# Thermax® N990 in EPDM PEM Cell Stack Gaskets

Polymer electrolyte membranes (PEM) are used in fuel cells and in electrolysis. A PEM fuel cell contains membrane electrode assemblies (MEA) which consist of electrodes, electrolyte, catalyst, and gas diffusion layers. During operation, hydrogen enters on the anode side where it is split into protons and electrons. The protons permeate though the PEM to the cathode side. The electrons travel along an external circuit to the cathode side. This flow of electrons represents the current output of the fuel cell which can be used to supply power to vehicles, homes, etc. On the cathode side, a stream of oxygen is delivered which reacts with the protons passing through the PEM and the electrons arriving through the external circuit to form water. In an electrolysis PEM, the opposite process occurs, inputting water and electricity to create hydrogen and oxygen. This is viewed as a source of green hydrogen (hydrogen produced using renewable energy).

In practice, a number of PEM cells will be combined into a stack to meet the product requirements. As part of this stack, there are elastomeric gaskets within each cell which prevent the reactant gases from leaking. Elastomers that are potentially suitable for this application include EPDM, silicone, FKM, and some TPEs. Requirements for the gasket compound include good processability, resistance to acids, resistance to humidity, hydrogen stability, heat resistance and thermal stability, low temperature flexibility, low compression set, good outgassing characteristics, and high electrical resistivity.

## The benefits of Thermax® N990 found in this study include:

- Reduction in mixing power consumption as compared to furnace grade carbon blacks
- Improvement in dispersion
- Lower viscosity compared to silica
- Increased modulus
- Increased tensile strength and toughness
- Good compression set and low temperature flexibility
- Increased heat resistance
- Increased chemical (acid) resistance
- High volume resistivity
- Extension of polymer leading to potential cost reduction

The EPDM formulations can be found in Table 1. Four different fillers were tested, N550, N762, N990, and a precipitated silica. Loadings were set to achieve a compound hardness of 55. Mooney viscosity, capillary rheometry, MDR, Shore A hardness, tensile, heat aging, acid resistance, compression set, compressive stress relaxation, and electrical resistivity tests were run on all compounds. Testing results can be found in the figures on the following pages. The compounding and testing were completed at Smithers in Akron, Ohio.

**Table 1. EPDM formulations**

| Ingredient | N550 | N762 | N990 | Silica |
|---|---|---|---|---|
| Keltan 4450S | 100.0 | 100.0 | 100.0 | 100.0 |
| N550 | 20.0 | - | - | - |
| N762 | - | 25.0 | - | - |
| **Thermax® N990** | **-** | **-** | **45.0** | **-** |
| Mansil-030 | - | - | - | 20.0 |
| DOP | 9.0 | 9.0 | 9.0 | 9.0 |
| Antioxidant S | 1.1 | 1.1 | 1.1 | 1.1 |
| Akrosorb 19251 (72% TAIC) | 4.9 | 4.9 | 4.9 | 4.9 |
| VC 40K | 4 | 4 | 4 | 4 |
| **Total** | **139.0** | **144.0** | **164.0** | **139.0** |

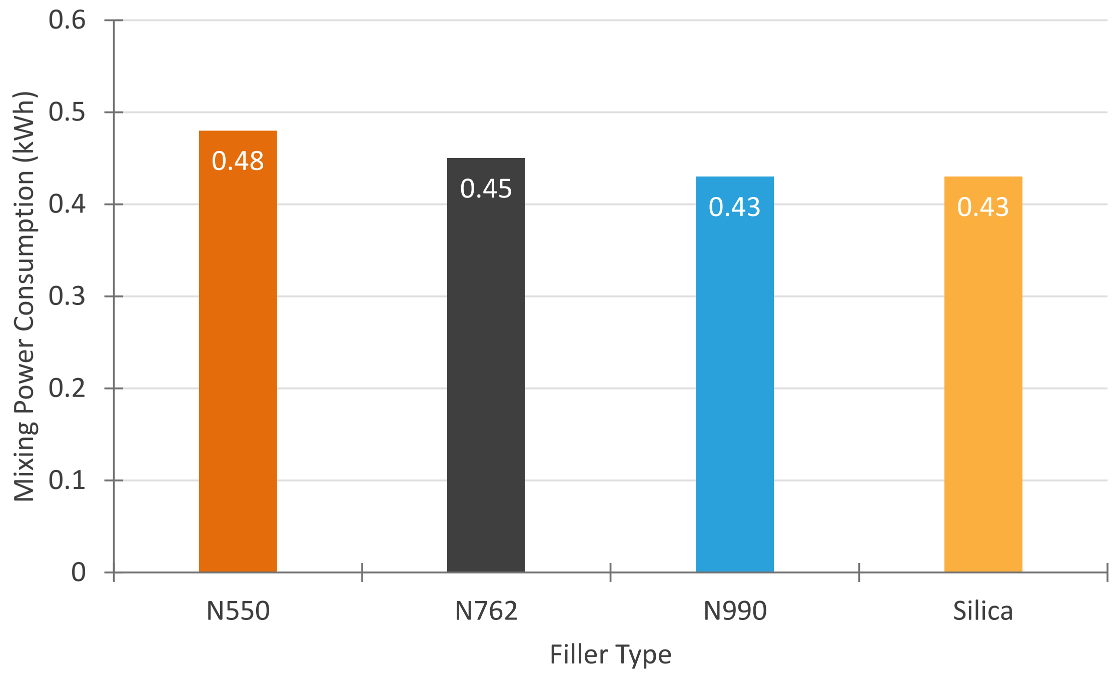


**Figure 1.** Mixing power consumption of the compounds. Power consumption of the N990 and silica compounds was lower than the N550 and N762 compounds.

