

**Styron 663 W/O Additives**

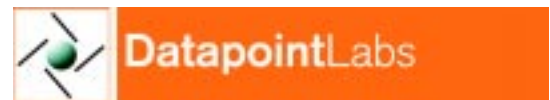
# Test Report: Styron 663 W/O Additives

<b>Client</b>	Anna Pla-Dalmau
<b>Company</b>	Fermilab
<b>Address</b>	Pine Street PO Box 500 Batavia, IL United States
<b>Sample Received</b>	11/3/2003
<b>Sample Source</b>	Client
<b>Report Prepared</b>	11/7/2003
<b>Prepared By</b>	
<b>Title</b>	Engineer
<b>Issued By</b>	
<b>Title</b>	Operations Manager

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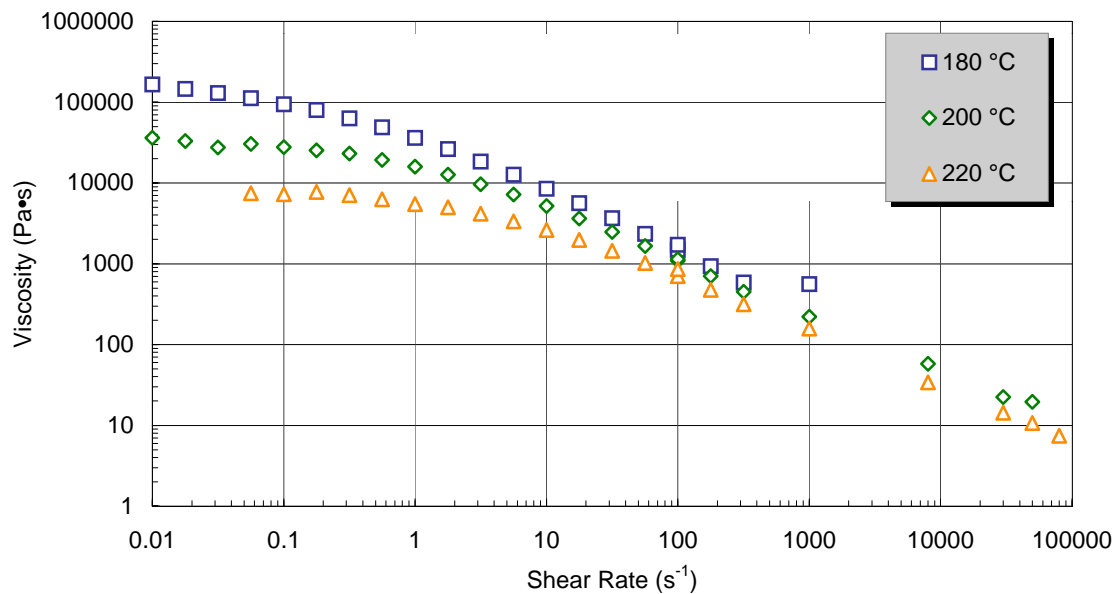
## Viscosity Summary

### Viscosity Data

180 °C		200 °C		220 °C	
Shear Rate s <sup>-1</sup>	Viscosity Pa·s	Shear Rate s <sup>-1</sup>	Viscosity Pa·s	Shear Rate s <sup>-1</sup>	Viscosity Pa·s
0.01	165730.00	0.01	36060.40	0.06	7474.18
0.02	146620.00	0.02	33037.00	0.10	7286.40
0.03	130050.00	0.03	27548.10	0.18	7716.84
0.06	112120.00	0.06	30435.50	0.32	7076.47
0.10	94597.30	0.10	27877.20	0.56	6293.13
0.18	80120.80	0.18	25376.80	1	5478.89
0.32	63217.40	0.32	23052.80	1.78	4994.86
0.56	48977.70	0.56	19316.70	3.16	4183.11
1	36292.10	1	15952.50	5.62	3359.89
2	26306.90	2	12689.90	10.00	2627.96
3	18441.80	3	9655.87	18	1978.72
6	12654.20	6	7207.06	32	1442.22
10	8502.51	10	5180.58	56	1022.58
18	5611.85	18	3627.26	100	706.87
32	3650.92	32	2486.84	178	476.88
56	2340.71	56	1659.07	316	315.05
100	1485.94	100	1088.82	100	859.98
178	936.96	178	703.49	1000	158.21
316	588.44	316	448.70	8000	34.15
100	1714.60	100	1139.50	30000	14.34
1000	558.33	1000	220.85	50001	10.67
		8000	57.70	80000	7.46
		30000	22.44		
		50001	19.53		

