

Advancure™ Curative for Vamac®

Technical Report: CTR-06001

August 2006

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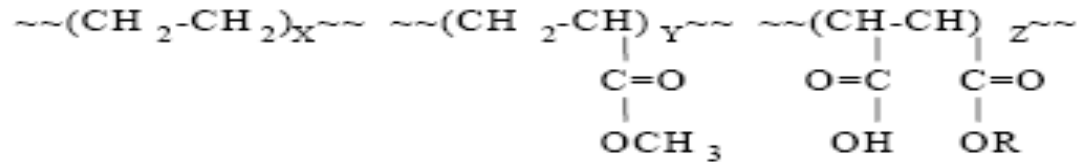
Kevin Dominic – Gold Key Processing, Ltd.

Background



- **DuPont Vamac[®] ethylene acrylic elastomers is designed to withstand high and low temperatures and aggressive new automotive fluids in under hood automotive applications such as seals, gaskets, ducts, hoses, boots and dampers.**
- **The most often cure system used in Vamac[®] compounds is a combination of HMDC (hexamethylenediamine carbamate) with DOTG (di-*o*-tolylguanidine) or DPG (diphenylguanidine).**
- **During the vulcanization process the HMDC breaks down into HMDA (hexamethylene diamine) which is the active curing agent.**
- **The HMDC curative is the second highest cost component of Vamac[®] compounds.**

Hexamethylenediamine Cure Mechanism



Ethylene

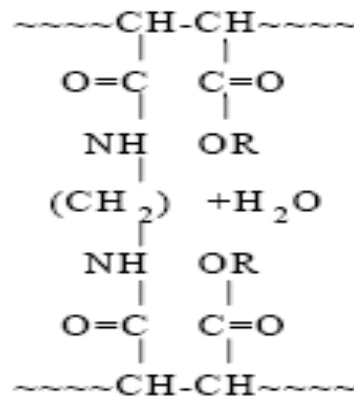
Methyl Acrylate

Cure Site

+

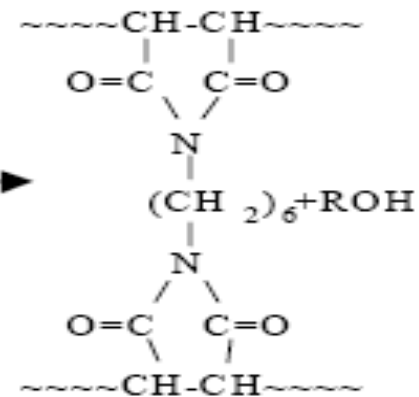


Hexamethylene Diamine



Amide Crosslink

Postcure



Imide Crosslink



- **Advancure is a 47% active liquid concentrate of hexamethylenediamine (HMDA) absorbed on amorphous silica in powder form.**
- **Advancure is based on patented curing technology from DuPont and is enhanced with an innovative dispersion technology from Chem Technologies.**
- **Advancure is a free-flowing, dust-free beaded powder that can be used to cure the majority of Vamac[®] products at a lower cost compared to traditional curing technologies.**
- **Advancure HMDA (hexamethylene diamine) is a lower cost alternative to HMDC (hexamethylenediamine carbamate) types.**
- **For the same activity level, replace 1 phr of hexmethylenediamine carbamate with 1.56 phr of Advancure.**

**Advancure (HMDA)
versus
HMDC From Several Sources**

**Vamac[®] G Model Compound
Laboratory Studies**

**Testing done in Gold Key Processing
& Chem Technologies Laboratories**

Formulation



● Vamac[®] G	100.00
● N774 Carbon Black	90.00
● Stearic Acid	2.00
● Polyoxyethylene octadecyl ether phosphate	1.50
● 1-ocadecanamine	0.50
● Di(2-ethylhexyl) sebacate	10.00
● DOTG (di-<i>o</i>-tolylguanidine)	4.00
● HMDC or HMDA	see next slide

Curative Variables



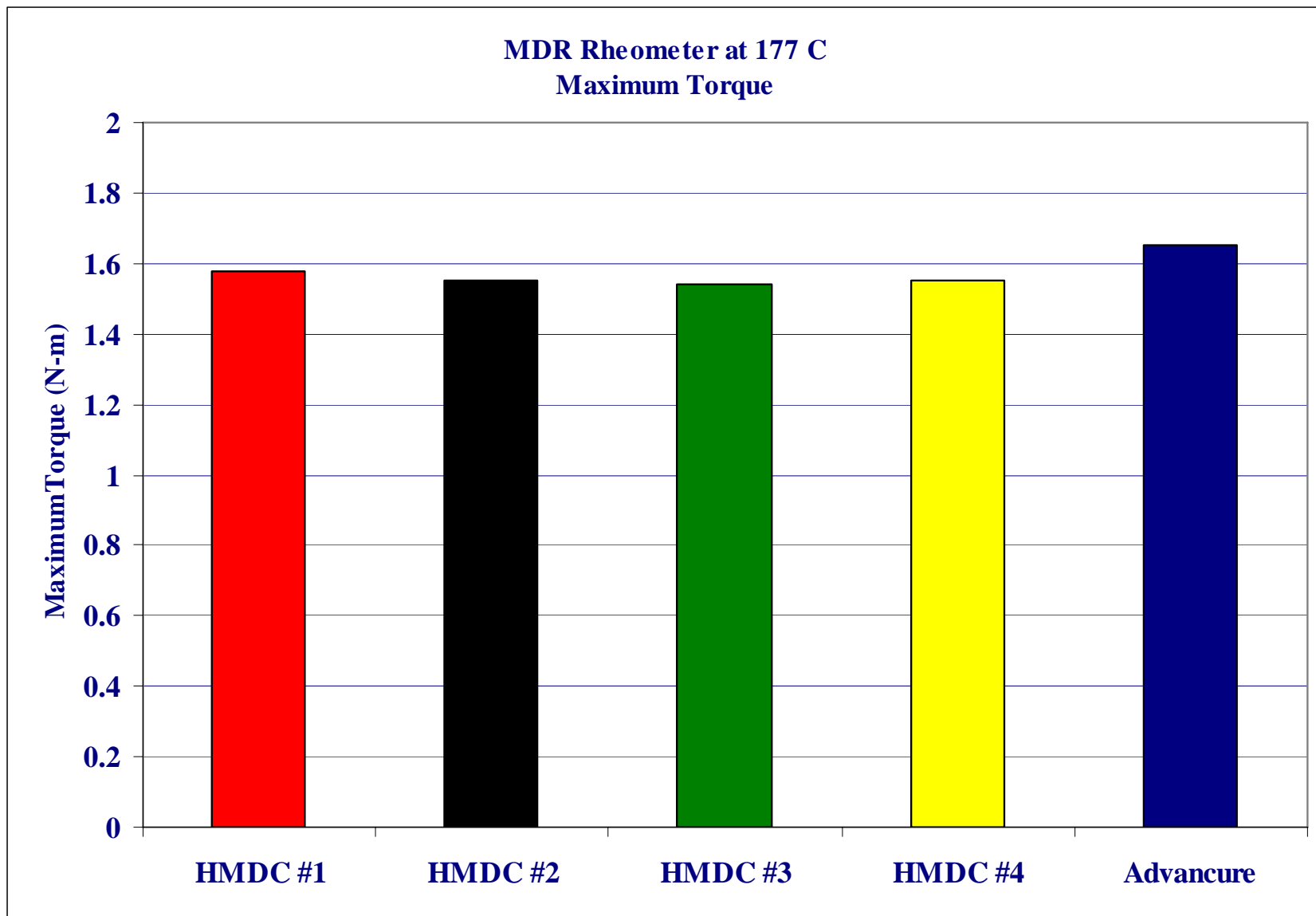
- **HMDC #1 – Diak 1, a trademark of DuPont.**
 - at 1.50 phr
- **HMDC #2 – Vulcofac HDC, a trademark of Safic.**
 - at 1.50 phr
- **HMDC #3 – Trilink 1, a trademark of Lianda**
 - at 2.00 phr
- **HMDC #4 – Intercure 1, a trademark of Interbusiness**
 - at 1.50 phr
- **Advancure – HMDA from Chem Technologies**
 - at 2.34 phr

Testing Procedures

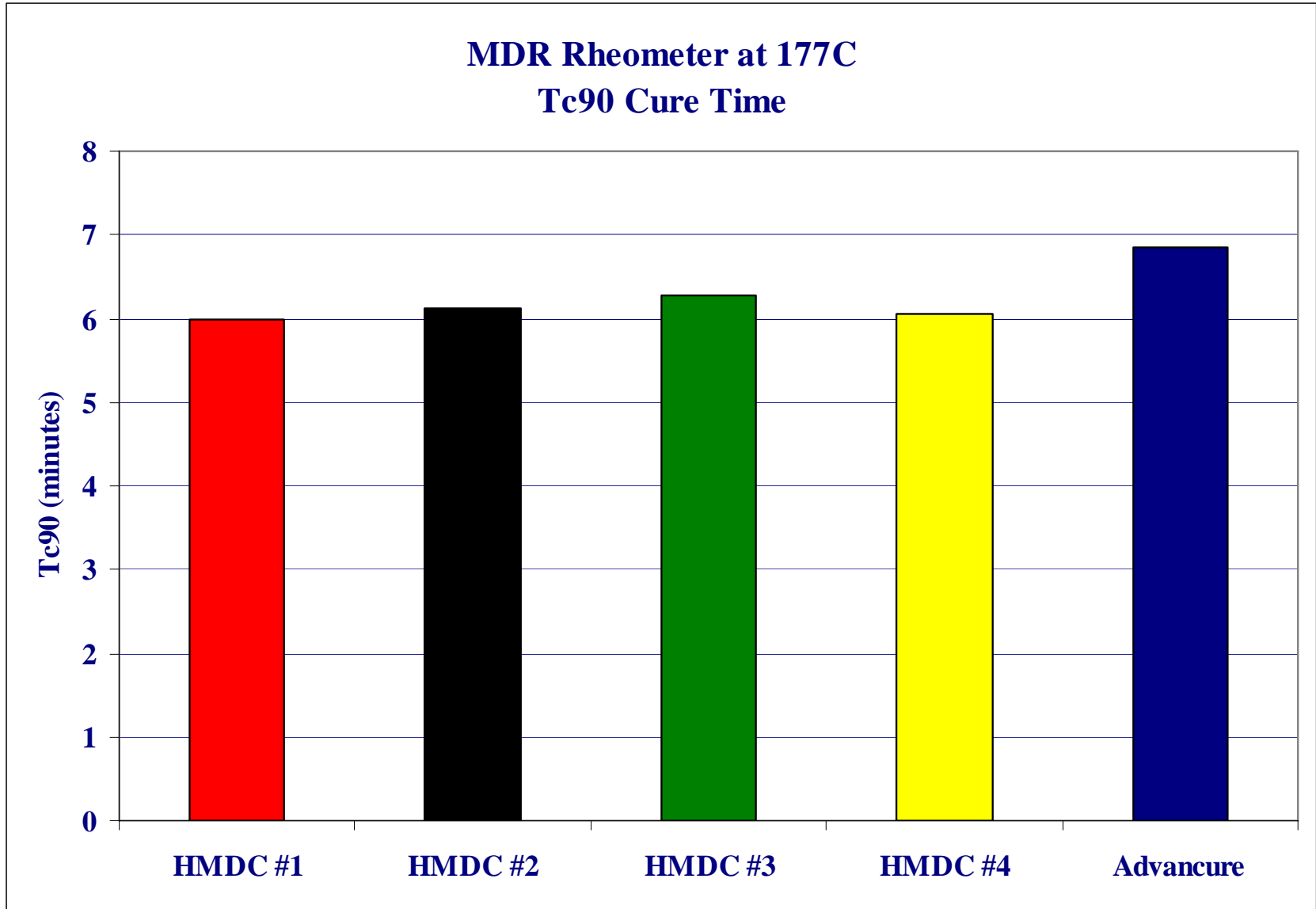


- **Mixing was done in a Moriyama 1.5 L lab mixer with a dump temperature of 93°C.**
- **MDR Rheometer at 177°C, ASTM D 5289.**
- **Mooney at 121°C, ASTM D 1646.**
- **Physical Properties (hardness, tensile, modulus, elongation). Press-cured 5 minutes at 177°C, post cured 4 hours at 177°C. ASTM D 412.**

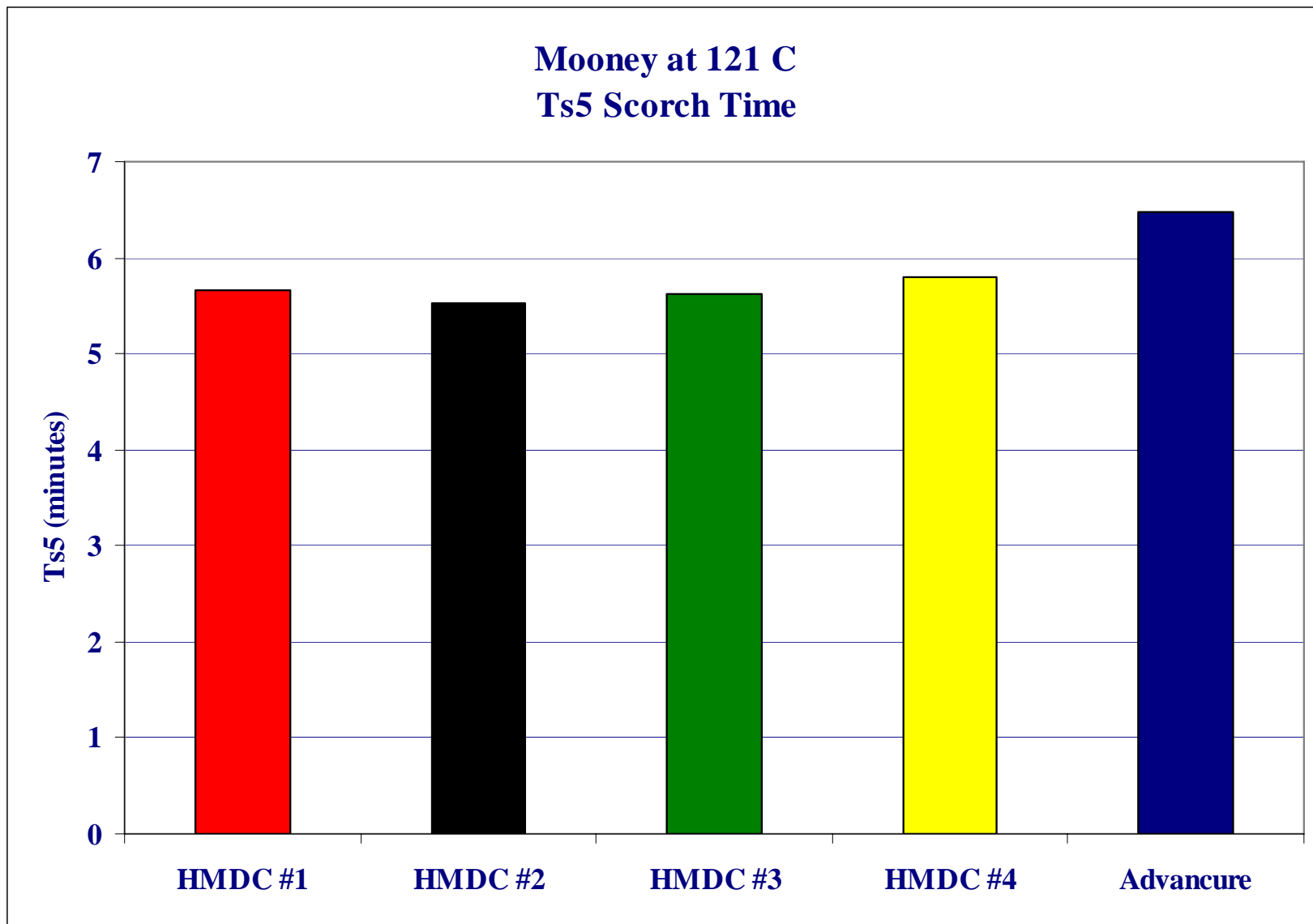
The Advancure compound had slightly higher torque than the HMDC controls.



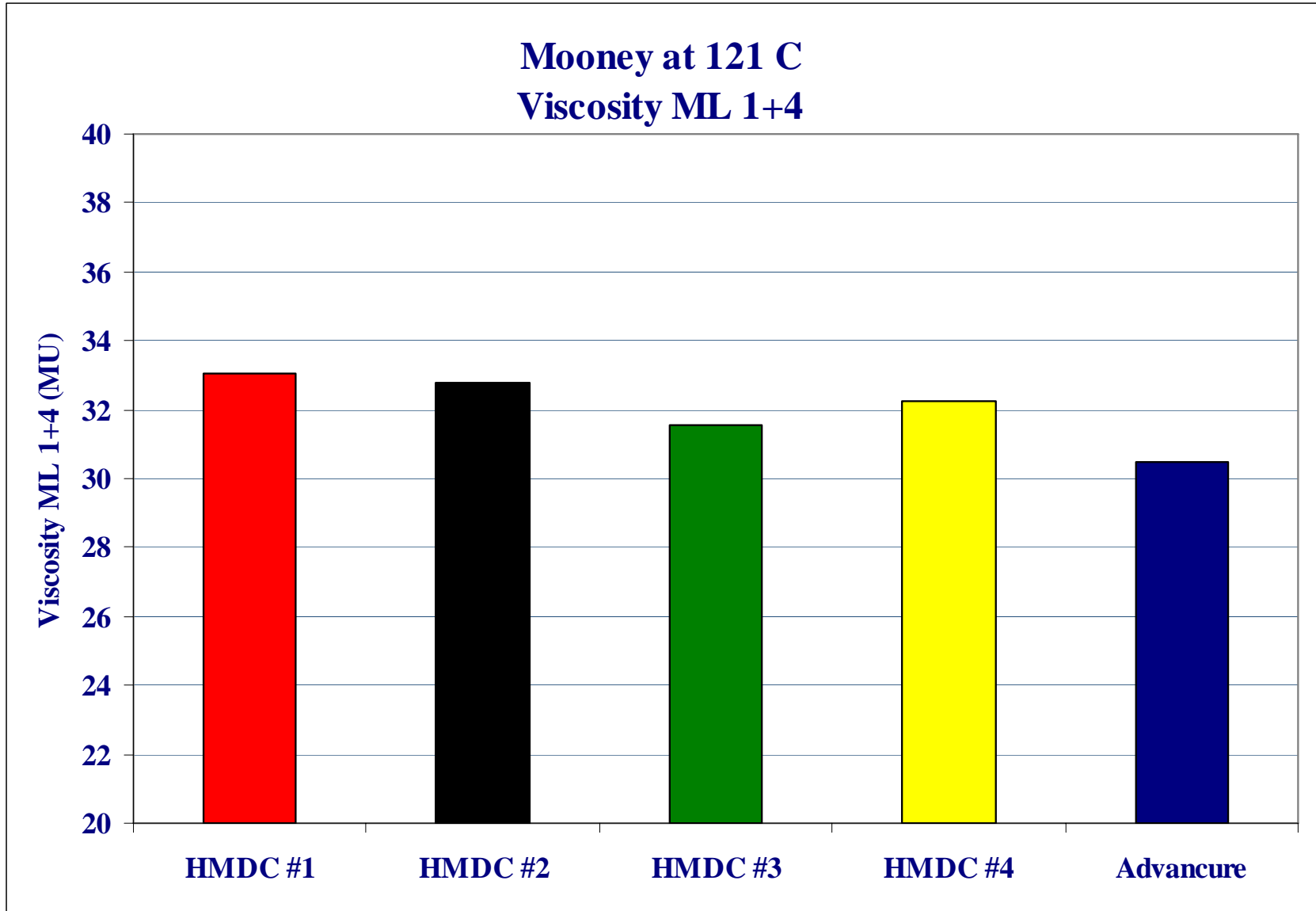
The Advancure compound had a slightly longer cure time than the HMDC control compounds due its higher maximum torque value.



