

PVC Compounding:

Polyvinyl Chloride (PVC), otherwise known as vinyl or vinyl plastics, has already been commercial reality for more than half century. Reason for the acceptance of PVC includes, low ingredient cost, wide processing versatility, improved performance, increased decorative potentiality. These reasons can all be traced to the wide range of properties possible, not only with variations in the resins, but also due to the ability of PVC compounds to be modified by a wide variety of additive types and levels.

PVC is a major highly versatile thermoplastic. Four basic polymerization processes are followed for the manufacture of PVC & other VCM co-polymers, viz. mass, suspension, solution and emulsion.

Suspension process is the most favoured technique with nearly 75% of PVC being produced with it. Emulsion and mass polymerization are used to the extent of 20-25%. The solution technique is used only for speciality vinyl coatings which are generally VCM copolymer and terpolymers with vinyl acetate and acrylates.

Major types of PVC Resins

Polymerization Types	Salient properties	Main End-use Applications
Mass	High purity and porosity. Excellent transparency and electrical properties	Film, Bottles, Containers, cables etc.
Suspension	Overall good, coarser particle size, properties,	Pipe, Fittings, Leathercloth, Cables, Footwear, Bottles, etc.
Emulsion	Finer particle size, low DOP absorption at room temperature, Not very pure	Leather cloth, Plastisol coating applications
Solution (Mainly copolymer)	Solubility. Film formation and adhesion	Coatings

Types of PVC & their Applications

The most commonly used K-values in case of suspension PVC polymer are in the range of 55-60, 65-70 & 70-75.

PVC polymer having the K-value in the range of 55-60 is used largely for rigid PVC applications like films, Pipe fittings, bottles etc.

K-value in the range of 65-70 is used mainly for Plasticized applications, like cables, footwear, hoses, soft films etc. whereas rigid formulations are recommended for rigid PVC pipes, profiles, films etc.

Suggested K-value of PVC resins

Applications	Process	K-Value
1. Rigid		
1.1 Rigid Transparent	Calendering Extrusion Blown	57 - 60
1.2 Blister Pack	Calendering/ Extrusion with T-Die	57 - 60
1.3 Bottles, Containers	Blow moulding	55 - 60
1.4 Blow Moulding	Stretch Blow moulding	55 - 60
1.5 Free Foam Boards	Extrusion	55 - 60
1.6 Rigid Opaque	Blow Moulding Bottles, Containers	57 - 62
1.7 Pipe Fittings	Injection moulding	
1.8 Rigid Transparent Films	Extrusion Blown	65 - 69
1.9 Rigid Pipes, Profiles, Conduits, etc.	Extrusion	65 - 69
2. Flexible		
Flexible Films	Extrusion Blown, Calendering	65 - 69
Cables	Extrusion	65 - 69
Speciality Cables	Extrusion	69 - 75
Footwear	Injection Moulding	65 – 69
Leather Cloth, Coated Fabrics, dip moulded article	Calendering, coatings, dip moulding	65 - 69

Compounding Ingredients

In the massive form poly-vinyl-Chloride is a colorless rigid material with limited heat stability and with a tendency to adhere to metallic surfaces during processing. This is the reason it is necessary to compound the polymer with other ingredients to make useful plastics materials. By such means it is possible to produce a wide range of products including rigid piping to soft elastic cellular materials.

A PVC compound may contain the following ingredients:

- 1) Polymer
- 2) Stabilizers
- 3) Lubricants
- 4) Plasticizers
- 5) Fillers
- 6) Pigments
- 7) Polymeric Processing aids 8) Impact modifiers etc.

Other miscellaneous materials also used occasionally include fire retardants, optical brighteners and blowing agents.

PVC resins manufactured for use in dry-blending process are specially manufactured with particle porosity suitable for dry-blending in the type of formulation required for the application in question. Dry blending consists of mixing the solid constituents of a suitable PVC formulation with the liquid ingredients in such a manner that a uniform, dry, free-flowing powder results. The ingredients may include solids such as fillers, stabilizers, flame retardants, smoke suppressants, pigments and lubricants along with PVC resin to which liquid ingredients, including stabilizers, primary plasticizers, secondary plasticizers and liquid lubricant may be added. The finished powder must be uniform without solid agglomerates.