Viscosity Summary Continued

Viscosity vs Shear Rate



Viscosity Summary Continued

**Second Order Model (Moldflow)**

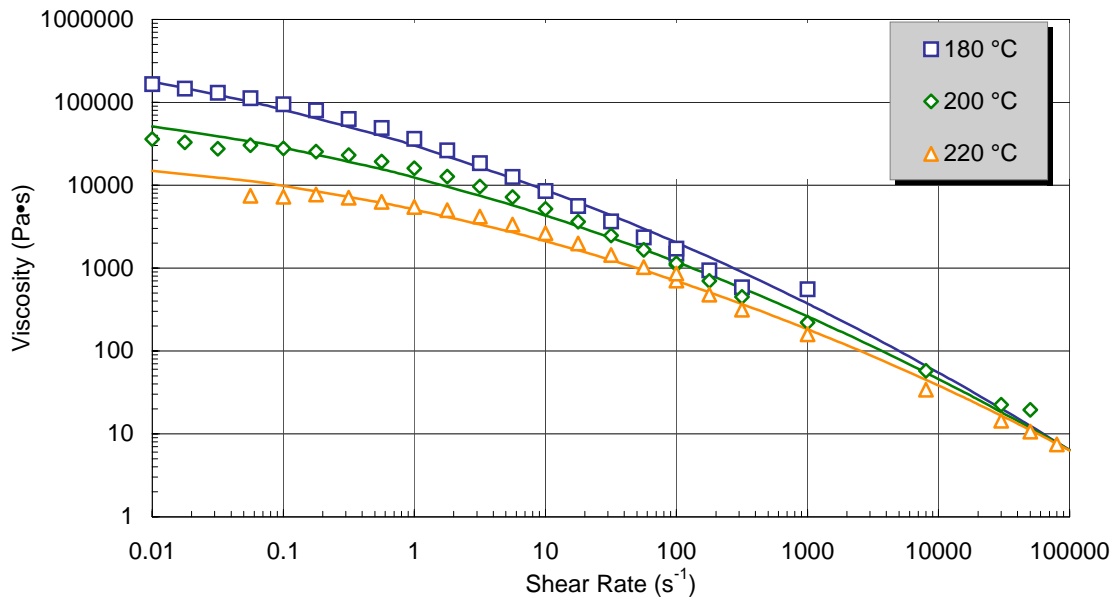
$$\ln \eta = A_1 + A_2 \ln \dot{\gamma} + A_3 T + A_4 (\ln \dot{\gamma})^2 + A_5 \ln \dot{\gamma} T + A_6 T^2$$

NOTE: model used for moldflow application, not good for this wide of a range

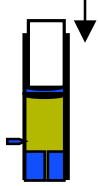
**Coefficients (SI units)**

<b>A1</b>	18.279
<b>A2</b>	-1.17277
<b>A3</b>	-0.04430
<b>A4</b>	-0.02159
<b>A5</b>	0.0038177
<b>A6</b>	1.230E-07

**Viscosity vs Shear Rate**



# Viscosity



<b>Method</b>	ASTM D 3835 - 96 Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer	
<b>Instrument</b>	Goettfert Rheograph 2003 Capillary Rheometer	
<b>Specimen</b>	type drying other preparation	pellets 4 hrs @ 70°C none
<b>Parameters</b>	initial pressure barrel diameter die entry angle die inner diameter die length preheating time	0 MPa 12 mm 180 ° 0.5 mm 20 mm 6 min
<b>Data Correction</b>		
<b>Precision</b>	temperature die inner diameter die length	+/- 0.1 °C +/- 0.0069 mm +/- 0.025 mm
<b>Uncertainty</b>	per standard	

