

Environmentally Friendly Coatings for Electronics

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1 Introduction

To meet the ever-increasing environmental demands on electronic coatings, important new developments have been required to reduce VOC and comply with the numerous EU Directives to reduce hazardous substances, particularly lead. [(Reduction of Hazardous Substances ROHS, Waste Electrical and Electronic Equipment WEEE and End of life for Vehicles (EOLV)]

The continuous miniaturisation of Printed Circuit Boards and electronic modules, with increasing performance of the circuits, makes higher requirements on the coatings. In particular there are increasing demands from the user for thermal stability and adhesion on various substrates.

Products have been developed using processes suitable for state of the art application equipment in the two main classifications of **Thin Film** and **Thick Film** coatings, defined by the final cured coating thickness being greater or less than 300µm. Thin coatings are the lacquers or varnishes generally applied to PCBs for overall or selective protection. Thick film coatings may be needed as selective coating and/or “dam & fill” for greater protection against vibration or mechanical stress than a thin film can provide. The same materials are used for encapsulation of particular components or potting/filling of electronic devices such as sensors.

For all products the recent Bectron developments and all established products are refined in their application in close cooperation with customer users.

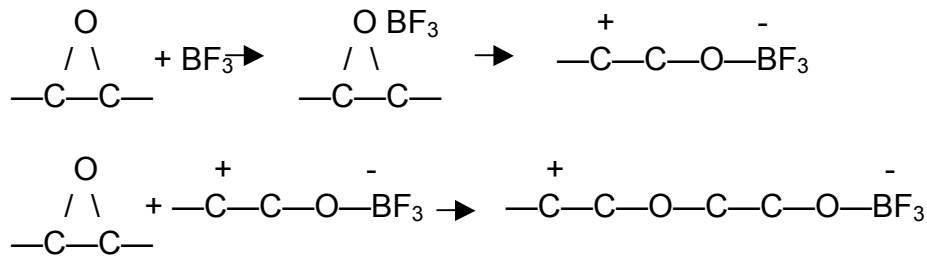
2 Thin Film Bectron Coatings

2.1 VOC Free Thin Film Coating (Bectron EP 5621)

2.1.1 Product Description

Instead of the classical thin film coatings, which are dependent on a solvent to reduce the viscosity, either liquid or water, a new product has been developed which contains no solvent and is essentially VOC free. The working viscosity is low enough to be used in major equipment in current use, with few exceptions.

Bectron EP5621 is clear one-component coating based on a modified epoxy resin system with the chemistry described below.



The Lewis acid holds the epoxy by which a carbonium ion is formed, which in turn reacts with the next epoxide group. These reactions are very fast. Because the intermediate products are highly reactive, they provide a range of secondary reactions, which also lead to further side-reactions. The network formed is irregular, so the mechanical properties, particularly the flexibility are intermediate. On the other hand, the polyether structure formed causes good adhesion of the film on most materials.

As the Lewis Acid used for the thermal curing is a borontrifluoride complex, sufficient storage stability of 6 months at room temperature is assured. By UV curing, the Lewis acid is produced by a photoreaction. The epoxy resin used has a cycloaliphatic structure, which can be modified to give optimum processing.

2.1.2 Application

The key characteristics for application of Bectron EP5621 are;

- Low viscosity (40 seconds ISO 6 mm cup at 23°C)
- Application by high speed Select Coating (Nordson Asymtek Film Coater Cross Cut Nozzle at 60°C) or Spray at ambient temperature
- Dipping, selective flooding or dispensing.
- Suitable for low level ICs hybrids and SMD components
- Fluorescent for ease of inspection and coloured available (Figure 1)

2.1.3 Curing

- **UV Cure 300 Joule/cm²**
- 24 hours at 25°C after UV exposure
- Thermal Cure 30 minutes @ 120°C in conventional oven
- (Developments are in progress to reduce cure temperature)
- Combined UV & thermal reduces cure time.
- No degradation or emissions during curing

