VYCOM
OLEFIN AND PVC SOLUTIONS

WHERE QUALITY
MEETS PERFORMANCE

FLAMETEC
USER MANUAL
HOW-TO GUIDE

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Introduction

FLAMETEC ®

Vycom's Flametec™ proprietary family of fire safe materials offers the semiconductor and cleanroom industry a full portfolio of product offerings that is specially formulated to exceed the fire compliances for polymers in applications for tools, wet benches, cabinetry, furniture and other equipment. Our materials offer superior chemical resistance while providing optimal physical properties for fabrication, forming and workability.

FLAMETEC™ Cleanroom PVC-C (FM 4910 Listed) fire safe material is specially formulated to exceed FM 4910 fire compliances for polymers in semiconductor and cleanroom applications. This proven material offers excellent chemical resistance while providing physical properties for fabrication, forming and workability.

FLAMETEC™ Thermax PVC (FM 4910 Listed) is designed to meet FM 4910 fire propagation and smoke generation criteria for use in cleanroom equipment materials such as wet benches, process tools, and cleanroom furniture and cabinetry. Flametec Thermax provides a PVC solution with high workability characteristics and superior aesthetics.

FLAMETEC™ CP-7D Flame Retardant Polypropylene (FM 4910 Listed) is a proprietary formulation of fire safe polypropylene designed to meet FM 4910 flammability requirements for use in wet process tools, furniture and cabinetry construction in semiconductor applications.

FLAMETEC™ CP-5 Flame Retardant Polypropylene (UL 94 V-0) was formulated to meet the SEMI S93 specification for fire safety in cleanroom applications. Flametec CP-5 provides a more competitive alternative when FM 4910 listing is not required.

FLAMETEC™ Kytec PVDF (FM 4910 Listed) is manufactured from an ultra white polyvinylidene fluoride resin. Kytec is suited for harsh thermal, chemical and UV environments. Typically used in semiconductor, petrochemical and nuclear industries.

Vycom, a worldwide leader in Olefin and PVC materials for a variety of industries and applications has hit the mark with a new how-to video series for its Flametec product family. The videos cover topics such as fabricating, welding and building wet benches and cabinetry with Flametec materials.

Videos can be viewed on Vycom's website:

http://www.vycomplastics.com/marketing-videos.php

Vycom, headquartered in Scranton, Pennsylvania, is a world leader in the production of thermal plastic sheet products, and is dedicated to growth through investing in state-of-the-art processing equipment, developing rigid quality control standards, creating new material formulations, and expanding the physical plant to provide the scope and quantities of materials required by customers' rapidly growing demands. Along with its subsidiary companies, Vycom's physical plant occupies over 1.3 million squire feet of production, storage and office space. The plant's annual production capacity is in excess of 300 million pounds.

Material Properties

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The following recommendations are based upon information from material suppliers and careful examination of published information, and are believed to be accurate. Chemical reactions in polymers can be very complex. There are so many factors affecting the reaction of chemical attacks that it is impossible to construct charts to cover all possibilities. Since the resistance of polymers can be affected by concentration, duration, temperature, presence of other chemicals and other factors, this information should be considered as a general guide in material selection.

NOTE!	**A =** No attack, slight absorption **B =** Slight attack by absorption. Small reduction in mechanical properties likely **C =** Moderate attack by absorption. Material will have limited life **D =** Material will decompose or dissolve in a short time * = No data available

	Polymer Chemical Resistance Chart								
	Conc. %	**PVC**		**CPVC**		**PP**		**PVDF**	
Chemical		**23°**	**60°**	**23°**	**82°**	**21°**	**60°**	**23°**	**100°**
A									
Acetaldehyde		D	D	D	D	A	C	D	*
Acetic Acid	20	A	A	A	A	A	A	A	A
Acetic Acid	80	A	A	*	*	A	C	A	A
Acetone		D	D	D	D	A	A	A	*
Acetylene		A	A	*	*	A	*	A	A
Acids	Mixed	A	A	*	*	*	*	*	*
Acrylic acid		D	D	D	D	A	A	*	*
Allyl chloride		D	D	*	*	B	D	A	*
Alum (s)		A	A	A	A	A	A	A	A
Ammonia, gas		A	A	*	*	A	A	A	A
Ammonia, liquid		D	D	*	*	A	A	*	*
Ammonium fluoride	25	A	D	A	A	A	A	A	A
Amyl Acetate		A	A	D	D	A	A	A	*

Chemical	Polymer Chemical Resistance Chart								
	Conc. %	PVC		CPVC		PP		PVDF	
		23°	60°	23°	82°	21°	60°	23°	100°
Amyl chloride		D	D	*	*	D	D	A	A
Aniline		D	D	D	D	A	A	A	*
Aniline chlorohydrate		D	D	*	*	*	*	*	*
Aniline hydrochloride		D	D	*	*	A	A	*	*
Antimony trichloride		A	A	*	*	A	A	A	B
Aqua regia		D	D	*	*	C	D	A	B
Arsenic acid	80	A	A	*	*	A	A	A	A
Arylsulfonic acid		A	A	*	*	*	*	*	*
ASTM oil, no. 1, no. 2, no. 3		A	A	*	*	*	*	*	*
B									
Barium salts		A	A	A	A	A	A	A	A
Beer		A	A	*	*	A	A	A	A
Beet sugar liquor		A	A	*	*	B	B	A	A
Benzaldehyde	10	A	D	*	*	A	B	A	*
Benzene		D	D	D	D	A	C	A	*
Benzoic acid		A	A	A	A	A	A	A	A
Bleach	12	A	A	A	A	A	B	A	A
Borax		A	A	A	*	A	A	A	A
Boric acid		A	A	A	A	A	A	A	A
Brines		A	*	*	*	A	A	A	A
Bromic acid		A	A	*	*	A	A	A	A
Bromine, vapor	25	A	A	*	*	C	C	A	A
Bromine, liquid		D	D	*	*	C	C	A	A
Bromobenzene		D	D	*	*	*	*	A	*
Bromotoluene		D	D	*	*	*	*	*	*
Butadiene		A	A	*	*	D	D	A	A
Butane		A	A	*	*	A	A	A	A
Butyl acetate		A	D	D	D	A	B	A	*
Butyl alcohol		A	A	A	D	A	A	A	A
Butyl phenol		A	D	*	*	A	A	A	A