All processing methods start with a blending step in which additives (and possibly) are mixed with the PVC resin. The result may be a dry blend (or in some cases a damp or wet blend), a plastisol, an organosol, a blended latex, or a solution. This is followed by one or more melting and fusion steps to produce the end product.

Whether a PVC compound is flexible, semi-rigid or rigid the fusion process includes the entire sequence of structural and phase changes which the PVC resin and other component particles undergo during transformation from the original powdery state into the final processed and shaped state.

Stabilizers

When PVC is heated to 170~180°C, chlorine and hydrogen in the molecules are eliminated and release of hydrogen chloride becomes evident. Once such decomposition starts, unstable structures are formed in the molecule, which further accelerate HCl elimination and decomposition. As PVC is heated to soften during the extrusion or moulding process, prevention of hydrogen chloride elimination due to heat and subsequent decomposition is required. The stabilizer prevents such initial elimination of hydrogen chloride from PVC.

Therefore, use of stabilizers (metal compounds) is essential to prevent the chain reaction of decomposition. They can also impart to the PVC enhanced resistance to daylight, weathering and heat ageing and have an important influence on the physical properties and the cost of a formulation. They are invariably supplied in the form of application - specific blends of which the main constituents are metal soaps, metal salts and organometallic compounds. The choice of heat stabiliser depends on a number of factors including the technical requirements of the PVC product, regulatory approval requirements and cost.

PVC is required to be stabilized during high temperature processing on three counts:

Firstly, discoloration of compound, secondly, evolution of HCL and thirdly, development of unsaturation followed by severe cross-linking which can catastrophically raise the torque/melt viscosity leading to mechanical damage to processing equipments.

The main heat stabilisers in a formulation are usually combined with co-stabilisers which are organic materials such as polyols or epoxidised esters: they provide an additive synergistic effect, especially in the case of some forms of heat stabiliser, an enhancement of overall stabiliser performance. Every stabiliser has typical uses, although a number of different types may be used in the same application sector.

Lead-based systems are being voluntarily phased out within Europe under the Vinyl 2010/VinylPlus voluntary commitments of the PVC industry. They are being replaced by Ca/Zn or Ca/organic stabilizers.

The majority of Tin stabilisers are used for rigid wrapping films, roofing and transparent rigid sheets for construction applications. Tin stabilisers are employed for drinking water applications in some countries where lead has been banned in this application for many years. The major metals contained in stabilisers are lead (Pb), barium (Ba), calcium (Ca), and tin (Sn). The stabilisers are classified into Pb stabilisers, Ba-Zn stabilisers, Ca-Zn stabilisers, and Sn stabilisers. Ba-Zn stabilisers and Ca-Zn stabilisers are used as metallic soaps such as stearates, while Sn stabilisers are used as organic tin (dialkyl tin compounds). Other than metallic soap, Pb stabilisers are used as basic sulphate, basic carbonate, or basic phosphate.

The PVC stabilizers can be grouped in four ways: Lead based stabilizers, Tin based stabilizers, mixed metal based stabilizers and finally non-metal based stabilizers. Their structures and mode of action are discussed below:-

Excellent stabilizers do act in a variety of ways, with both preventive and curative measures to stabilize PVC.

Following are the major functions:

1. HCL Absorption
2. Elimination of labile Chlorine
3. Prevention of Autoxidation
4. Addition of polyene sequence
5. Carbenium ion elimination

Example of Stabilizers:

Lead based Stabilizers: TBLS, DBLS, DBLP, DBLP,LS

Tin Based Stabilizer: Di-Butyl Tin Dilaurate, Di-Octyl Tin Maleate, Dibutyl Tin Bis isooctyl Mercapto acetate, Monomethyl TinTris 2-Mercapto ethyl oleate. Etc.

Ca/Zn stabilizers are very popular for rigid films for food packaging & in pipes/ cables as also bottles for mineral water. Examples are Calcium Stearate, Zinc stearate.

Non-metallic Stabilizers are like epoxy based stabilizer used as a secondary stabilizer.

