phenol resins

61,327 metric tons per year

The TransAct Difference

Phenolic thermosetting resin products are some of the most adaptive materials in the marketplace and hundreds of industries benefit from their use. Five generations of product designers worldwide have come to rely on phenolic-resin-based materials many times a day. TransAct Energy Corp is proud of its materials that can pass the test of time, whether used in the morning coffee maker, the Apollo lunar module, or the newest automotive safety systems.

The market demands custom product development as resin applications become more specialised. The type of phenolic resin, its molecular weight, monomer and moisture content, viscosity or molten flow, pH, particle size, reactivity during cure, and cure vapour emission level are but some properties that determine our products' suitability for a customer.

The TransAct phenolic resin team's mission is to develop, manufacture, and service useful products that provide clear value for our customers. TransAct's experience and ability to select product formulation options and to use a variety of manufacturing methods allow tailoring TransAct resins to meet the requirements and expectations of our customers. We welcome the opportunity to customise a phenolic resin product for your application.

TransAct Energy Corp supplies modified and un-modified novolac and resol phenolic resin products as pastilles, powders, flakes, lumps, and solvent- or water-based liquids. In general, customers use TransAct products to create impervious bonding matrices with fillers and substrates, to form protective coatings, to create rigid foams, as a source of amorphous carbon, or as chemically reactive additives.

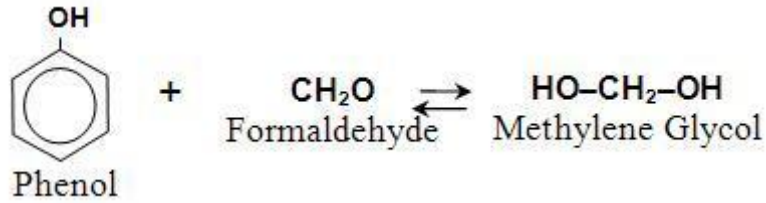
What are TransAct Phenolic Resins?

Resins are polymers made by repeatedly linking discrete molecules (monomers) together to form chains or networks. TransAct phenolic resins are oligomers (polymers with a few repeating units) synthesized by repeatedly linking phenolic (hydroxy-aromatic) monomers with aldehyde chemicals. The majority of TransAct products are combinations of phenol (hydroxybenzene, C_6H_6O) and formaldehyde (methanal, CH_2O), though specialized applications may require use of substituted

phenols (e.g., cresols, resorcinol, cashew nutshell liquid distillate), or other aldehydes (e.g., furfural). Phenolic resin manufacturers polymerize phenol by substituting formaldehyde on the phenol's aromatic ring via a condensation reaction. The selection of suitable reaction parameter results in optimum molecular weight distribution and residual monomer content necessary for maximum efficiency when used by the customer. The wide range of reaction conditions and monomers available to the resin producer allows for the production of a variety of resins specifically designed for use in individual applications.

We present the general chemistry of the polymerization of phenol with formaldehyde, the most common molecules used, to provide a general background of resin manufacture.

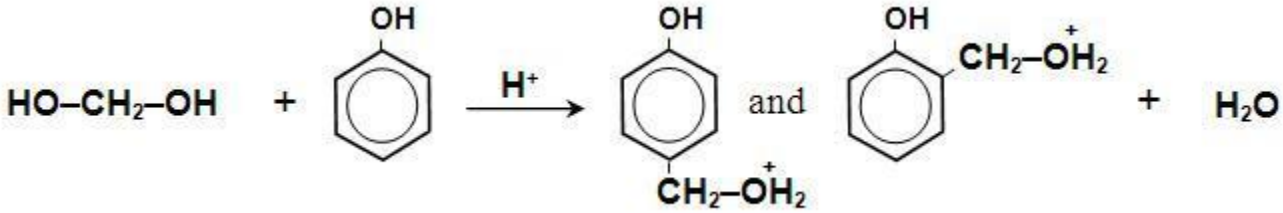
In aqueous solution, formaldehyde exists in equilibrium with methylene glycol.