		Polymer Chemical Resistance Chart							
	Conc. %	PVC		CPVC		PP		PVDF	
Chemical		23°	60°	23°	82°	21°	60°	23°	100°
Butyl stearate		A	*	*	*	*	*	A	*
Butyric acid		A	D	C	D	A	A	A	A
C									
Cadmium cyanide		A	A	A	A	*	*	*	*
Calcium salts		A	A	A	A	A	A	A	A
Calcium hypochlorite	30	A	A	A	A	A	A	A	A
Calcium hydroxide		A	A	A	A	A	A	A	A
Calcium nitrate		A	A	A	*	A	A	A	A
Calcium oxide		A	A	*	*	A		A	A
Calcium sulfate		A	A	A	A	A	A	A	A
Camphor		A	*	*	*	A	C	*	*
Cane sugar		A	A	*	*	A	A	A	A
Carbitol		A	*	*	*	*	*	*	*
Carbon disulfide		D	D	*	*	C	C	A	*
Carbon monoxide		A	A	*	*	A	A	A	A
Carbon tetrachloride		A	D	*	*	C	D	A	A
Carbonic acid		A	A	*	*	A	A	A	A
Castor oil		A	A	D	D	A	A	A	A
Caustic potash		A	A	A	A	A	A	*	*
Cellusolve		A	D	*	*	*	*	*	*
Cellusolve acetate		A	*	*	*	*	*	*	*
Chloral hydrate		A	A	*	*	A	B	A	*
Chloramines		A	*	*	*	A	A	*	*
Chloric acid	20	A	A	*	*	A	A	*	*
Chloride, water		A	A	*	*	A	A	*	*
Chlorinated solvents		D	*	D	D	*	*	*	*
Chlorine, gas, dry		D	D	*	*	C	C	A	A
Chlorine, gas, wet		D	D	*	*	C	C	A	A
Chlorine, liquid		D	D	*	*	C	C	A	A
Chlorine, water		A	A	*	*	A	A	A	A

Polymer Chemical Resistance Chart

Chemical	Conc. %	PVC		CPVC		PP		PVDF	
		23°	60°	23°	82°	21°	60°	23°	100°
Chloroacetic acid		A	A	A	B	A	A	*	*
Chloracetyl chloride		A	*	*	*	*	*	A	*
Chlorobenzene		D	D	D	D	C	D	A	B
Chloroform		D	D	D	D	C	D	A	*
Chloropicrin		D	*	*	*	A	D	A	*
Chlorosulfonic acid		A	D	*	*	C	C	A	*
Chrome acid	10	A	A	A	B	A	B	A	A
Chrome acid	15	A	A	A	B	A	B	A	A
Citric acid		A	A	A	A	A	A	A	A
Clorox		A	A	*	*	B	B	*	*
Coconut oil		A	A	*	*	A	B	A	A
Coke oven gas		A	A	*	*	*	*	*	*
Copper salts		A	A	A	A	A	A	A	A
Corn oil		A	*	C	C	A	B	A	A
Corn syrup		A	A	*	*	A	A	A	A
Cottonseed oil		A	A	*	*	A	A	A	A
Cresol		D	D	D	D	A	B	A	B
Cresylic acid	50	A	A	*	*	*	*	A	*
Crotonaldehyde		D	D	*	*	A	C	A	*
Crude oils		A	*	A	A	*	*	A	A
Cupric salts		A	A	A	A	*	*	*	*
Cyclohexane		D	D	D	D	A	B	A	A
Cyclohexanone		D	D	D	D	A	B	A	*
D									
Detergents		A	A	*	*	A	A	*	*
Dextrin		A	A	A	A	A	A	A	A
Dextrose		A	A	A	A	A	A	*	*
Dibutoxyethyl phthalate		D	D	D	D	*	*	D	*
Diesel fuels		A	A	*	*	A	C	A	A
Diethyl ether		A	*	*	*	B	C	A	*

	Polymer Chemical Resistance Chart								
	Conc. %	**PVC**		**CPVC**		**PP**		**PVDF**	
Chemical		**23°**	**60°**	**23°**	**82°**	**21°**	**60°**	**23°**	**100°**
Disodium phosphate		A	A	A	A	A	A	A	A
E									
Epsom salts		A	*	*	*	*	*	A	A
Esters		D	D	D	D	B	B	*	*
Ethyl acetate		D	D	D	D	B	B	B	*
Ethyl acrylate		D	D	D	D	*	*	A	*
Ethyl alcohol	95	A	A	D	D	A	A	A	A
Ethyl chloride		D	D	D	D	C	D	A	A
Ethyl ether		D	D	D	D	D	D	A	*
Ethylene glycol		A	A	C	D	A	B	A	A
Ethylene oxide		D	D	*	*	A	A	A	A
F									
Fatty acids		A	A	*	*	A	A	A	A
Ferric salts		A	A	A	A	A	A	A	A
Fish soluble		A	A	*	*	B	B	*	*
Fluorine, dry, gas		A	D	*	*	A	A	A	A
Fluorine, wet, gas		A	D	*	*	*	*	A	A
Fluosilicic acid	25	A	A	*	*	A	A	A	A
Formaldehyde		A	A	C	D	A	A	A	*
Formic acid		A	D	*	*	A	A	A	A
Freon - F11, F12, F113, F114		A	A	*	*	C	C	A	A
Freon - F21, F22		D	D	*	*	*	*	A	A
Fructose		A	A	A	*	A	A	A	A
Furfural		D	D	*	*	C	C	A	*
G									
Gallic acid		A	A	*	*	A	A	A	*
Gases		A	A	*	*	*	*	A	A
Gasoline		A	A	D	D	B	B	A	A
Glucose		A	A	A	*	A	A	A	A
Glycerin		A	A	A	A	A	A	A	A

	Polymer Chemical Resistance Chart								
	Conc. %	PVC		CPVC		PP		PVDF	
Chemical		23°	60°	23°	82°	21°	60°	23°	100°
Glycolic acid		A	A	*	*	A	A	A	*
Glycols		A	A	*	*	A	A	*	*
Grape sugar		A	A	*	*	A	A	*	*
Green liquor		A	A	A	A	*	*	*	*
H									
Heptane		A	A	A	*	B	B	A	A
Hexane		A	D	*	*	D	D	A	A
Hexyl alcohol		A	A	*	*	B	B	A	*
Hydrobromic acid	20	A	A	*	*	A	A	A	A
Hydrochloric acid	10	A	A	A	A	A	A	A	A
Hydrochloric acid	30	A	A	*	*	A	A	A	A
Hydrofluoric acid	48	A	D	B	B	*	*	*	*
Hydrofluoric acid	50	A	D	*	*	*	*	*	*
Hydrofluoric acid	70	C	D	*	*	*	*	*	*
Hydrofluosilicic acid		A	A	*	*	A	A	A	A
Hydrogen		A	A	*	*	A	A	A	A
Hydrogen peroxide	30	A	A	A	A	A	A	A	A
Hydrogen peroxide	50	A	A	*	*	*	*	A	A
Hydrogen peroxide	90	A	A	*	*	A	B	A	*
Hydrogen sulfide		A	A	A	A	A	A	A	A
Hydroquinone		A	A	*	*	A	A	A	A
Hydroxylamine sulfate		A	A	*	*	A	A	*	*
Hypochlorine acid		A	A	A	B	*	*	*	*
I									
Iodine	10	D	D	*	*	B	B	A	*
K									
Kerosene		A	A	A	*	C	C	A	A
Ketones		D	D	D	D	B	C	*	*
L									
Lactic acid	25	A	A	A	A	A	A	A	*

