Bringing New Value To Chemicals

ADDITIVES FOR PLASTICS PROCESSING

Kao Corporation

ADDITIVES FOR PLASTICS PROCESSING

CONTENTS

Preface

Many kinds of additives such as stabilizer, antioxidant, ultraviolet ray absorbent, blowing agent, coloring agent, plasticizer, lubricant, antistatic agent, antifogging agent, and mold release agent are used in processing plastics.

Appropriate additives for actual use should be chosen in consideration of types of plastics to be processed, processing method and the desired qualities of the end products.

Development and marketing of polymer specialities are also included in Kao Corporation's business. Among these polymer specialities are polyester resins, polyamide resin, polyurethane components, etc. along with their molding technologies.

Kao's additives for plastic processing are developed with the background of such polymer specialities business.

This booklet is intended primarily to introduce Kao's additives for use in plastics processing.

Table 1. The list of kao's additives for plastics processing

Items	Types	Kao's product names	
Lubricant	Internal lubricant	EXCEPARL BS KALCOL 8688 KALCOL 8098 MANNITOL KAO	EXCEL T-95 EXCEL 84 RHEODOL SP-P10 RHEODOL SP-S10V
	External lubricant	LUNAC S-30 LUNAC S-40 LUNAC S-90	KAO WAX 230-2 KAO WAX 220 KAO WAX 85P
	Service lubricant	KAO WAX EB-G KAO WAX EB-P KAO WAX EB-FF	FATTY AMIDE S FATTY AMIDE T FATTY AMIDE O-N
Antistatic agent	Internal type	ELEC TS-2B ELEC TS-3B ELEC TS-5 ELEC TS-15B ELEC TS-6B	ELEC TS-7B ELEC TS-8B ELEC TS-9B ELEC EA ELEC PC
	Master batch	ELESTMASTER 326 ELESTMASTER HE-110	ELESTMASTER S-520 ELESTMASTER 320
	External type	ELEC QN ELEC AC	EMASOL SUPER L-10(F)
Antifogging agent	Internal type	RHEODOL SP-10 EXCEL T-95 RHEODOL TW- P120 RHEODOL SP-S10V EXCEL 300	PHEODOL TW-L120 PHEODOL SP-P10 EXCEL 150 RHEODOL TW-S120V RHEODOL SP-O10V
	External type	RHEODOL SP-L10 RHEODOL SP-S10V	RHEODOL TW-L120 RHEODOL TW-S120V
Plasticizer	Phthalates	VINYCIZER 124 VINYCIZER 85	VINYCIZER 105 VINYCIZER 911
	Trimellitates	TRIMEX N-08 TRIMEX NEW NSK TRIMEX N-810A	TRIMEX T-08 TRIMEX T-08LP TRIMEX T-08NB TRIMEX T-10
	Others	HA-5 VINYCIZER 30 VINYCIZER 50	VINYCIZER 40

1 Lubricants

1-1) Functions, mechanism and types of lubricants.

Lubricants are the additives used to improve the processability or to obtain better surface characteristics of end products.

According to the mechanism and chemical properties, they are classified as shown in the Table 2.

Table 2. Functions, mechanism and types of lubricants

Types	Function	Characteristics	Effects
Internal lubricants	Reduction of internal friction in plastics	Compared to external lubricants, the molecular weight is smaller and the compatibility with plastics is better. e.g. Butyl stearate, long-chained fatty alcohol, glycerin monostearate, sorbitan monostearate.	(1) Smooth gelation of powdered resin, which avoids precipitous increase of mechanical torque at gelation. (2) Reduction of melting viscosity of polymers, which causes increased flowability and extrusion and reduced mechanical torque. (3) The above effects result in elevated productivity as well as energy saving by reduced load to processing machines and also the reduction of stabilizers to be incorporated. (4) Decrease of resin discoloring from friction heat.
External lubricants	Reduction of friction between plastics and the metal surface of processing machines.	Compared to internal lubricants, molecular weight is larger and the compatibility with plastics is inferior. e.g. Stearic acid, hydrogenated castor oil, ethylene bis-stearamide, metal soap, long alkyl chained hydrocarbon.	(1) Prevention of sticking of plastics to metal surface. (2) Easier release from mold or roll. (3) Smoothing of surface of molded or rolled plastics.
Service lubricants	Migrated and crystalized on plastics surface after molding, it reduces friction coeficients of plastics surface and avoids blocking.	Molecular weight is larger and the compatibility with plastics is inferior. High melting points. e.g. Ethylene bis-stearamide Stearamide Oleamide	(1) Prevention of adhesion between films.. (2) Improvement of slipping properties of film. e.g. smooth opening of bag.

Kao's lubricants are introduced in the Table 3.

