EASTMAN

Eastman™ cellulose-based specialty polymers

Contents

Eastman cellulose-based specialty polymers

This publication provides the protective coating, printing ink, and related industries with a general discussion of the commercially available organic acid esters of cellulose: cellulose acetate (CA), cellulose acetate propionate (CAP), and cellulose acetate butyrate (CAB). It includes basic information on physical properties, solubility properties in various solvents and monomers, and intercompatibility properties of various cellulose esters. Typical uses for cellulose esters are discussed briefly as a general guide to selecting esters for various applications.

CAs are the least soluble and compatible of Eastman's portfolio of cellulose esters. They require stronger solvents but, as a result, offer excellent chemical resistance. They have high glass transition temperatures and produce tough and hard films. CAPs have improved compatibility and solubility and are used in applications where low odor is required.

CAB esters are used as binders in protective and decorative coatings for metal, wood, textiles, cloth, paper, plastic, and leather. Eastman CABs are used as binders by formulators because they provide excellent color and color retention, toughness, flexibility, flow control, and good weather resistance.

CAB esters are also useful as coatings additives where they can provide a significant performance edge. Frequently described as versatile problem solvers, cellulose esters provide qualities such as good flow and leveling, faster drying, sag resistance, viscosity control, intercoat adhesion, and metal flake orientation.

These esters are compatible with many resins and are also soluble in low-cost solvent systems. Most CABs are soluble in esters, ketones, glycol ethers, glycol ether esters, blends of alcohols and aromatic hydrocarbons, and they are quite tolerant of diluents such as aromatic hydrocarbons and alcohols. Films produced from Eastman CAB are optically clear, very tough, and hard and possess a high degree of ultraviolet stability.

The data in this publication is intended as a source of basic information. Additional data on the properties and performance of specific esters and formulation and application details are available on www.eastman.com and are covered in separate publications.

Detailed literature on these products and technical assistance with their selection and use are also available through your Eastman representative. Eastman also manufactures cellulose-based polymers used in controlled drug delivery. These polymers are produced under strict manufacturing conditions required by the U.S. Food and Drug Administration for pharmaceutical excipients. More information can be obtained by contacting the Excipients Business Group or Technical Service through your Eastman representative.

Performance benefits in coatings

When used as an additive, modifying resin, or major film former in printing inks and coatings applications, cellulose esters provide a number of performance benefits including:

- Reduced dry time
- Improved flow and leveling
- Reduced cratering
- Sag control
- Color control in multipigment systems
- Improved sprayability
- Reduced picture framing
- Viscosity control
- Redissolve resistance
- Resistance to yellowing
- Stable carrier for metallic pigments
- Metallic flake control
- Efficient pigment dispersion medium
- Reduced blocking
- Solvent craze resistance
- Polishability
- UV stability
- Reduced plasticizer migration
- Gloss control

Eastman cellulose esters: CA, CAP, & CAB

Eastman manufactures CA, CAP, and CAB. All three products are available with a range of substituents and molecular weights that determine their solubility, compatibility, viscosity, and hardness.

Viscosities are determined using the falling-ball method, according to ASTM D1343 in the solution described as Formula A, ASTM D817. Viscosities in poise are converted to ASTM seconds equivalent to values obtained under ASTM D817. In Eastman nomenclature for cellulose esters, the viscosity of each individual ester is indicated in its product code. For example, Eastman CAB-381-2 has a viscosity of 2 seconds, Eastman CAB-381-20 has a viscosity of 20 seconds, and Eastman CAB-531-1 has a viscosity of 1 second.

Types

Cellulose acetate butyrate (CAB)

There is a wide range of butyryl, acetyl, and hydroxyl levels available in Eastman CABs and, consequently, a wide range of properties. An ester with a medium butyryl level, such as Eastman CAB-381, is widely soluble and compatible with resins and plasticizers. It serves in many coatings applications including wood finishes; automotive topcoats; rubber and plastic coatings; cloth coatings; glass coatings; flexographic, gravure, and screen-printing inks; hot melts; and adhesives. It is also used as a medium in which to disperse pigments on a differential-speed two-roll mill. CABs are stable to ultraviolet light and do not react with dyes, fluorescent colors, or metallic pigments. Because this product is useful in so many different types of coatings, it is commonly referred to as the general-purpose butyrate.

Eastman CAB-551, an ester with the highest practical butyryl level, is used in cross-linked finishes to improve dry-to-touch time, reduce cratering, provide a better pigment-dispersion medium, improve intercoat adhesion, and improve coating performance. Because it is soluble in many monomers, including styrene, Eastman CAB-551 is a valuable ingredient in ultraviolet-cured coatings and inks.

Certain Eastman CABs are manufactured at high hydroxyl levels to provide alcohol solubility. Solutions of these cellulose esters in alcohol are used where conventional solvents such as aromatics, esters, or ketones are not feasible. With their high hydroxyl content, these butyrates are useful in curing finishes, such as baking enamels and acid-catalyzed coatings.

Selection of a CAB must be made with care because there is a wide latitude of solubility, compatibility, and performance. Butyrate esters of low molecular weight (low viscosity) are designed to be used as additives or as reactive intermediates in curing finishes. The CAB molecule may be considered a polyol, especially when the hydroxyl content is high. Cross-linking the butyrates with amino resins or isocyanates enhances solvent resistance and performance of the coatings.

Cellulose acetate propionate

CAP properties are intermediate between CA and CAB. They resemble CA in many performance properties and are similar to CAB in solubility and compatibility. Like acetates, the propionates have low odor and thus can be used where this is a requirement. These properties make propionates especially useful in inks, overprint varnishes (OPVs), plastic coatings, paper coatings, and various reprographic processes. The solubility of high-hydroxyl propionate in alcohol-water mixtures makes it useful in flexographic inks and OPVs to provide low odor, nonyellowing characteristics, fast solvent release, and good adhesion to plastic films and paper.

Propionate esters can be used effectively to disperse pigments. Propionates are also stable to ultraviolet light and do not react with dyes, fluorescent colors, or metallic pigments.

Cellulose acetate

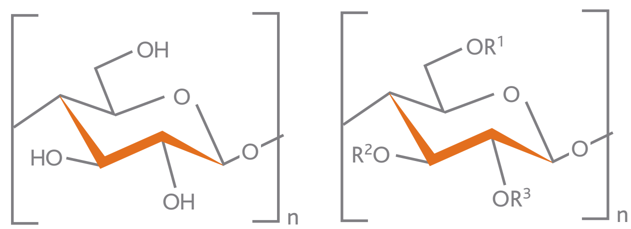
Lacquer-type CAs possess certain characteristics that make them difficult to formulate as coatings. However, these characteristics are valuable in certain areas of the protective-coating field.

CAs are soluble only in strong solvents such as acetone, methyl ethyl ketone, and ethyl acetate, and they have very low tolerance for hydrocarbons. These esters only have limited compatibility with commercially available resins. Only very active plasticizers such as dimethyl phthalate or triacetin will remain in the film without exudation. The hardness and melting point of CAs are relatively high.

These characteristics would seem to limit uses, but they yield desirable properties for a number of applications. These include solvent- and grease-resistant coatings for paper products, wire, and cloth; dopes and cements for model airplanes; lacquers for electrical insulation and for the manufacture of capacitors; barrier and release coatings for pressure-sensitive tapes; and protective coatings for plastic items such as shoe heels and pen barrels.

CA weathers well and is nonyellowing on long-term exposure to the sun, making it useful as a coating for signs and decals. The transparency of CA coatings and their ability to transmit sunlight, particularly beneficial ultraviolet rays, have led to extensive use of these film formers for coating wire screening for greenhouse windows, poultry runs, and similar structures. The good physical strength of the coatings yields a tough, tear-resistant screen.