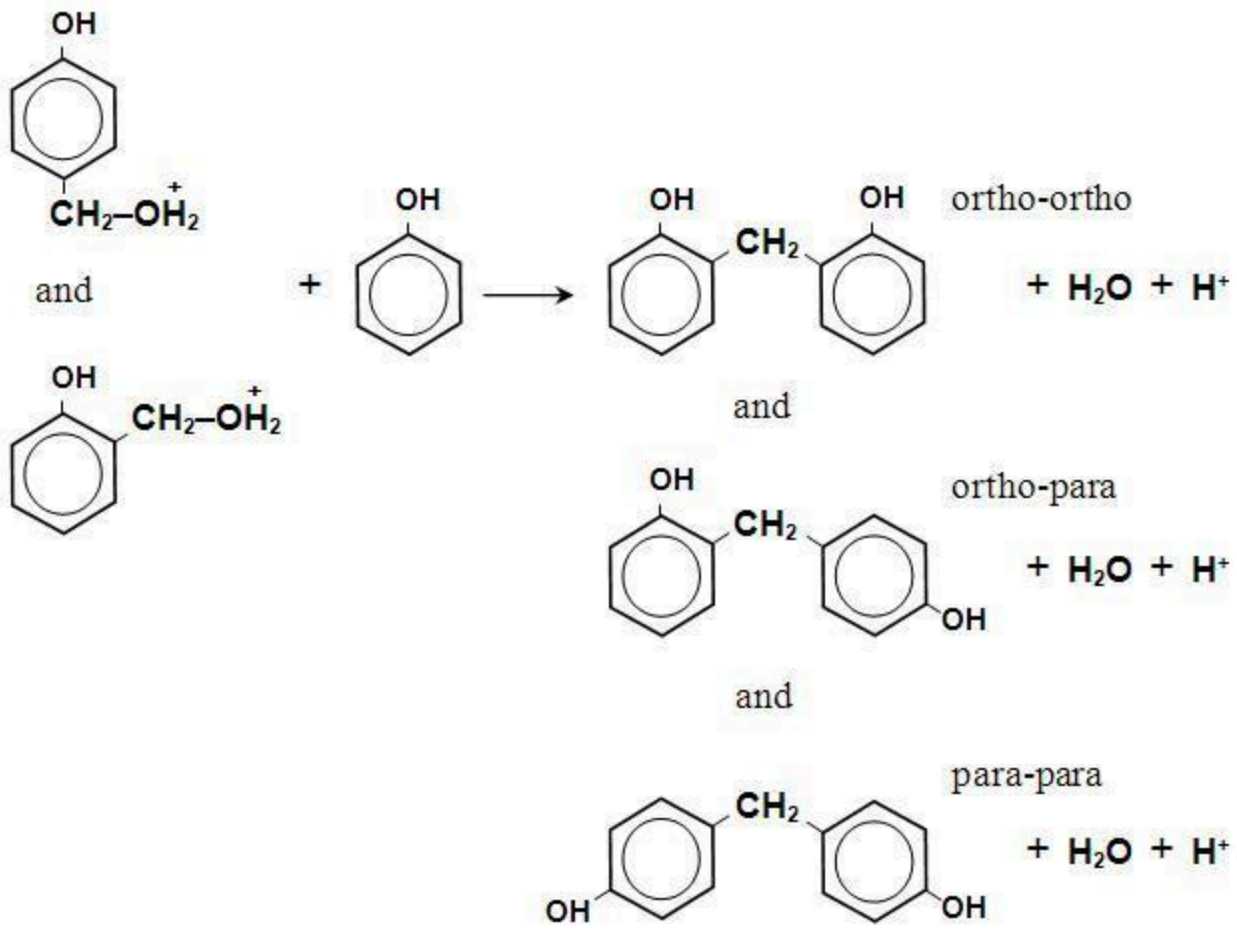
Depending on the pH of the catalyst, these monomers react to form one of two general resin types: NOVOLAC RESINS and RESOL RESINS.

Novolac Resins

An acidic catalyst and a molar excess of phenol to formaldehyde are conditions used to make novolac resins. The following simplified chemistry illustrates the wide range of polymers possible. The initial reaction is between methylene glycol and phenol.



The reaction continues with additional phenol, and splitting off of water.



