EMMOUNT Technologies, LLC
88 Country Downs Circle
Fairport, NY 14450
585/223-3996
585/223-3480, Fax
emmount@earthlink.net

January 13, 2006

To Whom It May Concern
Customer A
Anywhere

Subject: Viscosity Measurements

Summary:
1. Five sample resins were received and measured with a capillary rheometer at 200, 225 and 250 C.
2. Next the raw data was reduced and Rabinowitsch corrected shear rates and viscosity values were calculated.
3. Corrected data was fit to a six constant curve fitting equation for the compact representation and easy manipulation of the results
   a. Ln (η) = A1 + A2*T + A3*T^2 +A4*T*Ln(SR) +A5*Ln(SR) +A6*Ln(SR)^2
   b. T= Temperature degrees C and SR = corrected shear rate sec^{-1}
4. The calculated results are listed in Tables 2 through 6
5. The experimental data and the curve fit results are compared in Figures 1 through 5 and represent the measurements very well.
6. The Curve fitting Coefficients are:

Customer Samples: PO # 2						
Resin designation	A1	A2	A3	A4	A5	A6
ALTOFINA PS	26.26329	-0.09779	1.18E-04	0.004159	-1.12757	-0.03952
CHEVRON SBS	27.22475	-0.11088	1.47E-04	0.003982	-1.04434	-0.03832
CHEVRON PS	18.07421	-0.0296	-3.37E-05	0.00417	-1.0915	-0.03854
CHEVRON SBS	25.24758	-0.10125	1.49E-04	0.002602	-0.83161	-0.03004
BASF PS	15.94935	-0.01984	-3.23E-05	0.002494	-0.72246	-0.0364
	Ln (η) = A1 + A2* Ln(SR) + A3* Ln(SR)^2+A4*T*Ln(SR) +A5* T +A6* T^2					

Discussion:

Five samples of polystyrene and SBS polymer pellet were supplied for measurement. They were designated:

ALTOFINA PS
CHEVRON SBS
CHEVRON PS
CHEVRON SBS
BASF PS

All samples ran well and showed no unusual flow behavior during the testing

Table 1 lists the curve fitting constants for each of the individual resins tested

Curve fitting constants were calculated using POLYMATH, a commercially available nonlinear multiple regression software using the method of steepest decent of Marquart.

Customer Samples:							
Resin designation		A1	A2	A3	A4	A5	A6
ALTOFINA PS		26.26329	-0.09779	1.18E-04	0.004159	-1.12757	-0.03952
CHEVRON SBS		27.22475	-0.11088	1.47E-04	0.003982	-1.04434	-0.03832
CHEVRON PS		18.07421	-0.0296	-3.37E-05	0.00417	-1.0915	-0.03854
CHEVRON SBS		25.24758	-0.10125	1.49E-04	0.002602	-0.83161	-0.03004
BASF PS		15.94935	-0.01984	-3.23E-05	0.002494	-0.72246	-0.0364
		Ln (η) = A1 + A2* Ln(SR) + A3* Ln(SR)^2+A4*T*Ln(SR) +A5* T +A6* T^2					

Table 1: Summary of curve fitting coefficients for individual polymers

Tables 2 through 6 summarize the results of the viscosity calculations in tabular form for future review. Figures 1 through 5 summarize the experimental data and plot the results from the curve fit equation to permit an evaluation of the goodness of the fit for each curve fit. These figures show excellent agreement between the curve fit and the experimental data. Curve fitting results obtained from POLYMATH are also attached for review.

Measurement and calculations:

An Instron Capillary Rheometer Model 3211 was used to collect the data for these resins. This is a constant speed rheometer where a ram forces polymer through a capillary at the bottom of a barrel full of polymer. The force required to move the polymer at a constant volumetric flow rate is then a measure of the viscosity of the fluid. This is in contrast to a melt indexer which measures volumetric flow rate at constant stress (dead weight). A 0.0500-inch (.127 cm) by 3 inch (7.62 cm) long, 60 L/D capillary with a 90 degree entrance angle was used to minimize entrance pressure lose effects and consequently no Bagley entrance pressure loss correction was necessary or applied. The Rheometer was set and run at 6 constant cross head speeds to generate pressure readings at each temperature tested. For each resin tested two full barrels full of material was extruded prior to any measurements to insure complete purging of the capillary of material of a different resin or from a different temperature. This insured that the data collected represented fresh polymer. Prior to beginning the experiments the rheometer was electrically calibrated according to the instructions.