Polymer Chemical Resistance Chart

Chemical	Conc. %	PVC		CPVC		PP		PVDF	
		23°	60°	23°	82°	21°	60°	23°	100°
Lactic acid	80	A	*	A	A	A	A	*	*
Lauric acid		A	A	*	*	*	*	A	A
Lauryl acetate		A	A	*	*	*	*	*	*
Lauryl chloride		A	A	*	*	*	*	A	A
Lead salts		A	A	A	A	A	A	A	A
Linoleic oil		A	A	*	*	*	*	*	*
Linseed oil		A	A	C	C	A	A	A	A
Liquors		A	A	*	*	B	C	A	A
Lithium salts		A	A	A	A	*	*	A	A
Lubricating oils		A	A	A	A	A	B	A	A
M									
Machining oils		A	A	*	*	A	B	*	*
Magnesium salts		A	A	A	A	A	A	A	A
Maleic acid		A	A	A	A	A	A	A	A
Malic acid		A	A	*	*	A	A	A	A
Manganese sulfate	10	A	A	A	A	A	A	A	A
Manganese sulfate	20	A	A	*	*	*	*	A	A
Mercuric salts		A	A	A	A	A	A	A	A
Mercury		A	A	A	A	A	A	A	A
Methane		A	A	*	*	*	*	A	A
Methyl acetate		D	D	*	*	*	*	A	*
Methyl alcohol		A	A	D	D	A	A	A	A
Methyl cellosolve		D	D	D	D	*	*	*	*
Methyl chloride		D	D	D	D	C	D	A	A
Methyl ethyl ketone		D	D	D	D	D	D	D	*
Methyl isobutyl ketone		D	D	D	D	D	D	D	*
Methyl methacrylate		D	D	*	*	A	A	A	A
Methyl sulfate		A	D	*	*	A	A	*	*
Methyl sulfuric acid		A	A	*	*	A	A	A	*
Methylene bromide		D	D	*	*	*	*	A	A

Chemical	Polymer Chemical Resistance Chart								
	Conc. %	PVC		CPVC		PP		PVDF	
		23°	60°	23°	82°	21°	60°	23°	100°
Methylene chloride		D	D	D	D	C	D	A	*
Methylene iodine		D	D	*	*	*	*	A	A
Milk		A	A	*	*	A	A	A	A
Mineral oils		A	A	A	A	A	B	A	A
Molasses		A	A	*	*	A	A	A	A
Motor oils		A	A	A	A	A	B	A	A
N									
Naphtha		A	A	*	*	C	D	A	A
Naphthalene		D	D	*	*	B	B	A	A
Natural gas		A	A	*	*	A	A	A	A
Nickel acetate		A	*	*	*	*	*	A	A
Nickel salts		A	A	A	A	A	A	A	A
Nicotine	84	A	A	*	*	A	A	A	*
Nicotinic acid		A	A	*	*	A	A	A	A
Nitric acid	0 - 60	A	A	A	C	A	A	A	A
Nitric acid	68	D	D	D	D	A	B	A	A
Nitrobenzene		D	D	D	D	D	D	A	A
Nitroglycerin		D	D	*	*	C	D	A	A
Nitroglycol		D	D	*	*	*	*	*	*
Nitrous oxide		A	D	*	*	*	*	D	*
O									
Oleic acid		A	A	A	A	A	C	A	A
Oleum		D	D	D	D	D	D	A	A
Oxalic acid		A	A	A	A	A	B	A	*
Oxygen		A	A	*	*	A	A	A	A
Ozone		A	A	*	*	C	D	A	A
P									
Palmitic acid	10	A	A	*	*	A	A	A	A
Palmitic acid	70	A	D	*	*	*	*	A	A
Paraffin		A	A	A	*	A	B	A	A

	Polymer Chemical Resistance Chart								
	Conc. %	PVC		CPVC		PP		PVDF	
Chemical		23°	60°	23°	82°	21°	60°	23°	100°
Peracetic acid	40	A	D	*	*	*	*	*	*
Perchloric acid	15	A	D	A	B	A	A	A	A
Perchloric acid	70	A	D	*	*	A	D	A	A
Perphosphate		A	*	A	*	*	*	*	*
Phenol		D	D	C	D	A	A	A	*
Phenylhydrazine		D	D	D	D	C	D	A	*
Phosphoric acid	10 - 85	A	A	A	A	A	A	A	A
Phosphorous, yellow		A	D	*	*	*	*	*	*
Phosphorus pentoxide		A	D	*	*	A	A	A	A
Photographic solutions		A	A	*	*	A	A	*	*
Plating solutions		A	A	*	*	A	A	A	A
Potash		A	A	A	A	*	*	*	*
Potassium amylxanthate		A	D	*	*	*	*	*	*
Potassium salts		A	A	A	A	A	A	A	A
Potassium permanganate	10	A	A	*	*	A	A	A	A
Potassium permanganate	25	A	D	*	*	A	A	A	A
Propane, gas		A	A	*	*	A	A	A	A
Propylene dichloride		D	D	D	D	D	D	A	A
Propylene oxide		D	D	D	D	A	A	D	*
Pyridine		D	D	D	D	B	C	D	*
Pyrogallic acid		A	D	*	*	*	*	A	*
R									
Rayon coagulating bath		A	A	*	*	A	A	*	*
Rochelle salts		A	A	*	*	*	*	*	*
S									
Salicylic acid		A	A	*	*	A	A	A	A
Sea water		A	A	A	A	A	A	A	A
Selenic acid		A	A	*	*	A	B	A	A
Silicic acid		A	A	A	*	A	A	*	*
Silver salts		A	A	A	A	A	A	A	A

Polymer Chemical Resistance Chart

Chemical	Conc. %	PVC		CPVC		PP		PVDF	
		23°	60°	23°	82°	21°	60°	23°	100°
Soaps		A	A	A	A	A	A	*	*
Sodium salts		A	A	A	A	A	A	A	A
sodium chlorate		A	D	A	A	A	A	A	A
sodium chlorite		D	D	D	D	A	A	A	A
Stannic chloride		A	A	*	*	A	A	A	A
Stannous chloride		A	A	*	*	A	A	A	A
Starch		A	A	A	A	A	A	A	A
Stearic acid		A	A	A	*	A	A	A	A
Stoddard solvents		D	D	*	*	*	*	*	*
Succinic acid	68	A	A	*	*	*	*	A	*
Sulfuric dioxide		A	A	*	*	*	*	*	*
Sulfuric trioxide		A	A	*	*	*	*	*	*
Sulfuric acid	0 - 80	A	A	A	A	A	A	A	A
Sulfuric acid	90 - 93	A	D	A	A	C	C	A	A
Sulfuric acid	94 - 100	D	D	D	D	D	D	A	B
T									
Tall oil		A	A	A	A	*	*	A	A
Tannic acid		A	A	A	A	A	A	A	A
Tartaric acid		A	A	A	A	A	A	A	A
Thread cutting oils		A	A	*	*	*	*	A	A
Toluene		D	D	D	D	C	D	A	A
Transformer oils		A	A	*	*	A	A	*	*
Tributyl citrate		A	*	*	*	*	*	*	*
Tributyl phosphate		D	D	D	D	A	A	A	*
Trichloroacetic acid		A	*	*	*	*	*	A	*
Trillion		D	D	*	*	A	A	*	*
Trimethyl propane		A	A	*	*	A	A	*	*
Trisodium phosphate		A	A	A	A	A	A	*	*
Turpentine		A	A	*	*	C	C	A	A
U									