Figure 1 **Chemical structures of cellulose and organic ester derivatives**



Cellulose | Cellulose acetate butyrate

R^1, R^2, R^3 = Acetyl, Butyryl, or H

Table 1 **Typical properties**[a]

Eastman cellulose ester	Viscosity[b]		OH %	Melting range °C	T_g °C	Wt/vol			Comments
						lb/gal	kg/L	MW_n[c]	
Cellulose acetate butyrate									
CAB-551-0.01	0.01	0.038	1.5	127–142	85	9.67	1.16	16,000	
CAB-551-0.2	0.20	0.76	1.8	130–140	101	9.67	1.16	30,000	Butyryl level: flexibility, solubility, and compatibility
CAB-553-0.4	0.30	1.14	4.8	150–160	136	10.00	1.20	20,000	
CAB-531-1	1.90	7.22	1.7	135–150	115	9.75	1.17	40,000	
CAB-500-5	5.00	19.00	1.0	165–175	96	9.83	1.18	57,000	
CAB-381-0.1	0.10	0.38	1.3	155–165	123	10.00	1.20	20,000	
CAB-381-0.5	0.50	1.90	1.3	155–165	130	10.00	1.20	30,000	
CAB-381-2	2.00	7.60	1.3	171–184	133	10.00	1.20	40,000	
CAB-381-2 BP	2.20	8.36	1.8	175–185	130	10.00	1.20	40,000	
CAB-381-20	20.00	76.00	1.8	195–205	141	10.00	1.20	70,000	
CAB-381-20 BP	16.00	60.80	0.8	185–195	128	10.00	1.20	70,000	
CAB-321-0.1	0.10	0.38	1.3	165–175	127	10.00	1.20	12,000	
CAB-171-15	15.00	57.00	1.1	230–240	161	10.50	1.26	65,000	
Cellulose acetate propionate									
CAP-504-0.2	0.20	0.76	5.0	188–210	159	10.53	1.26	15,000	
CAP-482-0.5	0.40	1.52	2.6	188–210	142	10.20	1.22	25,000	
CAP-482-20	20.00	76.00	1.8	188–210	147	10.20	1.22	75,000	
Cellulose acetate									
CA-398-3	3.00	11.40	3.5	230–250	180	10.90	1.31	30,000	Viscosity
CA-398-6	6.00	22.80	3.5	230–250	182	10.90	1.31	35,000	
CA-398-10	10.00	38.00	3.5	230–250	185	10.90	1.31	40,000	
CA-398-30	30.00	114.0	3.5	230–250	189	10.90	1.31	50,000	

[a]Properties reported here are typical of average lots. Eastman makes no representation that the material in any particular shipment will conform exactly to the listed properties. All Eastman cellulose esters are filtered and in the form of fine, white, dry powder except CA-394-60S, an unfiltered pellet form. Like most organic materials in powder form, these materials are capable of creating a dust explosion. Refer to NFPA Pamphlet No. 654, "Prevention of Fire and Dust Explosions in the Chemical, Dye, Pharmaceutical, and Plastics Industries."

[b]ASTM D817 (Formula A) and D1343

[c]Number-average molecular weight values, MWn, are polystyrene-equivalent molecular weights determined using size exclusion chromatography.

Table 2 **Solubility in common solvents at 10% NV concentrations**

Solvents	Evaporation rate	Eastman CA-398-3	Eastman CAB-171-15	Eastman CAB-321-0.1	Eastman CAB-381-0.5
Ketones					
Acetone	5.7	S	S	S	S
MEK (methyl ethyl ketone)	3.8	S	S	S	S
Eastman MPK (methyl *n*-propyl ketone)	2.3	I	S	S	S
Eastman MIBK (methyl isobutyl ketone)	1.6	I	I	S	S
Eastman MIAK (methyl isoamyl ketone)	0.5	I	I	S	S
Eastman MAK (methyl *n*-amyl ketone)	0.4	I	I	S	S
Cyclohexanone	0.3	S	S	S	S
Eastman DIBK (diisobutyl ketone)	0.2	I	I	I	I
DAA (diacetone alcohol)	0.12	S	S	S	S
Eastman C-11 ketone	0.02	I	I	I	I
Esters					
Ethyl acetate (99%)	4.1	PS	S	S	S
Eastman isopropyl acetate	3.0	I	I	S	S
Eastman *n*-propyl acetate	2.3	I	S	S	S
Eastman isobutyl acetate	1.4	I	I	S	S
Eastman *n*-butyl acetate	1.0	I	I	S	S
Eastman IBIB (isobutyl isobutyrate)	0.4	I	I	I	I
Eastman *n*-butyl propionate	0.5	I	I	S	S
Eastman EEP solvent	0.12	I	I	S	S
Eastman 2-ethylhexyl acetate	0.03	I	I	I	I
DBE (dibasic esters)	0.007	PS	S	S	S
Eastman Texanol™ ester-alcohol	0.002	I	I	I	I
Glycol ethers					
Eastman PM solvent	0.7	I	I	S	S
EE (ethylene glycol monoethyl ether)	0.3	I	I	S	S
PTB (propylene glycol monotertiary butyl ether)	0.25	I	I	I	I
Eastman EP solvent	0.2	I	I	I	I
PP (propylene glycol monopropyl ether)	0.2	I	I	I	I
PB (propylene glycol monobutyl ether)	0.08	I	I	I	I
Eastman EB solvent	0.06	I	I	I	I
Eastman DM solvent	0.02	PS	PS	S	S
DPM (dipropylene glycol monomethyl ether)	0.02	I	I	S	S
Eastman DE solvent	0.02	I	I	S	S
Eastman DP solvent	0.01	I	I	S	S
Eastman DB solvent	0.003	I	I	I	I
Eastman EEH solvent 85/15 ethylene glycol/ diethylene glycol 2-ethylhexyl ether	0.003	I	I	I	I
Glycol ether esters					
Ethylene glycol monoethyl ether acetate	0.2	I	I	S	S
Eastman EB acetate	0.03	I	I	I	S
EGDA (ethylene glycol diacetate)	0.02	S	PS	S	S
Eastman DE acetate	0.008	PS	PS	S	S
Eastman DB acetate	0.002	I	PS	I	S
Eastman PM acetate	0.4	I	PS	S	S
Alcohols					
Ethyl alcohol (anhydrous)	1.9	I	I	I	I
Ethyl alcohol (95%)	1.7	I	I	I	I
Isopropyl alcohol (99%)	1.7	I	I	I	I
Miscellaneous solvents					
Chlorinated: methylene chloride	14.5	S	S	S	S
Aprotic:					
THF (tetrahydrofuran)	6.3	S	S	S	S
DMF (dimethyl formamide)	0.2	S	S	S	S
n-methyl-2-pyrrolidone	0.04	S	S	S	S

Blends: Nonsolvents for CABs such as alcohols and aromatic hydrocarbons can be blended to produce very active solvent systems. For example, a 15% solution of Eastman CAB-381-0.5 in MPK has the same viscosity as the same concentration in a toluene/alcohol 80/20 blend. The tolerance of CABs for aromatic hydrocarbons in solvent systems is very high. They are also tolerant of aliphatic hydrocarbons such as VM&P naphtha,

Eastman CAB-381-20	Eastman CAB-500-5	Eastman CAB-531-1	Eastman CAB-551-0.01	Eastman CAB-551-0.2	Eastman CAB-553-0.4	Eastman CAP-482-0.5	Eastman CAP-504-0.2
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	PS
S	S	S	S	S	S	S	I
S	S	S	S	S	S	S	I
S	S	S	S	S	S	S	I
S	S	S	S	S	S	S	S
I	PS	PS	S	S	I	I	I
S	S	S	S	S	S	S	S
I	S	S	S	S	I	I	I
S	S	S	S	S	S	S	I
S	S	S	S	S	S	S	S
S	S	S	S	S	I	S	I
S	S	S	S	S	S	S	S
S	S	S	S	S	I	I	I
I	PS	PS	S	PS	S	PS	I
SI	S	S	S	S	I	I	I
S	S	S	S	S	S	S	PS
I	I	S	S	S	I	I	I
S	S	S	S	S	S	S	S
I	S	S	S	S	S	S	I
S	S	S	S	S	S	S	S
S	I	S	S	S	S	S	S
I	I	S	S	S	S	I	I
I	I	I	S	S	S	PS	S
I	I	I	S	S	S	I	PS
I	I	S	S	S	S	I	S
I	I	I	S	S	S	I	S
I	I	S	S	S	S	S	S
S	I	S	S	S	S	S	S
S	I	S	S	S	S	S	S
S	I	S	S	S	S	S	S
I	I	S	S	S	S	S	S
I	I	I	S	I	PS	I	I
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	I
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S
I	I	I	I	I	S	I	I
I	I	I	I	I	S	I	S
I	I	I	I	I	I	I	I
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S

although to a reduced degree. The range of possible blending ratios can far exceed the 80/20 ratio used in this example, especially when more complex solvent systems are used. CABs are often added to the coating as a solution, and zero VOC systems based on a mixture of parachlorobenzotriflouride (e.g., Oxsol™ 100) and acetone (90/10) have been used as well as high-purity methyl acetate or acetone alone.