The apparent shear rate (SR_{ap}), stress at the wall (τ_w) and apparent viscosity (η_{ap}) were calculated from the cross head speed, plunger force and capillary dimensions using the well-known relationships:

$$SR_{ap} = 4Q/\pi R^3$$

$$\tau_w = R\ \Delta P/2L$$

$$\eta_{ap} = \tau_w / SR_{ap}$$

The Rabinowitsch correction was applied to the apparent date through the shear rate using equation:

$$SR = 1/\pi R^3 * \{3Q + \Delta P\ dQ/d\ \Delta P\}$$

This can be rearranged to yield:

$$SR = Q/\pi R^3\ \{3 + dLn\ (Q)/dLn\ (\Delta P)\} = (SR_{ap}/4) * \{3 + dLn\ (Q)/dLn\ (\Delta P)\}$$

The cross head and plunger force data are transformed into Q and ΔP data and plotted on a Ln Ln plot and curve fit to a second order in ΔP, the resulting equation is differentiated and the vales for dLn (Q)/dLn (ΔP) calculated at each point and the corrected shear rate is determined.

$$Ln\ (Q) = B0 + B1 * Ln(\Delta P) + B2 * Ln(\Delta P)^2$$

$$dLn\ (Q)/dLn(\Delta P) = B1 + 2*B2*Ln(\Delta P)$$

Once the corrected shear rate is know the corrected viscosity is calculated from:

$$\eta = \tau_w / SR$$

The results of the calculations for each resin at all three temperatures measured are tabulated and attached. The viscosity is presented in Poise and the stress data are tabulated in dynes/cm^2.

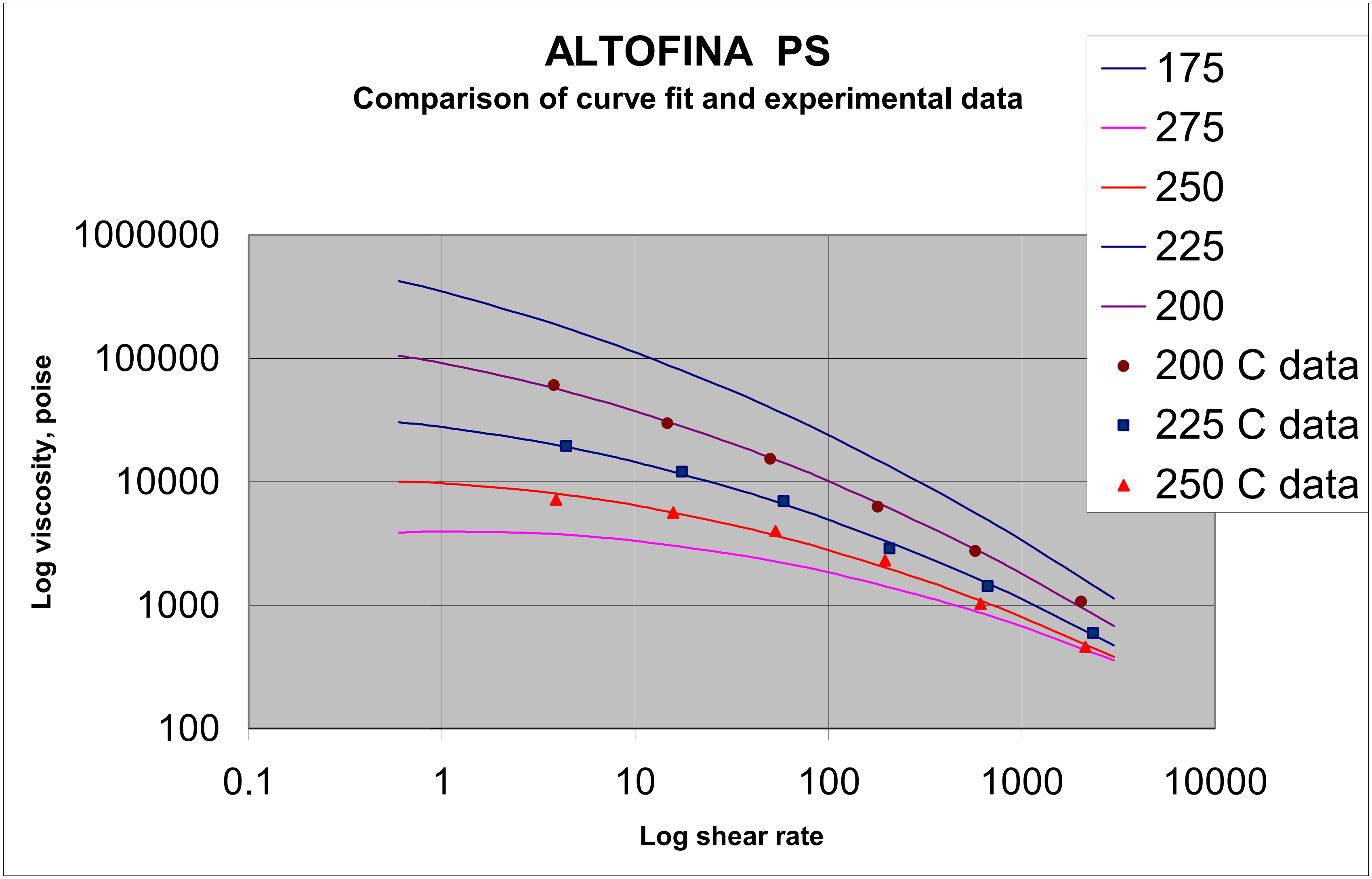

ALTOFINA PS
Comparison of curve fit and experimental data
175
275
250
225
200
200 C data
225 C data
250 C data
1000000
100000
10000
1000
100
0.1
1
10
100
1000
10000
Log viscosity, poise
Log shear rate