Table 3 Kao's lubricants

Class.	Product name	Chemical composition	Physical form	Melting Point(℃)	Resins to apply	Standard dosage (PHR)	Characterisitics	FDA No.	Packing
Internal lubricant	EXCEPARL BS	Butyl stearate	Clear, liquid	22.5 ± 1.5	PVC, EVA	0.8～2.0	Accelerated and smooth gelation and increased flowability without reducing clarity and heat resistance	175-300	15 kgs Can 170 kg drum
	KALCOL 8688 KALCOL 8098	Stearyl alcohol	White, beads	57.0 ± 2.0 58.0 ± 2.0	PS, ABS	0.5～2.0	Typical lubricants for smooth gelation and increased flowability of PVC, without reducing clarity and heat resistance. Flowability of ABS and PS is increased. Discolouring is prevented.	175-300	20 kgs bag 170 drum,
	EXCLE T-95 EXCEL 84	Stearic acid monogly ceride	White, powder	65.5 ± 2.5 59.0 ± 2.5	PVC, PP	0.5～2.0	Increased flowability with smooth gelation. Heat stability of plastics is elevated by adding Ca-Zn stabilizer. Discolouring is reduced by adding Sn stabilizer. Antistaticity is also obtained.	175-300	100 kgs. packing case 20 kgs. packing case
	RHEODOL SP-P10 RHEODOL SP-S10	Sorbitan monopalmitate Sorbitan monostearate	Light yellow, powder	45.0 ± 2.0 52.5 ± 2.0	PVC	0.5～1.5	Increased flowability with smooth gelation. Heat resistance is improved by adding Ca-Zn stabilizer. Antistatic and antifogging properties are also exhibited.	178-3400	20 kgs. packing case
	MANNITOL KAO	Mannitol	White, powder	166.0 ± 2.0	PVC	0.2～0.5	It shows also heat stability, which is greatly increased by the addition of Ca-Zn stabilizer.	175-300	20 kgs. packing case 111kgs. drum
External lubricant	LUNAC S-30 LUNAC S-40 LUNAC S-90	Stearic acid	White, beads	57.0 ± 2.0 58.5 ± 1.5 67.0 ± 1.5	PVC, PS, EVA, Phenol	0.5～1.5	Typical lubricants having good release properties from metal. Within 1 PHR, clarity and heat stability are not reduced, Flexible PVC may suffer bleeding with more than 0.5 PHR of addition.	178-3570	20 kgs. bag
	KAO WAX 85-P	Hydrogenated castor oil	White, powder	84.0 ± 2.0	PVC	0.5～1.5	Retarding effect for gelation. Discolouring is prevented.	175-300	20 kgs. bag
	KAO WAX 220 KAO WAX 230-2	Special ester wax	White, powder	57.0 ± 3.0 98.0 ± 4.0	PVC, PE PP, ABS/PVC ABS/ PC	0.3～0.7	The most suitable lubricant for calender rolling, offering excellent release property at high temperature. The most suitable lubricant for extrusion, offering retarded gelation and excellent release property at high temperature.	181-27	20 kgs. packing case
Service lubricant	KAO WAX EB-G KAO WAX EB-P KAO WAX EB-FF	Ethylene bis-stearamide	White, bead White, powder White, fine powder	144.0 ± 2.5 144.0 ± 2.5 144.0 ± 2.5	ABS, PS, PVC	0.5～3.0	Typical lubricants for improving flowability of ABS and PS. They prevent blocking of flexible PVC.	175-300	15 kgs bag 20 kgs. bag 500kgs bag
	FATTY AMIDE S FATTY AMIDE T FATTY AMIDE O-N	Stearamide Oleamide	White, powder White, powder Light brown, flake	102.5 ± 2.5 99.5 ± 2.5 72.5 ± 2.5	PE, PP	0.1～0.5	Typical anti-blocking agent as well as slipping agent.	175-300	20 kgs. bag

1-2) Typical recipes incorporating lubricants.

1-2-1 For polyvinyl chloride (PVC)

The typical formulations incorporating lubricants for molding processes are shown as follows.

1. Rigid sheet for extrusion

	Parts
PVC ($\overline{P}$=800)	100.0
Organotin stabilizer	3.5
Exceparl BS	0.5
KAO WAX 220	0.3
Polyethylene wax	0.1
LUNAC S-40 (Stearic acid)	0.3

2. Clear rigid sheet for calender rolling

	Parts
PVC	100.0
Plasticizer	0 ～ 10.0
Organotin stabilizer	2.0 ～ 2.5
KAO WAX EB-P	0.3

3. Clear rigid PVC for injection molding

	Parts
PVC	100.0
Organotin mercaptides	3.0
KAO WAX 220	0.3
Calcium stearate	0.2
Exceparl BS	0.5

4. Clear PVC for blow molding

		Parts
i)	PVC	100.0
	ABS (or MBS)	5.0 ～ 10.0
	Organotin mercaptide stabilizer	2.5 ～ 3.0
	FATTY AMIDE S	0.3 ～ 0.5

		Parts
ii)	PVC	100.0
	MBS	5.0 ～ 15.0
	Epoxy plasticizer	5.0
	Ca-Zn stabilizer (liquid)	3.0
	KALCOL 8688	0.5 ～ 1.0

5. Rigid film (FDA grade)

	Parts
PVC ($\overline{P}$ = 800)	100.0
Ca-Zn stabilizer	3.0
Epoxidized soyabean oil	7.0
Butyl stearate	0.7
KALCOL 8688	0.3
KAO WAX 220	0.2

1-2-2 For polyolefine, polystyrene and ABS resins.

It is general that lubricants are added to the compound together with stabilizer and antioxidant at the pelletizing stage after polymerization.

Typical formulations are as follows:

i) ABS resin for injection molding

	Parts
ABS resin	100.0
Stabilizer	1.0
Antioxidant	0.2
KAO WAX EB-P	1.0 ～ 3.0

ii) Polystyrene sheet

	Parts
Polystyrene	100.0
LUNAC S-90 (Stearic acid)	0.1 ～ 0.5

iii) Low density polyethylene film

	Parts
LDPE	100.0
FATTY AMIDE O-N	0.05 ～ 0.2

1-3) Evaluation of lubricity

1-3-1) Melt flow test

This method is specified in ASTM D1238 designation (or JIS K6760). It covers measurement of the rate of extrusion of molten resins through a specified orifice under prescribed temperature, load, and piston position in the barrel as the timed measurement is being made.