S = Soluble; SH = Soluble with slight haze; PS = Partially soluble; I = Insoluble

Selection

CA esters

The four-solution-grade CAs only differ in molecular weight; the chemical compositions of the CAs suitable for coatings are the same. The selection of these esters therefore depends on the viscosity that can be used.

CAP esters

Eastman offers three propionate esters. CAP esters are slightly harder than their CAB counterparts and are virtually odorless. These esters are slightly less compatible than the more commonly used butyrate esters and find use in applications where high block and print resistance is required or where extremely low odor is desired. The high hydroxyl level of Eastman CAP-504-0.2 provides high cross-linking and solubility in alcohol.

CAB esters

The selection of a CAB should be based on the requirements of the application. Where toughness with some heat resistance is of prime importance, as in cable lacquers, esters with lower butyryl content (e.g., Eastman CAB-171) should be considered. If compatibility with a thermosetting acrylic resin is desired, as in an enamel application, a high-butyryl, low-viscosity ester (e.g., Eastman CAB-551) may be more useful. Other ester types between these two in butyryl content afford intermediate properties and a choice of viscosity ranges.

The properties of CAB esters are easily modified by the addition of plasticizers and/or resins to modify adhesion, flexibility, heat-sealing ability, moisture resistance, and other characteristics. Cross-linking with amino, isocyanate, or other reactive resins can alter properties and performance to a marked degree. As a rule, the higher-butyryl esters permit more and wider variation in modification and solubility than do the lower-butyryl esters.

Another consideration in selecting a CAB is its degree of chemical resistance. In laboratory comparisons made by immersing sample CAB films in various organic and inorganic reagent solutions, the ester of lowest butyryl content exhibited the best general chemical resistance. This property varied in other esters of the CAB series depending on their solubility and compatibility characteristics.

To select the optimum Eastman CAB ester for a specific application, the formulator must consider the characteristic properties of each ester type, effect of viscosity, and possible modification. The effects of the composition of CABs are discussed in the following.

Effect of butyryl content on properties

The large size and low polarity of the butyryl group on the molecule cause the cellulose chains to spread farther apart, lowering the attraction between them. The degree to which this change occurs depends on the number of butyryl groups present.

- **Flexibility and use of plasticizers**
  In thermoplastic systems, the amount of plasticizer required with each CAB to obtain a desired flexibility depends on the nature of the plasticizer and the butyryl content of the ester. The higher the butyryl content of the ester at a given viscosity, the greater the flexibility and the lower the plasticizer requirement for a given flexibility. Plasticizers may also influence the resistance to moisture, oils, and greases; toughness and hardness; flammability; electrical characteristics; and resistance to weathering. CABs of high butyryl content are more compatible with plasticizers than the lower-butyryl esters. Generally, the plasticizers found to be useful with vinyl chloride-acetate resins perform well with CABs.

- **Solubility and chemical resistance**
  For the many types and applications of CAB, a wide range of solvents is desirable to control evaporation rate, performance in application, and final film properties. As the butyryl content of the ester increases, solubility increases. The ester not only becomes more soluble (lower viscosities in similar solvents), it is also soluble in a wider range of solvents. Eastman CAB-381 and other types with higher butyryl content will dissolve in aromatic hydrocarbon-alcohol mixtures; and those with very high hydroxyl levels, such as Eastman CAB-553, will dissolve in alcohols and even tolerate a substantial portion of water. The higher-butyryl esters will also dissolve in, or at least tolerate monomers, such as styrene and acrylates, used in ultraviolet-cured coatings and inks. In thermoplastic systems, chemical resistance is generally greater with lower-butyryl esters. In thermoset systems, the hydroxyl level determines the crosslink density, which is directly proportional to chemical resistance.

- **Tolerance for diluents**
  Using diluent (nonsolvent) without sacrificing film quality helps lower cost. A higher butyryl content will increase the tolerance of diluents. Eastman CAB-171 will tolerate about 15% toluene in a solvent composition, while Eastman CAB-381 will tolerate more than 90% toluene. The tolerance for aromatic hydrocarbons is much greater than for aliphatic hydrocarbons.

- **Compatibility with resins**
  The higher-butyryl esters are more compatible with modifying resins and other film formers than the lower-butyryl esters. In general, CABs are compatible with most acrylics, polyesters, phenolics, ureas, and isocyanates. They are also compatible with some epoxies and polyvinyl acetates. CABs are often incompatible with melamines, urea-formaldehydes, and most alkyds.

  Compatibility with alkyds is mostly limited to short-oil coconut-based alkyds, although exceptions exist. Significant compatibility information is available in the technical data sheets available for each CAB type. Compatibility is typically tested by casting films of various ratios of CAB to resin on a glass plate. A clear film indicates good compatibility. If a CAB shows incompatibility, selecting a CAB with higher butyryl content often will improve compatibility.

- **Moisture resistance**
  Eastman CAB films are considered to be water resistant, although they do transmit water vapor to a degree. Other factors being equal, the higher the butyryl content, the higher the resistance to moisture. This property may be altered by high hydroxyl level or by the addition of plasticizers, waxes, resins, or other additives.

- **Grease resistance**
  Where frequent contact with greases and oils is an important factor, the esters with high hydroxyl content should be considered. As might be expected from the general trend of plasticizer compatibility, the lower-butyryl esters have greater resistance to such materials.

- **Tensile strength, hardness, and melting point**
  Eastman CAB has been selected for many applications because of high tensile strength, good hardness, and high melting point. Generally, these features decrease gradually as the butyryl content increases. However, the viscosity of the ester, which is discussed in the following sect ion, also markedly influences these properties.

Effect of viscosity on properties

As might be expected, the viscosity (directly related to the molecular weight) of an ester has considerable influence on its physical properties. Films or coatings made from cellulose esters of higher viscosities have the advantage of greater toughness and better mechanical properties, whereas the lower-viscosity esters permit a higher-solids concentration at a given solution viscosity. High-viscosity types such as Eastman CAB-381-2, CAB-381-20, and CAB-531-1 are particularly effective in increasing cold-crack resistance due to improved dimensional stability. High molecular weight with resulting high viscosity is not usually a requirement when CAB is used as an additive in thermosetting finishes. The CAB cross-links and builds molecular weight during the curing process. With thermoplastic film formers where the CAB does not cross-link, very low molecular weight CABs used as modifiers or additives may cause brittle films, cold-cracking, and related malfunctions. Thus, with thermoplastics, the CAB used should be a reasonably good film former in its own right.

- **Toughness**

  A greater degree of film toughness may be obtained with the higher-viscosity grade of a particular ester type. This difference has been shown by subjecting films of Eastman CAB-381-0.5 and CAB-381-2 to the MIT Folding Endurance Test (ASTM D2176). In this test, the film, under tension, is folded mechanically around a curved surface through a total angle of approximately 135 degrees to both right and left of the null position. The number of double folds required to sever the sample is reported as the MIT Folding Endurance. Results from the test indicate that substitution of the higher-viscosity CAB-381-2 for the low-viscosity CAB-381-0.5 ester in a given film formulation can triple the fold endurance.

  Another indication of the influence of viscosity on toughness is obtained by tensile strength measurements. Results show that the higher the viscosity of the ester, the greater the tensile strength of the film. Tensile strength among the ester types ranges from 4,500 to 11,000 psi. Elongation varies from 5% to 15%, and Tukon hardness from 15 to 27 Knoops. These properties are related to the butyryl content, hydroxyl content, and molecular weight of each CAB type. For example, unmodified films of CAB-381-0.5 have given tensile strength values of about 8,000 lb/in.^{2} (562 kg/cm^2), while similar films of CAB-381-2 have given values of about 10,000 lb/in.^{2} (703.1 kg/cm^2).

- **Hardness, solubility, compatibility, density, and melting point**

  Increasing the viscosity of a particular ester type results in a very small decrease in solubility and compatibility with virtually no change in hardness and density. The melting point, however, increases with viscosity. Eastman CAB-381-20, for example, melts at approximately 200°C (392°F), whereas Eastman CAB-381-0.5 melts at approximately 160°C (320°F).

