Polyphenylene Sulfide (PPS)

Category: Engineering Plastics

General Description: Resins available as unfilled, 40% glass fiber reinforced, 65% glass fiber reinforced, and mineral filled.[1027]

Coatings: Finely divided powders having a modest molecular weight and high melt flow.[1027]

Processing Methods: Injection molding, extrusion, and melt cured.[1027]

Applications: Chemical process pipe, pump housings, shafts and impellers, oil field equipment, valves, corrosion resistant industrial parts, non-stick cookware, capacitor housings electrical packaging, and connectors and sockets.[1027]

Permeability Data by Material Supplier Trade Name: See Tables 47-01 and 47-02.

Table 47-01. Various Gases Through Chevron Phillips Ryton Polyphenylene Sulfide Film

Material Family	**POLYPHENYLENE SULFIDE (PPS)**						
Material Supplier/Grade	**CHEVRON PHILLIPS RYTON**						
Product Form	**FILM**						
Manufacturing Method	Formed as a baked coating by spraying unfilled PPS onto aluminum foil. Foil was then dissolved in a sodium hydroxide bath.						
Reference Number	102						
MATERIAL CHARACTERISTICS							
Sample Thickness (mm)	0.127					0.875	
TEST CONDITIONS							
Penetrant	oxygen	carbon dioxide	hydrogen	ammonia	hydrogen sulfide	oxygen	air
Test Method	ASTM D1434 method M						
PERMEABILITY (source document units)							
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	30	75	420	15	3	15 - 20	20 - 30
Gas Permeability ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	11.8	29.6	165	5.9	1.2	5.9 - 7.9	7.9 - 11.8
PERMEABILITY (normalized units)							
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	11.8	29.5	165	5.9	1.2	5.9 - 7.9	7.9 - 11.8

Table 47-02. Various Liquids Through Chevron Phillips Ryton Polyphenylene Sulfide Film

Material Family	**POLYPHENYLENE SULFIDE (PPS)**
Material Supplier/Grade	**CHEVRON PHILLIPS RYTON**
Product Form	**FILM**
Manufacturing Method	Formed as a baked coating by spraying unfilled PPS onto aluminum foil. Foil was then dissolved in a sodium hydroxide bath.
Reference Number	102

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.127

TEST CONDITIONS

Penetrant	water	hydrochloric acid	acetic acid	benzene	methyl alcohol	water vapor
Concentration (%)		37				
Temperature (°C)	23					
Test Method	Die cut samples were fitted to tops of glass bottles by a rubber gasket and a lid, with a surface area of 96.8 cm^2.					ASTM E96 condition E
Test Note	Liquids were placed in bottles, gaskets and film put in place, and the lid screwed on. Apparatus was inverted to put liquid in direct contact with film. Weight loss measurements were made at one week intervals throughout four weeks of conditioning.					

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	0.81	0.08	2.0	6.3	0.3	1.66
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.35	0.03	0.79		0.12	0.66

PERMEABILITY (normalized units)

Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.32	0.03	0.79	2.48	0.12	0.65

Chapter 48

Polysulfone

Category: Engineering Plastic

General Description: Polysulfone is a tough, rigid, high-strength, amorphous thermoplastic that maintains its properties over a wide temperature range. Transparent, opaque, and glass-fiber reinforced grades of Solvay Advanced Polymers Udel resin are available.[1028]

Processing Methods: Injection molding, blow molding, extrusion, shapes can be machined for prototype evaluations; film and sheet can be thermoformed on conventional equipment.

Applications: Solvay Advanced Polymers Udel polysulfone membranes can be used for production of cheese, whey, orange juice, and apple juice, as well as for recovery of protein and lactose and the sterilization and clarification of beer, wine and vinegar. Udel resin offers unique properties, such as the ability to be put into solution for creating porous filaments or casting into flat sheet, that allow it to be used in micro, ultra, and reverse osmosis membranes.[1028]

Permeability Data by Material Supplier Trade Name: See Tables 48-01 through 48-03.

Table 48-01. Various Gases Through Solvay Advanced Polymers Udel Polysulfone

Material Family	POLYSULFONE				
Material Supplier/Grade	SOLVAY ADVANCED POLYMERS UDEL				
Reference Number	15				
TEST CONDITIONS					
Penetrant	ammonia	carbon dioxide	helium	hydrogen	methane
Temperature (°C)	23				
Relative Humidity (%)	dry				
Test Method	ASTM D1434				
PERMEABILITY (source document units)					
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	1070	950	1960	1800	37.5
Gas Permeability ($mm^3/m \cdot MPa \cdot day$)	4160	3690	7620	6990	146
PERMEABILITY (normalized units)					
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	421	374	772	709	14.8

Table 48-02. Various Gases Through Solvay Advanced Polymers Udel Polysulfone

Material Family	**POLYSULFONE**				
Material Supplier/Grade	**SOLVAY ADVANCED POLYMERS UDEL**				
Reference Number	15				

TEST CONDITIONS

Penetrant	nitrogen	oxygen	sulfur hexafluoride	dichloro-difluoromethane	dichloro-tetrafluoroethane
Temperature (°C)	23				
Relative Humidity (%)	dry				
Test Method	ASTM D1434				

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	40	230	1.8	0.59	0.25
Gas Permeability ($mm^3/m \cdot MPa \cdot day$)	155	894	6.99	2.29	0.97

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	15.7	90.5	0.71	0.23	0.098

Table 48-03. Water Vapor Through Solvay Advanced Polymers Udel Polysulfone

Material Family	**POLYSULFONE**	
Material Supplier/ Trade Name	**SOLVAY ADVANCED POLYMERS UDEL**	
Product Form	**SLOT CAST THIN FILM**	
Reference Number	15	

TEST CONDITIONS

Penetrant	water vapor	
Temperature (°C)	38	71
Relative Humidity (%)	90	100
Test Method	ASTM E96	

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	18	69

PERMEABILITY (normalized units)

Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	7.1	27.2

Polyvinyl Alcohol (PVOH)

Category: Polyhydric Alcohol

General Description: White-to-cream granular powder. DuPont Elvanol polyvinyl alcohol (PVOH, sometimes also referred to as PVA) is a water-soluble synthetic polymer with excellent film-forming, emulsifying, and adhesive properties. This versatile polymer offers high oxygen barrier.[1029]

Processing Methods: Cast or blown films, blow molding, and injection blow molding.

Applications: Water-soluble films: pouches and sachets manufactured with films of DuPont Elvanol are water soluble, dissolving as they release their content into cold or warm aqueous solutions. Applications include water treatment chemicals, dyes, laundry detergents, agricultural chemicals, disinfectants, industrial cleaning chemicals, and other areas benefitting from ready-to-use, pre-measured dosages or reduced packaging waste.[1029]

PVOH is also used in strippable coatings, nonwovens, and agricultural chemicals.[1029]

Permeability to Water and Other Vapors: The degree of hydrolysis affects the water sensitivity of both the resin and film. Water resistance increases with increasing hydrolysis. The super hydrolyzed grades should be used when maximum water resistance and humidity resistance are desired.[1029]

Permeability Data by Material Supplier Trade Name: See Tables 49-01 and 49-02.

Table 49-01. Oxygen and Carbon Dioxide Through PVOH

Material Family	POLYVINYL ALCOHOL (PVOH)		
Product Form	FILM		
Reference Number	250		
TEST CONDITIONS			
Penetrant	oxygen		carbon dioxide
Temperature (°C)	24		
Relative Humidity (%)	0	75	0
PERMEABILITY (source document units)			
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	0.06	0.22	0.11
PERMEABILITY (normalized units)			
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.02	0.09	0.04

Table 49-02. Oxygen Through Air Products and Chemicals Vinex PVOH

Material Family	POLYVINYL ALCOHOL (PVOH)					
Material Supplier/Trade Name	AIR PRODUCTS AND CHEMICALS VINEX					
Grade	**1003**	**2144**	**5030**	**1003**	**2144**	**5030**
Reference Number	283					

MATERIAL CHARACTERISTICS

Specific Gravity	1.25					
Melt Flow Index	5 - 7 g/10 min. (230/2.16)	6 - 8 g/10 min. (230/2.16)	9 - 11 g/10 min. (190/10.1)	5 - 7 g/10 min. (230/2.16)	6 - 8 g/10 min. (230/2.16)	9 - 11 g/10 min. (190/10.1)
Sample Thickness (mm)	0.03	0.033	0.038	0.03	0.033	0.038

TEST CONDITIONS

Penetrant	oxygen	
Relative Humidity (%)	0	50
Pressure Gradient (mmHg)	760	

PERMEABILITY (source document units)

Gas Permeability ($cm^3/100\ in^2 \cdot day \cdot atm$)	0.0350	0.0435	0.0327	1.2	1.45	1.5

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.0163	0.0223	0.0193	0.56	0.74	0.88

Acrylonitrile-Butadiene-Styrene Copolymer (ABS)

Category: Engineering Plastic, Styrene Copolymer

General Description: Acrylonitrile-butadiene-styrene copolymer (ABS) includes a range of resins, each manufactured with usually more than 50% styrene and varying amounts of acrylonitrile and butadiene.The three components are combined by a variety of methods involving polymerization, graft copolymerization, and physical blending.[1004]

GE Plastics Cycolac: Grades consist of an elastomeric and amorphous thermoplastic component. The elastomeric component is usually polybutadiene or a butadiene copolymer.[1031]

Processing Methods: Injection molding and extrusion.

Applications: Medical devices, cosmetics, housewares, automobiles, and business equipment.[1031]

Permeability to Oxygen and Other Gases: Terluran: gases and water vapor can diffuse through it.[1032]

Permeability to Water Vapor: Terluran is impermeable to water.[1032]

See *Collected Comparative Barrier Properties of Plastics and Elastomers* for more information.

Permeability Data by Material Supplier Trade Name: See Tables 50-01 through 50-04.

Table 50-01. Oxygen and Water Vapor Through GE Plastics Cycolac ABS

Material Family	ACRYLONITRILE-BUTADIENE-STYRENE COPOLYMER (ABS)	
Material Supplier/Grade	GE PLASTICS CYCOLAC	
Reference Number	1033	
TEST CONDITIONS		
Temperature (°C)	25	24
Relative Humidity (%)		90
Penetrant	oxygen	water vapor
PERMEABILITY (source document units)		
Gas Permeability ($cc \cdot mil/24\ hr \cdot 100\ in^2 \cdot atm$)	100	
Vapor Permeability ($g \cdot mil/24\ hr \cdot 100\ in^2$)		12
PERMEABILITY (normalized units)		
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	39.3	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		5.88

Table 50-02: Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through Dow Chemical ABS Film

Material Family	**ACRYLONITRILE-BUTADIENE-STYRENE COPOLYMER (ABS)**						
Material Supplier/Grade	**DOW CHEMICAL**						
Product Form	**FILM**						
Reference Number	250						

MATERIAL COMPOSITION

Note	low acrylonitrile content				medium acrylonitrile content		

TEST CONDITIONS

Penetrant	oxygen	nitrogen	carbon dioxide	water vapor	oxygen	nitrogen	carbon dioxide
Temperature (°C)	24			24-38	24		

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)				5 - 16			
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	200 - 260	25 - 35	900 - 1200		120 - 140	10 - 15	400 - 600

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	79 - 102	9.8 - 13.8	354 - 472		47 - 55	3.9 - 5.9	157 - 236
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)				2.0 - 6.3			

Table 50-03. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through BASF AG Terluran ABS Film

Material Family	**ACRYLONITRILE-BUTADIENE-STYRENE COPOLYMER (ABS)**
Material Supplier/Grade	**BASF AG TERLURAN 997 VE**
Product Form	**FILM**
Features	low flow
Reference Number	137

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.1

MATERIAL COMPOSITION

Note	with butadiene acrylic rubber

TEST CONDITIONS

Penetrant	water vapor	oxygen	nitrogen	carbon dioxide
Temperature (°C)	23			
Relative Humidity (%)	85-0 gradient			
Test Method	DIN 53122	DIN 53380		
Test Note	Values for permeability depend on the conditions under which the film was produced and may differ by as much as 50% from those given.			

PERMEABILITY (source document units)

Vapor Transmission Rate ($g/m^2 \cdot day$)	27			
Gas Permeability ($cm^3 \cdot 100\ mm/m^2 \cdot day \cdot bar$)		800	200	3000

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot \mu m/m^2 \cdot day \cdot atm$)		81	20.3	304
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	2.7			

Table 50-04. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through BASF AG Terluran ABS Film

Material Family	**ACRYLONITRILE-BUTADIENE-STYRENE COPOLYMER (ABS)**	
Material Supplier/Grade	**BASF AG TERLURAN 967 K**	**BASF AG TERLURAN 877 M**
Product Form	**FILM**	
Features	moderate flow	
Reference Number	137	

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.1

MATERIAL COMPOSITION

Note	with butadiene acrylic rubber

TEST CONDITIONS

Penetrant	water vapor	oxygen	nitrogen	carbon dioxide	water vapor	oxygen	nitrogen	carbon dioxide
Temperature (°C)	23							
Relative Humidity (%)	85-0 gradient				85-0 gradient			
Test Method	DIN 53122	DIN 53380			DIN 53122	DIN 53380		
Test Note	Values for permeability depend on the conditions under which the film was produced and may differ by as much as 50% from those given.							

