INORGANIC FLAME RETARDANTS,
SYNERGISTS, AND SMOKE SUPPRESSANTS

Typical PVC cable formulations.

Components (and resultant properties)	Quantity (phr)	
PVC (K value ¼ 70)	100	100
Diisononyl phthalate	55	55
Calcium carbonate	10	10
ATH	50	40
Antimony oxide	–	5
Lead-based stabilizer	4	4
Lubricant Polyethylene wax	0.5	0.5
Properties		
LOI (ASTM D 2863-77)(% O_2)	27	31
Tensile strength (DIN 53504)	17.8 MPa	16.3 MPa
Elongation at break (DIN 53504)(%)	220	250

Comparison of Some Flame Retardant and Non-flame Retardant Plasticizers

Comparison of PVC formulations using various plasticizers at 60 phr.

Identity of phosphate	Viscosity at 25C (mm/s)	Density at 25C (g/cc)	Shore A hardness	Cold flex Clash and Berg (C)	Oxygen index (%)
Isopropylated phenyl	44.5	1.183	74	2	32.6
Isopropylated phenyl	57	1.164	76	1	32.5
Isopropylated phenyl	93	1.136	78	þ1	32
Isopropylated phenyl	48	1.174	75	2	32.5
Cresyl diphenyl	36	1.202	73	4	33
Tricresyl	60	1.158	74	0	32.5
Trixylenyl	95	1.134	76	þ4	32
t-Butylphenyl diphenyl	81	1.165	89	þ11	32
2-Ethylhexyl diphenyl	16	1.087	70	24	28.6
Isodecyl diphenyl	22	1.065	71	20	28.1
For comparison					
Dioctyl phthalate	56	0.980	71	24	24
Diisononyl phthalate	85	0.970	75	19	24
Tetrabromophthalate	1036	1.54	94	þ18	37.5

Cone calorimetry comparison of PVC with various additives.

Additive(s) to PVC	Additive level (phr)	Burning time (s) in cone cal.	Peak heat release rate (kW/m²)	Time to peak heat release (s)	Char (wt%)	LOI (% O_2)
Antimony oxide	6	134	36.8	48	12	29.8
Diisodecyl phthalate	50	128	45.1	35	6	23.5
AO/zinc borate (ZB)	6/6	144	42.1	38	22.4	30.5
Triaryl phosphate (TAP)	50	148	40.8	46	7.7	31.8
TAP/ZB	50/6	200	30.6	54	10.8	34.7
TAP/AO	50/6	180	44.4	70	9.2	32.9
TAP/AO/ZB	50/6/6	176	23.9	34	18.3	33.3
TAP/AO/ZB/ATH	50/6/6/30	300	25.4	52	10.5	37.1

Comparison of Various Combinations of Plasticizers and Other Additives

PVC automobile upholstery formulation for meeting MVSS 302.

Component	phr
PVC	100
Diisodecyl phthalate	68–80
$CaCO_3$	20–50
Epoxidized soybean oil	5
Stabilizer	3
Sb_2O_3	1.5–2.0
Zinc borate	1.5–2.0

PVC wire and cable insulation formulation to meet UL NM requirements.

Component	phr
PVC resin	100
Plasticizer (7–11 phthalate)	42
Magnesium hydroxide	28
Calcium carbonate	20
Stabilizer	3
Antimony oxide	3
Stearic acid	0.5
Properties	
LOI	31.0%
Tensile strength	2610 psi
Tensile modulus	20330 psi
Elongation	139%
Melt flow index	0.9 g/10 min

PVC plenum wire formulation for low flammability and low smoke.

Component	Parts by weight
PVC	100
phosphate plasticizer	30
Dioctyl tetrabromophthalate	20
Epoxidized soybean oil	3
Alumina trihydrate	28
Ammonium octamolybdate	32
Zinc molybdate	10
Tribasic lead sulfate	7
Stearic acid	0.5
Paraffin wax	0.5

PVC blend plenum wire starting-point formulations.

Component	A phr	B phr	C phr
PVC	100	100	100
ethylene–acrylate–CO	15	15	15
Dodecyl diphenyl phosphate plasticizer	10	10	10
Dioctyl tetrabromophthalate plasticizer, f.r.	25	25	25
Alumina trihydrate	38	38	38
Huntite–hydromagnesite mix	12	12	12
Hindered phenolic stabilizer (Ciba)	4	4	4
Tribasic lead sulfate stabilizer	3	3	3
Antimony trioxide f.r. synergist	3	3	3
Ammonium octamolybdate (AOM, anti-smoke)	25		10

Zinc stannate (ZS, f.r. synergist and anti-smoke)	–	25	15
Cone calorimetry data at 40 kW/m^2			
Time to ignition (s)	897	705	Never
Peak rate of heat release (kW/m^2)	35	35	–
Average specific extinction area (m^2/kg)	433	342	–