TECHNICAL MANUAL

Divinycell® H



DIAB

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GENERAL INFORMATION

Introduction

For more than thirty years foam core materials have been the natural choice for building sandwich structures destined for service in the marine, wind energy and transportation markets. Very good mechanical properties and ease of processing combined with good thermal stability and a reasonable price have made them the material of choice for the vast majority of composite component manufacturers.

In recent years, however, 'traditional' wet lay-up processes have started to be replaced by more advanced manufacturing methods such as prepregs, resin infusion and RFI. All these processes require vacuum consolidation, often at elevated temperature or with high exotherm peaks due to the larger amount of laminate that is being consolidated at the same time.

This has put new demands on core materials to deliver better thermal stability and strength properties at elevated temperatures. In addition, irrespective of the chosen processing method, the composites industry is always looking to produce components and structures that are lighter and stronger than the previous generation.

The Next Generation of Core Materials

DIAB has responded to this challenge not only by considerably enhancing the performance properties of its popular Divinycell H grade, but has also developed a core material, designated Divinycell HP, that sets new standards in terms of processability and mechanical properties. DIAB has also added an entirely new core material to its range that offers excellent FST (fire, smoke and toxicity) properties coupled with good mechanical and processing characteristics. Designated Divinycell F, the new material has been developed primarily for commercial aircraft interior applications.

Divinycell cores provide an ideal balance between performance and cost. In addition to their high strength to weight ratios, they have excellent ductile qualities to make them ideal for a wide range of applications where impact or slamming loads are likely to be experienced. Other features include excellent peel strength and dimensional stability, high insulation properties, low water absorption and good chemical resistance.

Divinycell Grades

Divinycell is available in a variety of grades and densities to match a broad range of application performance requirements. Divinycell cores are compatible with virtually all resin systems and the majority of composite manufacturing processes and are approved by all major classification societies.

Divinycell H Grade –
All purpose grade, suitable for the vast majority of composite applications.

GENERAL INFORMATION

Divinycell Grades

Divinycell HP Grade –
Elevated temperature grade, developed to be fully compatible with low and medium temperature prepreg systems.

Divinycell F Grade –
Divinycell F is an ultra low FST (fire, smoke and toxicity) and high temperature core material specifically developed for commercial aircraft interior applications.

Divinycell P Grade –
Divinycell P is a recyclable, thermoplastic sandwich core material that is typified by excellent FST (fire, smoke & toxicity) properties and a wide processing envelope.

Divinycell HT Grade –
Aerospace prepreg grade. It is suitable for a very wide range of structural and non-structural applications including aircraft interiors.

Divinycell HCP Grade –
Buoyancy grade, which offers excellent hydraulic compressive properties, developed to meet the demand for a light weight, high-performance buoyancy material.

Standard & Special Finishing

All Divinycell grades can be supplied with a wide range of standard and custom finishes to facilitate installation, enhance component quality and for specific processes such as DIAB Core Infusion™. These include: grid scoring, grooving, perforating and double contouring.

Ready-Made Kits

For those involved in series production, Divinycell core materials can be supplied in ready-made construction kits where each piece is pre-cut, shaped as necessary and numbered to fit exactly into its designated place in the mold. This substantially reduces build times, saves labor costs, improves quality and cuts waste.

The DIAB Sandwich Concept

The DIAB Sandwich Concept is a proven construction technique that combines low weight with exceptionally high strength thereby making it ideal for a wide range of applications in the marine, wind energy, transportation and industrial markets.

A sandwich consists of two high strength skins or facings separated by a core material. The skins take up the bending stresses and give the structure a hard wearing surface. The light DIAB core absorbs the shear stresses generated by loads and distributes them over a larger area.

GENERAL INFORMATION

The DIAB Sandwich Concept

Compared to monolithic composite laminates or metals, the sandwich concept significantly reduces weight and increases stiffness while maintaining strength. Even higher strength and stiffness properties can be achieved by increasing the thickness of the core without a weight penalty.

The excellent strength-to-weight ratio of the sandwich concept can be used in a variety of ways – higher speeds, longer range, greater payload capacity or reduced power demand – all of which result in better operating economy.

Divinycell sandwich composites require minimum maintenance and should any repairs be necessary, they can be carried out easily without any loss of structural integrity.

For further information see the DIAB Sandwich Handbook.

DIAB - Much More Than a Core Materials Manufacturer

DIAB has pioneered the use of the sandwich concept to make structures that are significantly lighter and stronger than those made from steel, aluminum and wood. The company is very much the technology leader.

In addition to being the first company to introduce core kits, it has been in the vanguard of new environmentally-friendly processing developments such as DIAB Core Infusion™.

DIAB has always been much more than just a materials supplier. It establishes long-term partnerships with customers by providing high performance core materials and an extensive range of technical support services.

DIAB Technologies

DIAB Technologies partner and help customers to take full advantage of the benefits of the DIAB Sandwich concept. Their aim is to maximize time, labor and materials savings and improve quality while at the same time foresee and eliminate potential problems.

With their unique, long term experience and intimate knowledge of sandwich composites and their application, they can help customers with specific challenges or be involved in the complete product development cycle – design, engineering, prototyping, process development, training and manufacture.

PRODUCT INFORMATION

Divinycell H - All Purpose Grade

Divinycell H has been widely used over many years in virtually every application area where sandwich composites are employed. These include the marine (leisure, military and commercial), land transportation, wind energy, civil engineering/infrastructure and general industrial markets.

Divinycell H is compatible with virtually all commonly used resin systems (polyester, vinyl ester and epoxy) including those with high styrene contents. Its good temperature performance with high residual strength and good dimensional stability, makes Divinycell H ideal for hand laminating, vacuum bagging, RTM (resin transfer molding) and other closed molding processes.

In its application range Divinycell H has the highest strength to density ratio. It exhibits at both ambient and elevated temperatures impressive compressive strength and shear properties (normally the most important for a sandwich core material).

In addition the ductile qualities of Divinycell H make it ideal for applications subject to fatigue, slamming or impact loads. Where a more brittle core material might well shatter or delaminate as a result of an impact, the ductility of Divinycell H allows it to absorb energy when deflected without structural failure. Other key features of Divinycell H include consistent high quality, excellent adhesion / peel strength, excellent chemical resistance, low water absorption and good thermal / acoustic insulation.

Divinycell H is available in an ultra-wide range of densities 38, 48, 60, 80, 130, 160, 200 and 250 kg/m^3 .

PRODUCT INFORMATION

Storage

- Store product indoors in its original packaging.
- The packaging must be placed on pallets of at least the same size as the boxes or placed on a flat surface.
- Maximum storage temperature is recommended not to exceed +45°C/+115°F. During trans–port and short term storage the temperature may be higher.
- The material must be conditioned for at least 48 hours at room temperature before it is used in production.
- If product is stored outside in its original packaging for more than 24 hours it must be covered with plastic foil to avoid contamination.

