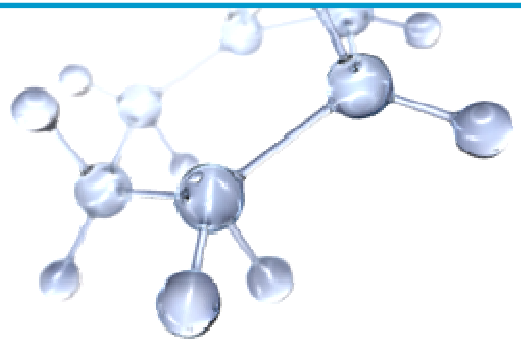
Uses of Phthalates and Other Plasticizers



Allen Godwin
ExxonMobil Chemical Company
July 26, 2010

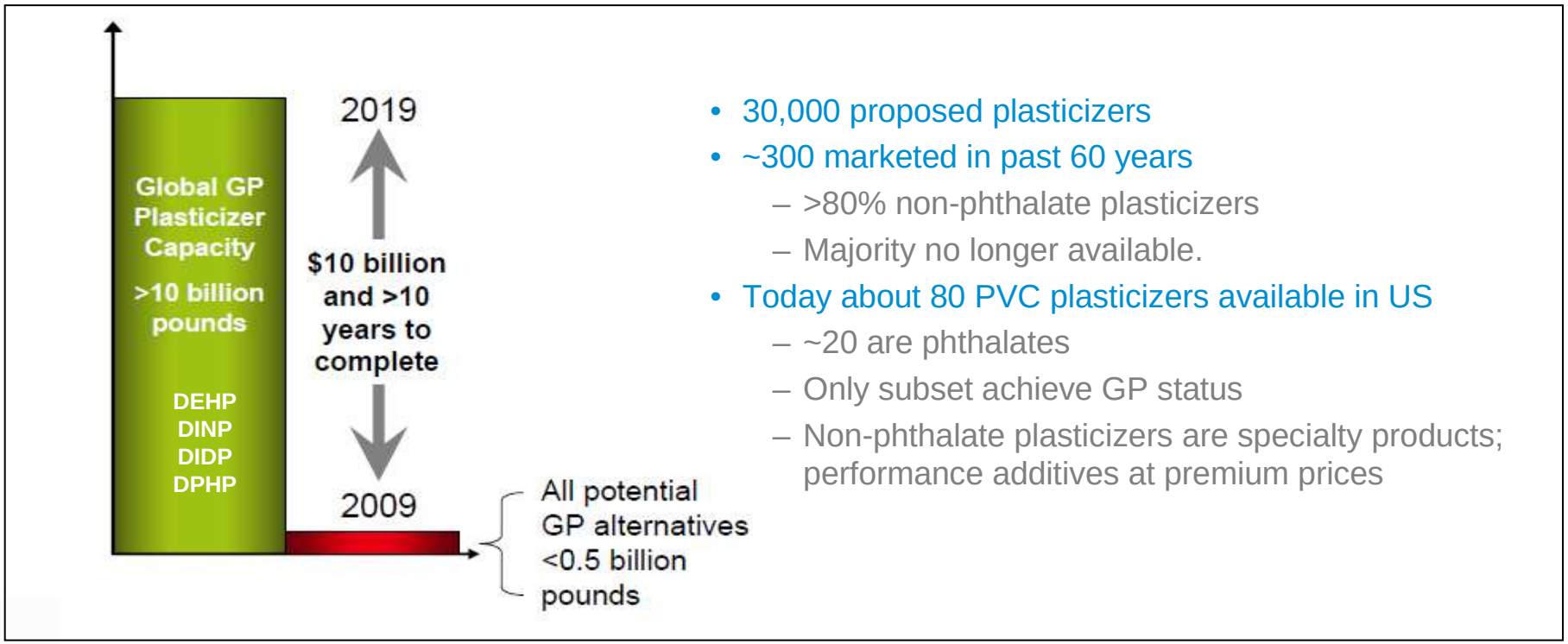
Very Few Plasticizers are General Purpose

General Purpose Plasticizer:

- Offers the optimized balance of performance and costs
- Offers flexibility at the lowest cost
- Provides good low temperature properties and acceptable volatility
- Can be used with a variety of processing techniques
- Usable in almost every market segment

