing run

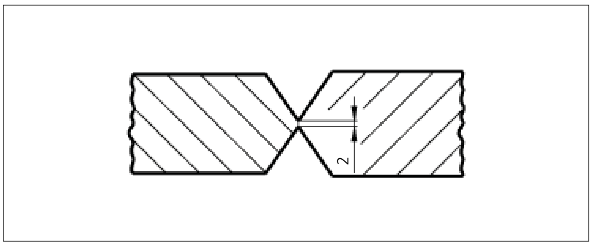


Figure D.28: Double V-butt welding

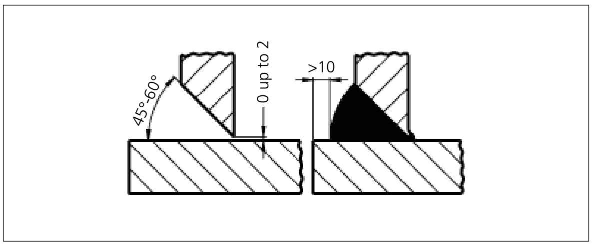


Figure D.29: T-joint with single bevel groove with fillet weld

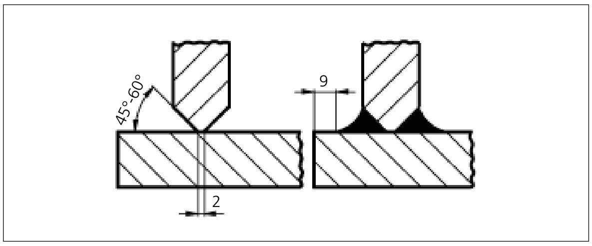


Figure D.30: T-joint with double bevel groove

8.4.3 Performing the welding process

Due to the hot gas passing out of the nozzle of the welding device, the adjacent surfaces of the parts to be welded are heated up to welding temperature. The welding filler, continuously flowing out of the manually guided device, is pressed into the welding groove. The discharged material pushes the device ahead thus determining the welding speed. The heating of the adjacent surfaces must be in accordance with the welding speed. Basically the welding seams have to executed in such a way, that it is assured that no re-working will be required. If still necessary, it should however be performed only after final inspection, so that eventual welding faults can be discovered during visual scrutiny. While re-working, avoid the build-up of notches.

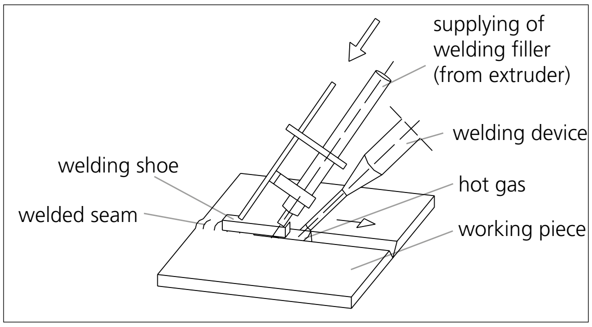


Figure D.31: Extrusion welding

8.4.4 Visual inspection of welding seam

During visual inspection, the surface properties, correct execution as per the technical drawings as well as the evenness of the welding seam are evaluated.

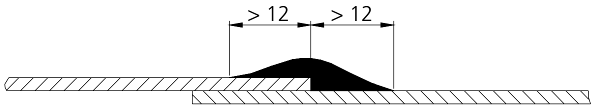


Figure D.32: Lap joint with fillet weld

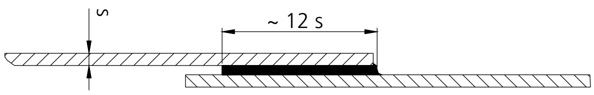


Figure D.33: Lap joint with lap weld (for liners with a thickness of up to 3.5 mm)

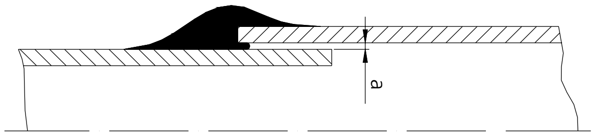


Figure D.34: Lap joint with extrusion welding (for liners/sheets with a thickness of up to 3.5 mm)

Figure D.35: Welding shoes

Figure D.36: Handheld extrusion welding device Type K1

9 Detachable joints

9.1 Flange connections of piping systems

If pipes and fittings are connected by means of flanges, the following guidelines have to be adhered to:

- Aligning of parts
  Before pre-tensioning the screws, the sealing faces have to be aligned plane-parallel to each other and fit tight to the sealing. Pulling of the flanges connection resulting in tensile stress has to be avoided under any circumstance.
- Tightening of screws
  The length of the screws has to be chosen in such a way, that the screw thread is flush with the nut. Under the screw heads and nuts washers have to be placed. The connecting screws have to be tightened crosswise using a torque wrench (required torque values see www.agru.at).

9.2 General information

It is recommend to brush over the thread, e. g. with molybdenum sulphide, so that the thread stays also at longer operation time easy-running. For the selection of sealing material the chemical and thermal resistance has to be considered.

9.3 Unions in piping systems

If pipe joints made of thermoplastics are connected by means of unions, the following rules should be observed:

For avoiding of impermissible loads during the installation, unions with round sealing rings should be used. The union nut should be tightened manually or by means of a pipe band wrench (common pipe wrenches should not be used). Avoid using union connections in areas where bending stress in the piping system can be expected.

NOTE: seal threads only with Teflon, do not use hemp.