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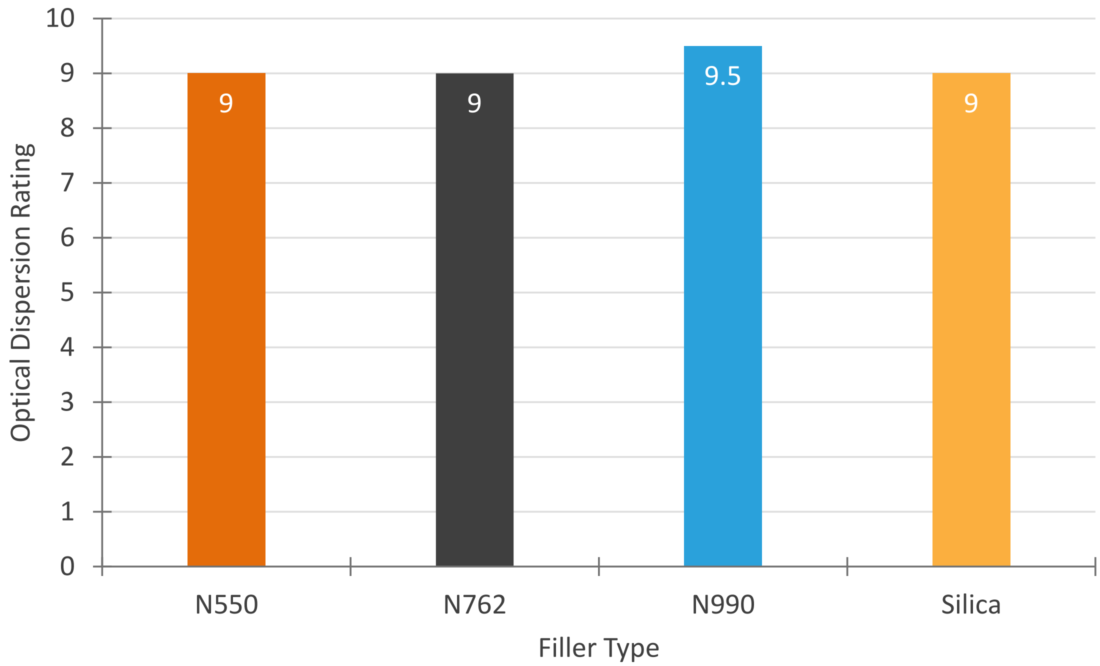


**Figure 2.** Optical dispersion rating of the compounds. All compounds were dispersed well. The N990 compound had the best dispersion rating.

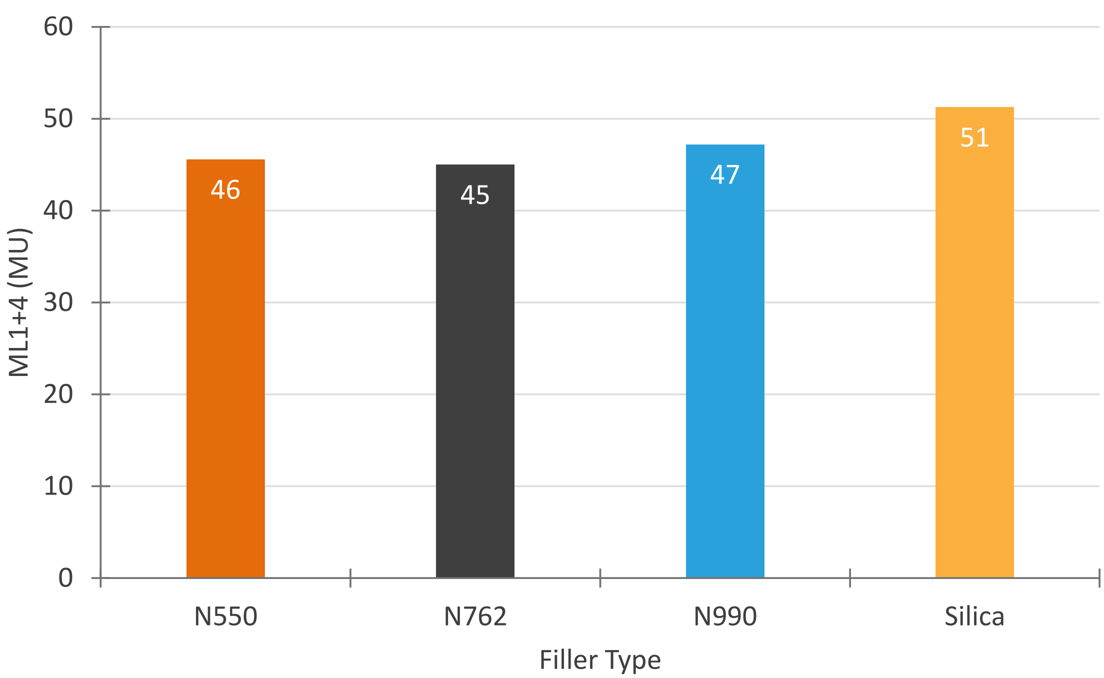


**Figure 3.** Mooney viscosity of the compounds. The silica compound had significantly higher viscosity than the other compounds.

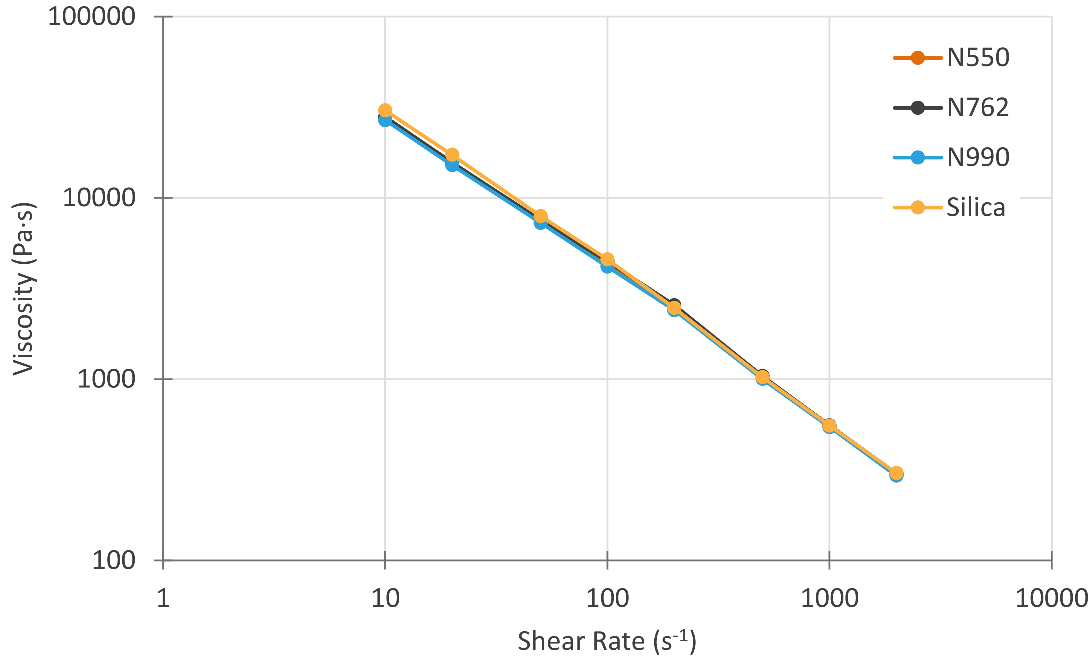


**Figure 4.** Steady state viscosity versus shear rate of the compounds measured on a capillary rheometer at 100°C with a 1 mm die. At low shear rates, the viscosity of the silica compound was significantly higher than the other compounds. At high shear rates, the viscosities aren't significantly different.