Specialty Plasticizer:

- Imparts one or more special properties but may offer compromised properties in other areas
- Unavailable in sufficient quantities or at competitive pricing to supply a large portion of flexible PVC market
- Cannot be used in all or most flexible PVC processing techniques because of its physical form



- 30,000 proposed plasticizers
- ~300 marketed in past 60 years
  - >80% non-phthalate plasticizers
  - Majority no longer available.
- Today about 80 PVC plasticizers available in US
  - ~20 are phthalates
  - Only subset achieve GP status
  - Non-phthalate plasticizers are specialty products; performance additives at premium prices

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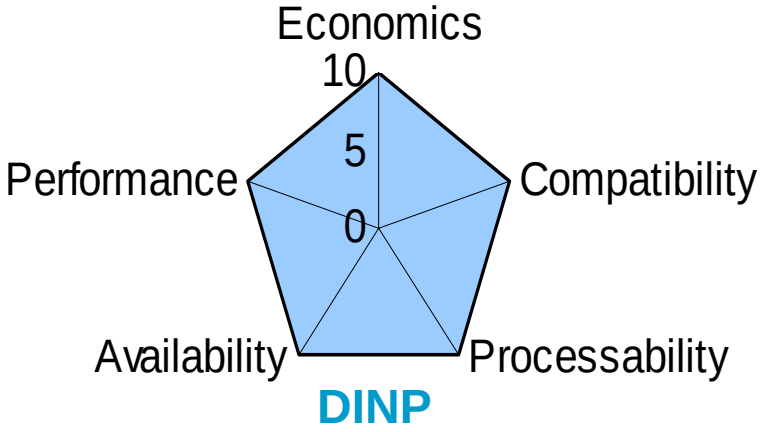
Not all Phthalates are Used as Plasticizers

- Plasticizers
  - Plasticizers are chemicals that are added to other polymeric substances to improve the flexibility of the polymer or to aid in processing the polymer
  - Once fused, the compound of PVC resin and plasticizer is stable; with heat, extreme stress, or an extracting media would be required to release some of the plasticizer
  - Plasticizers are poor solvents for the polymer
  - Plasticizers are have low volatility
  - Plasticizers will lose the ability to improve flexibility if the plasticizer is chemically attached to the polymer
  - For phthalate esters, the plasticizer range extends from esters prepared from C4 alcohols to C13 alcohols. However because of high volatility, C4 - C6 phthalate esters are no longer used as PVC plasticizers in most countries

- Solvents
  - Solvents are included in a variety of formulations,
    - help solubilize a necessary ingredient or to
    - aid in spreading or the application of the product
  - Solvents are not designed to be a permanent part of the finished product
  - Evaporation rate of the solvent is designed for the application
  - C1 to C3 (i.e. DEP, DMP, DPP) phthalate esters are solvents, not PVC plasticizers. C4 phthalates (i.e. DBP) find some specialty uses as solvents, but its use is declining

Property Comparison of Plasticizers

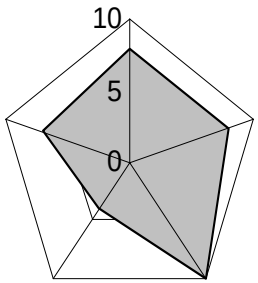
General Purpose Plasticizer:



DINP

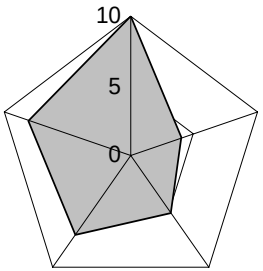
Attributes:

Low cost	Resistance to hydrolysis
UV resistant	Chemically resistant
Adhesion	Low maintenance
Heat stable	Long service life
Stain resistant	Non staining
Low emissions	Stability
Low fogging	Chemically stable
Low conductivity	Good look & feel
Low volatility	



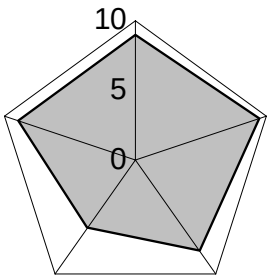
Citrates

limited volumes, performance lacking in permanence, high costs



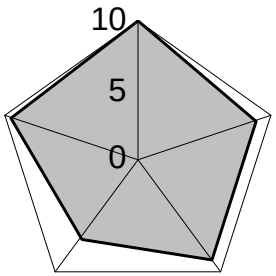
ESO

processability issues; long term compatibility problems



DOTP

Slightly more difficult to process and less compatible.