9.4 Adhesive joints

Adhesive joints for polyolefines are not recommended. The connection strength values that can be achieved hereby are far below the minimum requirements which would be needed for practical use.

Double Containment Piping

1 General information

1.1 Advantages

- Application of highly corrosion resistant materials such as PE, PP or PVDF (ECTFE)
- Different combinations of media pipe and protective pipe
- Exact identification of the leak area by means of an electronic detection system therefore low repair expenses
- No succesive damages
- Option to divide the system into several protection sections - therefore higher flexibility in operation

Figure A.1: Reference picture PP-ECTFE

1.2 Application range

Buried:

- Buried piping systems conveying ground water endangering media through sensitive areas
- Industrial sewage water systems
- Dumping ground seepage water pipes to reservoirs or waste water treatment plants

Aboveground:

- Processing pipelines for dangerous chemicals
- In industrial plants
- In the chemical industry
- In the semiconductor production

1.3 Components

Inner pipe: The media is transported through the inner media pipe.

Outer pipe: The outside- or encasing pipe provides protection against media leakage.

Annular space: the annular space between inner and outer pipe. The annular space is used for leak detection.

Leak detection system: The leak detection system comprises a monitoring space (sleeve), monitoring device (e.g. sensor) and an indicating device.

Figure A.2: Reference picture PP-ECTFE

1.4 Dimensions

In practice, due to various operating conditions, several pipe materials are commonly used. The following material combinations are available for double containment piping systems:

	outer pipe (protective pipe)	inner pipe (media pipe)	welding
Standard	PP	PP	S
	PE	PE	S
	PE	PP	K
	PE	PVDF	K
	PP	PVDF	K
on request	PVDF	PVDF	S
	PE	ECTFE	K
	PP	ECTFE	K
	PVDF	ECTFE	K
	ECTFE	ECTFE	S

Table A.1: Available combinations

S = Simultaneous welding
K = Cascade welding

Dimensions of standard combinations for cascade welding:

PE/PP - PE/PVDF - PP/PVDF - PE/ECTFE - PP/ECTFE

outer pipe		inner pipe	
d_1	SDR_1	d_2	SDR_2
90	17	32	11 (21)
125	17	63	11 (21)
160	17	90	11 (33)
200	17	110	11 (33)
280	17	160	11 (33)

Table A.2: Dimension combinations for cascade welding

Dimensions of standard combinations for simultaneous welding:

PP/PP - PE/PE

outer pipe		inner pipe	
d_1	SDR_1	d_2	SDR_2
160	33	90	17
160	33	90	11
280	33	160	11
315	33	200	11
355	33	250	11

Tabelle A.1: Dimension combinations for simultaneous welding

Figure A.3: PE-PVDF

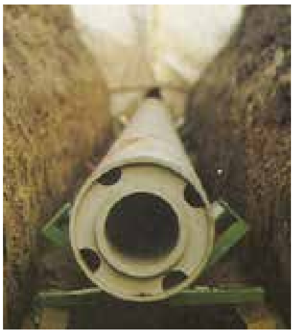


Figure A.4: PP-PP

Figure A.5: PE-PE

2 Connection methods

The welding of a dual pipe can be performed by use of different welding methods. Either simultaneous welding or cascade welding are applicable. While placing an order, the intended welding method which will be used has to be stated, because the protrusion of the inner pipe will differ depending on the method.

2.1 Simultaneous welding

In the case of simultaneous welding the inner and outer pipe are welded at the same time. Here the dual pipe can be installed or welded like a single pipe but with different welding parameters.

Advantages of simultaneous welding:

- Less time for welding required
- Easy and fast installation
- Use of the standard heating elements (not applicable if leak detection cables are to be installed)

Disadvantages of a simultaneous welding:

- No visual control of the inner pipe welding seam is possible
- Inner and outer pipe must be of the same material

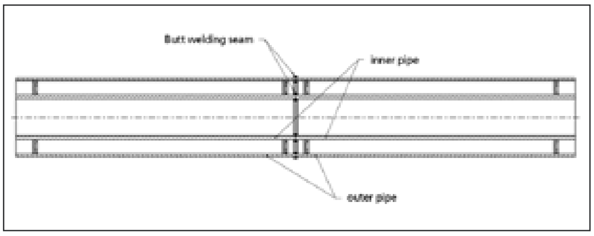


Figure A.6: Simultaneous welding with butt welding

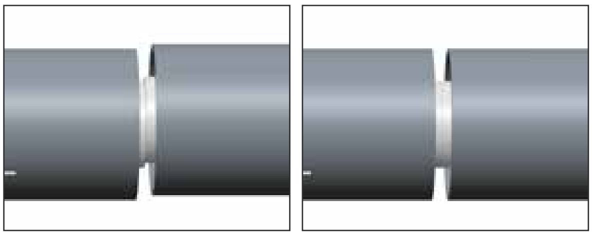


Figure A.7:
Step 1: Checking the offset of the inner pipe (left: with offset; right: without offset)

