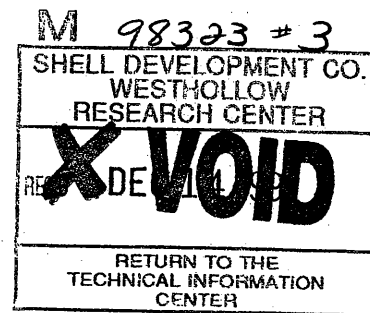


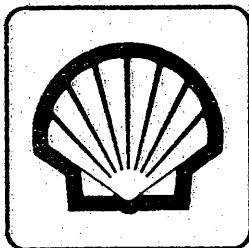
CARILON® Polymer Blends for Reduced Water Vapor Transmission Rate



E. R. George, L. E. Gerlowski

Technical Progress Report **WRC 271-91**
Project No. 62182

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CARILON® Polymer Blends for Reduced Water Vapor Transmission Rate

Technical Progress Report WRC 271-91

Project No. 62182

CARILON® Polymers – Barrier Packaging

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	Page
I. Introduction.....	2
II. Theory.....	3
III. Experimental.....	3
IV. Results and Discussion.....	5
A. CARILON Polymer - Liquid Crystal Polymer Blends.....	5
B. CARILON Polymer - Polypropylene Blends.....	6
C. CARILON Polymer - Polypropylene Blends Compatibilized with Kraton G1901X Rubber and Pebax Elastomer.....	8
D. CARILON Polymer - Nucrel Blends Compatibilized with Kraton 1901X Rubber and Pebax Elastomer.....	9
E. Binary and Ternary CARILON Polymer Blends with EPR and Polypropylene.....	10
F. CARILON Polymer - EPR Blends Compatibilized with Nucrel.....	11
V. Conclusion.....	11
VI. References.....	13
VII. Tables.....	14

ABSTRACT

The high water vapor transmission of CARILON® polymers severely limits the potential market size for use in food packaging. Except for this one disadvantage, it appears that CARILON polymers could successfully compete in this market with metal and glass. To overcome this deficiency, we report here the use of polymer blending techniques to disperse a second hydrophobic, immiscible polymer phase in a CARILON polymer matrix in order to reduce the water vapor transmission rate (WVTR) through CARILON polymer food containers. CARILON polymer blends with polypropylene and the appropriate compatibilizer reduced the WVTR to meet the requirements of most food packaging applications; however, these systems exhibit gross phase separation and unacceptable impact resistance and flexibility. CARILON polymer blends with ethylene-propylene rubbers (EPR) reduce the WVTR >60 percent while producing an aesthetically pleasing food package with a good balance of properties. Nucrel 535, an ethylene carboxylic acid copolymer was an effective compatibilizer for the CARILON polymer - EPR blends. Because of processing requirements of injection molding, low LVN CARILON polymer (<1.2 dl/g) is required for blending with these low viscosity EPR's for acceptable containers. Nucrel 535 can also be used as the hydrophobic dispersed phase to reduce WVTR. Pebax elastomer and Kraton 1901X rubber are effective compatibilizers for the Nucrel providing for a balance of WVTR and impact resistance.

Technical Progress Report WRC 271-91

**CARILON® POLYMER BLENDS FOR
REDUCED WATER VAPOR TRANSMISSION RATE**

by

E. R. George, L. E. Gerlowski

I. INTRODUCTION

The objective of our investigation was to produce a monolayer, retortable food container which exhibits a WVTR of less than 3% weight loss of water per year. CARILON polymers typically exhibit >10% weight loss of water per year unmodified. CARILON polymers are expected to have a sufficient oxygen barrier for most food packaging applications. Table I lists the permeation protection required for various foods and beverages for a one year shelf life at 25° C (1). Three percent water loss per year meets the requirements of most food packaging applications.

The use of coatings, surface treatments and blends with other polymers are the major techniques by which to alter the barrier properties of polymers (2). We have successfully applied PVDC coatings to CARILON polymers with good success (3), but the issue of recyclability and environmental issues with halogen containing materials may prevent this coating as a viable option. Other coatings will be investigated at WRC.

We have also fluorinated CARILON polymers with good success (4), but the process is uneconomical and again the issue of halogens may prevent this as a viable option. Sulfonation is another technique which might be explored for improved barrier properties. Of particular interest is a recent patent issued by British Petroleum covering the sulfonation of engineering polyketones (5).

We report here a summary of our work to reduce the WVTR in CARILON polymers via the blending of CARILON polymer with hydrophobic polymers. In this configuration, the CARILON polymer supplies the oxygen barrier and structural integrity of the container and the second immiscible polymer phase provides the water barrier. Machado (6) recently discovered a miscible blend of CARILON polymers with NOVOLAC resins for reduced WVTR. We will limit our report to two phase systems.

The polymer-polymer immiscible blend approach relies on several key technical features: first, the second hydrophobic phase must form high aspect ratio platelets to provide a long diffusional path for the water molecules through the container wall; second, there must be sufficient adhesion between the two phases in order for the container to retain physical properties; and, third, the container must maintain its shape and properties after food sterilization. The use of compatibilizers is one approach to promote interfacial adhesion. The problem which challenges the polymer physicist is that if adhesion is good between the two phases, then a fine dispersion of the minor phase in the matrix phase is the resultant morphology, a desired morphology for good impact resistance. Reduced water vapor transmission rate requires the second phase to have a platelet morphology. One must understand the effect of mixing and interfacial adhesion in

order to balance WVTR with physical properties.

We have reported CARILON polymer blend systems with liquid crystal polymers (7), polypropylene (8), Kraton® 1901X rubber and Nucrel® 535 (9), polypropylene and Kraton® 1901X rubber (10) and polypropylene and Pebax® (11). We report here a summary of these results and recent work using binary and ternary blends of CARILON polymer with polypropylene and ethylene propylene rubbers and binary and ternary blends of CARILON polymer with ethylene-propylene rubbers and Nucrel 535.

II. THEORY

We have measured the water transport properties of CARILON polymers and found that CARILON polymer has a high water solubility (S) and a low water diffusion coefficient (D). The overall permeability (P) is a function of the product of these two properties;

$$P = S \cdot D$$

The solubility is a thermodynamic property of the polymer. To change this property would require chemical backbone alterations or a miscible blend with another polymer. Modification of the backbone is not practical and miscible blends are rare; therefore, we examined means to affect the diffusion coefficient. By incorporating a second hydrophobic polymer phase increases the path length of the diffusing water molecules.

For miscible polymer pairs the permeability often follows the empirical relationship (12).

$$\ln P = V_1 \ln P_1 + V_2 \ln P_2$$

where P, P₁ and P₂ are the permeability of the blend, neat component 1 and neat component 2, respectively. V₁ and V₂ are the volume fraction of components one and two, respectively. Blends of CARILON polymers with LCP's appear to follow this relationship (7).

III. EXPERIMENTAL

A. COMPOUNDING

All compounding was performed on our Haake 30 mm corotating twin screw extruder operated at melt temperatures of 240°C. Most blends were compounded and then injection molded. For some of the polypropylene blends with Kraton 1901X rubber and Pebax respectively, masterbatches of the PP-compatibilizer pairs were compounded then tumble blended into neat polymer before

molding. The LCP blends were compounded at a melt temperature of 300° C.

B. INJECTION MOLDING

Physical properties were measured on family test specimens molded on our 2.5 ounce Arburg injection molder with zone settings:

<u>Zone 1</u>	<u>Zone 2</u>	<u>Zone 3</u>	<u>Nozzle</u>
250° C	255° C	260° C	265° C

All samples were tested dry as molded. WVTR measurements are reported as percent weight loss of water per year measured in a Mocon Permaton W1 at 100° F and 90% RH, in 25 mil double seam sealed lunch buckets. All samples were injection molded on our 80 ton, 8.0 ounce Krause-Maffei at similar zone settings to the Arburg machine. The mold temperature was 200° F.

C. CARILON POLYMER - LIQUID CRYSTAL POLYMER BLENDS

Vectra® A900, a liquid crystal copolyester from Celanese, was blended with CARILON polymer 88/008 (220° C MP, 1.8 LVN) at 1, 5 and 20 weight percent.

D. CARILON POLYMER - POLYPROPYLENE BLENDS

Polypropylene PP WRS5-907, a 20 melt flow, cracked PP was blended with CARILON polymer 89/052 (220° C MP, 1.1 LVN) across the entire composition range. These blends were not evaluated for WVTR but may be a viable option. DSC was employed to measure transition heats and temperatures. The PP appeared to increase the crystallinity in CARILON polymers.

Masterbatches (MB) of PP/Kraton® 1901X rubber and PP/Pebax® elastomer were dry blended at 10 to 20 weight percent into CARILON polymer 90/064 (220° C MP, 1.1 LVN).

E. CARILON POLYMER - NUCREL BLENDS

Binary and ternary blends of CARILON polymer 89/048 (220° C MP, 1.5 LVN) were prepared with Kraton 1901X rubber and Nucrel 535, an ethylene-methacrylic acid copolymer. The Nucrel was added up to 10 wt percent and the Kraton 1901X was employed as a compatibilizer. The same blend systems were also prepared with CARILON polymer 90/064 (220° C MP, 1.1 LVN). Binary and ternary blends of CARILON polymer 90/064 (220° C MP, 1.1 LVN) were prepared with Pebax elastomer and Nucrel 535 at the same levels.

F. CARILON POLYMER - ETHYLENE PROPYLENE RUBBER (EPR) BLENDS

CARILON polymer 90/064 (220° C MP, 1.1 LVN) was compounded at 5, 10 and 20 percent by weight with three EPR from Exxon.

1. Vistalon 719, a high ethylene content EPR
2. Exxolor VA1801, a maleated EPR
3. Vistalon 7000, a high ethylene content EPDM

We also blended ternary systems containing 5 percent of each EPR with Huntsman PP 5520 (a 5MF homopolymer) and PP DS7C60, an 18MF Unipol impact copolymer.

The samples containing 20% EPR were soaked in M15 gasoline for 15 days and percent weight gain was measured.

Nucrel was employed as a compatibilizer for the Vistalon 7000. Two and five wt percent Nucrel 535 was compounded with 20 wt. percent Vistalon 7000.

IV. RESULTS AND DISCUSSION

Table II lists all the polymer blend combinations that were investigated. CARILON polymer 90/064 was used in most blend systems. This polymer was produced by the continuous process at the MDU and a low LVN seed polymer was employed during synthesis. Polymers used as the second hydrophobic phase include Vectra A900, a liquid crystal polymer, three grades of polypropylene, Nucrel 535, and three grades of EPR. Kraton 1901X rubber, Pebax, Nucrel 535 and the EPR were screened as compatibilizers in various combinations. The range of each component added in wt percent is shown in parentheses.

