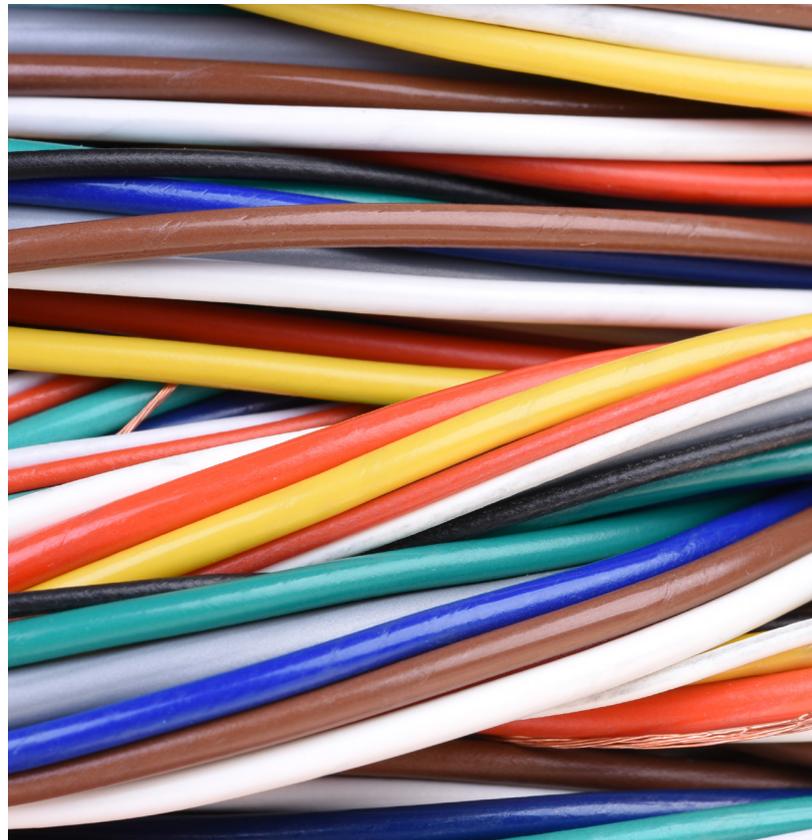
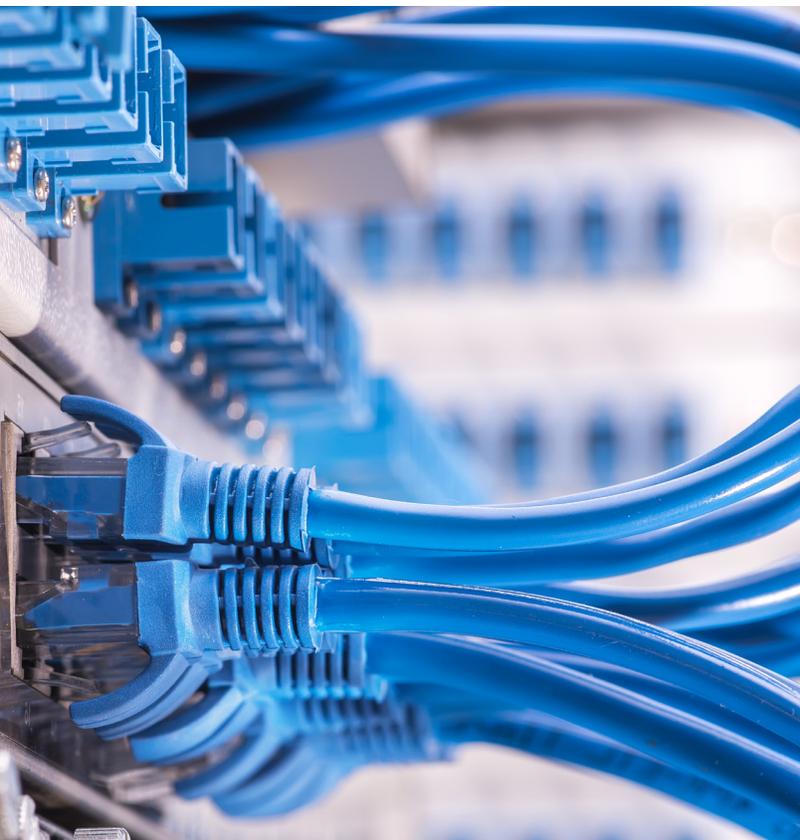


