

## High Performance Ester Plasticizers

### Abstract

Traditional elastomer polymers, such as nitrile, polychloroprene, chlorinated polyethylene and chlorosulfonated polyethylene, have for years used moderate- to low-performance ester plasticizers. However, longevity requirements for rubber articles made from these elastomers have created a need for higher-performance ester plasticizers. With the increasing high-temperature demands required by automotive, other elastomers such as acrylic, high-saturated nitrile, epichlorohydrin and ethylene propylene diene monomer EPDM are replacing the more traditional elastomers.

Plasticizers commonly used for the traditional and the high-temperature polymers are extractable, incompatible or too volatile. This paper provides information on plasticizers that are designed for traditional elastomers and high-performance polymers. The test data will include heat aging, extraction by hydrocarbons and low-temperature as molded after aging.

The information provided indicates that the permanence of the plasticizer after these various agings is the key to the retention of physical properties.

### Introduction

End uses for elastomer compounds are quite diverse, but they can be loosely categorized as being either general performance or higher performance applications. Each of these performance categories requires a different set of considerations in terms of compounding with ester plasticizers. An ester plasticizer, in its simplest concept, is a high-boiling organic solvent that when added to an elastomeric polymer reduces stiffness and permits easier processing.<sup>1</sup> For general performance applications, compounders require moderate performance in several areas without particular emphasis on any one. Some general performance ester plasticizers used in the marketplace today are DOA, DIDA, DIDP, DOP, DINP and other phthalates and adipates made from straight-chain alcohols of 7–11 carbons in length.

Ester plasticizers are commonly used only for their as-molded, low-temperature contribution. Ester plasticizers used for high-performance applications must have excellent non-volatility upon heat aging and extraction resistance to various fluids. Measuring retention of low-temperature properties after aging is an indicator of plasticizer permanence.

In this paper, several elastomers are evaluated to show how choosing the appropriate monomeric or polymeric ester plasticizer can enhance the performance and longevity of rubber parts.

## Discussion

Ester plasticizers discussed in this paper will be both monomeric and polymeric. Polymeric polyester plasticizers may be used in higher-performance applications where superior plasticizer non-volatility and fluid chemical extraction resistance are critical.

Polymeric plasticizers are produced by reacting a dibasic carboxylic acid with a glycol or a mixture of different dibasic glycols. When the molecules are reacted, the chain propagation or building may be terminated by the use of monofunctional carboxylic acids or alcohols. Some polymeric plasticizers are also produced using no terminator.

Following is a representation (Figure 1) of the production of an acid, alcohol and a non-terminated polymeric polyester, which assumes that stoichiometrically correct quantities of dibasic carboxylic acid, glycol and monofunctional carboxylic acid or alcohol have been reacted together to yield a polymeric plasticizer of a viscosity (or molecular weight) within a given range.