Effect of hydroxyl content on properties

Eastman CAB contains hydroxyl functionality at varying levels, depending on ester type. Most butyrates are manufactured with a hydroxyl content best suited for general applications (about 1.5%), permitting good solubility, compatibility, and performance in coatings applications. When considering the hydroxyl functionality in the stoichiometry of a crosslinking coatings system, the following calculations may be useful.

Hydroxyl number = 33 X wt% hydroxyl

Hydroxyl equivalent wt = 1,700 ÷ wt% hydroxyl

- **Moisture regain**

  When exposed to the atmosphere, cellulose esters will regain moisture depending on relative humidity (Table 3). Regain increases with increasing hydroxyl content. Normally, CAB is shipped in multiwall bags to retard moisture regain. Near-moisture-proof packages are used only for special requirements. If the powder is left exposed to a humid atmosphere, the moisture content will increase to 4%–5%. This increase may not be detrimental to most thermoplastic lacquer coatings but can cause difficulty with polyurethane coatings and catalyzed amino systems. For coatings in which the presence of water is detrimental, it may be necessary to dry the butyrate using oven heating, azeotroping, or a molecular sieve.

Table 3 **Equilibrium moisture regain**

Eastman cellulose ester	Relative humidity			
	25%	50%	75%	95%
CAP-482-0.5	0.7	1.0	2.8	4.5
CAB-381-0.5	0.4	0.9	1.8	2.6
CAB-531-1	0.4	0.8	1.5	2.2

- **Water tolerance**

  All Eastman CABs will tolerate some water in lacquer solutions, especially if water-soluble solvents are present. The higher the hydroxyl level, the more water will be tolerated. If the hydroxyl level is as high as 5 wt%, as much as 40% water can be tolerated in the solutions.

- **Moisture resistance**

  The moisture resistance of CAB films can be altered by the degree of hydrolysis. The greater the hydroxyl content of the ester, the more hydrophilic are films formed from it. Thus, if any degree of moisture resistance is required from a film of high-hydroxyl butyrate, it is necessary to react the hydroxyls with an isocyanate or amino resin or some other reactive intermediate.

- **Solubility**

  The solubility of CAB varies with changes in the hydroxyl content of the ester. As the hydroxyl content of the ester increases, solutions tend to become clearer. When the hydroxyl content is greater than 4%, the ester is soluble in highly polar solvents such as alcohol/water blends but is much less tolerant of hydrocarbon solvents.

- **Reactivity**

  The reactive hydroxyl group that may be cross-linked with urea-formaldehyde, melamine, or polyisocyanate resins, provides the ability to formulate a variety of curing coatings and inks. The selection of higher-hydroxyl cellulose esters such as Eastman CAB-553-0.4 for use in curing systems produces films with high cross-link density and, consequently, excellent chemical and physical properties.

  CAB can be used as a film former, as an additive to other film formers, and as a reactive polyol in curing coatings. Even the very lowest molecular weight CAB ester will function as an additive to improve application and performance characteristics while serving as a polyol and cross-linking with the reactive polymers to form hard, tough, insoluble coatings. The degree of hydrolysis selected for each of the Eastman CABs usually provides the best combination of solubility, weathering, moisture resistance, and other film properties. For example, Eastman CAB-553-0.4 is alcohol-soluble and also very reactive which makes it the ideal CAB for acid-cured conversion varnishes.

Cellulose esters as coatings additives and modifiers

Many industrial finishes have weaknesses that can be overcome by the addition of a small amount of butyrate. There is no simple rule as to which butyrate to use, except that it must be soluble in and compatible with the balance of the coatings composition. The amount of CAB required to solve a problem in a coatings composition may vary from as little as 0.1% to as high as 40%–50%.

A small amount of CAB may be added to thermoplastic or thermosetting finishes to improve application and performance properties. The most notable improvements are reduced cratering, quicker dust-free time, and better pigment control in thermosetting finishes; in thermoplastic finishes, CAB improves dry-to-touch times and gives better pigment control (Figure 2).

Figure 2 **Benefits of using Eastman cellulose esters as additives or modifying resins in printing inks and coatings applications**

Due to their rapid viscosity build, cellulose esters prevent:

- Film distortions and craters.
- Sags and runs.
- Picture framing.
- Poor metal flake orientation.
- Color separation in multipigment systems.
- Pigment flooding and floating.
- Inconsistent gloss control with matting agents.
- Poor holdout.

Due to their Newtonian rheology, cellulose esters improve:

- Flow and leveling.
- Rheology control.
- Appearance (reduction of surface defects such as pinholes and craters).
- Spraying (atomization).
- Roll coat application.
- Curtain coat application (reduction of holes).

Due to their high T_g, cellulose esters provide:

- Rapid dry-to-touch times (reduced dirt pickup).
- Excellent hardness and hardness development.

Due to their cellulosic polymer nature and its pendant groups, CABs have:

- Good UV stability.
- Excellent dimensional stability (cold-crack resistance).
- Heat and moisture stability (exterior durability).
- Increased intercoat adhesion (attributed to the good wetting properties of CAB and the controlled level of solvent attack on one coat by a subsequent coat).

As an illustration, 10%–20% CAB is used with thermoplastic acrylic resins to provide better cold-crack resistance, better sprayability, and reduced dry-to-touch times. CAB is used with both thermoplastic and thermosetting acrylic resins as a pigment-dispersion medium.

In many thermosetting coating formulations, additions of 1%–5% CAB (based on solids) can minimize cratering, running, and sagging of the finish. Levels of 1%–10% CAB are used with thermosetting acrylic resins or polyester resins for flow control, quicker dust-free time, increased intercoat adhesion, and better pigment control. Addition of 15%–30% CAB in thermosetting acrylic enamels provides a coating that dries like a lacquer to a hard surface that can be sanded to remove orange peel, sags, or embedded dirt. Spot repairs can then be made with the original coating composition. During the final bake at converting temperature, the enamel reflows to eliminate sand marks and provides a glossy thermoset finish.

Since CAB has numerous hydroxyls, its use in urethane compositions must be as a portion of the total polyol content and the amount of isocyanate resin can be adjusted as needed. It is possible to produce aliphatic urethane/CAB-based coatings without the use of any polyester polyols. CAB is used as a reactive molecule in many coatings, as with polyurethane and amino resins, and serves as a flow-control agent in other active systems. For example, Eastman CAB-381-0.1 is not soluble in styrene but it is soluble in a blend of styrene and unsaturated polyester. Up to a 10% level of the butyrate is added to styrene/unsaturated polyester coatings to control flowout and to prevent running and sagging on vertical surfaces. Eastman CAB-553-0.4, fully soluble in alcohol, is widely used as a polyol in the formulation of amino coatings. In this role, it functions both as a polyol and as an additive to improve flow, reduce cratering, provide quicker dust-free time, and serve as a pigment-grinding medium. Although limited in compatibility, Eastman CAB-171-15 is used in coatings where its high viscosity and limited solubility are needed. It is also useful where thermoplastic lacquers with good resistance to heat, chemicals, or solvents are required, as in wire coatings, textile coatings, and printable films.

There are numerous applications in which Eastman CAB serves as a useful component for viscosity modification, release, binding, or other purposes. These applications include plastic wood fillers, printing inks, pressure-sensitive tapes, heat-seal adhesives, gel lacquers, and glass lacquers.

Markets, technologies, and substrates

Many coatings formulators regard Eastman cellulose esters as problem solvers in their coatings systems. In the first half of this brochure, the focus has been on the cellulose esters themselves. The following pages will focus on their use in terms of markets, coatingstechnology, and specific substrates.

Automotive coatings

Eastman cellulose esters have been used for decades in OEM base coats, refinish primers, base coats and clear coats, and monocoats. Eastman CAB is often an integral component in achieving desired color effects, particularly through consistent metallic flake orientation in automotive base coats (examples of the impact on flake orientation as well as flow and leveling begin in the “Coil Coatings” section). They also assist in color matching even with difficult but valuable colors such as moonlight silver, antique gold, and stardust.

In addition, Eastman CAB provides faster, more uniform drying properties as well as excellent redissolve resistance. These are valuable properties for achieving consistent color match, particularly under varied application conditions found in refinish shops.