DINCH ™

Some processability issues, only available from one supplier; capacity limited

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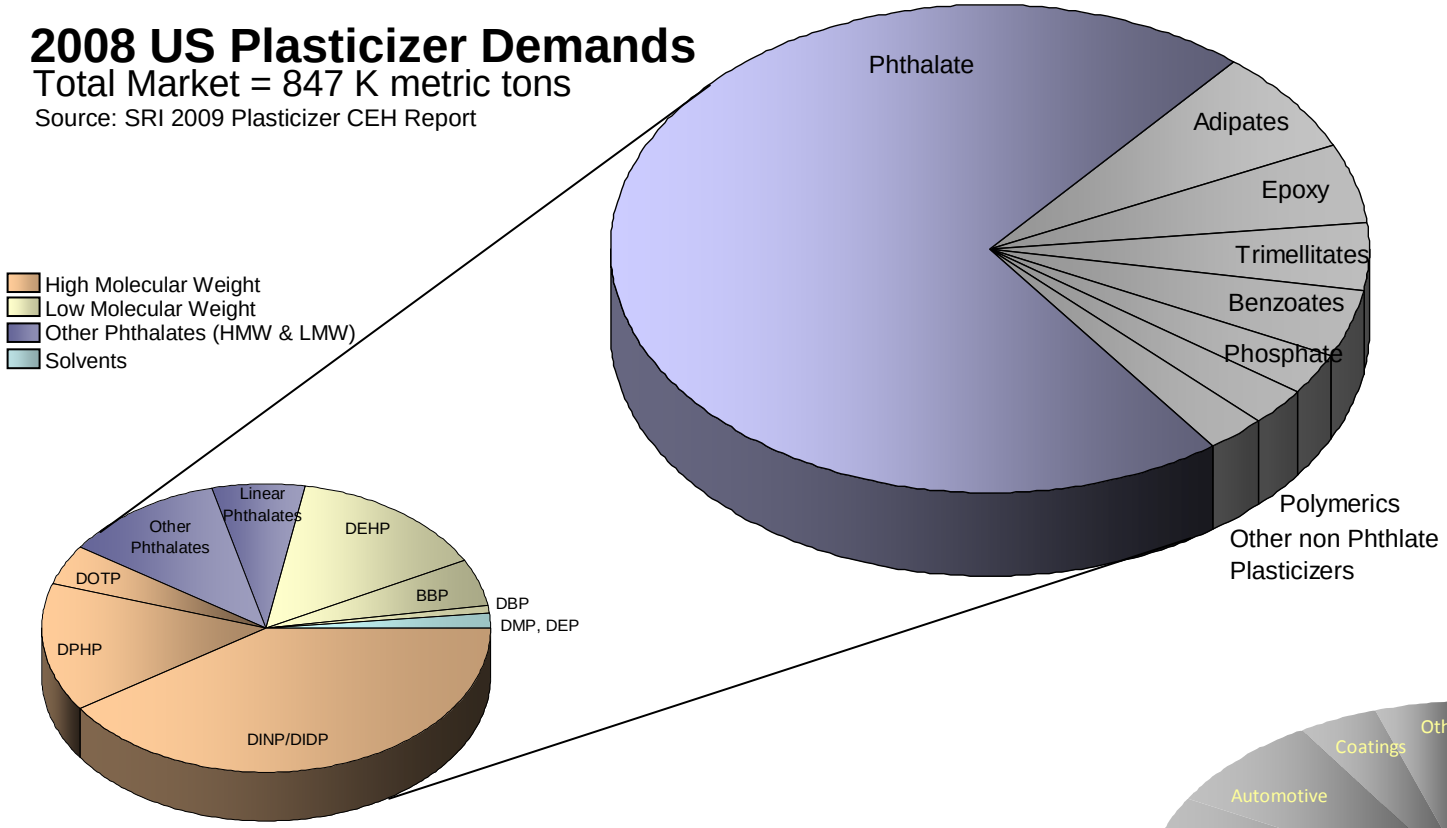
Market and Uses of Plasticizers

