SABIC
Innovative
Plastics™

Cycloy* PC/ABS resins

Cycloy
Product brochure

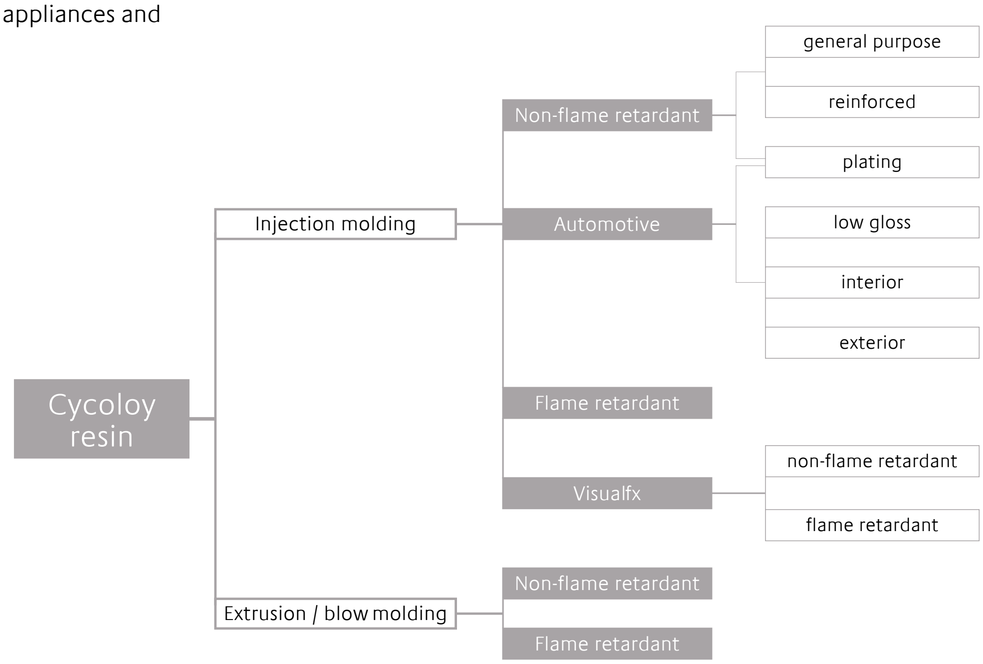
Sharing our futures

Cycoloy* resins are amorphous PC/ABS blends which combine the most desirable properties of both resins; the excellent processability of ABS and the superior mechanical properties and heat resistance of polycarbonate. Impact is maintained down to -30°C (-22°F) while heat resistance can be in the range of 95°C-140°C (203°F-284°F) (Vicat B120).

Cycoloy PC/ABS thermoplastic alloys

Cycoloy resin offers

- Various heat performance grades in a wide range of colors and Visual**fx***
- Excellent UV stability
- Chlorine/bromine-free flame retardancy (except C2100HF)
- Chrome plating applications
- Mineral reinforced grades
- Superior processability for injection molding, extrusion and blow molding processes Cycoloy resin 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.



Automotive

Business machines

Telecommunications

Electrical / Lighting

Appliances

Volvo V70 Cycoloy IP carrier made of Cycoloy resin

2.1 Automotive

With the balance of properties, superior impact strength, process robustness, paint ability, UV stabilization and chrome plating grades, Cycoloy* blends are proven in a range of interior and exterior automotive applications as instrument panels, pillar, bezel, grilles, interior and exterior trim.

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 behavior
- Excellent property retention after aging
- Aesthetic differentiation possible with Cycoloy Visual**fx*** portfolio

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 color range and quality aesthetics
- High flow for thin-wall molding
- Good ductility
- High dimensional stability
- Excellent processability; low juicing/plate-out
- Improved hydrolytic stability
- Wide color range and quality aesthetics via the Visual**fx*** offering

PalmIII™ by 3Com®

2.3 Telecommunications

Cycoloy* resin is recognised in the telecommunications industry as the material of choice for mobile telephone housings, accessories and smart cards (GSM SIM cards).

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 colors
- Decorability (IMD, earthtone and Visual**fx***, 2K molding, printing)
- Excellent processability
- High flow for thin-wall molding
- Improved platability
- High impact resistance/ductility also at subzero temperatures

Flame retardant Cycoloy resins are also established materials for indoor enclosures and battery chargers, where they offer
- Excellent UV stability
- Chlorine and bromine-free flame retardant grades (except C2100HF)
- Medium to high heat performance
- High dimensional stability
- Excellent processability

Siemens mobile phone made of Cycoloy resin

2.4 Electrical/Lighting

Cycoloy* resin grades for electrical applications have been specifically developed to meet industry standards but without resulting in over-engineered parts.

For a wide range of products, including injection molded electronic enclosures, electricity meter covers and cases, domestic switches, plugs and sockets and extruded conduits, the Cycoloy product family offers
- Wide range of chlorine and bromine-free flame retardant portfolio available
- High impact resistance/ductility
- Heat resistance in the range of 95°C to 140°C (203°F to 284°F) (Vicat B120)
- High tracking resistance
- A quality surface finish, high gloss or textured, in a wide range of colors and aesthetic finishes in the Cycoloy resin Visual**fx*** portfolio
- Excellent UV stability
- Excellent processability
- Compatibility with laser marking processes
- High dimensional stability
- Design flexibility for intricate molding with optimum integration possibilities
- Excellent flow for thin-wall designs

2.5 Appliances

The range of Cycoloy flame retardant and non-flame retardant 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
- Chlorine and bromine-free flame retardant grades (except C2100HF)
- High impact performance/ductility
- Inherent UV stability
- Medium/high heat performance
- Excellent processability
- Decorability with broad range of colors and aesthetic finishes in the Cycoloy resin Visual**fx** portfolio

3 Product selection

3.1 Product description

3.1.a Cycoloy* resin
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
- Visual**fx*** availability (FXC8XY Series)

3.1.b Cycoloy resin
C2000 series
- Standard core FR product series with various FR systems for a wide range of applications
- Unreinforced flame retardant grades
- UL94V0/5V ratings

3.1.c Cycoloy resin
C3000 series
- Blow molding and extrusion grades
- Multi purpose and flame retardant grades
- DIN VDE 0604 compliant (C3650)

3.1.d Cycoloy resin
C6000 series
- Flame retardant grades with high flow, thin wall together with balance of impact and processing robustness
- UL94V0/5V ratings
- Chlorine/bromine-free flame retardancy
- Visual**fx** availability (FXC6XY Series)