PERMEABILITY (source document units)

Vapor Transmission Rate ($g/m^2 \cdot day$)	27				31			
Gas Permeability ($cm^3 \cdot 100\ \mu m/m^2 \cdot day \cdot bar$)		500	100	2000		450	100	2000

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)		50.7	10.1	203		45.6	10	203
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	2.7				3.1			

Acrylonitrile-Styrene-Acrylate Copolymer (ASA)

Category: Styrenic

General Description: Luran S is the trade name for BASF's styrene-acrylonitrile copolymers which are impact-modified with acrylate rubber.[1034]

Processing Methods: Injection molding and extrusion.

Applications: Automotive components, electrical equipment subjected to high temperatures, parabolic reflectors, solar energy systems, movement sensors, surfboards, and caddy cars.[1034]

Permeability to Oxygen and Other Gases: Depending upon the pressure gradient, gases and water vapor may diffuse through Luran S sheets.[1034]

Permeability to Water and Water Vapor: Luran S moldings are impermeable to water.[1034]

Permeability Data by Material Supplier Trade Name: See Tables 51-01 through 51-03.

Table 51-01. Nitrogen, Hydrogen, and Methane Through BASF Luran S ASA Film

Material Family	ACRYLONITRILE-STYRENE-ACRYLATE COPOLYMER (ASA)							
Material Supplier/Trade Name	BASF AG LURAN S							
Grade	776 S	757 R	776 S	757 R	776 S	797 S	776 S	757 R
Product Form	BLOWN FILM				FILM		BLOWN FILM	
Reference Number	143				142		143	
MATERIAL CHARACTERISTICS								
Sample Thickness (mm)	0.1							
TEST CONDITIONS								
Penetrant	hydrogen		methane		nitrogen			
Temperature (°C)	23							
Test Method	DIN 53380				DIN 53380 part 2 method M		DIN 53380	
Test Note					Values depend on conditions under which film was produced. Figures may differ by as much as 50%.			
PERMEABILITY (source document units)								
Gas Permeability ($cm^3/m^2 \cdot day \cdot bar$)	5000		110		100	75	70	60
PERMEABILITY (normalized units)								
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	507		11.1		10.1	7.6	7.1	6.1

Table 51-02. Oxygen and Carbon Dioxide Through BASF Luran S ASA Film

Material Family	ACRYLONITRILE-STYRENE-ACRYLATE COPOLYMER (ASA)							
Material Supplier/Trade Name	BASF AG LURAN S							
Grade	776 S	797 S	776 S	757 R	776 S	797 S	776 S	757 R
Product Form	FILM		BLOWN FILM		FILM		BLOWN FILM	
Reference Number	142		143		142		143	

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.1

TEST CONDITIONS

Penetrant	oxygen		carbon dioxide	
Temperature (°C)	23			
Test Method	DIN 53380 part 2 method M	DIN 53380	DIN 53380 part 2 method M	DIN 53380
Test Note	Values depend on conditions under which film was produced. Figures may differ by as much as 50%.		Values depend on conditions under which film was produced. Figures may differ by as much as 50%.	

PERMEABILITY (source document units)

Gas Permeability ($cm^3/m^2 \cdot day \cdot bar$)	550	500	180	150	2300	2000	1400	1000

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	55.7	50.7	18.2	15.2	233	203	142	101

Table 51-03. Water Vapor Through BASF Luran S ASA Film

Material Family	**ACRYLONITRILE-STYRENE-ACRYLATE COPOLYMER (ASA)**		
Material Supplier/Grade	**BASF AG LURAN S 776 S**	**BASF AG LURAN S 797 S**	**BASF AG LURAN S 757 R**
Product Form	**FILM**		
Manufacturing Method			blown film
Reference Number	142		143

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.1

TEST CONDITIONS

Penetrant	water vapor	
Temperature (°C)	23	
Relative Humidity (%)	85-0 gradient	
Pressure Gradient (Mbar)	23.87	19.86
Test Method	DIN 53122	
Test Note	Values for permeability depend on the conditions under which the film was produced. Figures determined may differ by as much as 50%.	

PERMEABILITY (source document units)

Vapor Transmission Rate ($g/m^2 \cdot day$)	35	30

PERMEABILITY (normalized units)

Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	3.5	3

Chapter 52

Polystyrene (PS)

Category: Styrenic

General Description: The polystyrene family of resins includes general purpose PS, crystal PS, oriented and foamed crystal PS, modified or impact PS and high impact PS. General purpose PS is generally the lower cost material.[1004]

Processing Methods: Extrusion, orientation, thermoformed, foamed, with most crystal PS being injection molded.[1004]

Applications: Yogurt, cream, butter, meat trays, egg cartons, fruit and vegetable trays, as well as cakes, croissants, and cookies. Medical and packaging/ disposables, bakery packaging, and large and small appliances.[1043]

Permeability, General: For some applications, it is desirable to increase the barrier (decrease the permeability) of polystyrene packaging. Polystyrene film or sheet can be coated with a vinylidene chloride copolymer latex. The film can be used directly, and the sheet can be thermoformed. A typical product is a single service jelly container.[1036]

Alternatively, a multilayer sheet can be made by coextrusion. In this structure, high impact polystyrene (HIPS) provides structural strength and thermoformability. The vinylidene chloride copolymer provides additional oxygen and moisture barrier. The result is a rigid barrier container for foods. Permeation through multilayer film may be treated as a series of permeations through single films.[1036]

Permeability to Oxygen and Other Gases: The oxygen permeabilities for the styrene based polymers drop slowly as the temperature decreases. This is typical behavior for polymers below T_g.[1036]

Permeability to Water Vapor: For polystyrene, permeability to water vapor increases slightly with temperature.[1037]

Permeability Data by Material Supplier Trade Name: See Tables 52-01 through 52-04 and Graphs 52-01 through 52-02.

Table 52-01. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through Polystyrene

Material Family	**POLYSTYRENE (PS)**			
Reference Number	1036			

TEST CONDITIONS

Penetrant	oxygen	nitrogen	carbon dioxide	water vapor
Relative Humidity (%)	0			90

PERMEABILITY (source document units)

Gas Permeability (nmol/m · s · GPa)	600 – 800	40 – 50	2000 – 3000	
Vapor Permeability (nmol/m · s)				0.5 – 2.5

PERMEABILITY (normalized units)

Vapor Transmission Rate (cm^3 · mm/m^2 · day · atm)	117 - 157	8 - 10	393 - 590	
Permeability Coefficient (g · mm/m^2 · day)				0.78 - 3.9

Table 52-02. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through Dow Chemical Styron Polystyrene

Material Family	**POLYSTYRENE (PS)**			
Material Supplier/Grade	**DOW CHEMICAL STYRON**			
Product Form	**FILM**			
Reference Number	250			

TEST CONDITIONS

Penetrant	oxygen	nitrogen	carbon dioxide	water vapor
Temperature (°C)	24			24-38

PERMEABILITY (source document units)

Vapor Transmission Rate (g · mil/100 in^2 · day)				2 - 10
Gas Permeability (cm^3 · mil/100 in^2 · day)	300 - 400	40 - 50	1000 - 1500	

PERMEABILITY (normalized units)

Permeability Coefficient (cm^3 · mm/m^2 · day · atm)	118 - 157	15.8 - 19.7	394 - 590	
Vapor Transmission Rate (g · mm/m^2 · day)				0.79 - 3.9

Table 52-03. Oxygen and Water Vapor Through Polystyrene

Material Family	POLYSTYRENE (PS)			
Reference Number	264		296	
TEST CONDITIONS				
Penetrant	oxygen	water vapor	oxygen	water vapor
Temperature (°C)	23	40	22.8	37.8
Relative Humidity (%)	0	90	0	90
Test Method			ASTM D1434	ASTM F1249
PERMEABILITY (source document units)				
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	260		>350	
Gas Permeability ($cm^3 \cdot 25\ \mu/m^2 \cdot day \cdot atm$)	4030			
Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)		8.5		10
Vapor Transmission Rate ($g \cdot 25\ \mu/m^2 \cdot day$)		131.8		
PERMEABILITY (normalized units)				
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	102.4		>140	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		3.4		4.0

Table 52-04. Water Vapor and Reagents Through Dow Chemical Styron Polystyrene Resin

Material Family	POLYSTYRENE (PS)
Material Supplier/Grade	DOW CHEMICAL STYRON
Product Form	FILM
Reference Number	250

TEST CONDITIONS

Penetrant	methyl alcohol	ethyl alcohol	n-heptane	ethyl acetate	formaldehyde	tetrachloro ethylene	acetone	benzene
Temperature (°C)	24							35

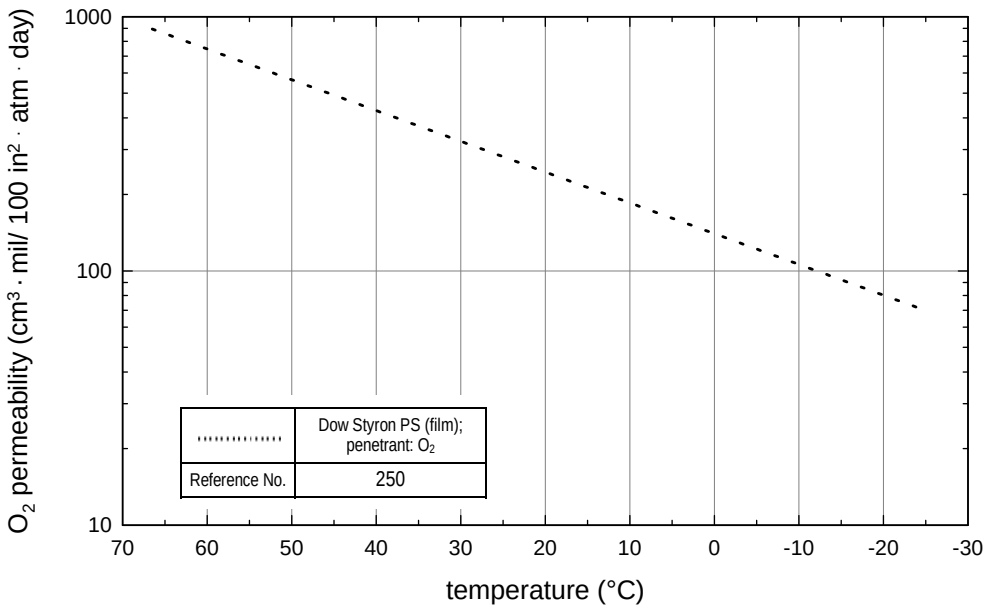
PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	1 - 6	1 - sample failed during test	sample failed during test	4 - 5	sample failed during test	1200

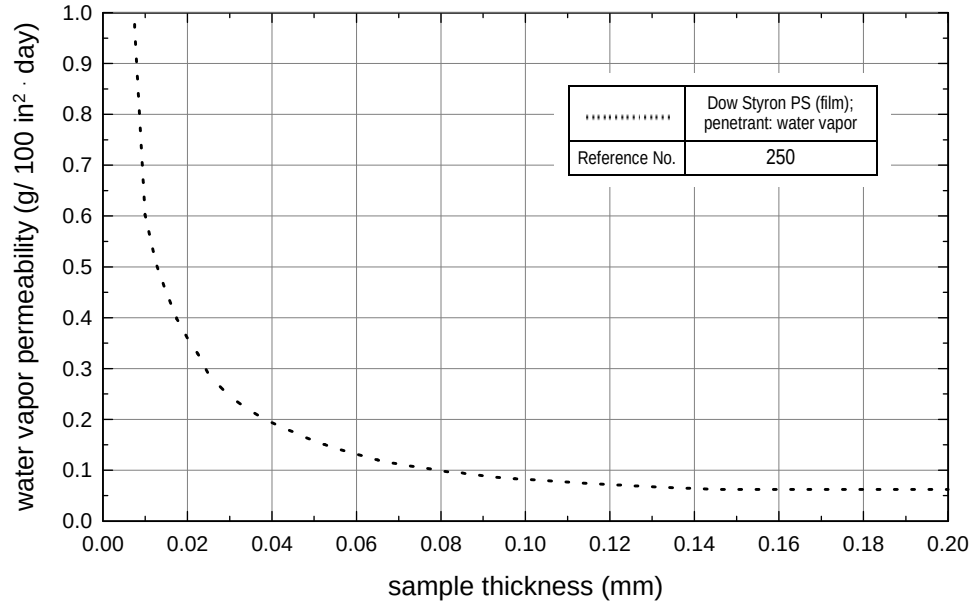
PERMEABILITY (normalized units)

Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.39 - 2.4	0.39 - sample failed	sample failed	1.6 - 2.0	sample failed	472

Graph 52-01. Oxygen vs. temperature through Dow Chemical Styron polystyrene film.



Graph 52-02. Water vapor vs. thickness through Dow Chemical Styron polystyrene film.