Figure 1

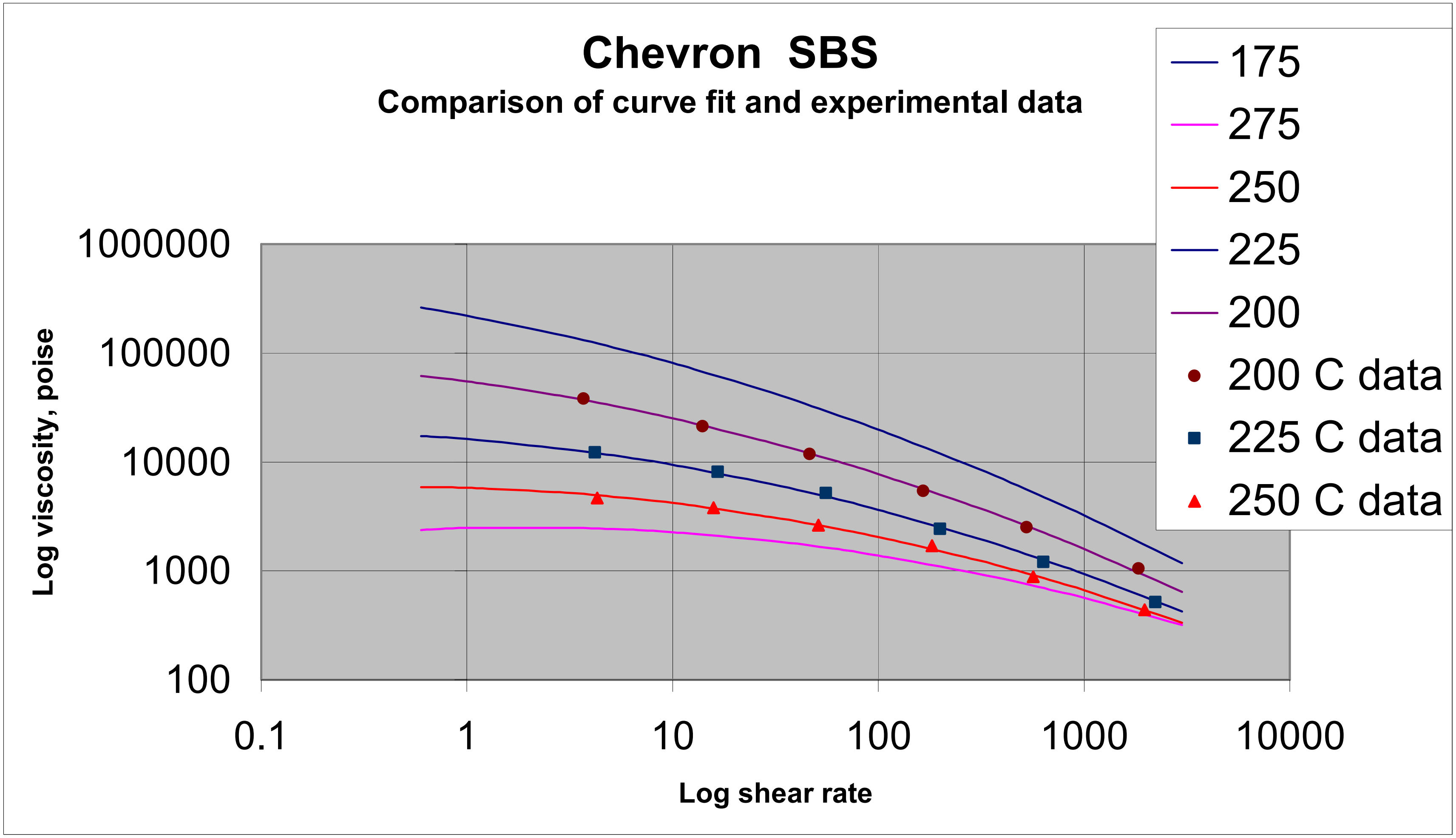
