The **Anti Corrosion** Industry

>> Focusing on anti corrosion solutions <<

Atlac™

Resin solutions tailored to the needs of customers and end-users

a **DSM**Brand

DSM Composite Resins

The **Atlac** product range

Unlimited. DSM

CONTENT

DSM COMPOSITE RESINS

DSM Composite Resins is the largest producer of unsaturated polyester resins in Europe. With production facilities in many different European countries, DSM Composite Resins offers a wide range of resins, matching every conceivable processing and end-use requirement, in the most diverse applications. Local Sales offices and Technical Service laboratories enable close cooperation and partnerships between customers and DSM Composite Resins. Central Research & Development is fully equipped to develop and test new resins and to fine tune systems for optimal results in specific processing techniques. The development, service and manufacture of composite resins are certified according to ISO 9001.

ANTI CORROSION ATLAC RESINS

For several decades Atlac resins have proven themselves highly suitable in applications where chemical and thermal resistance in combination with excellent mechanical properties are required. Atlac resins have outstanding corrosion resistance to a wide range of organic and inorganic acids, alkalines, solvents and bleaches. They are widely used for fibre-reinforced applications such as storage tanks, vessels, pipes and ducts. The Atlac resins can be processed by means of a wide range of fabrication techniques, including hand lay-up, spray-up, filament winding and polymer concrete.

The **Atlac** history

It was in the 50s that Atlas Powder Co in Wilmington Delaware (USA) developed a new class of unsaturated polyester resins with outstanding chemical resistant properties. The polymer backbone was based on propoxylated bisphenol A, reacted with fumaric acid into a solid, powdered resin and was sold under the brand name Atlac.

Customers had to dissolve the powder themselves in styrene to turn it into a liquid that was easy to handle in laminating processes. Various grades of Atlac resins were developed with differing flexibility and heat deflection temperatures. The most widely sold type was Atlac 382.

Atlac resins were enormously successful. Their resistance to acids, solvents and alkaline solutions made a whole new class of process equipment possible. In particular, they brought exceptionally high levels of chemical resistance that had never been possible with traditional construction materials.

New processes like filament winding and centrifugal casting for cylindrically shaped products boosted the use of Atlac resins further. Key applications were found in the pulp and paper and metal/mining industries, chlorine production and metal plating shops. The chemical industry saw storage tanks, scrubbers, reactors and stacks made of Atlac resins.

Atlac resins were often the only construction material that could withstand harsh acidic solutions like sulphuric and hydrochloric acid at temperatures up to 90°C. They were also used for sensitive applications such as wine storage vessels and water purification plants. Many storage tanks, transport pipes, stacks and scrubbers that were constructed in the 60s, are still successfully operating today.

Vinyl ester resins were born at the beginning of the 70s. Although they use a different chemistry, the backbone of the molecule was still the same base chemical (bisphenol A) that made Atlac resins so successful.

After ICI had taken over Atlas Powder Company their laboratories developed the next generation of vinyl ester resins. At the end of the 80s, ICI sold the European Atlac business to DSM Resins. In their R&D laboratories a higher grade of vinyl ester resin was developed, called Atlac 590. In this polymer an epoxy novolac backbone was used instead of a conventional epoxy bisphenol A.

The material showed even better solvent resistance, and a very high heat deflection temperature (HDT). These properties opened up new applications like flue gas desulphurisation installations, necessary additions to municipal waste incinerators, which operate at high temperatures and in very acidic conditions.

In the mid 90s, DSM Resins and BASF combined their activities in the field of unsaturated polyester technology under the name DSM Composite Resins. This resulted in the extension of the Atlac product line with the addition of BASF Palatal A 430 (now renamed Atlac 430).

In the year 2000 DSM Composite Resins introduced the fourth generation of chemical resistant resins: epoxy bisphenol A vinyl ester urethanes. Some 40 years of know-how about unsaturated polyester, vinyl ester and vinyl ester urethane chemistry and technology were combined in these resin systems.

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What is **GRP**?

Glassfibre Reinforced Plastic (GRP) is a combination of two or more materials (reinforcing agents & matrix), differing in form or composition on a macro scale.

In (glass) fibre – reinforced composites, fibres are intended to carry the load, while the surrounding resin matrix sets the fibres in the required orientation. When the materials are compatible, the matrix also acts as a load transfer medium between the fibres, and protects them from environmental damages due to temperature changes, humidity and corrosion.

The term GRP implies glass reinforcement and not any other fibre such as aramid, carbon or polyester (FRP).
There are hundreds of plastic types available (such as thermoplastics, thermosets, and elastomers), and also many variants of glass reinforcement (such as chopped strand matt, woven rovings and combination mats) – which also differ between manufacturers.
Therefore, GRP is a description representing an extensive family of composites with an extremely variable range of properties.
The type of GRP usually specified for tanks and pipes is a composite of glass fibres with more chemically resistant resin types like vinyl ester, isophthalic polyester or epoxy.

COMPOSITE PIPES AND TANKS

Pipe systems and storage tanks are constructed from a wide variety of materials such as metals (carbon steel, stainless, alloys), plastics (thermoplastics, thermosets, elastomers), inorganic materials (concrete, ceramics) and wood. The ageing behaviour of GRP material depends on different circumstances (time, temperature, media, pressure, etc.). The rate of succes (lifetime) is related to the composition of the GRP part.
Corrosive and erosive attack determines the service life. The exact function of the pipe or tank and its operating conditions are the main considerations in material selection. Cost is also an important factor. But whole life cost analysis should be used, which not only compares material costs, but should also compare transportation, installation, maintenance and operational costs during the service life of the pipeline or tank. The environmental impact of a failing pipe or tank also has to be taken into account. In many cases GRP pipes and tanks will offer a strong, reliable and cost effective alternative.

The many advantages of composites may be summarized as follows:

- Superior strength- and-stiffness-to-weight ratios. For the same strength, composites can be 80% lighter than steel and 60% lighter than aluminium.
- Ability to withstand high continuous operating temperatures compared to thermoplastics: up to 110°C in many composites; even exceeding 200°C in special cases.
- Highly corrosion resistant in almost every chemical environment.
- Electrically insulating in general (depending on reinforcement selected).
  - > When required, composites can be made electrically conductive or selectively conductive.
- Low thermal conductivity in general, but can be made conductive when required.
- Exceptional freedom of design; composites can be formed into many complex shapes.
- Outstanding durability; well-designed composites are expected to have an almost infinite lifetime, even in extremely harsh environments.
- Corrosion resistance: the non-reactive nature of many resins and reinforcements can be custom selected to resist degradation by many common materials and in corrosive environments.
- Lower maintenance and replacement costs.

APPLICATIONS

GRP products are often used in very aggressive or corrosive environments.
Such applications include:

- Fire water systems (fire water (oxygen) can cause corrosion, especially in partially dry systems). Also the below ground environment can be highly aggressive.
- Chemical process lines.
- Cooling water lines (see fire water systems).
- Demiwater (de-mineralised water is a highly aggressive medium often causing corrosion).
- (Industrial) Effluent systems.
- High-pressure pipelines (often containing aggressive media such as a


combination salt water and oil, or brine). The smooth inner surface of GRP also results in lower friction and higher flow efficiency.
- Jacket pipes (corrosive soil, non conductive in railway areas where stray current is a problem).
- Exhaust lines and chimneys (corrosive medium, light weight).
- Handling and storage of almost all aggressive chemicals.

GRP composites have found a wide range of applications in industrial environments over the last four decades. Most progress has been made in the areas of composite pipe work, storage tanks and fluid handling equipment.

The high cost of replacing steel (alloys) and the increased service life in new constructions, favour the use of composites that withstand extreme conditions. For example, in the offshore oil and gas industry, the cost of manufacturing and erecting oilrigs could be reduced significantly if heavy metal pipelines were replaced by lighter composite products. GRP leads to lower life cycle costs, reduced problems with corrosion and a reduction in structural support sizes and material handling problems during construction. The resistance of GRP to corrosion helps to improve reliability and safety. GRP pipes can be used for fire water systems, seawater cooling, draining systems, (chemical) process lines, fuel lines, sewerage systems and much more. The cost advantages of GRP plant is increased even more when they substitute expensive corrosion resistant alloys such as copper-nickel alloys, duplex / super duplex stainless steel, and titanium.

The selection of suitable resin plays an important role for imparting durability of the composites when exposed to aqueous fluids or gasses. DSM is happy to assist in this complicated matter; our specialists are at your service (Atlac.Advice@dsm.com).

The Atlac Product Range includes:

Resin Type	Chemical Nature	Typical Properties
Atlac 382	Propoxylated bisphenol A fumarate polyester resin	Suitable for high temperature water, acid and salt solutions and medium temperature alkali solutions.
Atlac 430	Bisphenol A based vinyl ester resin	Provides resistance to a wide range of acids, alkali and bleaches for the use in corrosive environments in the chemical industry. The favorable combination of thermal resistance and elongation makes the resin suitable for applications exposed to intermittent temperatures.
Atlac *E-Nova* FW 1045	Flexibilized epoxy bisphenol A vinyl ester urethane	Provides improved resistance to a wide range of acids, alkali, bleaches *and solvents* for the use in corrosive environments in the chemical industry. The favorable combination of thermal resistance and elongation also makes this resin suitable for applications exposed to intermittent temperatures.
Atlac 590	Novolac based vinyl ester resin	Provides excellent thermal and chemical resistance against solvents, acids and oxidizing media like chlorine. The resin offers high retention of strength at elevated temperatures.
Atlac *E-Nova* FW 2045	Epoxy bisphenol A vinyl ester urethane	Provides the same excellent thermal and chemical resistance against solvents, acids and oxidizing media as Novolac (Atlac 590), but offers additional resistance to alkalines.
E-Nova Technology		The Atlac *E-Nova* technology combines the easy processing of polyester with the chemical resistance of vinyl ester. Low foam curing is possible with standard MEKP peroxides and compared to traditional vinyl ester resins, it shows excellent fibre wetting.

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Reinforcements

Fabrication of a GRP laminate usually begins with the interior layers (the surface to be in contact with corrosive material). The first laminate layers are commonly known as the corrosion barrier layer. Its function is to provide corrosion protection. A surfacing veil saturated with resin forms the base for successive layers. The corrosion barrier layer generally consists of the surfacing veil and two layers of chopped strand mat.

Four types of glassfibre reinforcement are frequently used with Atlac resins. They are:

> Surfacing veil
> Chopped strand mat
> Woven roving
> Continuous strand roving

SURFACING VEILS

The purpose of a surfacing veil is to provide reinforcement for the resin rich inner liner of a corrosion barrier to prevent cracking and crazing. A second function is to prevent protrusion of the chopped strand mat fibres to the surface, which could allow wicking of the corrosive media into the laminate.

The interior surface, which is normally 1 to 2 mm thick, contains about 90% of resin and 10% of veil material.

The primary type of surfacing veil used in corrosion applications is "C"glass veil. However, in applications where "C"-glass veil is not suitable, other veil types made from thermoplastic polyester or carbon fibres may be used. "C"glass veil is typically recommended for most corrosion environments, but synthetic veil is preferred in environments such as those containing fluoride compounds. Synthetic veil is preferred in other environments, (see our corrosion guide for full details). In severe environments, like alkaline, multiple plies of veil may be recommended. Carbon veil is often used in abrasive environments or to provide a conductive liner for static electricity control. Veils made with other types of glasses, such as "A" and "ECR", are used less often in the corrosion industry but may be acceptable in certain applications.

CHOPPED STRAND MAT

Chopped strand mat reinforcement consists of a felted matrix of chopped strand "E" or "ECR" glass fibres, 12.5 - 50 mm long and loosely held together by a styrene-soluble resin binder. "ECR" mat is made with more corrosion-resistant "E" type glass fibres. Chopped strand mat is available in a variety of thicknesses (225 g/m^2, 300 g/m^2, 450 g/m^2 600 g/m^2). Two mats (450 g/m^2) are generally used with the surfacing veil to form the corrosion barrier layer that provides additional corrosion protection.

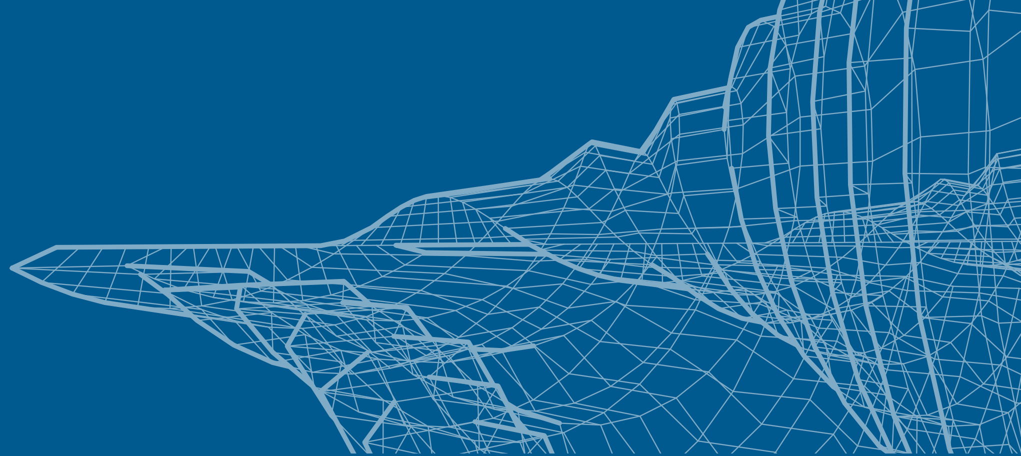
Chopped strand mats are also used in the structural layer between layers of woven roving or as the sole reinforcement for the structural wall. The chopped mat layers in the finished laminate consist of about 70% resin and 30% glass.

WOVEN ROVING

Woven roving consists of continuous glass fibre rovings that are woven together to form a heavy mat, which is available in a variety of thicknesses and weights. Alternating layers of woven roving and chopped strand mat are used in the structural portion of hand lay-up laminates. The resulting laminates are generally about 40-50% glass.

CONTINUOUS ROVING

Continuous strand roving comes in various densities and sizing finishes for applications in filament winding and pultrusion. It results in laminates with high glass contents (50-70%) for increased strength. Gun roving is used as a substitute for chopped strand mat in the corrosion barrier and the structural wall. The resulting laminates are generally about 30-40% glass.



Curing **Systems**

Atlac high performance resins can be cured with a wide variety of peroxides and accelerators. Cobalt and/or amine accelerators have to be added by the fabricator for curing at room temperature of non pre-accelerated Atlac resin types. The proper choice of the curing system depends to a large extent on the application technique and the requirements of the final product. Gel times varying from 2 to 200 minutes can be obtained with the correct choice of curing system.

All types of polyester, vinyl ester and bisphenol A resins can be cured with similar systems, using readily available materials. Catalysts (peroxides / hardeners) for unsaturated polyesters are unstable, energy rich molecules which decompose into highly reactive molecule fractions - defined as radicals - under the influence of heat, metal salts and amines (accelerators), or ultra violet light. These radicals are capable of reacting with the polyester or styrene molecule, forming new radicals, and starting of a chain reaction.

Polyester, vinyl ester and similar resin systems can be, and often are, cured at ambient temperature. The chemical reaction provoked by the catalysts and accelerators creates an exothermic (heat generating) reaction that promotes optimum cure. However control of the temperature is critical to avoid de-lamination caused by stress and shrinkage from excessive temperatures.

THICK LAMINATES

Fabrication of thick laminates easily results in overheating during cure and a tendency to warpage due to thermally induced stresses and strains. But exotherm temperatures are very much resin dependant. Sometimes it is necessary to control the heat build-up in laminates, for example when flat sheets (minimum warpage) or very thick sections are laid up in one operation. The fabrication of flanges, in particular, can be critical when a combination of relatively short gel times and low exotherm (minimum shrinkage) are required. Compared with the traditional Atlacs, Atlac *E-Nova* FW 1045 and FW 2045 can be more easily cured fulfilling these conditions. For specific resin related curing systems, the expertise centre should be contacted.