Chapter 53

Oriented Polystyrene (OPS)

Category: Styrenic

General Description: Thin sheets are produced with an orientation ratio ranging from 2 × 2 to 3 × 3.[1038]

Processing Methods: Most often these sheets (colored or natural) are thermoformed. The sheets can be colored by way of masterbatch, and the formulation includes mainly a general purpose polystyrene (GPPS) of high molecular weight, mixed with a small amount of elastomer, sometimes blended with an even smaller amount of HIPS in order to improve toughness, and not to decrease clarity.[1038]

Applications: Dow Chemical Trycite polystyrene films can be printed and laminated to foams for food service plates and trays offering improved aesthetics. The films can also be used as a laminate to polystyrene sheet for a high gloss shine.[1140] Bakery, convenience food items.[1038]

Permeability and Orientation: The effect of orientation on the permeability of polymers is difficult to assess because the terms orientation and elongation or strain have been used interchangeably in the literature. The circumstances of the orientation (elongation) are important. In polystyrene, orientation reduces the permeability by 30%.[1036]

When biaxially oriented polystyrene film is strained uniaxially by 3%, the permeabilities of several small permanent gases increase by almost 100% immediately and then decay to the original permeability. Most of the effect is due to the changing diffusivity.[1036]

Permeability Data by Material Supplier Trade Name: See Table 53-01 through 53-02.

Table 53-01. Oxygen Through Unoriented and Oriented Polystyrene

Material Family	ORIENTED POLYSTYRENE (OPS)	
Reference Number	1036	
TEST CONDITIONS		
Penetrant	oxygen	
Temperature (°C)	23	
Degree of Orientation (%)	0	300
PERMEABILITY (source document units)		
Gas Permeability (nmol/m · s · Gpa)	840	600
PERMEABILITY (normalized units)		
Vapor Transmission Rate ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	165	118

Table 53-02. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through Dow Chemical Trycite Polystyrene Film

Material Family	**POLYSTYRENE (PS)**			
Material Supplier/Grade	**DOW CHEMICAL TRYCITE**			
Product Form	**FILM**			
Reference Number	250			

TEST CONDITIONS

Penetrant	oxygen	nitrogen	carbon dioxide	water vapor
Temperature (°C)	24			

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)				9
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	250 - 350	50 - 60	700 - 1100	

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	98.4 - 138	19.7 - 23.6	276 - 433	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)				3.5

Chapter 54

General Purpose Polystyrene (GPPS)

Category: Styrenic

General Description: General purpose polystyrene (GPPS) resins are crystal-clear materials formulated to a range of strength values and processing parameters.[1039]

Processing Methods: Injection molding and extrusion coating.

Applications: Medical and packaging/disposables, particularly where clarity is required.[1039]

Permeability Data by Material Supplier Trade Name: See Tables 54-01 through 54-02.

Table 54-01. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through BASF AG Polystyrol GPPS Film

Material Family	**GENERAL PURPOSE POLYSTYRENE (GPPS)**			
Material Supplier/Grade	**BASF AG POLYSTYROL 168 N**			
Product Form	**FILM**			
Features	transparent			
Reference Number	26			
MATERIAL CHARACTERISTICS				
Sample Thickness (mm)	0.1			
TEST CONDITIONS				
Penetrant	water vapor	oxygen	nitrogen	carbon dioxide
Temperature (°C)	23			
Relative Humidity (%)	85-0 gradient			
Test Method	DIN 53122	DIN 53380		
PERMEABILITY (source document units)				
Vapor Transmission Rate ($g/m^2 \cdot day$)	12			
Gas Permeability ($cm^3/m^2 \cdot bar \cdot day$)		1000	250	5200
PERMEABILITY (normalized units)				
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)		101	25.3	527
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	1.2			

Table 54-02. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through Dow Chemical Styron GPPS

Material Family	**GENERAL PURPOSE POLYSTYRENE (GPPS)**	
Material Supplier/Trade Name	**DOW CHEMICAL STYRON**	
Product Form		**SHEET**
Features		oriented
Manufacturing Method	injection molding	
Reference Number	263	

TEST CONDITIONS

Penetrant	oxygen	nitrogen	carbon dioxide	water vapor	oxygen	nitrogen	carbon dioxide	water vapor
Temperature (°C)	23			24-38	23			24-38
Test Method	ASTM D1434			ASTM E96	ASTM D1434			ASTM E96

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)				2-10				9
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	300 - 400	40 - 50	1000 - 1500		250 - 350	50 - 60	700 - 1100	

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	118 - 158	16 - 20	393 - 591		98 - 138	20 - 24	276 - 433	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)				0.79 - 3.9				3.5

Chapter 55

High Impact Polystyrene (HIPS)

Category: Styrenic

General Description: Designed for toughness, these opaque resins are ideal for both molded and extruded applications that require greater physical performance properties.[1039]

Processing Methods: Injection Molding and extrusion thermoforming.

Applications: Refrigeration accessories, small appliances, electric lawn and garden equipment, toys, and remote controls.

Permeability Data by Material Supplier Trade Name: See Tables 55-01 through 55-02.

Table 55-01. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through BASF AG Polystyrol HIPS Film

Material Family	**IMPACT RESISTANT POLYSTYRENE (HIPS)**			
Material Supplier/Grade	**BASF AG POLYSTYROL 476 L**			
Product Form	**FILM**			
Reference Number	26			
MATERIAL CHARACTERISTICS				
Sample Thickness (mm)	0.1			
TEST CONDITIONS				
Penetrant	water vapor	oxygen	nitrogen	carbon dioxide
Temperature (°C)	23			
Relative Humidity (%)	85 – 0 gradient			
Test Method	DIN 53122	DIN 53380		
PERMEABILITY (source document units)				
Vapor Transmission Rate ($g/m^2 \cdot day$)	13			
Gas Permeability ($cm^3/m^2 \cdot day \cdot bar$)		1600	400	10,000
PERMEABILITY (normalized units)				
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)		162	40.5	1013
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	1.3			

Table 55-02. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through Dow Chemical Styron HIPS

Material Family	**IMPACT RESISTANT POLYSTYRENE (HIPS)**
Material Supplier/Trade Name	**DOW CHEMICAL STYRON**
Manufacturing Method	injection molding
Reference Number	262

TEST CONDITIONS

Penetrant	oxygen	nitrogen	carbon dioxide	water vapor
Temperature (°C)	23			24-38
Test Method	ASTM D1434			ASTM E96

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)				2 - 10
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	300 - 400	40 - 50	1000 - 1500	

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	118 - 157	15.8 - 19.7	394 - 591	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)				0.8 - 3.9

Chapter 56

Styrene-Acrylonitrile Copolymer (SAN)

Category: Styrenic

General Description: SAN resins are random, amorphous, transparent copolymers.[1004] SAN resins are polar in nature resulting in hygroscopic behavior. Therefore, drying before processing is recommended. The styrene portion provides clarity, stiffness, and processability; the acrylonitrile portion provides chemical and heat resistance.[1042]

- *BASF Luran.* Excellent transparency.[1040]
- *TYRIL Resins.* Designed by Dow and are suitable for self-coloring.[1042]

Processing Methods: Injection molding, extruding, coated, metallized, and hot stamped.

Applications: Household: mixing bowls, electric mixers, refrigerator inserts, tableware, vacuum flask casings, food storage containers, toiletries, cosmetics packaging, writing implements, and industrial batteries.

Permeability to Oxygen and Other Gases: Permeability to gases depends upon the conditions under which the film or moldings were produced. Permeability to carbon dioxide is about five times higher and permeability to nitrogen about five times less, than that of oxygen.[1041]

Permeability to Water and Other Vapors: Luran is impermeable to water but allows water vapor to permeate it in given amounts.[1041]

Permeability Data by Material Supplier Trade Name: See Tables 56-01 through 56-03 and Graphs 56-01 through 56-02.

Table 56-01. Oxygen, Nitrogen, Carbon Dioxide, and Water Vapor Through Dow Chemical Tyril SAN

Material Family	**STYRENE-ACRYLONITRILE COPOLYMER (SAN)**
Material Supplier/Grade	**DOW CHEMICAL TYRIL**
Product Form	**FILM**
Reference Number	250

MATERIAL COMPOSITION

Note	low acrylonitrile content	medium acrylonitrile content	low acrylonitrile content

TEST CONDITIONS

Penetrant	oxygen	nitrogen	carbon dioxide	water vapor
Temperature (°C)	24			24 – 38

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)					5 - 14
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	80 - 100	40 - 70	10	400	

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	31.5 - 39.4	15.7 - 27.6	3.9	157	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)					2.0 - 5.5

Table 56-02. Oxygen and Water Vapor Through BASF Luran SAN Copolymer Film

Material Family	STYRENE-ACRYLONITRILE COPOLYMER (SAN)							
Material Supplier/Trade Name	BASF AG LURAN							
Grade	**358 N**	**368 R**	**378 P**	**388 S**	**358 N**	**368 R**	**378 P**	**388 S**
Product Form	FILM							
Features	high flow, transparent	moderate to low flow, transparent	moderate to high flow, transparent	low flow, transparent	high flow, transparent	moderate to low flow, transparent	moderate to high flow, transparent	low flow, transparent
Reference Number	30							

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.1

TEST CONDITIONS

Penetrant	oxygen	water vapor
Temperature (°C)	23	
Relative Humidity (%)		85-0 gradient
Test Method	DIN 53380	DIN 53122

PERMEABILITY (source document units)

Gas Permeability ($cm^3/m^2 \cdot day \cdot bar$)	200 - 500	200 - 300	
Vapor Transmission Rate ($g/m^2 \cdot day$)			20 - 25

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	20.3 - 50.7	20.3 - 30.4	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)			2 - 2.5

Table 56-03. Reagents Through Dow Chemical Tyril SAN

Material Family	**STYRENE-ACRYLONITRILE COPOLYMER**
Material Supplier/Grade	**DOW CHEMICAL TYRIL**
Product Form	**FILM**
Reference Number	250

TEST CONDITIONS

Penetrant	methyl alcohol	ethyl alcohol	n-heptane	ethyl acetate	formaldehyde	tetrachloro-ethylene	acetone
Temperature (°C)	24						

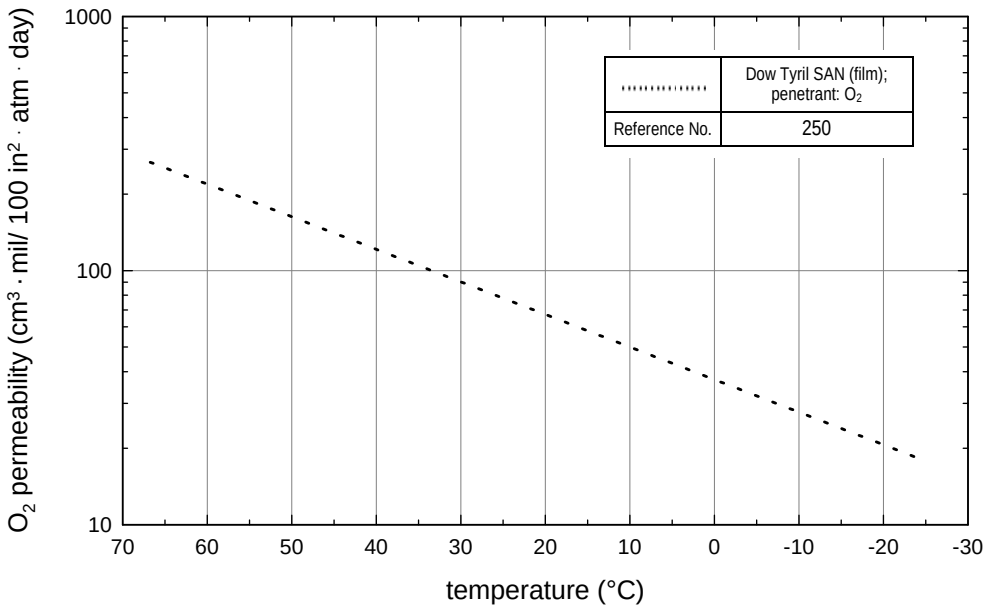
PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	sample failed	2 - 20	sample failed	5 - 10	sample failed

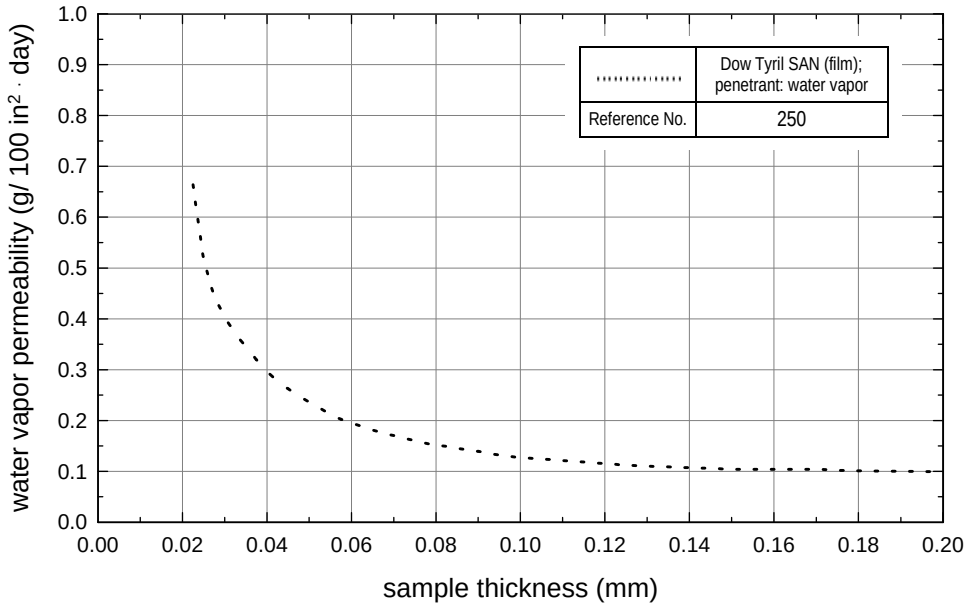
PERMEABILITY (normalized units)

Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	sample failed	0.8 - 7.9	sample failed	2.0 - 3.9	sample failed

Graph 56-01. Oxygen vs. temperature through Dow Chemical Tyril SAN film.