UNIPLEX™ FRP-45

TETRABROMOPHTHALATE ESTER

APPLICATION GUIDE FOR PVC



Hallstar works collaboratively with companies around the world to deliver chemistry solutions that enhance next-generation products.

As manufacturers find themselves under pressure to innovate, their ability to compete globally depends increasingly on how well they can leverage the knowledge of technology suppliers.

Hallstar's expertise in polymer modification and optimization, coupled with our application knowledge across a wide range of industrial products, is unique in the specialty chemical industry. Our ability to continually invent and formulate chemistry solutions to meet the unmet needs of our customers—is based on years of specialized esterification experience.

Taking a collaborative approach to new chemistry solutions is what Hallstar is all about. Together we can explore new approaches and possibilities, and anticipate what it takes to succeed tomorrow, next year and for years to come. Explore what our innovative plasticizers can do, then give us a call.

LET'S WORK WONDERS™

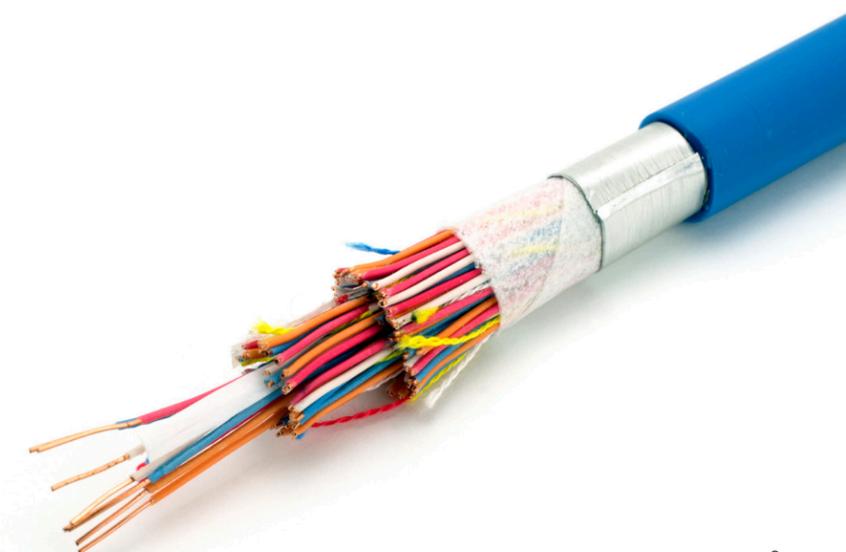
UNIPLEX™ FRP-45 TETRABROMOPHTHALATE ESTER

Uniplex™ FRP-45 is a liquid flame retardant with plasticizer functionality. It is compatible with PVC, adhesives, coatings and SBR, CR and EPDM. Properties of FRP-45 include:

- High flame retarding efficiency
- Excellent plasticizing efficiency
- Good heat stability
- Compatible with multiple types of plasticizers
- Low emissions
- Good dielectric properties

As a special FR functioning plasticizer, FRP-45's main use is for PVC wire and cable insulation jackets, as well as fabric coatings and films. In wire and cable, it passes the plenum (UL910) fire retardant test. In order to improve FRP-45 efficiency, a small volume of Sb_2O_3 should be used as the enhancer. If Sb_2O_3 cannot be used, adding more FRP-45 can achieve the targeted FR performance.