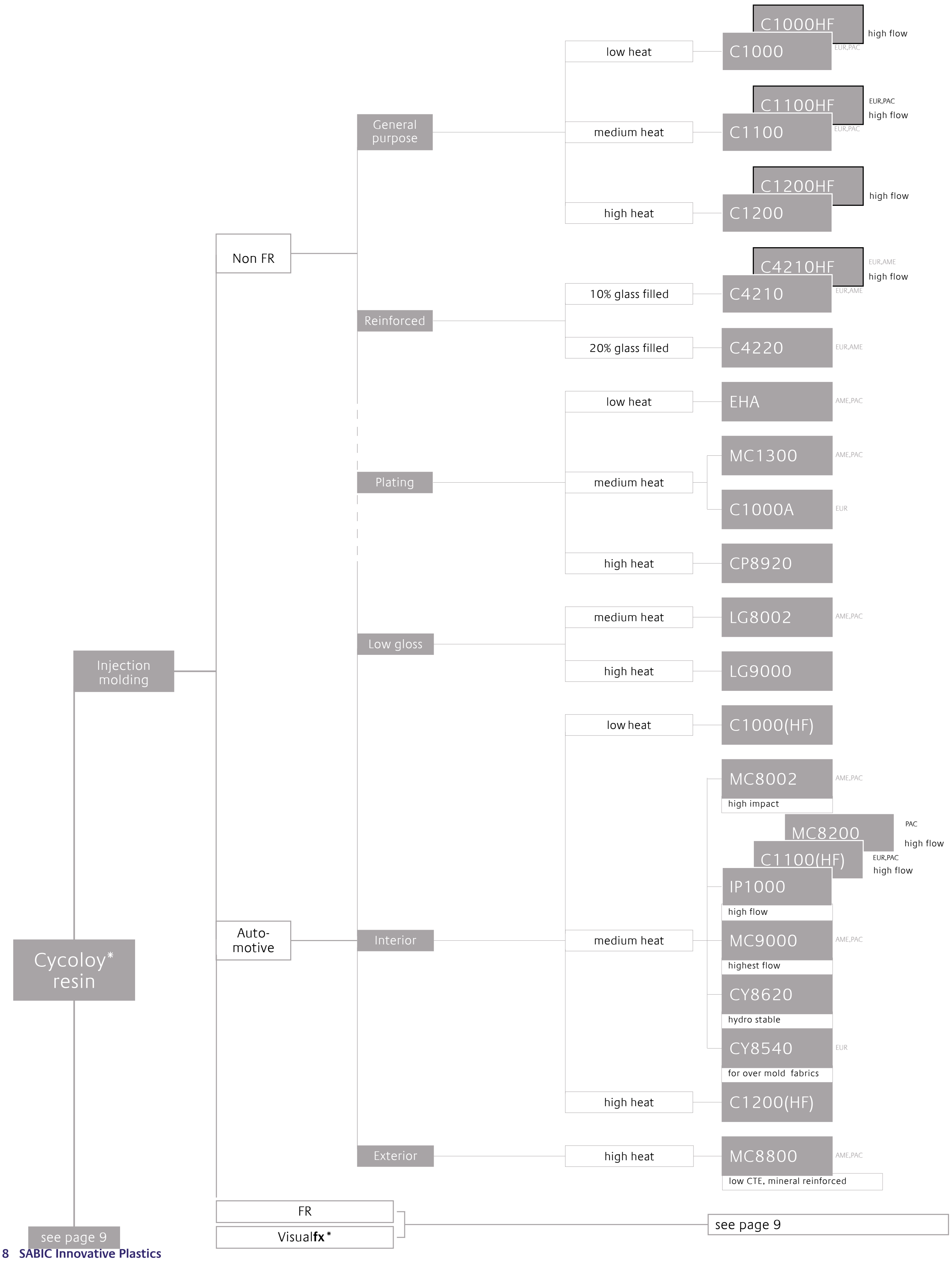
3.1.e Cycoloy resin
Visualfx grades

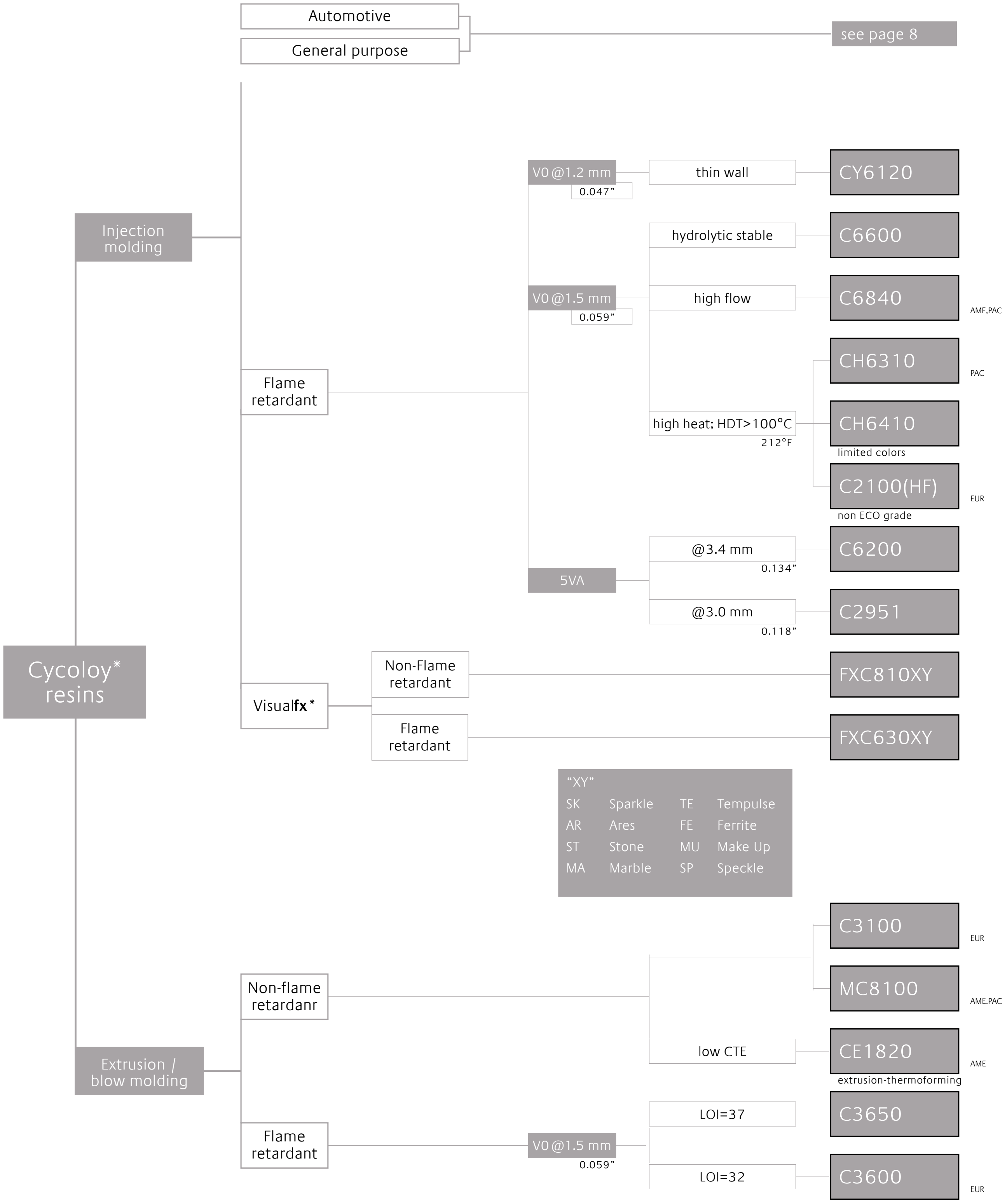
The Cycoloy Visual**fx** portfolio consists of two major families of colors and special effects, backed by a range of dedicated services. Available in a broad spectrum of product performance are
- Earth tones like Speckle, Marble and Stone
- Magix metallic materials including Sparkle, Ares, Make up and Ferrite

Using standard processing equipment, Cycoloy Visual**fx** materials provide parts with a consistently high quality surface finish straight from the mold. Furthermore, in many cases the range of special effects eliminates the need for secondary operations, such as painting, metalising or sublimation printing, providing cost-effective product differentiation.

As the aesthetic effects of Cycoloy will influence the properties of the final material and molding behavior may be affected, it is recommended that application testing is carried out.

SABIC Innovative Plastics offers customers a full range of processing and design support.