POSTCURING

Postcuring is necessary to obtain the optimum heat and chemical resistance of the Atlac high performance resins. Recommended postcure conditions are 3 to 6 hours at 90 to 100°C - longer times and adjusted postcure schedules being required for thicker laminates and/ or more complex shapes. Lower temperatures are ineffective; higher temperatures can lead to embrittlement. Laminates must be at least 24 hours old before postcuring. Laminates up to one year old can be postcured successfully. It is strongly recommended for glass fibre reinforced parts that are exposed to a chemical environment. Chemical resistance of parts or laminates from Atlac resins that have been postcured at temperatures below 90-100°C have to be tested according to the requirements of the specific application. The glass transition temperature (Tg) and heat deflection temperature (HDT) strongly depend on the temperature at which postcuring is carried out.

CURING AGENTS AND ADDITIVES

The gel time can be changed by varying peroxide levels, cobalt additions or the use of inhibitors. If cobalt levels are too low, this can lead to poor cure at low workshop temperatures. Different cure systems for the Atlac resins are available for the required gel times at various ambient processing temperatures (see resin specific technical information brochure). When faster gel and cycle times are needed or thin sections have to be cured, the methylethyl ketone peroxide types (MEKP) may be substituted for acetyl acetone peroxide (AAP). Unsaturated polyester and vinyl ester urethane resins can be cured with standard medium activity MEKP, resulting in a wide range of gel times. The addition of standard MEKP to vinyl ester resins result in an initial foaming (in traditional vinyl esters – Atlac 430 ...

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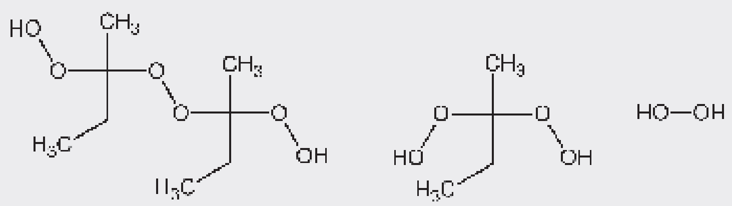
and Atlac 590) and in thick laminates MEKP cure systems may lead to overheating during cure and warpage of the laminate. However, the MEKP systems are particularly effective at lower temperatures. For longer gel times, MEKP systems can easily be inhibited. Cumene hydroperoxide (CuHP) systems for vinyl esters are preferred for many applications due to the absence of foaming after the addition of peroxide. CuHP systems allow a wide choice of gel times followed by well-controlled cure. This enables relatively thick laminates to be made in one go, reducing the risk of overheating and warpage.

PEROXIDES

Methyl Ethyl Ketone Peroxide – Medium Activity (St-MEKP)

This is a colorless liquid, usually supplied at a 50% concentration in a phlegmatizing solution. This is the most common peroxide and the levels added to the resin normally range between 1.0% and 2.5%. For Atlac resins, it should be used together with cobalt salts and, when necessary with amines and or inhibitors.



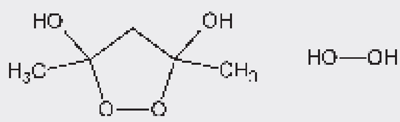
Structure 1: Methyl Ethyl Ketone Peroxide (MEKP)

MEKP is the most widely used catalyst system. It is used with promoters, usually 6% cobalt naphthenate or 6% or 10% cobalt octoate. The MEKP used most often is supplied at 9% active oxygen. Water in the catalyst will adversely affect resin cure, but MEKP can be checked for excessive water content by mixing small amounts with equal parts of styrene. A haze in the mixture indicates excessive water. For optimum results, it is important to maintain the recommended ratio of MEKP to Cobalt in the cure system.

Methyl Ethyl Ketone Peroxide – Low Activity (LA-MEKP)

This is a colorless liquid, usually supplied at a 50% concentration in a phlegmatizing solution. It is often used when long gel times are required or when the ambient temperature is high. This MEKP-peroxide is especially recommended for the cure of vinyl ester resins, because it gives less foaming. The gassing is observed starting immediately after the peroxide and the accelerator has been mixed in. This "gassing" is oxygen evolved by the decomposition of the H_2O_2 present in the peroxide formulation. Low activity MEKP contains less hydrogen peroxide than the medium activity MEKP, and hence gives less oxygen. Further on the ratio of the peroxides present in the mixture differs from medium activity MEKP (see structure 1).

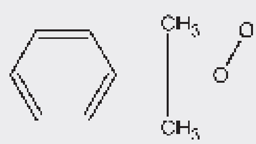
It should be noted that this decomposition of hydrogen peroxide without resulting in a gelation of the resin is also the reason why Acetyl Aceton Peroxide (AAP) cannot be used for the curing of standard vinylester resins. The gassing can be a real problem as no time is available for degassing. This will result in oxygen inclusions and micro porosity in the molding. The *E-Nova* Technology combines the easy processing of polyester with the chemical resistance of vinyl esters and low foam curing is possible with standard MEKP peroxides.



Structure 2: Acetyl Aceton Peroxide (AAP)

Cumene Hydroperoxide (CuHP)

CuHP is a clear liquid. The use of Cumene Hydroperoxide can eliminate the foaming experienced with traditional epoxy vinyl ester resins (Atlac 430 and 590) catalyzed with MEKP/cobalt catalyzed systems. Another advantage of these systems is that peak exotherms are lowered resulting in less shrinkage, and less warpage. In cool weather, a small amount of dimethylaniline may be used to accelerate cure. Care must be taken to ensure that a thorough cure is obtained, particularly at ambient temperatures. A postcure is recommended to ensure a thorough cure.

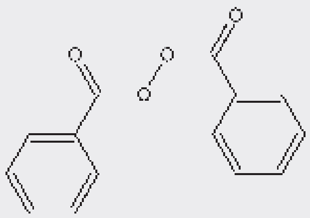


Structure 3: Cumene hydroperoxide

“freedom to construct”

Benzoyl Peroxide (BPO)

Dibenzoyl Peroxide is available on the market in powder, emulsion and paste forms. In combination with amine accelerators it shows a very fast cure, which is hardly influenced by humidity and fillers. Even at low temperatures a relatively good cure will be obtained.



Structure 4: Benzoyl Peroxide (BPO)

BPO/amine systems may cause higher exotherm temperatures, and are more difficult to fully postcure. However, in applications were hypochlorite or peroxides are present, BPO/amine curing is recommended. In these cases cobalt (metals) do have a detrimental effect on the chemical resistance performance.

NOTE: The promoter should never be mixed directly with a peroxide catalyst (such as MEKP). Mixing would cause a violent reaction, and a fire or explosion could result.

Recommended Peroxides

Peroxide	Resin type	Remarks
Standard Methyl Ethyl Ketone Peroxide (St. MEKP)	Atlac 382, 430, 590 and Atlac *E-Nova* FW 1045 / FW 2045	General purpose Ease of inhibition No / Slightly foaming (Atlac 382 / Atlac *E-Nova* FW 1045 / FW 2045) Foaming (Atlac 430 / 590)
Low Activity Methyl Ethyl Ketone Peroxide (LA-MEKP)	Atlac 382, 430, 590 and Atlac *E-Nova* FW 1045 / FW 2045	Long geltimes High temperatures Slightly foaming (Atlac 430 / 590)
Acetyl acetone peroxide (AAP)	Atlac 382 and 590	High reactivity topcoats Thin sections Low temperature
Cumene Hydroperoxide (CuHP)	Atlac 430, 590 and Atlac *E-Nova* FW 1045 / FW 2045	Low exotherm (Atlac 430 and 590) Very low exotherm + extra long getime (Atlac *E-Nova* FW 1045 / FW 2045)
Benzoyl Peroxide (BPO-50)	Atlac 382, 430, 590 and Atlac *E-Nova* FW 1045 / FW 2045	Amine accelerator required to cure Recommended when Cobalt cure is prohibited Low temperature High humidity

ACCELERATORS AND PROMOTERS

Promoters and accelerators are used to speed up and enhance the cure.

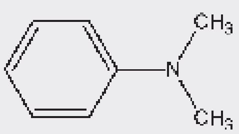
Cobalt octoate / naphthenate

Cobalt solutions are blue or purple liquids and are available on the market with different percentages of active cobalt that can be used with MEKP and CuHP curing systems. Dilution in styrene will prevent formation of small particles of cobalt and will facilitate uniform mixing. Other cobalt accelerators can be used, such as naphtenate and versatate, but both show a low reactivity. Furthermore, when stored for long periods in unsatisfactory conditions, they lose their reactivity.

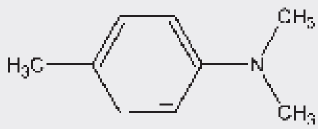
Amines

Dimethylaniline (DMA) is a yellow amine liquid with a strong odor. DMA can be used with MEKP, BPO (ambient cure), and CuHP catalyst systems. The addition of DMA is not required with MEKP and CuHP systems. However, small amounts of DMA may be used in conjunction with cobalt to improve Barcol development and/or shorten the cure time. With ambient temperature BPO systems, the addition of DMA is required.

Dimethyl-para-toluidine (DMPT) is a yellow amine liquid with a strong odor. DMPT can be used in BPO/amine curing systems in those applications where a very short gel time is required.



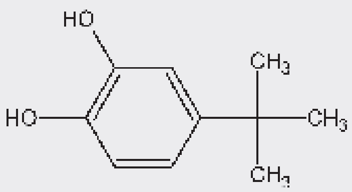
Structure 5: Dimethylaniline (DMA)



Structure 6: N,N-Dimethyl-p-toluidine (DMPT)

INHIBITORS

Inhibitors are used to lengthen the gel time of vinyl ester and polyester resins to give a controllable cure. The most widely available is a 10% solution of tertiary-butyl-catechol (TBC). Inhibitors should be used with care as additions above 0,25% can lead to undercure, low Barcol, or reduced corrosion resistance. Recommended inhibitor levels vary from type to type and from resin to resin. Some common inhibitors include tertiary butyl catechol (TBC), hydroquinone (HQ), and toluhydroquinone (THQ). Tertiary-butyl catechol is not effective with cumene hydroperoxyde systems.



Structure 7: tertiary-butyl-catechol (TBC)

UV STABILIZERS

A five-year study conducted on laminates made from Atlac resins, showed that little or no degradation occurred. If an ultraviolet absorber is deemed to be necessary, either an additional level of 0.2% throughout the laminating resin or 0.2% to 0.5% in the topcoat is effective. Recommended UV absorbers are Tinuvin 320 and Cyanosorb UV5411 (Tinuvin - Ciba Geigy, Cyanosorb - Cyanamid).

ELECTRICALLY CONDUCTIVE MATERIALS

The creation or improvement of the electrical conductivity of a composite is generally achieved by the introduction of carbon, in some form, into the laminate.

This can be achieved by incorporating a carbon based veil - one or more carbon fibres into the band of reinforcement on a filament winding machine - or by incorporating carbon (or graphite) in powder form into a resin before lamination. Once the level of conductivity required has been met, the pipe system or other equipment must be satisfactorily earthed. (Information regarding conductivity requirements can be found in ISO 14692).

ABRASION RESISTANT ADDITIVES

Abrasion resistance in corrosion resistant composite material is generally required for equipment handling slurries or solids in suspension, which would generally erode or abrade standard corrosion resistant materials. Typical additives that may be included within internal and/or external barriers, or throughout the total thickness of a laminate, are usually based upon various forms of aluminium oxide or silicon carbide (SiC). Secondary fillers or additives are generally required to achieve a satisfactory material dispersion and resin viscosity. The characteristics of abrasion vary immensely from one application to another.

FLAME OR FIRE RETARDANT ADDITIVES

Antimony pentoxide may be used with some resin systems, and alumina trihydrate will improve the fire resistance of both halogenated and non-halogenated resins. In the case of alumina trihydrate, the high level of filler required may have negative effects on corrosion resistance, mechanical properties and general handling properties of the resin.

Fabrication of **tanks and pipes**

Parts for the anti corrosion industry can be produced according to different production techniques.

PRODUCTION TECHNIQUES

Machine-made GRP pipes derive mainly from two generic processes:

> **Filament winding**

> **Centrifugal casting**

Each has its own specific qualities and advantages.

Tanks and vessels are often a combination of filament (helical) winding, hand lay-up or Resin Transfer Moulding. Below these production techniques are discussed in detail.

Filament winding

In the filament winding process, a number of continuous glass fibre rovings, woven glass tapes or unidirectional glass fabrics are impregnated with a matrix resin. These wetted fibres are applied onto the outside of a rotating mandrel in a pre-determined pattern and under controlled tension.

The filament winding technique can roughly be divided into two principle types:

- Continuous filament winding
- Helical winding

With continuous filament winding (also called tangential winding), the glass fibres are wound in a closed pattern, or an overlap onto the outside of a (continuously advancing) mandrel, adding chopped fibres, resin and optional additives and fillers. The winding angle and the amount of materials applied at each rotation determine the wall thickness and the wall construction.

With helical winding, repeated passes of wetted fibres around a rotating mandrel in a specific helical pattern, results in a multiple layered wall construction of continuous fibres (either woven or as a unidirectional roving). The angles can vary in theory between 0 and 90° (in practice they average between 45° and 73°), and can be adapted to specific strength requirements of the product.

Centrifugal casting

In the centrifugal casting process, glass fibres and/or mats are placed or applied at the inside of a hollow mandrel (steel tube). As the steel tube rotates at high speed, resin is injected wetting out the reinforcement and optional fillers and additives. These materials are compressed against the wall due to the centrifugal forces, thus forming a dense pipe wall. The main difference compared to filament winding is that high filler content can be achieved.

Hand lay-up/spray-up

Hand lay-up , also called contact moulding, is a production technique suitable for low volume production of GRP components. The fibres are manually placed onto a mould surface and impregnated with resin, usually by using a hand roller. More layers are added and after curing, the composite part can be removed from the mould. The process is very flexible as it can produce very small parts, up to very large parts in a wide variety of shapes and properties. The cycle time per part is very long, and hence this production technique is used mainly for small series or for large complex shapes.
For larger series the spray-up technique is more favourable.

Resin Transfer Moulding

Resin injection, also called resin transfer moulding (RTM), produces strong fibre reinforced plastic parts with two smooth surfaces. Several layers of dry continuous strand mat, woven roving or cloth are placed in a closable mould. A liquid resin is then injected into the mould, which is subsequently cured. As an option, a pre-form can be used as a core material, enhancing the economics and efficiency of this production technique. The advantages of RTM are the possibility to manufacture complex, high performance structures with a good surface finish, design flexibility, the possibility to integrate more components into one part and to produce parts without styrene emission.

DUAL LAMINATES

Dual-Laminates have been used in chemical plant such as towers, scrubbers, process vessels and tanks for over thirty years in highly corrosive applications, where chemicals such as chlorine and chlor-alkali products, strong acids, strong bases, organic compounds and other corrosive media are present.
Dual laminates consist of a thermoplastic inner liner protected by a fibreglass composite outer layer, thus combining the advantages of thermoplastic corrosion resistance with the high mechanical properties of GRP.
Thermoplastic liner materials include most grades used for manufacturing thermoplastic pipe and equipment, such as polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), polypropylene (PP), the fluoropolymer family and others.

PVC and CPVC are usually bonded directly to the FRP laminate using a bonding resin (Palatal A 410-01 and/or blends with Atlac *E-Nova* FW 2045. For details contact the expertise centre), while other thermoplastic liners are typically manufactured with an embedded fabric or fibreglass backing. This fabric backing can provide a mechanical bond with the fibreglass structural composite but requires compatibility of the base materials.