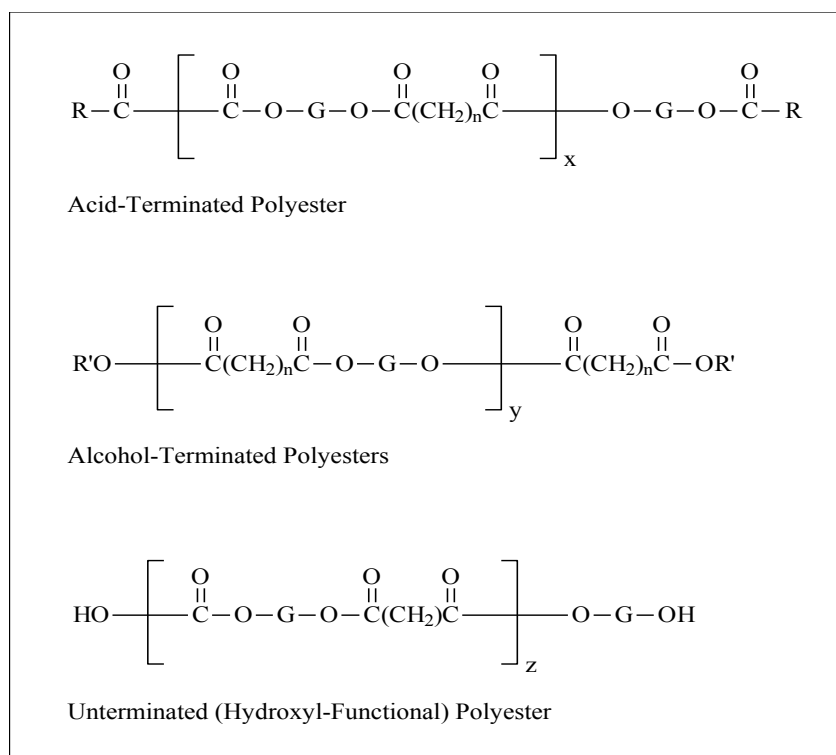


Fig. 1. Polyester plasticizer structures

Polymeric plasticizers have many advantages when compared to monomeric plasticizers. Table I compares monomeric and polymeric ester plasticizers on performance trends.

**TABLE I**
**Monomeric-Polymeric Performance Trends**

<u>Property</u>	<u>Monomeric Trend</u>	<u>Polymeric Trend</u>
Processing Ease	Good to Excellent	Poor to Excellent
Compatibility	Dependent on Chemical Structure	Dependent on Chemical Structure
Softening Efficiency	Good to Excellent	Poor to Fair
Low Temperature Flexibility	Good to Excellent	Poor to Fair
Extraction Resistance		
Organic	Fair to Excellent	Poor to Good
Volatility	Poor to Good	Good to Excellent

**Polymeric Esters Permanence** - The permanence of a polymeric plasticizer in an elastomer compound depends upon three major factors that include structure, molecular weight/viscosity and polarity. Polymeric composed of branched structures are more permanent, especially in applications requiring migration and extraction resistance. Branching tends to hinder movement or entangle the plasticizer with the polymer matrix. Although linear structures are more migratory, they do yield better low-temperature properties and are less volatile. Higher molecular weight polymeric esters provide greater permanence. These large molecules have less mobility and thus are more difficult to remove.<sup>2</sup>

Polymeric esters must be selected carefully when considering the varying solubility parameters of elastomers. Polymeric esters typically are polar materials and find good compatibility in polar elastomers, such as nitrile. Polymeric esters that are marginally compatible are less permanent, which can lead to increased migration, higher volatility and more extraction.

Polymeric polyesters are difficult to categorize by performance due to their varying structure and molecular weight. Table II classifies the polymeric esters by their general performance trends. Within a given acid type, as molecular weight increases or branching appears, property trends change.

**TABLE II**

**Comparison of Polymeric Plasticizers**

<b>Acid Type</b>	<b>Excellent</b>	<b>Good</b>	<b>Fair</b>	<b>Poor</b>
<b>Glutarates</b>	Compatibility  Humidity and migration resistance	Non-volatility  Extraction resistance	Plasticizing efficiency Low temperature properties	-----
<b>Adipates</b>	-----	Compatibility Plasticizing efficiency Low temperature properties Non-volatility Extraction resistance	Migration resistance	Humidity resistance
<b>Azelates</b>	Compatibility Plasticizing efficiency Low temperature properties	Non-volatility Migration resistance Extraction resistance	-----	-----
<b>Sebacates</b>	Compatibility Plasticizing efficiency Low temperature properties Humidity, migration, and extraction, resistance	Non-volatility	-----	-----
<b>Phthalates</b>	Compatibility Humidity resistance	Non-volatility	Extraction and migration resistance	Plasticizing efficiency Low temperature properties

## Specialty monomeric esters

Specialty monomeric esters are of three structure types. Two of the structures, alcohol-dibasic acid-alcohol (AAA) and monobasic acid-glycol-monobasic acid (AGA), can be classified as diesters. There is a significantly greater number of AAA than AGA types. The alcohol of the AAA type may be normal or branched structures (dibasic acid are commonly normal structure). The monobasic acids of the AGA type esters may be normal or branched structures (the glycols are commonly normal structure). A third structure is composed of monobasic acid and alcohol (AA). Either or both components of the AA type can have branched or normal structure. The following trends relate to structures of these esters.

