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# **Markets and Applications for Metallocene LLDPE (mLLDPE) Resins That Process Like HP-LDPE/LLDPE Blends**

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**THE GLOBAL POLYETHYLENE MARKET**

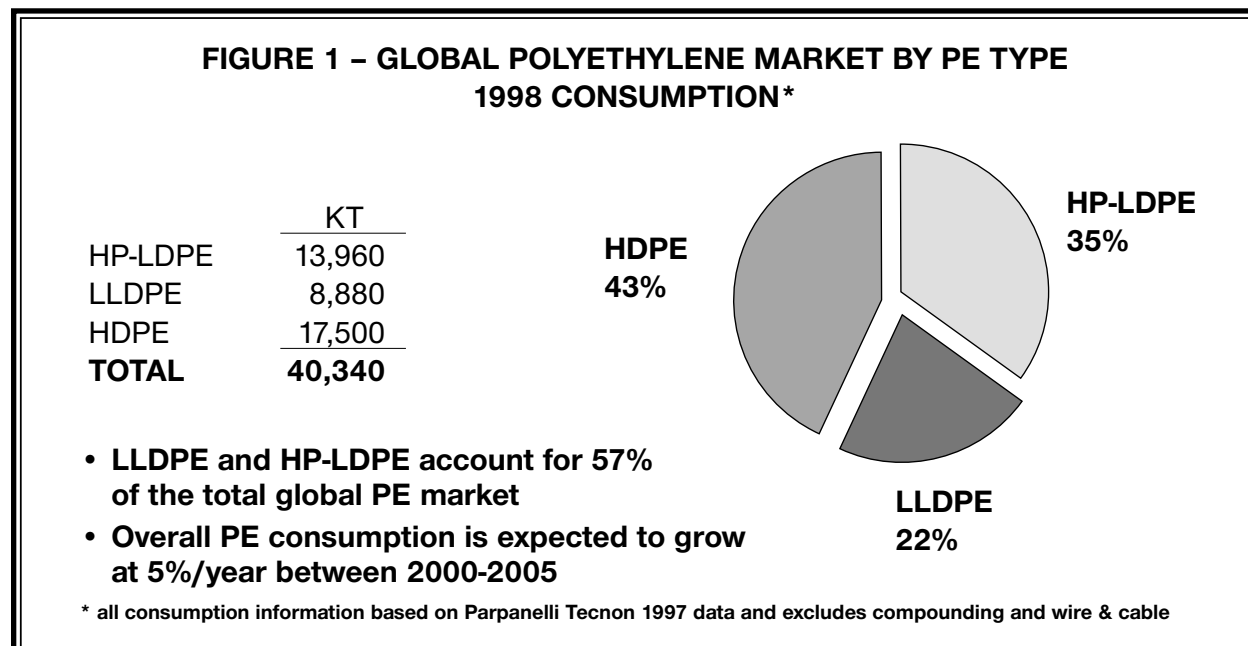
As the title suggests, the content of this paper will center on polyethylene markets and applications where both HP-LDPE and LLDPE are used today, especially in blends.

In order to best understand this area, we first need to look at the global polyethylene market, further break it down into the HP-LDPE and LLDPE segments and then their regional and application sub-segments. Based on this information, a clearer picture of where and how HP-LDPE and LLDPE resins are used will become apparent.

The polyethylene business in the early years was typically made up of low-density polyethylene (HP-LDPE) produced by high-pressure processes and high-density polyethylene

(HDPE, > 935 kg/m<sup>3</sup>) produced in a lower-pressure process. In the 1970's, the low-pressure gas-phase process was commercialized for production of both HDPE and a "new" polyethylene product at lower densities (< 935 kg/m<sup>3</sup>) termed LLDPE. This product, although at densities similar to HP-LDPE, had a structure that was quite different and, hence, processing and property differences as well.

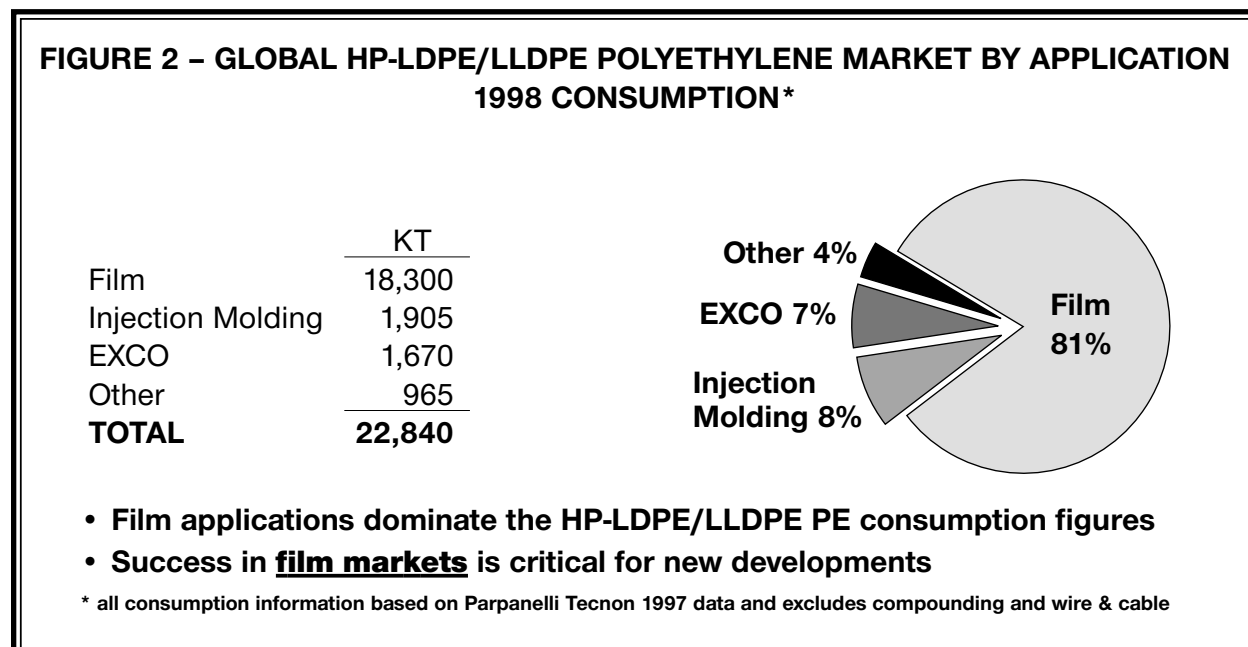
The chart in Figure 1 shows the 1998 global consumption for each of these three resin types. The combination of HP-LDPE and LLDPE (the resins that are the focus of this article) represents about 57% of the total worldwide polyethylene consumption.