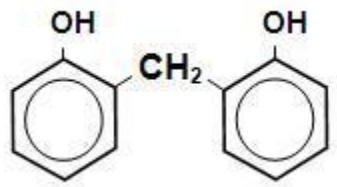
The reaction creates a methylene bridge at either the ortho position or the para position of the phenolic aromatic rings. The "rule of thumb" is that the para position is approximately twice as reactive as the ortho position, but there are twice as many ortho sites (two per phenol molecule) so the fractions of ortho-ortho, para-para and ortho-para bridges are approximately equal.

Branching occurs because reaction can occur at any of three sites on each ring. As the reaction continues, the random orientations and branching quickly result in an extremely complex mixture of polymers of different sizes and structures. The reaction stops when the formaldehyde reactant is exhausted, often leaving up to 10% of un-reacted phenol. Distillation of the molten resin during manufacturing removes the excess phenol and water.

The final novolac resin is unable to react further without the addition of a cross-linking agent. Plenco novolac resins come with and without a curing agent. The resins having the curing agent incorporated cure or "thermoset" to the desired degree when processed by the customer.

Because an additional agent is required to complete the resin's cure, the industry commonly refers to novolac resins as "two-stage" or "two-step" products. The most common phenolic resin cross-linking agent is hexamethylenetetramine, also known as hexa, hexamine, or HMTA. Ground and blended with the resin, hexa serves as a convenient source of formaldehyde when heated to molding and curing temperatures. A special attribute of hexa is that it reacts directly with resin and phenol without producing appreciable amounts of free formaldehyde. Hexa cures the resin by further linking and polymerizing the molecules to an infusible state. Due to the bond angles and multiple reaction sites involved in the reaction chemistry, the resulting polymer is not a long straight chain but rather a complex three-dimensional polymer network of extreme molecular weight. This tightly cured bonding network of aromatic phenolics accounts for the cured materials' hardness, and heat and solvent resistant properties.

Certain catalysts can affect the orientations of the methylene linkages. Catalysts that preferably promote ortho-ortho linkages tend to preserve the more reactive para positions:

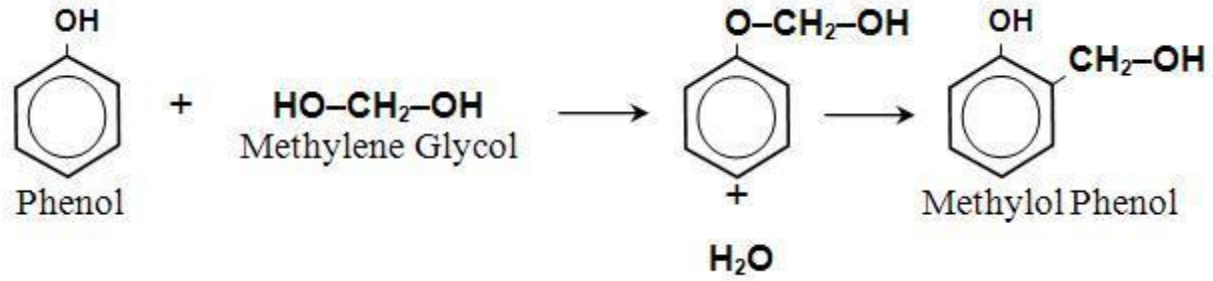


ortho-ortho
oligomer

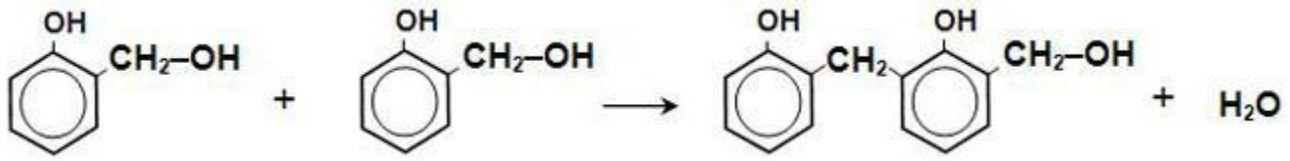
Novolac resins made with these catalysts tend to cure more rapidly than the standard randomly linked resins. Novolac resins are amorphous (not crystalline) thermoplastics. As they are most typically used, they are solid at room temperature and will soften and flow between 150° and 220°F (65°C - 105°C). The number average molecular weight (Mn) of a standard phenol novolac resin is between 250 and 900. As the molecular weight of phenol is 94 grams per mole, a Mn of 500 corresponds to a resin where the average polymer size in the entire distribution of polymers is five linked phenol rings. Novolac resins are soluble in many polar organic solvents (e.g., alcohols, acetone), but not in water.