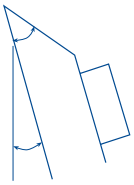
Machining

PRODUCT INFORMATION

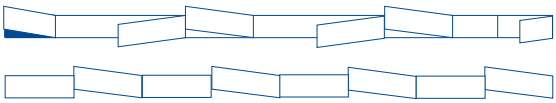
This part of the manual is not to be considered as a complete set of instructions for machining Divinycell. The intention, based on our internal experiences, is a guide when making the first attempts to machine the materials in various ways. Easiest way to get started is to use typical wood working machines and tools.

Divinycell is fairly easy to machine but its low thermal conductivity and other plastic properties can be a source of problems. These problems can often be handled by using these recommendations:

- Not using too tight/fine tools. There should be plenty of room for dust and chips.
- Cutting speed not below 40 m/s.
- Sharp tools, use carbide or carbide–tipped tools for longer life time.
- Use an aggressive tooth angle on the tools.



- For band sawing in general one can use tools with standard setting (every other tooth) but when using a guide (template) it is preferred to use a blade where the teeth are in line. This allows you to follow the guide without carving into the template.



- Sanding paper as standard 40–80 grit.
- Because of the low thermal conductivity and other plastic properties there will be a skin coating on the tools after a while. This skin is easiest removed mechanically in combination with some detergent.
- Turning. This type of machining using a lathe is very difficult to manage with satisfactory results when using standard cutting edges. The best way to get good results is to use a combination of turning and substitute the cutting head with a milling machine and head.
- When drilling in Divinycell, standard types of drilling heads can be used.

AVERAGE PHYSICAL PROPERTIES - SI UNITS

Table shows average values for the nominal densities and minimum values within the brackets for the minimum density.

Property	Unit	H 35	H 45	H 60	H 80	H 100	H 130	H 160	H 200	H 250
Nominal Density [1] ISO 845	kg/m³	38	48	60	80	100	130	160	200	250
Compressive Strength [2] ASTM D 1621	MPa	0.45 (0.3)	0.6 (0.5)	0.9 (0.7)	1.4 (1.15)	2.0 (1.65)	3.0 (2.4)	3.4 (2.8)	5.4 (4.5)	7.2 (6.1)
Compressive Modulus [2] ASTM D 1621	MPa	40 (29)	50 (45)	70 (60)	90 (80)	135 (115)	170 (145)	200 (175)	310 (265)	400 (350)
Tensile Strength [2] ASTM D 1623	MPa	1.0 (0.8)	1.4 (1.1)	1.8 (1.5)	2.5 (2.2)	3.5 (2.5)	4.8 (3.5)	5.4 (4.0)	7.1 (6.3)	9.2 (8.0)
Tensile Modulus [2] ASTM D 1623	MPa	49 (37)	55 (45)	75 (57)	95 (85)	130 (105)	175 (135)	205 (160)	250 (210)	320 (260)
Shear Strength ASTM C 273	MPa	0.4 (0.3)	0.56 (0.46)	0.76 (0.63)	1.15 (0.95)	1.6 (1.4)	2.2 (1.9)	2.6 (2.2)	3.5 (3.2)	4.5 (3.9)
Shear Modulus ASTM C 273	MPa	12 (9)	15 (12)	20 (16)	27 (23)	35 (28)	50 (40)	73 (50)	73 (65)	97 (81)
Shear Strain ASTM C 273	%	9 (4)	12 (8)	20 (10)	30 (15)	40 (25)	40 (30)	40 (30)	45 (35)	45 (35)

1) Typical density variation +/– 10%.

2) Perpendicular to the plane. All values measured at +23°C.

Continuous operating temperature is –200°C to +70°C. The foam can be used in sandwich structures, for outdoor exposure, with external skin temperatures up to +85°C. For optimal design of applications used in high operating temperatures in combination with continuous load, please contact DIAB Technical Services for detailed design instructions. Normally Divinycell H can be processed at up to +90°C with minor dimensional changes. Maximum processing temperature is dependent on time, pressure and process conditions. Therefore users are advised to contact DIAB Technical Services to confirm that Divinycell H is compatible with their particular processing parameters.

Coefficient of linear expansion: approx. 40 x 10^{-6}/°C

AVERAGE PHYSICAL PROPERTIES - IMPERIAL UNITS

Table shows average values for the nominal densities and minimum values within the brackets for the minimum density.

Property	Unit	H 35	H 45	H 60	H 80	H 100	H 130	H 160	H 200	H 250
Nominal Density [1] ISO 845	lb/ft³	2.4	3.0	3.8	5.0	6.3	8.1	10.0	12.5	15.6
Compressive Strength [2] ASTM D 1621	psi	65 (44)	87 (72)	130 (102)	203 (167)	290 (239)	435 (348)	493 (406)	783 (653)	1,044 (885)
Compressive Modulus [2] ASTM D 1621	psi	5,800 (4,206)	7,250 (6,525)	10,150 (8,700)	13,050 (11,600)	19,575 (16,675)	24,650 (21,030)	29,000 (25,382)	44,965 (38,435)	58,015 (50,763)
Tensile Strength [2] ASTM D 1623	psi	145 (116)	203 (160)	261 (218)	363 (319)	508 (362)	696 (508)	783 (581)	1,030 (914)	1,334 (1,160)
Tensile Modulus [2] ASTM D 1623	psi	7,105 (5,366)	7,975 (6,525)	10,875 (8,265)	13,775 (12,325)	18,850 (15,225)	25,375 (19,575)	29,730 (23,206)	36,250 (30,450)	46,400 (37,710)
Shear Strength ASTM C 273	psi	58 (44)	81 (67)	110 (91)	167 (138)	232 (203)	319 (276)	377 (319)	508 (464)	653 (566)
Shear Modulus ASTM C 273	psi	1,740 (1,305)	2,175 (1,740)	2,900 (2,320)	3,915 (3,335)	5,075 (4,060)	7,250 (5,800)	10,590 (7,252)	10,590 (9,427)	14,070 (11,748)
Shear Strain ASTM C 273	%	9 (4)	12 (8)	20 (10)	30 (15)	40 (25)	40 (30)	40 (30)	45 (35)	45 (35)

1) Typical density variation +/– 10%.

2) Perpendicular to the plane. All values measured at +73.4°F.

Continuous operating temperature is –325°F to +160°F (–200°C to +70°C). The foam can be used in sandwich structures, for outdoor exposure, with external skin temperatures up to +185°F (+85°C). For optimal design of applications used in high operating temperatures in combination with continuous load, please contact DIAB Technical Services for detailed design instructions. Normally Divinycell H can be processed at up to +194°F (+90°C) with minor dimensional changes. Maximum processing temperature is dependent on time, pressure and process con–ditions. Therefore users are advised to contact DIAB Technical Services to confirm that Divinycell H is compatible with their particular processing parameters.