Chemical	Polymer Chemical Resistance Chart								
	Conc. %	**PVC**		**CPVC**		**PP**		**PVDF**	
		23°	**60°**	**23°**	**82°**	**21°**	**60°**	**23°**	**100°**
Urea		A	A	A	A	A	A	A	A
Urine		A	A	A	A	A	A	*	*
V									
Vaseline		D	D	*	*	A	C	*	*
Vegetable oils		A	A	C	C	A	B	A	A
Vinegar		A	A	A	A	A	A	A	A
Vinyl acetate		D	D	D	D	A	A	A	A
W									
Water, deionized		A	A	A	A	A	A	A	A
Water, demineralized		A	A	A	A	A	A	A	A
Water, distilled		A	B	A	A	A	A	A	A
Water, salt		A	A	A	A	A	A	A	A
Whiskey		A	A	*	*	A	A	A	A
White liquor		A	A	A	A	*	*	*	*
Wines		A	A	*	*	A	A	A	A
X									
Xylene		D	D	D	D	C	C	A	A
Z									
Zinc salts		A	A	A	A	A	A	A	A

Material Identification

Flame Tests/ Melt Tests

Flame tests identify the ease of ignition, rate of burning, color of flame and soot, as well as odors of combustion products.

	No Flame	Extinguishes on Removal of Flame Source			Continues to Burn after Removal of Flame Source				
Material	Odor	Odor	Flame Color	Drips	Odor	Flame Color	Drips	Flame Reduction	Remarks
CPVC	No	Hydrochloric Acid	Yellow, green tip	No	-	-	-	-	Chars, melts
PP	No	Pungent, bitter	Yellow	No	Sweet	Blue, yellow tip	Yes	Slow	Floats in water, difficult to scratch
PVC	No	Hydrochloric Acid	Yellow, green tip	No	-	-	-	-	Chars, melts
PVDF	Acidic	-	-	-	-	-	-	-	Deforms

Specific Gravity

The relative density of a polymer is very helpful in determining its identity. Polypropylenes (most) float in water (s.g. < 1.0) whereas virtually all other (non-cellular) polymers sink. Although the addition of fillers can change the relative density of polymers, even so, the method narrows down the number of possible choices.

Material	Density
CPVC	1.50
PP	0.99 - 1.38
PVC	1.42
PVDF	1.78

2

This chapter provides fractions, decimals and millimeters chart for equivalency. With the number of uses and applications for Flametec and the differing environments of service, it is important to take into account accurate dimensions during fabrication and installation.

Also included within this chapter are useful temperature conversions, between Celsius and Fahrenheit.

C° to F° = Multiply by 9, then divide by 5, then add 32.

F° to C° = Deduct 32, then multiply by 5, then divide by 9.

Temperature Conversion Chart

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
200	392	222	432	244	471	266	511	289	552	311	592	333	631	355	671	377	711
201	394	223	433	245	473	267	513	290	554	312	594	334	633	356	673	378	712
202	396	224	435	246	475	268	514	291	556	313	595	335	635	357	675	379	714
203	397	225	437	247	477	269	516	292	558	314	597	336	637	358	676	380	716
204	399	226	439	248	478	270	518	293	559	315	599	337	639	359	678	381	718
205	401	227	441	249	480	271	520	294	561	316	601	338	640	360	680	382	720
206	403	228	442	250	482	272	522	295	563	317	603	339	642	361	682	383	721
207	405	229	444	251	484	273	523	296	565	318	604	340	644	362	684	384	723
208	406	230	446	252	486	274	525	297	567	319	606	341	646	363	685	385	725
209	408	231	448	253	487	275	527	298	568	320	608	342	648	364	687	386	727
210	410	232	450	254	489	276	529	299	570	321	610	343	649	365	689	387	729
211	412	233	451	255	491	277	531	300	572	322	612	344	651	366	691	388	730
212	414	234	453	256	493	278	532	301	574	323	613	345	653	367	693	389	732
213	415	235	455	257	495	279	534	302	576	324	615	346	655	368	694	390	734
214	417	236	457	258	496	280	536	303	577	325	617	347	657	369	696	391	736
215	419	237	459	259	498	281	538	304	579	326	619	348	658	370	698	392	738
216	421	238	460	260	500	282	540	305	581	327	621	349	660	371	700	393	739
217	423	239	462	261	502	283	541	306	583	328	622	350	662	372	702	394	741
218	424	240	464	262	504	284	543	307	585	329	624	351	664	373	703	395	743
219	426	241	466	263	505	285	545	308	586	330	626	352	666	374	705	396	745
220	428	242	468	264	507	286	547	309	588	331	628	353	667	375	707	397	747
221	430	243	469	265	509	287	549	310	590	332	630	354	669	376	709	398	748

Inch Fraction	Inch Decimal	Millimeter
1/64	.0156	0.3969
1/32	.0313	0.7938
	.0394	1.0000
3/64	.0469	1.1906
1/16	.0625	1.5875
5/64	.0781	1.9844
	.0787	2.0000
3/32	.0938	2.3813
7/64	.1094	2.7781
	.1181	3.0000
1/8	.1250	3.1750
9/64	.1406	3.5719
5/32	.1563	3.9688
	.1575	4.0000
11/64	.1719	4.3656
3/16	.1875	4.7625
	.1969	5.0000
13/64	.2031	5.1594
7/32	.2188	5.5563
15/64	.2344	5.9531
	.2362	6.0000
1/4	.2500	6.3500
17/64	.2656	6.7469
	.2756	7.0000
9/32	.2813	7.1438
19/64	.2969	7.5406
5/16	.3125	7.9375
	.3150	8.0000
21/64	.3281	8.3344
11/32	.3438	8.7313
	.3543	9.0000
23/64	.3594	9.1281
3/8	.3750	9.5250
25/64	.3906	9.9219
	.3937	10.0000
13/32	.4063	10.3188
27/64	.4219	10.7156
	.4331	11.0000
7/16	.4375	11.1125
29/64	.4531	11.5094
15/32	.4688	11.9063
	.4724	12.0000
31/64	.4844	12.3031
1/2	.5000	12.7000
	.5118	13.0000
33/64	.5156	13.0969
17/32	.5313	13.4938
35/64	.5469	13.8906
	.5512	14.0000
9/16	.5625	14.2875
37/64	.5781	14.6844
	.5906	15.0000
19/32	.5938	15.0813
39/64	.6094	15.4781
5/8	.6250	15.8750
	.6299	16.0000
41/64	.6406	16.2719
21/32	.6563	16.6688
	.6696	17.0000
43/64	.6719	17.0656
11/16	.6875	17.4625
45/64	.7031	17.8594
	.7087	18.0000
23/32	.7188	18.2563
47/64	.7344	18.6531
	.7480	19.0000
3/4	.7500	19.0500
49/64	.7656	19.4469
25/32	.7813	19.8438
	.7874	20.0000
51/64	.7969	20.2406
13/16	.8125	20.6375
	.8268	21.0000
53/64	.8281	21.0344
27/32	.8438	21.4313
55/64	.8594	21.8281
	.8661	22.0000
7/8	.8750	22.2250
57/64	.8906	22.6219
	.9055	23.0000
29/32	.9063	23.0188
59/64	.9219	23.4156
15/16	.9375	23.8125
	.9449	24.0000
61/64	.9531	24.2094
31/64	.9688	24.6063
	.9843	25.0000
63/64	.9844	25.0031