Graph 56-02. Water vapor vs. thickness through Dow Chemical Tyril SAN film.



Styrene-Butadiene Block Copolymer (SBS)

Category: Styrenic, thermoplastic

General Description: BASF AG Styrolux is the trade name for a line of anionically produced styrene-butadiene block copolymers that possess complex molecular structure and are characterized by their optical and mechanical properties.[1136]

Processing Methods: Extruded, thermoformed, and injection molded.

Applications: Primarily food packaging, packed fruit and vegetables, fresh pasta and cheese, as thermoformed cups and lids, and also in applications including shrink film, must stay fresh as long as possible. Styrolux co-extruded with other thermoplastics, provides transparent barrier-layer composites.[1136]

Permeability: Styrolux demonstrates high permeability to gas and water vapor compared with other types of polymer.[1136]

Permeability Data by Material Supplier Trade Name: See Tables 57-01 through 57-02.

Table 57-01. Oxygen, Nitrogen, and Carbon Dioxide Through BASF AG Styrolux SBS

Material Family	STYRENE-BUTADIENE BLOCK COPOLYMER (SBS)					
Material Supplier/Grade	BASF AG STYROLUX 684 D			BASF AG STYROLUX 656 C		
Product Form	FILM					
Features				high flow		
Reference Number	29					
MATERIAL CHARACTERISTICS						
Sample Thickness (mm)	0.1					
TEST CONDITIONS						
Penetrant	oxygen	nitrogen	carbon dioxide	oxygen	nitrogen	carbon dioxide
Temperature (°C)	23					
PERMEABILITY (source document units)						
Gas Permeability ($cm^3/m^2 \cdot day \cdot bar$)	2600	700	15,000	1600	350	8000
PERMEABILITY (normalized units)						
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	263	70.9	1520	162	35.5	811

Table 57-02. Water Vapor Through BASF AG Styrolux SBS

Material Family	**STYRENE-BUTADIENE BLOCK COPOLYMER (SBS)**	
Material Supplier/Grade	**BASF AG STYROLUX 684 D**	**BASF AG STYROLUX 656 C**
Product Form	**FILM**	
Features		high flow
Reference Number	29	

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.1

TEST CONDITIONS

Penetrant	water vapor
Temperature (°C)	23

PERMEABILITY (source document units)

Vapor Transmission Rate ($g/m^2 \cdot day$)	13.8	11.3

PERMEABILITY (normalized units)

Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	1.38	1.13

Chapter 58

Polyvinyl Chloride (PVC)

Category: Vinyl

General Description: Polyvinyl Chloride is produced by the polymerization of the gas vinyl chloride. It is one of the world's most widely used plastics. PVC by itself is hard, brittle, and difficult to process. With the addition of plasticizers and other additives the compound becomes flexible and much more versatile. The wide application of PVC results from the material's versatility since it can be used as a rigid compound or blended with plasticizers to produce flexible grades.

Plastisols are the result of a special class of fine particle PVC resin (dispersion grade) being dispersed in liquid plasticisers. Organosols are the product of a plastisol and a volatile diluent or a solvent. Commercial PVC copolymers include grades copolymerized with vinyl acetate, vinylidene chloride, and maleate and fumarate esters.[1004]

Processing Methods: Extrusion and thermoforming.

Applications: Packaging is a major market for PVC. Rigid grades are blown into bottles and made into sheets for thermoforming boxes and blister packs. Flexible PVC compounds are used in food packaging applications because of their strength, transparency, processability, and low raw material cost.[2027] Major markets for PVC are in building/construction, packaging, consumer and institutional products, and electrical/electronic uses.[1004]

Permeability to Oxygen and Other Gases: PVC is valued for its permeability to vapor, preventing condensation.[1064] Although rigid PVC compounds provide very good oxygen impermeability because of a closely packed, semi-crystalline structure, flexible PVC does not exhibit sufficient barrier properties for many packaging applications. This limitation arises because the addition of plasticizers in flexible PVC compounds causes an increase in molecular chain mobility and intermolecular distances. The result is larger and more direct pathways for the diffusion of oxygen molecules and other gases.[2027]

Permeability to Water and Other Vapors: Flexible PVC is permeable to steam preventing condensation and allowing foods such as meat or cheese to breathe.[1064]

Permeability Data by Material Supplier Trade Name: See Tables 58-01 through 58-07 and Graphs 58-01 through 58-03.

Table 58-01. Oxygen and Carbon Dioxide Through Polyvinyl Chloride (PVC)

Material Family	POLYVINYL CHLORIDE (PVC)			
Reference Number	1005			
MATERIAL COMPOSITION				
Note	plasticized		rigid	
TEST CONDITIONS				
Penetrant	oxygen	carbon dioxide	oxygen	carbon dioxide
Temperature (°C)	23			
Relative Humidity (%)	50			
PERMEABILITY (source document units)				
Gas Permeability [mol/(m ·s ·Pa)]	6 – 400 x 10^{-17}	20 – 600 x 10^{-17}	1.0 – 4 x 10^{-17}	4 – 10 x 10^{-17}
PERMEABILITY (normalized units)				
Permeability Coefficient (cm^3 ·mm/m^2 ·day ·atm)	10.14 – 784	39.2 – 1176	1.96 – 7.84	7.84 – 19.6

Table 58-02. Water Vapor Through Polyvinyl Chloride (PVC)

Material	POLYVINYL CHLORIDE (PVC)	
Reference Number	1005	
MATERIAL COMPOSITION		
Note	plasticized	rigid
TEST CONDITIONS		
Penetrant	water vapor	
Temperature (°C)	23	
Relative Humidity (%)	100	
PERMEABILITY (source document units)		
Vapor Permeability [mol/(m ·s ·Pa)]	25 – 188 x 10^{-15}	12.5 – 188 x 10^{-15}
PERMEABILITY (normalized units)		
Vapor Transmission Rate (g ·mm/m^2 ·day)	4900 – 36,848	2450 – 36,848

Table 58-03. Oxygen, Carbon Dioxide, and Water Vapor Through Polyvinyl Chloride (PVC) Film

Material Family	**POLYVINYL CHLORIDE (PVC)**		
Product Form	**FILM**		
Reference Number	250		

MATERIAL COMPOSITION

Note	unplasticized		

TEST CONDITIONS

Penetrant	oxygen	carbon dioxide	water vapor
Temperature (°C)	24		38

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)			3
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	5 - 20	20 - 50	

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	2.0 - 7.9	7.9 - 19.7	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)			1.2

Table 58-04. Oxygen Permeability vs. Temperature Through Rigid Polyvinyl Chloride (PVC) Film

Material Family	**POLYVINYL CHLORIDE (PVC)**		
Product Form	**FILM**		
Reference Number	63		

TEST CONDITIONS

Penetrant	oxygen		
Temperature (°C)	20	23	35
Relative Humidity (%)	dry		

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	12.2	13.2	18.8
Gas Permeability ($cm^3 \cdot 20\ \mu/m^2 \cdot day \cdot atm$)	240	260	370

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	4.8	5.2	7.4

Table 58-05. Water Vapor Through Rigid Polyvinyl Chloride (PVC) Film

Material Family	POLYVINYL CHLORIDE (PVC)	
Reference Number	264	296

TEST CONDITIONS

Penetrant	water vapor	oxygen	water vapor
Temperature (°C)	40	22.8	37.8
Relative Humidity (%)	90	0	90
Test Method		ASTM D1434	ASTM F1249

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/ 100\ in^2 \cdot day \cdot bar$)		8	
Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	3		4.25
Vapor Transmission Rate ($g \cdot 25\ \mu/m^2 \cdot day$)	46.5		

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)		3.2	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	1.2		1.7

Table 58-06. Cyclohexanone, Chlorobenzene, Hexane, Butyl Alcohol, Trichloroethene, Methyl Salicylate, and Tetrahydrofuran Through Rigid Polyvinyl Chloride (PVC) Bottles

Material Family	POLYVINYL CHLORIDE (PVC)
Product Form	BOTTLES
Reference Number	293

TEST CONDITIONS

Penetrant	cyclohexanone	chlorobenzene	hexane	butyl alcohol	trichloroethene	methyl salicylate	tetrahydrofuran
Temperature (°C)	23						
Exposure Time (days)	180						

PERMEABILITY (source document units)

Penetrant Weight Loss (%)	failed	6.06	0.18	failed

Table 58-07. Ethyl Acetate, Isopropyl Acetate, Acetone, Butyl Acetate, Toluene, Xylene, Methyl Isobutyl Ketone, and Methyl Ethyl Ketone Through Rigid Polyvinyl Chloride Bottles

Material Family	**POLYVINYL CHLORIDE (PVC)**
Product Form	**BOTTLES**
Reference Number	293

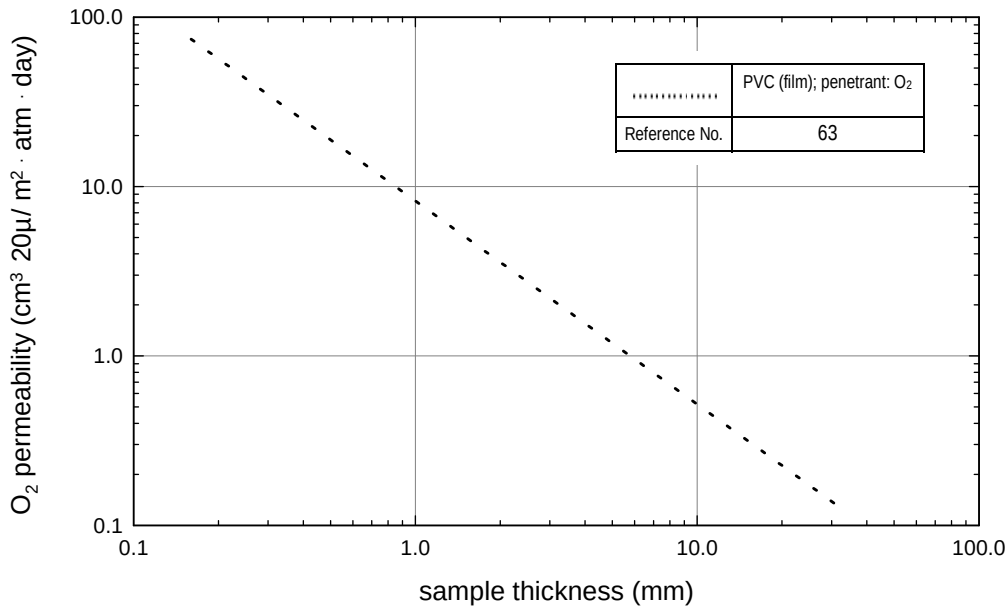
TEST CONDITIONS

Penetrant	ethyl acetate	isopropyl acetate	acetone	butyl acetate	toluene	xylene	methyl isobutyl ketone	methyl ethyl ketone
Temperature (°C)	23							
Exposure Time (days)	180							

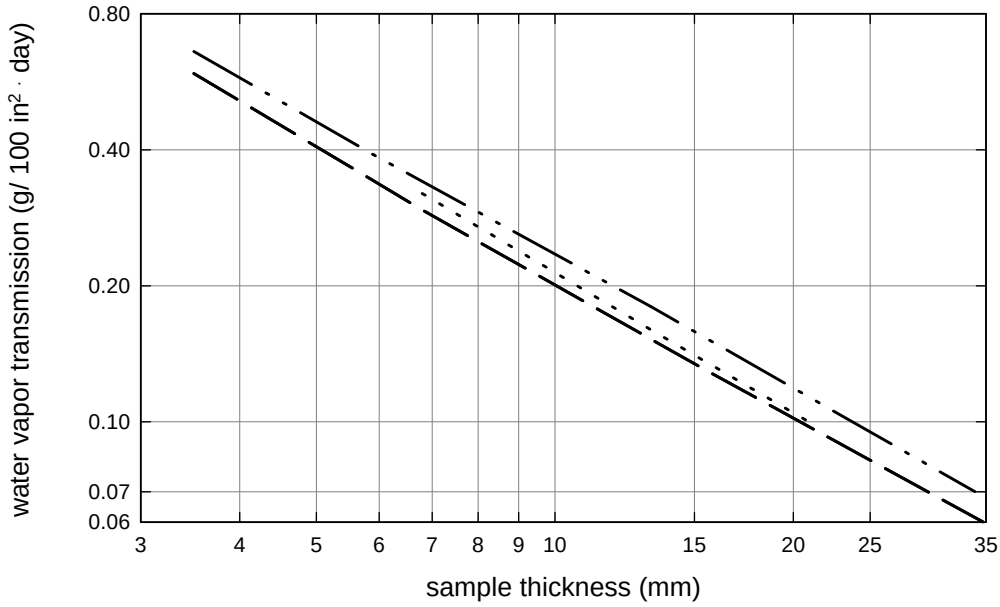
PERMEABILITY (source document units)

Penetrant Weight Loss (%)	failed

Graph 58-01. Oxygen permeability vs. thickness through polyvinyl chloride (PVC).