Coefficient of linear expansion: approx. 22.2 x 10^{-6}/°F (40 x 10^{-6}/°C)

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 35

Divinycell H 35	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	38	kg/m^3	2.4	lb/ft^3	ISO 845
Compressive strength [2]	0.45	MPa	65	psi	ASTM D 1621
Compressive modulus [2]	40	MPa	5,800	psi	ASTM D 1621
Tensile strength [2]	1.0	MPa	145	psi	ASTM D 1623
Tensile modulus [2]	49	MPa	7,105	psi	ASTM D 1623
Shear strength	0.4	MPa	58	psi	ASTM C 273
Shear modulus	12	MPa	1,740	psi	ASTM C 273
Shear strain	9	%	9	%	ASTM C 273
Thermal conductivity [3]	0.029	W/mK	0.201	Btu·in/(ft^2·h·°F)	ASTM C 518
Water absorption	0.005	kg/m^2	10.2	lb/ft^2	ASTM C 272 A
Water vapour permeability [4]	*)	m^2/(s·10^{-8})	*)	ft^2/(s·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	*)	°C	*)	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F)

3) Thermal conductivity at +20°C (+68°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 45

Divinycell H 45	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	48	kg/m^3	3.0	lb/ft^3	ISO 845
Compressive strength [2]	0.6	MPa	87	psi	ASTM D 1621
Compressive modulus [2]	50	MPa	7,250	psi	ASTM D 1621
Tensile strength [2]	1.4	MPa	203	psi	ASTM D 1623
Tensile modulus [2]	55	MPa	7,975	psi	ASTM D 1623
Shear strength	0.56	MPa	81	psi	ASTM C 273
Shear modulus	15	MPa	2,175	psi	ASTM C 273
Shear strain	12	%	12	%	ASTM C 273
Thermal conductivity [3]	0.028	W/mK	0.194	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	4.0	m^2/(s·10^{-8})	3.7	ft^2/(s·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	*)	°C	*)	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F)

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. $\leq$ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 60

Divinycell H 60	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	60	kg/m^3	3.8	lb/ft^3	ISO 845
Compressive strength [2]	0.9	MPa	130	psi	ASTM D 1621
Compressive modulus [2]	70	MPa	10,150	psi	ASTM D 1621
Tensile strength [2]	1.8	MPa	261	psi	ASTM D 1623
Tensile modulus [2]	75	MPa	10,875	psi	ASTM D 1623
Shear strength	0.76	MPa	110	psi	ASTM C 273
Shear modulus	20	MPa	2,900	psi	ASTM C 273
Shear strain	20	%	20	%	ASTM C 273
Thermal conductivity [3]	0.029	W/mK	0.201	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	4.0	m^2/(s · 10^{-8})	3.7	ft^2/(s · 10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	+105	°C	+221	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F).

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 80

Divinycell H 80	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	80	kg/m^3	5.0	lb/ft^3	ISO 845
Compressive strength [2]	1.4	MPa	203	psi	ASTM D 1621
Compressive modulus [2]	90	MPa	13,050	psi	ASTM D 1621
Tensile strength [2]	2.5	MPa	363	psi	ASTM D 1623
Tensile modulus [2]	95	MPa	13,775	psi	ASTM D 1623
Shear strength	1.15	MPa	167	psi	ASTM C 273
Shear modulus	27	MPa	3,915	psi	ASTM C 273
Shear strain	30	%	30	%	ASTM C 273
Thermal conductivity [3]	0.031	W/mK	0.215	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	4.0	m^2/(s · 10^{-8})	3.7	ft^2/(s ·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	*)	°C	*)	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F).

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 100

Divinycell H 100	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	100	kg/m^3	6.3	lb/ft^3	ISO 845
Compressive strength [2]	2.0	MPa	290	psi	ASTM D 1621
Compressive modulus [2]	135	MPa	19,575	psi	ASTM D 1621
Tensile strength [2]	3.5	MPa	508	psi	ASTM D 1623
Tensile modulus [2]	130	MPa	18,850	psi	ASTM D 1623
Shear strength	1.6	MPa	232	psi	ASTM C 273
Shear modulus	35	MPa	5,075	psi	ASTM C 273
Shear strain	40	%	40	%	ASTM C 273
Thermal conductivity [3]	0.033	W/mK	0.229	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	< 4.0	m^2/(s · 10^{-8})	< 3.7	ft^2/(s ·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	+126	°C	+259	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F).

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 130

Divinycell H 130	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	130	kg/m^3	8.1	lb/ft^3	ISO 845
Compressive strength [2]	3.0	MPa	435	psi	ASTM D 1621
Compressive modulus [2]	170	MPa	24,650	psi	ASTM D 1621
Tensile strength [2]	4.8	MPa	696	psi	ASTM D 1623
Tensile modulus [2]	175	MPa	25,375	psi	ASTM D 1623
Shear strength	2.2	MPa	319	psi	ASTM C 273
Shear modulus	50	MPa	7,250	psi	ASTM C 273
Shear strain	40	%	40	%	ASTM C 273
Thermal conductivity [3]	0.036	W/mK	0.250	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	< 4.0	m^2/(s · 10^{-8})	< 3.7	ft^2/(s ·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	*)	°C	*)	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F).

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 160

Divinycell H 160	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	160	kg/m^3	10.0	lb/ft^3	ISO 845
Compressive strength [2]	3.4	MPa	493	psi	ASTM D 1621
Compressive modulus [2]	200	MPa	29,000	psi	ASTM D 1621
Tensile strength [2]	5.4	MPa	783	psi	ASTM D 1623
Tensile modulus [2]	205	MPa	29,730	psi	ASTM D 1623
Shear strength	2.6	MPa	377	psi	ASTM C 273
Shear modulus	73	MPa	10,590	psi	ASTM C 273
Shear strain	40	%	40	%	ASTM C 273
Thermal conductivity [3]	*)	W/mK	*)	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	< 4.0	m^2/(s · 10^{-8})	< 3.7	ft^2/(s ·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	*)	°C	*)	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F).

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 200

Divinycell H 200	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	200	kg/m^3	12.5	lb/ft^3	ISO 845
Compressive strength [2]	5.4	MPa	783	psi	ASTM D 1621
Compressive modulus [2]	310	MPa	44,965	psi	ASTM D 1621
Tensile strength [2]	7.1	MPa	1,030	psi	ASTM D 1623
Tensile modulus [2]	250	MPa	36,250	psi	ASTM D 1623
Shear strength	3.5	MPa	508	psi	ASTM C 273
Shear modulus	73	MPa	10,590	psi	ASTM C 273
Shear strain	45	%	45	%	ASTM C 273
Thermal conductivity [3]	0.043	W/mK	0.298	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	< 4.0	m^2/(s · 10^{-8})	< 3.7	ft^2/(s ·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	+136	°C	+277	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F).