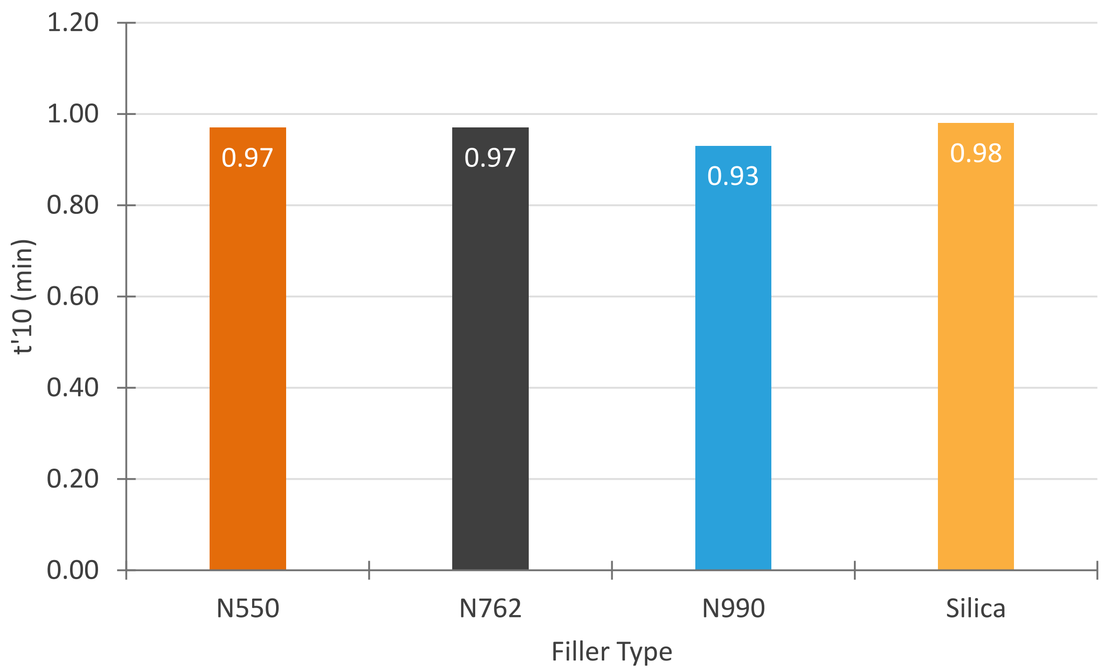


**Figure 5.** Scorch time, t'10, of the compounds measured on an MDR according to ASTM D5289. The N990 compound had a slightly shorter scorch time than the other compounds.

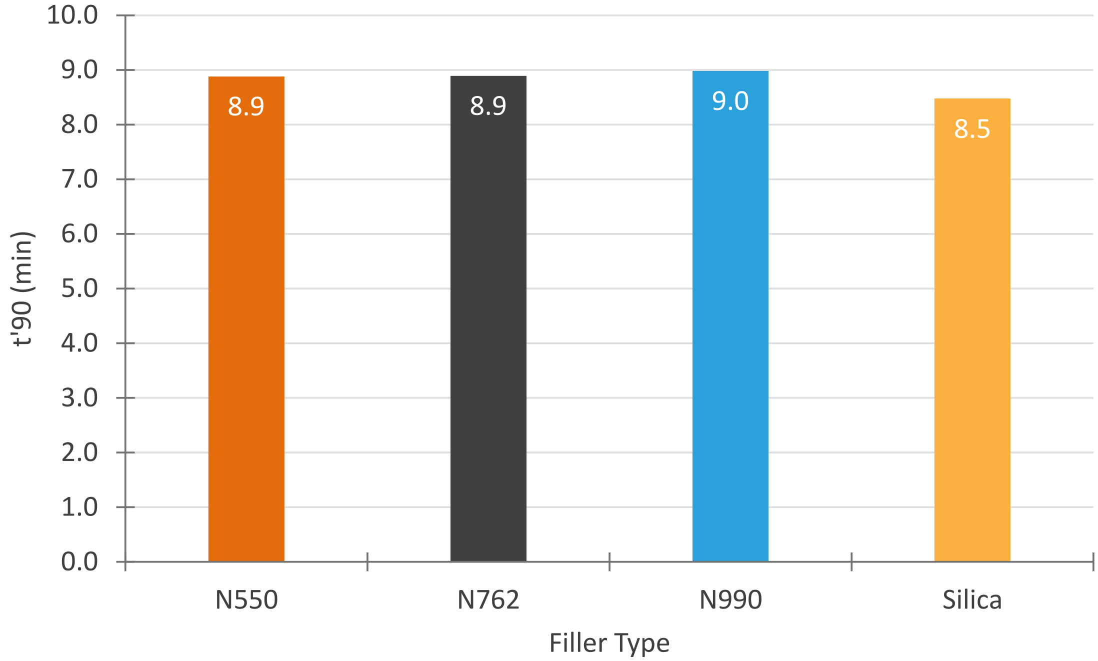


**Figure 6.** Cure time, t'90, of the compounds measured on an MDR according to ASTM D5289. The silica compound had a shorter cure time than the other compounds.

