CASE STUDY

Choosing the Best Process Oil Chemistry for EPDM Roofing Membranes

Summary

Product type: EPDM compounds
Application: Roofing membranes
Key benefits: Improved Cure Time | Higher Heat Aged Tensile Strength | Enhanced Tear Resistance | Extrudability and Puncture Resistance | Cost Efficiency

The Challenge

Suppliers of EPDM roofing membranes must offer industry standard performance warranties of up to 40 years on a newly installed roof. The membrane material must have good physical properties that are retained as the material ages at high-temperature and under harsh conditions. During installation, a roofing membrane must exhibit good elongation properties which help in getting around various obstacles on a roof. It must also have good tear and puncture resistance to bear the stress of installation. After installation, the roofing membrane is mostly static. As the material ages, it must continue to exhibit good tensile strength and elongation, and resist heat degradation. Formulators of EPDM roofing material must also consider the processability of the material to ensure an efficient production process. These considerations include the power requirement for mixing, viscosity and extrudability.

EPDM compounds are typically composed of four groups of ingredients:

- EPDM polymer
- Plasticizer (Process oil)
- Fillers (carbon black, clay, etc.)
- Additives (activators, curing agents, etc.)

Formulators generally tend to focus on enhancing the polymer chemistry to improve the performance characteristics while not giving due consideration to the role of process oil. The process oil is typically one of the more inexpensive components of the EPDM rubber formulation; it functions as an extender and a plasticizer. Process oil improves mixing and curing while softening the finished rubber. It also decreases the viscosity of the rubber mixture improving its processability and makes it easier to incorporate dry ingredients into the mix.

Process oil selection can impact processability, durability, aging characteristics, and end-use performance of the roofing material. Formulators must match plasticizer chemistry with the elastomer to achieve performance goals. The data available regarding the impact of process oil selection on performance characteristics is limited. The challenge is to optimize the processability, physical properties and performance characteristics of EPDM sheet membrane for roofing applications through selection of the most suitable process oil.

The Solution

EPDM is compatible in large amounts with Bright Stock process oils due to the shared low polarity of both the polymer and process oil. Historically, Paraffinic Bright Stocks have been the plasticizer of choice for manufacturers of roofing membranes. A study was conducted to compare the effect of four different process oils on the processability, general properties and performance characteristics of EPDM rubber.

Four identical EPDM compounds were prepared using a standard paraffinic bright stock, HyPrene P150BS, HyPrene V175BS, and HyPrene P300N. HyPrene is the process oil brand of Ergon Refining, Inc. which produces genuine naphthenic and paraffinic oils through distillation of virgin crude followed by a modern, high pressure, severe hydrotreating process. The formulations of the four EPDM compounds were identical except for the process oil used. Table 1 shows the common formulation of the EPDM compounds.

Formulation		
Material	PHR	Batch, g
Royalene 512	100	390
N650	90	351
Soft Clay	80	312
Austin Black 325	25	97.5
Process Oil	**70**	**273**
Zinc Oxide	3	11.7
Stearic Acid	1.25	4.88
MBT	1.5	5.85
TMTM	2	7.8
Sulfur	1	3.9
Total	**373.75**	**1457.63**

Table 1: Formulation of the EPDM compounds produced and tested during the study

The compounds were separately mixed in a 1.6L Banbury mixer, cooled, and sheeted out on a two-roll mill. A sulfur cure system was used for curing. Table 2 shows the properties of the four process oils used in the study. The study measured and compared the characteristics of the EPDM compounds produced using the four process oils with respect to the following:

- Processability
- General Properties
- Performance

Properties	Standard Paraffinic Bright Stock CONTROL	HyPrene P150BS	HyPrene V175BS	HyPrene P300N
Viscosity, cSt at 40°C	540.4	464	974.3	59.9
Flash Point, COC, °C	324	307	296	268
Flash Point, PMCC, °C	280	278	252	235
Pour Point, °C	-24	-7	-12	-18
Density at 15.6°C, g/cm³	0.8868	0.8928	0.9138	0.861
Viscosity Gravity Constant, (VGC)	0.7929	0.8000	0.8193	0.7920
Molecular Weight, g/mole	700	690	731	440
UV Absorptivity at 260 nm	1.81	1.73	2.73	0.1
Sulfur, ppm	1676	83	440	4.0
Refractive Index, 20°C (68°F)	1.4897	1.4916	1.5023	1.4738
Aniline Point, °C	129	128	122	122
Acid Number, mg KOH/g	0.07	0.01	0.01	0.01
Carbon Type Analysis, %, D2140				
C_a	2	4	7	0
C_n	25	26	28	29
C_p	73	70	65	71
Clay-Gels, wt%				
Asphaltenes	<0.01	<0.01	<0.01	<0.01
Polar Compounds	3.7	1.37	3.12	0.42
Aromatics	17.36	22.38	28.09	7.72
Saturates	78.94	76.25	68.79	91.86