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

TECHNICAL DATA - TABLES

CHARACTERISTICS DIVINYCELL H 250

Divinycell H 250	SI Units		Imperial Units		Test
Property	Value	Unit	Value	Units	Procedure
Nominal density [1]	250	kg/m^3	15.6	lb/ft^3	ISO 845
Compressive strength [2]	7.2	MPa	1,044	psi	ASTM D 1621
Compressive modulus [2]	400	MPa	58,015	psi	ASTM D 1621
Tensile strength [2]	9.2	MPa	1,334	psi	ASTM D 1623
Tensile modulus [2]	320	MPa	46,400	psi	ASTM D 1623
Shear strength	4.5	MPa	653	psi	ASTM C 273
Shear modulus	97	MPa	14,070	psi	ASTM C 273
Shear strain	45	%	45	%	ASTM C 273
Thermal conductivity [3]	0.047	W/mK	0.326	Btu·in/(ft^2·h·°F)	EN 12667
Water absorption	*)	kg/m^2	*)	lb/ft^2	ISO 2896
Water vapour permeability [4]	< 4.0	m^2/(s·10^{-8})	< 3.7	ft^2/(s·10^{-9})	ISO 12572
Coefficient of linear expansion	40	· 10^{-6}/°C	22.2	· 10^{-6}/°F	
Dimension stability temperature	*)	°C	*)	°F	DIN 53424
Continuous temp. range	–200 to +70	°C	–325 to +160	°F	
Max. processing temperature	+90	°C	+194	°F	
Heat distortion temperature	*)	°C	*)	°F	DIN 53424
Dissipation factor	*)	–	*)	–	
Dielectric constant	*)	–	*)	–	
Resin consumption	*)	kg/m^2	*)	lb/ft^2	
Poissons ratio	*)		*)		

1) Typical density variation ± 10%.

2) Perpendicular to the plane. All values measured at +23°C (+73.4°F)

3) Thermal conductivity at +10°C (+50°F).

4) Water vapour permeability has been tested for densities 45–80 kg/m^3. Higher densities yields lower values, hence, the water vapour perm. ≤ 4.0 · 10^{-8} m^2/s.

*) Testing is ongoing. Values will be published as soon as completed. Meanwhile please contact DIAB Technical Services for advice.

FATIGUE PROPERTIES

Introduction

The imposition of repetitive short-time stress or deformation, particularly continual cyclic load, on parts or test specimens is fatigue. It is the principal stress involved in, for example, slamming on boat hulls and vibration on non-moving parts of vehicles and aircraft.

Fatigue is a unique stress, with characteristic mechanisms of failure and approaches to design that are distinctly different from those of static or impact stresses. In addition to the failure mechanism that is dominant in the fatigue of structural metals, i.e. crack propagation, plastics also exhibit a failure mechanism distinctly their own due to their viscoselastic nature. This mechanism is failure by softening due to hysteretic heating. Consequently, understanding the fatigue behaviour of plastics for purposes of design and material selection requires a somewhat different approach from that traditionally used for structural metals.

The mechanisms that control plastics fatigue failure are complex and involve variables such as microscopic flaws and heat transfer rates. Therefore, the generation of material properties for engineering purposes has been based primarily on empirical testing rather than on mathematical analysis. Fatigue test data are very helpful in understanding plastics fatigue deformation, ranking materials and qualitatively guiding design. However, their numerical application to design calculations is usually limited to end use situations that are similar to the test conditions.

Fatigue Stresses

The variety of stress modes in which fatigue occurs in commercial parts is virtually endless, and to some extent the variety of fatigue test stresses reflects this. For example, fatigue test commonly are made in tension, compression, bending, alternating tension and compression, cycling around zero stress, cycling superimposed on a static preload and tests made at constant deformation or constant load.

In fatigue testing in general, and plastic fatigue testing in particular, different test modes do not necessarily yield numerically comparable data, and significant interactions between test variables and stress mode are common. Therefore, in the interest of comparability all data cited in this section were obtained by the same method – 4 point beam bending with Pmin/Pmax = 0.05.

Fundamental Performance Properties

Failure by crack propagation

All materials in the fabricated state contain defects in the form of voids, contamination or material discontinuities. Under load, these defects can cause localized stress concentrations. At relatively high loads such stress concentrations can exceed the strength of the material, causing localized failure at the defect.

Fundamental Performance Properties

FATIGUE PROPERTIES

In a fatigue situation where the load cycles from a low to a high value continually, such failure stresses may occur during each cycle, each time causing increments of damage. The result over a large number of cycles is the gradual evolution of a crack or series of cracks which propagate to the point where the stressed cross section of a part or specimen is weakened sufficiently to fracture catastrophically. The number of cycles to failure depends on stress, size and number of defects, inherent strength and notch sensitivity of the material.

For engineering purposes and material selection, both plastics and metals are tested by determining experimentally the relationship between stress and life. Specimens are subjected to cyclic loading at different levels of stress, S, and the number of cycles to failure, N, is measured at each level. The results are graphed as stress as a function of cycles to failure, which is commonly called a S-N curve or Wöhler curve.

The basic advantage of S-N curves is that they yield directly a graphic estimate of expected life in terms of a key design parameter – stress. Thus in a design situation that is very similar to the test conditions the designer can derive a design stress directly from the S-N curve at the design life of the part. To such a design stress a safety factor must be applied in recognition that a key variable in both the test and the part is uncontrollable, namely flaws. Even where numerical application to design is impractical, the S-N curve is useful in ranking materials and in measuring the effects of the many secondary variables that affect fatigue performance of plastics, such as frequency and thickness.

Failure by softening due to hysteretic heating

Because plastics are viscoelastic, stress and strain are not in phase during cycling loading. A major consequence is that during each cycle a portion of the mechanical energy applied is dissipated as heat. This is called hysteresis. The magnitude of hysteretic heating during each cycle depends on the applied stress, frequency and a material constant, the loss compliance. Plastics are thermal insulators and under continual cyclic load they tend to heat up due to the cumulative effect of heat generated during each cycle.

There are two possible consequences of a plastic heating up in fatigue.

1. After some temperature rise the heat transfer rate to the surroundings as a result of conduction, convection and radiation equals the rate of heat generated under each cycle. At that point the temperature will stabilize. The material will continue to bear cyclic load but at a lower stress level due to the reduction in strength and stiffness that occurs at elevated temperatures.

FATIGUE PROPERTIES

Fundamental Performance Properties

2. The heat generated during each cycle exceeds the rate of heat transfer to the surroundings. In this case the temperature will increase continuously until the properties of the plastic fall to the point where it no longer can bear load. This constitutes a thermal failure.