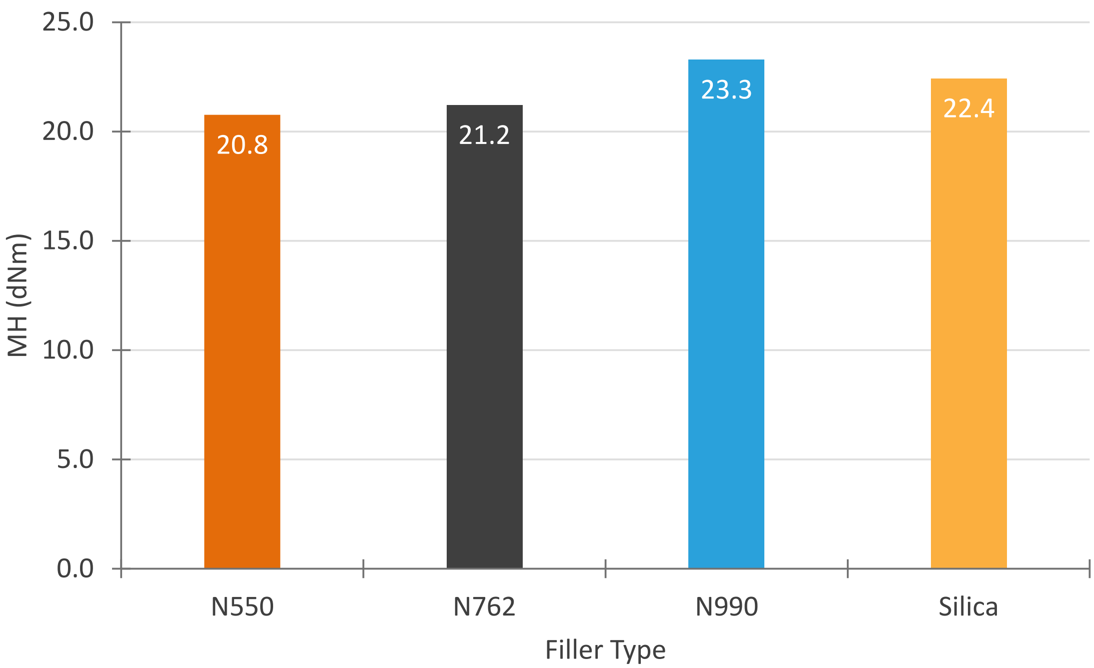


**Figure 7.** Maximum torque, MH, of the compounds measured on an MDR according to ASTM D5289. The N990 compound had the highest MH followed by the silica compound.

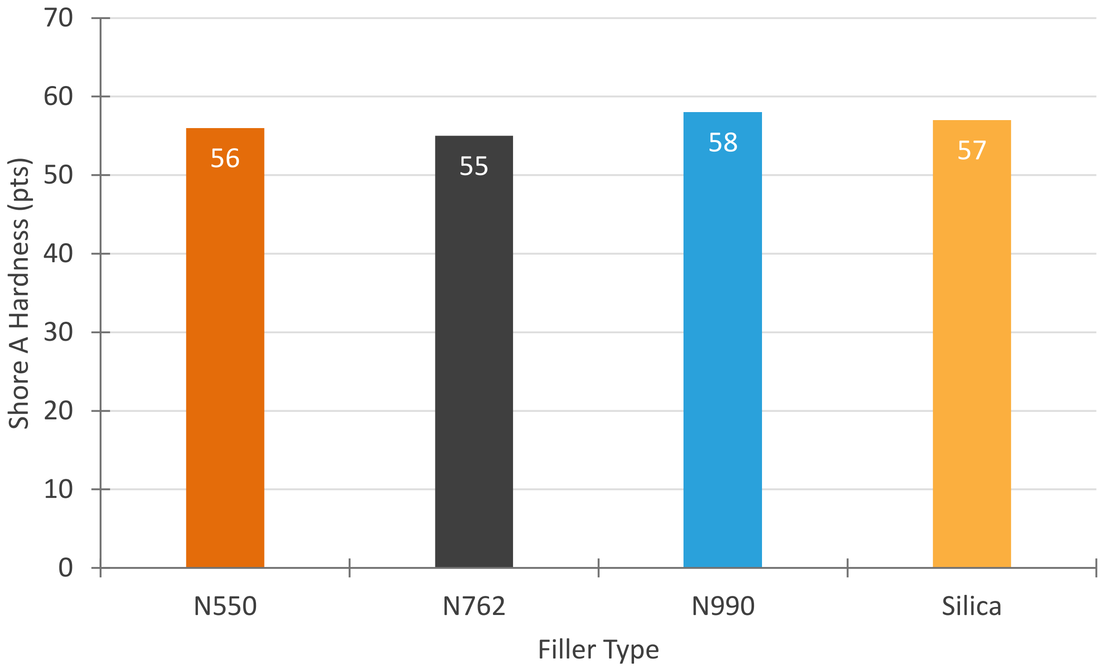


**Figure 8.** Shore A hardness of the compounds measured according to ASTM D2240. Hardness values were all within 55±3 points.

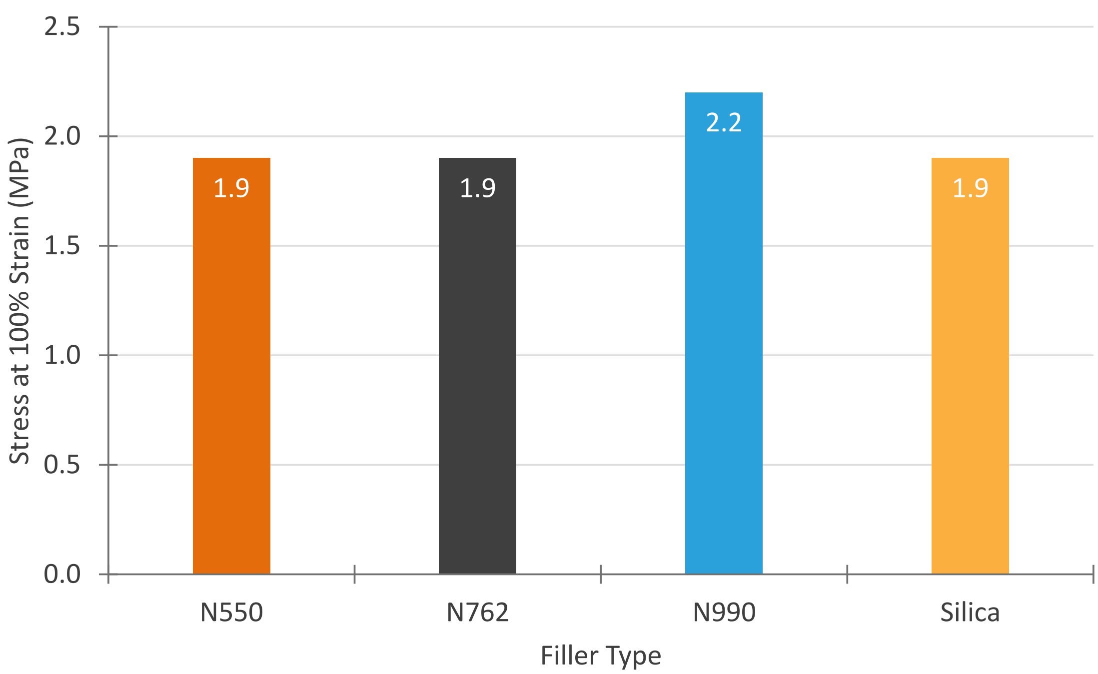


**Figure 9.** Stress at 100% strain of the compounds measured according to ASTM D412. The N990 compound had higher 100% modulus than the other compounds.