Table 2: Physical properties of the four process oils used in the study

Processability

Good processability of EPDM rubber is necessary to ensure an efficient production process which delivers consistently high quality. To compare the processability of the four EPDM compounds, the power requirement during mixing, viscosity, curing behavior, and extrudability of the compounds were examined.

Figure 1 compares the maximum viscosity at 100°C and integrated power requirement, during mixing, for the four EPDM compounds tested. HyPrene P150BS shows the best processability as it has the lowest power requirement. HyPrene V175BS is more viscous than the other neat process oil products; this is the main reason for its higher power requirement. Increasing the mixing temperature by several degrees at the time of compounding can help lower the mixing power requirement and improve the processability of HyPrene V175BS.

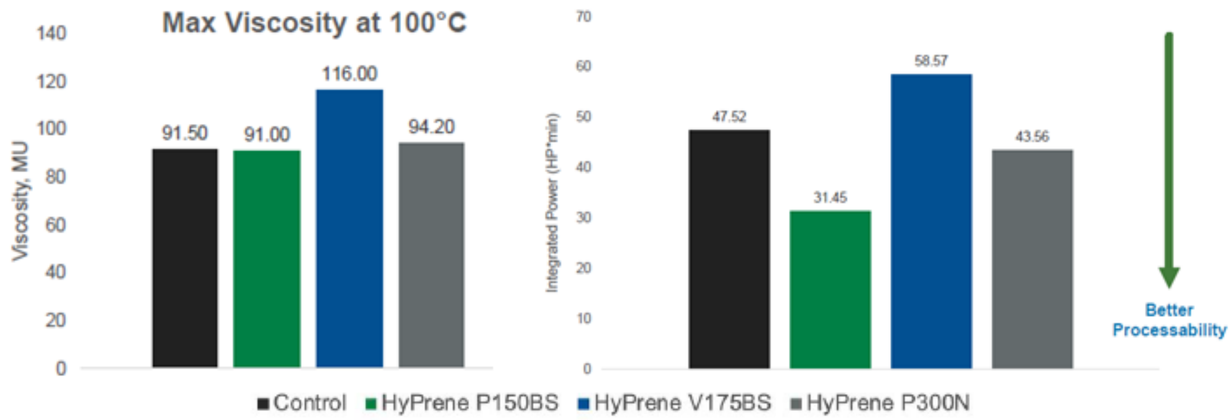

Figure 1: Comparison of the max viscosity and integrated power requirement during mixing

As the compound is worked, heat can build-up in the mixture leading to premature vulcanization of the compound. The time period during which the rubber compound can be safely worked at a given temperature, before curing begins, is called the scorch time. Longer scorch time means better safety margin during processing. The scorch time should not be looked at in isolation; cure time of the compound must also be considered. In order to speed up production, it is desirable to have a short cure time, without excessive scorch risk.

Figure 2 shows the scorch time, max torque, and cure time (50% and 90% cure) for the EPDM compounds based on the four process oils. HyPrene V175BS has the shortest cure time but also has the highest scorch risk. HyPrene P150BS shows the best performance with high scorch resistance and a low T90 cure time. All the samples are likely to have a higher cross-linked density than the control, as indicated by higher max torque. HyPrene P300N shows the highest cross-linking, making it an interesting option.