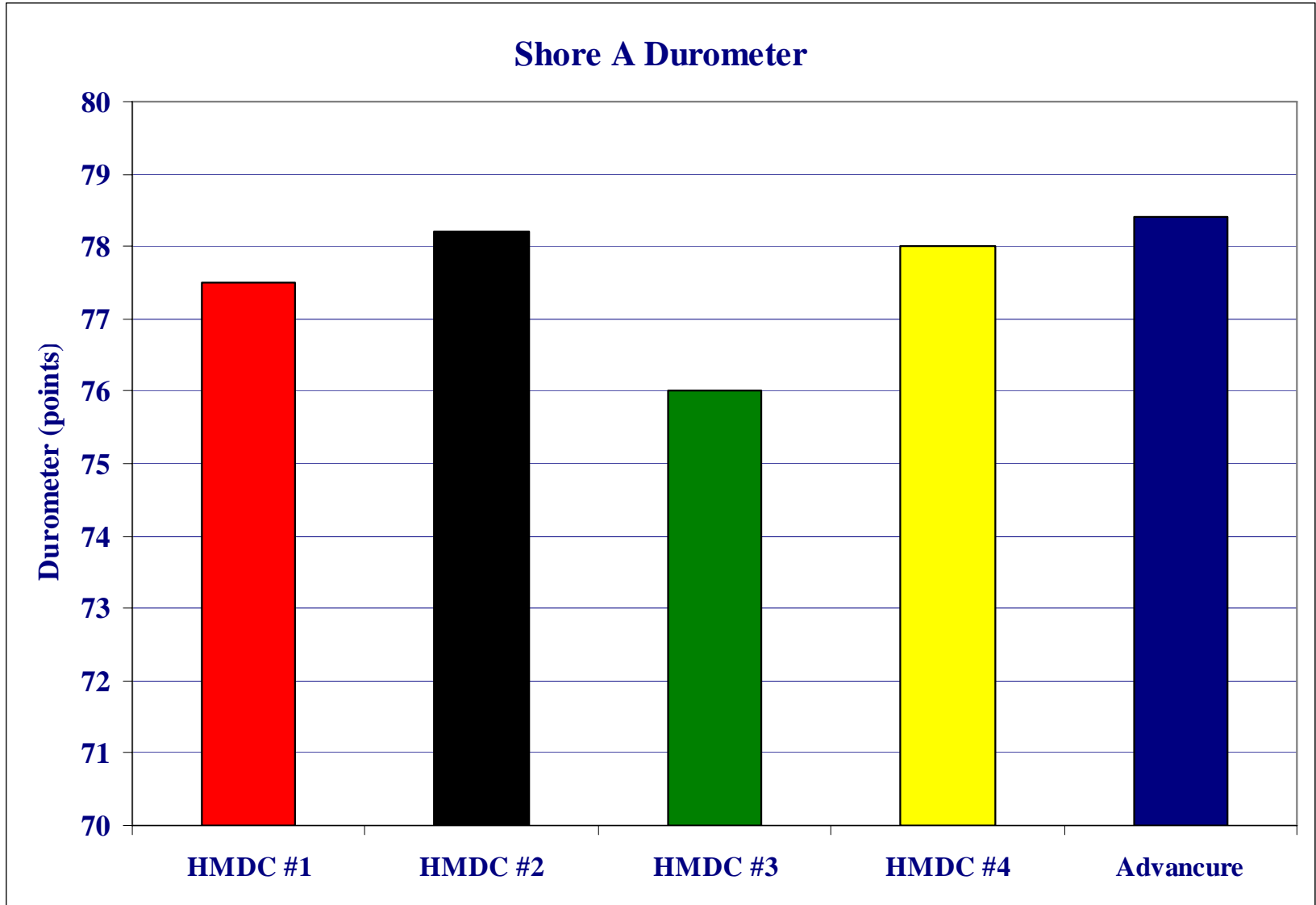
The Advancure compound had a slightly longer Ts5 scorch to the HMDC controls.



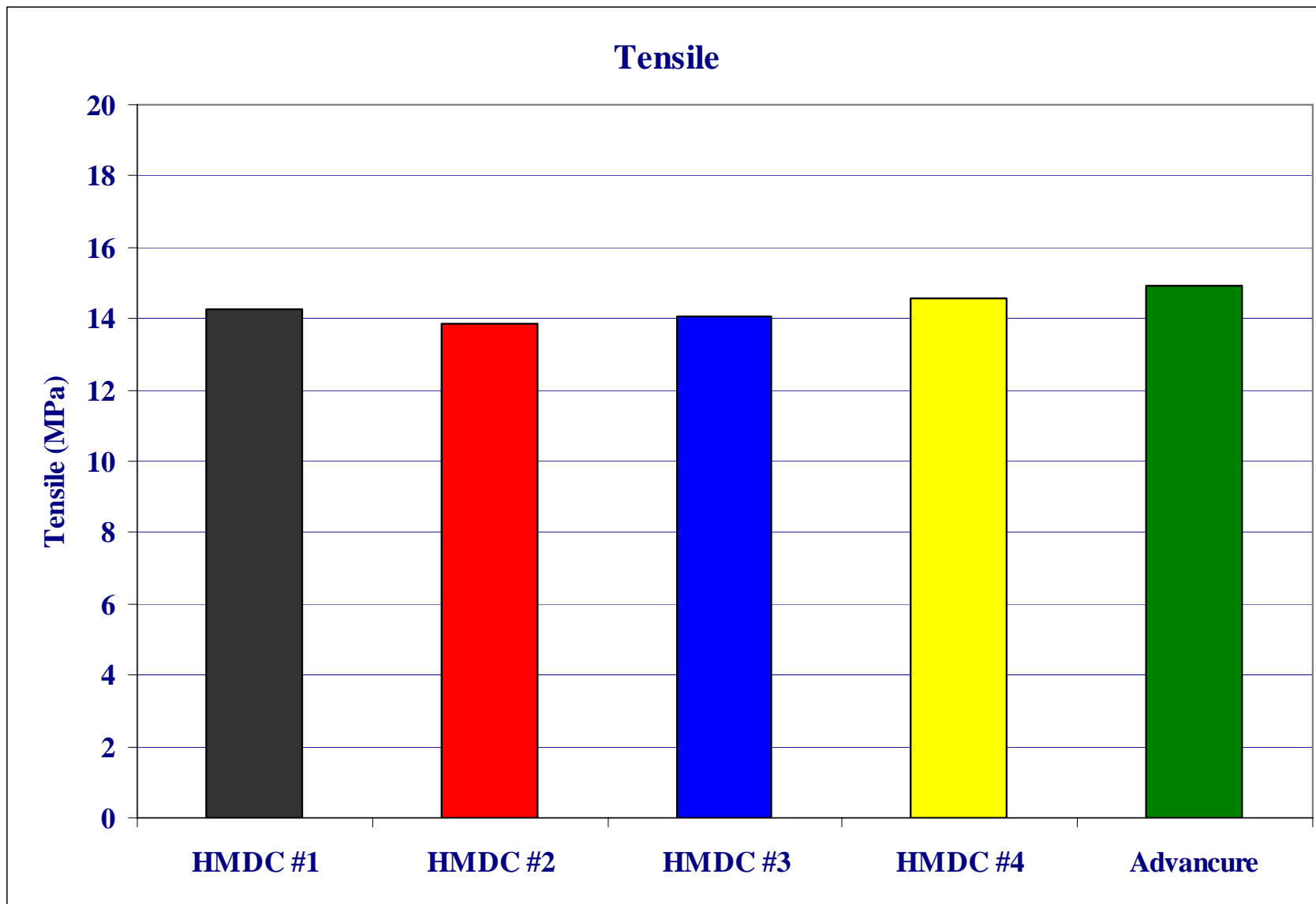
The Advancure compound had a slightly lower viscosity level than the control compounds.



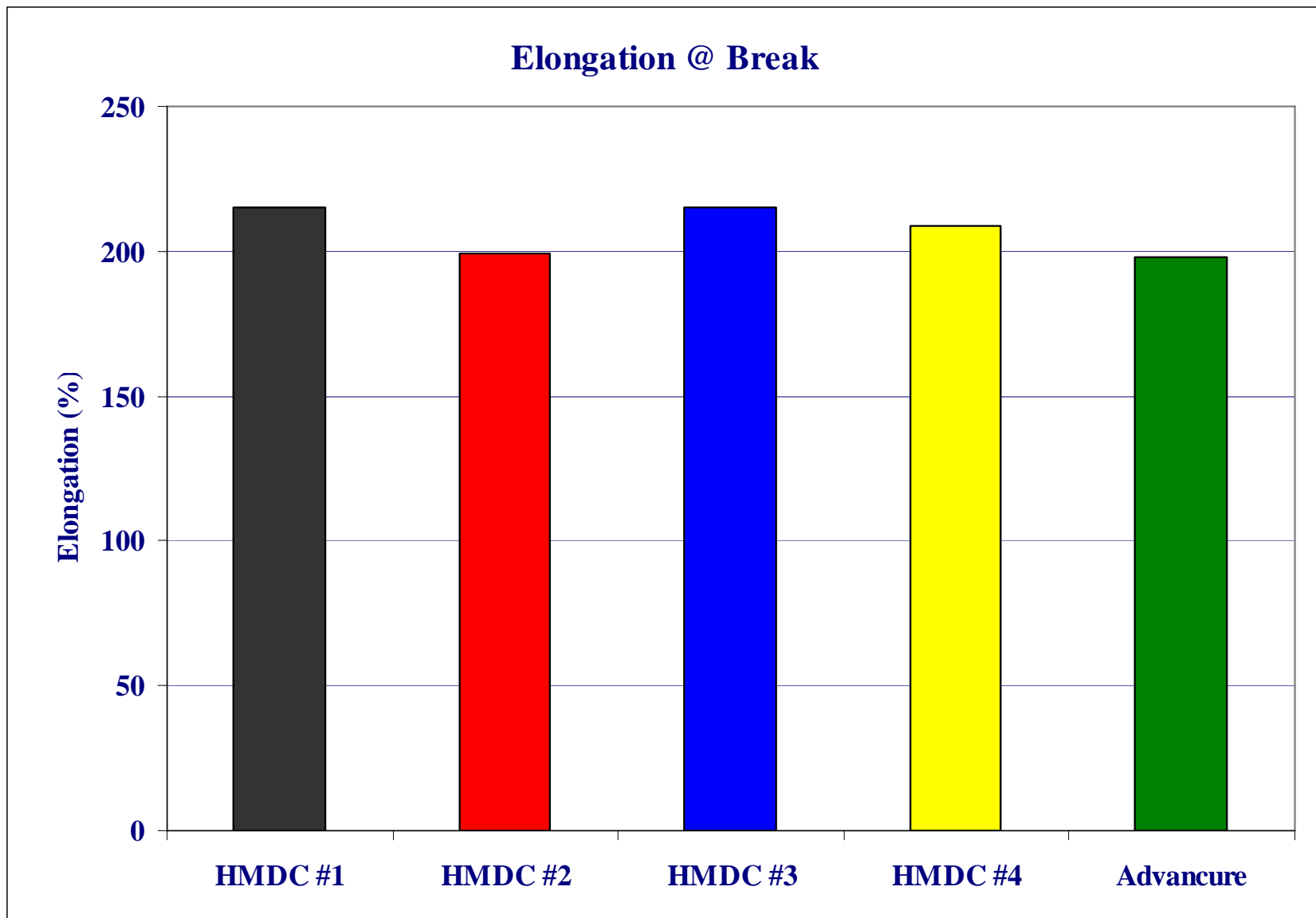
The Advancure compound had a similar durometer to HMDC #1, 2 and 4 controls. HMDC #3 had a lower durometer.



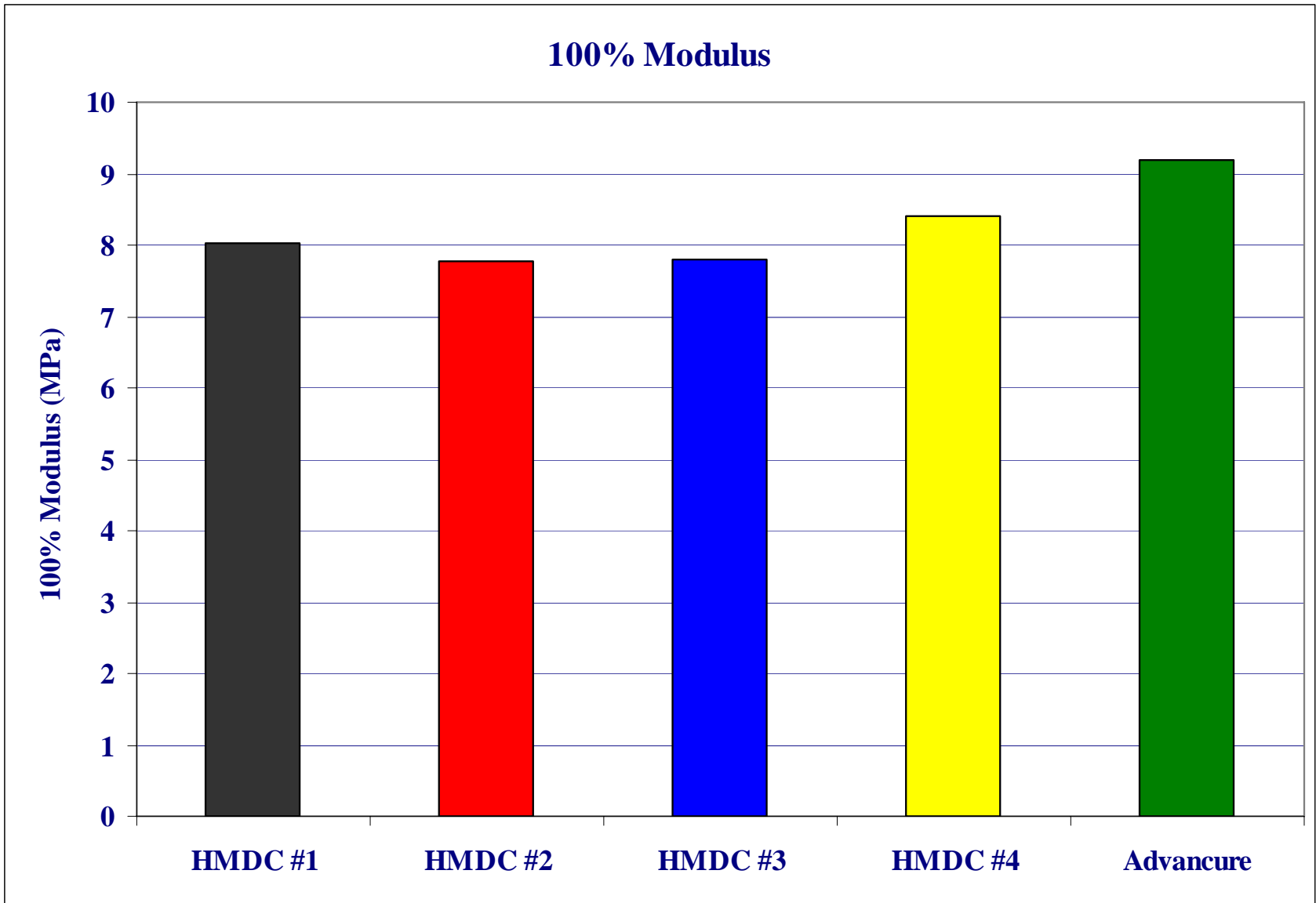
The Advancure compound had slightly higher tensile.



The compounds had slightly lower elongation at break values.



The Advancure compound had higher modulus than the HMDC control compounds.