A. CARILON POLYMER - LIQUID CRYSTAL POLYMER BLENDS

Blends of engineering thermoplastics with liquid crystal polymers (LCP) have been shown to increase their melt processability as evidenced by lower melt viscosity and lower injection pressures (13). Mechanical properties and heat deflection temperature typically increase while thermal expansion decreases. The addition of Vectra A900, an LCP, exhibited these expected features and furthermore enhanced barrier properties in CARILON polymer 88/008.

Figure 1 plots water vapor transmission rate versus weight percent Vectra A900. Experimental data compared well to the empirical relationship for miscible polymers. Theoretically, this reduction could be improved further if a true skin-core morphology could be introduced via

processing. The agreement of the WVTR data with that expected for a miscible system is surprising. The LCP requires higher processing temperatures, and this probably induced chemical reactions between the polyketone and LC polyester.

Table III lists the processing variables of the CARILON polymer-LCP blends. During compounding the extruder RPM increased (at constant torque) with increasing LCP content. Lower injection pressures were also required. Perhaps low levels of LCP can be employed for enhanced processability of high molecular weight CARILON polymers. Secondly, this may provide for a wider molding window for thin wall packaging products.

Table II lists a complete set of physical properties for this series of CARILON polymer compounds. The addition of 1 percent Vectra improved properties "across the board" with only a slight decrease of notched Izod impact resistance. At higher levels the LCP embrittles CARILON as evidenced by lower elongation and Gardner impact resistance.

B. CARILON POLYMER - POLYPROPYLENE BLENDS

The alloying of polypropylene with ETP's is a major area of research in the world today. This area is particularly being pursued in Japan (14). Polypropylene is inexpensive and yet exhibits a good property balance making it one of the top 3 plastics in the world on a volume basis. Effectively blending ETP's with polypropylene can provide a balance of product performance and economy. We should vigorously pursue our patent position on Carilon polymer - polypropylene blends since this would be an area where the Japanese and others are likely to practice patent "fencing".

We summarize here our efforts to produce polymer alloys of CARILON polymers with polypropylene that exhibit a good property balance. We would like to control the blend morphology to disperse the polypropylene as platelets in order to reduce WVTR in CARILON polymers. We have reported earlier work on CARILON polymer - PP blend systems (4,15).

CARILON polymer 89/052 was blended with PP WRS5-907, a 20 melt flow cracked polypropylene, at 10 percent increments across the entire phase diagram. The cracking process can introduce oxygen containing species on the PP which can enhance specific interactions with the polyketone. Blends of this CARILON polymer with lower melt flow, uncracked PP were unable to be extruded into continuous strands, evidence for gross phase separation. Binary blends of CARILON polymer 89/052 with PP WRSS-907 exhibit

a good balance of properties at each end of the compositional phase diagram (<20 wt % of the minor component). Compatibilizers would be required to further improve mechanical properties. A recent monograph discusses most aspects of alloying and blending of polymers and also cites recent patent activity (16).

Of particular interest in compatibilizer technology for CARILON polymer - polypropylene blends is U. S. Patent 3,948,873 (17), which discusses the synthesis of a graft copolymer with a PP or polyethylene backbone with polyketone grafts (branches). This would be an ideal compatibilizer for CARILON polymer - PP blends since it could reduce interfacial adhesion between the phases providing for enhanced physical properties in the alloy.

We report here blends of low LVN CARILON polymer with three types of polypropylene. We employed Kraton 1091X, Pebax and three EPR as compatibilizers. The most efficient compatibilizers appeared to be Kraton 1901X and Exxolor VA 1801 a maleated EPR. Both these polymers contain anhydride polar groups which thermodynamically mix well with polyketones and non-polar hydrocarbon blocks which mix relatively well with PP. These polymers were chosen because of availability and economy. The technology described in U. S. Patent 3,948,873 would likely provide the most suitable compatibilizer for CARILON polymer-PP binary blends.

Compatibilizers promote the adhesion between two chemically dissimilar phases. The relative effectiveness of the compatibilizer will determine the dispersed phase size at constant mixing conditions. The compounding method, molding conditions, molecular weight of the blend components, and the effectiveness of the compatibilizer are important variables which affect the final morphology and physical properties of the polymer blend. For example, if maximum impact resistance is desired in a polymer blend then it is typically desired to disperse the second elastomeric phase at small (<2 micron) dimensions. For the purpose of this investigation we desire a second hydrophobic phase to be dispersed as platelets in order to create a tortuous path for water diffusion, effectively reducing the water loss from food containers.

Figure 2 shows the flex modulus versus weight percent PP WRS5-907 in CARILON polymer 89/052. The flex modulus is higher for all blends than would have been expected by the rule of mixtures (indicated by the straight line). This can be attributed to a nucleating effect of the CARILON polymer on PP. Upon cooling the molded part, CARILON polymer crystallizes first, promoting enhanced crystallinity in the PP phase. The degree of

crystallinity is proportional to modulus and typically leads to improved barrier properties in polymers.

This nucleating effect was confirmed by DSC. The PP showed a peak recrystallization temperature of 101° C, but in blends with CARILON polymer it was increased to 112° C. Secondly, the heat of fusion for the PP phase (a measure of crystallinity) was higher in the blends than in the neat PP. Table V lists the heat of fusion for neat PP and that for high PP content blends.

Figure 3 plots notched izod impact resistance versus weight percent PP. The high CARILON polymer content blends exhibited an izod value typical for a rule of mixtures. The other end of the compositional phase diagram exhibited poor blend properties.

A similar trend was observed in the tensile properties (Figure 4). As for the izod impact values, CARILON polymer blends with up to 20 wt percent PP exhibited measurable levels of Gardner impact resistance while all other blends were extremely brittle. The cracked PP is extremely brittle and is expected to have a negative effect on impact resistance in ternary blends. For the purposes of reduced WVTR small levels of PP will be required (<20%) where a good property balance may be realized.

C. CARILON POLYMER - POLYPROPYLENE BLENDS COMPATIBILIZED WITH KRATON G 1901X RUBBER AND PEBAX ELASTOMER

From our previous work (10,15) we determined that CARILON polymers blended with 15% PP5520 and 5% Kraton 1901X rubber reduced the WVTR to an acceptable level for most food packaging applications. We reproduced this work in CARILON polymer 90/064 and also screened Pebax, a polyether block amide elastomer as a compatibilizer. Secondly, we measured mechanical properties in order to more fully understand the blend system.

Table VI lists the impact resistance and WVTR of these polymer blends. The blends were prepared by dry blending the precompounded PP/compatibilizer MB into the CARILON polymer and were subsequently injection molded. Gross phase separation resulted in a significantly reduced WVTR but also an extremely brittle compound unsuitable for food packaging. The phase separation in the thin wall moldings was visible to the unaided eye.

Figure 6 is a STEM of the 20% PP 5520/Kraton 1901X sample taken from a 1/8" injection molded tensile bar. The phase sizes are quite large, and it is interesting to note the dispersion of the Kraton 1901X rubber within the PP phase. An ideal compatibilizer would be located at

the CARILON polymer - PP interface promoting adhesion and improved impact resistance. Thin wall molding promotes a smearing of the PP phase into platelets and even pushes a pure PP phase to the surface of the container.

D. CARILON POLYMER - NUCREL 535 BLENDS COMPATIBILIZED WITH KRATON G1901X RUBBER AND PEBAX ELASTOMER

The addition of Nucrel at 10 wt. percent significantly reduced the WVTR in CARILON polymer 90/064; however, the falling weight impact resistance was significantly reduced. Kraton 1901X rubber was an effective compatibilizer for Nucrel producing a good balance of impact resistance and WVTR. Pebax elastomer was a more efficient compatibilizer than Kraton 1901X rubber and produced a smaller dispersed phase. This effectively impact modified 90/064 polymer with no substantial reduction in WVTR. Table VII lists impact resistance and WVTR for this series.

These results can be understood by looking at the blend morphologies with STEM. Figure 7a and 7b illustrate the CARILON polymer - Nucrel blend with 1 and 5 wt percent Kraton G1901X rubber as compatibilizer. The Kraton rubber resides at the Nucrel-CARILON polymer interface producing an overall cell size of ~2 microns in diameter.

These micrographs are taken from 1/8" injection molded test specimens. The dispersed phase is expected to elongate and form platelets upon molding the 25 mil thin wall containers. The 2 micron dispersed phase reduced WVTR but produces a sample with a lower Gardner impact than the neat CARILON polymer control.

Figure 8a and 8b illustrate the morphology for the CARILON polymer - Nucrel blend compatibilized with 1 and 5 wt. percent, respectively of Pebax elastomer. The dispersed phase size is ~1 micron in diameter resulting in a sample with an impact resistance greater than the control. The Pebax disperses at the CARILON polymer - Nucrel interface reducing interfacial tension. The smaller dispersed phase is not as effective for reducing WVTR.

TEM studies of a number of three and four component polymer blends have been reported (18) where their morphologies are dominated by the relative abilities to spread on one another. The CARILON polymer more efficiently spreads onto the dispersed Pebax phase than onto Kraton 1901X rubber resulting in a smaller dispersed cell size. These two systems illustrate the factors involved in order to control blend morphologies in three component systems.

E. BINARY AND TERNARY CARILON POLYMER BLENDS WITH EPR AND POLYPROPYLENE

Figures 9-11 plot the WVTR for binary blends of CARILON polymer 90/064 with the three respective EPR before and after retort. A similar trend was observed for all three EPR. EPR with Exxolar VA1801 being the most effective for reduced WVTR. Figures 12-14 plot the flex modulus and Gardner impact resistance for the same blend series. All the EPR significantly reduce modulus, but a characteristic trend of Gardner impact resistance unique for each EPR was observed.

The addition of VISTALON 719 reduced Gardner impact from ~40 in.lb. to ~ 20 in. lb. when added at 20 wt. percent, a 50 percent reduction (Figure 12). Note that the 90/064 control has a very low room temperature Gardner impact resistance attributed to its low LVN and perhaps an unusually high level of seed polymer added at the MDU.

The Exxolar VA1801, a maleated EPR, improved the Gardner impact resistance approximately 50 percent (Figure 13). The functionalized EPR probably reacts to some degree with CARILON polymer leading to smaller dispersed particle sizes but also reduced melt processability.

The Vistalon 7000, an EPDM, significantly reduced the Gardner impact resistance even at low levels (Figure 14).

Tables VIII-X list the physical properties for binary and ternary blends of CARILON polymer 90/064 with EPR and two polypropylenes. A similar trend is observed for all three EPR systems. Tensile strength is reduced upon the addition of any additive to the neat control. Gardner impact resistance was significantly reduced in any compound containing polypropylene. Notched izod impact was slightly reduced in all systems.