- 1) Normal structure provides better low temperature than branched structures
- 2) Normal structure provides better heat resistance and oxidation stability than branched structures
- 3) Branched structure provides better oil extraction resistance and lower migration
- 4) Increased molecular weight gives better volatility resistance

The most popular dibasic acid structures are glutaric (C-5), adipic (C-6), azelaic (C-9) and sebacic (C-10). As polarity is important to the application of ester plasticizers and the application to polar elastomers, it is necessary to note that some of the AAA types use glycol ether alcohols. The presence of the oxygen atoms of the glycol ether alcohols causes higher polarity than occurs with common (carbon only) alcohols. These glycol ether diesters are of significant value as plasticizers for highly polar elastomers, such as 28–40 percent of acrylonitrile and acrylic elastomers.

The AA structure ester plasticizers are much less polar than diesters because of the lower amount of oxygen in their structure. The AA type has only one carbonyl group, while the diesters have two carbonyl groups. These monoesters are useful as low-temperature plasticizers for polychloroprene.

<u>Type</u>	<u>Chemical Name</u>	<u>Abbreviation</u>
AAA	Dibutyl sebacate	DBS
	Dioctyl Adipate	DOA
	Dioctyl sebacate	DOS
	Diisodecyl glutarate	DIDG
	Dioctyl azelate	DOZ
	Diisodecyl Adipate	DIDA
	Dibutoxyethoxyethyl formal	-----
	Dibutoxyethoxyethyl adipate	DBEEA
	Dibutoxyethoxyethoxyethyl glutarate	DBEEEG
	Dibutoxyethyl Adipate	DBEA
	Dibutoxyethoxyethyl sebacate	DBEES
	Dibutoxyethyl sebacate	DBES
	Tetraethyleneglycol di(2-ethylhexoate)	-----
	Triethyleneglycol di(2-ethylhexoate)	-----
AGA	Triethyleneglycol caprate-caprylate	[3EGCC]
AA	Isooctyl tallate (oleate)	-----
	Butyl tallate (oleate)	-----

Table III shows examples of low-temperature performance, before and after heat aging. The table also shows the effect of molecular weight and structure upon permanence; by inference, the higher the molecular weight, the less volatile and the better the low temperature after heat aging.

**TABLE III**  
**Low-temperature brittleness (ASTM D2137), °C for NBR compounds**  
**containing monomeric plasticizers tested after exposures shown.**  
**Compound: 34% [-C≡N] NBR, 20 PPHR plasticizer (10.2% of compound).**

<u>Monomerics</u>	<u>DOP</u>	<u>DOA</u>	<u>DBEA</u>	<u>3EGCC*</u>	<u>DBEEA</u>	<u>DBEES</u>
As Molded	-33	-42	-43	-42	-40	-39
After Air Oven						
70 h at 125°C	-25	-23	-27	-30	-31	-34
Ave. Molec. Wt.	390	370	346	430	434	505

**\*3EGCC=Triethyleneglycol caprate-caprylate**

Diocetyl phthalate is very compatible with NBR, but because of its inflexible benzene ring structure, it is not a good low-temperature plasticizer. Dioctyl adipate (DOA) has good initial low temperature, and even though it is not the smallest of the molecules, because of its low polarity, it is volatile. The four remaining ester plasticizers are polar esters. They contain high oxygen content compared to the other esters. Thus, the combination of molecular weight and polarity provides good compatibility and permanence at the particular aging temperature. That is evident by their better low-temperatures after aging.

Figure 2 summarizes the compound property trends of several low-temperature esters.