### THE HP-LDPE AND LLDPE BLEND MARKET

Looking now specifically at the 1998 global consumption figures for both HP-LDPE and LLDPE broken down by application type (Figure 2), it is very apparent that film applications dominate at around 70% of the total consumption. This is a very important data point to realize, since when undertaking resin developments that will “play” in these HP-LDPE and LLDPE markets, **success in film is critical.**

Developments that are not first successful in the film area will not likely be able to gain enough momentum (volume) to be commercialized. Accordingly, development efforts will need to be initially centered on the film application segment. With a success here, development in other markets, such as molding and extrusion coating, can follow.



**MARKETS AND APPLICATIONS FOR METALLOCENE LLDPE (mLLDPE)**

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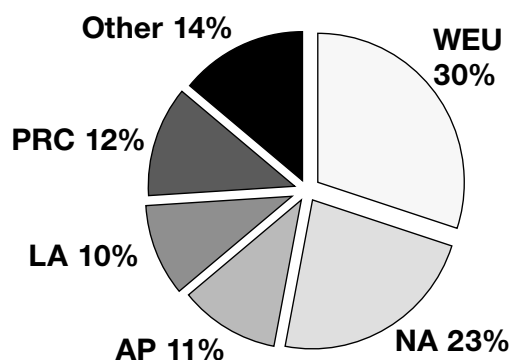
A further breakdown of the 1998 global consumption of HP-LDPE and LLDPE in film by geographic region is shown in Figure 3.

The film markets in Western Europe and North America are the largest at 30% and 23%, respectively. These markets are, as well, the most “mature” in their uses of both HP-LDPE and LLDPE and perhaps the best understood.

As such, in the commercialization of new resin developments, they will typically “lead” the other smaller and less mature regions of Latin America, Asia Pacific and China. Learnings from these mature film markets will certainly be applicable to the other geographic regions.

**FIGURE 3 – GLOBAL HP-LDPE/LLDPE FILM MARKET BY REGION  
1998 CONSUMPTION\***

	KT
Western Europe ( <b>WEU</b> )	5,390
North America ( <b>NA</b> )	4,230
Asia Pacific ( <b>AP</b> )	2,080
Latin America ( <b>LA</b> )	1,830
China ( <b>PRC</b> )	2,235
Other	2,535
<b>TOTAL</b>	<b>18,300</b>



- Western Europe and North America combined represent the largest share of the HP-LDPE/LLDPE film market and the best understood
- These regions will establish the technical direction and **lead** new developments with mLLDPE resins
- HP-LDPE/LLDPE film markets in Latin America, Asia Pacific and China are similar and will **follow** these developments

\* all consumption information based on Parpanelli Tecnon 1997 data and excludes compounding and wire & cable

Figure 4 focuses on the film market consumption of HP-LDPE and LLDPE in both Western Europe and North America, which, as previously noted, are the most mature regions. In Western Europe, HP-LDPE is dominant at about 68% of the film market. In North America the trend is the opposite, with LLDPE having the largest share of the film market at 58%. However, these data do not reveal a well-known fact: **HP-LDPE and LLDPE**

**resins for film applications are rarely used pure, and in fact are almost always used in blends with one another.** The reasons for this are diverse, but the fact remains.

The blends usually reside in one of two “domains”: the LLDPE-rich (LL-r) or HP-LDPE-rich (LD-r). An understanding of the film-blend domains is required for successful development of replacements for these blends.