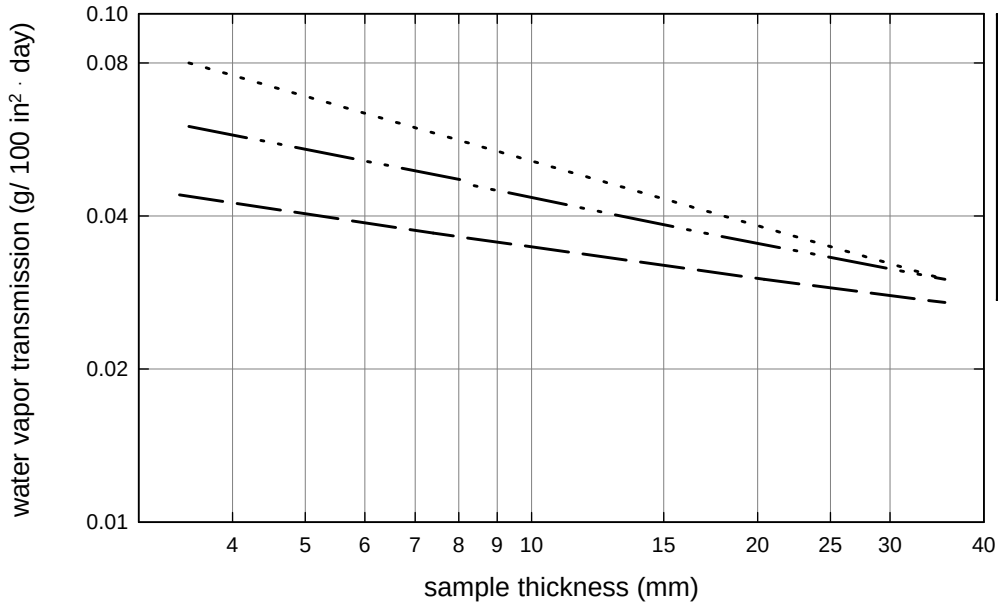


Graph 58-02. Water vapor permeability vs. thickness through polyvinyl chloride (PVC).



·····	American Mirrex 3002 PVC (pharmaceutical pack.; high impact, transparent, FDA DMF 952; film); 38.7°C; 90% RH
—·—·—	American Mirrex 1025 PVC (pharmaceutical pack.; high impact, transparent, FDA DMF 1060; film); 38.7°C; 90% RH
— — —	American Mirrex 3004 PVC (high impact, transparent, FDA grade, food grade; film); 38.7°C; 90% RH
— — —	American Mirrex 3007 PVC (high impact, transparent, FDA grade, food grade, non-contact heating; film); 38.7°C; 90% RH
Reference No.	286

Graph 58-03. Water vapor permeability vs. thickness through polyvinyl chloride (PVC).



·····	American Mirrex EZ23 PVC (transparent; 40 g/m² PVDC coated; film); 38.7°C; 90% RH
—·—·—	American Mirrex EZ23 PVC (transparent; 60 g/m² PVDC coated; film); 38.7°C; 90% RH
— — —	American Mirrex EZ23 PVC (transparent; 80 g/m² PVDC coated; film); 38.7°C; 90% RH
Reference No.	286

Chapter 59

Polyvinylidene Chloride (PVDC)

Category: Vinyl

General Description: Polyvinylidene Chloride (PVDC) resin is a copolymer of vinylidene chloride with vinyl chloride or other monomers.[1004] Dow Plastics vinyl chloride and vinylidene chloride, Saran, is usually supplied as a white, free flowing powder.[1045]

- *Saran MA Resins.* Vinylidene chloride and methyl acrylate monomer.[1045]
- *Saran-F Resins.* Solvent-soluable copolymers of vinylidene chloride with other monomers generally used for coating cellophane and polyester films.[1045]
- *Saran 100 HB.* Monolayer lamination film, displays an extraordinary barrier to oxygen, moisture, odors, flavors.[1045]

Compared to other Saran films, the oxygen barrier of Saran 100 HB is up to ten times higher, and the moisture barrier is up to five times higher. Saran 100 HB is a copolymer of vinylidene chloride and vinyl chloride. The copolymer has unusually dense and highly crystalline molecular chains which create a tortuous path for gas or water vapor molecules.[1045]

Processing Methods: Extrusion, co-extrusion, Saran F- lacquer solution films.

- *Multilayer Extrusion.* Saran resins are used in combination with a myriad of other polymers in flexible and rigid multilayer products. Multilayer cast and blown film co-extrusion processes for Saran can be used with all polyethylenes, polypropylenes, and nylons.[1051]

Applications: Monolayer films (Saran) for food wrap and medical packaging, co-extruded films and sheet structures as a barrier layer in medical, and packaging including fresh red meats, cheese, and sausages. Coatings are applied to containers to prevent gas transmission.[1045]

- *Rigid Packaging.* PVDC is used in combination with skin layers, materials such as polypropylene, high density polyethylene, polystyrene, that provide the necessary structural properties to the package.[1045]
- *Blister packs.* Coated with PVDC if barrier properties are required.[1045]

Permeability to Oxygen and Other Gases: PVDC materials exhibit exceptional barrier resistance to oxygen and carbon dioxide.[1004] Their low oxygen transmission rate is unaffected by moisture including high humidity conditions.[1045] Films providing barrier against gas (to prevent oxidation), odors, steam, oils or fats, are PVDC, either alone or in a thin layer together with other materials such as cellophane, aluminum, or paper.[1045]

Permeability to Water and Other Vapors: These materials exhibit exceptional barrier resistance to water and many organic solvents.[1004]

See *Collected Comparative Barrier Properties of Plastics and Elastomers* for more information.

Permeability Data by Material Supplier Trade Name: See Tables 59-01 through 59-20 and Graphs 59-01 through 59-06.

Table 59-01. Oxygen and Water Vapor Through Dow Chemical Saran 469, 516, and 525

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**		
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**		
Grade	**469**	**516**	**525**
Product Form	blown film		
Reference Number	1046		

MATERIAL COMPOSITION

Chemical Type	vinyl chloride and vinylidene chloride

TEST CONDITIONS

Penetrant	oxygen	water vapor	oxygen	water vapor	oxygen	water vapor
Temperature (°C)	23	38	23	38	23	38
Relative Humidity (%)	75	90	75	90	75	90
Test Method	ASTM D1434	ASTM E96	ASTM D1434	ASTM E96	ASTM D1434	ASTM E96

PERMEABILITY (source document units)

Gas Permeability (cc · mil/100 in² · day)	0.10		0.10		0.10	
Vapor Transmission Rate (g · mil/100 in² · day)		0.13		0.13		0.13

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.04		0.04		0.04	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.06		0.06		0.06

Table 59-02. Oxygen and Water Vapor Through Dow Chemical Saran MA 119, MA 123, and MA 134

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**					
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**					
Grade	**MA 119**		**MA 123**		**MA 134**	
Product Form	blown film					
Reference Number	1046					
MATERIAL COMPOSITION						
Chemical Type	vinyl chloride and vinylidene chloride					
TEST CONDITIONS						
Penetrant	oxygen	water vapor	oxygen	water vapor	oxygen	water vapor
Temperature (°C)	23	38	23	38	23	38
Relative Humidity (%)	75	90	75	90	75	90
Test Method	ASTM D1434	ASTM E96	ASTM D1434	ASTM E96	ASTM D1434	ASTM E96
PERMEABILITY (source document units)						
Gas Permeability (cc · mil/100 in² · day)	0.08		0.08		0.08	
Vapor Transmission Rate (g · mil/100 in² · day)		0.05		0.05		0.05
PERMEABILITY (normalized units)						
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.03		0.03		0.03	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.025		0.025		0.025

Table 59-03. Oxygen and Water Vapor Through Dow Chemical Saran 313 and 867

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**	
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**	
Grade	**313**	**867**
Product Form	blown film	
Reference Number	1046	

MATERIAL COMPOSITION

Chemical Type	vinyl chloride and vinylidene chloride	vinylidene chloride and methyl acrylate

TEST CONDITIONS

Penetrant	oxygen	water vapor	oxygen	water vapor
Temperature (°C)	23	38	23	38
Relative Humidity (%)	75	90	75	90
Test Method	ASTM D1434	ASTM E96	ASTM D1434	ASTM E96

PERMEABILITY (source document units)

Gas Permeability (cc · mil/100 in^2 · day)	1.2		1.1	
Vapor Transmission Rate (g · mil/100 in^2 · day)		0.27		0.20

PERMEABILITY (normalized units)

Permeability Coefficient (cm^3 · mm/m^2 · day · atm)	0.47		0.43	
Vapor Transmission Rate (g · mm/m^2 · day)		0.13		0.01

Table 59-04. Oxygen and Water Vapor Through Dow Chemical Saran F 239 and F 278 at Different Coating Weights

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**							
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**							
Grade	F 239				F 278			
Reference Number	1048							
MATERIAL COMPOSITION								
Chemical Type	vinylidene chloride, acrylonitrile, and methyl methacrylate				vinylidene chloride, methacrylonitrile, and methyl methacrylate			
MATERIAL CHARACTERISTICS								
Coating Weight (g/m^2)	2.2	4	2.2	4	2.2	4	2.2	4
Sample Thickness (mm) (calculated)	0.01375	0.025	0.01375	0.025	0.01375	0.025	0.01375	0.025
TEST CONDITIONS								
Penetrant	oxygen		water vapor		oxygen		water vapor	
Temperature (°C)	23		38		23		38	
Relative Humidity (%)	75		90		75		90	
Test Method	ASTM D1434							
PERMEABILITY (source document units)								
Gas Permeability ($cc/100\ in^2 \cdot day \cdot atm$)	0.61	0.35			0.35	0.20		
Vapor Transmission Rate ($g/m^2 \cdot day$)			12.0	5.8			6.6	3.2
($g/100\ in^2 \cdot day$)			0.76	0.38			0.43	0.21
PERMEABILITY (normalized units)								
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.013	0.0138			0.0075	0.0079		
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)			0.255	0.228			0.140	0.126

Table 59-05. Oxygen and Water Vapor Through Dow Chemical Saran F 310 and F 271 at Different Coating Weights

Material Family	POLYVINYLIDENE CHLORIDE (PVDC)							
Material Supplier/Trade Name	DOW CHEMICAL SARAN							
Grade	F 310				F 271			
Reference Number	1048							

MATERIAL COMPOSITION

Chemical Type	vinylidene chloride and acrylonitrile				vinylidene chloride, acrylonitrile, and methyl methacrylate			

MATERIAL CHARACTERISTICS

Coating Weight (g/m^2)	2.2	4	2.2	4	2.2	4	2.2	4

TEST CONDITIONS

Penetrant	oxygen		water vapor		oxygen		water vapor	
Temperature (°C)	23		38		23		38	
Relative Humidity (%)	75		90		75		90	
Test Method	ASTM D1434							

PERMEABILITY (source document units)

Gas Permeability ($cc/100\ in^2 \cdot day \cdot atm$)	1.5	0.83			0.70	0.35		
Vapor Transmission Rate ($g/m^2 \cdot day$)			43	20			9.30	4.65
($g/100\ in^2 \cdot day$)			2.8	1.3			0.60	0.30

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3\ mm/m^2 \cdot day \cdot atm$)	0.032	0.033			0.0149	0.0138		
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)			0.913	0.786			0.197	0.183

Table 59-06. Oxygen and Water Vapor Through Dow Chemical Saran F 279 and F 281 at Different Coating Weights

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**							
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**							
Grade	**F 279**				**F 281**			
Reference Number	1048							
MATERIAL COMPOSITION								
Chemical Type	vinylidene chloride, methacrylonitrile, and methyl methacrylate							
MATERIAL CHARACTERISTICS								
Coating Weight (g/m^2)	2.2	4	2.2	4	2.2	4	2.2	4
TEST CONDITIONS								
Penetrant	oxygen		water vapor		oxygen		water vapor	
Temperature (°C)	23		38		23		38	
Relative Humidity (%)	75		90		75		90	
Test Method	ASTM D1434							
PERMEABILITY (source document units)								
Gas Permeability ($cc/100\ in^2 \cdot day \cdot atm$)	0.35	0.20			0.28	0.15		
Vapor Transmission Rate ($g/m^2 \cdot day$)			6.6	3.2			6.3	3.0
($g/100\ in^2 \cdot day$)			0.43	0.21			0.41	0.20
PERMEABILITY (normalized units)								
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.0074	0.00786			0.0059	0.0059		
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)			0.140	0.126			0.134	0.118