Advancure (HMDA) Versus HMDC in Various Vamac[®] Formulations

Formula #1: Standard Vamac compound with 10 phr plasticizer

Formula #2: Standard Vamac compound with no plasticizer

**Formula #3: Vamac compound with no plasticizer and with
“flex” cure**

DuPont Laboratories

Formulations



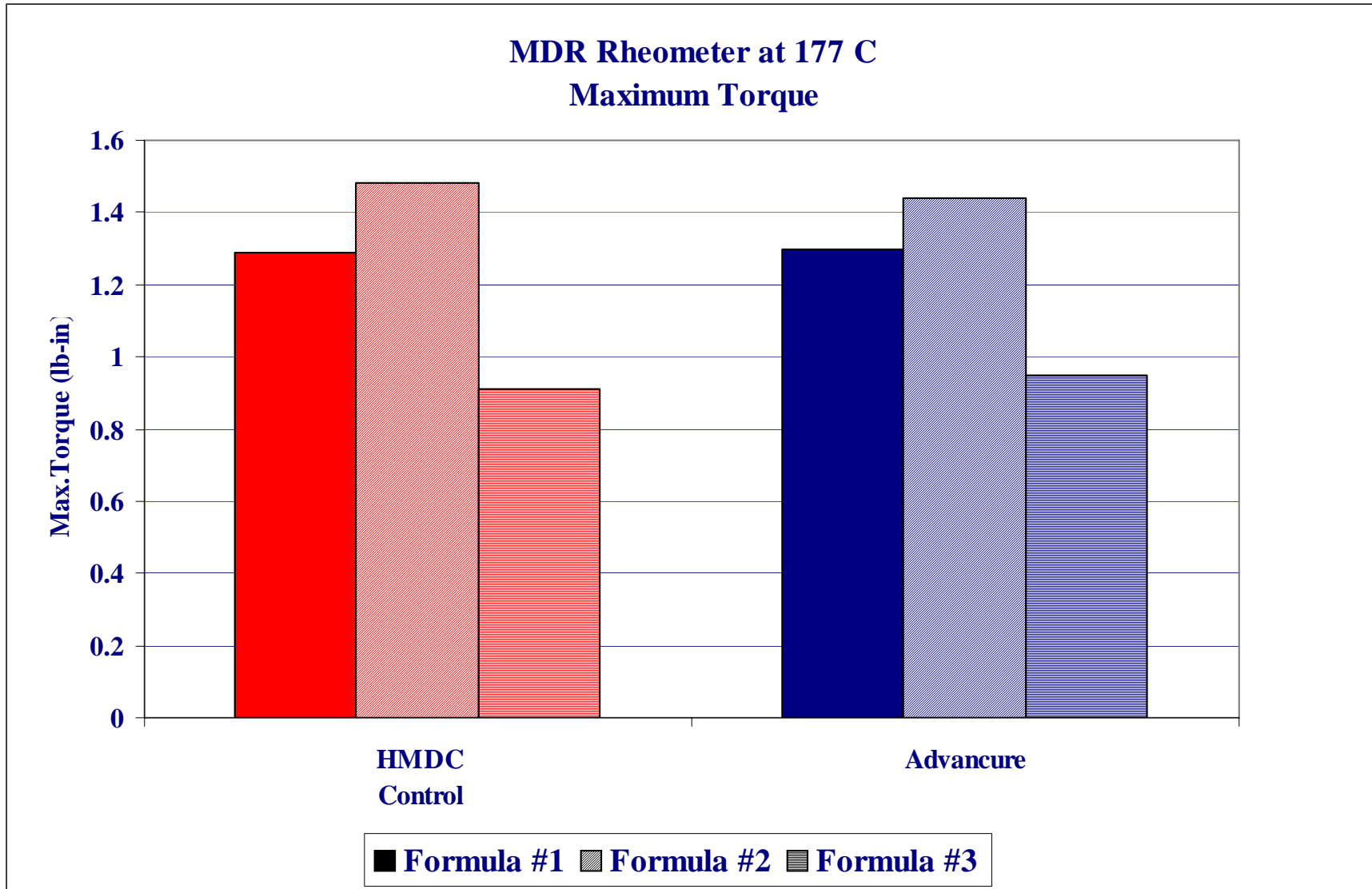
<i>Ingredient</i>	<i>Formula #1</i>	<i>Formula #2</i>	<i>Formula #3</i>
● Vamac® G	100.00	100.00	100.00
● N550 Carbon Black	60.00	50.00	50.00
● Ether/Ester Plasticizer	10.00	0.00	0.00
● Stearic Acid	1.50	1.50	1.50
● Polyoxyethylene octadecyl ether phosphate	1.00	1.00	1.00
● 1-ocadecanamine	0.50	0.50	0.50
● 4,4' Di(a,a-dimethylbenzyl) diphenylamine	2.00	2.00	2.00
● DPG (N,N'-diphenylguanidine)	0.00	0.00	2.00
● DOTG (di-o-tolylguanidine)	4.00	4.00	2.00
● HMDC (Diak 1)	1.50	1.50	1.20
● <i>or</i>			
● Advancure	2.34	2.34	1.87
● Formula #1: Standard Vamac compound with 10 phr plasticizer			
● Formula #2: Standard Vamac compound with no plasticizer			
● Formula #3: Vamac compound with no plasticizer and with “flex” cure			

Diak 1 and Vamac are trademarks of DuPont.

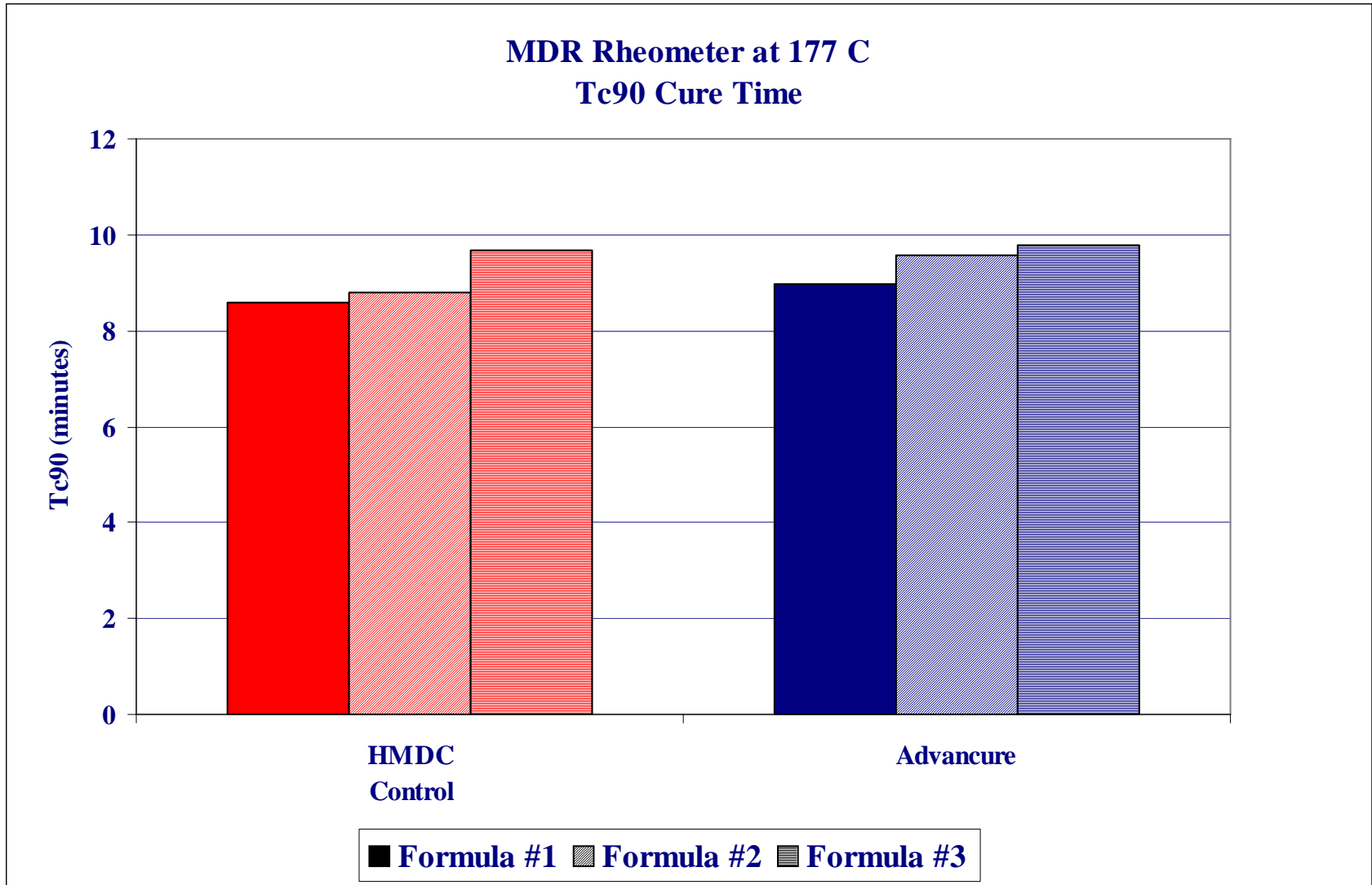
Cure Data

MDR Rheometer, ASTM D5289
Mooney, ASTM D1646

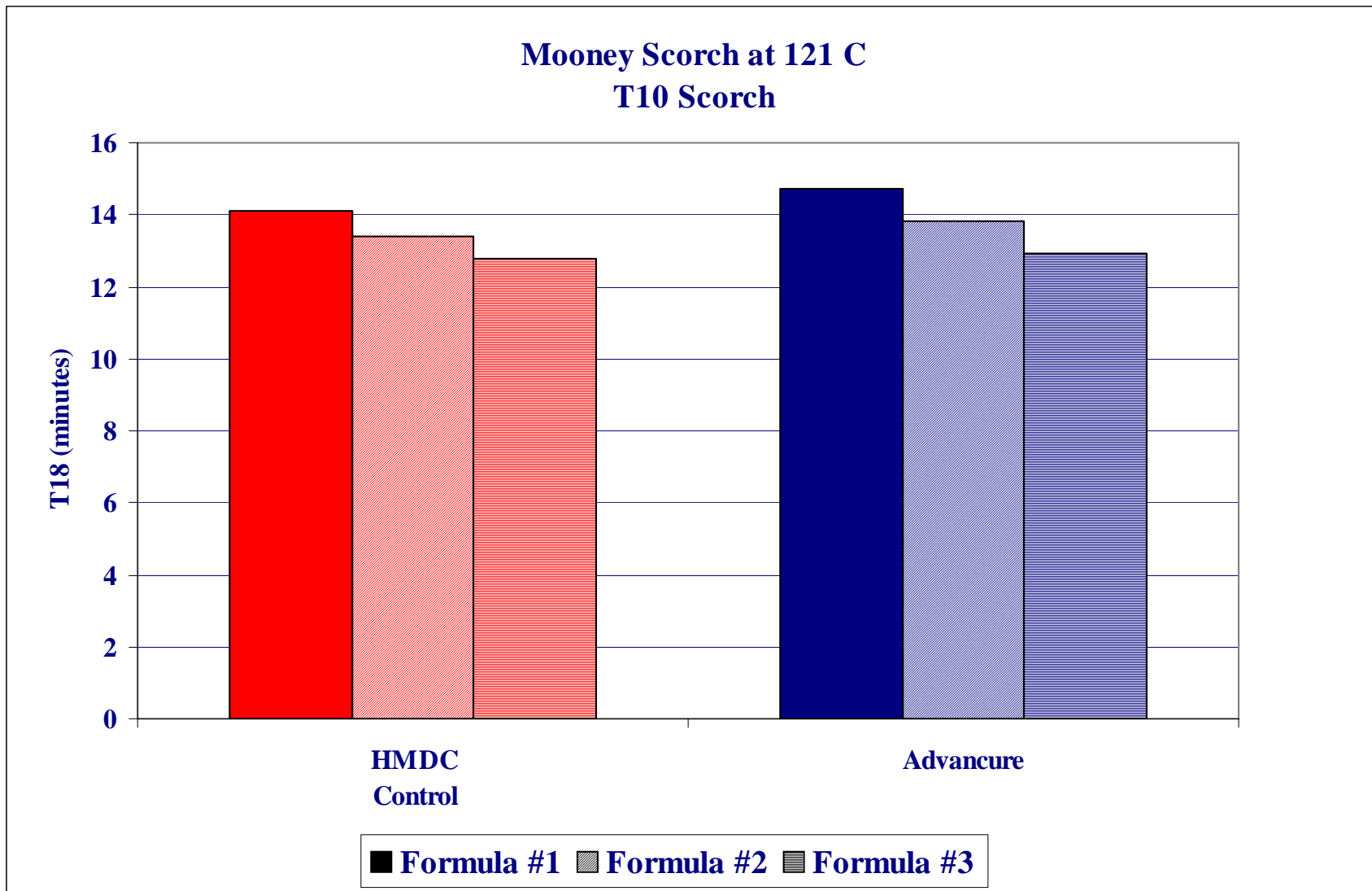
The Advancure compounds had similar torque values to the HMDC control compounds.



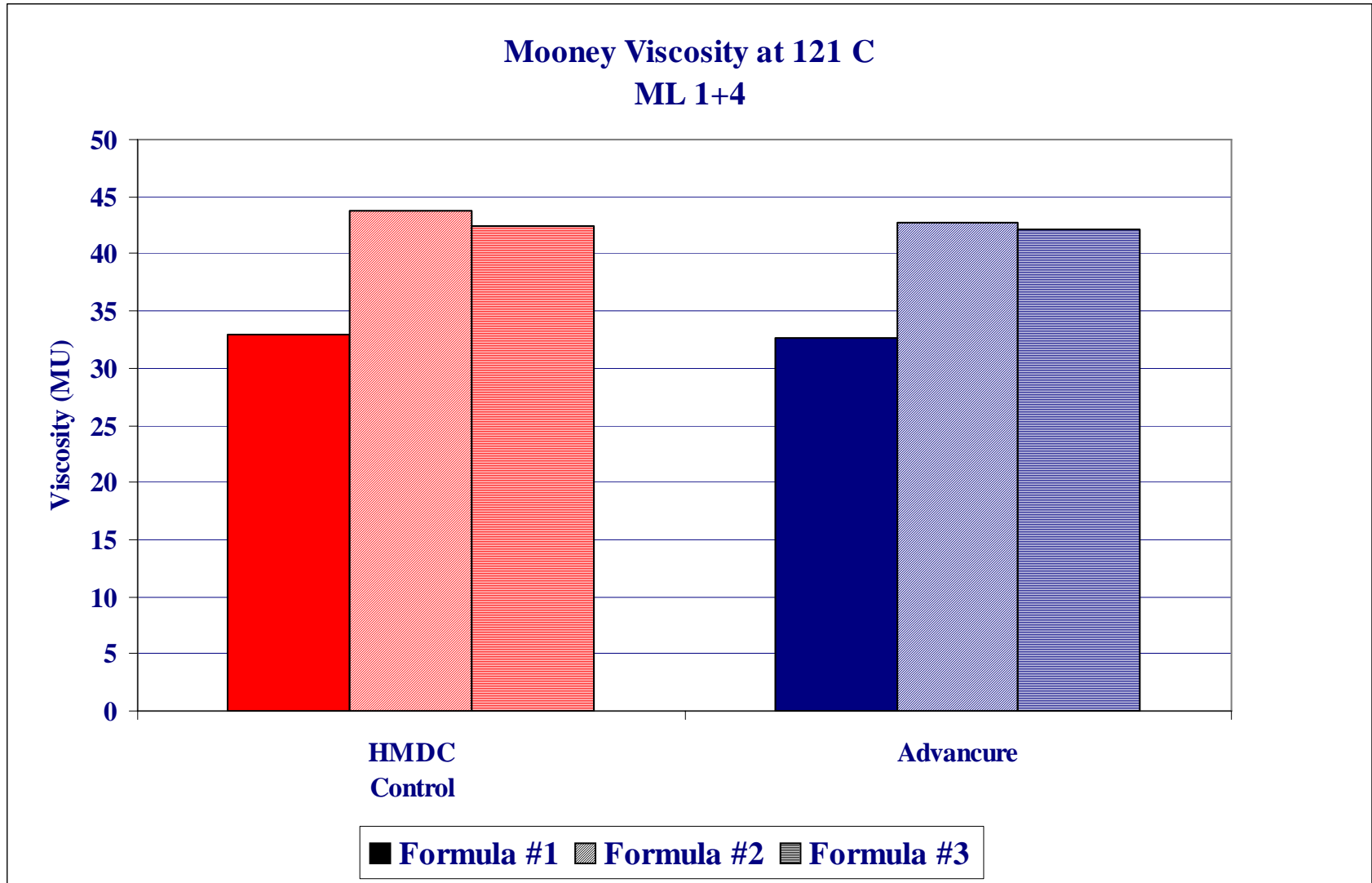
The Advancure compounds had similar cure times to the HMDC control compounds.



The Advancure compounds had similar scorch times to the HMDC control compounds.



The Advancure compounds had similar viscosity to the HMDC control compounds.