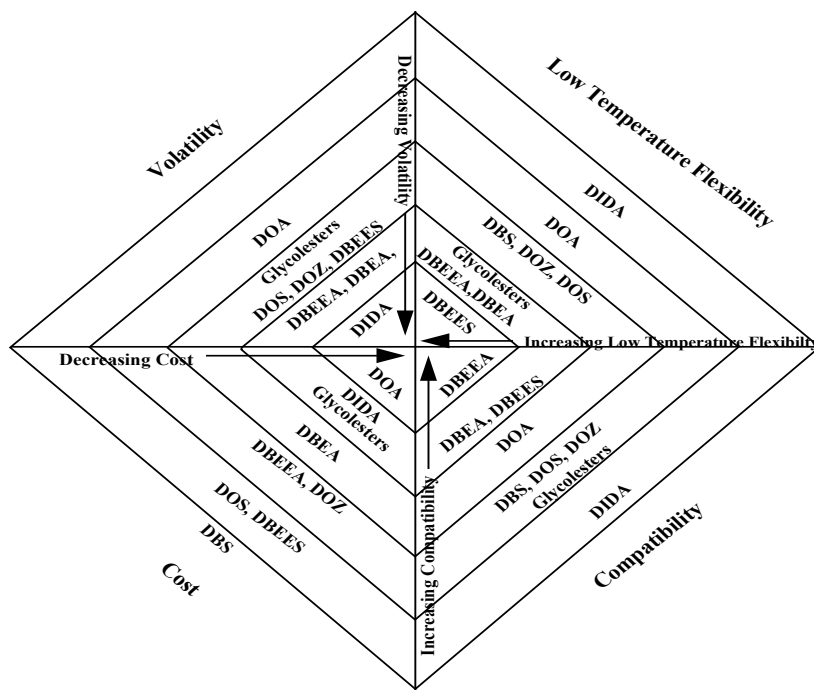


Fig. 2. Low-temperature ester composite.

## Polymeric ester: high performance applications

Polymeric esters are used in many high-performance applications that require a combination of low volatility and extraction resistance to various fluids. General purpose monomeric esters typically cannot hold up to severe service conditions. Rubber compounds in underhood automotive applications must retain their effective use over a long period of time. Polymeric esters are especially suited for high performance elastomers, such as nitrile, high saturated nitrile and polyacrylates. Polymeric esters also have found utility in chlorinated polyethylene, chlorosulfonated polyethylene and fluoroelastomers.

## HNBR

One example of how polymeric esters can enhance a high-performance elastomer is depicted in Figure 3. High-saturated nitrile is used in many high-heat applications. The use of 8-10 trimellitate is well documented as the plasticizer of choice for HNBR. As the graph depicts, a phthalate/adipate polymeric ester with a molecular weight of 1000 will enhance long-term heat aging properties.

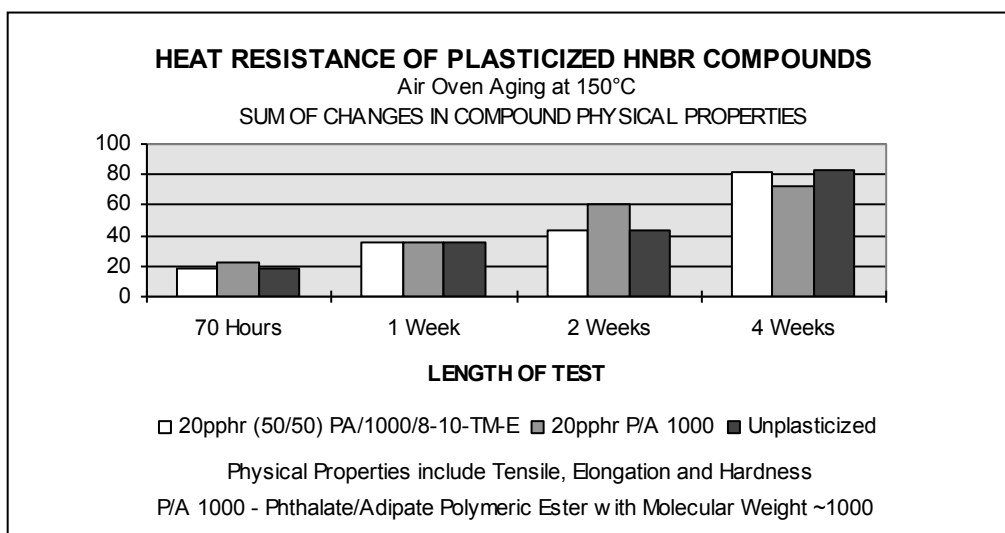


Fig. 3. Heat resistance of plasticized HNBR compounds

Many plasticizers have been evaluated in HNBR for compatibility. The high degree of saturation and potential crystalline character severely limit the choice of plasticizers. After several screening evaluations, a plasticizer that did show some compatibility advantages was a polyester glutarate (G-24,000). This plasticizer has a molecular weight of 5,000. The G-24,000 and 8-10 TM-E were compared in a standard HNBR recipe at 20 PPHR (Table VI).

