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Review of the Flexible PVC Supply Chain, Cost Drivers and Trends

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VINYL DIVISION

Review of the Flexible PVC Supply Chain,
Cost Drivers and Trends

Outline

- **PVC Resin Review**
 - Definition
 - Raw Material feed stocks
 - Cost drivers
- **Plasticizer Review**
 - Definition
 - Raw Material Feed stocks
 - Cost drivers

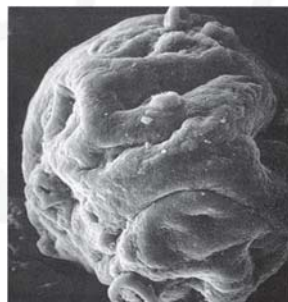
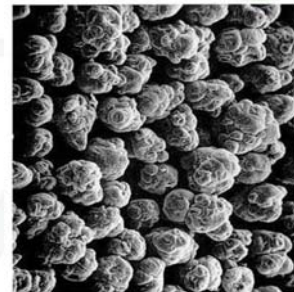


Outline

- **Trends in the flexible PVC market**
 - Regulatory
 - Market Trends
 - Building and Construction
 - Wire and Cable
 - Medical
 - Automotive
- **PVC formulation review**

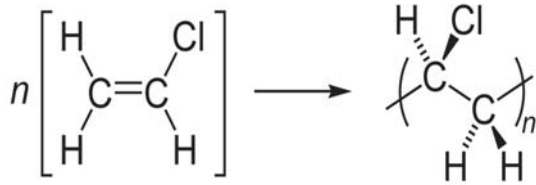
What is PVC

- **Thermoplastic polymer**
- **Third most widely used plastic**
- **Can be compounded with various additives to provide a desired performance**
 - Unusable as a thermoplastic without the use of stabilizers, lubricants, etc.
- **Recyclable**
- **White powder**
- **50 - 200 μ m diameter particles**

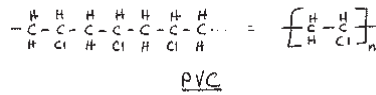
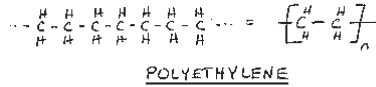


What is PVC

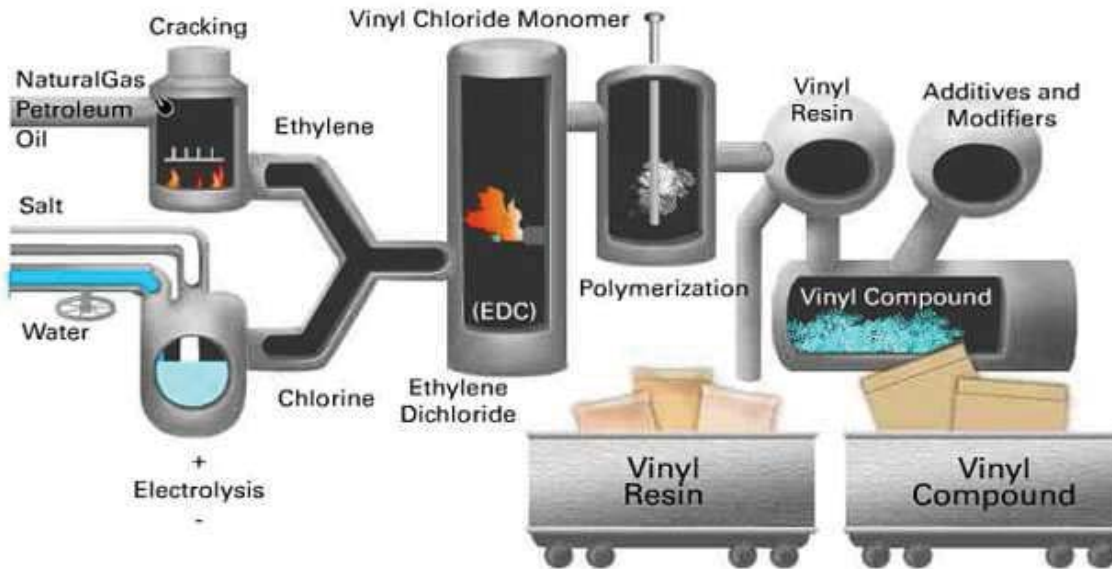
- **56.8% Chlorine, 38.4% Carbon, 4.8 % Hydrogen**
- **Can be compounded with various additives to provide a desired performance**