*Polymer rheology characterizes the complex flow behavior of plastics. A capillary rheometer measures viscosity as a function of temperature and shear rate. The Goettfert rheometer utilizes direct measurement of melt pressures through a side mounted pressure transducer.*

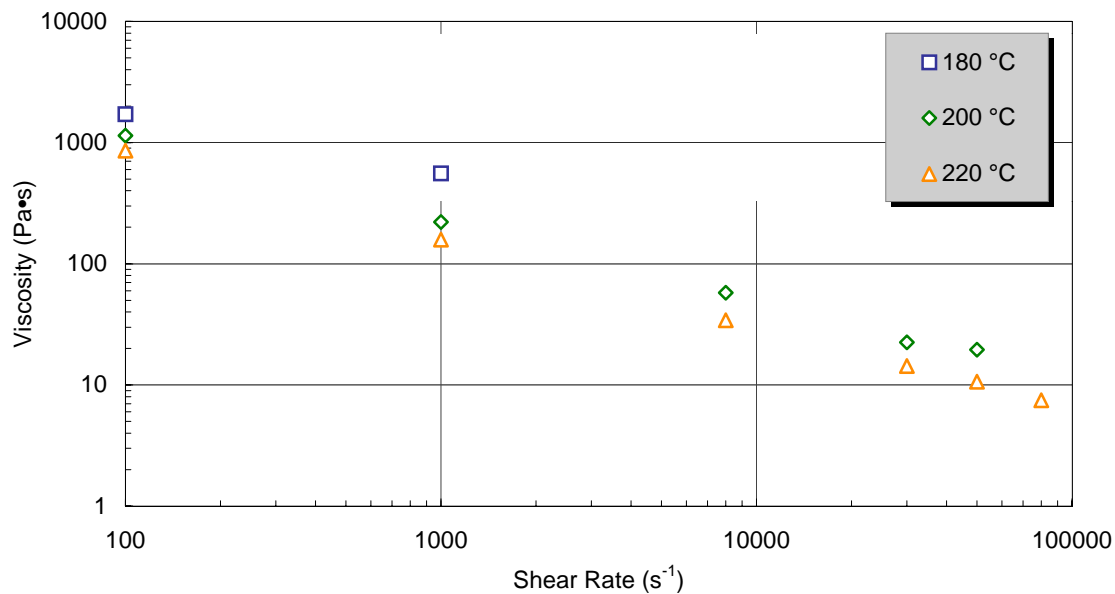
*Data are modeled using empirical or semi-empirical equations.*

## Viscosity Data

180 °C		200 °C		220 °C	
Shear Rate s <sup>-1</sup>	Viscosity Pa·s	Shear Rate s <sup>-1</sup>	Viscosity Pa·s	Shear Rate s <sup>-1</sup>	Viscosity Pa·s
100	1714.60	100	1139.50	100	859.98
1000	558.33	1000	220.85	1000	158.21
		8000	57.70	8000	34.15
		30000	22.44	30000	14.34
		50001	19.53	50001	10.67
				80000	7.46

Viscosity Continued

Viscosity vs Shear Rate



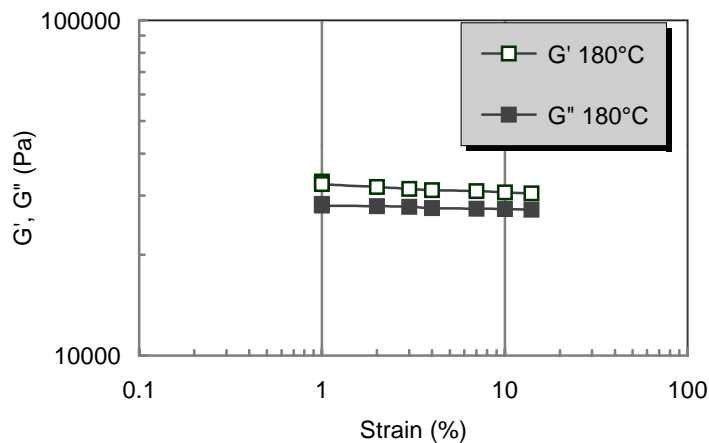
## Cone & Plate Rheology: Styron 663 W/O Additives 180°C