Eastman CAB is used in both thermoplastic and thermoset formulations. At additive levels, Eastman CAB can impart improved flow properties, reduced sand scratch telegraphing, and improved atomization. Eastman CAB is also a useful additive for improving drying speed, polishability, and flow properties in automotive clear coats resulting in excellent appearance and increased body shop productivity. It is particularly useful in formulation of matting additives to provide consistent gloss for lower sheen applications in coatings for automotive plastics.

In addition to the valuable application and appearance benefits of Eastman CAB, it has excellent weathering properties. Eastman CAB is also used in pigment dispersions for automotive applications to provide consistent tints and to achieve the maximum color development from a given pigment. Pigment chips and pastes produced with CAB in two-roll mill dispersion methods often provide higher clarity than any other dispersion method with other grinding vehicles.

Coatings for metal

In addition to automotive metal coatings, Eastman CAB lacquers are especially useful on structural aluminum and foil, stainless steel, chromium, brass, silver, and tin where protection of the metal surface and maintenance of the metallic luster are desired. By appropriate selection of modifying resins, butyrate lacquers may be formulated into clear or pigmented coatings that have good adhesion to metallic surfaces and that are resistant to salt, fog, oxygen, and other tarnishing and corroding elements.

A small amount of polyester resin combined with CAB produces tough, flexible films for metal protection. Curing coatings based on CAB in combination with polyester resins and amino resins have good chemical resistance. Low-viscosity- grade Eastman CAB-381 esters are widely compatible with modifying resins, have high tolerance for lacquer diluents, and are commonly used in clear coatings for metal.

The outstanding weather resistance of thermoplastic acrylic resins is complemented by CAB to provide superior original and refinish automotive coatings. The use of CAB in pigmented acrylic lacquers improves sprayability, flow properties, and resistance to solvent crazing and provides better orientation of metal pigment. CAB used in the base coat of a base coat/clear coat system provides improved metal flake orientation and resistance to redissolve from the topcoat solvents.

Both thermoplastic and thermosetting thermal reflow coatings incorporating CAB can be sanded after a low bake, yet they are sufficiently thermoplastic to reflow and give a very high gloss when heated to a moderately high temperature.

Coatings for plastic

Portions of the surface of molded plastic articles are frequently coated with a lacquer that primarily serves a decorative purpose; for example, metallic coatings on cell phones or casings for other electronics. In automotive applications, coatings of various colors may be coated on the reverse side of clear plastic parts to match other interior colors or to give a metallic appearance. But the coating may also be functional, such as an aid to polish out machine and mold marks, a barrier coating to reduce or prevent plasticizer migration from molded articles, or an aid to reduce damage from marring, abrasion, and weathering.

Eastman CAB has been used for many years in coatings for various plastic materials. CAB may be used in the barrier coat to protect the plastic from attack by strong solvents in subsequent coating layers. CABs are frequently used for aluminum flake orientation in CAB/acrylic metallic lacquers for casings of consumer electronics. Butyrate/acrylic compositions give good results when used on ABS (acrylonitrile-butadiene-styrene copolymer), acrylic, or cellulose plastics. The clear systems yield very hard, brilliant films; the pigmented systems are bright and show exceptionally good gloss retention.

Eastman CAB polymers are effective as release coatings for silicone rubber molds used in forming rigid polyurethane articles. The base release coating not only protects the mold from attack by the polyurethane components, it also becomes an integral part of the plastic article and serves as a tie coat for other coatings on the molded article.

Plasticized polyvinyl chloride products have found wide acceptance by consumers in diversified applications such as upholstery for automobiles and furniture; automotive door panels, dashboard pads, and headliners; drapery sheeting; purses and luggage; and garments. Vinyl plastics are coated for various reasons, including: (1) to change the color of the plastic, (2) to control surface gloss, (3) to impart a dry feel, and (4) to retard or prevent plasticizer migration. Vinyl lacquers modified with CAB and an acrylic resin are suggested starting points for developing coatings for hard-to-coat vinyl plastics.

Coatings with exceptionally good flexibility can be prepared by blending Eastman CAB with urethane elastomers for application to thermoplastic elastomers. The coated elastomeric plastics are used in exterior auto parts, gears, seals, gaskets, valves, tubing, footwear, toys, and sports equipment.

Addition of Eastman CAB to 2K polyurethane coatings can provide faster drying properties while maintaining chemical resistance and weathering properties. Eastman CAB also improves the "hand" of 2K polyurethane films, providing a more natural feel to the finished coating. The use of Eastman CAB reduces the drying time of the coating and provides hydroxyl groups for subsequent cross-linking with isocyanate prepolymers.

Coatings for wood

Eastman CAB offers the furniture lacquer supplier and furniture manufacturer an excellent material with which to obtain desirable properties. It can be formulated into coatings that possess good durability, stain resistance, plasticizer migration resistance, depth of finish, color, and color stability. In addition, Eastman CAB has excellent sprayability and flowout, fast through dry, and good film clarity. Full advantage of these qualities is being taken in coatings for furniture, plywood paneling, particleboard, and hardboard. A major use of CAB in wood lacquers is in a nonyellowing coating for white or pastel-painted furniture. This coating is often a butyrate/acrylic composition.

A CAB/urea-formaldehyde composition may be used in coating kitchen cabinets, taking advantage of the superior moisture resistance and color stability of Eastman CAB polymer. High quality furniture finishes exhibiting outstanding toughness and chemical resistance can be prepared by blending CAB with an isocyanate prepolymer. A typical furniture lacquer consists of Eastman CAB, thermoplastic acrylic, plasticizer, and solvent. A silica flatting agent is often used to impart the desired sheen to the finish. Acrylic resins, noted for good light stability and good resistance to stain and plasticizer migration, are often used in formulations where these properties are important. Hard resins with good color are used to improve sanding and rubbing properties, film depth, and clarity. Alkyd resins are used to obtain excellent film clarity, flow out and leveling, good depth, improved adhesion, and high nonvolatile content.

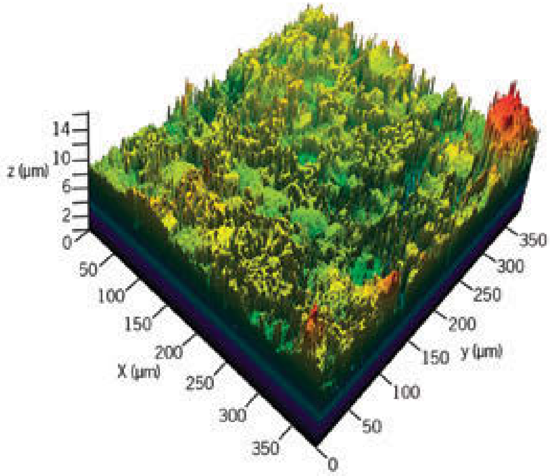
Urea-formaldehyde resins are used in curing coatings to obtain excellent mar resistance, good sanding and rubbing qualities, and good adhesion to most surfaces. Nonoxidizing alkyds can be added to these formulas to give coatings that handle like lacquers and perform like synthetic finishes.

In urethane clear coats where silica flatting agents are used, Eastman CABs have been shown to reduce gloss differences as a function of film thickness. Not only will the film thickness be more constant by using CABs, but also at thicker coating areas on a substrate, commonly observed gloss differences will be reduced as well, resulting in a more even appearance.

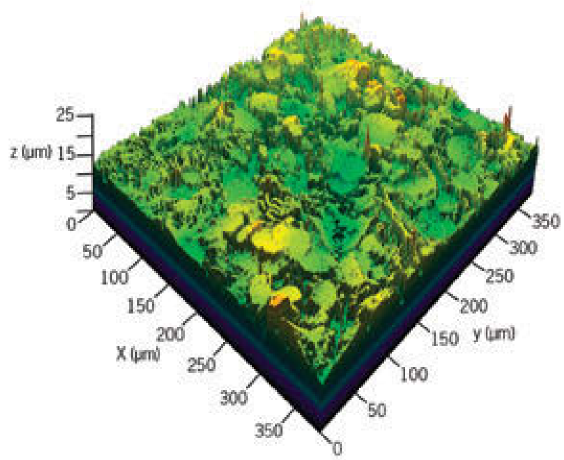
Table 4 **Selector guide**

Technology	Recommended Eastman CAB	Comments
CAB or "butyrate" lacquer	551-0.2,531-1	High butyryl CABs have best solubility and adhesion
Acid cure/precut	553-0.4	Best alcohol solubility and reactivity
2K PU	551-0.01, 551-0.2, 531-1,381 series	551-0.01 can be used for higher solids; 381 series gives slightly harder films
UV, unsaturated systems, other additive uses	551 series, 381 series	Improved adhesion and appearance

Figure 3 **Improved metallic/pearlescent flake alignment Eastman CAB locks flakes in proper orientation.**



Coil coating without CAB
Surface roughness = 2.2
Flop index = 12.2



Coil coating with 1% CAB-531-1 (100%)
Surface roughness = 1.2
Flop index = 15.0

Coil coatings

From brightly colored metallic- and pearlescent-finished household appliances to decorative façade and cladding applications in building and construction, high quality appearance coils are specified with increasing regularity. High-performance Eastman CABs ensure fewer surface defects, improved metallic and pearlescent flake alignment, improved flow and leveling, better gloss consistency, and purer white color value.