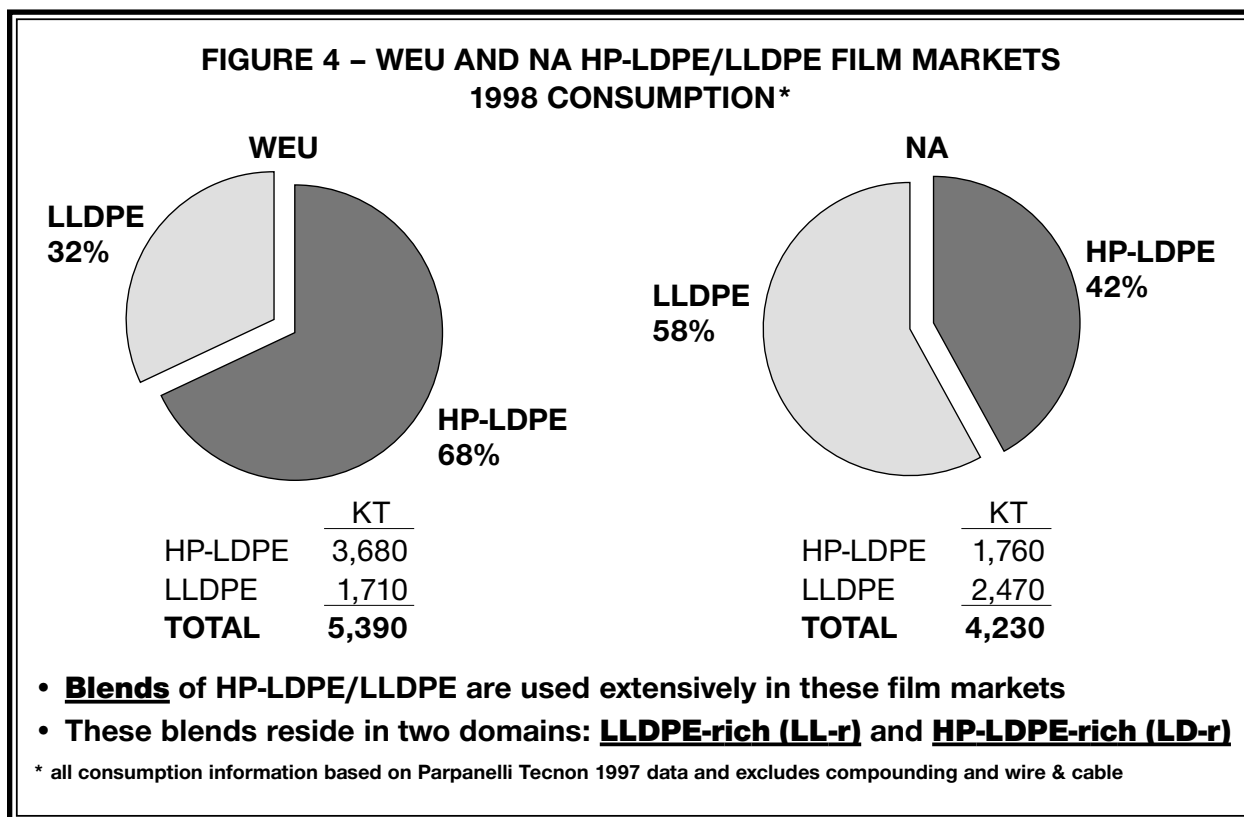


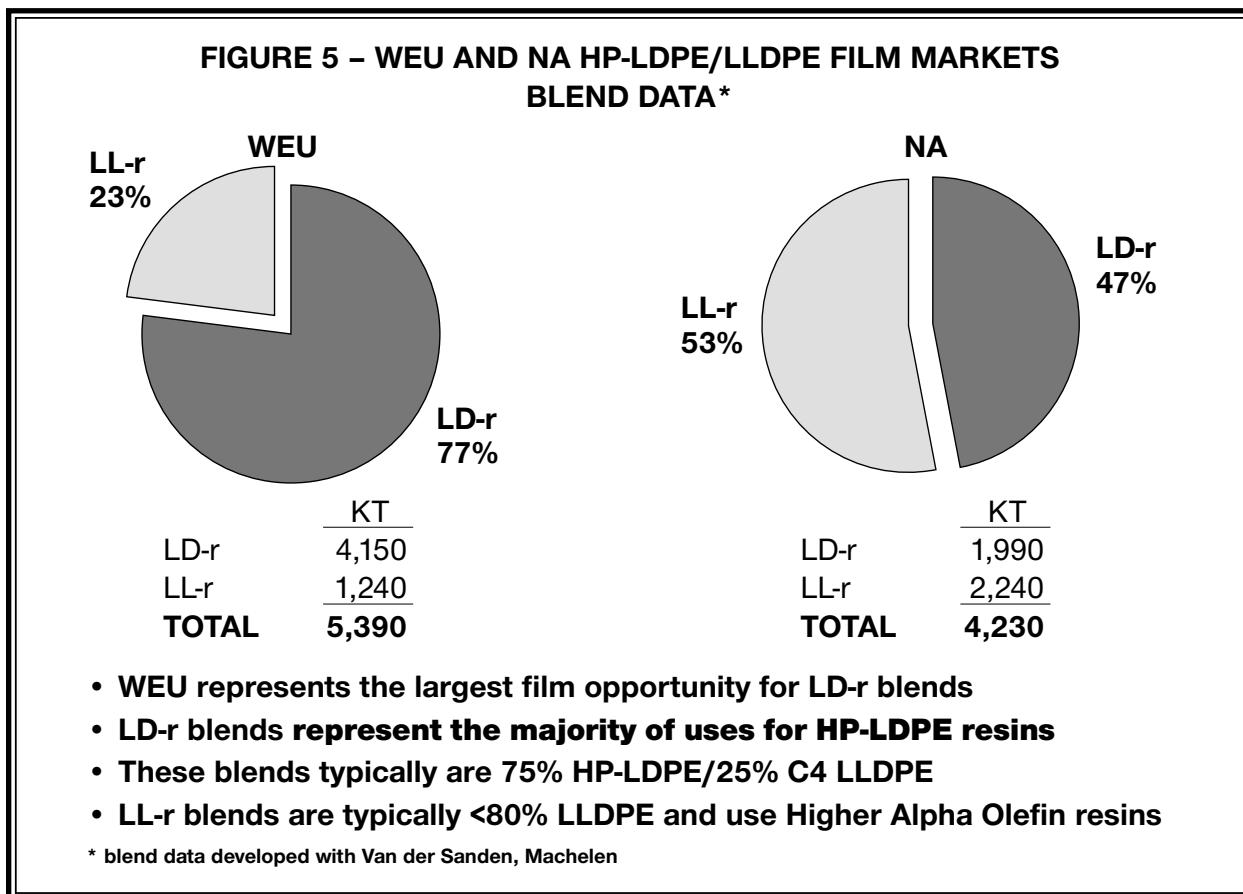
Figure 5 shows the division of film blend domains (LD-r and LL-r) in Western Europe and North America. Looking at LLDPE and HP-LDPE resin usage in individual film applications in the two geographic regions generated the data. The LD-r domain in Western Europe is by far the largest segment. As well, the combined use of LD-r blends in North America and Western Europe surpasses the combined North American and Western European use of LL-r blends (~6,000 KT versus ~3,500 KT).