Physical Properties - Unaged

Press Cure: 5 min. at 175°C

Post Cure: 4 hours at 175°C

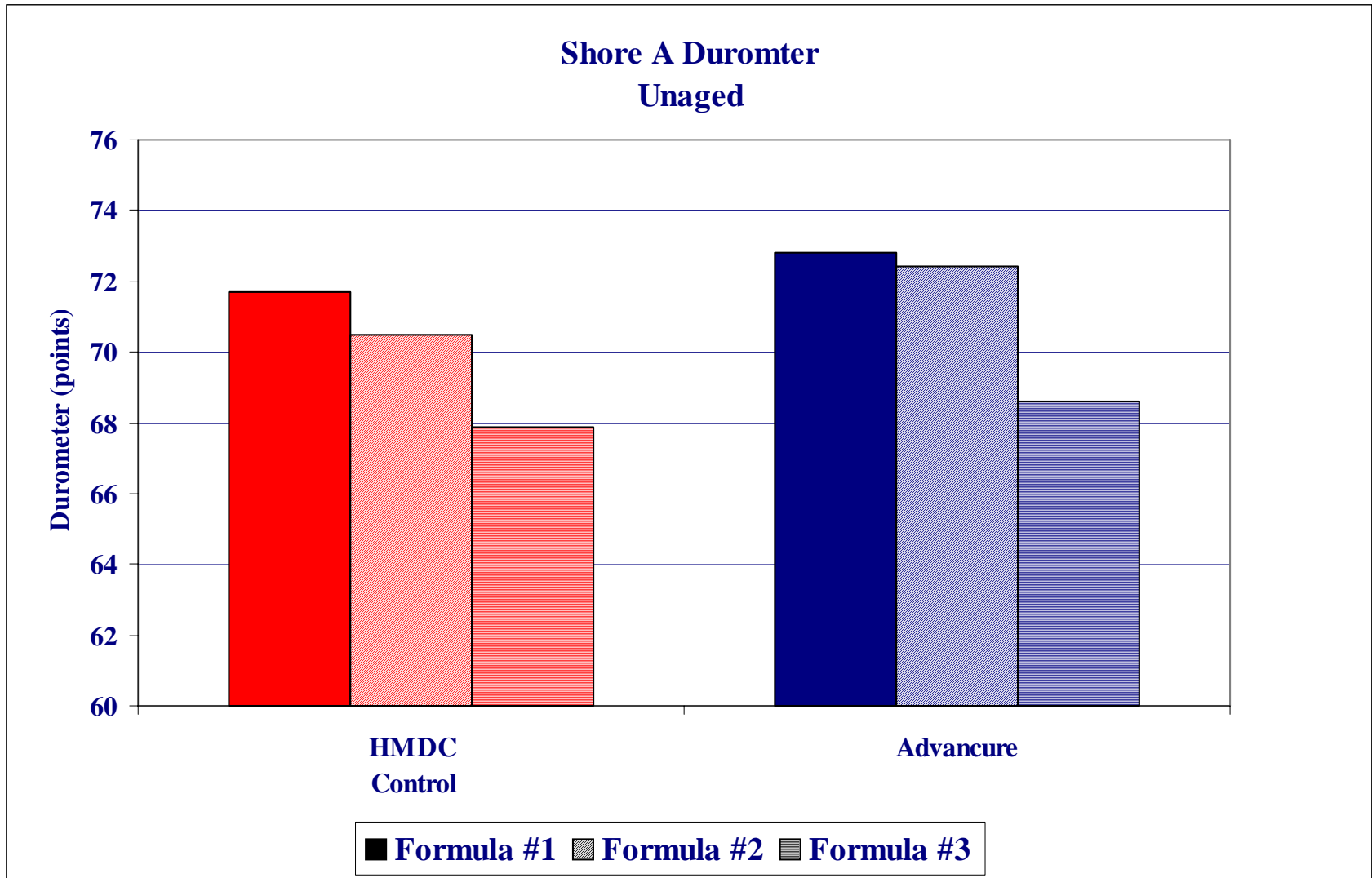
Shore A Durometer, ASTM D2240

Stress Strain, ASTM D412

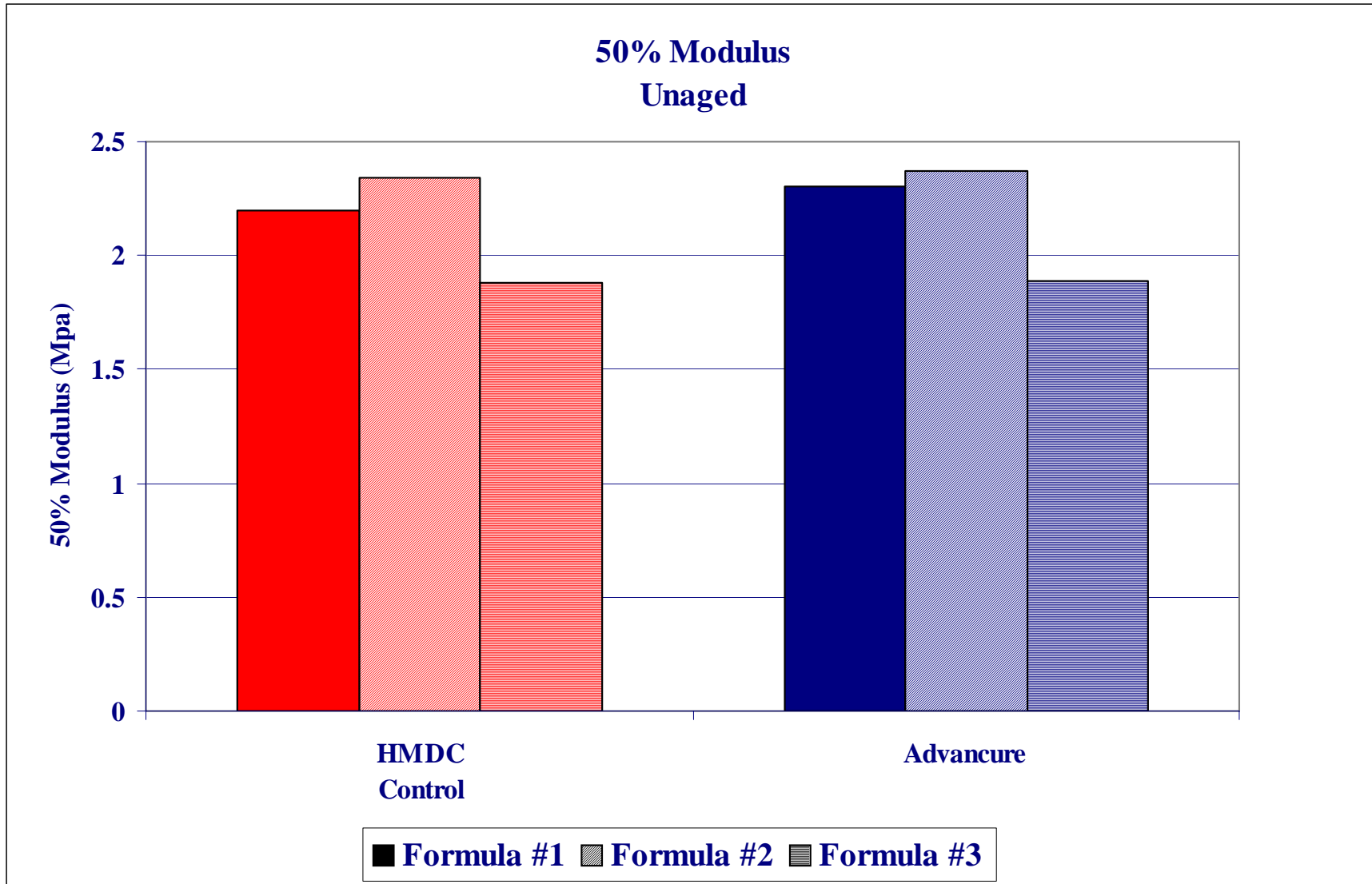
Die C Tear, ASTM D624

Compression Set, ASTM D395

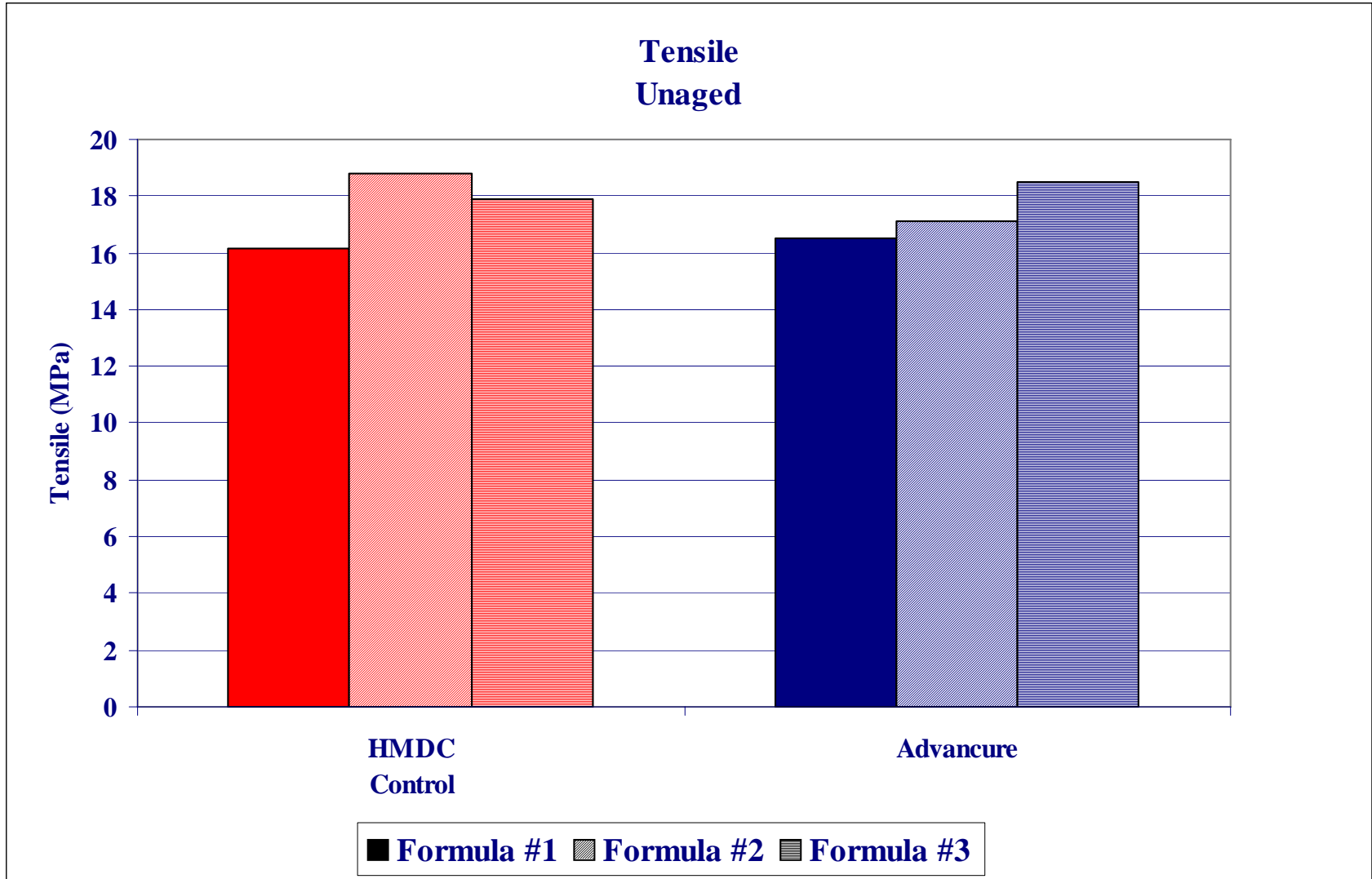
The Advancure compounds had slightly higher durometer values to the HMDC control compounds.



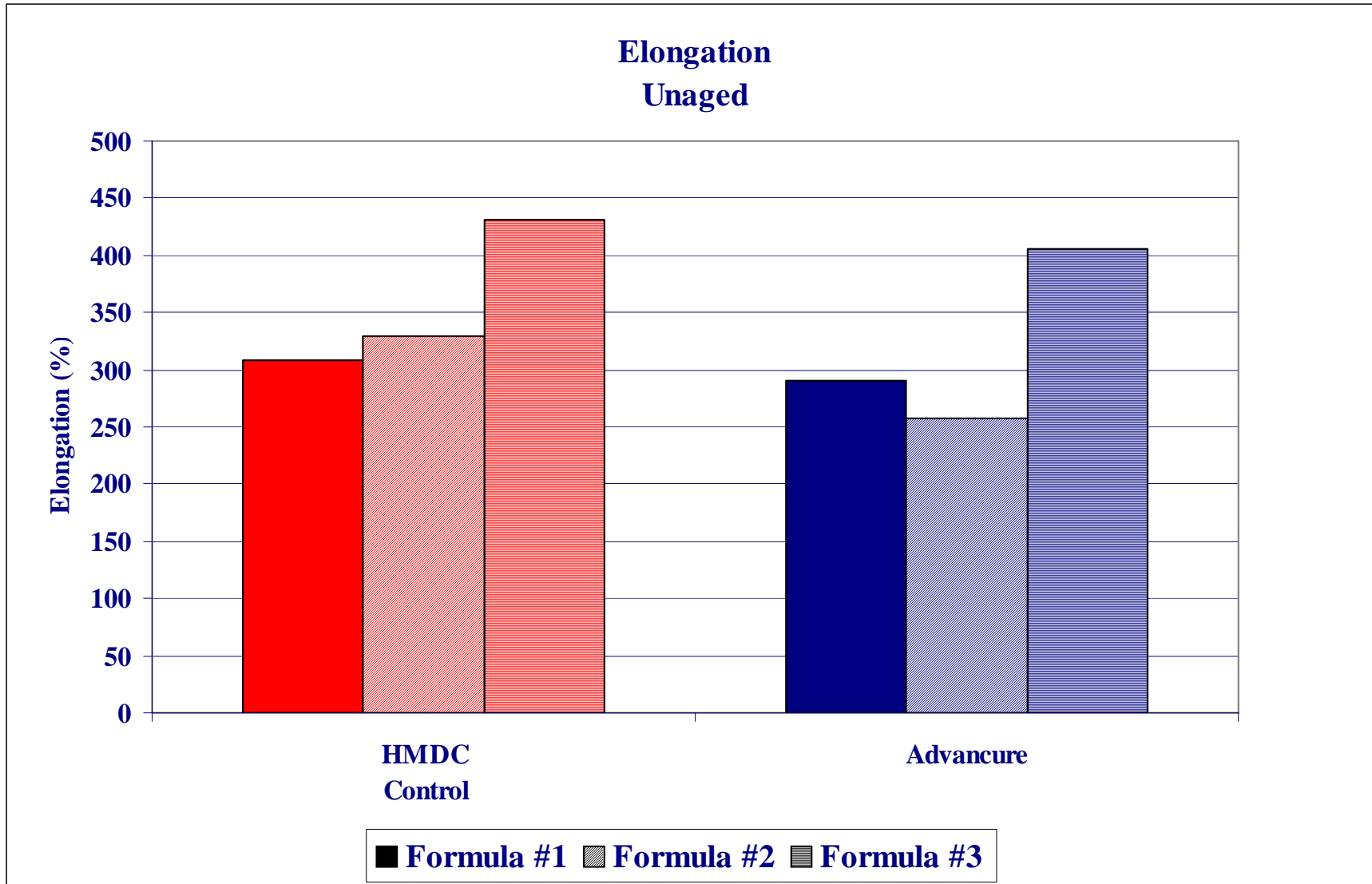
The Advancure compounds had similar 50% modulus values to the HMDC control compounds.



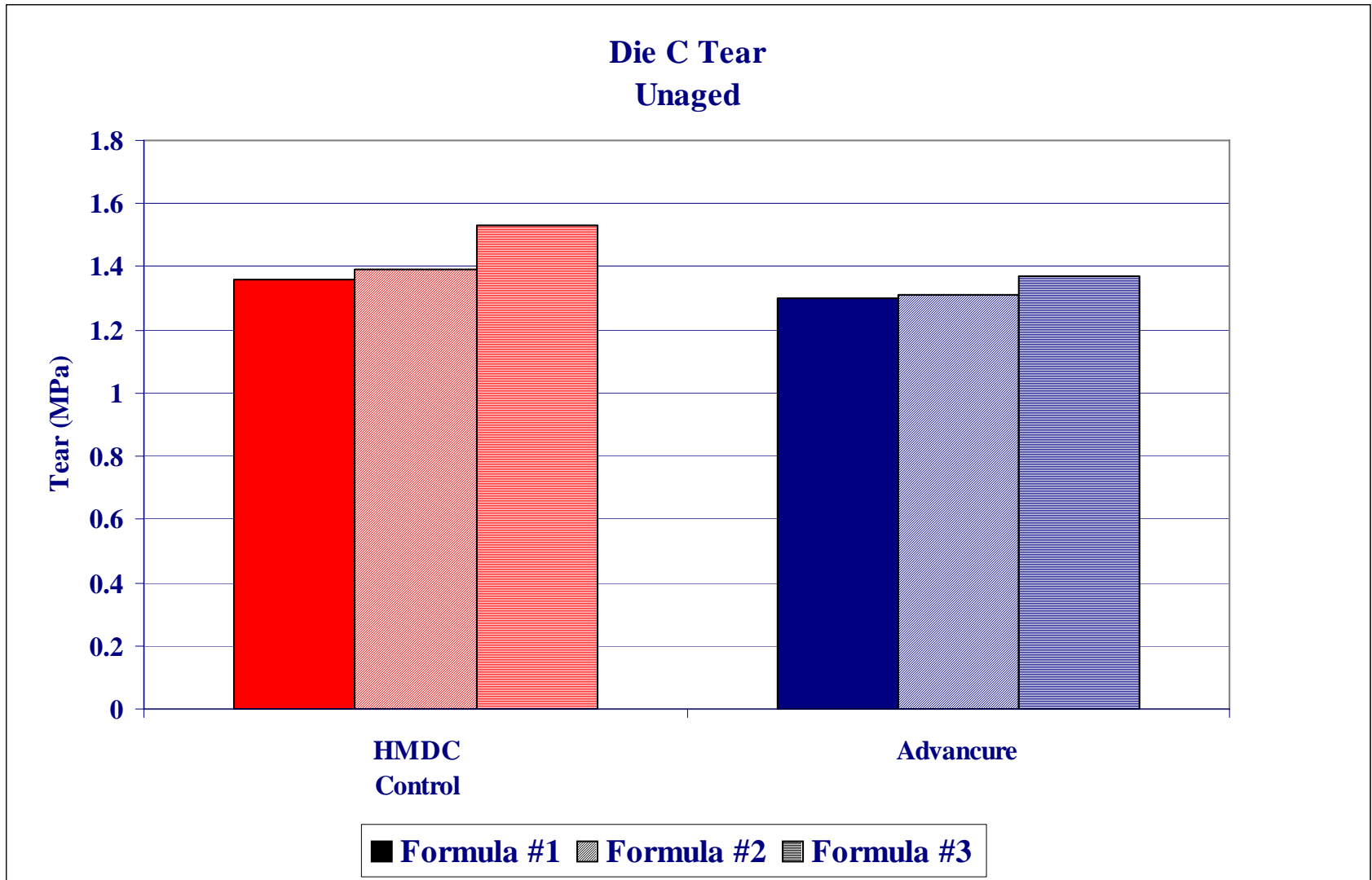
The Advancure compounds had similar tensile values to the HMDC control compounds.



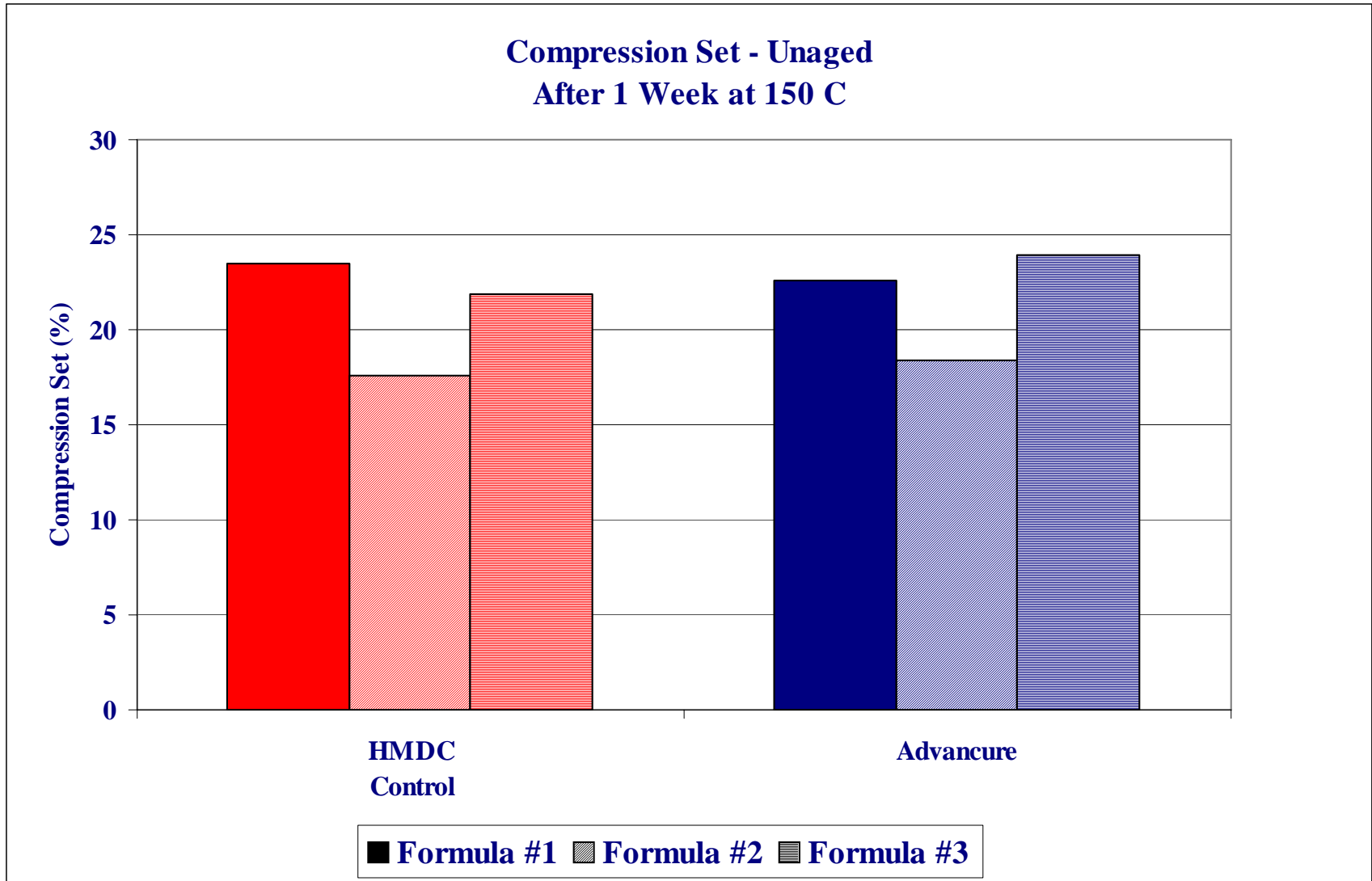
The Advancure compounds had slightly lower elongation values to the HMDC control compounds.