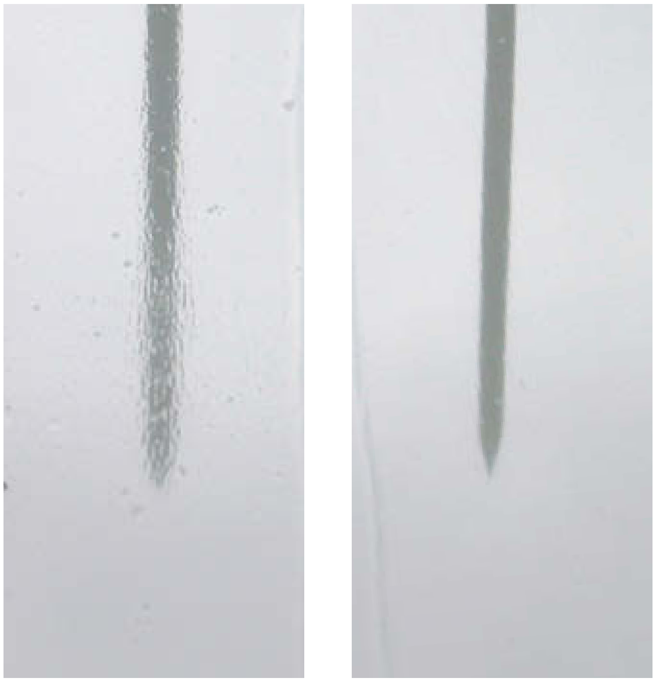
The confocal microscopy image of the metallic coil coating without Eastman CAB shows a multitude of high peaks, indicating a rough surface. The image of the system containing Eastman CAB shows far fewer peaks and large domains of flat areas. The Eastman CAB-containing system has aligned the metallic flakes such that they are flatter and more even. The flop values are also in agreement with the surface roughness profiles, with the Eastman CAB-containing system producing a much higher flop value that is visually very bright. The formulation without Eastman CAB produces a far lower flop value and visually is darker with a more "grainy" appearance.

Improved flow and leveling

Eastman CABs reduce or eliminate common defects, leading to the higher gloss levels that the market demands.

Leveling additives minimize irregularities in the surface and tend to have minimal effect on surface tension. Eastman CAB ensures that the coating remains smooth over the substrate after application and during curing. It is believed that CAB moves throughout the coating during the curing process thereby resulting in equalization of the surface tension across the coating. By maintaining an even surface tension throughout the film, undesirable flow as a result of surface tension differences is prevented. Eastman CAB also acts as a “force multiplier,” bringing about synergistic effects with other commonly used flow and leveling additives.

Figure 4 **Demonstration of flow/level improvement with the use of CAB**



Without CAB
Poor flow/leveling
Less reflection

With CAB
Good flow/leveling
Excellent reflection

Table 5 **Eastman portfolio of CAB additives for coil coatings**

CAB	Use	Level (%)
531-1 551-0.2	Metallic, pearlescent flake alignment	0.5–1.0
381-0.5 551-0.01	Matting efficiency	0.5–1.0
551-0.01	Flow and leveling	0.1–1.0
551-0.2 381-0.5 553-0.4	Pigment dispersion and codispersants	0.1–1.0
551-0.01	Increase gloss	0.1–1.0
553-0.4	Higher hydroxyl functionality can improve adhesion, reactivity.	0.1–1.0
381-20 381-2	High molecular weight. Over thinned batches can be brought into specification	0.5–5.0

Cellulose esters in graphic arts

Eastman produces essential raw materials which enable the formulator for the inks, graphic arts, and imaging markets to improve performance, enhance appearance, and increase productivity. CAP and CAB have been used as versatile ink formulating tools for printing packaging films, heat transfer printing inks, and screen inks for many years. They have been used as additives as well as modifiers or even main film formers. Eastman CAP and CAB are used to improve resistance to heat, grease, and UV degradation. They are also used as a pigment-grinding resin and show good stability with many pigments, including bronze ones.

Products formulated with Eastman cellulose esters release solvent rapidly enabling faster print speeds and improved blocking performance. Low viscosity grades of cellulose esters are used in radiation curable inks to improve wetting and adhesion and decrease surface defects for enhanced film formation and appearance. These advantages are also realized in a variety of thermoplastic and thermoset and radiation curable overprint varnishes.

Eastman CAP and CAB have many excellent qualities for use as binder resins in inks for shrink sleeve applications. This is a rapidly growing application area for liquid inks. This process allows the application of durable eye-catching decorative designs onto substrates such as Eastman Embrace™ copolyester, PVC, and OPS (oriented polystyrene) used for bottles and other containers. Whether the sleeve-shrinking process is by steam or dry heat and/or on glass or plastic substrates, Eastman CAP will provide superior quality compared to other resin systems. Details on moisture resistance, temperature resistance, blocking, and defect reduction as well as starting formulations can be found in Technical Tip TT-64 on our website.

In printing on difficult materials such as polyethylene, polypropylene, polyester, PVC, and OPS that are commonly used in packaging applications, different chemical approaches have been used to improve adhesion. Cellulose esters work well with many of these chemicals including polyethyleneimine (PEI), organic titanates, and zirconium complexes.

PEI is an adhesion promoter which is widely used in printing inks to give improved adhesion to difficult substrates, particularly corona-treated polyolefins such as OPP (oriented polypropylene) or polyethylene. Some formulas may increase viscosity or even gel when using PEI (polyetherimide). However, the use of acetoacetyl-*o*-toluidide (AAOT) can greatly improve pot-life. For details on this technology, consult Technical Tip TT-63 on our website.

Table 6 **Selector guide**

Technology	Eastman cellulose ester	Comments
Digital	CAB-551, CAP-482	Solvent based and UV
Flexography	CAP-504, CAP-482, CAB-553, CAB-551	Solvent selection will be limited by the chemical resistance of the image roll.
Gravure	CAP-482, CAP-504, CAB-381, CAB-531, CAB-553, CAB-551, CAB-500, CA-398	The inert image roll allows wide selection of resin and solvents.
Screen	CAP-482, CAB-381, CAB-531, CAB-500, CA-398	Viscosity is a benefit in these applications.
OPV	CAB-551, CAB-381	Flow and leveling and improved adhesion

Coatings for cloth

Coated fabrics, such as protective clothing, electrical tape, draperies, and shades, are often purchased with emphasis on the properties of the surface coating rather than those of the textile fiber base. Flexible cloth lacquers made from Eastman CAB-381 are used in coating nonyellowing window shades and flame-resistant artificial leathers. More rigid formulations are used to stiffen loosely woven cloth for drapery linings and shirt collars.

As an illustration of the properties of Eastman CAB-171, the historical use in airplane dope formulations is still frequently quoted. Coated fabrics on such aircraft required low dimensional changes over large humidity and temperature ranges to maintain tautness but also needed to exhibit superior weather and chemical resistance. CAB-171, one of the toughest CABs, now finds use in a variety of specific applications where the demonstrated requirements need to be met.

Elastomeric polyurethanes, when properly pigmented and applied, produce excellent coatings for fabrics used in the production of sportswear, rainwear, footwear, hats, coats, handbags, luggage, and upholstery for furniture and automobiles. CAB is used with urethane elastomers that are applied to cloth by the transfer-coating method. Blending CAB with these resins increases hardness, reduces tack, raises blocking point, improves slip, and reduces dirt pickup of the coating.