Welding Introduction

3

The Principle of Thermoplastic Welding

In order to weld thermoplastics, the material has to be heated to reach its melting state. The pieces to be welded must then be pressed together with a certain amount of pressure, over a given amount of time. This will cause the surface molecules of the parts to interlock, fusing the parts together, creating a bond between the materials, referred to as a weld.

High-Speed Hot Gas Welding

Flametec materials can be hot gas welded together to provide approximately 80% of the tensile strength of solid sheet. Actual performance will depend upon the equipment used, the welding conditions employed, and the individual techniques of the person doing the welding. As a result, the recommendations given in this document are intended to be general guidelines and do not guarantee performance.

Equipment

When thermoplastics are being welded, the quality of gas used as the heat transfer medium is a critical factor in the quality of the weld. High-speed hot gas welding requires the use of gas supplied at low pressure and high volume, and must be free of oil and moisture. Common shop compressors generally do not supply air of adequate quality for use in high-speed hot gas welding. Many manufacturers of hot gas welding equipment also have blowers available, that are specifically suited for this purpose.

When Flametec materials are being welded, the accuracy of the temperature controlling equipment is equally as important as the quality of the gas.

The quality of the weld produced is therefore dependent on having a constant temperature at the welding tip. Welding equipment for use with Flametec materials preferably should control the temperature by regulating power to the heating element, not by varying the gas flow. The ideal temperature control for welding Flametec material should incorporate closed loop controls which hold the temperature constant even while gas flow or supply voltages fluctuate.

A high-speed welding tip is designed to perform three functions (Figure 3a):

- Preheating the base material.
- Guiding and preheating the welding rod.
- Applying pressure to the weld area.

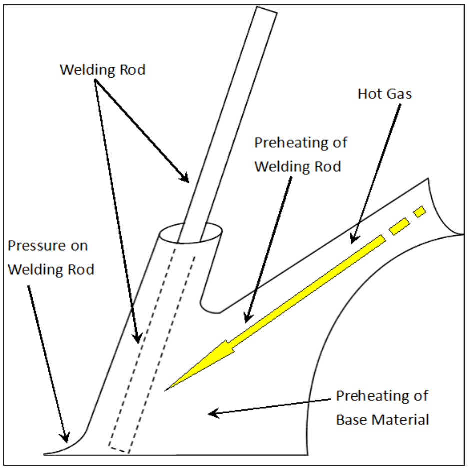


Figure 3a

Material Preparation

The ends of the pieces of material to be joined must be beveled in order to produce the best weld. The bevel may be produced with an adjustable saw, a router or other suitable tools. The angle between the bevels of the two pieces to be joined should be between 60° and 70° (degrees), except when one piece is joined perpendicularly to another, in which case, the angle is reduced to 45° (Figure 3b).

The parts to be assembled must be very clean. To remove surface residue, slight grinding or scraping with a sharp blade at the area to be welded and the weld rod, is strongly recommended.

If the joint will not be tacked prior to welding, it is recommended to leave a gap of 0.5mm - 1 mm wide between the two pieces to be joined so that the welding material may penetrate to the root of the bevel and overflow slightly on the other side. If the parts will first be tacked, they should be butted together with no gap. The parts to be joined should be mounted firmly in place with appropriate clamps as necessary (Figure 3b).

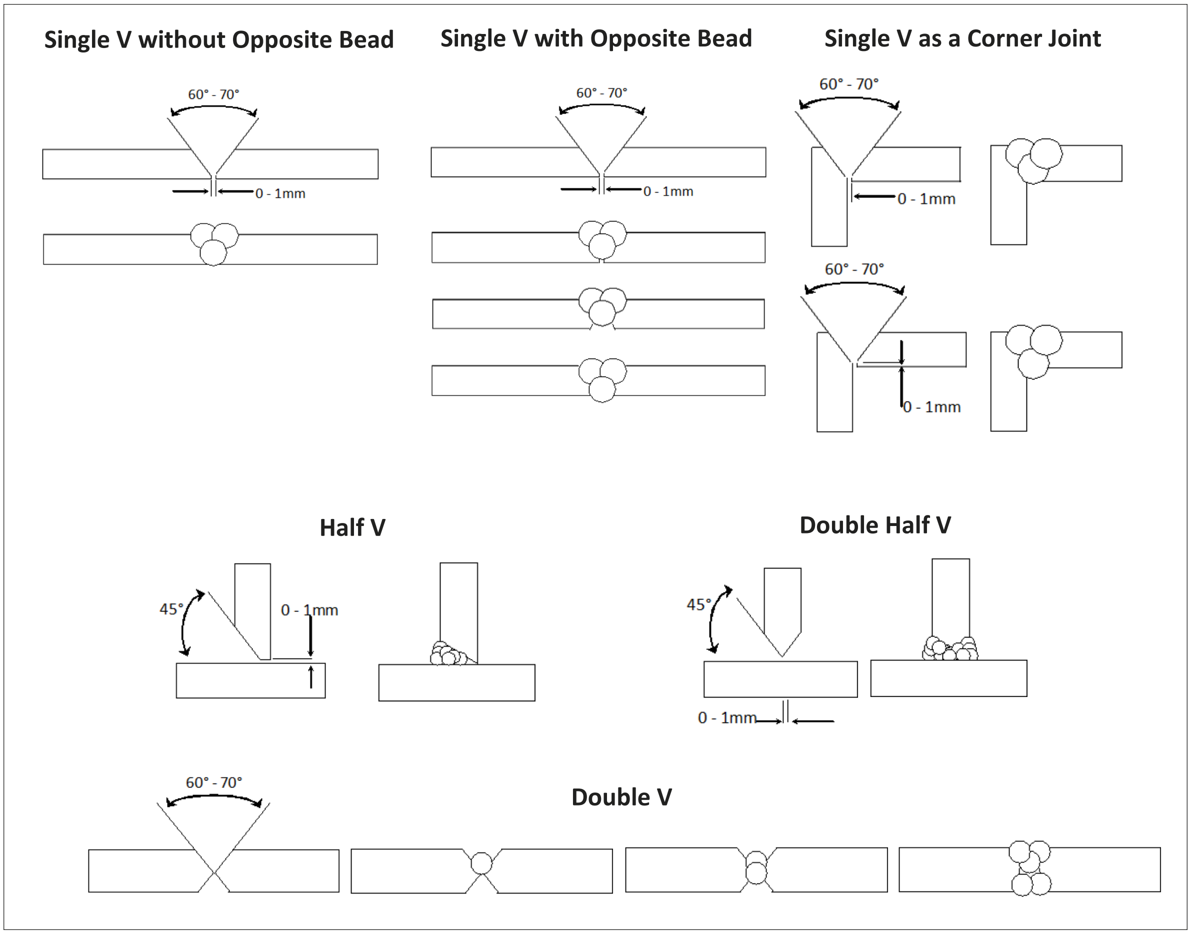


Figure 3b

Welding Rod Selection

When Flametec materials are being joined, the welding rod selected should also be produced from the same polymer (i.e. PVC rod, PVC sheet). Triangular rod may be used where the appearance of the joint is the most important factor, but round welding rod should be used when structural integrity is desired.