LINER ESSENTIALS

The inner corrosion resistant liner consists mainly of resin, reinforced with a corrosion veil or veils, sometimes backed by a chopped strand fibreglass mat. The veil(s) may be either a corrosion grade fibreglass (C- or ECR-glass), or an organic veil such as polyester (Nexus), ECTFE (Halar) or graphite. An organic veil would be used in environments known to attack glass, such as sodium hydroxide, hydrofluoric acid, etc. After curing, the liner thickness can vary between 0.25 to 5 mm at 10% to 50% reinforcement for C/ECR-glass. The fibreglass chopped strand E-glass mat that backs up the veil, generally contains up to 30% reinforcement. These are however just general guidelines; the final corrosion resistant liner may vary depending upon the corrosive properties of the fluid contained. The performance of the liner is highly dependent on the quality and compatibility of both the resin and the reinforcing material, and liner designs are not interchangeable. Each new combination of materials has to be examined carefully. To avoid confusion, the corrosion liner and the corrosion allowance should be specified. Some specifications include the corrosion liner in calculating required overall pipe wall thickness, but generally specifications require the liner be treated as a sacrificial corrosion allowance, and not to be used in any of the pipe structural calculations for pressure and vacuum handling capability.

Design and **product quality**

MECHANICAL PROPERTIES

The mechanical properties of composites depend on the production technique, the product design (e.g. fibre orientation) and compatibility of base materials (glass, finish and resin). Ageing is a property of any plastic material. The behaviour of plastics depends on time and temperature, resulting in a regression of the original properties. This ageing effect can be influenced by:

- Environmental circumstances (weather)
- Medium
- Stresses

It differs for each plastic material and / or composite composition. This complicates the comparability of the different variants of this material and for this reason, long term (regression) testing according to ASTM D 2992 is required for pressurized pipe systems. An indication of the long-term behaviour can also be obtained by determining the Ultimate Elastic Wall Stress (UEWS). Comparing the UEWS of the system with the UEWS of the component that is qualified by regression analysis according to ASTM D 2992-B. See also section “Ultimate Elastic Wall Stress”.

JOINTS

Although the joints of GRP can be a weak spot, the number of defective joints per kilometre/ per year are for steel pipe systems, some 4-5 times higher than GRP pipe joints. The reason for this is corrosion. (Source: Veritec Offshore Technology).

Specific GRP jointing systems:

- Adhesive bonded joints
- (Integral) Mechanical (rubber sealed) joints; either tensile resistant or non-tensile resistant
- Laminated joints
- Threaded joints
- Flanged joints
- Third party mechanical joints

Each joint has its own specific strength and weakness and can be designed either to endorse full end thrust loads or with limited or no axial load ability.

Making a reliable joint in GRP requires – as with any other material – a certain level of skill, knowledge and good workmanship. Fabricating a joint in GRP should be no more difficult than with traditional materials.

QUALIFICATION AND DESIGN OF GRP PIPES

Due to the diversity of GRP (base material combinations and production techniques), the subject of design becomes quite complicated. Extra complexity comes from the fact that the properties differ in time. The ageing effect results in loss of strength and stiffness properties. This regression depends largely on the quality of the combination of base materials and their compatibility and production technique.

Therefore, it is very important to determine the design parameters of each variant, not only initially, but also in the context of the service life. In December 2002, a new ISO standard was published, dealing with this subject in combination with qualification of components, system design, installation and quality assurance issues: ISO 14692. The scope of this document refers to offshore applications, but the standard can also be used as a basis for onshore applications. The main principle for this document is the link between the properties of the specific GRP product and the safety in the installed pipe system.

The qualification involves a test program that involves full-scale hydrostatic performance tests, establishing a long-term design basis, not only for pipes, but also for the system as a whole including joints and fittings. Verification of the long-term performance of pipes, fittings and joints is done by means of:

a. Regression analysis according to ASTM D 2992-B at the maximum design temperature on pipes.
b. Medium term testing on joints and fittings. For this test, two representative samples have to be tested for 1000 hrs at maximum temperature and at a test pressure exceeding the pressure level at 1000 hrs resulting from the regression analysis performed on pipes. In practice this will be ± 2.5-5 times the nominal pressure rating. This figure differs from each manufacturer, depending on the type of product, manufacturing procedures, etc.

The manufacturer can carry out qualification testing provided it is witnessed and certified by a recognized independent authority. Alternatively, testing and certification may be carried out by an independent testing organization. This should be confirmed by submitting a certificate stating the test results.

HYDROSTATIC DESIGN BASIS

To achieve a safe allowable design basis, it is necessary to consider the behaviour of GRP material in a pressurized condition. The burst strength is not to be considered as a good basis for determining an allowable stress. Another point that can be distinguished when pressurizing a component is weeping. The weeping phenomenon is caused by plastic deformation in the material. Weeping starts at pressure levels clearly exceeding those governed by the UEWS.

Bursting pressure and weeping pressure are generally derived from short-term destructive test results; but these test results have only secondary value since there is no fixed ratio between the short-term value and the long-term load ability.

The right ratio can be determined by testing a component according to ASTM D 2992 and determine the hydrostatic design basis/stress. Subsequently, 5 additional samples have to be tested according to ASTM D 1599. Generally, the following variety is seen for these ratios:

The design stress has to be relative to the long-term properties.
Please note that the regression analysis and UEWS are in general determined on pipes only. The suitability of the hydrostatic design basis for the other components in a system can then be demonstrated by 1000 hrs medium term testing according to ISO 14692.

ULTIMATE ELASTIC WALL STRESS

Executing such an extensive test program limits the development of new materials.
In cooperation with institutes and the industry, DSM has participated in the development of a new, fast and reliable method called the Ultimate Elastic Wall Stress (UEWS) for bi-axially loaded pipes. UEWS represents the highest stress at which the strain is reversible (comparable to the yield-point of steel). This test offers a comfortable method to determine the performance level at short notice and can be performed fully automated.

DSM has implemented this new, fast and reliable test method to determine applicability of test data for new material combinations.

The Ultimate Elastic Wall Stress method links properties of new material combinations to the existing full-scale test program.
DSM will be happy to elaborate on this subject and to offer support in this matter.

Ratios

Bursting stress/design stress	=	8-12 times the design pressure
Weeping stress/design stress	=	3-6 times the design pressure
UEWS / hydrostatic design stress	=	1.5-3 times the design pressure

Test methods and international standards

Test methods

Subject	ASTM	EN	ISO
Short term hydraulic failure pressure	D 1599	1229	7511
Long term hydrostatic pressure	D 2992	1447	7509
Hydrostatic pressure – time to failure	D 1598	1447	7509
Cyclic internal pressure	D 2143	1638	15306
Regression analysis	D 2992	705	10928
Strain corrosion	D 3681	1120	10952
Initial longitudinal tensile properties	D 2105/D638	1393	8513
Initial circumferential tensile strength	D 2290/D638	1394	8521
Initial deflection	D 2412	1226	10466
Initial specific ring stiffness	D 2412	1228	7685
Long-term specific ring stiffness	--	1225	10468
Long-term bending strain/ring deflection-wet condition	D 5365	1227	10471
Beam deflection	D 2925	--	--
Thermal coefficient of expansion	D 696	11359	
Barcol hardness	D 2583	--	--
Ignition loss/glass-void-water content	D 2584		1172
DSC analysis	E 1356	11357	11357
Electrical conductivity of insulating materials	D 257	14692	
Adhesive bonded /laminated joint	D 4161	1449	8533
Flanged joint	D 4024	1450	8483
Mechanical integral joint	D 4161	1448/1119	8639/7432

Please note that there can be significant differences in methods and requirements between the ASTM, EN and ISO standards on identical subjects.

Pipe product specifications

ASTM D 2310:	Classification for machine-made fibreglass pipe
ASTM D 2996:	Specification for filament-wound glass fibre pipe
ASTM D 2997:	Specification for centrifugally cast fibreglass pipe
ASTM D 3262:	Standard specification for reinforced plastic mortar sewer pipe
ASTM D 3517:	Specification for fibreglass pressure pipe
ASTM D 3753:	Specification for fibreglass reinforced polyester manholes
ASTM D 3754:	Specification for fibreglass sewer and industrial pressure pipe
ASTM D 3840:	Specification for fibreglass pipe fittings for non pressure applications
ASTM D 5685:	Specification for fibreglass pressure pipe fittings
EN 1115:	Plastics piping systems for underground drainage and sewerage under pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP)
EN 1636:	Plastics piping systems for non-pressure drainage and sewerage - Glass-reinforced thermosetting plastics (GRP) based on polyester resin (UP)
EN 1796:	Plastics piping systems for water supply with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP)
EN 14364	Plastics piping systems for drainage and sewerage with or without pressure - Glass-reinforced thermosetting plastics (GRP) based on unsaturated polyester resin (UP) - Specifications for pipes, fittings and joints
ISO 10467:	Plastics piping systems for pressure and non-pressure drainage and sewerage — Glass reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin
ISO 10639:	Plastics piping systems for water supply, with or without pressure — Glass-reinforced thermosetting plastics (GRP) systems based on unsaturated polyester (UP) resin
ISO 14692:	Petroleum and natural gas industries - Glass-reinforced plastics (GRP) piping

Tanks:

ASTM D 3299:	Specification for filament wound glassfibre reinforced thermoset resin corrosion resistant tanks
ASTM D 4097	Specification for contact moulded glassfibre reinforced thermoset resin corrosion resistant tanks
ASTM D 4021	Glass fibre reinforced polyester underground petroleum storage tanks
EN 13121	GRP tanks and vessels for use above ground
EN 976	Underground tanks of glass-reinforced plastics (GRP) - Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum base fuels
EN 977	Underground tanks of glass-reinforced plastics (GRP) - Method for one side exposure to fluids
EN 978	Underground tanks of glass-reinforced plastics (GRP)
EN 12917	Underground tanks of glass-reinforced plastics (GRP) - Horizontal cylindrical tanks for the non-pressure storage of liquid petroleum based fuels - Assessment of conformity to EN 976-1 and EN 976-3
EN 13280	Specification for glass fibre reinforced cisterns of one piece and sectional construction, for the storage, above ground, of cold water

Case **histories**

Beside the enormous number of laboratory tests to find out the chemical resistance performance of Atlac resins, the best way of collecting practical information about the performance of chemical plant based on Atlac resins is to look at current and past cases. DSM Composite Resins has built-up an extensive case history file dating back over four decades, proving the extreme corrosion resistant properties of our resins. Many examples show that Atlac composites are assuring many years of service life, without any maintenance problems.

A few **historical examples**

ATLAC 382

One of the eldest cases, after more than 30 years in service, is this wet chlorine chilling filtration tower at ICI - UK. The total construction is based on Atlac 382 – Bisphenol A based unsaturated polyester. The tower was installed in 1974 and is still battling, to this day, against the extremely corrosive environment of wet chlorine gas.

ATLAC 430

Illustrating the good alkaline resistance of Atlac 430 are these two tanks at DSM Pharma containing Sodium hydroxide, 25% at 50-60°C. The tanks, both 165 m^3 were installed in 2001. One of the drivers in the selection of Atlac 430, beside the good corrosion resistance properties, was the low weight, resulting in low transport and installation costs, and the maintenance- free nature of these FRP-tanks.

ATLAC *E-NOVA* FW 1045

The history of this resin may not go back so far, but nevertheless, Atlac *E-Nova* FW 1045 shows good chemical resistance properties, including resistance against alkalines, combined with easy processing properties. This resin can also be easily made thixotropic. These were the reasons for selecting this resin for the production of a gas scrubber processing hot gasses in an alkaline environment.

ATLAC 590

This novolac vinyl ester resin was introduced in the market in 1994, and many case histories have been collected. In cases of high temperature applications and/or presence of solvents, Atlac 590 can guarantee many years of trouble-free service life. This was a requirement for the glass flake coated reactor at the DSM site in Geleen. Installed in 1995, it consists of a structural FRP laminate and a glass flake coating inner liner - both based on Atlac 590. The resin has to deal with water, solvents, inorganic salts and acids at 60°C.

ATLAC *E-NOVA* FW 2045

Like Atlac 590, Atlac *E-Nova* FW 2045 also performs well at high temperatures and in contact with organic solvents. This resin has therefore been selected for a 50 m^3 storage tank at DSM Pharma in Venlo, to store waste water at 80°C containing reasonable amounts of ethylacetate. This tank has been installed at the end of 2003 and was recently succesfully inspected (2005) for the first time. Beside the easy processing properties of this resin (less foaming, fast impregnation and fibre wet-out, suitable for thick laminates), inspections are much easier due to the high transparency of the produced laminate.

We are willing to help with your enquiries. Please e-mail your questions about materials or applications to: Atlac.Advice@dsm.com The full range of Atlac products is included and available in our standard printed "Corrosion Guide" or as interactive guide on the Atlac.com website.

CHEMICAL RESISTANCE ENQUIRIES

For the chemical resistance sector we have our Expertise Centre in the Netherlands where we use the latest facilities and technology, backed by over four decades of product and market knowledge, to provide fit-for-purpose advice and to innovate new solutions. Such developments normally take place in close cooperation with customers.

Many tests have now been undertaken according to the chemical resistance quality standard: ASTM C581 and EN13121/2. With Atlac resins we now have a history that goes back more than forty years, where components have been in continuous service and subjected to all kinds of different chemical solutions and aggressive environments. By logging all these experiments, combined with our ongoing development and testing program, we have been able to build up an extensive knowledge base of how our resins perform in contact with a vast range of corrosive media in different concentrations and at different temperatures. This accumulated intelligence has been entered into a central database known as CRIS (Corrosion Resistance Information System). Continuously new data are added in the system from our contacts and from our own in-house testing program. So far we have more than 5000 entries in our corrosion resistance database. Wherever possible we present the results within 24-48 hours and in 5 different languages! The Expertise Centre is fully equipped with all the necessary state of the art equipment for analysis and environmental testing.

Atlac 382

>> Product Information <<

CHEMICAL / PHYSICAL NATURE

Atlac 382 is a propoxylated bisphenol A fumarate unsaturated polyester resin, dissolved in styrene.

PERFORMANCE

Atlac 382 is suitable for high temperature water, acid and salt solutions and medium temperature alkali solutions.

MAJOR APPLICATIONS

Atlac 382 can be used in all fabrication methods, but is especially adapted to meet the requirements of filament winding, centrifugal casting, hand lay-up and spray-up applications. Atlac 382 may also be used to formulate glassflake coatings and mortars.

APPROVALS

Cured non-reinforced Atlac 382 conforms to type 1310 according to DIN 16946/2 and is classified group 5 according to DIN 18820/1 and group 6 according to EN13121/2.

Liquid product specifications

Properties	Range	Unit	TM
Appearance	sl. hazy	-	TM 2265
Viscosity, 23°C	560 - 660	mPa.s	TM 2013
Density, 23°C	1030	kg/m³	TM 2160
Solid content	49-51	%	TM 2033
Gel time from 25 - 35°C	5-12	min	TM 2625
Cure time from 25°C to peak	22-30	min	TM 2625
Peak temperature	140-170	°C	TM 2625

Curing system

0.5% Accelerator NL-51P
1.0% Accelerator NL-63-10P
1.5% Butanox M-50

Test methods

Test methods (TM) referred to in the tables are available on request.

