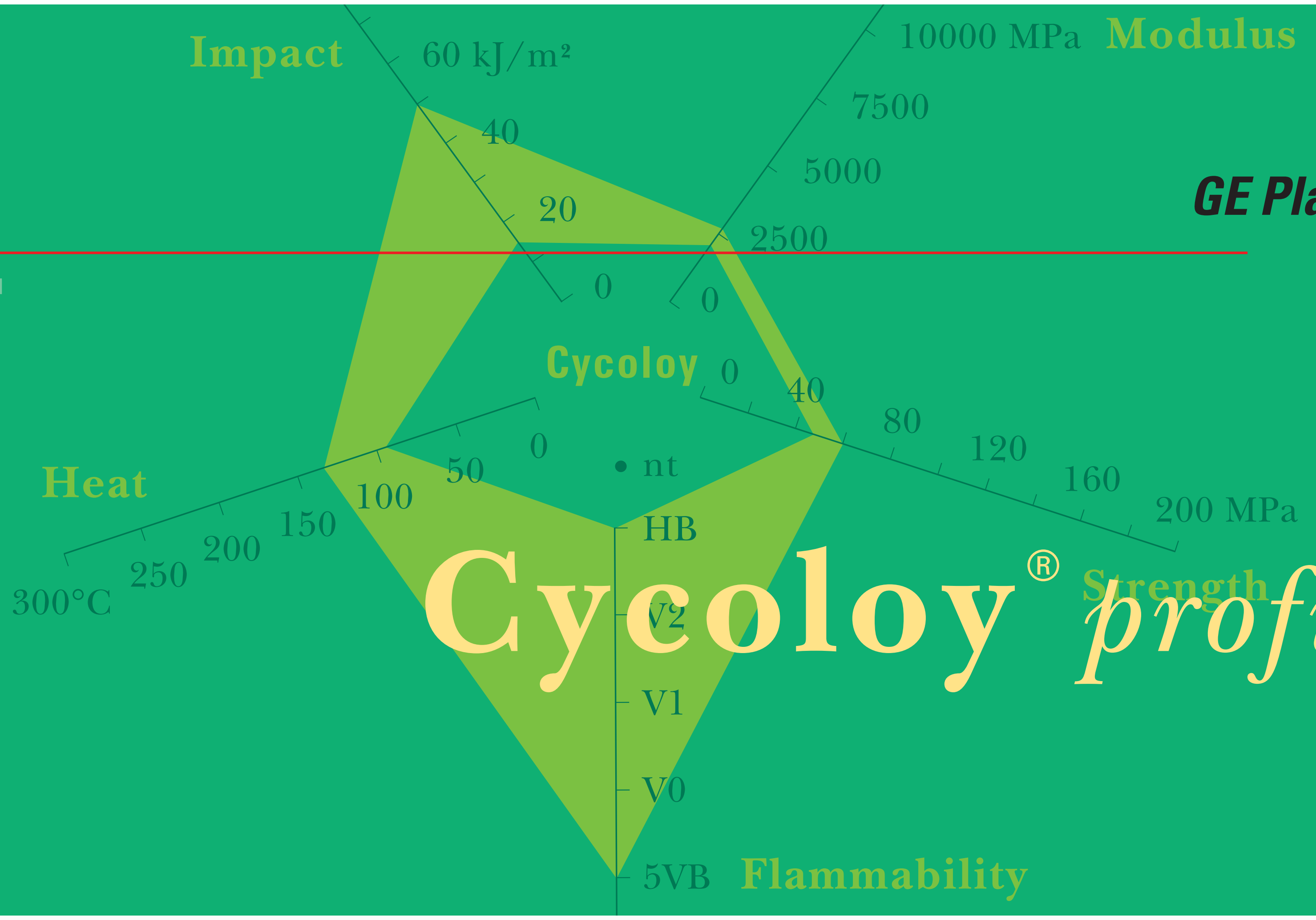
GE Plastics

EN/10/2001

Cycoloy® *profile*



overview

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1 Introduction Cycoloy®

PC/ABS Thermoplastic Alloys

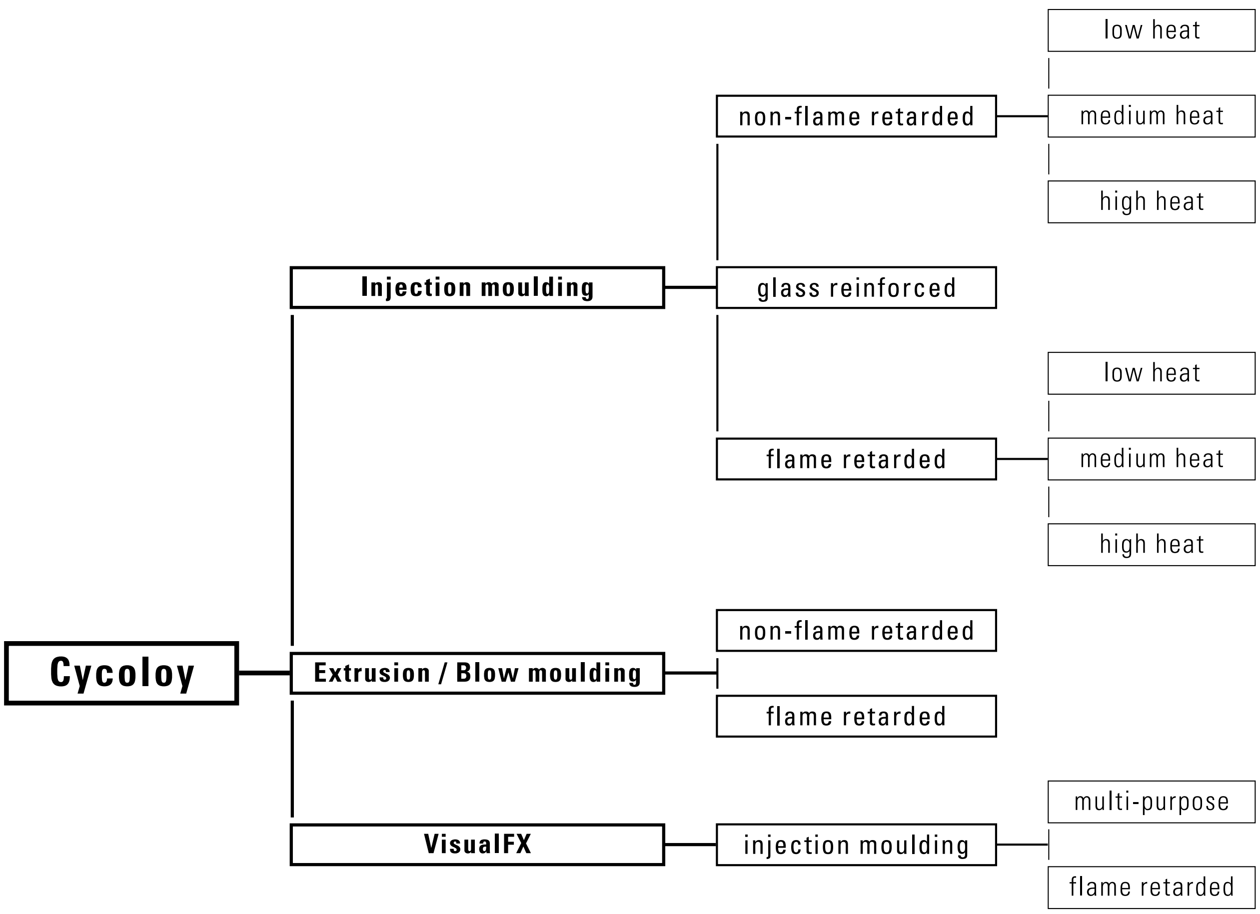
PC+ABS

Cycoloy® resins are amorphous PC/ABS blends which combine the most desirable properties of both resins; the excellent processibility of ABS and the superior mechanical properties and heat resistance of polycarbonate. Impact is maintained down to -30°C while heat resistance can be in the range of 95°C-140°C (Vicat B120).

Cycoloy® resins offer:

- Various heat performance grades in a wide range of colours
- Excellent UV stability
- Chlorine/bromine-free flame retardancy (except C2100HF)
- Superior processibility for injection moulding, extrusion and blow moulding processes
- Excellent dimensional stability
- High ductility/toughness also at subzero temperatures
- Excellent paint adhesion properties

Cycoloy® blends have an excellent fit in automotive and telecommunications applications and in business machine housings. Their broad property profiles also make them very suitable for appliances and electrical applications.



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2 Markets

Automotive

Business Machines

Telecommunications

Electrical/Lighting

Appliances

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2.1 Automotive

With their characteristic superior impact strength, UV stability and consistent processability, Cycoloy® blends have been proven in a range of automotive interior parts like instrument panels, dashboard components and pillar trims.

Volvo V70 Cycoloy IP carrier

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The key features of Cycoloy® blends in these applications include:

- High impact resistance/ductility also at subzero temperatures (safety performance)
- High dimensional stability also at elevated temperatures (exposure to sunlight, curing of paint)
- Excellent UV stability
- High flow for long or complex parts
- Good paint and foam adhesion
- Reduced gloss level
- Anti-squeak behaviour
- Exellent property retention after aging

Automotive interior trims

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2.2 Business Machines

Cycoloy® resin offers the business machine industry an optimum cost/performance balance for the enclosures and internal parts of products such as lap- and desk-top computers, copiers, printers, plotters and monitors.

The material's tailor-made properties include:

- Chlorine and bromine-free flame retardancy (in full compliance with eco-labels like Blue Angel RAL-UZ 78 and TCO '99).
- Excellent UV stability
- Wide colour range and quality aesthetics
- High flow for thin-wall moulding
- Good ductility
- High dimensional stability
- Excellent processibility; low juicing/plate-out
- Improved hydrolytic stability

PalmIII™ by 3Com®

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2.3 Telecommunications

Cycoloy® resin is recognised in the telecommunications industry as the material of choice for mobile telephone housings.

Its key properties in these areas include its:

- High dimensional stability
- Excellent balance of flow, mechanical and thermal properties
- Excellent UV stability
- Wide range of colours, and visual effects
- Decorability (IMD, Magix, 2K moulding, printing)
- Excellent processibility
- High flow for thin wall moulding
- Improved platability
- High impact resistance/ductility also at subzero temperatures

The proprietary pigmentation technology of Cycoloy® Magix provides a wide range of metallic surface effects.
In-mould finishing offers further opportunities for high quality, cost-effective product differentiation in a one-step process. Ongoing innovative developments include, for example, the use of elastomeric resin (TPE’s) for foil overmoulding to give a soft feel finish straight from the tool.

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FR Cycoloy® resins are also established materials for indoor enclosures and battery chargers, where they offer:

- Excellent UV stability
- Chlorine and bromine-free flame retarded grades (except C2100HF)
- Medium to high heat performance
- High dimensional stability
- Excellent processibility

Nokia® 3310 coloured covers

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2.4 Electrical

Cycoloy® grades for electrical applications have been specifically developed to meet industry standards (without resulting in over-engineered parts).

For a wide range of products, including injection moulded electronic enclosures, electricity meter covers and cases, domestic switches, plugs and sockets and extruded conduits, the Cycoloy® product family offers:

- Chlorine and bromine-free flame retarded grades (except C2100HF)
- High impact resistance/ductility
- Heat resistance in the range of 95°C to 135°C (Vicat B120)
- Ball pressure test in the range of 85°C to 130°C
- High tracking resistance (CTI >250V)
- A quality surface finish, high gloss or textured, in a wide range of colours
- Excellent UV stability
- Excellent processibility
- Compatibility with laser marking processes
- High dimensional stability
- Design flexibility for intricate moulding with optimum integration possibilities
- Excellent flow for thin-wall designs

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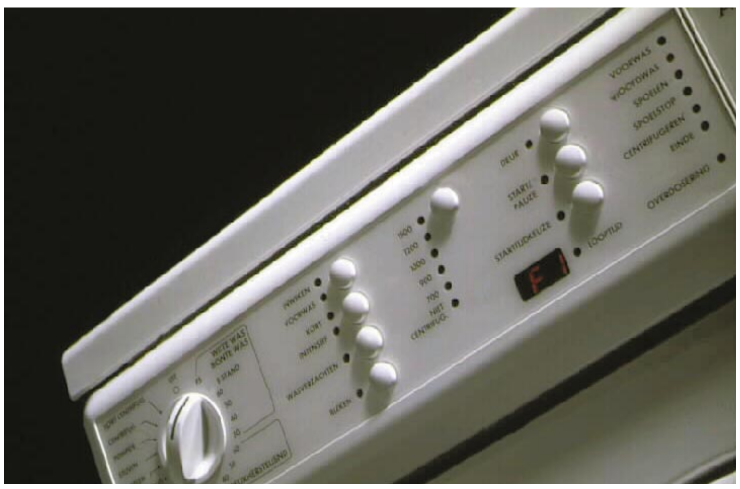
2.5 Appliances

The range of Cycoloy® flame retarded and non-flame retarded resins offers tailor-made material solutions for the internal and external parts of appliances such as washing machines, dryers and microwave ovens.

The key features of the material in these applications include its:

- Chlorine and bromine-free flame retarded grades (except C2100HF)
- High impact performance/ductility
- Inherent UV stability
- Medium/high heat performance
- Excellent processibility
- Decorability



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3 Product Selection

3.1 Product description

3.1.1 Cycoloy® C1000 series

- Unreinforced multi purpose grades
- Includes low, medium and high heat grades
- Excellent property/processing balances in demanding applications
- High flow grades for thin-wall parts

3.1.2 Cycoloy® C2000 series

- Unreinforced flame retarded grades
- UL94V0/5V ratings
- Chlorine/bromine-free flame retardancy for business machine applications
- Brominated FR additives for applications requiring very high heat performance (C2100HF)

3.1.3 Cycoloy® C3000 series

- Blow moulding and extrusion grades
- Multi purpose and flame retarded grades
- DIN VDE 0604 compliant (C3650)

3.1.4 Cycoloy® C6000 series

- Flame retarded grades with improved flow and processing robustness
- UL94V0/5V ratings
- Chlorine/bromine-free flame retardancy
- Improved hydrolytic stability

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3.1.5 Cycoloy® VisualFX™ grades

The Cycoloy® Visualfx™ portfolio consists of four major families of colours and special effects, backed by a range of dedicated services. Available in a broad spectrum of product performance are:

- Earth tones like Speckle, Marble and Stone
- Magix® luster materials including Sparkle and Ares

Using standard processing equipment, Cycoloy® Visualfx™ materials provides parts with a consistently high quality surface finish straight from the mould. Furthermore, in many cases the range of special effects eliminates the need for secondary operations, such as painting, metallising or sublimation printing, providing cost-effective product differentiation.
As the aesthetic effects of Cycoloy® will influence the properties of the final material and moulding behaviour may be affected, it is recommended therefore that application testing is carried out. GE Plastics offers customers full processing and design support.

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3.2 Selection tree

click on a **section** to jump to the related tree

Cycoloy

- **injection moulding**
  - non-flame retarded | glass reinforced | flame retarded
- **extrusion / blow moulding**
  - non-flame retarded | flame retarded
- **VisualFX**
  - injection moulding

GRADE	Heat • Impact Flammability • Flow

Heat: Vicat B/120 in °C (ISO 306)
Impact: Izod Notched at 23°C in kJ/m² (ISO 180/1A)

Flammability: Flame class at mm thickness (UL94)
Flow: MVR at 260°C/5.00kg in cm³/10min (ISO1133)
Flow*: MVR at 260°C/2.16kg in cm³/10min (ISO1133)
n.t.: not tested

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injection moulding › non-flame retarded

Heat level	Feature	Grade	Heat • Impact	Flammability • Flow	Notes
low heat		**C1000**	115°C • 40 kJ/m²	HB/1.6-3.1 • 15 cm³/10min	***global grade*** · *automotive · appliances · electrical*
low heat	*high flow*	**C1000HF**	116°C • 35 kJ/m²	HB/1.6-3.1 • 24 cm³/10min	***global grade*** · *automotive · appliances · electrical · telecom*
low heat	*reduced squeak plating*	**C1000A**	112°C • 38 kJ/m²	n.t. • 14 cm³/10min	*automotive · telecom*
medium heat		**C1100**	123°C • 41 kJ/m²	HB/1.6-3.1 • 14 cm³/10min	***global grade*** · *automotive · appliances · electrical*
medium heat		**IP1000**	128°C • 55 kJ/m²	n.t. • 13 cm³/10min	***global grade*** · *automotive · appliances · electrical · telecom*
medium heat	*high flow*	**C1100HF**	128°C • 50 kJ/m²	HB/1.6-3.1 • 20 cm³/10min	*automotive · appliances · electrical · telecom*

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- **injection moulding**
  - non-flame retarded
    - medium heat
      - *reduced squeak plating*
        - **C1100A** — 120°C • 53 kJ/m² — n.t. • 12 cm³/10min
          automotive
      - *low gloss*
        - **LG9000** — 124°C • 31 kJ/m² — n.t. • 20 cm³/10min
          global grade *· automotive*
    - high heat
      - **C1200** — 134°C • 47 kJ/m² — HB/1.2 • 12 cm³/10min
        global grade *· automotive · appliances · electrical*
      - *high flow*
        - **C1200HF** — 134°C • 41 kJ/m² — HB/1.2 • 22 cm³/10min
          global grade *· automotive · appliances · electrical · telecom*
  - glass reinforced
    - **C4210** — 139°C • 8 kJ/m² — HB/1.6-3.1 • 20 cm³/10min

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- **injection moulding**
  - flame retarded
    - low heat
      - *Cl and Br-free*
        - **CU6800** — 90°C • 15 kJ/m² — V1/1.20 mm • 21*cm³/10min
          global grade *· business machines · appliances · electrical · telecom*
        - **C2800** — 95°C • 30 kJ/m² — V0/1.5 - V2/0.9 mm • 15*cm³/10min
          global grade *· business machines · appliances · electrical · telecom*
    - medium heat
      - *Cl and Br-free*
        - **C2950** — 112°C • 44 kJ/m² — V0/1.5 - HB/0.7 • 10*cm³/10min
          global grade *· business machines · appliances · electrical · telecom*
        - **C6600** — 100°C • 15 kJ/m² — V0/1.60 mm • 19*cm³/10min
          global grade *· business machines · appliances · electrical · telecom*
        - **C6200** — 102°C • 15 kJ/m² — V0/1.5 mm - HB/0.7 • 13*cm³/10min
          global grade *· business machines · appliances · electrical · telecom*
    - high heat
      - *brominated*
        - **C2100HF** — 144°C • 43 kJ/m² — V0/1.5 mm • 18 cm³/10min
          appliances · telecom

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- **extrusion / blow moulding**
  - non-flame retarded
    - **C3100** — 134°C • 49 kJ/m² · n.t. • 2 cm³/10min
      automotive
  - flame retarded
    - *halogen-free*
      - **C3600** — 113°C • 40 kJ/m² · V0/1.5-2.5 • 9 cm³/10min
        profiles
    - *Cl and Br-free*
      - **C3650** — 110°C • 45 kJ/m² · V0/1.6 mm • 12 cm³/10min
        global grade *· extrusion · profile/sheet (VDE0604/VDE0472)*

- **VisualFX**
  - injection moulding
    - multi-purpose
      - **FXC810SK** — 130°C • 24 kJ/m² · HB/1.2 • 22 cm³/10min
        global grade *· automotive · appliances · telecom*
      - **FXC810AR** — 130°C • 24 kJ/m² · HB/1.2 • 22 cm³/10min
        global grade *· automotive · appliances · telecom*
    - flame retarded
      - *Cl and Br-free*
        - **FXC830SK** — 98°C • 8 kJ/m² · V0/1.5 mm • 13 cm³/10min
          global grade *· business machines · appliances · electrical · telecom*
        - **FXC830AR** — 98°C • 8 kJ/m² · V0/1.5 mm • 13 cm³/10min
          global grade *· business machines · appliances · electrical · telecom*

3.3 Typical properties

Typical values only.
Variations within normal tolerances are possible for various colours.