Cycoloy* resin
Injection molding
Non FR
General purpose
low heat
C1000
C1000HF
EUR,PAC
high flow
medium heat
C1100
C1100HF
EUR,PAC
EUR,PAC
high flow
high heat
C1200
C1200HF
high flow
Reinforced
10% glass filled
C4210
C4210HF
EUR,AME
EUR,AME
high flow
20% glass filled
C4220
EUR,AME
Plating
low heat
EHA
AME,PAC
medium heat
MC1300
AME,PAC
C1000A
EUR
high heat
CP8920
Low gloss
medium heat
LG8002
AME,PAC
high heat
LG9000
Auto-motive
Interior
low heat
C1000(HF)
medium heat
MC8002
AME,PAC
high impact
MC8200
PAC
high flow
C1100(HF)
EUR,PAC
high flow
IP1000
high flow
MC9000
AME,PAC
highest flow
CY8620
hydro stable
CY8540
EUR
for over mold fabrics
high heat
C1200(HF)
Exterior
high heat
MC8800
AME,PAC
low CTE, mineral reinforced
FR
Visualfx*
see page 9
see page 9


Cycoloy* resins
Injection molding
Automotive
General purpose
see page 8
Flame retardant
V0 @1.2 mm
0.047"
thin wall
CY6120
V0 @1.5 mm
0.059"
hydrolytic stable
C6600
high flow
C6840
AME,PAC
high heat; HDT>100°C
212°F
CH6310
PAC
CH6410
limited colors
C2100(HF)
EUR
non ECO grade
5VA
@3.4 mm
0.134"
C6200
@3.0 mm
0.118"
C2951
Visualfx*
Non-Flame retardant
FXC810XY
Flame retardant
FXC630XY
"XY"
SK Sparkle
AR Ares
ST Stone
MA Marble
TE Tempulse
FE Ferrite
MU Make Up
SP Speckle
Extrusion / blow molding
Non-flame retardanr
C3100
EUR
MC8100
AME,PAC
low CTE
CE1820
AME
extrusion-thermoforming
Flame retardant
V0 @1.5 mm
0.059"
LOI=37
C3650
LOI=32
C3600
EUR

4.1 General properties

Cycloy* resins are high impact, amorphous thermoplastic alloys which combine the processability of ABS together with the superior mechanical properties, impact and heat resistance of polycarbonate.

A broad, high performance property profile has established Cycoloy resin 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 (-22°F) while heat resistance can be in the range of 95°C-140°C (203°F-284°F) (Vicat B120).

4.2.a 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.

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 figure 1. 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 using the Young's modulus Y, then the stiffness of the part should be recalculated using the secant modulus Y*, as shown in figure 2.

Figure 1
Stress-strain curve of non-flame retardant Cycoloy resin at room temperature

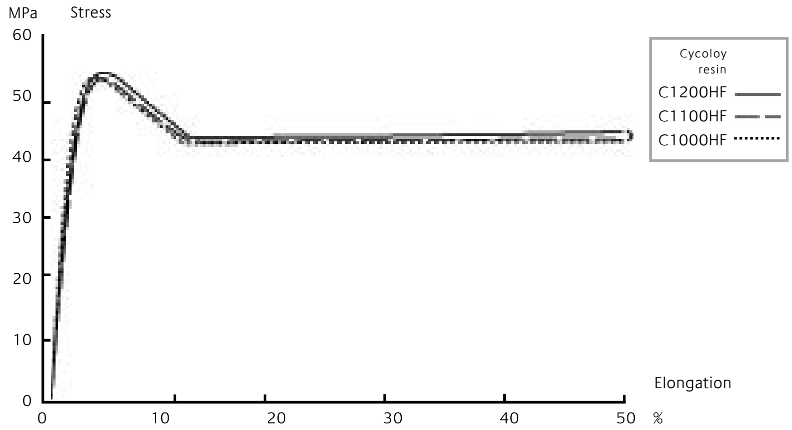
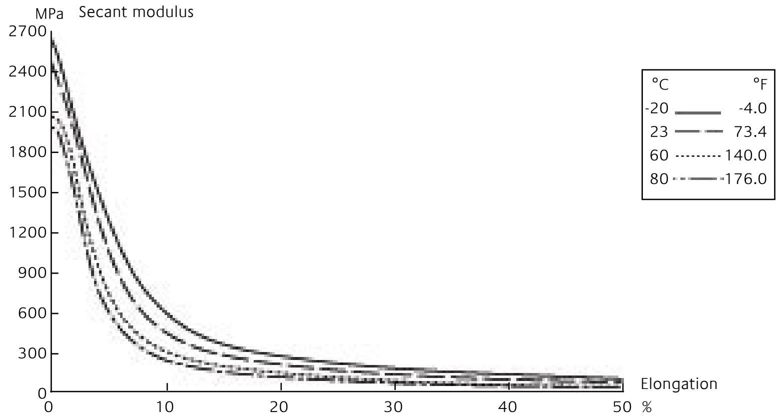


Figure 2
Secant modulus curve of Cycoloy resin C1100HF



A further important consideration in the calculation of part stiffness is the temperature at which the load is applied.

As can be seen in figure 3, the stress/strain curves of thermoplastics are strongly influenced by temperature. therefore, it is recommended calculating the stress/strain curve at the temperature at which the load is to be applied in actual use.

4.2.b Strength

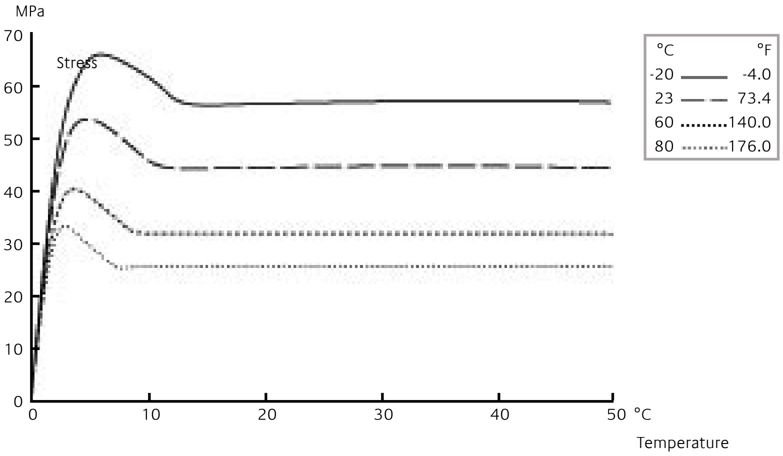
The strength of a part is defined as the maximum load that can be applied to a part without causing part failure under given conditions. In order to be able to determine the strength of a part, failure has to be first defined. The right definition of failure depends on the application and how much deformation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

■ Figure 3
Stress-strain curve of Cycoloy resin C1100HF (ISO 527) ASTM shows the similar trend



4.2.c 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.

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

For ductile polymers such as Cycoloy* resin, the load at which yield occurs in a part is mainly affected by the last two factors. Of even more significance to design is the fact that, under the appropriate circumstances, the impact behavior of a ductile material will undergo a transition from a ductile and forgiving response to a brittle and catastrophic one.

Usually this change in behavior is described in terms of a ductile/brittle transition, as illustrated in figures 4, 5, 6, 7, 8 and 9 (see page 12 for figures 6, 7, 8 and 9).