Table XI lists the WVTR, Gardner impact resistance, and tensile properties for all blends containing 15 percent polypropylene. Also included are the ternary systems of Kraton 1901X rubber, polypropylene, and CARILON polymers a reference case. All the properties are similar in that a significant reduction in WVTR was observed in all blends. The Gardner impact resistance was significantly reduced in all cases except the system containing Kraton 1901X rubber and PP DS7C60 (Sample 8). The molded cups all exhibit gross phase separation with again sample 8 exhibiting the best overall appearance.

Figures 15-17 illustrate the WVTR before and after retort for each EPR at 20 percent, and 5 percent of each EPR combined with 15 percent PP 5520. The 20 percent level of EPR reduced WVTR while retaining a good balance of

properties, particularly Exxolor VA1801 and Vistalon 719. The ternary systems are more effective for reducing WVTR but exhibit visible phase separation and poor property sets.

Table XII lists the melt rheology for selected blends. All blends negatively effect melt stability with the exception of Vistalon 719. The Exxolor VA1801 had the most negative effective on melt rheology. However, all systems exhibited adequate melt processability.

Table XIII lists the weight gain after 15 days in M15 gasoline, WVTR, and flex modulus for the blends containing 20% EPR. The EPR did not significantly affect gasoline absorption, significantly reduced WVTR and produced a more flexible part. This should be a good candidate system for fuel delivery systems.

Figure 18 illustrates the dispersed phase morphology of the three EPR dispersed in CARILON polymer. The maleated EPR (Exxolor VA1801) exhibited the more distinct platelet at the surface of the container. This can account for its enhance barrier performance. All blends exhibited a skincore morphology with the dispersed EPR phase more elongated at the surface.

F. CARILON POLYMER - EPR BLENDS COMPATIBILIZED WITH NUCREL

We added 5 wt. percent Nucrel to the binary blend containing 20% Vistalon 7000. The maleated rubber is not preferred because it is expected to be difficult for FDA approval. Table XIV lists the WVTR and physical properties of the blend series. The addition of Nucrel further improved the WVTR and produced an aesthetically pleasing container with a good balance of properties.

V. CONCLUSION

We have developed polymer blend systems with CARILON polymers and a dispersed hydrophobic phase to reduce WVTR. Morphology control is critical in order to produce a balance of acceptable mechanical properties with reduced WVTR. CARILON polymer blends with 20% EPR produce nice containers with >60 percent reduction in WVTR and a good balance of mechanical properties. The addition of 5 percent Nucrel 535 acts as a compatibilizer for this system with a further reduction of WVTR.

Nucrel may also be employed as the hydrophobic phase and compatibilized with Kraton G 1901X rubber. This system reduced WVTR >50 percent and exhibited the best impact resistance of any system exhibiting this level of WVTR reduction.

CARILON polymer - polypropylene blends reduce the WVTR to acceptable levels for most food packaging applications, but mechanical properties and gross phase separation may be unacceptable for some applications. New compatibilizer technology would be required for utilization.

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Table I. Permeation protection required for various foods and beverages for a one year shelf life at 25°C**

FOOD OR BEVERAGE	ESTIMATED MAXIMUM TOLERABLE OXYGEN GAIN, PPM	ESTIMATED MAXIMUM WATER GAIN OR LOSS WT. PERCENT	HIGH OIL BARRIER REQ'D?	HIGH VOLATILE ORGANICS BARRIER REQ'D?
CANNED MILK, MEATS	1 TO 5	-3	YES	-
BABY FOODS	1 TO 5	-3	YES	YES
BEER, ALE, WINE	1 TO 5*	-3	-	YES
INSTANT COFFEE	1 TO 5	+2	YES	YES
CANNED VEG, SOUPS, SPAGHETTI	1 TO 5	-3	-	-
CANNED FRUITS	5 TO 15	-3		YES
NUTS, SNACKS	5 TO 15	+5	YES	-
DRIED FOODS	5 TO 15	+1	-	-
FRUIT JUICES, DRINKS	10 TO 40	-3	-	YES
CARBONATED SOFT DRINKS	10 TO 40*	-3	-	YES
OILS, SHORTENING	50 TO 200	+10	YES	-
SALAD DRESSINGS	50 TO 200	+10	YES	YES
JAMS, PICKLES, VINEGARS	50 TO 200	-3	-	YES
LIQUORS	50 TO 200	-3	-	YES
PEANUT BUTTER	50 TO 200	+10	YES	-

* Less than 20% loss of CO₂ is also required.

** (Data taken from ref. 19.)

Table II. Blend Combinations

Base Polymer	Compatibilizer	Dispersed Polymer Phase
88/008		Vectra (1-20)
89/052		PP WRS5-907 (0-100) (cracked)
89/048	Kraton 1901x (0-10)	Nucrel (5-10)
90/064	Kraton 1901x (2.5-5.0)	PP 5520 (7.5-15)
90/064	Pebax (2.5-5.0)	PP 5520 (7.5 -15)
90/064	Pebax (0-5)	Nucrel (10)
90/064	Kraton 1901x (0-5)	Nucrel (10)
90/064		Vistalon 719 (1-20)
90/064	Nucrel (0-5)	Vistalon 7000 (1-20)
90/064		Exxolor VA 1801 (1-20)

Base Polymer	Compatibilizer	Dispersed Polymer Phase (range)
90/064	Vistalon 719 (5)	PP 5520 (is) 15
90/064	Vistalon 719 (5)	PP DS7C60 (is) 15
90/064	Vistalon 7000 (5)	PP 5520 (is) 15
90/064	Vistalon 7000 (5)	PP DS7C60 (is) 15
90/064	Exxolor VA 1801 (5)	PP 5520 (is) 15
90/064	Exxolor VA 1801 (5)	PP DS7C60 (is) 15
MX 500		Vistalon 719 (20-30)
MX 500		Vistalon 7000 (20-30)
MX 500	Nucrel (2-5)	Vistalon 7000 (20)

Table III. Injection Pressures and Screw RPM for CARILON™ Thermoplastic Polymer Blend with VECTRA® A900

SAMPLE	RPM AT CONSTANT TORQUE	INJECTION PRESSURE
88/008 (control)	290	475
+ 1% Vectra® A900	325	400
+ 5% Vectra® A900	346	375
+20% Vectra® A900	389	300

Table IV. Mechanical Properties of CARILON™ Thermoplastic Polymer Blend with VECTRA® A900

<u>PROPERTY</u>	<u>CONTROL 88/008</u>	<u>+1% VECTRA® A900</u>	<u>+5% VECTRA® A900</u>	<u>+20% VECTRA® A900</u>
FLEX MODULUS (PSI)	280,000	291,000	315,000	452,000
TENSILE STRENGTH AT YIELD (PSI)	9,400	9,200	9,300	9,800
AT BREAK (PSI)	7,600	7,900	7,000	9,700
ELONGATION TO BREAK (PSI)	61	118	44	5
GARDNER IMPACT (IN.LB.) R.T.	309	>320	55	14
- 20°F	121	102	14	3
NOTCHED IZOD IMPACT (FT.LB./IN.)	4.2	3.5	3.1	1.7
H.D.T. (°C) AT 264 PSI	125	140	139	-

Table V. Heat of Fusion for PP WRSS-907 and Blends CARILON® 89/052

SAMPLE	MEASURED ΔH (Cal/g)	EXPECTED ΔH Cal/g
PP Control	20.8	20.8
PP + 10% CARILON	18.9	18.7
PP + 20% CARILON	18.8	16.6
PP + 30% CARILON	15.4	14.6
PP + 40% CARILON	14.0	12.5

ΔH = Heat of fusion measured by DSC

Table VI. Impact Resistance and WVTR for CARILON® 90/064 Polymer Blended with PP5520.

Sample	Gardner Impact (in.lb.)	Notched Izod Impact (ft.lb/in.)	WVTR (%loss/yr) Before Retort	WVTR (%loss/yr) After Retort
90/064 (Control)	100	2.0	7.7	11.0
+10% PP5520 /1901xMB	28	2.3	4.8	6.0
+20% PP520 /1901xMB	12	2.2	2.1	3.6
+10% PP520 /Pebax MB	20	2.8	7.1	110.1
+20% PP5520 /Pebax MB	14	2.1	5.7	7.8

Table VII. Impact Resistance and WVTR for Selected Blends

Sample	Gardner Impact (in.lb.)	Notched Izod Impact (ft.lb/in.)	WVTR (%loss/yr) Before Retort	WVTR (%loss/yr) After Retort
90/064 Control	100	2.0	7.7	11.0
10% Nucrel + 1% 1901x	45	3.2	5.6	7.7
10% Nucrel + 5% 1901x	56	4.3	4.7	6.0
10% Nucrel + 1% Pebax	113	4.4	6.4	9.4
10% Nucrel + 5% Pebax	176	6.1	8.8	10.9
10% Nucrel	16		5.5	7.6

Table VIII. Physical Properties of CARILON® Polymer 90/064, Vistalon 719 and Polypropylene Blends.

Sample	Notched Izod Impact (ft.lb/in.)	Flex Mod (psi)	Gardner (in.lb.)	Tensile @ Br	
				Strength (psi)	Elongation (%)
Control	1.7	259,000	42	6790	87
+5% Vistalon 719	1.2	243,000	42	7897	25
+20% Vistalon 719	1.1	168,000	21	5397	40
+5% Vistalon 719 +15% PP5520	1.1	233,000	7	6243	18
+5% Vistalon 719 +15% PP DS7C60	1.2	219,000	8	6354	22

Table IX. Physical Properties of CARILON 90/064, Exxolor VA 1801, Polypropylene Blends.

Sample	Notched Izod Impact (ft/lb/in)	Flex Mod (psi)	Gardner Impact (in. lb.)	Tensile @ Br	
				Strength (psi)	Elongation (%)
Control	1.7	259,000	42	6790	87
+5% Exxolor	1.2	232,000	40	7620	26
+10% Exxolor	1.2	201,000	59	6647	26
+20% Exxolor	1.1	157,000	62	5400	41
+5% Exxolor +15% PP5520	1.0	209,000	6	5200	18
+5% Exxolor +15% PPDS7C60	1.1	209,000	9	5900	20

Table X. Physical Properties of CARILON® Polymer 90/064, Vistalon 7000, Polypropylene Blends

Sample	Notched Izod Impact (ft.lb/in)	Flex Mod (psi)	Gardner (in.lb.)	Tensile @ BR	
				Strength (psi)	Elongation (%)
Control	1.71	259,000	42	6790	87
+5% Vistalon	1.1	225,000	17	7761	26
+10% Vistalon	1.2	196,000	16	6640	26
+20% Vistalon	1.1	257,000	11	5143	29
+5% Vistalon +15% PP5520	1.1	224,000	8	6211	24
+5% Vistalon +15% PP DS7C60	1.1	213,000	7	6081	25

Table XI. Comparison of EPR-PP Blends to Kraton 1901x-PP Blends.