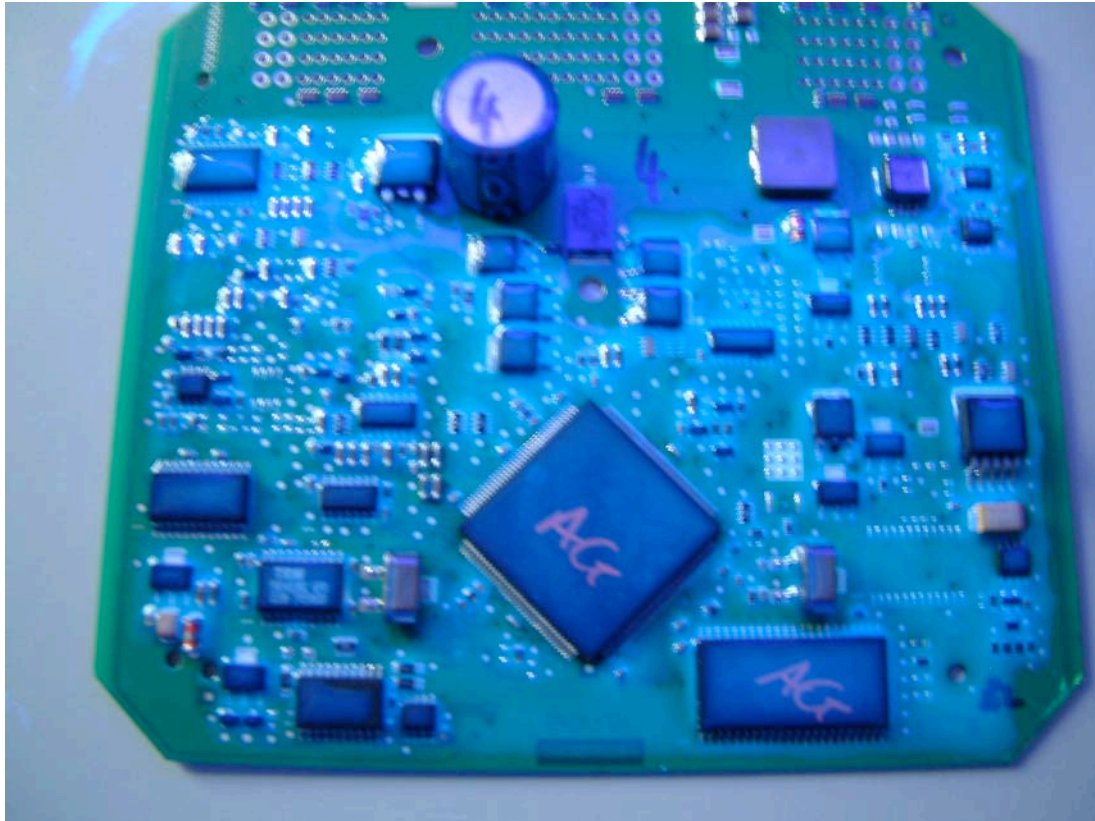


Figure 1

2.1.4 Key Cured Film Properties of Bectron EP5621

- Film Thickness of 60-200 μm
- Reliable adhesion and compatibility with solder mask, solder paste and flux
- High performance, thermal and electrical, under harsh environments
- Good stability against atmosphere in automotive and marine engines

2.1.5 Storage, Handling, Environment and Safety

The curing of the resin is emission-free with no degradation products therefore producing no VOC and introducing no hazards. As an epoxy it requires the normal handling precautions against skin contact. No hazard classification required for shipping.

2.2 Lead Free Thin-Film Coating PL4122 BLF

The Product Range Bectron PL4122, single component thin film coating, is well known in its established use in many automotive and other applications. This tried and trusted product is now available in an entirely lead free version as **PL4122 BLF** with no loss of performance in coating or cured film properties.