Figure 4
Effect of temperature upon impact response

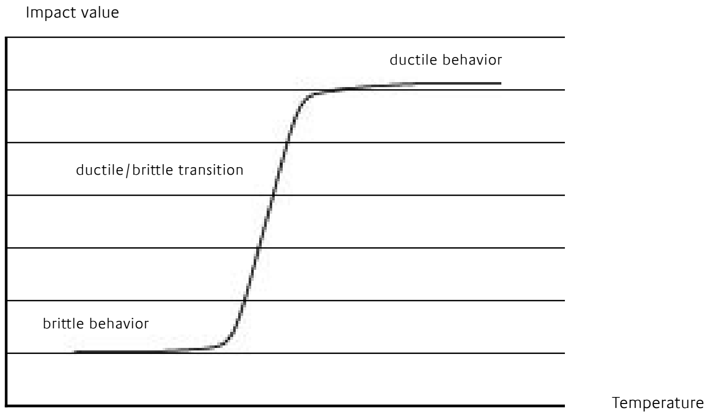
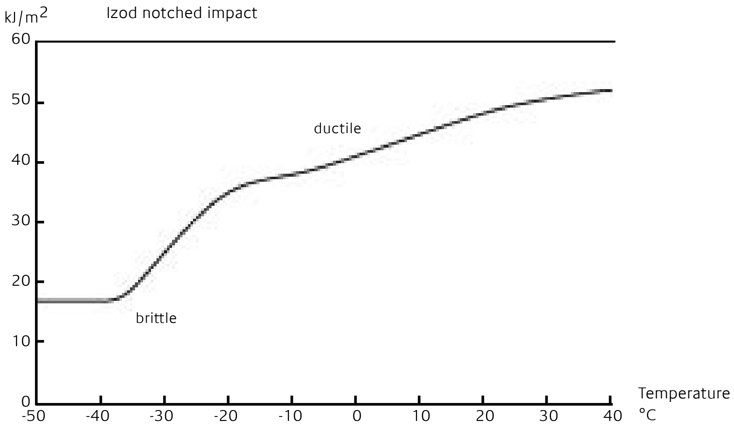
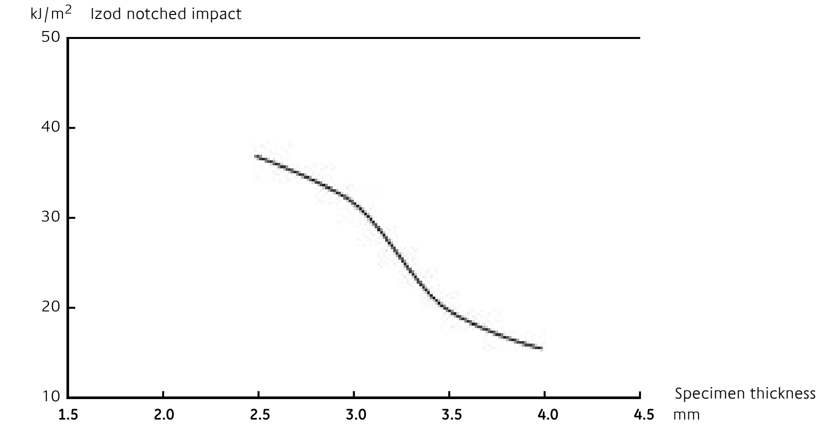


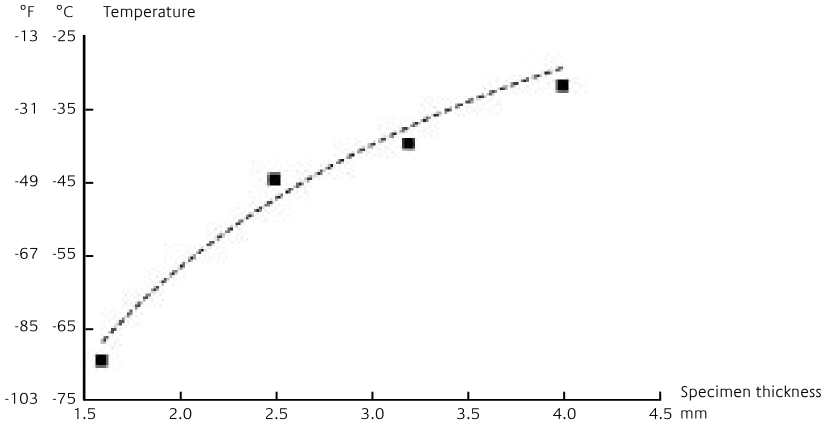
Figure 5
Izod notched impact of Cycoloy resin C1100HF at 4 mm (ISO 180/1a) ASTM shows the similar trend



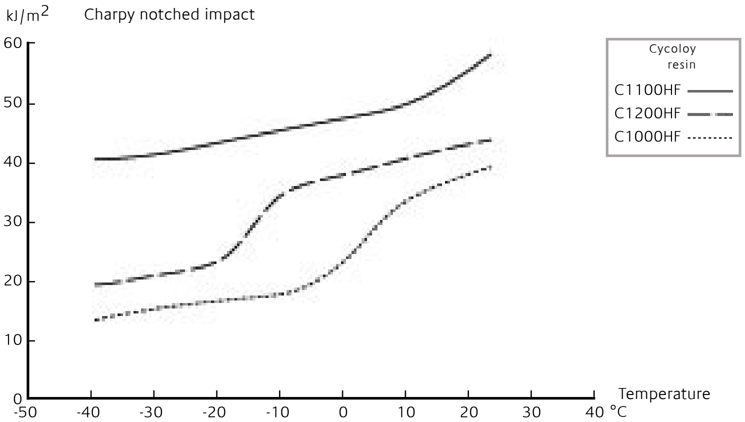
■ **Figure 6**
Izod notched impact of Cycoloy* resin C6200 as a function of thickness



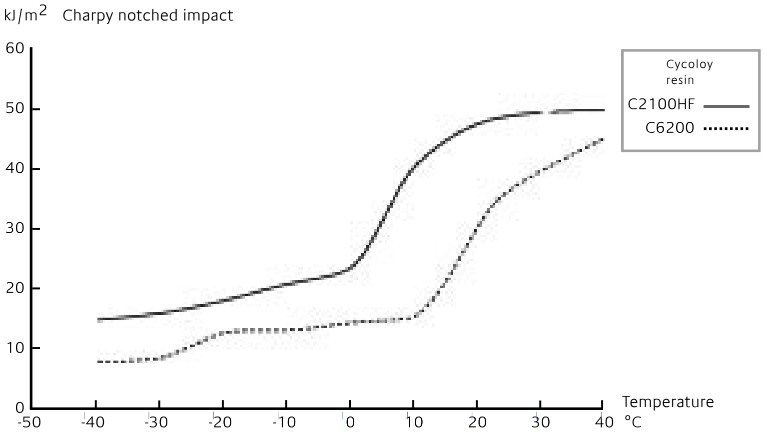
■ **Figure 7**
Ductile-brittle transition temperatures for Cycoloy resin C1100HF for different thicknesses



■ **Figure 8**
Charpy notched impact of non-flame retardant Cycoloy resin at 4 mm (ISO 179/1a)



■ **Figure 9**
Charpy notched impact of flame retardant Cycoloy resin 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 molded and subjected to the impact test. Examples of the various tests include Izod, Charpy, Tensile, Falling Dart and Flexed Plate.

Figure 10 shows 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.

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.

4.2.d Behavior 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 behaviors are heavily influenced by the operating environment and component design.

Creep behavior

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

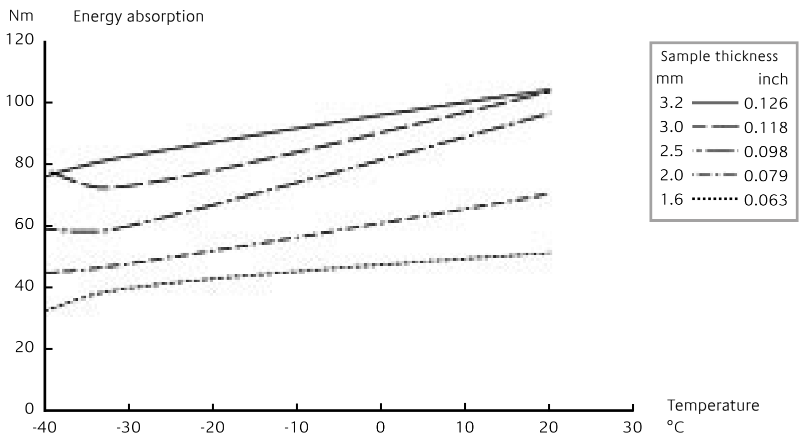
Creep is defined as the increasing rate of deformation of a geometrical shape when subjected to a constant load over a defined period of time. The creep rate for any material is dependent on temperature, load and time.