Table 59-07. Oxygen Through Dow Chemical Saran F 310 Coatings on Polyethylene Coated Paper and Polyethylene Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**					
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**					
Grade	**F 310**					
Reference Number	1048					
MATERIAL COMPOSITION						
Chemical Type	vinylidene chloride and acrylonitrile					
MATERIAL CHARACTERISTICS						
Substrate	polyethylene coated paper				polyethylene film	
Substrate Thickness (mm)	0.025				0.0375	
Coating Thickness (Saran)	control	0.0015	0.002	0.00225	control	0.0025
TEST CONDITIONS						
Penetrant	oxygen					
Temperature (°C)	23					
Test Method	ASTM D1434					
PERMEABILITY (source document units)						
Gas Permeability (cc/100 in^2 · day · atm)	200	1.7	1.4	1.2	340	2.0
PERMEABILITY (normalized units)						
Permeability Coefficient (cm^3 · mm/m^2 · day · atm)	0.5	0.045	0.0378	0.327	12.75	0.08

Table 59-08. Nitrogen Through Dow Chemical Saran F 310 Coatings on Polyethylene Coated Paper and Polyethylene Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**					
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**					
Grade	**F 310**					
Reference Number	1048					
MATERIAL COMPOSITION						
Chemical Type	vinylidene chloride and acrylonitrile					
MATERIAL CHARACTERISTICS						
Substrate	polyethylene coated paper				polyethylene film	
Substrate Thickness (mm)	0.025				0.0375	
Coating Thickness (Saran)	control	0.0015	0.002	0.00225	control	0.0025
TEST CONDITIONS						
Penetrant	nitrogen					
Temperature (°C)	23					
Test Method	ASTM D1434					
PERMEABILITY (source document units)						
Gas Permeability (cc/100 in^2 · day · atm)	97	0.8	0.6	0.5	140	0.4
PERMEABILITY (normalized units)						
Permeability Coefficient (cm^3 · mm/m^2 · day · atm)	2.425	0.0212	0.0162	0.0136	5.25	0.016

Table 59-09. Carbon Dioxide Through Dow Chemical Saran F 310 Coatings on Polyethylene Coated Paper and Polyethylene Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**					
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**					
Grade	**F 310**					
Reference Number	1048					
MATERIAL COMPOSITION						
Chemical Type	vinylidene chloride and acrylonitrile					
MATERIAL CHARACTERISTICS						
Substrate	polyethylene coated paper				polyethylene film	
Substrate Thickness (mm)	0.025				0.0375	
Coating Thickness (Saran)	control	0.0015	0.002	0.00225	control	0.0025
TEST CONDITIONS						
Penetrant	carbon dioxide					
Temperature (°C)	23					
Test Method	ASTM D1434					
PERMEABILITY (source document units)						
Gas Permeability (cc/100 in^2 · day · atm)	740	4.7	4.4	4.0	900	5.0
PERMEABILITY (normalized units)						
Permeability Coefficient (cm^3 · mm/m^2 · day · atm)	18.5	0.125	0.1188	0.109	33.75	0.2

Table 59-10. Oxygen Through Dow Chemical Saran F 310 Coatings on Polypropylene and Polyester Films

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**
Grade	**F 310**
Reference Number	1048

MATERIAL COMPOSITION

Chemical Type	vinylidene chloride and acrylonitrile

MATERIAL CHARACTERISTICS

Substrate	polypropylene film	polyester film	
Substrate Thickness (mm)	0.015	0.0125	
Coating Thickness (Saran)	0.0025	control	0.0025

TEST CONDITIONS

Penetrant	oxygen
Temperature (°C)	23
Test Method	ASTM D1434

PERMEABILITY (source document units)

Gas Permeability ($cc/100\ in^2 \cdot day \cdot atm$)	0.6	9.7	0.3

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.0105	0.2425	0.0083

Table 59-11. Air Through Dow Chemical Saran F 310 Coatings on Polyester and Nylon Films

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**			
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**			
Grade	**F 310**			
Reference Number	1048			
MATERIAL COMPOSITION				
Chemical Type	vinylidene chloride and acrylonitrile			
MATERIAL CHARACTERISTICS				
Substrate	polyester film		nylon film	
Substrate Thickness (mm)	0.0125		0.025	
Coating Thickness (Saran)	control	0.0025	control	0.0025
TEST CONDITIONS				
Penetrant	air			
Temperature (°C)	23			
Test Method	ASTM D1434			
PERMEABILITY (source document units)				
Gas Permeability (cc/100 in^2 · day · atm)	2.1	0.07	10.8	0.5
PERMEABILITY (normalized units)				
Permeability Coefficient (cm^3 · mm/m^2 · day · atm)	0.026	0.00105	0.27	0.01375

Table 59-12. Various Gases Through Dow Chemical Saran F Resin Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**			
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**			
Grade	**F RESIN**			
Reference Number	1048			
MATERIAL COMPOSITION				
Chemical Type	vinylidene chloride and acrylonitrile			
MATERIAL CHARACTERISTICS				
Sample Thickness (mm)	0.025			
TEST CONDITIONS				
Penetrant	oxygen	nitrogen	carbon dioxide	air
Temperature (°C)	23			
Test Method	ASTM D1434			
PERMEABILITY (source document units)				
Gas Permeability (cc/100 in^2 · day · atm)	0.17	0.04	0.25	0.07
PERMEABILITY (normalized units)				
Permeability Coefficient (cm^3 · mm/m^2 · day · atm)	0.00425	0.001	0.00625	0.00175

Table 59-13. Water Vapor Through Dow Chemical Saran F 310 Polyethylene Coated Paper and Polyethylene Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**					
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**					
Grade	**F 310**					
Reference Number	1048					
MATERIAL COMPOSITION						
Chemical Type	vinylidene chloride and acrylonitrile					
MATERIAL CHARACTERISTICS						
Substrate	polyethylene coated paper				polyethylene film	
Substrate Thickness (mm)	0.025				0.0375	
Coating Thickness (Saran)	control	0.0015	0.002	0.00225	control	0.0025
TEST CONDITIONS						
Penetrant	water vapor					
Temperature (°C)	38					
Test Method	TAPPI T646					
PERMEABILITY (source document units)						
Vapor Transmission Rate (g/100 in^2 ·day)	1.2	0.9	0.8			
PERMEABILITY (normalized units)						
Vapor Transmission Rate (g ·mm/m^2 ·day)	0.03	0.024	0.022	0.03	0.32	

Table 59-14. Water Vapor Through Dow Chemical Saran F 310 Polypropylene, Polyester, and Nylon Films

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**					
Material Supplier/Trade Name	**DOW CHEMICAL SARAN**					
Grade	**F 310**					
Reference Number	1048					
MATERIAL COMPOSITION						
Chemical Type	vinylidene chloride and acrylonitrile					
MATERIAL CHARACTERISTICS						
Substrate	polypropylene film		polyester film		nylon film	
Substrate Thickness (mm)	0.015		0.0125		0.025	
Coating Thickness (Saran)	control	0.0025	control	0.0025	control	0.0025
TEST CONDITIONS						
Penetrant	water vapor					
Temperature (°C)	38					
Test Method	TAPPI T646					
PERMEABILITY (source document units)						
Vapor Transmission Rate ($g/100\ in^2 \cdot day$)	0.4	0.3	2.5	0.9	2.9	1.1
PERMEABILITY (normalized units)						
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.006	0.00525	0.03125	0.0135	0.0725	0.03

Table 59-15. Oxygen and Water Vapor Through Dow Chemical Saran 100 HB Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**
Material Supplier/Trade Name	**DOW CHEMICALSARAN**
Grade	**100 HB**
Reference Number	1086

MATERIAL COMPOSITION

Chemical Type	copolymer of vinylidene chloride and vinyl chloride

TEST CONDITIONS

Penetrant	oxygen	water vapor
Temperature (°C)	23	38
Relative Humidity (%)	75	90

PERMEABILITY (source document units)

Gas Permeability (cc ·mil/100 in^2 ·day ·atm)	0.08	
(cc ·mil/m^2 ·day ·atm)	0.005	
(g ·mil/100 in^2 ·day)		0.05
(g ·mil/m^2 ·day ·atm)		0.003

PERMEABILITY (normalized units)

Permeability Coefficient (cm^3 ·mm/m^2 ·day ·atm)	0.31	
Vapor Transmission Rate (g ·mm/m^2 ·day)		0.02

Table 59-16. Air Through Dow Chemical Saran 18, 18L, 19, 28, and 560 Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**				
Material Supplier/Trade Name	**DOW CHEMICAL SARAN WRAP**				
Grade	**18**	**18L**	**19**	**28**	**560**
Product Form	**MONOLAYER FILM**				**CO-EXTRUDED FILM**
Features	barrier properties, biaxially oriented, transparent	barrier properties, biaxially oriented, preshrunk, transparent	barrier properties, biaxially oriented, transparent		
Applications	chub packaging machines, laminations	laminations	chub packaging machines		unit packaging
Reference Number	256				

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.019	0.0254	0.152

TEST CONDITIONS

Penetrant	air
Temperature (°C)	23
Relative Humidity (%)	10
Test Method	ASTM D1434

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	0.36	0.48	0.36	0.5	0.08

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.14	0.19	0.14	0.2	0.03

Table 59-17. Oxygen Through Dow Chemical Saran 18, 18L, 19, 28, and 560 Film

Material Family	POLYVINYLIDENE CHLORIDE (PVDC)				
Material Supplier/Trade Name	DOW CHEMICAL SARAN WRAP				
Grade	**18**	**18L**	**19**	**28**	**560**
Product Form	MONOLAYER FILM				CO-EXTRUDED FILM
Features	barrier properties, biaxially oriented, transparent	barrier properties, biaxially oriented, preshrunk, transparent	barrier properties, biaxially oriented, transparent		
Applications	chub packaging machines, laminations	laminations	chub packaging machines		unit packaging
Reference Number	256				

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.019	0.0254	0.152

TEST CONDITIONS

Penetrant	oxygen
Temperature (°C)	23
Relative Humidity (%)	10
Test Method	ASTM D3985

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	1.2	1.6	1.2	1.8	0.25

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.47	0.63	0.47	0.71	0.1

Table 59-18. Carbon Dioxide Through Dow Chemical Saran 18, 18L, 19, 28, and 560 Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**				
Material Supplier/Trade Name	**DOW CHEMICAL SARAN WRAP**				
Grade	**18**	**18L**	**19**	**28**	**560**
Product Form	**MONOLAYER FILM**				**CO-EXTRUDED FILM**
Features	barrier properties, biaxially oriented, transparent	barrier properties, biaxially oriented, preshrunk, transparent	barrier properties, biaxially oriented, transparent		
Applications	chub packaging machines, laminations	laminations	chub packaging machines		unit packaging
Reference Number	256				

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.019	0.0254	0.152

TEST CONDITIONS

Penetrant	carbon dioxide
Temperature (°C)	23
Relative Humidity (%)	10
Test Method	ASTM D1434

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	5.4	7.2	5.4	8.0	1.2

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	2.1	2.8	2.1	3.2	0.47

Table 59-19. Nitrogen Through Dow Chemical Saran 18, 18L, 19, 28, and 560 Film

Material Family	POLYVINYLIDENE CHLORIDE (PVDC)				
Material Supplier/Trade Name	DOW CHEMICAL SARAN WRAP				
Grade	**18**	**18L**	**19**	**28**	**560**
Product Form	MONOLAYER FILM				CO-EXTRUDED FILM
Features	barrier properties, biaxially oriented, transparent	barrier properties, biaxially oriented, preshrunk, transparent	barrier properties, biaxially oriented, transparent		
Applications	chub packaging machines, laminations	laminations	chub packaging machines		unit packaging
Reference Number	256				

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.019	0.0254	0.152

TEST CONDITIONS

Penetrant	nitrogen
Temperature (°C)	23
Relative Humidity (%)	10
Test Method	ASTM D1434

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	0.18	0.24	0.18	0.3	0.04

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.07	0.09	0.07	0.12	0.02

Table 59-20. Water Vapor Through Dow Chemical Saran 18, 18L, 19, 28, and 560 Film

Material Family	**POLYVINYLIDENE CHLORIDE (PVDC)**				
Material Supplier/Trade Name	**DOW CHEMICAL SARAN WRAP**				
Grade	**18**	**18L**	**19**	**28**	**560**
Product Form	**MONOLAYER FILM**				**CO-EXTRUDED FILM**
Features	barrier properties, biaxially oriented, transparent	barrier properties, biaxially oriented, preshrunk, transparent	barrier properties, biaxially oriented, transparent		
Applications	chub packaging machines, laminations	laminations	chub packaging machines		unit packaging
Reference Number	256				