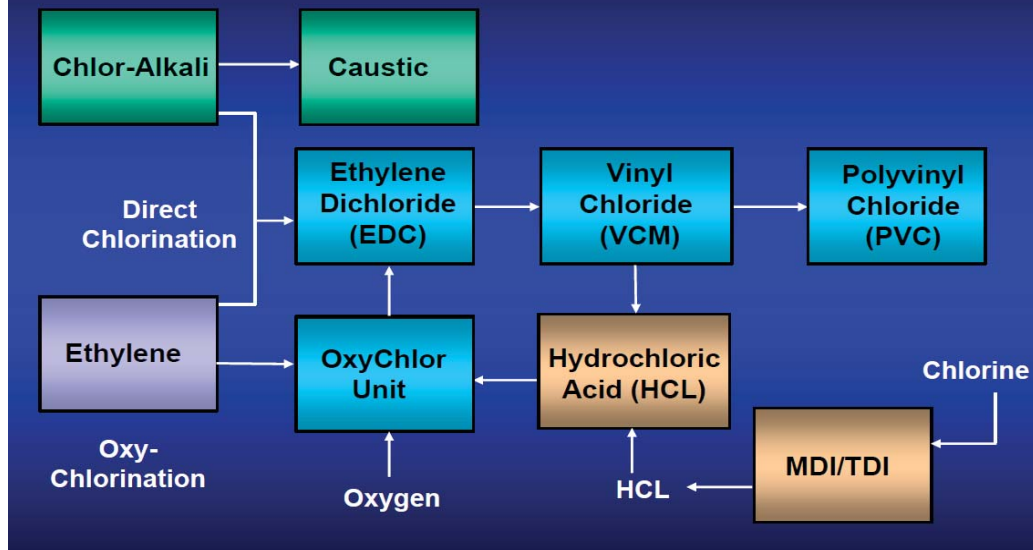
WE OFTEN REPRESENT POLYMERS
LIKE THIS :