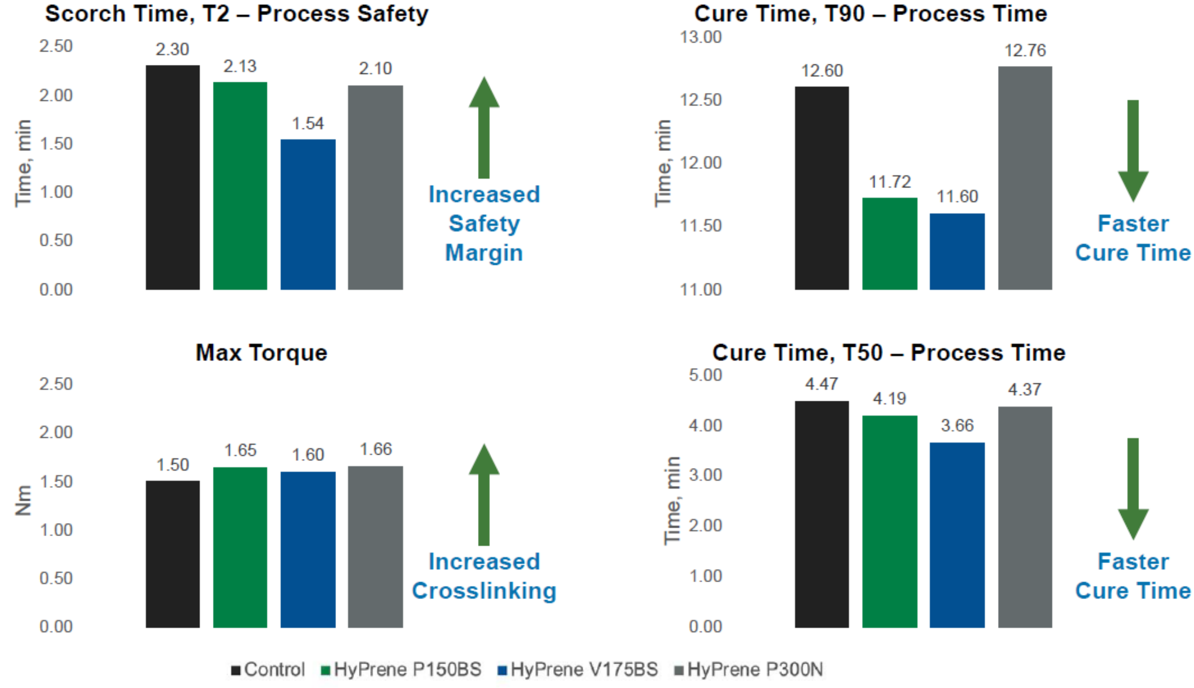

Figure 2: Comparison of scorch time, max torque, and cure time

Figure 3 shows a summary of the performance of the three HyPrene process oils in relation to the control. The control's performance was used as a baseline and assigned a ranking value of 0 for all the summary spider diagram comparisons. If a process-oil performed better than the control, it was assigned a positive value, and if its performance was inferior to the control, a negative value was assigned.

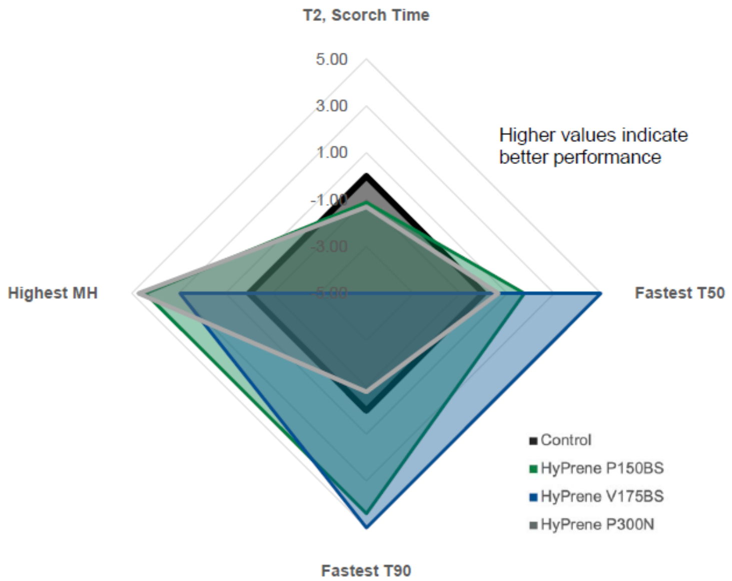

Figure 3: Summary of the performance of the three HyPrene process oils in relation to the control

During production, membrane sheets are formed by calendering or pressing the material between a series of rolls with progressively thinning clearance. In the laboratory, extrusion by Garvey Die was performed as a proxy for calendering; better extrusion properties are indicative of better calendering performance. Each mix was extruded, and the surface and edge quality were rated. The surface was given an alphabetic rating with ‘A’ being the best, and the edge was given a numerical rating with higher meaning better. Figure 4 shows that HyPrene P150BS has both the best surface and the best edge rating indicative of superior extrudability and calendering properties.