			Unit	Test Method ISO / IEC*	DIN / VDE*	ASTM / other*	Test Specimen: MPTS (multi-purpose test specimen) as defined in ISO 3167. Smaller test specimens may be machined from MPTS. All dimensions in mm.	
Mechanical								
Tensile stress	at yield (at break)	at 50 mm/min	MPa	527				
	at yield (at break)	at 5 mm/min	MPa	527			MPTS (150 x 10 x 4)	
Tensile strain	at yield (at break)	at 50 mm/min	%	527				
	at yield (at break)	at 5 mm/min	%	527			MPTS	
Tensile modulus		at 1 mm/min	MPa	527			MPTS	
Flexural stress	at yield	at 2 mm/min	MPa	178			80 x 10 x 4	
Flexural modulus		at 2 mm/min	MPa	178			80 x 10 x 4	
Hardness	Ball indentation	H 358/30	MPa	2039-1			10 x 10 x 4	
	Rockwell	R, M or L	scale	2039-2		D785		
Abrasion resistance	Taber, CS-17, 1 kg	per 1000 cycles	mg/1000 cy			GE*		
Impact								
Izod	notched	at +23°C [-30°C]	kJ/m²	180-1A			80 x 10 x 4	
Charpy	notched	at +23°C [-30°C]	kJ/m²	179/1eA			80 x 10 x 4	
Thermal								
Vicat B/50	50N (method B)	at 50°C/h	°C	306			80 x 10 x 4	
B/120	50N (method B)	at 120°C/h	°C	306				
HDT/Ae 1.82 MPa	edgewise, span 100 mm	at 1.80 MPa	°C	75/Ae				
/Be 0.45 MPa		at 0.45 MPa	°C	75/Af			110 x 10 x 4	
Ball pressure	passes at °C		°C	335-1*				
Relative Temperature Index	RTI	Electrical properties	°C			UL746B*		[1]
		Mechanical properties with Impact	°C			UL746B*		
		Mechanical properties without Impact	°C			UL746B*		
Thermal conductivity			W/m°C		52612	C177		
Coefficient of Thermal Expansion	CTE (23°C-60°C)	in flow direction	1/°C		53752	D696	4 x 4 x 10	[2]
Flammability								
UL94 rating	flame class rating	at mm thickness	class at mm			UL94*	125 x 13, thickness as noted	[1] [2]
UL94 - 5VB rating								
Limiting Oxygen Index	LOI		%	4589		D2863	150/80 x 10 x 4	[2]
Glow wire	passed at °C	at 1 mm (3.2 mm) thickness	°C at mm	695-2-1*				
Needle flame	passed at 10 sec	at 3.2 mm	—	695-2-2*				
Hot Wire Ignition	HWI	Performance Level Class	PLC			UL746A*		[1] [3]
High-Current Arc Ignition	HAI	Performance Level Class	PLC			UL746A*		
Electrical								
Dielectric strength	in oil	at 0.8 mm / 1.6 mm / 3.2 mm	kV/mm	243*		D149		
Surface resistivity			Ohm	93*		D257		
Volume resistivity			Ohm·cm	93*		D257		
Relative permittivity	or Dielectric constant	at 50 Hz	—	250*		D150		
		at 1 MHz	—	250*		D150		
Dissipation factor	or Loss tangent	at 50 Hz	—	250*		D150		
		at 1 MHz	—	250*		D150		
Comparative Tracking Index	CTI (CTI-M) Ral7035	50 drops [M: wetting agent]	V	112/3rd*		D3638		[4]
Comparative Tracking Index	CTI	Performance Level Class	PLC			UL746A*		[1] [3]
Arc Resistance	D-495	Performance Level Class	PLC			UL746A*		
High Voltage Arc-Tracking Rate	HVTR	Performance Level Class	PLC			UL746A*		
Physical								
Density			g/cm³	1183		D792		
Moisture absorption	at saturation	at 23°C, 50% R.H.	%	62	53495	D570		
Water absorption	at saturation	at 23°C, in water	%	62	53495	D570		
Mould shrinkage		in flow direction	%			D955	Tensile bar	[5]
Rheological								
Melt Volume Rate	MVR	at xxx°C / y.yy kg	cm³/10 min	1133	53735		granules	

1) *as recognized on UL yellow cards; UL recognition may differ with colour*
2) *these ratings are not intended to reflect hazards presented by this or other material under actual fire conditions*
3) *measured at 3 - 3.2 mm thickness - values may differ for other thicknesses*
4) *values may differ with pigmented materials*
5) *only typical data for material selection purposes - not to be used for part/tool design; for glass reinforced grades: values may differ with glass fibre orientation*

NB : not broken · – : not relevant · n.t.: not tested

Injection moulding page 15

non-flame retarded page 15

Typical values only.
Not to be used for
specification purposes.

			low heat			medium heat				
				high flow	reduced squeak plating			high flow	reduced squeak plating	low gloss
			C1000 *global grade*	**C1000HF** *global grade*	**C1000A**	**C1100** *global grade*	**IP1000** *global grade*	**C1100HF**	**C1100A**	**LG9000** *global grade*
Mechanical		**Unit**								
Tens. stress	y (b) 50	MPa	55 (40)	55 (45)	45 (40)	55 (45)	54 (55)	55 (45)	50 (50)	50 (45)
	y (b) 5	MPa	50 (40)	50 (40)	45 (35)	45 (40)	51 (55)	55 (45)	45 (40)	50 (40)
Tens. strain	y (b) 50	%	4 (>50)	4 (25)	4 (>50)	4 (>50)	5 (>50)	4 (>50)	5 (>50)	4 (10)
	y (b) 5	%	4 (40)	4 (>50)	4 (>50)	4 (>50)	5 (>50)	5 (>50)	5 (>50)	4 (10)
Tens. modulus		MPa	2500	2400	2000	2400	2150	2400	2100	2300
Flex. stress	y	MPa	85	85	70	80	80	75	74	81
Flex. modulus		MPa	2300	2500	2000	2300	2200	2300	2100	2400
Hardness	Ball	MPa	112	105	87	100	91	98	88	93
	Rockwell	scale	R117	R117	R110	R117	R116	R117	R108	R116
Abrasion	Taber	mg/1000 cy	62	71	71	79	70	81	80	82
Impact										
Izod notch.	23° (-30°) C	kJ/m^2	40 (15)	35 (14)	38 (30)	41 (17)	55 (50)	50 (28)	53 (51)	31 (13)
Charpy notch.	23° (-30°) C	kJ/m^2	40 (15)	40 (14)	35 (30)	42 (20)	60 (58)	57 (51)	56 (54)	31 (13)
Thermal										
Vicat B/50		°C	113	114	109	120	126	126	117	122
B/120		°C	115	116	112	123	128	128	120	124
HDT/Ae 1.82 MPa		°C	92	95	93	100	106	100	99	97
/Be 0.45 MPa		°C	115	117	113	120	126	120	118	120
Ball Pressure		°C	110	75	75	120	120	75	75	75
RTI Electrical		°C	60	60	n.t.	60	n.t.	60	n.t.	n.t.
Mech. with Impact		°C	60	60	n.t.	60	n.t.	60	n.t.	n.t.
without Impact		°C	60	60	n.t.	60	n.t.	60	n.t.	n.t.
Thermal conductivity		W/m°C	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CTE flow		1/°C	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$
Flammability										
UL94		class at mm	HB/1.6-3.1	HB/1.6-3.1	n.t.	HB/1.6-3.1	n.t.	HB/1.6-3.1	n.t.	n.t
UL94 - 5VB			–	–	–	–	–	–	–	n.t.
LOI		%	<21	<21	<21	<21	<21	<21	<21	<21
Glow wire	1 mm (3.2 mm)	°C at mm	750 (–)	– (650)	– (650)	750 (–)	n.t.	– (650)	– (650)	n.t.
Needle flame		—	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
HWI - PLC		PLC	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
HAI - PLC		PLC	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
Electrical										
Diel. str. oil 0.8/1.6/3.2 mm		kV/mm	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17
Surface resistivity		Ohm	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$
Volume resistivity		Ohm·cm	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$
Rel. permitt.	50 Hz	—	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.6
	1 MHz	—	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6
Dissipation f.	50 Hz	—	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.001
	1 MHz	—	0.007	0.007	0.007	0.007	0.005	0.007	0.007	0.009
CTI (CTI-M) Ral4035		V	250	250	250	250	250	250	250	275
CTI		PLC	n.t.	n.t.	n.t.	n.t.	2	n.t.	n.t.	n.t.
Arc D-495		PLC	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
HVTR		PLC	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
Physical										
Density		g/cm^3	1.12	1.12	1.06	1.12	1.15	1.12	1.15	1.13
Moisture abs.	23°C	%	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Water abs.	sat./23°C	%	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
Mould shrink.	flow	%	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.5-0.7	0.4-0.6
Rheological										
MVR		cm^3/10 min	15 [2)]	24 [2)]	14 [2)]	14 [2)]	13 [2)]	20 [2)]	12 [2)]	20 [2)]
			C1000 *global grade*	**C1000HF** *global grade*	**C1000A**	**C1100** *global grade*	**IP1000** *global grade*	**C1100HF**	**C1100A**	**LG9000** *global grade*

[1)] *MVR at 260°C/2.16 kg*
[2)] *MVR at 260°C/5.00 kg*

P S C W

NB : not broken · – : not relevant · n.t.: not tested

page 14 Injection moulding page 16

page 14 non-flame retarded: high heat (C1200); high flow (C1200HF)

flame retarded: low heat – Cl and Br-free (CU6800, C2800); medium heat – Cl and Br-free (C2950, C6600, C6200); high heat – brominated (C2100HF)

Typical values only.
Not to be used for
specification purposes.

		Unit	C1200 *global grade*	C1200HF *global grade*	CU6800 *global grade*	C2800 *global grade*	C2950 *global grade*	C6600 *global grade*	C6200 *global grade*	C2100HF
Mechanical										
Tens. stress	y (b) 50	MPa	55 (50)	55 (45)	55 (45)	55 (40)	60 (50)	60 (50)	60 (50)	60 (50)
	y (b) 5	MPa	50 (40)	55 (45)	50 (40)	50 (40)	55 (45)	55 (45)	50 (40)	55 (45)
Tens. strain	y (b) 50	%	4 (>50)	4 (>50)	3 (>50)	3 (>50)	4 (>50)	4 (>50)	4 (>50)	6 (>50)
	y (b) 5	%	5 (>50)	5 (>50)	3 (>50)	3 (>50)	4 (>50)	4 (>50)	4 (>50)	5 (>50)
Tens. modulus		MPa	2400	2400	2700	2700	2800	2700	2800	2400
Flex. stress	y	MPa	85	80	85	90	90	90	88	91
Flex. modulus		MPa	2300	2300	2500	2600	2700	2700	2700	2400
Hardness	Ball	MPa	110	106	110	113	94	110	114	104
	Rockwell	scale	R120	R115	R122	R122	R123	R122	R122	R122
Abrasion	Taber	mg/1000 cy	62	63	15	72	54	50	82	62
Impact										
Izod notch.	23° (-30°) C	kJ/m^2	47 (19)	41 (18)	15 (7)	30 (10)	44 (14)	15 (10)	15 (10)	43 (18)
Charpy notch.	23° (-30°) C	kJ/m^2	48 (20)	45 (18)	15 (7)	30 (9)	45 (15)	15 (10)	15 (8)	43 (20)
Thermal										
Vicat	B/50	°C	132	132	85	92	109	95	98	142
	B/120	°C	134	134	90	95	112	100	102	144
HDT	/Ae 1.82 MPa	°C	110	108	72	78	90	80	84	117
	/Be 0.45 MPa	°C	130	128	85	88	103	90	96	136
Ball Pressure		°C	125	125	75	85	100	75	90	125
RTI	Electrical	°C	60	60	60	60	85	80	85	60
	Mech. with Impact	°C	60	60	60	60	85	70	75	60
	without Impact	°C	60	60	60	60	85	80	85	60
Thermal conductivity		W/m°C	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CTE	flow	1/°C	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$
Flammability										
UL94		class at mm	HB/1.2	HB/1.2	V1/2.0	V0/1.5-V2/0.9	V0/1.5-HB/0.7	V0/1.6	V0/1.5-HB/0.7	V0/1.5
UL94 - 5VB			n.t.	n.t.	5VB/2.0	5VB/2.3	5VB/2.3	5VB/2.0	5VB/2.3	5VB/2.5
LOI		%	<21	23	29	32	32	32	32	30
Glow wire	1 mm (3.2 mm)	°C at mm	750 (–)	750 (–)	– (960)	850 (960)	960 (–)	– (960)	960 (960)	960 (–)
Needle flame		—	n.t.	n.t.	n.t.	1.6	1.6	1.6	1.6	1.6
HWI - PLC		PLC	3	3	n.t.	2	1	n.t.	2	n.t.
HAI - PLC		PLC	1	1	n.t.	0	0	n.t.	0	n.t.
Electrical										
Diel. str. oil	0.8/1.6/3.2 mm	kV/mm	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17
Surface resistivity		Ohm	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$
Volume resistivity		Ohm·cm	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$
Rel. permitt.	50 Hz	—	2.8	2.8	2.8	2.8	2.8	2.7	2.8	3.0
	1 MHz	—	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6
Dissipation f.	50 Hz	—	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.005
	1 MHz	—	0.007	0.007	0.006	0.006	0.006	0.006	0.008	0.008
CTI (CTI-M) Ral4035		V	250	250	600	600	600	600	600	250
CTI		PLC	2	2	n.t.	–	1	n.t.	2	n.t.
Arc D-495		PLC	n.t.	n.t.	n.t.	6	6	n.t.	6	n.t.
HVTR		PLC	n.t.	n.t.	n.t.	3	2	n.t.	3	n.t.
Physical										
Density		g/cm^3	1.15	1.15	1.20	1.17	1.17	1.20	1.20	1.20
Moisture abs.	23°C	%	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Water abs.	sat./23°C	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Mould shrink.	flow	%	0.5-0.7	0.5-0.7	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.5-0.7
Rheological										
MVR		cm^3/10 min	12 [2)]	22 [2)]	21 [1)]	15 [1)]	10 [1)]	19 [1)]	13 [1)]	18 [2)]
			C1200 *global grade*	C1200HF *global grade*	CU6800 *global grade*	C2800 *global grade*	C2950 *global grade*	C6600 *global grade*	C6200 *global grade*	C2100HF

1) MVR at 260°C/2.16 kg
2) MVR at 260°C/5.00 kg

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NB : not broken · – : not relevant · n.t.: not tested

Typical values only.
Not to be used for
specification purposes.

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			Injection moulding	Extrusion / Blow moulding			VisualFX			
							injection moulding			
			glass reinforced	non-flame retarded	flame retarded		multi-purpose		flame retarded	
					Cl and Br-free	halogen-free			Cl and Br-free	
Mechanical		Unit	**C4210**	**C3100**	**C3600**	**C3650** *global grade*	**FXC810SK** *global grade*	**FXC810AR** *global grade*	**FXC830SK** *global grade*	**FXC830AR** *global grade*
Tens. stress	y (b) 50	MPa	– (–)	55 (45)	65 (50)	65 (55)	55 (45)	55 (45)	55 (40)	55 (40)
	y (b) 5	MPa	70 (60)	50 (45)	55 (45)	60 (60)	55 (45)	55 (45)	50 (40)	50 (40)
Tens. strain	y (b) 50	%	3 (>50)	5 (>50)	5 (>35)	5 (>50)	5 (15)	5 (15)	4 (>50)	4 (>50)
	y (b) 5	%	3 (5)	5 (>50)	4 (>50)	3 (>50)	5 (15)	5 (15)	4 (>50)	4 (>50)
Tens. modulus		MPa	4700	2200	2700	2600	2400	2400	2800	2800
Flex. stress	y	MPa	105	78	100	100	86	86	100	100
Flex. modulus		MPa	4500	2100	2800	2700	2400	2400	2800	2800
Hardness	Ball	MPa	116	100	104	108	112	112	116	116
	Rockwell	scale	R121	R116	R124	R124	R121	R121	R122	R122
Abrasion	Taber	mg/1000 cy	–	55	54	54	63	63	82	82
Impact										
Izod notch.	23° (-30°) C	kJ/m²	8 (6)	49 (38)	40 (14)	45 (13)	24 (12)	24 (12)	8 (5)	8 (5)
Charpy notch.	23° (-30°) C	kJ/m²	9 (6)	49 (40)	41 (14)	48 (13)	25 (13)	25 (13)	7 (5)	7 (5)
Thermal										
Vicat B/50		°C	137	133	111	108	128	128	94	94
B/120		°C	139	134	113	110	130	130	97	97
HDT/Ae 1.82 MPa		°C	126	105	92	91	108	108	80	80
/Be 0.45 MPa		°C	137	124	104	102	128	128	86	86
Ball Pressure		°C	125	130	100	75	125	125	90	90
RTI	Electrical	°C	n.t.	n.t.	60	n.t.	60	60	n.t.	n.t.
	Mech. with Impact	°C	n.t.	n.t.	60	n.t.	60	60	n.t.	n.t.
	without Impact	°C	n.t.	n.t.	60	n.t.	60	60	n.t.	n.t.
Thermal conductivity		W/m°C	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CTE	flow	1/°C	$4 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$	$8 \cdot 10^{-5}$
Flammability										
UL94		class at mm	n.t.	n.t.	V0/1.5-2.5	V0/1.6	n.t.	n.t.	n.t.	n.t.
UL94 - 5VB			n.t.	n.t.	5VB/2.5	n.t.	n.t.	n.t.	n.t.	n.t.
LOI		%	24	24	32	37	23	23	32	32
Glow wire	1 mm (3.2 mm)	°C at mm	– (960)	750 (–)	850 (960)	– (850)	– (750)	– (750)	850 (960)	850 (960)
Needle flame		—	n.t.	n.t.	1.6	1.6	n.t.	n.t.	1.6	1.6
HWI - PLC		PLC	n.t.	n.t.	n.t.	n.t.	3	3	n.t.	n.t.
HAI - PLC		PLC	n.t.	n.t.	n.t.	n.t.	1	1	n.t.	n.t.
Electrical										
Diel. str. oil 0.8/1.6/3.2 mm		kV/mm	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17	35/25/17
Surface resistivity		Ohm	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$
Volume resistivity		Ohm·cm	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$	$>10^{15}$
Rel. permitt.	50 Hz	—	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	1 MHz	—	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Dissipation f.	50 Hz	—	0.004	0.002	0.004	0.004	0.003	0.003	0.004	0.004
	1 MHz	—	0.006	0.003	0.006	0.006	0.005	0.005	0.006	0.006
CTI (CTI-M) Ral4035		V	n.t.	250	600	600	250	250	600	600
CTI		PLC	n.t.	n.t.	n.t.	n.t.	2	2	n.t.	n.t.
Arc D-495		PLC	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
HVTR		PLC	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
Physical										
Density		g/cm³	1.22	1.15	1.18	1.18	1.15	1.15	1.20	1.20
Moisture abs.	23°C	%	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Water abs.	sat./23°C	%	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Mould shrink.	flow	%	0.3-0.5	0.5-0.7	0.4-0.6	0.4-0.6	0.5-0.7	0.5-0.7	0.4-0.6	0.4-0.6
Rheological										
MVR		cm³/10 min	20 [2)]	2 [2)]	9 [2)]	12 [2)]	22 [2)]	22 [2)]	13 [1)]	13 [1)]
			C4210	**C3100**	**C3600**	**C3650** *global grade*	**FXC810SK** *global grade*	**FXC810AR** *global grade*	**FXC830SP** *global grade*	**FXC830AR** *global grade*

1) MVR at 260°C/2.16 kg
2) MVR at 260°C/5.00 kg

NB : not broken · – : not relevant · n.t.: not tested

4 Properties and Design

4.1 General properties

Cycoloy® resins are high impact, amorphous thermoplastic alloys which combine the processibility of ABS together with the superior mechanical properties, impact and heat resistance of polycarbonate. A broad, high performance property profile has established Cycoloy® as a first choice material for many demanding applications across diverse industries.