2.2.1 Product description

Bectron **PL4122 BLF** is a transparent coating varnish based on a urethane modified alkyd resin in a solvent system based only on aliphatic hydrocarbons to meet the most demanding standards of pin corrosion. It is entirely free of lead and aromatic solvents and cures by oxidation from atmospheric exposure.

PL4122 BLF is available with the same range of solids and viscosity levels to suit all the established applications of the well known original products, at 37% to 45% solids. It is provided as colourless varnish, translucent Orange varnish or with fluorescent dye for inspection under UV lamp (or black light).

2.2.2 Application & processing

PL4122BLF is suitable for use on assembled most printed circuit boards, particularly for automotive and marine transport uses. In addition it is useful for hybrids, SMD modules and for protection of discreet electronic components.

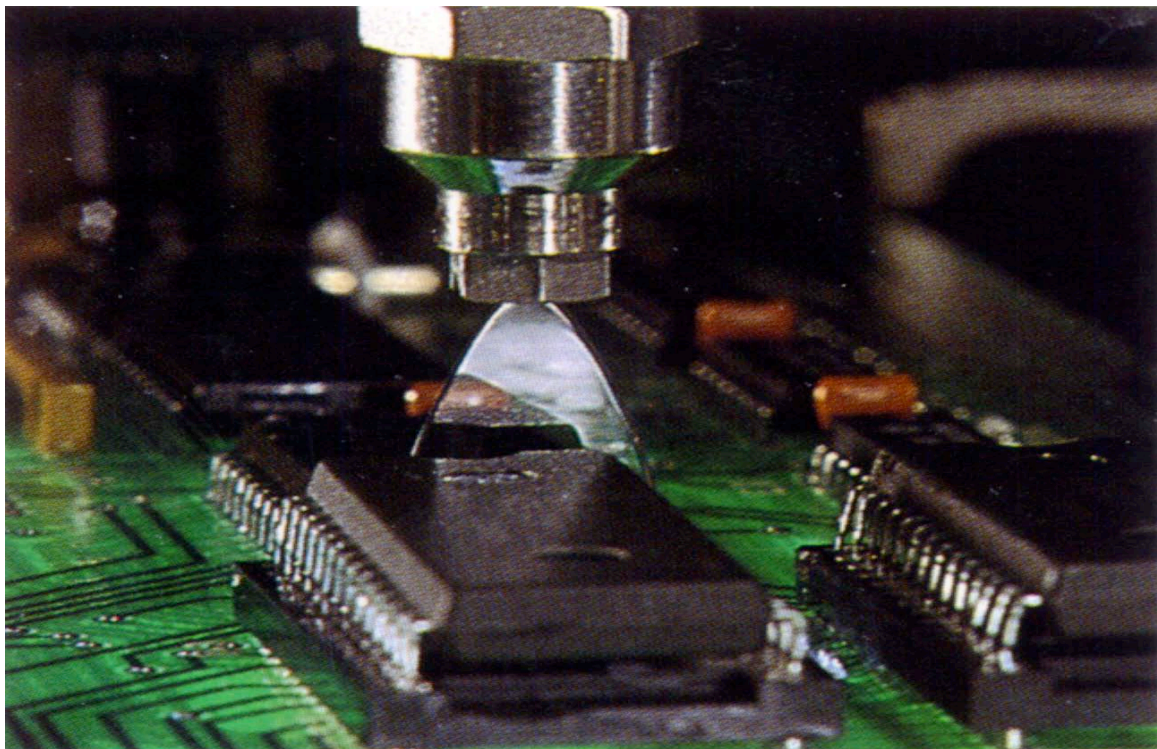


Figure 2

The selective coating shown in Figure 2 is widely practiced in the most demanding applications for precise coverage of chosen areas to be protected while leaving critical connectors or other areas free of coating.