Sample	WVTR % Loss 1 yr		Gardner (in.lb.)	Tensile @ Br	
	Retort Before	Effect After		Strength (psi)	Elongation (%)
1.+5 % 719 +15% P5520	1.6	3.5	7	6243	18
2.+5% 719 +15% PP DS7C60	1.9	2.6	8	6354	22
3.+5% VA1801 +15% PP5520	2.0	2.9	6	5200	18
4.+5% VA1801 +15% PP DS7C60	1.9	2.5	9	5900	20
5.+5% 7000 +15% PP5520	2.0	2.7	8	6211	24
6.+5% 7000 +15% PP DS7C60	2.0	2.7	7	6081	25
7.+5% 1901x +15% PP 5520	1.5	2.0	9	6035	19
8.+5% 1901x +15% PP DS7C0	2.5	3.2	46	6547	24

Table XII. Melt Rheology for CARILON® Polymer 90/064, EPR, Polypropylene Blends.

Sample	Melt Viscosity (Pa · Sec.)		
	$\eta(0)$	$\eta(10)$	$\eta(28)$
Control	77	157	745
+20% 719	482	339	731
+5% 719 +15% PP 5520	274	414	1720
+20% VA1801	400	1670	7400
+5% VA 1801 +15% PP 5520	311	634	2300
+20% 7000	577	645	3275
+5% 7000 +15% PP 5520	233	362	1425
+5% 1901x +15% PP 5520	204	428	1958

Table XIII. MI5 Gasoline Absorption, WVTR, and Modulus of CARILON® Polymer, Ethylene-Propylene Rubber Blends.

Sample	% Wt. Gain in MI5 Gasoline (15 Days)	WVTR		Flex Modulus
		Retort Before	Effect After	
(% wt loss/year)				
Control (90/064)	1.10	8.0	12.0	259,000
+20% Vistalon 719	1.95	4.8	6.2	168,000
+20% Exxolor VA 1801	1.80	3.9	5.0	157,000
+20% Vistalon 7000	2.20	5.3	7.0	157,000

Table XIV. Tensile Properties and WVTR of CARILON® Polymer-EPR-Nucrel Blends.

Sample	WVTR		Tensile Strength @ Break	
	Retort Before	Effect After	Strength (psi)	Elongation (%)
90/064 Control	7.0	11.0	6790	(87)
+20% Vistalon 7000	5.3	7.0	5143	(29)
5% Nucrel 20% Vistalon 7000	3.0	4.5	4760	(28)
+2% Nucrel 20% Vistalon 7000	3.7	5.6	5407	(36)

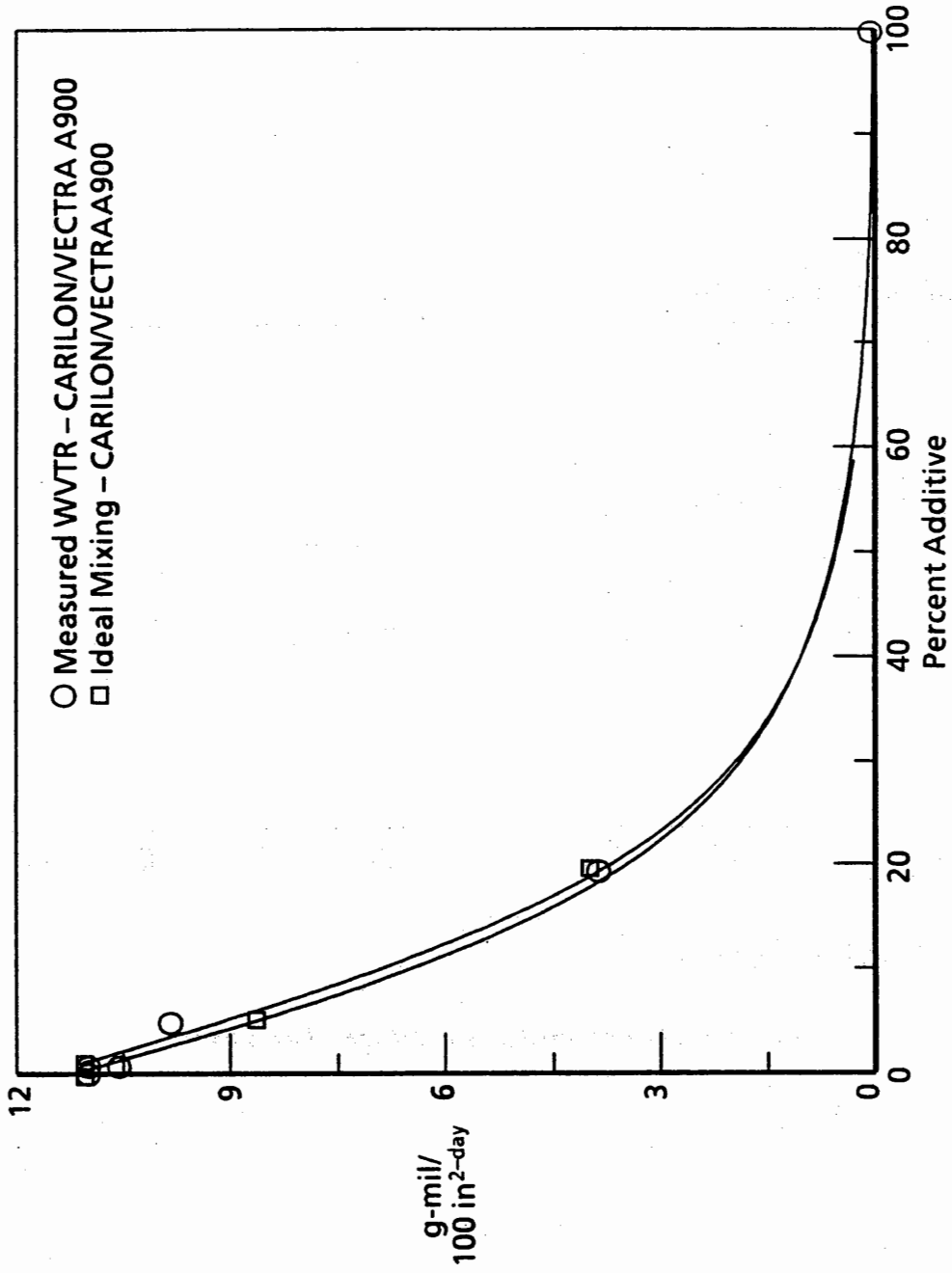


Figure 1. WVTR vs. Percent Additive for CARILON™ Thermoplastic Polymer 88/008 Blended with VECTRA A900®