The test specimen is charged in the cylinder of an extrusions plastometer. The temperature of the cylinder is kept constant.

The rate of extrusion of resin from the orifice situated at the bottom of the apparatus is measured, when the specimen in the cylinder is pressured by means of the piston of the apparatus.

The higher is the rate of extrusion, the better the lubricating effect.

1-3-2) Spiral flow test

This method is employed to measure the mold feedability in injection molding.

Specimen is injected using spiral mold, and the length of the molded spiral is measured. The longer is the molded spiral, the higher the effect of the tested lubricant.

1-3-3) Roll milling test

This method covers the evaluation of gelation characteristics by measuring the gelation time of the compound charged under the constant roll temperature, rotation and roll clearance. This method covers also the evaluation of the releasability of the resin from the roll by measuring the release position of the film specimen after milling the resin for a definite time.

1-3-4) Plastograph

This method was developed by Bravender A.G. of West Germany. This testing method is employed to evaluate gelation characteristics and lubricity of the specimen resin by measuring the mixing torque and the variation of the temperature of the charged compound under the constant temperature and rotation of the two blades of the testing apparatus.

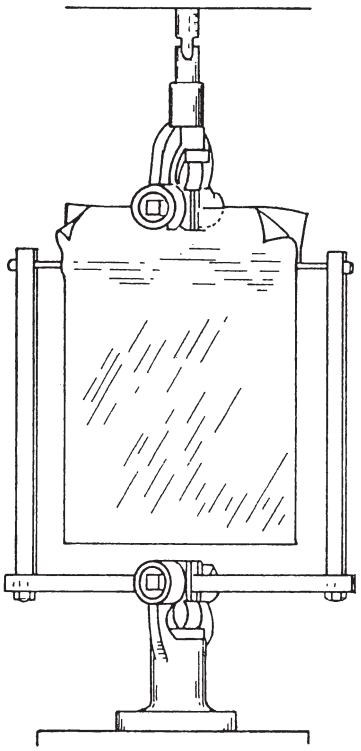
1-3-5) Blocking test

This method is specified by the ASTM D1893 designation and yields quantitative information regarding the degree of blocking existing between the layers of plastic films. It is not intended to measure susceptibility of blocking

A definite sized aluminum rod is placed between the layer of the two definite sized plastic films put together and clamped to the supporting frame. (Fig. 1)

Determine the actual blocking force loaded to the rod when the rod is pulled down ward at a constant rate, separating the surfaces of each test specimen.

Fig. 1



1-3-6) Testing method for coefficients of friction of plastic film.

This method is specified by the ASTM D1894 designation and covers the determination of coefficients of starting and sliding friction of plastic sheeting when sliding over itself of other substances.

2 Antistatic agents

2-1) Functions and mechanism of antistatic agents.

Electric nonconductivity is one of the various advantages that plastics possess generally. However, there are cases where this advantage turns to be a defect that static electric charge accumulates on the surface of plastics. Static electricity gives troubles such as electric shock, dust attraction and sticking of films.

Antistatic agents are used to solve the problems as related above by giving antistatic properties to plastics without altering the general mechanical properties of the plastics.

Antistatic agents have in their molecules both hydrophobic and hydrophilic radicals. Practically, the hydrophobic radicals turn to the surface of plastics, while the hydrophilic radicals turn to the air attracting the moisture in the atmosphere.

The static charge accumulation in plastics is dissipated, through the conductivity of water absorbed by antistatic agents.

At the same time, antistatic agents show the action of reducing the accumulation of frictional static charge, Thus, antistatic effect is obtained.

2-2) Types of antistatic agents

From usage standpoint, they are classified broadly into two types, namely external antistatic agent and internal antistatic agent.

The external type is applied on the surface of plastic articles by spraying or dipping with dilutee solution, and after drying it makes very thin conductive layer on the surface. The internal type is used by incorporating it into plastics before processing. The incorporated antistatic agents migrate to the surface after processing and make very thin electric conductive layer.

Master batch type is a kind of internal type and used for convenience in handling and usage. This type is made by blending high loading of the antistatic agent into resin and formed to pellet shape. Kao has 3 kinds of master batch type; 8.5% (on weight) of antistatic agent is blended into polypropylene and high-density polyethylene respectively and 20% (on weight) of antistatic agent is blended into polystyrene.

By making use of these master batchs, facile and homogeneous blending of antistatic agents may be secured.

The characteristics and the cautions on use for each type of antistatic agent are summarized in the Table 4.
Kao's antistatic agents are introduced in the Table 5.

2-3) Antistatic performances

The Table 6 and Table 7 shows some cases where antistatic effects were obtained on a several kinds of plastic. A remarkable reduction of surface electric resistance, compared to the plastics not containing antistatic agent, is the evidence of antistatic effects by use of antistatic agents.