While welding rod is commonly available in sizes up to 1/4” (6mm) in diameter, the strongest joints are obtained by using smaller diameter rod, welding with multiple beads as necessary. In order to obtain the strongest weld, it is recommended to use rod no larger than 5/32” (4mm) in diameter.

It is important to match the diameter of the welding tip with the diameter of the rod selected. An oversized tip will negatively affect guidance and pressure applied to the rod and may also cut into the parts being welded.

Tack Welding

The initial step in the process is the “tack weld”. The objective is to put the parts in place, align them, and prevent any slippage of the material during the structural welding process. Tacking is done with a pointed shoe tip. The operator places the tacking tip directly on the material to be welded and draws it along the joint. Hot gas from the welder softens the material, and pressure applied by the operator to the tip fuses the material together. Continuous or spot tack welding may be used as necessary. Larger surfaces, or thick gauge materials, require additional clamping.

Any tank should be continuously tack welded to achieve a leak free connection. This prevents solutions from penetrating, or leaking, between the tank wall and the bottom, in case of a problem with the filler weld.

The Welding Process

The optimum temperature range for hot gas welding vary dependent on the type of polymer and welding equipment being used (and the way in which the temperature is measured.) If the welding torch incorporates closed-loop controls which maintain the temperature selected on a dial setting, the optimum range are determined by polymer type. If temperature cannot be directly selected on a dial setting, it must be measured by the operator and then adjusted by varying power to the heating element or regulating the gas flow. The temperature should be measured with a pyrometer, approximately 3/16” (5mm) inside the main opening of the high-speed welding tip. The actual temperature within the range that will produce the best weld will depend on a number of factors (and must be adjusted accordingly):

- Diameter of rod
- Brand of rod
- Speed of welding
- Ambient temperature

To make it easier to initiate welding, a sharp angle may be cut on the lead end of the welding rod. The welding rod should not be inserted into the high-speed welding tip until immediately before the operator is ready to begin welding. **Burning of the rod may otherwise result.**

To begin welding, the operator should grasp the welding torch like a dagger, with the airline trailing away from his or her body, or over their shoulder, so that they'll be able to operate quickly and smoothly once welding has begun. Hold the welding tip approximately 3.15" (80mm) above the area to be welded to prevent scorching of the material before work begins. Insert the welding rod into the pre-heating tube and then place the pointed tip of the shoe on the material at the starting point of the weld.

Holding the welder at roughly a 45° degree angle, push the rod through the tip until it contacts the base material. Using slight hand pressure, continue to feed the rod with the other hand. If the rod is not guided, the welding rod will stretch fully apart. The weight of the welder is the only pressure needed as the weld is pulled along the joint.

As the welding progresses, visual inspection of the weld may indicate its quality. Browned or charred edges occur when the welder is moving too slowly and overheating. If the rod has been softened too much by overheating, it will stretch and break or flatten out.

Once welding begins, it must be continued at a fairly constant rate of speed. The welding torch must not be held sill, or burning will result. To stop welding before the rod is used up, the operator should tilt the welder backward, cut the rod off with the tip of the shoe, and immediately remove the remaining rod from the welding tip. Welding may also be terminated by pulling the welder tip up over the remaining rod and cutting the rod. For best results, the welding tip should be cleaned occasionally with a wire brush.

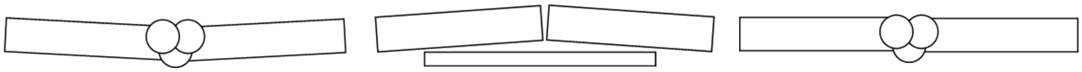
Multiple beads should be applied as necessary unit the joint is completely filled as shown in figure 1b. If the joint to be welded is a double V or a double have V joint, the best results are obtained if layers of beads are put down alternately on opposites sides of the joint. The following table presents recommendations for bead lay-up for different materials thicknesses and joint configurations.

Recommendations for Bead Lay-Up

Material Thickness		Number of Beads x Rod Diameter
Single V Joint	1/8” (3mm)	3 x 1/8” (3mm)
	5/32” (4mm)	1 x 1/8” (3mm) + 2 x 5/32” (4mm)
	3/16” (5mm)	6 x 1/8” (3mm)
Double V Joint	5/32” (4mm)	2 @ 1 x 5/32” (4mm)
	3/16” (5mm)	2 @ 3 x 1/8” (3mm)
	1/4” (6mm)	2 @ 3 x 1/8” (3mm)
	5/16” (8mm)	2 @ 1 x 1/8” (3mm) + 2 x 5/32” (4mm)
	3/8” (10mm)	2 @ 6 x 1/8” (3mm)

Heat Stress Problems

During hot air welding, the material will expand while it is forced into position. When cooling, it will shrink back to its original volume. A welded sheet that was straight while still hot, may be bent after cooling. Using a double V joint is one way to avoid this problem. Another way for an experienced operator to avoid this problem is to pre-bend the parts prior to welding (Figure 3c).



Sheet warpage caused by shrinkage during cooling process.

Pre-bending prior to weld.

After welding the sheet pulls itself straight.

Figure 3c

Weld Factor

When properly hot gas welded, Flametec sheet can be expected to perform to approximately 80% of its nominal tensile strength.

The Welding Process

The heating element should be set at the desired welding temperature. With a microprocessor controlled machine, only the sheet thickness and length, as well as the melting / welding pressure, have to be programmed. The machine will then make the necessary calculations and perform the necessary machine settings with respect to time and pressure. With a non-microprocessor controlled machine, the operator has to calculate the welding surface, then multiply the cross section with the optimum melting / fusing pressure and set the machine gauges accordingly. Temperature and times have to be manually adjusted. Once the machine is set up, the sheets are inserted on either side of the table, tightly, against the setting bar and clamp.

The heating element should be brought into position and the pieces of material should be pressed against the heating plate with the desired melting pressure. The purpose for the higher pressure melting time is to assure that the material makes solid contact with the heating element. Once a bead has formed along the entire weld area, the pressure should be dropped to a nominal heating pressure. This pressure should be sufficient to hold the pieces against the element, but prevent excessively large beads from forming. The goal is to heat up the fusion area without pushing molten material out of the weld zone. With microprocessor controlled machines, the melting time is preset and can be extended, stopped or reprogrammed, depending on the accuracy of the cut. The better the cut, the shorter the melting time.

