CHEM TECHNOLOGIES, LTD.

Beyond the obvious from innovation to application

Chem Technologies High Dispersible Crystex® Bead

Technical Report

CTR-06002

October 2006 (updated December 7, 2008

Confidential to Chem Technologies

- **Crystex® is a tradename of Flexsys' insoluble, amorphous sulfur.**
- **The Chem Technologies bead product uses the Crystex® HS OT 20 as the active ingredient.**
- **Chem Technologies also makes a Crystex® bead with Crystex® HD OT 20 as the active ingredient.**
- **Chem Technologies also makes a bead dispersion of rhombic Rubbermaker's sulfur.**

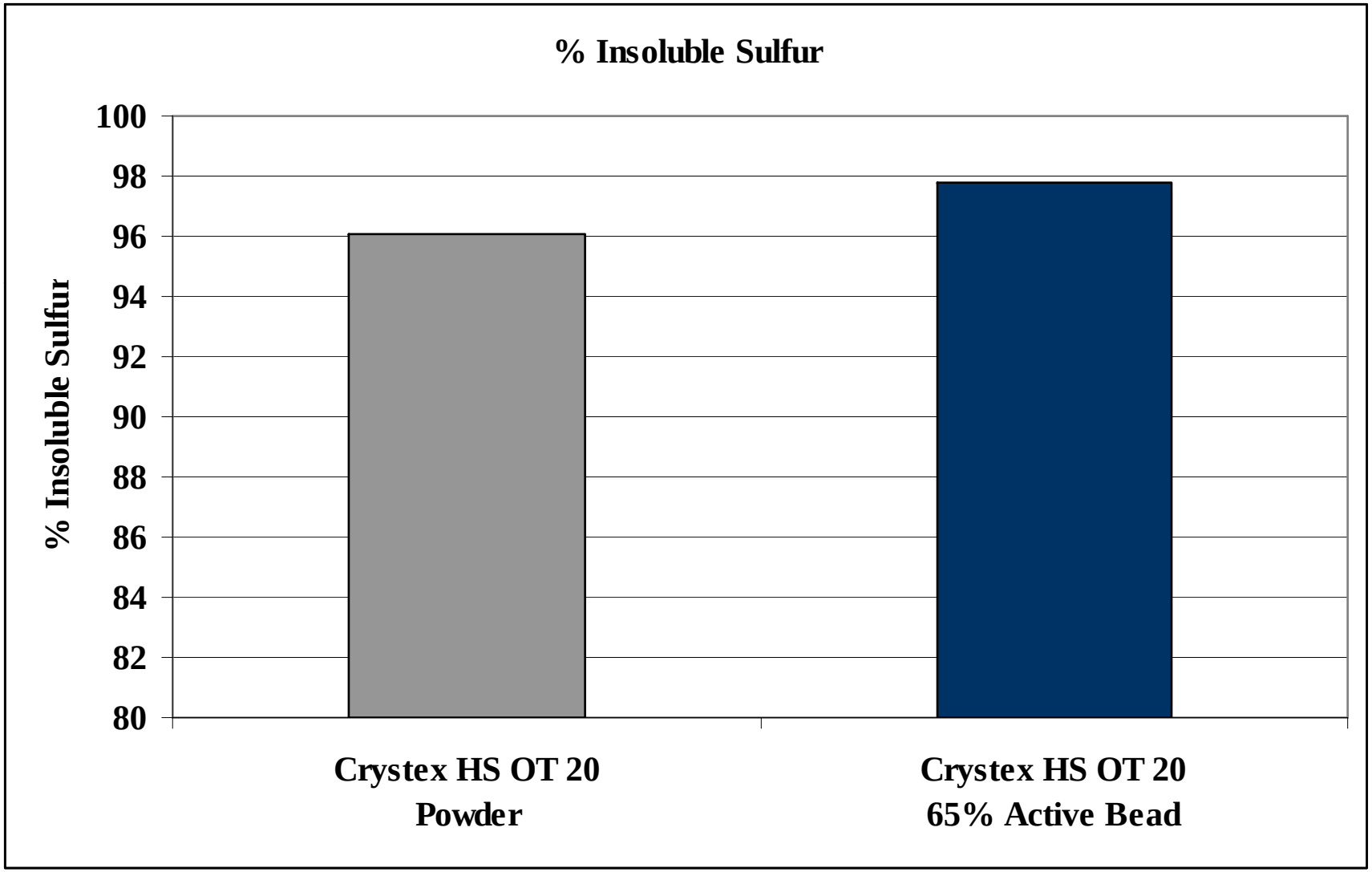
Crystex® Bead Dispersion Study

- Crystex® sulfur is often used in rubber compounds where sulfur bloom cannot be tolerated such as compounds that require high degree of tack or adhesion.
- Crystex® sulfur is very difficult to disperse into rubber because of its fine particle size. It is recommended that lower mixing speeds and longer mixing times are used when mixing compounds with Crystex®.
- Chem Technologies has made 65% active bead dispersion of Crystex® OT 20 sulfur (52% total Crystex® sulfur) that disperses more easily into rubber.
- Polymer bound dispersions of Crystex® are available but some of Crystex® sulfur is converted to rhombic rubbermaker's sulfur during the high temperatures seen in mixing.
- Chem Technologies bead products are made at low temperatures (100 F or less).
- The laboratory studies included analytical analysis of the bead product to determine % retained Crystex® sulfur.
- The Crystex® bead dispersion was evaluated versus the control Crystex® HS OT powder in both a NR steel belt coat compound and a NR/BR compound.

Dispersion & Bloom in Both NR & NR/BR Compounds

	Crystex® HS OT20 Powder	*Crystex® HS OT20 65% Bead (52% total sulfur)*
Dispersion	**Good**	**Excellent**
Bloom	**Slight**	**No Bloom**

The Crystex® bead product has the same % of insoluble sulfur as the original control Crystex® HS OT 20 powder. Chem Tech is able to maintain the level of insoluble sulfur because the process to make the bead dispersion sees temperatures of less than 100°F.