The alternative processes dipping (selective or overall), spray or small scale brush application (for repair) are also important. Good wetting and spreading is easily achieved on all electronic surfaces.

The viscosity can be adjusted if necessary with the use of the Thinner 239.

2.2.3 Curing

- ♣ Air curing requires 16 hours at 23°C
- ♣ Accelerated Curing 30 minutes at 80°C, preferably in a ventilated oven.
- ♣ Shelf life in sealed containers is 6 months

2.2.4 Key Cured Film Properties

The properties of the cured film of **PL4122 BLF** are already well known in chemical stability adhesion to electronic components and surfaces and dielectric properties as highlighted below.

- ♣ Dielectric & Physical Properties
 - Specific Volume resistance - 10¹⁶ ohm.cm
 - 7 days water immersion - 10¹⁵ ohm.cm
 - Dielectric Strength - 112 kV/mm
 - Tracking index - CTI > 600M
 - Combustion behaviour - UL Listed
 - Temperature Index - 134°C
- ♣ Chemical resistance to
 - Moisture
 - Salt water
 - Weak acids and alkalis
 - Petroleum fluids and oils
 - Aromatic solvents

2.2.5 Storage, Handling, Environment and Safety

PL4122 BLF needs to be stored and handled with the normal precautions applicable to a flammable liquid (flash point 32°C depending on solids).

3 Thick Film Coatings (Bectron PK 55..)

In addition to the thin film coatings described there are the thick film coatings based on 1 component polyurethane which have an important role in protection of electronic systems without increasing environmental risks.

The unique properties of the 1 component polyurethane Bectron PK43.. are well known and used extensively in automotive applications.

Bectron PK43.. is a 100% solids and VOC free resin which produces no significant emissions during curing, and contains neither lead nor tin.

It is therefore a fully environmentally-friendly composition in all respects.

Recent developments have increased the thermal stability from 125°C for PK43 to Bectron PK55.. stable up to 155°C.

3.1 Product-description

3.1.1 Chemistry

The 1 component system is dependent on the unique principle of a protected isocyanate in Figure 3 below.

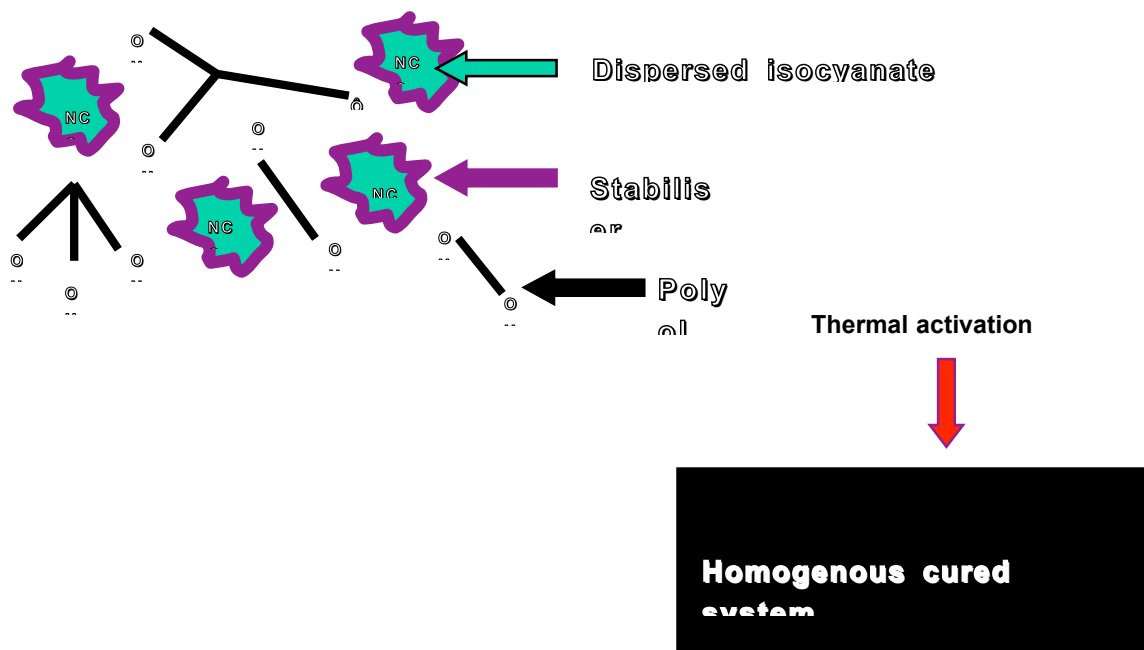
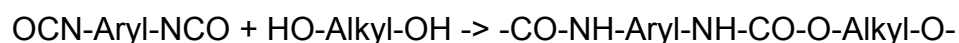