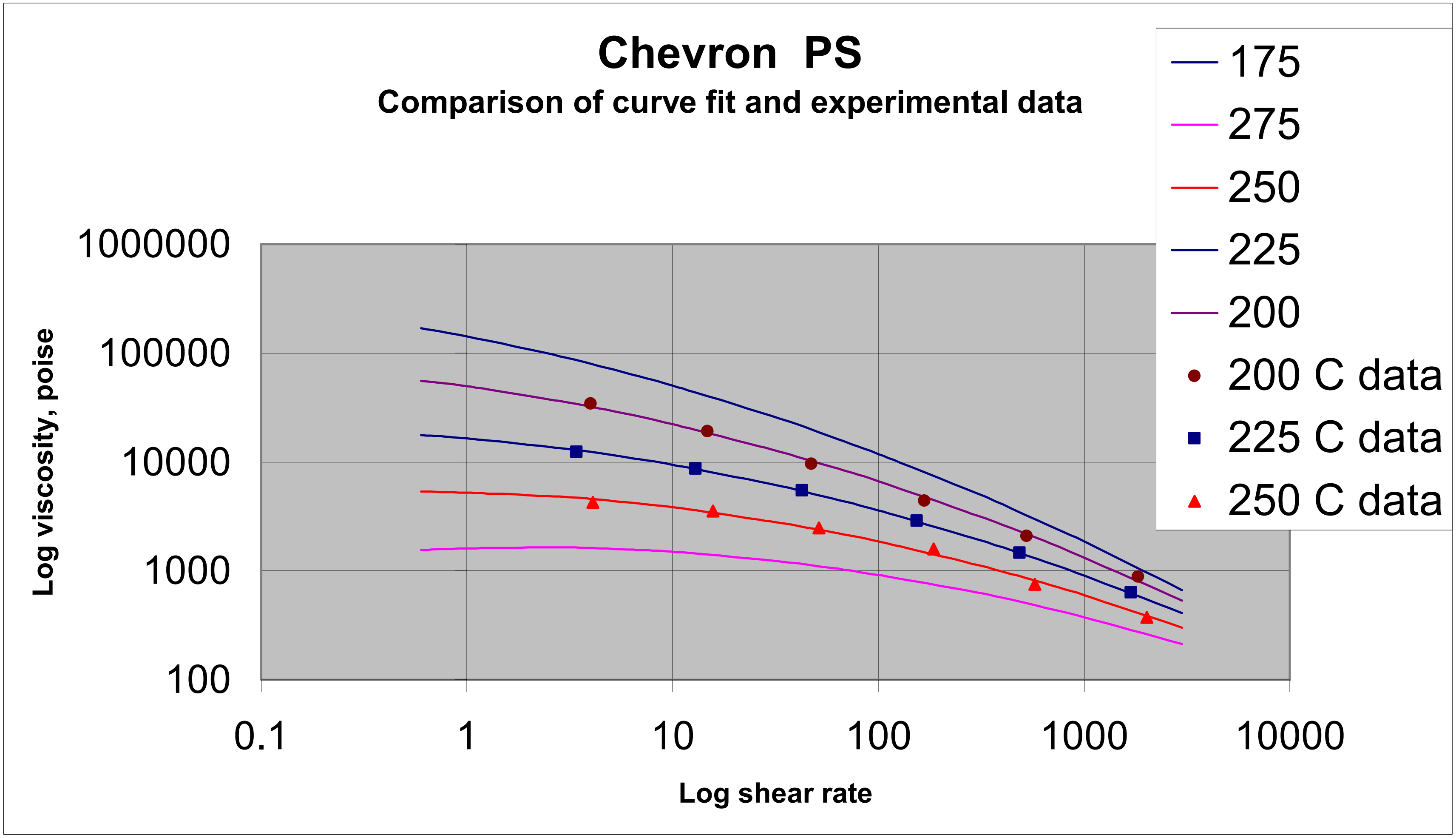