<b>Method</b>	ASTM D 4440 - 95a Rheological Measurement of Polymer Melts Using Dynamic Mechanical Procedures	
<b>Instrument</b>	Rheometrics ARES	
<b>Specimen</b>	type	disc
	conditioning	none
	other preparation	punched
<b>Parameters</b>	plate diameter	25 mm
	cone angle	0.1 radians
	gap	50 $\mu\text{m}$
	temperature	180 °C
	frequency range	0.01-500 rad/s
	strain	1 %
<b>Precision</b>	temperature	$\pm 2$ °C

*Polymer rheology characterizes the complex flow behavior of plastics. A dynamic mechanical rheometer measures complex viscosity as a function of temperature and frequency. Assuming the applicability of the Cox Merz relationship, the frequency bears a 1:1 relationship to the shear rate.*

### Strain Sweep



7903f1.txt

Cone and plate DMA measurements are not included in our current scope of accreditation.

**Tested By:** JA  
**Certified By:** BC  
**Test Date:** 11/6/2003

## Cone &amp; Plate Rheology: Styron 663 W/O Additives 180°C Continued

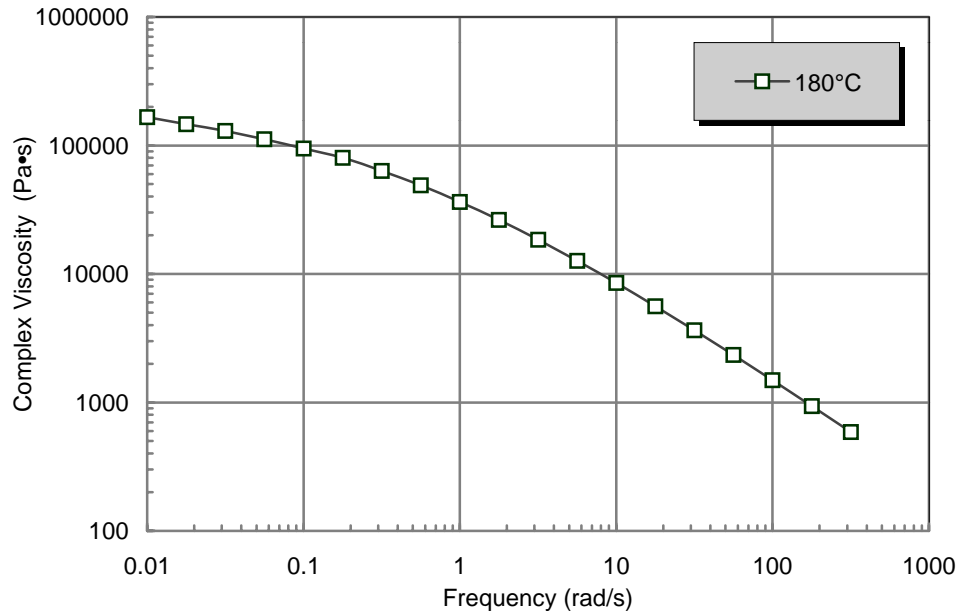
## DMA Data

Temp °C	$\omega$ rad/s	$\eta^*$ Pa*s	G' Pa	G'' Pa
180	1.00E-02	1.66E+05	1.63E+02	1.65E+03
180	1.78E-02	1.47E+05	6.02E+02	2.54E+03
180	3.16E-02	1.30E+05	1.37E+03	3.88E+03
180	5.62E-02	1.12E+05	2.46E+03	5.81E+03
180	1.00E-01	9.46E+04	4.39E+03	8.38E+03
180	1.78E-01	8.01E+04	7.52E+03	1.21E+04
180	3.16E-01	6.32E+04	1.21E+04	1.59E+04
180	5.62E-01	4.90E+04	1.87E+04	2.02E+04
180	1.00E+00	3.63E+04	2.68E+04	2.45E+04
180	1.78E+00	2.63E+04	3.68E+04	2.88E+04
180	3.16E+00	1.84E+04	4.82E+04	3.28E+04
180	5.62E+00	1.27E+04	6.12E+04	3.63E+04
180	1.00E+01	8.50E+03	7.54E+04	3.93E+04
180	1.78E+01	5.61E+03	9.05E+04	4.21E+04
180	3.16E+01	3.65E+03	1.06E+05	4.49E+04
180	5.62E+01	2.34E+03	1.23E+05	4.78E+04
180	1.00E+02	1.49E+03	1.39E+05	5.15E+04
180	1.78E+02	9.37E+02	1.57E+05	5.70E+04
180	3.16E+02	5.88E+02	1.74E+05	6.57E+04