The G-24,000 and 8-10 TM-E were found to provide comparable performance with regard to Mooney viscosity reduction at 150°C and compatibility and have equal weight losses after 70 hours at 150°C. The G-24,000 was less extractable in Fuel C and ASTM #1 and #3 Oils. The compound with 8-10 TM-E has improved low-temperature properties and permanence following distilled water immersion dry out.

**TABLE IV**
**Plasticizer Comparison in HNBR at 20 PPHR**

<b><u>Plasticizer</u></b>	<b><u>None</u></b>	<b><u>8-10 TM-E</u></b>	<b><u>Polyester Glutarate (G-24,000)</u></b>
Mooney Viscosity at 150°C	83.0	39.5	48.5
Duro A, Hardness	79	69	73
Gehman Torsion, °C at 10,000 psi	-27	-35	-31
Air Oven, 7 d at 150°C, % weight change	-2.4	-2.6	-2.4
ASTM Fuel C Immersion, 70 h at 40°C, % weight change, dryout	-1.5	-11	-4.8
ASTM #1 Oil Immersion, 70 h at 150°C, % weight change	-4.1	-11	-1.2
Distilled Water Immersion, 70 h at 100°C, % weight change	+ 3.0	+ 3.6	+ 9.9

The results for Fuel C and ASTM #1 Oil show that 8-10 TM-E is totally extracted from the compound. The G-24,000 is much less extractable in these hydrocarbon mediums.

**Acrylics**

Acrylic elastomers are used for applications requiring 149-177°C continuous service with intermittent exposure to 204°C. Acrylic elastomers have a saturated backbone with pendant groups attached through a carbonyl of such things as ethyl, butyl, ethylene and oxyethyl. In addition, acrylic elastomers are similar to nitrile in their polarity. A large variety of plasticizers are compatible with acrylics. However, because of a high-temperature post-cure required by some acrylics and the higher maximum temperature of application, only a few plasticizers show a reasonable degree of utility. Another property of acrylics that limits the amount of plasticizer incorporated is tensile strength. Acrylics generally do not have and are not used in applications requiring high tensile strength. Many compounders try to use the least amount of plasticizer to achieve their end requirements.

Polymeric plasticizers that are efficient in lowering hardness, provide good low-temperature properties and have low volatility in both post-cure and heat aging are ideal candidates for acrylics. Two polymeric plasticizers that meet these requirements are polyester adipates with a molecular weight of 1000. A study of A-1000A, A-1000B and Dibutoxyethoxyethoxyethyl glutarate (DBEEEG) in Vamac D for original and aged physical properties indicates some major benefits of using polymeric esters. Table V



highlights data from this study conducted by DuPont Dow Elastomers L.L.C.®. DBEEEG, a high molecular weight glycol ether ester monomeric plasticizer, is commonly recommended for acrylic elastomers. In this study, A-1000A and A-1000B show they are equal or better than DBEEEG at softening efficiency and original low temperature. A-1000A and A-1000B provide better permanence after heat aging, resulting in the retention of physical properties.

The compound containing A-1000B shows advantages in compression set and retention of low-temperature properties. It is important to note the original tensile strengths of each compound. As was stated earlier, acrylic elastomers have low tensile strength without plasticizer. The addition of plasticizer will decrease tensile strength. The A-1000A and A-1000B compounds have original tensile strengths of 11.2 MPa and 11.3 MPa, respectively, which is a marked difference from the DBEEEG (8.8 MPa) compound.

