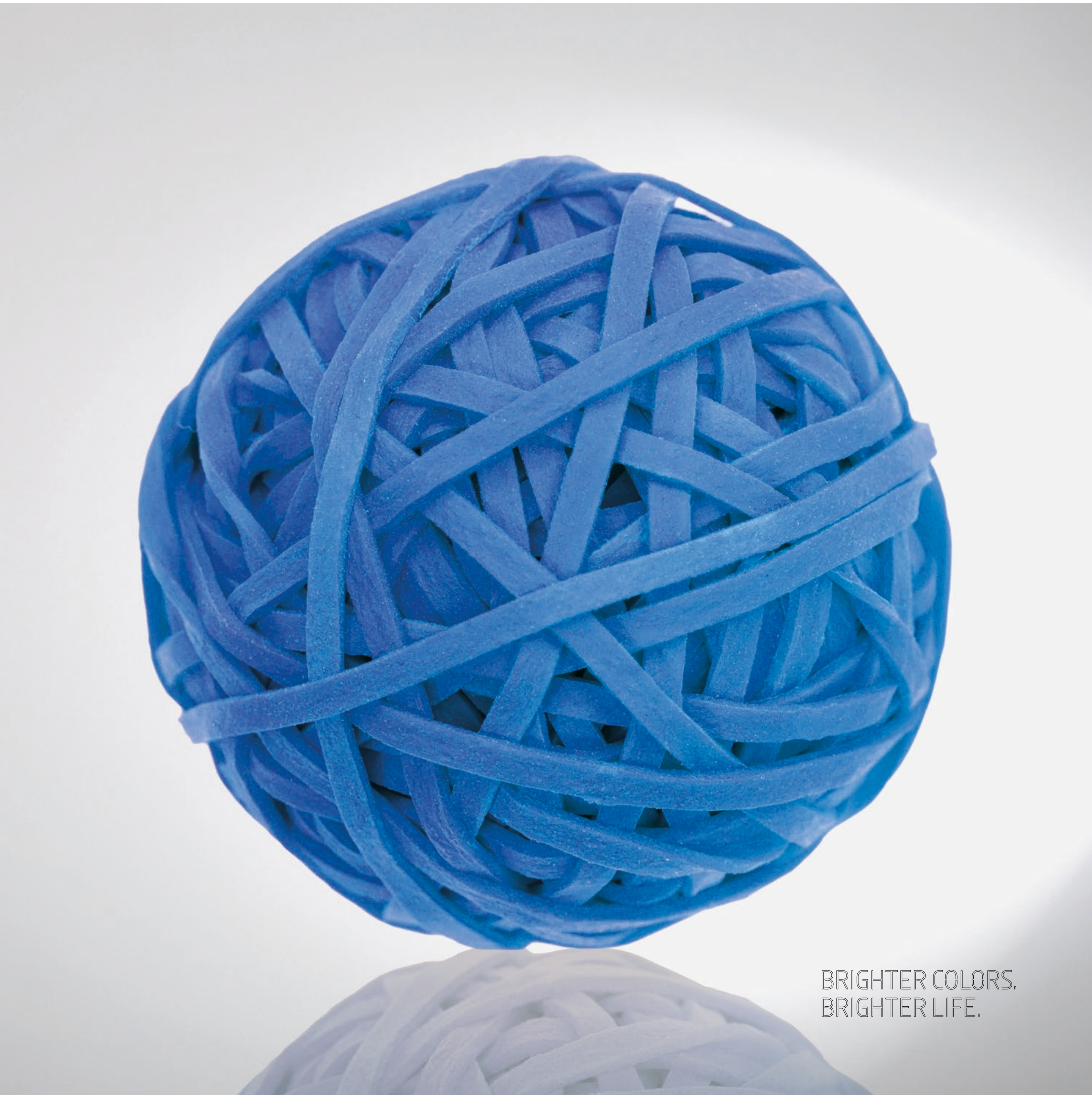
heubach

THE COLORATION **OF PLASTICS AND RUBBER**



THE COLORATION **OF PLASTICS AND RUBBER**

The coloration of plastics is an area of technology in which everyone has an opinion, everyone else can do it better and cheaper and where the mistakes are highly visible and usually expensive. This brochure sets out to provide the reader with a practical insight in polymers, processes and applications applying to the plastics industry and the coloring solutions available from the Heubach ranges of organic colorants.

TRADEMARKS:

GRAPHTOL®	**HOSTASIN™1**
HANSA®	**HOSTASOL™1**
HOSTALEN®1	**HOSTAVIN®1**
TELALUX™	**NOVOPERM®**
HOSTANOX®1	**POLYSYNTHREN®**
HOSTAPERM®1	**PV FAST®**
HOSTAPRINT™1	**SOLVAPERM®**

Section 1 of this brochure is an introduction and guide to the coloration of plastics and includes chapters covering colorant classification, colorant selection criteria and an overview of the Heubach product ranges for plastics coloration. This is followed by a product by product guide to the main areas of application using the following key:

■ Suitable
● Limited suitability (preliminary testing required)
— Not suitable

Section 2 provides a concise guide; polymer by polymer to the coloring possibilities with Heubach organic colorants which includes polymer properties, processing and coloring techniques and details of the individual colorants, their suitability for an application and their application data in the selected polymer and process. The coloring attributes, technical data and application values given are derived from Heubach laboratory testing under specific conditions which are detailed in Section 3 of this brochure. These may differ according to actual working conditions, e. g. machine related data, applied concentrations, exposure to temperature and shear stress over prolonged periods of time, and/or the type and grade of polymer used. Users are therefore recommended to verify the suitability of a colorant for a particular use with preliminary trials under the relevant working conditions.

Additionally in Section 3 a chapter concerns itself with Colour Index registrations, chemical designations, the physical attributes of the colorants and includes chemical resistance data.

A full index to the sections and chapters contained within this brochure can be found on pages 4 and 5.

NOTE ON THE THERMAL STABILITY OF DIARYLIDE PIGMENTS

Pigments indicated with the symbol * throughout this brochure are collectively identified chemically as diarylide pigments. Due to the potential for thermal decomposition (refer to the relevant material safety data sheets) from these pigments, a heat stability of 200 °C is given, even when the coloring attributes of the pigment would remain stable at higher temperatures.

Further information can be found in ETAD INFORMATION NOTICE No. 2 »Thermal Decomposition of Diarylide Pigments« – September 1990.

HEUBACH SHADE CARDS AND TECHNICAL BROCHURES

The Heubach Plastics & Coatings Business strives to provide a high level of technical information regarding its products. Technical brochures and shade cards are continually being updated to include new products, cater for new applications and to provide customers with the relevant technical data in order to meet the demands of a fast changing industry. Please contact your local Heubach sales organization or regional Technical Application Centre to ensure that the most up to date information is on hand and with any questions that may arise.

Heubach also provides a number of services, product data sheets and technical information on the Internet. For information specific to plastic applications click on to:

Heubach.com/Plastics

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1
INTRODUCTION TO THE COLORATION OF PLASTICS AND PRODUCT OVERVIEWS

1.1
INTRODUCTION

Plastics are essential materials used in all aspects of daily life, their unique forming capabilities, thermal, tensile and electrical properties together with their resistance to chemicals and other harsh environments combine to make them the most flexible of engineering materials.

Plastics are synthetic, polymeric materials which can be formed under heat and pressure, upon cooling they regain their polymeric structure. Plastics are produced from polymers; chemical compounds composed of long chain molecules in small repeating units (monomers). Plastics are rarely processed alone; they can be modified with inorganic compounds to impart various physical characteristics, they are often stabilized with additives and processing aids to improve or modify performance properties and they can be co-polymerized or alloyed with other plastics to achieve distinctive physical and resistance properties.

The coloration of plastics is not only for decorative purposes, it is used for identification, safety, product branding, segmentation and environmental purposes. Coloration can be achieved using organic and inorganic pigments, solvent, disperse and other polymer soluble dyes. Effect pigments such as: aluminum and bronze powders, pearlescent and phosphorescent pigments can be added to enhance the optical properties of plastics. Pearlescent pigments can be used in certain instances to impart laser marking properties.

Pigment preparations made up of finely dispersed pigment particles in a polymeric or polymer compatible material are often used in dispersion critical applications. Pigments require a high level of dispersion to breakdown agglomerates which occur in the production process, transportation and storage of these colorants.

The physics of dispersion involve the breaking down of the internal forces that hold the primary pigment particles together in an agglomerated form.

The aim of dispersion is to produce a homogeneous mixture of carrier and pigment which is compatible with the end polymer to be colored. Dispersion aids (wetting agents) such as; waxes, stearates, plasticizers, surfactants or liquid adhesives are incorporated to improve the dispersion process.

Colorants are classified as either pigments or dyes. Pigments can be inorganic or organic, colored, white or black. Pigments are practically insoluble in the medium in which they are incorporated. Most inorganic pigments demonstrate good resistance to the influence of weathering, have hiding power and a high resistance to heat. Many however, lack color strength, are dull and a limited choice of shades (colors) is available. Certain groups of traditionally used inorganic pigments; cadmium, lead chromate and molybdate chemistries are legislated against in many countries and applications.

Organic pigments offer a comprehensive range of shades, color strengths and levels of brightness. A wide variety of chemistries provide for differing heat stability's and fastness properties. Organic pigment selection is critical to obtaining the desired properties at the most economical cost. Unlike pigments which are practically insoluble in plastics; Polymer-, Solvent- and Disperse soluble dyes achieve their solubility during the processing phase of plastic materials and lose their crystal structure to go in total solution as a molecular distribution.

Soluble dyes are generally suitable for the coloration of amorphous polymers; U-PVC (unplasticized), PS, SAN, ABS, PMMA, PC, PEI and PSU etc. Many can also be used in the coloration of thermoplastic polyester and selected members of the polyamide family. They are not suitable for the coloration of plasticized polymers and polymer blends containing ethylene bonds due to their potential to migrate out of the polymer. In combination with butadiene modified polymers their resistance to migration should be initially tested.

THE MOST COMMON DISPERSION TECHNIQUES ARE:

- Internal mixing (banbury type)
- Twin screw extrusion
- Kneader mixing
- Twin or triple roll milling
- Compounding extrusion
- Ball or bead milling

A potential exists for organic colorant chemistries to react with polymer additives, processing stabilizers and impurities present in plastics. In addition, interactions or a reduction of properties in combination with lubricants and additives included during processing of these polymeric materials are possible. The effects of such interactions could lead to the formation of degradation products, to unstable shades, reduced thermal properties or migration problems. Processors are strongly advised to verify all data by testing each color formulation under the actual conditions of use.

1.2
COLORATION SELECTION CRITERIA

The selection of colorants for a particular application is dependant on many factors. The most critical thereof are discussed below. Values for the heat stability of a colorant are usually derived from a pre-determined concentration i. e. Standard Depth $^1/_3$. The **limiting concentration** of a colorant determines its thermal stability profile in the stated polymer. The limit concentration determines the lowest dilution at which a colorant is thermally stable at a given temperature. The values obtained are valid for the stated grade and type of polymer; they are not automatically valid for other grades and for all polymers.

Particle size: In paste and liquid dispersions the particle size and hence the specific surface area of a pigment influence the rheology of the system. The larger the particle size, the lower the specific surface area of a pigment and consequently the viscosity is also lower. A pigment with a high specific surface area will require additional »wetting out« in order to obtain an optimum dispersion. In many instances, pigments manufactured from the same chemistry are offered in differing milled forms. A coarser milling produces larger particles; this in turn leads to a higher opacity and lower color strength in comparison with a finer milled product. **Particle size distribution** is also an important factor in obtaining an optimum dispersion in plastics applications. A narrow band distribution with a minimum of over- and undersized particles will more readily disperse in to a thermoplastic system, particularly when physical dispersion forces and pigment wetting are at a premium.

Dimensional stability: Many organic pigments have been shown to influence the crystalline behaviour of polyolefins by inducing a nucleating effect. The effect that the shrinkage in the direction of flow is no longer equal to that across the direction of flow is known as warpage or dimensional misbehavior, particular prevalent in the processing of HDPE.

Pigment dispersibility: In critical applications such as thin films, transparent packaging, fibers, monofilaments, thin wall articles and components with integral hinges, the optimum pigment dispersion is essential to provide the functionality in use. For these applications organic colorants that have been specifically manufactured for use in plastics e. g. controlled in the synthesis for crystallite growth and subsequently for particle size and distribution should be selected. These, having then been tested for ease of dispersion in a plastic medium according to industry standard tests such as European Standard EN 13900-5 »The determination of a filter pressure value in PP«, LDPE thin-film testing or dispersion hardness in PVC provide the assurance of suitability for the given application.

The **light fastness** of a colorant is primarily determined by its chemistry. Particle size and distribution can also be influencing factors. The light fastness values are obtained by exposing a colorant dispersed in a polymer matrix to a UV light source together with a Blue wool scale. The results are assessed against the Blue wool scale whereby fastness to step 8 indicates very high light fastness and to step 1 indicates very low light fastness. A high level of dispersion is critical to obtaining the values quoted for a particular colorant.

The **weather fastness** properties of a colorant are a feature of molecular structure and particle size. Many factors, most importantly polymer stabilization, pigment concentration and the strength of UV radiation can influence the result. Accelerated weathering in a weather-o-meter can provide a good indication of the performance of a given formulation however, a pre-test under the applied conditions of use is always recommended.

In plasticized polymers certain organic pigments can bleed out onto a contact substrate. This is a form of migration referred to as »bleeding«. **Fastness to bleeding** is tested for in plasticized PVC and is measured against the ISO Grey scale whereby step 5 = no bleeding and 1 = excessive. In the presence of additives with a migratory nature i. e.; Antistatic agents, a pigment can migrate with the additive from the polymer matrix onto the surface.

Relative color (tinting) strength is the means of comparing the tinting strengths of two or more colorants. The DIN 53235 standard determines the test method for the assessment of colorants in reduced shade to International Standard Depth $^1/_3$ (SD$^1/_3$) against a standard reference. The SD $^1/_3$ value obtained for a colorant is given in grams of colorant per kilogram of polymer assuming the addition of either 1% or 5% titanium dioxide. The lower the given value of a colorant the higher it's relative color strength.

Coloration costs refer to the total cost of coloring an end article and take into consideration the relative color strengths of the colorants as well as the kilo price of a given product. The formulation to calculate the coloration costs is given as:

$$\frac{\text{Colorant price €/kg} \times \text{SD } ^1/_3 \text{ in g/kg}}{100} = \text{Coloring cost in €/kg}$$

1.3
COLORANT RANGES

Heubach offers specifically selected ranges of organic colorants under the PV Fast, Graphtol, Hostasol, Solvaperm and Polysynthren names recommended for the coloration of plastics. Under the names of Hostaprint and Hostasin Heubach manufactures pigment preparations for the coloration of PVC and Rubber. The Hostalux range from Heubach are optical brightening agents for enhancing the optical properties of plastics.

The **PV Fast®** range of pigment powders are high performance organic pigments with excellent heat resistance, high light fastness and very good bleed fastness properties. These pigments are designed for their ease of dispersion in thermoplastic materials and are specifically suitable for fibers, thin wall and dispersion critical technical applications.

The **Graphtol®** pigment powders are a range of classic and novel organic chemistries specifically selected for plastics applications. Graphtol pigments present a wide range of shades and technical properties which offer the user economical coloring solutions.

Solvaperm® dyes are high-quality polymer soluble colorants that were developed for coloring polystyrene (PS) and its derivatives. They are in addition suitable for a wide range of other polymers including thermoplastic polyesters and polycarbonate.

Hostasol®[1] dyes are fluorescent colorants suitable for PS, SAN, ABS, PC, PMMA and U-PVC. Some possibilities exist for the coloration of various grades of polyamide and in thermoplastic polyester applications.

The **Polysynthren®** range of polymer-soluble colorants have been especially developed for the coloration of thermoplastic polyester (with the exception of Polysynthren Yellow RL). They produce intensely colored, brilliant shades with outstanding fastness properties. The main applications are in PET fibers, filaments and bottles. Polysynthren's also find applications in other technical polymers, however pre-testing is required. Polysynthren Yellow RL is a colorant that has been developed for the coloration of polyamide, there it exhibits excellent fastness properties.

The **Hostaprint®[1]** range contains pigment preparations based on a vinyl chloride/acetate co-polymer provide for optimum pigment dispersion in a free-flowing, low dusting form. Hostaprint preparations are recommended for the mass coloration of plasticized (P) and unplasticized (U) PVC. Hostaprint preparations are based on 50 % single pigment dispersions from our organic pigment range.

The **Hostasin®[1]** range contains organic pigment dispersions are based on an oxidation resistant polyolefin copolymer carrier that is fully compatible with natural rubber and common synthetic rubbers. They are in a dust-free, free-flowing form and the optimized pigment dispersion allows for maximum color development and reproducibility.

The **Telalux™** range consists of Optical Brightening Agents (OBA) and offers a broad range of products with excellent fastness properties for enhancing the brightness and purity of plastics and synthetic fibers. They also produce whitening effect in natural polymers.

The above mentioned colorant ranges are specifically manufactured for and are tested in plastics applications. In addition, selected colorants under the trade names **Permanent, Novoperm®** and **Hostaperm®[1]** can be used in the coloration of plastics. Usage is dependant upon the polymer being processed and the application technology. These products are however, not regularly tested in plastics and their specifications are determined in non-plastic test medium. For further information regarding potential use of these colorants, contact with your local Heubach sales organization or regional Technical Application Center is advised.

1.4
OVERVIEW OF THE PRODUCT RANGES AND MAIN FIELDS OF APPLICATION

PV FAST PIGMENTS

PRODUCT NAME PV FAST	COLOUR INDEX	PP	PE	PVC	PS / SAN	ABS	PC	POM	PA	PET	PBT	PMMA	Rubber / TPV	SBC	TPO	TPU
YELLOW H9G	Pigment Yellow 214	■	■	■	■	■	–	■	–	–	●	●	■	■	■	■
YELLOW H4G	Pigment Yellow 151	■	■	■	●	●	–	–	–	●	●	–	■	■	■	■
YELLOW H2G	Pigment Yellow 120	■	■	■	■	■	–	–	–	–	–	●	■	■	■	●
YELLOW HG 01	Pigment Yellow 180	■	■	■	■	■	■	■	–	–	■	■	■	■	■	■
YELLOW HG	Pigment Yellow 180	■	■	■	■	■	■	■	–	–	■	■	■	■	■	■
YELLOW H2GR	Pigment Yellow 191	■	■	■	■	■	■	●	–	–	■	■	■	■	■	■
YELLOW HGR	Pigment Yellow 191	■	■	■	■	■	■	●	–	–	■	■	■	■	■	■
YELLOW HR 02*	Pigment Yellow 83	–	●	■	–	–	–	–	–	–	–	–	■	■	●	●
YELLOW HR*	Pigment Yellow 83	–	●	■	–	–	–	–	–	–	–	–	■	■	●	●
YELLOW H3R	Pigment Yellow 181	■	■	■	■	■	–	■	–	–	■	●	■	■	■	■
ORANGE H4GL 01	Pigment Orange 72	■	■	■	■	■	–	■	–	–	–	●	■	■	■	■
ORANGE H2GL	Pigment Orange 64	■	■	■	■	■	●	●	–	–	●	●	■	■	■	●
ORANGE GRL	Pigment Orange 43	■	■	■	■	■	■	–	●	–	■	●	■	■	■	■
ORANGE 6RL	Pigment Orange 68	■	■	■	■	■	■	■	■	–	■	●	■	■	■	■
SCARLET 4RF	Pigment Red 242	■	■	■	■	■	■	■	–	■	■	■	■	■	■	■
RED B	Pigment Red 149	■	■	■	■	■	■	■	●	■	■	■	■	■	■	■
RED D3G	Pigment Red 254	■	■	■	●	●	–	■	–	–	●	–	■	■	■	■
RED HB	Pigment Red 247	■	■	■	■	■	■	–	–	–	■	●	■	■	■	■
RED BNP	Pigment Red 214	■	■	■	■	■	■	■	–	●	■	■	■	■	■	■
RED HF4B	Pigment Red 187	■	■	■	■	■	■	■	–	–	■	■	■	■	■	■
RED E3B	Pigment Violet 19	■	■	■	■	■	■	●	●	●	●	●	■	■	■	■
RED E5B	Pigment Violet 19	■	■	■	■	■	■	●	●	●	●	●	■	■	■	■
PINK E	Pigment Red 122	■	■	■	■	■	■	●	●	●	●	●	■	■	■	■
PINK E 01	Pigment Red 122	■	■	■	■	■	■	●	●	●	●	●	■	■	■	■
PINK E2B	Pigment Red 122	■	■	■	■	■	■	●	●	●	●	●	■	■	■	■
VIOLET BLP	Pigment Violet 23	■	■	■	■	–	–	–	●	–	–	–	■	■	■	●
VIOLET RL	Pigment Violet 23	■	■	■	■	●	–	–	●	–	–	–	■	■	■	●
BLUE A4R	Pigment Blue 15 : 1	■	■	■	■	■	●	●	●	●	●	■	■	■	■	■
BLUE A2R	Pigment Blue 15 : 1	■	■	■	■	■	●	■	●	■	●	■	■	■	■	■
BLUE BG	Pigment Blue 15 : 3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
GREEN GNX	Pigment Green 7	■	■	■	■	■	■	■	●	●	■	■	■	■	■	■
BROWN HFR	Pigment Brown 25	■	■	■	–	–	–	■	–	–	–	●	■	●	■	■
BROWN RL	Pigment Brown 41	■	■	■	■	–	–	■	–	–	–	●	■	●	■	■

** = Diarylide*

1.4
OVERVIEW OF THE PRODUCT RANGES AND MAIN FIELDS OF APPLICATION

GRAPHTOL PIGMENTS

PRODUCT NAME GRAPHTOL	COLOUR INDEX	PP	PE	PVC	PS / SAN	ABS	PC	POM	PA	PMMA	Rubber / TPV	SBC	TPO	TPU
YELLOW GG*	Pigment Yellow 17	–	●	■	–	–	–	–	–	–	■	■	●	●
YELLOW 3GP	Pigment Yellow 155	■	■	■	■	–	–	●	–	●	■	●	●	●
YELLOW GR*	Pigment Yellow 13	–	●	■	–	–	–	–	–	–	■	■	●	●
YELLOW H2R	Pigment Yellow 139	■	■	■	–	–	–	–	–	–	●	●	●	●
ORANGE GPS*	Pigment Orange 13	–	●	■	–	–	–	–	–	–	■	■	–	–
ORANGE RL*	Pigment Orange 34	–	●	■	–	–	–	–	–	–	■	■	–	–
RED HFG	Pigment Orange 38	■	■	■	–	–	–	–	–	–	■	■	●	■
RED LG	Pigment Red 53:1	■	■	■	■	■	■	–	–	●	■	■	●	●
RED LC	Pigment Red 53:1	■	■	■	■	■	■	–	–	●	■	■	●	●
RED BB*	Pigment Red 38	–	●	■	–	–	–	–	–	–	■	■	●	●
RED F3RK 70	Pigment Red 170	■	■	●	–	–	–	–	–	–	–	–	●	–
FIRE RED 3RLP	Pigment Red 48:3	■	■	■	■	■	–	–	–	–	■	■	●	■
RED HF2B	Pigment Red 208	■	■	■	–	–	–	–	–	–	■	■	●	●
RED F5RK	Pigment Red 170	■	■	●	–	–	–	–	–	–	–	–	●	–
RED P2B	Pigment Red 48:2	■	■	■	■	–	–	–	–	–	■	■	●	■
CARMINE HF4C	Pigment Red 185	■	■	■	■	–	–	–	–	–	■	■	●	■
CARMINE HF3C	Pigment Red 176	■	■	■	■	–	■	–	–	■	■	■	●	■
RUBINE L4B	Pigment Red 57:1	■	■	■	●	–	–	–	–	–	■	■	●	■
BORDEAUX HF3R	Pigment Violet 32	●	●	■	–	–	–	–	–	–	●	●	●	●
BLUE AN 01	Pigment Blue 15	–	–	■	–	–	–	–	–	–	■	●	●	●
BLACK CLN	–	■	■	■	●	●	–	■	–	–	■	■	■	■