2008 US Plasticizer Demands

Total Market = 847 K metric tons

Source: SRI 2009 Plasticizer CEH Report

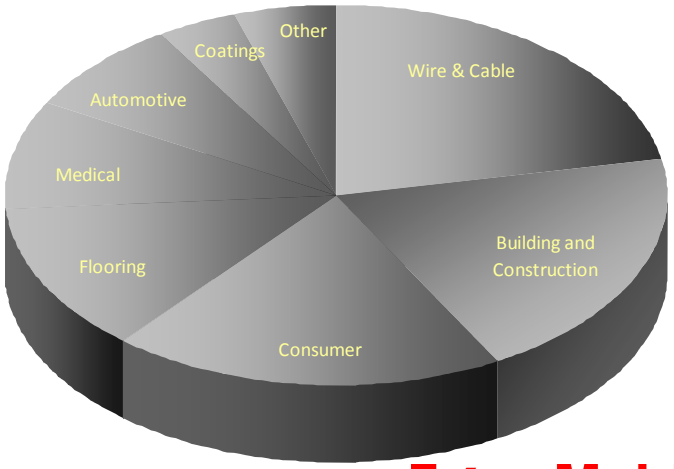


2008 US Phthalate Demand

Uses of Phthalates as Plasticizers

Source: Flexible Vinyl Alliance 2010

Excludes Phthalates used exclusively as solvents (i.e. Perfumes, Lotions, etc.)



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Examples of Plasticizers Used in Different Market Segments

Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Solvents (Non Plasticizer Uses)	Cosmetics / creams	✓	✓	✓	✓																		
	Fragrances/ Perfumes/ Candles/ Shampoos, etc	✓	✓	✓	✓																		
Flooring	Vinyl tile					✓	✓		✓	✓	✓				✓								
	Resilient Flooring					✓	✓	✓	✓	✓	✓				✓								
	PVC backed carpeting								✓	✓	✓												
Automotive	Interior Trim									✓	✓	✓		✓			✓		✓				✓
	Exterior trim								✓	✓	✓	✓		✓			✓						
	Undercoating/sealants					✓	✓		✓	✓	✓												
	Exterior paint					✓																	
	Wiring									✓	✓	✓	✓	✓			✓						
Constuction (other than wire and cable, flooring)	Caulks and Sealants					✓			✓						✓								
	Wall Paper					✓			✓	✓	✓												
	Hoses						✓		✓	✓	✓			✓									
	Paint (lacquers)					✓	✓		✓														
	Vinyl siding capstock								✓	✓	✓	✓					✓						
	Roofing									✓	✓	✓		✓			✓						
	Urethane sealants								✓	✓	✓	✓			✓					✓			
Medical	Invasive Use						✓							✓		✓	✓						
	Other, non invasive								✓	✓	✓					✓							
	PVC Examination gloves					✓	✓		✓								✓					✓	
Clothes	Shoes						✓		✓	✓	✓							✓	✓				
	Inks								✓	✓	✓			✓									
	Handbags / luggage					✓	✓		✓	✓								✓	✓				
Household/ other	Furniture							✓	✓	✓	✓	✓			✓					✓			
	Garden hose						✓		✓	✓	✓								✓				
	Table Cloths						✓	✓	✓	✓	✓							✓					
	Shower Curtains					✓		✓	✓	✓	✓							✓					
	Floor Mats					✓		✓	✓	✓	✓							✓					
	Blanket storage bags						✓		✓	✓	✓								✓				
	Toys							✓	✓							✓		✓	✓	✓	✓	✓	
	Food								✓	✓	✓					✓		✓	✓	✓			
Wire and Cable	Building wire									✓	✓	✓	✓	✓									
	Wire and Cable-other						✓		✓	✓	✓	✓	✓	✓									

Snapshot of vinyl industry only, attempts to highlight some of the more important end uses but not meant to represent a complete picture of the North American vinyl market.