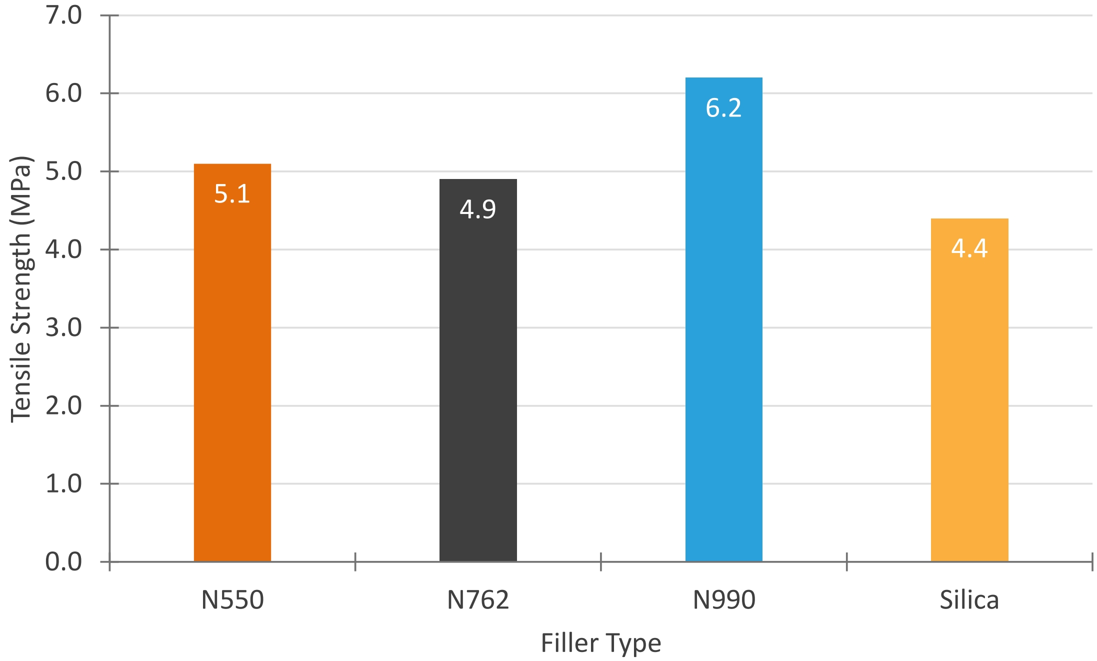


**Figure 10.** Tensile strength of the compounds measured according to ASTM D412. Tensile strength was highest for the N990 compound. The silica compound had the lowest tensile strength.

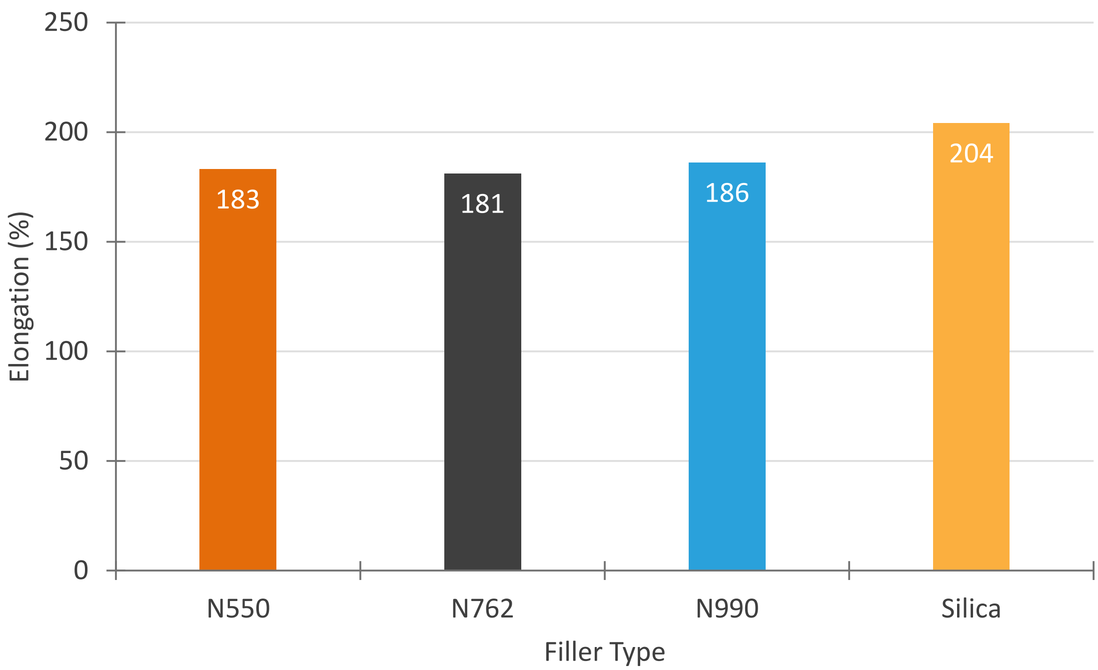


**Figure 11.** Elongation at break of the compounds measured according to ASTM D412. Elongation was similar for the carbon black compounds. The elongation of the silica compound was higher.