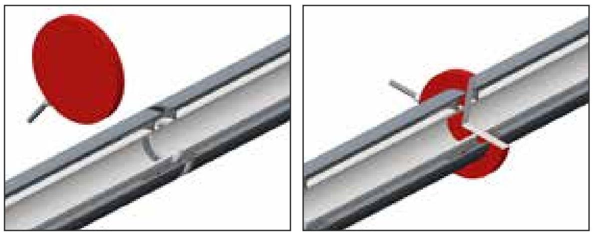


Figure A.9:
Step 3: Heating of the joining areas

Figure A.8:
Step 2: Planing of the joining areas

Figure A.10:
Step 4: Welding of inner and outer pipe

2.1.1 Welding parameter

outer pipe [mm]			inner pipe [mm]			welding force	pre-heating time	cooling time	bead heigth outer pipe
d_1	SDR	s_1	d_2	SDR	s_2	F [kp]	tAw [sec.]	tAk [min]	[mm]
160	33	4.9	90	17	5.4	58	50	7	1.5
160	33	4.9	90	11	8.2	69	80	12	2
280	33	8.6	160	11	14.6	214	145	18	2.5
315	33	9.7	200	11	18.2	303	180	22	2.5
355	33	10.9	250	11	22.7	432	220	27	3

Table A.3: Welding parameter for PE/PE simultaneous welding

outer pipe [mm]			inner pipe [mm]			welding force	pre-heating time	cooling time	bead heigth outer pipe
d_1	SDR	s_1	d_2	SDR	s_2	F [kp]	tAw [sec.]	tAk [min]	[mm]
160	33	4.9	90	17	5.4	38	70	8	1.5
160	33	4.9	90	11	8.2	45	120	15	1.5
280	33	8.6	160	11	14.6	142	200	22	2.5
315	33	9.7	200	11	18.2	200	290	30	2.5
355	33	10.9	250	11	22.7	285	300	33	3

Table A.4: Welding parameter for PP/PP simultaneous welding

2.2 Cascade welding

For the butt welding of the inside pipe the outside pipe is pulled back until the inside pipe is clamped into the clamps of the welding machine. The inside pipe is welded by heating element butt welding in accordance with the DVS guideline 2207.

The outside pipe can be joined with split heating element butt welding, or with electrofusion welding. If a split heating element is used take care that a minimum ring gap between inside pipe and heating element of 10 mm is given. Further do not damage the inside pipe during the adjusting of the heating element. By the welding of the outside pipes with an electrofusion welding socket the inside stop in the middle of the socket should be removed before placement on the out-side pipe, this will allow room for welding the inside pipe. After the welding of the inside pipe the loose outside pipe will be pulled on the to be welded pipe and will be welded on the circumference with electrofusion sockets. This welding is only possible with an outside pipe out of PEHD. A further possibility for the joining of the outside pipes is the welding with a sleeve. The procedure can be compared with the welding of electrofusion sockets. In this situation the sleeve is welded in place by hot gas or extrusion welding.

Advantages of the cascade welding:

- Easier installation of the leak detection cable
- The welding seam of the inside pipe can be checked visually
- This method can be applied for all material combinations

Disadvantages of the cascade welding:

- Higher time expenditure per welding
- Varied installation and so higher installation expenses

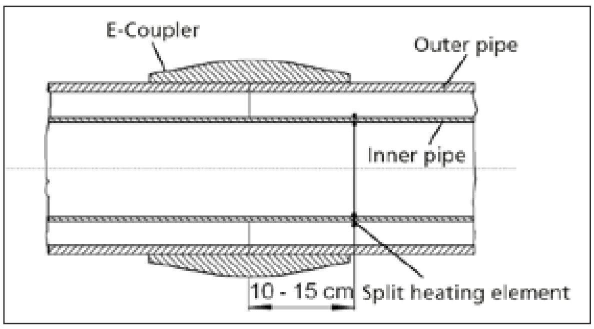


Figure A.11: Cascade welding inner pipe with butt welding-Outer pipe with electrofusion welding

Figure A.12: Inner pipe welded with butt welding

Figure A.13: Inner pipe welded with butt welding

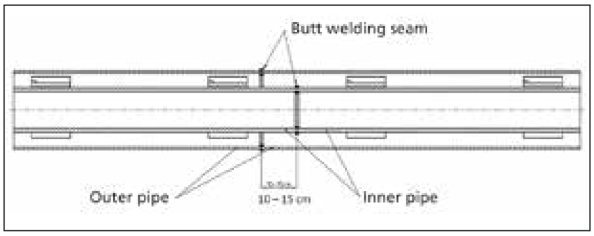


Figure A.14: Cascade welding inner pipe with butt welding outer pipe with butt welding with a split heating element

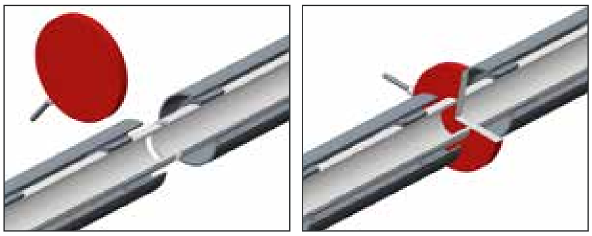


Figure A.15: Step 1: Heating and welding of the inner pipe

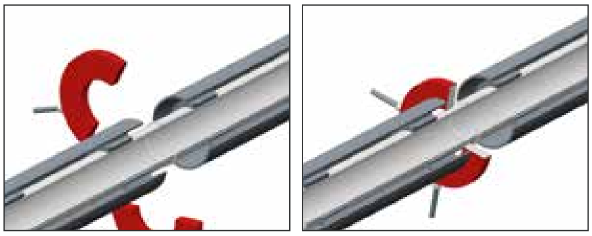


Figure A.16: Step 2: Heating of the outer pipe with a split heating element

Figure A.17: Welding of the outside pipe

3 Poly-Flo System

The new Poly-Flo system is an addition to our double containment piping system range. The pipes and fittings are produced in one step (extruded / injection moulded) and fully pressure resistant.