Mfg. of PVC Resin



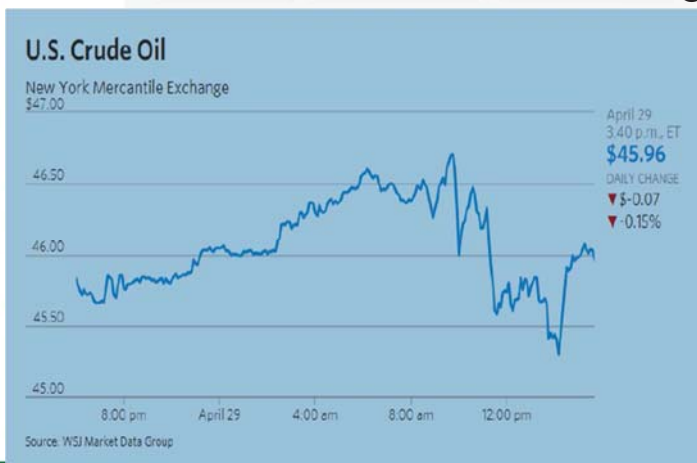
Chlor-alkali/Vinyls Flow Chart



TA **TEKNOR APEX**
Compounding Creativity with Technology

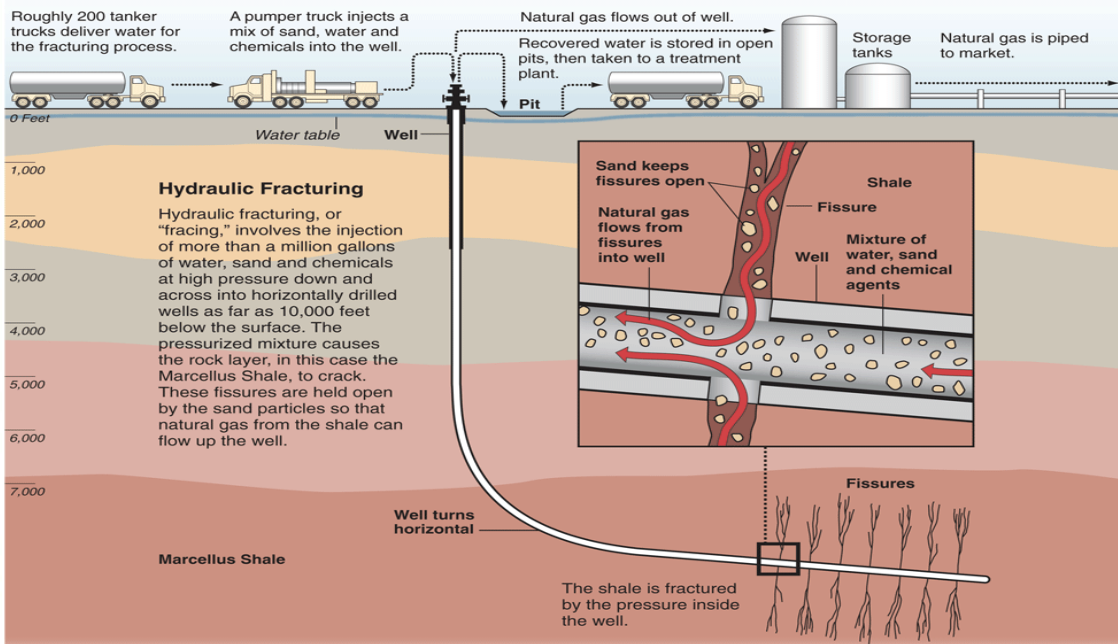
PVC Feed stocks

- **Natural Gas is the predominate feedstock in NA for ethylene.**
 - Oil remains the overall global cost driver



- Oil has climbed 20% during April
- Global crude market remains oversupplied
- OPEC attempted a production freeze but failed.
- US production had a slight decline in Feb (down .6% or 51,000 barrels/day)

Hydraulic Fracturing Process



PVC Cost Drivers

- **Natural Gas, Crude oil.**
 - Nat gas pricing expected to stay comparable to 2015, on avg.
- **Export market**
 - Dependent upon capacity; strength of USD
- **Polymer demand (ethylene)**
- **NA supply and demand**
 - Ex. VCM outage
 - NA Building and Construction Market

Plasticizer Chemistry

Four main groups:

1) Monomeric plasticizers

Phthalate Esters

Trimellitate Esters

Aliphatic Diesters

Citrate Esters

Bio-based Plasticizers

2) Polymeric Plasticizers

3) Epoxy Plasticizers

4) Flame Retardant Plasticizers

Plasticizer Chemistry

• Phthalate Esters

• DEHP

• DIDP

• DINP

• DPHP

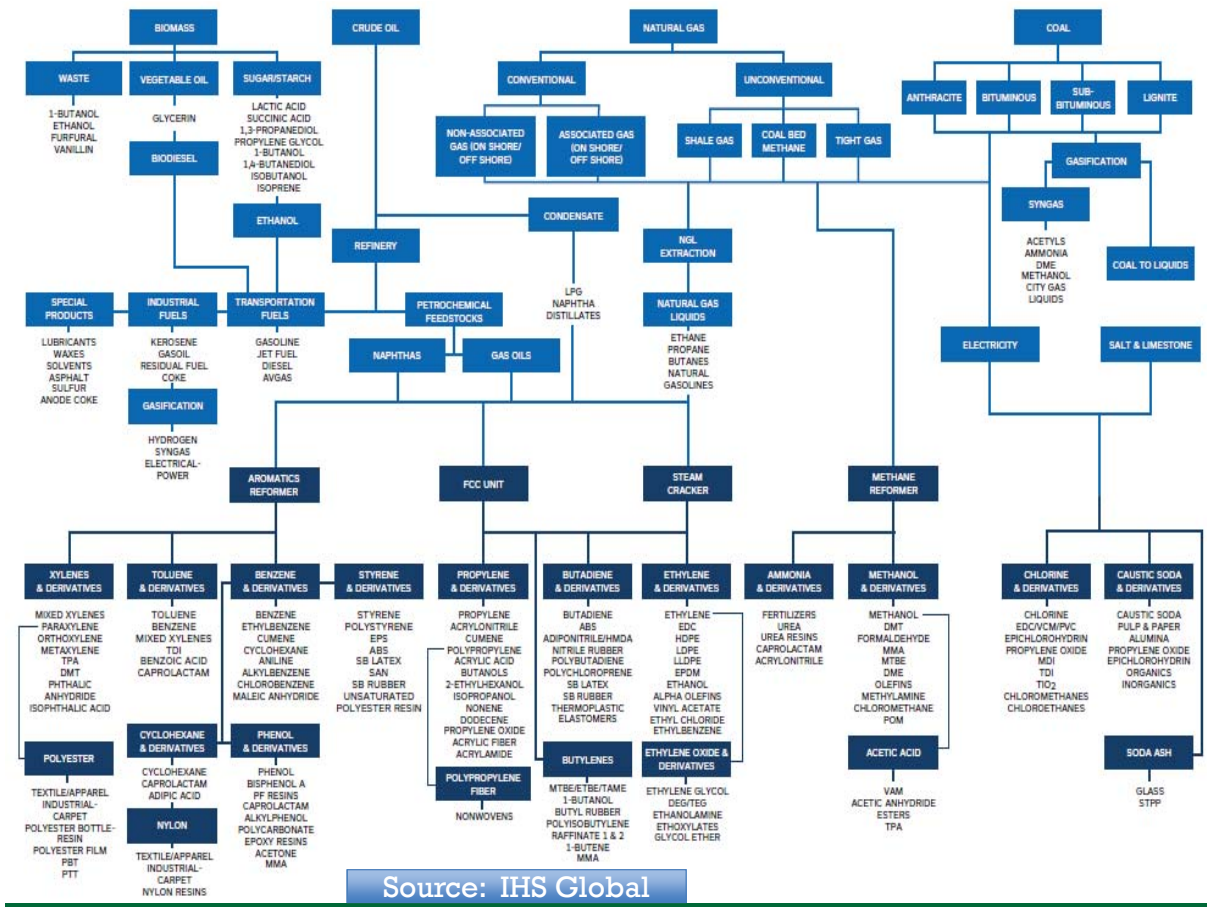
• DOTP

• Linear Plasticizers: L9, 9-11, 7-11

• Low Temperature Plasticizers

• DOA, DOS, DOZ

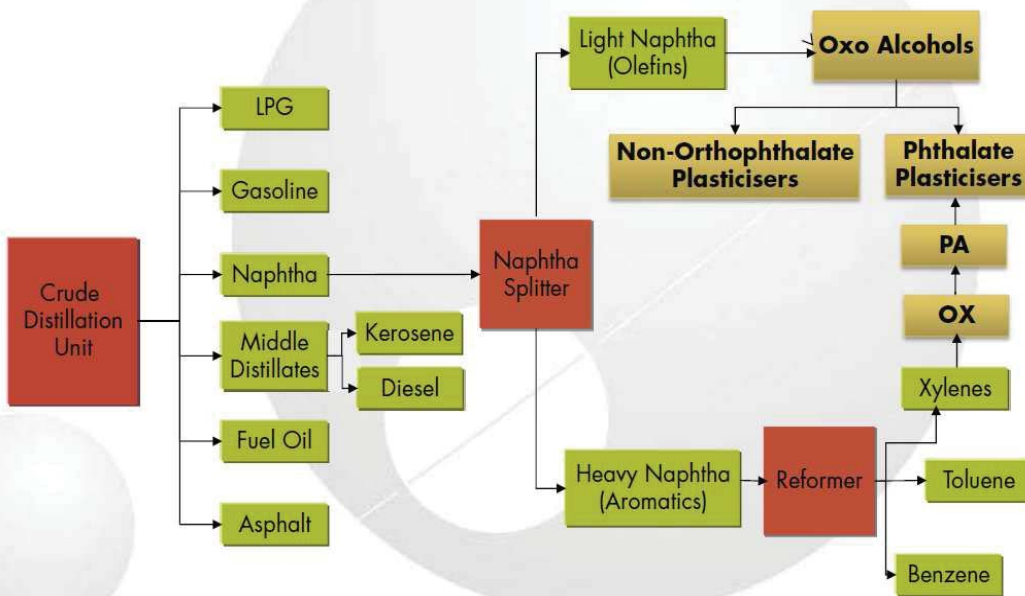
• Epoxy Plasticizers



Source: IHS Global

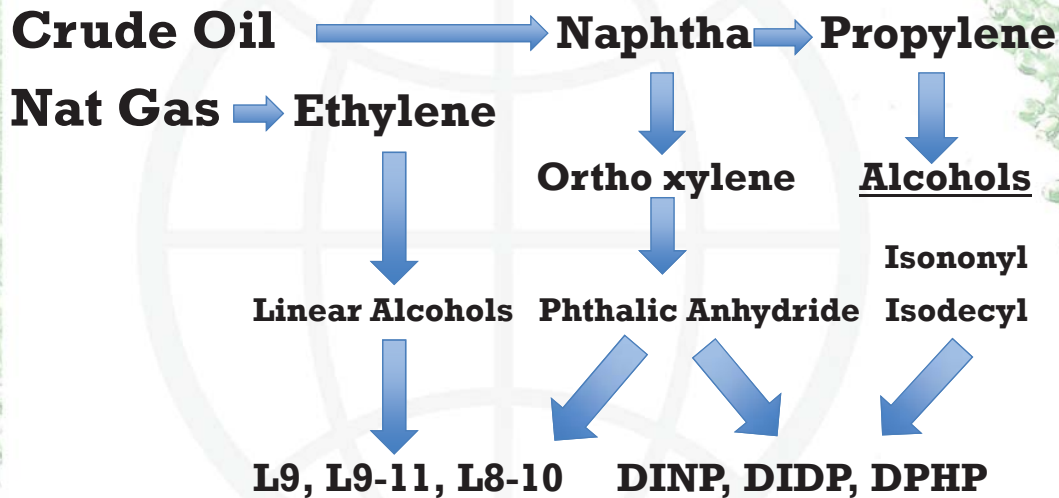
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REFINERY TO OX, PA – SIMPLIFIED FLOWSHEET



Source: Tecnon OrbiChem

Plasticizer Feed stocks



Plasticizer Price Drivers

- **Crude and Natural Gas have significant influence**
 - Lower cost feedstock does not necessarily dictate lower pricing for the derivative
- **Chemicals to monitor**
 - Ethylene
 - Propylene
 - Ortho xylene
- **Global supply and demand of derivatives**
 - Ex. Phthalic Anhydride capacity coming off line causing a recent increase
 - Ex. European exports of plasticizers (DOA, TOTM, DINP) competitively
- **Number of products and manufacturers have consolidated over the last 20 years**
 - Monsanto, Aristech plasticizer businesses acquired
 - Only one manufacturer of DIDP in NA (ExxonMobil)
 - Only one manufacturer of DEHP in NA (Eastman)

Trends in PVC Industry

- **Regulatory**
- **Market Trends**
- **Flexible Compound Technology**

Regulatory

- **Higher Scrutiny of PVC plasticizers**
 - • FDA recently petitioned (by a NGO) to remove approvals of 30 phthalates listed for food contact
 - CA Prop 65 list continues to grow.
 - •DINP listed in 2014