Pentaerythritol is commonly used with Ba/Cd system while sorbitol, glycerol with Ca/Zn systems.

Lubricants

Lubricants are essential to reduce friction. Since friction can arise out of two separate processes, generally two different types of lubricants may be required. The internal lubricants are those which reduce the friction arising out of polymer chain slippage with respect to each other. External lubricants are those that help reduce friction between metal surface and the polymer chains in contact with it. There are certain lubricants which can perform this dual role and so they are called internal-external lubricants

Internal lubricants are quite compatible with PVC with the result that addition of internal lubricant not only reduce internal friction but also melt viscosity giving better overall flow at lower power requirements. In this sense, internal lubricants are similar to plasticizers but no. detrimental effect on mechanical properties. Plasticizers tends to decrease hardness and particularly Tg. Though compared to plasticizers, lubricants have only limited compatibility with PVC.

External lubricants have poor compatibility with PVC and tend to migrate towards surfaces thereby increasing lubricity between melt and metal surfaces. Thus they have less effect on melt viscosity as compared to internal lubricants.

Lubricants have significant effect on gelation time of PVC also. The internal lubricant due to its solvating or plasticizing effect may reduce gelation time or it may not affect it or it may even delay it by reducing friction between particles before melting. While external lubricant tends to increase gelation time as it tends to reduce not only friction but also adhesion of PVC chains to metal walls through which heat is flowing. This is one important way of characterizing the lubricants for their properties.

Lubricant selection is a difficult process as it calls for several parameters to be considered like polarity, compatibility etc. Mechanism by which a lubricant acts internally is by reducing Vander Waal's force between polymer molecules thereby allowing chain slippage to occur easily. While a lubricant acts externally by either coating metal surface if it is very compatible with PVC or by reducing PVC particulate adhesion with metal surface, if it is somewhat compatible with PVC.

Examples are Metallic Stearates, Fatty Acid Esters/Amide, Fatty acids, hydrocarbon wax etc.

Plasticizers

Plasticizer plasticize PVC and makes it softer. In addition, plasticizers help stabilize PVC, make it more processable by reducing viscosity, allow to flexible at different range of temperature and add to special properties like impact resistance and flame retardancy etc. Thus, proper choice of plasticizer became an important part of PVC compounding.

Use of plasticizer in PVC is common giving rise to far more variety of products than what is feasible with unplasticized PVC.

Nearly 40-50% of all suspension PVC produced and nearly 95% of all emulsion PVC finds usage in plasticized applications. Since typically in a plasticized PVC application the wt% of PVC is 30-60% as against 90% or more in UPVC applications.

The most popular general-purpose plasticizers are the phthalates, although epoxies, phosphates, adipate diesters, sebacates and polyesters are also in common use. With some 500 different plasticizers to chose and combine form, an unlimited number of formulations is possible.

The choice of plasticizer is exacting because it affects the physical properties of the end product. The choice of plasticizer often comes down to finding one that satisfies the endproduct property requirements, is compatible with the resin, and is least expensive.

Epoxy plasticizers also provide heat and light stabilization. The phosphates improve flame resistance, but may weaken heat and light stability. The polyesters and trimellitates are used where durability is vital, but where low-temperature properties are less important. Aliphatic diesters, on the other hand, impart good low temperature properties. Other considerations include: approval for food packaging, specific gravity and compatibility with other additives in the formulation. Secondary plasticizers can be used in smaller quantities to impart some special properties like heat stability etc.

Fillers

Fillers are primarily known for cost reduction, there are other important advantages that can be derived from fillers viz. increased rigidity and flexural modulus, increased hardness, and density and increased functional depending upon role they play in PVC compounding. Most fillers being non-burning may act as flame retardant or smoke suppressant agents to a mild extent.

Examples are Calcium Carbonate, Clay and Talc, Silicas and Glass Fibres, Flame Retardant Agents etc.