Measurement of Dispersion

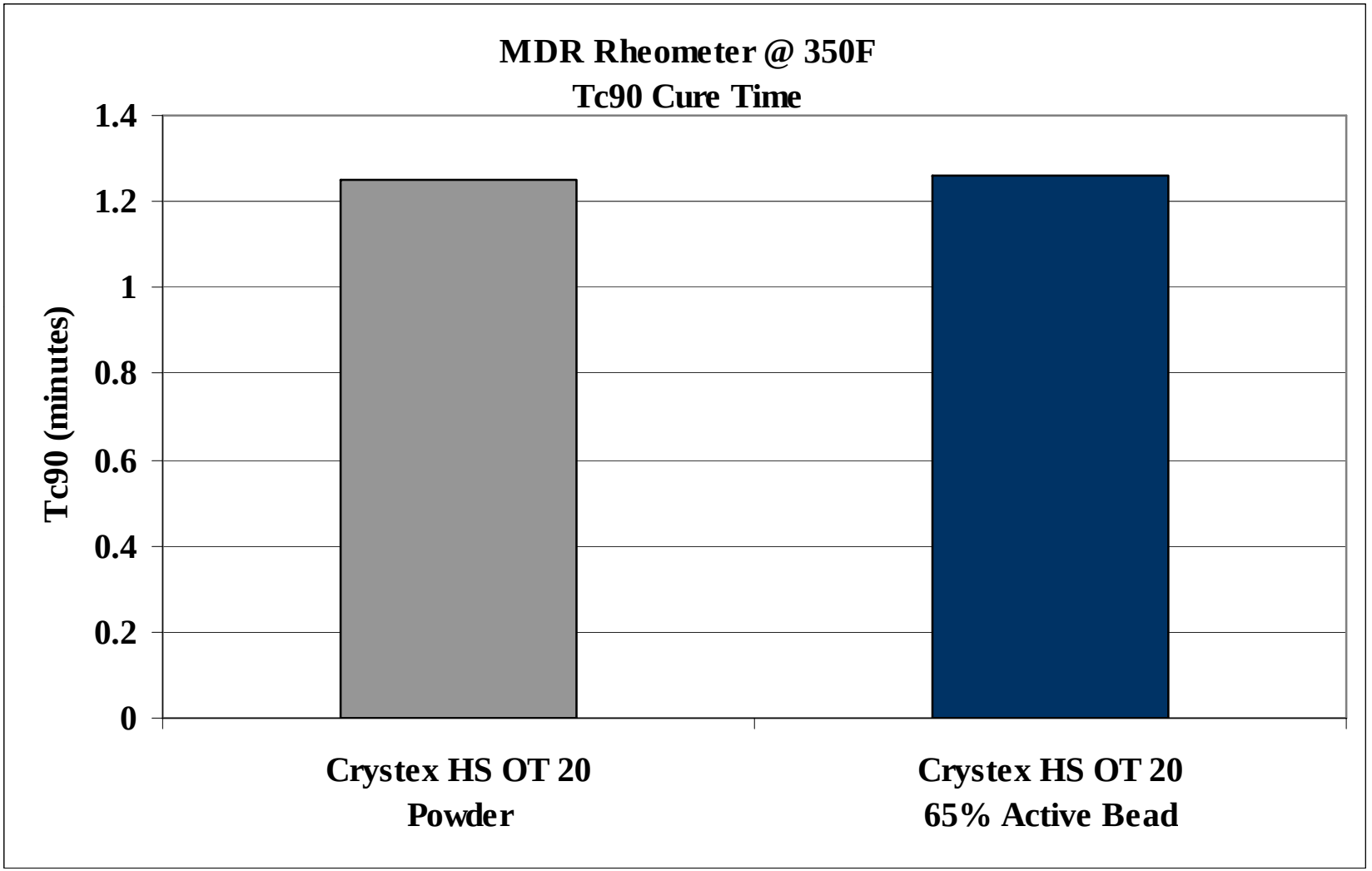
- Higher tensile and elongation are indications of better dispersion in a rubber compound.
- A good measurement of dispersion is to divide the tensile or elongation by the standard deviation of tested tensile samples.
- A higher number indicates better dispersion in the rubber.

NR / BR Compound

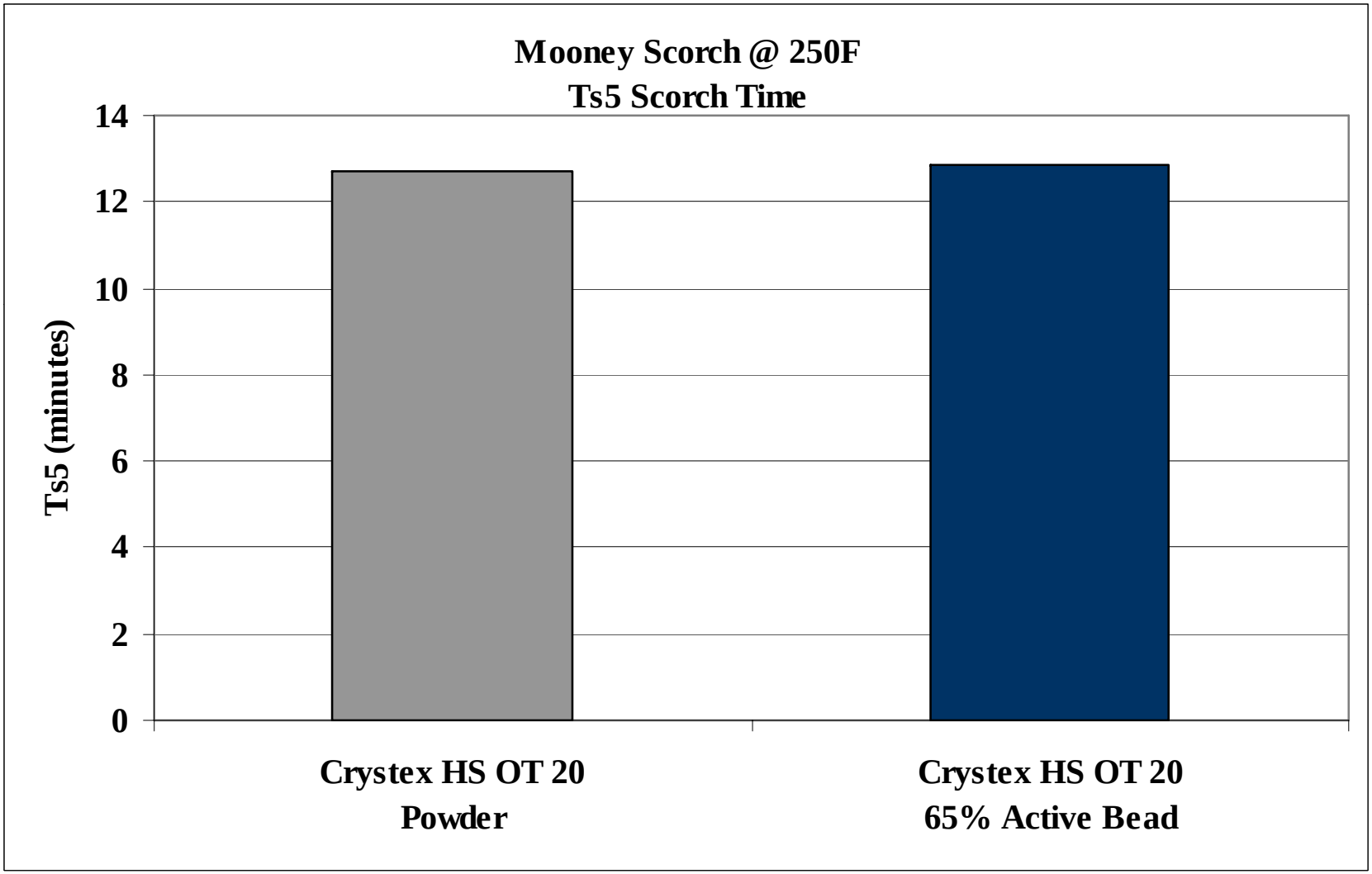
Ingredient	Crystex® HS OT 20 Powder	Crystex® HS OT 20 Bead 65% Active
• Natural Rubber	50.00	50.00
• High Cis-polybutadiene	50.00	50.00
• N330 Carbon Black	50.00	50.00
• Naphthenic Oil	9.25	4.62
• Stearic Acid	2.00	2.00
• IPPD Antiozonant	2.00	2.00
• 6PPD Antiozonant	2.00	2.00
• Microcrystalline Wax	2.00	2.00
• Zinc Oxide	3.00	3.00
• TBBS Accelerator	1.50	1.50
• Crystex® HS OT 20 Powder	3.75	
Or	(3 phr sulfur)	
• Crystex® HS OT 20 Bead		4.62 (2.4 phr sulfur)