 - » •Safe harbor levels established (lower than DIDP)
 - » •Safe use determination conducted for roofing
 - » •Customer's rethinking PZ selection for the most rudimentary of applications
- **Evolving Regulatory Environment for Materials**
 - EU REACH regularly adds new candidate and authorized chemicals to the restrictions list
 - » •DEHP (current exemption for Medical use)
 - Currently unknown what the impact will be of China REACH and Korea REACH
 - RoHS list recently enlarged to include new chemicals including DEHP
 - TSCA re-authorization needs to be finalized
- **Global Harmonization Standard in place for SDS**

Market Trends

- **Medical Industry**
 - DEHP (DOP) remains the predominate plasticizer. All legacy products look to remain on DOP due to positive track record (no proof of human harm)
 - New devices likely to use phthalate alternatives (adipates, DEHT, trimellitates) due to market pressure. DEHT has an very good toxicological profile.
 - New RPVC compounds developed to resist environmental stress cracks (select thermoplastics are susceptible when in contact with flexible PVC)
- **Building and Construction**
 - Ortho-phthalates replaced in not critical applications
 - Big box stores phasing out ortho-phthalates in flooring
 - Plasticizer replacement most prevalent in applications with the least amount of risk.
 - Indoor air quality remains important as the building envelope tightens.
 - Products are being graded regarding compliance to certifications (ex. Greenguard, Floor Score, etc.)
 - USGBC Continues to be a strong influence in the Build Environment
 - USGBC reached out to the Vinyl industry to work on material credits