Calcium carbonate (CaCO_3) is the predominant filler used in polyvinyl chloride (PVC) compounding. Most CaCO_3 fillers are selected grades of mineral calcite. They are typically called ground limestone, whiting, or simply calcium carbonate. Surface treatment of the filler is an important criterion. Surface treatment applies to any agent that alters the surface of a filler, pigment, or fibre. The treatment is generally designed to improve dispersion by displacing the adsorbed water layer. Stearic acid is very effective and is commonly used. Considerable improvements in the properties of composites can result from surface treatments but the most important advantage is the reduction of viscosity in processing compared with untreated one. Other non-carbonate filler includes Kaolin, Talc, Mica, Wollastonite, silica, calcium silicate etc. Insulation resistance is a term applied by the electrical industry to volume resistivity as measured on wire. Depending on the specific grade, CaCO_3 fillers can have a significant effect on resistivity.

Pigments

The use of pigments makes it possible to produce a great variety of materials in colours varying from pastels to deep hues, as well as the various colours and marble like shades. Broadly speaking, there are two types of colourants used in plastics, namely, dyes and pigments, both organic and inorganic, the essential difference between them being that of solubility. Dyes are fairly soluble in plastics, whereas pigments, being insoluble, are dispersed throughout the mass. The choice is either depends on resin compatibility or the need for solubility of almost equal importance is colour stability-that the dye-stiff or the pigment is stable at mould temperatures and on exposure to the light, moisture and air expected in the end use applications. Colorants also are chosen for strength, electrical properties, specific gravity, clarity and resistance to migration.

A pigment first of all must meet given end use requirements, such as light-fastness, transparency or opacity, brilliance, down to specific shade. It also must disperse well. Use of suitable dispersing additives play a vital role in efficient dispersion of pigments. The dispersion of the pigment is a process by which pigment particles are wetted down by the resin in the liquid or molten stage. How well a pigment disperses depends on the temperature at which the two materials are mixed, the particle size of the pigment, and the molecular weight of the polymer. The mixing time and equipment are very important.

Flame Retardant

Flame Retardants are used to affect combustion in plastics. There are many flame retardants, whose choice depends primarily on the resin to which they are being added. For example, the flame retardant might be added to keep temperatures below a given combustion level, or to smother a reaction between the material and oxygen or other combustion-aiding gases, or, finally, to work on combustion through various types of vaporization.

Flame retardants thus work on four basic principles: either they insulate, create an endothermic cooling reaction, coat the product thereby excluding oxygen, or actually influence combustion through reaction with materials that have different physical properties.

Flame retardants can be inorganics such as alumina trihydrate (ATH), antimony oxide, or zinc borate, or organics such as phosphate esters and halogenated compounds of various types.

Blowing Agents

A blowing and foaming agent is used alone or in combination with other substances to produce a cellular structure in a plastic mass. The term covers a wide variety of products and techniques, but compounders are limited to chemical agents, which decomposes to react under the influence of heat to form a gas.

Chemical blowing agents range from simple salts such as ammonium or sodium bicarbonate to complex nitrogen-releasing agents. The basic requirements for an ideal chemical blowing agent are:

1. The gas release temperature must be within a narrow range.
2. The release rate must be controllable but rapid.
3. The gas must not be corrosive.
4. The compound must be stable in storage.
5. The residue should be colourless, non-staining, and free of unpleasant odours.
6. The compound and residue must be non-toxic.
7. The residue must be compatible with the plastic to be foamed and have no effect on its properties.
8. Nitrogen-releasing compounds dominate the field of chemical blowing agents. Some of the products commercially available are the azo compounds, such as azodicarbonamide (azo-bisformamide), the N-nitroso compounds, and sulphonyl hydrazides. Azodicarbonamide has been for years the principal choice of the chemical blowing agent family. The temperature range in which azodicarbonamide liberates coincides with the temperature at which a number extensively in vinyl plastisols and calendered vinyl, as well as during the early stages of extrusion and injection moulding of structural foams based on polyethylene, polypropylene, vinyl, styrene and ABS.