Design calculations for Cycoloy® resin are no different than for any other material. Physical properties of plastic are dependent on the expected temperature and stress levels. Once this dependency is understood, and the end-use environment has been defined for an application, standard engineering calculations can be used to accurately predict part performance.

4.2 Mechanical properties

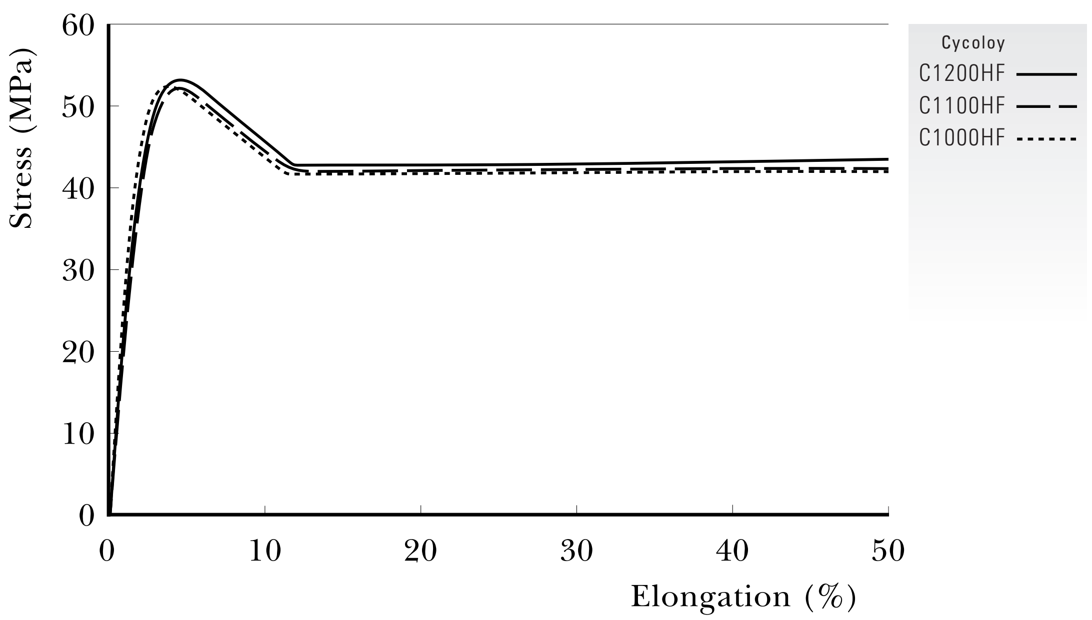
Cycoloy® resin exhibits excellent mechanical properties. These are retained across a broad range of temperatures and also through time. Impact is maintained down to -30°C while heat resistance can be in the range of 95°C-140°C (Vicat B120).

4.2.1 Stiffness

The stiffness of a part is defined as the relationship between the load and the deflection of a part. The most important material property for stiffness is the stress/strain curve. In general, the Young's modulus, which is determined from the stress/strain curve, is the best parameter to be used when comparing the stiffness of materials.

FIGURE 1

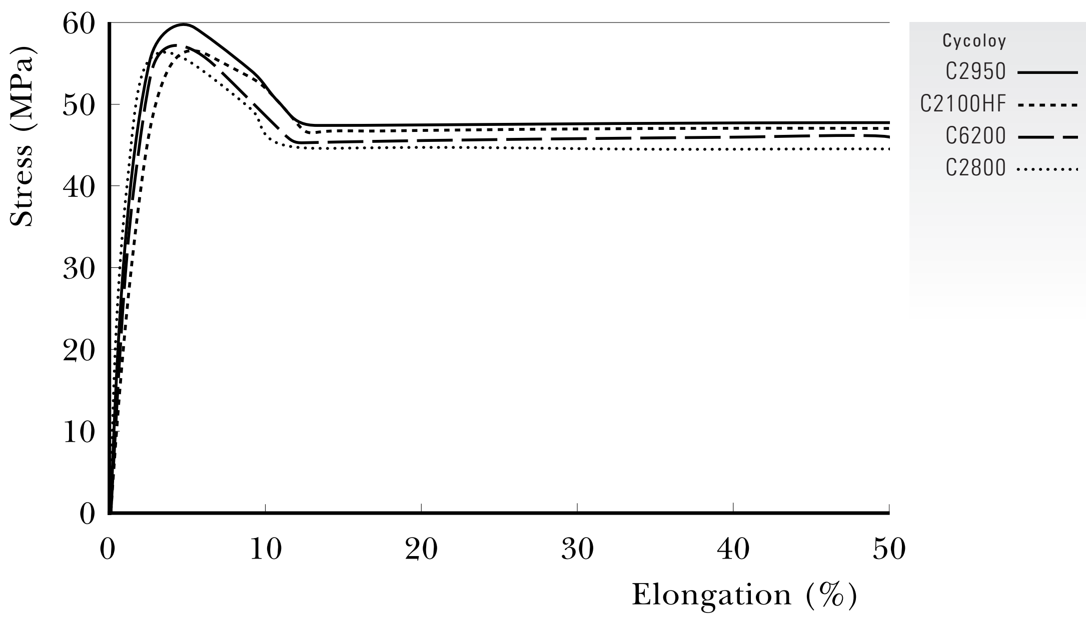
Stress-strain curve of non-flame retarded Cycoloy at room temperature



However, when the Young's modulus is used, the stress/strain relationship can be seen to be linear in the range 0 to 0.5% of elongation, as shown in ■ FIGURES 1 and 2. The range in which the stress/strain curve can be predicted with a straight line is limited, particularly for thermoplastics. If the actual stress levels in a part are widely different from what would be predicted

■ **FIGURE 2**

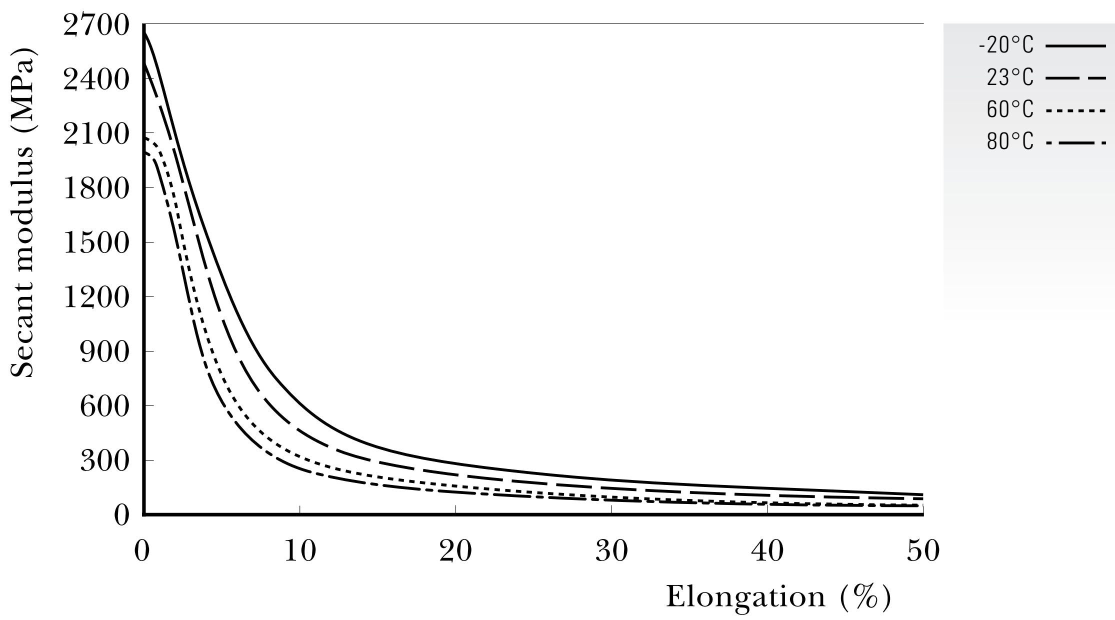
Stress-strain curve of flame retarded Cycoloy at room temperature



using the Young's modulus Y, then the stiffness of the part should be recalculated using the secant modulus Y*, as shown in ■ FIGURE 3.

■ **FIGURE 3**

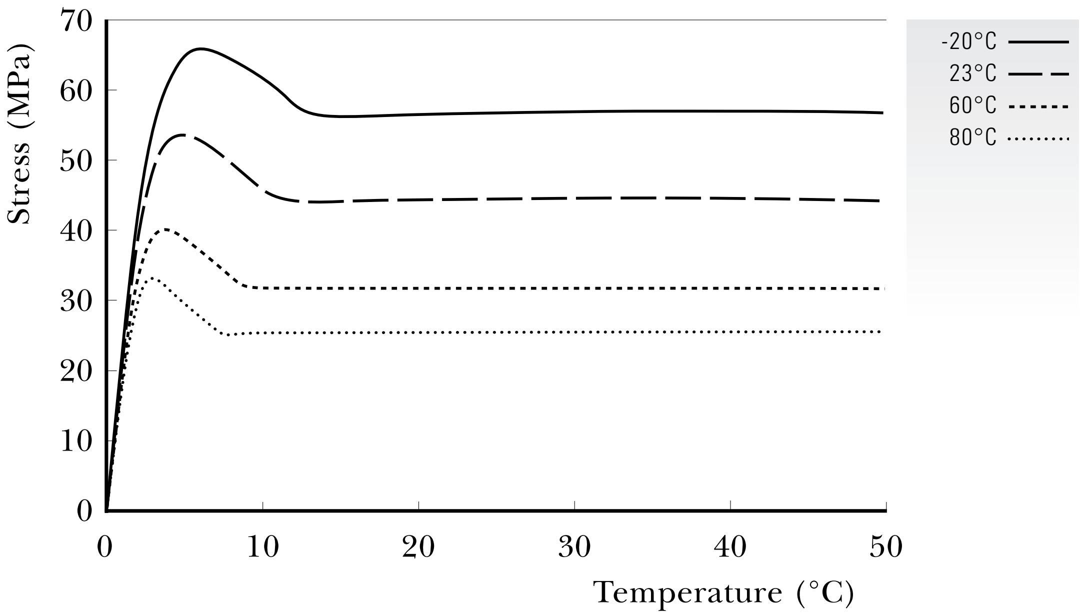
Secant modulus curve of Cycoloy C1100HF



A further important consideration in the calculation of part stiffness is the temperature at which the load is applied. As can be seen in the ■ FIGURE 4, the stress/strain curves of thermoplastics are strongly influenced by temperature. It is recommended therefore to calculate the stress/strain curve at the temperature at which the load is to be applied in actual use.

■ FIGURE 4

Stress-strain curve of Cycoloy C1100HF



4.2.2 Strength

The strength of a part is defined as the maximum load that can be applied to a part without causing part failure under given conditions. In order to be able to determine the strength of a part, failure has to be first defined. The right definition of failure depends on the application and how much deformation is allowed.

Material strength is a stress/strain related property which is inherent in the material. The tensile test provides the most useful information for engineering design. For unfilled Cycoloy® grades subjected to small strains, the stress increases proportionally with the strain. However, early in the test non-linearity will occur.

In fact close observation of the stress/strain curve reveals that a proportional part does not exist. With larger strains, yield will occur and the maximum stress is reached. If the strain is further increased, necking will occur. The neck will propagate through the structure until the material fails. The speed of deformation in the application is vital.

4.2.3 **Impact strength**

Impact strength can be described as the ability of a material to withstand an impulsive loading. There are several factors which determine the ability of a plastic part to absorb impact energy.

FIGURE 5

Effect of temperature upon impact response

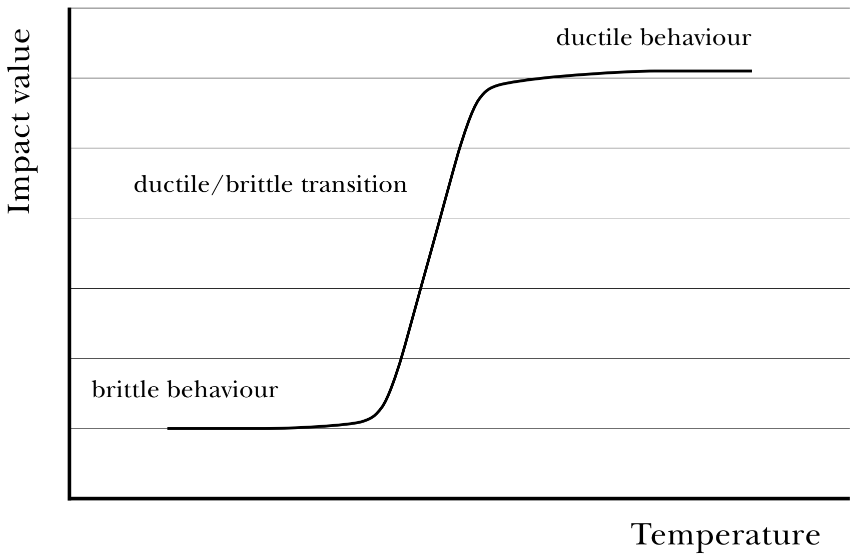


FIGURE 6

Izod notched impact of Cycoloy C1100HF at 4 mm (ISO 180/1a)

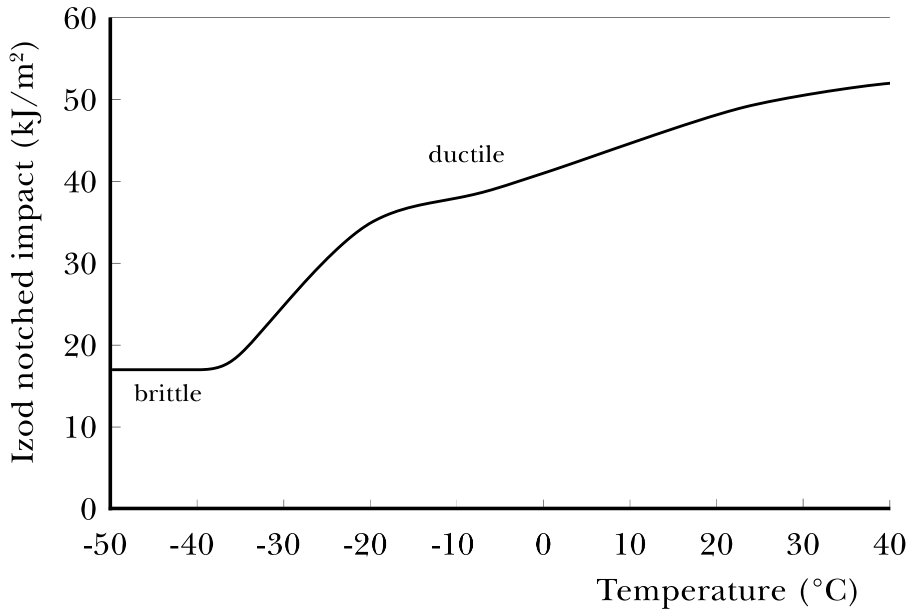


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FIGURE 7

Izod notched impact of Cycoloy C2800
as a function of thickness

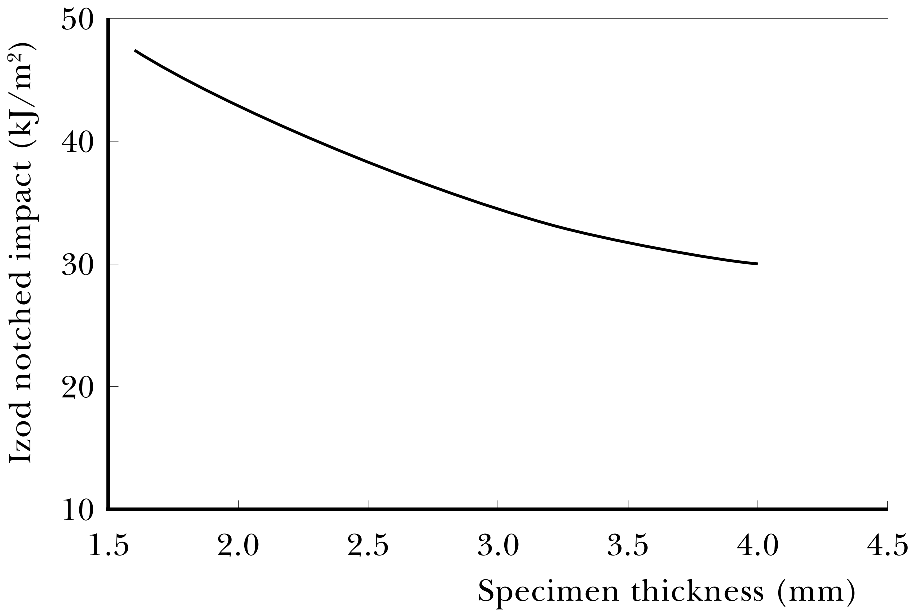
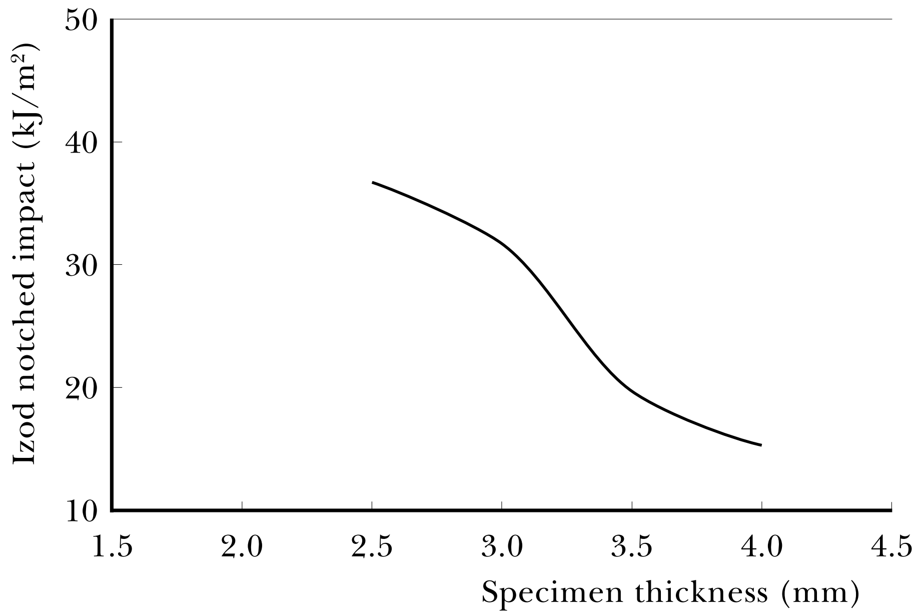