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.019	0.0254	0.152

TEST CONDITIONS

Penetrant	water vapor
Temperature (°C)	38
Relative Humidity (%)	90
Test Method	Permatran W

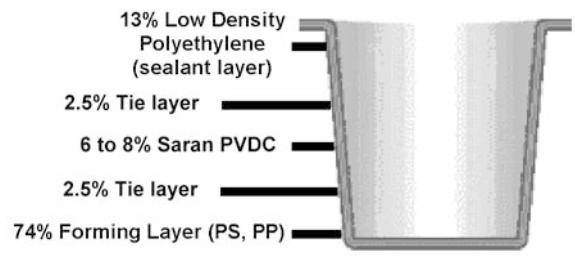
PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	0.27	0.3	0.25	0.4	0.04

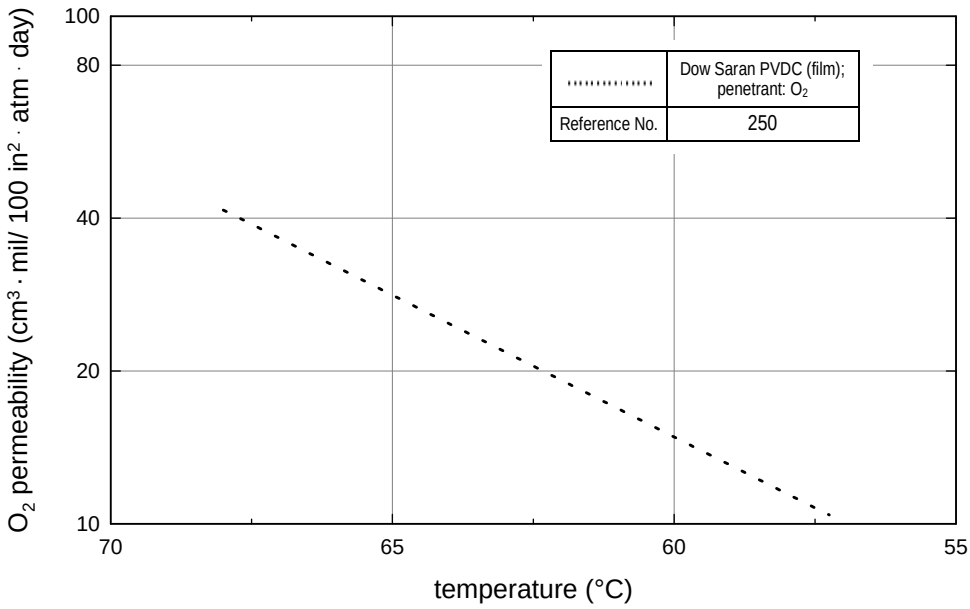
PERMEABILITY (normalized units)

Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.11	0.12	0.1	0.16	0.02

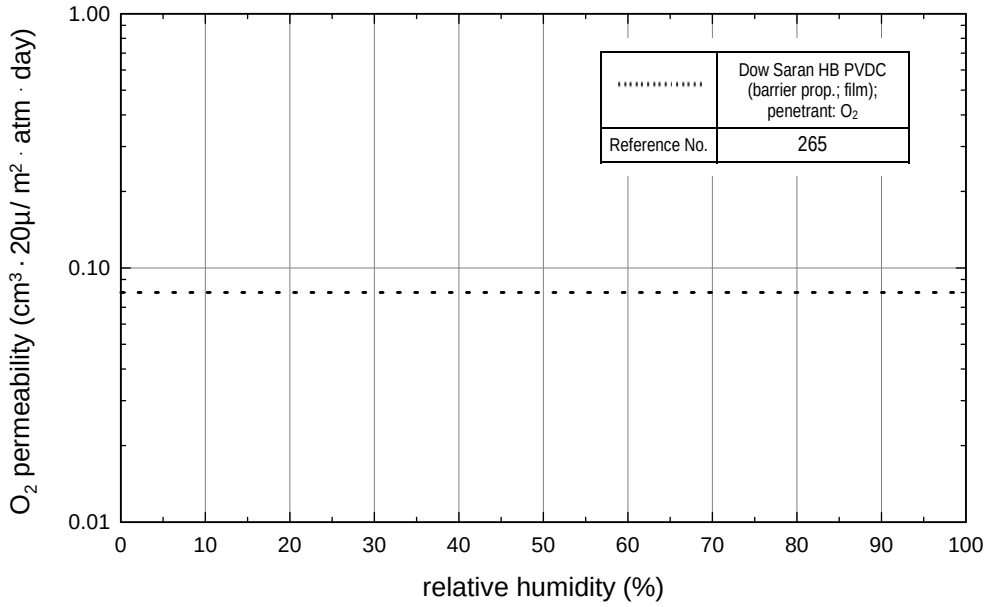
Graph 59-01. Multilayer configuration.[1051]



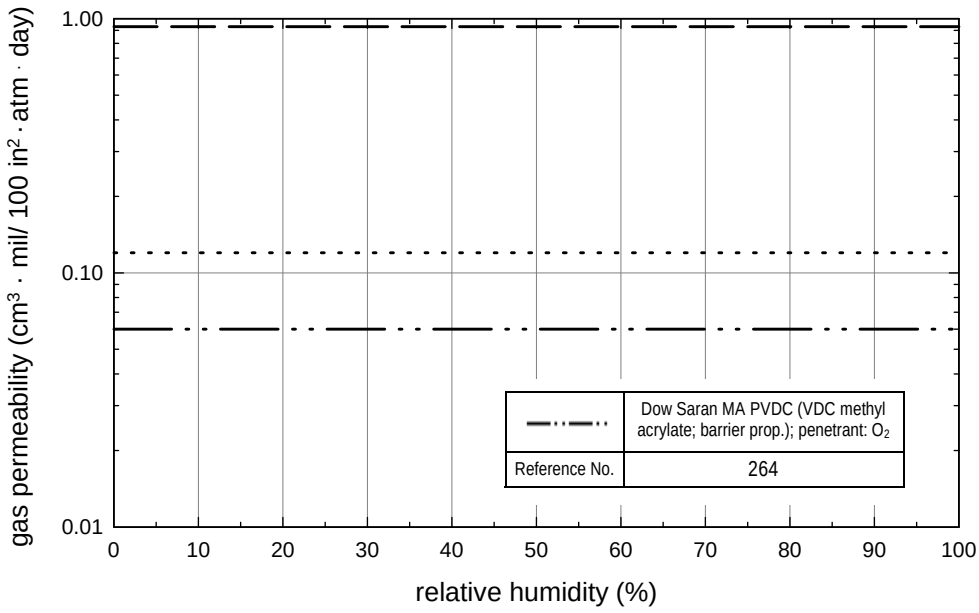
Graph 59-02. Oxygen permeability vs. temperature through Dow Chemical Saran film.



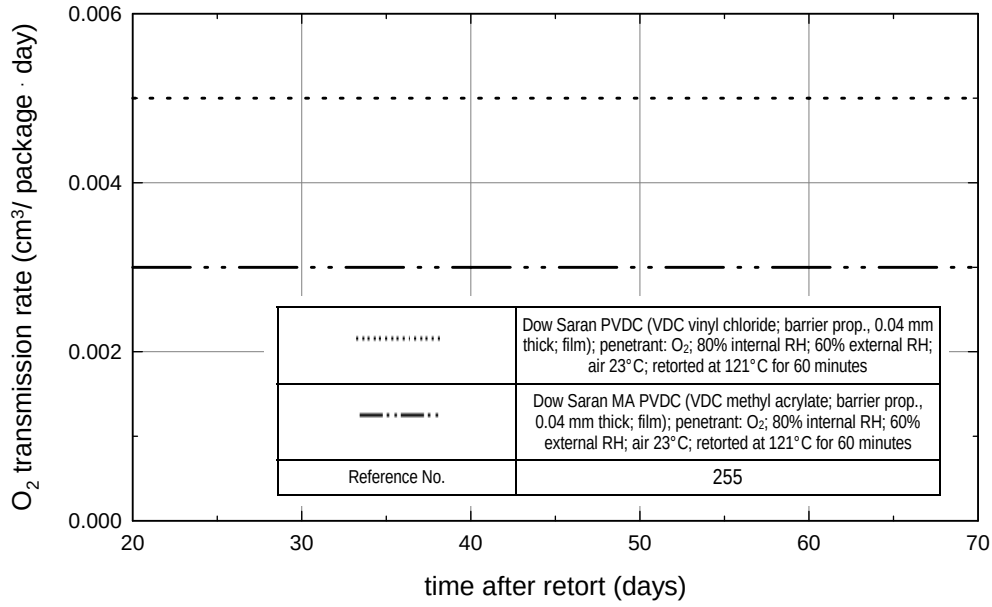
Graph 59-03. Oxygen permeability vs. relative humidity through Dow Chemical Saran film.



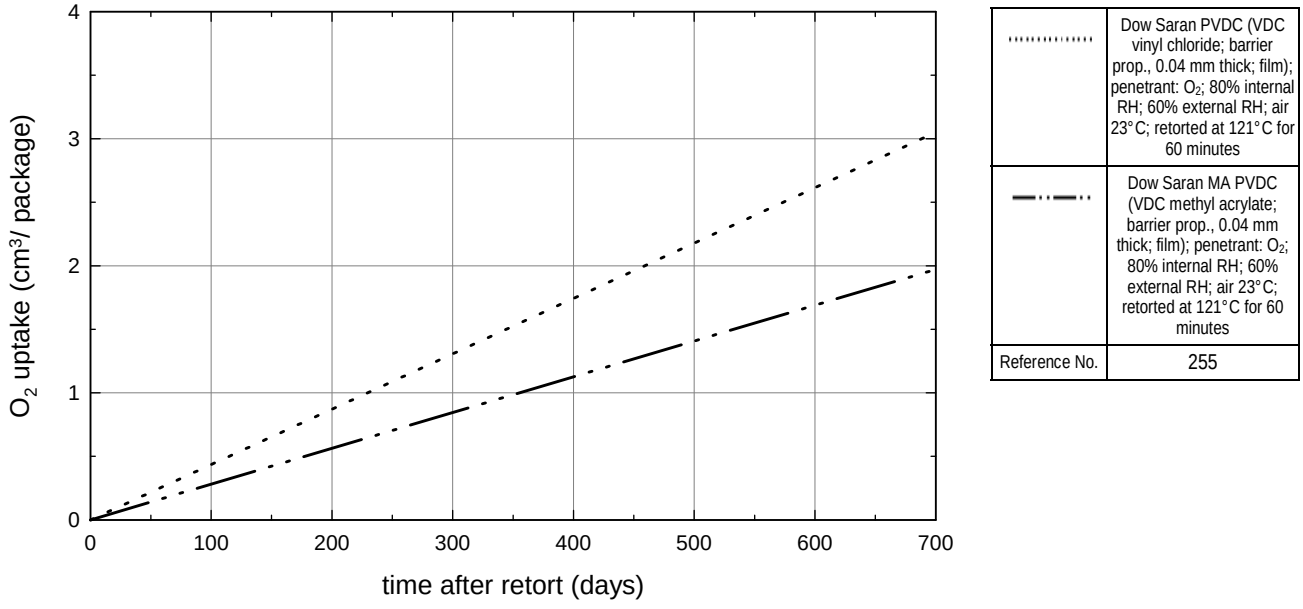
Graph 59-04. Carbon dioxide and oxygen permeability vs. relative humidity through Dow Chemical Saran MA film.



Graph 59-05. Oxygen transmission rate vs. time after retort through Dow Chemical Saran film.



Graph 59-06. Oxygen uptake vs. time after retort through Dow Chemical Saran film.



Polyvinylidene Chloride Coated Films (PVDC) Coated Polyester Films

General Description: PVDC resin is a copolymer of vinylidene chloride with vinyl chloride or other monomers,[1004] and is used as a coating over Mylar, a biaxially oriented, polyester thermoplastic film, Sclairfilm BL-1 LLDPE Film, and Dartek B-601 and B-602 Nylon 66 and PVDC coated nylon.

Processing Method: For use on form-fill-seal and overwrap equipment.

Applications: Coatings are applied to prevent gas transmission, and used both in unsupported form, or as a component of a lamination.