These LD-r blends are typically made up of 75% HP-LDPE/25% C4 LLDPE.

**Most important of all, the LD-r blends represent by far the majority of the usage of HP-LDPE in film markets. Very few film markets are based on pure HP-LDPE.**

The LL-r blends are most common in the North American market and are usually comprised of > 80% Higher Alpha Olefin (HAO) LLDPE and < 20% HP-LDPE.

The rest of this article focuses on development of resins that replace blends used in film markets with mLLDPE.



### mLLDPE PRODUCT CONCEPT TO REPLACE HP-LDPE/LLDPE BLENDS

In order for a mLLDPE product to replace the largest blend segment (LD-r) in film applications, the following characteristics need to be met:

- (1) processing similar to LD-r blends and improved relative to pure ZN LLDPE on **all** extruder types
- (2) film end-use performance, which is superior to the incumbent LD-r blend-based films

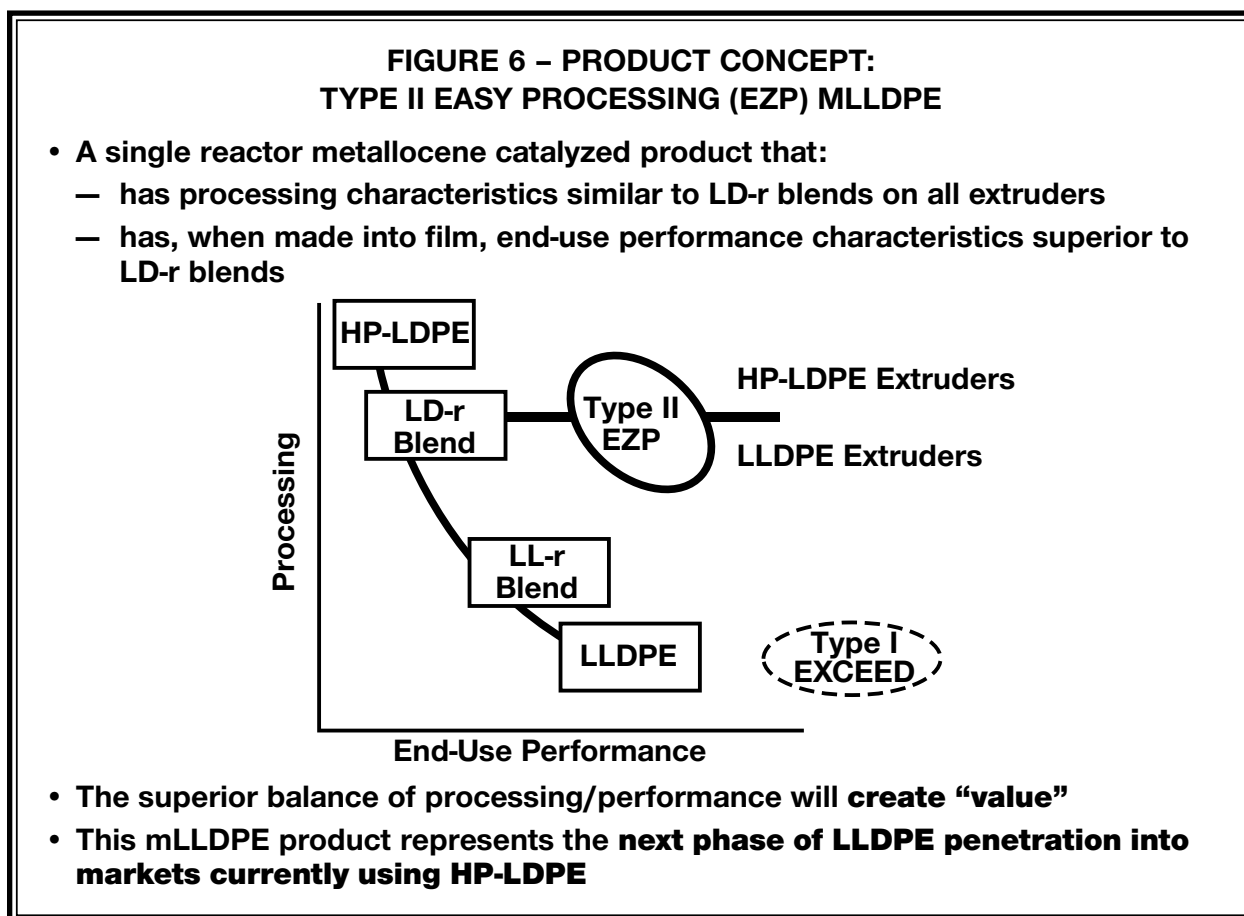
A pictorial view of this product concept is displayed in Figure 6.