Chevron SBS
Comparison of curve fit and experimental data
Log viscosity, poise
1000000
100000
10000
1000
100
0.1
1
10
100
1000
10000
Log shear rate
175
275
250
225
200
200 C data
225 C data
250 C data

Figure 2



Chevron PS
Comparison of curve fit and experimental data
175
275
250
225
200
200 C data
225 C data
250 C data
1000000
100000
10000
1000
100
Log viscosity, poise
0.1
1
10
100
1000
10000
Log shear rate

Figure 3

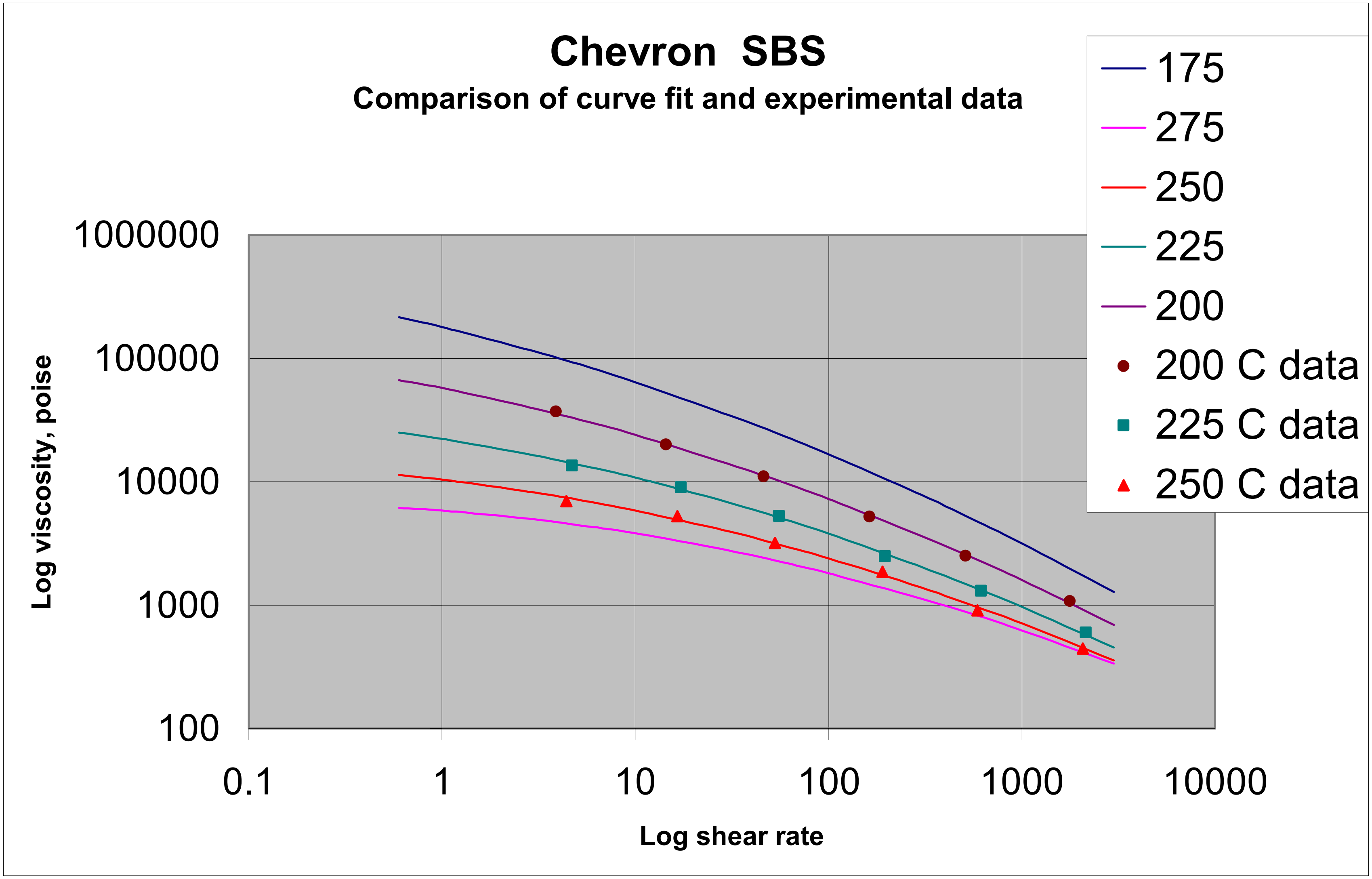

Chevron SBS
Comparison of curve fit and experimental data
175
275
250
225
200
200 C data
225 C data
250 C data
1000000
100000
10000
1000
100
0.1
1
10
100
1000
10000
Log viscosity, poise
Log shear rate