The Advancure compounds had slightly lower Die C tear to the HMDC control compounds.



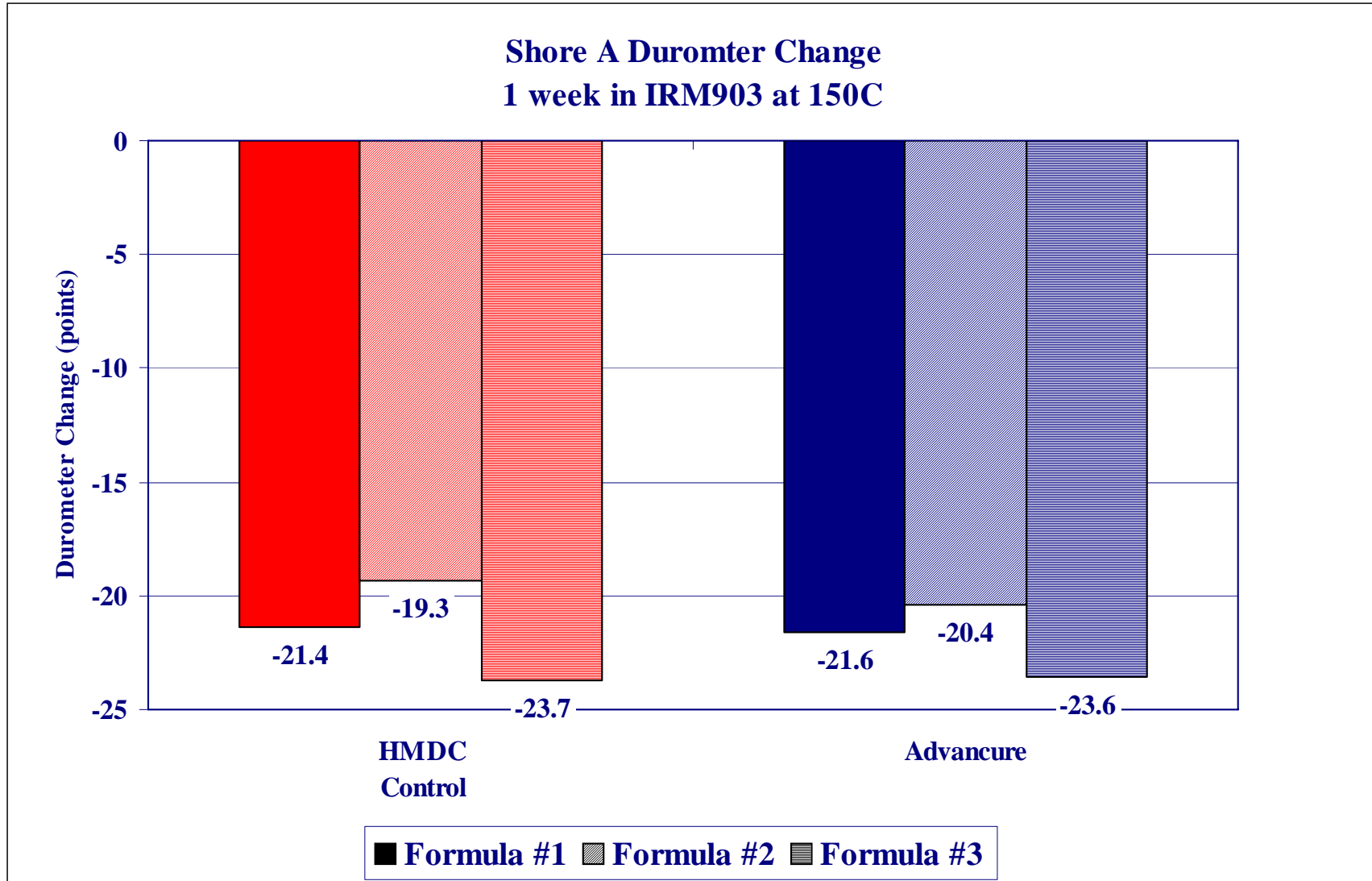
The Advancure compounds had similar compression set to the HMDC control compounds.



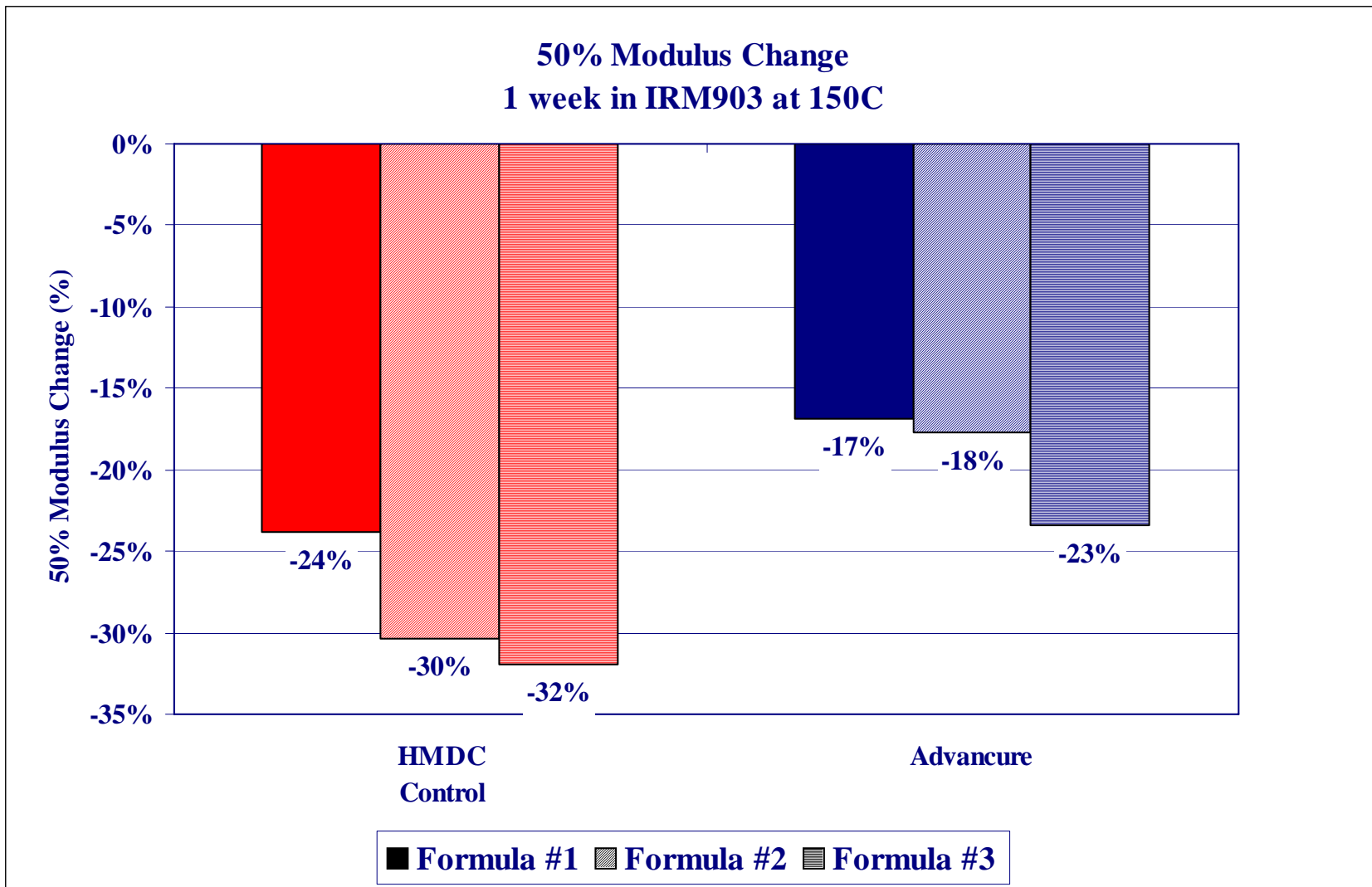
Aged Physical Properties

**Aged 1 week at 150C
in IRM903 Oil, ASTM D471**

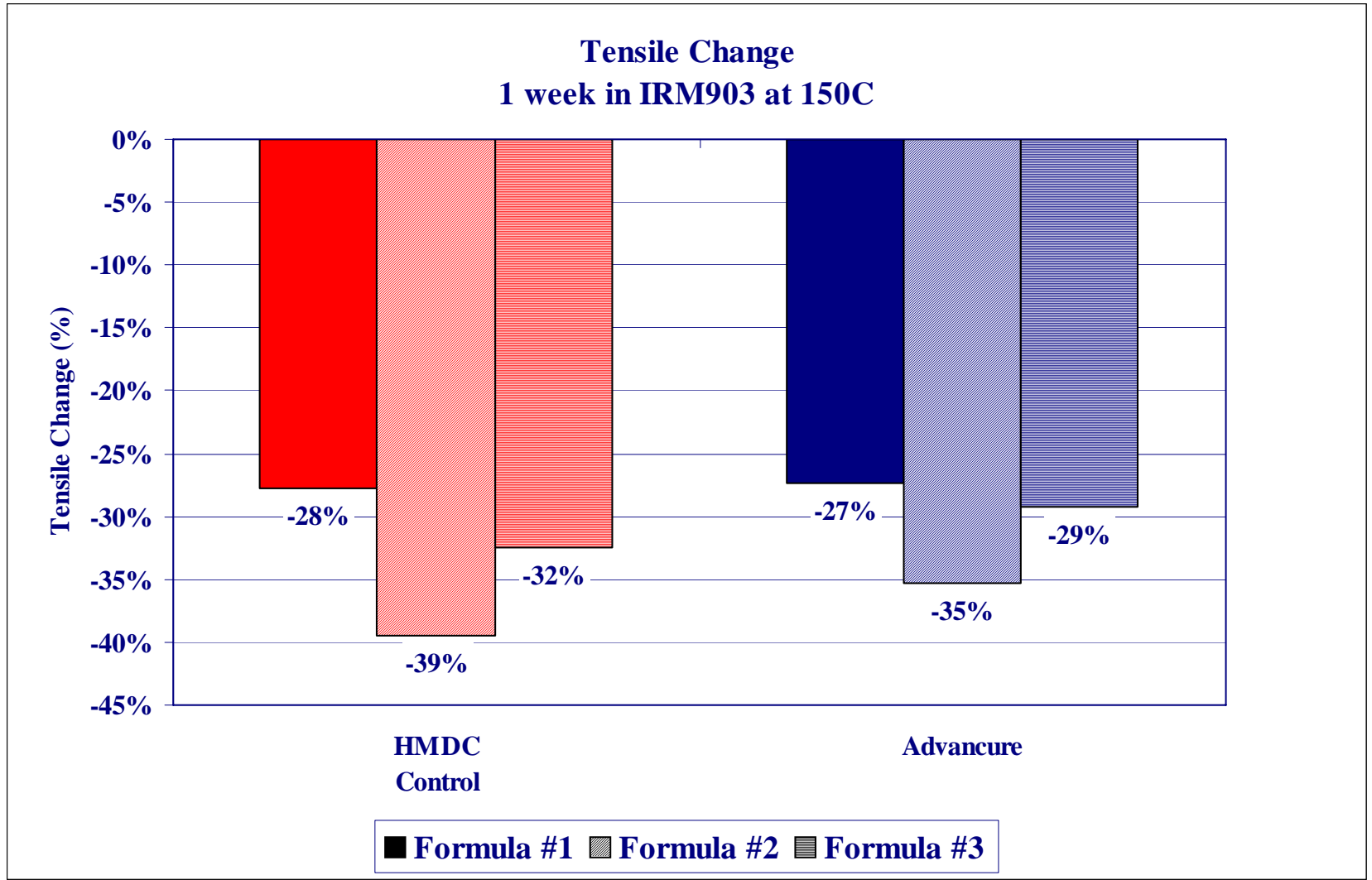
The Advancure compounds had similar change in durometer to the HMDC control compounds.



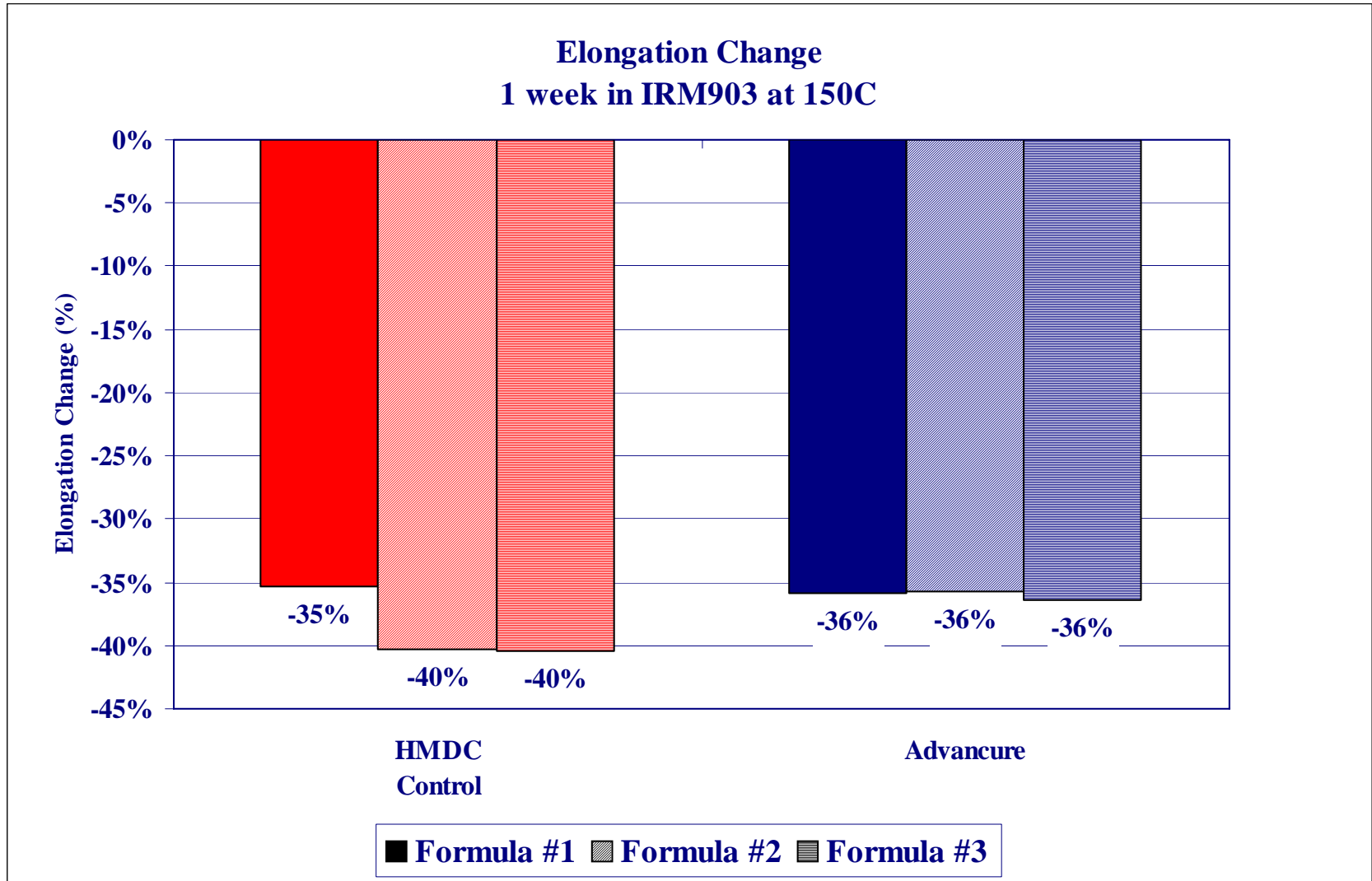
The Advancure compounds had less change in 50% modulus than the HMDC control compounds.



The Advancure compounds had similar change in tensile to the HMDC control compounds.



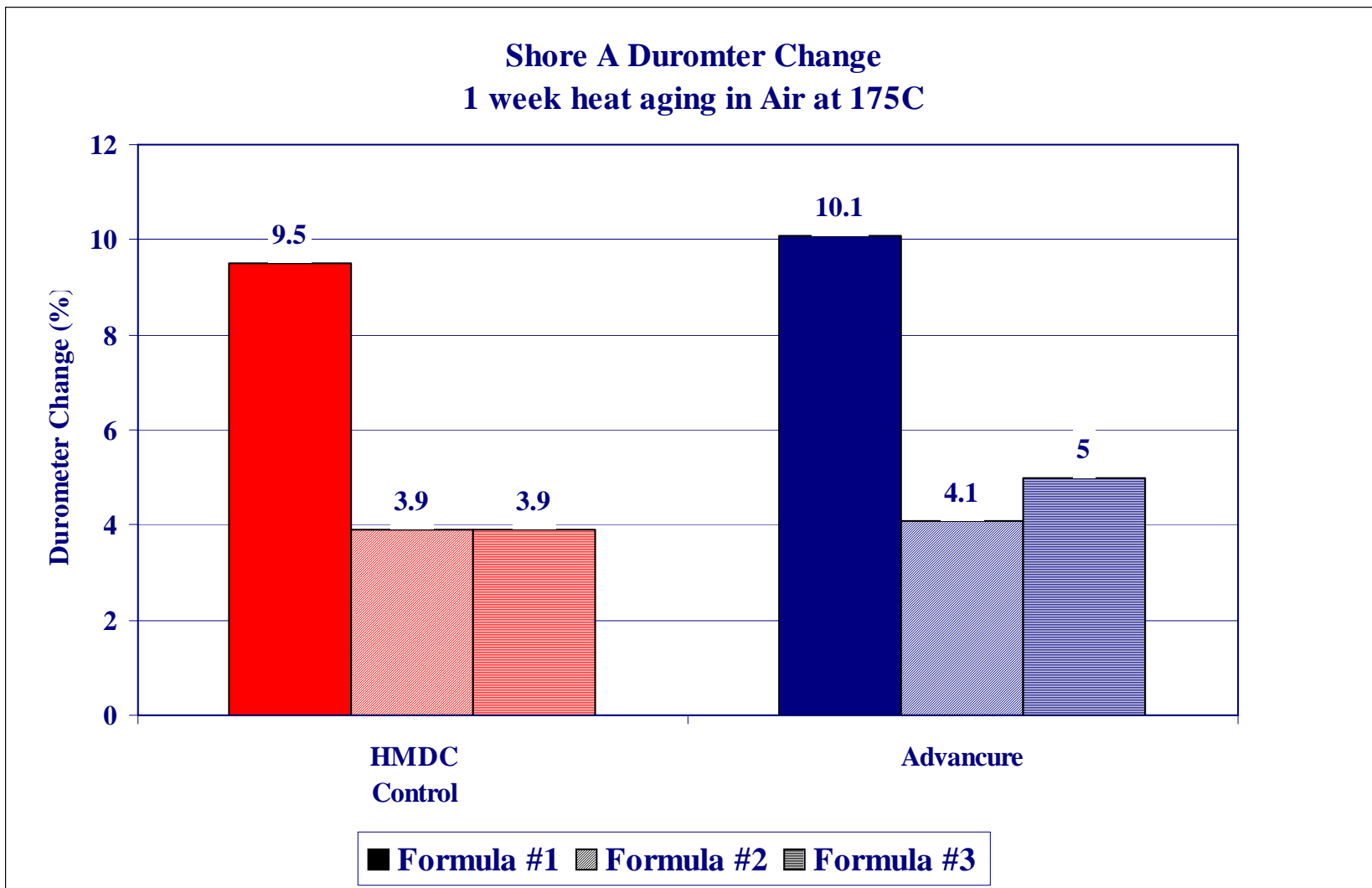
The Advancure compounds had similar to less elongation change than the HMDC control compounds.