**TABLE V**

**Plasticizer Evaluation in Vamac D at 10 PPHR**

<b>Plasticizer Variable</b>	<b>A-1000A</b>	<b>A-1000B</b>	<b>DBEEEG</b>
<b>Original-Post cured 2 h at 175°C</b>			
Tensile Strength, Mpa	11.2	11.3	8.8
Hardness, Shore A, Pts.	72	69	71
<b>Aged 1008 h at 150°C</b>			
% Elongation Change	-14.6	-21.6	-25.9
Hardness, Shore A (pts change)	11	13	17
% weight loss	3.75	3.85	7.13
<b>Low Temperature Testing</b>			
DSC, Inflection, °C, original	-31.9	-33.8	-36.8
After 1008 h at 150°C	-28.4	-30.1	-28.1
Gehman, T-10, °C	-21.9	-25.4	-25
<b>Compression Set, Method B, Dried Pellets</b>			
70 h at 150°C - Post cured (Cooled 2 h in Clamps)	41	37	48

An important application for ethylene acrylic elastomers is transmission seals. Table IV compares the two polymeric adipate esters to the traditionally used DBEEEG. From an initial analysis, it appears there is no advantage of the polymeric esters versus the DBEEEG, except that the DBEEEG compound increases in hardness and the polymeric ester compounds show a slight decrease in hardness. This data indicates that the DBEEEG compound is being extracted and replaced by the transmission fluid. The transmission fluid is not as efficient in lowering the hardness as DBEEEG. The data for the polymeric ester compounds indicates that the plasticizer is partially extracted and is thus more permanent.

The two polymeric adipates provide the best combination of heat aging and transmission fluid immersion resistance.

**TABLE VI**

<b>Plasticizer Variable</b>	<b><u>A-1000-A</u></b>	<b><u>A-1000B</u></b>	<b><u>DBEEEG</u></b>
<b>Transmission Fluid Immersion, 1000 h at 150°C (302°F)</b>			
Hardness, Duro A, pts.	54	53	58
Hardness Change, pts.	-2	-3	+5
Weight Change, %	+12	+14	+13
Volume change, %	+18	+20	+18
180° Bend, all pass	Yes	Yes	Yes

## **Chlorinated polyethylene**

Chlorinated polyethylene (CPE) was developed for use in applications involving serviceability where oil resistance, ozone and weathering resistance are important. CPEs can generally be used in applications that encounter service temperatures up to 149°C. This polymer owes its ozone and weathering resistance and relatively good heat aging properties to the fact that it has a saturated backbone. In addition, the presence of chlorine in the elastomer imports enhanced oil resistance.

Common plasticizers for CPE are high oxirane content epoxidized soybean oil, and tri-octyl trimellitate (TOTM). These plasticizers provide a good overall balance of heat and oil resistance that is needed for applications up to 150°C. Polymeric plasticizers have not been used to a great extent because of observed porosity in cured compounds.

The porosity problem has not been investigated thoroughly, but is believed to be related to the chlorine content and cure systems breaking down the polymeric esters. In our evaluations of polymeric esters, one plasticizer did provide the necessary permanence properties needed for CPE, without causing porosity in cured compound. The polymeric adipate A-1000A can be used in all cure systems for CPE without a problem. A comparison of physical properties for A-1000A, ESO and TOTM in CPE is provided in Table VII. The adipate-based polyester A-1000A provided a number of interesting properties relative to TOTM and ESO, as follows:

- ♦ Greater Mooney viscosity reduction
- ♦ Lower percent change of elongation, hardness and weight after an aging for 70 hours at 150°C
- ♦ Lower change of hardness, volume and weight after Fuel C immersion
- ♦ Significantly lower change after immersion in ASTM 2 oil for 70 hours at 150°C

**TABLE VII**

**Plasticizers for CPE at 35 PPHR**

<b>Plasticizer Variable</b>	<b>ESO</b>	<b>A-1000A</b>	<b>TOTM</b>
<b>Molecular Weight</b>	<b>1000</b>	<b>1000</b>	<b>550</b>
<b>Low Temperature</b>			
D-2137, °C	-35	-34	-42
D-1053, °C	72	69	71
<b>Air Oven, 70 h at 150°C</b>			
% Elongation Change	-20	-6	-30
% Weight Change	-1.8	-2.6	-3.9
<b>ASTM 2 Oil, 70 h at 150°C</b>			
% Elongation Change	-20	-9	-32
% Weight Change	+41	+38	+43

**Acrylonitrile**

Nitrile rubber is typically used in applications up to 125°C. The majority of nitrile compounds are plasticized with monomeric esters. The oil and fuel applications for NBR generally require that the plasticizer be extracted to some extent to meet volume swell requirements. There are many applications that require more permanence, especially in terms of heat and hydrocarbon extraction. Basically, all polymeric esters have good compatibility in NBR. The compatibility of ester plasticizers can vary depending upon the ACN content of the nitrile and the amount used. The higher ACN content nitriles require higher polarity esters, and the lower ACN content nitriles require esters of lower polarity. Because the majority of the polymeric esters can be used in nitrile, we will only highlight a few products that have some high-performance properties.