Typical data cured product - non reinforced

Properties	Range	Unit	TM
Density, 20°C	1120	kg/m³	-
Hardness	40	Barcol	TM 2604
Tensile strength	62	MPa	ISO 527-2
Elongation at break	2.1	%	ISO 527-2
Tensile modulus	3.4	GPa	ISO 527-2
Flexural strength	113	MPa	ISO 178
Flexural modulus	3.4	GPa	ISO 178
Impact resistance - unnotched sp.	9	kJ/m²	ISO 179
Heat Deflection Temperature (HDT)	120	°C	ISO 75-A
Glass transition temperature (Tg)	137	°C	DIN 53445

Curing system

0.8% Accelerator NL-51P
0.5% Accelerator NL-63-10P
1.5% Butanox M-50

Postcure

24hrs at 20°C followed by 3 hrs at 100°C

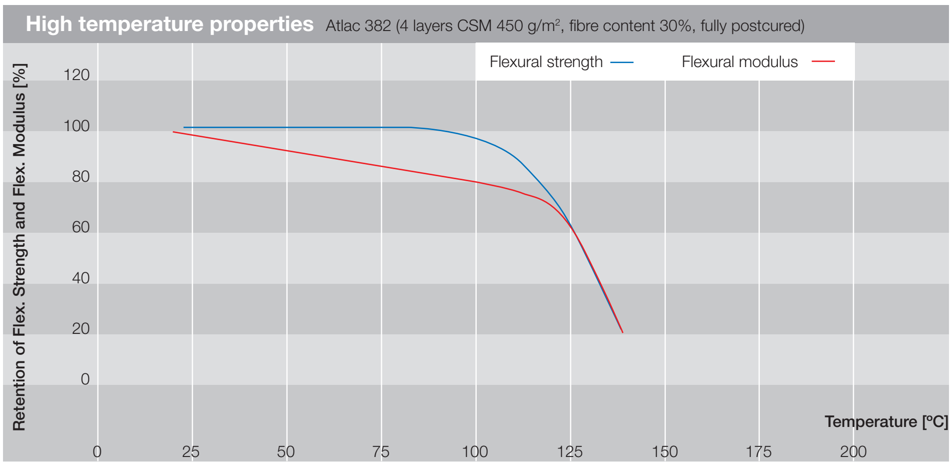
Supplier curing agents

Akzo Nobel Chemicals

Atlac 382

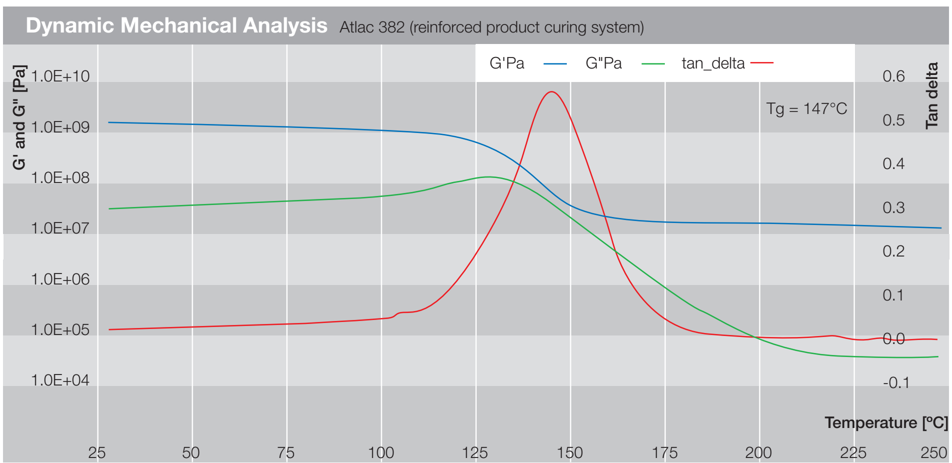
Typical data reinforced product

Curing System		Laminate build up		
0.8% Accelerator NL-51P		450 g/m² CSM	450 g/m² CSM	
0.5% Accelerator NL-63-10P		450 g/m² CSM	800 g/m² WR	
1.5% Butanox M-50		450 g/m² CSM	450 g/m² CSM	
Postcure 24hrs at 20°C followed by 3 hrs at 100°C		450 g/m² CSM	800 g/m² WR	
			450 g/m² CSM	
			800 g/m² WR	
Properties / Unit				**Test methods**
Glass content	%	30	44	ASTM D 2584
Tensile strength	MPa	85	164	ISO-527-2
Modulus of elasticity in tension	GPa	7.5	10.7	ISO-527-2
Flexural strength	MPa	139	260	ISO-527-2
Modulus of elasticity in bending	GPa	6.6	8.8	ISO-178
Density	kg/m³	1330		-
Impact resistance - unnotched sp.	kJ/m²	80		ISO-179
Linear expansion	C^{-1}	31×10^{-6}		-
Thermal conductivity	W/m.K	0.22		-



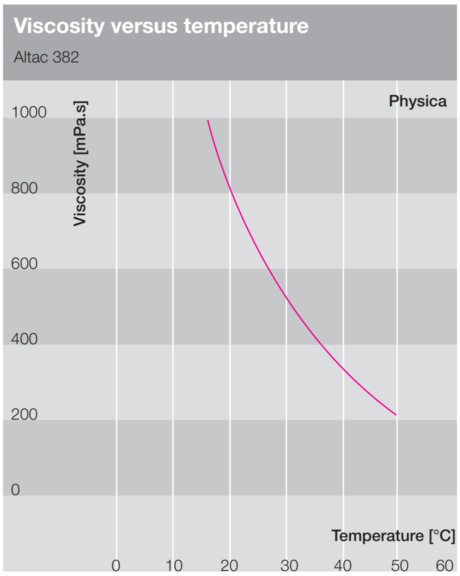
GRAPH 1:
HIGH TEMPERATURE PROPERTIES

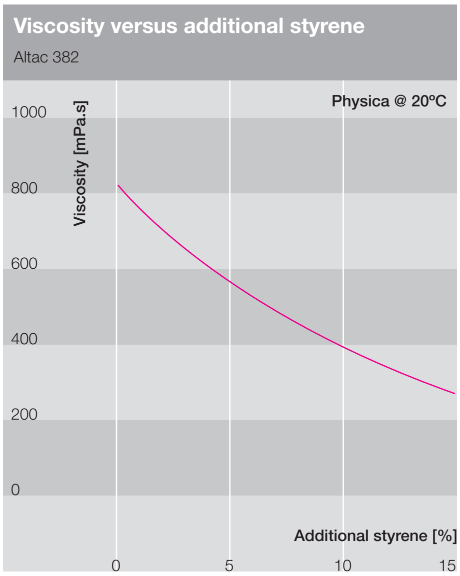
The flexural moduli and strengths of the resin over a temperature range of 20-180°C were measured according to ISO-178. The laminates were based on 4 layers of 450 g/m² chopped strand mat with a fibre content of 30% w/w. Standard cure systems have been used and all specimen have been fully postcured.



GRAPH 2:
DYNAMICAL MECHANICAL ANALYSIS (DMA)

In torsion mode the DMA measures the storage modulus (G') and loss modulus (G") of the resin (frequency is 6.22 rad/sec). Based on the moduli the tan delta (tan_δ) can be calculated. The peak in the tan_δ curve corresponds to the glass transition temperature (Tg), indicating the change from glassy to the rubbery state. Standard (post)curing systems have been used.





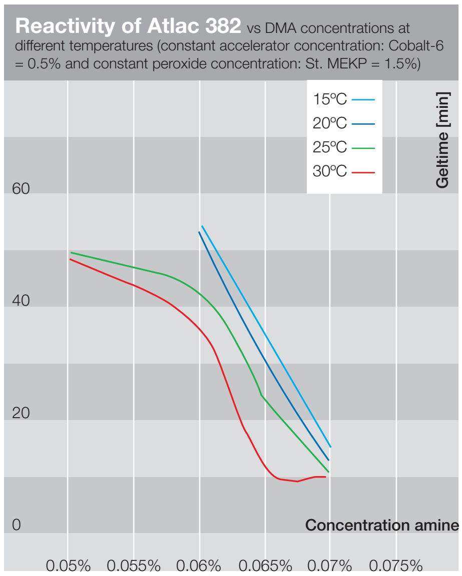
GRAPH 3A:
VISCOSITY VERSUS TEMPERATURE
GRAPH 3B:
VISCOSITY VERSUS ADDITIONAL STYRENE

The viscosity of the Atlac resin can be influenced by temperature and / or the styrene content. Additional styrene, up to approx. 5% can be used without affecting the chemical resistance and mechanical properties.

Atlac 382: typical geltimes, using standard MEKP / Cobalt

Used curing agents: standard methyl ethyl ketone peroxide (St. MEKP), Cobalt 6% and dimethylaniline (DMA)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	0.5% Cobalt-6	0.5% Cobalt-6	0.5% Cobalt-6
	0.07% DMA	0.06% DMA	0.05% DMA
	1.5% St. MEKP	1.5% St. MEKP	1.5% St. MEKP
20°C	0.5% Cobalt-6	0.5% Cobalt-6	0.5% Cobalt-6
	0.07% DMA	0.065% DMA	0.060% DMA
	1.5% St. MEKP	1.5% St. MEKP	1.5% St. MEKP
25°C	0.5% Cobalt-6	0.5% Cobalt-6	0.5% Cobalt-6
	0.07% DMA	0.065% DMA	0.06% DMA
	1.5% St. MEKP	1.5% St. MEKP	1.5% St. MEKP
30°C	0.5% Cobalt-6	0.5% Cobalt-6	0.5% Cobalt-6
	0.07% DMA	0.065% DMA	0.06% DMA
	1.5% St. MEKP	1.5% St. MEKP	1.5% St. MEKP



Atlac 382: typical geltimes, using BPO / amine

Used curing agents: benzoyl peroxide (BPO-50) and dimethylaniline (DMA)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
10°C	0.4% DMA	0.3% DMA	0.2% DMA
	4.0% BPO	3.0% BPO	2.0% BPO
15°C	0.35% DMA	0.25% DMA	0.15% DMA
	3.5% BPO	2.5% BPO	1 .5% BPO
20°C	0.3% DMA	0.2% DMA	0.175% DMA
	3.0% BPO	2.0% BPO	1.0% BPO

When curing has to take place at low temperatures (outdoor jointing or repairing, lining, etc.) and or high humidity BPO/amine curing is recommended.

This curing system is also recommended in applications were hypochlorite or peroxides are present.

“freedom to construct”

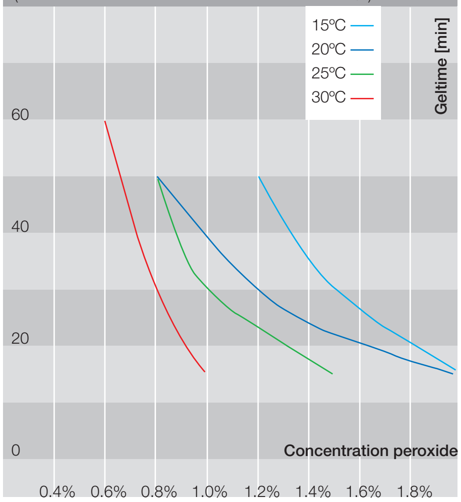
Atlac 382A: typical geltimes, using standard MEKP / Cobalt

Used curing agents: standard methyl ethyl ketone peroxide (St. MEKP) and Cobalt 6%

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	1.0% Cobalt-6 2.0% St. MEKP	1.0% Cobalt-6 1.5% St. MEKP	1.0% Cobalt-6 1.2% St. MEKP
20°C	1.0% Cobalt-6 2.0% St. MEKP	1.0% Cobalt-6 1.2% St. MEKP	1.0% Cobalt-6 0.8% St. MEKP
25°C	1.0% Cobalt-6 1.5% St. MEKP	1.0% Cobalt-6 1.0% St. MEKP	1.0% Cobalt-6 0.8% St. MEKP
30°C	1.0% Cobalt-6 1% St. MEKP	1.0% Cobalt-6 0.8% St. MEKP	1.0% Cobalt-6 0.7% St. MEKP

Reactivity of Atlac 382A

vs STANDARD MEKP concentrations at different temperatures
(constant accelerator concentration: Cobalt-6 = 1%)




Liquid resin


Cured resin, Standard MEKP / cobalt curing system


Cured resin, BPO / amine curing system

POSTCURING

Postcuring is necessary to obtain the optimum heat and chemical resistance of the Atlac high performance resins. Recommended postcure conditions are 3 to 6 hours at 90 to 100°C – longer times and adjusted postcure schedules being required for thicker laminates and/or more complex shapes. Lower temperatures are ineffective; higher temperatures can lead to embrittlement.

TOPCOAT

Topcoats applied, as final layer in linings for the outside surface must contain paraffin wax to obtain full cure (preventing air inhibition). The resin requires about, 0.1 - 0.2 % addition of wax. The wax should have a melting point of 54 - 57°C and is best added into the resin as 10% solution in styrene. Topcoats must be cured quickly for the wax to be effective. Use a MEKP or AAP cure system to obtain a gel time of 15 minutes or less. Properly cured topcoats will not become tacky when rubbed with acetone.

INHIBITOR SYSTEMS

Control of geltime may also be achieved by the use of inhibitors; the most widely available is a 10% solution of tertiary-butyl-catechol (TBC). Additions above 0.25% can lead to undercure. Use at workshop temperature below 15°C is not recommended. TBC is not effective with cumene hydroperoxide systems.

THIXOTROPY

Atlac 382 can be made thixotropic by using the standard (polyester) fumed silica types: Aerosil R 200 or Cab-O-Sil M5 (0.5% - 2%). They should be blended into the resin using a high-shear stirrer (Cowless type). To improve a maximum thixotropic effect, it is recommended to use a wetting agent (e.g. 0.2% w/w Tween 20 – ICI). Thixotropic agents should not be used in laminates intended for service with hypochlorite solutions or fluorine. In this case, sagging can only be reduced to a minimum by very short gel times (20-25 min). In case of Wacker HDK 20 or Aerosil R202, Byk R605 can be used as a wetting agent.

Grades of Atlac resins:

Different pre-formulated grades of Atlac available for use.

Resin Type	Grade	Remark
Atlac 382	Atlac 382	Standard
	Atlac 382A	Amine promoted
	Atlac 382 flakes / powder	Solid version to be dissolved by users Exceptional shelf life

Atlac 430

>> Product Information <<

CHEMICAL / PHYSICAL NATURE

Atlac 430 is a vinyl ester based on bisphenol A epoxide, dissolved in styrene.

PERFORMANCE

Atlac 430 provides resistance to a wide range of acids, alkali, and bleaches for the use in corrosive environments in the chemical processing industry. The favorable combination of thermal resistance and elongation makes this resin suitable for applications exposed to intermittent temperatures.

MAJOR APPLICATIONS

Atlac 430 can be used in all fabrication methods, but is especially adapted to meet the requirements of filament winding, centrifugal casting, hand lay-up and spray-up applications.

APPROVALS

Cured non-reinforced Atlac 430 conforms to type 1310 according to DIN 16946/2 and is classified group 5 according to DIN 18820/1. According to EN13121/2 Atlac 430 is classified group 7A.

Liquid product specifications

Properties	Range	Unit	TM
Appearance	clear	-	TM 2265
Viscosity, 23°C	440-500	mPa.s	TM 2013
Density, 23°C	1060	kg/m^3	TM 2160
Solid content	59-62	%	TM 2033
Gel time from 25 - 35°C	10-15	min	TM 2625
Cure time from 25°C to peak	17-24	min	TM 2625
Peak temperature	140-160	°C	TM 2625

Curing system

1.0% Accelerator NL-49P

2.0% Butanox LPT

Test methods

Test methods (TM) referred to in the tables are available on request.