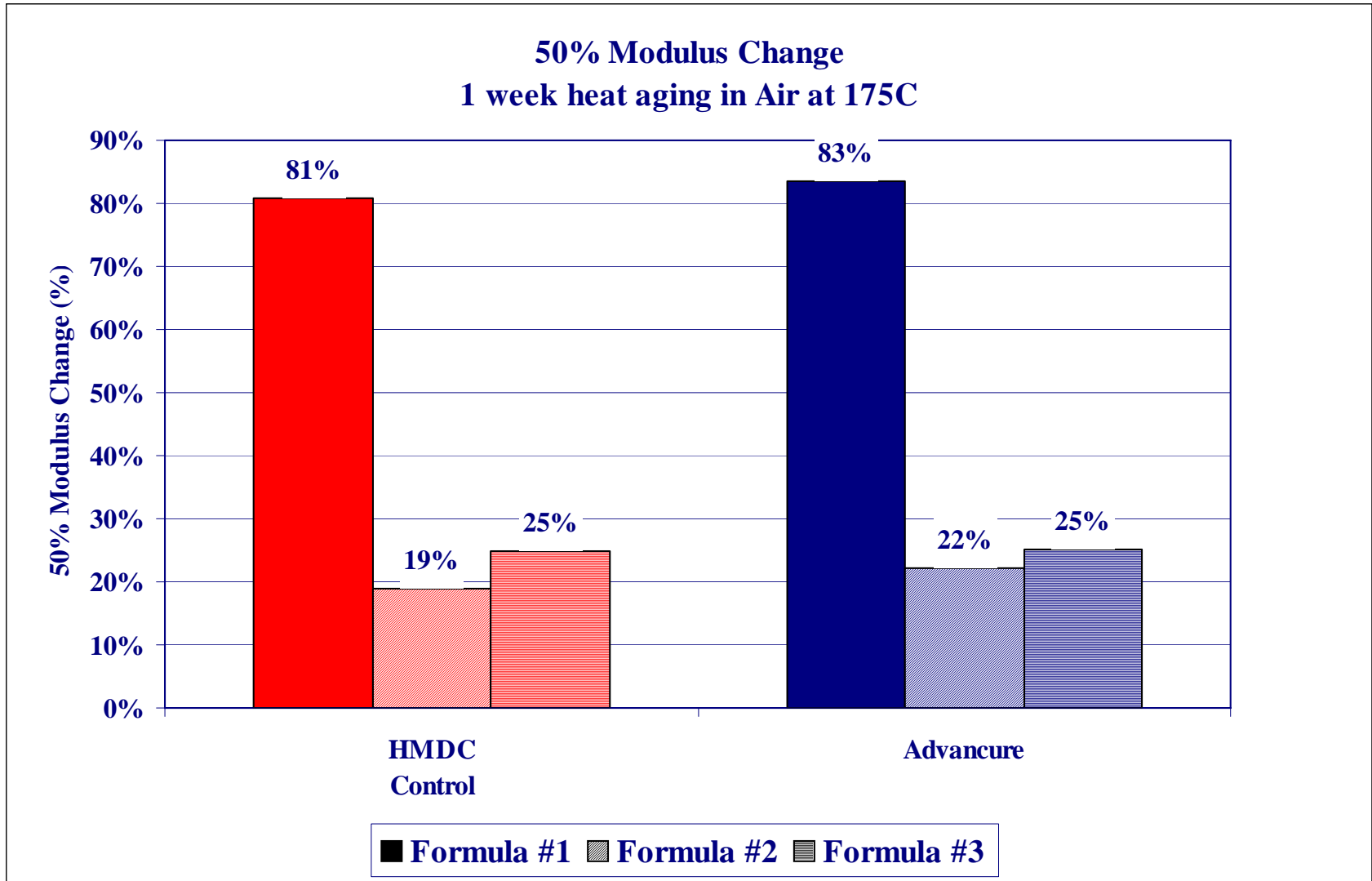
Aged Physical Properties

**Aged 1 week at 175°C in Air,
ASTM D572**

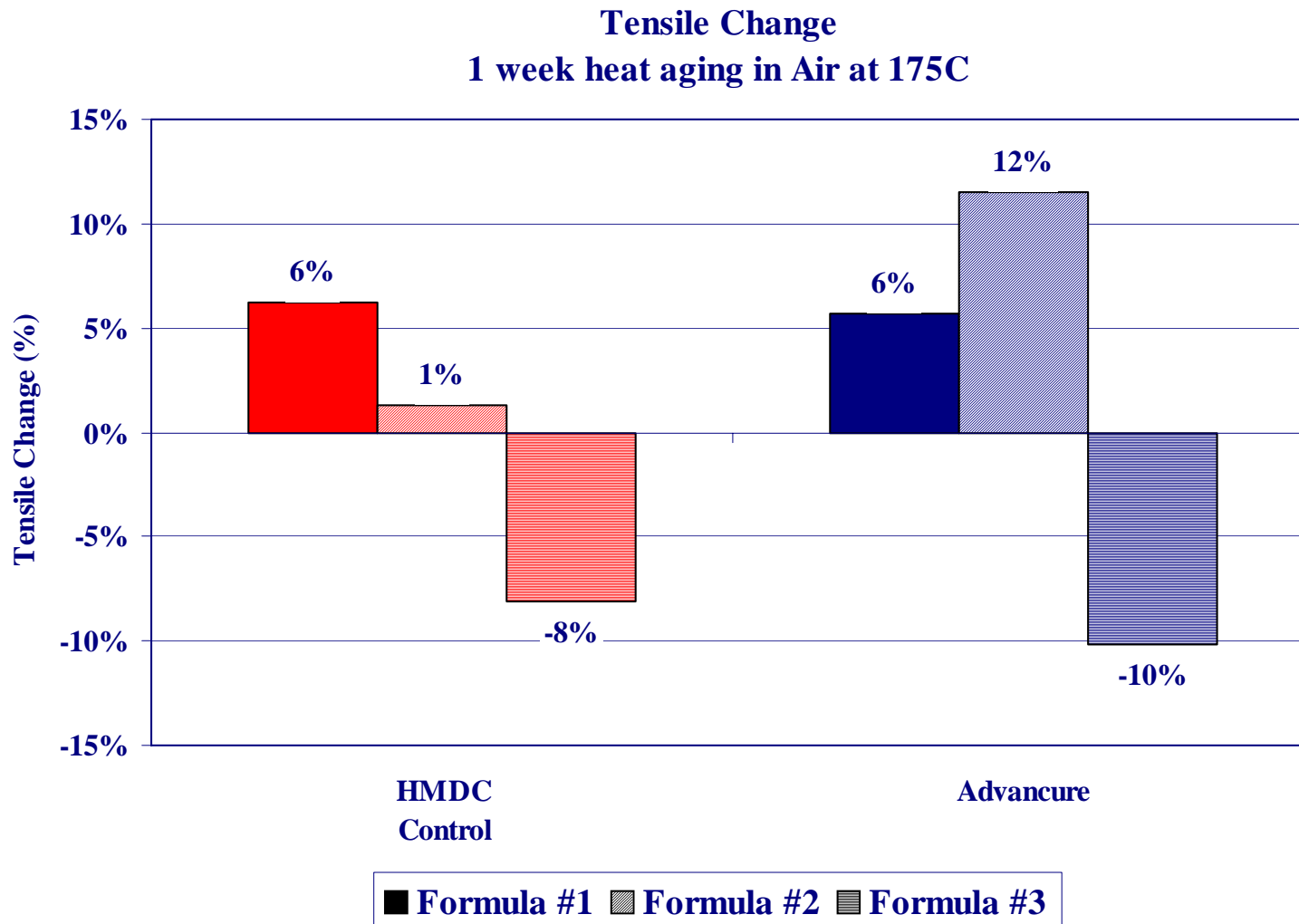
The Advancure compounds had similar retained durometer to the HMDC control compounds.



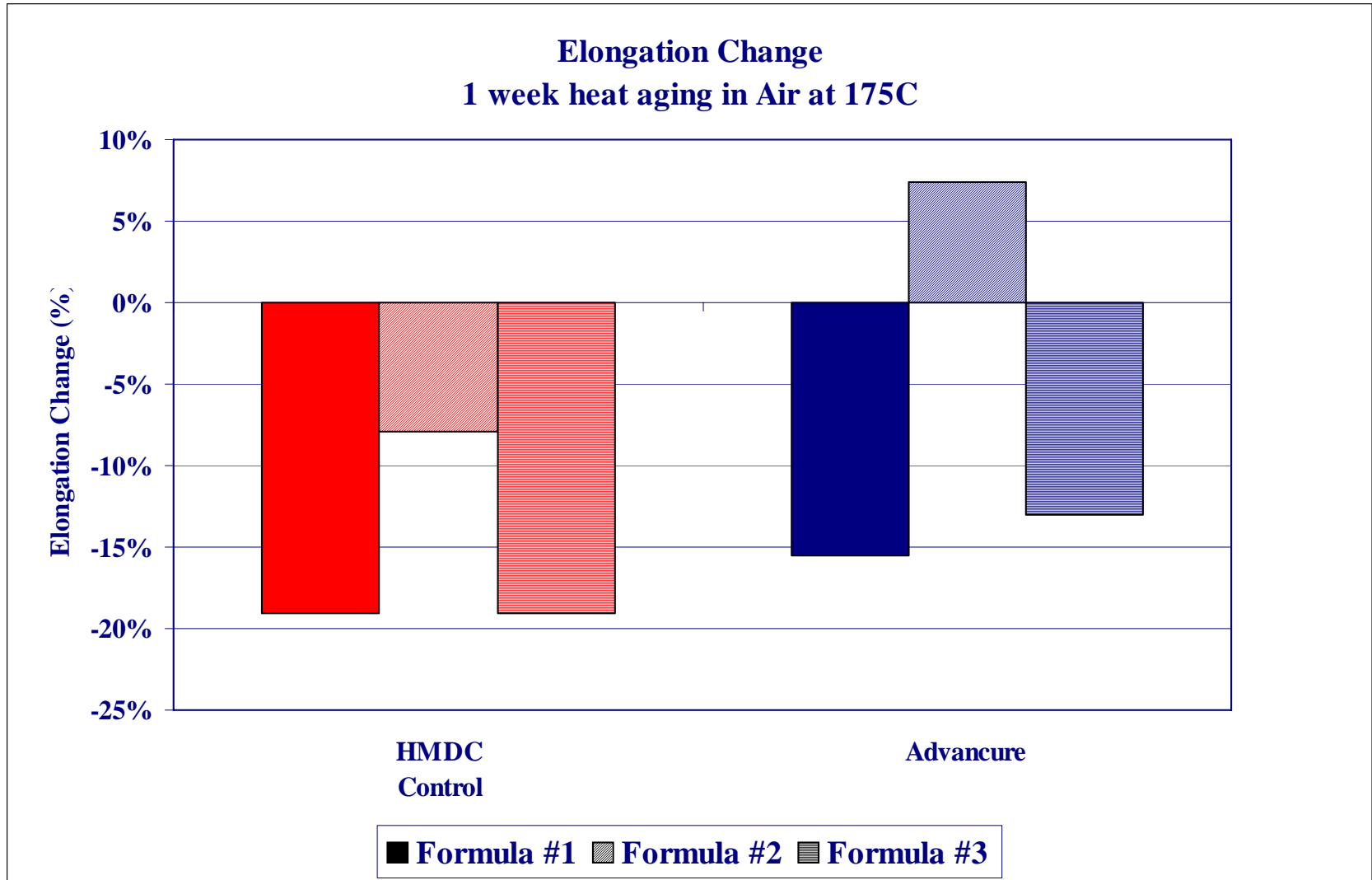
The Advancure compounds had similar change in 50% modulus to the HMDC control compounds.



The Advancure compounds had similar to higher change in tensile compared to the HMDC control compounds.



The Advancure compounds had higher elongation to the HMDC control compounds.



Factory Mixing Trials

**Gold Key Processing
Krupp Intermesh 45 L**

**Testing – Gold Key Processing and
Chem Technologies Laboratories**

Formulation



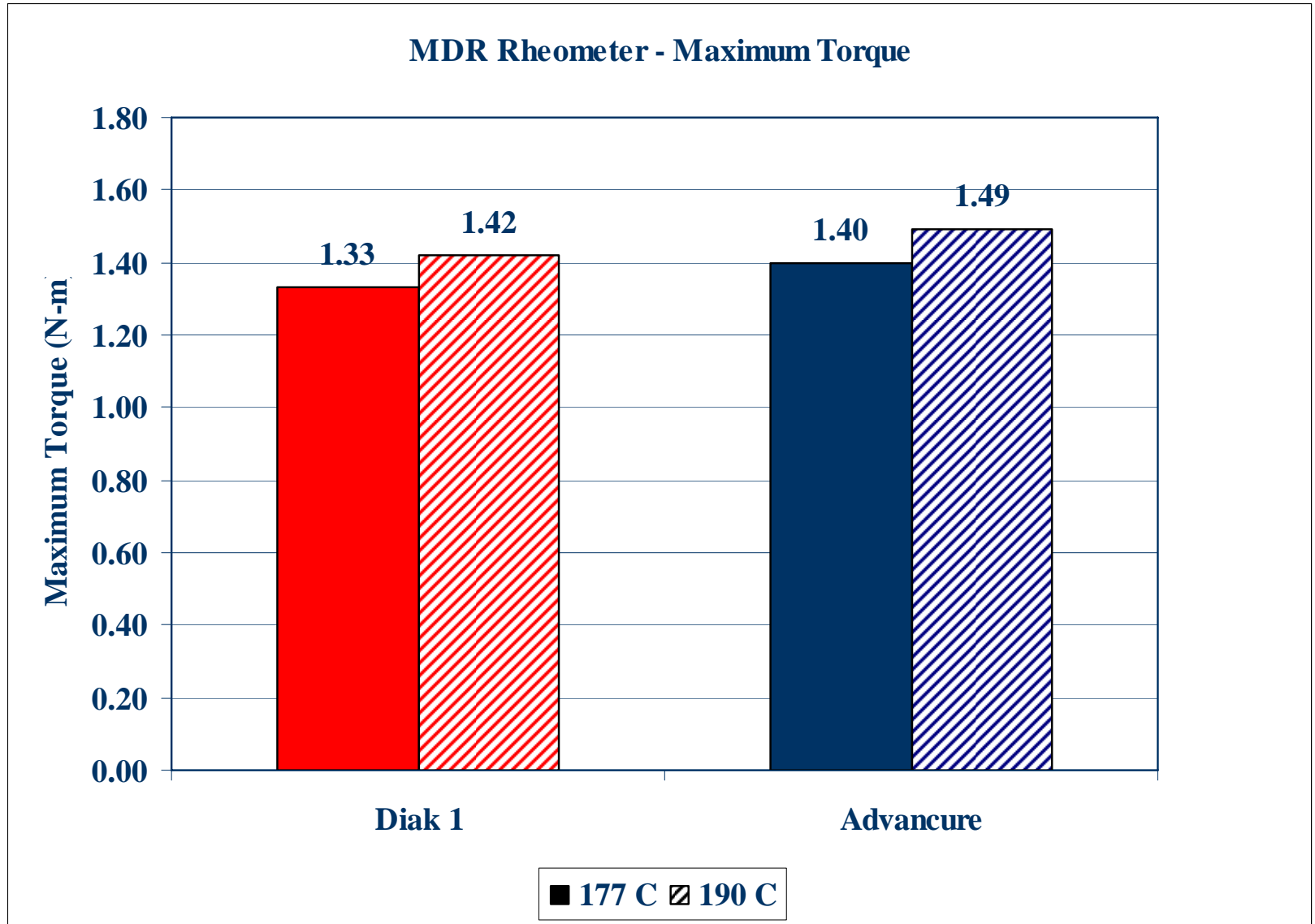
● Vamac[®] G	100.00
● N774 Carbon Black	90.00
● Stearic Acid	2.00
● Polyoxyethylene octadecyl ether phosphate	1.50
● 1-ocadecanamine	0.50
● Di(2-ethylhexyl) sebacate	10.00
● DOTG (di-<i>o</i>-tolylguanidine)	4.00
● <i>HMDC (Diak 1)</i>	<i>1.50</i>
<i>Or</i>	
● <i>Advancure</i>	<i>2.30</i>

Diak 1 and Vamac are trademarks of DuPont.