Table 4. The characteristics and the coutions on use for each type of antistatic agent

	Internal type	Master pallet type	External type
Characteristics	(1) When the antistatic agent on the surface of plastics is removed by friction or washing, the antistatic agent remained in plastics migrate to the surface. Therefore, semi-permanent anti-staticity is obtained. (2) Because internal or master batch type can be blended in resin at the same time with other additives such as stabilizer, antioxidant, colorants, etc., the manufacturing technique is more simple compared to the case of using external type. (3) Because the migrating rate of the additives to the surface depends upon the diffusing rate of the additives in the resin, the kinds of the additive and their amount of addition should be properly determined in accordance with the type of resin, processing method and the purposes of use. (4) It is difficult for the additives to migrate in the resin having high glass transition temperature such as polystyrene, rigid PVC, and the antistatic effect is reduced. So, it is required to add more amount of the additive to obtain satisfactory result.		(1) The antistatic treatment is very easy. (2) The effect may be attained immediately after coating and drying. (3) It can be used regardless of the kinds of resin and processing methods. (4) It is liable to come off by water or solvent, so the effect is not so durable as internal type.
Usage	It is blended in the pelletizing process or in the mixing process prior to molding.	It is mixed with virgin pellet to obtain the required concentration.	The antistat is diluted with water or with appropriate solvent to the optimum concentration. The solution is applied to the surface of molded plastics by means of spraying, dipping or brushing.
Cautions on use	(1) They must be used at moderate temperature, because they are sensitive to higher temperature. They are liable to make coloring of resin, when the resin is processed at high temperature or remains in molding machine for a long time. (2) Stress cracking may be caused by inhomogeneous blending of the antistats in plastics. Therefore, good care should be taken for blending the antistats. (3) There are cases where the tone of color is changed by the interaction with pigments and the other additives. So careful check is necessary prior to deciding the recipes. (4) Because antistatic agents may convert the surface characteristics of plastics, there are cases where adhesibility of printing ink and heat sealability of film are harmed.		(1) The concentration of antistatic solution must be controlled carefully, and the amount of application must be the minimum and constant. (2) When using organic solvents, care must be taken for ventilation and fire. (3) Some kinds of antistatic agents may rust metal. So it is important to take care for the nearby metal stuffs. (4) Some kinds of antistats may cause rash on human skin. So, some protection is necessary in handling.

Table 5. List of Kao's antistatic agents

Class.	Product name	Plastics	Rate of addition (PHR)			Ionic character or composition	LD/50 (g/kg)	Form (at room temperature)	Packing
			Injection	blowing	Film				
Internal type	ELEC TS-2B	LD-PE HD-PE PP	0.1 — 0.5	0.2 0.3 —	— — —	Nonionic	>5.0	White, beads	17 kgs. in packing case
	ELEC TS-3B	LD-PE PP	0.2 0.5	0.2 —	0.2 —	Nonionic	>5.0	White, beads	17 kgs. in packing case
	ELEC TS-5	LD-PE PP Rigid PVC	0.2 0.5 —	0.2 — 1.0	0.2 0.5 0.2	Nonionic (Food additive grade)	>5.0	White, powder	10 kgs. in packing case
	ELEC EA	HD-PE PP PS, ABS	0.3 0.3 2.0	0.2 — —	0.5 — 2.0	Nonionic	>5.0	Light yellow, liquid of block	16 kgs. in can
	ELEC PC	PS, ABS Rigid PVC	1.0 —	— —	1.0 2.0	Anionic	>5.0	White, powder	20 kgs. in packing case
Master batch type	ELESTMASTER 320 ELESTMASTER 326 ELESTMASTER HE-110 ELESTMASTER S-520	PP PP HD-PE PS	3.0 4.0 3.0 7.0	— 4.0 3.0 —	3.0 4.0 3.0 7.0	Master pellet contains 20% ELEC TS-3B 10% ELEC TS-2B 8.5% ELEC EA 20% ELEC PC respectively	 >5.0 >5.0 >5.0	 Square pellet Round pellet Round pellet	20 kgs. in bag
External type	ELEC QN ELEC AC	All types of plastics	To be diluted in 50～200 times of IPA or water.			Cationic Amphoteric	>5.0 >5.0	Clear, lizuid Brown, liquid	15 dgs. in can.
	EMASOL SUPER L-10 (F)		To be diluted in 50～200 times of ethanol or water.			Nonionic (Food additive grade)		Light yellow, liquid	18 kgs. in can

Remarks (1) In case that ELEC QN which has metal corrosive property is unfavourable, ELEC AC is recommendable instead.
(2) For packing or wrapping food, EMASOL SUPER L-10 (F) is recommendable due to its high safety.