Typical data cured product - non reinforced

Properties	Range	Unit	TM
Density, 20°C	1145	kg/m^3	-
Hardness	40	Barcol	TM 2604
Tensile strength	95	MPa	ISO 527-2
Elongation at break	6.1	%	ISO 527-2
Tensile modulus	3.6	GPa	ISO 527-2
Flexural strength	150	MPa	ISO 178
Flexural modulus	3.4	GPa	ISO 178
Impact resistance - unnotched sp.	28	kJ/m^2	ISO 179
Heat Deflection Temperature (HDT)	105	°C	ISO 75-A
Glass transition temperature (Tg)	130	°C	DIN 53445

Curing system

0.5% Accelerator NL-49P

1.0% Butanox LPT

Supplier curing agents

Akzo Nobel Chemicals

Postcure

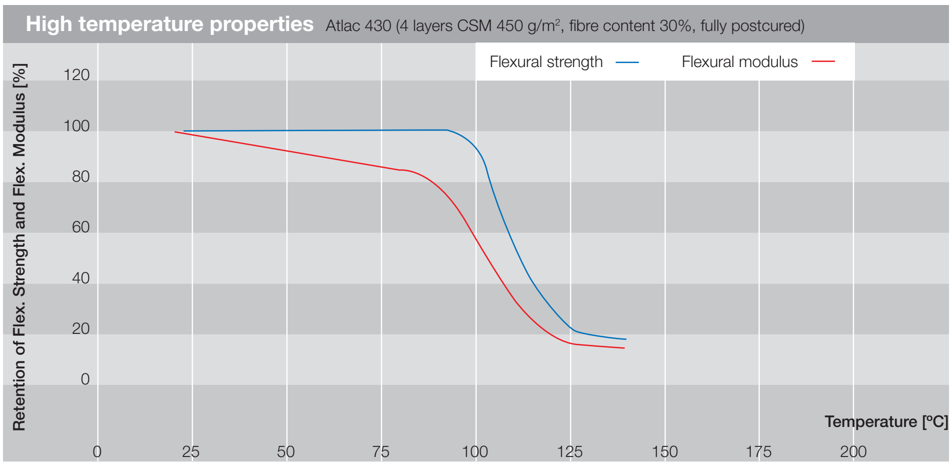
24hrs at 20°C followed by 24 hrs at 80°C

HDT and Tg postcure: 24 hrs 120°C

Atlac 430

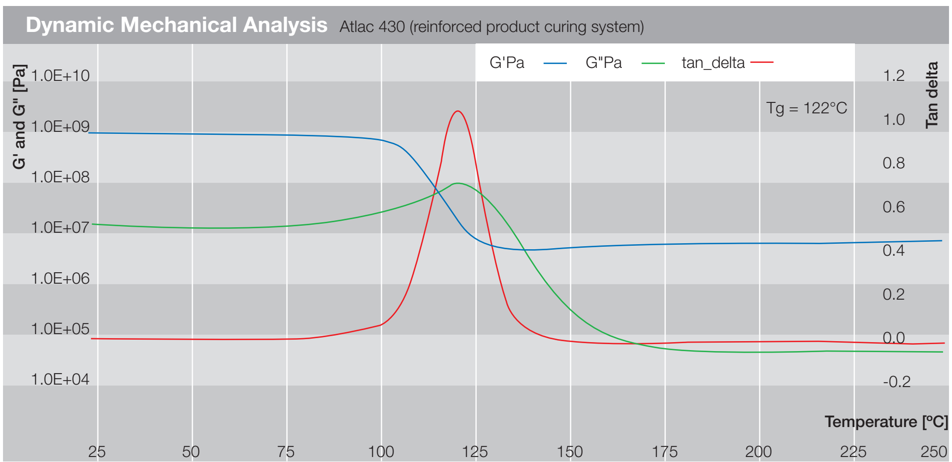
Typical data reinforced product

Curing System		Laminate build up		
0.5% Accelerator NL-49P		450 g/m² CSM	450 g/m² CSM	
1.0% Butanox LPT		450 g/m² CSM	800 g/m² WR	
Postcure 24hrs at 20°C followed by 24 hrs at 80°C		450 g/m² CSM	450 g/m² CSM	
		450 g/m² CSM	800 g/m² WR	
			450 g/m² CSM	
			800 g/m² WR	
Properties / Unit				**Test methods**
Glass content	%	38.6	39	ASTM D 2584
Tensile strength	MPa	138	146	ISO-527-2
Modulus of elasticity in eension	GPa	10	10.4	ISO-527-2
Flexural strength	MPa	210	216	ISO-527-2
Modulus of elasticity in bending	GPa	10	8.4	ISO-178
Density	kg/m³	1400		-
Impact resistance - unnotched sp.	kJ/m²			ISO-179
Linear expansion	C^{-1}	30 x 10^{-6}		-
Thermal conductivity	W/m.K	0.20		-



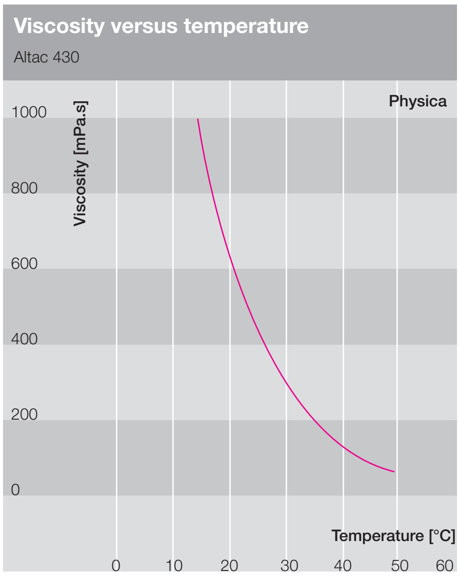
GRAPH 1:
HIGH TEMPERATURE PROPERTIES

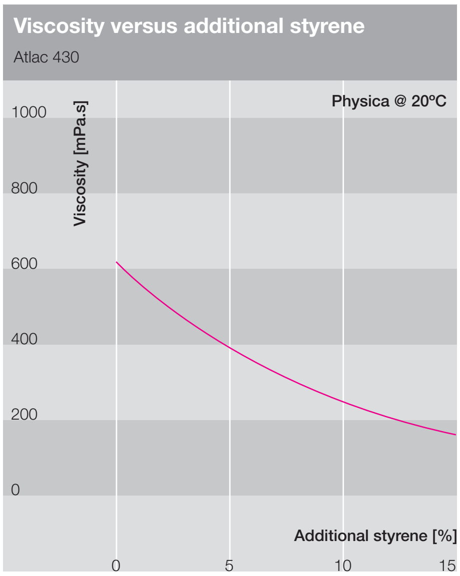
The flexural moduli and strengths of the resin over a temperature range of 20-180°C were measured according to ISO-178. The laminates were based on 4 layers of 450 g/m² chopped strand mat with a fibre content of 30% w/w. Standard cure systems have been used and all specimen have been fully postcured.



GRAPH 2:
DYNAMICAL MECHANICAL ANALYSIS (DMA)

In torsion mode the DMA measures the storage modulus (G') and loss modulus (G") of the resin (frequency is 6.22 rad/sec). Based on the moduli the tan delta (tan_δ) can be calculated. The peak in the tan_δ curve corresponds to the glass transition temperature (Tg), indicating the change from glassy to the rubbery state. Standard (post)curing systems have been used.





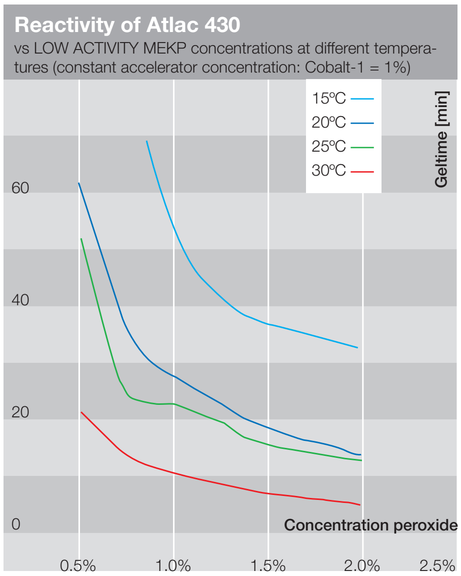
GRAPH 3A:
VISCOSITY VERSUS TEMPERATURE
GRAPH 3B:
VISCOSITY VERSUS ADDITIONAL STYRENE

The viscosity of the Atlac resin can be influenced by temperature and / or the styrene content. Additional styrene, up to approx. 5% can be used without affecting the chemical resistance and mechanical properties.

Typical geltimes, using low activity MEKP / Cobalt

Used curing agents: low activity methyl ethyl ketone peroxide (LA-MEKP), Cobalt 1% and tertiair-butyl-catechol (TBC)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	2.0% Cobalt-1 2.0% LA-MEKP	1.0% Cobalt-1 2.0% LA-MEKP	1.0% Cobalt-1 1.0% LA-MEKP
20°C	1.0% Cobalt-1 2.0% LA-MEKP	1.0% Cobalt-1 1.0% LA-MEKP	0.5% Cobalt-1 1.0% LA-MEKP
25°C	1.0% Cobalt-1 1.0% LA-MEKP	0.5% Cobalt-1 1.0% LA-MEKP	0.5% Cobalt-1 0.75% LA-MEKP
30°C	0.5% Cobalt-1 1.0% LA-MEKP	0.5% Cobalt-1 0.5% LA-MEKP	1.0% Cobalt-1 1.0% LA-MEKP 0.04% TBC



Typical geltimes, using BPO / amine

Used curing agents: benzoyl peroxide (BPO-50), dimethylaniline (DMA) and dimethyl-para-toluidine (DMPT)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
10°C	0.35% DMA + 0.05% DMPT 4.0% BPO	0.25% DMA + 0.05% DMPT 3.0% BPO	0.15% DMA + 0.05% DMPT 2.0% BPO
15°C	0.4% DMA 4.0% BPO	0.3% DMA 3.0% BPO	0.2% DMA 2.0% BPO
20°C	0.3% DMA 2.0% BPO	0.3% DMA 1.0% BPO	0.175% DMA 1.0% BPO

When curing has to take place at low temperatures (outdoor jointing or repairing, lining, etc.) and or high humidity BPO/amine curing is recommended.

This curing system is also recommended in applications were hypochlorite or peroxides are present.

“freedom to construct”

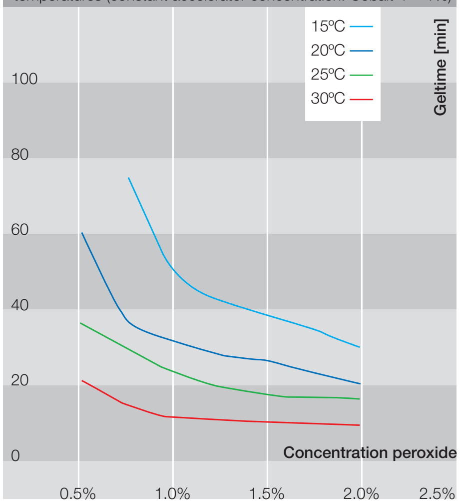
Typical geltimes, using Cumene Hydroperoxide / Cobalt

Used curing agents cumene hydroperoxide (CuHP), Cobalt 1% and TBC

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	2.0% Cobalt-1 2.0% CuHP	1.0% Cobalt-1 2.0% CuHP	1.0% Cobalt-1 1.0% CuHP
20°C	1.0% Cobalt-1 2.0% CuHP	1.0% Cobalt-1 1.0% CuHP	0.8% Cobalt-1 1.0% CuHP
25°C	1.0% Cobalt-1 1.0% CuHP	0.7% Cobalt-1 1.0% CuHP	0.5% Cobalt-1 1.0% CuHP
30°C	0.5% Cobalt-1 1.0% CuHP	0.5% Cobalt-1 0.7% CuHP	1.0% Cobalt-1 1.0% CuHP 0.075% TBC

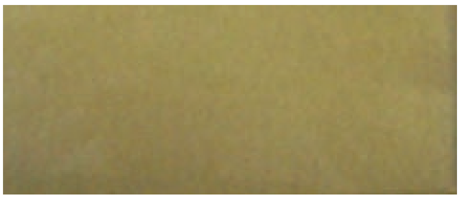
Reactivity of Atlac 430

vs CUMENE HYDROPEROXIDE concentrations at different temperatures (constant accelerator concentration: Cobalt-1 = 1%)




Liquid resin


Cured resin, Standard MEKP / cobalt curing system


Cured resin, BPO / amine curing system

POSTCURING

Postcuring is necessary to obtain the optimum heat and chemical resistance of the Atlac high performance resins. Recommended postcure conditions are 3 to 6 hours at 90 to 100°C – longer times and adjusted postcure schedules being required for thicker laminates and/or more complex shapes. Lower temperatures are ineffective; higher temperatures can lead to embrittlement.

TOPCOAT

Topcoats applied, as final layer in linings for the outside surface must contain paraffin wax to obtain full cure (preventing air inhibition). The resin requires about, 0.1 - 0.2 % addition of wax. The wax should have a melting point of 54 - 57°C and is best added into the resin as 10% solution in styrene. Topcoats must be cured quickly for the wax to be effective. Use a MEKP cure system to obtain a gel time of 15 minutes or less. Properly cured topcoats will not become tacky when rubbed with acetone.

INHIBITOR SYSTEMS

Control of geltime may also be achieved by the use of inhibitors; the most widely available is a 10% solution of tertiary-butyl-catechol (TBC). Additions above 0.25% can lead to undercure. Use at workshop temperature below 15°C is not recommended. TBC is not effective with cumene hydroperoxide systems.

THIXOTROPY

Atlac 430 can be made thixotropic by using the hydrofobe fumed silica types: Wacker HDK 20, Cab-O-Sil TS 720 and Aerosil R202 (1% - 2%). They should be blended into the resin using a high-shear stirrer (Cowless type). To improve a maximum thixotropic effect, it is recommended to use a wetting agent (e.g. Byk R605 – Byk Chemie). Thixotropic agents should not be used in laminates intended for service with hypochlorite solutions or fluorine. In this case, sagging can only be reduced to a minimum by very short gel times (20-25 min).

Grades of Atlac resins:

Different pre-formulated grades of Atlac available for use.

Resin Type	Grade	Remark
Atlac 430	Atlac 430	Standard
	Atlac 430 UV	Light-curable
	Atlac 430 LSE	Paraffinated
	Atlac 430 S	Extra stabilized

Atlac 590

>> Product Information <<

CHEMICAL / PHYSICAL NATURE

Atlac 590 is a novolac based vinyl ester, dissolved in styrene.

PERFORMANCE

Atlac 590 provides excellent thermal and chemical resistance against solvents, acids and oxidizing media like chlorine. The resin offers high retention of strength at elevated temperatures.

MAJOR APPLICATIONS

Atlac 590 can be used in all fabrication methods, but is especially adapted to meet the requirements of filament winding, centrifugal casting, hand lay-up and spray-up applications. Atlac 590 may also be used to formulate glassflake coatings and mortars.

APPROVALS

Cured non-reinforced Atlac 590 conforms to type 1310 according to DIN 16946/2 and is classified group 5 according to DIN 18820/1 and group 8 according EN13121/2.

A KIWA approval (BRL-K 541/01) was achieved for underground petrol storage tanks.

Atlac 590 passed testing at TÜV for use in flue gas cleaning plants.

Liquid product specifications

Properties	Range	Unit	TM
Appearance	clear	-	TM 2265
Viscosity, 23°C	208-282	mPa.s	TM 2013
Density, 23°C	1080	kg/m^3	TM 2160
Solid content	61.5-64.5	%	TM 2033
Gel time from 25 - 35°C	21.4-27.8	min	TM 2625
Cure time from 25°C to peak	26.4-35.7	min	TM 2625
Peak temperature	144-176	°C	TM 2625

Curing System

3.0% Accelerator NL-49P

2.0% Butanox M-50

Test methods

Test methods (TM) referred to in the tables are available on request.