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Non Plasticizer Uses -- Solvent

Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Solvents (Non Plasticizer Uses)	Cosmetics / creams	✓	✓	✓	✓																		
	Fragrances/ Perfumes/ Candles/ Shampoos, etc	✓	✓	✓	✓																		

Subset	Desired Plasticizer attributes	Typical Products	Not Preferred
Cosmetics/ creams	High solvency low cost, low odor, safe, no irritation	C1-C4 phthalates	DINP, DIDP, DPHP, DTDP, linear phthalates, trimellitates
Fragrances, Perfumes, Candles, Shampoos, etc	High solvency low cost, low odor, safe, no irritation	C1-C4 phthalates	DINP, DIDP, DPHP, DTDP, linear phthalates, trimellitates

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Plasticizers for Wire and Cable Insulations

Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Wire and Cable	Building wire									✓	✓	✓	✓	✓									
	Wire and Cable-other						✓		✓	✓	✓	✓	✓	✓									

Subset	Desired Plasticizer attributes	Typical Products	Not Preferred
Building wire	Very safe for long term use, Low volatility, low conductivity, ease of processing	Higher MW plasticizers such as DIDP, DPHP, trimellitates, L911P, L11P, DTDP	Low MW phthalates including DEHP, citrates, Cyclohexanoates, natural oil based
Wire and Cable-other	Safety is always important. Other properties vary depending upon service life requirements, or low temperature flexibility, migration resistance to other plastics, resistance to oil and grease, or automotive interior fogging requirements	DEHP, DINP, DIDP, DPHP, trimellitates, L9P, L11P, L911P, DTDP. DOTP	Low MW phthalates , citrates, Cyclohexanoates, natural oil based plasticizers

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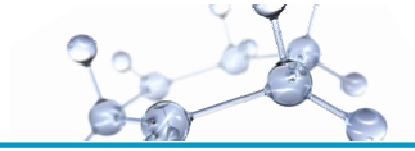
Plasticizers for Construction Products*



Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Constuction (other than wire and cable, flooring)	Caulks and Sealants					✓			✓						✓								
	Wall Paper					✓			✓	✓	✓												
	Hoses						✓		✓	✓	✓			✓									
	Paint (lacquers)					✓	✓		✓														
	Vinyl siding capstock								✓	✓	✓	✓					✓						
	Roofing									✓	✓	✓		✓			✓						
	Urethane sealants								✓	✓	✓	✓			✓					✓			

Subset	Desired Plasticizer attributes	Typical Products	Not Preferred
Caulks and Sealants	Low indoor air emissions, film coalescer, long shelf life	BBP, dibenzoates, C7 phthalates,	DTDP, TINTM, polymerics, citrates
Wall Paper	Low indoor air emissions, film coalescer, long shelf life, printability	DINP, DIDP, DPHP, some BBP	citrates, DINCH, trimellitates, natural oil plasticizers
Hoses	NSF potable water or FDA approval, high clarity, low water solubility, hydrolytic stability	DINP, DIDP, DPHP, trimellitates	citrates, low MW phthalates,
Paint (lacquers)	Good film forming properties, low temperature, low odor	DEHP, DINP, DBP	trimellitates, DIDP, DPHP, L911P.
Vinyl siding capstock	Some vinyl siding capstock may use plasticized PVC-here requirements are good UV stability, low volatility	DINP, DIDP, DPHP, L9P, polymerics	C1-C7 phthalates, trimellitates, citrates, natural oil plasticizers
Roofing	long service life (up to 20 years), UV resistance, low volatility	DIDP, DPHP, L9P, L11P, L911P, trimellitates	C1-C8 phthalates, citrates, natural oil plasticizers
Urethane sealants	good shelf life, compatibility, UV resistant, low volatility	Mesamoll, L11P, dibenzoates, DIDP, DINP, L911P, L9P	citrates, natural oil plasticizers

* Other than wire/ cable and flooring

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Plasticizers for Automotive Vinyl Materials

Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Automotive	Interior Trim									✓	✓	✓		✓			✓		✓				✓
	Exterior trim								✓	✓	✓	✓		✓			✓						
	Undercoating/sealants					✓	✓		✓	✓	✓												
	Exterior paint					✓																	
	Wiring									✓	✓	✓	✓	✓			✓						