Resol Resins

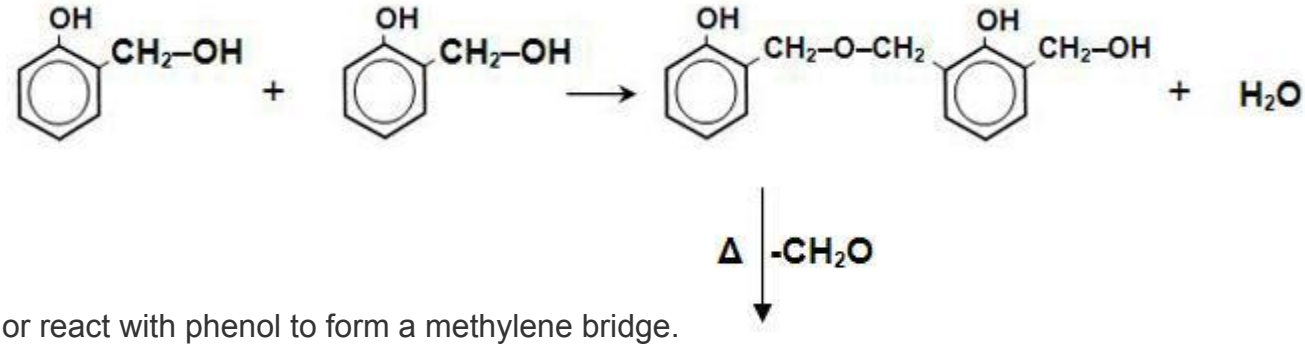
A basic (alkaline) catalyst and, usually but not necessarily, a molar excess of formaldehyde is used to make resol resins. The following two stages describe a simplified view of the reaction: First, phenol reacts with methylene glycol to form methylol phenol:



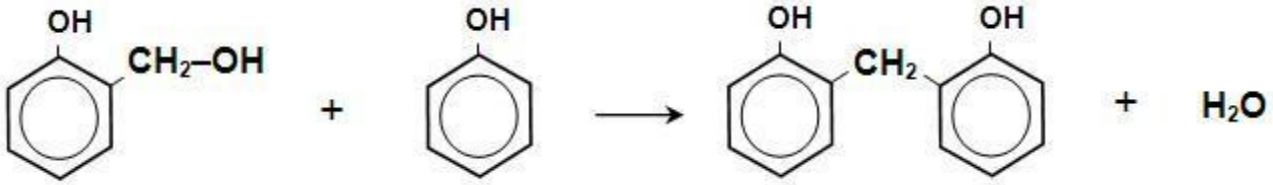
Methylol phenol can react with itself to form a longer chain methylol phenolic:



or form dibenzyl ether:



or react with phenol to form a methylene bridge.



The most important point in resol resin chemistry is that, when an excess of formaldehyde is used, a sufficient number of methylol and dibenzyl ether groups remain reactive to complete the polymerization and cure the resin without incorporation of a cure agent such as hexa. For this reason, the industry commonly refers to resol resins as "single-stage" or "one-step" type products. Resol resin manufacture includes polymerizing to the desired extent, distilling off excess water and quenching or tempering the polymerization reaction by rapid cooling. Because resol resins continue the polymerization reaction at even ambient temperatures, albeit at much slower rates than during manufacturing, they demonstrate limited shelf lives dependent on the resin character, storage conditions and application.

By manipulating the phenolic to aldehyde monomer ratio, pH, catalyst type, reaction temperature, reaction time, and amount of distillation, a variety of resin structures demonstrating a wide range of properties are possible. The typical number average molecular weight (Mn) of a straight phenol resol resin is between 200 and 450. TransAct Energy Corp supplies resol resins as liquids or in solvents with viscosities from 50 to 50,000 cps, or as solids in the form of lumps, granules, or fine powders. Organic solvents and the amount of water or phenol monomer left in the resin control the viscosity of the liquid resin products. Resol resins are usually water-soluble to a certain degree.