Typical data cured product - non reinforced

Properties	Range	Unit	TM
Density, 20°C	1175	kg/m^3	-
Hardness	45	Barcol	TM 2604
Tensile strength	90	MPa	ISO 527-2
Elongation at break	4	%	ISO 527-2
Tensile modulus	3.5	GPa	ISO 527-2
Flexural strength	155	MPa	ISO 178
Flexural modulus	3.6	GPa	ISO 178
Impact resistance - unnotched sp.	13	kJ/m^2	ISO 179
Heat Deflection Temperature (HDT)	140	°C	ISO 75-A
Glass transition temperature (Tg)	150	°C	DIN 53445

Curing System

0.3% Accelerator NL-51P

1.0% Butanox M-50

Supplier curing agents

Akzo Nobel Chemicals

Postcure

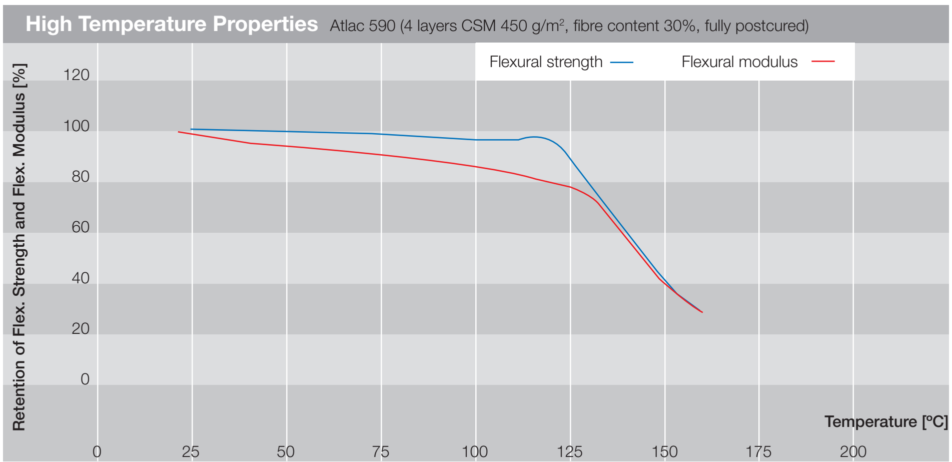
24hrs at 20°C followed by 3 hrs at 100°C and 1hr 150°C

Atlac 590

Typical data reinforced product:

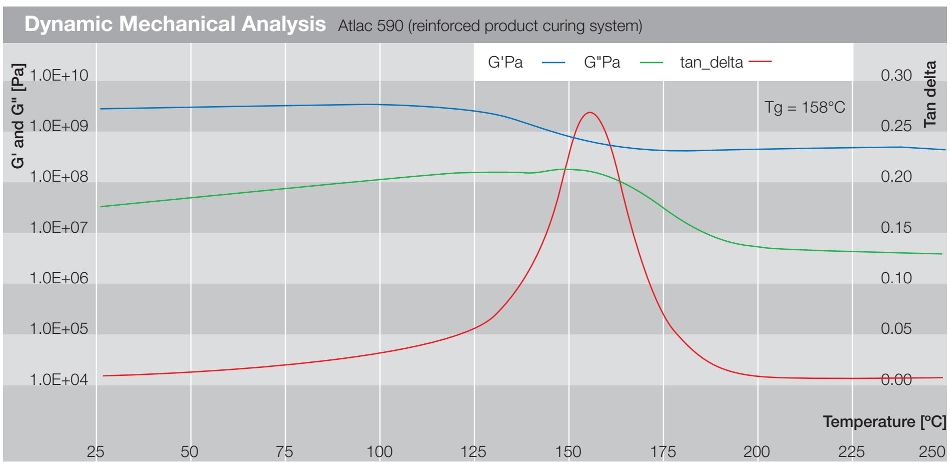
Curing system	Laminate build up	
0.3% Accelerator NL-51P	450 g/m² CSM	450 g/m² CSM
1.0% Butanox M-50	450 g/m² CSM	800 g/m² WR
Postcure 24hrs at 20°C followed by 3 hrs at 100°C and 1hr 150°C	450 g/m² CSM	450 g/m² CSM
	450 g/m² CSM	800 g/m² WR
		450 g/m² CSM
		800 g/m² WR

Properties / Unit				Test methods
Glass content	%	34	45	ASTM D 2584
Tensile strength	MPa	111	184	ISO-527-2
Modulus of elasticity in tension	GPa	10.1	12.3	ISO-527-2
Flexural strength	MPa	208	292	ISO-527-2
Modulus of elasticity in bending	GPa	9.8	10.4	ISO-178
Density	kg/m³	1394		-
Impact resistance - unnotched sp.	kJ/m²	115		ISO-179
Linear expansion	C^{-1}	30×10^{-6}		-
Thermal conductivity	W/m.K	0.19		-



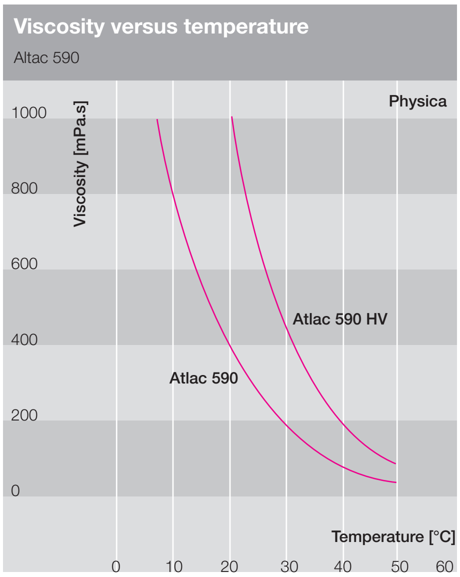
GRAPH 1: HIGH TEMPERATURE PROPERTIES

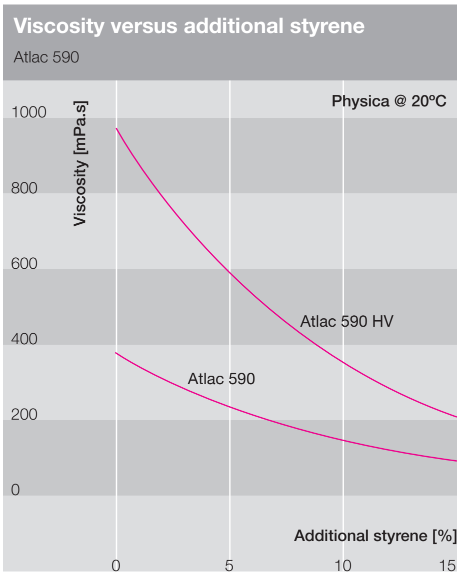
The flexural moduli and strengths of the resin over a temperature range of 20-180°C were measured according to ISO-178. The laminates were based on 4 layers of 450 g/m² chopped strand mat with a fibre content of 30% w/w. Standard cure systems have been used and all specimen have been fully postcured.



GRAPH 2: DYNAMICAL MECHANICAL ANALYSIS (DMA)

In torsion mode the DMA measures the storage modulus (G') and loss modulus (G") of the resin (frequency is 6.22 rad/sec). Based on the moduli the tan delta (tan_δ) can be calculated. The peak in the tan_δ curve corresponds to the glass transition temperature (Tg), indicating the change from glassy to the rubbery state. Standard (post)curing systems have been used.





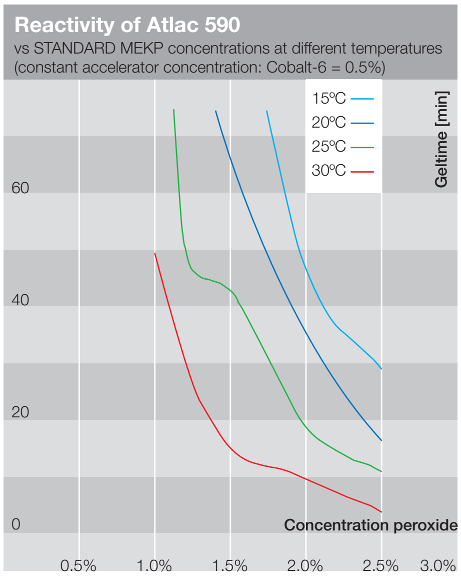
GRAPH 3A:
VISCOSITY VERSUS TEMPERATURE
GRAPH 3B:
VISCOSITY VERSUS ADDITIONAL STYRENE

The viscosity of the Atlac resin can be influenced by temperature and / or the styrene content. Additional styrene, up to approx. 5% can be used without affecting the chemical resistance and mechanical properties.

Typical geltimes, using standard MEKP / Cobalt

Used curing agents: standard methyl ethyl ketone peroxide (St. MEKP), Cobalt 6% and dimethylaniline (DMA)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	1.0% Cobalt-6	1.0% Cobalt-6	0.3% Cobalt-6
	2.5 % St. MEKP	2.0% St. MEKP	2.0% St. MEKP
	0.2% DMA	0.2% DMA	
20°C	0.3% Cobalt-6	0.3% Cobalt-6	0.3% Cobalt-6
	2.5% St. MEKP	2.0% St. MEKP	1.5% St. MEKP
	0.05% DMA	0.05% DMA	
25°C	0.2% Cobalt-6	0.2% Cobalt-6	0.1% Cobalt-6
	2.0% St. MEKP	1.5% St. MEKp	1.2% St. MEKP
	0.05% DMA		
30°C	0.1% Cobalt-6	0.1% Cobalt-6	0.1% Cobalt-6
	1.5% St. MEKP	1.2% St. MEKP	1.0% St. MEKP



Typical geltimes, using BPO / amine

Used curing agents: benzoyl peroxide (BPO-50) and dimethylaniline (DMA)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
10°C	0.4% DMA	0.3% DMA	0.2.% DMA
	4.0% BPO	3.0% BPO	2.0% BPO
15°C	0.35% DMA	0.3% DMA	0.2% DMA
	3.5% BPO	3.0% BPO	1.75% BPO
20°C	0.3% DMA	0.2.% DMA	0.15% DMA
	3.0% BPO	2.0% BPO	1.5% BPO

When curing has to take place at low temperatures (outdoor jointing or repairing, lining, etc.) and or high humidity BPO/amine curing is recommended.

This curing system is also recommended in applications were hypochlorite or peroxides are present.

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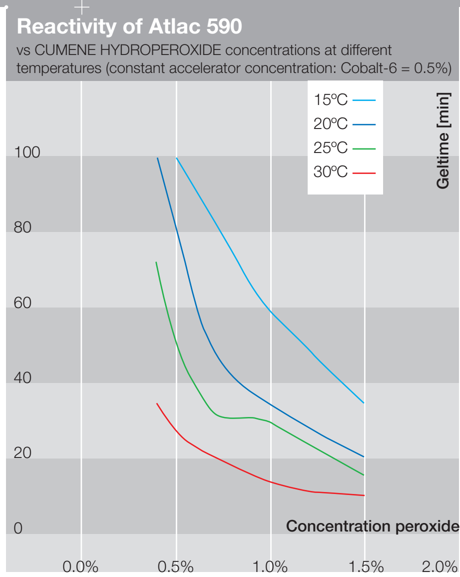
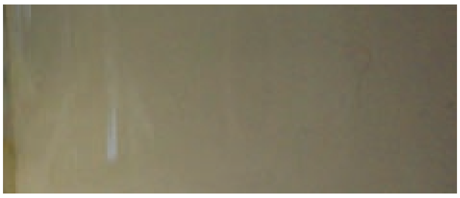
Typical geltimes, using Cumene Hydroperoxide / Cobalt

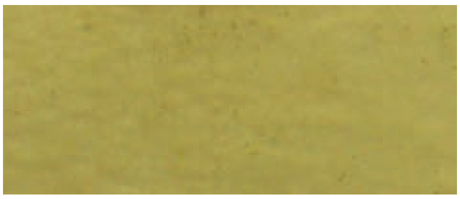
Used curing agents: cumene hydroperoxide (CuHP), Cobalt 6% and dimethylaniline (DMA)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	0.3% Cobalt-6 2.0% CuHP 0.1% DMA	0.15% Cobalt-6 1.5% CuHP 0.05% DMA	0.15% Cobalt-6 1.0% CuHP
20°C	0.2% Cobalt-6 1.5% CuHP 0.05% DMA	0.1% Cobalt-6 1.5% CuHP	0.1% Cobalt-6 1 .0% CuHP
25°C	0.2% Cobalt-6 1.0% CuHP	0.1% Cobalt-6 1.0% CuHP	0.1% Cobalt-6 1.0% CuHP + inhibitor
30°C	0.1% Cobalt-6 1 .5% CuHP	0.1% Cobalt-6 0.7% CuHP	0.1% Cobalt-6 0.7% CuHP + inhibitor




Liquid resin


Cured resin, Standard MEKP / cobalt curing system


Cured resin, BPO / amine curing system

POSTCURING

Postcuring is necessary to obtain the optimum heat and chemical resistance of the Atlac high performance resins. Recommended postcure conditions are 3 to 6 hours at 90 to 100°C – longer times and adjusted postcure schedules being required for thicker laminates and/ or more complex shapes. Lower temperatures are ineffective; higher temperatures can lead to embrittlement.

TOPCOAT

Topcoats applied, as final layer in linings for the outside surface must contain paraffin wax to obtain full cure (preventing air inhibition). The resin requires about, 0.1 - 0.2 % addition of wax. The wax should have a melting point of 54 - 57°C and is best added into the resin as 10% solution in styrene. Topcoats must be cured quickly for the wax to be effective. Use a MEKP or AAP cure system to obtain a gel time of 15 minutes or less. Properly cured topcoats will not become tacky when rubbed with acetone.

INHIBITOR SYSTEMS

Control of geltime may also be achieved by the use of inhibitors; the most widely available is a 10% solution of tertiary-butyl-catechol (TBC). Additions above 0.25% can lead to undercure. Use at workshop temperature below 15°C is not recommended. TBC is not effective with cumene hydroperoxide systems.

THIXOTROPY

Atlac 590 can be made thixotropic by using the hydrofobe fumed silica types: Wacker HDK 20, Cab-O-Sil TS 720 and Aerosil R202 (1.0% – 2.0%). They should be blended into the resin using a high-shear stirrer (Cowless type). To improve a maximum thixotropic effect, it is recommended to use a wetting agent (e.g. Byk R605 – Byk Chemie). Thixotropic agents should not be used in laminates intended for service with hypochlorite solutions or fluorine. In this case, sagging can only be reduced to a minimum by very short gel times (20-25 min).

Grades of Atlac resins:

Different pre-formulated grades of Atlac available for use.

Resin Type	Grade	Remark
Atlac 590	Atlac 590	Standard
	Atlac 590 HV	High viscous version (for filament winding)
	Atlac 590 T	Thixotropic, hot-cure relining

Atlac *E-Nova* FW 1045

>> Product Information <<

CHEMICAL / PHYSICAL NATURE

Atlac *E-Nova* FW 1045 is a flexibilized epoxy bisphenol A vinyl ester urethane resin, dissolved in styrene.

PERFORMANCE

Atlac *E-Nova* FW 1045 provides improved resistance to a wide range of acids, alkali, bleaches and solvents for the use in corrosive environments in the chemical processing industry. The favorable combination of thermal resistance and elongation makes also this resin suitable for applications exposed to intermittent temperatures.

The *E-Nova* technology combines the easy processing of polyester with the chemical resistance of vinylester. Low foam curing is possible with standard MEKP peroxides and compared to traditional vinylester resins it shows excellent fibre wetting. Atlac *E-Nova* FW 1045 can be easy made thixotropic.

MAJOR APPLICATIONS

Atlac *E-Nova* FW 1045 can be used in all fabrication methods, but is especially adapted to meet the requirements of filament winding, centrifugal casting, hand lay-up and spray-up applications.

APPROVALS

Cured non-reinforced Atlac *E-Nova* FW 1045 conforms to type 1310 according to DIN 16946/2 and is classified group 5 according to DIN 18820/1 and group 7B according to EN13121/2. Atlac *E-Nova* FW 1045 received from the DIBt (Deutsches Institute für Bautechnik) a general approval for parts to store chemicals.

Liquid product specifications

Properties	Range	Unit	TM
Appearance	clear	-	TM 2265
Viscosity, 23°C	350-450	mPa.s	TM 2013
Density, 23°C	1070	kg/m³	TM 2160
Solid content	58-62	%	TM 2033
Gel time from 25 - 35°C	20-30	min	TM 2625
Cure time from 25°C to peak	30-40	min	TM 2625
Peak temperature	145-175	°C	TM 2625

Curing system

3.0% Accelerator NL-49P

2.0% Butanox M-50

Test methods

Test methods (TM) referred to in the tables are available on request.