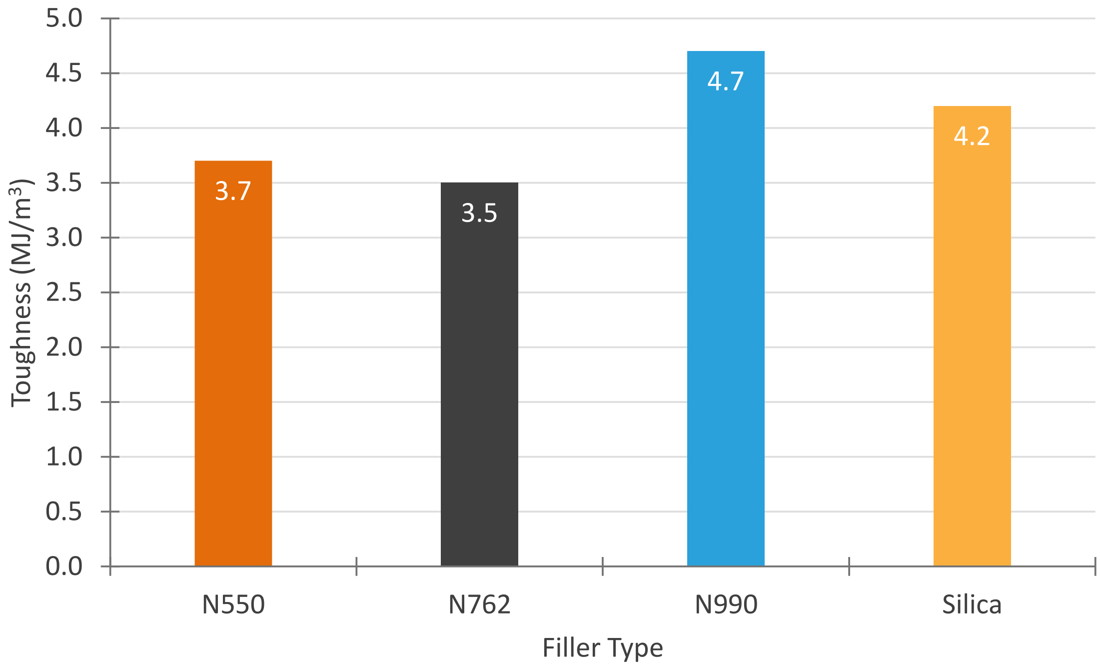


**Figure 12.** Toughness of the compounds measured by tensile testing according to ASTM D412. Toughness is the area under the stress/strain curve. The N990 compound had the highest toughness.

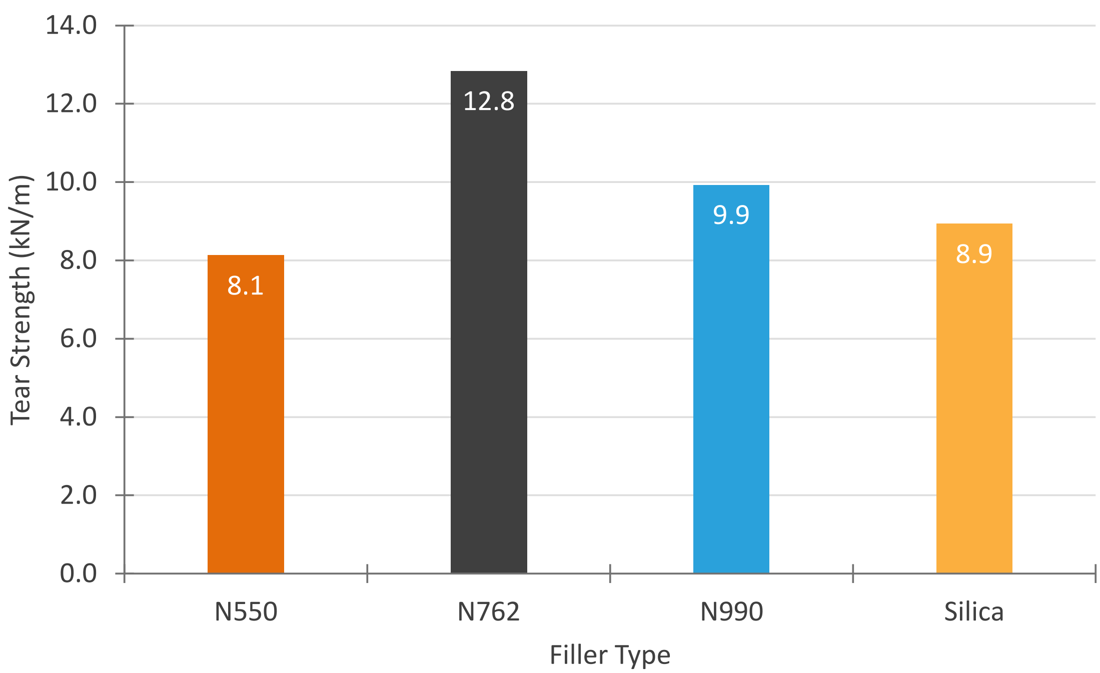


**Figure 13.** Tear strength of the compounds measured according to ASTM D624. The N762 compound had the highest tear strength followed by the N990 compound.

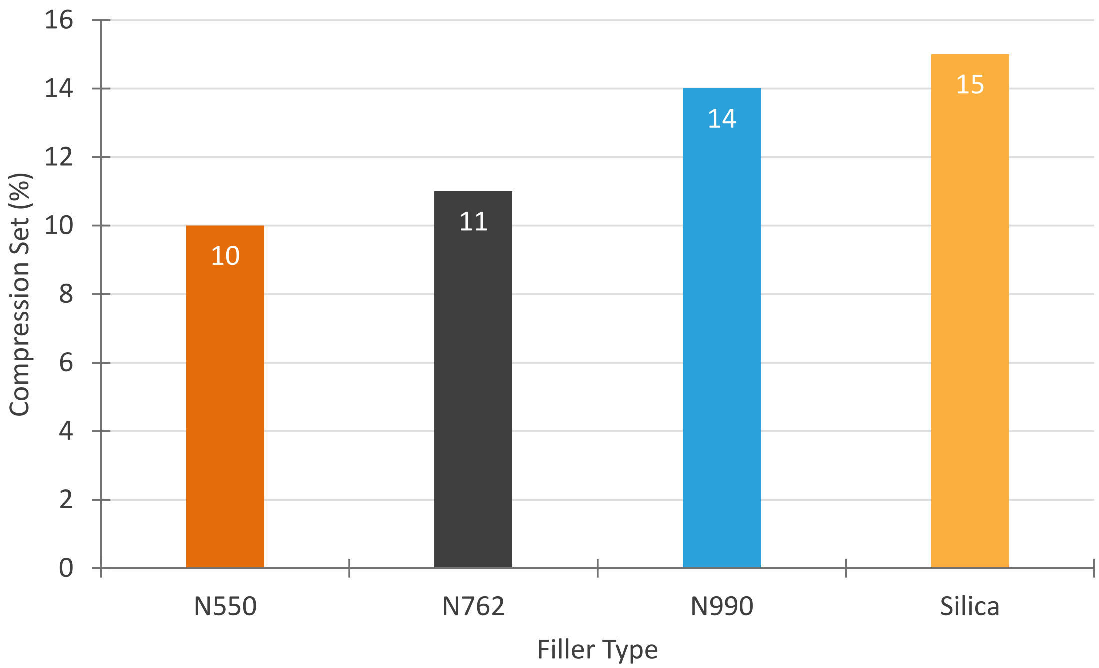


**Figure 14.** Compression set of the compounds measured after 72 hours at 140°C according to ASTM D395. The silica compound had the worst compression set followed by the N990 sample. The worse compression set of the N990 compound as compared to the other carbon black compounds was due to the compound's higher total filler loading.