Coatings for paper

High quality paper lacquers are being made that take advantage of the excellent clarity, gloss, and flexibility of films made from Eastman CAB-381. Its wide compatibility and possible high degree of modification permit the production of lacquers that possess good scuff and mar resistance, good resistance to grease and water, and excellent adhesion to most inked papers. Through amino resin modification, it is possible to produce paper coatings that have the desirable properties of the butyrate ester as well as heat and solvent resistance.

Coatings for leather

Because it is a water-white, nonyellowing, tack-free material, Eastman CAB is useful alone or in combination with other resins as a film former in solventborne lacquers and in lacquer emulsions for leather topcoats. CAB is used worldwide in topcoats for leather items such as automotive upholstery, footwear, and furniture. These topcoats containing CAB are tough and have good resistance to abrasion and plasticizer migration.

Eastman CAB can contribute slip and hand to topcoats of various thicknesses over fine or less expensive leathers. CAB remains stable and will not degrade or yellow in the presence of the amine accelerators found in polyurethane shoe soles and polyurethane upholstery foam. On contact with vinyl, CAB will not extract plasticizers. Compared with other cellulosic film formers, Eastman CAB has excellent light stability; thus, it can be used over white or other light-colored base coats.

Thermally reflowable lacquers

The basic principle of thermal reflow involves the application of a specially formulated lacquer to a substrate in sufficient quantity to produce a dry-film thickness of 1.5–2.0 mils. Following application, a 1-minute flash, and a low-temperature bake, the object is inspected, sanded, and repaired as necessary. The final high-temperature bake thermally softens the coating, allowing reflow and leveling.

Thermally reflowable lacquers are formulated to have adequate levels of plasticizer and retarder solvent to impart thermal reflow characteristics. Retarder solvents, such as ethylene glycol diacetate, are retained by the film during the low-temperature bake. During the high-temperature bake, the retarder solvents are volatilized. However, prior to volatilization of the solvents, the film becomes fluid enough to reflow and produces a coating with very high gloss and distinctness of image, thus eliminating the polishing often required with lacquers.

Because of its low glass transition temperature and melting range (relative to other CABs), Eastman CAB-551-0.2 ester is most useful in formulating thermally reflowable lacquers.

Melt coatings

Useful applications for butyrate hot melts include adhesive and decorative coatings for paper, wallboard, boxboard, and wire. In the electronics industry, hot melts are used for potting materials and for coating wire-wound coils and parts that may be subject to damage by oxidation, moisture, or handling. Likewise, metal objects may be protected from corrosion and abrasion by strippable coatings formulated with CAB. Butyrate hot melts are used as stop-off coatings in the plating industry and as protective strippable coatings for industrial and government-specification packaging.

Since the formulation of hot melts varies widely depending on performance requirements, various Eastman CABs may be used. Generally, Eastman CAB-381 or CAB-500 esters are selected. The composition of a hot melt consists basically of a cellulose ester, plasticizer, and stabilizers.

Vacuum-metallizing and bronzing lacquers

Lacquers are used extensively in vacuum metallizing plastic articles. In this process, most plastics require a surface coating. A lacquer base coat, applied to the surface to be metallized, provides smoothness and functions as an adhesive link between the plastic surface and the metallic film. Then a lacquer is applied as a topcoat over the metallic film for protection against marring, rupture, oxidation, and abrasion. CAB/acrylic lacquers have performed satisfactorily over vacuum-metallized surfaces. Lacquers in which Eastman CAB is used as the film former excel as carriers of bronze powder since they do not gel or show color drift.

Preparation of pigment chips

Because of good pigment wetting characteristics (particularly the higher hydroxyl types), cellulose esters are used as pigment dispersion media. Difficult-to-disperse pigments such as carbon black, phthalocyanine blues and greens, transparent iron oxide, and perylene reds can be dispersed in CAB to provide easy-to-use pigment chips. These chips can be added directly to coating formulations without additional processing, or they may be predissolved to form a paste for addition to the coating.

Radiation curable coatings

Cellulose esters are used as additives in technologies such as radiation curing (RC) as well. In such coatings, they often provide similar benefits as in solventborne coatings, such as flow and leveling, improved gloss control, adhesion, and reduction of surface defects. CAB-551 types are frequently used in overprint varnishes at levels of 1%–5%. In applying RC coatings, Eastman CABs can reduce or eliminate holes in curtain coatings and reduce spattering in high-speed roll coat applications. Most commonly, the CAB is dissolved in a monomer and then added to the formulation. The viscosities of certain CABs in a variety of monomers are shown in Table 7.

Table 7 **Brookfield viscosities in common monomers at 5% concentrations and 24°C (75°F)**

Additive	(Wt%)	HDODA	TMPTA	DPGDA	TPGDA	Styrene
CAP-504-0.2	5	NA	NA	NA	NA	NA
CAB-553-0.4	5	1,550	1,550	1,190	40,000	NA
CAB-381-0.1	5	60	1,670	113	180	NA
CAB-321-0.1	5	53	1,420	93	128	NA
CAB-551-0.2	5	87	2,080	136	204	30
CAB-551-0.01	5	29	661	40	57	7

Formulating techniques

CAB esters

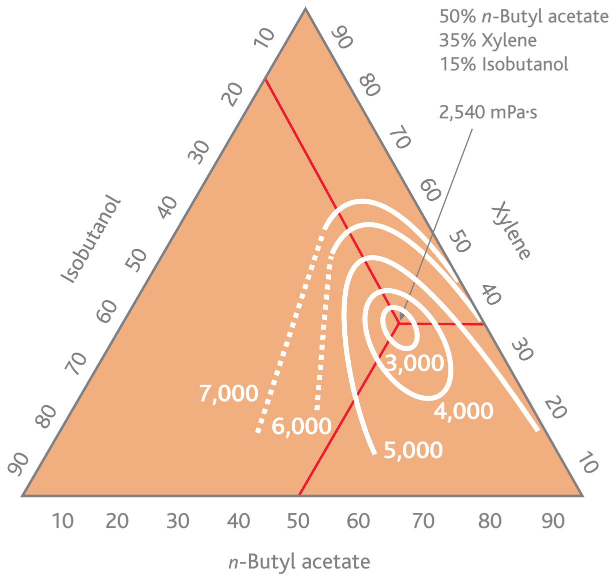
Eastman CABs are used in coatings as main film formers, resin modifiers, or additives. In this section on formulating techniques, the focus is on the use of solvents with CABs to optimize film formation and viscosity for various applications.

Cellulose esters (CE) are supplied as a white powder that performs best if it is put into a homogeneous solution before placing it into a formulation with other ingredients. The following instructions are to serve as a general guide for getting products like CAB into solution. Best practice is to start with placing the solvent or solvents into the mixing vessel before slowly adding the powder resin. The agitation should be sufficient so that the powder is quickly dispersed to prevent lumps of undissolved resin from forming. If lumps are formed, the lumps will eventually dissolve but the dissolution time is significantly longer. High speed shear and heat help the CE powder to dissolve.

Care should be taken to not charge a tank of nonpolar solvent with the CE powder. This is to prevent a static charge from accumulating during the mixing process which could facilitate a dust explosion. Also, care should be taken to not allow the solution to heat up near the flash point of the solvents. (See Eastman publication E-241, *Handling precautions for cellulose esters in formulating coatings* for more details) Cellulose esters dissolve best in active oxygenated solvents. Since cellulose esters are produced from a natural resource, each batch differs slightly in composition, therefore, it is best to visually confirm that the resin has completely dissolved before preceding to the next step in the formulation.

Within a given solvent blend, the optimum ratio of solvents can reduce the viscosity significantly as shown in the following tertiary diagram (Figure 5). The optimum ratio of *n*-butyl acetate, xylene, and isobutanol results in a viscosity of 2,540 Cps (mPa·s); changing the ratio to 35% *n*-butyl acetate, 35% xylene, and 30% isobutanol would nearly triple the viscosity. Eastman's technical support team will be able to assist you in optimizing your formulations.

Figure 5 **Solubility of Eastman CAB-381-0.525% solids solution of CAB-381-0.5 at 23°C (mPa•s)**



CAB coatings are formulated with a solvent balance designed to give the best performance in the equipment used for application. In spray-applied lacquer coatings, this usually means appropriate amounts of low-boiling active solvents to ensure low-viscosity solutions, latent solvents for low viscosity and reduced cost, medium-boiling active and latent solvents for flow-out, hydrocarbon solvents to reduce cost and provide solubility and compatibility with modifying resins, and retarder solvents to prevent blushing. An example is shown in Table 8.