FIGURE 8

Izod notched impact of Cycoloy C6200
as a function of thickness



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In addition to the type of material these factors include:

- Wall thickness
- Geometric shape and size
- Material flow
- Operating temperature and environment
- Rate of loading

FIGURE 9

Ductile-brittle transition temperatures for Cycoloy C1100HF for different thicknesses

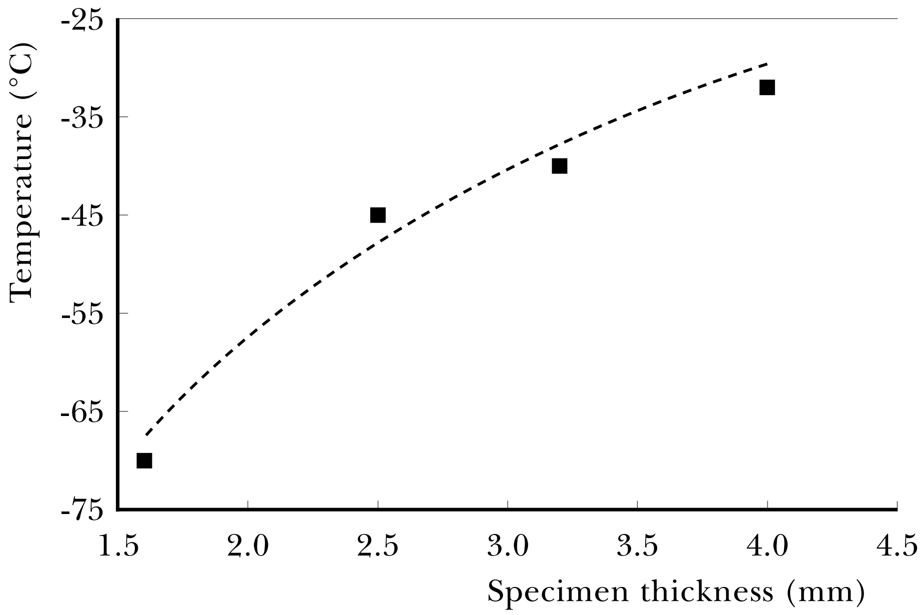
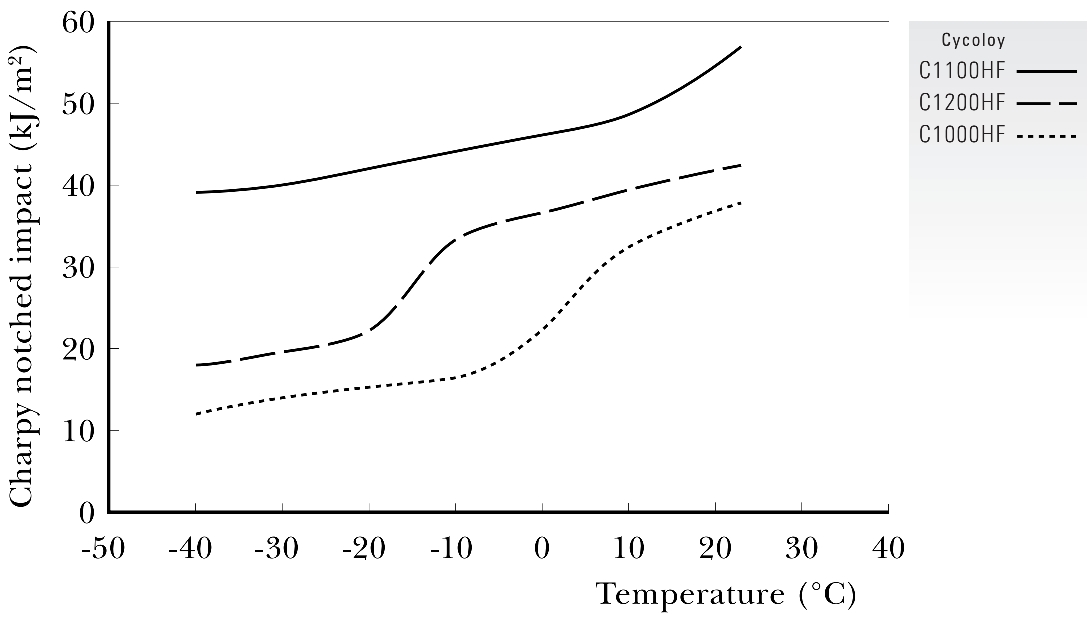


FIGURE 10

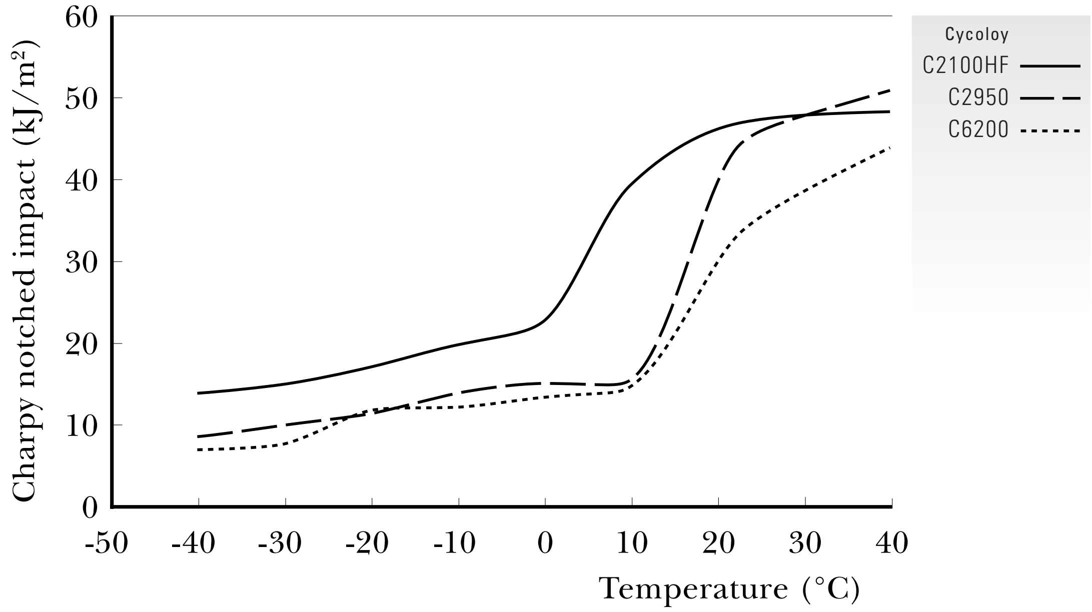
Charpy notched impact of non-flame retarded Cycoloy at 4 mm (ISO 179/1a)



For ductile polymers such as Cycoloy® resin, the load at which yield occurs in a part is affected by the last two factors. Of even more significance to design is the fact that, under the appropriate circumstances, the impact behaviour of a ductile material will undergo a transition from a ductile and forgiving response to a brittle and catastrophic one. Usually this change in behaviour is described in terms of a ductile/brittle transition, as illustrated in **FIGURES 5, 6, 7, 8, 9, 10** and **11**.

■ **FIGURE 11**

Charpy notched impact of flame retarded Cycoloy at 4 mm (ISO 179/1a)



There are many methods and norms for evaluating the impact resistance of a material. The most common norms include ISO, ASTM and DIN. In general, standard samples are moulded and subjected to the impact test. Examples of the various tests include Izod, Charpy, Tensile, Falling Dart and Flexed Plate.

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■ FIGURES 12 and 13 show the multi-axial energy absorption in the instrumented puncture test. In some cases a notch is deliberately introduced into the test sample in order to concentrate stress at the point of impact.

■ **FIGURE 12**

Instrumented puncture test: energy absorption of Cycoloy C1200HF (ISO 6603-2)

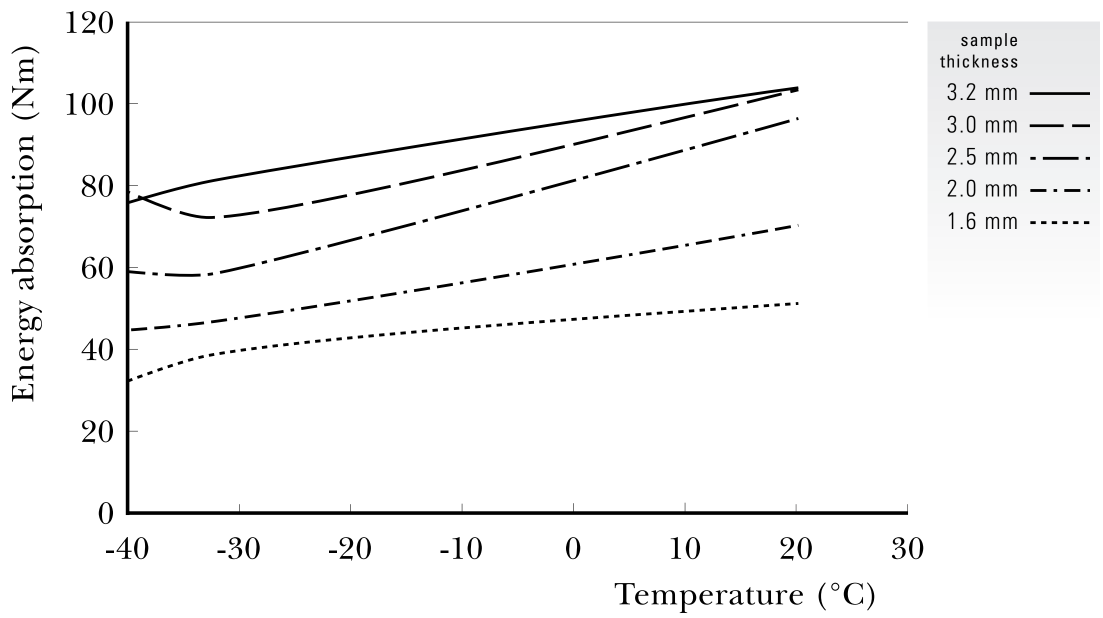

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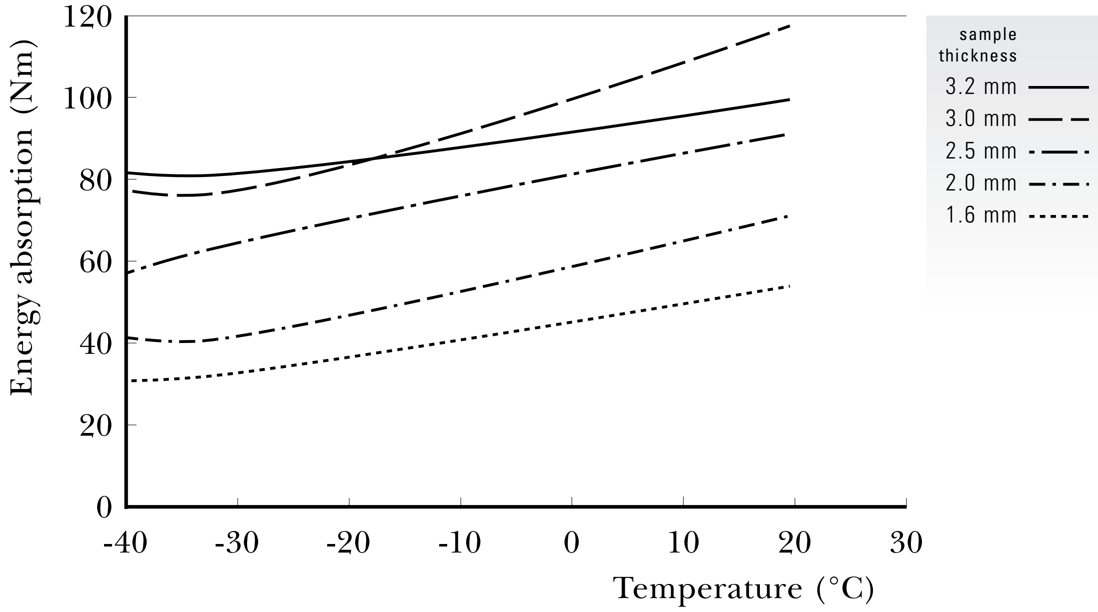
FIGURE 13

Instrumented puncture test: energy absorption of Cycoloy C1000HF (ISO 6603-2)



It should be noted that the results from these tests are highly dependent on the thickness of the test sample and should not be used to predict actual part performance.

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4.2.4 Behaviour over time

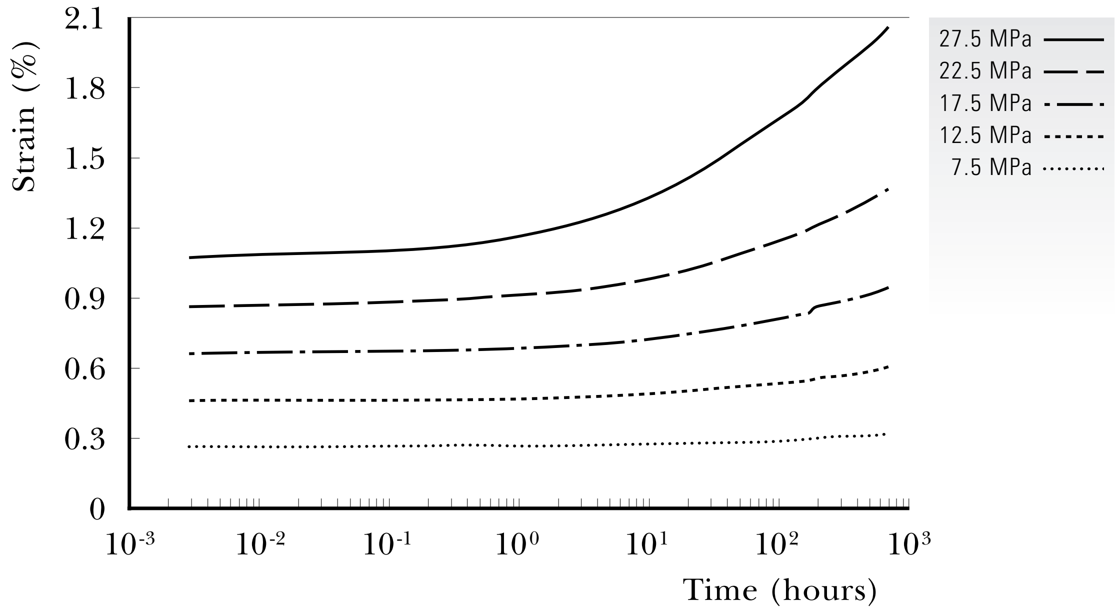
There are two types of phenomena which should be considered. Static time dependent phenomena such as creep are caused by the single, long-term loading of an application. Dynamic time dependent phenomena such as fatigue, on the other hand, are produced by the cyclic loading of an application. Both types of behaviour are heavily influenced by the operating environment and component design.

Creep behaviour

Under the action of an applied force, a viscoelastic material undergoes a time dependent increase in strain which is called creep or cold

FIGURE 14

Creep performance of Cycoloy C1000 at room temperature



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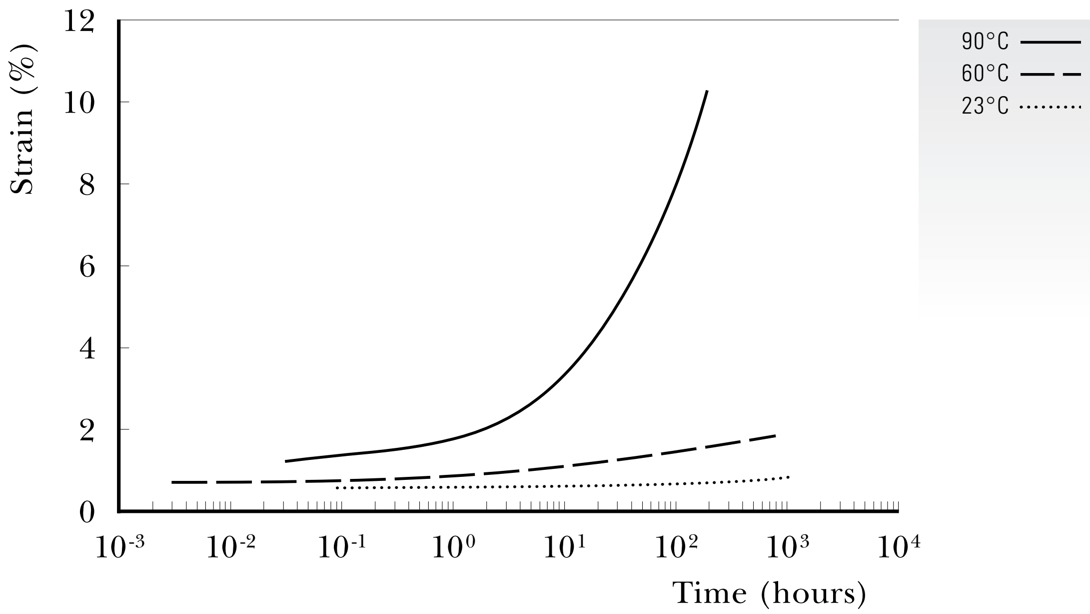
flow. Creep is defined as the increasing rate of deformation of a geometrical shape when subjected to a constant load over a defined period of time. The creep rate for any material is dependent on temperature, load and time.

Creep behaviour is initially examined using plots of strain as a function of time, over a range of loads and at a given temperature. Measurements may be taken in the tensile, flexural or compression mode. As shown in ■ FIGURE 14, the creep behaviour of Cycoloy® resin increases in direct proportion to the applied force but varies greatly with temperature, as illustrated in ■ FIGURE 15. The curves illustrate the initial deformation due to the applied load on a specimen. Up to this point, the response is elastic in nature and therefore the specimen will fully

■ FIGURE 15

Creep performance of Cycoloy C1100 at 15 MPa



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recover after the load is removed. However, continued application of the load will result in a gradual increase in deformation. In other words it 'creeps'.