Advantages:

- Cost saving vs. fabricated systems
- Low space requirement of pressure pipe system
- Low weight due to small annular space
- No pre-fabrication of pipes and fittings required
- No welding of the distance clips necessary when cutting 5m pipe
- Faster installation, lower installation costs
- Outer and inner dimensions of fitting and pipe correspond exactly
- No special welding clamps required

3.1 Dimensionen

Material:

- PP-R/PP-R
- PE 100-RC/PE 100-RC

Dimension:

- DIM 50/32 – SDR17/11
- DIM 90/63 – SDR17/11
- DIM 160/110 – SDR17/11

3.2 Connection method simultaneous welding

Simultaneous welding as well as cascade welding are feasible.

The advantages of simultaneous welding are the fast installation time and the possibility to use standard butt welding machines.

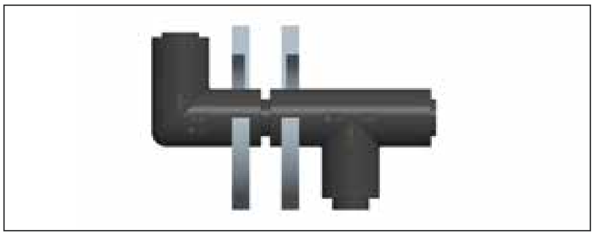


Figure A.18:
Step 1: Control the offset on the inner pipe

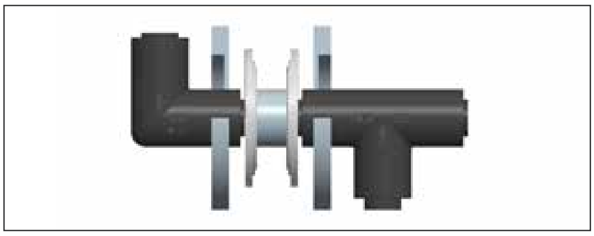


Figure A.19:
Step 2: Planing stat planning

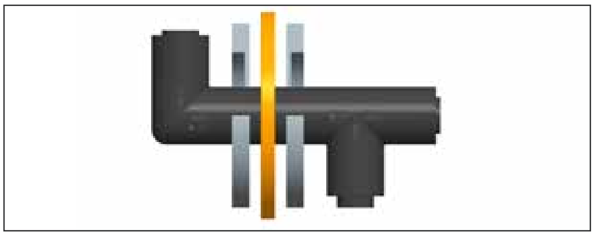


Figure A.20:
Step 3: Heating the joining areas

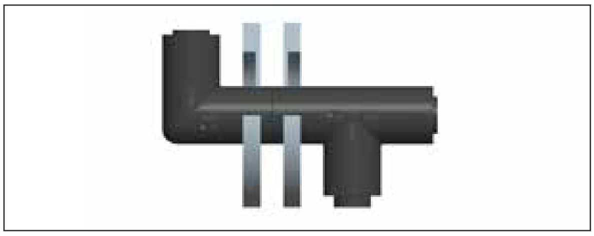


Figure A.21:
Step 4: Welding the inner and outer pipe

3.2.1 Simultan IR-welding

Infrared simultaneous welding is a particularly suitable welding method for Poly-Flo, since in comparison to butt welding a constant, small welding bead is produced, which is decisive for a more spacious ring-space. The parameters already programmed into the machine, allow an easy and safe operation.

Figure A.22: SP 110-S V3

Figure A.23: SP 250-S V3

3.2.2 Simultan butt welding

Simultaneous butt welding is a process that can be carried out with any conventional butt welding machine. Following, the welding parameters required for this.

Figure A.24: ST CNC 2.0

Welding parameter for PE 100-RC / PE 100-RC Poly-Flo:

OD	1. Equalising		2. Preheating	3. Changeover	4. Joining		
	Equalising force	Bead height (minimum)	Preheating time	Joining pressure build-up time (maximum)	Joining pressure build-up time	Joining force	Cooling time (minimum)
	[kg]	[mm]	[sec.]	[sec.]	[sec.]	[kg]	[min]
50/32	12	0,5	25	5	5	12	6,5
90/63	35	0,5	53	6	6	35	8
160/110	125	1,5	80	7	7	125	13

Table A.5: Welding parameter of heating element butt-welding according to DVS 2207-1 for PE 100-RC / PE 100-RC Poly-Flo
Heating element temperature: 220 ± 10 °C

Welding parameter for PP-R / PP-R Poly-Flo:

OD	1. Equalising		2. Preheating	3. Changeover	4. Joining		
	Equalising force	Bead height (minimum)	Preheating time	Joining pressure build-up time (maximum)	Joining pressure build-up time	Joining force	Cooling time (minimum)
	[kg]	[mm]	[sec.]	[sec.]	[sec.]	[kg]	[min]
50/32	8	0.5	36	5.0	5	8	6.5
90/63	28	0.5	70	5.5	6	28	8
160/110	85	1.0	120	7.0	8	85	13

Tabelle A.2: Welding parameter of heating element butt welding according to DVS 2207-11 for PP-R / PP-R Poly-Flo
Heating element temperature: 210 +/- 10°C

3.3 Cascade welding

Inner pipe: (IR-) butt welded (Recommendation: for DIM50/32 and DIM90/63 with IR butt welding)

Outside pipe: induction welded

Advantages:

- The welding seam of the inner pipe can be checked visually
- A pressure test on the inner pipe is possible before the outer pipe will be welded.