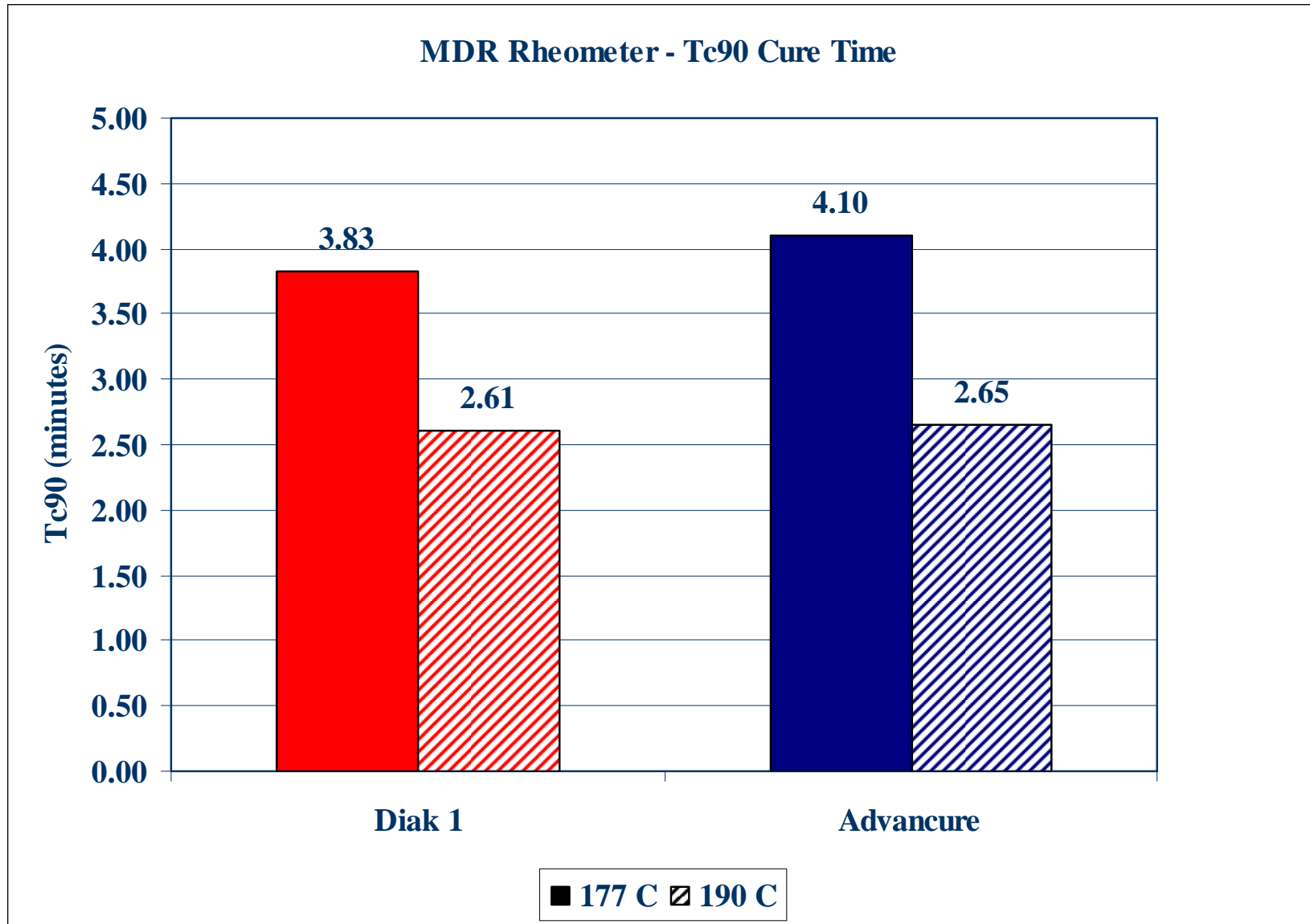


- **Mixing was done in a Krupp 45L intermesh mixer with a dump temperature of 93°C.**
- **MDR Rheometer at 177°C, ASTM D 5289.**
- **Mooney at 121°C, ASTM D 1646.**
- **Physical Properties (hardness, tensile, modulus, elongation). Press-cured 5 minutes at 177°C, post cured 4 hours at 177°C. ASTM D 412.**

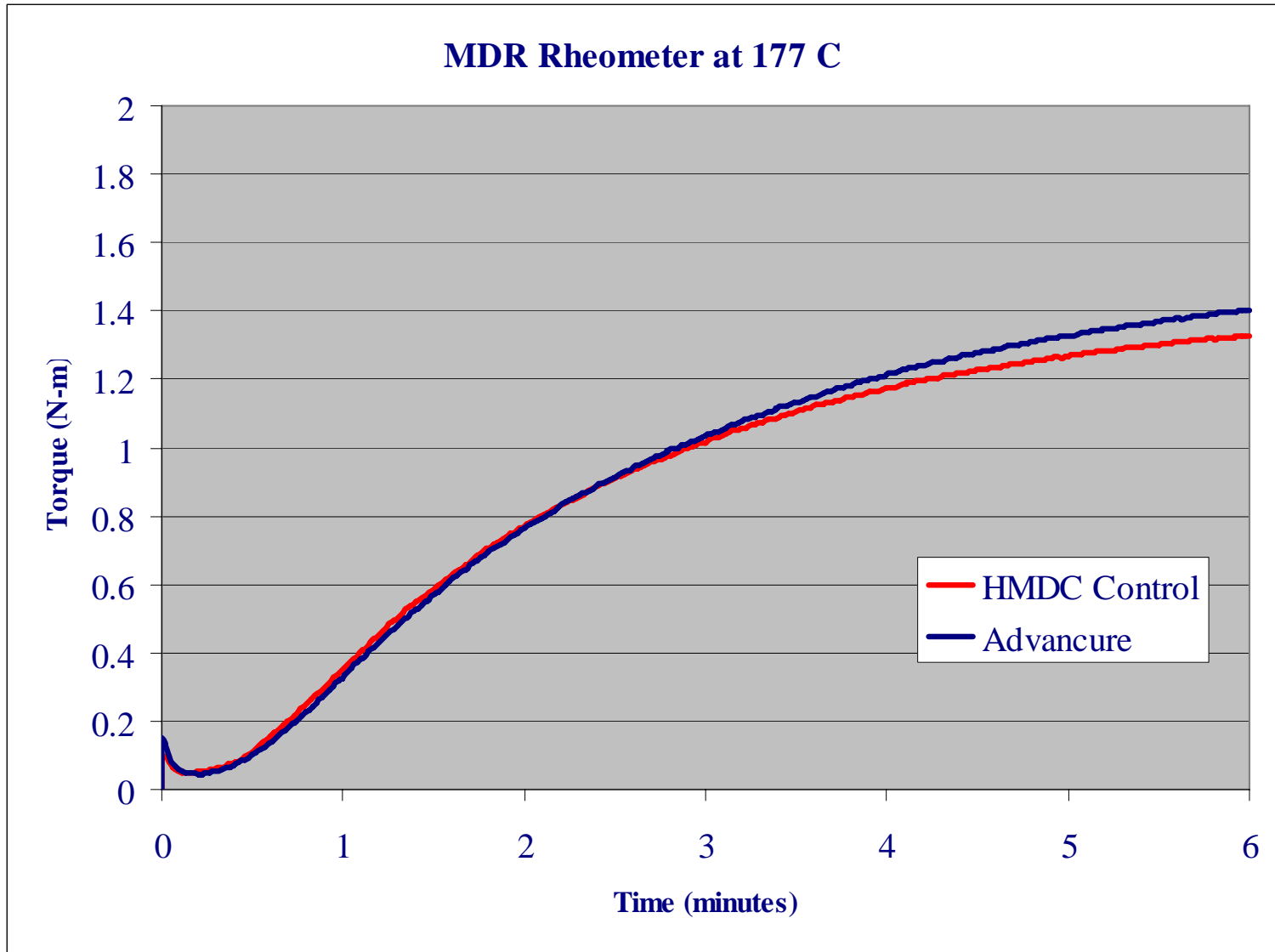
The Advancure compound had slightly higher maximum torque values than the HMDC control compound.



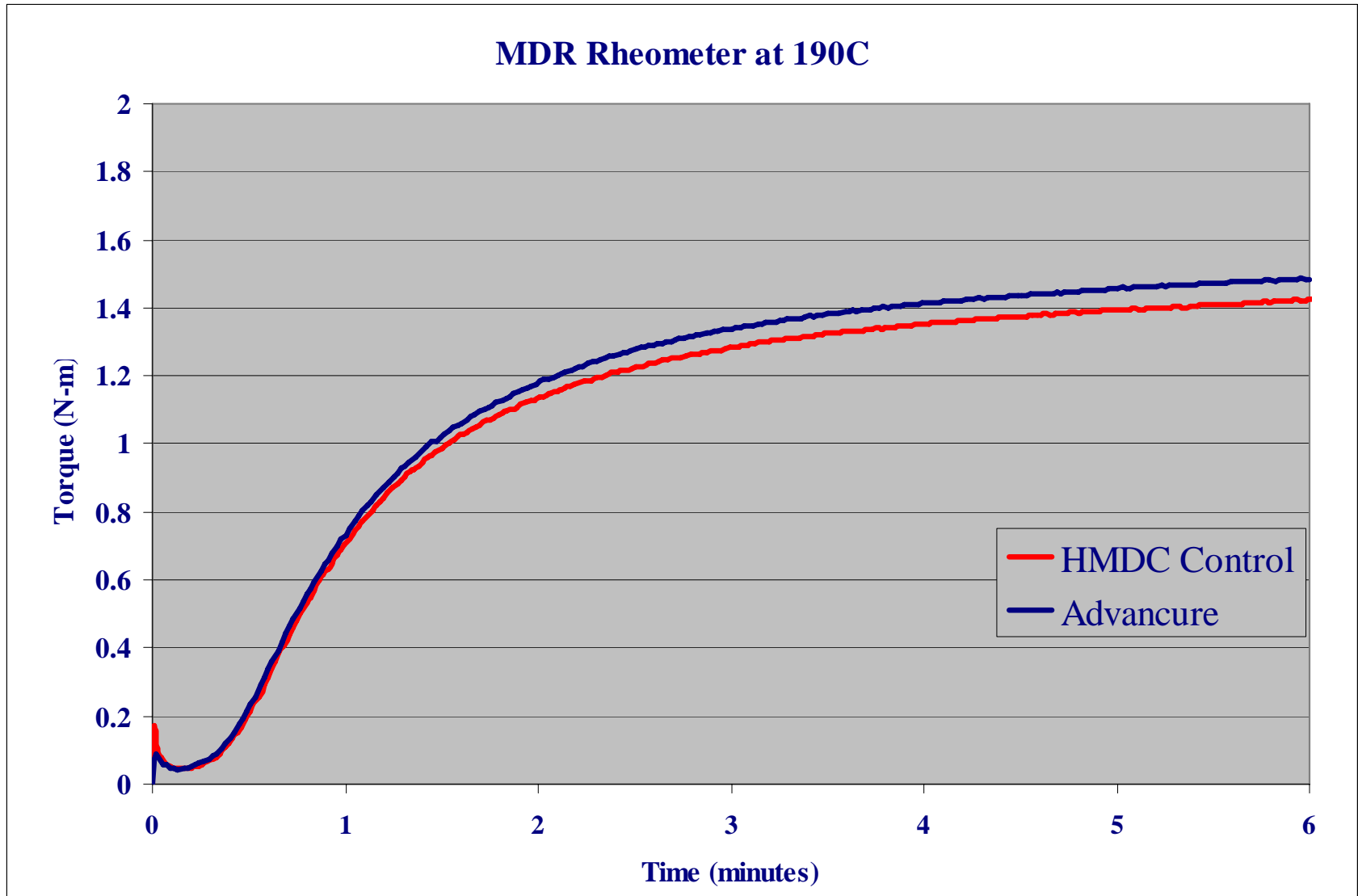
The Advancure compound had a similar Tc90 cure times to the HMDC control compound.



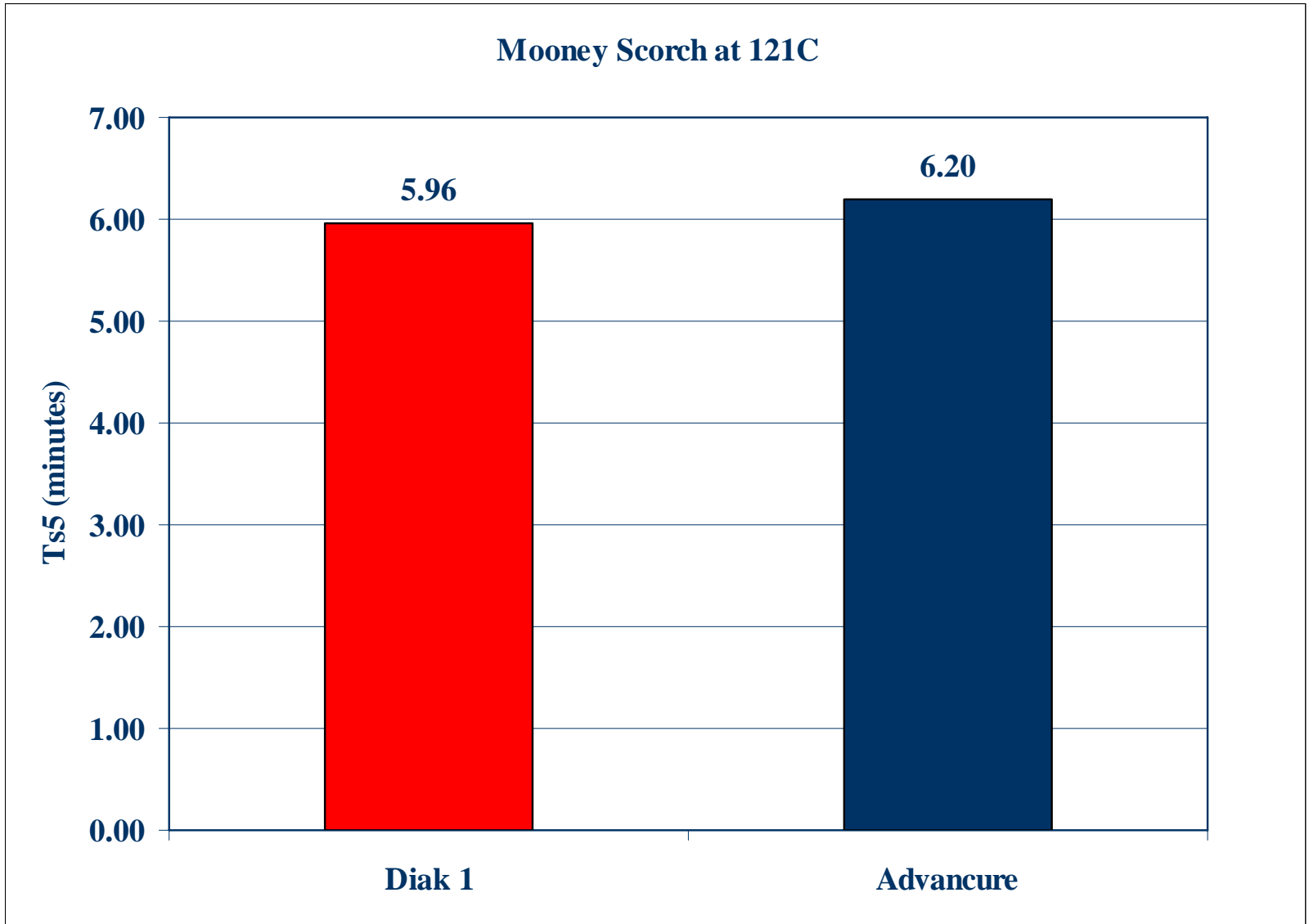
The Advancure compound has a rheometer curve similar to the HMDC control but with a higher state of cure.



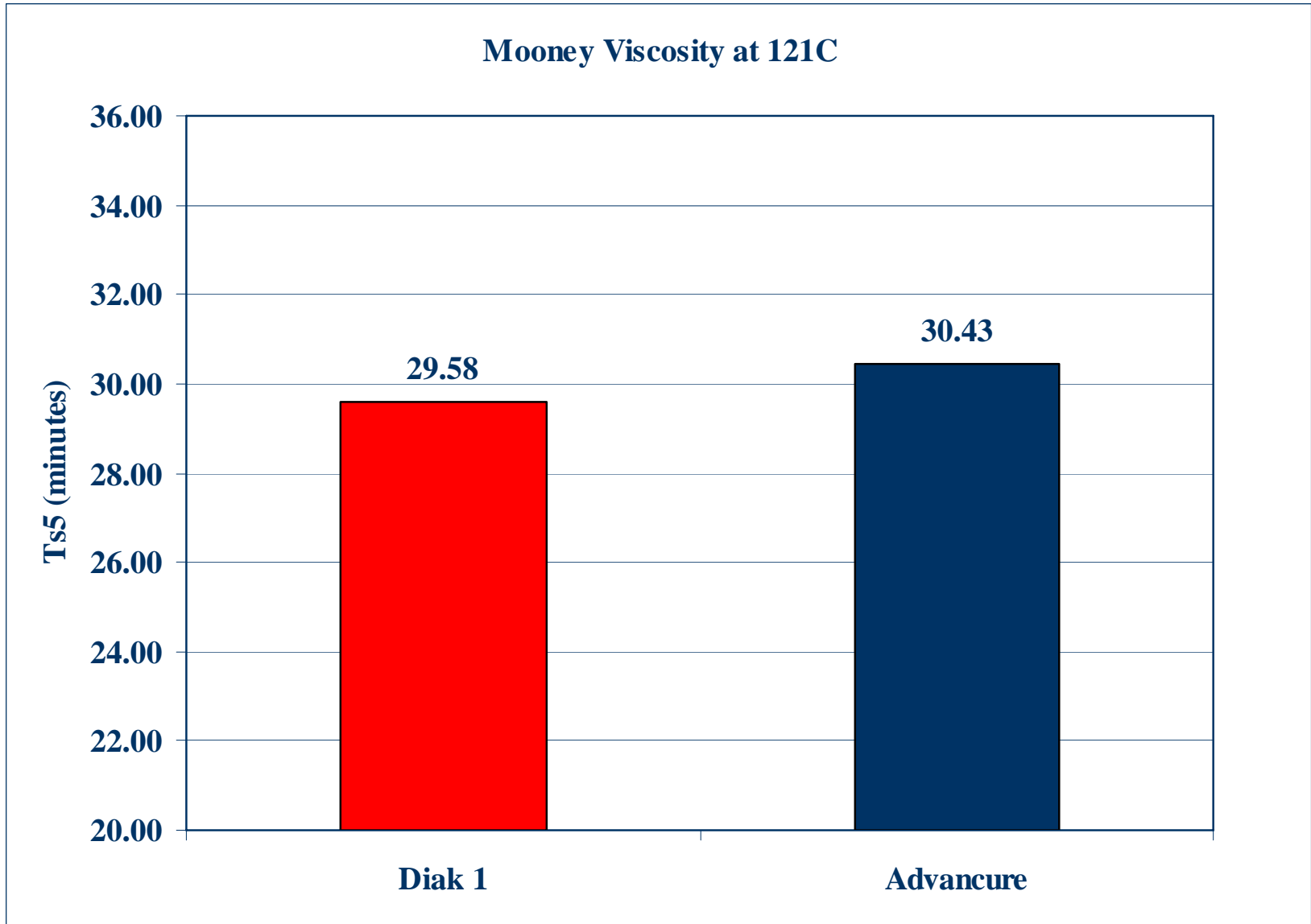
The Advancure compound has a rheometer curve similar to the HMDC control but with a higher state of cure.