- The extra oil from 65% active bead product was compensated for in the formulation.

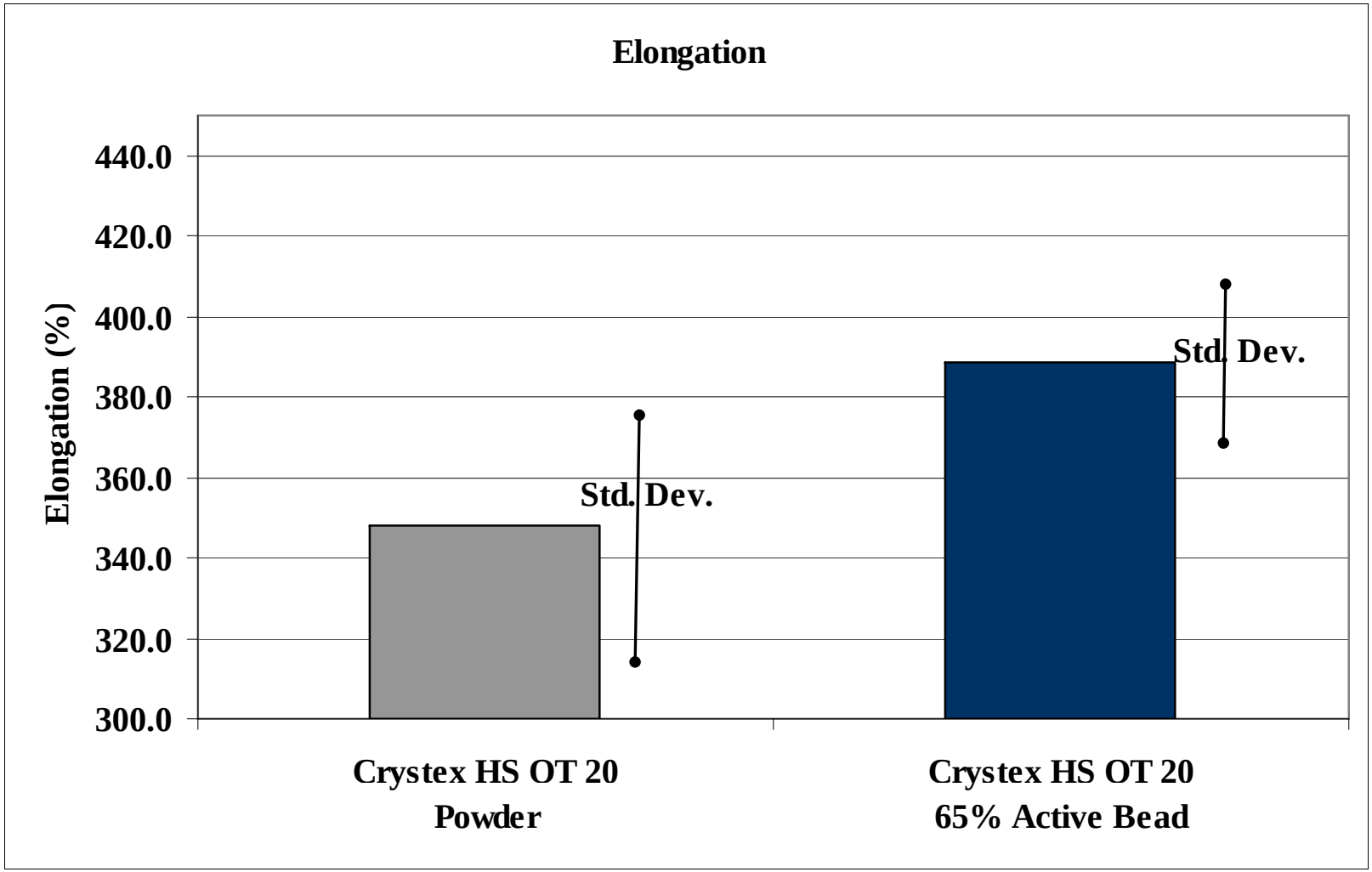
The Crystex® bead compound has similar T90 cure time to the Crystex® powder control compound.