Failure modes for different types of plastics

Type	Failure Mode
Rigid PVC	Crack propagation
Urethane	Crack propagation
Phenolic	Crack propagation
Epoxy	Crack propagation
PMMA	Crack propagation or thermal failure
PET	Crack propagation or thermal failure
Alkyd	Crack propagation or thermal failure
Polycarbonate	Crack propagation or thermal failure
Polypropylene	Thermal failure
Polyethylene	Thermal failure
Nylon	Thermal failure

Fatigue Testing

Four–point bending test until fracture

The fatigue properties have been determined by cycling sandwich beams in four-point bending. All tests were carried out in a Schenck 40 kN servo-hydraulic machine, an MTS 50 kN servo-hydraulic machine and an Instron 100 kN universal testing machine. A state of dominant shear stress was achieved, by using a four-point bending test. The face material and the dimensions of the test beam were selected such that the core material, rather than the face material, was the limiting factor.

The four-point bending tests were carried out with the stress rations
R = 0.05, R = 0.5 and R = 1 where R = τ_{min} / τ_{max}

Fatigue Testing

FATIGUE PROPERTIES

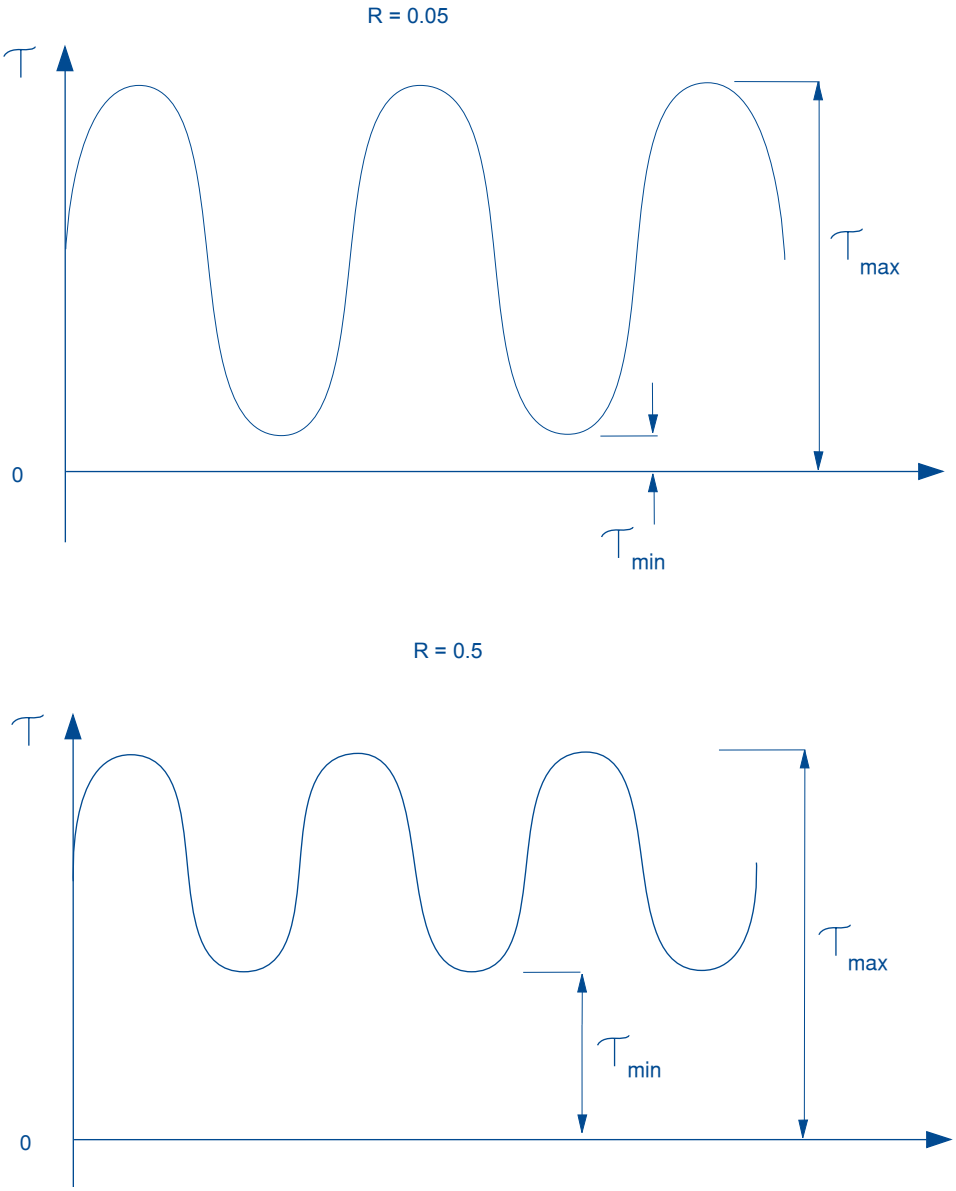


Figure 1: Illustration of R values

The frequency has been 5 Hz (5 load cycles/second).

A higher frequency will increase the temperature due to hysteretic heating and cause a failure due to softening.

FATIGUE PROPERTIES

Fatigue Testing

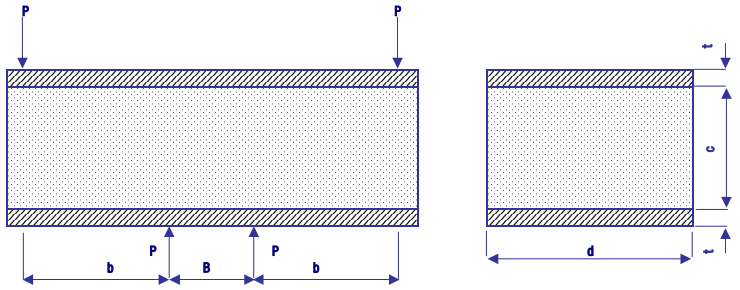


Figure 2

Four-point bending test: $M_{max} = P \cdot b$ $\tau_{max} = P$

The maximum normal stress in the face material is: $\sigma_{max} = \frac{P \cdot b}{c \cdot d \cdot t}$

The maximum shear stress in the core is: $\tau_{max} = \frac{P}{c \cdot d}$

The ratio of shear stress in the core to the normal stress in the face is:
$\sigma_{max} / \tau_{max} = b/ t$

Hence, the ratio b/t should be low enough (we assume a safety factor of 2) so that fracture does not occur in the face material: $(b/t)max = 0.5 \cdot \sigma_{max} / \tau_{max}$

With respect to the discussion above, the following values were chosen: b = 180 mm (7 in), a = 80 mm (3.1 in) and L = 500 mm (20 in). The thickness of the core material was 60 mm (2 3/8 in). The width of the beam should not influence the results significantly, but was selected to be large enough to prevent lateral buckling, d = 60 mm (2 3/8 in). The loads P must be applied in such a way that local failure under the load points is avoided. Therefore, the length of the load plates was set equal to the core thickness c.