Typical data cured product - non reinforced

Properties	Range	Unit	TM
Density, 20°C	1145	kg/m³	-
Hardness	45	Barcol	TM 2604
Tensile strength	85	MPa	ISO 527-2
Elongation at break	5-6	%	ISO 527-2
Tensile modulus	3.3	GPa	ISO 527-2
Flexural strength	140	MPa	ISO 178
Flexural modulus	3.5	GPa	ISO 178
Impact resistance - unnotched sp.	30	kJ/m²	ISO 179
Heat Deflection Temperature (HDT)	125	°C	ISO 75-A
Glass transition temperature (Tg)	150	°C	DIN 53445

Curing system

0.3% Accelerator NL-51P

0.2% Accelerator NL-63-10P

1.5% Butanox M-50

Supplier curing agents

Akzo Nobel Chemicals

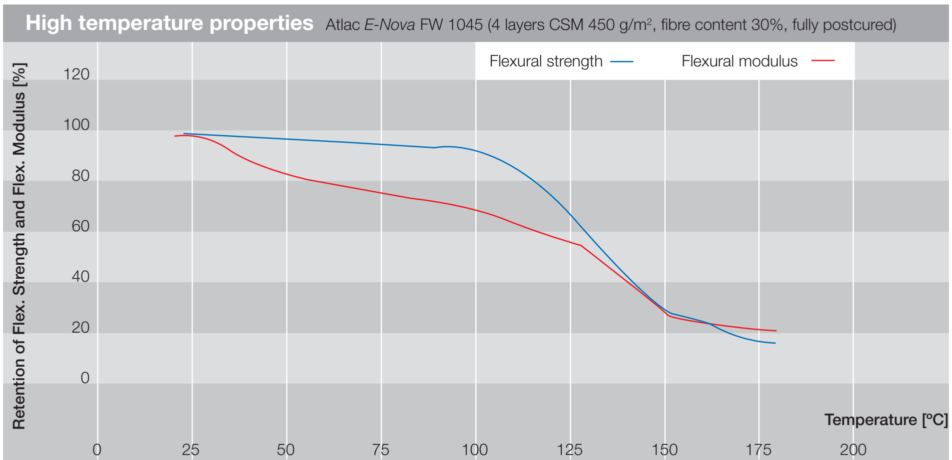
Postcure

24hrs at 20°C followed by 3hrs at 100°C and 3 hrs at 150°C

Atlac *E-Nova* FW 1045

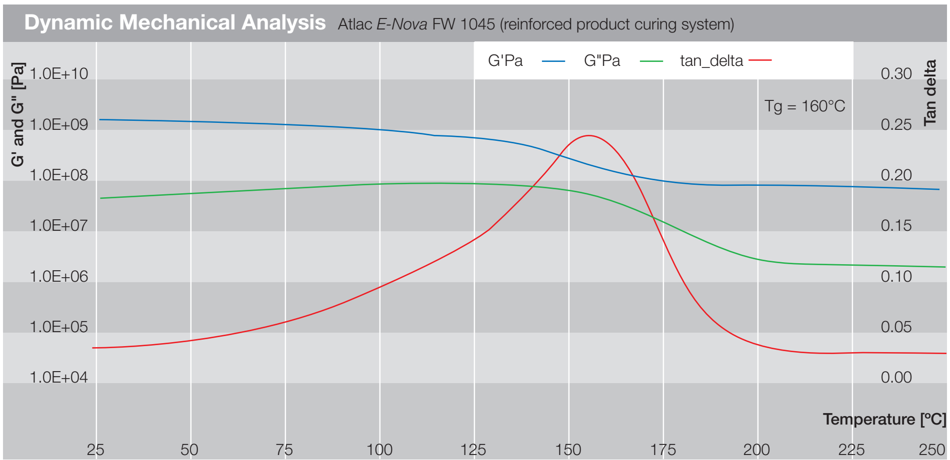
Typical data reinforced product

Curing system		Laminate build up		
0.3% Accelerator NL-51P		450 g/m² CSM	450 g/m² CSM	
0.2% Accelerator NL-63-10P		450 g/m² CSM	800 g/m² WR	
1.5% Butanox M-50		450 g/m² CSM	450 g/m² CSM	
Postcure 24hrs at 20°C followed by 3hrs at 100°C and 3 hrs at 150°C		450 g/m² CSM	800 g/m² WR	
			450 g/m² CSM	
			800 g/m² WR	
Properties / Unit				**Test methods**
Glass content	%	32.5	44	ASTM D 2584
Tensile strength	MPa	120	182	ISO-527-2
Modulus of elasticity in tension	GPa	8.8	12.0	ISO-527-2
Flexural strength	MPa	200	248	ISO-527-2
Modulus of elasticity in bending	GPa	8.1	8.9	ISO-178
Density	kg/m³			-
Impact resistance - unnotched sp.	kJ/m²			ISO-179
Linear expansion	C^{-1}	30×10^{-6}		-
Thermal conductivity	W/m.K	0.20		-



GRAPH 1:
HIGH TEMPERATURE PROPERTIES

The flexural moduli and strengths of the resin over a temperature range of 20-180°C were measured according ISO 178. The laminates were based on 4 layers of 450 g/m² chopped strand mat with a fibre content of 30% w/w. Standard cure systems have been used and all specimen have been fully postcured.

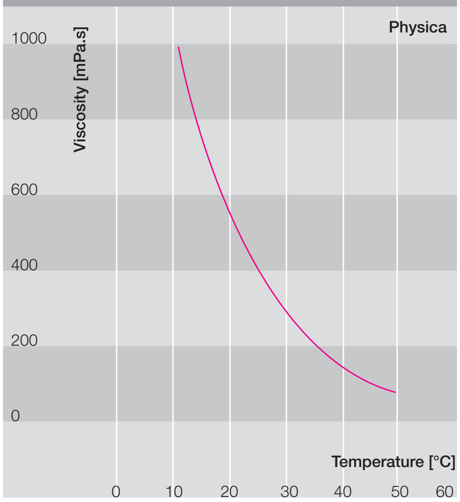


GRAPH 2:
DYNAMICAL MECHANICAL ANALYSIS (DMA)

In torsion mode the DMA measures the storage modulus (G') and loss modulus (G") of the resin (frequency is 6.22 rad/sec). Based on the moduli the tan delta (tan_δ) can be calculated. The peak in the tan_δ curve corresponds to the glass transition temperature (Tg), indicating the change from glassy to the rubbery state. Standard (post)curing systems have been used.

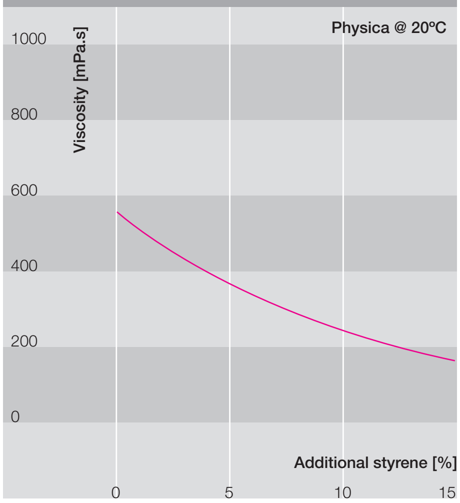
Viscosity versus temperature

Altac *E-Nova* FW 1045



Viscosity versus additional styrene

Atlac *E-Nova* FW 1045



GRAPH 3A: VISCOSITY VERSUS TEMPERATURE

GRAPH 3B: VISCOSITY VERSUS ADDITIONAL STYRENE

The viscosity of the Atlac resin can be influenced by temperature and / or the styrene content. Additional styrene, up to approx. 5% can be used without affecting the chemical resistance and mechanical properties.

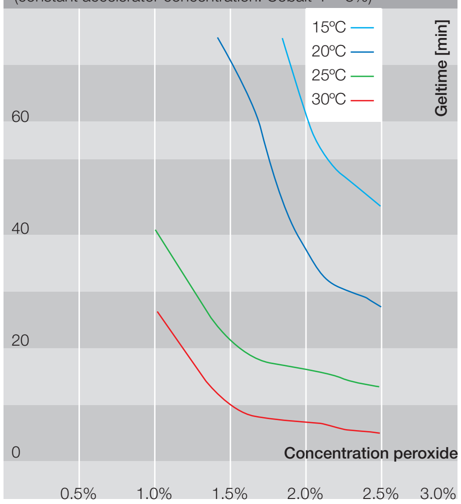
Typical geltimes, using standard MEKP / Cobalt

Used curing agents: standard methyl ethyl ketone peroxide (St. MEKP), Cobalt 1%, TBC and DMA

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	3.0% Cobalt-1	3.0% Cobalt-1	3.0% Cobalt-1
	2.0% St. MEKP	2.0% St. MEKP	1.75% St. MEKP
	0.075% DMA	0.025% DMA	0.020% DMA
20°C	3.0% Cobalt-1	3.0% Cobalt-1	3.0% Cobalt-1
	2.0% St. MEKP	2.5% St. MEKP	1.75% St. MEKP
	0.050% DMA		
25°C	3.0% Cobalt-1	3.0% Cobalt-1	2.0% Cobalt-1
	2.0% St. MEKP	1.25% St. MEKP	1.5% St. MEKP
30°C	3.0% Cobalt-1	2.0% Cobalt-1	2.75% Cobalt-1
	1.25% St. MEKP	1.5% St. MEKP	1.5% St. MEKP
			0.01% TBC

Reactivity of Atlac *E-Nova* FW 1045

vs STANDARD MEKP concentrations at different temperatures
(constant accelerator concentration: Cobalt-1 = 3%)



Typical geltimes, using BPO / amine

Used curing agents: benzoyl peroxide (BPO-50) and dimethylaniline (DMA)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
10°C	0.375% DMA	0.275% DMA	0.225% DMA
	3.5% BPO	3.0% BPO	2.25% BPO
15°C	0.3% DMA	0.3% DMA	0.175% DMA
	3.0% BPO	2.0% BPO	1.75% BPO
20°C	0.1% DMA	0.2% DMA	0.3% DMA
	1.75% BPO	1.5% BPO	1.6% BPO

When curing has to take place at low temperatures (outdoor jointing or repairing, lining, etc.) and or high humidity BPO/amine curing is recommended.

This curing system is also recommended in applications were hypochlorite or peroxides are present.

“freedom to construct”

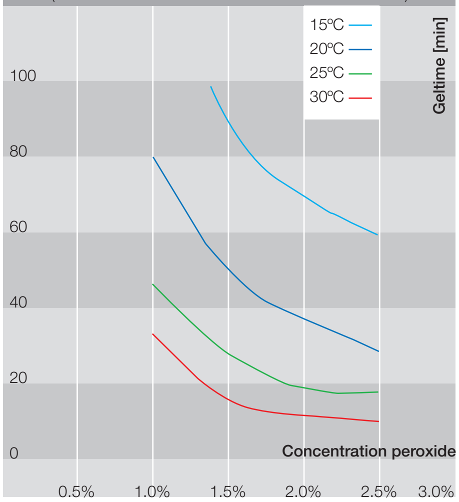
Typical geltimes, using low activity MEKP / Cobalt

Used curing agents: low activity methyl ethyl ketone peroxide (LA-MEKP), Cobalt 1% and DMA

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	3.0% Cobalt-1	3.0% Cobalt-1	3.0% Cobalt-1
	3.5% LA-MEKP	3.5% LA-MEKP	3.0% LA-MEKP
	0.1% DMA	0.025% DMA	
20°C	3.0% Cobalt-1	3.0% Cobalt-1	3.0% Cobalt-1
	3.0% LA-MEKP	2.5% LA-MEKP	1.5% LA-MEKP
	0.05% DMA		
25°C	2.0% Cobalt-1	2.0% Cobalt-1	3.0% Cobalt-1
	2.0% LA-MEKP	2.0% LA-MEKP	1.75% LA-MEKP
	0.05% DMA		
30°C	3.0% Cobalt-1	3.0% Cobalt-1	2.0% Cobalt-1
	1.5% LA-MEKP	1.0% LA-MEKP	1.0% LA-MEKP

Reactivity of Atlac *E-Nova* FW 1045

vs LOW ACTIVITY MEKP concentrations at different temperatures (constant accelerator concentration: Cobalt-1 = 3%)




Liquid resin


Cured resin, Standard MEKP / cobalt curing system


Cured resin, BPO / amine curing system

POSTCURING

Postcuring is necessary to obtain the optimum heat and chemical resistance of the Atlac high performance resins. Recommended postcure conditions are 3 to 6 hours at 90 to 100°C – longer times and adjusted postcure schedules being required for thicker laminates and/or more complex shapes. Lower temperatures are ineffective; higher temperatures can lead to embrittlement.

TOPCOAT

Topcoats applied, as final layer in linings for the outside surface must contain paraffin wax to obtain full cure (preventing air inhibition). The resins requires about, 0.1 - 0.2 % addition of wax. The wax should have a melting point of 54 - 57°C and is best added into the resin as 10% solution in styrene. Topcoats must be cured quickly for the wax to be effective. Use a MEKP cure system to obtain a gel time of 15 minutes or less. Properly cured topcoats will not become tacky when rubbed with acetone.

INHIBITOR SYSTEMS

Control of geltime may also be achieved by the use of inhibitors; the most widely available is a 10% solution of tertiary-butyl-catechol (TBC). Additions above 0.25% can lead to undercure. Use at workshop temperature below 15°C is not recommended. TBC is not effective with cumene hydroperoxide systems.

THIXOTROPY

Atlac *E-Nova* resins can be made easily thixotropic by using the standard (polyester) fumed silica types: Aerosil R 200 or Cab-O-Sil M5 (0.5% - 2%). They should be blended into the resin using a high-shear stirrer (Cowless type). To improve a maximum thixotropic effect, it is recommended to use a wetting agent (e.g. 0.2% w/w Tween 20 – ICI). Thixotropic agents should not be used in laminates intended for service with hypochlorite solutions or fluorine. In this case, sagging can only be reduced to a minimum by very short gel times (20-25 min). In case of Wacker HDK 20 or Aerosil R202, Byk R605 can be used as a wetting agent.

Grades of Atlac resins:

Different pre-formulated grades of Atlac *E-Nova* are already available for use.

Resin Type	Grade	Remark
Atlac *E-Nova* FW 1045	Atlac *E-Nova* FW 1045	Standard
	Atlac *E-Nova* PL 1645	Pultrusion

Atlac *E-Nova* FW 2045

>> Product Information <<

CHEMICAL / PHYSICAL NATURE

Atlac *E-Nova* FW 2045 is a modified epoxy bisphenol A vinyl ester urethane resin, dissolved in styrene.

PERFORMANCE

Atlac *E-Nova* FW 2045 provides the same excellent thermal and chemical resistance against solvents, acids and oxidizing media as an epoxy novolac vinyl ester, but offers in addition also resistance against alkaline.

The *E-Nova* technology combines the easy processing of polyester with the chemical resistance of vinyl ester. Low foam curing is possible with standard MEKP peroxides and compared to traditional vinyl ester resins it shows excellent fibre wetting. Atlac E-Nova FW 2045 can be easy made thixotropic.

MAJOR APPLICATIONS

Atlac *E-Nova* FW 2045 can be used in all fabrication methods, but is especially adapted to meet the requirements of filament winding, centrifugal casting, hand lay-up and spray-up applications.

APPROVALS

Cured non-reinforced Atlac *E-Nova* FW 2045 conforms to type 1310 according to DIN 16946/2 and is classified group 5 according to DIN 18820/1 and group 7B according EN13121/2. Atlac *E-Nova* FW 2045 received from the DIBt (Deutsches Institute für Bautechnik) a general approval for parts to store chemicals.