Physical Properties	
Appearance	Amber clear liquid
Viscosity, cps, @25°C	1800
Pour Point, °C	-20
Specific Gravity	1.54
Density lb/gal	13
Bromine Content, %, min.	45
Gardner, max.	3
Acid Value, mg KOH/g, max.	0.05
Purity %, min.	95



FRP-45 IN FLEXIBLE PVC

Recipe	Loading (PHR)
PVC Resin	100
FRP-45	Variable
DOP	Variable
ESO	5
Stabilizer	3
Stearic Acid	0.5

FRP-45

FRP-45 PHR	DOP PHR	Sb ₂ O ₃ PHR	Shore A	Oxygen Index	Modulus @100% (psi)	Elongation (%)	Brittle Point ASTM D-746 °C
-	50	-	85	23	1270	320	-26
10	44	-	86	27	1420	310	-24
30	31	-	89	29	1610	300	-20
50	18	-	91	31	1650	300	-14
78	-	-	92	37	2110	290	-8

FRP-45/SB₂O₃

FRP-45 PHR	DOP PHR	Sb ₂ O ₃ PHR	Shore A	Oxygen Index	Modulus @100% (psi)	Elongation (%)	Brittle Point ASTM D-746 °C
-	50	4	87	27	1440	280	-26
10	44	4	88	29	1530	270	-24
30	31	4	90	32	1600	260	-20
50	18	4	92	35	1850	240	-16
78	-	4	94	40	2070	220	-8

FRP-45 IN PVC W&C INSULATION MATERIAL

Recipe	Loading (PHR)
PVC Resin	100
FRP-45	Variable
TOTM	Variable
Stabilizer	5
Sb ₂ O ₃	1.5



Formulation	I	II	III	IV	V
FRP-45	-	20	40	60	93.4
TOTM	60	47.2	34.4	21.5	-

Physical Properties

Shore A	88	88	88	90	92
Modulus @100% (psi)	1640	1740	1760	1830	1980
Tensile Break (psi)	1860	1880	2050	2320	2510
Elongation (%)	308	286	278	263	239
ASTM D746 (°C) Brittle Point	-22	-20	-14	-14	-6
(70°C 24) Heat Weight Loss - ASTM D1203	0.3	0.5	0.2	0.1	0.1

FR Properties

Oxygen Index	27	31	33	36	42
NBS Smoke Volume - ASTM E662					
Smolder Test	200	190	180	170	140
Flame Test	450	450	440	180	170

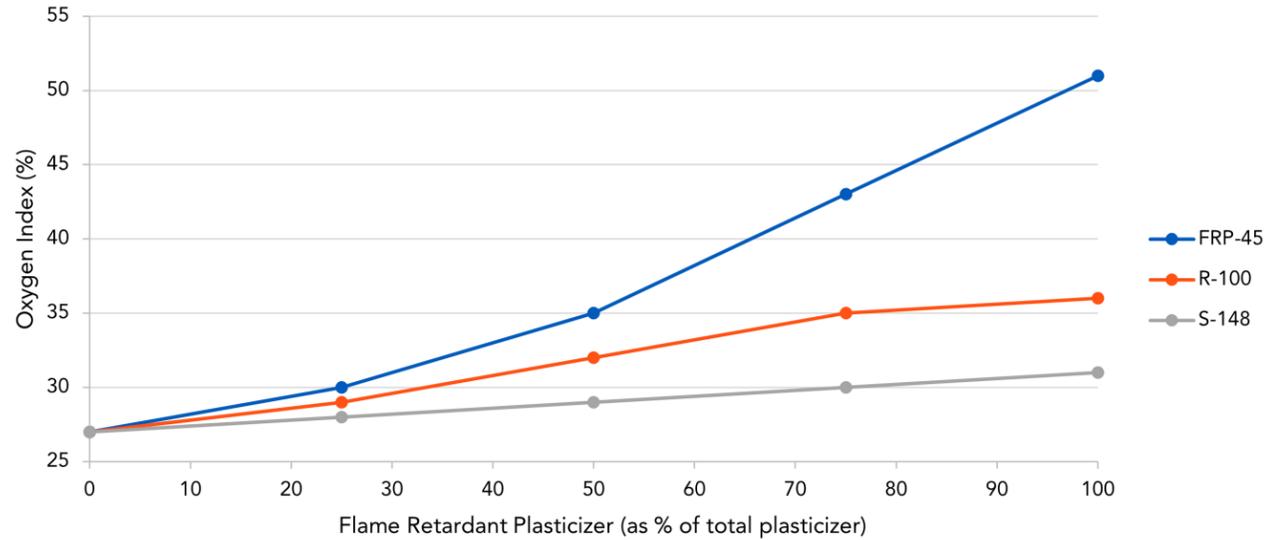
UL1581 - 105°C (135°C for 7 days heat aging)