The test programme starts with determination of the ultimate shear strength in a static four-point bending test. The beams are then tested in fatigue at different stress-ratios of the ultimate shear strength. The test is stopped when the shear crack propagation is in a macro stage, and the number of load cycles is recorded. At least three beams need to be tested at each level of stress ratio.

FATIGUE PROPERTIES

Fatigue Testing

The result is presented in a S/N curve with stress on the y-axis and the number of load cycles on the x-axis.

As can be seen from the curves the S/N relationship for Divinycell is essentially linear. At a stress-ratio of 40 % Divinycell can be subjected to 5-25 million load cycles before failure. We have not tested at higher numbers of load cycles, but normally a plastic material will tend to level off and become asymptotic to a characteristic stress level. This stress is call the endurance limit.

Four-point bending, residual strength after cycling

The tests were carried out in accordance with the procedures in "Fatigue Testing, Four-point bending test until fracture", with the following exceptions:

1. The tests were carried out in a 250 KN servo hydraulic machine.

2. The deflection (d) was measured with an electric gauge.

3. Bending stiffness $EI = \frac{b \cdot L^2}{16} \cdot \frac{P}{\delta}$

4. Beam dimensions.

After determination of the static properties the beams were cycled 10^6-10^7 cycles with a stress ratio of 20-30%. The bending stiffness was checked during and after the test. None of the beams showed any decrease in physical properties after cycling.

OXYGEN INDEX

Introduction

Oxygen index is the minimum percentage of oxygen required in the surrounding air to sustain a fire. Normally, there is 21% oxygen in air. Materials that have an oxygen index greater than 21 are said to be self-extinguishing.

Test method

The oxygen index for a Divinycell H 60, with 10 mm core thickness, is 28.8 %, which classifies Divinycell as self-extinguishing. The value was determined in accordance with ISO 4589-2.

THERMAL INSULATION

Introduction

When an installation has a different temperature than the surrounding air there will always be a heat flow. Hot installations have a higher temperature than the surrounding air and the heat flow goes from the installation to the surrounding air. Cold installations have a lower temperature than the surrounding air and the heat flow goes from the surrounding air to the cold installation.

The force that creates the heat flow in both cases is the temperature differential between the installation and the surrounding air. Independent of the heat flow direction, it is in almost all cases desireable to decrease the heat flow. This can be achieved by applying an insulation with good thermal impedance/resistance. The choice of insulation material and dimensioning depends on how large a temperature loss is acceptable and the economy of the system. Consideration also has to be given to the surface temperature of the insulation in the installation. In a hot installation an excessive surface temperature could mean a risk of burn injuries. When the insulation is applied on a cold installation there is always a requirement for a defined surface temperature to avoid condensation.

Thermal conductivity is the material property that states the value of thermal insulation capacity for a given material. The lower the termal conductivity, the better the insulation properties. Thermal conductivity is however not a constant, but a property that is affected by temperature, density and moisture content. The influence of temperature is that a high temperature means a higher value of thermal conductivity. The Divinycell data sheets show the thermal conductivity at +10°C (+50°F). The temperatures are the average temperature of the panel.

Eg. λ +10 is λ at $\frac{T_1 + T_2}{2}$ = +10°C (+50°F)

where T_1 is the temperature on the hot surface and T_2 on the cold surface. In almost all insulation material it is the air or the gas inside the material that gives it its insulating capacity. The thermal conductivity for air is approximately 0.025 W/(m · K) or 0.173 Btu · in/(ft · h · °F). The heat transfer through the solid material increases the thermal conductivity for most of the insulation materials to 0.025 – 0.040 W/(m · K) or 0.173-0.277 Btu · in/(ft · h · °F). If the air or gas in the material is replaced with water, which has a thermal conductivity of 0.6 W/(m · K) or 4.16 Btu · in/(ft · h · °F), the thermal conductivity will of course decrease significantly. The insulation capacity is decreased even more if the water freezes to ice, which has a thermal conductivity of 2.2 W/(m · K) or 15.3 Btu · in/(ft · h · °F) at 0 °C. There will always be a water vapour penetration on cold installations through the insulation towards the cold side where the vapour will condense. Tests show that a water content of even 3 % by volume increases the thermal conductivity by 20-30 %.

THERMAL INSULATION

DEFINITION OF THERMAL PROPERTIES (in accordance with ISO 31/IV)

Designation	Symbol	SI Unit	Imperial Unit
Thermodynamic temperature	T	K	K
Celsius or Fahrenheit temperature	t	°C	°F
Temperature difference [1)]	ΔT	K, °C	K, °F
Heat	Q	J	Btu
Specific heat	q	J/kg	Btu/lb
Heat power	P	W	Btu/h
Heat flow rate	F	W	Btu/h
Density of heat flow rate	q	W/m^2	$Btu/(ft^2 \cdot h)$
Thermal conductance	G	W/K	Btu/(h · °F)
Thermal conductivity [2)]	λ	W/(m · K)	$Btu \cdot in/(ft^2 \cdot h \cdot °F)$
Thermal resistance	R	K/W	°F · h/Btu
Thermal impedance/resistance [5)]	M_n	$m^2 \cdot K/W$	$ft^2 \cdot h \cdot °F/Btu$
Surface thermal impedance/resistance	M_a	$m^2 \cdot K/W$	$ft^2 \cdot h \cdot °F/Btu$
Coefficient of heat transfer [3,5)]	α	$W/(m^2 \cdot K)$	$Btu/(ft^2 \cdot h \cdot °F)$
Thermal transmittance [4,5)]	k	$W/(m^2 \cdot K)$	$Btu/(ft^2 \cdot h \cdot °F)$
Heat capacity	C	J/K	Btu/°F
Specific heat capacity	c	J/(K · kg)	Btu/(lb · °F)

1) K (Kelvin) can be changed to °C (Celsius) or °F (Fahrenheit) in all units where K occurs since all units refer to a temperature difference.

2) The thermal conductivity for a material is the heat flow rate that passes perpendicular through a cube with 1 m sides between two opposite sides at a temperature difference bwteeen the two surfaces of 1 K.

3) The coefficient of heat transfer is the heat flow rate that is transferred between a surface of 1 m^2 and the air at a temperature difference of 1 K. α depends on the movement of the air.

4) The thermal transmittance is the heat flow rate that passes perpendicular through a wall of known structure and an area of 1 m^2 at a temperature difference of 1 K.

5) Difference use of symbols between ISO 31/1V and ASTM C 168; M = R, α = h and K = C.