Characteristics

Bonding Strength

The primary use of phenolic resin is as a bonding agent. Phenolic resin effortlessly penetrates and adheres to the structure of many organic and inorganic fillers and reinforcements, which makes it an ideal candidate for various end uses. A brief thermal exposure to complete the cross-linking or "thermoset" process results in attainment of final properties. The unique ability of phenolic resin to "wet out" and to cross-link throughout the fillers and reinforcements provides the means to engineer the desired mechanical, thermal, and chemically resistant properties.

Applications benefiting from the hardness, and heat and chemical resistance properties afforded phenolic resins include abrasive grinding wheels, friction linings, refractory products, and other molded parts used in high temperature or aggressive environments. For years, phenolic resin's exceptional compatibility with cellulose fillers has been used to great benefit for particleboard, plywood, hardboard, oriented strand board, substrates for melamine laminates and decking applications. Composites for demanding applications such as on oil platforms, missile components, and heat shields are produced using phenolic resins along with process technologies such as resin transfer molding (RTM), pultrusion, or filament winding.

Liquid phenolic resins penetrate and saturate paper and other substrates to provide good mechanical strength, electrical properties, or filtration capabilities. Typical examples of these applications include NEMA electrical laminates, decorative laminates, clutch and transmission papers, and filtration products.

High Temperature Performance

A key characteristic of thermoset phenolic resin is its ability to withstand high temperature under mechanical load with minimal deformation or creep. In other words, cured phenolic resin provides the rigidity necessary to maintain structural integrity and dimensional stability even under severe conditions. For this reason, phenolic resin binders meet the challenges of high temperature environments in demanding applications such as refractory, friction, foundry and aerospace products. Examples of

applications that take special advantage of the dimensional stability of phenolic molding compounds are natural gas valves, automotive brake pistons, pulleys, and hydraulic and water pump housings and seals.

Chemical Resistance

Phenolic resins accommodate the harsh exposure of severe chemical environments. The inherent nature of phenolic resin provides an impervious shield to protect a variety of substrates from the corrosive effects of chemicals. Laboratory tests confirm minimal degradation from many chemicals after prolonged exposure, often at elevated temperatures. Typical exposures include gasoline, alcohol, oil, glycol, brake fluid, various hydrocarbons, and also weak acids and bases. Protective linings inside tankers used for bulk transfer of acids and other corrosive chemical products are often composed of phenolic resins.

Low Smoke and Toxicity

Burning phenolic resin typically generates hydrogen, hydrocarbons, water vapor, and carbon dioxide. Phenolic resin produces a relatively low amount of smoke at a relatively low level of toxicity. Manufacturers use phenolic resins extensively to address the safety concerns of the transportation industry. Automotive and mass transit industries choose phenolic resin for its high heat resistance and excellent flame, smoke, and toxicity properties. Another critical application is in air support systems for the mining industry and related electrical conduit supports. Phenolic resins designed to meet specific flammability ratings are available. Selective use of inorganic fillers and reinforcements often enhances protection in the event of contact with an ignition source.

High Carbon and Char Yield

Phenolic resins demonstrate higher char yields than other plastic materials when exposed to temperatures above their point of decomposition. In an inert atmosphere at high temperatures (600° - 2,000°F, 300 - 1,000°C), phenolic resin will convert to a structural carbon known as vitreous carbon. In many ways, this material behaves similar to ceramic and may actually contribute to structural integrity when exposed to fire situations. Manufacturers of structural composite gratings and pipes for offshore oilrigs, where fires are a constant threat, utilize phenolic resins for the characteristic. Phenolic resin is also useful in designing vitreous carbon articles such as special analytical electrodes, crucibles for melting rare earth metals, rocket nozzles, extremely high temperature bearings and seals, and heat shields for missiles. Automotive applications that benefit from the formation of a thin carbonized layer, such as brake blocks and pads, brake linings, and clutch facings also use phenolic resins.

The aerospace, defense, and electrical industries are heavily reliant on phenolic resins. Phenolic resin advantages include high heat resistance, excellent dimensional stability, as well as having a United Laboratories rating. Phenolic molding compound applications

within these industries include electrical commutators, switches, business equipment, and wiring devices. Phenolic resin retains its strength at high temperatures, resists creep under load, and possesses chemical and corrosive resistance. Phenolic resins are widely incorporated in household appliances because of their excellent electrical resistance, dimensional and thermal stability, and resistance to water and solvents.

