kuraray EVAL

Technical Bulletin No. 120

PROCESSING
EVAL™ RESINS

EVAL™ resins are easily processed on conventional plastic fabrication equipment and do not require special modifications like that for polyvinylidene chloride (PVDC) or polyvinyl chloride (PVC).

EVAL™ resins can be processed on commercially available equipment in the following processes:

- Monolayer film extrusion (blown or cast)
- Coextruded film extrusion (blown or cast)
- Sheet coextrusion
- Coextrusion blow molding
- Profile coextrusion
- Coextrusion coating
- Laminating
- Injection molding
- Powder coating

EVAL™ resins can be coextruded with all types of polyolefins, nylons, polystyrene, polyvinyl chloride and polyesters. Downstream processing such as thermoforming, vacuum forming and printing are easily accomplished with structures containing EVAL™ resins or EVAL™ films. Similar to other polymers, EVAL™ resins can be modified by excessive heat. Care should be taken to insure the use of proper extrusion conditions and equipment designs.

This bulletin discusses various equipment considerations and processing parameters for EVAL™ resins.

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THERMAL AND RHEOLOGICAL CHARACTERISTICS

Thermal Characteristics

Table 1 shows various thermal properties for EVAL™ resins. Figure 1 shows the relationship between ethylene content, melting point, crystallization temperature and glass transition point.

Table 1

Thermal Properties

Property	L101	F100	F101	H101	E105
Melt Index, g/10 min. @ 190°C, 2160 g	3.9*	0.8	1.6	1.6	5.5
Density, g/cc	1.20	1.19	1.19	1.17	1.14
Melting Point, °C	191	183	183	175	165
Crystallization Temp., °C	167	161	161	151	142
Glass Transition Point, °C	72	69	69	62	55

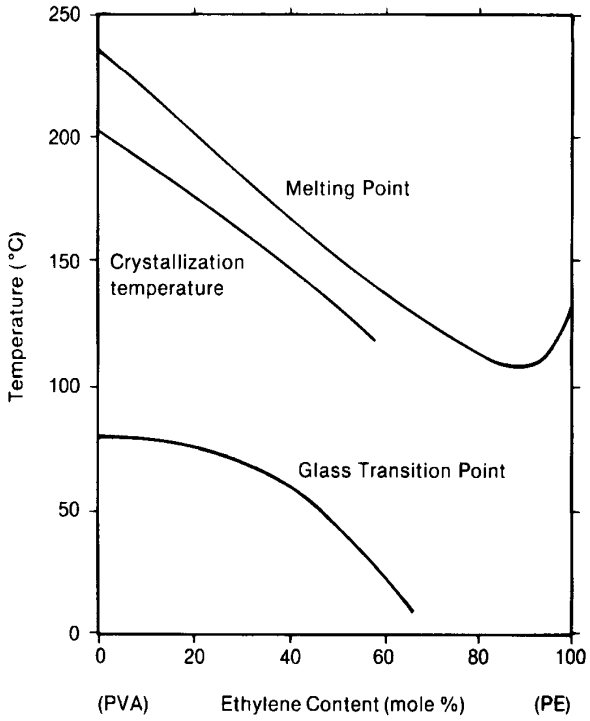
*melt index @210 °C

Figure 1

Melting Point, Crystallization Temperature and Glass Transition Point

vs.

Ethylene Content

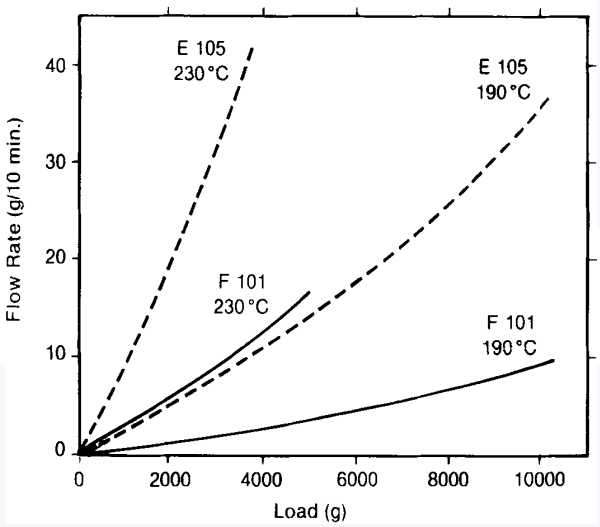


Rheological Characteristics

EVAL™ resins exhibit thermal stability properties similar to other resins used in many multi layer structures. Figure 2 shows the change in melt index under various loads for EVAL™ F101 and E105.