016260-1

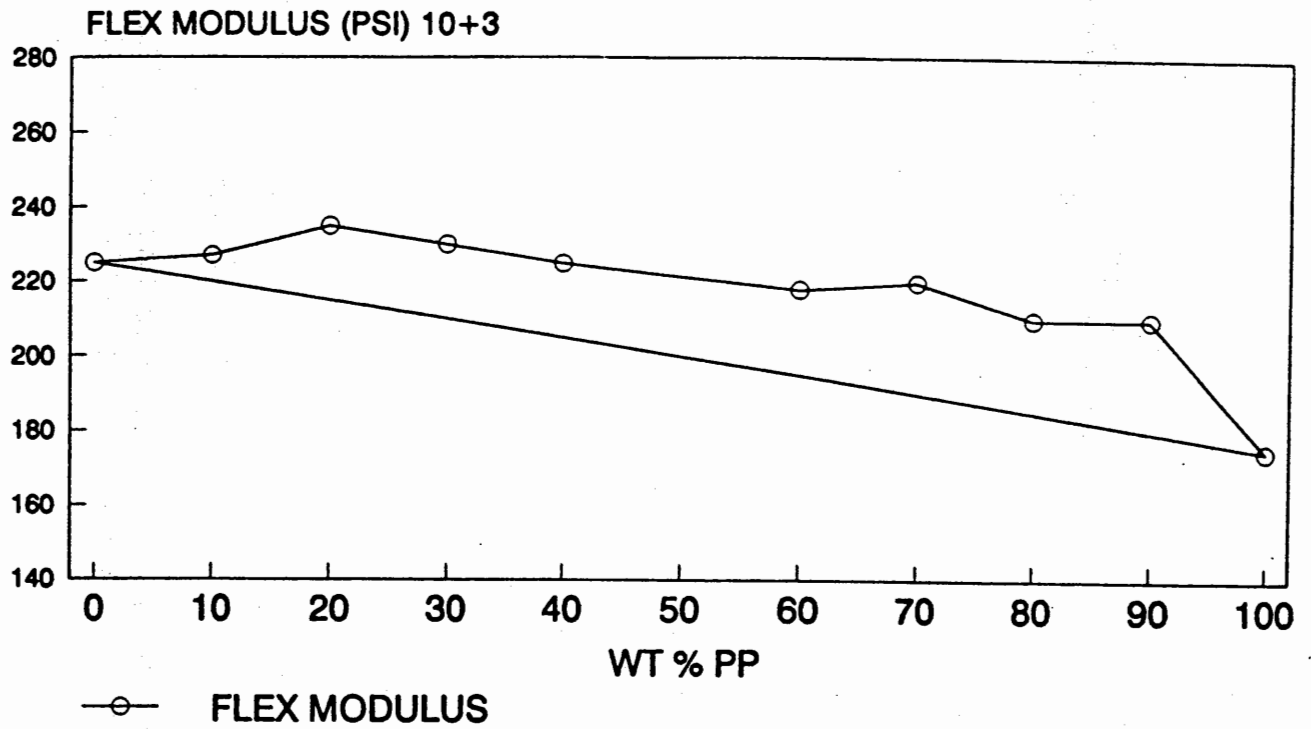


Figure 2. Flex Modulus vs. Weight Percent PP

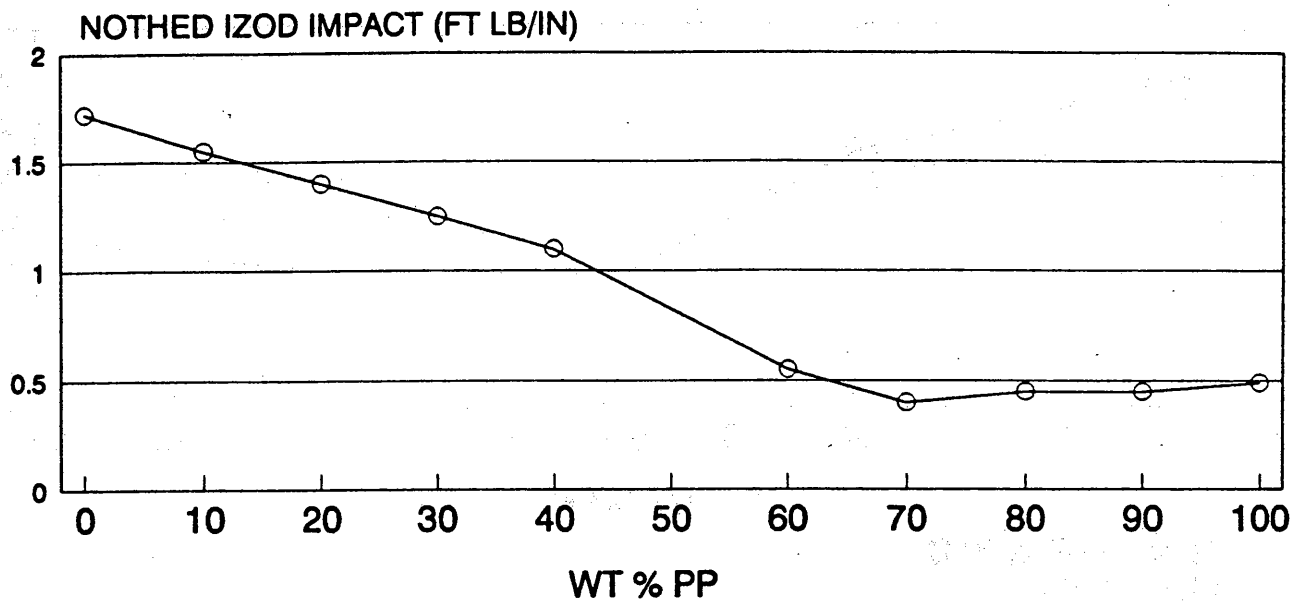


Figure 3. Notched Izod Impact Resistance vs. Weight Percent PP

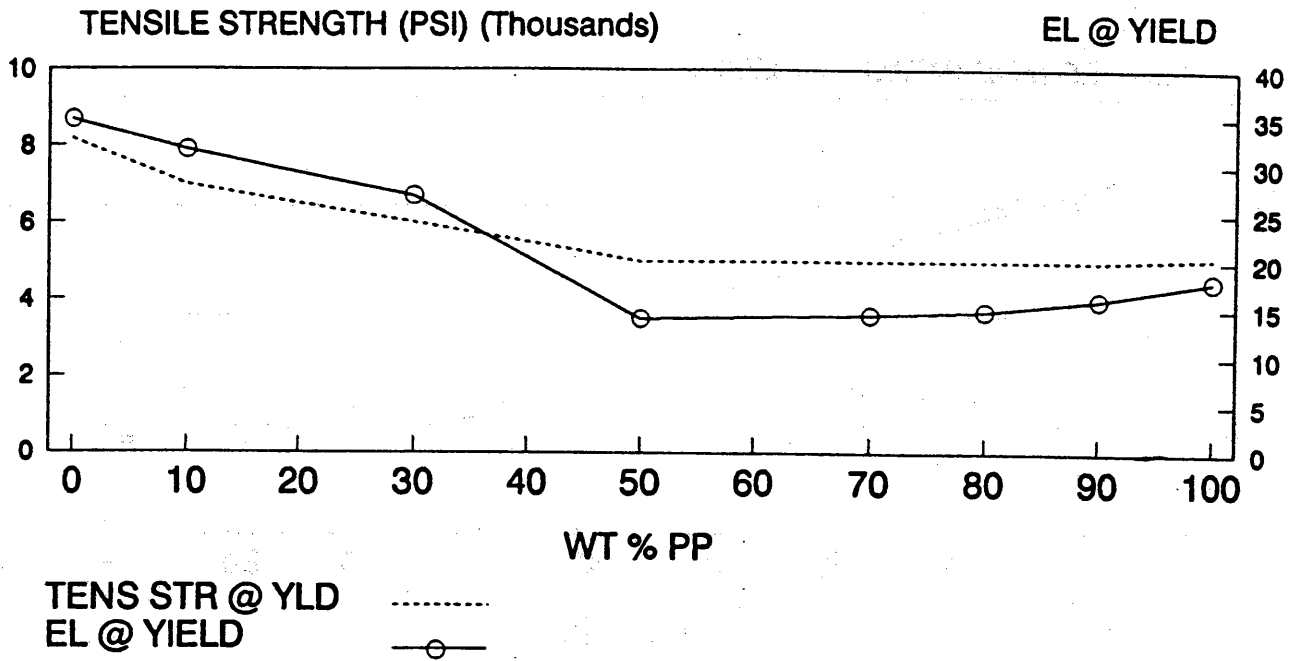


Figure 4. Tensile Strength vs. Weight Percent PP

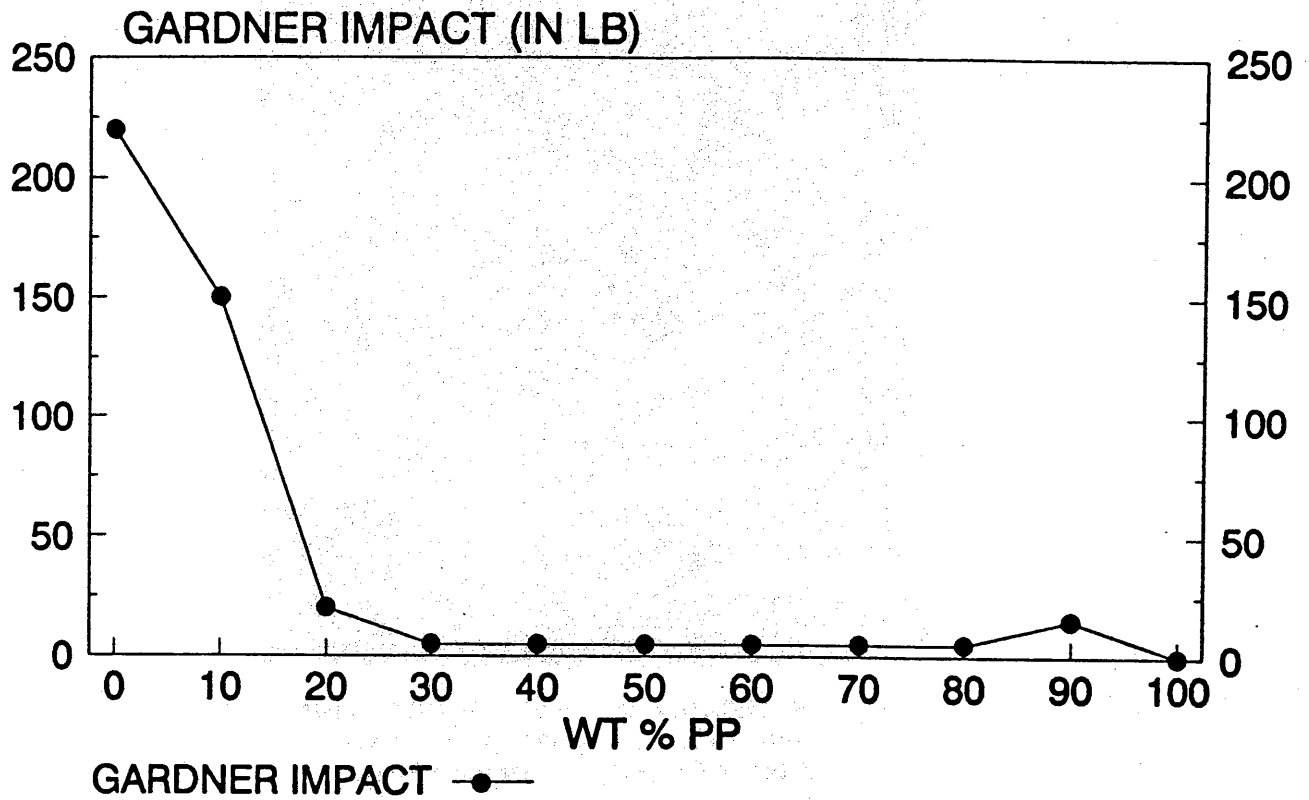
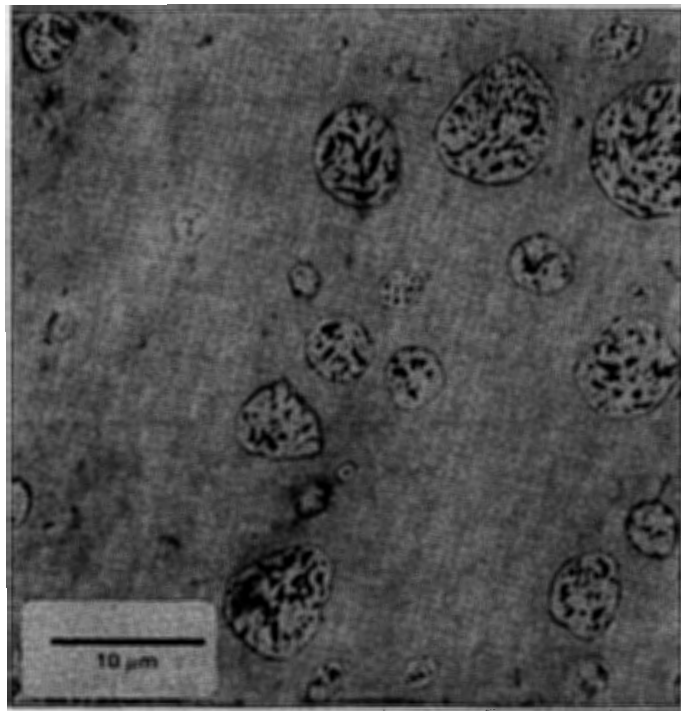
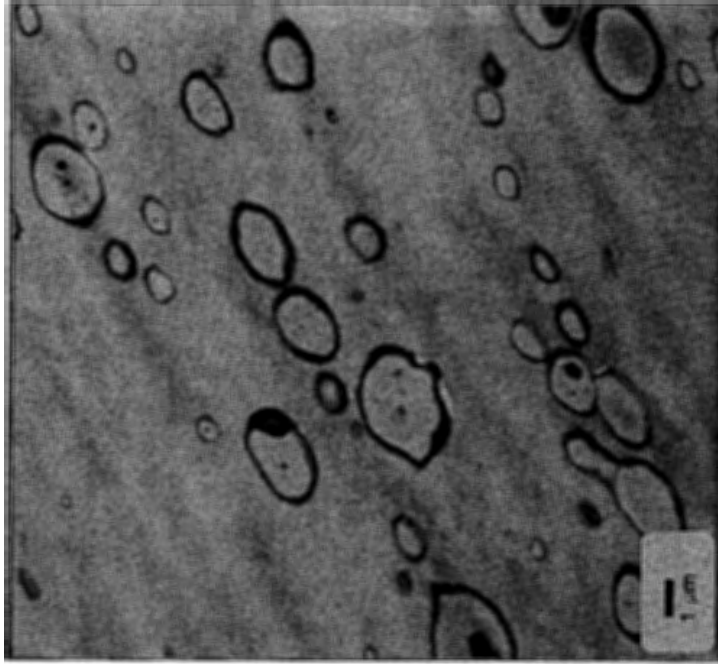