Applications

Ablation

Phenolic resin chars when heated to temperatures greater than 480°F (250°C). This process continues at very high temperatures greater than 1,000°F (>500°C), until the resin completely converts to amorphous carbon. This characteristic contributes to the unique ablative properties of phenolic resins. An ablative surface is a heat shield designed to wear away in a controlled fashion at very high temperatures. Examples are rocket nozzles, rocket blast shields, and atmospheric reentry shields. Several aerospace ablative applications specify Plenco resins.

Abrasives

The variety of abrasive products available in the market is practically endless, as they have to meet the specific needs of the individual grinding applications and substrates. Applications range from simple cut off wheels to precision sanding tasks, and involve materials like metal, wood, minerals, and composites. Generally, there are three groups of abrasive products: bonded, coated, and non-woven.

Bonded abrasives:

Bonded abrasives like grinding wheels are comprised of abrasive particles embedded in a bonding matrix. While the grit used may be from a wide variety of minerals and abrasive particles, phenolic resin is the matrix binder of choice. Achieving the optimal combination of resistance to burst or fracture strength, flexibility and porosity, coupled to the manufacturing method, requires optimization of the binding resin to the specific application of the wheel in question. Modification of the blend of phenolic novolac powder, hexa, and liquid resol resin is usually needed to achieve such optimization. For increased strength, fiberglass reinforcement inlays are used. These inlays are themselves typically saturated with a special liquid phenolic resin.

TransAct Energy Corp tailors powdered and liquid resins for bonded abrasives to the specific needs of the customers and their unique cold forming or hot molding process. Accelerated cure resins are available as well as dust reduced powdered novolac-hexa products. Plenco resins are available as solvent-based flexible phenolic resins for use in fiberglass reinforcement inlays as well.

Coated Abrasives:

Coated abrasives are flexible grinding materials typically available as sheets, discs or belts. These applications require abrasive grains fixed to the surface of a variety of backings, like paper or fabric, by special liquid phenolic resin binders. The manufacture of coated abrasives with their unique properties requires multiple production steps. Plenco resins in solvent or aqueous liquid solutions meet the special requirements of this application.

Non-Woven Abrasives:
Household and industrial applications use non-woven abrasives, also called abrasive pads. The characteristically green pads used for cleaning the dishes are the most publicly visible non-woven abrasive. Manufacturers of non-woven abrasive parts typically employ the use of liquid phenolic binders. Plenco phenolic resins provide the excellent wetting properties and the short drying times needed by abrasive pad manufacturers to meet the technical requirements while achieving a high line speed for improved productivity.

Adhesives

Wood bonding applications such as particleboard or wafer-board have traditionally used phenolic resin binders. Due to their specific "affinity" for wood and wood fibers, special liquid phenolic resins may be required for the specialty wood adhesives industry typically in combination with a polyvinylacetate (PVAc) backbone polymer. Plenco liquid phenolic resol resins with low free phenol and low free formaldehyde contents are available especially for use in adhesive applications. TransAct Energy Corp can also supply low ash content, soluble solid resol resins, and of course a wide range of novolac resin-hexa systems.

Carbon

Phenolic resins have an excellent affinity for graphitic and other forms of carbon. Manufacturers often use the resin simply as a binder and adhesive for their carbon materials. At high temperature, phenolic resins form a char of amorphous carbon. This means phenolic bonded carbon materials can be heat treated to yield an all carbon structure. Because of these unique properties, phenolic resins find application in the manufacture of electrodes, carbon-carbon composites, carbon seals, and washers. Phenolic resins are the binder of choice for manufacturing the carbon brushes used in electrical motors, starters and the like. Depending on the manufacturing process, powdered or liquid solutions of novolac resin-hexa blends, powdered resol resins, and liquid resol binding systems provide the desired binding properties. Several Plenco phenolic resins meet the requirements demanded by this technically challenging application.

Coatings

Cured phenolic resins demonstrate exceptional chemical resistance. Railroad cars, storage tanks and heat transfer equipment are coated using phenolic resins as part of baked phenolic coating systems. Plenco straight phenolic resin systems approved for

coating applications are available and the researchers at TransAct Energy Corp are ready to tailor a resin system to the requirements of the customer.