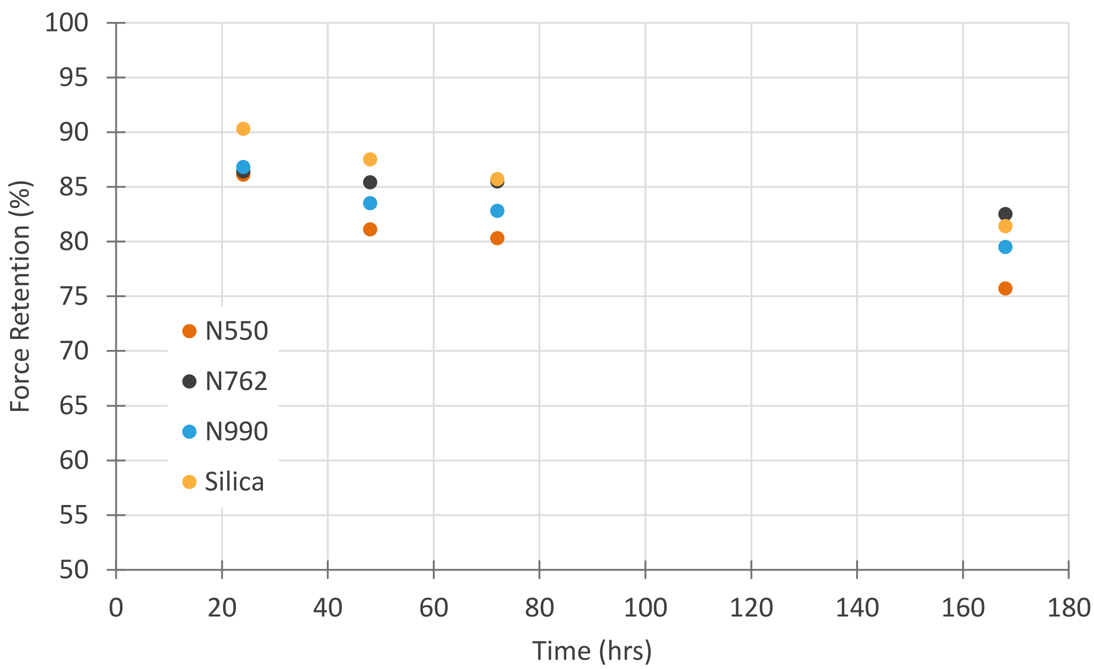


**Figure 15.** Compressive stress relaxation of the compounds measured at 120°C according to ASTM D6147. After 168 hours, the N550 compound had the lowest force retention %. The best performance was had by the N762 compound followed by the silica compound and N990 compound.

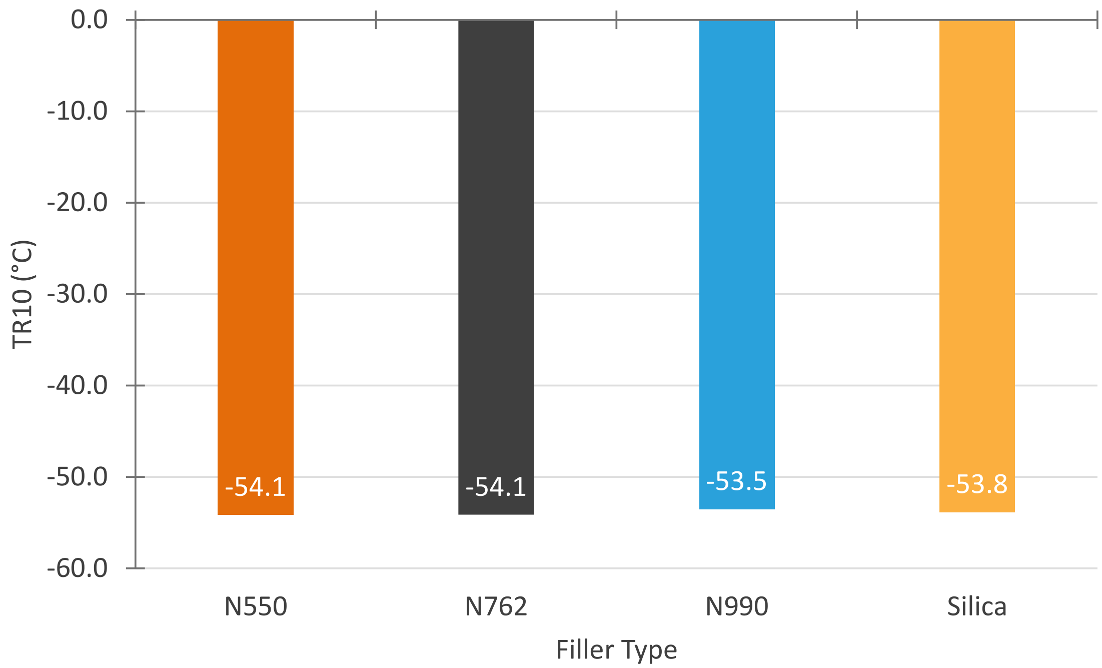


**Figure 16.** TR10, the temperature at which the vulcanizate retracts 10%, of the compounds measured according to ASTM D1329. All compounds had similar TR10 values. The TR10 correlates to the brittle points and low-temperature flexibility of compounds.