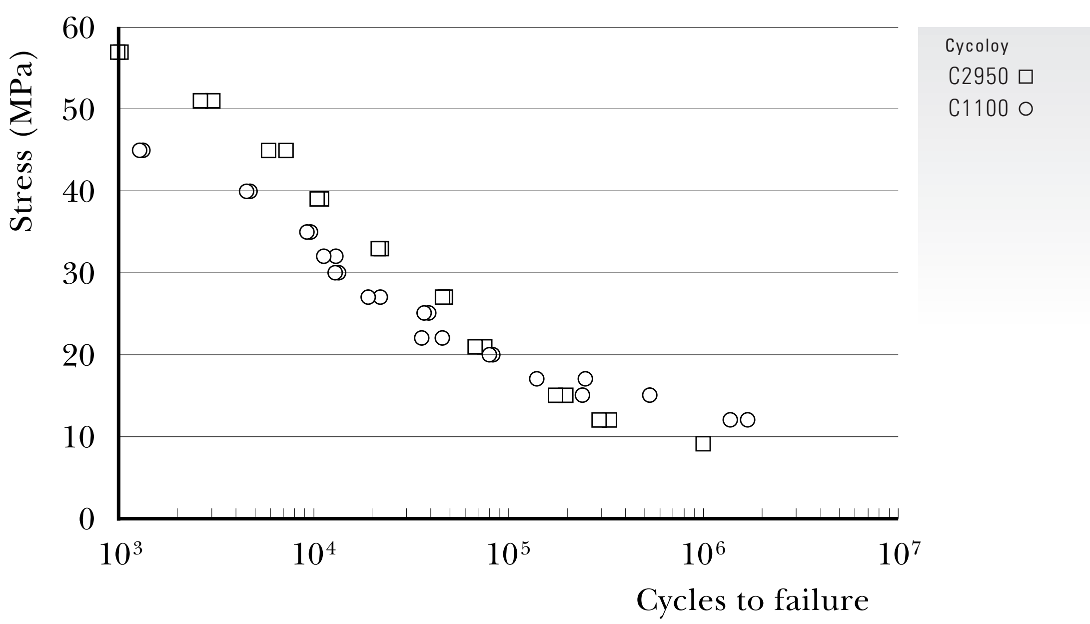
Fatigue endurance

Structural components subjected to vibration, components subjected to repeated impacts, reciprocating mechanical components, plastic snap-fit latches and moulded-in plastic hinges are all examples where fatigue can play an important role. Cyclic loading can result in mechanical deterioration and fracture propagation through the material, leading to ultimate part failure, often at a stress level considerably below the yield point of the material.

In such applications, an uniaxial fatigue diagram, as shown in ■ FIGURE 16, could be used to predict product life. These curves can be used to

■ FIGURE 16

Fatigue performance of Cycoloy C1100 and C2950 at 23°C and 5 Hz



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determine the fatigue endurance limit, or the maximum cycle stress that a material can withstand without failure.

Fatigue tests are usually conducted under flexural conditions, although tensile and torsional testing is also possible. A specimen of material is repeatedly subjected to a constant deformation at a constant frequency, and the number of cycles to failure is recorded. The procedure is then repeated over a range of deflections or applied stresses. The test data are usually presented as a plot of log stress versus log cycles; this is commonly referred to as an S-N curve.

S-N curves obtained under laboratory conditions may be regarded as "ideal". However, practical conditions usually necessitate the use of a modified fatigue limit, as other factors may affect performance, including, most notably, the type of loading, the size of the component and the loading frequency.

However, fatigue testing can only provide an indication as to a given material's relative ability to survive fatigue. It is therefore essential that tests are performed on actual moulded components, under actual end-use operating conditions.

4.3 Mould shrinkage

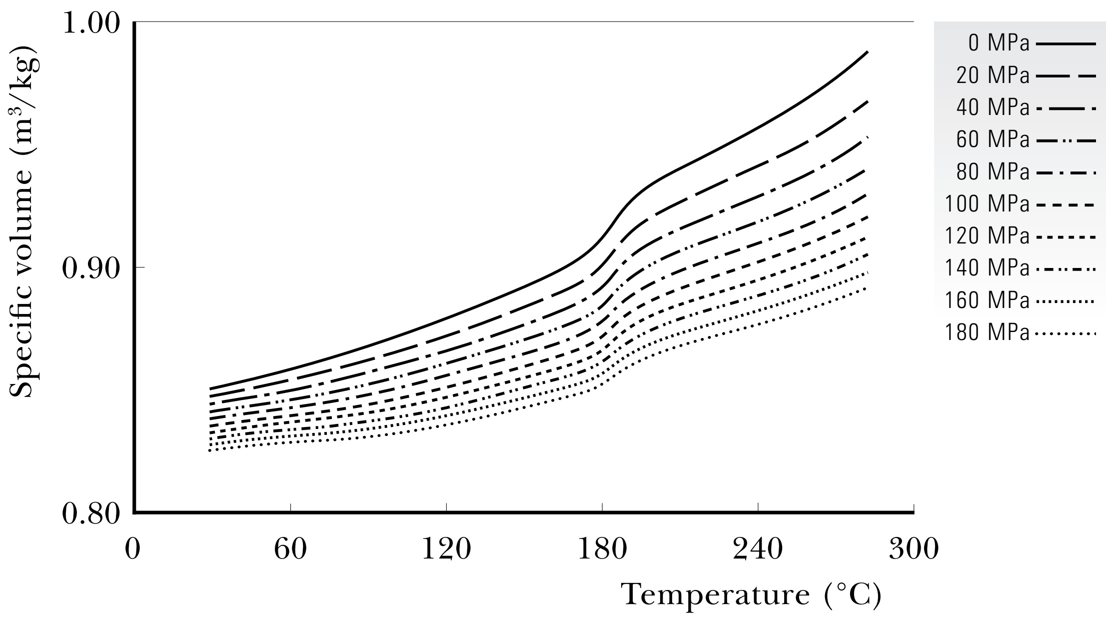
Mould shrinkage refers to the shrinkage that a moulded part undergoes when it is removed from a mould and cooled at room temperature. Expressed as an average percentage, mould shrinkage can vary considerably depending on the mould geometry, the processing conditions, the type of resin and the wall thickness.

As an amorphous material, Cycoloy® resin exhibits lower shrinkage than semi-crystalline materials. The levels of shrinkage in both cross-flow and with-flow direction are also closer to each other for amorphous materials, which makes it easier

to produce precise parts. The influence of the material on shrinkage is usually expressed by the PVT (Pressure-Volume-Temperature) relationship, which is illustrated in FIGURE 17.

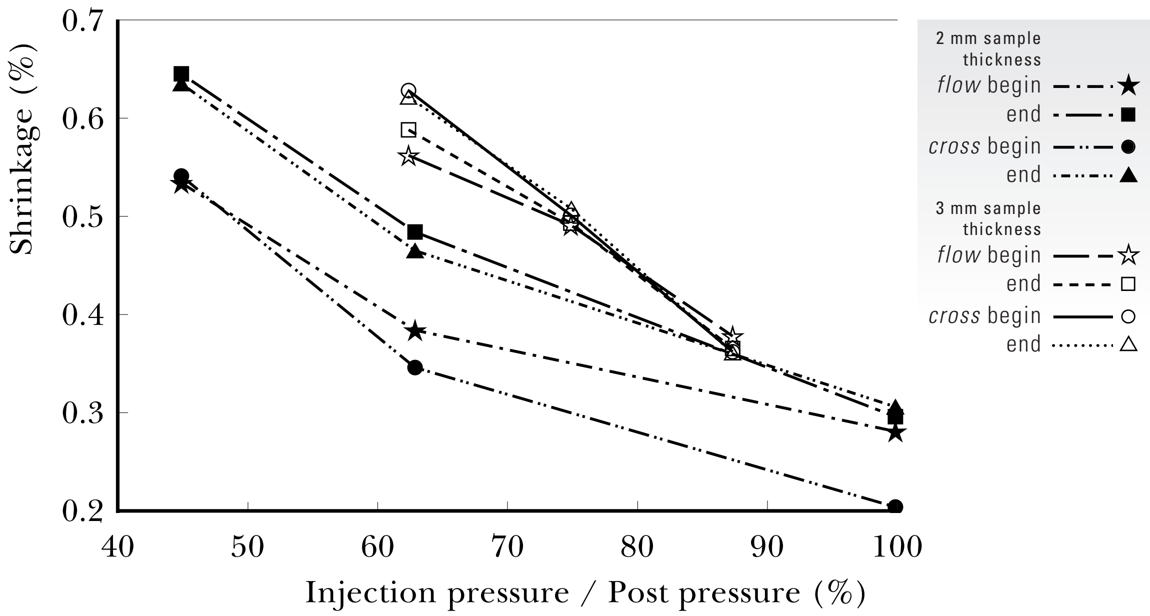
FIGURE 17

PVT-diagram of Cycoloy C2800



Uneven cooling, caused by mould surface temperature differences during the cooling process, can cause differential shrinkage. The packing or holding pressure phase in the injection moulding process also has a significant effect on shrinkage, as illustrated in ■ FIGURE 18. In general, the higher the holding pressure and the longer it is effective, the smaller the shrinkage.

■ FIGURE 18
Schrinkage of Cycoloy C2800



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4.4 Environmental resistance

4.4.1 Chemical resistance

Certain combinations of chemical environment, temperature and stress can adversely affect thermoplastic resins, Cycoloy resin included. For this reason, lubricants, cleaning solvents or any other material that may come into contact with the finished part should be evaluated carefully for compatibility. In general, the chemical resistance of Cycoloy resin is equal to, or slightly better than, that of Lexan polycarbonate resin. It is stable in the presence of water, most detergents and cleaners, waxes and greases. ■ TABLE 1 shows comparable data for GE Plastics' polymers, while ■ TABLE 2 shows specific data for Cycoloy resins (see page 28).

■ TABLE 1
Chemical compatibility of GE Plastics' polymers

	Amorphous						Semi-Crystalline			
Chemicals	**Lexan®** *Remex*	**Cycoloy®** *Remex*	**Cycolac®** *Remex*	**Noryl®** *Remex*	**Noryl Xtra®**	**Ultem®**	**Xenoy®** *Azloy* *Remex*	**Valox®** *Azmet* **Enduran®**	*Azdel*	**Noryl GTX®**
Hydrocarbons										
aliphatic	–/•	•	+	+	–	+	•	+	•	+
aromatic	–	–	–	–	–	++	–/•	+	+	+
halogenated-fully	–/•	•	–	–	–	+	–	–/•	–	+
halogenated-partly	–	–	–	–	n	–	–	–	–/•	•
Alcohols	+	n	+	+	+	+	+	+	+/++	+

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TABLE 1 (continued)

Chemicals	Amorphous						Semi-Crystalline			
	Lexan® *Remex*	**Cycoloy®** *Remex*	**Cycolac®** *Remex*	**Noryl®** *Remex*	**Noryl Xtra®**	**Ultem®**	**Xenoy®** *Azloy* *Remex*	**Valox®** *Azmet* **Enduran®**	*Azdel*	**Noryl GTX®**
Phenols	–	–	–	–	–	–	n	–	+	–
Ketones	–	–	–	–	–	–	–	•/+	+	•
Amines	–	–	–/•	–/•	–	n	n	n	n	–
Esters	–/•	–	•	+	+	•/+	–	•/+	+	+
Ethers	–	–	•	•	•	+	n	+	•	+
Acids										
inorganic	–/•	•	+	+	•	•/+	•/+	+	++	•
organic	•	•	–	•	•	•/+	•/+	•	+	•
oxidising	–	–	–	•	•	•	•/+	–	–	•
Alkalis	–	•	+	+	+	–	–	–	++	+
Automotive fluids										
Greases (non-reactive organic esters)	n	+	+	•/+	•/+	+	+	++	n	+
Oils (unsaturated aliphatic mixtures)	n	–/•	•/+	•/+	•/+	+	++	++	+	+
Waxes (heavy oils)	n	+	+	•/+	•/+	+	+	++	+	+
Petrol	–	–	–	–	–	+	++	++	+	+
Cooling liquid (glycol)	n	•	•	•/+	+	+	++	++	n	+

P S C W

Chemicals	Amorphous						Semi-Crystalline			
	Lexan® *Remex*	**Cycoloy®** *Remex*	**Cycolac®** *Remex*	**Noryl®** *Remex*	**Noryl Xtra®**	**Ultem®**	**Xenoy®** *Azloy* *Remex*	**Valox®** *Azmet* **Enduran®**	*Azdel*	**Noryl GTX®**
Automotive fluids										
Brake fluid (heavy alcohol)	n	–	–	+	+	–	++	+	n	+
Cleaners, Detergents	n	•/+	•/+	•/+	•/+	+	+	+	n	++
Water hot (< 80°C)	–/•	•/+	–/•	++	++	–/•	•	–	+	–
Environmental										
UV Resistance*	•/+	•/+	•/+	•	–/•	•/+	+	•	–/•	–

* *UV resistance is affected by colour pigments: black materials generally perform better*

++ **very good** found unaffected in its performance with regard to time, temperature and stress
• according to agency requirements

\+ **good** found acceptable in normal exposure
• long term exposure may result in minor loss of properties
• higher temperatures may result in major loss of properties

• **fair** found marginal
• only for short exposures at lower temperatures or when loss of mechanical properties is not critical

– **poor** not recommended
• will result in failure or severe degradation

n **not tested**

Ratings as shown are purely indicative. Finished part performance should always be evaluated on the actual part.

P S C W

TABLE 2

Chemical compatibility of Cycoloy

			C1000			C1200			C2100HF			C2800			C2950		
group	**chemical**	**duration** (hours)	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1
Hydrocarbons																	
aliphatic	n-Heptane	1*	+	n	n	+	n	n	+	n	n	+	n	n	+	n	n
aromatic	Toluene	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Alcohols	Ethanol	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ketones	Acetone	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amines	Aniline	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Esters	Ethyl acetate	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ethers	Diethyl ether	1	+	•	–	+	+	•	+	–	–	+	–	–	+	–	–
Acids																	
inorganic concentrate	Hydrochloric, 37%	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
inorganic dilution	Hydrochloric, 10%	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
organic concentrate	Acetic, 99.5%	1	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–
Alkalis	Sodium Hydroxide sol., 32%	24	+	+	+	+	+	+	+	+	+	+	–	–	+	+	–

* *tested only on ISO175*

			C1000			C1200			C2100HF			C2800			C2950		
group	**chemical**	**duration** (hours)	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1	**strain** (%) 0	0.5	1
Automotive fluids																	
Greases	Molycote MoS_2 grease	24*	+	n	n	+	n	n	+	n	n	+	n	n	+	n	n
Oils	Motor oil	24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Waxes	Liquid car wax	24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gasoline	Unleaded petrol	1	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–
Brake fluid	Break fluid	1	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–
Cleaners	Water and soap, 5%	24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Andy®	24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Glassex®	24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Miscellaneous	1:1 Olive oil/Oleic acid	24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Sun cream	24	+	–	–	+	–	–	+	–	–	+	–	–	+	–	–
	Cockpit spray	24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Transpiration	1*	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n

* *tested only on ISO175*

\+ **good** found acceptable in normal exposure
- long term exposure may result in minor loss of properties
- higher temperatures may result in major loss of properties

• **fair** found marginal
- only for short exposures at lower temperatures or when loss of mechanical properties is not critical

– **poor** not recommended
- will result in failure or severe degradation

n **not tested**

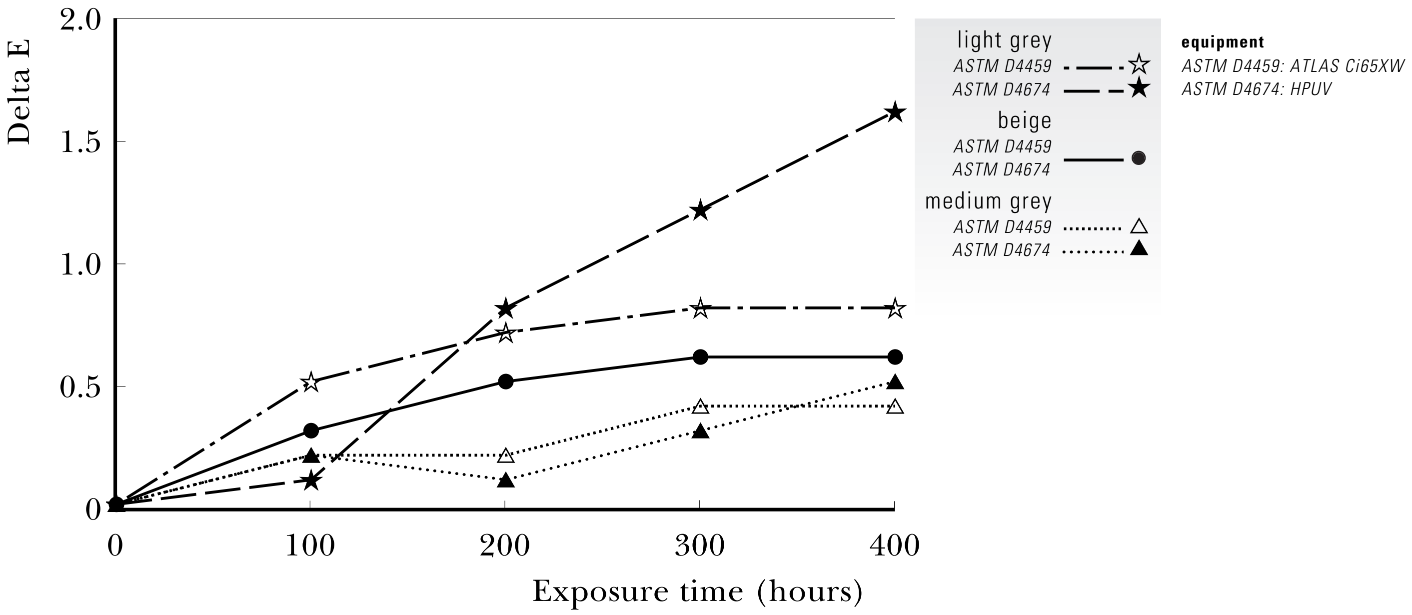
Ratings as shown are purely indicative. Finished part performance should always be evaluated on the actual part.

4.4.2 Cleaning and degreasing

Cleaning or degreasing of Cycoloy resin finished parts can be performed using isopropyl alcohol or mild soap solutions. Cleaning with partially halogenated or aromatic hydrocarbons, ketones (such as MEK) or ethers should be avoided.

■ **FIGURE 19**

UV performance of Cycoloy C2950



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4.4.3 Ultraviolet exposure

Cycoloy resin has been proven to be very successfull in demanding applications subjected to intense sunlight and humidity. In markets such as business machines, appliances and automotive, for example, Cycoloy resins exhibit excellent ultraviolet (UV) stability according to the most commonly used industry standards, as shown in ■ **FIGURES 19, 20** and **21**.