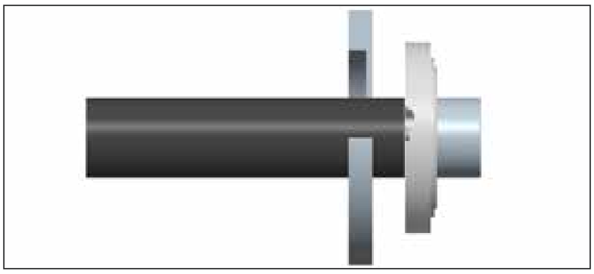


Figure A.25: Step 1: Shorting the outer pipe with a special planing tool. This process is not necessary for the fittings

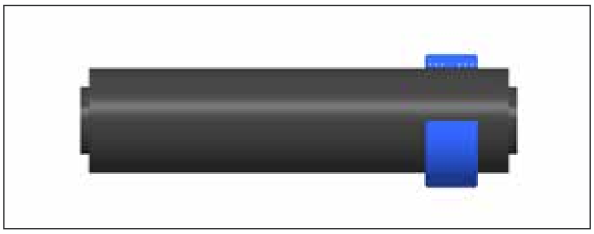


Figure A.26: Step 2: Slide the induction ring onto the pipe

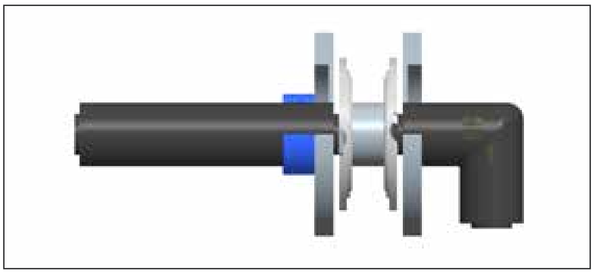


Figure A.27: Step 3: Planing the inner pipe

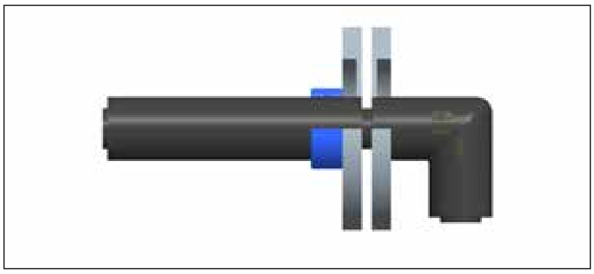


Abbildung A.1: Step 4: Check the offset on the inner pipe

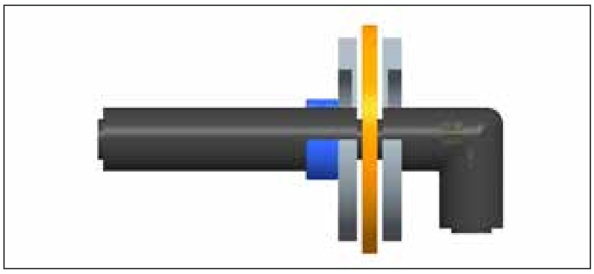


Figure A.28: Step 5: Heating the joining areas

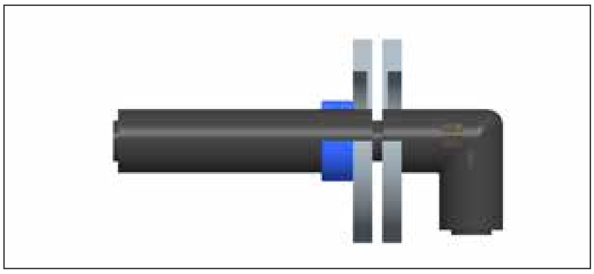


Figure A.29: Step 6: Welding process / cooling time of inner pipe

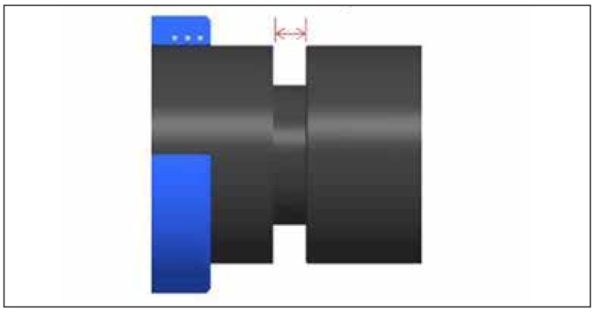


Figure A.30: Step 7: Distance check of outer pipes (max. 10mm)

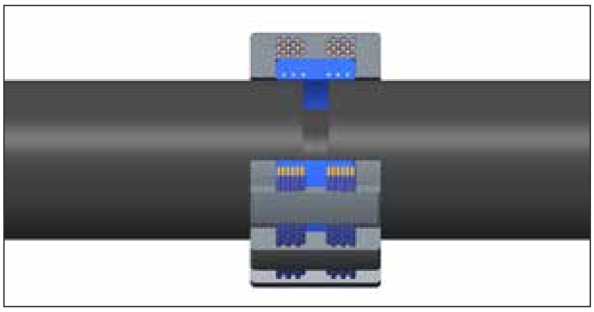


Figure A.31: Step 8: Induction welding of outer pipe with an induction welding machine