** = Diarylide*

SOLVAPERM DYES

PRODUCT NAME	COLOUR INDEX	POLYMER							
SOLVAPERM		PS	SAN	ABS	PC	PETP PBTB	PMMA	PA	U-PVC
YELLOW 3G	Solvent Yellow 93	■	■	–	■	–	■	–	■
YELLOW 2G	Solvent Yellow 114	■	■	■	■	■	■	–	■
ORANGE 3G	Solvent Orange 60	■	■	■	■	■	■	●	■
RED 2G	Solvent Red 179	■	■	■	■	■	■	■	■
RED G	Solvent Red 135	■	■	■	■	■	■	●	■
RED PFS	Solvent Red 111	■	■	■	■	■	■	●	■
RED BB	Solvent Red 195	■	■	■	■	■	■	–	■
RED VIOLET R	Solvent Violet 59 Disperse Violet 26	■	■	■	■	●	■	●	■
VIOLET RSB	Solvent Violet 13	■	■	■	■	■	■	–	■
BLUE 2B	Solvent Blue 104	■	■	■	■	■	■	●	■
GREEN GSB	Solvent Green 3	■	■	■	■	■	■	–	■
GREEN G	Solvent Green 28	■	■	■	■	■	■	–	■
BLACK PCR	–	■	■	■	■	■	●	–	■

POLYSYNTHREN POLYMER SOLUBLE COLORANTS

PRODUCT NAME	COLOUR INDEX	POLYMER						
POLYSYNTHREN		PS	SAN	ABS	PC	PETP PBTB	PMMA	PA
YELLOW NG	Pigment Yellow 147	●	●	●	■	■	●	–
YELLOW RL	Pigment Yellow 192	–	–	–	–	●	–	■
RED GFP	Solvent Red 135	■	■	■	■	■	■	●
VIOLET G	Solvent Violet 49	●	●	●	■	■	■	–
BLUE R	Solvent Blue 122	■	■	■	■	■	■	–
BLUE RLS	Solvent Blue 45	■	■	■	■	■	■	–
BROWN 3RL	Pigment Orange 70	●	●	●	■	■	●	–
BROWN R	Solvent Brown 53	■	■	■	■	■	■	–
BLACK H	Solvent Black 27	■	●	●	■	●	■	■

1.4
OVERVIEW OF THE PRODUCT RANGES AND MAIN FIELDS OF APPLICATION

HOSTASOL FLUORESCENT DYES

PRODUCT NAME	COLOUR INDEX	POLYMER							
HOSTASOL		PS	SAN	ABS	PC	PETP PBTB	PMMA	PA	U-PVC
YELLOW 3G	Solvent Yellow 98	■	■	■	■	■	■	●	■
RED GG	Solvent Orange 63	■	■	■	■	■	■	●	■
RED 5B	Vat Red 41	■	●	●	■	●	■	–	■

HOSTAPRINT PIGMENT PREPARATIONS

PRODUCT NAME	COLOUR INDEX
HOSTAPRINT	
YELLOW GG 34*	Pigment Yellow 17
YELLOW HG 34	Pigment Yellow 180
YELLOW HR-N*	Pigment Yellow 83
YELLOW HGR 34	Pigment Yellow 191
YELLOW H2R 34	Pigment Yellow 139
ORANGE H4GL 34	Pigment Orange 72
RED HFG	Pigment Orange 38
RED D3G 34	Pigment Red 254
RED HF2B	Pigment Red 208
CARMINE HF4C	Pigment Red 185
PINK E	Pigment Red 122
VIOLET RL 34	Pigment Violet 23
BLUE A2R 34	Pigment Blue 15:1
BLUE B2G 34	Pigment Blue 15:3
GREEN GG	Pigment Green 7
BROWN RL 34	Pigment Brown 41
BROWN HFR 34	Pigment Brown 25
BLACK L	Pigment Black 7

** = Diarylide*

HOSTASIN PIGMENT PREPARATIONS

PRODUCT NAME	COLOUR INDEX
HOSTASIN	
YELLOW GR 30*	Pigment Yellow 13
YELLOW HR 30*	Pigment Yellow 83
ORANGE G 30*	Pigment Orange 13
RED B 30*	Pigment Red 38
RED HF2B 30	Pigment Red 208
BLUE A2R 30	Pigment Blue 15:1
GREEN GG 30	Pigment Green 7

** = Diarylide*

1.5
OPTICAL BRIGHTENING AGENTS (OBA)

Optical brightening agents, often referred to as Optical Brighteners or Fluorescent Whitening agents are extensively used in the coloration of plastics and synthetic fibers. The main fields of application in plastics are polyvinyl chloride, polyolefins, ethylene vinyl acetate copolymers, polystyrene, polyester and polyurethane. Optical brighteners allows for a whitening effect in natural polymers. In shades of white and in pastel colors their addition results in cleaner (purer), more brilliant (higher chroma) and bluer tints. The addition of optical brighteners leads to a consumer perception of »new, uncontaminated and clean colors«. Under ultraviolet light plastics containing optical brighteners fluoresce, this feature is often used for security marking, identification and quality control aspects of finished goods.

Optical brighteners absorb ultraviolet (UV) light in the range 360–380 nanometers (nm) and re-emit this light in the visible spectrum in the range 420–460 nm. They are applied in a similar way to soluble colorants in plastics applications using conventional equipment. Behavior during processing is also similar to that of soluble dyes; the optical brighteners dissolve mono-molecularly in the polymer melt.

Optical brighteners are most effective when added in low concentrations and produce particularly good brightening and coloring effects when used in combination with solvent dyes. In combination with titanium dioxide and many types of filler, which also absorb light in the UV range, the excitation energy available to the optical brightener and therefore its effectiveness is reduced. The same scenario is applicable when an OBA is used in combination with UV Absorbers. However, when combined with a Hindered Amine Light Stabilizer (HALS) which do not absorb UV light, not only is an increase in the level of whiteness observed, the light fastness value of the OBA particularly in polypropylene and polystyrene can be improved. Addition levels of optical brighteners vary according to the application and polymer, the following provides an indication:

For transparent polymers: 5–20 ppm (0.0005–0.002 %)
For colored formulations: 20–100 ppm (0.002–0.01 %)
For white formulations: 100–1000 ppm (0.01– 0.1 %)
For fiber applications: 150–200 ppm (0.015–0.02 %)

For very low addition levels and to facilitate metering on the machine many OBA’s are available in dilutions blended with calcium carbonate. In the production of OBA based concentrates, the concentration of optical brightener is typically in the range from 5 % to 20 %.

Solubility limits in the polymeric carrier at the melt processing temperature must be considered. In addition, the presence of plasticizers, particularly those used in PVC applications can promote migration or bleeding of the OBA. Selection of a suitable grade and the addition level are important considerations in these instances.

The selection of optical brightener for a given application is important. Although technical data sheets often refer to OBA’s as being suitable in a wide range of polymers and applications, care should be taken. The thermal stability, light fastness and solubility vary according to the chemical type and the selected polymer. Other considerations include their use in the presence of plasticizers and other polymer additives such as antistatic agents which can lead to a migration of an OBA to the surface of the polymer. In grades of LDPE with a particularly low density and high melt flow the potential for blooming exists. Sublimation resistance is important in the coloration of polyester fibers and chemically aggressive polymer melts can reduce properties.

The following selection guide provides an overview of the Heubach range of Optical Brighteners and their suitability in a wide range of polymers.

For the brightening of polyester fibers and filaments optical brighteners can be added as: powder, as a dispersion in ethylene glycol or as concentrate based on a polymeric carrier. The property table found on the following page illustrates the fastness values determined in (DTY) polyester yarn with a titer of dtex 144 f 48 in a »bright« PET from the addition of 2 % masterbatch (corresponding to 200 ppm optical brightener). The fastness tests and assessments were carried out in a accordance with the current DIN and ISO specifications listed and are valid for the above mentioned conditions. Processors are strongly advised to confirm the results under actual conditions of use in the specified system.

1.5
OPTICAL BRIGHTENING AGENTS (OBA)

OVERVIEW OF THE TELALUX RANGE AND AREAS OF APPLICATION
OPTICAL BRIGHTENERS FOR PLASTICS AND SYNTHETIC FIBERS

PRODUCT NAME

TELALUX	PET PBT	PE	PP	PS	SAN	ABS	PC	PMMA	PA	PVC-U	PVC-P	EVA	PUR
KCB P	■	■	■	■	■	■	■	■	■	■	■	■	–
KS P	■	■	■	■	■	■	■	■	■	■	●	–	●
KSN P	■	■	■	■	■	■	■	■	■	■	●	–	–
KSC P	–	–	–	–	–	–	–	–	–	■	■	–	–
KS1 P	■	–	–	●	●	●	–	–	■	–	–	–	–
NSM P	–	–	–	–	–	–	–	–	–	–	–	–	■
OB	■	■	■	■	■	■	■	■	■	■	■	■	●
OB1	■	–	–	●	●	●	–	–	■	–	–	–	–

FASTNESS PROPERTIES

144 F 48 DTEX PET (BRIGHT) DTY	ISO 105-B06			ISO 105-B01 LIGHT FASTNESS	ISO 105-C04 (WASHING 4) 95 °C / 203 °F			ISO 105-P01 (DRY HEAT) 210 °C / 410 °F 30 S			ISO 105-P02 (STEAM PLEATING) 130 °C / 266 °F 15 MIN		
	1 x Blue Scale	3 x Grey Scale	5 x Grey Scale	Grey Scale	Grey Scale	Grey Scale	Grey Scale	Grey Scale	Grey Scale	Grey Scale	Grey Scale	Grey Scale	Grey Scale
PRODUCT NAME				Method 2	N	PET	CO	N	PET	CO	N	PET	CO
KS1 P	7	5	4–5	5	5	5	5	5	5	5	5	5	5
KSN P	7	5	4–5	5	5	5	5	5	5	5	5	5	5
KS P	7	5	4–5	5	5	5	5	5	5	5	5	5	5

2 POLYMER
BY POLYMER GUIDE

2.1
PVC AND PLASTISOLS

GENERAL INFORMATION

Polyvinyl Chloride (PVC) continues to be one of the most important commercially produced plastics. More than 80 % of PVC produced is manufactured by the suspension polymerization method, emulsion and bulk polymerization make up the rest. PVC cannot be processed in its pure form, it is relatively unstable to heat, light and shear friction and requires a diversity of processing additives in order to bring it in to processable thermoplastic material.

Stabilizers such as barium, tin and zinc salts are added to overcome these problems. The processing additives and stabilizers have an influence on the base color and the transparency of the polymer. In addition, they also have a noticeable effect on the fastness properties of pigments and dyes used in the coloration of PVC. Stabilizers containing sulphur may cause a deepening of shade in the presence of lead-containing pigments due to the formation of lead sulphide. Barium-cadmium stabilizers and lubricants can lead to plate-out.

Unplasticized U-PVC (rigid grades) account for approximately 55 % of world production, the largest single use is in pipes: for water supply and distribution, agricultural irrigation, chemical processing, drainage, waste, guttering and vents, sewer systems and conduits for cables. The construction industry is the second largest consumer of U-PVC for window profiles, roofing sheets and interior moldings and trims. Other applications include interiors for household appliances and calendered films for packaging items.

Plasticized P-PVC (flexible grades) is produced by adding plasticizers: DOP, DIDP, DINP etc. or monomeric polymeric types to the blend via »Hot rolls« or internal mixers. The plasticizer content can vary greatly – typically around 30 %. Applications for plasticized (P-PVC) include flooring, footwear and wire and cable insulation. The presence of plasticizer can have a great influence of the migration behaviour of solvent dyes and many organic pigments. As a result many colorants recommended for use in U-PVC may have restrictions in plasticized grades. The same applies to PVC pastes (Plastisols) which contain up to 50 % plasticizer.

The processing temperatures for U- and P-PVC are generally between 130 °C and 220 °C. PVC can be processed by all methods commonly used to form thermoplastics; injection and blow molding, sheet and film extrusion and calendering. Organic colorant selection for PVC is a function of dispersibility, the limit concentration and coloration cost together with application dependant properties such as weather fastness and light stability.

COLORING OF U-PVC

Organic pigments (PV Fast and Graphtol) and soluble dyes (Solvaperm and Hostasol) can be used for the coloration of U-PVC. Dyes are also suitable as a tinting medium to control the optical properties of the polymer. Hostaprint Pigment preparations are often used in critical dispersion applications e. g. calendered thin-films. In clear U-PVC highly transparent and intensive shades can be obtained using soluble dyes. The Hostasol range exhibit in low concentrations a pronounced edge fluorescence, in combination with titanium dioxide and other opaque pigments these fluorescent dyes produce brilliant shades. Soluble dyes demonstrate good fastness properties in U-PVC, however the light and weather fastness can be influenced by the PVC base stabilization.

COLORING OF P-PVC

Organic pigment selection is based on bleed-fastness, thermal properties, dispersion and price. The Graphtol and PV Fast pigments as well as the Hostaprint and Telasperse PVC preparations are generally suitable for P-PVC coloration. The »bleed fastness« values for Graphtol and PV Fast pigments have been evaluated by placing the pigmented sample in contact with a white-pigmented plasticized PVC film at 140 °C for 2 hours. The assessment of bleeding was made against the ISO Grey Scale in accordance with EN 20105-A03. Step 5 on this scale denotes no bleeding onto the contact material. Soluble dyes will migrate in the presence of plasticizer and therefore are not suitable for P-PVC coloration.

Note: E-PVC (Emulsion PVC) contains emulsifiers and sodium carbonate which can react with certain organic pigment chemistries leading to unstable colors. A pre-test to establish suitability of a colorant in E-PVC is recommended.

2.1
PVC AND PLASTISOLS

HOSTAPRINT PREPARATIONS

The Hostaprint preparations are pre-dispersed single pigments based on a vinyl chloride/vinyl acetate copolymer. They provide for optimum pigment dispersion in a free-flowing, low dusting form and are recommended for the coloration of plasticized and unplasticized PVC (with the exception of PVC Plastisols). They are also particularly suited for the manufacture of inks for printing on PVC, PVDC, Cellophane, Polyurethane, Paper and Aluminum foils.

The Hostaprint preparations are based on 50 % single pigment dispersions and their fastness properties equate to those of the powder pigments on which they are based. The Hostaprint pigment preparations are standardised in a plasticized PVC compound and in a printing application.

Hostaprint preparations can be treated similarly to powder pigments, they do however, offer clear advantages in their handling and dispersibility – factors that are of particular importance in the manufacture of colored films. They also permit accurate, economical dosing, leading to a reduction in waste and a uniform distribution of color. The need to control temperature and shear force to allow full pigment dispersion is also negated.

COLORING OF PVC CABLE SHEATHING

PVC cable sheathing has to be colored with pigments which do not noticeably impair the electrical resistance of the insulation. The main factors to be taken into account are volume resistivity (important for all insulation) and dielectric loss (a measure of the loss incurred in the conversion of electrical energy into heat due to dipole oscillation in the insulating material). Dielectric loss does not occur with direct current, thus the loss increases as the frequency increases. In polyethylene, a non-polar material, oscillation cannot be induced even by alternate current, and so the issue of dielectric loss does not arise.

The dielectric loss factor is represented as $\varepsilon \tan \delta$, where ε is the dielectric constant and $\tan \delta$ the loss angle. It thus follows that pigments to be used for coloring PVC cable sheathing must not have an adverse influence on the volume resistivity or the dielectric loss angle.

Heubach pigments recommended for cable sheathing which gave satisfactory results as regards $\tan \delta$ values under testing on production batches containing 0.1% and 0.5% pigment concentrations are indicated in the following tables. The dielectric properties of a PVC cable compound are not noticeably effected by the Hostaprint carrier and these pigment preparations (pigment type providing) are also suitable.

In addition, color formulations to reach RAL shades in accordance with DIN 47002 and British Standard (BS 6746) shades for the coloration of PVC cable sheathing are provided.

COLORING OF PLASTISOLS

In addition to spread coating, rotary casting of PVC is also colored from Plastisol pastes. They can also be used for coloring polyester and methacrylate casting resins (not suitable for epoxy casting resins). Plastisols are dispersions of fine particle sized PVC resin in a monomeric plasticizer liquid such as DIDP, DOP, DINP or polymeric plasticizer. Additives such as heat and light stabilizers, pigments, flame retardants and processing aids are added to meet specific end product and processing requirements. Depending on requirements plastisols can be poured, pumped, sprayed, rotation molded or cast, they are liquids at room temperature and upon heating fuse and reach their optimum properties. Methods of processing plastisols include roller pastes, spread coating, coil and dip coating and foamed applications. End applications include tarpaulins and apparel, hollow and inflatable products, coatings for tool handles and handle grips, foamed coatings for steering wheels, toys and medical devices.

Suitable pigment dispersions are obtained in plasticizer pastes on a triple-roll mill, bead mill or in a dissolver these are then added to the plastisol preparation. The Graphtol and PV Fast pigments are suitable for the coloration of plastisols. Selection is according to the fastness and thermal properties required. Bleed fastness of pigments and their limit concentrations must be taken in to consideration.

For a detailed list of properties refer to the Graphtol and PV Fast pigment recommendations for P-PVC.

2.1
PVC AND PLASTISOLS

COLORING RECOMMENDATIONS AND APPLICATION DATA–PIGMENTS FOR POLYVINYL CHLORIDE (PVC)

PRODUCT NAME			LIGHT FASTNESS					
	SD $^1/_3$	Hue angle	Reduction (0.1% + 0.5 TiO_2)	Full shade (0.1%)	Bleed fastness	Cable sheating	Limit conc. P-PVC	Limit conc. U-PVC
PV FAST	g/kg	°					%	%
YELLOW H9G	9.20	97.4	7	7	5	●	0.005	0.005
YELLOW H4G	12.00	92.5	7–8	7–8	5	■	0.005	0.005
YELLOW H2G	10.40	90.0	8	8	5	–	0.005	0.005
YELLOW HG 01	4.50	90.4	7	7	5	■	0.005	0.005
YELLOW HG	5.50	88.7	7	8	5	■	0.005	0.005
YELLOW H2GR	9.50	84.0	5–6	6–7	5	■	0.005	0.005
YELLOW HGR	11.70	78.3	6	7	5	■	0.005	0.005
YELLOW HR 02*	2.20	81.3	7–8	7	5	■	0.005	0.005
YELLOW HR*	2.50	82.8	7–8	7	5	■	0.005	0.005
YELLOW H3R	13.10	65.3	8	7–8	5	●	0.005	0.005
ORANGE H4GL 01	5.70	60.1	7–8	7–8	5	●	0.005	0.005
ORANGE H2GL	6.90	46.7	7	7	5	●	0.005	0.005
ORANGE GRL	6.10	42.3	7–8	7–8	4–5	■	0.005	0.005
ORANGE 6RL	9.10	37.0	7–8	7	5	–	0.005	0.005
SCARLET 4RF	8.80	27.3	7–8	8	5	–	0.005	0.005
RED B	5.20	21.6	7	7	5	■	0.005	0.005
RED D3G	6.20	17.2	8	7–8	5	■	0.005	0.005
RED HB	9.40	12.9	6–7	6–7	5	■	0.005	0.005
RED BNP	5.70	15.0	8	8	5	■	0.005	0.005
RED HF4B	7.70	6.2	7–8	7	5	■	0.010	0.005
RED E3B	13.10	359.1	8	8	5	●	0.005	0.005
RED E5B	11.40	356.1	7	7	5	■	0.005	0.005
PINK E	7.70	339.7	7–8	7–8	5	■	0.005	0.005
PINK E 01	8.10	339.4	7	7	5	■	0.005	0.005
PINK E2B	8.80	338.2	7–8	7–8	5	■	0.005	0.005
VIOLET BLP	2.90	302.9	7–8	7–8	4	■	0.010	0.005
VIOLET RL	2.50	302.7	7–8	7–8	4	■	0.010	0.005
BLUE A4R	3.60	249.6	8	8	4	■	0.005	0.005
BLUE A2R	3.30	249.3	8	8	5	■	0.005	0.005
BLUE BG	4.00	240.7	8	8	5	■	0.005	0.005
GREEN GNX	8.90	180.4	8	8	5	■	0.005	0.005
BROWN HFR	7.50	25.9	8	8	4–5	–	0.005	0.005
BROWN RL	6.90	44.1	8	8	4	–	0.005	0.005

** = Diarylide*

COLORING RECOMMENDATIONS AND APPLICATION DATA–PIGMENTS FOR POLYVINYL CHLORIDE (PVC)

PRODUCT NAME			LIGHT FASTNESS					
	SD $^{1}/_{3}$	Hue angle	Reduction (0.1% + 0.5 TiO_2)	Full shade (0.1%)	Bleed fastness	Cable sheating	Limit conc. P-PVC	Limit conc. U-PVC
GRAPHTOL	g/kg	°					%	%
YELLOW GG*	4.20	94.3	6–7	7	3	■	0.100	0.025
YELLOW 3GP	6.10	92.9	8	8	3–4	■	0.005	0.005
YELLOW GR*	2.40	89.1	6–7	6–7	3	■	0.100	0.025
YELLOW H2R	3.50	77.1	6–7	7	5	●	0.005	0.005
ORANGE GPS*	5.40	52.4	4–5	5–6	3	■	0.100	0.025
ORANGE RL*	4.60	39.1	6	7	2–3	■	0.100	0.025
RED HFG	8.90	33.4	6–7	8	4	–	0.005	0.005
RED LG	7.10	23.8	2–3	3–4	4–5	–	0.005	0.005
RED LC	7.20	21.8	2–3	3–4	4–5	■	0.005	0.005
RED BB*	3.30	17.4	4	7–8	3	■	0.050	0.010
FIRE RED 3RLP	7.50	12.0	5–6	6–7	5	■	0.005	0.005
RED HF2B	5.10	11.5	6–7	7–8	4–5	■	0.010	0.010
RED P2B	5.20	2.1	5–6	6	5	■	0.005	0.005
CARMINE HF4C	4.50	356.6	7	7–8	5	●	0.005	0.005
CARMINE HF3C	5.40	358.4	7	7–8	5	■	0.005	0.005
RUBINE L4B	4.50	354.5	3–4	6	5	■	0.010	0.010
BORDEAUX HF3R	3.60	336.5	7	7–8	5	■	0.005	0.005
BLUE AN 01	3.40	251.3	8	8	4	●	0.005	0.005

** = Diarylide*

2.1
PVC AND PLASTISOLS

COLORING RECOMMENDATIONS AND APPLICATION DATA – PIGMENT PREPARATIONS FOR POLYVINYL CHLORIDE (PVC)

PRODUCT NAME		LIGHT FASTNESS					
	SD 1/3	Reduction (0.1% + 0.5 TiO_2)	Full shade (0.1%)	Bleed fastness	Cable sheating	Limit conc. P-PVC	Limit conc. U-PVC
HOSTAPRINT	g/kg					%	%
YELLOW GG 34*	8.40	6–7	7	3	■	0.20	0.05
YELLOW HG 34	11.00	7	7	5	■	0.01	0.01
YELLOW HR-N*	4.40	7–8	7	5	■	0.01	0.01
YELLOW HGR 34	23.40	6	7	5	■	0.01	0.01
YELLOW H2R 34	7.00	6–7	7	5	■	0.01	0.01
ORANGE H4GL 34	11.40	7–8	7–8	5	■	0.01	0.01
RED HFG	17.80	6–7	8	4	–	0.01	0.01
RED D3G 34	12.40	8	7–8	5	■	0.01	0.01
RED HF2B	10.20	6–7	7–8	4–5	■	0.02	0.02
CARMINE HF4C	9.00	7	7–8	5	●	0.01	0.01
PINK E	15.40	7–8	7–8	5	■	0.01	0.01
VIOLET RL 34	5.80	7–8	7–8	4	■	0.02	0.01
BLUE A2R 34	6.60	8	8	5	■	0.01	0.01
BLUE B2G 34	8.00	8	8	5	■	0.01	0.01
GREEN GG	17.80	8	8	5	■	0.01	0.01
BROWN RL 34	13.80	8	8	4	■	0.01	0.01
BROWN HFR 34	15.00	8	8	4–5	■	0.01	0.01
BLACK L	–	8	8	5	■	0.01	0.01

** = Diarylide*

COLORING RECOMMENDATIONS AND APPLICATION DATA – SOLUBLE DYES FOR UNPLASTICIZED POLYVINYL CHLORIDE (U-PVC)

PRODUCT NAME			LIGHT FASTNESS	
	SD $^{1}/_{3}$	Hue angle	Reduction (0.1% + 0.5 TiO_2)	Full shade (0.1%)
SOLVAPERM	g / kg	°		
YELLOW 3G	0.48	96.1	7–8	8
YELLOW 2G	0.17	96.7	7–8	8
ORANGE 3G	0.51	65.4	6	8
RED 2G	0.49	35.5	6	7
RED G	0.72	28.5	7	8
RED PFS	0.77	18.6	5–6	7
RED BB	0.20	356.2	6	8
RED VIOLET R	0.41	333.8	6	7–8
VIOLET RSB	0.35	286.2	6	7–8
BLUE 2B	0.38	258.2	6	7–8
GREEN GSB	0.42	201.8	4–5	7
GREEN G	0.68	170.6	7–8	8

COLORING RECOMMENDATIONS AND APPLICATION DATA – FLUORESCENT DYES FOR UNPLASTICIZED POLYVINYL CHLORIDE (U-PVC)

PRODUCT NAME			LIGHT FASTNESS	
	SD $^{1}/_{3}$	Hue angle	Reduction (0.1% + 0.5 TiO_2)	Full shade (0.1%)
HOSTASOL	g / kg	°		
YELLOW 3G	–	–	4–5	7
RED GG	–	–	4	7
RED 5B	–	–	3	4

2.1
PVC AND PLASTISOLS

WEATHER FASTNESS OF PIGMENTS IN PVC

The following selection of PV Fast and Graphtol pigments were assessed for their fastness under accelerated weathering conditions from colored PVC films in a barium / zinc stabilized plasticized PVC. The pigment test conditions were; 0.2 and 0.5 % »full shade« and reduction; 1.0 % pigment with 0.5 % titanium dioxide. The stabilized PVC compound was also assessed for weathering under the same conditions with and without the addition of 0.5 % titanium dioxide.