Table 6. Effects of internal antistatic agents

Resin		Molding method.	ELEC (PHR) (additive amounts to resin)	Surface resistivity (Ω) (25℃, 45RH)	Resin properties		
Type	Commercial name				Tensile strength kg/cm²	Elongation %	Blocking properties g/cm
Low density polyethylene	Sumikathene H 702-2	Inflation film	NIL	$>10^{17}$	144	454	0.50
			TS-3B 0.2	$10^{11}-10^{12}$	140	423	0.72
			TS-5 0.2	$10^{12}-10^{13}$	152	505	0.61
High density polyethylene	Staflene E 505	Inflation film	NIL	$>10^{17}$	202	150	
			EA 0.3	$10^{10}-10^{11}$	274	150	
	Hizex 2200J	Injection molding	NIL	$>10^{17}$	260	163	
			TS-2B 0.5	$10^{11}-10^{12}$	267	184	
			EA 0.3	$10^{10}-10^{11}$	274	152	
	Sholex 5003	Blow molding	NIL	$>10^{17}$	240	950	
			TS-2B 0.2	$10^{12}-10^{13}$	223	940	
			TS-3B 0.2	$10^{12}-10^{13}$	220	948	
			EA 0.1	$10^{11}-10^{12}$	230	935	
Polypropylene	Chisso PP 1088	Inflation film	NIL	$>10^{17}$			0.17
			TS-2B 0.6	$10^{12}-10^{13}$			0.12
			EA 0.5	$10^{11}-10^{12}$			1.52
	Mitsui Noblene JHG	Injection molding	NIL	$>10^{17}$	363	103	
			TS-2B 0.5	$10^{10}-10^{11}$	362	105	
			TS-3B 0.5	$10^{12}-10^{13}$	373	100	
			EA 0.3	$10^{10}-10^{11}$	364	93	
polystyrene	Styron 475	Injection molding	NIL	$>10^{17}$	230	114	
			EA 2.0	$10^{11}-10^{12}$	222	117	
			PC 1.0	$10^{11}-10^{13}$	220	115	
Acrylonitrile-butadienestyrene copolymer	Cycolac T 11001	Injection molding	NIL	$>10^{17}$	440	55	
			EA 2.0	$10^{11}-10^{12}$	434	57	
Rigid PVC	Kanvinyl S-1008	Calender sheet (Opaque)	NIL	$>10^{17}$			
			TS-5 2.0	$10^{12}-10^{13}$			
			PC 2.0	$10^{11}-10^{12}$			
			ELESTMASTER (PHR) (additive amounts to resin)				
Polypropylene	Mitsui Noblen JH-G	Injection molding	NIL	$>10^{17}$	341	514	
			326 5.0	$10^{11}-10^{12}$	325	519	
High density polyethylene	Suntec QJ 340	Injection molding	NIL	$>10^{17}$	210	212	
			HE 110 5.0	$10^{10}-10^{11}$	214	218	
Polystyrene	Styron 475	Injection molding	NIL	$>10^{17}$	230	103	
			S-520 7.0	$10^{11}-10^{12}$	225	105	

Table 7. The effects of external antistatic agents

Molded plastics	Antistatic agents	Dilution (times)	Application method	Surface resistivity (Ω)	* Results of dirt chamber test	Remarks
Polypropylene, molded by injection	——				×	
	ELEC QN	50	Spray	$<1.0\times10^{9}$	○	
		100	Spray	5.8×10^{9}	○	
	ELEC AC	50	Spray	1.1×10^{10}	○	
		100	Spray	3.8×10^{10}	○	
	EMASOL SUPER L-10 (F)	50	Dipping	9.4×10^{10}	△	For food packing or wrapping
		100	Dipping	2.3×10^{11}	△	
ABS, molded by injection	——				×	
	ELEC QN	50	Spray	$<1.0\times10^{9}$	○	
		100	Spray	5.3×10^{9}	○	
	ELEC AC	50	Spray	1.2×10^{10}	○	
		100	Spray	2.2×10^{11}	○	
	EMASOL SUPER L-10 (F)	50	Dipping	1.1×10^{11}	○	For food packing or wrapping
		100	Dipping	1.5×10^{11}	○	
Polystyrene, molded by injection	——				×	
	ELEC QN	50	Dipping	$<1.0\times10^{9}$	○	
		100	Dipping	5.3×10^{9}	○	
	ELEC AC	50	Dipping	9.0×10^{9}	○	
		100	Dipping	3.6×10^{10}	○	
	EMASOL SUPER L-10 (F)	50	Dipping	7.5×10^{10}	○	For food packing or wrapping
		100	Dipping	3.8×10^{10}	×	
Rigid PVC sheet	——			$>1.0\times10^{17}$	×	
	ELEC QN	50	Spray	$<1.0\times10^{9}$	○	
		100	Spray	5.8×10^{9}	○	
	ELEC AC	50	Spray	1.1×10^{10}	○	
		100	Spray	3.8×10^{10}	○	
	EMASOL SUPER L-10 (F)	50	Spray	7.0×10^{10}	○	For food packing or wrapping
		100	Spray	1.0×10^{11}	○	

Remarks: ○ good
△ moderate
× low

* Dirt chamber test is explained in the paragraph 2-4-1.

The durability of effects

The change on 6 months standing of the injected polypropylene specimens dipped in the solution of antistatic agent revealed that the specimen still had sufficient antistic effect as shown in the Table 8.

Table 8. The result of 6 months standing of the specimen of injected polypropylene parts, dipped in the solution of antistatic agent

Antistatic agent	Dilution (times)	surface resistivity (Ω)			
		1 day after	7 days after	1 month after	6 months after
ELEC QN	200	1.2×10^{10}	2.2×10^{10}	8.3×10^{10}	1.4×10^{11}
ELEC AC	100	3.8×10^{10}	4.5×10^{10}	1.2×10^{11}	3.6×10^{12}

2-4) Evaluation methods for antistatic effect

It is necessary to evaluate if the antistats blended or applied are virtually effective.

The methods commonly employed for the evaluation of antistatic agents are introduced hereafter.

2-4-1) Sensory method

• Dirt chamber test

This method is specified by ASTM D2741 designation to cover the determination of the relative susceptibility of plastics to soot accumulation.

The specimen of plastics is put in a chamber to be exposed to the soot created by burning toluene-wetted paper and circulated in the chamber.