<b>A-1000A</b>	(Polyester Adipate) - Good combination of low temperature, efficiency, property retention after oil aging, fuel hoses
<b>G-24,000</b>	(Polyester Glutarate) - High temperature and oil resistance hydrocarbon solvent resistance, print roll compounds
<b>A-150,000</b>	(Polyester Adipate) - High temperature and oil resistance oil seals
<b>S-160,000</b>	(Polyester Sebacate) - High temperature and oil resistance, hydrocarbon solvent resistance, oil field wire and cable

## Olefinic and EPDM

Olefinic thermoplastic elastomers can be subdivided into two major areas, TPO and TPV. Thermoplastic olefins and thermoplastic elastomers are based on blends of vulcanized rubber and semi-crystalline plastics, such as polypropylene (PP).

Polypropylene in its isotactic and syndiotactic forms can become very brittle at low temperatures due to their inherent crystallinity and relatively high  $T_g$ . Based on work done by Ellul of AES, it was discovered that certain “non-polar” aliphatic esters, particularly monomeric tallates and sebacates, can effect a large depression in the glass transition ( $T_g$ ) of the PP amorphous component. In this work, the plasticizer was distributed in the PP and the vulcanized elastomer EPDM phases equally.<sup>3</sup>

The following ester plasticizers and paraffinic oil were then mixed with the EPDM rubber to determine physical properties and  $T_g$ .

- Di-2ethylhexyl sebacate (DOS)
- Isodecyl tallate
- Butyl tallate
- Paraffinic oil--Sunpar® 150

The  $T_g$  at various volume fractions of these esters is listed in Table VIII.

**TABLE VIII**  
**EPDM/Diluent Compositions -  $T_g$**

	<u>Volume Fraction</u>	<u>Calculated <math>T_g</math>, °C</u>
DOS	.52	-72
Butyl Tallate	.562	-76
Isodecyl Tallate	.562	-85
Paraffinic Oil	.562	-52

The ester plasticizers provided significantly lower  $T_g$  than the paraffinic oil.

*Plasticization of PP, effect on  $T_g$  and comparison to EPDM* - The data reported by Ellul of AES shows DOS as an excellent plasticizer for the amorphous phase of PP and significant depression of  $T_g$ . Plasthall® 100 and paraffinic oil were also mixed with PP and compared to DOS for  $T_g$ . Table IX lists the results.

**TABLE IX**  
**PP/Diluent Compositions -  $T_g$**

	<u>Volume Fraction</u>	<u><math>T_g</math>, °C</u>
DOS	.40	-35
Isooctyl Tallate (P100)	.40	-35
Paraffinic Oil	.40	-12

A comparison of the tallate (P100) and DOS shows the  $T_g$  behavior to be similar.

*Effect of various plasticizers on  $T_g$  of dynamically vulcanized EPDM–PP TPEs* - The way to successful plasticization of dynamically vulcanized blends of elastomer and polypropylene was to identify plasticizers that had a low  $T_g$  and a high boiling point and that were compatible over a broad temperature range with both rubber and polyolefin plastic components. The study conducted by AES evaluated various diluents ranging from mineral or synthetic oils to various types of esters on the effect on  $T_g$  of TPV based on EPDM/PP TPEs; these are shown in Table X.