Subset	Desired Plasticizer attributes	Typical Products	Not Preferred
Interior Trim	Low fogging, ease of processing, chemically stable, UV resistant, heat stable, long service life, good surface feel or softness	DIDP, DPHP, L9P, L911P, L11P plus trimellitates and polymeric, sebaccates, adipates	C1-C9 phthalates, citrates, DOTP,
Exterior trim	Low volatility, ease of processing, chemically stable, UV resistant, heat stable	DINP, DIDP, DPHP, L9P, L911P, L11P plus trimellitates and polymeric	C1-C4 phthalates, citrates
Undercoating/ sealants	Ease of processing, adhesion, stability	DIDP, DINP, DPHP, BBP, Dibenzoates	C1-C4 phthalates, citrates, trimellitates, DINCH
Exterior paint	Heat/cold resistant paint, compatibility, UV resistant, stain resistance	BBP	phthalates, trimellitates, citrates
Wiring	low volatility, oil extraction resistance, heat stable, low conductivity, low fogging	DIDP, DPHP, L9P, L911P, L11P, trimellitates and polymeric	C1-C8 phthalates, citrates, DINCH,

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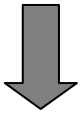
Plasticizers for Vinyl Flooring and Carpets

Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Flooring	Vinyl tile					✓	✓		✓	✓	✓				✓								
	Resilient Flooring					✓	✓	✓	✓	✓	✓				✓								
	PVC backed carpeting								✓	✓	✓												



Subset	Desired Plasticizer attributes	Typical Products	Not Preferred
Vinyl tile	Ease of processing, low migration rates into adhesives, long service life	BBP, Dibenzoates, DINP, DEHP, DIDP, DPHP	C1 to C4 phthalates, Higher MW products such as trimellitates; natural oil plasticizers, citrates, DINCH
Resilient Flooring	Ease of processing, stain resistance, foam stability, low emissions, low odor, long service life, low maintenance	BBP, Dibenzoates, DINP, DEHP, DOTP, DPHP	C1 to C4 phthalates, Higher MW products such as trimellitates or C10 phthalates; natural oil plasticizers, citrates, DINCH
PVC backed carpeting	Ease of processing, resistance to hydrolysis, chemical stability, low emissions, low odor	DINP, DIDP, DOTP	C1 to C4 phthalates, trimellitates, citrates, DINCH

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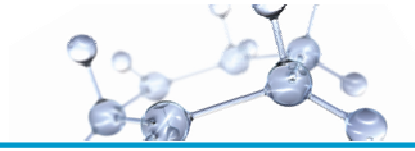
Plasticizers for Medical Products



Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Medical	Invasive Use						✓							✓		✓	✓						
	Other, non invasive								✓	✓	✓					✓							
	PVC Examination gloves					✓	✓		✓								✓					✓	

Subset	Desired Plasticizer attributes	Typical Products	Not Preferred
Invasive Use	Prior approvals, long history of safe service, resists color change in sterilization, low color, low odor, high purity	DEHP, trimellitates, citrates, polymerics	C1-C7 phthalates, DINP, DIDP, DTDP, DPHP, linear phthalates
Other, non invasive	Migration resistance, high clarity, low odor, chemically stable	DINP, DIDP, DPHP, citrates	C1-C7 phthalates
PVC Examination gloves	Food contact approval, no skin irritation, easy to process, no pinholes	DINP, TXIB, DEHP, polymerics	C1-C7 phthalates, trimellitates

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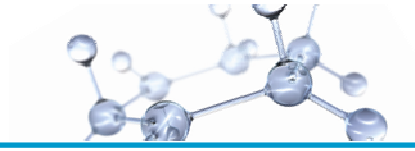
Plasticizers for Clothing Products



Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Clothes	Shoes						✓		✓	✓	✓							✓	✓				
	Inks								✓	✓	✓			✓									
	Handbags / luggage					✓	✓		✓	✓								✓	✓				

Subset	Desired Plasticizer attributes	Typical Products	Not Preferred
Shoes	Higher quality- flexibility, low density, stable, low wear	DINP, DIDP, DPHP, DEHA, DINA, DEHP, DOTP	DTDP, L11P, L911P, C1-C3 phthalates, trimellitates
Inks	Low migration, low water solubility, permanent, ease of processing	trimellitates, DINP, DIDP,	C1-C6 phthalates, DTDP, L11P, L911P
Handbags / luggage	Low migration, low odor, non staining, chemical resistance	DINP, DIDP, BBP, DEHA, DINA	trimellitates, citrates