Creep behavior 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.

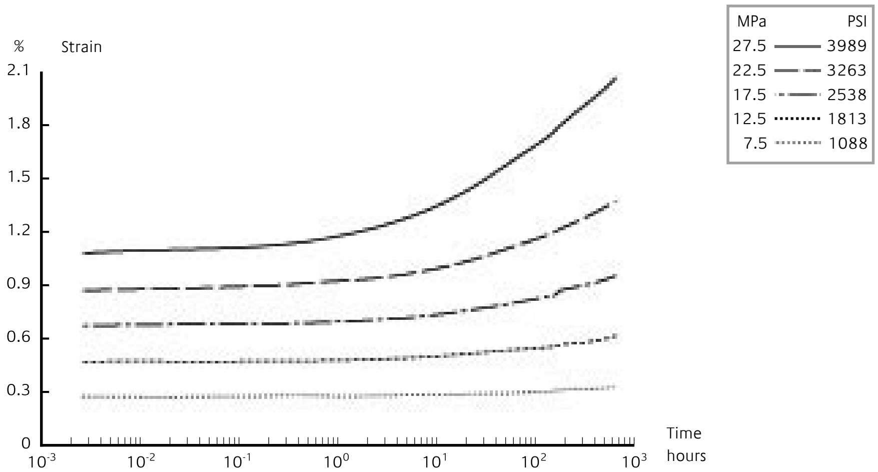
As shown in figure 11, the creep behavior of Cycoloy* resin increases in direct proportion to the applied force but varies greatly with temperature, as illustrated in figure 12 (see next page).

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 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'.

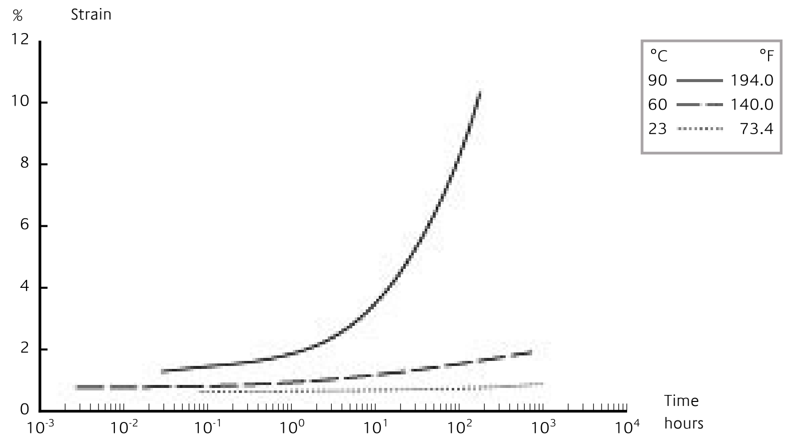
■ **Figure 10**
Instrumented puncture test energy absorption of Cycoloy* resin C1200HF (ISO 6603-2) ASTM shows the similar trend



■ **Figure 11**
Creep performance of Cycoloy resin C1000 at room temperature ASTM shows the similar trend



■ **Figure 12**
Creep performance of Cycoloy resin C1100 at 15 MPa (2175 PSI) (ISO)



Fatigue endurance

Structural components subjected to vibration, components subjected to repeated impacts, reciprocating mechanical components, plastic snap-fit latches and molded-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 13, could be used to predict product life. These curves can be used to 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.

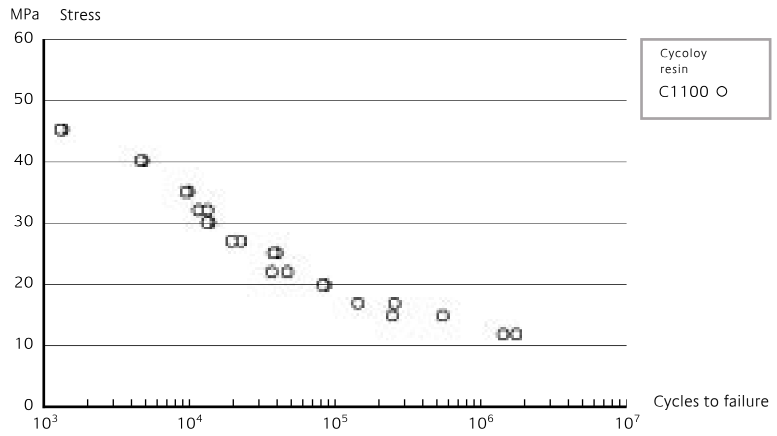
However, fatigue testing can only provide an indication as to a given material’s relative ability to survive fatigue. It is therefore essential that tests are performed on actual molded components, under actual end-use operating conditions.

4.3 Mold shrinkage

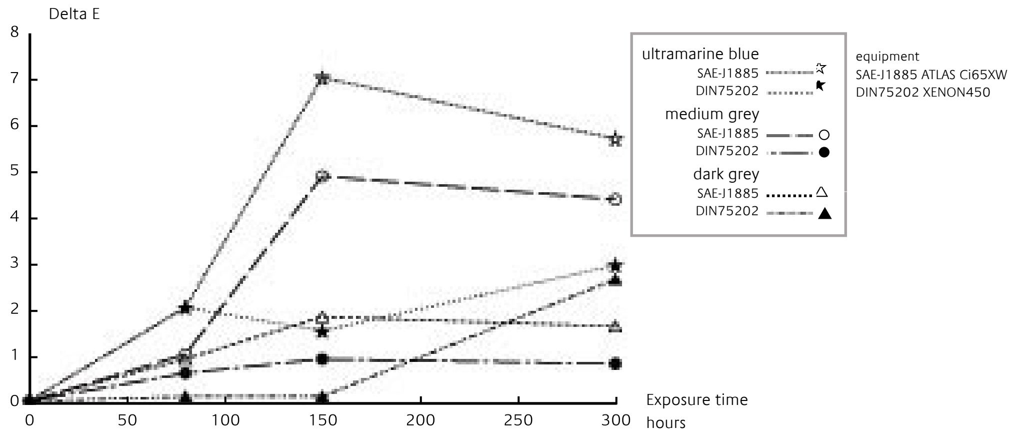
Mold shrinkage refers to the shrinkage that a molded part undergoes when it is removed from a mold and cooled at room temperature.

Expressed as an average percentage, mold shrinkage can vary considerably depending on the mold geometry, the processing conditions, the type of resin and the wall thickness.

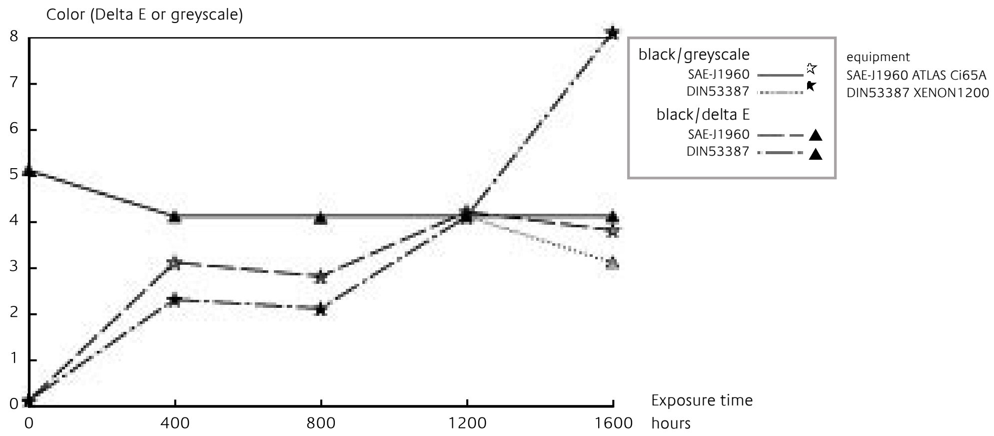
■ **Figure 13**
Fatigue performance of Cycoloy* resin C1100 at 23°C (73.4°F) and 5 Hz



■ **Figure 14**
UV performance of Cycoloy resin C1100



■ **Figure 15**
UV/weathering performance of Cycoloy resin C1100



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.