Impact Modifiers

The function of an impact modifier is to INCREASE the toughness of a brittle, glassy polymer so that it will not break when subjected to impact. Although individual mechanisms have been suggested, it is more apparent that these mechanisms are inter-related:

1. Crack Stopping, whereby the impact modifier stops the propagation cracks initiated by a sudden blow. Proper particle size and efficient distribution of the impact modifier are essential so that the concentration of impact modifier particles is adequate to be the right place when needed.
2. Yield promoting, whereby the impact modifier lowers the yield point (stress) of the PVC, allowing it to yield or deform rather than fracture when subjected to a sudden blow. This mechanism is the generation of heat when the elastomeric-type impact modifier is deformed in a viscoelastic manner. The instantaneous heating of the surrounding PVC matrix results in raising the glass transition point to allow yield rather than brittle fracture.

Types of impact modifiers: Organic impact modifiers: ACR (All-acrylic), MACR (Butadiene modified acrylic), MBS (methacrylate-butadiene-styrene copolymers), MABS (methacrylateacrylonitrile-butadiene-styrene copolymers), non-predefined elastomers (NPDEs), ABS polymer etc.

Compounding of PVC

Compounding is the most important operation in the PVC processing, whereas, the PVC resin is formulated into a compound with the desired properties, with respect to processing and end product by addition of selected additives.

Adding and mixing additives into Plastics is an integral part of a much broader operation called compounding, in which ingredients including the colourants are initially mixed together into a nearly a homogeneous mass as far as possible.

The nature of resin and additives called for compounding a wide range of mixers (dry powders, slurries, pastes, granules etc.) and a corresponding range of mixing operations.

Compounding involves the fusion of different materials into a homogeneous mass that is uniform in composition and structure. The actions in this type of mixing consists of mixing, folding, stretching, wiping, compressing and shearing. However, component materials may be dryblended either in preparation for compounding or for direct fabrication.

The major types of plastics, compounding equipment in current use are,

Batch type mixers

Two roll mills

Two roll mills have been the basic processing equipment in rubber and plastic processing plants. Two roll mill as mechanical device used to transfer a raw material into a condition ready to use or into a stage preparatory for further processing. Compounding of flexible PVC compounds or soft colour matches can be done on two roll mill. Sheets manufactured using two roll mill are further passed through grinder to get the granules which are suitable for further finished product processing.



Banbury mixer

Banbury mixer is the trade name of the first internal mixer introduced to the rubber industry.

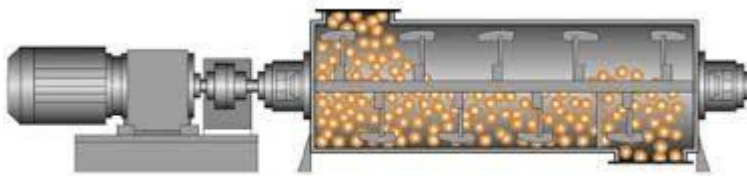
The Banbury mixer consists of an enclosed mixing chamber, in which two tear-drop shaped rotators operate, with a feeding hopper section to receive material for mixing, an air-operated ram mounted above the feed hopper and a door at the bottom, which may be either the sliding or the hinged type, to discharge the batch.

Revolving in opposite directions, and at slightly different speed, the two rotors keep the material in constant circulation with kneading and blending action between the rotors, and a shearing and action between chamber walls and rotors. The masticated compound further dropped to extruder through which the material flows and using either die-face cutting or strand cutting and converted into regular shape granules.



Continuous mixers

Continuous mixers high shear, fluxing mixers, have been preceded by two batch mixers, the internal mixer and the two roll mills. This mode of mixing PVC compounds lends itself to the discharging off fused material for further processing to strainer-extruder, mills and calenders.



Farrel continuous mixers

Material amount of preblend usually prepared in large ribbon blenders are fed automatically to the Farrel continuous mixers. The feed sections of the two rotors are always kept in a starved condition. The two rotors turn in opposite directions and each identical rotors can be subdivided into three functional sections. These mixers are suitable to process rigid / semirigid flexible dry blends.