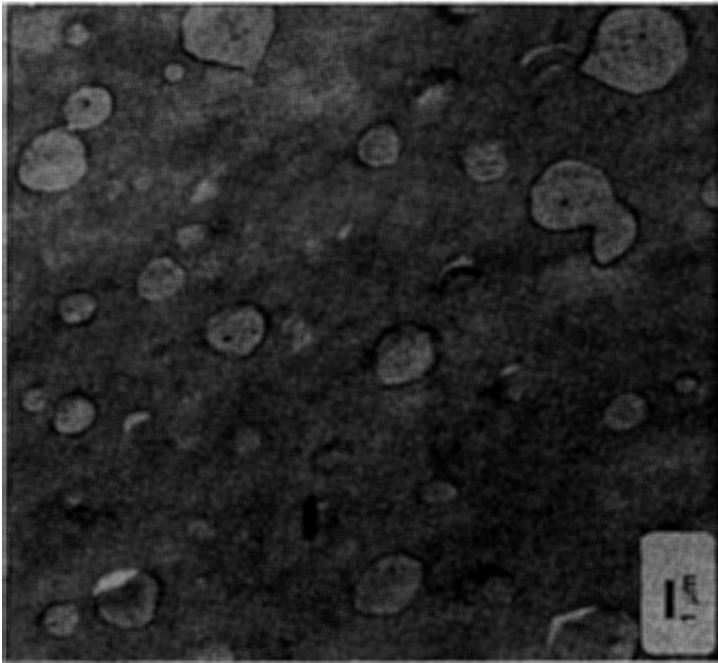
Figure 5. Gardner Impact Resistance at -30°C vs. Weight Percent PP



**Figure 6. STEM Micrograph of CARILON™ 90/064
Modified with 15% PP 5520 (Light Phase)
and KRATON® 1901X Rubber (Dark Phase)**

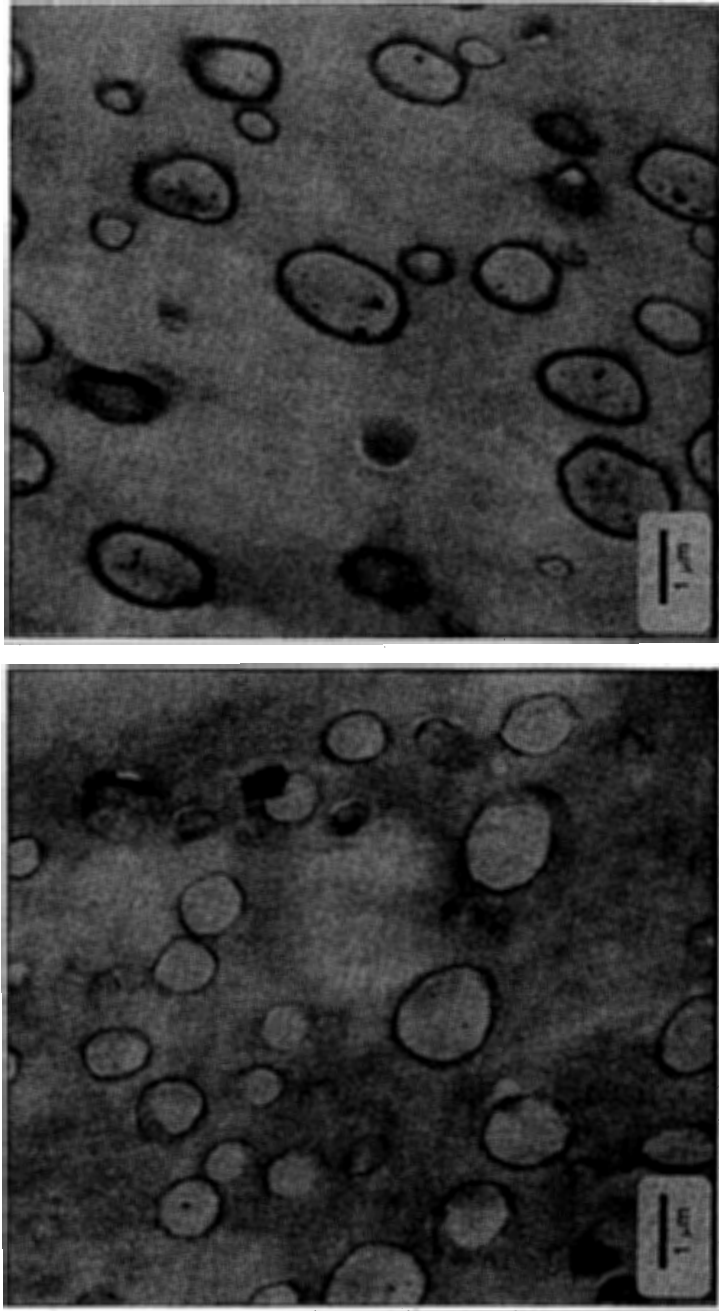


(b) 10% NUCREL 535
5% KRATON 1901X



(a) 10% NUCREL 535
1% KRATON 1901X

Figure 7. STEM of CARILON™ - NUCREL Blends Compatibilized
with 1 and 5 Weight Percent KRATON® G 1901X Rubber
Magnification: 5000X



(a) 10% NUCREL
1% PEBAX

(b) 10% NUCREL
5% PEBAX

Figure 8. STEM of CARILON™ - NUCREL Blends Compatibilized with PEBAX Elastomer
Magnification: 10,000X