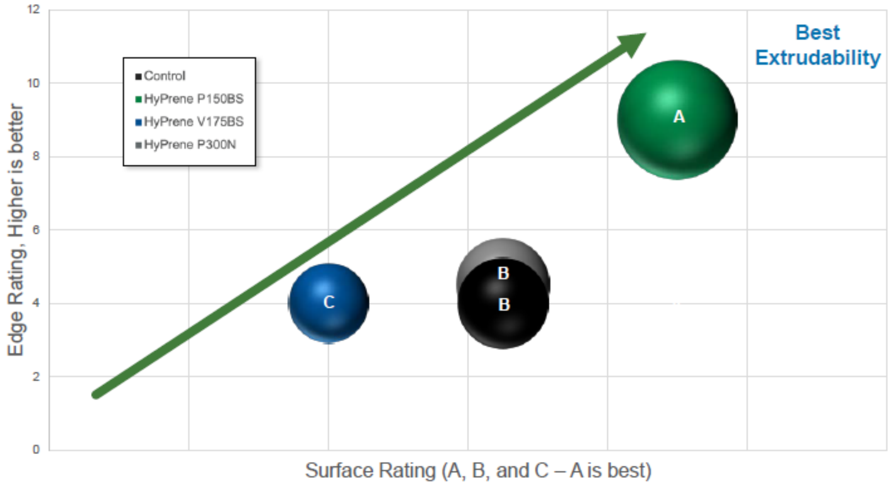

Figure 4: Edge and Surface rating of EPDM extruded using a Garvey Die (ASTM D2230)

Figure 5: Comparison of the edge and surface of samples produced using HyPrene P150BS and control

General properties

When formulating an EPDM compound, it is critical to ensure that the standard properties are within the desirable range. One of the basic specification metrics is durometer shore A hardness. Roofing membranes should have a shore A hardness between 70 – 75 points. In this study, both the original and aged shore A values were within the desirable range for all samples tested (Figure 6).

The tensile strength, ultimate elongation, and modulus were also measured for each cured specimen. Figures 6 shows that HyPrene V175BS has the highest initial tensile strength. The control exhibits the highest ultimate elongation, followed by HyPrene P150BS.

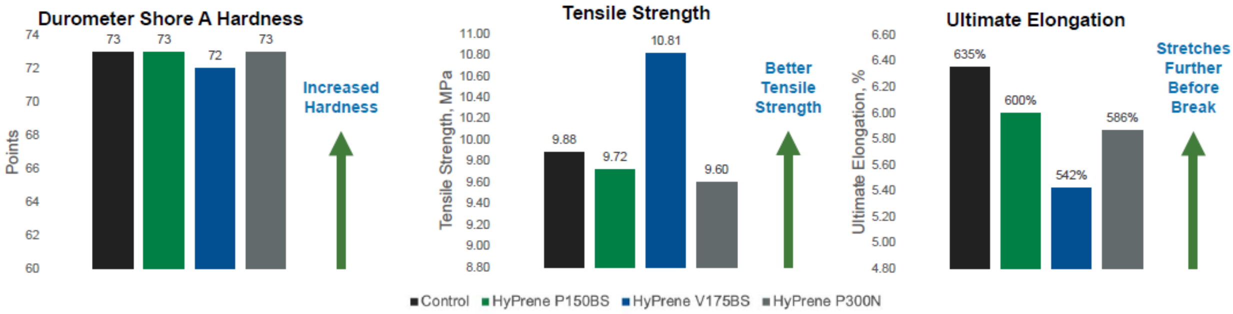

Figure 6: Comparison of the Shore A hardness, tensile strength, and ultimate elongation

Figure 7 shows that HyPrene V175BS offers the advantage of increased modulus (50% & 100%). HyPrene P150BS also shows an original modulus advantage compared to the control.