Figure 2

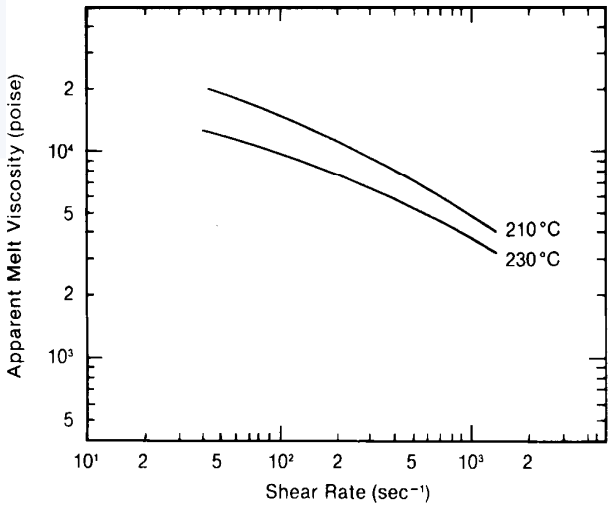
EVAL® Resins Flow Rate



To obtain a good, uniform multi layer structure, it is important to match viscosities of the various resins used as closely as possible. Whenever possible, the resin with the highest viscosity should be used as the middle layer of the multi layer structure. Figures 3 through 6 are melt viscosity curves for various EVAL™ resins.

MELT VISCOSITY CURVES

Figure 3
L101



MELT VISCOSITY CURVES

Figure 4
F101

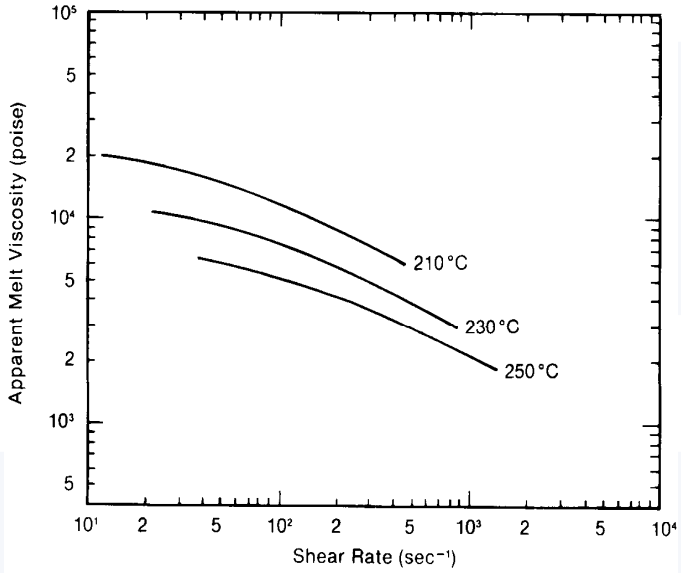
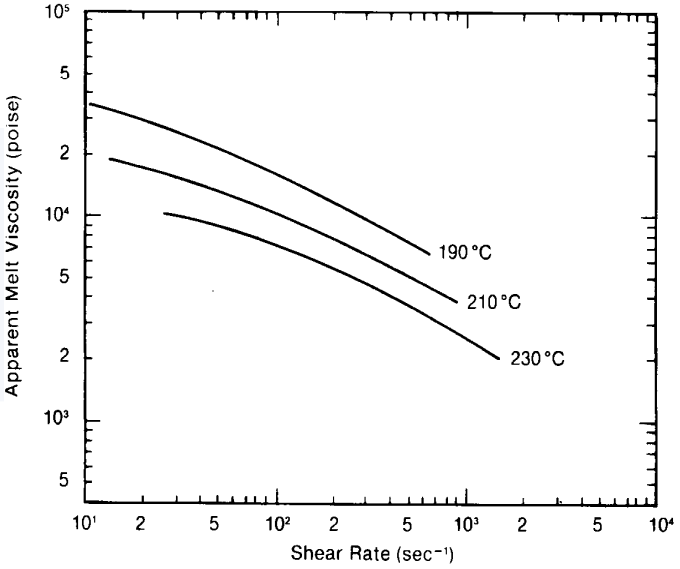
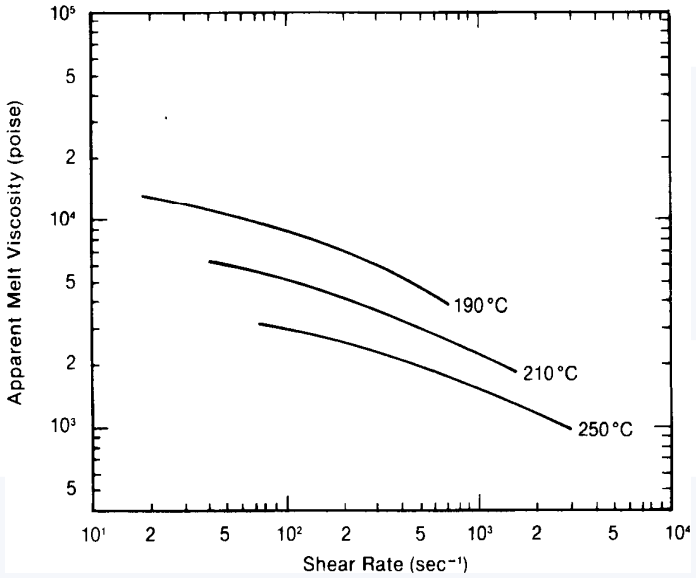