Modulus @100% (psi)	1770	1870	2000	2020	2220
Tensile Break (psi)	1625	1800	2010	2170	2370
Elongation (%)	280	270	260	250	220
Shore A	89	89	89	91	94

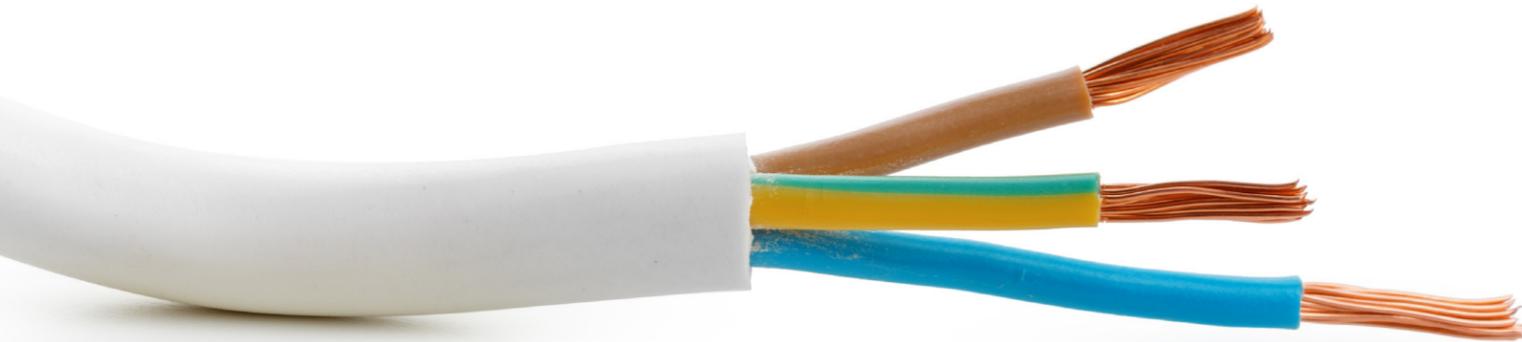
FRP-45 IN FLEXIBLE PVC WIRE AND CABLE

In PVC wire and cable, FRP-45 has both an FR and plasticizing effect. In the following chart, when added at the same level, FRP-45 has a higher oxygen index than traditional phosphates such as Santicizer® 148 (isodecyl diphenyl phosphate) and Reofos® 100.

Flame Retardant Plasticizer vs Oxygen Index



Recipe	Parts
PVC Resin	100
TOTM	Variable
Flame Retardant Plasticizer	Variable
Stabilizer	5
Sb ₂ O ₃	1.5



FRP-45 IN FLEXIBLE PVC WIRE AND CABLE

In normal grade PVC wire and cable formulation, some FR plasticizer is used to replace the primary plasticizer (TOTM) in order to reach an oxygen index of 29 and 32. The results below show less FRP-45 is needed to achieve the desired oxygen index target, but the material physical performance is equal to or better than the performance of formulations using phosphates, especially in terms of elongation and modulus.