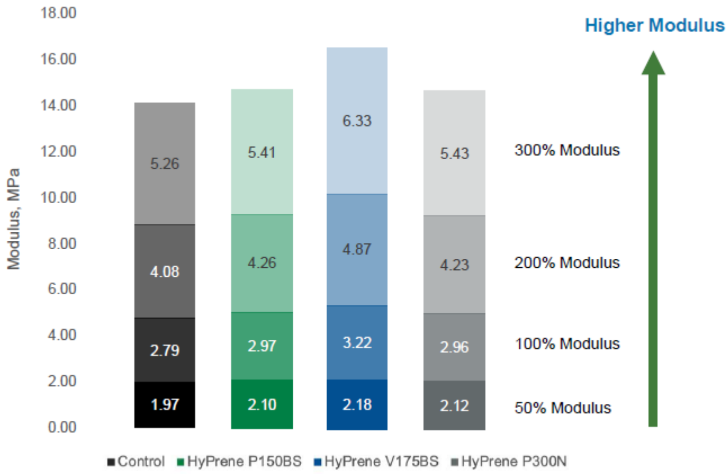

Figure 7: Comparison of the modulus for the four specimens

Performance

Tear and puncture resistance properties are essential for a roofing membrane to help endure the stress of transportation, installation and traffic. To examine how the studied materials will perform in a roofing membrane application, puncture resistance, tear resistance and heat aged tear, tensile strength, and ultimate elongation were measured.

As shown in Figure 8, all HyPrene based samples exhibit significantly improved puncture resistance in comparison to the control. HyPrene P150BS shows the best puncture resistance followed by HyPrene V175BS.

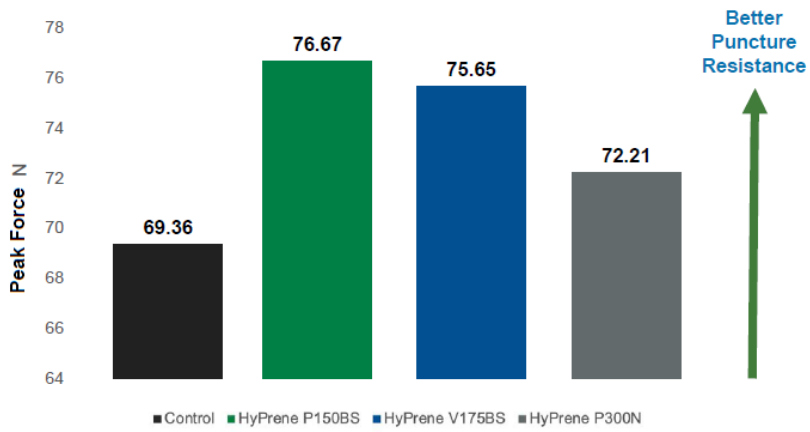

Figure 8: Comparison of puncture resistance. Peak force is the force required to puncture the specimen

To test heat aged properties, all samples were aged for 70 hours at 100 °C in an air oven. Figure 9 shows that the control produces the highest aged ultimate elongation while HyPrene V175BS shows the highest aged tensile strength.