**TABLE X**  
**Effect of Plasticizer Type on  $T_g$ ,  $T_m$ , and  $X_c$  of a Dynamically Vulcanized Thermoplastic Elastomer Blend<sup>a</sup>**

TPE	Plasticizer	$T_g$ , <sup>b</sup> °C Rubber	$T_g$ , <sup>b</sup> °C Plastic	$T_m$ , °C	$X_c$ , %
TIA	NONE	-41	+10	165	45
TIB	Polyurea grease	-47	-1	159	50
TIC	Paraffinic Oil	-46	-5	158	49
TID	Napthenic Oil (Cyclolube 213)	-48	-5	158	47
TIE	Napthenic Oil (Cyclolube 4053)	-50	-5	157	49
TIF	Napthenic Oil (Cyclolube 410)	-51	-5	158	-
TIG	Amoco 9012 polypropylene	-45	-10	159	47
TIH	Alkylalkylether diester glutarate	-55	-11	159	-
TIJ	Diisooctyldecanedioate	-56	-14	158	51
TIJ	Dioctyl sebacate	-60	-18	158	53
TIK	Dioctyl azelate	-60	-22	-	-
TIL	Diisooctylnonyl adipate	-64	-24	-	-
TIM	Butoxyethyl oleate	-66	-20	158	46
TIN	n-butyl oleate	-71	-24	155	48
TIO	n-butyl tallate	-70	-24	155	45
TIP	Isooctyl tallate	-75	-26	155	51

<sup>a</sup>Dynamically vulcanized TPE,<sup>25</sup> 30 EP (D) M-70 isotactic polypropylene blend, plus 40 percent plasticizer phenolic resin system curative

<sup>b</sup> $T_g$ s measured from tan delta peak at 10hz.

The data clearly demonstrates that certain types of esters are extremely effective in lowering the  $T_g$  temperatures of both EPDM and PP components of the TPE. The data also indicates that only the amorphous component of the PP is plasticized, while the crystalline fraction remains essentially intact. This is an extremely important finding because it implies that semicrystalline polymers can be successfully plasticized with certain aliphatic esters without much detracting of elevated temperature performance.

Polymeric esters of 6000 molecular weight were found to be ineffective due to lower compatibility with EPDM and PP.

Low-temperature impact strength - One method used for measuring the strength of a compound at low temperatures is Notched Izod impact. Table XI lists the impact strength for several esters and paraffinic oil at -40°C in a TPV.

**TABLE XI**  
**Effect of Plasticizer Type on T<sub>g</sub>s and Impact Behavior at -40°C**  
**of a Thermoplastic Elastomer Blend<sup>a</sup>**

TPE	Plasticizer	T <sub>g</sub> , <sup>b</sup> °C Rubber Phase	T <sub>g</sub> , <sup>b</sup> °C Plastic Phase	Notched Izod Impact - 40°C/J/m
T2A	Paraffinic Oil	-59	-14	82
T2B	Diisooctyldodecanedioate	-66	-20	124
T2C	Diisobutyl adipate	-59	-28	138
T2D	Diisooctyl adipate	-65	-29	205
T2E	Diisooctylnonyl adipate	-64	-24	243
T2F	4-carbon linear tallate	-81	-29	414
T2G	8-carbon linear tallate	-82	-28	678
T2H	8-carbon branched tallate	-77	-29	850
T2I	10-carbon linear tallate	-79	-30	561
T2J	13-carbon linear tallate	-73	-24	687
TIK	28-carbon linear tallate	-76	-24	649

<sup>a</sup>Dynamically vulcanized TPE,<sup>25</sup> 30 EP (D) M-isotactic polypropylene (30/70), plus 32 percent plasticizer

<sup>b</sup>T<sub>g</sub>s measured from tan delta peak at 10hz.

### Summary

The basic function of an ester plasticizer is to modify a polymer or resin to enhance its utility. Ester plasticizers make it possible to process elastomers easily while also providing flexibility in the end-use product. Plasticizer–elastomer interaction is governed by many factors, such as solubility parameter, molecular weight and chemical structure. Ester plasticizers are selected based upon cost/performance evaluation. The rubber compounder must evaluate ester plasticizers for compatibility, processability, permanence and performance properties. The study of these properties by the rubber compounder will contribute to the selection of a high-performance ester plasticizer.

### References

1. ASTM D883, "Plastics Nomenclature," American Society for Testing Materials, Philadelphia, PA., 1991