Ko-kneader

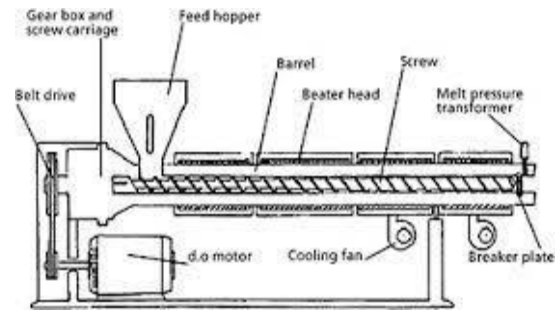
Ko-kneader, a continuous mixer, is basically a single screw extruder but with the same important modifications, which makes it unique. A specially threaded screw rotates and reciprocates axially inside a cylindrical barrel. Ko-kneader are suitable to process rigid, semi rigid or flexible dry blend. Die-face cutting or strand cutting, both are possible using ko-kneader.



Plastificator

The plastificator, an intensive, high shear combined compounder and plasticizer handling plasticized PVC. It consists of a conical rubber rotor revolving at constant speed in a barrel conforming to the shape at the rotor and extending into an extrusion screw. Premix is proportioned by two screws from a feed hopper into the gap between the tapered rotor and its barrel, it is plasticized & fluxed the material which is rolled into agar like pieces by the ribbed-cone surface, is moved into the screw section and conveyed under compression to granulator consisting of a die plate and palletizing knives.

Single screw extruder



The heart of the extruder is screw. Its function is to convey resin blend from the hopper and deliver it into the die at a uniform rate and as a homogeneous melt. This blend is conveyed in three states: First, as a blend of solids (powder blend), then as a mixture of solids semifluxed crumb, and finally as a melt. To achieve these three basic types of fully flighted screw designs are in use,

1. The constant pitch, decreasing channel depth type.
2. The metering type and
3. The constant channel depth, varying pitch type.

As usual the extender will have a breaker plate, screen pace and a stand die with a die face cutting or strand cutting arrangements.

Twin screw Extruder



In twin-screw extruder, two screws are arranged side by side. One design incorporates screws they are intermeshing and self wiping. Since the screws rotate in the same direction, material moves helically along the inside barrel wall path from the feed section to the discharge point.

The geometry of the screw components is such that the root of one screw is constantly wipe by the flight top of the second screw with a uniformly small clearance between them at every point. Thus, dead spots are eliminated, the residence time of each melt particle is uniform and purging times are shortened. Because of the polymers, pastes, flakes, powders of low density, and material molten polymers, efficiently conveyed irrespective of friction coefficients. With positive conveying operations, with partially filled screw flights are possible while degassing is going on in some zones or additional components are introduced into others.

Dry Blending of PVC Compounds High Speed Mixer



Generally, rigid dry blend will be processed with the high-powered intensive mixtures. Such blends must be dry, free-flowing powders with a minimum of agglomerates for extrusion of rigid pipe & profile extrusions. Dry blending should not be confused with preblending, which is just gentle physical mixing of ingredients. The main advantages of this compounding method are:

1. Low heat history (because of fast cycle, low heat exposure)
2. Lower equipment investment.
3. Lower raw material costs & faster extrusion rates.

Such high intensity mixers convert horsepower into mechanical energy. The high shear action of the mixing blends is responsible for uniform dispersion and thorough mixing. This type of blender can prepare batches, including the mixing and cooling, with relatively short cycles (10-15 min) and achieve excellent dispersion. PVC resin is heated to a point where residual moisture is driven off and the resin becomes absorptive (80-95°C); at this point, the liquid compounding ingredients are added. When approx. 100°C is reached, filler, lubricant, pigment and modifiers are added, and the mixing cycle continues to about 110-115°C. Next, the blend is cooled to approx. 50°C and stored for further processing. The mixing and cooling processes can be automated, and each cycle will consume 5-8 min.

Testing of PVC Resin

The most significant properties of commercial PVC resins required to be evaluated are:

1. K-Value
2. Bulk Density
3. Plasticizer absorption
4. Electrical conductivity of water extract
5. Powder flow
6. Sulphated Ash content
7. Fish eye content