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

4.4 Environmental resistance

4.4.a 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 SABIC Innovative Plastics' polymers, while table 2 shows specific data for Cycoloy resins (see pages 16 and 17).

4.4.b
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.

4.4.c
Ultraviolet exposure

Cycoloy resin has been proven to be very succesful 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 14 and 15.

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

■ Table 1

Chemical compatibility of SABIC Innovative Plastics' polymers

	Amorphous						Semi-Crystalline			
	Lexan* resin	Cycoloy* resin	Cycolac* resin	Noryl* resin	Noryl Xtra resin	Ultem* resin	Xenoy* resin	Valox* resin		Noryl GTX* resin
Chemicals	**Remex*	Remex	Remex	Remex			Remex			
Hydrocarbons										
aliphatic	– / •	•	+	+	–	+	•	+	•	+
aromatic	–	–	–	–	–	++	– / •	+	+	+
halogenated-fully	– / •	•	–	–	–	+	–	– / •	–	+
halogenated-partly	–	–	–	–	n	–	–	–	– / •	•
Alcohols	+	n	+	+	+	+	+	+	+ / ++	+
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	+
Brake fluid (heavy alcohol)	n	–	–	+	+	–	++	+	n	+
Cleaners, Detergents	n	• / +	• / +	• / +	• / +	+	+	+	n	++
Water hot (< 80°C)	– / •	• / +	– / •	++	++	– / •	•	–	+	–
Environmental										
UV resistance*	• / +	• / +	• / +	•	– / •	• / +	+	•	– / •	–

Table 2

Chemical compatibility of Cycoloy* resin

Group	Chemical	Duration (hours)	C1000 Strain (%) 0	C1000 0.5	C1000 1	C1200 Strain (%) 0	C1200 0.5	C1200 1	C2100HF Strain (%) 0	C2100HF 0.5	C2100HF 1
Hydrocarbons											
Aliphatic	n-Heptane	1*	+	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	+	+	+	+	+	+	+	+	+
Iinorganic dilution	Hydrochloric, 10%	1	+	+	+	+	+	+	+	+	+
Organic concentrate	Acetic, 99.5%	1	+	–	–	+	–	–	+	–	–
Alkalis	Sodium Hydroxide sol., 32%	24	+	+	+	+	+	+	+	+	+
Automotive fluids											
Greases	Molycote MoS_2 grease	24*	+	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

* 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

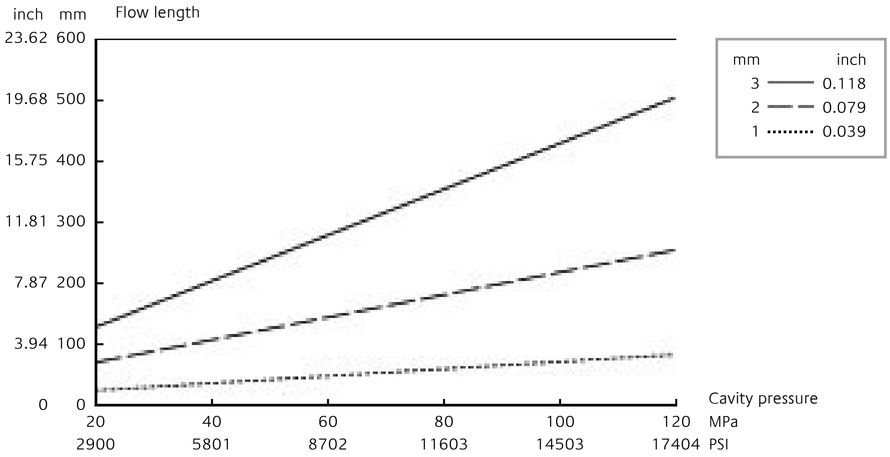
Ratings as shown are purely indicative. Finished part performance should always be evaluated on the actual part.

4.5 Viscosity

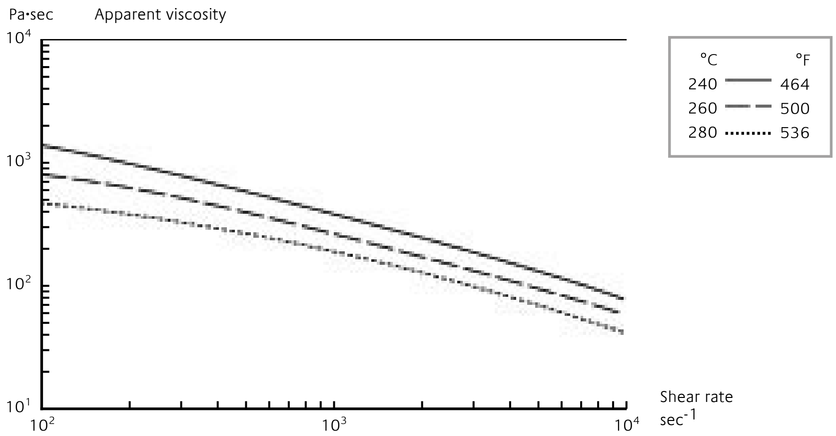
The viscosity of polymers is a key property for many processes in which plastics are treated before the final shape has been achieved. Injection molding, extrusion and blow molding are the most common conversion processes. The viscosity of a material determines its resistance to flow at a given melt 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 molding.

Computer software such as MoldFlow can help to calculate the filling characteristics of a material in a certain tool, as shown in figure 16. Calculations are made based on material characteristics such as viscosity (see figure 17), thermal conductivity and no-flow temperatures. The flow lengths of all SABIC Innovative Plastics' materials are given as calculated radial flow, based on the MoldFlow model.

■ Figure 16
Applied MoldFlows multi-layer module for radial flow of Cycoloy* resin C1100HF at 265°C (509°F)



■ Figure 17
Capillary melt viscosity of Cycoloy resin C1100HF (ISO 11443)



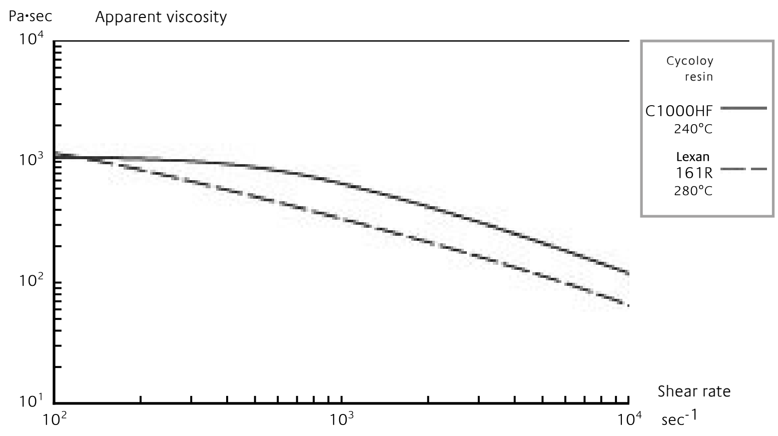
4.6 Shear properties

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).