**The product concept is referred to as Univation Technologies “TYPE II Easy Processing (EZP) mLLDPE.”**

(TYPE I mLLDPE has been commercial since September 1995 and is sold in the marketplace by Exxon Chemical as EXCEED™ resins.)

What the new EZP mLLDPE resin will offer is an **enhanced balance of processing and performance**. This is required in order that “value” may be created. This value needs to be shared along the value chain in order to entice resin suppliers, processors and converters to adopt the new resin. Value, usually manifesting itself as lower unit cost, will always be a prime driving force for change. No one in the value chain is likely to change without appropriate motivation.

**Note that replacement of these LD-r blends with EZP mLLDPE resin actually represents the next phase of penetration of HP-LDPE by LLDPE.**

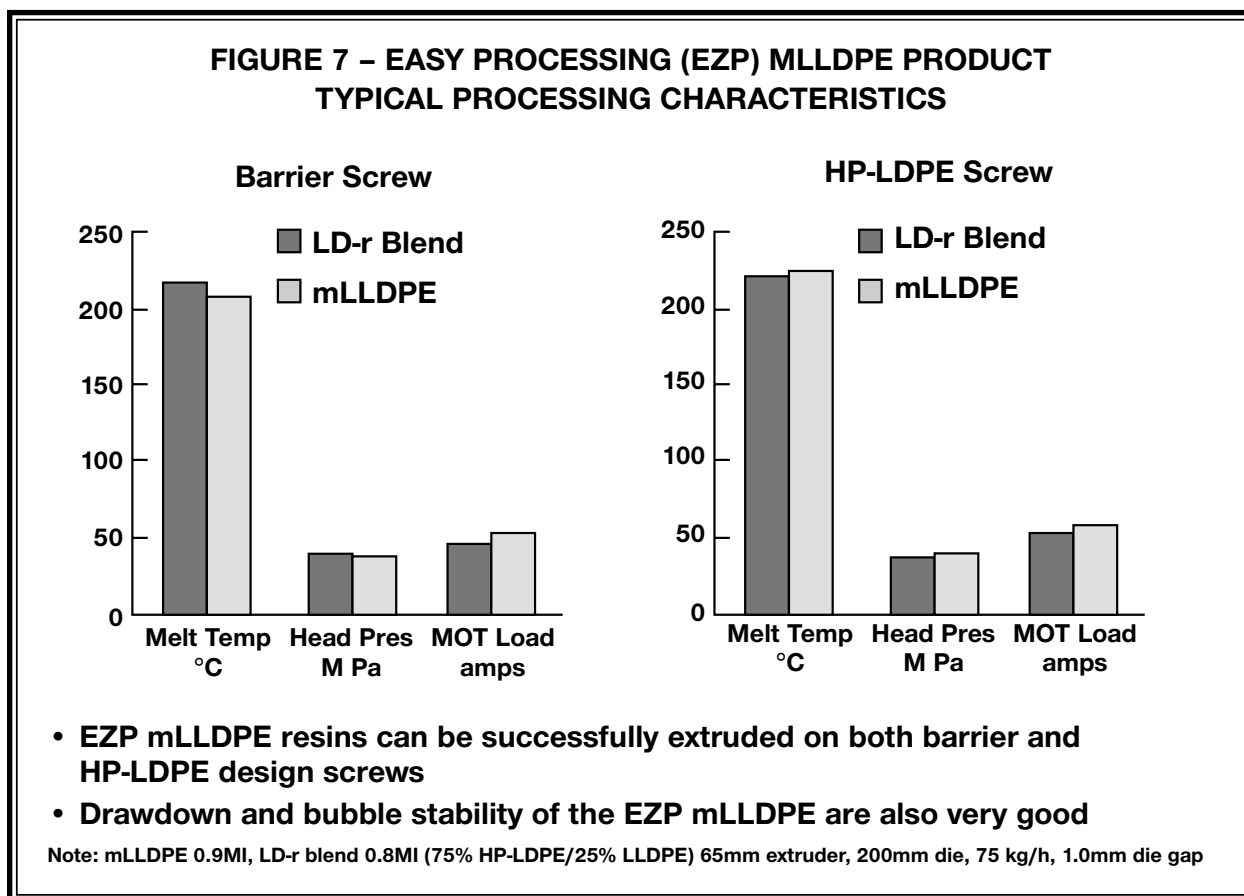


**EASY PROCESSING (EZP) mLLDPE  
PROCESSING DATA**

Figure 7 displays typical extrusion data for a 0.9MI EZP mLLDPE resin compared with a LD-r blend on two different extruders. One is equipped with a barrier screw, typical in LLDPE extrusion, the other with a screw designed for HP-LDPE. All other extruder hardware is equivalent.