Figure 4

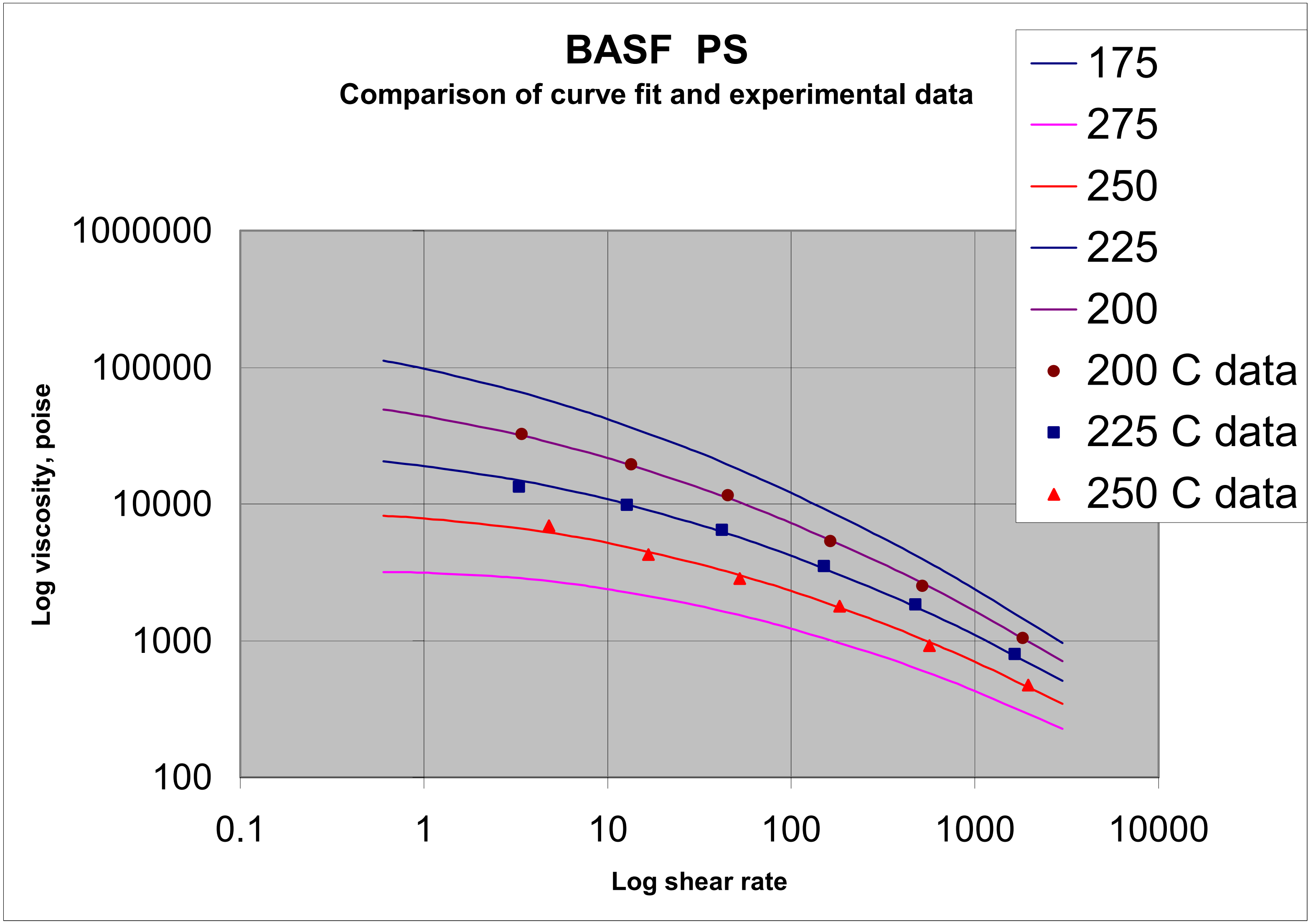

BASF PS
Comparison of curve fit and experimental data
175
275
250
225
200
200 C data
225 C data
250 C data
1000000
100000
10000
1000
100
Log viscosity, poise
0.1
1
10
100
1000
10000
Log shear rate

Figure 5

Capillary Rheometer data sheet			capillary diameter, cm	0.127	
investigator	Eldridge M. Mount III		capillary length, cm	7.62	
Date	23-Feb-05		entrance angle	90	
sample identification	ALTOFINA PS				
Temp C	apparent shear rate	Apparent viscosity	Corrected shear rate	corrected viscosity	shear stress
	1/sec	poise	1/sec	poise	dynes/cm2
200	3.5	64087	3.8	60553	227081
200	11.8	36899	14.7	29553	435812
200	35.4	21492	50.0	15227	761524
200	118.1	9535	180.2	6250	1126230
200	354.3	4451	575.4	2741	1576951
200	1181.1	1830	2026.6	1067	2161857
225	4.5	18860	4.4	19339	84869
225	15.0	13954	17.5	11976	209304
225	45.0	9099	58.8	6965	409434
225	150.0	3980	207.8	2872	596948
225	450.0	2096	666.9	1415	943303
225	1500.0	931	2346.8	595	1396892
250	4.5	6168	3.9	7155	27754
250	15.0	5891	15.7	5633	88367
250	45.0	4689	53.3	3960	211025
250	150.0	3009	195.7	2306	451295
250	450.0	1395	610.8	1028	627913
250	1500.0	650	2140.7	455	974842