Testing of PVC compounds

- Specific Gravity – Lower the value, volume wise better is the output
- Shore hardness – Indicates degree of plasticization
- Bulk density – Higher bulk density gives higher output
- Mechanical properties – Indicates the strength of compounds
- Vicat softening point – In case of rigid formulation, higher the softening point better it is
- Heat distortion temp. – In case of rigid, higher the value better is the performance
- Static heat stability – Higher the heat stability, longer is the run time
- Gelation time – Indicates fusion characteristics
- Volume Resistivity – Electrical property, higher the value, better is the electrical resistance
- Surface Resistivity – Lower the value, better are the static properties
- Volatile loss – In case of plasticized application, lower the losses, longer is the shelf life
- Heat Aging test – Lower the value, longer is the shelf life
- Cold bend – Lower the temp., resistance, better is the flexibility
- Cold Flex – Lower the low temp. resistance, better is the flexibility
- Water absorption – Lower the value better, is the surface finish
- Compatibility – Lesser the migration, better is the surface finish

List of Applications with recommended important additives in formulations:

<u>Application</u>	<u>Resin</u>	<u>Stabilizer</u>	<u>Lubricant</u>	<u>Other ingredients</u>
PVC conduit Pipes	K-67	Lead or Tin stabilizer	Stearates or waxes	Coated CaCO ₃ as a filler may be added depending upon the requirement
PVC potable water pipes	K-67	Lead stabilizer	Stearates or waxes	Coated CaCO ₃ as a filler recommended for ISI or non ISI pipes
Transparent Rigid PVC films	K-57 to K-62	Tin Stabilizer	Esters & complex Esters	MBS as a Impact modifier and Acrylic type processing aids as per the requirement
Bottle compounds	K-57 to K-60	Ca-Zn or Tin stabilizer Epoxy based soyabean oil	Esters or waxes	MBS type of impact modifiers are recommended

Cable compounds	K-67 to K-70	Lead or Ca-Zn	Specialized Ester waxes, stearates	Depending on the type of cables, plasticizers like DOP (General purpose), DOA (Low temp.), DIDP/TOTM (Heat Resistance), Polymeric (Low migratory), CP-50 (Economical) CaCO ₃ as a filler depending up on the requirement
Shoes	K-67	Ca-Zn or Ba-Zn stabilizer	Esters, Waxes or Stearates	Depending on the softness, DOP & CP50 are be added
Profiles	K-67	Lead or Ca-Zn stabilizer	Esters, Stearates or Waxes	MBS or ABS type as a impact modifiers Acrylic type as a processing aid
Leather cloth	K-67 or Paste grade K-67	Ca-Zn or Ba-Zn	Viscosity controllers, Release agents	Combination of blowing agents are used as per the requirement

Guideline formulations of few important PVC applications:

PVC - Pipe

	ISI (in phr)	Commercial (in phr)
PVC (K-67)	100	100
One pack stabilizer	2.2 – 2.4	2.4 – 3.0
Coated Calcium Carbonate	8.0 – 12	15 – 40
External Lubricant	As required	As required
Pigment	As required	As required

Calendered PVC Sheet and Film formulations

	Clear (in phr)	Opaque (in phr)	Non-stress whitening clear (in phr)
PVC resin (K=60)	100	100	100
MBS or ABS impact modifier	10 - 15	-	-
High efficiency impact modifier	-	-	10 – 15

General purpose MBS or ABS (or acrylic or high efficiency MBS or ABS impact modifier)	-	8 - 12	(6 - 10)
Acrylic processing aid	1.5 – 2.0	1.5 – 2.0	1.5 – 2.0
Acrylic lubricant processing aid	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0
Tin stabilizer	2.0	1.6 – 2.0	2.0
Internal Lubricant	0.5 - 0.8	0.5 - 0.8	0.5 - 0.8
External Lubricant	0.2 - 0.4	0.2 - 0.4	0.2 - 0.4
Release agent	0.05 - 0.2	0.05 - 0.2	0.05 - 0.2
Blue toner (1% in PVC)	0.06	-	0.06
TiO ₂		As needed	

PVC Injection Moulded Pipe Fitting Formulation:

PVC resin (K=57)	100
High efficiency MBS, ABS, Impact modifier, (CPE)	1.0 - 3.0
Acrylic processing aid (for high efficiency acrylic processing aid)	0.8 – 1.0
Tin Stabilizer	1.5
Internal Lubricant	1.0 – 1.5
External Lubricant	0.2 – 0.3
Calcium Carbonate	1.0 – 2.0
TiO ₂	As required