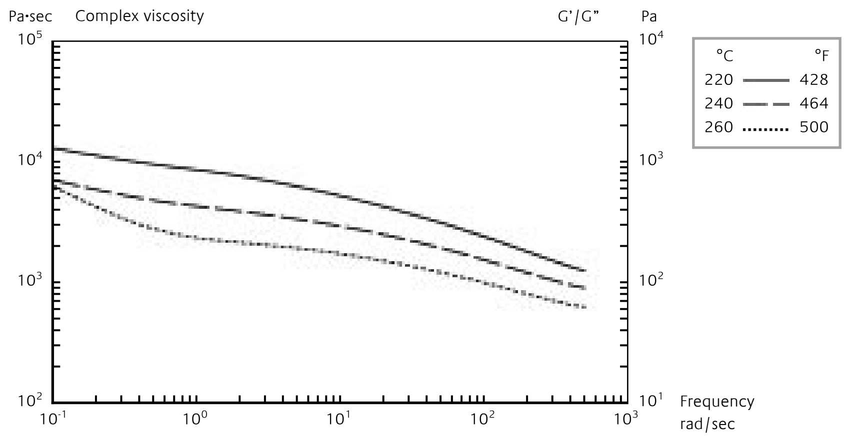
Cycoloy* resins demonstrate a more non-Newtonian behavior than Lexan* resins. This means that the viscosity of Cycoloy resin can be influenced by the shear rate in the high shear region, the MVR can be the same but the MV can be totally different, as shown in figure 18.

4.6.a 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 from 0.1 to 400 rad/s (see figure 19).



■ Figure 18
Capillary melt viscosity of Cycoloy resin vs. Lexan (ISO 11443)



■ Figure 19
Plate-plate melt viscosity of Cycoloy resin C3600 (ISO 6721-10)

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

5.1 Injection molding
5.1.a Equipment

Dryer
A closed loop, dehumidifying, re-circulating 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 molding machine.

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

Injection molding equipment
- Cycoloy resins can be molded on standard injection molding machines. When determining the size of equipment to be used for molding 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 molding machine with a throughput of 50 kg (110 lb) per hour would need a 200-kg (440 lb) 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 use

- 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 colors and flame retardant 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 (4350 PSI) to 70 (10150 PSI) 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 molding conditions will determine the actual tonnage required

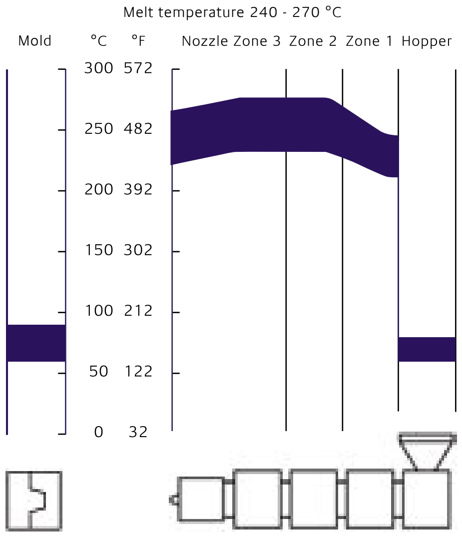


Figure 20
Typical molding temperatures for Cycoloy resin injection molding non-flame retardant low heat
- C1000
- C1000HF
- C1000A
drying 90-100°C (194-212°F)

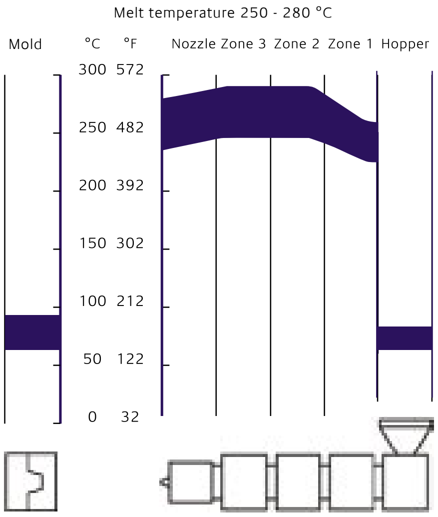


Figure 21
Typical molding temperatures for Cycoloy resin injection molding non-flame retardant
medium heat
- C1100
- C1100HF
- C1100A
- LG9000
flame retardant
high heat
- C2100HF
drying 95-105°C (203-221°F)

5.1.b 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 molding and helps to ensure optimum part performance and appearance. The recommended drying temperature range is 90°C- 110°C (194-230°F), 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 (-22°F), 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 (36°F) from the recommended drying temperature.

The time required to achieve sufficient drying varies from two to four 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

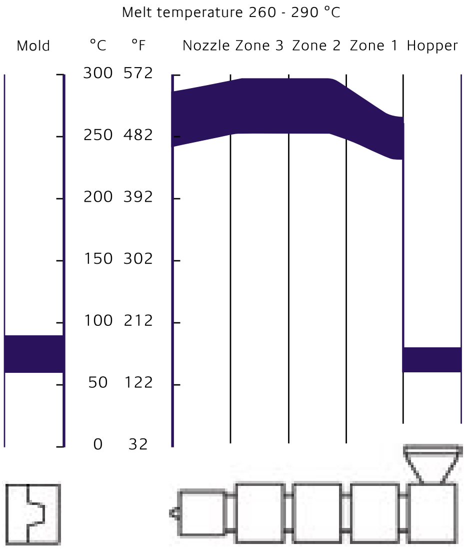
- Cycoloy resins have excellent thermal stability within the recommended melt temperature range, which is shown in figures 20, 21 (on page 20), 22 and 23

- 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

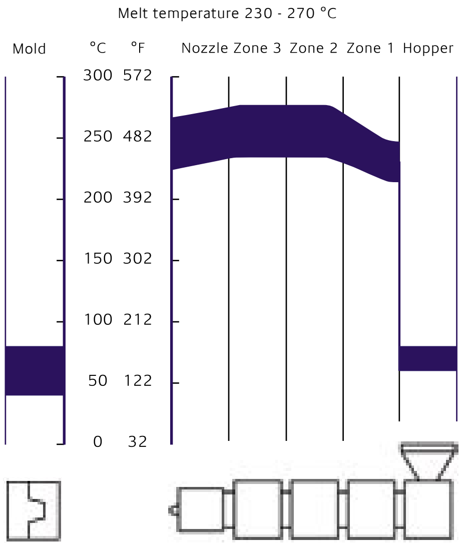
■ **Figure 22**
Typical molding temperatures for Cycoloy resin injection molding
non-flame retardant
high heat
- C1200
- C1200HF

drying 100-110°C (194-230°F)



■ **Figure 23**
Typical molding temperatures for Cycoloy resin injection molding
flame retardant
low and medium heat
- C6200

drying 80-90°C (176-194°F)



- 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

- Figures 24 and 25 show the Izod impact behavior 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 molding 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 guidelines can be determined and the ductile/brittle transition can be estimated as a function of the injection molding temperature and residence time

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 mold 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 molding 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 molding machine. It is always calculated in relation to the melt temperature.

The recommended residence time for Cycoloy resin is between four - eight 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 molding 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 three - seven 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 (5.9-9.84 inch/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 molding problems.

Screw cushion

A screw cushion of 3-7 mm (0.118"-0.276") 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, mold temperature, part geometry, wall thickness, flow length, and other mold and equipment considerations. Generally, the lowest pressures which provide the desired properties, appearance and molding cycle are preferred.

Mold temperature
Cycoloy resin should always be molded in temperature-controlled molds within the recommended temperature range of 60°C-90°C (140-194°F). Higher mold temperatures result in better flow, stronger knit-lines, lower molded-in stress and higher gloss on polished parts. Using a lower mold temperature than that recommended will result in high molded-in stress and will compromise part integrity.