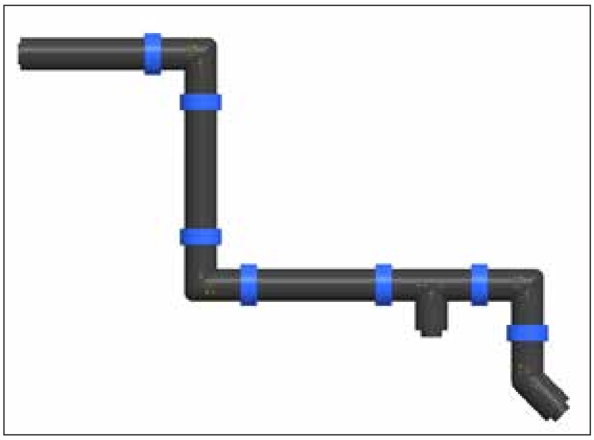


Figure A.32: Fertig geschweißte Rohrleitung

Figure A.33: Induction welding machine

Tools for DIM50/32, DIM90/63 and DIM160/110 Cascade welding

- milling tool
- Ring inductor
- Poly Flo fixation clamp

Figure A.34: milling tool

Figure A.35: Ring inductor

Figure A.36: fixation clamp

4 Leakage detection

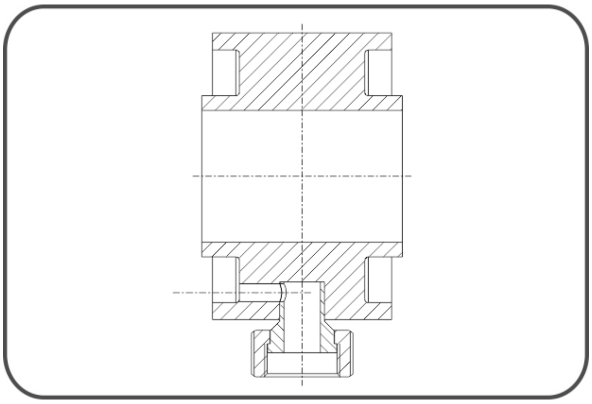
A leakage detection system is used to monitor the transport of media in double containment piping systems. The same is installed in or throughout the annular gap between the inside and outside pipe. If a leakage should occur, the operator immediately is notified by the permanent leakage detection system. The outer pipe protects the environment until the repair work is completed.

Nowadays the following leakage detection systems for piping systems are available:

4.1 Leakage detection system

4.1.1 Sensors

For leakage detection using sensors, the sensors are installed at the lowest point of the piping system. In case of a leaking the leaked medium will flow to the lowest point in the annular gap, where a sensor is installed. The sensors in use are based on various detection principles and allow the allocation of the position of the leakage. This measurement ensures a constant control of the system, because the sensors are connected with a terminal, which makes monitoring very easy. By installing fixed points, the pipeline system can be split into separate safety zones. A further advantage is, that in case of a leakage the detection system can be re-used. Due to the simple installation of the leakage detection system, it is one of the most widespread systems used in practice.



4.1.2 Visual leakage detection

In case of a leakage the medium can be seen through inspection glasses. These must be installed on all lowest points of the pipeline system. In case of a leakage the leaked medium will flow to the lowest point and it will be visible there. The inspection glasses should be equipped with bleed ports to allow an analysis of the medium in case of a leakage. A constant control of the system by the visual method is however not possible because the controls depend on the operator. It is also possible to install a valve at the lowest point at the outside pipe of the double containment pipe for leakage detection.

4.1.3 Leak detection cables

This special leak detection method was developed to detect and show the leak places . The cables are installed over the whole length in the ring gap of the piping system. The position of the leak can be located exactly with a system map.

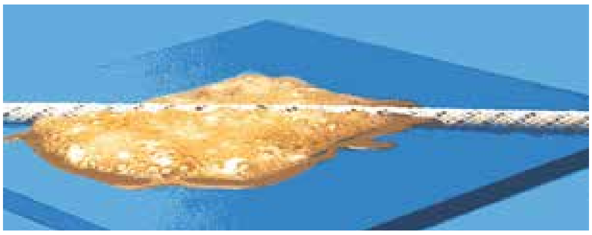


Figure A.37: Leak detection cables

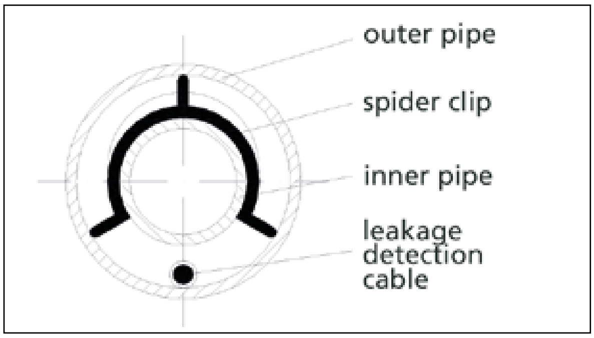


Figure A.38: Leakage detection with leakage detection cable

4.1.4 Differential control

(Comparison inside pressure to ring gap pressure)

With differential pressure control the ring gap is supplied with under- or over pressure. By the over-pressure method the gas flows out of the ring gap in the inside or media pipe during pressure loose in the ring gap, as a result of this an alarm is triggered by a pressure manometer. If a leak develops by the under pressure or vacuum control it will lead into a pressure loss in the media pipe following a pressure increase in the ring gap, which will also trigger an alarm. For the dimensions the stress of the different pressure in the ring gap should be noticed.