Table 2: ALTOFINA polystyrene

Capillary Rheometer data sheet			capillary diameter, cm	0.127	
investigator	Eldridge M. Mount III		capillary length, cm	7.62	
Date	23-Feb-05		entrance angle	90	
sample identification	Chevron SBS				
Temp C	apparent shear rate	Apparent viscosity	Corrected shear rate	corrected viscosity	shear stress
	1/sec	poise	1/sec	poise	dynes/cm2
200	3.5	39488	3.7	37980	139919
200	11.8	25101	14.0	21137	296467
200	35.4	15472	46.4	11823	548206
200	118.1	7603	166.0	5409	898002
200	354.3	3696	524.4	2497	1309730
200	1181.1	1641	1839.3	1054	1938216
225	4.5	11469	4.2	12166	51609
225	15.0	8946	16.6	8070	134184
225	45.0	6384	55.8	5145	287292
225	150.0	3230	199.7	2426	484554
225	450.0	1702	635.0	1207	766111
225	1500.0	765	2221.7	516	1146873
250	4.5	4435	4.3	4683	19956
250	15.0	3995	15.8	3790	59924
250	45.0	2982	51.0	2633	134184
250	150.0	2057	182.0	1696	308624
250	450.0	1112	567.2	883	500610
250	1500.0	573	1969.7	437	860155

Table 3: CHEVRON SBS

Capillary Rheometer data sheet			capillary diameter, cm	0.127	
investigator	Eldridge M. Mount III		capillary length, cm	7.62	
Date	23-Feb-05		entrance angle	90	
sample identification	Chevron PS				
Temp C	apparent shear rate	Apparent viscosity	Corrected shear rate	corrected viscosity	shear stress
	1/sec	poise	1/sec	poise	dynes/cm2
200	3.5	38841	4.0	34506	137625
200	11.8	23984	14.8	19172	283278
200	35.4	12753	47.2	9573	451868
200	118.1	6263	167.4	4418	739733
200	354.3	3114	526.9	2094	1103292
200	1181.1	1374	1835.6	884	1622826
225	3.5	11652	3.4	12321	41287
225	11.8	9516	12.9	8691	112394
225	35.4	6635	42.7	5507	235109
225	118.1	3743	153.4	2882	442120
225	354.3	2000	485.1	1461	708768
225	1181.1	905	1689.4	633	1068886
250	4.5	3912	4.1	4270	17605
250	15.0	3701	15.7	3533	55509
250	45.0	2849	51.4	2493	128220
250	150.0	1965	185.7	1587	294746
250	450.0	961	576.8	750	432658
250	1500.0	504	2018.4	374	755790

Table 4: CHEVRON polystyrene

Capillary Rheometer data sheet			capillary diameter, cm	0.127	
investigator	Eldridge M. Mount III		capillary length, cm	7.62	
Date	23-Feb-05		entrance angle	90	
sample identification	Chevron SBS				
Temp C	apparent shear rate	Apparent viscosity	Corrected shear rate	corrected viscosity	shear stress
	1/sec	poise	1/sec	poise	dynes/cm2
200	3.5	41268	3.9	37069	146226
200	11.8	24275	14.4	19960	286718
200	35.4	14306	46.2	10977	506918
200	118.1	7224	163.3	5224	853274
200	354.3	3625	512.1	2508	1284498
200	1181.1	1617	1778.7	1074	1909544
225	4.5	14017	4.7	13523	63078
225	15.0	10391	17.3	8990	155860
225	45.0	6499	55.7	5246	292453
225	150.0	3232	195.8	2476	484841
225	450.0	1781	617.3	1299	801665
225	1500.0	858	2151.4	598	1287366
250	4.5	6805	4.4	6964	30622
250	15.0	5811	16.5	5282	87162
250	45.0	3734	53.0	3171	168017
250	150.0	2353	189.7	1860	352893
250	450.0	1190	591.2	906	535590
250	1500.0	612	2065.6	444	917499

Table 5: CHEVRON SBS

Capillary Rheometer data sheet			capillary diameter, cm	0.127	
investigator	Eldridge M. Mount III		capillary length, cm	7.62	
Date	23-Feb-05		entrance angle	90	
sample identification	BASF PS				
Temp C	apparent shear rate	Apparent viscosity	Corrected shear rate	corrected viscosity	shear stress
	1/sec	poise	1/sec	poise	dynes/cm2
200	3.5	31234	3.4	32343	110673
200	11.8	22139	13.5	19422	261487
200	35.4	14727	45.4	11506	521827
200	118.1	7380	163.4	5333	871624
200	354.3	3677	519.2	2509	1302848
200	1181.1	1602	1820.0	1040	1892341
225	3.5	12559	3.3	13361	44499
225	11.8	10584	12.8	9801	125009
225	35.4	7623	42.0	6436	270089
225	118.1	4452	150.6	3493	525841
225	354.3	2453	475.8	1827	869330
225	1181.1	1113	1652.2	796	1314317
252	4.5	7327	4.8	6923	32973
252	15.0	4744	16.7	4258	71164
252	45.0	3331	52.6	2851	149896
252	150.0	2191	183.8	1788	328579
252	450.0	1158	566.4	920	521254
252	1500.0	612	1949.7	471	917499

Table 6: BASF polystyrene

POLYMATH Results
ALTOFINA PS 03-03-2005

Nonlinear regression (mrqmin)