After the definite time the specimen is taken out from the chamber, then soot accumulation on the surface of the specimen is rated visually.

2-4-2) Evaluation by electric properties

• Surface resistivity

This method is specified by ASTM D257 preparing proper electrodes on the surface of the specimen, the surface resistivity between the electrodes is measured by a high resistance meter.

• Decay of charged static electricity

The surface of the specimen is charged by corona discharge, and then the decay of static electricity is measured by means of static potential meter.

"Static honestmeter". made in Japan and sold commercially, enables to measure the decay on standing of the antistatic accumulation which is made visible by use of oscillograph. To make correct determination by this method, it is essential to conduct the evaluation under the constant temperature and humidity.

3 Antifogging agents

Some moisture in the agricultural greenhouses and food packing made of PVC or polyolefine film may be converted to fine waterdroplets which may remain on the inner surface of PVC or polyolefine film, when the temperature of the inside of greenhouses or food packing is for higher than outside.

Such water droplets on the surface of plastic films causes the reduction of transmission rate of sunlight to plants, which may result in lower percentage of sunshine, and dropping of water may lead to some disadvantages such as poor fruition.

As to food packing film, water droplets tend to make the package seem unclear and accordingly packages may take on an unappealing appearance.

Antifogging agent is used to avoid such disadvantages caused by the water droplets condensed on the plastic films.

3-1) Mechanism of antifogging agents

Antifogging agents, applied on the surface of plastics or blended in plastic, orientate on the surface, just as antistatic agents do. This orientation of each molecule of antifogging agents results in making wettable the surface of plastics. The moisture collected on the film surface is not converted into water droplets, that is, the surface is uniformly covered by continuous phase of water, and fogging is avoided.

3-2) Types of antifogging agents

Most of antifogging agents belong to internal type which is to be incorporated in plastics, with some examples of external types used by applying on the surface of plastics.

3-2-1) Internal type

This type of antifogging agent consists principally of the surfactants having good acute effect and durability.

In actual use, a few different antifogging agents are generally combined. Although good antifogging effect is essential, the following characteristics are also required for antifogging agent.

i) Transparency of film is not affected.
ii) Heat stability is not reduced.
iii) bleeding or blooming is not caused.

The following surfactants are recommendable as the antifogging agents possessing the favourable characteristics as mentioned above.

- Sorbitan fatty acid ester
  Kao's product names:
  RHEODOL SP-L10, RHEODOL SP-P10,
  RHEODOL SP-S10, RHEODOS SP-O10

- Polyoxyethylene sorbitan fatty acid ester
  Kao's product names:
  RHEODOS TW-S120, RHEODOL
  TW-120, RHEODOL TW-O120

- Fatty acid monoglycerede
  Kao's product names:
  EXCES T-95, EXCES 150, EXCES 300.

3-2-2) External type

This type of antifogging agent is diluted with water or solvent and is coated to the film or sheet and used for the cases where internal types exhibit unsatisfactory effect to the plastics such as rigid PVC or where only temporary effect suffices the user's demand. Therefore, its application is fairly limited.

The following surfactants are typically used as the external ones.

- Sorbitan fatty acid ester
  Kao's product names:
  RHEODOL SP-L10, RHEODOL SP-O10,

- Polyoxyethylene sorbitan fatty acid ester
  Kao's product names:
  RHEODOL TW-L120,
  RHEODOL TW-O120

The details of the above-introduced Kao's antifogging agents are summarized in the Table 9.

3-3) Kao's antifogging agents

Kao's antifogging agents are introduced in the Table 9.

Table 9. Kao's antifogging agents

Product name	Chemical composition	Form at Room temp.	Resins to apply for	Characteristics	FDA No.	Packing
RHEODOL SP-L10	Sorbitan monolaurate	Light brown, liquid	PVC, Polyolefine	Most typical one. Excellent in early effect and low temperature effect. Most suitable for food packing film.	178-3400	17 kgs. in can
RHEODOL SP-P10	Sorbitan monopalmitate	Yellowish brown, beads	PVC Polyolefine	The initial effect and durability are well blanced. suitable for greenhouse covering sheet.	178-3400	20 kgs. in Packing case
RHEODOL SP-S10V	Sorbitan monostearate	Light yellow, beads	PVC Polyolefine	Superior durability and effectiveness at high temperature	178-3400	20 kgs. in Packing case
RHEODOL SP-O10V	Sorbitan monooleate	Yellowigh brown, liquid	PVC Polyolefine	Suitable for polyolefine film for food packing. Good early effect and low temperature effect.	178-3400	17 kgs. in can
RHEODOL TW-L120	Polyoxyethylene sorbitan monopaurate	Light yellow, liquid	PVC	Superior in early effect. synergistic effect may be obtained by using together with RHEODOL SP series. Coloring may be caused by using it at high temperature processing.		18 kgs. in can
RHEODOL TW-P120	Polyoxyethylene sorbitan monopalmitate	Light yellow, liquid	PVC			18 kgs. in can
RHEODOL TW-O120V	Polyoxyethylene sorbitan monooleate	Light yellow, liquid	PVC			18 kgs. in can
EXCEL T-95	Stearic acid monoglyceride (high purity)	White, powder	PVC Polyolefine	Superior in durability and heat stability. Also available as lubricant and antistatic agent.	175-300	10 kgs. in Packing case
EXCEL 150	Stearic acid monoglyceride (high grade)	White, powder	PVC Polyolefine	Suitable for polyolefine food packing film. Available as antistatic agent.	175-300	10 kgs. in Packing case
EXCEL 300	Oleic acid monoglyceride	Clear, liquid	PVC Polyolefine	Superior in durability. Caution is required for high temperature processing because coloring may occur. Exhibits lubricating property.	175-300	17 kgs. in can

3-4) Usage of antifogging agents

Because antifogging agents play an important role in plastics processing, the following remarks should be regarded for the choice of proper antifogging agent.