4.2 Installation system

With the installation of the double containment piping system are in comparison with the installation of a single pipe possible changes in the length due to thermal expansion or contraction require special attention. The temperature changes of the inside and outside pipe can be different or even opposite through the distance between the pipes. This can lead to considerable length expansions of the pipes to one another. If it can not picked up constructive stress will be developed which is an additional demand on the pipe lines. One can distinguish between three different design systems:

4.2.1 Unimpeded heat expansion

(flexible system)

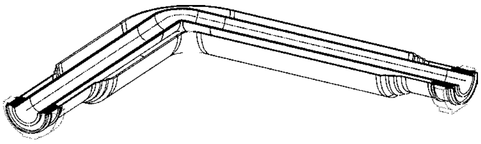
The inner and outer pipe are installed in such a way, that a length expansion of both pipes and even towards each other is enabled. In terms of planning it needs to be considered that the length expansion of the inner pipe takes place inside the outer pipe.

Advantages:

- Applicable for higher operating temperatures
- Reduced stress of the double containment piping system because length expansion is not hindered

Disadvantages:

- Higher expenses
- Often requires more space because of the required compensation elbows



4.2.2 System with impeded heat expansion

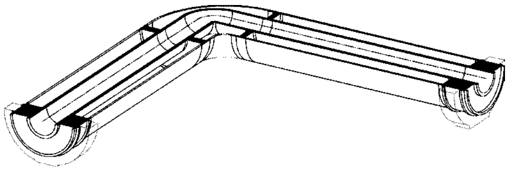
The inside and outside pipe are fixed together by dog bones. The length expansion of the whole double containment pipe line will be picked up through sufficient measures (compensator, straight). This method is only sensible when the inside an outside pipe are made out of the same material and few temperatrue changes between inside and outside pipe occur.

Advantages:

- low expenses
- usually low fixing expenses

Disadvantages:

- high stress in the double containment piping system
- need often much area because of the compensation elbow



4.2.3 Fixed system

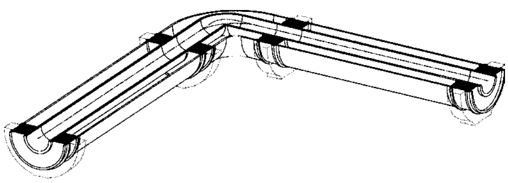
Inner, outer pipe and the surrounding are fixed to each other with dog bones in each direction. A length expansion of the inner and outer pipe is not possible.

Advantages:

- low expenses
- low space requirement

Disadvantages:

- high dog bone forces (efforts for fixation)



4.3 Project questionnaire

To obtain an accurate assessment of the project, it is preferable to fill out the following questionnaire.

Questionnaire I: ("Application and installation conditions") contains the dimensions, materials, pressure ratings, general application parameter and the leak detection system. Please find the questionnaire on this page.

Questionnaire II: ("Application conditions for buried piping systems") should be filled in if the piping system shall be installed underground and therefore a static calculation is necessary. Please find the questionnaire on page 192.

Please complete the questionnaires and return it to the given address if necessary.

Company:	☐	Phone:	☐
Name:	☐	Telefax:	☐
Site:	☐		
Project:	☐		
Operating conditions Flow medium[1]:	☐		

Operating temperature:	inside min. ☐ °C		inside max. ☐ °C	
Operating temperature:	outside min. ☐ °C		outside max. ☐ °C	
Installation temperature:	☐ °C		Medium density:	☐ kg / m³
max. operating over pressure:	☐ bar		required time to fail:	☐ years

Required material combination:

Inner pipe:	PEHD ☐	PP ☐	PVDF ☐	ECTFE ☐
outer pipe:	PEHD ☐	PP ☐	PVDF ☐	ECTFE ☐

Requested wall thickness combination and dimensions outside pipe/inside pipe:

Simultaneous welding

Outer pipe d_1	Outer pipe SDR	Inner pipe d_2	Inner pipe SDR	PE	PP
50	17	32	11	Poly-Flo	☐
90	17	63	11	Poly-Flo	☐
160	33	90	17	Standard	☐
160	33	90	11	Standard	☐
160	17	110	11	Poly-Flo	☐
280	33	160	11	Standard	☐
315	33	200	11	Standard	☐
355	33	250	11	Standard	☐

cascade welding

Outer pipe d_1	Outer pipe SDR	Inner pipe d_2	Inner pipe SDR	PE	PP
90	17	32	11 (21)	☐	☐
125	17	63	11 (21)	☐	☐
160	17	90	11 (33)	☐	☐
200	17	110	11 (33)	☐	☐
280	17	160	11 (33)	☐	☐

☐ **others:**

outer pipe: d_1 ☐ SDR ☐ inner pipe: d_2 ☐ SDR ☐

Installation:

- ☐ aboveground system, plant
- ☐ aboveground system, outdoor in the shade
- ☐ with direct UV radiation
- ☐ buried piping system[2]

Leak detection system:

- ☐ selective with sensors
- ☐ constant detection with leak detection cables
- ☐ visual control
- ☐ other leakd detection methods

Table A.6: Questionnaire for calculation of double containment piping systems

[1] For the material choice of the piping system is the exact combination of the medium necassery to control the chemical resistance.

[2] By buried systems please demand on our questionnaire „Application conditions for buried piping system".

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Approvals and Standards

1 Approvals

The high quality standard of our products is documented by a series of approvals.