The PVC test films were produced on a twin-roll mill and then pressed to the required thickness of 1 mm. Thereafter they were exposed in an artificial light using a cycle of 102 minutes dry and 18 minutes wet. The black panel temperature was set at 55 °C and the relative humidity at 60 %. The assessment to the Grey scale was carried out after 2500 and 5000 hour's exposure.

The values given provide only an indication of the fastness to weathering from single pigment in a specified PVC compound under the above described conditions. For further information on the subject of weathering in plastics refer to page 42 in this brochure or contact your regional Heubach Technical Application Center.

WEATHER FASTNESS DATA IN PVC BARIUM / ZINC STAB. – ARTIFICIAL LIGHT EXPOSURE

	GREY SCALE (HOURS)	
	2500	5000
P-PVC		
Natural PVC compound	5	4–5
Compound + 1% TiO_2	4–5	4–5
GRAPHTOL YELLOW 3GP		
0.2 % Pigment	4	3–4
0.5 % Pigment	4	3–4
1.0 % Pigment + 0.5 % TiO_2	3–4	–
PV FAST YELLOW H4G		
0.2 % Pigment	4	–
0.5 % Pigment	4–5	4
1.0 % Pigment + 0.5 % TiO_2	4–5	4
PV FAST YELLOW H2G		
0.2 % Pigment	4–5	–
0.5 % Pigment	4–5	4
1.0 % Pigment + 0.5 % TiO_2	4–5	4
PV FAST YELLOW HR 02		
0.2 % Pigment	4	3
0.5 % Pigment	4–5	3
1.0 % Pigment + 0.5 % TiO_2	4–5	3
PV FAST YELLOW HR		
0.2 % Pigment	4–5	3
0.5 % Pigment	5	4
1.0 % Pigment + 0.5 % TiO_2	4–5	3–4

	GREY SCALE (HOURS)	
	2500	5000
PV FAST YELLOW H3R		
0.2 % Pigment	4	–
0.5 % Pigment	4–5	–
1.0 % Pigment + 0.5 % TiO_2	4–5	–
PV FAST ORANGE H4GL 01		
0.2 % Pigment	3–4	–
0.5 % Pigment	4–5	3
1.0 % Pigment + 0.5 % TiO_2	4–5	–
PV FAST ORANGE H2GL		
0.2 % Pigment	3	–
0.5 % Pigment	3–4	–
1.0 % Pigment + 0.5 % TiO_2	–	–
PV FAST ORANGE GRL		
0.2 % Pigment	4	–
0.5 % Pigment	4	3–4
1.0 % Pigment + 0.5 % TiO_2	4	–
PV FAST ORANGE 6RL		
0.2 % Pigment	4	–
0.5 % Pigment	4	–
1.0 % Pigment + 0.5 % TiO_2	4	–

WEATHER FASTNESS DATA IN PVC BARIUM / ZINC STAB. – ARTIFICIAL LIGHT EXPOSURE

	GREY SCALE (HOURS)	
	2500	5000
PV FAST RED B		
0.2 % Pigment	4	–
0.5 % Pigment	4–5	3
1.0 % Pigment + 0.5 % TiO_2	4–5	–
PV FAST RED D3G		
0.2 % Pigment	5	4
0.5 % Pigment	5	5
1.0 % Pigment + 0.5 % TiO_2	5	5
PV FAST RED BNP		
0.2 % Pigment	4	–
0.5 % Pigment	4	3–4
1.0 % Pigment + 0.5 % TiO_2	4–5	–
PV FAST RED HF4B		
0.2 % Pigment	3–4	–
0.5 % Pigment	4	–
1.0 % Pigment + 0.5 % TiO_2	3–4	–
PV FAST RED E3B		
0.2 % Pigment	5	4
0.5 % Pigment	5	4
1.0 % Pigment + 0.5 % TiO_2	5	4–5
PV FAST RED E5B		
0.2 % Pigment	5	3–4
0.5 % Pigment	5	3–4
1.0 % Pigment + 0.5 % TiO_2	4–5	3–4
PV FAST PINK E		
0.2 % Pigment	4	3
0.5 % Pigment	4–5	4
1.0 % Pigment + 0.5 % TiO_2	5	4–5
PV FAST PINK E 01		
0.2 % Pigment	4	3
0.5 % Pigment	4–5	4
1.0 % Pigment + 0.5 % TiO_2	5	4
PV FAST PINK E2B		
0.2 % Pigment	4	3
0.5 % Pigment	4–5	4
1.0 % Pigment + 0.5 % TiO_2	5	4–5

	GREY SCALE (HOURS)	
	2500	5000
PV FAST VIOLET BLP		
0.2 % Pigment	5	4
0.5 % Pigment	5	4
1.0 % Pigment + 0.5 % TiO_2	5	4–5
PV FAST VIOLET RL		
0.2 % Pigment	5	4
0.5 % Pigment	5	4
1.0 % Pigment + 0.5 % TiO_2	5	4–5
GRAPHTOL BLUE AN 01		
0.2 % Pigment	4–5	4–5
0.5 % Pigment	5	4–5
1.0 % Pigment + 0.5 % TiO_2	5	5
PV FAST BLUE A4R		
0.2 % Pigment	4–5	4–5
0.5 % Pigment	5	4–5
1.0 % Pigment + 0.5 % TiO_2	5	5
PV FAST BLUE A2R		
0.2 % Pigment	4–5	4–5
0.5 % Pigment	5	4–5
1.0 % Pigment + 0.5 % TiO_2	4	5
PV FAST BLUE BG		
0.2 % Pigment	5	4–5
0.5 % Pigment	5	5
1.0 % Pigment + 0.5 % TiO_2	5	5
PV FAST GREEN GNX		
0.2 % Pigment	4–5	4
0.5 % Pigment	5	4–5
1.0 % Pigment + 0.5 % TiO_2	5	5
PV FAST BROWN HFR		
0.2 % Pigment	5	4–5
0.5 % Pigment	5	4–5
1.0 % Pigment + 0.5 % TiO_2	5	5
PV FAST BROWN RL		
0.2 % Pigment	5	4–5
0.5 % Pigment	5	4–5
1.0 % Pigment + 0.5 % TiO_2	5	5

Weather fastness to ISO Grey scale:
5 excellent
1 poor

2.1
PVC AND PLASTISOLS

CABLE SHEATING FORMULATIONS – COLORING OF PVC CABLE SHEATHING (RAL SHADES IN ACCORDANCE WITH DIN 47002)

RAL SHADE	PIGMENTS	%
1021 RAPE YELLOW	Graphtol Yellow GR*	1.500
	TiO_2	1.000
2001 RED ORANGE	Graphtol Yellow GR*	0.800
	Graphtol Carmine HF3C	0.170
	Carbon Black	0.002
	TiO_2	1.000
2003 PASTEL ORANGE	Graphtol Yellow GR*	0.400
	Graphtol Red BB*	0.050
	TiO_2	1.500
3000 FLAME RED	Graphtol Yellow GR*	0.760
	Graphtol Red BB*	0.400
	Carbon Black	0.003
	TiO_2	1.000
3017 ROSE	Graphtol Carmine HF3C	0.110
	Graphtol Yellow GR*	0.030
	TiO_2	1.000
3020 TRAFFIC RED	Graphtol Red BB*	0.500
	Graphtol Yellow GR*	0.160
	TiO_2	1.000
4001 RED LILAC	Graphtol Carmine HF3C	0.032
	PV Fast Blue A4R	0.007
	Carbon Black	0.004
	TiO_2	0.500
4002 RED VIOLET	Graphtol Red BB*	0.100
	PV Fast Blue A4R	0.006
	TiO_2	0.500
4008 SIGNAL VIOLET	Graphtol Carmine HF3C	0.080
	PV Fast Blue A4R	0.012
	TiO_2	0.500
5015 SKY BLUE	PV Fast Blue A4R	0.060
	Carbon Black	0.003
	TiO_2	0.500
6010 GRASS GREEN	Graphtol Yellow GR*	0.220
	PV Fast Green GNX	0.080
	Carbon Black	0.012
	TiO_2	0.400

RAL SHADE	PIGMENTS	%
6016 TURQUOISE GREEN	PV Fast Green GNX	0.240
	Graphtol Yellow GR*	0.020
	Carbon Black	0.007
	TiO_2	0.380
6018 YELLOW GREEN	Graphtol Yellow GR*	0.130
	PV Fast Green GNX	0.060
	Carbon Black	0.003
	TiO_2	0.660
6027 LIGHT GREEN	PV Fast Green GNX	0.020
	Carbon Black	0.003
	TiO_2	1.000
7000 SQUIRREL GREY	PV Fast Blue A4R	0.005
	Carbon Black	0.012
	TiO_2	0.660
7004 SIGNAL GREY	Carbon Black	0.010
	TiO_2	0.600
7015 SLATE GREY	Carbon Black	0.050
	TiO_2	0.500
7037 DUSTY GREY	PV Fast Yellow H2G	0.005
	Carbon Black	0.015
	TiO_2	0.600
8004 COPPER BROWN	PV Fast Brown RL	0.200
	PV Fast Yellow H3R	0.050
	Carbon Black	0.003
	TiO_2	0.500
8015 CHESTNUT BROWN	PV Fast Brown RL	0.400
	Carbon Black	0.020
	TiO_2	0.500
8016 MAHOGANY BROWN	PV Fast Brown RL	0.400
	Carbon Black	0.035
	TiO_2	0.500
9005 JET BLACK	Carbon Black	0.250

* = Diarylide

BRITISH STANDARDS SHADES (BS 6746) FOR PVC CABLE SHEATHING

SHADE	PIGMENTS	%	ALTERNATIVE PIGMENTS	%
WHITE	TiO_2	0.500		
CREAM	PV Fast Yellow H4G TiO_2	0.010 1.000		
YELLOW	Graphtol Yellow GR* PV Fast Yellow HR 02*	0.050 0.150	PV Fast Yellow HGR	0.300
ORANGE	Graphtol Orange RL*	0.110		
RED	Graphtol Yellow GR* Graphtol Carmine HF3C	0.200 0.200		
PINK	Graphtol Carmine HF3C PV Fast Yellow HR 02* Carbon Black	0.010 0.005 0.001		
BLUE	PV Fast Blue A2R	0.050		
TURQUOISE	PV Fast Green GNX TiO_2	0.010 0.300		
GREEN	Graphtol Yellow GG* PV Fast Green GNX	0.150 0.040	Novoperm Yellow F2G PV Fast Green GNX Carbon Black	0.150 0.035 0.005
BROWN	Graphtol Orange RL* Carbon Black	0.100 0.022		
GREY	Carbon Black PV Fast Blue A2R TiO_2	0.015 0.003 0.100		
BLACK	Carbon Black	0.300		

* = Diarylide

2.2
THERMOPLASTIC ELASTOMERS (TPE) AND RUBBER

Thermoplastic Elastomers (TPE) are plastic materials which are in structure and processing between plastics and rubber. On the one hand at room temperature they have elastomeric properties and on the other hand they can be processed and recycled like conventional thermoplastics.

Due to their different compositions, TPE's are devided in polymer blends and block copolymers. Polymer blends are compounds consisting of at room temperature hard and soft polymers.

Block copolymers have these two components in one molecule. Due to the different desired properties a huge amount of TPE types are on the market ranging from Shore A 10 to Shore D 75.

TPE's have captured a significant, continuously growing share of the plastics market. They combine the mechanical properties of vulcanized elastomers with the processability an recyclability of thermoplastics. At the same time, they are distinguished by an agreeable »soft touch«. The diverse areas of application currently range from sports shoe, ski boots, film and rollers to hoses, automotive interiors, etc.

GROUP	**BLENDS**	**BLOCK COPOLYMERS**
STRUCTURE	2-phase system, mixture of crosslinked or non-crosslinked elastomers in mainly PP	Segmented blocks of different flexibility and hardness
KEY TYPES	**TPE-O** Thermoplastic polyolefins with a non-crosslinked elastomer phase **TPE-V** Thermoplastic vulcanized rubber = polyolefin with a crosslinked elastomer phase	**TPE-S** Styrene Block copolymer **TPE-U** Thermoplastic polyurethane elastomer **TPE-E** Thermoplastic polyester elastomer **TPE-A** Thermoplastic polyamide elastomer

STYRENE BLOCK COPOLYMERS (TPE-S / SBC'S)
are thermoplastic elastomers possessing the mechanical properties of rubber and the processing characteristics of thermoplastic polymers. SBC's consist of a minimum of three blocks, two hard polystyrene end blocks and a soft, elastomeric (polybutadiene, polyisoprene) mid-block. These block copolymers find applications in such diverse fields as: thermo-forming, pressure sensitive adhesives, impact modifiers and in mixtures/compounds with other polymers and fillers. Often referred to as »soft-touch« polymers SBC's are used in children's toys, automotive parts, personal hygiene and packaging applications. They can be injection molded, profile and film extruded and are suitable for food contact applications.

Coloration of SBC's is mainly from granular masterbatch or polymer compounds. Coloring recommendations are given in the following tables. Fastness to bleeding from organic pigments is not an issue however, the use of polymer soluble dyes must be treated with extreme caution. Even though SBC's are broadly amorphous polymers, the elastomeric component can lead to a certain degree of contact migration. It is necessary to test for it in the final article before mass production.

Recommended is the PV Fast range of pigments and to a limited extend a number of the Graphtol pigments.

THERMOPLASTIC POLYURETHANE (TPE-U / TPU)
is a melt processable elastomer. TPU can be processed by all the methods normally employed for thermoplastic materials e. g. injection, blow and compression molding, extrusion and solution »spread« coating.

TPU is a linear segmented block copolymer composed of hard and soft segments. The hard segments can be either aromatic or aliphatic (based on isocyanates) which combined with short chain diols to form a hard block. The aromatic types have considerably better light fastness but are more expensive. The soft segments can be of either polyether or polyester depending on the application. TPU offers a broad range of physical properties and high elasticity, it bridges the gap between rubber and plastics without the use of plasticizers. TPU is often compounded with glass or mineral fillers. It is also used extensively in polymer blends to enhance or modify properties. Applications for TPU's are numerous and include wheels, drive belts, inflatables, flexible tubing, inline skates, sporting goods, wire & cable and coated fabrics (laminating films) such as synthetic »artificial« leather. Many »Soft touch« effects are produced from thermoplastic polyurethane. For the solution spread coating of fabrics, two distinctive systems can be employed, the first a »one-component polyurethane« is thermoplastic and is discussed in this chapter, the second; »two-component polyurethane« is thermosetting and is discussed in chapter 2.8.

Coloration of TPU is mainly from granular masterbatch, polymer compounds or liquid solutions (pastes). Pastes, used for solution spread coating of fabrics contain 20–50 % pigment and are either based on DMF or THF for aromatic type »one-component polyurethanes« or isopropanol/toluene mixtures for aliphatic types. The coated layer, especially in the coloration of artificial leather is very thin (usually 50–80 µm), very high pigmentation levels are required and care must be taken to ensure that organic pigments have a high fastness to bleeding. Selected organic pigments must be insoluble in the solvent or solvent mixture. In aromatic types a high resistance to DMF is required. In pure dimethyl formamide, quinacridone pigments (P. R. 122 and P. V. 19) must be treated with care to avoid re-crystallization even after prolonged periods of time. In other solvent mixtures this is not an issue. In addition to the Graphtol and PV Fast pigments, a number of Hansa, Hostaperm, Novoperm and Permanent pigments are also suitable for the production of pastes.

2.2 THERMOPLASTIC ELASTOMERS (TPE) AND RUBBER

THERMOPLASTIC OLEFINS TPE-O / TPE-V (TPO'S)

Olefinic based elastomers (TPO's) are polypropylenes or blends of ethylene-propylene rubber which are combined with a co-monomer (elastomeric polymer) in a gas phase dual reactor. The combination adds flexibility to the polymer without the addition of a plasticizer. Flexibility is achieved through an internal plastification obtained internally during the production process. In this process, the co-monomers (elastomers) create an enlarged free volume that decreases the crystallinity of the ethylene- propylene rubber blends or polypropylene polymer. The advantages of TPO's are low temperature impact resistances, high tensile strength and no loss of plasticizing agent after processing.

TPO's can be processed by injection and blow molding, sheet and profile extrusion or as films. The main applications are for automotive exterior and interior parts, films and other packaging materials and for roofing and other water resistant membranes.

Blends such TPE-O and TPE-V, or block copolymers such as TPE-S, TPE-U, TPE-E and TPE-A can be colored without problem using high-performance pigments from the PV Fast and Graphtol ranges.

Coloring recommendations for TPE-E, TPE-S and TPE-U are given in the following tables according to different lab tests, done in injection molding.

For the coloration of TPE-O and TPE-V all pigments from Graphtol and PV Fast range should be suitable with the exception of all Diarylide pigments.

Due to different types within one TPE family and different shades of uncolored TPE pre-tests with pigments are always recommended.

PIGMENTS FOR TPE-E, TPE-S AND TPE-U

PRODUCT NAME	TPE-E	TPE-S	TPE-U
PV FAST			
YELLOW H9G	●	■	■
YELLOW H4G	■	■	■
YELLOW H2G	–	■	●
YELLOW HG 01	■	■	■
YELLOW HG	■	■	■
YELLOW H2GR	■	■	■
YELLOW HGR	■	■	■
YELLOW H3R	■	■	■
ORANGE H4GL 01	■	■	■
ORANGE H2GL	■	■	■
ORANGE GRL	●	■	■
ORANGE 6RL	■	■	■
SCARLET 4RF	■	■	■
RED B	●	■	■
RED D3G	■	■	■
RED HB	●	●	●
RED BNP	■	■	■
RED HF4B	■	■	■
RED E3B	■	■	■
RED E5B	■	■	■
PINK E	■	■	■
PINK E 01	■	■	■
PINK E2B	■	■	■
VIOLET BLP	●	■	●
VIOLET RL	●	■	●
BLUE A4R	●	■	■
BLUE A2R	■	■	■
BLUE BG	■	■	■
GREEN GNX	■	■	■
BROWN HFR	●	■	■
BROWN RL	■	●	■

PIGMENTS FOR TPE-E, TPE-S AND TPE-U

PRODUCT NAME	TPE-E	TPE-S	TPE-U
GRAPHTOL			
YELLOW 3GP	●	●	■
YELLOW H2R	■	■	■
RED HFG	●	■	■
RED LG	■	■	●
RED LC	●	■	●
RED F3RK 70	–	●	–
FIRE RED 3RLP	■	■	■
RED HF2B	●	■	●
RED F5RK	–	●	–
RED P2B	■	■	■
CARMINE HF4C	●	■	■
CARMINE HF3C	■	■	■
RUBINE L4B	●	■	■
BORDEAUX HF3R	●	■	■
BLACK CLN	■	■	■

2.2 THERMOPLASTIC ELASTOMERS (TPE) AND RUBBER

ETHYLENE VINYL ACETATE (EVA)
EVA is a random copolymer of vinyl acetate (VA) monomer and ethylene. The VA content can vary from 5%–40% by weight. Higher monomer contents improve the flexibility and impact strength of the polymer; lower monomer levels reduce the crystallinity and softening point. The MFI and wetting out capability improve as the molecular weight decreases.

EVA is a flexible, transparent polymer with good low temperature stability and chemical resistance. In thermoplastic applications EVA can be extruded, co-extruded, blow molded, injection molded and used as a polymer modifier for other grades of plastic. Applications for EVA include packaging film, heavy duty bags, wire and cable sheathing, flexible tube and pipes and shoe soles.

The processing temperatures vary greatly according to grade and process, the softening point of the polymer is around 75 °C and above 250 °C EVA starts to degrade.

The recommended Graphtol and PV Fast pigments for coloring EVA are included in the tables found on page 36. The Hostasin pigment preparations are also suitable, further information to this range of pigment preparations is to be found on the following page.

Soluble dyes are not recommended for the coloration of EVA due to the potential for migration from the ethylene component of the polymer.

RUBBER (NATURAL AND SYNTHETIC)
Natural rubber is a high molecular weight polymer of isoprene. It is obtained from latex milk which is the sap of the Hevea (rubber) tree. The rubber tree grows throughout the tropics and is cultivated in plantations, primarily in Southeast Asia. The latex milk is coagulated and washed, then on exposure to air and mild heat gives natural rubber. To obtain a processable polymer the natural rubber undergoes a mastication process; a mechanical procedure under severe conditions to produce a soft gummy mass. Thereafter the material is vulcanized; a process usually in the presence of sulfur that introduces a network of cross-linking which transforms the »soft gummy mass« in to a strong, elastomeric, processable rubber.

Conventional synthetic rubbers are similar to natural rubber in that they are cross-linked thermoset polymers. World-wide today approximately 65 % of all rubber processed is synthetic. The most significant forms of synthetic rubber used are:

Synthetic Polyisoprene	IR	Tires (added to natural rubber)
Polyisobutadiene (Butyl) rubber	IBR	Inner tubes for tires
Styrene Butadiene rubber	SBR	Shoe soles, belts, flooring
Polychloroprene rubber	CR	Neoprene wetsuits
Nitrile rubber	NBR	Petrol hoses, Fuel tanks
Ethylene Propylene rubber	EPM/ EPDM	Pond liners, Roofing

A more recent development is the manufacture of synthetic thermoplastic rubber referred to as Melt Processable Rubber (MPR) and ThermoPlastic Vulcanate (TPV). These materials combine the processability of a thermoplastic polymer with the functional performance of rubber and are cheaper, recyclable and easier to color.