Figure 5
H101



MELT VISCOSITY CURVES

Figure 6
E105



EQUIPMENT CONSIDERATIONS

Extruders and Screws

EVAL™ resins are easily processed on conventional extruders without special modification. The following two types of screws can be used for processing EVAL™ resins.

Metering Screws

The recommended design for metering screws is as follows:

L / D Ratio	24 to 30	
Compression Ratio	2.6 to 3.6	
Zone Distribution	Feed	8 to 10 D
	Compression	8 to 10 D
	Metering	8 to 10 D

Barrier Screws

Barrier screws are the most popular type screws for processing EVAL™ resins because of their superior output capacity compared to metering screws. A barrier screw generally provides increased output over that of a metering screw without causing severe degradation of the polymer.

The recommended design for barrier screws is as follows:

L / D Ratio	24 to 30
Compression Ratio	2.5 to 3.0
Zone Distribution	
Feed	6 to 7.5 D (25% of screw length)
Transition and Melting	12 to 15 D (50% of screw length)
Metering	6 to 7.5 D (25% of screw length)

As with any polymer extrusion system, polymer retention in the extruder should be minimized to prevent polymer discoloration, gels, fish eyes and severe changes in melt viscosity. A general representation of metering and barrier screws is shown in Figure 7.

Mixing Zone

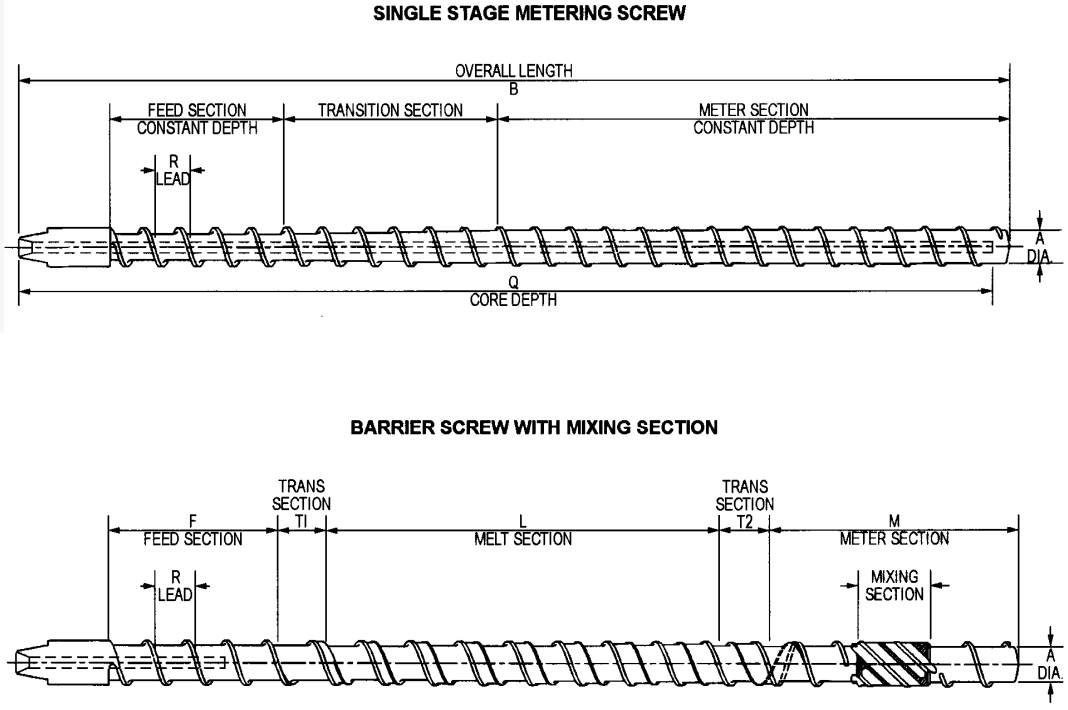
Screws with mixing heads may be used for extruding EVAL™ resin though this is generally not recommended. The use of a mixing head can restrict the melt flow of EVAL™ resins causing degradation of the polymer under prolonged heat and time.