- *DuPont Teijin Films; Mylar M30 Coated.* Particularly well suited for the packaging of long shelf life or moisture- and oxygen-sensitive products.[1121]
- *DuPont Teijin Films; Mylar M34 Coated.* Designed to be reverse printed on the coated side, then combined with a sealant layer such as polyethylene or Surlyn® ionomer resin—locking in the PVDC coating.[1121]
- *DuPont Teijin Films; Mylar 50 M44E Coated.* Used as a substrate in combination with sealant webs, to produce a highly durable structure with excellent oxygen barrier.[1121]
- *DuPont Teijin Films; Mylar M45 Coated.* Designed to be combined with a sealant layer, and can be combined with other webs by adhesive or extrusion laminating.[1121]
- *DuPont Teijin Films; Mylar M45 MC2 Polyester Film.* Has a vacuum deposited layer of aluminum on one side and is overcoated on both sides with a heat sealable PVDC copolymer. The film can be used to package snacks, candy, nuts, pharmaceuticals, dry chemicals, and other materials that require protection from moisture, oxygen, and light.[1121]
- *DuPont Sclairfilm BL-1 LLDPE Film; Coated*. Suitable for meat, cheese, snacks, MAP/CAP and other applications requiring good barrier properties and excellent sealing characteristics.[1121]
- *DuPont Dartek B-601 and B-602 Nylon 6,6; Coated.* Specially formulated for use in high humidity applications. Used for any packaging or industrial end use requiring high barrier properties and can be easily thermoformed for assorted shapes and products such as meats and cheeses.[1121]

Permeability Data by Material Supplier Trade Name: See Tables 60-01 through 60-13 and Graph 60-01.

Table 60-01. DuPont Teijin Films Mylar M30 Polyester Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**					
Material Supplier/Trade Name	**DUPONT TEIJIN FILMS MYLAR® M30 POLYESTER FILM**					
Product Form	transparent polyester packaging film, solvent coated on both sides with PVDC					
Reference Number	1066					
MATERIAL CHARACTERISTICS						
Sample Thickness (mm)	0.14		0.21		0.25	
TEST CONDITIONS						
Penetrant	oxygen	water vapor	oxygen	water vapor	oxygen	water vapor
PERMEABILITY (source document units)						
Gas Permeability (cc/m² ·24 hr ·atm)	8		8		8	
(cc ·mm/m² ·24 hr ·atm)	0.1		0.2		0.2	
Vapor Transmission Rate (g/m² ·day)		8		8		8
(g ·mm/m² ·day)		0.11		0.17		0.2
Combined (cc ·mil/100 in² ·24 hr ·atm)	0.25	0.28	0.51	0.43	0.51	
PERMEABILITY (normalized units)						
Permeability Coefficient (cc ·mm/m² ·24 hr ·atm)	0.1		0.2		0.2	
Vapor Transmission Rate (g ·mm/m² ·day)		0.11		0.17		0.2

Table 60-02. DuPont Teijin Films Mylar M34 Polyester Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**
Material Supplier/Trade Name	**DUPONT TEIJIN FILMS MYLAR® M34 POLYESTER FILM**
Product Form	transparent polyester packaging film, solvent coated on one side with PVDC
Reference Number	1066

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.14	0.21	0.25

TEST CONDITIONS

Penetrant	oxygen	water vapor	oxygen	water vapor	oxygen	water vapor

PERMEABILITY (source document units)

Gas Permeability ($cc/m^2 \cdot 24\ hr \cdot atm$)	9		8		8	
($cc \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.1		0.2		0.2	
Vapor Transmission Rate ($g/m^2 \cdot day$)		9		8		8
($g \cdot mm/m^2 \cdot day$)		0.12		0.17		0.2
Combined ($cc \cdot mil/100\ in^2 \cdot 24\ hr \cdot atm$)	0.25	0.30	0.51	0.43	0.51	

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.1		0.2		0.2	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.12		0.17		0.2

Table 60-03. DuPont Teijin Films Mylar M44 and Mylar 50 M44E Polyester Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**			
Material Supplier/Trade Name	**DUPONT TEIJIN FILMS MYLAR® M44 AND 50 M44E POLYESTER FILM**			
Product Form	transparent polyester packaging film, one side coated with PVDC			
Reference Number	1066			
MATERIAL CHARACTERISTICS				
Sample Thickness (mm)	0.14		0.21	
TEST CONDITIONS				
Penetrant	oxygen	water vapor	oxygen	water vapor
Test Method	ASTM D3985	ASTM E96, E	ASTM D3985	ASTM E96, E
PERMEABILITY (source document units)				
Gas Permeability ($cc/m^2 \cdot 24\ hr \cdot atm$)	8		6	
($cc \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.1		0.1	
Vapor Transmission Rate ($g/m^2 \cdot day$)		8		8
($g \cdot mm/m^2 \cdot day$)		0.1		0.08
Combined ($mil/100\ in^2 \cdot 24\ hr \cdot atm$)	0.25			0.20
PERMEABILITY (normalized units)				
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot 24hr \cdot atm$)	0.1		0.1	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.1		0.08

Table 60-04. DuPont Teijin Films Mylar M45 Polyester Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**
Material Supplier/Trade Name	**DUPONT TEIJIN FILMS MYLAR M45 POLYESTER FILM**
Product Form	Transparent polyester packaging film, one side coated with PVDC
Reference Number	1066

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.14	0.21

TEST CONDITIONS

Penetrant	oxygen	water vapor	oxygen	water vapor
Test Method	ASTM D3985	ASTM E96	ASTM D3985	ASTM E96, E

PERMEABILITY (source document units)

Gas Permeability ($cc/m^2 \cdot 24\ hr \cdot atm$)	6		6	
($cc \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.078		0.11	
Vapor Transmission Rate ($g/m^2 \cdot day$)		6		6
($g \cdot mm/m^2 \cdot day$)		0.09		0.13
Combined ($cc \cdot mil/100\ in^2 \cdot 24\ hr \cdot atm$)	0.20	0.23	0.28	0.33

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.078		
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.09	

Table 60-05. DuPont Teijin Films Mylar 50 MC2 Polyester Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**			
Material Supplier/Trade Name	**DUPONT TEIJIN FILMS MYLAR® 50 MC2 POLYESTER FILM**			
Product Form	transparent polyester packaging film, one side coated with PVDC			
Reference Number	1066			
MATERIAL CHARACTERISTICS				
Sample Thickness (mm)	0.14		0.25	
TEST CONDITIONS				
Penetrant	oxygen	water vapor	oxygen	water vapor
Test Method	ASTM D3985	ASTM E96, E	ASTM D3985	ASTM E96, E
PERMEABILITY (source document units)				
Gas Permeability ($cc/m^2 \cdot 24\ hr \cdot atm$)	0.15		0.15	
($cc \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.0021		0.0038	
Vapor Transmission Rate ($g/m^2 \cdot day$)		0.6		0.6
($g \cdot mm/m^2 \cdot day$)		0.008		0.015
Combined ($cc \cdot mil/100\ in^2 \cdot 24\ hr \cdot atm$)	0.005	0.02	0.010	0.04
PERMEABILITY (normalized units)				
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.1		0.0038	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.08		0.015

Table 60-06. Oxygen and Water Vapor DuPont Sclairfilm® BL-1 LLDPE Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**
Material Supplier/Trade Name	**DUPONT SCLAIRFILM® BL-1 LLDPE FILM**
Product Form	one-side PVDC-coated LLDPE sealant film
Reference Number	1066

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.051

Test Conditions

Penetrant	oxygen	water vapor
Test Method	ASTM D3985	ASTM E96, E

PERMEABILITY (source document units)

Gas Permeability ($cc/m^2 \cdot 24\ hr \cdot atm$)	14	
($cc \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.72	
Vapor Transmission Rate ($g/m^2 \cdot day$)		6.2
($g \cdot mm/m^2 \cdot day$)		0.32
Combined ($cc \cdot mil/100\ in^2 \cdot 24\ hr \cdot atm$)	7.8	0.81

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.72	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.32

Table 60-07. Oxygen and Water Vapor DuPont Dartek B-601 and B-602 Nylon 6,6 Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**	
Material Supplier/Trade Name	**DUPONT DARTEK B-601 AND B-602 NYLON 6.6 FILM**	
Product Form	one-sided PVDC-coated transparent Nylon 6,6	
Reference Number	1066	
MATERIAL CHARACTERISTICS		
Sample Thickness (mm)	0.038	
TEST CONDITIONS		
Penetrant	oxygen	water vapor
Test Method	ASTM D3985	ASTM E96, E
PERMEABILITY (source document units)		
Gas Permeability ($cc/m^2 \cdot 24\ hr \cdot atm$)	7.7	
($cc \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.29	
Vapor Transmission Rate ($g/m^2 \cdot day$)		9
($g \cdot mm/m^2 \cdot day$)		0.34
Combined ($cc \cdot mil/100\ in^2 \cdot 24\ hr \cdot atm$)	0.74	0.86
PERMEABILITY (normalized units)		
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot 24\ hr \cdot atm$)	0.29	
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)		0.34

Table 60-08. Oxygen under Different Conditions Oriented Nylon Film, PVDC Coated

Material Family	**POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)**			
Material Supplier/Trade Name	**ORIENTED NYLON FILM**			
Reference Number	265			
TEST CONDITIONS				
Penetrant	oxygen			
Temperature (°C)	20			
Relative Humidity (%)	0	65	85	100
PERMEABILITY (source document units)				
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	0.7	0.35		
PERMEABILITY (normalized units)				
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.28	0.14		

Table 60-09. Organic Solvents Through Oriented Nylon Film, PVDC Coated

Material Family	POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)			
Material Supplier/Trade Name	ORIENTED NYLON FILM			
Reference Number	266			
MATERIAL CHARACTERISTICS				
Sample Thickness (mm)	0.015			
TEST CONDITIONS				
Penetrant	chloroform	xylene	methyl ethyl ketone	kerosene
Temperature (°C)	20			
Relative Humidity (%)	65			
PERMEABILITY (source document units)				
Vapor Transmission Rate ($g/100\ in^2 \cdot day$)	0.56	0.05	0.10	<0.003
PERMEABILITY (normalized units)				
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.13	0.01	0.02	<0.0007

Table 60-10. Oxygen and Water Vapor Through Oriented Nylon Film, PVDC Coated

Material Family	POLYVINYLIDENE CHLORIDE COATED FILMS (PVDC COATED)				
Material Supplier/Trade Name	ORIENTED NYLON FILM				
Reference Number	268				
MATERIAL CHARACTERISTICS					
Sample Thickness (mm)	0.017				
TEST CONDITIONS					
Penetrant	water vapor	oxygen			
Temperature (°C)	40	20			35
Relative Humidity (%)	90	65	85	100	0
Test Method	JIS Z0208	ASTM D3985			JIS Z1701
PERMEABILITY (source document units)					
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)		0.52			1.03
Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	1				
PERMEABILITY (normalized units)					
Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot 24\ hr \cdot atm$)		0.2			0.41
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.39				

Table 60-11. Water Vapor, Oxygen, Nitrogen, and Carbon Dioxide Through Honeywell Capran Nylon 6 Film, PVDC Coated

Material Family	**NYLON 6 (PVDC COATED)**
Material Supplier/Grade	**HONEYWELL CAPRAN**
Product Form	**FILM**
Reference Number	285

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.0254

MATERIAL COMPOSITION

Note	PVDC coated

TEST CONDITIONS

Penetrant	water vapor	oxygen	nitrogen	carbon dioxide
Temperature (°C)	37.8	23		
Relative Humidity (%)	90	0	0	0
Test Note		STP conditions		

PERMEABILITY (source document units)

Vapor Transmission Rate ($g/day \cdot 100\ in^2$)	0.2			
Gas Permeability ($cm^3/100\ in^2 \cdot day \cdot atm$)		0.5	0.1	1.4

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)		0.2	0.04	0.55
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	0.08			

Table 60-12. Oxygen vs. Relative Humidity Through Biaxially Oriented, PVDC Coated Polypropylene Film

Material Family	**POLYPROPYLENE (PVDC COATED)**			
Product Form	**FILM**			
Features	biaxially oriented; PVDC coated			
Reference Number	265			

TEST CONDITIONS

Penetrant	oxygen			
Temperature (°C)	20			
Relative Humidity (%)	65	85	100	0

PERMEABILITY (source document units)

Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)	0.55	1.1

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)	0.22	0.43

Table 60-13. Oxygen and Water Vapor Through Oriented, PVDC Coated and Uncoated Polypropylene Film

Material Family	**POLYPROPYLENE (PVDC COATED)**
Product Form	**FILM**
Features	oriented
Reference Number	268

MATERIAL CHARACTERISTICS

Sample Thickness (mm)	0.02	0.022	0.02	0.022	0.02	0.022	0.02	0.022	0.02	0.022

MATERIAL COMPOSITION

Note		PVDC coated		PVDC coated		PVDC coated		PVDC coated		PVDC coated

TEST CONDITIONS

Penetrant	water vapor	oxygen			
Temperature (°C)	40	35	20		
Relative Humidity (%)	90	0	65	85	100
Test Method	JIS Z0208	JIS Z1707	ASTM D3985		

PERMEABILITY (source document units)

Vapor Transmission Rate ($g \cdot mil/100\ in^2 \cdot day$)	<1								
Gas Permeability ($cm^3 \cdot mil/100\ in^2 \cdot day$)		226	1.23	135	0.65	135	0.65	135	0.65

PERMEABILITY (normalized units)

Permeability Coefficient ($cm^3 \cdot mm/m^2 \cdot day \cdot atm$)		89.0	0.48	53.2	0.26	53.2	0.26	53.2	0.26
Vapor Transmission Rate ($g \cdot mm/m^2 \cdot day$)	<0.39								

Graph 60-01. Oxygen vs. relative humidity through biaxially oriented, PVDC coated polypropylene film.