The systems out of PE, PP and PVDF are approved as per approval principles of DIBt and following registration numbers:

- The high quality standard of our products is documented by a series of approvals.
- The systems out of PE, PP and PVDF are approved as per approval principles of DIBt and following registration numbers:
- PE
  Z-40.23.232
  Z-40.23.231
- PP
  Z-40.23.234
  Z-40.23.233
- PVDF
  Z-40.23.201
  Z-40.23.202

PE, PP and PVDF pipes and fittings according European pressure equipment directive 97/23/EG:

- PP-H and PVDF - fittings and valves
  DGR-0036-QS-785-15
- Fittings PE 100 and PE 80
  DGR-0036-QS-7222964--15-001
- Fittings PP-H and PP-R
  DGR-0036-QS-7222964--15-001
- Fittings PVDF
  DGR-0036-QS-7222964--15-001
- Pipes PP-H, PP-R, PE 80, PE 100
  DGR-0036-QS-7222964--15-001

Further approvals:

- PP-R-pipes
  ON87272
- PP-H-pipes
  ON83054
- PE-pipes and fittings OENORM EN 12201
- PE-pipes and fittingsDIN EN 12201-1:2011-11
- PE-pipes and fittings DNV
- PP-H pipes and PP-R pipes DNV
- PP-R fittings DNV

2 3rd party control

In addition to internal controls, regular tests on products and of internal procedures, performed by independently accredited test institutes, are of prime importance. This external control is one element of product approvals in several application ranges and countries, where the modalities of the external control are regulated in registration and approval certificates.

Presently following institutes are commissioned for the production:

- TUV-Sued-Industrieservice
- MPA-Darmstadt
- SKZ-Wuerzburg
- LKT-TGM-Wien
- OFI-Wien

3 Standards

AGRU pipes, fittings and semi finished products are manufactured from standardized moulding materials and produced according relevant international standards.

Hereafter a summary of the most important standards for PE, PP, PVDF and ECTFE.

- AGRU pipes, fittings and semi finished products are manufactured out of standardized moulding materials and produced according relevant international standards.
- Hereafter a summary of the most important standards for PE, PP, PVDF and ECTFE.
- OENORM B 3800
  Behaviour of building materials and components in fire
- OENORM B 5014, part 1
  Sensory and chemical requirements and testing of materials in contact with drinking water
- OENORM EN 12201
  Plastics piping systems for water supply - Polyethylene (PE)
- OENORM EN 13244
  Plastics piping systems for buried and aboveground pressure systems for water for general purposes, drainage and sewerage - Polyethylene (PE)
- DIN EN ISO 17855-1:2015-02
  Plastics - Polyethylene (PE) moulding and extrusion materials
- DIN EN ISO 19069-1:2015-06
  Plastics - Polypropylene (PP) moulding and extrusion materials

Extrusion materials

- OENORM EN ISO 15494
  Plastics piping systems for industrial applications - Polybutene (PB), polyethylene (PE) and polypropylene (PP) - Specifications for components and the system - Metric series (ISO 15494:2003)
- DIN 4102
  Fire behaviour of building materials and building components
- ISO 4065
  Thermoplastic pipes
- ISO 10931 part 1 - part 5
  Plastics piping systems for industrial applications - Polyvinylidene fluoride (PVDF)

Bestellbeispiel für AGRU Formteile:

AGRU - CODE:
xx . xxx . xxxx . xx

Material		Teil Nr.		Dimension		Rohrreihe
↓		↓		↓		↓
xx	.	xxx	.	xxxx	.	xx

Bestellbeispiel:
PE 100-RC Bogen 90°, DA 63 mm, SDR 11 Code:
70.001.0063.11

Material-Code Nr.:
70 PE 100-RC schwarz
28 PE 100-el schwarz
11 PP-R grau
12 PP-H grau
15 PP-H weiss
16 PP-R natur
17 PPs grau
19 PPs-el schwarz
30 PVDF natur
40 ECTFE natur

Order Sample for AGRU fittings:

AGRU - CODE:
xx . xxx . xxxx . xx

material		part no.		dimension		pipe series
↓		↓		↓		↓
xx	.	xxx	.	xxxx	.	xx

Order Sample:
PE 100-RC bend 90°, OD 63 mm, SDR 11 Code:
70.001.0063.11

Samples of Material-Code No.:
70 PE 100-RC black
28 PE 100-el black
11 PP-R grey
12 PP-H grey
15 PP-H white
16 PP-R natural
17 PPs grey
19 PPs-el black
30 PVDF natural
40 ECTFE natural

Bestellbeispiel für AGRU Platten

AGRU - CODE
xx . xxx . xxxx . xx

Material		Teil Nr.		Dimension		Rohrreihe
↓		↓		↓		↓
xx	.	xxx	.	xxxx	.	xx

Bestellbeispiel:
PVDF Platte, 2000 x 1000 mm, 2 mm dick Code:
30.600.2010.02

Material-Code Nr.:
70 PE 100-RC schwarz
28 PE 100-el schwarz
29 PEHD natur
11 PP-R grau
12 PP-H grau
15 PP-H weiss
16 PP-R natur
17 PPs grau
19 PPs-el schwarz
30 PVDF natur
40 ECTFE natur

Order Sample for AGRU sheets

AGRU - CODE
xx . xxx . xxxx . xx

material		part no.		dimension		pipe series
↓		↓		↓		↓
xx	.	xxx	.	xxxx	.	xx

Order Sample:
PVDF sheet, 2000 x 1000 mm, 2 mm thick Code:
30.600.2010.02

Material-Code No.:
70 PE 100-RC black
28 PE 100-el black
29 HDPE natural
11 PP-R grey
12 PP-H grey
15 PP-H white
16 PP-R natural
17 PPs grey
19 PPs-el black
30 PVDF natural
40 ECTFE natural

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