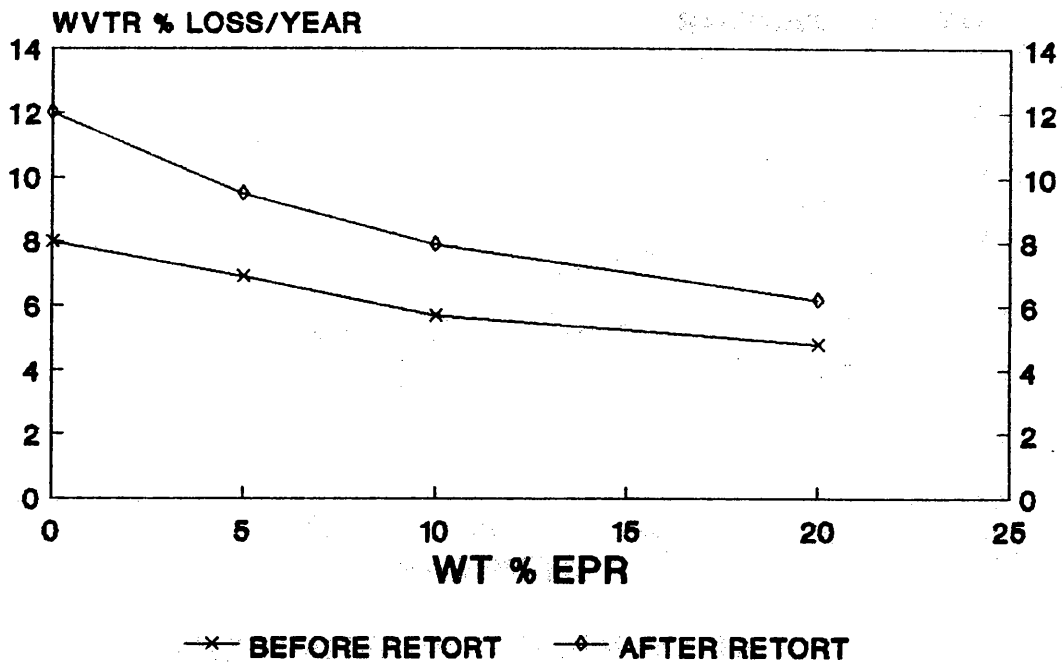


Figure 9. CARILON™ Blends with VISTALON 719

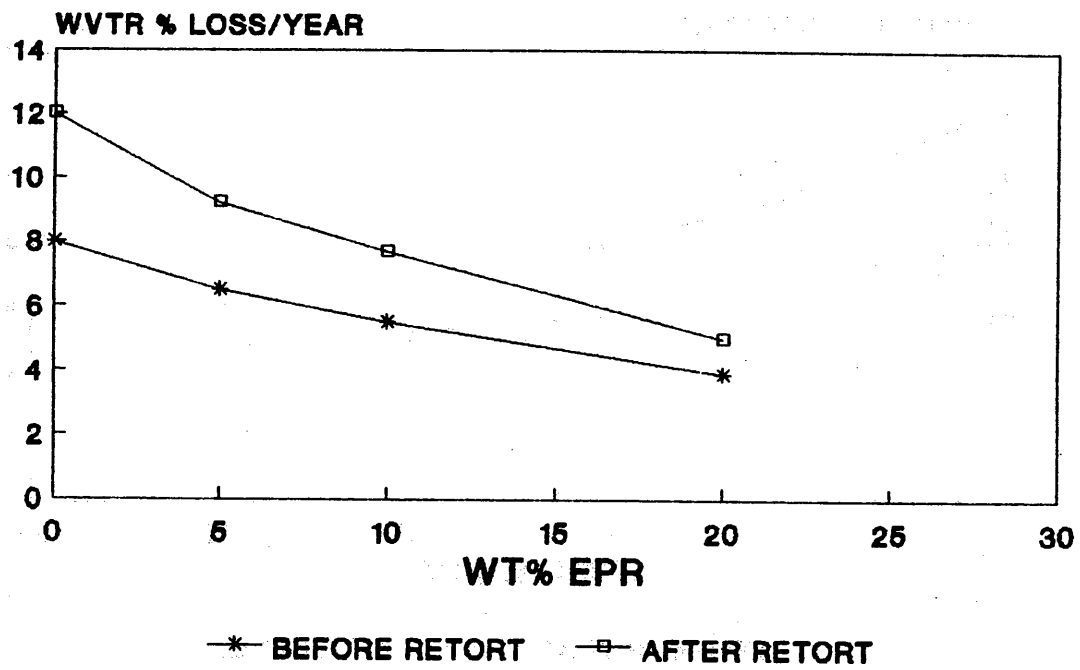


Figure 10. CARILON™ Blends with EXXOLOR VA1801

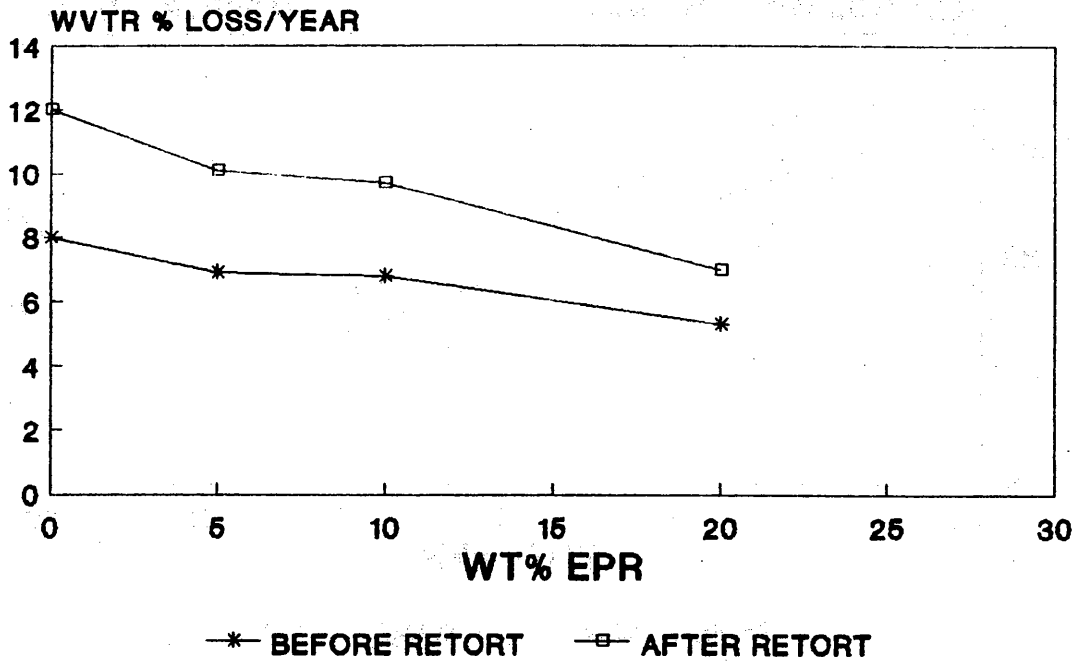


Figure 11. CARILON™ Blends with VISTALON 7000

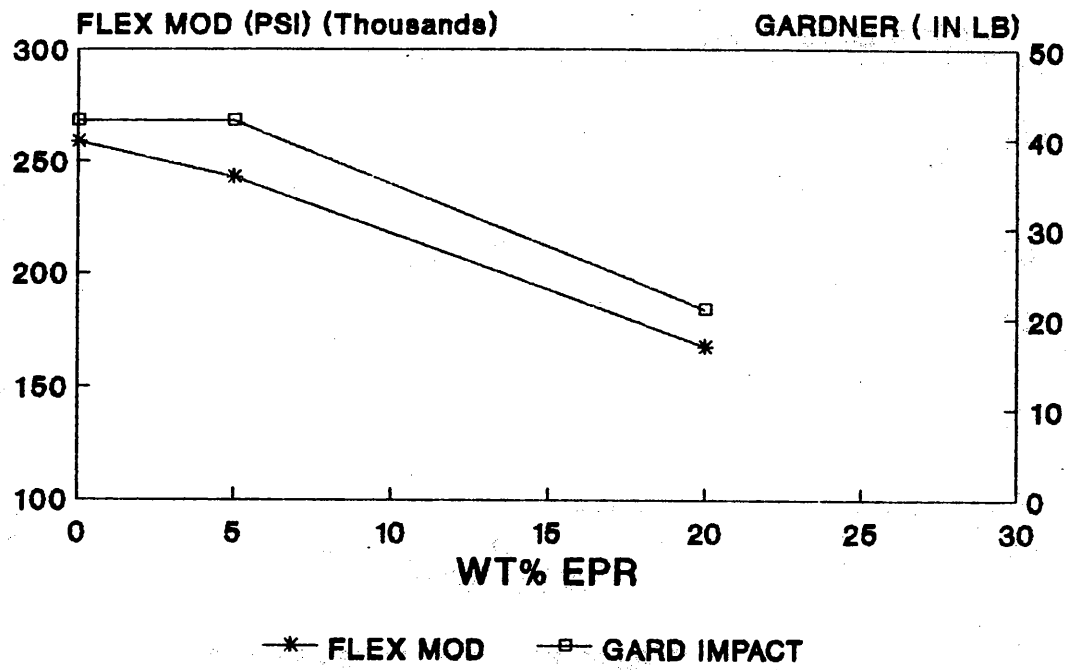


Figure 12. CARILON™ Blends with VISTALON 719

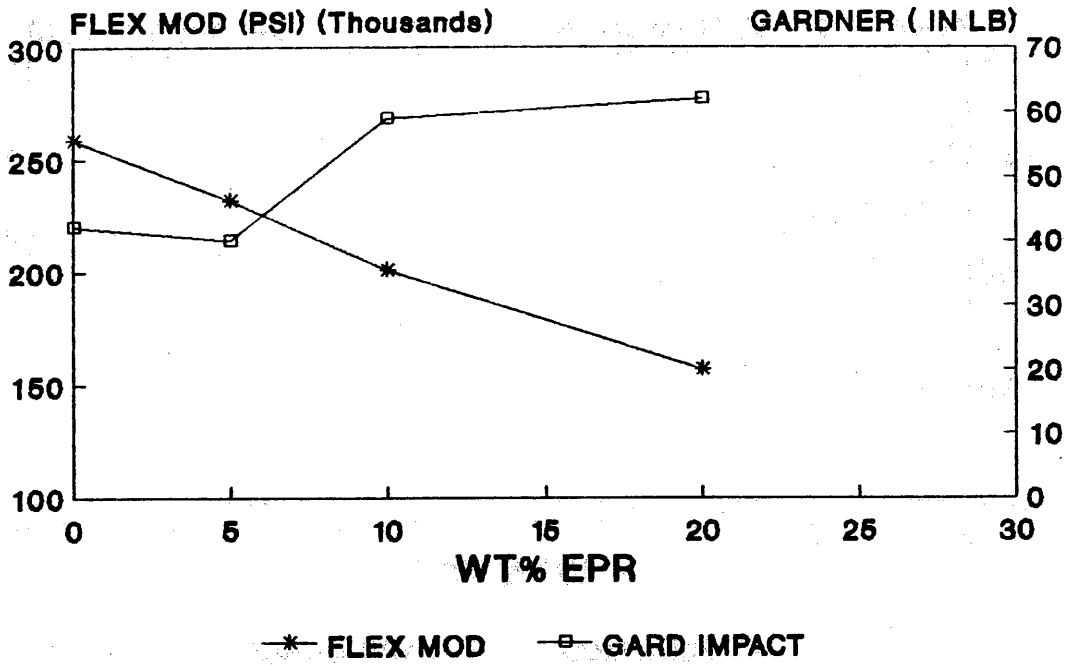


Figure 13. CARILON™ Blends with EXXOLOR VA 1801

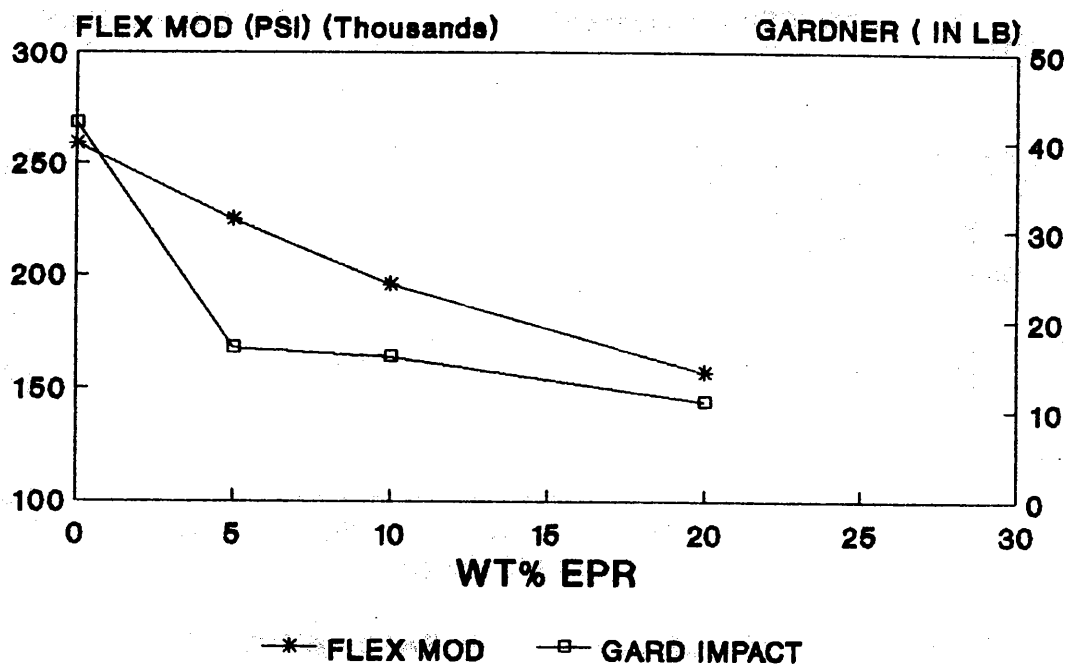


Figure 14. CARILON™ Blends with VISTALON 7000

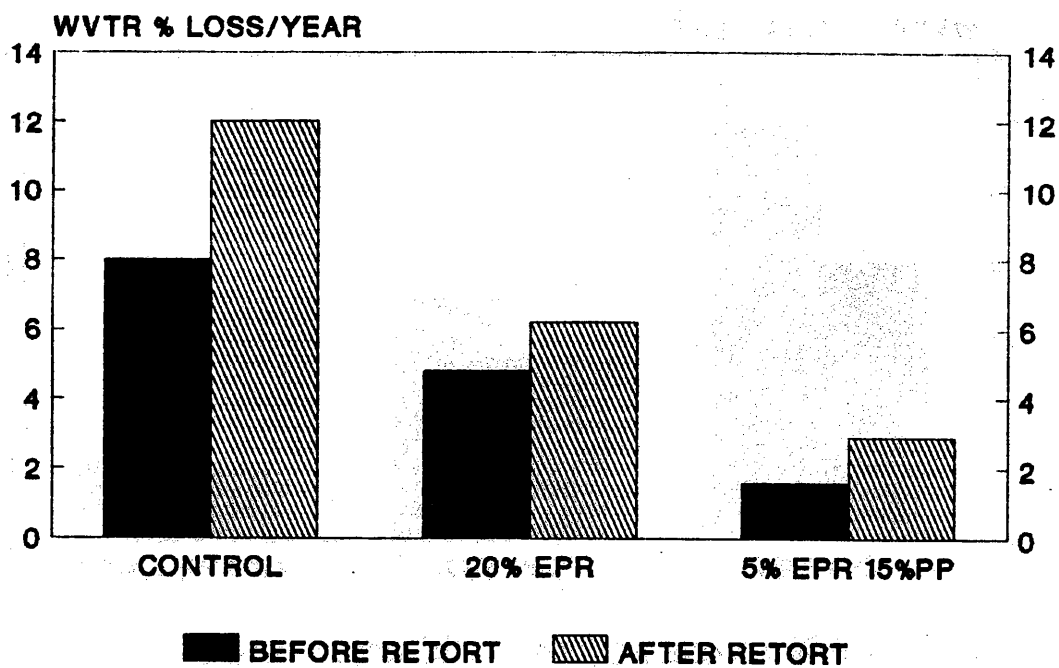