The EZP mLLDPE resin offers melt-temperature, head-pressure and motor load-processing characteristics very similar to the LD-r blends. There are subtle differences in melt temperature

between the two extruder types, pointing to the fact that some slight adjustments to temperature profiles and air-ring settings will be required when switching to EZP mLLDPE resins. These adjustments will be dependent on the individual extruders themselves. New extrusion hardware, however, is not typically required to run EZP mLLDPE resins. As with all LLDPE resins, drawdown and bubble stability of the EZP mLLDPE resins is very good.

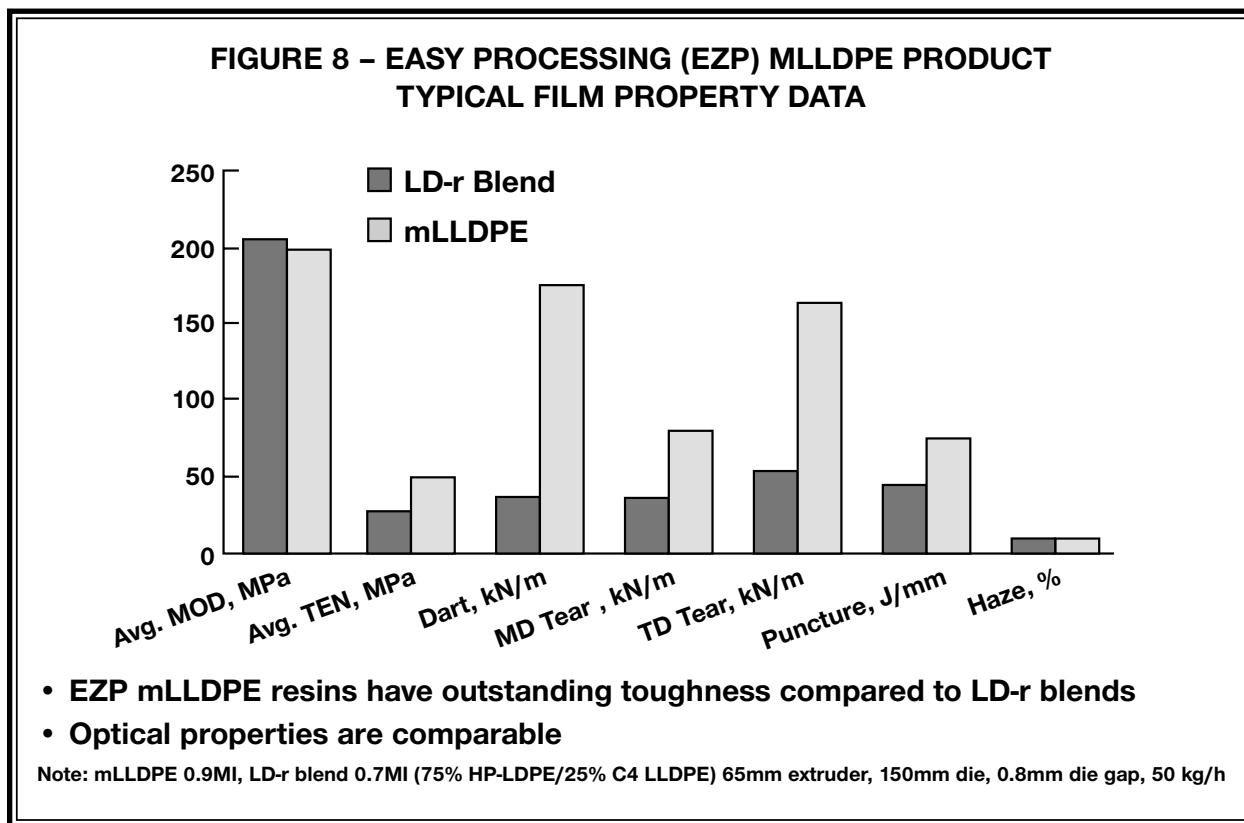


**EASY PROCESSING (EZP) mLLDPE FILM PROPERTY DATA**

Typical properties of films made from EZP mLLDPE resin are charted in Figure 8. When compared to films made with LD-r blends, film made from the EZP mLLDPE resin offers superior toughness (tensiles, puncture, impact, and tear) at the same stiffness (modulus). Optical properties are similar to the incumbent LD-r blend. An additional feature of these metallocene-based resins is that the film produced from them shows very little tendency to “block” or stick together, an important feature to film converters and users.

The processing and property data from Figures 7 and 8 demonstrate the EZP mLLDPE product capability to meet the product concept that was previously articulated: balance of processing and film performance is improved as compared to LD-r blends.

We now turn our attention to application examples of EZP mLLDPE resins.



**EASY PROCESSING (EZP) mLLDPE APPLICATION RESULTS**

The first film application example is for **heavy-duty sacks**, shown in Figure 9.

The extruder setup was typical of a LLDPE line and employed a dual lip air ring and Internal Bubble Cooling (IBC), often used by lines producing thicker films. The incumbent material was an 80% HP-LDPE/20% LLDPE blend.

The EZP mLLDPE resin provided outputs equivalent to the LD-r blend at 300 kg/h and in fact reached a winder limitation on the extruder (not reached by the LD-r blend) when downgauged films were made with the EZP mLLDPE resin.

Blocking performance of the EZP mLLDPE films was excellent, and no melt fracture (sharkskin) was apparent in the EZP mLLDPE films.