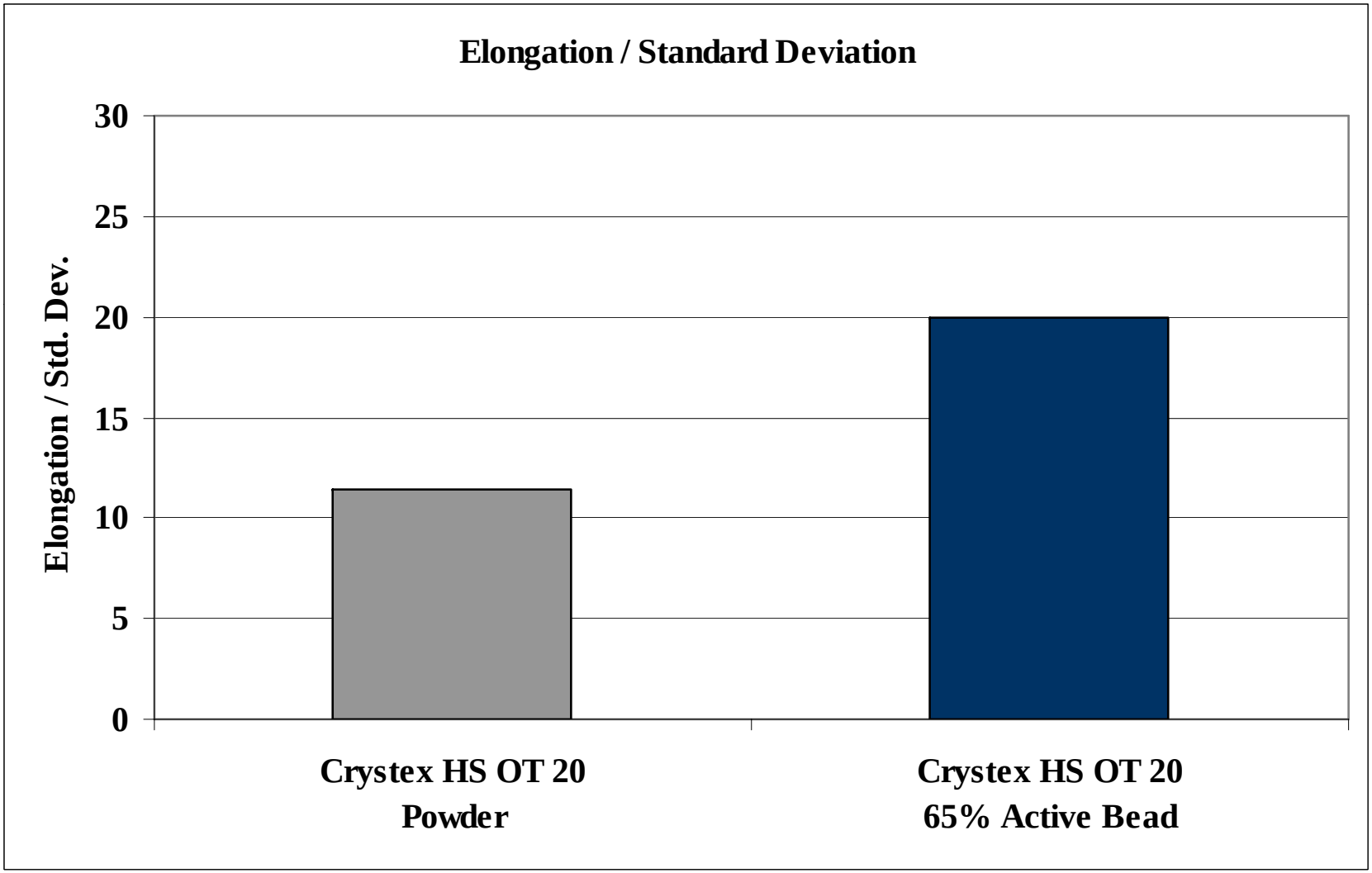
The Crystex® bead compound has similar Ts5 scorch time to the Crystex® powder control compound.



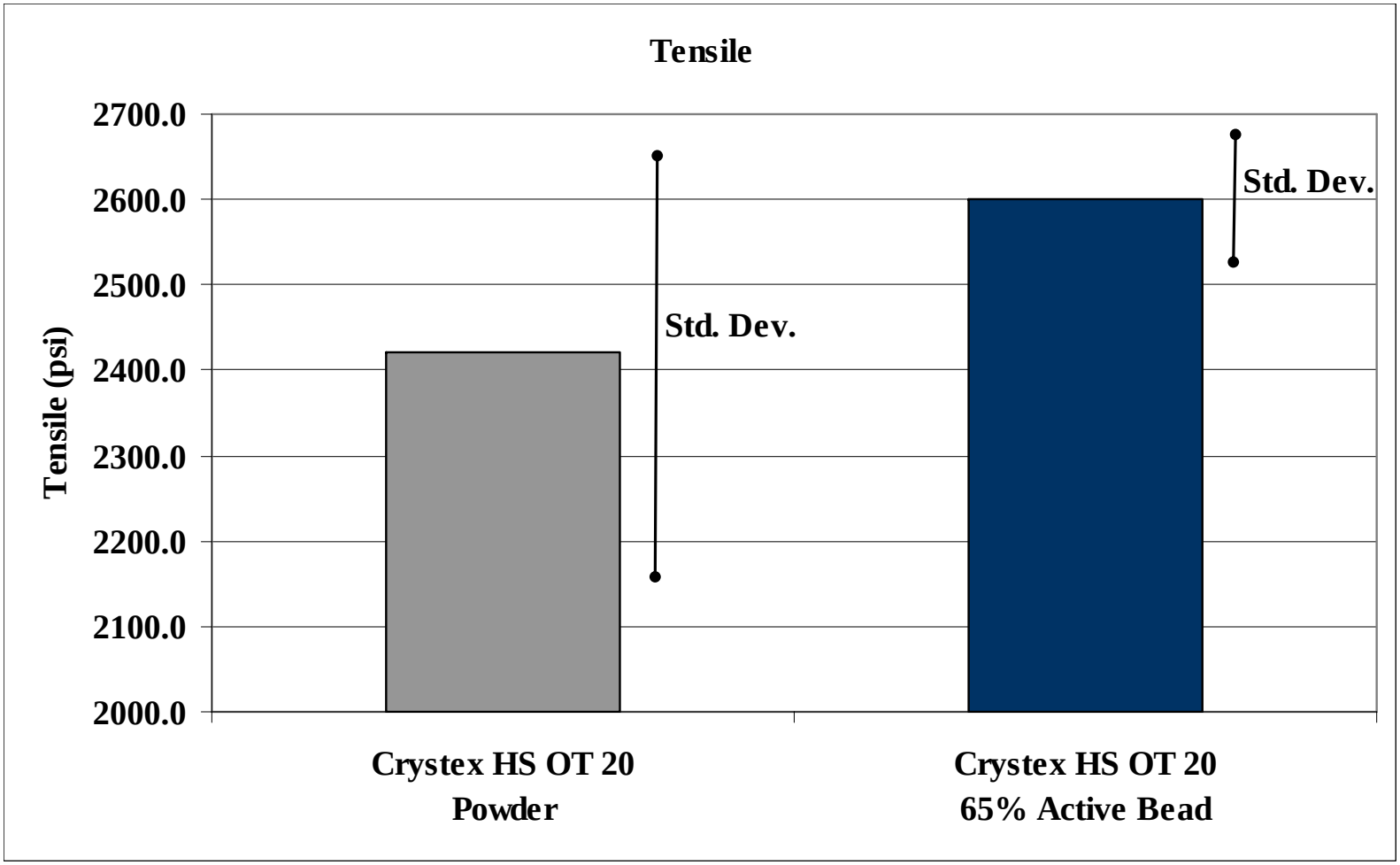
The Crystex® Bead has slightly higher elongation and lower standard deviation than the Crystex® powder control.