3-4-1) Antifogging effect

It is to be noted that the desired antifogging effect varies widely, depending upon the purpose of use.

The characteristics of antifogging agents are classified into some groups, according to their specific advantages such as good early effect, durability, effectiveness at low temperature or high temperature, etc.

It is impossible for only a single type of antifogging agent to impart all the effects required. High temperature effect and low temperature effect, for example, are incompatible with each other and also the same with early effect and durability of effect. Therefore, the two incompatible effects may be unable to coexist in a single antifogging agent, and it is necessary to use together a few kinds of antifogging agents to obtain well-balanced effects.

(1) Early effect ⟷ (2) Durability of effect

(3) Effect at low temperature ⟷ (4) Effect at high temperature

The following products are recommendable for each effect specified above.

For the effect (1) — Sorbitan fatty acid ester.
Product names: RHEODOL SP-L10, RHEODOL SP-P10
For the effect (2) — Sorbitan fatty acid ester and glycerol fatty acid ester.
Product names: RHEODOL SP-S10, RHEODOL SP-O10, EXCES T-95, EXCEL 300
For the effect (3) — Polyoxyethylene sorbitan fatty acid esters.
Product names: RHEODOL TW-L120, RHEODOL TW-P120
For the effect (4) — Sorbitan fatty acid ester and glycerol fatty acid ester.
Product names: RHEODOL SP-S10, RHEODOL SP-O10, EXCES T-95, EXCEL 300

3-4-2) Choice of proper antifogging agents in accordance with the types of resins.

It must be taken into consideration that the behaviors of antifogging agents vary with the types of resins such as the resin of high crystallinity like PE, PP and non crystallizing resin like flexible PVC containing greater amount of plasticizer.

3-4-3) Other requirements of antifogging agents

1) heat stability

It must be noted that heat decomposition of antifogging agent causes coloring. Some kinds of antifogging agent is unstable with heat. Especially ethoxylated products exhibit inferior heat stability.

2) The compatibilities with other additives

The compatibilities with stabilizer, plasticizer, antistatic agent and filler are required and should be taken into good attention, because the reactions of antifogging agents with other additives may degrade the quality of the film.

3) Other respects

It is probable and should be taken into consideration accordingly that antifogging agents may affect clarity, adhesibility, fungicidal effect and electric properties.

3-4-4) Examples of typical formulations incorporating antifogging agents.

(A) PVC film for greenhouse (Calender rolling)

	Parts
PVC	100.0
DOP (product name: VINYCIZER 80) or BBP	20.0 ～ 40.0
Epoxydized soyabean oil (Product name: KAPOX S-6)	2.0 ～ 5.0
TCP (phosphate)	1.0 ～ 5.0
Stabilizer	1.3 ～ 3.0
Lubricant (Product name: LUNAC S-40)	0.2 ～ 0.5
Internal antifogging agent (RHEODOL SP-P10, RHEODOL SP-S10/ RHEODOL TW-L120 = 7/3 EXCEL T-95/RHEODOL TW-L120 = 8/2)	1.0 ～ 2.0

(B) For food packing PVC film (T die)

	Parts
PVC	100.0
DOA	30.0 ～ 40.0
Epoxydized soyabean oil	3.0 ～ 4.0
Stabilizer	1.0 ～ 2.5
Internal antifogging agent (RHEODOL SP-P10, RHEODOL SP-P10)	1.0 ～ 2.5

(C) Polyethylene film for food packing

	Parts
Low density polyethylene	100.0
Internal antifogging agent (RHEODOL SP-L10, RHEODOL SP-P10, EXCEL 150)	0.5 ～ 2.0

3-5) Evaluation methods for antifogging agents

The following methods are actually employed to evaluate the effect of antifogging agents blended in film.

3-5-1) For food packing film

Packing and sealing up meat, vegetable or fruit with the specimen film, the package is left at the range of temperature from 0℃ to 5℃. The rating is visually conducted on standing, by observing the tendency to the condensation of micro water droplets on the interior surface of the specimen.

3-5-2) For greenhouse

Using the film of specimen, construct barrel roofed greenhouse in the open air. During the definite time (e.g. 5～6 months) the temperature in the greenhouse is measured and the aspect of waterdroplets setting on the film surface is rated visually from time to time.

- Convenient and simple method of evaluation.

3-5-3) Antifogging effect at high temperature

Hot water of about 50℃ is poured into a beaker, and after sealing the beaker with the film of specimen, the beaker is put and left

in a thermostat maintaining the same temperature with the hot water in the beaker.

The condensation of the water on the inner side of the sealing film is observed on standing for the evaluation.

3-5-4) Antifogging effect at low temperature

The beaker containing a proper amount of water is sealed with the film of specimen and exposed to the constant temperature of 5℃.

The effect is rated visually on standing.

3-5-5) Durability

After dipping the film of specimen for 1 minute in water at room temperature, then the film is taken out from the water and dried up with air. This film is exposed to vapor for a definite time and then the visual rating is conducted.