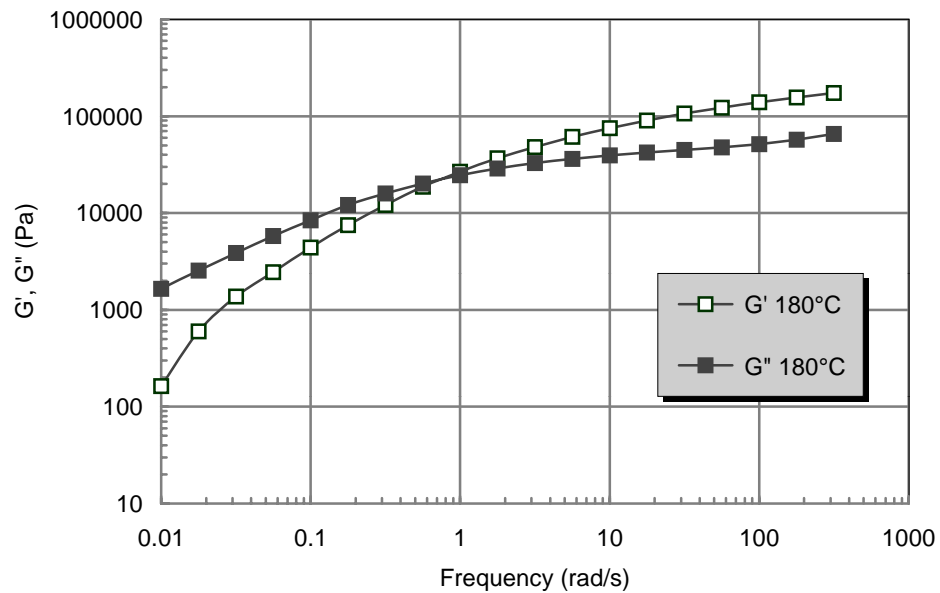
NOTE: Shaded cells denote torque below instrument limits.

## Cone &amp; Plate Rheology: Styron 663 W/O Additives 180°C Continued

## Complex Viscosity Plot



## G'-G'' Plot



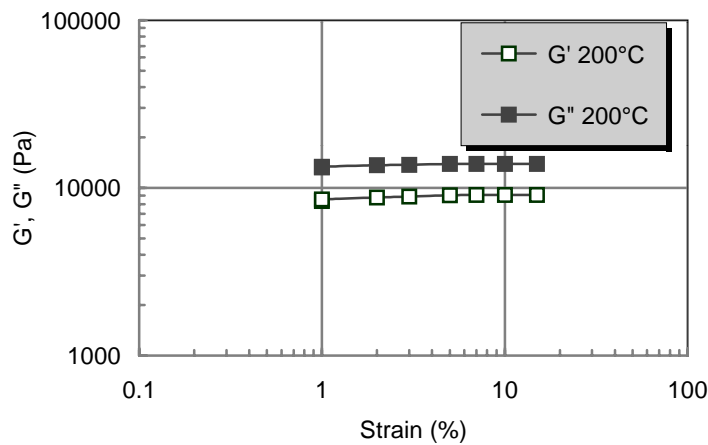
# Cone & Plate Rheology: Styron 663 W/O Additives 200°C



<b>Method</b>	ASTM D 4440 - 95a Rheological Measurement of Polymer Melts Using Dynamic Mechanical Procedures	
<b>Instrument</b>	Rheometrics ARES	
<b>Specimen</b>	type	disc
	conditioning	none
	other preparation	punched
<b>Parameters</b>	plate diameter	25 mm
	cone angle	0.1 radians
	gap	50 μm
	temperature	180 °C
	frequency range	0.01-500 rad/s
	strain	15 %
<b>Precision</b>	temperature	±2 °C

*Polymer rheology characterizes the complex flow behavior of plastics. A dynamic mechanical rheometer measures complex viscosity as a function of temperature and frequency. Assuming the applicability of the Cox Merz relationship, the frequency bears a 1:1 relationship to the shear rate.*

## Strain Sweep



7903f(200).txt

Cone and plate DMA measurements are not included in our current scope of accreditation.