5.1.c Tooling and venting
Good mold 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.d Interruption of production
When the molding cycle is interrupted, the following steps are recommended. Cycoloy resins may be held in the barrel for a period of 10 to 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 molding cycle, of more than 15 minutes, it is recommended to purge the barrel, as explained below.

5.1.e Purging of the barrel
With long-term interruption of the molding cycle, it is recommended to purge the barrel using the standard shut-down procedure

- Close the hopper feed slide and continue to mold 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 molding start-up by banking the heaters at 160°C (320°F) 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 (392°F)

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

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

5.1.f 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 color. It should not be used in applications where impact performance, a high quality surface and/or agency compliance are required.

5.2 Thin-wall molding

In the electronics market, applications such as mobile phones and lap-top computers, with a wall thickness below 1.2 mm and a flow lengthwall 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 molding 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 molding cycle time consists of cooling the part down for ejection out of the mold. The theoretical cooling time decreases exponentially in relation to the decreasing wall thickness. A reduction in the total injection molding cycle increases effective capacity which consequently reduces investment costs.

However, processors as well as designers need to be aware that successful thin-wall molding requires critical tooling, special machinery, precision molding 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.a 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 mold cavity. Mold 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.b Injection molding equipment

Processing requirements for thin-wall molding Cycoloy resin are different from conventional injection molding with respect to the use of higher pressure and speed. A relatively higher clamping force (70-100 MPa) (10150-14500PSI) is recommended. The standard injection molding 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.

The shot size for thin-wall applications may be smaller than is typical with conventional injection molding 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.c 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 SABIC Innovative 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 molding, proper drying and consideration of material residence time and temperature in the barrel are required.

5.3 Extrusion

5.3.a 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 two to four hours, depending on the type of dryer. For non-flame retardant Cycoloy resin grades the recommended drying temperature is 100°C-110°C (212-230°F) and for flame retardant grades it is 90°C-100°C (194-212°F).

5.3.b 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.
- Color 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.c Processing

The recommended processing conditions for both flame retardant and non-flame retardant grades are summarized in figures 24 and 25.

Melt temperature

Best results will be obtained by starting-up with a mid-range melt temperature of 245°C (473°F).

5.3.d Purging of the barrel

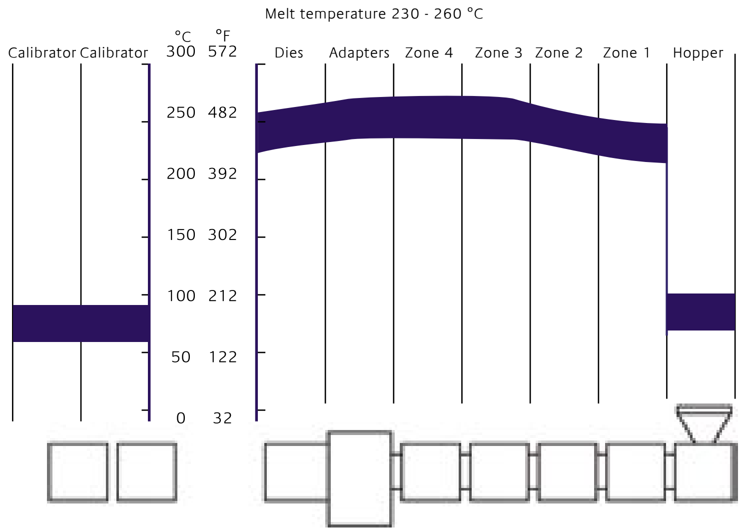
Standard ABS, PMMA, PC or SAN are recommended for cleaning the extruder. Commercially available purging agents such as SABIC Innovative Plastics' Kapronet* can be used, provided that they are compatible with the recommended temperature window.

5.3.e Recycling

Please refer to section 5.1.f.

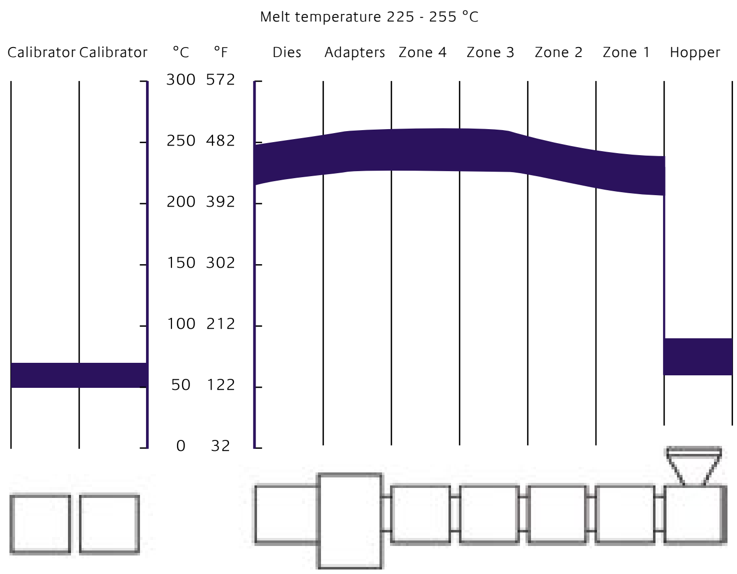
■ **Figure 24**
Typical processing temperatures for Cycoloy* resin extrusion / blow molding
non-flame retardant
- C3100

drying 90-100°C (194 - 212°F)



■ **Figure 25**
Typical processing temperatures for Cycoloy resin extrusion / blow molding
flame retardant
- C3600
- C3650

drying 90-100°C (194 - 212°F)



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 (516°F- 572°F)
- 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, aluminum, 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 resin parts can be easily solvent bonded to parts made from Cycoloy resin, Cycolac ABS or Lexan* polycarbonate with Methyl Ethyl Ketone (MEK) or in mixtures of MEK with Cyclohexanone, ideally 50:50.

Cleaning parts

Thorough cleaning of Cycoloy resin parts before bonding is essential in order to avoid part failure. All oil, grease, paint, mold 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 resin 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.

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

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

6.4 Painting

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

Pre-treatment

- Handwashing the part with cleaning agents based on alcohol or aliphatic hydrocarbons

- 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

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 color 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 resin. 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 (725 PSI). This is achieved through optimal part and tool design and proper molding procedures. In general, if stress levels are above 10 MPa (1450 PSI), painting will become critical.

6.5 Metalization

Properties usually associated with metals such as reflectiveness, abrasion resistance, electrical conductivity and decorative surfaces can be added to plastics through metalization. Two commonly applied technologies are discussed here

- Vacuum metalization
- Plating

Vacuum metalization

Vacuum metalization through Physical Vapour Deposition involves the depositing of an evaporated metal, mostly aluminum, 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 metalization, the aluminum must be protected against environmental influences. This is because of the ultra-thin layer thickness combined with the reactive nature of aluminum 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 metalization because of the good surface quality of Cycoloy resin parts after molding. However, in certain cases, application of a basecoat is recommended to enhance reflectiveness, in particular where a glass-filled Cycoloy resin material has been specified.

In most cases a surface activation pre-treatment is required. Glow discharge takes place in a vacuum vessel in the presence of a low pressure gas such as air. This method gives an increased surface energy and micro porosity to the Cycoloy resin part. Cleaning with a cloth or solvents is not recommended because of the sensitivity to scratches that can be seen after metalization. The best method is to keep the moldings clean and to metalize the parts as soon as possible after molding, 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* resin 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 metalization 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, SABIC Innovative 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 painting and metalization of engineering thermoplastics can be found in the following SABIC Innovative Plastics brochures
- Assembly Guide
- Design Guide
- Painting Guide
- Metalization Guide sabic-ip.com

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