Figure 3

After a major research and development program the thermal resistance of the product has been increased from 125°C to **155°C** to produce the new range PK55.. which has lost none of remarkable performance which this patented chemistry can offer. PK55.. is therefore a more serious alternative to silicones in high temperature applications avoiding many of their manufacturing problems.

Chemically the products consist of a single-component, solvent-free dispersion of a solid, totally encapsulated polyisocyanate in Polyol. The choice and quantity of filler determine the flow characteristics of the resin, from thixotropic rheology to low viscosity.

By heating, the encapsulation of the polyisocyanate breaks down and the poly-addition reaction follows to form a duroplastic resin material. Simplified, the chemical reaction can be described as follows:



The aromatic polyisocyanate reacts with the aliphatic polyol to form polyurethane. Because the polyol contains primary OH-Groups, the reaction rate is relatively high. In addition the product contains a catalyst to accelerate the reaction and reduce the curing time. The catalyst contains neither lead nor tin.

From thermogravimetric studies on model compounds it is well known that polyurethane can cleave into different structures depending on the temperature.

n-Alkyl-NH-CO-O-Alkyl approx. 230°C – 250°C

Aryl-NH-CO-O-Alkyl approx. 200°C

n-Alkyl-NH-CO-O-Aryl approx. 180°C

Aryl-NH-CO-O-Aryl approx 120°C – 130°C

Substitution, catalyst and matrix-effects all play an additional role.

In a complex mixture such as a fully cured moulding material, the temperature stability is governed not only by thermal dissociation of the polyurethane but also such factors as the migration of plasticizer (flexibiliser), reaction of the fillers with the polymer and resistance to oxidation by atmospheric oxygen. In this way the density of cross-linking and the surface composition have further influence. By careful tuning of all the described factors, the long-term temperature-stability of our single-component Bectron PK of resins has been increased.

3.1.2 Product Range and Properties

The product range summarised in the table below maintains the unique offering of a matrix of 4 levels of hardness of the cured resin produced by a range of viscosities of the liquid resin.

The range covers viscosity of 3000 to 11000 mPas and Hardness over the range from Shore A of 30 (elastic) to Shore D 40 (medium hard) shown below. All the grades are non-Newtonian offering shear thinning behaviour and the higher viscosity grades are thixotropic.

Bectron	PK 43/553	PK 43/554	PK 43/555	PK 436...
Viscosity	PK 4330	PK 4340	PK 4351 M	
▼	PK 4332	PK 4342		PK 4364 B
▼		PK4344	PK 4353	
Decrease				
Bectron	PK5532	PK5542	PK5553	PK5562

Bectron	PK .3.	PK .4.	PK .5.	PK .6.
	Shore A	Shore A	Shore D	Shore D
Hardness	35 +- 10	70 +- 10	30 +- 10	40 +- 10
▶▶▶	Very soft	Soft	Resilient	hard

3.2 Applications

3.2.1 Application Processes

Bectron PK55 range maintains the potential of protecting circuit boards as thick film conformal coating (avoiding expensive housing) by providing a coating layer >1mm thickness normally using the high viscosity grades.