**Tested By:** JA  
**Certified By:** BC  
**Test Date:** 11/6/2003

## Cone &amp; Plate Rheology: Styron 663 W/O Additives 200°C Continued

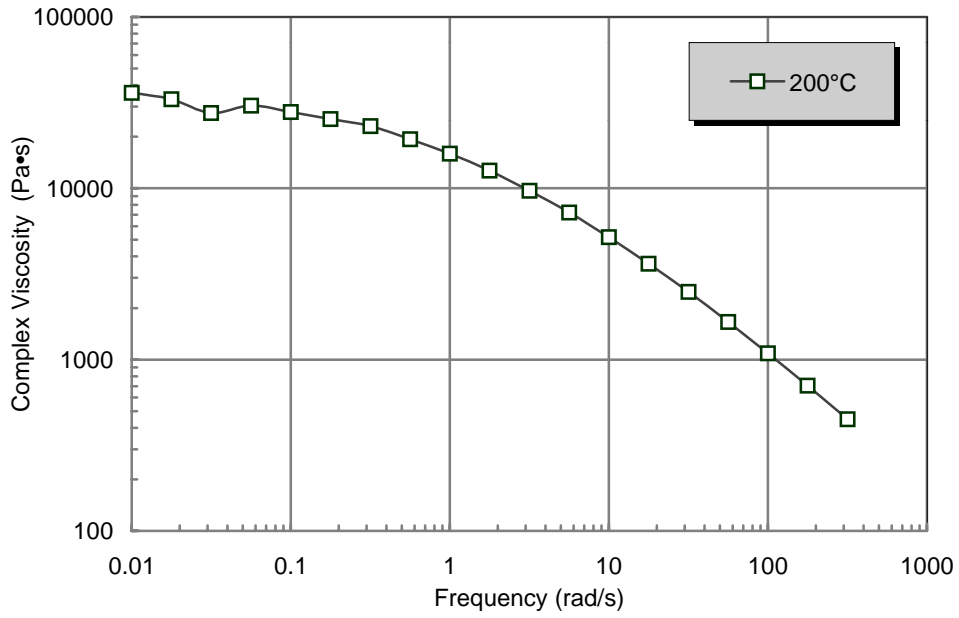
## DMA Data

Temp °C	$\omega$ rad/s	$\eta^*$ Pa*s	G' Pa	G'' Pa
200	1.00E-02	3.61E+04	3.15E+01	3.59E+02
200	1.78E-02	3.30E+04	8.29E+01	5.82E+02
200	3.16E-02	2.75E+04	3.28E+01	8.71E+02
200	5.62E-02	3.04E+04	2.90E+02	1.69E+03
200	1.00E-01	2.79E+04	8.13E+02	2.67E+03
200	1.78E-01	2.54E+04	1.23E+03	4.34E+03
200	3.16E-01	2.31E+04	2.89E+03	6.69E+03
200	5.62E-01	1.93E+04	5.14E+03	9.57E+03
200	1.00E+00	1.60E+04	8.89E+03	1.32E+04
200	1.78E+00	1.27E+04	1.40E+04	1.77E+04
200	3.16E+00	9.66E+03	2.13E+04	2.19E+04
200	5.62E+00	7.21E+03	3.02E+04	2.70E+04
200	1.00E+01	5.18E+03	4.11E+04	3.15E+04
200	1.78E+01	3.63E+03	5.38E+04	3.56E+04
200	3.16E+01	2.49E+03	6.82E+04	3.92E+04
200	5.62E+01	1.66E+03	8.32E+04	4.23E+04
200	1.00E+02	1.09E+03	9.92E+04	4.50E+04
200	1.78E+02	7.03E+02	1.16E+05	4.78E+04
200	3.16E+02	4.49E+02	1.32E+05	5.12E+04