■ **FIGURE 20**

UV performance of Cycoloy C1100

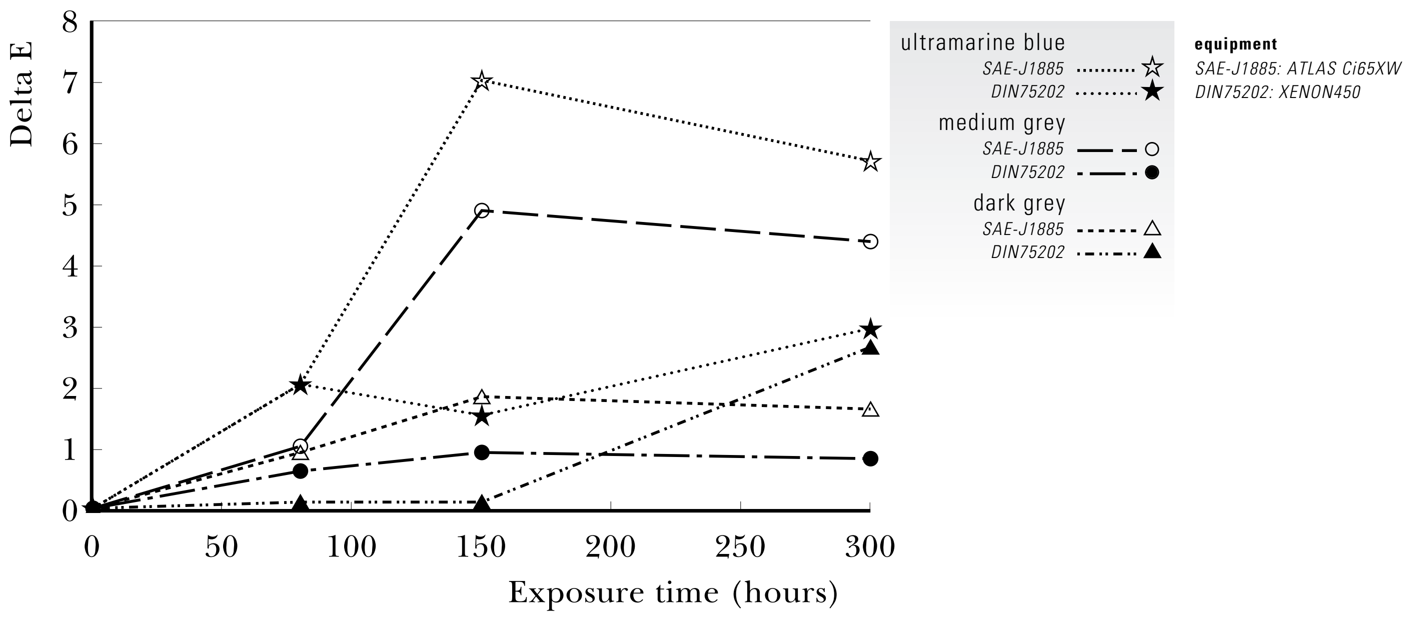

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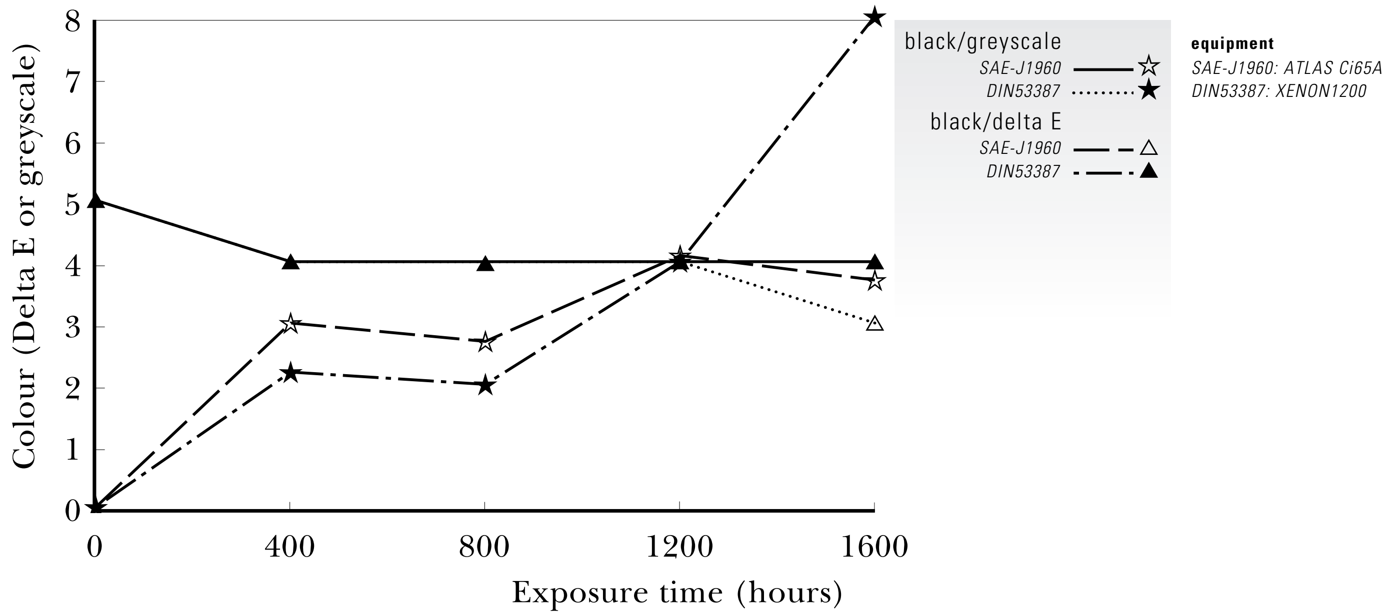
FIGURE 21

UV/weathering performance of Cycoloy C1100



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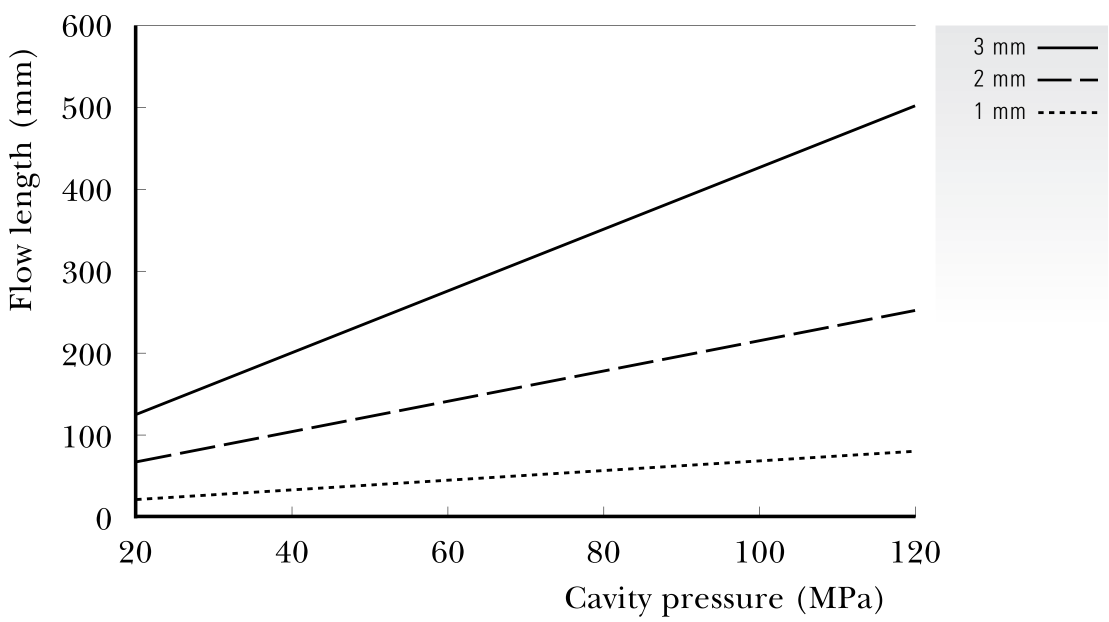
However, as with many other polymers, Cycoloy resin does demonstate some sensitivity to UV radiation and/or weathering in the form of slight colour change and loss of mechanical properties after long-term exposure.

4.5 Viscosity

The viscosity of polymers is a key property for many processes in which plastics are treated before the final shape has been achieved. Injection moulding, extrusion and blow moulding are the most common conversion processes.

FIGURE 22

Applied moldflow's multi-layer module for radial flow of Cycoloy C1100HF at 265°C



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The viscosity of a material determines its resistance to flow at a given melt temperature due to internal resistance. It is therefore a critical factor in determining the flow length which a material can achieve in a tool during injection moulding. Computer software such as MoldFlow® can help to calculate the filling characteristics of a material in a certain tool, as shown in FIGURES 22 and 23.

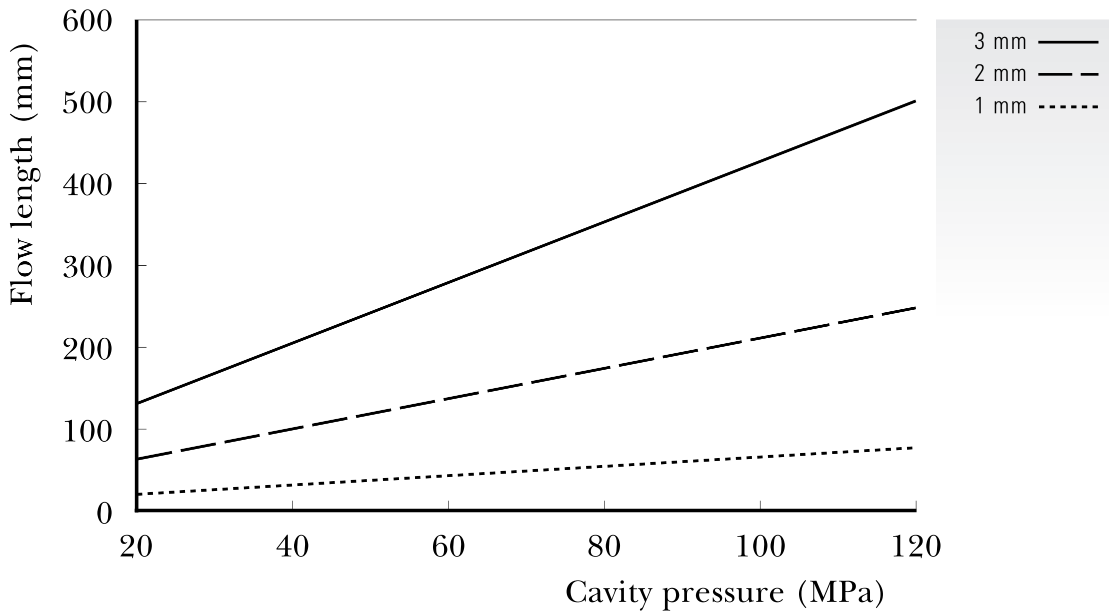

FIGURE 23

Applied moldflow's multi-layer module for radial flow of Cycoloy C2800 at 250°C

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Calculations are made based on material characteristics such as viscosity (see FIGURES 24 and 25), thermal conductivity and no-flow temperatures. The flow lengths of all GE Plastics' materials are given as calculated radial flow, based on the MoldFlow® model.

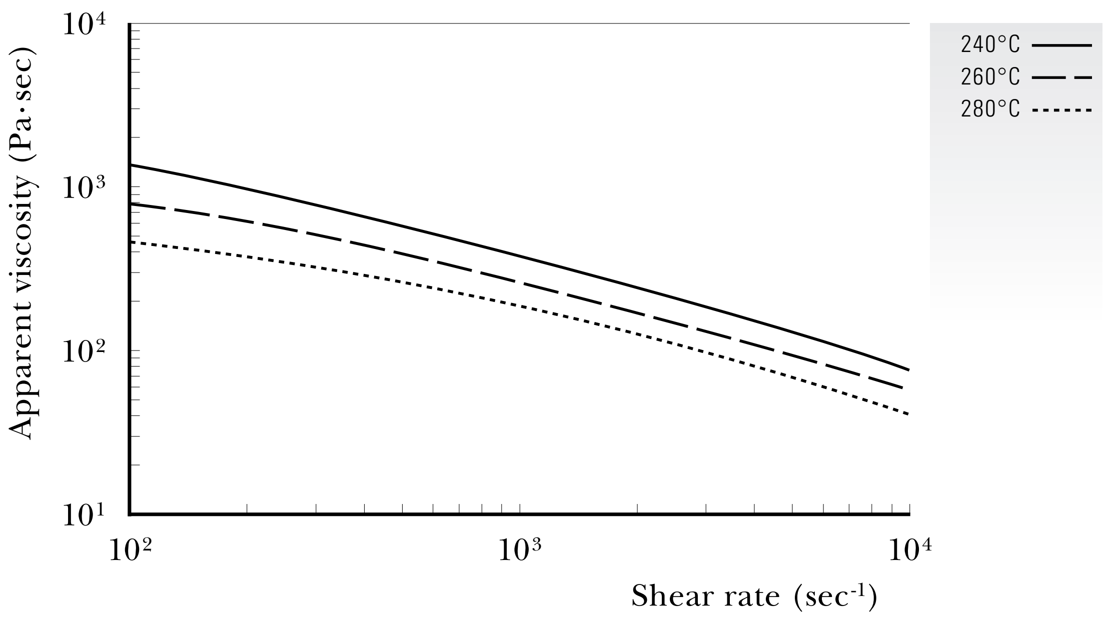

FIGURE 24

Capillary melt viscosity of Cycoloy C1100HF (DIN 54811)

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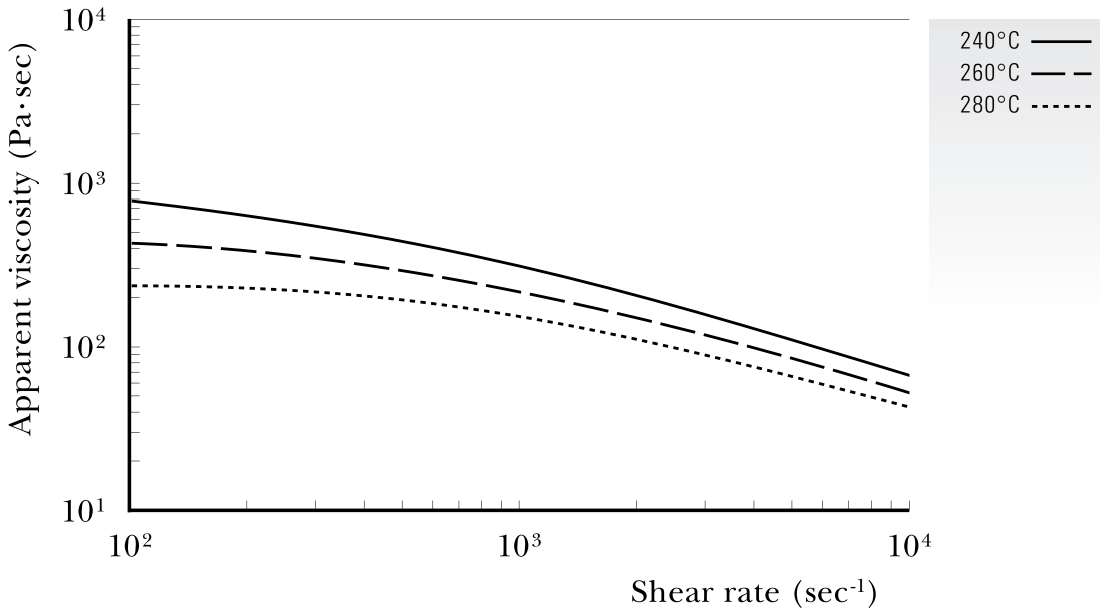
■ **FIGURE 25**

Capillary melt viscosity of Cycoloy C2800 (DIN 54811)



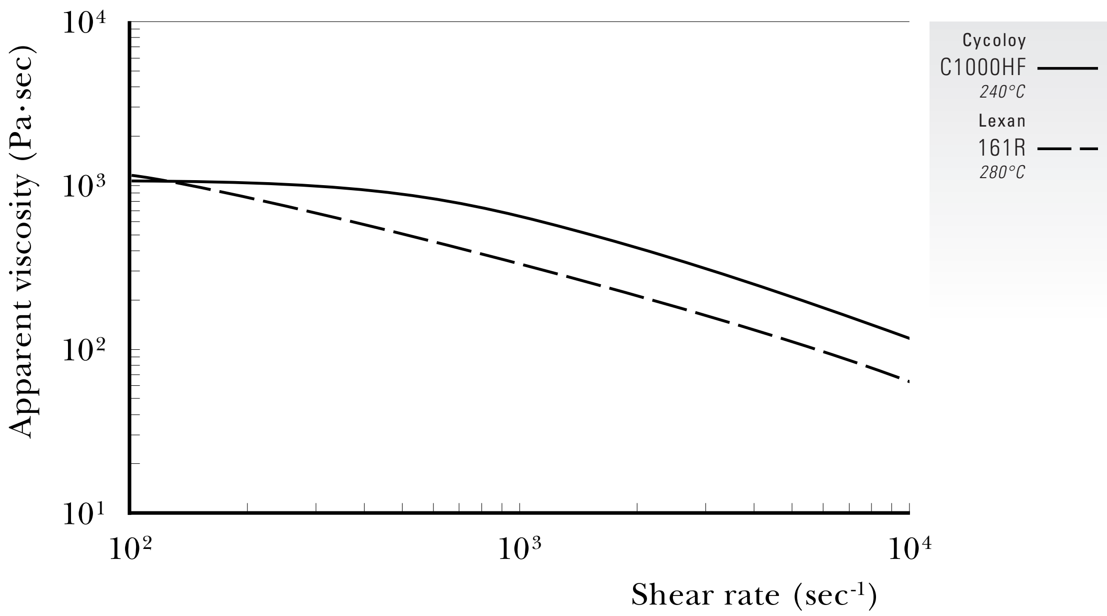
4.6 Shear properties

Melt viscosity (MV) tests are carried out over a wide range of shear rates. As materials demonstrate significantly different MV curves, a material comparison made of melt viscosity is more reliable than that based on the melt volume rate (MVR).

Cycoloy resins demonstrate a more non-Newtonian behaviour than Lexan resins. This means that the viscosity of Cycoloy resin can be influenced by the shear rate: in the high shear region, the MVR can be the same but the MV can be totally different, as shown in ■ FIGURE 26.

■ **FIGURE 26**

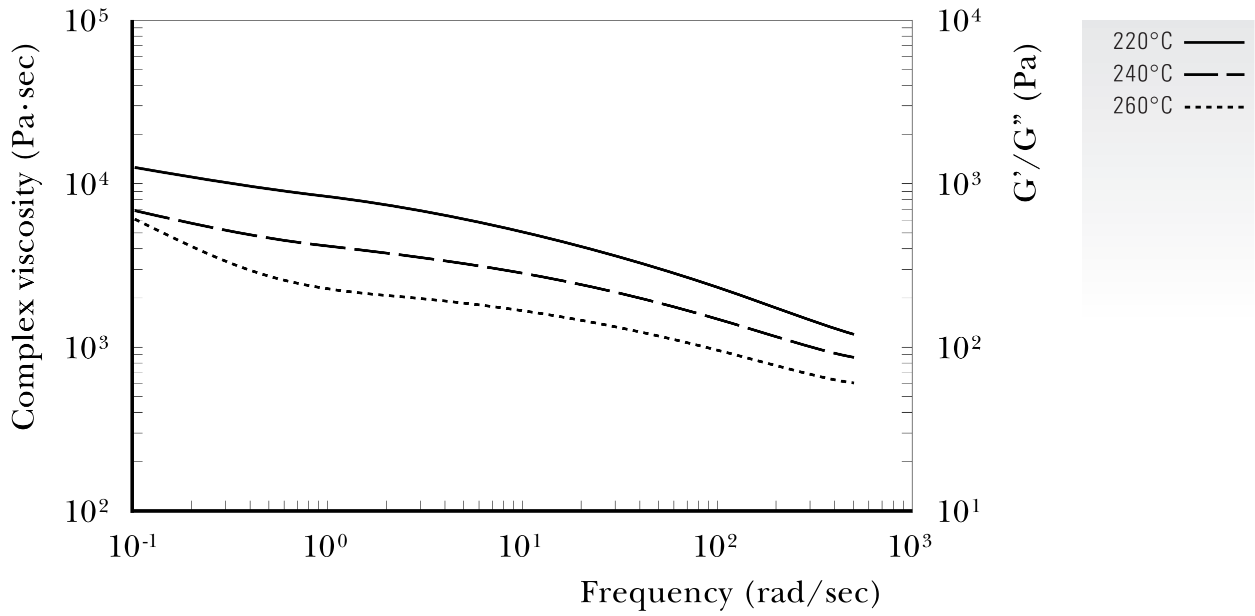
Capillary melt viscosity of Cycoloy vs. Lexan (DIN 54811)



4.6.1 Extrusion

For extrusion, the key parameter is the MV at a low shear rate, measured as dynamic shear viscosity within a typical extrusion frequency ranging form 0.1 to 400 rad/s (see ■ FIGURE 27).