Model: lnvisc = a1+a2*T+a3*T^2+a4*T*ln(SR)+a5*ln(SR)+a6*ln(SR)^2

Variable	Ini guess	Value	95% confidence
a1	1	26.263286	7.4556192
a2	1	-0.0977879	0.0662904
a3	1	1.178E-04	1.47E-04
a4	1	0.0041589	9.932E-04
a5	1	-1.1275735	0.2436814
a6	1	-0.0395191	0.0109056

Nonlinear regression settings
Max # iterations = 64
Tolerance = 0.0001

Precision

R^2	= 0.9972737
R^2adj	= 0.9961377
Rmsd	= 0.0162192
Variance	= 0.0071027
Chi-Sq	= 8.5232686
Alamda	= 1.0E-10

General

Sample size	= 18
# Model vars	= 6
# Indep vars	= 2
# Iterations	= 7

POLYMATH Results
BASF PS 03-03-2005

Nonlinear regression (mrqmin)

Model: lnvisc = a1+a2*T+a3*T^2+a4*T*ln(SR)+a5*ln(SR)+a6*ln(SR)^2

Variable	Ini guess	Value	95% confidence
a1	1	15.949352	5.2909201
a2	1	-0.0198377	0.0470546
a3	1	-3.228E-05	1.044E-04
a4	1	0.0024938	7.25E-04
a5	1	-0.7224646	0.172173
a6	1	-0.0364047	0.0080375

Nonlinear regression settings
Max # iterations = 64
Tolerance = 0.0001

Precision

R^2	= 0.9981765
R^2adj	= 0.9974166
Rmsd	= 0.0115198
Variance	= 0.003583
Chi-Sq	= 4.2996524
Alamda	= 1.0E-10

General

Sample size	= 18
# Model vars	= 6
# Indep vars	= 2
# Iterations	= 7

POLYMATH Results
CHEVRON PS 03-03-2005

Nonlinear regression (mrqmin)

Model: lnvisc = a1+a2*T+a3*T^2+a4*T*ln(SR)+a5*ln(SR)+a6*ln(SR)^2

Variable	Ini guess	Value	95% confidence
a1	1	18.074209	6.1061115
a2	1	-0.0296002	0.0542401
a3	1	-3.37E-05	1.203E-04
a4	1	0.0041703	8.297E-04
a5	1	-1.091498	0.2027051
a6	1	-0.0385356	0.0092445

Nonlinear regression settings

Max # iterations = 64

Tolerance = 0.0001

Precision

R^2	=	0.9977819
R^2adj	=	0.9968577
Rmsd	=	0.0132698
Variance	=	0.0047543
Chi-Sq	=	5.70522
Alamda	=	1.0E-10

General

Sample size	= 18
# Model vars	= 6
# Indep vars	= 2
# Iterations	= 7

POLYMATH Results
CHEVRON SBS 03-03-2005

Nonlinear regression (mrqmin)

Model: lnvisc = a1+a2*T+a3*T^2+a4*T*ln(SR)+a5*ln(SR)+a6*ln(SR)^2

Variable	Ini guess	Value	95% confidence
a1	1	27.224751	4.3468627
a2	1	-0.1108814	0.0386486
a3	1	1.465E-04	8.572E-05
a4	1	0.0039818	5.911E-04
a5	1	-1.0443395	0.1432059
a6	1	-0.0383226	0.0065468

Nonlinear regression settings

Max # iterations = 64

Tolerance = 0.0001

Precision

R^2	=	0.9989011
R^2adj	=	0.9984432
Rmsd	=	0.0094577
Variance	=	0.0024151
Chi-Sq	=	2.8981471
Alamda	=	1.0E-10

General

Sample size	= 18
# Model vars	= 6
# Indep vars	= 2
# Iterations	= 7

POLYMATH Results
CHEVRON SBS 03-03-2005

Nonlinear regression (mrqmin)

Model: lnvisc = a1+a2*T+a3*T^2+a4*T*ln(SR)+a5*ln(SR)+a6*ln(SR)^2

Variable	Ini guess	Value	95% confidence
a1	1	25.247577	4.4862829
a2	1	-0.1012535	0.0399118
a3	1	1.49E-04	8.855E-05
a4	1	0.0026022	6.144E-04
a5	1	-0.8316146	0.1488564
a6	1	-0.0300419	0.0069152

Nonlinear regression settings

Max # iterations = 64

Tolerance = 0.0001

Precision

R^2	= 0.9988009
R^2adj	= 0.9983012
Rmsd	= 0.0097708
Variance	= 0.0025776
Chi-Sq	= 3.0931644
Alamda	= 1.0E-10

General

Sample size	= 18
# Model vars	= 6
# Indep vars	= 2
# Iterations	= 7