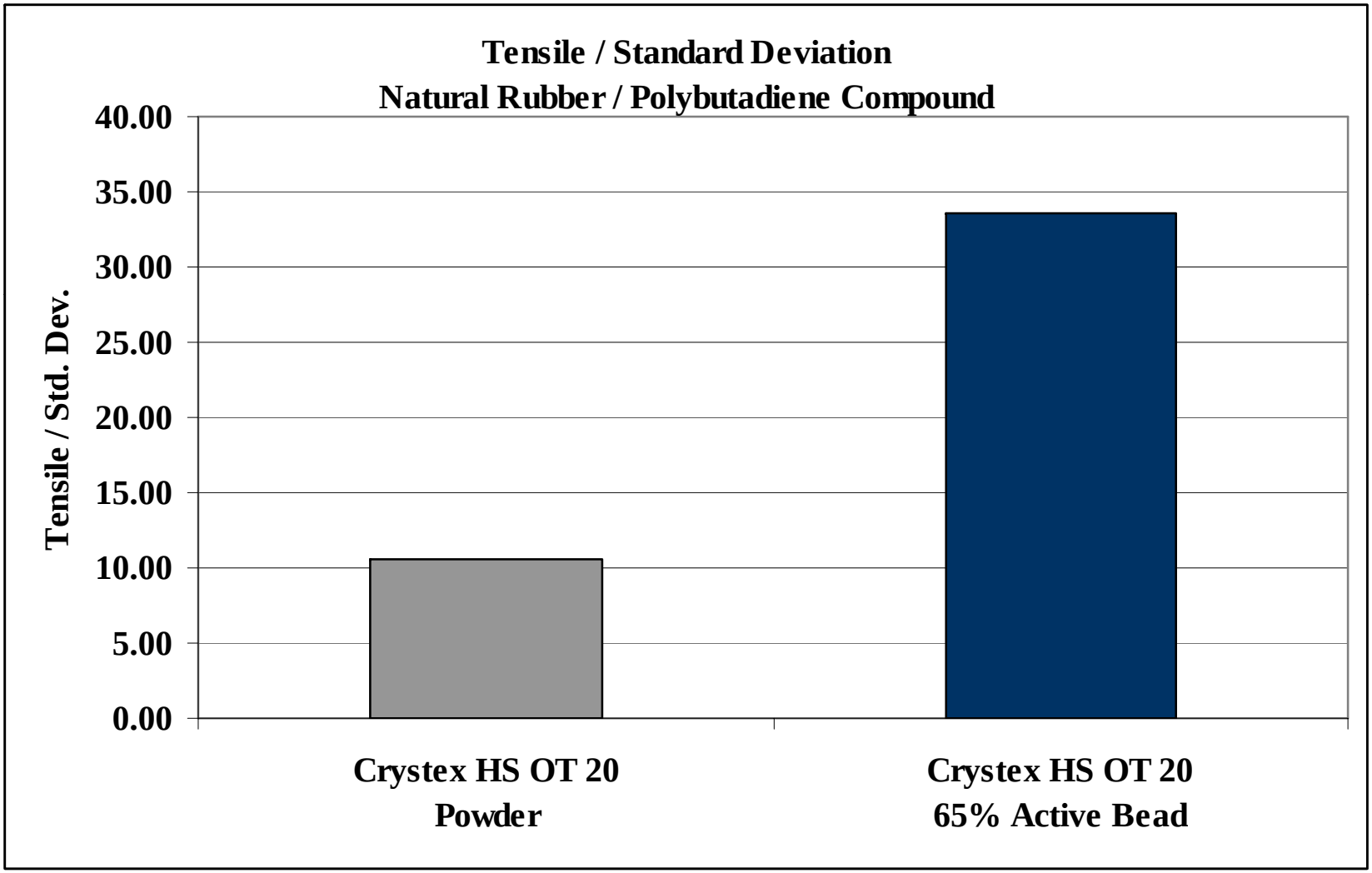
The Crystex® Bead has better dispersion than the Crystex® powder control.



The Crystex® Bead has higher tensile and lower standard deviation than the Crystex® powder control.



This measurement shows that the Crystex® bead has significantly better dispersion in the softer NR/BR compound.