Screw Coating

The screw should be chrome plated to help prevent the build up of degraded polymer on the screw.

Figure 7

Recommended Screws for EVAL® Resins



Extruder Output

Table 2 shows the output achieved using a metering screw for various EVAL™ resins.

Table 2

Output for Metering Screw

Extruder Size L / D	3.5” (90mm) 28:1			2.5” (60mm) 26:1		
Flight Screw Pitch	Full - flight Constant			Full - flight Constant		
Feed Zone Length, Channel Depth	8D 10.5mm			8D 7.5mm		
Compression Zone Length	1OD			9D		
Metering Zone Length, Channel Depth	1OD 3.5mm			9D 2.5mm		
Compression Ratio	3			3		
Screen Structure (mesh)	50/100/50/50			50/100/50/50		
EVAL™ Resin Grades	F 101	H 101	E 105	F 101	H 101	E 105
Extruder Temp. Profile, °F	365-430	355-430	350-420	355-430	350-430	340-410
Die Temperature, °F	420	410	385	420	410	385
Extruder Pressure, psi	~3000	~2100	~2100	~1000	~650	~650
Screw rpm	60	60	60	60	60	60
Motor Output	55KW	55KW	55KW	22KW	22KW	22KW
Output, Lb./hr.	265	265	265	110	110	110

Table 3 shows the output achieved using a barrier screw for EVAL™ F101 and E105.

Table 3

Output for Barrier Screw

Extruder Size	2.5” (60mm)	
L / D	24:1	
Feed Length	5D	
Solids Channel Depth Beginning	0.48	
Pre-melt Transition Length	1D	
Melting Length	10.5 D	
Post-melt Transition Length	1.4 D	
Metering Length	6.5 D	
Meter Depth	0.19	
EVAL™ Resin Grades	F101	E105
Extruder Temp. Profile, °F	350 – 395	345 – 380
Die Temperature, °F	400	400
Extruder Pressure, psi	~900	~2300
Screw rpm	75	75
Motor Output	24KW	19KW
Output, Lb./hr.	218	211

Dies

EVAL™ resins are suitable for use in either multi manifold or feedblock type die designs. Special die designs are not necessary, though care should be taken to streamline the flow channels as much as possible.

Blown film dies are typically a multi manifold design. Over the years as coextrusion blown film dies have increased in size the probability of gel generation in the EVOH layer has increased because of the complicated manifold design, which can result in increased dead spots and prolonged residence time in the die. The selection of a blown film die for EVOH structures is important to insure high quality barrier films. Blown film dies that minimize the amount of wetted surface area, minimize EVOH residence time and have no dead spots are most suitable for EVAL™ resins.

Melt Path

EVAL™ resins have an affinity to metal surfaces. If the EVOH extrusion system consists of concave or convex parts, acute angles, etc., EVAL™ resins can easily become restricted in these dead spot areas. Also, in a passage of fixed diameter, retention can occur on the wall if the diameter is too large for the flow. Retained resin exposed to heat for a prolonged period of time will degrade. The degraded resin will manifest itself as yellowish, brown or black gels.

The following points are recommended when designing an extrusion system for EVAL™ resins.

- Streamline the melt path through a passage that gradually becomes smaller from the barrel entry through the extruder and adapters to the die.
- Eliminate any concave, convex or acute angles in the melt path.
- Minimize the diameter of all adapters.
- Chrome plate all surfaces exposed to the EVAL™ melt path.

PROCESSING

Extrusion Temperatures

In processing any polymer, it is important that a homogeneous, completely melted and well-mixed mass at a uniform temperature is obtained. Also, the temperature must be well controlled to minimize thermal decomposition of the polymer being processed. EVAL™ resins are no exception to this rule.

Table 4 shows the recommended temperature set points for the extrusion of EVAL™ resins.

Table 4

Recommended Temperature Settings F
Degrees, °F

EVAL™ Grade	C_1	C_2	C_3	C_4	C_5	Adapter	Die
L	375	420	430	435	440	430	430
F	355	390	400	420	430	420	420
H	350	385	400	420	430	410	410
E	340	375	385	400	410	385	385

Table 5 provides the recommended maximum and minimum extrusion temperatures for EVAL™ resins.