The pre-processing of thermoset rubber is usually via calendar-roll mills or internal mixers, during this phase colorants and fillers are added. In the forming phase these rubbers can be sheet or profile extruded and injection molded, conventional processing temperatures are from 60 °C to 150 °C. With MPR and TPV processing temperatures can rise up to 220 °C, they can be processed using conventional extrusion technology or in internal mixers before being formed.

For all types of rubber the requirements on colorants are generally not high, for cross-linked grades; bleed-fastness, resistance to prolonged temperature exposure and for natural rubber compatibility in the vulcanization process are the important factors.

For the coloration of natural rubber, organic pigments in powder form have largely been replaced by pigment preparations which permit shorter mixing times and optimum pigment dispersion. In the coloration of thermoplastic rubber powder pigments are either compounded in or added in the form of pre-dispersed color concentrates (masterbatches).

The selection of organic pigments is based on bleedfastness and heat stability according to the grade used. Many applications for thermoset and thermoplastic rubber are to be found in hostile chemical environments and in outdoor use. In these instances, the appropriate selection of organic pigment is more critical.

Recommended for the coloration of thermoset and thermoplastic rubbers are the PV Fast and Graphtol powder pigments. The Hostasin range of pigment preparations which allows for excellent reproducibility through optimum pigment dispersion in a non-dusting form are compatible with natural rubber and most common synthetic grades.

2.2
THERMOPLASTIC ELASTOMERS (TPE) AND RUBBER

PIGMENTS FOR EVA AND RUBBER – COLORING OF THERMOPLASTIC ELASTOMER AND RUBBER

PRODUCT NAME	EVA	RUBBER/TPV
PV FAST		
YELLOW H9G	■	■
YELLOW H4G	■	■
YELLOW H2G	■	■
YELLOW HG 01	■	■
YELLOW HG	■	■
YELLOW H2GR	■	■
YELLOW HGR	■	■
YELLOW HR 02*	■	■
YELLOW HR*	■	■
YELLOW H3R	■	■
ORANGE H4GL 01	■	■
ORANGE H2GL	■	■
ORANGE GRL	■	■
ORANGE 6RL	■	■
SCARLET 4RF	■	■
RED B	■	■
RED D3G	■	■
RED HB	■	■
RED BNP	■	■
RED HF4B	■	■
RED E3B	■	■
RED E5B	■	■
PINK E	■	■
PINK E 01	■	■
PINK E2B	■	■
VIOLET BLP	■	■
VIOLET RL	■	■
BLUE A4R	■	■
BLUE A2R	■	■
BLUE BG	■	■
GREEN GNX	■	■
BROWN HFR	■	■
BROWN RL	■	■

PRODUCT NAME	EVA	RUBBER/TPV
GRAPHTOL		
YELLOW GG*	■	■
YELLOW 3GP	■	■
YELLOW GR*	■	■
YELLOW H2R	■	●
ORANGE GPS*	■	■
ORANGE RL*	■	■
RED HFG	■	■
RED LG	■	■
RED LC	■	■
RED BB*	■	■
FIRE RED 3RLP	■	■
RED HF2B	■	■
RED P2B	■	■
CARMINE HF4C	■	■
CARMINE HF3C	■	■
RUBINE L4B	■	■
BORDEAUX HF3R	■	●
BLUE AN 01	●	■
BLACK CLN	■	■

** = Diarylide*

HOSTASIN PIGMENT PREPARATIONS

The Hostasin pigment preparations are based on an oxidation resistant polyolefin copolymer that is compatible with natural rubber and most common synthetic rubbers. Since the pigments in the Hostasin preparations are already in a very finely dispersed form, relatively little mechanical effort and only a brief mixing time is required to obtain the full tinctorial strength of the pigment.

A further advantage of the Hostasin preparations is their ease of handling, being in a granular form they are free-flowing, easy to meter and they do not smear or dust, thus they provide for clean, loss free processing. The pigment content of the Hostasin preparations is approximately 50 % and is controlled to provide for a consistent and reproducible color yield.

COLORING OF NATURAL AND SYNTHETIC RUBBER

PRODUCT NAME	SBC	TPU	EVA	TPO	RUBBER/TPV	LIGHT FASTNESS	MIGRATION RESISTANCE
						REDUCTION	REDUCTION
HOSTASIN							
YELLOW GR 30*	–	–	■	–	■	6–7	5
YELLOW HR 30*	–	–	■	–	■	7–8	5
ORANGE G 30*	–	–	■	–	■	4–5	5
RED B 30*	–	–	■	–	■	4	5
RED HF2B 30	–	–	■	–	■	6–7	5
BLUE A2R 30	–	–	■	–	■	8	5
GREEN GG 30	–	–	■	–	■	8	5

** = Diarylide*

2.3
POLYOLEFINS

**Polyolefins can be sub-divided in to 3 main groups:
Low density polyethylene (LDPE),
high density polyethylene (HDPE)
and polypropylene (PP).**

They are classified according to: density, melt-flow behaviour, chain branching and in particular, the melt processing temperatures:

LDPE	160–220 °C
HDPE	180–300 °C
PP	200–300 °C

Within each group there are many grades which can differ considerably with regard to their properties. The selection of grade is dependant upon the processing technique involved, polyolefins can be film-blown, bottle-blown, injection molded and extruded.

Three further groups of polyolefins exist: Linear low density polyethylene (LLDPE), medium density polyethylene (MDPE) and very low-density polyethylene (VLDPE). LLDPE has applications in films and as a carrier resin for masterbatches. The later two MDPE and VLDPE are not of commercial consideration in terms of coloration.

The coloration of polyolefins must be considered in terms of the group selected; LDPE is relatively soft and has a melt flow index range from medium to very high. The higher the melt-flow and the lower the density of LDPE, the greater is the potential for pigment blooming to occur. The bleed-fastness figures quoted for P-PVC are a useful guide to suitability. In HDPE and PP, the thermal stability of organic pigments is the main criteria for selection. In injection molding applications it must be noted that many organic pigments have been shown to influence the crystalline behaviour of polyolefins (in particular HDPE) by inducing a nucleating effect. This in turn leads to dimensional instability of the molded part often referred to as warpage, distortion or dimensional misbehavior.

Soluble dyes are not recommended for the coloration of standard grade polyolefins due to their tendency to bloom or migrate out of the polymer matrix.

POLYETHYLENE (PE)
Polyethylenes are thermoplastic polymers consisting mainly of ethylene monomer, which are divided according to their density, melting point and molecular structure (branching).

HIGH DENSITY POLYETHYLENE (HDPE)
A highly crystalline polymer coming from a low pressure process based on Ti- or Cr-based catalysts, HDPE has a linear polymeric chain combined with a high density and melting point. New applications are opening for HDPE as well as other low pressure PE's by applying metallocene (single-site) catalysts, which allow the production of very narrow molar mass distributions and a more even arrangement of co-monomers. HDPE grades vary in their warpage behavior according to their method of manufacture, the selection of catalyst and their molar mass distribution. The narrower the molecular weight distribution of a grade, the lower its propensity to warp, in addition, due to the absence of the high and lower molar masses, the influence of organic pigments on the crystalline behavior is in many instances reduced.
Applications for HDPE include: large containers, fuel tanks, bottles and crates, wrapping film and pipes.

LINEAR LOW DENSITY POLYETHYLENE (LLDPE)
Based on the same technology as HDPE, but the density is reduced through the incorporation of longer α-olefins as co-monomers. Single-site catalysts allow an expansion of the application range, mainly by allowing higher co-monomer contents with a more even distribution.
Applications for LLDPE include: film and packaging.

LOW DENSITY POLYETHYLENE (LDPE)
A product from a high-pressure polymerization process, LDPE is characterized by its highly branched chain-structure. As a result of this, density and crystallinity are reduced while the processability in a variety of conversion technologies is greatly improved.
Applications for LDPE include: packaging, bottles, cold water tanks, films.

POLYPROPYLENE (PP)

is a semi-crystalline, linear hydrocarbon polyolefin and one of the most versatile polymers available, it is semi-rigid, translucent and tough, exhibiting good heat and chemical resistance. Compared to polyethylene, PP has a much higher softening point (163 °C), higher rigidity and hardness.

Applications for PP include: automotive, appliances, patio furniture, bottles, fibers and yarns, filament rope, tapes and webbing, films.

THREE DIFFERING GRADES OF PP ARE COMMERCIALLY AVAILABLE:

HOMO-POLYMERS

General purpose PP suitable for a wide range of applications.

BLOCK COPOLYMERS

Containing 5–15 % ethylene to improve resistance to low temperatures.

RANDOM COPOLYMERS

Incorporating randomly arranged co-monomer units a long the PP long chain molecule and often low levels of ethylene. These grades exhibit greater flexibility and improved clarity.

Polyethylene and Polypropylene (polyolefins) can be processed by all common thermoplastic forming processes; injection and blow molding, sheet, profile and film extrusion, rotational molding and melt-spun synthetic fibers.

The methods of polyolefin coloration are diverse: granular masterbatch, compounding, dry powder blends or liquid concentrates. Heat stability, dispersion quality for the final application and coloration costs are the main selection criteria together with application dependant properties such as weather fastness, light stability and warpage. Soluble dyes are not suitable for the coloration of these polymers due to the potential for contact migration.

For rotational molding applications in polyethylene, the processing temperatures are low; usually in the range 130 °C to 150 °C. However, the molding powder / pigment / additive blend can be exposed to these temperatures for extended periods dependant on the overall size of the molding, its complexity and wall thickness.

The recommended Graphtol and PV Fast pigments for the coloration of polyolefins are to be found in the following tables. Information regarding standard depth $^1/_3$ values, hue angle, heat resistance and light fastness values provided were assessed in HDPE. Suitability for use in low warpage applications is also provided; the results were assessed in Hostalen GC 7260 HDPE at 220 °C and 280 °C according to an internal test method for pigments with the required heat resistance at these temperatures. The results will vary according to the grade of HDPE and the processing parameters used.

A pretest of the complete formulation under the prevailing processing conditions is required.

2.3
POLYOLEFINS

COLORING RECOMMENDATIONS AND APPLICATIONS DATA – PIGMENTS FOR POLYOLEFINS (PO)

PRODUCT NAME							LIGHT FASTNESS		WARPAGE+	
	LDPE / LLDPE	HDPE	PP	SD $^1/_3$	Hue angle	Heat resistance	Reduction	Full shade	Suitability	
PV FAST				g/kg	°	%			220 °C	280 °C
YELLOW H9G	■	■	■	2.40	97.2	280	6	7	●	■
YELLOW H4G	■	■	■	3.80	91.6	290	8	8	●	■
YELLOW H2G	■	■	■	2.90	89.0	260	8	8	■	–
YELLOW HG 01	■	■	■	1.10	90.0	290	6–7	7–8	■	■
YELLOW HG	■	■	■	1.60	88.3	290	6–7	7–8	■	■
YELLOW H2GR	■	■	■	2.30	83.1	300	6	6–7	■	■
YELLOW HGR	■	■	■	3.50	79.6	300	7	8	■	■
YELLOW HR 02*	■	–	–	0.80	78.7	200	6–7	6	–	–
YELLOW HR*	■	–	–	0.90	78.9	200	6–7	6	–	–
YELLOW H3R	■	■	■	4.20	66.5	300	8	8	■	■
ORANGE H4GL 01	■	■	■	2.00	56.7	290	7–8	8	■	■
ORANGE H2GL	■	■	■	2.20	44.9	300	8	8	●	■
ORANGE GRL	■	■	■	2.10	39.9	280	8	8	–	–
ORANGE 6RL	■	■	■	2.20	33.9	300	7–8	8	■	■
SCARLET 4RF	■	■	■	2.30	27.2	300	7	7–8	–	–
RED B	■	■	■	1.30	23.9	280	7–8	8	–	–
RED D3G	■	■	■	1.50	17.4	300	8	8	–	–
RED HB	■	■	■	2.40	11.6	300	6–7	7	■	■
RED BNP	■	■	■	1.50	11.6	300	7–8	8	–	–
RED HF4B	■	■	■	1.90	3.1	260	7	7–8	■	–
RED E3B	■	■	■	3.00	357.5	300	8	8	●	■
RED E5B	■	■	■	2.40	354.8	300	8	8	●	■
PINK E	■	■	■	2.10	338.8	300	8	8	■	■
PINK E 01	■	■	■	2.10	338.1	300	8	8	■	■
PINK E2B	■	■	■	2.10	393.3	300	8	8	■	■
VIOLET BLP	■	■	■	0.60	301.1	280	7–8	8	–	–
VIOLET RL	■	■	■	0.60	300.7	280	7–8	8	–	–
BLUE A4R	■	■	■	0.80	248.0	300	8	8	–	–
BLUE A2R	■	■	■	0.80	248.2	300	8	8	–	–
BLUE BG	■	■	■	1.10	242.7	300	8	8	–	–
GREEN GNX	■	■	■	2.00	177.0	300	8	8	–	–
BROWN HFR	■	■	■	1.80	25.7	290	8	8	–	–
BROWN RL	■	■	■	1.90	38.5	300	8	8	–	–

** = Diarylide*
Warpage+ = Suitability for low warpage applications

COLORING RECOMMENDATIONS AND APPLICATIONS DATA – PIGMENTS FOR POLYOLEFINS (PO)

PRODUCT NAME							LIGHT FASTNESS		WARPAGE+	
	LDPE / LLDPE	HDPE	PP	SD $^{1}/_{3}$	Hue angle	Heat resistance	Reduction	Full shade	Suitability	
GRAPHTOL				g/kg	°	%			220 °C	280 °C
YELLOW GG*	■	–	–	1.10	94.7	200	5–6	6–7	–	–
YELLOW 3GP	■	■	■	1.60	90.8	260	7–8	7–8	–	–
YELLOW GR*	■	–	–	0.90	85.9	200	5	6–7	–	–
YELLOW H2R	■	■	■	1.10	75.8	240	7–8	8	●	–
ORANGE GPS*	■	–	–	1.70	50.6	200	4	5	–	–
ORANGE RL*	■	–	–	1.70	42.1	200	5	6–7	–	–
RED HFG	■	■	■	2.30	31.0	280	6	7	●	●
RED LG	■	■	■	1.60	22.1	270	2	4	●	–
RED LC	■	■	■	1.70	21.3	250	2	4	–	–
RED BB*	■	–	–	1.00	19.6	200	4	6	–	–
RED F3RK 70	■	■	■	2.20	13.1	270	7	8	●	–
FIRE RED 3RLP	■	■	■	2.00	10.5	240	6	7	■	–
RED HF2B	■	■	■	1.30	13.3	250	6–7	7	–	–
RED F5RK	■	■	■	1.70	8.4	250	7	7–8	●	–
RED P2B	■	■	■	1.20	359.9	240	5	6–7	■	–
CARMINE HF4C	■	■	■	1.30	359.8	250	6–7	6–7	■	–
CARMINE HF3C	■	■	■	1.40	358.7	270	7	7	■	–
RUBINE L4B	■	■	■	1.00	353.7	260	4	6	–	–
BORDEAUX HF3R	■	■	■	1.00	342.1	250	6	7	–	–

** = Diarylide*
Warpage+ = Suitability for low warpage applications

2.3
POLYOLEFINS

INFLUENCE OF WEATHERING

Weathering: defined as the adverse response of a material or product to climate, is a critical dynamic in the formulation of plastics for outdoor applications. The factors that can influence weathering can be categorized according to geographical location: Solar radiation (light energy), temperature and water (moisture) and to include local climatic variations; sudden temperature change, humidity, airborne pollutants, acid rain, etc.

In discussing the selection of colorants for use in plastics that will spend some or all of their life cycle outdoors it is of paramount importance that the selected polymer is formulated to withstand its application environment and anticipated life cycle. For polyolefins such as HDPE and PP additional stabilization against thermal oxidation and the damaging effects of UV radiation is usually required. The selection of polymer stabilizers; primary and secondary antioxidants, UV absorbers and hindered amine light stabilizers (HALS) is too specialised for discussion in this brochure. However, Heubach does offer an extensive range of polymer additives for stabilizing and polymer enhancing applications in a wide range of plastics. For details of these products, technical information and sampling, contact your local Heubach sales organization or regional Technical Application Centre.

It is however, a point to note that certain polymer additives used in the stabilization of Polyolefins have been found to influence the performance of organic pigments;

- Certain groups of primary antioxidants can induce polymer yellowing during exposure influencing the overall color of an article
- Phosphonite process stabilizers (secondary antioxidants) improve the melt characteristics and thermal stability of HDPE. Several organic pigments benefit from this interaction to demonstrate higher thermal stabilities.
- HALS chemistries containing triazine can cause a strong yellowing of the polymer during heat aging. A shift in the shade of the stabilized polymer will alter the overall optical properties of the end article.

The resistance of colorants to the primary influences of weathering in plastics application can best be assessed by conducting extensive outdoor trials under the conditions of use.

A commonly used alternative which provides guideline data under a specific »limited« set of conditions is to expose a sample from the end article to accelerated artificial weathering. Accelerated weathering is a useful tool to rapidly assess the material performance under service life conditions.

The evaluation of the effects of weathering on a colored article is carried out by assessing color change. Although no absolute pass and fail system exists, evaluation is often carried out against the ISO 105-A02 1993 Grey scale for assessing color change. The scale is numbered 1–5 whereby a staining level of 5 indicates no visible color change and a staining level of 1 is a major shift in shade whereby the original unexposed color is no longer recognizable. The scale is graduated in half steps and the plastic industry generally recognizes that when step 3 has been reached, the color change is no longer acceptable. Step 3–4 is considered the limit for a pass.

The color change can also be measured using CIE L.a.b. colorimetry. The Delta E value as a measure of total color difference is in the assessment of weathering not particularly useful, however the individual deltas are a useful method of producing comparative data and defining limits.

The assessment of fastness to weathering of the PV Fast and Graphtol pigments has been conducted in HDPE employing two differing polymer stabilization systems. Injection molded plates were exposed to accelerated artificial weathering using a cycle of 102 minutes dry and 18 minutes wet. The black panel temperature was set at 60 °C and the relative humidity at 60 %.

The polymer stabilization system employed was;

0.05 % Hostanox®[1] 010
0.10 % Hostavin®[1] ARO 8
0.15 % Hostavin N 321

The following results were obtained using pigment concentrations of 0.2 % »Full shade« and 0.2 % plus 0.5 % titanium dioxide in »Reduction«. The assessment to the Grey scale was carried out at 500 hours intervals, the data recorded in the results table presents the step reached after 3.000 and 5.000 hours exposure.

WEATHER FASTNESS DATA IN HDPE – ASSESSMENT TO GREY SCALE AFTER 3000 AND 5000 HOURS EXPOSURE

PRODUCT NAME	AFTER 3000 HOURS		AFTER 5000 HOURS	
STABILISATION	Full shade	Reduction	Full shade	Reduction
PV FAST				
YELLOW H4G	3–4	–	3	–
YELLOW H2G	4–5	4	4	–
YELLOW H3R	4–5	4	3–4	–
ORANGE H4GL 01	4–5	–	3–4	–
ORANGE H2GL	4–5	–	–	–
ORANGE GRL	5	3–4	4–5	–
ORANGE 6RL	3–4	3–4	–	–
RED B	4	–	–	–
RED D3G	5	4	3–4	3
RED E3B	5	4–5	5	4
RED E5B	4–5	4	4	3
PINK E	5	4–5	5	4
PINK E 01	5	4–5	5	4
PINK E2B	5	4–5	5	4
VIOLET BLP	4–5	4	4	3–4
VIOLET RL	4–5	4	4	3–4
BLUE A4R	5	5	5	5
BLUE A2R	5	5	5	5
BLUE BG	5	5	5	5
GREEN GNX	5	5	5	5
BROWN HFR	5	4	5	3
BROWN RL	4–5	4–5	4–5	4–5

2.4 STYRENICS

Styrene, a by-product of petroleum is the key component in the manufacture of a variety of thermoplastic materials. Polystyrene being the most recognizable, others include acrylo-nitrile-butadiene styrene (ABS), styrene-acrylonitrile (SAN), unsaturated polyester resins (covered in a later chapter) and expanded polystyrene foam (EPS).

POLYSTYRENE (PS) is a crystal clear transparent thermoplastic processable from 190–280 °C, it is hard and brittle and often referred to as »General purpose polystyrene« (GPPS). Below its glass transition temperature, around 100 °C it is a glass like, transparent and amorphous polymer.

Polystyrene can be modified with butadiene rubber to improve its impact properties either by copolymerizing styrene monomer with butadiene monomer (referred to as butadiene / styrene) or by blending finely dispersed particles of butadiene rubber in to the polystyrene providing opacity and impact modification to the polymer. These materials are referred to as medium (MIPS) or high impact (HIPS) polystyrene dependant on the level of dispersed rubber.

A third modification of polystyrene is expanded polystyrene foam (EPS), a lightweight, rigid plastic foam produced from solid beads of polystyrene. Expansion is achieved via small amounts of pentane gas which have been dissolved in the polystyrene in the cooling phase after polymerization. The gas then expands by exposure to steam to form a series of non-interconnecting cells. These are then molded to form blocks, boards or customized products such as drinking cups or food containers. During the molding phase the remaining pentane gas and steam fuse to form a homogeneous product.

The coloration of polystyrene (PS, MIPS & HIPS) is mainly from masterbatch granules, color compounding or concentrated liquid pastes. As the polymer is abrasive, liquid dispersants or waxes are added to protect organic pigments to improve pigment wetting and to increase pigmentation levels.

To maintain a high degree of transparency in GPPS soluble dyes provide the best coloring solution. Due its almost completely amorphous state, blooming or recrystallization of soluble dyes from GPPS is not possible. Soluble dyes are also the preferred method of tinting opaque shades in GPPS for the reason that many organic pigments either possess a degree of solubility, which can lead to unstable colors, or due to their limit concentration lack thermal stability at the required processing temperature.

Although not a usual occurrence, when formulating with soluble dyes in impact modified grades of polystyrene, a potential for blooming due to the presence of the butadiene rubber does exist and should be checked for in the end application. In opaque and semi translucent shades the PV Fast pigments are recommended, selected Graphtol grades are also suitable. The main consideration is heat stability followed by light fastness requirements. Solvaperm and Hostasol dyes are recommended for transparent colors and for increasing the brightness and intensity of shade in opaque colorations. The fastness properties and thermal stability of the recommended colorants can be found in the following tables.

The listed Solvaperm and Hostasol dyes can be used in the coloration of EPS. Initially the soluble dyes are either dissolved in solvent mixtures (e. g.: ethanol / methylene Chloride) or tumble blended directly on to the beads with the aid of a neutral solvent. Coloration is achieved in the mold during the foaming process at 120 °C in the presence of steam.

Deep-drawn EPS film is produced at around 220 °C by extruding GPPS in the presence of blowing agents. Structural EPS foam is formed by injection molding impact modified or GPPS grades of polystyrene together with chemical blowing agents in the presence of a wetting medium. No special demands are placed on the thermal stability of colorants in these processes and the selected pigments and soluble dyes recommended for polystyrene are suitable. Coloration in both processes is greatly influenced by the foam structure which adds a strong whitening effect and high concentrations of colorants are required even to reach pale shades.

ACRYLONITRILE-BUTADIENE STYRENE (ABS) is a terpolymer traditionally manufactured by polymerizing styrene and acrylonitrile in the presence of poly-butadiene. Some manufacturers today have moved away from this copolymerization to a special grafting process whereby in the first stage butadiene is polymerized and then cyanide and phenyl groups are grafted on through a chemical reaction. This grafting process optimizes the polymers properties and eliminates the well recorded problems of smell and polymer yellowing.

ABS has an amorphous structure; its base color can vary from white (similar to impact modified polystyrene) to a dull beige. The presence of a high proportion of butadiene rubber in certain grades can present a potential for migration from solvent dyes. Many grades offered contain anti-statics or other active ingredients, these also have the potential to promote migration.

The coloration of ABS is mainly from masterbatch granules or color compounding and is strongly influenced by the polymers opacity. Only high-performance organic pigments are suitable; heat stability and light fastness are the major considerations and the thermal stability of a pigment can vary from grade to grade of ABS.