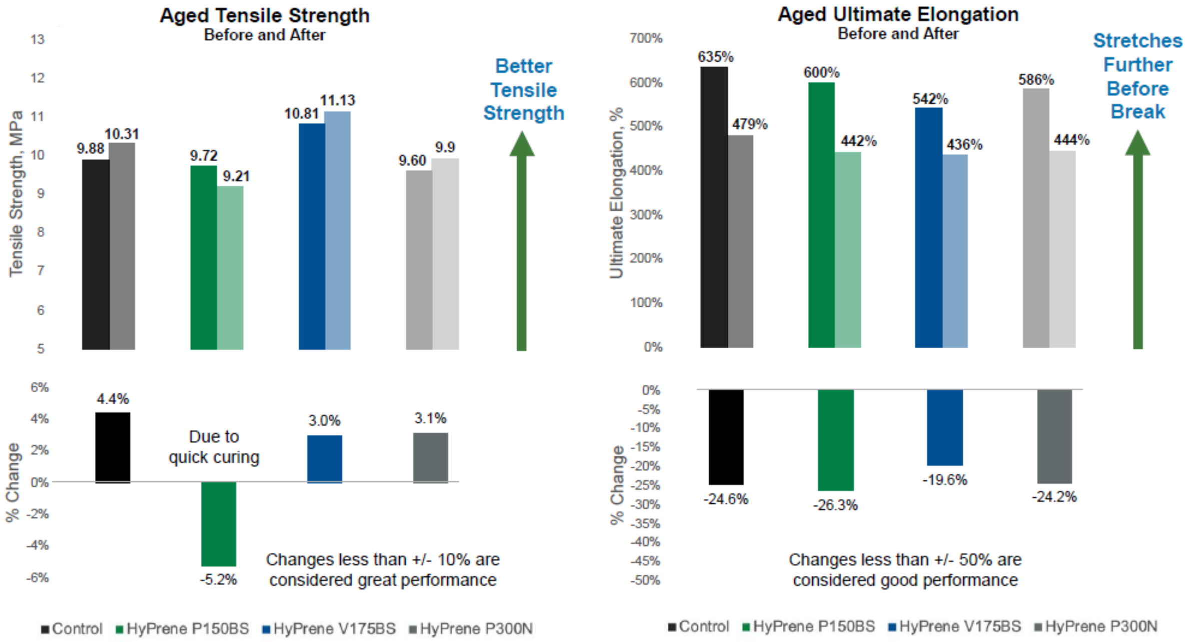

Figure 9: Comparison of heat-aged tensile strength and heat aged ultimate elongation (ASTM D573)

Tear B and Tear C tests were performed to evaluate tear propagation resistance and tear initiation resistance. As indicated by the tear B data, HyPrene V175BS offers high resistance to tear propagation compared to the control.

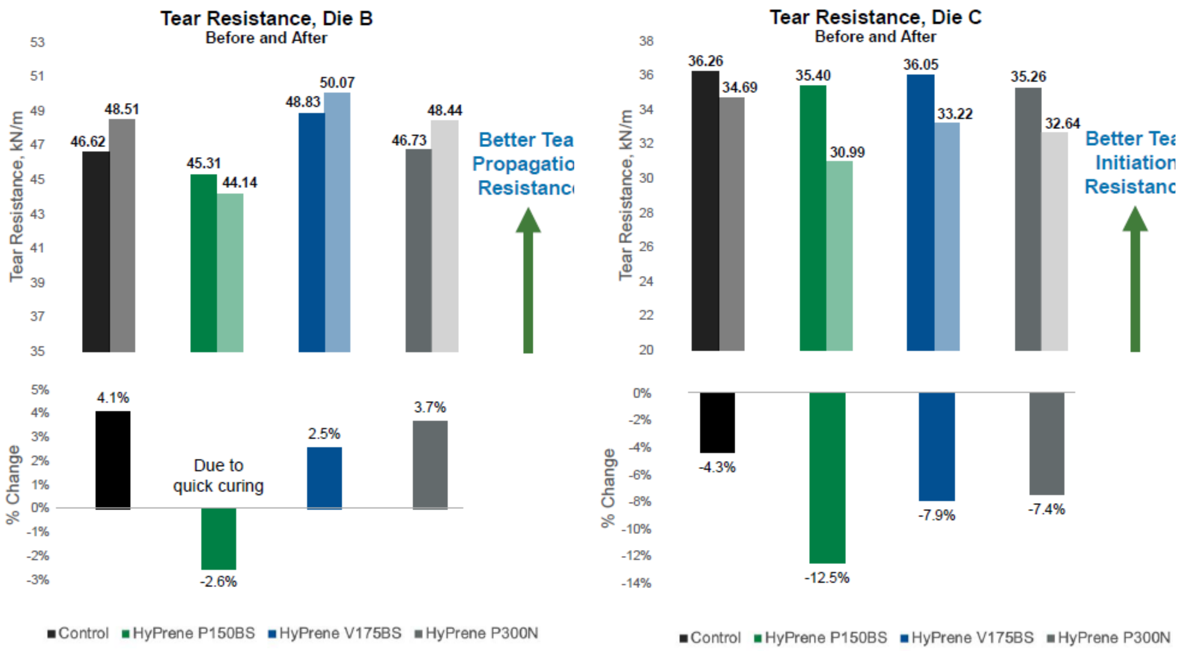

Figure 10: Comparison of heat aged tear propagation resistance (Tear B) and tear initiation resistance (Tear C)

It is important to ensure that the EPDM material retains its properties after heat aging as the roof is exposed to high temperatures when installed in hot climates. In heat aging tests, HyPrene V175BS shows the least amount of absolute value change in the specimen's properties of all the samples tested.