Table 5

Maximum and Minimum Extrusion Temperatures
Degrees, °F

EVAL™ Grade	Maximum	Minimum	Melting Point
L	465	405	376
F	465	390	361
H	465	385	347
E	480	365	329

When extruder temperatures exceed the recommended maximum, the polymer may decompose, causing gels or voids in the extrudate. On the other hand, if the temperatures are too low, a partially melted, non-homogeneous melt may result. This will result in a poor extrudate appearance, erratic gauge control or unmelted polymer in the extrudate.

Coextrusion with polymers such as polyesters, nylons, polycarbonate or polypropylene may cause the EVAL™ resin melt to come in contact with melt streams that are hotter than the recommended maximum temperature. This contact is usually for a short period of time and adverse effects are not encountered.

Extruder Shutdown

The following procedure is recommended when the extrusion operation is stopped:

Shut Down Time	Procedure
Up to 30 minutes	Maintain temperature settings; screw rotation can be stopped
Up to 3 hours	Maintain temperature settings; operate screw slowly (drool)
More than 3 hours	Change to another polymer, preferably LDPE, and follow shut down procedures in accordance with commercial practices

Polymer Change Over

Table 6 lists the recommended purge sequences to be taken for changeovers involving EVAL™ resin.

Table 6

Change Over Sequence

Resin before change	Resin after change	Sequence
LLDPE, LDPE, HDPE PP, PS	EVAL™ Resin	Direct
EVAL™ Resin	LLDPE, LDPE, HDPE PP, PS	Direct
Nylon	EVAL™ Resin	Nylon==>LDPE==> EVAL™ Resin
EVAL™ Resin	Nylon	EVAL™ Resin==>LDPE==>Nylon

Screen Packs

A screen pack and breaker plate placed between the extruder and die is common practice in commercial polymer extrusion. The use of a screen pack is recommended for extrusion of EVAL ™ Resins. The screen pack mesh used should be based on commercial polymer extrusion knowledge and common sense. Examples of typical screen combinations are 50 / 100 / 50 / 50 or 50/ 100 / 150 / 100.

Adhesive Resins

Typical plastic packaging using EVAL™ resin is a combination of several different polymers. These multi layer structures consist of inexpensive structural materials such as polypropylene, LDPE, nylon, etc. to provide strength and other desirable properties and EVAL™ resins as a barrier to oxygen, aromas, offensive odors, harsh chemicals and other gases.

EVAL™ resins have very poor adhesion to most polymers. Specially designed adhesive resins, commonly called “tie resins”, are used to bond the EVAL™ resin layer to other polymer layers. Nylon is the exception to this rule. EVAL™ resins adhere well to nylon without the use of an adhesive resin.

The following adhesive resins may be used in multi layer structures using EVAL™ resin as the barrier layer:

Manufacturer	Trade name
Equistar Plastics	Plexar™
E. I. du Pont de Nemours Co.	Bynel™
Mitsui Petrochemical Industries, Ltd.	Admer™

Utilization of Regrind

One of the serious economic concerns in coextrusion is the loss of trim scrap or flash. Due to the use of vastly different and/or thermally sensitive polymers, many multi layer structures such as those containing PVDC are extremely difficult or impossible to reprocess.

EVAL™ resin containing multi layer structures can be readily recovered and reused. Regrind containing up to 15% EVAL™ resins can be used as a distinct layer in the multi layer structure.

If regrind containing EVAL™ resins is stored unused for a prolonged period of time, moisture may be absorbed into the regrind. The regrind then must be dried prior to extrusion. If possible, it is recommended that regrind containing EVAL™ resin be processed and reused as soon as possible to avoid potential processing difficulties.

Moisture Absorption

EVAL™ resins are inherently hydrophilic. Effort should be made to prevent moisture absorption into EVAL™ resins. The presence of moisture in the resin may cause processing difficulties such as foaming or voids in the extrudate. EVAL™ resins are shipped in moisture proof containers. Under normal humidity conditions, a container may be left opened while being used for periods up to 24 hours. If high humidity conditions exist and the container is left open for prolonged periods of time, moisture may be absorbed into the EVAL™ resin.

If moisture is absorbed into the EVAL™ resin, the resin can be dried in a desiccant type, circulating air dryer at temperatures of 195° to 230° F (90° to 110° C) for two to three hours. For more information on drying EVAL™ resin, please refer to Technical Bulletin No. 100.

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