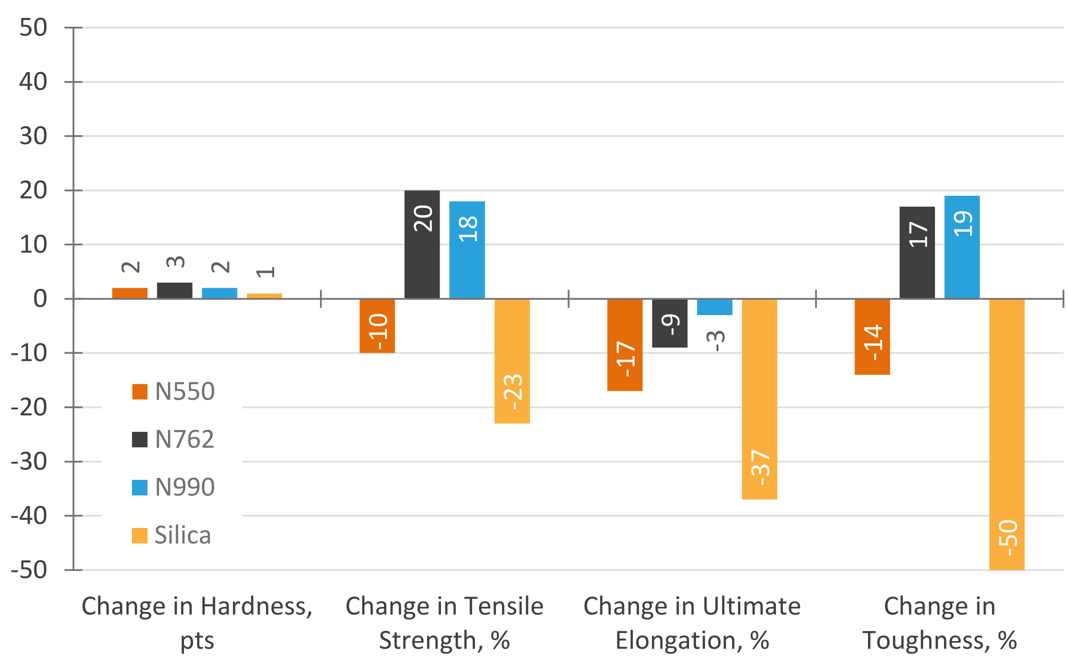


**Figure 17.** Change in properties after heat aging for 168 hours at 140°C according to ASTM D573. All compounds had minimal change in hardness. The N990 compound had an increase in tensile strength and toughness and a minimal decrease in elongation. The silica compound had significant reductions in tensile strength, elongation, and toughness.

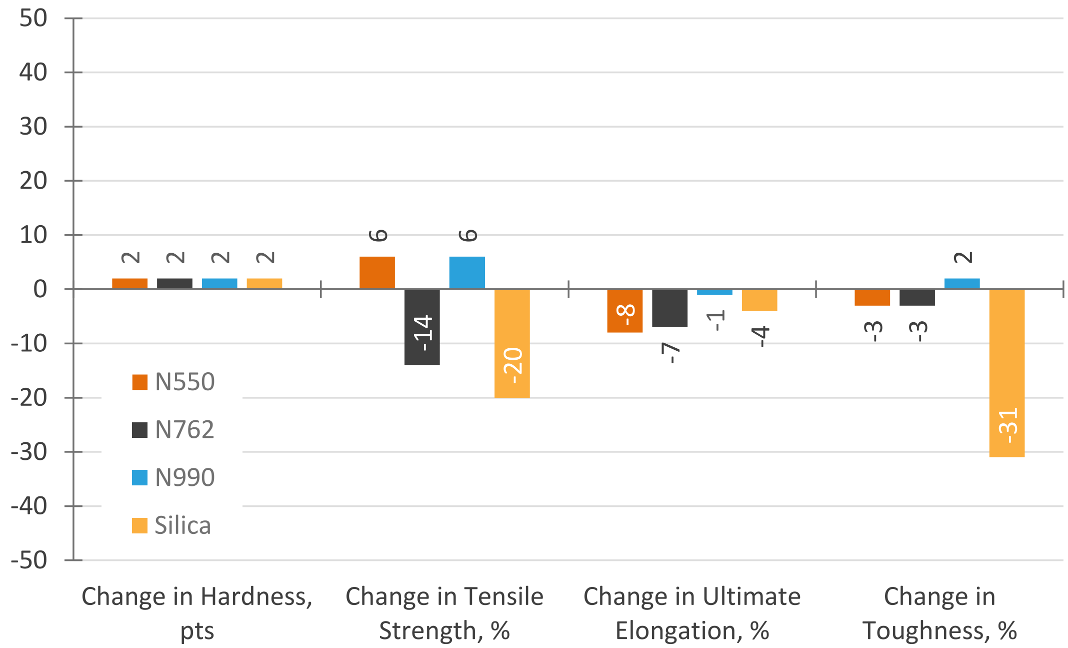


**Figure 18.** Change in properties after fluid immersion in sulfuric acid (pH = 2) for 168 hours at 140°C according to ASTM D471. All compounds had minimal change in hardness. The N990 compound had an increase in tensile strength and toughness and a minimal decrease in elongation. The silica compound had significant reductions in tensile strength and toughness.

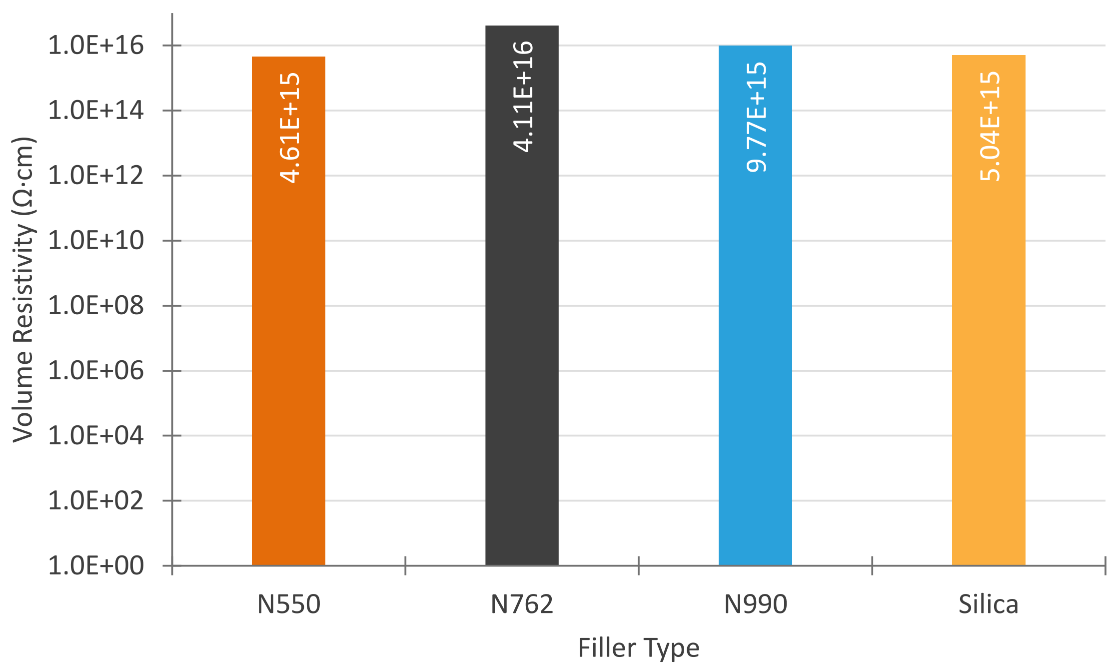


**Figure 19.** Volume resistivity of the compounds measured according to ASTM D257. All compounds were insulative.