Table 8 **Use of CAB in a thermoplastic air-dry acrylic/butyrate wood lacquer**

Ingredients	Wt%
Eastman CAB-551-0.2[a]	10.0
Paraloid™ B-66 acrylic[b] (100%)	7.0
Santicizer® 160[c] plasticizer	2.7
MEK (methyl ethyl ketone)	7.5
Eastman *n*-butyl alcohol	11.0
Toluene	7.0
Eastman MAK[a]	9.0
Eastman Tecsol™ C,[a] anhydrous	12.5
VM&P naphtha	9.0
Eastman *n*-butyl acetate	23.5
Eastman SAIB-90[a]	0.3
SF-69[d] (1% in xylene)	0.5
Total	100.0
Properties	
Solids, wt%	20.0
Viscosity, Ford 4, seconds	19.0
VOC, lb/lb solids	4.0
HAPs, lb/lb solids	0.73

[a]*Eastman Chemical Company*
[b]*Rohm & Haas*
[c]*Ferro Corporation*
[d]*General Electric*

Adding Eastman CABs as solutions

In converting finishes where CAB is used as an additive, the solvent composition can be very lean (high in hydrocarbon content) and still accommodate CAB. If the butyrate will not dissolve in the overall solvent blend, it can be cut in active solvents as a separate step and added to the formulation using agitation. The higher butyryl levels are usually selected for use with resins because of better tolerance for hydrocarbons. Esters and ketones are most commonly used to make cellulose ester solutions.

Other resins as cosolvents

While none of the butyrates will dissolve in hydrocarbon solvents, CABs with high butyrate levels (>38% butyryl) will tolerate very high levels of aromatic solvent. Eastman CAB-551-0.2 borders on being soluble in toluene and xylene. With this borderline solubility, it is often possible to achieve complete solubility by the addition of a resin such as a polyester or thermosetting acrylic. The low molecular weight converting resin performs as a cosolvent with the aromatic to dissolve butyrate. Aliphatic hydrocarbons should be used sparingly since the butyryl esters have poor tolerance for these materials; about 25% is the maximum amount that should be used in a butyrate incorporating Eastman CAB-381-0.5.

It is sometimes desirable to have an aromatic or high-flash naphtha as the last solvent out of the CAB film. This technique is occasionally used to accommodate a resin that prefers an aromatic solvent. With the higher-butyryl esters, the presence of aromatic as the last solvent out of a film does not appear to be detrimental.

Viscosity blending

Cellulose esters with different viscosities may be blended to produce any desired intermediate viscosity. This semilogarithmic chart may be used to determine blending ratios (Figure 6). As an example, Eastman CAB-381-20 (ester "A") may be combined with Eastman CAB-381-2 (ester "B") to produce any viscosity along the line connecting the two esters on the chart. As shown, 40 parts ester "A" blended with 60 parts ester "B" produces an intermediate viscosity of 5 seconds. It is important that the CABs to be blended are compatible with each other.

Figure 6 **Viscosity blending**

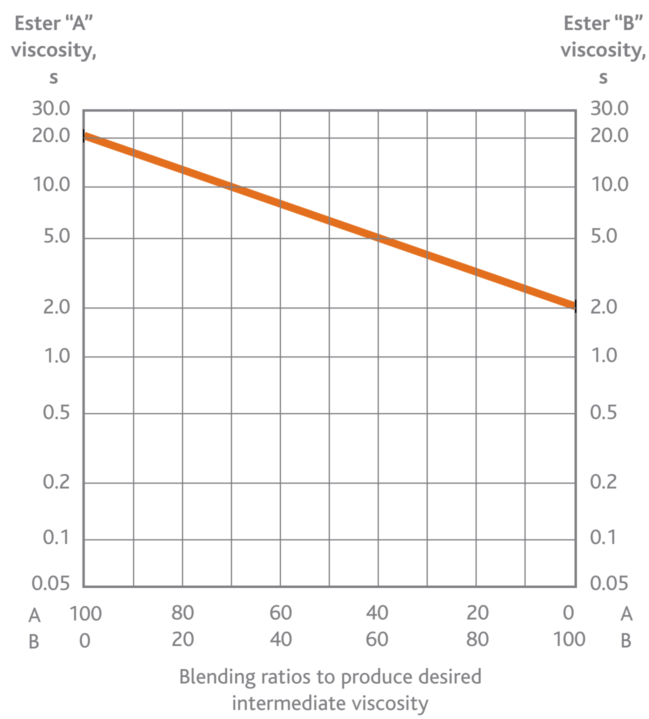


Table 9 **Intercompatibility**[a]

Table 9 shows the compatibility of various cellulose esters at different ratios. This is important when blending different CEs to achieve various properties.

	Eastman™ CAB-							Eastman CA-	Eastman CAP-	
	321-0.1	381-0.5	500-5	531-1	551-0.01	551-0.2	553-0.4	398-3	482-0.5	504-0.2
1 Part	**9 Parts**									
CAB-321-0.1	—	C	C	C	C	C	C	I	C	C
CAB-381-0.5	C	—	C	C	C	C	C	I	C	C
CAB-500-5	C	C	—	C	C	C	C	I	C	SI
CAB-531-1	C	C	C	—	C	C	C	I	C	SI
CAB-551-0.01	C	C	C	C	—	C	C	I	C	C
CAB-551-0.2	C	C	C	C	C	—	C	I	C	C
CAB-553-0.4	C	C	C	C	C	C	—	I	SI	C
CA-398-3	I	I	I	I	I	I	I	—	I	I
CAP-482-0.5	C	C	C	C	C	C	C	I	—	C
CAP-504-0.2	C	C	SI	VSI	C	C	C	I	C	—
1 Part	**4 Parts**									
CAB-321-0.1	—	C	C	C	C	C	C	I	C	C
CAB-381-0.5	C	—	C	C	C	C	C	I	C	C
CAB-500-5	C	C	—	C	C	C	C	I	C	I
CAB-531-1	C	C	C	—	C	C	C	I	C	C
CAB-551-0.01	C	C	C	C	—	C	C	I	C	C
CAB-551-0.2	C	C	C	C	C	—	C	I	C	C
CAB-553-0.4	C	C	C	C	C	C	—	I	C	C
CA-398-3	I	I	I	I	I	I	I	—	I	I
CAP-482-0.5	C	C	C	C	C	C	C	I	—	C
CAP-504-0.2	VSI	C	SI	C	C	C	C	I	C	—

[a]*Cellulose ester intercompatibility may vary depending on the solvent system used and on resins or other additives incorporated.*

C = Compatible; VSI = Very Slightly Incompatible; SI = Slightly Incompatible; I = Incompatible

Food contact status

Under regulations administered by the U.S. Food and Drug Administration (FDA), various grades of Eastman cellulosic products may lawfully be used in food contact applications. These products are manufactured, stored, handled, and transported under conditions adhering to 21 CFR 174.5 on general provisions applicable to indirect food additives (i.e., current good manufacturing practices for food contact substances). Regulatory information sheets are available on request.

EASTMAN

Eastman Chemical Company
Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

Telephone:
U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations, (1) 423-229-2000
Fax: (1) 423-229-1193

Eastman Chemical Latin America
9155 South Dadeland Blvd.
Suite 1116
Miami, FL 33156 U.S.A.

Telephone: (1) 305-671-2800
Fax: (1) 305-671-2805

Eastman Chemical B.V.
Fascinatio Boulevard 602-614
2909 VA Capelle aan den IJssel
The Netherlands

Telephone: (31) 10 2402 111
Fax: (31) 10 2402 100

Eastman (Shanghai) Chemical Commercial Company, Ltd.
Building C, No. 399 Shengxia Road,
Pudong New District
201210, Shanghai, P.R. China

Telephone: (86) 21 6120-8700
Fax: (86) 21 5027 9229

Eastman Chemical Asia Pacific Pte. Ltd.
9 North Buona Vista Drive
#05-01 The Metropolis Tower 1
Singapore 138588

Telephone: (65) 6831-3100
Fax: (65) 6732-4930

www.eastman.com

Eastman publication E-241, *Handling Precautions for Cellulose Esters in Formulating Coatings*, contains handling procedures for Eastman™ cellulose esters.

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