Film properties made with the EZP mLLDPE resin are compared to the film made from the LD-r blend in Figure 9.

The data are displayed via a “radar” chart. In the radar chart, all of the axes are set in such a way

so that values farther out on the axis are preferred, i.e., they are an improvement in the particular properties shown (all of the subsequent radar charts are set up in an identical fashion). As well, the incumbent (LD-r) film properties all have a value of “1” and the film properties of the EZP mLLDPE resin are represented as a ratio of their value to the value of the LD-r-based film.

For the heavy-duty sack trial, 160 micron film was produced and compared to the 220 micron film produced from the incumbent LD-r blend.

**The film made from the EZP mLLDPE resin offers significant potential value through downgauging without sacrificing end-use performance.**

**Remember that in addition, the EZP mLLDPE resin was processed at line speeds higher than the LD-r blend, thus providing more bags per unit time.**

Using the EZP mLLDPE completely replaces HP-LDPE in this application.

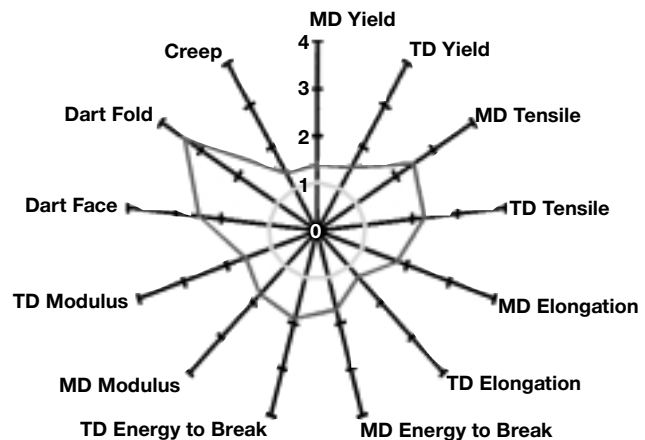
**FIGURE 9 – EASY PROCESSING (EZP) MLLDPE PRODUCT APPLICATION RESULTS: HEAVY-DUTY SACKS**

- **Extrusion Line**  
 Extruder: 120mm 25L/D  
 Die: 200mm  
 Die Gap: 1.2mm  
 Air Ring: Dual Lip, IBC  
 Screw: LL Design
- **Processing Results**  
 EZP mLLDPE output equivalent to LD-r blends at 300 kg/h  
 Film downgauged from 200 micron to 160 micron  
 Blocking performance significantly improved, trouble-free gusseting  
 No melt fracture (sharkskin)  
 Winder limitation reached with downgauged EZP mLLDPE

— LD-r 220 micron  
 — mLLDPE 160 micron

- **EZP mLLDPE resins provide films that offer significant potential value through downgauging without sacrificing end-use performance**
- **The use of pure mLLDPE resins represents a large penetration into HP-LDPE usage**

Note: LD-r 80% HP-LDPE/20% LLDPE



The next film application is for **pallet shrink film**, shown in Figure 10. In this case the extruder was more of a “combi” universal design used to process all types of low-density polyethylenes and their blends. The incumbent LD-r blend was 80% HP-LDPE/20% LLDPE, and in this example, the EZP mLLDPE resin was not used pure but in a blend with 20% HP-LDPE.

Output during the trial was about 10% higher for the EZP mLLDPE-rich resin when expressed in m/min. As was the case for the heavy-duty sack trial, no melt fracture was apparent in any of the films produced.

The film property data from the shrink film trial are shown in Figure 10.

**The EZP mLLDPE rich (mLLDPE-r) film was downgauged to 110 micron and displayed superior toughness along with equivalent optical and shrink properties relative to the LD-r blend film at 150 micron thickness.**

The film made from the EZP mLLDPE-rich blend was downgauged to offer value with no sacrifice in processing or performance. This trial with EZP mLLDPE resin demonstrates that in pallet shrink-film applications, using the EZP mLLDPE resin provides the capability to replace about 75% of HP-LDPE typically employed in pallet shrink films. (The amount of HP-LDPE used is lowered from 80% to 20%.)

**FIGURE 10 – EASY PROCESSING (EZP) MLLDPE PRODUCT APPLICATION RESULTS: PALLET SHRINK**

• **Extrusion Line**

Extruder: 120mm 25L/D  
 Die: 315mm  
 Die Gap: 0.8mm  
 Air Ring: Dual Lip, IBC  
 Screw: Universal Design

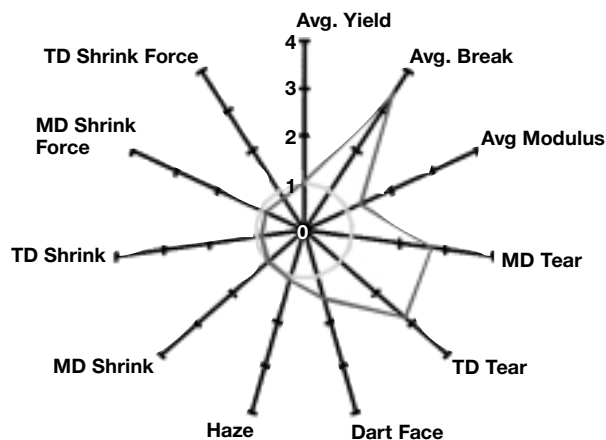
• **Processing Results**

Output (m/min) 10% higher using EZP mLLDPE resin compared to LD-r blend reference  
 Film downgauged from 150 micron to 110 micron  
 No melt fracture

— LD-r 150 micron  
 — mLLDPE-r 110 micron

- **Using EZP mLLDPE resin, HP-LDPE usage can be penetrated by 75% in pallet shrink film applications (80% down to 20%)**
- **The film using the EZP mLLDPE offers value through a downgauged product that is tougher, cleaner, and has similar shrink properties**

Note: LD-r: 80% HP-LDPE/20% LLDPE  
 mLLDPE-r: 80% mLLDPE/20% HP-LDPE



The final film application example is for **Form Fill Seal (FFS)**, which is most commonly used to package food as well as other items. See Figure 11.