Formulation	I	II	III	IV	V	VI
FRP-45	16	-	-	29	-	-
Isodecyl Diphenyl Phosphate	-	25	-	-	64	-
Phosphate Ester	-	-	20	-	-	35
TOTM	53	38	42	46	-	30
FR Properties						
Oxygen Index	29	29	29	32	31*	32
Physical Properties						
Shore A	85	81	85	86	81	85
Modulus @100% (psi)	1560	1170	1430	1690	1090	1500
Tensile Break (psi)	1710	2020	1750	1790	1890	2230
Elongation (%)	340	315	290	315	315	310
ASTM D746 (°C) Brittle Point	-20	-26	-18	-18	-20	-20
UL1581 - 105°C (135°C for 7 days heat aging)						
Tensile Strength (psi)	1930	2570	2720	1840	2880	2820
Elongation (%)	280	210	220	300	220	190
(%)** Retention of tensile/elongation after aging	113/82	127/67	155/75	103/95	152/70	150/61

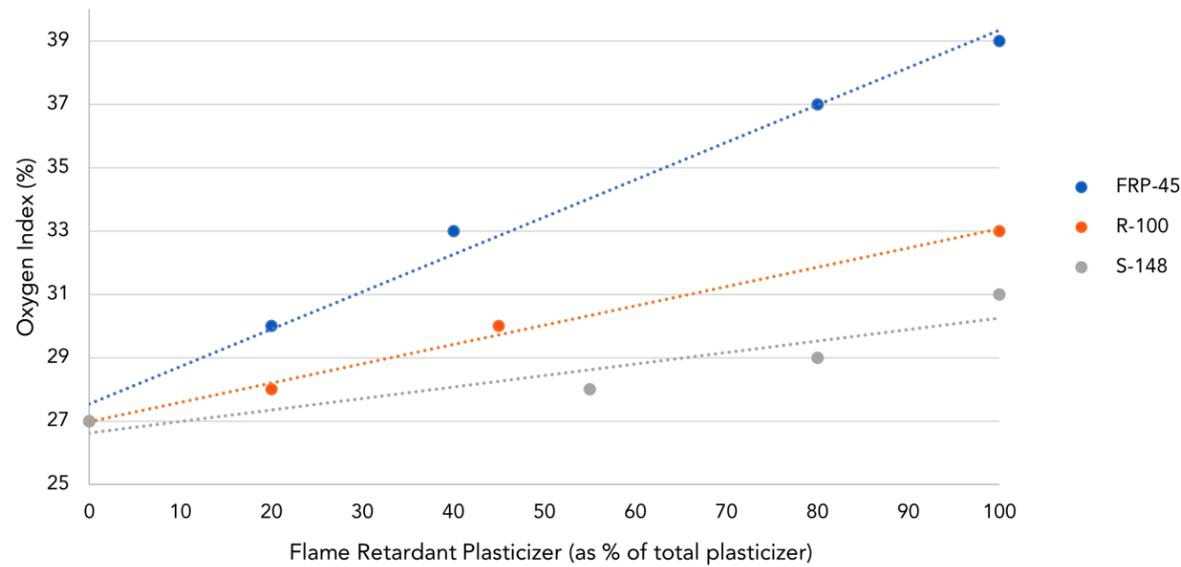
* S-148 failed to achieve target oxygen index

** 105°C, 70% 45%. By 105C test standards, the material needs to retain at least 70% of tensile and 45% of elongation.

FRP-45 IN FLEXIBLE PVC FILM

FRP-45 is used in soft PVC film and other FR plasticizer functions. In PVC material, FRP-45 has both flame retarding and plasticizing functions. As shown in the following chart, when added at the same level, FRP-45 PVC film can have a much higher OI than traditional phosphate FR material (like Santicizer® 148 or Reofos® 100).

Flame Retardant Plasticizer vs Oxygen Index



Recipe	Loading (PHR)
PVC Resin	100
DOP	Variable
Flame Retardent Plasticizer	Variable
ESO	5.0
Sb ₂ O ₃	4.0
BaCr Stabilizer	3.0
Stearic Acid	0.5

FRP-45 IN SOFT PVC FILM AGAINST OTHER FR PLASTICIZER

FRP-45 in PVC film has better physical properties than those containing phosphates, especially the modulus.