Figure 15. CARILON™ Blends with VISTALON 719 and PP 5520

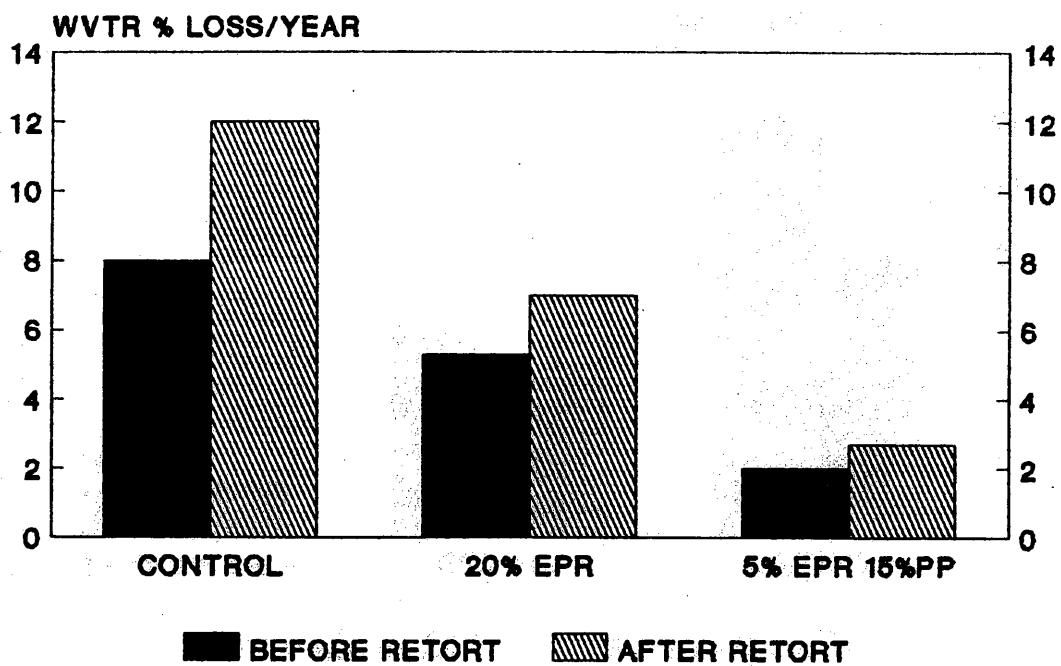


Figure 16. CARILON™ Blends with VISTALON 7000 and PP 5520

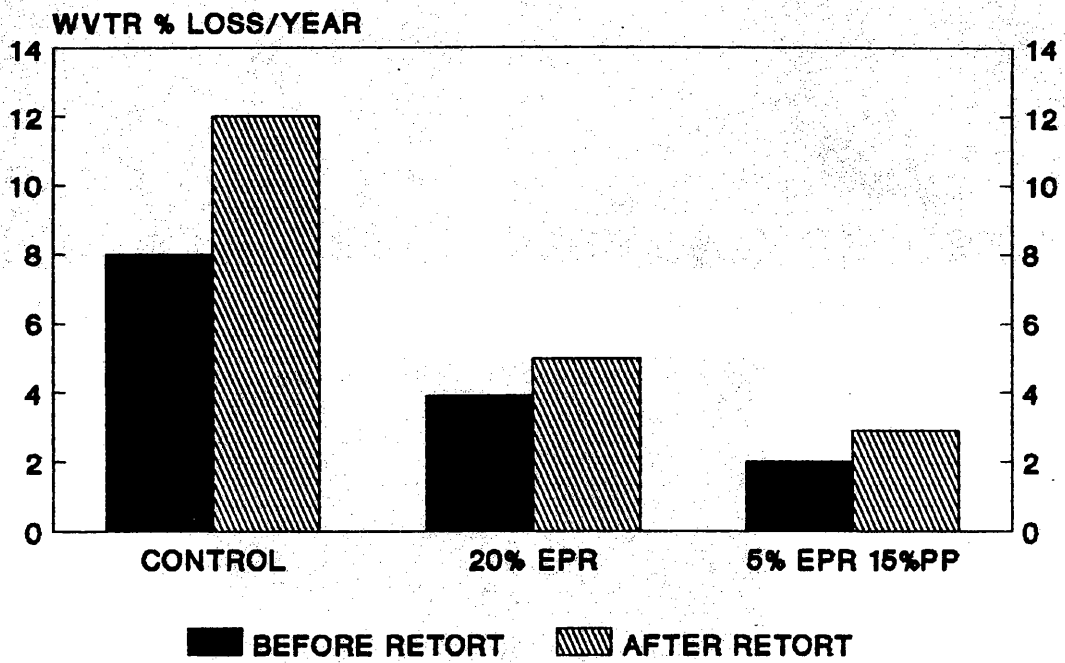
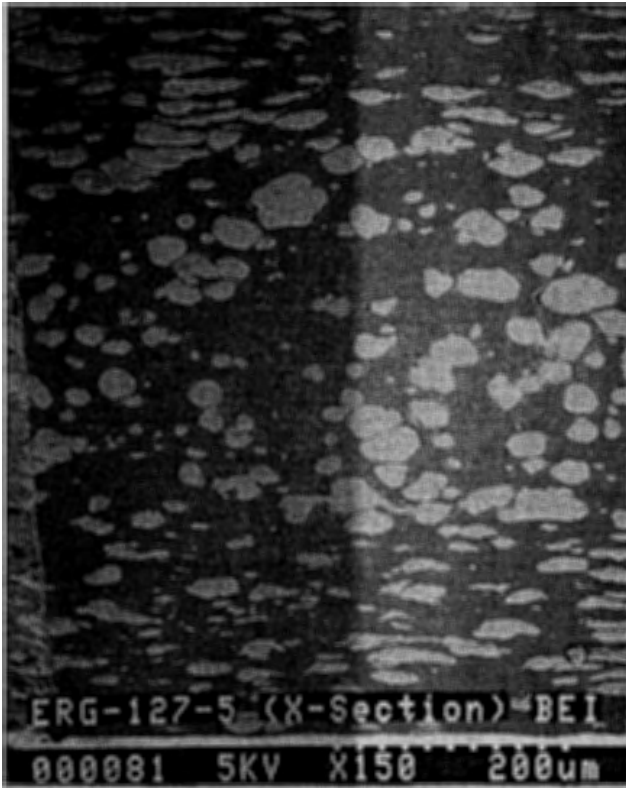
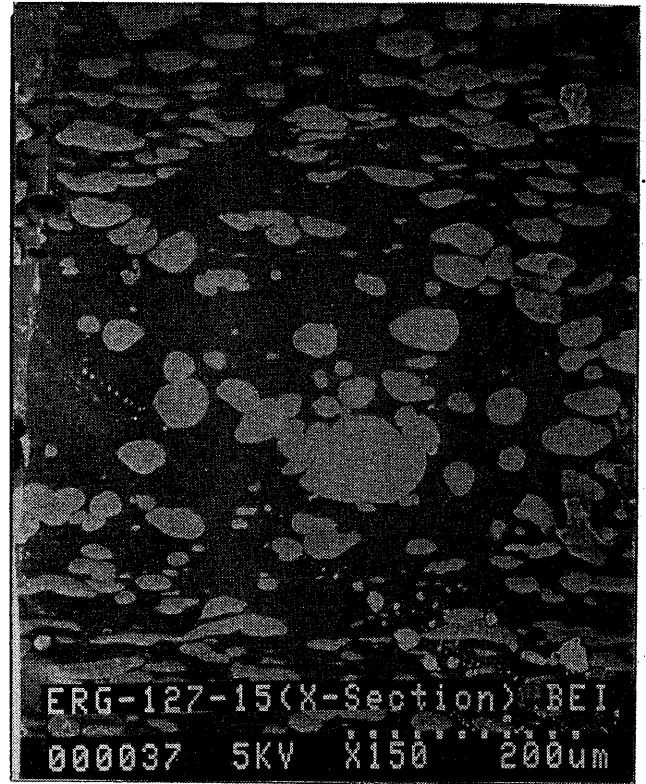


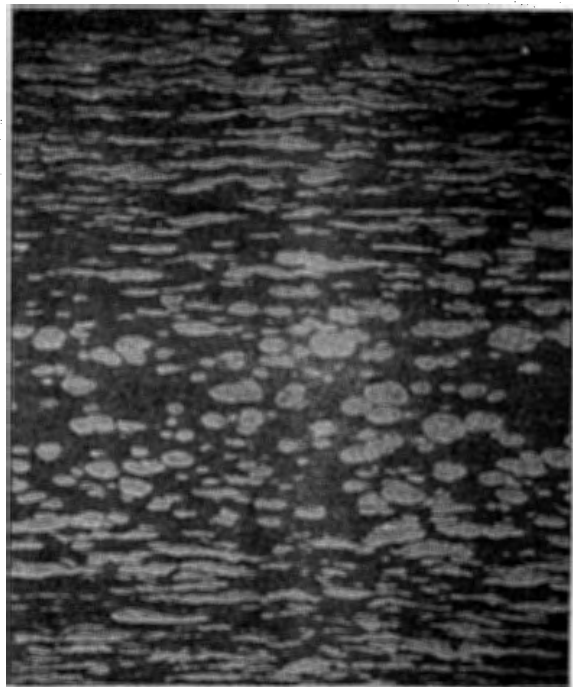
Figure 17. CARILON™ Blends with EXXOLOR VA 1801 and PP 5520



(a) 20% VISTALON 719



(b) 20% VISTALON 7000



(c) 20% EXXOLOR VA 1801

Figure 18. TEM of CARILON™ - EPR Blends, a Cross-Sectional View Across the 25 Mil Thick Injection Molded Container

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