Shoe Soles

PVC resin K-67	100 (K value around 70)
Plasticizer	70-90
Heat Stabilizer (tin stabilizer)	0.3 – 0.8

Lubricant	0.4 – 0.6
Pigment	As required
Fillers	As required

Floor coverings/ Wall coverings

	Floor covering	Wall covering
Foam Layer		
Paste grade Resin (K-value 65-70)	100 - 70	100
Micronised Suspension resin	0 - 30	-
Plasticizer	55	65
Azodicarbonamide	2.5	3 - 4
Stabilizer (or Kicker) (Tin Carbodilate/ Ca-Zn Liquid Stabilizer)	0.5 - 2.5	1 - 2.5
Filler (Calcium Carbonate) Titanium Dioxide	5	5-10
Foam Layer		
Paste grade resin (K-value 7580)	80 - 60	100
Micronized suspension resin	20 - 40	-
Plasticizer	40	55
Tin Stabilizer	1 - 2	1 - 2

Heat Resistance Cables

PVC K-67	100
DIDP/TOTM	40 – 50
Stabilizer	4 - 8
Epoxy	5.0 – 7.0
Stabilizer	1 – 3
Clay	5 – 10
Antioxidant	0.5 – 1.0

Low Temp. Cables

PVC K-70	100
DOA/DOS	30 - 40
Stabilizer	4 - 8
Lubricant	1 - 3

General purpose Cable compound

PVC cables (Insulation)

PVC K-67	100
DOP	40 - 70
Chlorinated P. oil	10 - 20
Stabilizer	4 - 8
Lubricant	1 - 3
CaCO ₃	0 - 10

General purpose Sheathing compound

PVC K-67	100
DOP	40 - 70
Chlorinated P. oil	10 - 20
Stabilizer	4 - 8
Lubricant	1 - 3
CaCO ₃	50 - 75

Microcellular PVC Footwear

PVC K-67	100
DOP	70 - 90
Stabilizer	4 - 6
Lubricant	1 - 2
Blowing agent	1 - 2
Liquid Internal Lubricant	0.5
Antioxidant	0.5 - 0.75

Petrol Resistance

PVC K-67	100
Polymeric Plasticizer	50
Stabilizer	4 - 6
Paraffin oil	0.2 - 0.3
Nitrile Rubber	25 - 30
Antioxidant	0.5 - 0.75

PVC Profile

PVC K-67	100
Stabilizer	2.0 – 4.0
External Lubricant	0.4 – 0.5
Internal Lubricant	0.2 – 0.3
Flow promoter	2.0 – 3.0
Light Stabilizer	1.0 – 2.0
TiO ₂	5.0 – 7.5
Impact modifier	10.0 – 15.0

* Kindly note, the above recommended formulations are suggested to our best of our knowledge. Users have to select & fine tune the dosage of additives as per their requirement & machinery used.

Few tips on Do's & Don'ts:

DO:

1. Check raw material to required specification
2. Evaluate new materials prior to switching over production scale operations
3. Follow proper sequence of addition in compounding
4. Optimize formulation and processing parameters
5. Keep records of processing parameters and establish your own products standards
6. Upkeep equipment maintenance
7. Ensure good house keeping

DON'T:

1. Arbitrarily change any single ingredients in formulation without correspondence required changes in other additives. In other words look as overall formulation.
2. Forget to check contaminants in the raw material
3. Over formulate to 'play safe'
4. Over Dry-Dry blends especially for flexible
5. Neglect Lubricant / Stabilizer balance in rigid

About the Author:

Mr. "Narendra S . Ayare, science graduate with Plastic Technology & Marketing Management diploma having 50 years grass root experience in the field of Plastics, Polymerization (PVC),Compounding, Processing, Application & Product development, Troubleshooting.

Accomplished value addition in the development process of all type of Plastic products to attain various required properties. Experience of working in a leading Petrochemical company in Technical sales & services.

***Accomplished leadership role in renowned additive manufacturing organization and instrumental in developing special products catering to the industries.
Widely travelled and presented papers in national and international conferences.***

Image Courtesy : Various Websites