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4

This chapter provides the DVS welding parameters for different processes including butt welding, extrusion welding and hot gas welding.

Butt-Welding

Butt welding thermoplastics involves holding / securing two pieces of the material with defined pressure against a heated plate element until the material melts. The two pieces are then brought together quickly and held with a defined pressure, so that they fuse into one piece. Some of the most common uses for butt welding are:

- Join two pieces of flat sheet
- Join both ends of a rolled or bent sheet to form a round or rectangular shape
- Join segments together to form fabricated fittings

Material Preparation

The edges of the pieces of material to be welded should be as square as possible so that they will contact the heating element and each other evenly. Cutting debris, and any oil or dirt, should be removed from the welding area. The pieces to be welded should be clean and dry. Solvents should not be used to clean the surfaces to be welded.

Welding Heating and Fusion Times

The time that the plastic should be held against the element under the heating pressure is dependent on the thickness of the sheet. Vycom material parameters are defined within the tables on pages 24 - 26.

Polypropylene (PP) - Flametec CP-5, Flametec CP-7D

DVS 2207 -11 Welding of thermal plastics - Heated tool welding of pipes, piping parts and panels made of PP.

Thickness	Temperature	Alignment $p = 0.1\ N/mm^2$	Preheat $p = 0.01\ N/mm^2$	Change Over Time	Joining Pressure	Cooling Time
				max time*	build up time	under pressure
inch	°C	mm	seconds	seconds	seconds	minutes
1/8	220	0.5	105	< 3	5.0	6.0
3/16	215	0.5	145	< 3	5.0 - 6.0	6.0 - 12.0
1/4	215	0.5	160	< 3	5.0 - 6.0	6.0 - 12.0
5/16	215	1	190	< 3	6.0 - 8.0	12.0 - 20.0
3/8	215	1	215	< 3	6.0 - 8.0	12.0 - 20.0
1/2	210	1	245	< 3	8.0 - 11.0	20.0 - 30.0
5/8	210	1	280	< 3	8.0 - 11.0	20.0 - 30.0
3/4	205	1.5	340	< 3	11.0 - 14.0	30.0 - 40.0
1	205	1.5	390	< 3	11.0 - 14.0	30.0 - 40.0

NOTE!	*Change-over time should be kept as minimal as possible due to risk of the plastified surfaces solidifying

Welding Overview

Polyvinyl Chloride (PVC) - Flametec Thermax PVC

DVS 2207 -12 Welding of thermal plastics - Heated tool welding of pipes, piping parts and panels made of PVC.

Thickness	Temperature	Alignment p = 0.5 N/mm^2	Preheat p = 0.03 N/mm^2	Change Over Time	Joining Pressure	Cooling Time
				max time*	build up time = 1 x wall thickness	under pressure
mm	°C	mm	seconds	seconds	seconds	minutes
1/8	225 -230	> 0.5	45	< 2	3.0	3.0
3/16	225 -230	> 0.5	75	< 2	5.0	5.0
1/4	225 -230	> 0.5	90	< 2	6.0	6.0
5/16	220 - 225	> 1.0	120	< 2	8.0	8.0
3/8	220 - 225	> 1.0	150	< 2	10.0	10.0
1/2	220 - 225	> 1.0	180	< 2	12.0	12.0
5/8	220 - 225	> 1.5	225	< 2	15.0	15.0
3/4	220 - 225	> 1.5	300	< 2	20.0	20.0
1	220 - 225	> 1.5	375	< 2	20.0	25.0

Chlorinated Polyvinyl Chloride (CPVC) - Flametec Cleanroom PVC-C

Thickness	Temperature	Alignment p = 0.5 N/mm^2	Preheat p = 0.03 N/mm^2	Change Over Time	Joining Pressure	Cooling Time
				max time*	build up time = 1 x wall thickness	under pressure
inch	°C	mm	seconds	seconds	seconds	minutes
3/16	225 -230	> 0.5	75	< 3	5.0	5.0
1/4	225 -230	> 0.5	90	< 3	6.0	6.0
3/8	225 -230	> 1.0	120	< 3	10.0	10.0
1/2	225 -230	> 1.0	150	< 3	12.0	12.0

NOTE!	***Change-over time should be kept as minimal as possible due to risk of the plastified surfaces solidifying**

Polyvinylidene Fluoride (PVDF) - Kytec PVDF

DVS 2207 -15 Welding of thermal plastics - Heated tool welding of pipes, piping parts and panels made of PVDF.

Thickness	Temperature	Alignment p = 0.1 N/mm²	Preheat p = 0.01 N/mm²	Change Over Time	Joining Pressure	Cooling Time
			time = 10 x wall thickness + 40s	max time*	build up time	under pressure
inch	°C	mm	seconds	seconds	seconds	minutes
1/8	245	0.5	70	< 3	3.2	5.5
3/16	245	0.5	90	< 3	4.5	8.0
1/4	240	0.5	100	< 3	5.0	9.0
5/16	240	1.0	120	< 3	5.5	11.5
3/8	240	1.0	140	< 3	6.5	14.0
1/2	235	1.0	160	< 3	7.5	16.5
5/8	235	1.3	190	< 3	8.5	20.0
3/4	235	1.7	240	< 3	10.5	26.0
1	235	2.0	290	< 3	13.0	32.0

NOTE!	*Change-over time should be kept as minimal as possible due to risk of the plastified surfaces solidifying

Hot-gas Welding

Requirements for welding devices and torches for hot-gas welding can be found in the DVS guideline 2207-3.

The joining of polymer faces are heated up by means of hot gas. The most common welding gas used is air. **It must be dry, oil-free and dust free.** If the air is not clean, an inert gas such as nitrogen can be used. The welding temperature and volume of air should be adjustable.

The materials to be welded should be free from dust or oil. Sheets should be chamfered using a table saw, milling machine or router. The angle should be 60° for round bends and 80° for triangle bends with corner welds at right angles (Figure 4a). The chamfer should be at 45°.