■ FIGURE 27
Plate-plate melt viscosity of Cycoloy C3600



5 Processing

Cycoloy® PC/ABS alloys can be successfully converted by injection moulding, extrusion (sheet, pipe and profile) and extrusion blow moulding. Extruded sheets can be easily thermoformed in various shapes. Cycoloy® resin is particularly suitable for thin-wall moulding. Fast cycle times are possible and any rejects can be ground and reused, providing contamination has not occurred during processing.

5.1 Injection moulding

5.1.1 Equipment

Dryer
A closed loop, dehumidifying, recirculating hopper dryer is recommended for drying Cycoloy® resins. This system uses rechargeable desiccant cartridges to provide dry air. A correctly designed dryer and hopper provide a steady flow of dry pellets to the intake of the moulding machine.

To avoid cross-contamination, the dryer must be kept clean.

Injection moulding equipment
- Cycoloy® resins can be moulded on standard injection moulding machines. When determining the size of equipment to be used for moulding a particular Cycoloy® resin part, the total shot weight and the total projected area are the two basic factors to be considered.
- The hopper dryer capacity should be sized to provide a residence time of 3 to 4 hours. For example, a moulding machine with a throughput

of 50 kg per hour would need a 200 kg hopper capacity to meet the drying time requirements.

- It is recommended to use a conventional 3-zone screw with an L:D ratio of 20:1 - 25:1 and a compression ratio of 1:2 - 1:2.5. In order to avoid excessive shear and material degradation, high compression ratio screws, or those with a short compression zone, should not be used.
- Conventional construction materials for screw and barrel are acceptable for the processing of Cycoloy® resin. However, screws and cylinders of a bimetallic type with high abrasion and corrosion resistance are preferred, especially for high organic pigment based colours and flame retarded grades.
- A vented barrel and screw is not a satisfactory alternative to pre-drying and therefore is not recommended for processing Cycoloy® resins.
- A free-flowing nozzle with its own heater band and control is recommended. Nozzle openings have to be as large as possible.
- Clamping forces are commonly used in a range from 30 to 70 N/mm^2. In other words, once the total projected area of the complete shot has been determined, including all cavity and runner areas subjected to injection pressure, 30 to 70 MPa of clamp force should be provided to avoid flashing of the part. Wall thickness, flow length and moulding conditions will determine the actual tonnage required.

5.1.2 Processing conditions

Pre-drying

Cycoloy® resin will absorb a small amount of water from the atmosphere after compounding and prior to processing. The amount absorbed will depend on environmental conditions. It may vary from 0.10% to 0.18 %, depending on the temperature and humidity of the storage area.

Properly pre-dried Cycoloy® resin is more stable during moulding and helps to ensure optimum part performance and appearance. The recommended drying temperature range is 90°C - 110°C, depending on the heat resistance

of the material. The specified drying temperature should be monitored at the inlet of the (hopper) dryer. The dew point of the air at the inlet of the hopper should be -30°C, or lower. The temperature of the dryer's air input should be checked with a calibrated pyrometer or thermometer. When monitoring the air temperature, the temperature swing should not vary more than 2°C from the recommended drying temperature.

The time required to achieve sufficient drying varies from 2 to 4 hours, depending on the type of dryer. Target moisture content should be a maximum of 0.04%, or 0.02% for plating operations. Drying times should not exceed 16 hours, in order to retain the best part properties.

Melt temperature

- The melt temperature is a key parameter for optimum processing and should be measured frequently with a hand-held pyrometer while the machine is on cycle.
- Cycoloy® resins have excellent thermal stability within the recommended melt temperature range, which is shown in FIGURES 28, 29, 30 and 31.
- The barrel temperature profile should be increased progressively up to the recommended melt temperature. The nozzle temperature setting should be slightly lower than the recommended melt temperature. If the melt temperature is not within the target range, the cylinder temperature settings should be adjusted accordingly.
- The midpoint of the target range will give good results with respect to part appearance and cycle time.
- If the cylinder temperature exceeds the upper limit of the suggested melt range, thermal degradation of the resin and loss of physical properties may result.

FIGURE 28

Typical moulding temperatures for Cycoloy injection moulding:

non-flame retarded
low heat

- C1000
- C1000HF
- C1000A

drying: 90-100°C

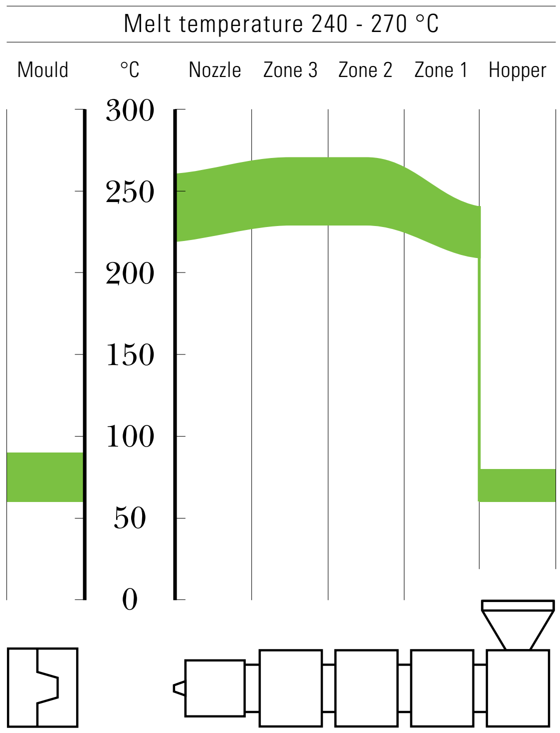


FIGURE 29

Typical moulding temperatures for Cycoloy injection moulding:

non-flame retarded
medium heat

- C1100
- C1100HF
- C1100A
- LG9000

flame retarded
high heat

- C2100HF

drying: 95-105°C

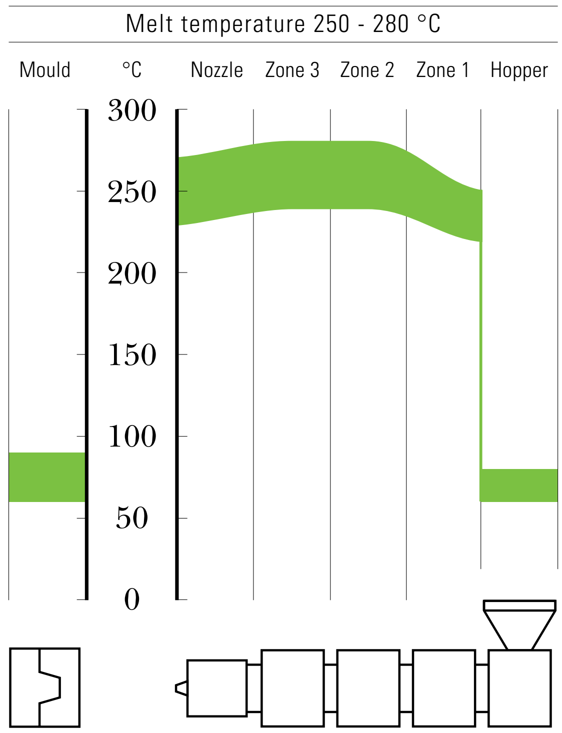


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FIGURE 30

Typical moulding temperatures for Cycoloy injection moulding:

non-flame retarded
high heat

- C1200
- C1200HF
- C1200HFM

drying: 100-110°C

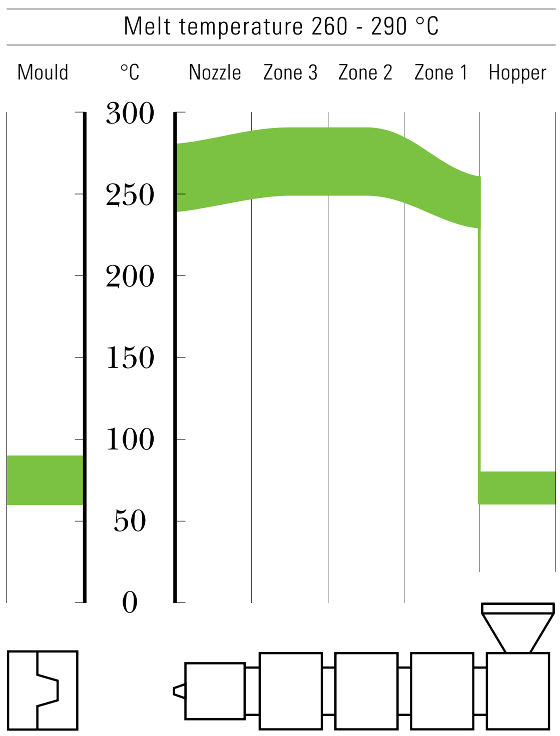


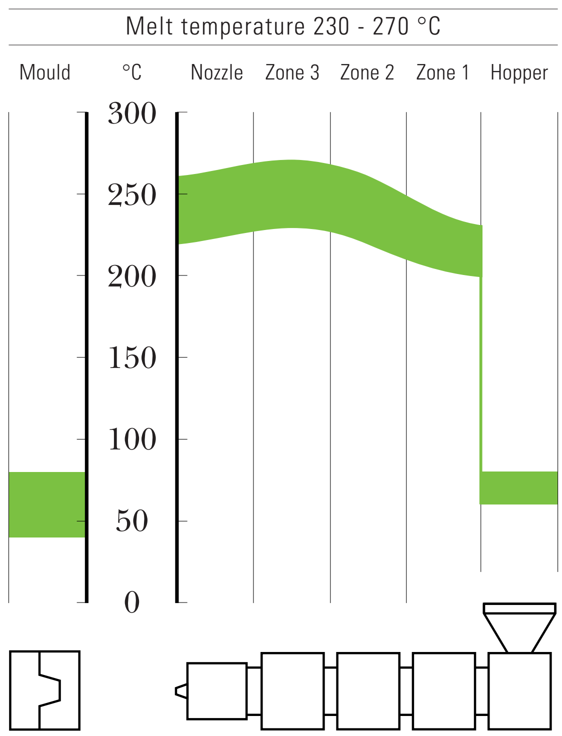
FIGURE 31

Typical moulding temperatures for Cycoloy injection moulding:

flame retarded
low and medium heat

- C2800
- C2950
- C6200

drying: 80-90°C



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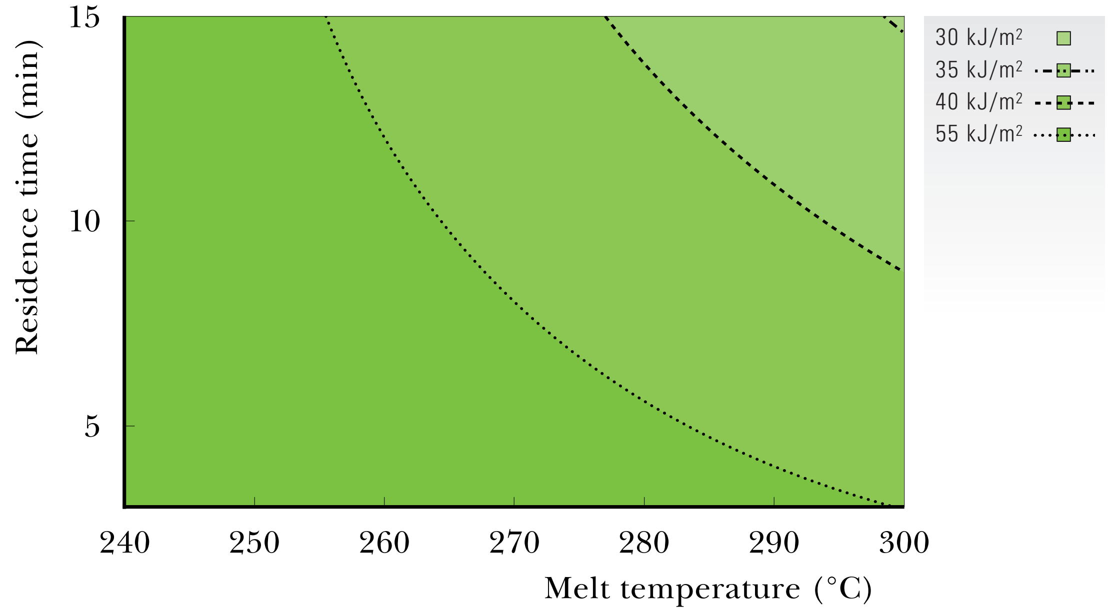
- The ■ FIGURES 32 and 33 show the Izod impact behaviour of Cycoloy® resin at different test temperatures as a function of melt temperature vs. residence time. From these graphs it is easy to determine an injection moulding processing window where the material maintains the mechanical and thermal properties it had as virgin material, and where processing conditions can be considered 'good'. In other words, safe operating guide-lines can be determined and the ductile/brittle transition can be estimated as a function of the injection moulding temperature and residence time.

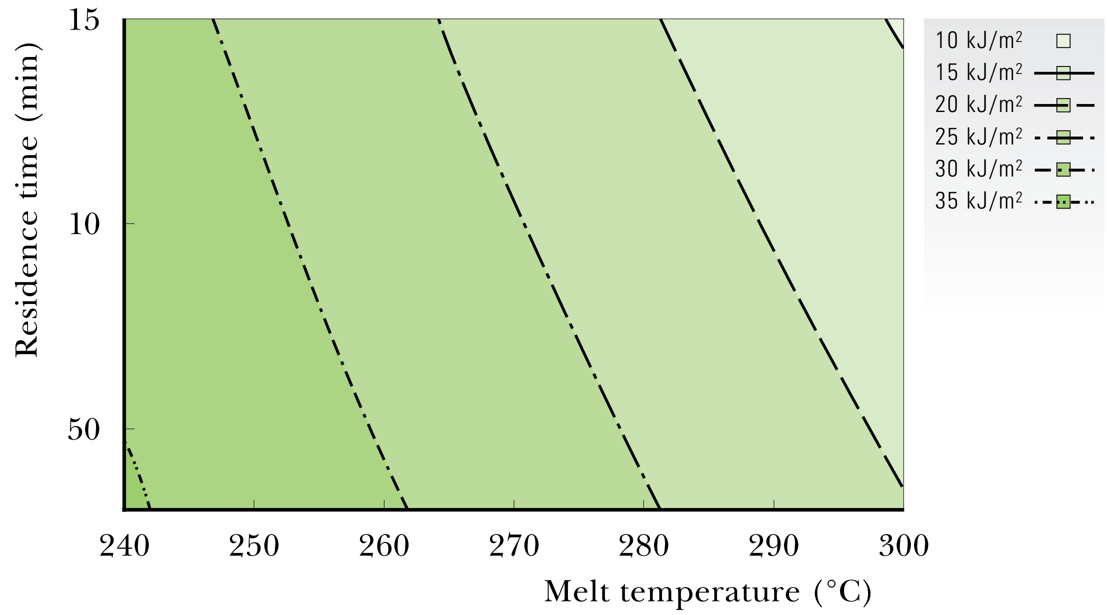
■ **FIGURE 32**

Izod Impact at 23°C of Cycoloy C1100HF as a function of injection moulding conditions



■ **FIGURE 33**

Izod Impact at -20°C of Cycoloy C1100HF as a function of injection moulding conditions



Shot capacity and residence time

Optimum results are obtained when the total shot weight is equal to 30% to 80% of the machine capacity. This includes all cavities, runners and sprues. Very small shots in a large barrelled-machine may create unnecessarily long residence times which may lead to resin degradation. If it is necessary to mould at the high end of the temperature range, a reduced residence time is required to lessen the possibility of material heat degradation. Therefore, for higher temperature moulding requirements, it is suggested that the minimum shot size is greater than 60% of the machine capacity.

The residence time is the total time the material is subjected to heat in the moulding machine. It is always calculated in relation to the melt temperature. The ideal residence time for Cycoloy® resin is between 4-8 minutes with a maximum of 12 minutes. A too long residence time can result in material degradation. A too short residence time, on the other hand, may cause moulding parameters to fluctuate, thereby reducing the plastification and the homogeneity of the material.
The residence time can be calculated by using the formula:

$$\text{residence time} = 8 \times \frac{\text{screw diameter}}{\text{plasticising stroke}} \times \text{cycle time}$$

Back pressure

A machine back pressure of 3-7 bar is recommended in order to improve melt quality and maintain a consistent shot size. If higher back pressures are used, this will result in higher melt temperatures and possible melt degradation.

Screw rotation speed

The screw surface speed is calculated by the formula:

$$\text{screw surface speed} = \frac{\pi \times \text{screw diameter} \times \text{rpm}}{60}$$

The screw speed (rpm) should be adjusted to allow screw rotation during the entire cooling cycle, without delaying the overall cycle. The recommended screw speed for Cycoloy® resin is dependent on the screw diameter but is in the range of 150-250 mm/s.

Suck back

The suck back stroke should be just enough to keep the resin in and the air out, to avoid melt degradation and subsequent moulding problems.

Screw cushion

A screw cushion of 3-7 mm is recommended, depending on the screw diameter.
The plasticising stroke (shot volume) should be adjusted accordingly.

Injection speed

Depending on part thickness, the fastest possible injection speed is desirable for Cycoloy® resin. Faster fill speeds provide longer flow, fill thinner wall sections and create a better surface finish. In thicker parts, however, slow fill speeds help to reduce voids.

Programmed injection is suggested for parts with small pin and submarine gates. A slow injection rate can be used at the start to eliminate gate blush, jetting and burning of the material.

Injection pressure

Holding pressures from 40% to 70% of the injection pressure are adequate for standard requirements. The actual injection pressure will depend on variables such as melt temperature, mould temperature, part geometry, wall thickness, flow length, and other mould and equipment considerations. Generally, the lowest pressures which provide the desired properties, appearance and moulding cycle are preferred.

Mould temperature

Cycoloy® resin should always be moulded in temperature-controlled moulds within the recommended temperature range of 60°C-90°C. Higher mould temperatures result in better flow, stronger knit-lines, lower moulded-in stress and higher gloss on polished parts. Using a lower mould temperature than that recommended will result in high moulded-in stress and will compromise part integrity.