THERMAL INSULATION

FORMULAS FOR CALCULATION OF THERMAL PROPERTIES

Symbol	Formula	SI Unit	Imperial Unit
t	$t = T - 273.15$	°C	°F
Δt	$\Delta t = T_1 - T_2$ T_1 = T on warm surface T_2 = T on cold surface	°C	°F
Φ	$\Phi = g \cdot A$	W	Btu/h
g	$g = \Delta T \cdot k$	W/m²	Btu/(ft² · h)
G	$G = \Phi/\Delta T = A \cdot k$	W/K	Btu/(h · °F)
R	$R = 1/G = 1/A \cdot k$	K/W	h · °F/Btu
M_n	$M_n = 1/k$ (d = thickness in m or ft)	m² · K/W	ft² · h · °F/Btu
M_a	$M_a = 1/\alpha$	m² · K/W	ft² · h · °F/Btu
k	$k = \frac{1}{\frac{1}{\alpha_1} + \frac{d_1}{\lambda_1} + \frac{d_2}{\lambda_2} + \frac{d_3}{\lambda_3} + \frac{1}{\alpha_2}}$ α_1 = a on warm surface α_2 = a on cold surface d = d_1 = thickness of first layer d_2 = etc $\lambda = \lambda_1 = \lambda$ of first layer λ_2 = etc	W/(m² · K)	Btu/(ft² · h · °F)
C	$C = c \cdot m$ (m = mass in kg or lb)	J/K	Btu/°F

WATER VAPOUR PROPERTIES

DEFINITION OF WATER VAPOUR PROPERTIES (in accordance with SS 02 15 82)

Designation	Symbol	SI Unit	Imperial Unit
Thermodynamic temperature	T	K	K
Celsius or Fahrenheit temperature	t	°C	°F
Temperature difference [1]	ΔT	K	K
Water vapour permeability [2] Water vapour content Water vapour pressure	 δv δp	 m^2/s $kg/(m \cdot s \cdot Pa)$	 ft^2/s $lb/(ft \cdot s \cdot psi)$
Water vapour permeance [3]	W_v	m/s	ft/s
Water vapour resistance	Z_v	s/m	s/ft
Water vapour transmission rate [4]	D	$kg/(m^2 \cdot s)$	$lb/(ft^2 \cdot s)$
Water vapour difference Water content Water pressure	 δv δp	 kg/m^3 Pa	 lb/ft^3 psi
Insulation thickness	d	m	ft
Water vapour flow	g	$kg/(m^2 \cdot s)$	$lb/(ft^2 \cdot s)$

1) K (Kelvin) can be changed to °C (Celsius) or °F (Fahrenheit) in all units where K occurs since all units refer to a temperature difference.

2) The water vapour permeability is the amount of water vapour per second at steady state that passes through 1 m^2 of a material with 1 m thickness when a difference in water vapour content between the two sides of the material is 1 kg/m^3.

3) The water vapour permeance is the amount of water vapour per second at steady state that passes through 1 m^2 of material with a given thickness when the difference in water vapour content between the two sides of the material is 1 kg/m^3.

4) The water vapour transmission rate is the amount of water per second at steady state that passes through 1 m^2 of a material when the difference in water vapour contenct between the two sides of the material is 1 kg/m^3.

WATER VAPOUR PROPERTIES

FORMULAS FOR CALCULATING WATER VAPOUR PROPERTIES

Symbol	Formula	SI Unit	Imperial Unit
t	$t = T - 273.15$	°C	°F
Δt	$\Delta t = T_1 - T_2$ T_1 = T on warm surface T_2 = T on cold surface	K	K
δv	$\delta v = d/Z$	m^2/s	ft^2/s
δp	$\delta p = dv \cdot 7.33 \cdot 10^{-6}$	kg/m · s · Pa	lb/(ft · s · psi)
W_v	$W_v = 1/Z$	m/s	ft/s
Z_v	$Z_v = \frac{\Delta v}{D}$	s/m	s/ft
g	$g = \frac{\Delta v}{Z_v + (d/v)}$	$kg/(m^2 \cdot s)$	$lb/(ft^2 \cdot s)$
Zp	$Zp = Zv/7.33 \cdot 10^{-6}$	$m^2 \cdot s \cdot Pa/kg$	$ft^2 \cdot s \cdot psi/lb$

WATER ABSORPTION

Introduction

The values in the data sheet are determined in accordance with ISO 2896. This method covers the determination of the water absorption of rigid cellular plastics by measuring the change in buoyant force resulting from immersion under a 5.1 cm (2 in) head of water for 96 h.

The purpose of this method is to provide a means for comparing relative water absorption tendencies between different cellular plastics. It is intended for use in specifications, product evaluation and quality control. It is applicable to specific end-use design requirements only to the extent that the end-use conditions are similar to the test conditions.

The water absorption is measured as a result of direct contact exposure to the water. The volume error associated with surface cells cut open during specimen preparation has to be taken into account when calculating the true specimen volume.

This is, however, complicated and is often a reason for errors. Both internal and external tests have shown negative water absorptions due to miscalculation of the volume of the cells cut open on the surface.

The results are reported in terms of ”amount of water absorbed per unit of surface area”. The unit is kg/m^2 or lb/ft^2 .

ASTM D 2842-69 could also be used for determination of water absorption. We do not recommend ASTM C 272-53 since it does not take the volume of the cells cut open on the surface into account.

DIELECTRIC PROPERTIES

Introduction

A dielectric material is defined as a non-conductor of electricity and a medium that lets electrical fieldlines through.

The dielectrical properties of a material are measured in terms of dielectric constant or permittivity and dissipation factor.

When we talk about the dielectric constant in common usage we mean the "relative dielectric constant". It is the ratio of the equivalent capacitance of a given configuration of electrodes with a material as a dielectric to the the capacitance of electrodes with vacuum (or air for most practical purposes) as the dielectric. Since the relative dielectric constant is a ratio it has no unit.

Table 1 – Typical dielectric constants

Material	Dielectric Constant (ε_r)
Vacuum	1.0000
Air (1 atm +20°C/+68°F)	1.0006
Water (+20°C/+68°F)	80
Divinycell	1.1
Rubber	3
Glass	5–10
Porcelain	6–8
Teflon	2.1
Polyethylene (PE)	2.3

The lower the dielectric constant, the lower the conducting capacity. The reduction can be understood in terms of polarization. It is the alignment of atomic or molecular dipoles in the dielectric when an electric field is applied. An electric dipole is a configuration of equal amounts of positive and negative charges with the positive charge displaced relative to the negative charge.

The dissipation factor is a measure of the A/C loss in the dielectric. The A/C loss shall generally be small, both in order to reduce the heating of the material and to minimize its effect on the rest of the network. In high frequency applications, a low value of loss index is particularly desirable, since for a given value of loss index the dielectric loss increases directly with frequency.

DIELECTRIC PROPERTIES

Factors affecting the dielectric properties

Dielectric materials are used over the entire electromagnetic spectrum from direct current to radar frequencies. There are only a few materials whose dielectric constants are even approximately constant over the frequency range. It is therefore necessary either to measure the dielectric constant at the frequency at which the material will be used or to measure it at several frequencies suitably placed, if the material is to be used over a frequency range.