By repeating this visual rating the durability of the effect is evaluated.

4 Plasticizers

Plasticizers are the materials to be incorporated in plastics to increase its workability and flexibility. The softening point and the melt viscosity of plastics are lowered by the addition of plasticizers into plastics and so their processing is facilitated.

Furthermore, plasticizers impart required flexibility to the end products of plastics.

4-1) Classification of plasticizers

Plasticizers are classified from various standpoints, however the most common classification is in accordance with chemical structure as specified below.

a) Phthalates
b) Fatty acid esters
c) Adipates
d) Trimellitates
e) Expoxides
f) Polyesters
g) Others

According to the compatibility with plastics, plasticizers are classified into primary plasticizer and secondary plasticizer.

The primary plasticizer shows good compatibility with PVC, and in general, phthalates are involved in this category. This is used for plasticizeing resin and also for obtaining high processability, because bleeding never occurs in spite of more than 50 parts of its addition to PVC.

The secondary plasticizers are mainly used for the purpose of improving some properties of plastics such as low temperature or high temperature stability. Most of this type of plasticizers have lower compatibility with resin than primary plasticizers, therefore these should be used always together with primary plasticizers within a certain limit of dosage.

4-2) The criteria for the choice of plasticizers

(1) Compatibility
(2) Plasticizing efficiency
(3) Volatility
(4) Stability against heat and light
(5) Exudation
(6) Migration
(7) Effect on low temperature flexibility of plastics
(8) Effect on electric resistivity of plastics
(9) Effect on extraction tolerance of plastics

For the choice of plasticizers it is also necessary to be careful to the interactions with other additives such as stabilizer, anti-oxidant, lubricant, filler, pigment, etc.

4-3) Kao's plasticizers

Kao's plasticizers are listed hereafter in the Table 10 .

Table 10. List of Kao's plasticizers

(1) Phthalate base

Product name	Chemical composition	Characteristics	Uses
VINYCIZER 124	Di-alky1 (C_{10-13}) phthalate (NF Type)	Extremely low volatility without the reduction of plasticity and processability. Excellent stability at high and low temperature.	High quality PVC leather and other PVC products.
VINYCIZER 85	Di-normal alky1 phthalate m.w. = 391 (n-DOP)	Lower volatility than DOP. Excellent stability at high and low temperature. Most suited for use in electric cable and wire. Due to its viscosity stability,it is suited for plastisol. Saving of low temperature resistant plasticizer is possible.	Film, sheet, synthetic leather, hose, electric cable and wire, plastisol.
VINYCIZER 105	Di-normal alky1 phthalate m.w. = 450 (n-DDP)	Compared to DIDP, volatility is lower. Excellent stability at high and low temperature. Suitable for electric cable and wire. Synthetic leather for automobiles. Saving of low temperature resistant plasticizer is possible, due to its good low temperature stability.,	Synthetic leather, electric cable and wire, sheet, base.

(2) Polyester base

Product name	Chemical composition	Characteristics	Uses
HA-5		Non-phthalate base primary plasticizer. Superior to ATBC (citric acid ester). Food industry grade.	Hose, synthetic leather, sheet.

(3) Fatty acid base

Product name	Chemical composition	Characteristics	Uses
VINYCIZER 30	Butyl Oleate m.w. = 340	Secondary plasticizer with excellent low temperature stability. superior to DOS in respect of low temperature flexibility. The volatility is in-between DOP and DBP. It imparts low and stable viscosity to plastisol. High lubricity 15-20% of total plasticizer amount can be replaced ty #30 without exudation. Well accepted also as rubber plasticizer.	Film, sheet, synthetic leather, hose, tile, plastisol.

(4) Adipate base

Product name	Chemical composition	Characteristics	Uses
VINYCIZER 40	Di-isobuty1 adipate m.w. = 258	Excellent compatibility, plasticity and low temperature stability,	Films, sheet, synthetic leather, electric cable and wire, PVAc.
VINYCIZER 50	Di-isobuty1 adipate m.w. = 426	Excellent secondary plasticizer which is resistive to low temperature. Better non-migrative property, non-volatility and electric non-conductivity compare to DOA.	Synthetic leather, film, sheet, electric cable and wire.

(5) Trimellitate base

Product name	Chemical composition	Characteristics	Uses
TRIMEX T-08 TRIMEX T-08LP TRIMEX T-08NB	Tri-2-Ethy1hexy1 trimellitate m.w. = 547	Primary plasticizer with highest heat resistance. Most suitable for thermal resistant electric cable and wire, synthetic leather, film. Stable at higher and lower temperature, better processability, better electric characteristics. T-08 has the best electric characteristics among the three types. N-08 has the best stability at higher and lower temperature and processability.	Heat resistant electric cable and wire. Heat resistant synthetic leather and film.
TRIMEX N-08	Tri-normal octy1 trimellitate m.w. = 547		
TRIMEX New NSK	Tri-normal octy1 trimellitate m.w. = 547		

(6) Expoxy base

Product name	Chemical composition	Characteristics	Uses
KAPOX S-6	Epoxydized soyabean oil with more than 6.3% of oxirane oxygen m.w. = about 1,000	Plasticizer and stabilizer with excellent thermal stability, low volatility, low migration and low exudation. It meets FDA approval conditions.	Film, sheet, synthetic leather, tile, electric cable and wire, plastisol, extruded parts.

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