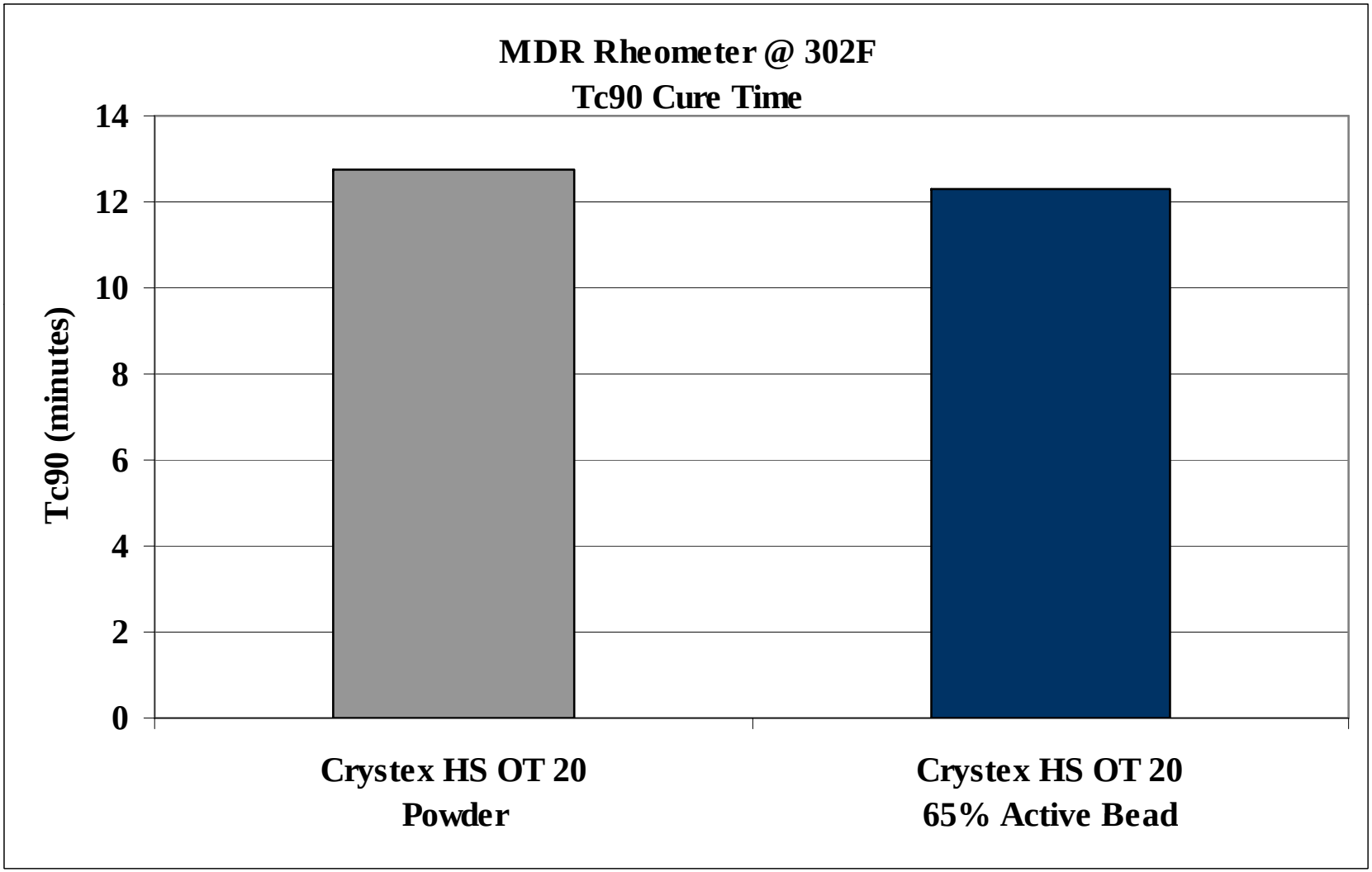


NR Compound

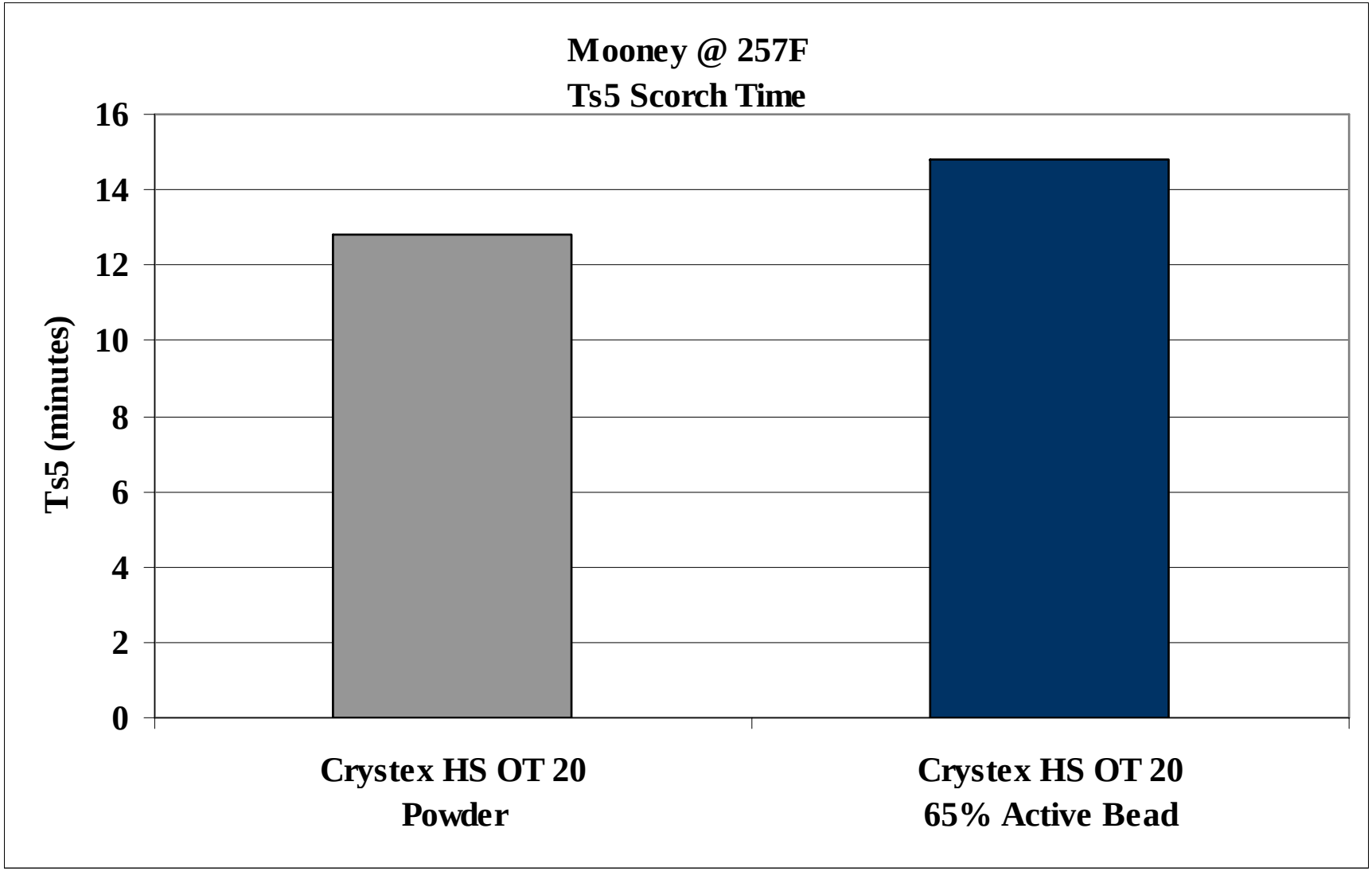
Ingredient	Crystex® HS OT 20 Powder	Crystex® HS OT 20 Bead 65% Active
• Natural Rubber	100.00	100.00
• N339 Carbon Black	55.00	55.00
• Naphthenic Oil	3.00	3.00
• Stearic Acid	0.50	0.50
• 6PPD Antiozonant	2.00	2.00
• TMQ Antidegradant	1.00	1.00
• Cobalt Naphthenate	1.00	1.00
• DCBS Accelerator	1.75	1.75
• Crystex® HS OT 20 Powder	5.00	
Or	(4 phr sulfur)	
• Crystex® HS OT 20 Bead		6.15 (3.2 phr sulfur)

- The extra oil from 65% active bead product was not compensated for in the formulation.