Table 2 – Electromagnetic spectrum

Wave length	Frequency	Designation
–500 mm	– 1.5 GHz	Radio waves
500 mm – 10 mm	1.5 GHz – 30 GHz	Radar waves
10 mm – 0.1 mm	30 GHz – 3 THz	mm wave
0.1 mm – 0.001 mm	3 THz – 300 THz	Infrared light
8000 Å – 4000 Å	–	Visible light
4000 Å – 1 Å	–	UV–light
100 Å – 0.01	–	X–ray
1 Å – 0.01 Å	–	Gamma radiation
1 Å (Ångström) = 10^{-10} m		

Radio and radar waves are produced in electrical oscillating circuits. Infrared, visible and UV-light and X-rays are due to changes in energy in the electron layers of the atoms in the material that transmits the radiation. Gamma radiation is created by changes in energy in the atom cores.

Another very important parameter that affects the dielectric constant is water vapour permeability and water absorption. The major electric effect is a great increase of the interfacial polarization, thus increasing the dielectric constant and the conductivity. The dielectric constant also increases with increasing density.

DIELECTRIC PROPERTIES

DEFINITION OF DIELECTRIC PROPERTIES

Designation	Symbol	SI Unit	Imperial Unit
Quantity of electricity	Q	C, As	C, As
Electric flow density	D	C/m^2	C/ft^2
Voltage	U	V	V
Electric field strength	E	V/m	V/F
Capacitance	C	F	F
Permittivity, capacitvity or dielectric constant	ε	F/m	F/ft
Permittivity of vacuum	ε_o	F/M	F/ft
Relative permittivity	ε_r	–	–
Dissipation factor, loss tangent or tan	d	–	–
Loss index or loss factor	ε_r''	–	–
Wave length	λ	m	ft
Frequency	f	Hz	Hz
Velocity of light in air	ν	m/s	ft/s

DIELECTRIC PROPERTIES

FORMULAS FOR CALCULATIONS OF DIELECTRIC PROPERTIES

Symbol	Formula	SI Unit	Imperial Unit
C	$C = Q/U$	F	F
E	$E = U/d$	v/m	v/ft
D	$D = Q/A$	C/m^2	C/ft^2
ε	$\varepsilon = D/E$	F/m	F/ft
ε	$\varepsilon = \frac{C \cdot d}{A}$	F/m	F/ft
ε_o	$\varepsilon_o = 8.854 \cdot 10^{-12}$	F/m	F/ft
ε_r	$\varepsilon_r = \varepsilon/\varepsilon_o$	–	–
ε_r"	$\varepsilon_r" = \varepsilon_r \cdot d$	–	–
d	$dp = \frac{1}{\omega \cdot Cp \cdot Rp}$ $ds = \omega \,.\, C_s \,.\, R^s$	–	–
ω	$\omega = 2\pi \cdot f$	rad/s	rad/s
λ	$\lambda = v/f$	m	ft
f	$f = 1/T$	s^{-1}	s^{-1}
v	$= 3 \cdot 10^8$	m/s	ft/s

N.B. The normal presentation of the dielectric loss is to represent a capacitor at a single frequency by capacitance C_p parallel to a resistance R_p. But it is occasionally desirable to represent it by a capacitance C_s in series with a resis–tance R_s.

THERMOFORMING

Scope

Thermoforming is carried out by heating Divinycell to its softening point and forcing it against the contour of a female or male mould. When the Divinycell has cooled down it can be removed from the mould and will keep its new form. The softening point is typically 90-120°C.

There are at least a dozen thermoforming methods; vacuum assisted, pressure, drape, sweep, match mould and free forming, to name just a few.

Heating

The Divinycell can be heated in different ways for example; heated platen press, in a circulating hot air oven or infrared heaters.

A piece of advice:

- If heating Divinycell in a heated platen press use fixed stops (no pressure on the material) to avoid compression of the material.
- Infrared heaters could be used up to 10–15 mm thickness. The IR–waves will not penetrate deep enough on thicknesses above that.
- If the temperature is too high the dimension stability will be affected and if it is too low the springback will be too big. An uneven temperature distribution will make the Divinycell twist.

Forming

If using preheating method, where the Divinycell is preheated to its softening point before it is moved to a mould, the time from removal from the heating unit until the pressure is applied must be short (seconds) to avoid cooling down of the Divinycell.

Vacuum Bagging

The vacuum bag is assembled on a cold sheet and mould. The mould is then placed in a hot air oven. The temperature inside the sheet is measured with a thermal gauge. When the right temperature is reached the vacuum is applied. The mould is then taken out of the oven and allowed to cool with the vacuum being maintained.

Temperatures & Times

The following temperatures can be used as starting values for the different qualities, independent of radius and thickness:

Quality	Temperature
H60	+100°C to +120°C (+212°F to +248°F)
HP	+100°C to +130°C (+212°F to +266°F)

THERMOFORMING

Temperatures & Times

The following times for the different thicknesses give an idea what is needed to reach the softening point temperatures in the centre of the core:

Thickness (mm)	10	20	30	40	50	60
Time (min)	3–7	5–10	10–15	15–20	20–30	30–45

The softening point in the centre of the core is about following temperatures:

Quality	Temperature
H60	+90°C (+194°F)
HP	+120°C (+248°F)

The temperature and time are dependent on the local conditions and thicknesses and should be calibrated prior to start of production.

Dimensional Stability

Divinycell will change its dimensions when heated in accordance with temperatures and times mentioned above. The following typical figures as percentages of the original dimension are valid:
Length/width = +/- 3%
Thickness = -3-0 %

Springback

To compensate for springback of Divinycell, the mould radius should be 5-10% smaller than the final radius. If the Divinycell is kept in the mould, and are kept warm for a longer time, the springback effect will decrease. For example, a detail has been kept in a mould at 90°C with vacuum bag and vacuum for 8 hours before cooliong, with a very good end result.

It should also be noted that the edges of thermoformed pieces have a tendency to straighten out. Care must also be taken to avoid springback during storage. Raised temperature increase the risk and speed of springback. Specially designed boxes or pallets may need to be used.

Effect on Physical Properties

The Divinycell is affected in two ways during thermoforming:

1. Decrease in density during heating.
2. Stretching of the outer radius.

Both will decrease the physical properties slightly. Typcial decrease is 0-5%. From design standpoint 10% should be used.

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DIAB has pioneered the use of the sandwich concept to make structures that are significantly lighter and stronger than those made from steel, aluminum and wood.

The company is very much the technology leader. In addition to being the first company to introduce core kits, it has been in the vanguard of new environmentally-friendly processing developments such as DIAB Core Infusion™.

We have always been much more than just a materials supplier. To this end we look to establish long-term partnerships with our customers by providing high performance core materials and an extensive range of technical support services.









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