5.1.3 Tooling and venting

Good mould venting is essential to prevent blistering or burning and to aid cavity filling. It is particularly important when selecting a fast injection speed. Ideally the vents should be located at the end of the material flow paths.

There is a wide variety of hot and cold runner systems available in the market. Careful attention is required in the selection of an appropriate melt delivery system.

5.1.4 Interruption of production

When the moulding cycle is interrupted, the following steps are recommended. Cycoloy® resins may be held in the barrel for a period of 10-15 minutes without purging. As with other engineering resins, air shots should be taken every 15 to 20 minutes to prevent melt degradation and to reduce problems in start-up.

For long-term interruption of the moulding cycle, of more than 15 minutes, it is recommended to purge the barrel, as explained below.

5.1.5 Purging of the barrel

With long-term interruption of the moulding cycle, it is recommended to purge the barrel using the standard shut-down procedure:

- Close the hopper feed slide and continue to mould on cycle until the screw does not retract.
- Eject the remaining material.
- Leave the screw in the forward position with the barrel heaters switched off.
- Reduce black speck contamination during moulding start-up by banking the heaters at 160°C for up to two days. The screw should be in the forward position.
- Standard ABS, PMMA, PC and SAN are the best purging agents for Cycoloy® resin. The cylinder may be purged at the processing temperature which should then be lowered gradually until it reaches 200°C.

In cases where carbonised material may be still present in the barrel/screw, purging agents like GE Plastics' Kapronet® can be used.

It is important to have adequate ventilation during the purging process.

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5.1.6 Recycling

If the application permits the use of regrind, reground sprues, runners, and non-degraded parts may be added to virgin Cycoloy® resin pellets up to a level of 25%. It is important to keep the ground parts clean and to avoid contamination from other materials. The pre-drying time for regrind Cycoloy® resin should be increased since moisture uptake will be different to that of virgin material.

Regrind utilization may produce a slight change in colour. It should not be used in applications where impact performance, a high quality surface and/or agency compliance are required.

5.2 Thin-wall moulding

In the electronics market, applications such as mobile phones and lap-top computers, with a wall thickness below 1.2 mm and a flow length: wall thickness (L:T) ratio of 100:1 are becoming commonplace. Ongoing product developments will reduce wall thickness still further while increasing the L:T ratio to as high as 200:1.

Thin-wall moulding with Cycoloy® resin allows manufacturers to optimise product differentiation and productivity, while retaining good mechanical properties such as impact and knit-line strength. Product differentiation can be achieved by thinning down the wall thickness to allow more space for internal components. Design freedom can be increased by introducing thin-wall technology. For example, parts can be designed with a wall thickness:rib ratio of 1:1 in some areas.

Productivity can be enhanced because 60% of the traditional injection moulding cycle time consists of cooling the part down for ejection out of the

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mould. The theoretical cooling time decreases exponentially in relation to the decreasing wall thickness. A reduction in the total injection moulding cycle increases effective capacity which consequently reduces investment costs. However, processors as well as designers need to be aware that successful thin-wall moulding requires critical tooling, special machinery, precision moulding and proper material selection. It is important to note that, while these changes rarely occur without additional investment, the productivity benefits of reduced material usage, faster cycle times and greater yield will typically far outweigh the added costs which are quickly recovered.

5.2.1 Tooling and venting

When the injection speed and pressure are increased, proper surface heat management is required. The tool venting must be optimised to allow the rapid removal of air out of the tool to improve knit-line strength. Due to high injection pressures, high steel quality must be used to avoid breathing of the mould cavity. Mould coatings can be considered to reduce tool abrasion and to improve part release. Valve gates and hot runners can be used to reduce the shear rate caused by high injection speeds.

5.2.2 Injection moulding equipment

Processing requirements for thin-wall moulding Cycoloy® resin are different from conventional injection moulding with respect to the use of higher pressure and speed. A relatively higher clamping force (70-100 MPa) is recommended. The standard injection moulding machine must be provided with a piston accumulator for rapid screw acceleration to achieve fast injection times. High responding hydraulic valves are required to avoid overpacking the part and to allow fast switching over from the injection to the packing phase. Closed loop, microprocessor-controlled injection machinery must be equipped with a high injection pressure barrel which requires exact filling and packing to produce consistent quality parts.

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The shot size for thin-wall applications may be smaller than is typical with conventional injection moulding and so the risk of material property degradation may be increased through overly long residence times in the barrel. With significantly smaller shot sizes material throughput should be such that the resin does not sit in the drying hopper for extended periods of time. Therefore, hoppers of a suitable size or leveling switches installed in the hoppers should be used to match projected material throughput.

5.2.3 Processing conditions

With today's thin-wall applications, fill times of between 0.1-1 second are possible. If fill times are longer, the material will simply freeze-off before the cavity is filled and packed. To inject the material at sufficient speed, injection units may need to generate high pressure.

Melt temperatures used for these applications should not exceed the GE Plastics' recommended maximum. It is often tempting to exceed these temperatures in order to fill the cavity, but this can be counter-productive. Too high a melt temperature and/or too long a material residence time in the barrel will cause a loss of the material's physical properties and/or create aesthetic problems in the part.

As with conventional moulding, proper drying and consideration of material residence time and temperature in the barrel are required.

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5.3 Extrusion

5.3.1 Pre-drying

Cycoloy® resin must be thoroughly dried before extrusion to ensure optimum part performance and appearance. Target moisture content should be a maximum of 0.02% and drying times should not exceed 16 hours, in order to retain the best part properties. The time required to achieve sufficient drying varies from 2 to 4 hours, depending on the type of dryer. For non-flame retarded Cycoloy® grades the recommended drying temperature is 100°C-110°C and for flame retarded grades it is 90°C-100°C.

5.3.2 Equipment

- A desiccant dryer with a dew point of -30°C is recommended.
- A single screw extruder with an L:D ratio of 25:1 till 30:1 and a maximum compression ratio of 1:2.5 is recommended, even if twin screw extruders have been used successfully.
- The appropriate choice of mixing element will lead to the best results.
- Colour master batches are not recommended since some of them are sensitive to temperature. This is because a high compression ratio, a high shear rate or long residence times can cause brownish discoloration.

5.3.3 Processing

The recommended processing conditions for both flame retarded and non-flame retarded grades are summarized in ■ FIGURES 34 and 35.

Melt temperature

Best results will be obtained by starting-up with a mid-range melt temperature of 245°C.

■ FIGURE 34

Typical processing temperatures for Cycoloy extrusion/ blow moulding:

non-flame retarded

• C3100

drying: 90-100°C

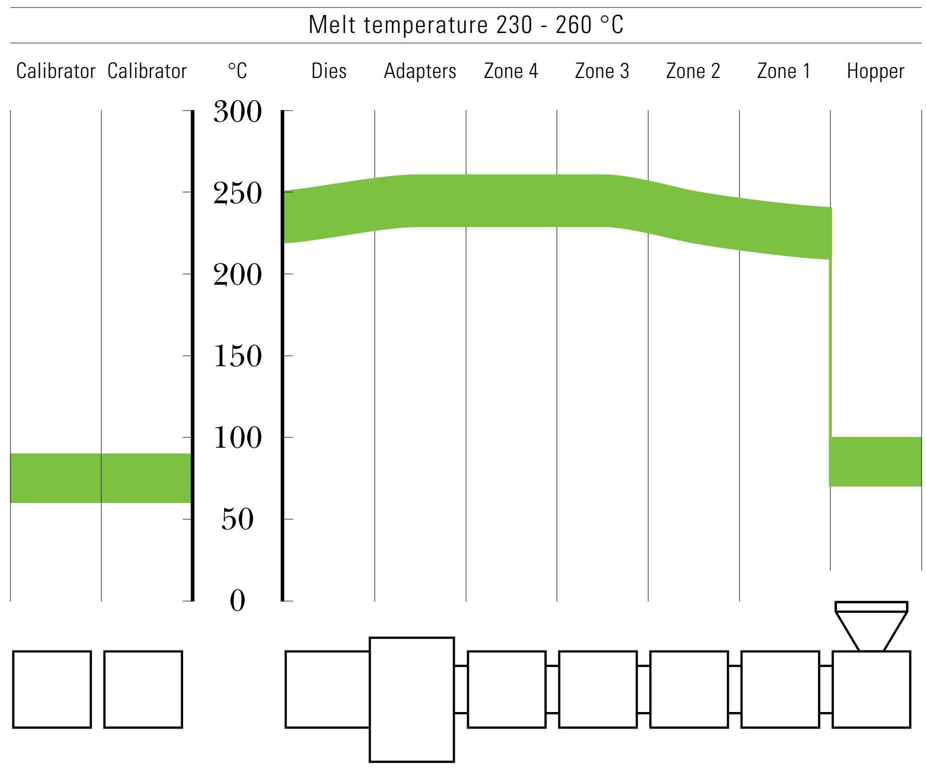


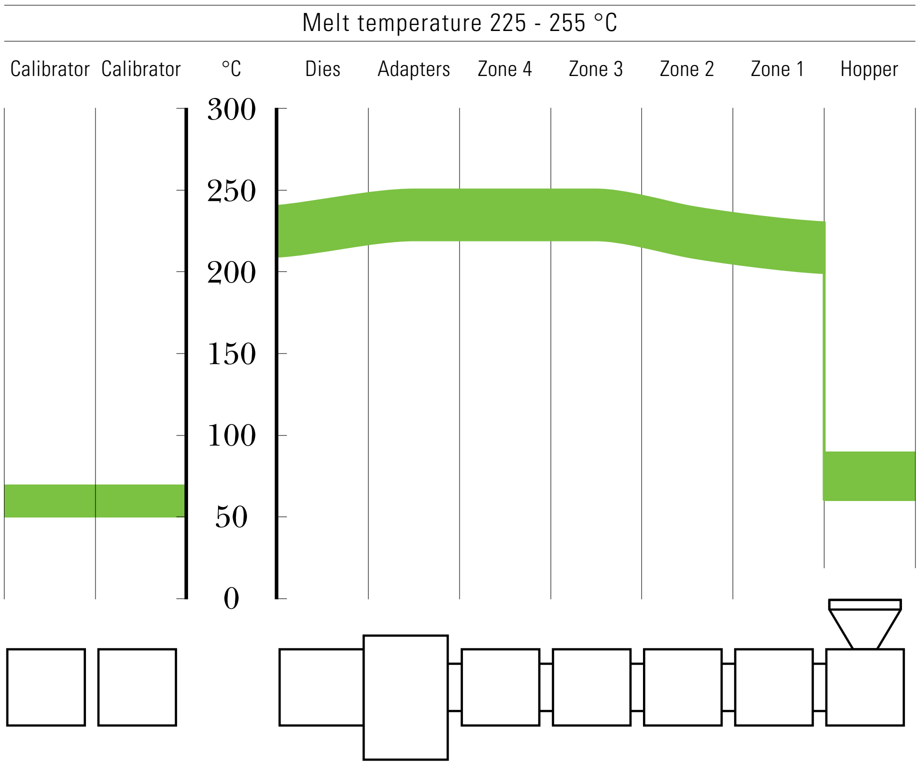
FIGURE 35

Typical processing temperatures for Cycoloy extrusion/ blow moulding:

flame retarded

- C3600
- C3650

drying: 90-100°C



5.3.4 Purging of the barrel

Standard ABS, PMMA, PC or SAN are recommended for cleaning the extruder. Commercially available purging agents such as GE Plastics' Kapronet® can be used, provided that they are compatible with the recommended temperature window.

5.3.5 Recycling

Please refer to section 5.1.6.

6 Secondary Operations

Most Cycoloy® parts, as finished components, may require machining, assembly or finishing operations. Cycoloy® resin makes a wide variety of secondary operations available to the design engineer.

6.1 Welding

Welding is a commonly used permanent assembly technique for engineering thermoplastics. Cycoloy® parts can be welded using different processes. Selecting the right process depends on the size, shape and function of the part:

- **Hot Plate Welding** allows excellent weld strengths to be achieved at temperatures of 260°C-300°C
- **Friction Welding** can be applied, using either the vibration, orbital or rotation method
- **Ultrasonic Welding** is commonly used, in particular for mobile telephone components. Welding amplitudes with 20 kHz ultrasonic processes should be in the range of 25-40 µm (0-peak)

6.2 Adhesives

Cycoloy® resin parts can be bonded to other plastics, glass, aluminium, brass, steel, wood and other materials. A wide variety of adhesives can be used, sometimes with the addition of a suitable primer (see TABLE 3). In general, Cycoloy® parts can be easily solvent bonded to parts made from Cycoloy®, Cycolac® ABS or Lexan® polycarbonate with Methyl Ethyl Ketone (MEK) or in mixtures of MEK with Cyclohexanone, ideally 50:50.

TABLE 3

Compatibility of adhesives with Cycoloy resin

	Epoxy 2K	PUR 1K	PUR 2K	PUR hot melt reactive	MS polymer	Silicone 1K	Silicone 2K	Acrylic 2K	Cyano-acrylate
primer	no	yes	no	no	no	yes/no	no	no	no
aggressive	high T°	no	no	no	no	alkoxy	no	yes	yes

Cleaning parts

Thorough cleaning of Cycoloy® parts before bonding is essential in order to avoid part failure. All oil, grease, paint, mould releases, rust oxides, etc., must be removed by washing with solvents which are compatible with Cycoloy® resin. These solvents include isopropyl alcohol, heptane or a light solution of non-alkaline detergents. Bond strength is further improved by sanding, sand blasting or vapour blasting the bonding surfaces.

6.3 Mechanical assembly

Mechanical assembly techniques are widely used with Cycoloy® parts. To achieve optimum results, mechanical fasteners should be kept free from oil and grease. Depending on the type of fastener, a permanent stress or deformation is applied locally. Clamp forces should be controlled or distributed over a large surface area. This is in order to decrease local stresses in the part after assembly and to minimise the risk of loosening the fasteners through creep and relaxation. Notches in the design as well as notches resulting from mechanical fasteners should also be avoided.

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Recommended assembly techniques:

- Thread-forming screws rather than thread cutting screws are recommended. Screws with a flank angle of 30° are preferred for minimal radial stresses
- Inserts which leave low residual stresses can be used. Installation by heat or ultrasound are the preferred techniques. Press and expansion inserts produce high hoop stresses in bosses and should therefore be used with caution
- Snap fit assembly
- Rivets
- Staking

6.4 Painting

A wide variety of colours and textures can be applied to Cycoloy® using commercially available organic paints and conventional application processes. Painting is an economical means of enhancing aesthetics and providing colour uniformity.

Pre-treatment

- Handwashing the part with cleaning agents based on alcohol or aliphatic hydrocarbons or:
- Powerwashing the part with cleaning agents based on detergents dissolved in water. These detergents can be either acidic by nature, (pH 3-4), or neutral, (pH 8-9). Alkaline-based detergents (pH >11) should be avoided.

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Paint selection

Paint selection is determined by the desired decorative effect, specific functional needs and the application technique to be applied.

A variety of conventional and waterborne paints can be successfully applied to Cycoloy® resin. Generic types include:

- Acrylic
- Epoxy
- Polyester
- Polyurethane

Special coatings

- Acrylic-based coatings can be used in applications where only UV protection and moderate scratch resistance is required
- Coatings can be used to help minimise colour degradation
- Conductive coatings offer shielding against radio frequency interference (RFI) or electromagnetic interference (EMI)

Paint solvents

It is important that solvent formulations are carefully considered when selecting a paint for use with amorphous resins such as Cycoloy®. It should be stressed that it can be difficult to achieve an ideal match between solvent and substrate. Although it is generally difficult to give rules for balancing solvent mixtures, there are some basic guidelines. For example, strong solvent action can be balanced with a non-dissolving liquid like butanol or dipentene. Solvents with strong embrittlement effects, on the other hand, can be balanced by adding stronger dissolving solvents. It should be noted that lower boiling point solvents cause embrittlement effects more quickly.

The occurrence of stress cracking is a result of solvent action on the one hand and stresses in the part on the other. The level of stress in the part should be ideally below 5 MPa. This is achieved through optimal part and tool design and proper moulding procedures. In general, if stress levels are above 10 MPa, painting will become critical.

6.5 Metallisation

Properties usually associated with metals such as reflectiveness, abrasion resistance, electrical conductivity and decorative surfaces can be added to plastics through metallization.

Two commonly applied technologies are discussed here:

- Vacuum metallisation
- Plating

Vacuum metallisation

Vacuum metallization through Physical Vapour Deposition involves the depositing of an evaporated metal, mostly aluminium, on a substrate. To achieve evaporation, the pure metal is heated in a deep vacuum. To ensure a good result when using this method with Cycoloy® resin, a glow discharge pre-treatment is highly recommended.

After vacuum metallisation, the aluminium must be protected against environmental influences. This is because of the ultra-thin layer thickness combined with the reactive nature of aluminium to humidity. Most commonly this protection is provided through the application of a Plasil/Glipoxan top layer, (a silicone-based monomer layer which is applied in the vacuum), or a clear coat top layer.

In general, unreinforced Cycoloy® resin does not require a basecoat or lacquer primer layer before metallisation because of the good surface quality of Cycoloy® parts after moulding. However, in certain cases, application of a basecoat is recommended to enhance reflectiveness, in particular where a glass-filled Cycoloy® material has been specified.

In most cases a surface activation pre-treatment is required.
Cleaning with a cloth or solvents is not recommended because of the sensitivity to scratches that can be seen after metallization. The best method is to keep the mouldings clean and to metallize the parts as soon as possible after moulding, or to store them in clean containers.

Plating
This can be done by two methods. In the first method, electro plating, current is used to effect an electrolytic deposition of metals derived from a dissolved metal salt. Most frequently used metals include chrome, nickel or gold. Cycoloy® C1000A has been specifically developed for this process in applications such as water taps and shower heads.

The second method, electroless plating, is executed without the addition of current to the galvanic process. Electroless plating can be further divided into non-selective (double-sided) and selective (single-sided) plating.
For non-selective electroless plating, all over coverage, a pre-etch is generally required with Cycoloy® resin.

Selective electroless plating starts with selective application, masking, of a catalytic lacquer which seeds the surface to initiate a deposition of metal after immersion in a metal salt solution.
If only EMI shielding is required, an electroless copper layer of 1-2 μm is applied with a finish of electroless nickel.

Hot foil stamping
In this dry metallisation technique, the metal foil is impressed on the plastic surface with a heated die or rubber roll. Standard foils are available for use with Cycoloy® resin parts, but it is recommended to test each grade and new application for compatibility and melting point.

6.6 Laser marking

The laser marking of thermoplastics is a complex process. The differing demands of applications, together with a diverse range of materials, pigments and additives, as well as the equipment itself, provide a large number of variables. Through its advanced research and development programme, GE Plastics has gained valuable insight into the thermal, optical, mechanical and chemical processes which take place during laser marking. An important result of this has been the development of a broad tailor-made range of materials using proprietary combinations of pigments and additives.

Note
General information on Secondary Operations like welding, mechanical assembly, bonding, painting and metallisation of engineering thermoplastics can be found in the following GE Plastics brochures:
- Assembly guide
- Design guide
- Painting guide
- Metallisation guide

Addresses

- More information relative to this **Cycoloy® profile** can be found on:
  www.geplastics.com/resins/materials/cycoloy.html
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