Liquid product specifications

Properties	Range	Unit	TM
Appearance	clear	-	TM 2265
Viscosity, 23°C	350-500	mPa.s	TM 2013
Density, 23°C	1070	kg/m^3	TM 2160
Solid content	59-61	%	TM 2033
Gel time from 25 - 35°C	15-25	min	TM 2625
Cure time from 25°C to peak	25-35	min	TM 2625
Peak temperature	145-175	°C	TM 2625

Curing system

3.0% Accelerator NL-49P

2.0% Butanox M-50

Test methods

Test methods (TM) referred to in the tables are available on request.

Typical data cured product - non reinforced

Properties	Range	Unit	TM
Density, 20°C	1160	kg/m^3	-
Hardness	45	Barcol	TM 2604
Tensile strength	90	MPa	ISO 527-2
Elongation at break	3-4	%	ISO 527-2
Tensile modulus	3.5	GPa	ISO 527-2
Flexural strength	140	MPa	ISO 178
Flexural modulus	3.7	GPa	ISO 178
Impact resistance - unnotched sp.	25	kJ/m^2	ISO 179
Heat Deflection Temperature (HDT)	145	°C	ISO 75-A
Glass transition temperature (Tg)	160	°C	DIN 53445

Curing system

0.3% Accelerator NL-51P

1.0% Butanox M-50

Supplier curing agents

Akzo Nobel Chemicals

Postcure

24hrs at 20°C followed by 3 hrs at 100°C and 3hrs 150°C

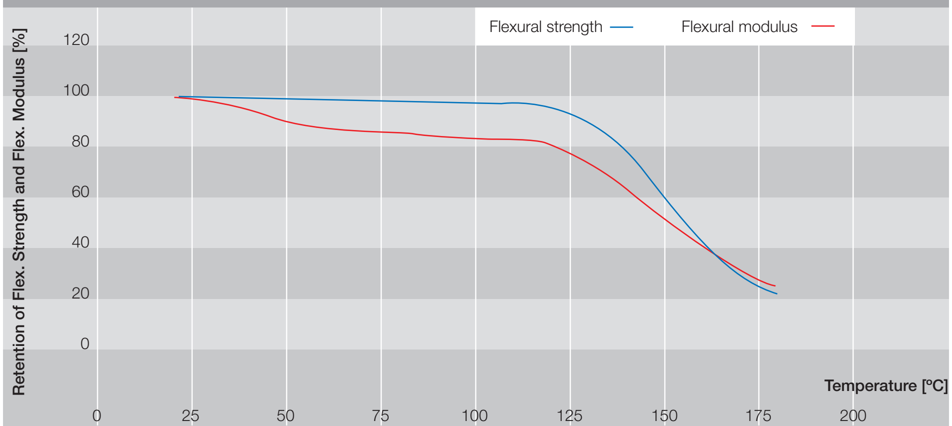
Atlac *E-Nova* FW 2045

Typical data reinforced product

Curing system	Laminate build up	
0.3% Accelerator NL-51P	450 g/m² CSM	450 g/m² CSM
1.0% Butanox M-50	450 g/m² CSM	800 g/m² WR
Postcure 24hrs at 20°C followed by 3 hrs at 100°C and 3hrs 150°C	450 g/m² CSM	450 g/m² CSM
	450 g/m² CSM	800 g/m² WR
		450 g/m² CSM
		800 g/m² WR

Properties / Unit				Test methods
Glass content	%	30	38	ASTM D 2584
Tensile strength	MPa	120	129	ISO-527-2
Modulus of elasticity in tension	GPa	8.3	8.6	ISO-527-2
Flexural strength	MPa	210	228	ISO-527-2
Modulus of elasticity in bending	GPa	8.7	7.9	ISO-178
Density	kg/m³			-
Impact resistance - unnotched sp.	kJ/m²			ISO-179
Linear expansion	C^{-1}	30×10^{-6}		-
Thermal conductivity	W/m.K	0.20		-

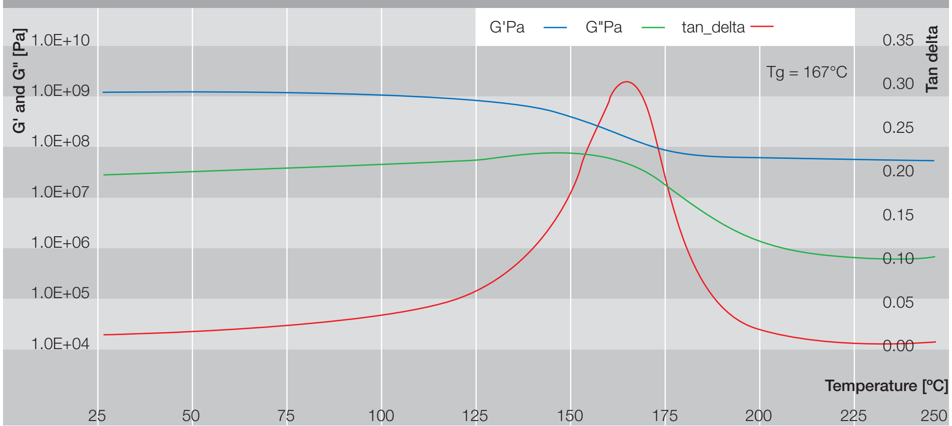
High temperature properties Atlac *E-Nova* FW 2045 (4 layers CSM 450 g/m², fibre content 30%, fully postcured)



GRAPH 1: HIGH TEMPERATURE PROPERTIES

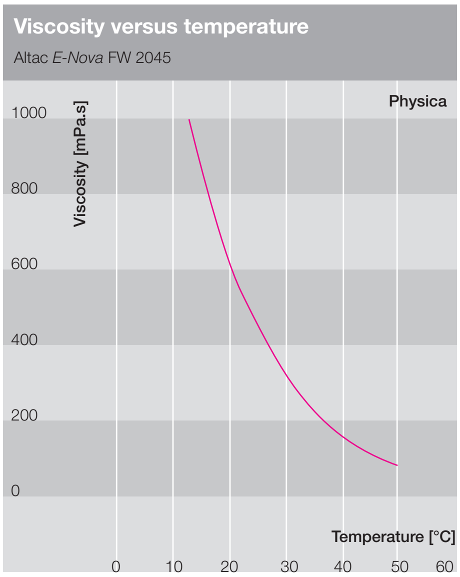
The flexural moduli and strengths of the resin over a temperature range of 20-180°C were measured according to ISO-178. The laminates were based on 4 layers of 450 g/m² chopped strand mat with a fiber content of 30% w/w. Standard cure systems have been used and all specimen have been fully postcured.

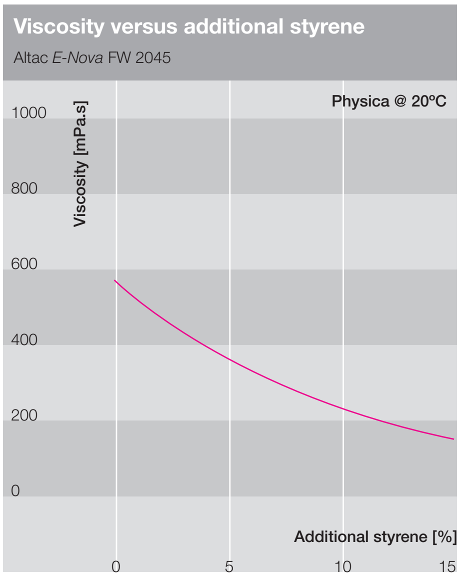
Dynamic Mechanical Analysis Atlac *E-Nova* FW 2045 (reinforced product curing system)



GRAPH 2: DYNAMICAL MECHANICAL ANALYSIS (DMA)

In torsion mode the DMA measures the storage modulus (G') and loss modulus (G") of the resin (frequency is 6.22 rad/sec). Based on the moduli the tan delta (tan_δ) can be calculated. The peak in the tan_δ curve corresponds to the glass transition temperature (Tg), indicating the change from glassy to the rubbery state. Standard (post)curing systems have been used.





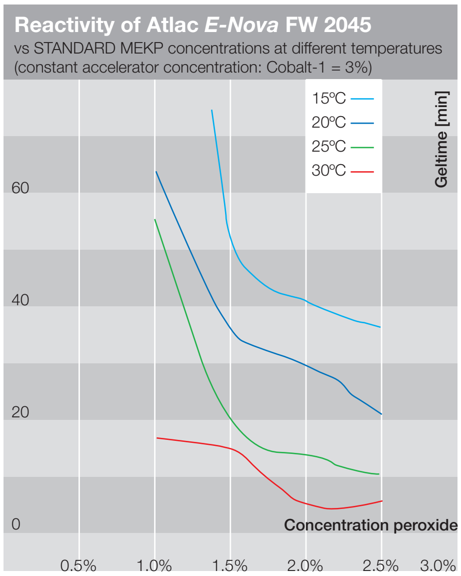
GRAPH 3A:
VISCOSITY VERSUS TEMPERATURE
GRAPH 3B:
VISCOSITY VERSUS ADDITIONAL STYRENE

The viscosity of the Atlac resin can be influenced by temperature and / or the styrene content. Additional styrene, up to approx. 5% can be used without affecting the chemical resistance and mechanical properties.

Typical geltimes, using standard MEKP / Cobalt

Used curing agents: standard methyl ethyl ketone peroxide (St. MEKP) and Cobalt 1%

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	3.0% Cobalt-1 3.0% St. MEKP	3.0% Cobalt-1 2.5% St. MEKP	3.0% Cobalt-1 1.5% St. MEKP
20°C	3.0% Cobalt-1 2.5% St. MEKP	3.0% Cobalt-1 2.0% St. MEKP	3.0% Cobalt-1 1.25% St. MEKP
25°C	3.0% Cobalt-1 2.0% St. MEKP	3.0% Cobalt-1 1.25% St. MEKP	3.0% Cobalt-1 1.0% St. MEKP
30°C	3.0% Cobalt-1 1.5% St. MEKP	1.0% Cobalt-1 2.0% St. MEKP	1.0% Cobalt-1 1.0% St. MEKP



Typical geltimes, using BPO / amine

Used curing agents: benzoyl peroxide (BPO-50) and dimethylaniline (DMA)

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
10°C	0.3% DMA 3.0% BPO	0.1% DMA 3.0% BPO	0.1% DMA 2.0% BPO
15°C	0.3% DMA 2.0% BPO	0.1% DMA 2.0% BPO	0.1% DMA 1.0% BPO
20°C	0.2% DMA 2.0% BPO	0.2% DMA 1.0% BPO	0.1% DMA 1.0% BPO

When curing has to take place at low temperatures (outdoor jointing or repairing, lining, etc.) and or high humidity BPO/amine curing is recommended.

This curing system is also recommended in applications were hypochlorite or peroxides are present.

"freedom to construct"

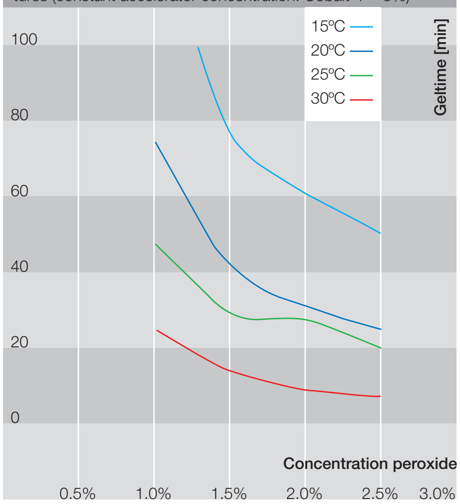
Typical geltimes, using low activity MEKP / Cobalt

Used curing agents: low activity methyl ethyl ketone peroxide (LA-MEKP), Cobalt 1% and DMA

Temperature	10 - 20 minutes	20 - 40 minutes	40 - 60 minutes
15°C	3.0% Cobalt-1 0.05% DMA 3.0% LA-MEKP	3.0% Cobalt-1 3.0% LA-MEKP	2.5% Cobalt-1 2.5% LA-MEKP
20°C	3.0% Cobalt-1 0.05% DMA 3.0% LA-MEKP	3.0% Cobalt-1 2.0% LA-MEKP	3.0% Cobalt-1 1.25% LA-MEKP
25°C	3.0% Cobalt-1 2.5% LA-MEKP	3.0% Cobalt-1 1.5% LA-MEKP	3.0% Cobalt-1 1.0% LA-MEKP
30°C	3.0% Cobalt-1 1.5% LA-MEKP	3.0% Cobalt-1 1.0% LA-MEKP	1.0% Cobalt-1 1.0% LA-MEKP

Reactivity of Atlac *E-Nova* FW 2045

vs LOW ACTIVITY MEKP concentrations at different temperatures (constant accelerator concentration: Cobalt-1 = 3%)




Liquid resin


Cured resin, Standard MEKP / cobalt curing system


Cured resin, BPO / amine curing system

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Grades of Atlac resins:

Different pre-formulated grades of Atlac *E-Nova* are already available for use.

Resin Type	Grade	Remark
Atlac *E-Nova* FW 2045	Atlac *E-Nova* FW 2045	Standard
	Atlac *E-Nova* FW 2245	Pre-accelerated
	Atlac *E-Nova* RE 2145	Thixotropic, hot-cure relining

Quality **and** safety

QUALITY LEADERSHIP

DSM Composite Resins production sites and Competence Centers are approved to ISO 9001. We have implemented a fully aligned Quality Management system based on Total Quality Management philosophy that promotes performance excellence across every aspect of our business, our people, processes and products. DSM safety, health and environmental best practice are already benchmarks within our industry and we will continue to focus our efforts on sustainable, durable processes with the highest possible yield and the minimum environmental impact.

PRODUCTION CONSISTENCY

Each of our production sites has seen major investment over recent years to streamline processes and improve environmental performance. DSM Composite Resin plants used highly automated, computer-controlled processed and all operations – from materials dosing and reactor operations, to blending – are closely monitored and controlled to ensure batch-to-batch consistency. Performance is continuously monitored and backed up by statically process control. Our rigorous quality programs cover every stage in the supply chain from incoming raw materials testing to customer deliveries.

STORAGE, HANDLING AND SAFETY

In line with all styrenated unsaturated polyester resin the Atlac high performance resins have flash points of approximately 32°C and are classified, under Directive 79/831/EEC, as flammable.

Styrene is subject to threshold limit regulations in all European countries and work places should be sufficiently well ventilated to meet those regulations.

Containers should be kept in a well-ventilated cool place. They should be kept closed and away from sources of ignition. 'No smoking' rules should be strictly enforced. When kept in a closed container out of direct sunlight and at a temperature of 25°C or less the storage life will exceed 6 months. It is recommended that eye protection and other protective clothing including gloves be worn when handling Atlac resins. When cleaning up spillages it is advisable that respiratory protection is also worn, since under such conditions the Treshold Limit Value (TLV) may be exceeded. Spillages may be absorbed in sand or earth and shoveled into a waste container equipped with a lid. This should be removed to a safe place and disposed of in accordance with the local regulations.

Contaminated clothing should be removed immediately and washed before re-use. Splashes on the skin should be wiped clean and the affected area washed clean with soap and water. Splashes in the eyes should be treated immediately by flushing with copious amounts of clean water for at least 15 minutes followed by medical attention. Persons affected by inhalation of vapors should be moved to fresh air and treated symptomatically. Medical advice should be sought. If the resin is accidentally ingested, 2 or 3 glasses of water or milk should be given and medical assistance obtained. In case of fire, suitable extinguishers are dry chemical, foam or water sprays. Water jets should not be used. Containers close to a fire should be kept cool by spraying with water.

Our Internet site (www.dsmcompositeresins.com / www.Atlac.com) contains all Material Safety Data Sheets (MSDS) of our products. The MSDS explain the product related risks and properties and provide information concerning international transport regulations.

In case of emergency call the following telephone number: + 31 46 476 555555

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