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Plasticizers for Miscellaneous Applications

Segment	Subset	DMP	DEP	DPP	DBP	BBP	DEHP	DOTP	DINP	DIDP	DPHP	Linear (C9-11)	DTDP	Trimellitates	Dibenzoates	Citrates	Polymerics	DINCH	Adipates	Mesamoll	Natural oil based	TXIB	Sebaccates
Household/ other	Furniture							✓	✓	✓	✓	✓			✓					✓			
	Garden hose						✓		✓	✓	✓								✓				
	Table Cloths						✓	✓	✓	✓	✓							✓					
	Shower Curtains					✓		✓	✓	✓	✓							✓					
	Floor Mats					✓		✓	✓	✓	✓							✓					
	Blanket storage bags						✓		✓	✓	✓								✓				
	Toys							✓	✓							✓		✓	✓	✓	✓	✓	
	Food								✓	✓	✓					✓		✓	✓	✓			

Subset	Desired Plasticizer attributes	Typical Products	Not Typically Used
Furniture	Low emissions, low odor, stain resistance, chemical resistant, ease of	DINP, DIDP, DPHP, BBP, L9P, L911P, DOTP	C1-C6 phthalates, citrates, natural oil plasticizers
Garden hose	Low water solubility, hydrolysis resistant, low migration, low odor, low	DEHP, DINP, DIDP, adipates	BBP, C1-C6 phthalates, trimellitates, DTDP, L11P, L911P
Table Cloths	Low cost, migration resistant, chemical resistant, stain resistant	DINP, DEHP, DIDP, DPHP, DOTP	C1-C6 phthalates,
Shower Curtains	Low odor, stable, migration resistance, low water solubility	DINP, DEHP, DIDP, DPHP, DOTP	C1-C6 phthalates,
Floor Mats	Foaming quality, low cost, low migration, low emissions, stain resistance	BBP, DINP, DIDP, DPHP, DOTP	C1-C6 phthalates,
Food Contact	FDA approvals, low color, low odor, low migration, low water solubility	DEHA, with minor levels of DIDP, DPHP, Mesamoll, DINCH, DINP,	C1-C7 phthaltes, DTDP, linear phthalates
Blanket storage bags	Low cost, low odor, migration resistant, high clarity, non-yellowing	DEHP, DINP, DIDP, DPHP, adipates	C1-C6 phthalates, DTDP, trimellitates
Toys	Properties: low odor, high purity, low migration, faster processing	DINCH, DOTP, citrates, Mesamoll, adipates, polymerics, natural oil	C1- C6 phthalates, TINTM, L911P, L11P

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Backup

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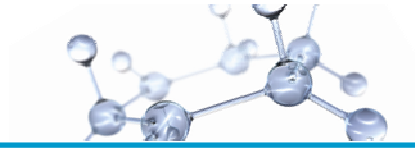
“Other” plasticizers

- Ten’s of thousands of these non-phthalates have been suggested for use as plasticizers. The most important products include the chemical classes:
  - Citrates
  - Dibenzoates
  - Polyol esters
  - Alkyl aromatic sulfonates
  - Cyclohexane diacid esters
  - Terephthalates
  - Epoxidized oils
  - Modified vegetable oils
  - Other dibasic acids (azelates, sebacates)
  - Phosphates
  - Isobutyrates
  - Hydrocarbon oils or extenders
- None of these classes are new; most have been available commercially in some form for more than 40 years

Vita for Allen Godwin



Dr. Allen Godwin is a Senior Research Associate for ExxonMobil Chemical and manages the Product Application Support group for the Americas OXO business group. After obtaining his PhD degree in Organic Chemistry from Texas A&M University, Allen worked as a post-doctorial Fellow at Florida State University and then joined Arco Chemical as an Analytical Chemistry Manager in their Chemical R&D group. In 1981 Allen joined ExxonMobil to work with their line of plasticizers. During the past 29 years, Allen has worked in plasticizer manufacturing, plasticizer technology, new product development, technology management, and new plasticizer research and development, in the US, Europe, and Asia. Allen has published four chapters on plasticizers for various text books and has presented papers on plasticizers and plasticizers technology through out the Americas. Allen holds more than 24 patents on new technologies and new plasticizers.

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