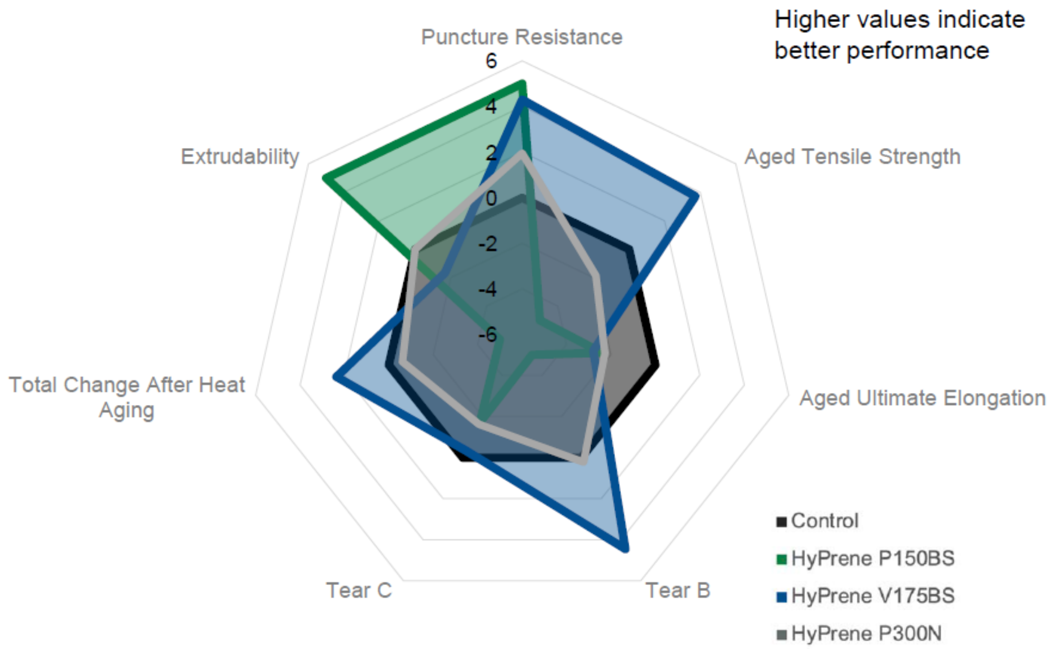

Figure 11: Performance summary of the samples tested

Conclusions

HyPrene bright stocks offer significant advantages over the industry-standard paraffinic bright stock. HyPrene V175BS improves cure time, heat aged tensile strength and modulus properties. It also enhances tear resistance before and after heat aging. HyPrene P150BS shows the best extrudability and puncture resistance. HyPrene P150BS and HyPrene V175BS are attractive alternatives to the industry standard paraffinic bright stock for roofing applications. The process oils offer formulators of EPDM rubber, cost efficient options for improving the essential properties of their material.

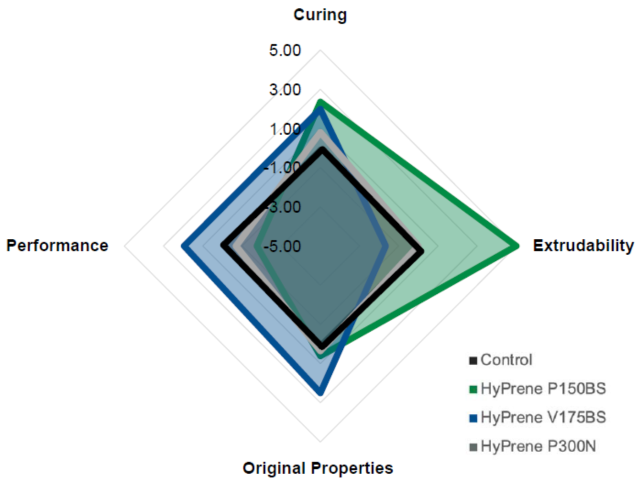

Figure 12: Overall comparison of original properties, curing behavior, performance, and extrudability