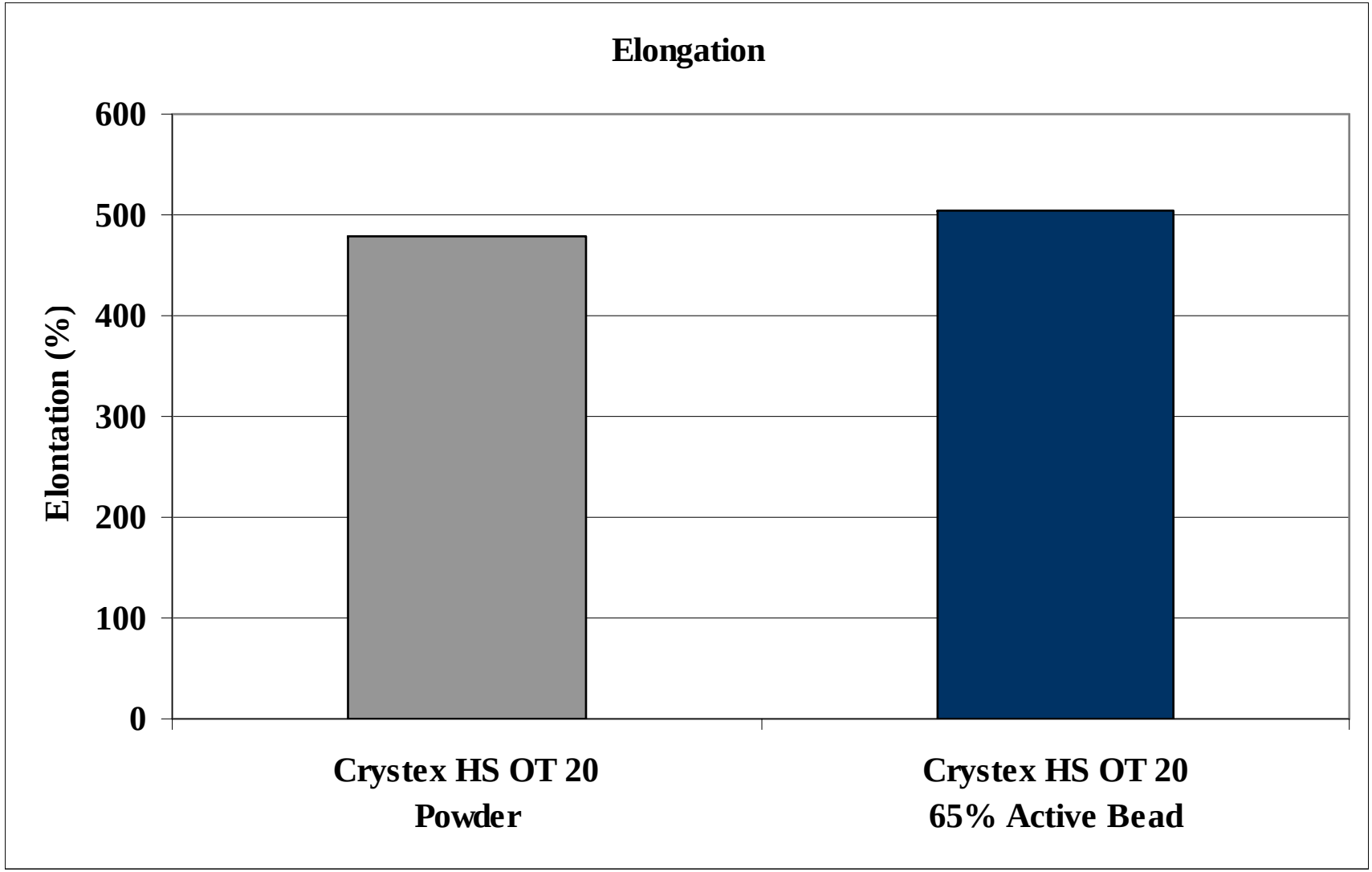
The Crystex® bead compound has similar T90 cure time to the Crystex® powder control compound.



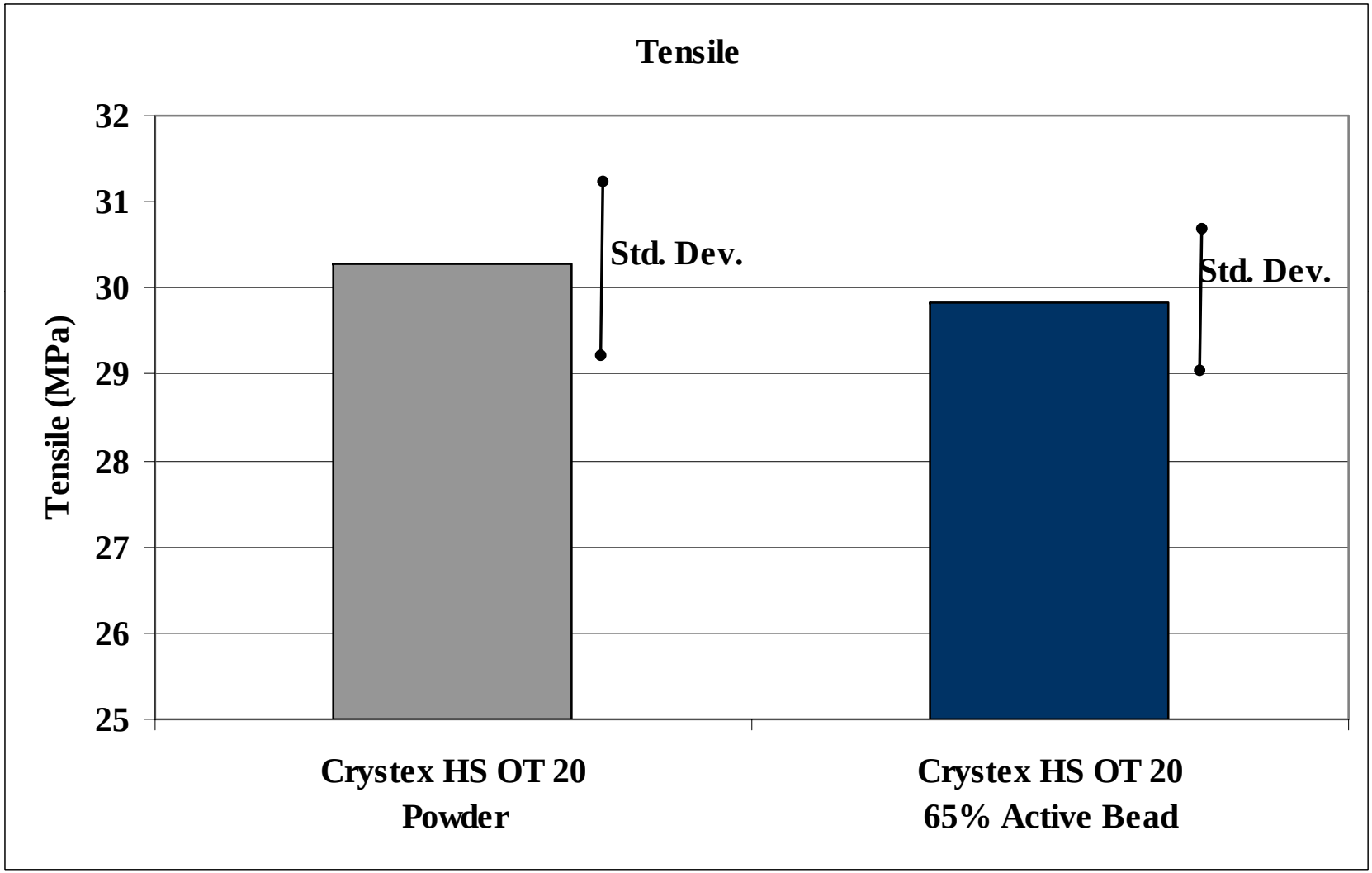
The Crystex® bead compound has slightly longer Ts5 scorch than the Crystex® powder control compound.