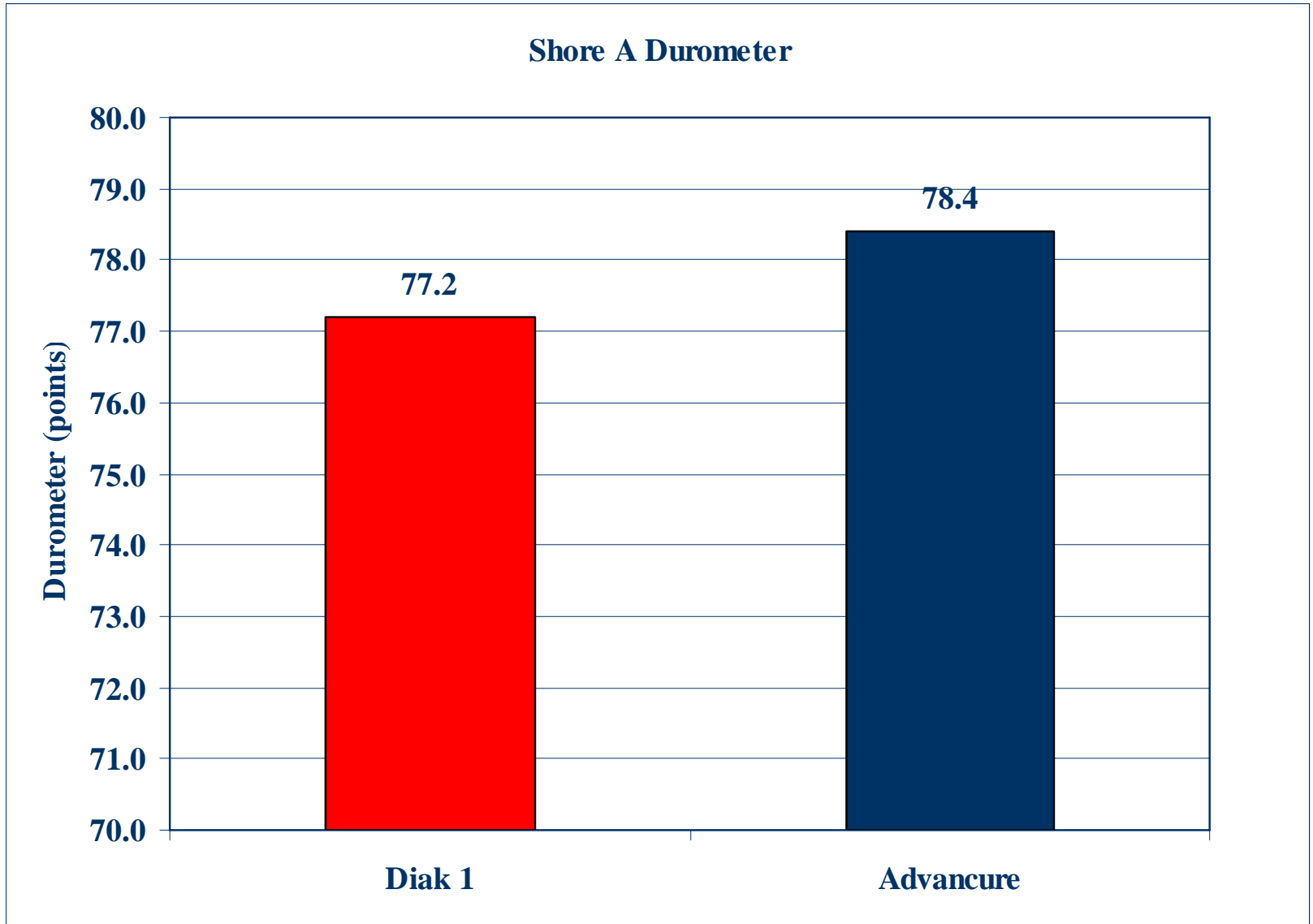
The Advancure compound had a similar scorch time to the HMDC control.



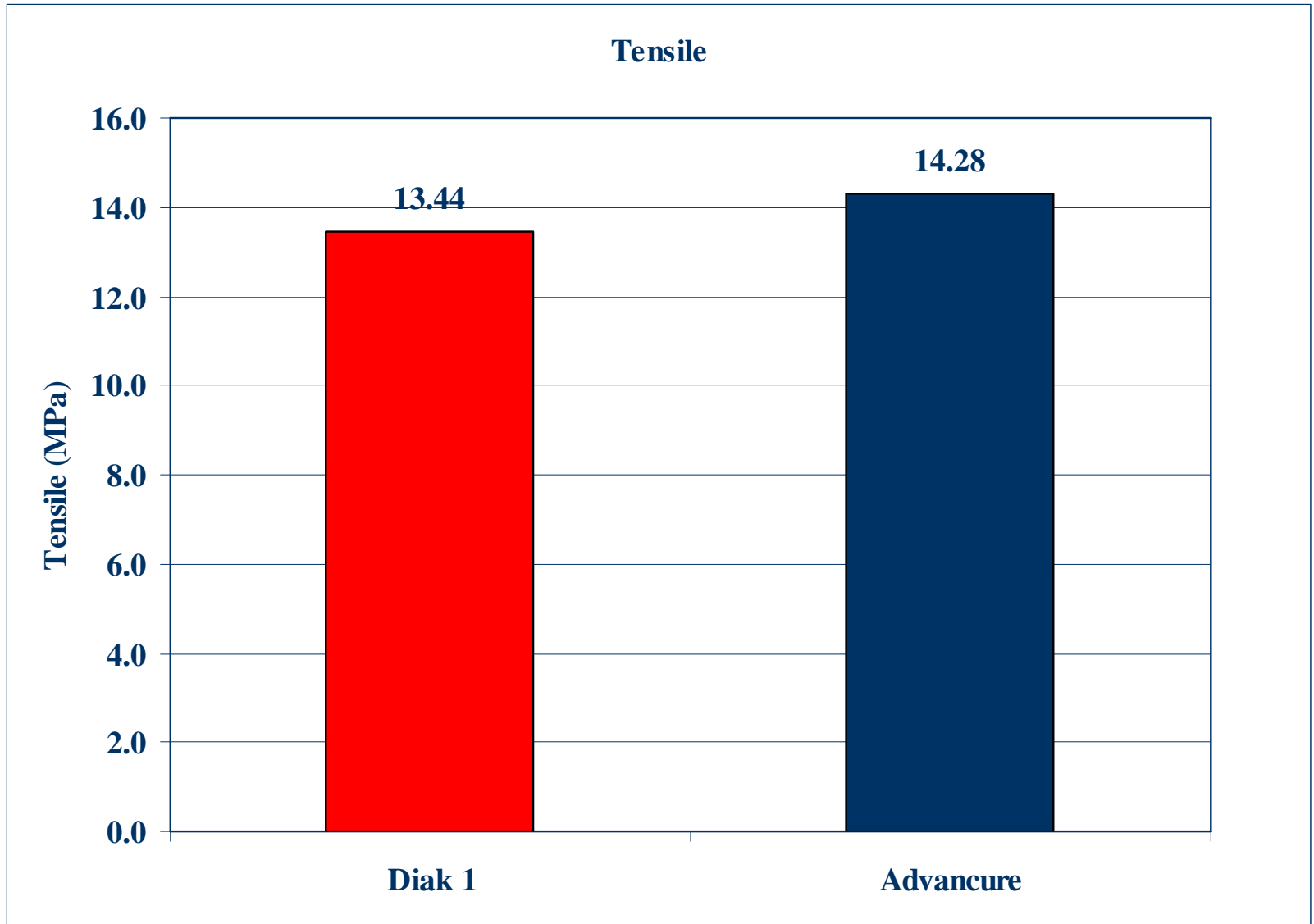
The Advancure compound had a similar Mooney viscosity to the HMDC control compound.



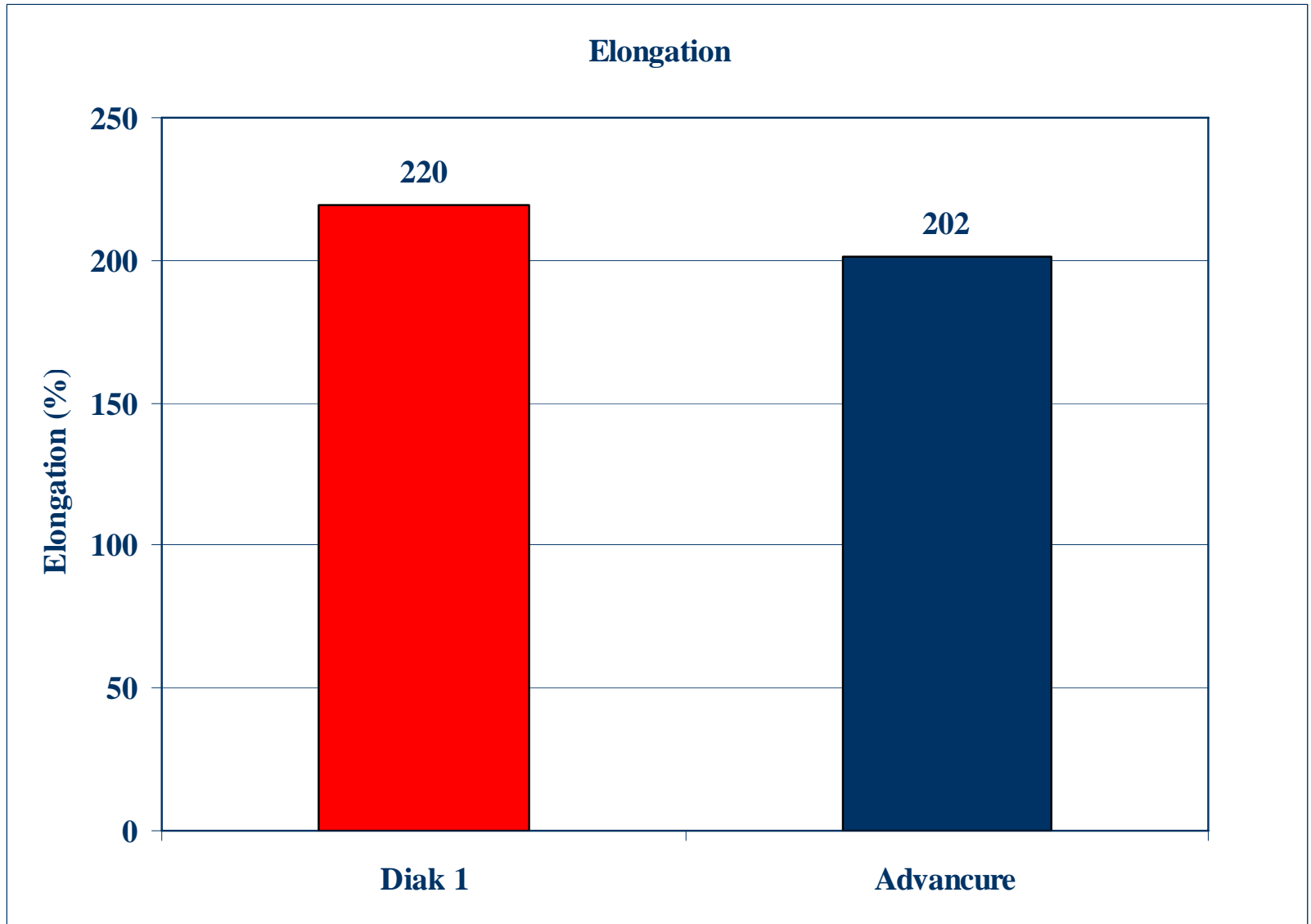
The Advancure compound had a similar Shore A durometer values to the Diak 1 compound.



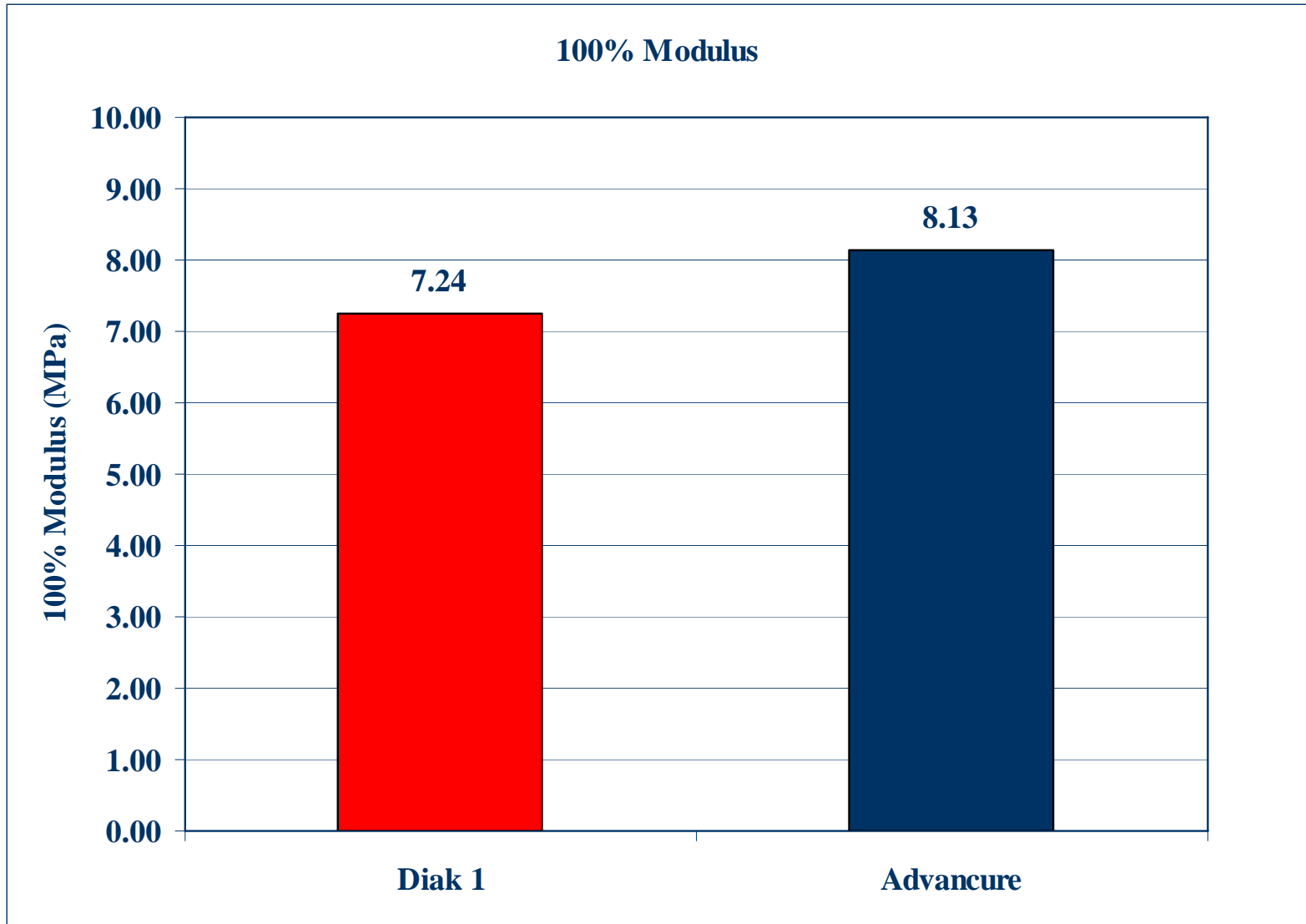
The Advancure compound had a slightly higher tensile than the Diak 1 compound.



The Advancure compound had slightly lower elongation than the Diak 1 compound.



The Advancure compound had slightly higher 100% modulus than the Diak 1 compound.

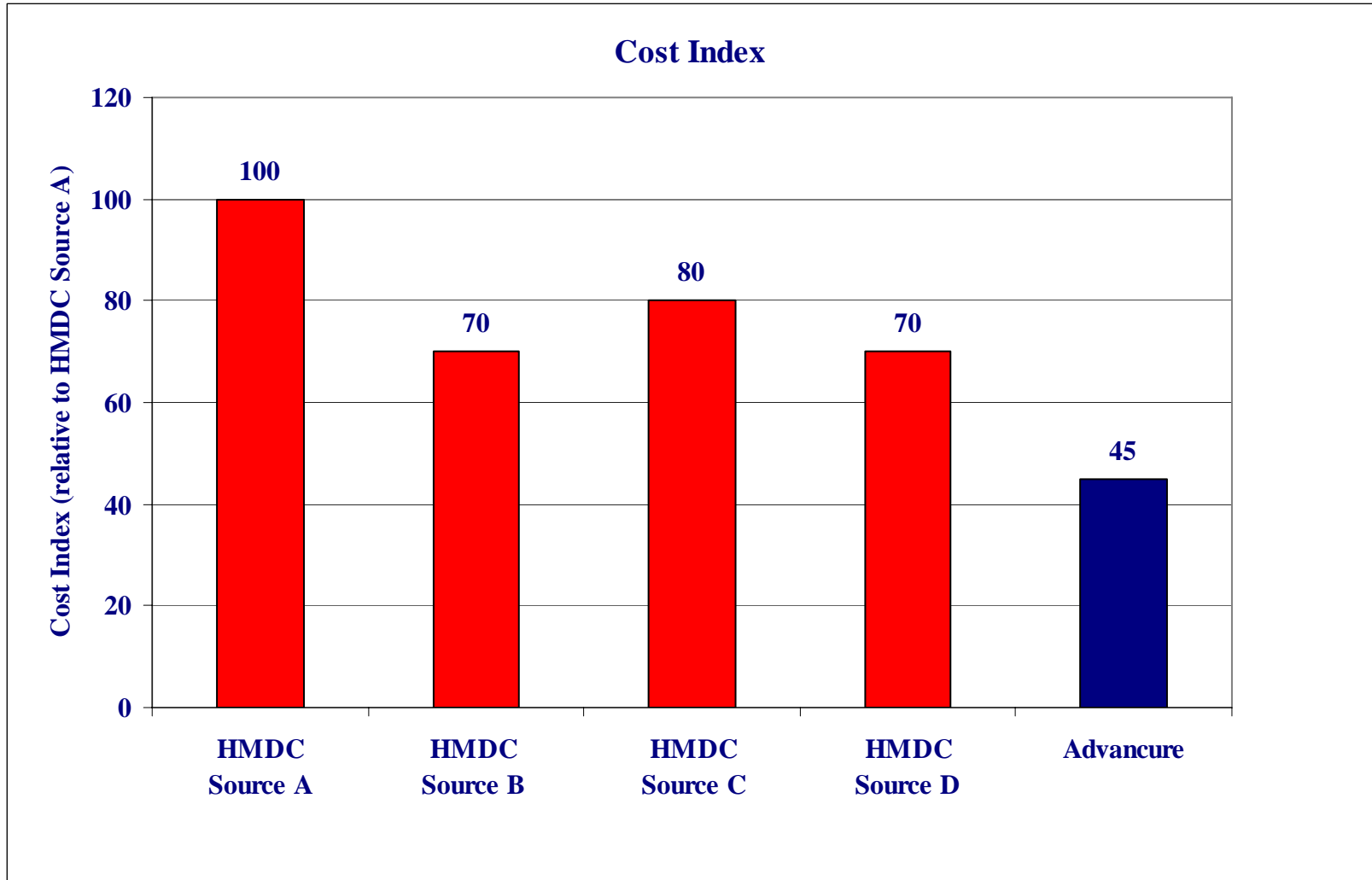




Costing & Conclusions



The Advancure curative offers a significant cost savings versus HMDC products.





- **The Advancure curative was tested in four different Vamac[®] G compounds in two different laboratory studies and also in factory trials. Advancure had equal cure and physical properties to the HMDC controls.**
- **Advancure can offer significant cost savings compared HMDC sources currently on the market.**
- **In a typical Vamac[®] formulation this cost savings could result in a \$0.15 to \$0.20 a pound compound savings.**



- **The confidential information, data and formulations contained in this document are the property of Chem Technologies, Ltd and DuPont. No guarantee as to the suitability or performance of the data contained in this presentation is made beyond the information contained herein.**