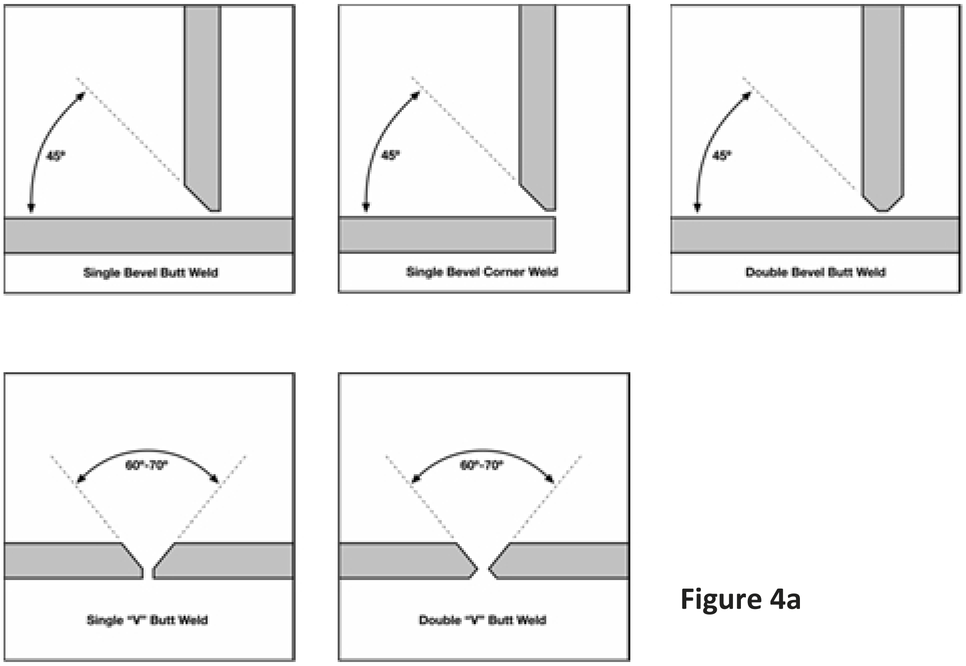

Figure 4a

The base material and the filler material are heated by a triangular movement of the welding torch, first along the seam, then up welding rod, and then back to then next segment of the seam and so on. Heat the base and filler material evenly.

- The pressure applied to the filler rod depends on the material being welded
- Hold the filler material vertically
- With the correct pressure and correct heat, side lobes form along the welded seam

Hot-gas Welding Parameters

High-speed (WZ) and Freehand (WF) welding parameters according to DVS 2207-3. The figures for WF and WZ quote in the table of DVS 2207-3 should be taken as a guide. The properties of the actual material to be welded may be different than those listed. Therefore the given welding parameters are only approximate and intended as a guide.

Welding Method	Material	Hot-gas Temperature*	Hot-gas Air Volume**	Welding Speed***	Welding Force	
		°C	l/min	mm/min	N	
					3mm	4mm
Freehand	PP	305 - 315	40 - 50	60 - 85	8 - 10	20 -25
	PVC	330 - 350		110 - 170		
	CPVC	340 - 360		55 - 85	15 - 20	
	PVDF	350 - 370		45 - 50		
High-speed	PP	300 - 340	45 - 60	250 - 350	15 - 20	25 - 35
	PVC	350 - 370				
	CPVC	370 - 390		180 - 220	20 - 25	30 - 35
	PVDF	365 - 385		200 - 250		

NOTE!

*** Measured 5mm (3/16") inside the main nozzle opening**
**** Intake of cold air volume at surrounding pressure**
***** Depending on the welding rod diameter and the design of the weld seam build up**

Extrusion Welding

Requirements for welding devices and torches for hot-gas welding can be found in the DVS guideline 2207-4.

Extrusion Welding Parameter Control

Prior to welding, the temperature of the extrudate and the hot gas are measured. In addition, the output rate and the hot gas flow rate is determined and adjusted. During welding, the welding speed is measure and kept as constant as possible.

The temperature of the extrudate and the hot gas are measure again at intervals. it is obvious that one person alone cannot perform all these tasks while welding the parts. It is therefore recommended that welding work is always carried out by at least two people.

Tasks of a Second Person

- Check the electrical
- Check the supply of the filler material
- If necessary, cleaning of the filler rod
- Measure the welding speed
- Check the plastification of the base material
- Control the position of the extruder
- Cover the weld seam after welding

Extrusion Weld Preparation

Immediately prior to starting the welding, the joining areas and the adjoining surfaces in the area of the weld need to be scraped or machined. Pieces with surfaces damaged by weather or chemicals must be scraped down to the undamaged area. This is especially important when repairing structures that have been in service. Cleansing agents with a solvent or swelling effect on the plastic material may not be used.

Welding Shoe Design

Welding shoes are of special importance. High quality welding joints can only be reached by shoes of correct shape, adjusted to the joint geometry.

General Requirements

- Shoes should be made out of a thermal resistant, anti-stick material with low thermal conductivity. Normally PTFE (Teflon) is used
- Shoes should be designed in a way that a lateral and frontal spill-over of the meld is avoided and that the necessary welding pressure is generated due to compression of the melt. This is noted in DVS 2207-4.

Extrusion Welding Parameters (according to DVS 2207-4)

Material	Extrudate Temp (Barrel Temp)*	Hot-gas Temp**	Hot-gas Volume
	°C	°C	l/min
PP	210 - 240	250 - 300	300
PVC	170 - 180	280 - 340	300
CPVC	195 - 205	300 - 360	300
PVDF	240 - 260	280 - 350	300

Conditions for Extrusion Welding

- Output rate of welding filler (the output rate in kg/h is determined by weighing the extruded material). The material is discharged within a certain period of time and weight on a scale and extrapolated for one hour.
- Hot-gas flow rate (indicated as liters/minute, determine by an air flow meter.
- Welding speed (depending on the output rate of the extruder and the volume of the joint). Indicated as mm/minute. Check repeatedly and take care of continuous speed.
- Welding pressure (cannot be found during the normal welding process). Besides the experience of the welder, the length and the design of the welding shoe is of importance.
- Due to heat conductivity, it is recommended that speed remain at no more than 1 foot per minute. This allows proper preheating of the material.

NOTE!	*** Extrudate temperature measure with a needle style probe as it exits PTFE shoe** **** Air temperature measure 5mm (3/16”) inside nozzle**

Ambient Influences

Criteria	Effects	Measures
High Air Humidity	Condensation on the material surface, bad joint quality	Immediately before welding, preheat the welded areas and dry the surface
	Welding filler absorbs humidity = pinholing in the cross section of the joint	Dry the welding filler / rod 3-4 hours at approximately 100°C
Low Temperatures <5°C / 41°F	Condensation on the material surface, bad joint quality	Preheating the welding areas up to room temperature
	Surface of the extruded material cools too quickly = pinholing in the cross section	Prevent the weld from cooling too quickly by covering the joint
Draft	Surface of the extruded material cools too quickly = pinholing in the cross section	Close doors and windows. If welding outdoors protect by walls or a screen

NOTE!	**Place welding rod back in storage bag / box when not in use!**

Other Fabrication Reference Materials

AWS G1-10M:2001

Guide for the Evaluation of Hot Gas, Hot Gas Extrusion and Heated Tool Butt Thermoplastic welds.

ASTM C 1147

Standard Practice for Determining the Short Term Tensile Weld Strength of Chemical Resistant Thermoplastics.

DVS 2207-3

High Speed and Free Hand Welding - Sheets and Pipes

DVS 2207-3 Addendum

High Speed and Free Hand Welding - Sheets and Pipes - Welding Parameters

DVS 2208-1

Welding of Thermoplastics - Machines and Devices for the Heated Tool Welding of Pipes, Pipelines Components and Sheets

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