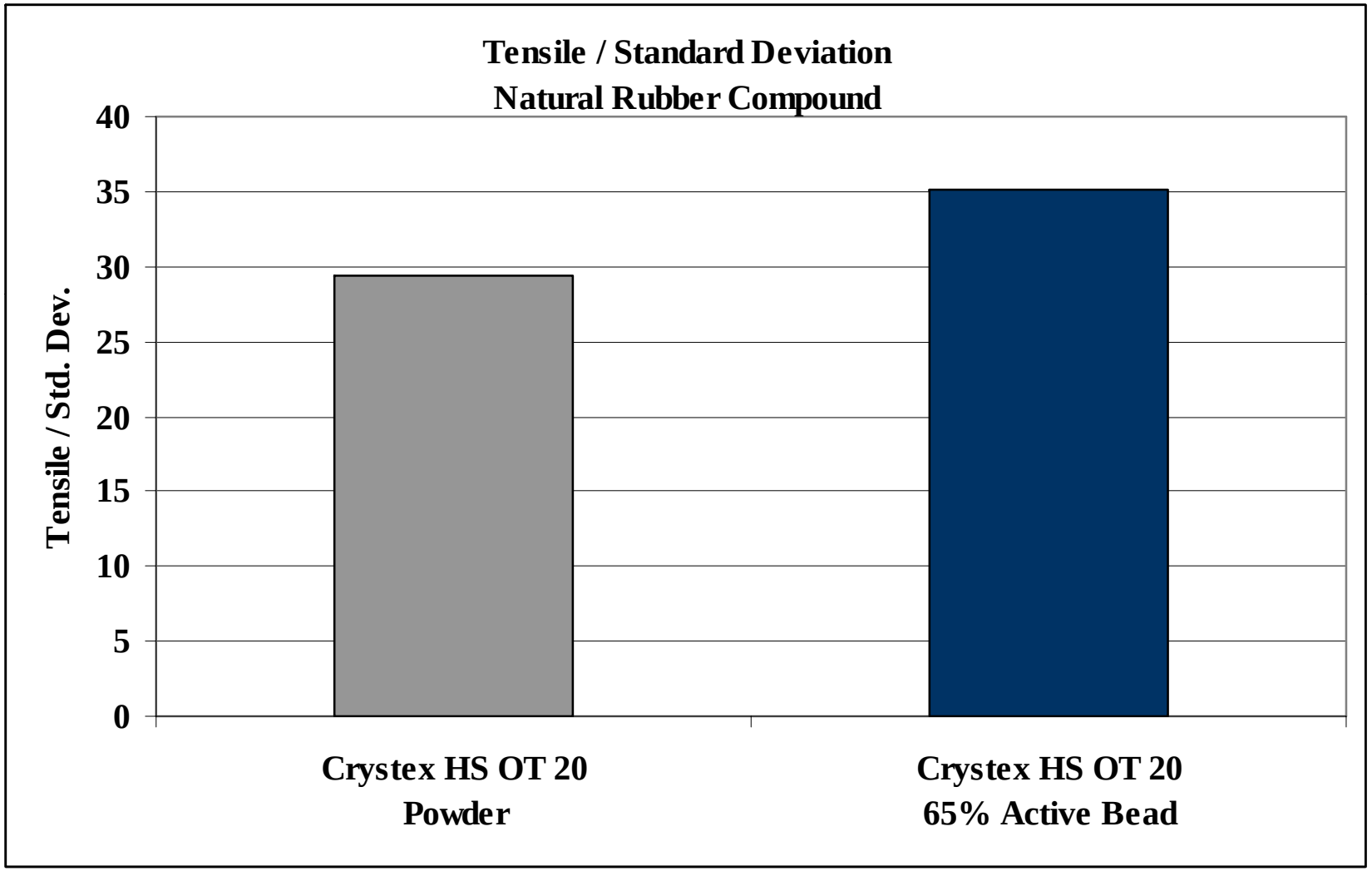
The Crystex® bead compound has higher elongation than the Crystex® powder control compound.



The Crystex® bead compound has similar tensile but slightly less standard deviation than the Crystex® powder control.



The data in the NR compound shows that the Crystex® bead product has slightly better dispersion than the control Crystex® HS OT 20 powder.



Conclusions

- **Chem Technologies Crystex® bead product showed better dispersion and no bloom in both a softer NR/BR compound and a harder NR compound.**
- **The Chem Technologies' Crystex® bead is manufactured at low temperatures resulting in no conversion of amorphous sulfur (Crystex®) sulfur to rhombic Rubbermaker's sulfur.**
- **The above properties should result in better final product appearance, adhesion and physical properties and could result in reduced mix stages and/or mix times.**