- **Consumer and Industrial Markets**
 - Compliance to proposition 65 labeling in CA driving products marketed nationally as well as globally
 - Use of bio-additives, such as plasticizers are being used in select applications to improve overall carbon footprint, reliance on petrochemicals
 - Deselection from Vinyl compounds has subsided
- **Automotive Sector**
 - Global builds to approach 70 million in 2016
 - PVC accounts for about 22 lbs./vehicle (2014)
 - Top applications include window encapsulation, roof ditch moldings, interior trim, electrical wiring, body side moldings, floor mats and seating.
 - TPV's being converted to PVC for window encapsulation.

Trends in Wire & Cable Materials

•New EU Cable Fire Safety Regulations “Construction Products Regulation” (CPR) – Implement July 1, 2016

- All cables will require flame test certificates and a CE mark
- Local jurisdictions will decide how flame retardant different applications need to be

•Desire for Electronics OEM’s to develop a “World Specification” with similar materials everywhere

- Apple, EMC, Google, others seeking one set of engineering prints for Data Centers worldwide
- Different Fire Safety Regulations by location require different materials to solve
 - Technology is currently unavailable to pass “Plenum” requirements in the US without use of Halogens
 - Generally Halogen Free is preferred but tradeoffs (physical properties, cost) necessary to achieve strict North American Fire Codes

What Is Flexible PVC Compounding?

Flexible PVC Compounding

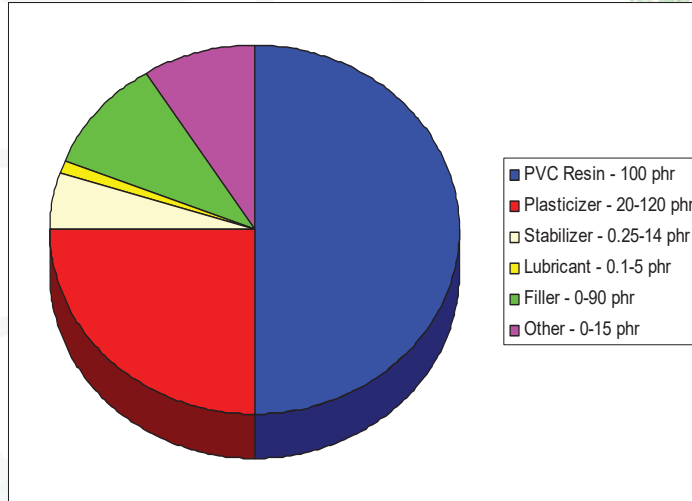
- Addition of components to a base PVC resin that allows for it to be processed into a final product with the desired properties at minimum cost.

Three factors must be considered when compounding flexible PVC:

- 1) What is the end use?
- 2) What is the processing method?
- 3) What are the economics?

Components of a Flexible PVC Compound

PVC Resin
Plasticizers
Stabilizers
Lubricants
Fillers
Other Additives -
UV Absorbers,
Fungicides,
Alloying Polymers,
etc..



Epoxy Plasticizers

Unique heat and light stabilizing functions
Characterized by the presence of oxirane oxygen
rings - acid acceptor



Epoxidized soybean oil

- non-toxic
- low volatility
- synergist with mixed metal stabilizers

Flame Retardant Plasticizers

Phosphate esters

- **Triaryl phosphate esters**
- **Alkyl Aryl Phosphate Esters**

Halogenated Phthalates

- impart flame retardancy
- increase ignition resistance
- Example - Brominated DOP

Chlorinated Paraffin's

- used as secondary plasticizer

Stabilizers

Why Are Stabilizers Used?

PVC unlike other thermoplastics - needs stabilization - Why?