Composites

Phenolic resins are the polymer matrix of choice in composite products especially when meeting high flame, smoke and toxicity (FST) properties. Phenolic resins provide for excellent strength at elevated temperatures in a variety of environments and are compatible with a multitude of composite fibers and fillers. Multiple applications benefit by using phenolic resins in the following composite part manufacturing processes:

- Resin Transfer Molding
- Pultrusion and Profile Extrusion
- Filament Winding
- Hand Lay-up

Lightweight and high strength honeycomb structured core materials for aircraft and other aerospace applications utilize phenolic binding resins, usually in a dipping-saturating process. The composite manufacturing processes and components vary significantly from product to product and process to process so that customized Plenco phenolic resins are the best answer for our customers to find the optimum process and composite performance.

Felt Bonding

Fiber felt manufacturers use phenolic resins with reclaimed or virgin fibers to produce thermal and acoustical insulation for the automotive and household appliance industries. Felt manufacturers achieve optimum rigidity, sound absorption and acoustical insulation performance by varying the density of the felt product. The versatility of the phenolic resin to affect the part density mirrors the versatility of substrate fibers used. Phenolic resins provide exceptional resistance under all environmental conditions. Specific applications are:

- Functional components used in visible areas (e.g., package deck)
- Below surface products used for padding and sound absorption (e.g., hood liner)
- Rigid parts used as substrate for decorative material

Felt manufacturers achieve specific performance requirements by judicious use of Plenco powder resins. Resin formulation provides for good mold release, improved compatibility with scrim materials, and accelerated cure speeds for production efficiency. Environmental considerations continue to grow in importance. Plenco phenolic resins for felt bonding applications exhibit low emission and odor levels. Low dust level versions of Plenco phenolic resins are available also.

Foam

Special phenolic resins in combination with the proper cure catalysts, surfactants and blowing agents produce foam products. Phenolic foam has a unique set of properties

such as excellent fire and heat resistance and a low smoke and toxicity rating when burned. Proper surfactants produce closed cell foams with excellent insulating R-values. Other surfactants produce open cell foams demonstrating unique water absorption properties. Typical application fields are:

- Floral foam (dry and wet foams)
- Orthopedic foam (for making foot print casts)
- Insulating Foams

TransAct phenolic resins are widely accepted by the foam industry for their superior consistency, crucial for the challenging production process.

Foundry

Many technologies are available to foundries for the production of dies for metal castings. Manufacturers using the shell molding process experience excellent dimensional accuracy, surface smoothness and high production rates using phenolic resin coated foundry sands. The shell molding process involves first creating mold cavities and cores by shaping sand coated with phenolic resin over a not metal form. Removed from the form and assembled, the mold and cores create the "negative" shape of the desired metal form. Hot metal is poured into the resin-sand mold and allowed to cool. Once hard, the excess resin-sand material is broken away revealing the metal part. Some recover the broken away sand for reuse. The careful selection of sand type, resin characteristics and coating method results in the desired mold and core properties such as strength, rigidity, flexibility, surface finish, part release and applicability to reuse.

TransAct Energy Corp provides phenolic novolac sand coating resins in pastille form, for consistent melting and coating, efficient transport, and low dust. Resin formulations make use of proprietary accelerants, plasticizers or release agents to achieve a wide range of properties. These additives together with a customized phenol level, melt point, and hexa amount achieve optimal performance for each foundry's requirements, like a low peel to improve release from the hot metal former. The Plenco product range includes resins for core sands, mold sands, and recyclable sand.

Friction

Phenolic thermoset resin is the choice for composite friction materials: the pads, blocks, linings, discs and adhesives used in brake & clutch systems that create retarding or holding forces with application against a moving part. The inherently heat resistant phenolic resin carbonizes and chars at extreme service temperatures, it does not melt and smear like other polymer matrices. This property results in restored friction properties when the material cools and "recovers" from hard braking. Formulas for

phenolic composite friction materials are combinations of friction and wear-controlling agents, reinforcing fibers and inert fillers blended with un-cured phenolic resin in an amount necessary to bond the other ingredients in place with sufficient strength and resiliency when finished. Judicious selection of the types and amounts of raw materials used allows for the optimization of performance with cost and consistency.