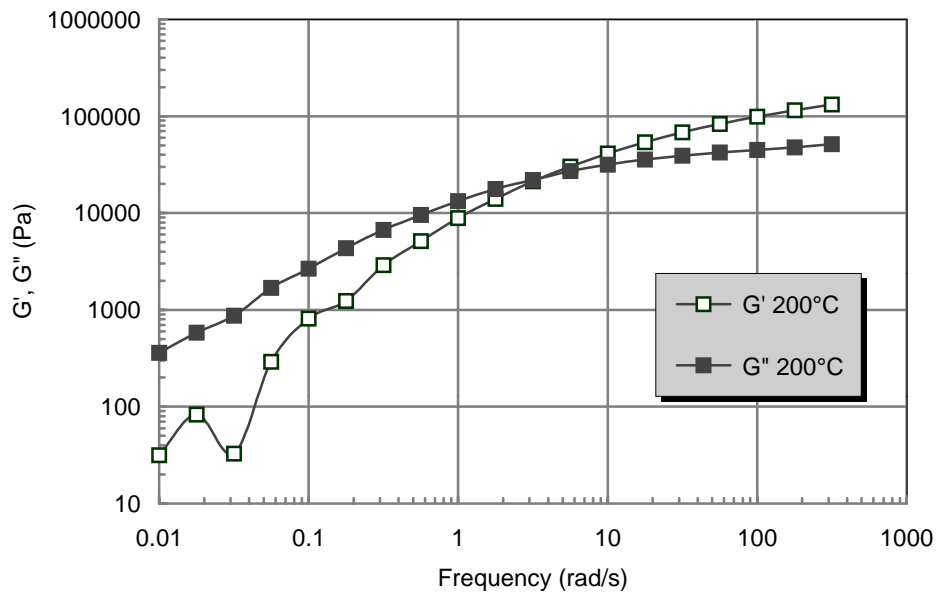
NOTE: Shaded cells denote torque below instrument limits.

Cone & Plate Rheology: Styron 663 W/O Additives 200°C Continued

**Complex Viscosity Plot**



**G'-G'' Plot**



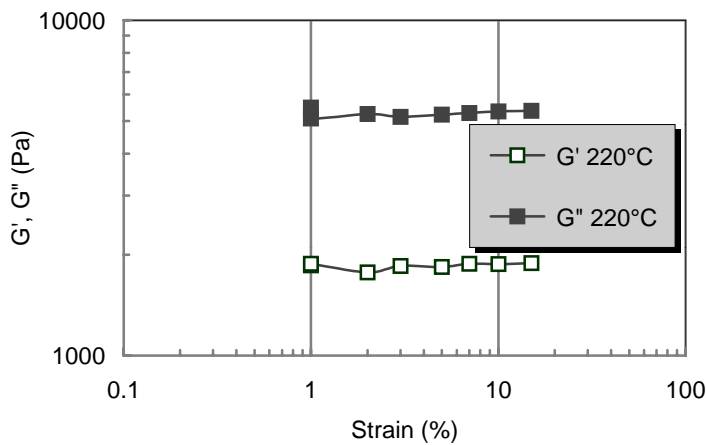
# Cone & Plate Rheology: Styron 663 W/O Additives 220°C



<b>Method</b>	ASTM D 4440 - 95a Rheological Measurement of Polymer Melts Using Dynamic Mechanical Procedures	
<b>Instrument</b>	Rheometrics ARES	
<b>Specimen</b>	type conditioning other preparation	disc none punched
<b>Parameters</b>	plate diameter cone angle gap temperature frequency range strain	25 mm 0.1 radians 50 μm 180 °C 0.01-500 rad/s 15 %
<b>Precision</b>	temperature	±2 °C

*Polymer rheology characterizes the complex flow behavior of plastics. A dynamic mechanical rheometer measures complex viscosity as a function of temperature and frequency. Assuming the applicability of the Cox Merz relationship, the frequency bears a 1:1 relationship to the shear rate.*

## Strain Sweep



7903f(220).txt

Cone and plate DMA measurements are not included in our current scope of accreditation.