Low viscosity examples are used for very many potting applications particularly of delicate sensors in automotive use.

A major feature is the possibility of achieving substantial coating thickness on a PCB by “dam and fill”. For example a dam formed by a high viscosity thixotropic grade can be filled with a lower viscosity grade of the same hardness followed by a single curing step. This is illustrated in Figure 4 below.

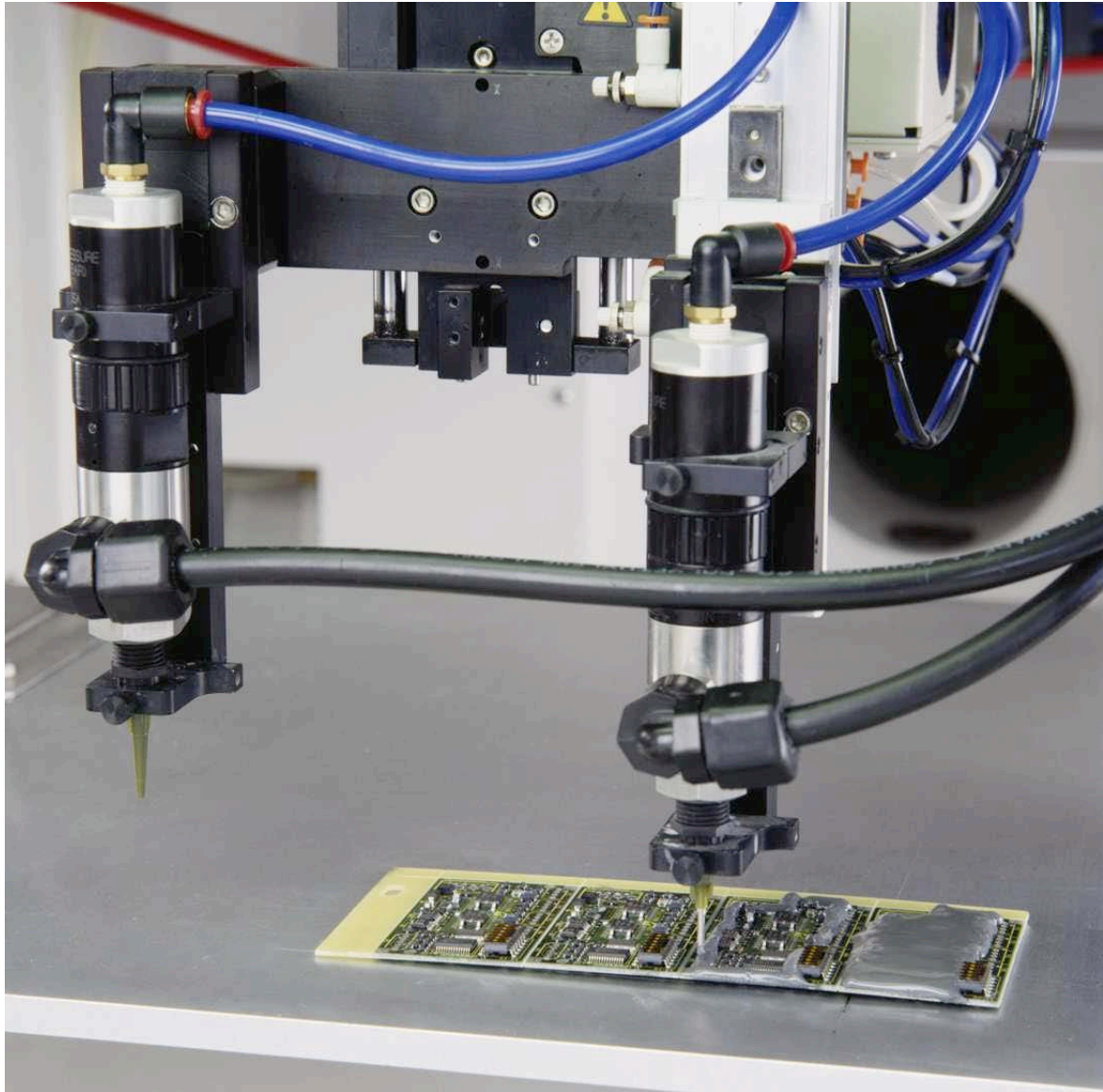


Figure 4

The consistent composition allows precise control of the viscosity by selection of the length and diameter of the dispensing nozzle to control the shear and thereby the viscosity of the resin as it meets the PCB.

Although the cured resin is extremely stable and chemically resistant, the uncured resin is easily cleaned from application equipment with conventional solvents and there is no curing in nozzles to cause annoying blockages.

Bectron PK55 is mostly applied through conventional dispensing nozzles. Coverage of large areas of a PCB can be achieved in short process times by use of application equipment such as the “Control-Coat and Swirl-Coat nozzles (Nordson Asymtek).

3.2.2 Curing

The curing is simply heating at 90°C for 30 minutes (80°C for 60 minutes) with longer times for the softest grades.

Curing can be shortened substantially by Infra Red where appropriate.

3.3 Cured Resin Properties

The Key material properties are:

Temperature cycling stability -50° to +155°C

Glass transition temperature -50 to -60°C

No exotherm on curing

Minimal shrinkage

Resistant to a wide range of automotive fluids

Motor oil, Petrol & Diesel

White Sprits

Anti-freeze

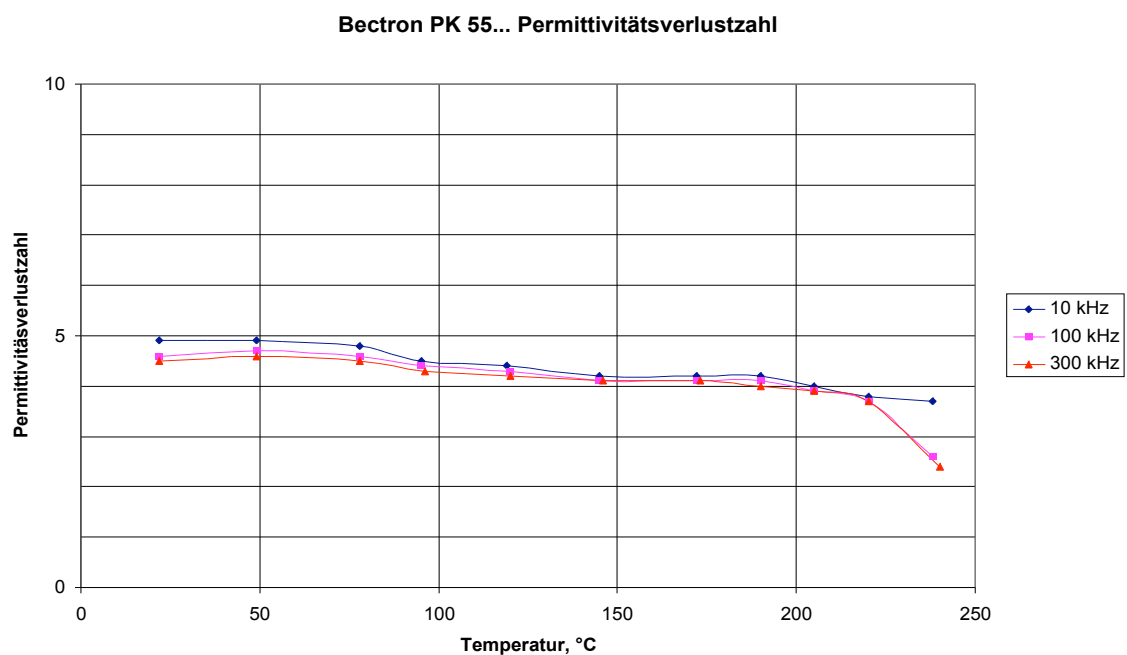
Brake Fluid

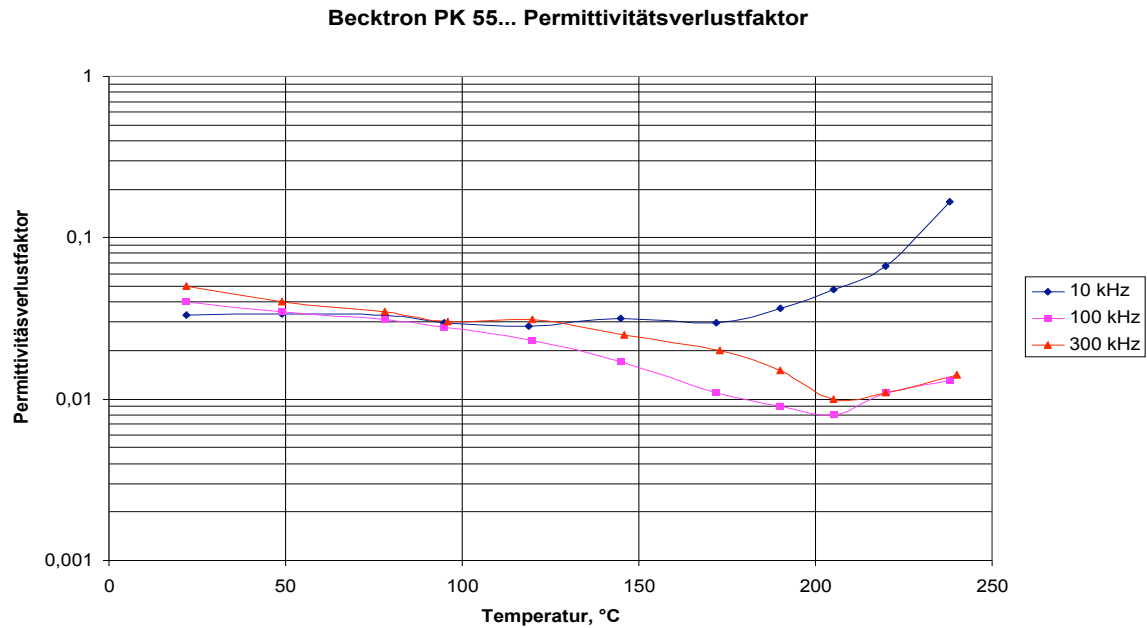
Battery acid

Cleaners

These properties allow excellent resilient protection against vibration and harsh chemical environments under all conditions, with consistent applied film thickness.

The excellent electrical properties are indicated in the diagrams below





3.4 Storage, Handling, Environmental and safety.

Bectron PK55.. resins do not require hazard labelling and no transport classification is required. The isocyanate is a solid, protected and dispersed in the liquid resin, which poses no hazard in the most demanding circumstances. Nevertheless, as it is a mixture of chemical compounds, normal precautions of good industrial practice are required for cleanliness, hygiene and good ventilation. The curing of the resin is emission-free with no volatile products.

In storage the resin needs to be protected from moisture and, for pumping and transfer, only low shear positive displacement pumps are needed to avoid high shear damaging the protected solid isocyanate and cause premature curing.

After long storage, the resin can show slight phase separation of the dispersion, particularly the low viscosity grades. Homogenisation before filling production storage containers is recommended, by rotation of the drums on a rolling table.

4. Conclusion

Modern developments in the Bectron Range of products make it possible to achieve the highest standards of coating performance with VOC free conformal coatings for both thick and film applications. Where solvent borne coatings can be used this is provided with a minimum hazard hydrocarbon based system in a lead free composition without loss of the key properties of the coated film.