The extruder for this trial was a HP-LDPE design with a single-lip air ring and a screw design optimized for HP-LDPE. The incumbent LD-r blend was 80% HP-LDPE/20% LLDPE. As was the case for the shrink-film trial, the EZP mLLDPE resin was not used neat but in a 10% blend with HP-LDPE.

Output of the EZP mLLDPE-rich blend was equivalent in kg/h to the LD-r blend. Drawdown

and reblock of the EZP mLLDPE rich blend were both superior to the incumbent LD-r blend.

The EZP mLLDPE-rich blend was extruded into 45-micron film and its properties are compared in Figure 11 to a 60-micron film of the LD-r blend. The downgauged film made from the EZP mLLDPE-rich blend offers superior toughness, improved convertibility and sealing performance (hot tack). Optical properties are equivalent.

**In this example, EZP mLLDPE replaces 85% of the HP-LDPE without sacrificing processing or end-use performance.**

**FIGURE 11 – EASY PROCESSING (EZP) MLLDPE PRODUCT APPLICATION RESULTS: FORM FILL SEAL**

• **Extrusion Line**

Extruder: 60mm 25L/D  
 Die: 200mm  
 Die Gap: 1.0mm  
 Air Ring: Single Lip  
 Screw: HP-LDPE Design

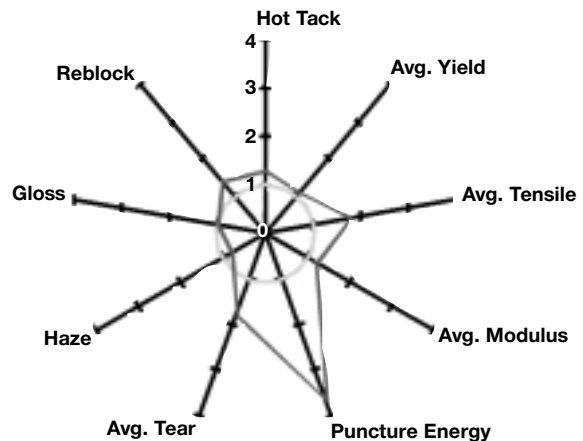
• **Processing Results**

Output (kg/h) of EZP mLLDPE resin equivalent to LD-r blend reference at 100 kg/h  
 Film downgauged from 60 micron to 45 micron  
 Drawdown and reblock much improved

— LD-r 60 micron  
 — mLLDPE 45 micron

- **Films extruded from EZP mLLDPE resin offer value through improved converting and downgauging**
- **Penetration of HP-LDPE by EZP mLLDPE is 85% in this application**

Note: LD-r: 80% HP-LDPE/20% LLDPE  
 mLLDPE-r: 90% mLLDPE/10% HP-LDPE



### **EASY PROCESSING (EZP) mLLDPE TECHNOLOGY COMMERCIALIZATION STATUS**

The commercialization of the EZP mLLDPE technology is well under way, as shown in Figure 12. Many tests have been successfully completed in commercial-scale, gas-phase reactors. Development activities over the last couple of years have focused on validating the product in the marketplace and optimizing the catalyst for use in UNIPOL® gas-phase reactors. Optimized catalyst for EZP mLLDPE will be produced at Univation's

world-scale catalyst manufacturing facility in Mont Belvieu, Texas. Catalyst cost is expected to be similar to current commercial gas-phase metallocene catalyst. The catalyst system will use the standard UNIPOL reactor and equipment system. It is expected the EZP mLLDPE technology will be fully commercialized and available for license in early 2000.

#### **FIGURE 12 – EASY PROCESSING (EZP) MLLDPE TECHNOLOGY COMMERCIALIZATION STATUS**

- **EZP mLLDPE catalyst is being manufactured at UNIVATION's world-scale catalyst plant in Mont Belvieu, Texas**
- **EZP mLLDPE catalyst cost is equivalent to commercial metallocene catalyst cost**
- **EZP mLLDPE catalyst uses standard UNIPOL® process and equipment with little or no modifications**
- **Seven runs in a semi-commercial 40KTa UNIPOL reactor in 1997 and 1998 to produce hopper cars of product for field testing**
- **Next steps include full commercialization in larger reactors with the technology available for licensing in 2000**

### **SUMMARY**

- Consumption of HP-LDPE in the film markets of North America and Western Europe is dominated by the use of HP-LDPE-rich (LD-r) blends
- An EZP mLLDPE resin is capable of offering a superior balance of processing and end-use performance relative to LD-r blends, which is necessary to create value
- EZP mLLDPE resins offer a route to penetrate the usage of HP-LDPE in film applications
- The technology to produce EZP mLLDPE resins is proceeding to commercialization rapidly and is expected to be available for licensing in early 2000





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