**Tested By:** JA  
**Certified By:** BC  
**Test Date:** 11/6/2003

## Cone &amp; Plate Rheology: Styron 663 W/O Additives 220°C Continued

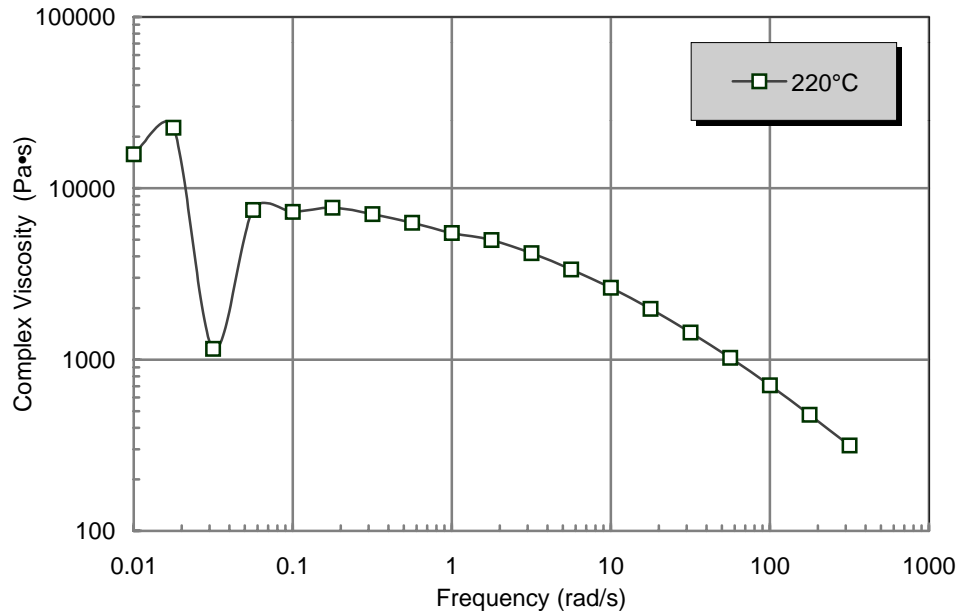
## DMA Data

Temp °C	$\omega$ rad/s	$\eta^*$ Pa·s	G' Pa	G'' Pa
220	1.00E-02	1.58E+04	4.72E+01	1.51E+02
220	1.78E-02	2.26E+04	-3.89E+02	9.77E+01
220	3.16E-02	1.16E+03	-1.22E+01	-3.45E+01
220	5.62E-02	7.47E+03	4.54E+01	4.18E+02
220	1.00E-01	7.29E+03	1.64E+02	7.10E+02
220	1.78E-01	7.72E+03	1.30E+02	1.37E+03
220	3.16E-01	7.08E+03	3.06E+02	2.22E+03
220	5.62E-01	6.29E+03	9.95E+02	3.40E+03
220	1.00E+00	5.48E+03	1.94E+03	5.12E+03
220	1.78E+00	4.99E+03	3.93E+03	7.97E+03
220	3.16E+00	4.18E+03	6.57E+03	1.15E+04
220	5.62E+00	3.36E+03	1.07E+04	1.56E+04
220	1.00E+01	2.63E+03	1.71E+04	1.99E+04
220	1.78E+01	1.98E+03	2.52E+04	2.46E+04
220	3.16E+01	1.44E+03	3.51E+04	2.91E+04
220	5.62E+01	1.02E+03	4.69E+04	3.32E+04
220	1.00E+02	7.07E+02	6.02E+04	3.70E+04
220	1.78E+02	4.77E+02	7.46E+04	4.02E+04
220	3.16E+02	3.15E+02	8.98E+04	4.31E+04

NOTE: Shaded cells denote torque below instrument limits.

## Cone &amp; Plate Rheology: Styron 663 W/O Additives 220°C Continued

## Complex Viscosity Plot



## G'-G'' Plot