Pigment concentration is also critical in obtaining the required heat stability and light fastness. Many PV Fast pigments are suitable for ABS coloration but a pre-test to determine fastness properties is recommended.

To obtain bright shades and also for use as shading (tinting) components polymer soluble dyes are often used.

The recommended PV Fast organic pigments, together with the Solvaperm and Hostasol soluble dyes for coloring ABS can be found in the following table. Their fastness and thermal properties will vary from manufacturer to manufacturer and according to the grade used.

STYRENE-ACRYLONITRILE (SAN) is a copolymer of styrene and acrylonitrile with an amorphous structure. The acrylonitrile elements improve the temperature resistance, impact strength, stiffness and optical properties in comparison with polystyrene. SAN is often used in polymer blends with PVC and ABS to alter flow characteristics and in masterbatch production as a carrier for colorants and polymer additives.

SAN can be injection molded, extruded and blow molded. It is resistant to grease, food staining, stress cracking, crazing, boiling water and a wide range of chemicals. It is ideally suited for use in kitchen, bath-room and office environments. Common applications include kitchen articles and tableware, cosmetics and personal care packaging, bathroom fittings and toothbrushes.

The coloration of SAN including the selection of colorants together with their fastness properties are broadly similar to the recommendations provided for coloring polystyrene. Processing temperatures are 210–290 °C.

2.4
STYRENICS

COLORING RECOMMENDATIONS AND APPLICATION DATA – PIGMENTS FOR POLYSTYRENE (PS), STYRENE-ACRYLONITRILE (SAN) AND ACRYLONITRILE

PRODUCT NAME	SD 1/3		HUE ANGLE	
	PS / SAN	ABS	PS / SAN	ABS
PV FAST	g/kg	g/kg	°	°
YELLOW H9G	2.30	2.80	99.8	97.4
YELLOW H4G	4.20	4.70	91.2	91.2
YELLOW H2G	3.00	4.60	88.7	90.5
YELLOW HG 01	1.40	1.30	90.5	89.9
YELLOW HG	1.50	1.50	87.6	88.9
YELLOW H2GR	2.70	3.00	83.4	82.9
YELLOW HGR	3.10	3.20	78.5	80.1
YELLOW H3R	4.40	5.00	65.1	64.7
ORANGE H4GL 01	2.30	2.40	56.1	56.5
ORANGE H2GL	2.70	2.90	42.9	44.4
ORANGE GRL	1.80	2.20	43.6	38.8
ORANGE 6RL	2.40	2.60	34.6	34.9
SCARLET 4RF	2.40	2.50	27.6	27.9
RED B	1.50	1.70	19.2	19.3
RED D3G	1.70	2.00	17.4	17.8
RED HB	2.00	2.50	11.1	13.4
RED BNP	1.50	1.70	13.2	13.1
RED HF4B	1.80	1.80	5.7	4.6
RED E3B	2.30	3.40	348.3	359.7
RED E5B	2.10	3.10	355.0	357.0
PINK E	2.20	2.70	340.1	341.2
PINK E 01	2.00	2.00	336.1	337.0
PINK E2B	2.50	2.50	338.0	338.5
VIOLET BLP	0.70	–	301.5	–
VIOLET RL	0.60	–	299.8	–
BLUE A4R	1.20	1.10	248.1	249.0
BLUE A2R	0.80	0.80	248.0	246.5
BLUE BG	1.10	1.20	242.7	241.8
GREEN GNX	2.00	2.20	177.0	179.4
BROWN RL	1.90	–	38.6	–
GRAPHTOL				
YELLOW 3GP	1.80	–	92.2	–
RED LG	1.70	1.80	22.0	22.9
RED LC	1.70	1.90	25.6	22.0
FIRE RED 3RLP	2.30	–	10.6	–
RED P2B	1.30	–	358.1	–
CARMINE HF4C	1.20	–	1.9	–
CARMINE HF3C	1.30	–	358.3	–
RUBINE L4B	1.30	–	352.3	–

LIGHT FASTNESS REDUCTION		LIGHT FASTNESS FULL SHADE		HEAT RESISTANCE	
PS / SAN	ABS	PS / SAN	ABS	PS / SAN	ABS
				°C	°C
6	6	7	6–7	280	260
8	8	8	8	300	280
8	8	8	8	260	250
6	6	7–8	7–8	300	300
6–7	6–7	6–7	6–7	300	290
6–7	6–7	7	7	300	300
7	7	7	7	300	300
8	8	8	8	300	280
8	8	8	8	300	290
7	7	7–8	6–7	300	270
7–8	7–8	8	8	300	290
7	6–7	7	6–7	300	300
7	7	7–8	7	300	300
8	8	8	8	300	280
8	7–8	8	7–8	300	270
6	5–6	6–7	6	300	300
6–7	6	6–7	7	300	300
8	7–8	8	8	300	290
8	8	8	8	300	300
7–8	7–8	7–8	7–8	300	300
8	7–8	8	8	300	300
8	7–8	8	8	300	300
7	7–8	8	8	300	300
6–7	–	7–8	–	260	–
6–7	–	7–8	–	270	–
8	6–7	8	6–7	300	280
8	8	8	8	300	300
8	8	8	8	300	300
8	8	8	8	300	290
8	–	8	–	300	–

7–8	–	8	–	260	–
3–4	2–3	4	3	300	260
3–4	3–4	4	3	300	260
4–5	–	6	–	250	–
5	–	5–6	–	240	–
6–7	–	7	–	270	–
7	–	7	–	300	–
4	–	6–7	–	260	–

2.4
STYRENICS

COLORING RECOMMENDATIONS AND APPLICATION DATA – COLORANTS FOR POLYSTYRENE (PS), STYRENE-ACRYLONITRILE (SAN) AND ACRYLONITRILE

PRODUCT NAME	SD 1/3		HUE ANGLE	
	PS / SAN	ABS	PS / SAN	ABS
SOLVAPERM	g/kg	g/kg	°	°
YELLOW 3G	1.29	–	94.5	–
YELLOW 2G	0.52	0.61	95.5	93.5
ORANGE 3G	1.60	1.80	63.0	62.5
RED 2G	1.48	1.80	28.0	31.0
RED G	2.00	2.40	23.9	24.7
RED PFS	2.56	2.30	24.5	13.0
RED BB	0.55	0.58	353.5	350.0
RED VIOLET R	0.93	1.00	329.0	324.5
VIOLET RSB	0.85	0.97	289.0	287.5
BLUE 2B	0.95	1.10	268.5	267.0
GREEN GSB	0.98	1.20	218.0	213.5
GREEN G	1.60	1.70	183.5	181.0
BLACK PCR	2.00	2.40	–	–
POLYSYNTHREN				
RED GFP	2.30	2.70	24.0	25.0
VIOLET G	–	0.90	–	343.0
BLUE R	0.90	0.97	283.0	279.5
BLUE RLS	1.80	1.90	279.5	277.0
BROWN 3RL	1.90	2.30	35.5	43.0
BROWN R	1.20	1.30	16.0	16.0
BLACK H	1.51	1.05	257.9	256.1

COLORING RECOMMENDATIONS AND APPLICATION DATA – FLUORESCENT DYES FOR POLYSTYRENE (PS), STYRENE-ACRYLONITRILE (SAN) AND ACRYLONITRILE

PRODUCT NAME	SD 1/3		HUE ANGLE	
	PS / SAN	ABS	PS / SAN	ABS
HOSTASOL	g/kg	g/kg	°	°
YELLOW 3G	–	–	–	–
RED GG	–	–	–	–
RED 5B	–	–	–	–

1) = 0.2% dye + 1% TiO_2
2) = 0.05% dye

LIGHT FASTNESS REDUCTION		LIGHT FASTNESS FULL SHADE		HEAT RESISTANCE	
PS / SAN	ABS	PS / SAN	ABS	PS / SAN	ABS
				°C	°C
7–8	–	8	–	300	–
7–8	6–7	8	7–8	300	300
6	5–6	8	7–8	300	300
6	5	7	7	300	300
7	7	8	7	300	300
5–6	3–4	7	5	300	300
6	5–6	8	6–7	300	280
6	5	7–8	6	300	300
6	5	7–8	6	300	290
6	4	7–8	5	300	300
4–5	4	7	6	300	300
7–8	5	8	6	300	300
7–8	5	8	6	300	300
7	7	8	7	300	290
–	6–7	–	6–7	–	240
6–7	5	7	6	300	300
6–7	5–6	7–8	5–6	300	300
7	7–8	8	8	300	300
7	7	8	8	300	300
5	4	5–6	4	300	280

LIGHT FASTNESS REDUCTION		LIGHT FASTNESS FULL SHADE		HEAT RESISTANCE	
PS / SAN	ABS	PS / SAN	ABS	PS / SAN	ABS
				°C	°C
4–5 [1]	3 [1]	7 [2]	5–6 [2]	300	300
4 [1]	4 [1]	7 [2]	6–7 [2]	300	300
3 [1]	3–4 [1]	4 [2]	6 [2]	300	250

2.5
INTRODUCTION TO POLYMETHYL METHACRYLATE (PMMA)

Polymethyl methacrylate (PMMA) or »acrylic« as it is commonly known is manufactured by bulk, solution, suspension and emulsion polymerization of methyl methacrylate (MMA) monomer.

COLORING RECOMMENDATIONS AND APPLICATION DATA – PIGMENTS FOR POLYMETHYL METHACRYLATE (PMMA)

PRODUCT NAME	HEAT RESISTANCE [°C]		LIGHT FASTNESS	
	Reduction (0.1% + 1.0 TiO_2)	Full shade (0.1%)	Reduction (0.1% + 1.0 TiO_2)	Full shade (0.1%)
PV FAST				
YELLOW H9G	240	250	6	7
YELLOW H4G	260	250	7–8	7–8
YELLOW HG 01	280	280	4	6
YELLOW HG	280	280	3–4	5–6
YELLOW H2GR	280	280	4	5
YELLOW HGR	280	280	3–4	4–5
YELLOW H3R	280	280	7–8	8
ORANGE H4GL 01	280	280	6–7	7–8
ORANGE H2GL	280	280	7	7–8
ORANGE GRL	240	280	7	8
ORANGE 6RL	280	280	7–8	8
SCARLET 4RF	280	280	7	7–8
RED B	280	280	6–7	8
RED BNP	260	280	7	7–8
RED HF4B	280	280	5	7
RED E3B	280	250	8	8
RED E5B	280	250	8	8
PINK E	280	260	8	8
PINK E 01	280	260	8	8
PINK E2B	280	260	8	8
BLUE A4R	280	280	7	8
BLUE A2R	280	280	8	8
BLUE BG	280	280	8	8
GREEN GNX	260	280	8	8

PMMA is a fully amorphous polymer and exhibits excellent transparency. Optical properties are better than those of glass at about half the density. It retains a good gloss while maintaining high surface hardness and weather resistance.

PMMA can be processed via film and sheet extrusion and can be easily vacuum formed by heating to 100 °C. Melt processing temperatures are from 190 °C to 260 °C and it can be readily injection molded. One of the main applications of PMMA is as a glass replacement in windows, light fittings, fish tanks and transparent protection screens.

It is used to produce laserdiscs, automotive and electronic parts, point of sale displays and Liquid Crystal Display (LCD) plates. PMMA exhibits a good compatibility to human tissue and is used in the production of contact lenses, in dentistry and cosmetic surgery.

The coloration of Polymethyl methacrylate is mainly from color compounding or from PMMA based masterbatches. Of utmost importance is the retention of optical properties in the polymer which limits the addition of additives, fillers and processing aids.

The Solvaperm and Hostasol dyes are favoured in coloring PMMA due to their high transparency, high saturation in transmission and complete solubility in the polymer. These recommendations together with applicable Graphtol and a number of suitable Polysynthren dyes are to be found in the following tables.

COLORING RECOMMENDATIONS AND APPLICATION DATA – COLORANTS FOR POLYMETHYL METHACRYLATE (PMMA)

PRODUCT NAME	**HEAT RESISTANCE [°C]**		**LIGHT FASTNESS**	
	Reduction ($0.1\% + 1.0\ TiO_2$)	Full shade (0.1%)	Reduction ($0.1\% + 1.0\ TiO_2$)	Full shade (0.1%)
GRAPHTOL				
CARMINE HF3C	260	280	4	7
SOLVAPERM				
YELLOW 3G	280	280	6 - 7	7
YELLOW 2G	280	280	7–8	8
ORANGE 3G	280	280	6	7 - 8
RED 2G	280	280	6	7
RED G	280	280	6–7	7–8
RED PFS	280	280	4–5	7
RED BB	280	280	6	8
RED VIOLET R	260	280	6	7–8
VIOLET RSB	280	280	6	7–8
BLUE 2B	280	280	6	7–8
GREEN GSB	280	280	4–5	7
GREEN G	280	280	6–7	7–8
POLYSYNTHREN				
YELLOW NG	280	280	8	8
RED GFP	280	280	6 - 7	7–8
BLUE R	280	280	6	7–8
BLUE RLS	280	280	6–7	7–8
BROWN 3RL	280	280	7	8
BROWN R	280	280	8	8
BLACK H	280	n. a.	4	4
HOSTASOL				
YELLOW 3G	280	280	5–6	7
RED GG	280	280	4	7–8
RED 5B	280	280	3	4

n. a. = Data not available

2.6 COLORATION OF SYNTHETIC POLYMER FIBERS

The most commonly colored melt-spun synthetic fibers: polypropylene, polyester and polyamide, together with polyacrylic are discussed in this section.

The melt-spinning extrusion process pumps the polymer melt through the small holes of a spinneret to form continuous filaments. The meltspun fibers can be extruded from the spinneret in different cross-sectional forms (round, trilobal, pentagonal, octagonal etc.). Dependant on the number of holes in the spinneret, monofilament (one hole) or multifilament (several holes) fibers are produced.

After leaving the spinneret the melt-spun fibers are »drawn« as they cool to impart strength. Drawing is the process of stretching and orientating fibers which pulls the molecular chains of the polymer together and orientates them along the fiber axis, thus creating a considerably stronger yarn. Texturing is a procedure used to increase the volume and the elasticity of a filament yarn. The most common texturing processes are; False-twist texturing, Stuffer-box and Air-jet texturing.

POLYPROPYLENE FIBERS are abrasion resistant, colorfast, and resistant to chemicals, mildew, perspiration, rot and weather. They are light-weight, stain and soil resistant and provide good bulk and cover. Major uses include clothing and apparel, automotive interior trims, shelf coverings and seats, home furnishings such as carpets, upholstery, wall-coverings, and bedding and Industrial products; disposable clothing, non-woven fabrics, ropes and geotextiles for the building and construction industries.

The coloration of polypropylene fibers is from single pigment concentrates (SPC's) which are then blended in a second stage extrusion process to produce bespoke (tailor-made) colors. The processing temperatures for the melt-spinning of PP fibers range from 230 °C up to 280 °C. Pigment selection is based on heat stability, dispersion characteristics and the required fastness properties such as resistance to light, heat and rubbing. Ease of dispersion is crucial to the selection of pigments for the production of highly concentrated SPC's that contain up to 40 % organic pigment (up to 70 % for inorganic pigments). The dispersion characteristics of an organic pigment can be controlled by the pigment manufacturer in the synthesis and finishing steps. Inorganic pigments are controlled by surface treatments and/or in the grinding process.

The production of SPC's is from dry pigments, pigment flushes or pigment preparations via a twin-screw extruder or kneader/flushing mixer. The level of dispersion is controlled by measuring pressure change using a filter pressure test extruder. Poor pigment dispersion gives rise to expensive processing difficulties at the melt-spinning stage such as filament breakages and a high number of screen changes. Recommended are the PV Fast and Graphtol powder pigments.

POLYESTER FIBERS are strong, resistant to stretching, shrinking and to most chemicals. They are easily washed, quick drying and resistant to wrinkling, mildew and abrasion. Major uses are; Apparel: all forms of clothing, Home furnishings: Carpets, curtains, draperies, sheets and pillow cases, wall-coverings and upholstery, Others: hoses, belts, ropes, netting, threads, automotive seats, sails and fiberfill for pillows, cushions and furniture.

Coloration can be introduced during the manufacture of PET in the polycondensation (polymerization) phase. In this method the colorant is pre-dispersed in ethylene glycol to produce a slurry. This is introduced into the reactor where it is distributed by stirring to become a homogeneous solution in the polymer melt. Colorants introduced in this form must be able to withstand temperatures of 240 °C–285 °C for 5–6 hours duration. The more flexible method of coloring melt spun polyester is from color concentrates. Colorants selected require a thermal stability of at least 285 °C for 15 minutes.

A range of organic pigments and polymer soluble colorants are suitable for the melt spinning coloration of polyester fibers. In addition to the above mentioned requirements; resistance to sublimation and textile fastness properties (color fastness to light, rubbing, steam pleating, dry heat etc.) are essential but demands vary according to the final application.

The recommended PV Fast, Solvaperm, Hostasol and Polysynthren colorants for inclusion in the polycondensation process and for the manufacture of concentrates are listed in the following tables followed by their textile fastness properties.

POLYAMIDE FIBERS are exceptionally strong, elastic and resistant to oil and most chemicals. They are easy to wash, low in moisture absorbency and produce smooth, soft, light-weight and long lasting fibers.

Major uses are;

- Apparel:
  blouses, dresses, hosiery, skiwear, windbreakers, swim-wear and cycle wear
- Home furnishings:
  Bedspreads, carpets, curtains and upholstery
- Industrial and others:
  hoses, belts, parachutes, racket strings, ropes and netting, sleeping bags, tents, threads, fishing-line and dental floss

Polyamide's (Nylon) PA 6 and PA 6.6 grades are used in the melt spinning of polyamide fibers. The melt phases of these grades of Nylon are chemically highly corrosive and have a reducing effect on many organic colorants. This and the processing temperature requirements reduce severely the available coloring options. The processing range for PA 6 is from 260 °C to 280 °C and for PA 6.6 from 280 °C to 340 °C. In addition, the requirements for fastness properties such as light, heat, perspiration and washing fastness are application dependant.

Melt spun polyamide fibers are usually colored from predispersed concentrates. The following table contains PV Fast pigments, Solvaperm, Hostasol and Polysynthren dyes which have been tested in selected PA 6 and PA 6.6 grades can therefore be considered for selection. It is important to note that due to the chemical variations in differing grades of polyamide available on the market, pre-testing of colorant and polymer is essential to determine suitability of use.

2.6
COLORATION OF SYNTHETIC POLYMER FIBERS

COLORING RECOMMENDATIONS AND APPLICATION DATA – PIGMENTS FOR SYNTHETIC FIBERS

PRODUCT NAME	PP FIBER	PET FIBER		PA FIBER	
	Suitability	Color concentrates	Poly-condensation coloration	PA 6 fiber	PA 6.6 fiber
PV FAST					
YELLOW H9G	■	–	–	–	–
YELLOW H4G	■	–	–	–	–
YELLOW H2G	●	–	–	–	–
YELLOW HG 01	■	–	–	–	–
YELLOW HG	■	–	–	–	–
YELLOW H2GR	■	–	–	–	–
YELLOW HGR	■	–	–	–	–
YELLOW H3R	■	–	–	–	–
ORANGE H4GL 01	■	–	–	–	–
ORANGE H2GL	■	–	–	–	–
ORANGE GRL	■	–	■	–	–
ORANGE 6RL	●	–	–	●	●
SCARLET 4RF	■	■	–	–	–
RED B	■	■	■	■	–
RED D3G	■	–	–	–	–
RED HB	■	–	–	–	–
RED BNP	■	■	–	–	–
RED HF4B	■	–	–	–	–
RED E3B	■	●	●	–	–
RED E5B	■	●	●	–	–
PINK E	■	■	●	●	–
PINK E 01	■	●	●	●	–
PINK E2B	■	●	●	●	–
VIOLET BLP	■	–	–	●	–
VIOLET RL	■	–	–	●	–
BLUE A4R	■	■	●	–	–
BLUE A2R	■	■	■	●	●
BLUE BG	■	■	●	■	●
GREEN GNX	■	■	●	●	●
BROWN HFR	■	–	–	–	–
BROWN RL	■	–	–	–	–

COLORING RECOMMENDATIONS AND APPLICATION DATA – COLORANTS FOR SYNTHETIC FIBERS

PRODUCT NAME	PP FIBER	PET FIBER		PA FIBER	
	Suitability	Color concentrates	Poly-condensation coloration	PA 6 fiber	PA 6.6 fiber
GRAPHTOL					
YELLOW 3GP	■	–	–	–	–
YELLOW H2R	■	–	–	–	–
RED HFG	●	–	–	–	–
RED LG	■	–	–	–	–
RED F3RK 70	●	–	–	–	–
FIRE RED 3RLP	■	–	–	–	–
RED P2B	■	–	–	–	–
CARMINE HF3C	■	–	–	–	–
RUBINE L4B	■	–	–	–	–
SOLVAPERM					
YELLOW 2G	–	●	–	–	–
ORANGE 3G	–	–	–	●	–
RED 2G	–	●	●	■	–
RED G	–	■	■	–	–
RED BB	–	■	●	–	–
VIOLET RSB	–	●	–	–	–
BLUE 2B	–	■	■	●	–
GREEN GSB	–	●	●	–	–
GREEN G	–	■	●	–	–
POLYSYNTHREN					
YELLOW NG	–	■	●	–	–
YELLOW RL	–	–	–	●	●
RED GFP	–	■	■	–	–
VIOLET G	–	■	■	–	–
BLUE R	–	■	■	–	–
BLUE RLS	–	■	■	–	–
BROWN 3RL	–	■	●	–	–
BROWN R	–	■	■	–	–
BLACK H	–	■	–	●	●
HOSTASOL					
YELLOW 3G	–	■	●	■	●
RED GG	–	■	●	■	●

2.6 COLORATION OF SYNTHETIC POLYMER FIBERS

TEXTILE FASTNESS PROPERTIES OF COLORANTS IN PET FIBERS

The textile fastness properties were determined in a semidull grade of polyethylene terephthalate (PET) from FDY with a titer of dtex 144 f 48 (round cross section). Coloration was from polyester based single color concentrates, the dosing rate given refers to the percentage of colorant incorporated in to the yarn.