In a general-purpose PVC film formulation, using part of the FR plasticizer to replace DOP can bring OI to 29 and 32. The test shows FRP-45 is needed far less than phosphates to achieve targeted OI.

Recipe	29 Oxygen Index			32 Oxygen Index		
FRP-45	10	-	-	30	-	-
Isodecyl Diphenyl Phosphate	-	36	-	-	54.5	-
Phosphate Ester	-	-	28	-	-	58.5
DOP	41	17	26	29	-	-
Physical Properties						
Shore A	85	81	83	86	81	85
Modulus @100% (psi)	1500	1260	1330	1520	1220	1310
Tensile Break (psi)	1810	2090	1720	2060	1665	1930
Elongation (%)	340	340	430	310	350	340
ASTM D746 (°C) Brittle Point	-26	-30	-26	-24	-28	-29
FR Properties						
Oxygen Index	29	29	29	32	31*	32

* Could not acheive OI = 32



FRP-45 IN FLEXIBLE PVC

The usage of Sb_2O_3 can be reduced by using FRP-45 to:

- Increase oxygen index
- Lower smoking (NBS Combustion Method)
- Improve brittle point (ASTM D-746)
- Decrease specific gravity

Product	Specific Gravity
FRP-45	1.54
Sb_2O_3	5.67

FRP-45 can enhance the FR performance of flexible PVC material and reduce the usage of Sb_2O_3 . This can help maintain the physical property and FRP performance of the material as well as reduce smoking.

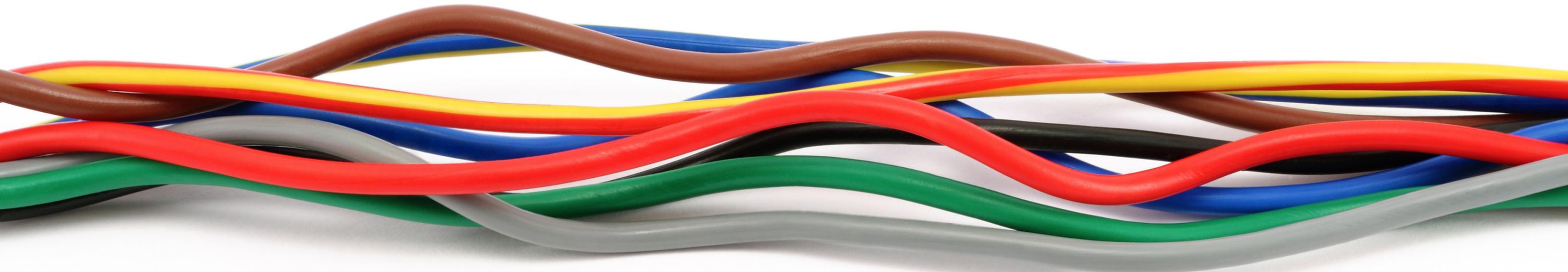
Recipe	Loading (PHR)
PVC Resin	100
FRP-45	Variable
DIDP	Variable
Stabilizer	10
Lubricant	1.5

FRP-45 / Sb_2O_3 RECIPE

FRP-45	Sb_2O_3	DIDP	OI	Modulus @100% (psi)	Elongation (%)	Shore A	Brittle Point °C	NBS Smoking (Flaming)
-	-	45	25.0	1990	310	92	-20	410
5	3	42	30.5	2100	310	93	-16	530
8	3	40	31.0	2060	280	93	-16	550
10	3	38	31.5	2130	300	92	-16	510
12	3	37	33.0	2140	280	93	-18	550

Sb_2O_3 RECIPE

FRP-45	Sb_2O_3	DIDP	OI	Modulus @100% (psi)	Elongation (%)	Shore A	Brittle Point °C	NBS Smoking with Flame
-	1	45	26.0	2120	250	91	-18	380
-	3	45	29.0	2130	220	93	-16	490
-	6	45	30.0	2190	220	93	-12	540
-	9	45	30.0	2200	280	94	-12	640
-	12	45	31.0	2140	260	94	-10	660





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