PVC undergoes dehydrochlorination when heated to 150°C~160°C where HCl is formed which, in turn, catalyzes further degradation - Autocatalytic decomposition

Compounder must balance

- short term color control
- long term heat stability
- processing effects - plate out tendencies, effect on melt rheology, lubrication characteristics, effect on rate of fusion, and possible chemical reactions with other components

Stabilizers can also influence weathering and heat aging of PVC compounds

Mixed Metal Stabilizers

Stabilizers are blends of additives formulated to provide specific performance attributes

- Metal Soaps
- Metal Salts
- Co-stabilizers

Main workhorses - Ba/Zn and Ca/Zn

Zinc

- excellent early color
- must be careful of high zinc levels

Barium

- provide long term stability
- poor early color protection

Calcium

- Used for medical applications

Powder vs. Liquid

- Highly application dependent
- Must compensate for lubricity

Lubricants

Lubricants

Internal Lubricants

External Lubricants

Internal Lubricants

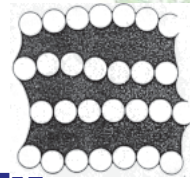
Facilitates movement of one polymer chain with respect to the other

**Main internal lubricant in flexible PVC
PLASTICIZER**

Promotes flow of molten polymer without affecting properties

Characterized as being somewhat polar and semi compatible - considerable solubility in PVC resin

Functions at processing temperatures



External Lubricants

Facilitates movement with respect to solid interfaces

Works in two ways

- **Lubricant has affinity for the metal surface**
 - » due to polar nature they have an affinity for the metal and coat the metal surface
 - » metal soaps and organic acids
- **Lubricant forms a film between polymer and metal due to incompatibility with polymer**
 - » Esters of low polarity, polyethylene's, and aliphatic organic waxes



Fillers

Fillers

Inorganic fine powders added to reduce cost or impart desirable properties

Higher filler levels result in higher specific gravity

Types of Fillers

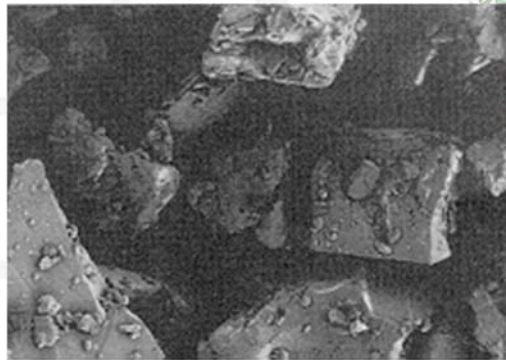
- Calcium carbonate
- Kaolin Clay
- Talc
- Flame Retardants/ Smoke Suppressants

Calcium Carbonate

Predominant filler used in flexible PVC compounding - range of particle sizes

Typically used for cost reduction

Low aspect ratio - cubical particle structure - acts as a filler not a reinforcement



Flame Retardants/ Smoke Suppressants

Antimony Oxide

- In absence of halogens - inert white pigment
- Synergistically acts as a flame retardant with halogens
- Used 3-5 phr

Aluminum Trihydrate (ATH)

- low cost flame retardant/ smoke suppressant
- Decomposes at 205°C - liberates water
- Can be surface treated

Magnesium Hydroxide

- higher cost than ATH
- decomposes at 320°C - liberates less water than ATH

UV Stabilizers

UV Stability

PVC is not inherently a weatherable plastic
Continued exposure to UV radiation results
in photo-degradation

- Discoloration
- Fading
- Loss of physical and mechanical properties

UV Absorbers and Hindered Amine Light
Stabilizers (HALS)

Pigments affect UV stability – TiO₂ added to
improve the weatherability of PVC

Types of UV Absorbers

Benzotriazoles

- Absorbs UV light that strikes the PVC surface dissipating light energy into heat

Benzophenones

- Maximum absorption is generally below 300 nm
- Less expensive than benzotriazoles

Hindered Amine Light Stabilizers (HALS)

- Very effective in mixed metal stabilized PVC formulation
- Low volatility
- Used in conjunction with UV absorbers
- Capable of stabilizing thin specimens of PVC
- Do not impart undesirable color to the PVC

PVC Alloys

Other polymers used to enhance the properties of flexible PVC

PVC/ NBR

PVC/ CPE

PVC/ Ethylene-VA-CO terpolymers

PVC/ TPU

Other Additives

Colorants

Biocides

Antifog Agents

Antioxidants

Blowing Agents

Antistat

Carbon Black