TEXTILE FASTNESS PROPERTIES IN PET FIBERS

DOSING RATE [%]	144 F 48 DTEX PET SD DTY	ISO 105-B06			ISO 105-B01
		1 x Blue Scale	3 x Grey Scale	5 x Grey Scale	(Light fastness) Blue Scale Method 2
0.80	**POLYSYNTHREN YELLOW NG**	7	4–5	4	7
0.50	**POLYSYNTHREN BROWN 3RL**	7	4–5	4–5	8
0.64	**POLYSYNTHREN BROWN R**	7	5	4–5	8
1.00	**PV FAST RED BNP**	7	4–5	4–5	7
1.00	**PV FAST SCARLET 4RF**	>7	5	5	8
0.80	**POLYSYNTHREN RED GFP**	7	4	3	6
1.20	**PV FAST RED B**	>7	5	4–5	6–7
1.00	**SOLVAPERM RED BB**	5–6	3	2	5
1.00	**PV FAST PINK E**	>7	4–5	4–5	7
1.00	**PV FAST PINK E2B**	>7	4–5	4–5	7
0.60	**POLYSYNTHREN VIOLET G**	7	4–5	4–5	6–7
0.80	**POLYSYNTHREN BLUE R**	5–6	2–3	2	4–5
0.60	**POLYSYNTHREN BLUE RLS**	4	1–2	–	4
0.60	**PV FAST BLUE A4R**	>7	5	5	8
0.60	**PV FAST BLUE BG**	>7	5	5	8
0.80	**SOLVAPERM GREEN G**	5	2	1	4–5
0.60	**PV FAST GREEN GNX**	>7	5	5	8
0.50	**HOSTASOL YELLOW 3G**	7	4	3–4	8
0.60	**HOSTASOL RED GG**	<4	1	–	4–5

ISO 105-C04			ISO 105-P01			ISO 105-X12		ISO 105-P02			ISO 105-X12	
(Washing 4) 95 °C/203 °F Grey Scale			(Dry heat) 210 °C/410 °F 30 s Grey Scale			(Rubbing) After ISO-P01 Grey Scale		(Steam pleating) 127 °C/266 °F 20 min. Grey Scale			(Rubbing) After ISO-P02 Grey Scale	
Nylon	PET	CO	Nylon	PET	CO	Dry	Wet	Nylon	PET	CO	Dry	Wet
4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	4–5	5	5	4–5	4–5
5	5	5	5	4–5	5	5	5	5	5	5	4	5
5	5	5	4	3–4	5	4	4–5	2	4	6	1–2	2–3
5	4–5	4–5	4–5	4–5	4–5	5	5	4–5	4–5	4–5	5	5
5	5	5	5	5	5	5	5	5	5	5	4–5	5
5	5	5	5	2–3	5	5	5	3–4	4–5	5	3	3–4
5	5	5	5	5	5	5	5	5	5	5	4–5	5
5	5	5	5	1–2	2–3	4	2–3	5	3	4	4	3–4
5	4–5	4–5	4–5	4–5	4–5	5	5	4–5	4–5	4–5	5	5
5	4–5	4–5	4–5	4–5	4–5	5	5	4–5	4–5	4–5	5	5
5	5	5	2–3	5	5	4–5	4–5	4	5	5	2	4
5	5	5	5	3–4	5	4–5	4–5	5	3–4	4–5	5	5
4–5	5	5	5	5	5	4–5	4–5	5	5	5	4–5	4–5
5	5	5	5	5	5	5	5	5	5	5	4–5	5
5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	3–4	4 - 5	4	3	5	4	4–5	3	3
5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	3–4	5	4–5	4	5	4	5	4	4
5	4	5	4–5	2–3	4	5	4–5	5	3–4	4–5	4–5	4–5

2.6
COLORATION OF SYNTHETIC POLYMER FIBERS

TEXTILE FASTNESS PROPERTIES OF COLORANTS IN PA FIBERS

The textile fastness properties were determined in a polyamide 6 filament yarn with a titer of dtex 48 f 8. Coloration was from polyamide 6 based single-color concentrates, the dosing rate given refers to the percentage of colorant incorporated in to the yarn.

FASTNESS PROPERTIES OF COLORANTS FOR POLYAMIDE FIBERS

COLORANT NAME	CONCENTRATION OF MONO BATCH	LIGHT FASTNESS EN ISO 105-B01		FASTNESS TO WASHING 60 °C EN 20105-C03 3 % [2)]		
	%	0.2 %	3.0 %	Fading	PA	WO
POLYSYNTHREN YELLOW RL	25	5	6–7	4–5	3–4	5
SOLVAPERM ORANGE 3G	10	7	7–8	4–5	3–4	4–5
HOSTASOL RED GG	10	–	1 [1)]	4	3	5
PV FAST RED B	25	3	6–7	5	5	5
PV FAST VIOLET RL	20	4–5	7	5	5	5
PV FAST VIOLET BLP	20	4–5	7	5	5	5
PV FAST BLUE BG	25	7–8	8	5	5	5
PV FAST GREEN GNX	25	7–8	8	5	5	5

Concentration
1) = 2.0 %
2) = Dosing of Mono Batch

FASTNESS TO PERSPIRATION EN ISO 105-E04 3 % 2)						FASTNESS TO SHAMPOOING 3 % 2)			HIGH TEMPERATURE LIGHT EXPOSURE DIN 75 202					
Alkaline			Acid						0.2 %			3.0 %		
Fading	PA	WO	Fading	PA	WO	Fading	PA	WO	1 x	2 x	3x	1x	2x	3x
5	5	5	5	5	5	5	5	5	7	6	2–3	7	6–7	3–4
5	4–5	5	5	4–5	5	5	4	4–5	6	6–7	3–4	7	6–7	3–4
4–5	5	5	4–5	5	5	4–5	4–5	4–5	–	–	–	1	1	1 [1)]
5	5	5	5	5	5	5	5	5	6	5–6	3–4	7–8	6–7	4
5	5	5	5	5	5	5	5	5	1	1	1	7	6–7	3–4
5	5	5	5	5	5	5	5	5	1	1	1	7	6–7	3–4
5	5	5	5	5	5	5	5	5	7–8	7 - 8	5	7–8	7–8	5
5	5	5	5	5	5	5	5	5	7–8	7–8	5	7–8	7–8	5

2.6
COLORATION OF SYNTHETIC POLYMER FIBERS

POLYACRYLONITRILE (PAN) FIBERS exhibit outstanding wickability and are quick drying. They are easily washable and retain their shape, they have superior resistance to UV degradation and are resistance to oils, chemicals and moths.
Major uses include;
- Apparel: Sweaters, socks, sports and children's wear,
- Home furnishings: Blankets, rugs, upholstery, luggage, awnings and outdoor furniture
- Industrial and others: Sail cloth, cleaning wipes, and reinforcement for concrete and stucco

Acrylic fibers (PAN) are produced by solution polymerizing acrylonitrile. The acrylonitrile is difficult to dye and is usually combined with a comonomer to improve the ability of the resulting fiber to absorb colorant. Solvent is then used to dissolve the polymer prior to fiber extrusion. PAN fibers can be dry or wet spun, they are used in staple or tow form. PAN has a high crystalline melting point of 317 °C and is soluble only in a limited range of solvents: Di-methyl Acetamide (DMAc), DMF and DMSO.

Unlike the coloration of Polyester, Polypropylene and Polyamide melt-spun fibers which are colored from color concentrate dispersions based on a polymeric material, colorants for PAN fiber extrusion are prepared as a solvent paste. The pigments must be totally insoluble in the solvent while retaining a pumpable viscosity. The range of suitable colorants for PAN fibers is therefore restricted, recommended Graphtol and PV Fast pigments and pigments from other ranges can be found in the following table.

PRODUCT NAME	
PV FAST	
YELLOW H9G	■
YELLOW H4G	●
YELLOW HG 01	■
YELLOW HG	■
YELLOW H2GR	●
YELLOW HGR	●
YELLOW HR 02*	■
YELLOW HR*	●
YELLOW H3R	■
ORANGE H4GL 01	■
ORANGE H2GL	■
ORANGE GRL	■
SCARLET 4RF	■
RED B	■
RED D3G	■
RED BNP	■
RED HF4B	■
VIOLET BLP	■
VIOLET RL	■
BLUE A4R	■
BLUE A2R	■
BLUE BG	■
GREEN GNX	■
BROWN HFR	●
BROWN RL	■

PRODUCT NAME	
GRAPHTOL	
YELLOW GG*	■
YELLOW GR*	●
YELLOW H2R	●
ORANGE GPS*	■
ORANGE RL*	●
RED BB*	■
RED F3RK 70	■
FIRE RED 3RLP	●
RED HF2B	■
RED F5RK	■
RED P2B	●
CARMINE HF4C	●
CARMINE HF3C	■
BORDEAUX HF3R	●
PERMANENT	
RED FGR	■
HOSTAPERM	
YELLOW H5G	■
SCARLET GO	■
RED P2GL-WD	■
VIOLET RL-NF	■

** = Diarylide*

2.7 COLORATION OF ENGINEERING POLYMERS

ENGINEERING POLYMERS are a group of thermoplastic materials which offer high strength, stiffness, toughness and resistance to wear, chemical attack and heat. Engineering polymers can be reinforced, filled or modified with a wide range of materials forming blends and alloys. Due to this diversity, any recommendations for their coloration can only be provided as a guideline. In all instances initial testing involving the final colorant formulation including additives and processing aids in the intended carrier system require evaluation under actual conditions of use in the final polymer system. The heat stability and light fastness values of organic colorants can be in some instances lower than those reached in polyolefins. Selected organic pigments can promote nucleation in semi-crystalline engineering polymers reducing properties and processability. Many of these polymers are hydroscopic, the presence of moisture will lead to a reduction in properties upon processing.

The chemistries of engineering polymers are varied and although often referred to as a group, the various chemical families must be treated separately. Colorant selection is of particular importance, not only with regard to heat stability, light- and weather fastness etc., but in some instances the chemical aggressiveness in the melt phase of some of these polymers can act as a reducing agent, breaking down the chemical bonds of many organic pigments and dyes. Melt processing temperatures, gating considerations, hot runner systems and tooling designs are all critical factors in the selection of the right colorant combination.

A number of solvent soluble dyestuff chemistries demonstrate a poor resistance to sublimation when processed at elevated temperatures. Sublimation is defined as the change of phase of a substance direct from a solid to a vapour; by-passing a liquid phase. It is a form of degradation which leads to processing problems, blooming, contact bleeding and staining on tooling and other metal surfaces.

The following solvent dyestuff chemistries exhibit a slight or poor resistance to sublimation according to Heubach testing methods;

SLIGHT: Solvaperm Yellow 2G, Solvaperm Orange 3G, Hostasol Yellow 3G
POOR: Solvaperm Yellow 3G, Solvaperm Red PFS, Hostasol Red GG, Hostasol Red 5B

Processing temperatures for engineering polymers vary considerably and place exacting demands on organic pigments and soluble dyes. In this chapter the coloration of the following polymers is discussed with colorant recommendations. In other engineering polymers contact to one of the regional Heubach Technical Application centres is advised.

POLYMER	PROCESSING TEMPERATURE RANGE [°C]
POLYOXYMETHYLENE (POM)	190–220
POLYESTER (PET)	270–310
POLYESTER (PBT)	240–280
POLYCARBONATE (PC)	280–340
POLYAMIDE (PA 6)	230–280
POLYAMIDE (PA 6.6)	280–320
POLYETHERIMIDE (PEI)	340–420
POLYSULFONE (PSU / PES)	350–380
POLYPHENYLENE SULPHIDE (PPS)	300–360

2.7
COLORATION OF ENGINEERING POLYMERS

POLYCARBONATE (PC)

Polycarbonate is a highly transparent (light transmission up to 92 % that of glass), amorphous light weight polymer It combines high strength, toughness and heat resistance with excellent dimensional and color stability.

Polycarbonate can be injection molded, sheet and film extruded, and gas blow molded to form non-carbonated drink bottles. Other major applications include optical lenses, lighting elements, sheeting and panels for glazing and construction, compact discs, electrical and medical devices. Structural foam grades of polycarbonate are also available however, these are usually painted to provide a high quality surface finish. Care must be taken when processing polycarbonate as minute traces of moisture can lead to a degradation of physical properties.

Due to a high melt viscosity, the processing temperatures of polycarbonate are high: 280 °C–340 °C, coloration is limited to selected organic and inorganic pigments and polymer soluble dyes. Masterbatch and color compounds are the common techniques for coloring polycarbonate, again when processing masterbatches care must be taken not to introduce moisture in to the system.

The major considerations when selecting organic colorants for polycarbonate are thermal stability and light fastness. The following tables of PV Fast and Graphtol pigments, Solvaperm and Hostasol fluorescent dyes together with the Polysynthren polymer soluble colorants have been positively tested and find regular applications in polycarbonate. Their heat stability and light fastness values obtained in the polymer are also provided.

COLORING RECOMMENDATIONS AND APPLICATION DATA – PIGMENTS FOR POLYCARBONATE (PC)

PRODUCT NAME			LIGHT FASTNESS		HEAT RESISTANCE
	SD $^{1}/_{3}$	Hue angle	Reduction	Full shade	
PV FAST	g / kg	°			°C
YELLOW HG 01	1.40	91.3	6–7	7–8	300
YELLOW HG	1.60	89.9	5–6	5–6	300
YELLOW H2GR	2.50	84.5	6	6–7	340
YELLOW HGR	3.50	82.0	4–5	6	330
ORANGE GRL	1.70	43.3	7–8	8	290
ORANGE H2GL	2.70	45.3	7–8	7	300
ORANGE 6RL	1.80	36.6	7	8	300
SCARLET 4RF	2.50	28.2	7–8	7–8	300
RED B	1.60	25.5	8	8	310
RED HB	2.80	13.5	4–5	5	310
RED BNP	1.70	14.2	7	7–8	300
RED HF4B	2.70	7.3	8	8	300
RED E3B	3.20	350.6	7	8	300
RED E5B	3.80	358.7	6–7	7	290
PINK E	2.30	341.1	8	8	310
PINK E 01	3.00	336.0	8	8	310
PINK E2B	2.30	338.5	8	8	320
BLUE BG	1.00	239.5	8	8	320
GREEN GNX	2.20	178.0	8	8	340

COLORING RECOMMENDATIONS AND APPLICATION DATA – COLORANTS FOR POLYCARBONATE (PC)

PRODUCT NAME			LIGHT FASTNESS		HEAT RESISTANCE
	SD $^1/_3$	Hue angle	Reduction	Full shade	
SOLVAPERM	g/kg	°			°C
YELLOW 3G	1.35	94.8	7–8	8	330
YELLOW 2G	0.53	94.5	7–8	8	330
ORANGE 3G	1.57	62.1	7	8	340
RED 2G	1.55	30.6	5–6	8	340
RED G	2.03	23.3	7–8	8	340
RED PFS	2.12	15.9	5–6	7	340
RED BB	0.59	352.1	7	8	330
RED VIOLET R	0.94	326.5	6–7	8	330
VIOLET RSB	0.85	286.5	7–8	8	310
BLUE 2B	0.96	266.3	6	7–8	340
GREEN GSB	1.02	214.3	6	7–8	340
GREEN G	1.63	183.9	7–8	8	310
POLYSYNTHREN					
YELLOW NG	1.33	91.6	8	8	300
RED GFP	2.29	23.4	7–8	8	340
VIOLET G	0.64	339.7	7–8	8	300
BLUE R	0.88	280.9	7–8	8	300
BLUE RLS	1.57	275.0	6	7	330
BROWN 3RL	1.97	40.6	8	8	340
BROWN R	1.09	13.0	8	8	340
BLACK H	1.41	250.8	3–4	4	320
HOSTASOL					
YELLOW 3G	–	–	6 [1)]	7–8 [2)]	340
RED GG	–	–	6 [1)]	7 [2)]	320
RED 5B	–	–	5–6 [1)]	6–7 [2)]	320

1) = 0.2% dye + 1.0% TiO_2 *2) = 0.05% dye*

2.7
COLORATION OF ENGINEERING POLYMERS

POLYACETALE / POLYOXYMETHYLENE (POM)
Polyacetales are hard, tough polymers with excellent dimensional stability and good impact resistance maintained across a wide temperature range.

Copolymers of polyacetale have better thermal stability and processability than homopolymers due to the presence of random ethylene oxide units in the molecular chain. These also open the processing window slightly. Both grades are highly crystalline and the natural polymer exhibits a translucent white color. Although polyacetale is not to a high degree hygroscopic, the presence of moisture will lead to processing problems and pre-drying is recommended.

Exceeding the thermal degradation temperature of POM will lead to rapid decomposition and to the formation of formaldehyde gas. This degradation process can be significantly accelerated by the poor selection of colorants. Since chemically identical pigments from differing manufacturers can vary in their behaviour and purity, only products specifically recommended for the coloration of polyacetale should be considered. Polyacetale displays very high shrinkage rates upon cooling and post-molding shrinkage can occur for up to 48 hours after processing. Polyacetale is suitable for injection molding of thin-wall and complex parts and for extrusion; mainly to produce semi finished parts. Applications include pump housings, impellers, gears, cams, cogs, automotive parts, hose connectors and garden sprinklers.

Coloration is from granular masterbatch, liquid concentrates and color compounds. Selection of organic pigments is critical as mentioned previously, certain chemistries breakdown in the aggressive melt phase of the polymer, others that for example contain high levels of volatiles or water in the molecule will induce polymer degradation. Many classes of organic pigments have a tendency in very low concentrations to become partially soluble leading to unstable shades. Polymer soluble dyes are not recommended for coloring polyacetale due to their potential to bloom from the polymer matrix. Dimensional stability is also an issue and certain groups of organic pigments can induce a nucleating effect leading to warpage in an injection molded part.

The following Heubach PV Fast and Graphtol pigments have been found to be thermally and chemically stable in POM;

PRODUCT NAME	LIGHT FASTNESS FULL SHADE
PV FAST	
YELLOW H9G	6–7
YELLOW HG 01	6–7
YELLOW HG	6–7
YELLOW H2GR	7
YELLOW HGR	7
YELLOW H3R	4–5
ORANGE H4GL 01	7–8
ORANGE H2GL	7–8
ORANGE 6RL	7–8
SCARLET 4RF	7
RED B	7–8
RED D3G	8
RED HB	6
RED BNP	7
RED HF4B	7
RED E3B	7
RED E5B	7–8
PINK E	8
PINK E 01	8
PINK E2B	8
BLUE A4R	8
BLUE A2R	8
BLUE BG	8
GREEN GNX	8
BROWN HFR	7
BROWN RL	8

THERMOPLASTIC POLYESTER (PET AND PBT)
Thermoplastic polyesters are divided into two main groups; Polyethylene Terephthalate (PET) and Polybutylene Terephthalate (PBT). Thermoplastic Polyester is a long-chain polymer with a hydrocarbon backbone structure containing ester linkages, hence the name.

PET – POLYETHYLENE TEREPHTHALATE is an amorphous polyester formed in a transesterification reaction. Dimethyl terephthalate (DMT) is reacted with ethylene glycol, the reaction is heated to around 210 °C to boil of the methane and then the temperature is further increased to 270 °C at which point polymerization takes place.

In recent years PET has not only replaced glass and other traditional materials, it has also replaced PVC, PE and PP in a number of applications due to its excellent design flexibility, high transparency, impact resistance and barrier properties. Main applications are in fibers (previously discussed), bottles, jars and containers and in packaging applications to produce films and tapes.

Most PET bottles are produced in two stages; initially a »preform« is injection molded, in the second stage the preform is heated to just above the glass transition temperature (Tg = 82 °C) and is placed in a bottle forming mold. Gas or air is then injected in to the preform and it is stretch-blown to fill the cavity. In stretch-blowing the amorphous preform, the long-chains in the polymer molecule harden and a strain induced crystallization takes place giving the bottle its exceptional clarity, resistance to internal pressure and toughness.

PBT – POLYBUTYLENE TEREPHTHALATE is a modified polyester formed also in a transesterification reaction. DMT is reacted with butylene glycol to produce a highly crystalline polyester. PBT has good mechanical strength and is resistant to chemicals, solvents and other tough and aggressive environments. It is widely used in the electronic, electric, fiber optic and automotive industries. It can be processed by injection molding, by extrusion in to sheets, films and profiles and can be melt-spun to produce fibers.

An extensive range of high-performance organic pigments and polymer soluble colorants can be used for the coloration of thermoplastic polyester*. The selection of inorganic pigments is often more critical due to their abrasiveness particularly when incorporated into filled grades of PBT. Colorant selection is based on heat stability and the required fastness properties for the end application. When selecting polymer soluble colorants it is important to note that solubility in the polymer melt is concentration dependant, particularly in filled grades.

Polymer soluble colorants are recommended for tinting and full shade applications.

Quinacridone pigments (Pigment Red 122 and Pigment Violet 19) have a tendency to become unstable at low concentrations in PBT.

The recommended PV Fast, Hostasol, Solvaperm and Polysynthren colorants for the coloration of PET and PBT sub-divided by application can be found in the following tables.

** The coloration of PET bottles produced by the »stretch-blow molding« process must be treated separately. Organic pigments that are not soluble in the polymer melt induce a nucleating effect on the PET influencing crystallite growth and thus, preventing stretch-blow molding of the preform.*

2.7
COLORATION OF ENGINEERING POLYMERS

COLORING RECOMMENDATIONS AND APPLICATION DATA – PIGMENTS FOR PBT AND PET

PRODUCT NAME	PBT		PET	
	unmodified	20 % glass filled	Stretch blow molding	Injection / Extrusion
PV FAST				
YELLOW H4G	■	●	–	●
YELLOW HG 01	■	■	–	■
YELLOW HG	■	■	–	■
YELLOW H2GR	■	■	–	■
YELLOW HGR	■	■	–	■
YELLOW H3R	■	■	–	■
ORANGE H2GL	●	●	–	–
ORANGE GRL	■	■	–	–
ORANGE 6RL	■	■	–	–
SCARLET 4RF	■	●	–	●
RED B	■	■	–	■
RED HB	■	–	–	–
RED BNP	■	■	–	●
RED HF4B	■	■	–	–
RED E3B	●	●	–	●
RED E5B	●	●	–	●
PINK E	●	●	–	■
PINK E 01	●	●	–	■
PINK E2B	●	●	–	■
BLUE A2R	■	■	●	■
BLUE A4R	●	●	–	●
BLUE BG	■	■	●	■
GREEN GNX	■	■	–	●
BROWN HFR	■	■	–	●

COLORING RECOMMENDATIONS AND APPLICATION DATA – SOLUBLE DYES FOR PET AND PBT

PRODUCT NAME	PET						PBT	
		LIGHT FASTNESS						
	SD $^1/_3$	Reduction SD $^1/_3$	Full shade SD $^1/_{25}$	Heat resistance	Stretch blow molding	Injection / Extrusion	unmodified	20 % glass filled
SOLVAPERM	g/kg			°C				
YELLOW 2G	0.34	7–8	8	300	■	■	●	●
ORANGE 3G	1.20	7–8	8	320	●	■	■	■
RED 2G	1.10	3–4	6 - 7	320	●	■	■	■
RED G	1.50	7–8	8	320	■	■	■	■
RED PFS	1.50	6 - 7	7	300	●	■	■	●
RED BB	0.40	7	8	300	■	●	■	■
RED VIOLET R	0.84	6	7	280	–	■	■	■
VIOLET RSB	0.65	7–8	8	300	●	■	■	■
BLUE 2B	0.67	5–6	7	320	●	■	■	■
GREEN GSB	0.84	5–6	7	300	■	■	■	■
GREEN G	1.20	7	7–8	300	■	■	■	■
BLACK PCR	1.40	6	6–7	300	●	■	■	●
POLYSYNTHREN								
YELLOW NG	0.95	8	8	300	■	■	●	●
YELLOW RL	0.90	7–8	8	320	●	■	–	–
RED GFP	1.70	7–8	8	320	■	■	■	■
VIOLET G	0.51	7–8	8	320	■	■	■	■
BLUE R	0.63	7	8	290	■	■	■	■
BLUE RLS	1.20	6	7	310	■	■	■	■
BROWN 3RL	1.50	8	8	320	■	■	■	■
BROWN R	0.82	8	8	320	■	■	■	■
BLACK H	1.18	3	3	280	●	●	■	■
HOSTASOL								
YELLOW 3G	–	7 [1)]	7 [2)]	300	■	■	●	●
RED GG	–	4 [1)]	7 [2)]	300	■	■	●	●

1) = 0.2 % dye + 1.0 % TiO_2 *2) = 0.05 % dye*

2.7
COLORATION OF ENGINEERING POLYMERS

POLYAMIDE (PA)

Polyamides are a family of engineering resins having outstanding toughness and wear resistance, a low coefficient of friction, excellent electrical properties and chemical resistance. The family consists of several different types. PA 6.6, PA 6, PA 6.10, PA 6.12, PA 11, PA 12, PA 6–6.6 copolymer and PA 4.6 are the most common. Of these, PA 6.6 and PA 6 dominate the market. Polyamide is defined as a polymer containing repeating amide groups, the nomenclatures refer to the number of methyl (-CH2-) units that occur on each side of the amide (CONH) groups.

Polyamides are hygroscopic polymers, they take up moisture readily. It's presence during processing particularly in higher temperature grades (PA 6 and PA 6.6) can severely degrade the mechanical properties of the final article. Polyamides can also absorb moisture after processing; this not only influences the dimensional stability of an article it can also lead to a color shift over time. These changes can occur for up to 150 days after processing until equilibrium has been reached. The process is reversible and the rate of absorption / desorption is dependant upon the grade, the ambient temperature and the relative humidity.