Formulas for basic friction applications may contain 5 to 10 different ingredients while specialized material formulas may include a score or two of raw materials. Only one type of bonding resin is typically used. The effect of that one binder on the final composite's properties depends on the total formulation and manufacturing method however. That is, no single type of resin product works optimally with all friction formulas or applications.

The salient step in the manufacture of phenolic composite friction materials is the molding and initial curing of the composite under heat and pressure. This molding step typically involves pressing a uniform blend of ingredients in a shaped mold preheated to 280° - 400°F (140° - 200°C) from one to three tons of pressure per square inch. The phenolic resin melts and flows during the molding operation to coat and then secure the other ingredients when the resin cross-links or "cures" to an infusible state. The resin's performance during the hot molding step is most important to assuring an efficient manufacturing process. Friction material manufacturers select the type and amount of binder resin product used as a complement to the envisioned manufacturing process, its compatibility with other raw materials, environmental concerns and the expected service requirements.

To this end, TransAct Energy Corp is uniquely suited to assist friction material designers with a number of liquid and solid novolac (2-stage) and resol (1-stage) phenolic resins demonstrating a wide variety of flow and cure character combinations. The resins can be custom formulated with cure accelerating or performance enhancing additives. Plenco resins are suitable for all types of brake and clutch uses, including pads for lawn & garden equipment and automotive brakes, blocks for on and off road trucks, and linings for industrial, oil field and marine friction applications.

Proppants (Frac Sand)

Oil and natural gas producers improve well yields using hydraulic fracturing fluids containing round specialty sands coated with phenolic resin. The industry refers to these sands as proppant or frac sands. The hydraulic fracturing fluid containing the proppant sand is pumped into the well effectively pressurizing the borehole and fracturing the surrounding rock. The fluid fills the nascent fissures and the resin-coated sand works as a prop to keep the fissure from sealing on release of pressure. Round

sand is used to provide a porous medium through which the oil and gas can easily flow. Proprietary proppant sands made with Plenco resins continually improve petroleum yields every day.

Refractory

High carbon yield, wear resistance, and excellent particle wetting and bonding properties make phenolic resins ideal for refractory products. There are two general categories of refractory products: shaped and unshaped. Hydraulically pressed refractory bricks, slide gates, shrouds, nozzles, and crucibles are examples of shaped products. Examples of unshaped products are tap-hole compounds, tundish liners and ramming mixes used in steel making. TransAct Energy Corp provides phenolic refractory resins as liquids in a variety of solvents, including water based systems. Manufacturers may also choose from a wide range of novolac-hexa powder resin products. Some companies combine phenolic resins with temperature resistant ceramic fibers in a vacuum forming process to manufacture riser sleeves, ladles, and hot toppings. This application typically uses novolac-hexa powder resins with low emission levels. Non-hexa cured Plenco resins are available for this application to reduce ammonia and formaldehyde emissions.

Rubber

Tires and technical rubber goods use straight phenolic novolac resins as reinforcing agents. TransAct novolac resin pastilles are the preferred choice for a manufacturer who compounds the resin into the rubber for superior mix consistency and reduced dusting when compared to using powders or resin in flaked form. Special effort assures consistent pastille size and shape to meet the requirements of the automated dosing systems used by the industry. Plenco phenolic novolac pastille resins are available in a variety of softening point and emission level versions. Some rubber applications require phenolic novolac-hexa powder resin products in combination with the rubber compound. TransAct Energy Corp provides novolac-hexa with customized flow and the hexa curing agent level specific to each application.

Substrate Saturation

Many applications use liquid phenolic resins to saturate substrates such as paper, fabrics, and wood. Phenolic resins receive preference because of their high mechanical strength, outstanding chemical resistance, and good flame resistant properties. Typically, solvent-borne resol resins are used, but depending on the specific products

and processes, aqueous resol resins or resol cured novolac resins in solvents are preferred. Typical application fields are:

- Paper laminates (decorative or functional)
- Engineered wood
- Filter paper impregnation (Oil filters, Gasoline filters, Air filters)

TransAct Energy Corp provides resins for the full range of technologies used in this application field and works to customize specific phenolic resins to the requirements of the individual customer.