Polyamides 6 and 6.6 are slightly alkaline in their melt phases creating a chemically aggressive environment which has a »reducing« effect on many organic compounds including colorants. As a general rule colorants based on »azo«, »-N=N-«, (nitrogen double bond) chemistry should be avoided. (This guideline applies to all polyamide grades containing a »6« in the nomenclature). Although a limited number of polymer soluble colorants are recommended for the coloration of PA 6 and PA 6.6 they do display solubility limits which when exceeded can lead to migration and plate-out.

Polyamides 11 and 12 exhibit properties between those of polyolefins and PA 6. Their melting points are lower and crystallinity is higher than in PA 6. PA 11 is manufactured from caster bean oil and PA 12 from butadiene; they are highly flexible polyamides with lower moisture absorption and superior resistance to hydrocarbons. Polymer soluble colorants are not recommended for the coloration of these grades.

POLYAMIDE 6 is manufactured by a »ring opening polymerization« of the monomer caprolactam. In this process the monomer rings are opened up to form a polymer chain. The melt processing range is from 230 °C–280 °C, it is easier to process than PA 6.6 and has a lower mold shrinkage. PA 6 can be modified with glass fibers to improve stiffness. Main applications in injection molding and extrusion processing are in the automotive sector, in home appliances, for power tool housings and to produce bearings, cogs, electrical connectors and kitchen utensils.

POLYAMIDE 6.6 is manufactured in an »acid catalyzed condensation polymerization« by reacting the monomers adipic acid with hexamethylene diamine. The melt processing range for injection molding and extrusion grades is from 280 °C–300 °C. PA 6.6 is relatively difficult to process due to a very low melt viscosity, a narrow processing window and high post mold shrinkage. Applications include under the bonnet automotive parts such as engine covers, fan blades and grilles. Industrial machine casings, wheels, castors, cams, bolts and rivets.

The coloration of injection molding and extrusion grades of Polyamides 6 and 6.6 is from colored compounds and pre-dispersed color concentrates. The following tables list a number of Hostasol and Solvaperm dyes together with selected PV Fast high-performance organic pigments which have been positively tested in grades of PA 6 and PA 6.6 under laboratory conditions. **It is essential for the processor to carry out preliminary trials in the desired application with the appropriate polymer grades to ensure suitability for the intended use.**

COLORING RECOMMENDATIONS AND APPLICATION DATA – COLORANTS FOR PA6 AND PA 6.6

PRODUCT NAME	**PA 6**					**PA 6.6**	
		HEAT RESISTANCE		**LIGHT FASTNESS**			
	SD $^{1}/_{3}$	Reduction	Full shade	Reduction	Full shade	SD $^{1}/_{3}$	Heat resistance
PV FAST	g/kg	°C	°C			g/kg	°C
ORANGE 6RL	1.6	300	300	7–8	8	1.9	300
RED B	1.8	280	280	6–7	6–7	–	–
RED E3B	4.0	280	270	7–8	7–8	–	–
RED E5B	4.5	280	270	6–7	7	–	–
PINK E	2.6	280	280	6–7	7	–	–
PINK E 01	2.7	280	280	6–7	7	–	–
PINK E2B	2.6	280	280	6–7	7	–	–
VIOLET BLP	0.7	< 260	260	7–8	7–8	–	–
VIOLET RL	0.7	< 260	260	7–8	7–8	–	–
BLUE A2R	0.7	280	280	8	8	0.8	280
BLUE BG	0.9	300	300	8	8	1.0	300
GREEN GNX	1.7	280	280	8	8	1.9	280
POLYSYNTHREN							
YELLOW RL	1.2	300	300	7–8	7–8	1.3	300
BLACK H	1.0	280	n. a.	3–4	4	–	–

n. a. = Data not available

SOLVAPERM							
ORANGE 3G	1.3	300	300	3–4	7–8	–	–
RED 2G	1.3	300	300	5–6	7–8	1.4	300
RED G	1.4	280	280	3–4	7–8	1.4	280
RED PFS	1.7	280	280	3–4	3–4	–	–
BLUE 2B	0.8	280	280	4–5	5–6	0.9	280
HOSTASOL							
YELLOW 3G	–	300	300	2–3	3–4	–	300
RED GG	–	280	300	1–2	2–3	–	290

2.7
COLORATION OF ENGINEERING POLYMERS

POLYETHERIMIDE (PEI), POLYSULFONE (PSU) AND POLYETHERSULFONE (PES)

These three polymers belong in the same chemical family, they are inherently flame resistant amorphous polymers. Polyetherimide (PEI), Polysulfone (PSU), and Polyethersulfone (PES) exhibit excellent thermal properties, high strength and broad chemical resistance. In addition they can be repeatedly exposed to hot water and steam sterilization. They are naturally transparent polymers with varying degrees of an amber tint.

Polyetherimide is processed from 340 °C–420 °C, Polysulfone and Polyethersulfone from 350 °C–380 °C. All three have a very high melt viscosity. To lower this by increasing the processing temperatures can lead to darkening of the moldings. Predrying is essential as these polymers readily take up moisture. Coloration is usually from color compounds, if granular masterbatches are used it is important that they do not introduce moisture into the polymer. Due to the extremely high processing temperatures coloration from organic pigments and dyes is limited. The following table of Polysynthren, Hostasol and Solvaperm dyes together with selected PV Fast pigments where found suitable under laboratory conditions in the polymer grades specified.

POLYPHENYLENE SULPHIDE (PPS)

Linear polyphenylene sulphide is a thermoplastic polycondensate, it is a semi-crystalline polymer with high temperature performance and excellent chemical resistance. To overcome its inherent brittleness PPS must be filled with reinforcement fibers and fillers. These improve the strength, the surface and electrical properties and the dimensional stability of the polymer. Polyphenylene sulphide is inherently flame retardant and the main applications are in the production of high performance electrical components.

Linear PPS polymer can be extruded, blow molded or compression molded into blocks, rods and other stock shapes that are often used for prototyping. Unfilled linear polymer can also be melt spun and melt blow to produce fibers and fabrics that are used for conveyor belts, flame resistant clothing and filtration media.

The base color of the polymer is beige and after a short exposure to UV radiation turns brown. The melt processing temperature range is 300 °C–360 °C (typically 320 °C for injection molding applications). Polyphenylene sulphide is usually color compounded.

COLORANTS FOR PSU AND PES

PRODUCT NAME

PV FAST	HOSTASOL
BLUE A2R	YELLOW 3G
BLUE BG	RED GG
GREEN GNX	RED 5B

POLYSYNTHREN	SOLVAPERM
VIOLET G	ORANGE 3G
BLUE R	RED G
	VIOLET RSB
	GREEN G

DYES FOR PEI

PRODUCT NAME

SOLVAPERM	POLYSYNTHREN
YELLOW 2G	VIOLET G
RED PFS	BLUE R
RED G	
RED VIOLET R	
BLUE 2B	
GREEN G	

COLORANTS FOR PPS

PRODUCT NAME

PV FAST	SOLVAPERM
YELLOW HG 01	ORANGE 3G
YELLOW HG	RED G
YELLOW H3R	RED VIOLET R
ORANGE GRL	BLUE 2B
RED HB	
RED B	**POLYSYNTHREN**
RED E3B	VIOLET G
RED E5B	BLUE R
PINK E	BROWN R
BLUE A2R	
BLUE BG	**HOSTASOL**
GREEN GNX	YELLOW 3G*
	RED GG*

- *PSU injection molded 370 °C–0.1% full shade*
- *PES injection molded 360 °C–0.2 % full shade*
- *PEI injection molded 360 °C–0.2 % full shade/0.2 % + 1.0 % TiO_2 reduction*
- *PPS injection molded 320 °C–0.1% full shade/0.5 % + 1.0 % TiO_2 reduction*

** 0.1% full shade/0.1% + 1.0 % TiO_2 reduction*

2.8 INTRODUCTION TO THERMOSETTING RESINS

THERMOSET PLASTICS

Thermoset plastics (often referred to as resins) react during processing to form crosslinked structures. In their uncured state they are liquid monomers or partially polymerized powders which can be formed (cast) or applied as a coating to create a finished article or film layer. Curing is a process of polymerization which with the addition of chemical curing agents i. e. catalysts, and or heat creates the crosslinked structure which thereafter can no longer be melted or reprocessed. The most common thermosets in use today are based on unsaturated polyester, methyl methacrylate, epoxy resins and polyurethane.

The polyester and epoxy types are also extensively used in the production of thermoset composites. Composites are thermoset resins reinforced with orientated, continuous fibers of carbon or a carbon and glass fiber combination built up into layers to form very strong, rigid structures.

In the production of thermoset composites, gelcoats are usually applied, either by spraying or brushing on to the mold surface prior to the application of the composite material. Gelcoats are usually based on unsaturated polyesters and provide thermoset composites with a high quality surface finish and a protective coating against water and weather. Gelcoats are manufactured in a high shear mixing of polyester resin with a thixotrope monomer, colorants and fillers to meet individual specifications.

UNSATURATED POLYESTER RESIN (UP RESIN)

Unsaturated polyester is a polycondensation product of dicarboxylic acid with dihydric alcohol dissolved in an unsaturated styrene monomer solution. This solution is subsequently cured using catalysts (predominantly organic peroxides) which affect a polymerization. Curing induces a crosslinking to produce a thermoset polyester resin.

There are two methods of curing UP resin: »hot« or high temperature curing and »cold« or room temperature curing. In »hot curing«, a peroxide catalyst is added to the UP resin and the mixture is then heated to between 70 °C and 80 °C. In »cold curing«, an accelerator, e. g. cobalt naphthenate is used. It is added with the catalyst to the UP resin and the reaction starts at room temperature. The curing reaction is exothermic and the generated heat can raise temperatures to around 140 °C. Unsaturated polyester resins in their uncured state are liquids; they can be cast (casting resin), coated on to a substrate and sprayed or brushed (Gelcoats). After curing they become crystal clear and brittle, to improve mechanical properties fillers are often added.

Pigments should preferably be added in a pre-dispersed form to the uncured UP resin, e. g. as pastes. These can be based on the uncured UP resin, a plasticizer (the curing process and properties of the cured resin are not noticeably influenced by low levels of plasticizer), or other compatible intermediaries.

Most dyes are fully soluble in the unsaturated polyester resin (uncured) and can be added directly. They can also be added pre-dissolved in dimethyl formamide, ethanol, butyl acetate or methylene chloride.

In coloring UP resins a number of points need to be taken in to consideration. Colorants must be resistant to peroxides, they should also not accelerate or retard the curing process to any significant extent. Pigments will react differently depending on the type of catalyst and the amount being used. Their light fastness can also influenced considerably by the selection of catalyst. Although reaction temperatures of 140 °C are not that demanding for pigments, in thick coatings and castings the rate of cooling is slow, this places an additional demands on the thermal stability of colorants.

The following table of recommendations including their influence on curing rates is based on evaluations under laboratory conditions in a »cold« curing application.

2.8 INTRODUCTION TO THERMOSETTING RESINS

EPOXY RESINS are low molecular weight, tacky liquids that are cured with hardeners to present a tough and hard crosslinked structure. As the hardeners (curing agents) become part of the final structure of the epoxy resin (unlike the catalysts and accelerators used in polyester resins) they can be formulated to offer a wide range of properties. Epoxy resins are excellent adhesives; they offer good chemical resistance, thermal stability and electrical properties. They can be processed by all standard thermoset techniques and are used in the production of fiber reinforced composites (laminates) and as binders for thermoset molding compounds. Epoxy resins have excellent hardness and wear resistance. They find applications in the aerospace industry, in the sport and leisure industries and in other areas where hard protective coatings are required.

The resin is transparent with a natural yellow/brown tint. For this reason pale shades and bright colors are difficult to achieve. Coloration is from powder pigments either predispersed in epoxy resin or in fillers and extenders also to be included in the system. There are no special selection requirements for pigments, they do not noticeably affect the curing process. However, the curing process is highly moisture sensitive, all additives and fillers must be pre-dried before use.

THERMOSETTING POLYURETHANE (PUR)

PUR is formed by reacting a polyol (an alcohol with more than two reactive hydroxyl groups) with a dissocyanate or a polymeric isocyanate in the presence of a catalyst. PUR is a thermoset polymer often referred to as »two-component« polyurethane, it is used to produce rigid foams as insulation materials, flexible foams for carpet backing, upholstered furniture and mattresses and in spread-coating applications for the coloration of artificial leather.

Polyol is the collective term for polyester-, polyether- and aliphatic Polyols. They are reacted with isocyanate to form a pre-polymer of polyurethane (PU). The market is dominated by polyether polyols which are manufactured from propylene oxide and ethylene oxide. Polyester polyols are usually a condensation reaction of ethylene glycol with a dicarboxylic acid. They tend to be more expensive than the polyether types and are more difficult to handle. However, they develop PU's with superior tensile, abrasion, flexing and oil resistant properties.

The coloring component of a polyurethane formulation is introduced in paste form in to the Polyol before it is reacted with an isocyanate. These pastes are dispersions of pigment either in a polyol or a plasticizer which are produced in a dissolver, on a triple-roll mill or in a bead mill.

Organic pigments are preferred for the coloration of PUR due to their high color strength and lack of abrasiveness. The long-term thermal stability of organic pigments should be considered in foam applications due to the heat build-up formed in the curing process which is an exothermic reaction that can generate temperatures up to 180 °C for prolonged periods of time. Light fastness is often a factor, depending on the end application. Both organic and inorganic pigments are used to improve the light fastness of the PUR. Strong solvents are used in the spread-coating process and organic pigments must exhibit good solvent resistance in addition to migration fastness and rub resistance.

In addition to the Graphtol and PV Fast pigments presented in the following tables a number of Hostaperm, Novoperm and Hansa grades are suitable for the coloration of thermoset polyurethane. The most commonly used are mentioned in the following table, further information is available via your local Heubach sales organization or regional Technical Application Center.

PIGMENTS FOR PUR

PRODUCT NAME	
GRAPHTOL	
YELLOW GG*	RED HF2B
YELLOW 3GP	RED P2B
YELLOW GR*	CARMINE HF3C
YELLOW H2R	CARMINE HF4C
RED HFG	RUBINE L4B
RED BB*	BORDEAUX HF3R**
FIRE RED 3RLP	BLUE AN 01**

PV FAST	
YELLOW H9G	RED HB
YELLOW H4G	RED BNP
YELLOW H2G	RED HF4B
YELLOW HG 01	RED E3B
YELLOW HG	RED E5B
YELLOW H2GR	PINK E
YELLOW HGR	PINK E 01
YELLOW HR 02*	PINK E2B
YELLOW H3R	VIOLET BLP**
ORANGE H4GL 01	VIOLET RL**
ORANGE H2GL	BLUE A2R
ORANGE GRL	BLUE A4R
ORANGE 6RL	BLUE BG
SCARLET 4RF	GREEN GNX
RED B	BROWN HFR
RED D3G	BROWN RL

** = Diarylide*

*** = Indicates a high potential to bleed*

COLORANTS FOR UNSATURATED POLYESTER (UP)

PRODUCT NAME	INFLUENCE ON CURING	LIGHT FASTNESS FULL SHADE (0.025 %)
PV FAST		
YELLOW HR 02*	×	8
YELLOW HR*	×	7–8
ORANGE H4GL 01	×	8
ORANGE H2GL	×	7
ORANGE GRL	×	7
RED B	×	7–8
RED E3B	×	7–8
RED E5B	×	8
VIOLET BLP	– –	7–8
VIOLET RL	– –	7–8
BLUE A2R	– –	8
BLUE BG	– –	8
GREEN GNX	×	8
GRAPHTOL		
YELLOW GG*	×	7–8
ORANGE RL*	–	8
RED HFG	–	8
SOLVAPERM		
ORANGE 3G	– –	6
RED G	+	7
RED BB	×	7
RED VIOLET R	– –	6–7
VIOLET RSB	×	7
GREEN G	– –	7
HOSTASOL		
YELLOW 3G	×	7–8

** = Diarylide*
× = *No significant influence on reaction time*
+ = *Speeds reaction time up significantly*
– = *Slows reaction time down significantly*
– – = *Slows reaction time down dramatically*

2.9 COLORATION OF BIODEGRADABLE AND BIO POLYMERS

BIO POLYMER DEFINITION

By definition of the association, biopolymers are either biodegradable polymers with approved biodegradability or polymers based on renewable raw materials (e.g. EN 13432). Most of the bio plastics are based on agricultural feedstock; sugar, starch etc.; many of them are biodegradable/compostable.

BIOPLASTICS

BIODEGRADABLE PLASTICS	BIO-BASED PLASTICS
• fossil resources • blends of renewable resources	• renewable resources • blends of renewable resources
COMPOSTABLE	**NON BIODEGRADABLE**

MAJOR BIO PLASTICS

- PHA (polyhydroxyalkanoate)
- PHB (polyhydroxybutyrate)
- PLA (polylactic acid)
- Lignin-, starch-, polyvinyl alcohol- and cellulose-based polymers
- Poly-ε-caprolactone

EN 13432 – REQUIREMENTS FOR PACKAGING RECOVERABLE THROUGH COMPOSTING AND BIODEGRADATION

EN 13432 content of non-biodegradable materials <5%/ fillers are allowed with a maximum concentration of 1% for each filler.

Packaging materials and packaging are not allowed to contain higher amounts of the listed substances (mainly metal ions) according to EN 13432.

ELEMENT	MAX. CONC. [PPM]
ZINC	150.00
COPPER	50.00
NICKEL	25.00
CADMIUM	0.50
LEAD	50.00
MERCURY	0.50
CHROMIUM	50.00
MOLYBDENUM	1.00
SELENIUM	0.75
ARSENIC	5.00
FLUORINE	100.00

COLORING POSSIBILITIES WITH PV FAST AND GRAPHTOL PIGMENTS ACCORDING TO EN 13432

Due to the high copper content in the phthalocyanine pigments (e.g. P.B. 15:3 = 11% copper), their concentration in the final article is restricted by the max. allowable amount of copper (50 ppm) by the EN 13432.

Based on our analytical results, the other listed pigments could be used up to 1% in the final article.

PIGMENT	COLOUR INDEX	MAX. CONC. [%]
PV FAST YELLOW H9G	P.Y. 214	1.000
PV FAST YELLOW H4G	P.Y. 151	1.000
GRAPHTOL YELLOW 3GP	P.Y. 155	1.000
PV FAST YELLOW HG 01	P.Y. 180	1.000
PV FAST YELLOW HG	P.Y. 180	1.000
PV FAST YELLOW H2GR	P.Y. 191	1.000
PV FAST YELLOW HGR	P.Y. 191	1.000
GRAPHTOL YELLOW H2R	P.Y. 139	1.000
PV FAST YELLOW H3R	P.Y. 181	1.000
PV FAST ORANGE H2GL	P.O. 64	1.000
PV FAST RED B	P.R. 149	1.000
GRAPHTOL RED LG	P.R. 53:1	1.000
PV FAST RED D3G	P.R. 254	1.000
GRAPHTOL RED F3RK 70	P.R. 170	1.000
PV FAST RED HB	P.R. 247	1.000
GRAPHTOL RED P2B	P.R. 48:2	1.000
PV FAST RED HF4B	P.R. 187	1.000
PV FAST RED E5B	P.V. 19	1.000
GRAPHTOL RUBINE L4B	P.R. 57:1	1.000
PV FAST PINK E	P.R. 122	1.000
PV FAST VIOLET RL	P.V. 23	1.000
PV FAST BLUE A4R	P.B. 15:1	0.050
PV FAST BLUE BG	P.B. 15:3	0.050
PV FAST GREEN GNX	P.G. 7	0.100
PV FAST BROWN HFR	P.Br. 25	1.000

2.10 LEAD CHROMATE PIGMENT REPLACEMENTS

WHY IS THE REPLACEMENT OF LEAD CHROMATE PIGMENT SO IMPORTANT?

- Most PVC processors are changing their PVC stabilization and moving to lead-free systems based on Ca/Zn and Ca/Sn products. This means lead-free products are now feasible and consequently lead chromate pigments are phased out of formulations.
- A lot of international regulations for food packaging, consumer goods and toys are limiting the heavy metal contents.
- Lead chromate pigments are hazardous and toxic to workers in the plant.
- Recycling is a big issue due to the fact that lead chromate pigments containing products are difficult to be recycled and need to be taken out of the recycling stream to avoid contamination of non- leaded products.
- Reach Legislation:
  According to ECHA's member state committee Pigment Yellow 34 and Pigment Red 104 were included in the list for substances of »very high concern« end of 2009.

WHAT ARE THE DIFFICULTIES REPLACING LEAD CHROMATE PIGMENTS IN EXISTING FORMULATIONS?

- Lead chromates can not be replaced with a single organic pigment.
- Each formulation has to be adjusted.
- Due to different reflection curves no replacement without metamerism is feasible.
- Requirements for fastness properties must be considered.

Heubach's pigment range provides customers with broad choices. Various possible pigment combinations according to required fastness properties can be used.

Diarylide pigments offer the most cost effective replacement solutions but the maximum processing temperature for Diarylide pigments is 200 °C. For higher processing temperature different combinations of selected Graphtol and PV Fast pigments are recommended.

If weather fastness is requested combinations of Graphtol and PV Fast pigments with titanate pigments instead of titanium dioxide give much better results.

Following some guide formulations for PVC and Polyolefin based on a standard created in our lab are given. Fastness properties have to be taken into account according to the final application.

GUIDE FORMULATIONS FOR LEAD CHROMATE REPLACEMENT IN PVC BASED ON U-PVC (UNPLASTICIZED PVC HEUBACH TYPE):

STANDARD: P. Y. 34 LEAD (SULPHO) CHROMATE – GREEN SHADE YELLOW
1 KG U-PVC PLUS 6.00 G P. Y. 34

2.30 g Graphtol Yellow GG*	2.40 g Permanent Yellow P-G-IN*	4.60 g Graphtol Yellow 3GP
1.30 g Graphtol Yellow GR*	1.20 g Graphtol Yellow GR*	2.00 g TiO_2
1.70 g TiO_2	1.25 g TiO_2	

STANDARD: P. Y. 34 LEAD CHROMATE – RED SHADE YELLOW
1 KG U-PVC PLUS 6.00 G P. Y. 34

2.25 g Graphtol Yellow GR*	4.60 g Graphtol Yellow 3GP
0.67 g PV Fast Yellow HR 02*	1.90 g PV Fast Yellow HGR
1.70 g TiO_2	1.60 TiO_2

STANDARD: P. R. 104 MOLYBDATE – ORANGE
1 KG U-PVC PLUS 6.00 G P. R. 104

6.00 g Graphtol Orange RL*	8.00 g Graphtol Yellow H2R
	2.00 g PV Fast Scarlet 4RF
	1.30 g TiO_2

3.50 g Graphtol Yellow H2R	11.00 g PV Fast Yellow H4G
0.50 g PV Fast Red D3G	1.00 g PV Fast Red D3G
2.00 g TiO_2	

GUIDE FORMULATIONS FOR LEAD CHROMATE REPLACEMENT IN HDPE (HDPE HEUBACH TYPE):

P. Y. 34 LEAD (SULPHO) CHROMATE – GREEN SHADE YELLOW

STANDARD:	GUIDE FORMULATIONS:
0.3 % P. Y. 34	0.14 % PV Fast Yellow HG
0.175 % TiO_2	0.32 % TiO_2

P. Y. 34 LEAD CHROMATE – RED SHADE YELLOW

STANDARD:	GUIDE FORMULATIONS:	
0.3 % P. Y. 34	0.07 % PV Fast Yellow HG	0.03 % PV Fast Yellow H4G
	0.12 % PV Fast Yellow HGR	0.23 % PV Fast Yellow H2GR
	0.02 % TiO_2	

P. R. 104 MOLYBDATE – ORANGE

STANDARD:	GUIDE FORMULATIONS:
0.6 % P. R. 104	0.70 % PV Fast Yellow H4G
	0.08 % PV Fast Red D3G

** = Diarylide*

2.10
TYPICAL LEAD CHROMATE FULL SHADE COLORS

GREENISH YELLOW

2 % P. Y. 34 Lead Chromate
Full shade in PP
Hue angle ~89°

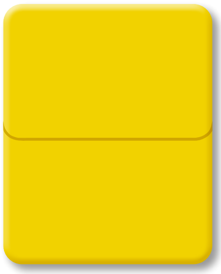
MID YELLOW

2 % P. Y. 34 Lead Chromate
Full shade in PP
Hue angle ~84°

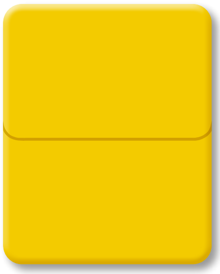
REDDISH YELLOW

2 % P. Y. 34 Lead Chromate
Full shade in PP
Hue angle ~77°

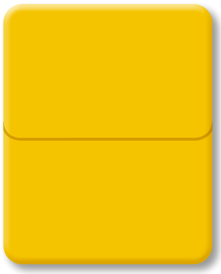
PV Fast Yellow H4G
Full shade in PP
Hue angle ~86°



PV Fast Yellow H4G
+ P. Y. 184
Full shade in PP



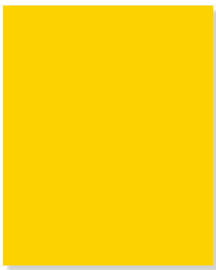
PV Fast Yellow H4G
+ P. Y. 53
Full shade in PP



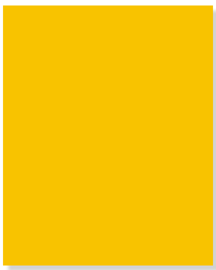
PV Fast Yellow H4G
+ P. Br. 24
Full shade in PP

PV Fast Yellow H4G
+ PV Fast Yellow H3R
Full shade in PP

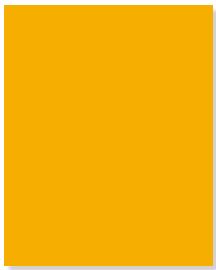
PV Fast Yellow H4G
+ P. Y. 184
Full shade in PVC



PV Fast Yellow H4G
+ P. Y. 53
Full shade in PVC



PV Fast Yellow H4G
+ P. Br. 24
Full shade in PVC



PV Fast Yellow H4G
+ PV Fast Yellow H3R
Full shade in PVC

3 COLORANT
TECHNICAL INFORMATION

3.1 PIGMENTS – CHEMICAL AND PHYSICAL DATA/ SOLVENT EXTRACTION DATA

3.2 PIGMENT PREPARATIONS – CHEMICAL AND PHYSICAL DATA/ SOLVENT EXTRACTION DATA

3.3 DYES – CHEMICAL AND PHYSICAL DATA/ SOLVENT SOLUBILITY DATA

3.1
PIGMENTS

PRODUCT NAME	COLOUR INDEX	CHEMICAL AND PHYSICAL DATA					
PV FAST		Density [g/cm^3]	Specifi c surface [m^2/g]	Average particle size [nm]	Bulk volume [l/kg]	Acid resistance	Alkali resistance
YELLOW H9G	Pigment Yellow 214	1.41	54	165	6.0	5	5
YELLOW H4G	Pigment Yellow 151	1.53	16	–	3.5	5	5
YELLOW H2G	Pigment Yellow 120	1.52	29	130	6.7	5	5
YELLOW HG 01	Pigment Yellow 180	1.43	52	91	4.1	5	5
YELLOW HG	Pigment Yellow 180	1.36	29	–	10.3	5	5
YELLOW H2GR	Pigment Yellow 191	1.69	38	131	5.0	5	5
YELLOW HGR	Pigment Yellow 191	1.77	20	296	7.8	5	5
YELLOW HR 02*	Pigment Yellow 83	1.45	77	48	4.0	5	5
YELLOW HR*	Pigment Yellow 83	1.47	22	31	4.0	5	5
YELLOW H3R	Pigment Yellow 181	1.48	27	302	6.0	5	5
ORANGE H4GL 01	Pigment Orange 72	1.53	33	109	5.0	5	5
ORANGE H2GL	Pigment Orange 64	1.58	27	94	3.8	5	5
ORANGE GRL	Pigment Orange 43	1.53	36	144	3.0	5	5
ORANGE 6RL	Pigment Orange 68	1.60	30	221	2.8	5	5
SCARLET 4RF	Pigment Red 242	1.61	41	226	5.4	5	5
RED B	Pigment Red 149	1.40	72	31	3.2	5	5
RED D3G	Pigment Red 254	1.62	30	117	2.5	5	5
RED HB	Pigment Red 247	1.44	26	177	3.2	5	5
RED BNP	Pigment Red 214	1.57	39	300	5.3	5	5
RED HF4B	Pigment Red 187	1.45	66	101	5.8	5	5
RED E3B	Pigment Violet 19	1.47	39	189	4.0	5	5
RED E5B	Pigment Violet 19	1.48	70	70	5.0	5	5
PINK E	Pigment Red 122	1.47	65	95	3.2	5	5
PINK E 01	Pigment Red 122	1.45	63	132	3.2	5	5
PINK E2B	Pigment Red 122	1.41	59	102	7.8	5	5
VIOLET BLP	Pigment Violet 23	1.50	93	36	5.0	5	5
VIOLET RL	Pigment Violet 23	1.44	90	31	3.5	5	5
BLUE A4R	Pigment Blue 15:1	1.61	70	46	4.6	5	5
BLUE A2R	Pigment Blue 15:1	1.63	106	30	3.5	5	5
BLUE BG	Pigment Blue 15:3	1.62	57	74	4.0	5	5
GREEN GNX	Pigment Green 7	2.04	44	36	3.3	5	5
BROWN HFR	Pigment Brown 25	1.41	90	61	10.3	5	5
BROWN RL	Pigment Brown 41	1.58	43	141	4.8	5	5

** = Diarylide*

SOLVENT EXTRACTION DATA

Water	Ethanol	Isopropanol	Butanol	Methyl ethyl ketone	Cyclohexanone	White spirit	Toluene	Xylene	Ethyl acetate	Butyl acetate	Dibutylphthalate	Dioctylphthalate	Butyl glycol	Paraffin	Linseed oil	Coconut oil	Di-isodicylphthalate
5	5	5	5	4–5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	4–5	4–5	4	4–5	4	5	5	5	5	5	5	5	4–5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
3	4	5	4–5	5	4–5	5	5	5	5	4–5	5	5	4–5	5	5	5	5
3–4	4–5	5	5	4–5	4–5	4–5	4–5	4–5	5	4–5	4–5	5	4–5	5	5	5	5
5	5	5	5	4–5	4–5	5	4–5	4–5	4–5	4–5	4–5	5	4–5	5	5	5	5
5	5	5	5	4–5	4–5	5	4–5	4–5	4–5	4–5	4–5	5	5	5	5	5	5
4–5	4–5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	4–5	4	5	4	4	4–5	4–5	4–5	5	4–5	4–5	4–5	4–5	5
5	5	5	5	5	4–5	5	4–5	4–5	5	5	5	5	5	5	5	5	5
5	5	5	5	4–5	4–5	5	5	5	5	5	5	5	4–5	5	5	5	5
5	5	5	5	4	4	5	4	4	4	4–5	5	5	4–5	5	5	5	5
5	5	5	5	4–5	4–5	5	4–5	4–5	4–5	4–5	5	5	4–5	5	5	4–5	5
5	4–5	4–5	4–5	4–5	4–5	5	4–5	4–5	4–5	4–5	5	5	4–5	5	5	5	5
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5	5	4–5	4–5	4–5	4–5	5	4–5	4–5	4–5	4–5	5	5	4–5	5	5	5	5
5	4	4–5	4	4	4	4–5	4–5	4–5	4–5	4–5	4–5	5	4	4–5	5	4–5	5
5	5	5	5	4	4	5	4–5	4–5	4–5	4–5	5	5	4–5	5	4–5	4	5

3.1
PIGMENTS

PRODUCT NAME	COLOUR INDEX	CHEMICAL AND PHYSICAL DATA					
GRAPHTOL		Density [g/cm^3]	Specifi c surface [m^2/g]	Average particle size [nm]	Bulk volume [l/kg]	Acid resistance	Alkali resistance
YELLOW GG*	Pigment Yellow 17	1.39	63	45	4.0	5	5
YELLOW 3GP	Pigment Yellow 155	1.40	50	–	5.2	5	5
YELLOW GR*	Pigment Yellow 13	1.36	50	38	4.0	5	5
YELLOW H2R	Pigment Yellow 139	1.63	55	62	5.5	5	5
ORANGE GPS*	Pigment Orange 13	1.41	38	130	4.8	5	5
ORANGE RL*	Pigment Orange 34	1.40	65	100	6.4	5	5
RED HFG	Pigment Orange 38	1.45	67	155	7.4	5	5
RED LG	Pigment Red 53:1	1.86	49	104	4.0	5	5
RED LC	Pigment Red 53:1	1.82	42	160	6.0	5	5
RED BB*	Pigment Red 38	1.44	29	–	7.0	5	5
RED F3RK 70	Pigment Red 170	1.44	19	307	4.0	5	5
FIRE RED 3RLP	Pigment Red 48:3	1.80	28	208	6.2	5	5
RED HF2B	Pigment Red 208	1.36	49	85	7.1	5	5
RED F5RK	Pigment Red 170	1.37	27	211	3.9	5	5
RED P2B	Pigment Red 48:2	1.67	63	82	5.7	4	4
CARMINE HF4C	Pigment Red 185	1.46	50	151	6.7	5	5
CARMINE HF3C	Pigment Red 176	1.41	60	115	9.6	5	5
RUBINE L4B	Pigment Red 57:1	1.53	75	83	5.8	4–5	5
BORDEAUX HF3R	Pigment Violet 32	1.78	58	155	5.4	5	5
BLUE AN 01	Pigment Blue 15	1.58	58	68	3.7	5	5

** = Diarylide*

SOLVENT EXTRACTION DATA

Water	Ethanol	Isopropanol	Butanol	Methyl ethyl ketone	Cyclohexanone	White spirit	Toluene	Xylene	Ethyl acetate	Butyl acetate	Dibutylphthalate	Dioctylphthalate	Butyl glycol	Paraffin	Linseed oil	Coconut oil	Di-isodicylphthalate
5	4–5	4–5	4–5	3–4	3–4	4–5	3	3	3–4	3–4	3–4	4–5	3–4	4	4–5	3–4	4–5
5	5	5	5	4	4	5	4–5	4–5	4	4–5	5	5	4–5	5	5	4–5	5
5	5	5	5	4–5	4	4–5	3	3	4–5	4–5	4–5	5	4–5	4–5	5	4–5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	4	4	3–4	3	3	4	2–3	2–3	3	3	3	4	3	4	3–4	2–3	4–5
5	5	5	5	4–5	4	5	4	4	4–5	4–5	4–5	4–5	4–5	4–5	5	4–5	5
5	4–5	4–5	4–5	4–5	4–5	5	5	5	5	5	5	5	4–5	5	4–5	5	5
4–5	4	4	4	4	3–4	4–5	4–5	4–5	4–5	4–5	4–5	5	3–4	4–5	5	4–5	5
5	4	4–5	4–5	4	4	4–5	4–5	4–5	4–5	4	4–5	4–5	4	5	4–5	5	4–5
5	4–5	4–5	4–5	4–5	4–5	5	4	4	4–5	4–5	4–5	5	4–5	5	5	5	5
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5	5	5	5	4–5	4–5	5	5	5	5	5	5	5	5	5	5	5	5
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5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	4–5	4	5	5	5	5	5	5	5	4–5	5	5	5	5

3.2
PIGMENT PREPARATIONS

CHEMICAL AND PHYSICAL DATA

PRODUCT NAME	COLOUR INDEX	DENSITY g/cm³	ACID RESISTANCE	ALKALI RESISTANCE
HOSTAPRINT				
YELLOW GG 34*	Pigment Yellow 17	1.35	5	5
YELLOW HG 34	Pigment Yellow 180	1.37	5	5
YELLOW HR-N*	Pigment Yellow 83	1.39	5	5
YELLOW HGR 34	Pigment Yellow 191	1.50	5	5
YELLOW H2R 34	Pigment Yellow 139	1.47	5	4
ORANGE H4GL 34	Pigment Orange 72	1.41	5	5
RED HFG	Pigment Orange 38	1.36	5	5
RED D3G 34	Pigment Red 254	1.45	5	5
RED HF2B	Pigment Red 208	1.37	5	5
CARMINE HF4C	Pigment Red 185	1.38	5	5
PINK E 34	Pigment Red 122	1.39	5	5
VIOLET RL 34	Pigment Violet 23	1.37	5	5
BLUE A2R 34	Pigment Blue 15:1	1.46	5	5
BLUE B2G 34	Pigment Blue 15:3	1.46	5	5
GREEN GG	Pigment Green 7	1.63	5	5
BROWN RL 34	Pigment Brown 41	1.43	5	5
BROWN HFR 34	Pigment Brown 25	1.41	5	5
BLACK L	Pigment Black 7	1.54	5	5

** = Diarylide*

CHEMICAL AND PHYSICAL DATA

PRODUCT NAME	COLOUR INDEX	DENSITY g/cm^3	ACID RESISTANCE	ALKALI RESISTANCE
HOSTASIN				
YELLOW GR 30*	Pigment Yellow 13	1.12	5	5
YELLOW HR 30*	Pigment Yellow 83	1.06	5	5
ORANGE G 30*	Pigment Orange 13	1.13	5	5
RED B 30*	Pigment Red 38	1.18	5	5
RED HF2B 30	Pigment Red 208	1.11	5	5
BLUE A2R 30	Pigment Blue 15:1	1.19	5	5
GREEN GG 30	Pigment Green 7	1.48	5	5

** = Diarylide*

3.3
DYES

PRODUCT NAME	COLOUR INDEX	CHEMICAL AND PHYSICAL DATA			
SOLVAPERM		Density g/cm³	Acid resistance	Alkali resistance	Melting point °C
YELLOW 3G	Solvent Yellow 93	1.33	5	5	180
YELLOW 2G	Solvent Yellow 114	1.47	5	5	264
ORANGE 3G	Solvent Orange 60	1.42	5	5	230
RED 2G	Solvent Red 179	1.45	5	5	260
RED G	Solvent Red 135	1.76	5	5	318
RED PFS	Solvent Red 111	1.41	5	5	170
RED BB	Solvent Red 195	1.29	5	5	214
RED VIOLET R	Solvent Violet 59	1.39	5	5	186
VIOLET RSB	Solvent Violet 13	1.40	5	5	190
BLUE 2B	Solvent Blue 104	1.23	5	5	240
GREEN GSB	Solvent Green 3	1.32	5	5	215
GREEN G	Solvent Green 28	1.24	5	5	245
POLYSYNTHREN					
YELLOW NG	Pigment Yellow 147	1.56	5	5	>300
YELLOW RL	Pigment Yellow 192	1.22	5	5	>320
RED GFP	Solvent Red 135	1.77	5	5	318
VIOLET G	Solvent Violet 49	1.62	5	5	>300
BLUE R	Solvent Blue 122	1.43	5	5	239
BLUE RLS	Solvent Blue 45	1.29	5	5	200
BROWN 3RL	Pigment Orange 70	1.58	5	5	365
BROWN R	Solvent Brown 53	1.66	5	5	>350
BLACK H	Solvent Black 27	1.36	4	5	>260
HOSTASOL					
YELLOW 3G	Solvent Yellow 98	1.17	5	5	110
RED GG	Solvent Orange 63	1.51	5	5	320
RED 5B	Vat Red 41	1.60	5	5	312

n.a. = Data not available

SOLVENT EXTRACTION DATA

Ethanol g/l	Benzyl alcohol g/l	Acetone g/l	Ethyl acetate g/l	Butyl acetate g/l	Methylene chloride g/l	Toluene g/l	Xylene g/l
< 1	4	8	9	10	190	25	25
< 1	2	< 1	6	< 1	6	3	1
< 1	4	1	1	1	10	5	5
< 1	3	< 1	1	< 1	1	3	2
< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 1	10	4	5	4	50	7	8
< 1	1	< 1	1	< 1	11	2	1
7	6	20	15	20	40	12	12
< 1	4	1	4	3	12	7	8
< 1	4	3	4	10	240	85	25
< 1	3	< 1	1	3	20	10	8
< 1	4	2	4	4	55	11	30
< 1	< 1	< 1	< 1	1	2	< 1	< 1
< 1	< 1	2	–	–	< 1	1	–
–	< 1	< 1	< 1	< 1	< 1	< 1	< 1
< 1	< 1	1	1	1	1	1	< 1
< 1	2	2	2	3	6	4	1
5	100	10	10	5	75	< 1	10
< 1	4	< 1	< 1	< 1	3	< 1	2
< 1	2	1	< 1	1	1	1	1
40	n. a.	n. a.	13	n. a.	n. a.	n. a.	n. a.
< 1	4	1	3	3	140	65	15
< 1	1	< 1	< 1	1	2	1	1
< 1	< 1	< 1	< 1	1	2	< 1	1

4 TEST **CONDITIONS**

4
TEST CONDITIONS

The values quoted for the fastness properties and the concentrations to standard depth of shade only apply for our test conditions.

Any change in operating parameters, e. g. type and settings of the equipment, specific polymer substrate, concentrations, processing temperature and time canresult in different values.

4.1 CONCENTRATION FOR SD $^1/_3$

The value quoted is the weight in grams (g) colorant per kg polymer required to obtain SD $^1/_3$ according to DIN 53235. For HDPE, PP, PS, ABS, PC and PA the value relates to the pigment concentration with 1% TiO_2, and for PVC with 5 % TiO_2.

4.2 HUE ANGLE

The hue angle has been determined by colorimetry according to DIN EN ISO 11664-4, from the measured X_{10}, Y_{10} and Z_{10} tristimulus values determined at standard illumination D65. The values listed in the tables refer to the opaque coloration in SD $^1/_3$.

4.3 HEAT RESISTANCE

Resistance to heat was tested according to DIN EN 12877 in HDPE, PP, PS, ABS, PC and PA at SD $^1/_3$ with 1% titanium dioxide in the injection molding process. The values quoted are the temperatures in °C at which, after a dwell time of 5 min, a color change equivalent to a ΔE^*_{ab} = 3 (DIN EN ISO 11664-4) is obtained.

4.4 LIGHT FASTNESS IN HDPE, PP, PS, ABS, PC, PMMA

The light fastness in white reduction was determined on injection molded plaques at SD $^1/_3$ with 1% titanium dioxide in an artificial light exposure according to DIN EN ISO 4892. For the light fastness in full shade, the same pigment concentration was tested without titanium dioxide. Assessments were made against the 8-step blue-wool scale according to ISO 105-B01. Where 8 refers to very good light fastness and 1 very poor light fastness.

4.5 LIGHT FASTNESS IN PVC

The light fastness in white reduction was determined at 0.1% pigment with 0.5 % titanium dioxide in an artificial light exposure according to DIN EN ISO 4892. The same concentration without titanium dioxide was tested for the light fastness of transparent formulations. Assessments were made against the 8-step blue-wool scale according to ISO 105-B01.

4.6 LIGHT FASTNESS IN POM

The light fastness in full shade has been determined at 0.1% pigment in an artificial light exposure according to DIN EN ISO 4892. Assessments were made against the 8-step blue-wool scale according to ISO 105-B01.

4.7 WARPAGE

Some organic pigments can have a negative influence on the dimensional stability of polyolefins. This behaviour is referred to as the »Potential to induce warpage« and is at its most extreme in HDPE injection molding applications. The influence of a pigment to induce warpage was tested for by measuring the dimensional changes in the horizontal and vertical planes of a rectangular injection molded plate in HDPE comparing colored (0.1% pigment) and uncolored plates The plates were injection molded at 280 °C. Those pigments which has a heat resistance below 280 °C has been injection molded at 220 °C.

■ Suitable - Technically recommended for the application according to internal testing methods.
● Limited suitability - Technically suitable for the application, some restrictions may apply.
– Not suitable - Technically unsuitable according to internal testing methods.

4.8 MIGRATION – BLEED FASTNESS

Fastness to bleeding was tested in plasticized PVC by direct contact of a pigmented film (0.1%) for 2 h at 140 °C with a white-pigmented film. Staining of the white pigmented film was evaluated against the »5 step grey scale for assessing staining« according to DIN EN 20105-A03 whereby »5« denotes no bleeding.

4.9 MIGRATION RESISTANCE (UNVULCANIZED RUBBER)

The coloration is evaluated using a white unvulcanized rubber web or small sheet (winding), which has been in contact with the colored unvulcanized rubber web during vulcanization in the open steam process. Staining of the white rubber sheet was evaluated against the »5 step grey scale for assessing staining« according to DIN 20105-A03 whereby »5« denotes no bleeding.

4.10 DETERMINATION OF LIMIT CONCENTRATION IN PVC

The limit concentration in PVC is the lowest concentration at which a colorant is resistant to a temperature 200 °C. This is tested for in plasticized and unplasticized PVC in a range of pigment concentrations from 0.005 % to 0.5 % plus 0.5 % titanium dioxide. The results are compared visually against colorations which have been prepared under standard conditions (P-PVC at 130 °C; U-PVC at 160 °C).

4.11 PHYSICAL AND CHEMICAL PROPERTIES

Density
The density was determined in accordance with DIN EN ISO 787-23.

Specific surface
The specific surface of pigment powders was determined by the BET method.

Particle size distribution by volume
Particle size distribution is determined by image analysis of transmission electron microscope images. By inspection of the images, primary particles are identified and their size is measured using a graphic tablet. From the sizes of approximately 1000 particles, size distribution by volume is calculated, and the median diameter D50 is used as a measure of mean particle size.

Bulk volume
The bulk volume is the quotient derived from the volume of a powder (including free space and voids) and its mass after the powder has been poured into a measuring vessel in the manner described in the regulations.

Resistance to acids and alkalis of pigments and dyestuffs
To determine the resistance

- of pigments to acids and alkalis, strips of plasticized PVC
- of dyestuffs to acids and alkalis, strips of rigid PVC

colored with 0.1% colorant and 0.5 % titanium dioxide were placed for 3 days in 5 % hydrochloric acid and 5 % caustic soda solutions respectively. Then compared with the untreated films. Assessments were made by references to the 5-step grey scale in accordance to DIN EN 20105-A03. Step 5 means no change in shade.

4.12 TEST COMPOUNDS

High density polyethylene (HDPE)
Polypropylene (PP)
Plasticized PVC
Rigid PVC
Polystyrene (PS)
Acrylonitrile-Butadiene-Styrene-Copolymer (ABS)
Polymethylmethacrylate (PMMA)
Polycarbonate (PC)
Polyethylene terephthalate (PET)
Polybutylene terephthalate (PBT)
PA 6
PA 6.6
Rubber
Polyoxymethylene (POM)

4.13 SOLVENT FASTNESS OF PIGMENTS

An assessment is made of the coloration of a solvent by a pigment in comparison with a scale of standardized comparative solutions.

For every solvent, about 1 ml pigment powder is transferred into a folded filter, the filter will be closed and immersed into the test tubes with approx. 20 ml of each solvent mixture. The sealed test tubes will be stored for 24 hrs. before evaluation. For the evaluation the filter with the pigment is removed and the coloration of the solvents is compared with a scale of standard solutions. The lowest rating is 1, the best rating is 5 with no coloration visible.

4.14 SOLVENT SOLUBILITY OF DYES

The solubility figures given represent the amount of dyestuff in grams which dissolves at room temperature in one liter solvent or solvent mixture without any significant residue.

4.15 WEATHER FASTNESS

The weather fastness has been determined according to to DIN EN ISO 4892 by using an artificial light weather-o-meter with a cycle of 102 minutes dry and 18 minutes wet. The black panel temperature was set at 55 °C and the relative humidity at 60 %. The evaluation of the sample was carried out after ISO 105-A02 against a Grey scale for assessing color change.

For further information on the subject of weathering in plastics refer to page 44 in this brochure or contact your regional Heubach Technical Application Center.

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PLA 2002 EN | 01.2023

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