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Appendices

Appendix A

Table A.1 Specification of acrylic polyol

Polyol	NVM	OH	Viscosity
Polyol #3	50.92	2.11	Z_2
Polyol #4	50.68	3.40	Z_3
Polyol #5	50.89	2.09	W+1/4
Polyol #6	51.66	3.60	X
Polyol #7	49.47	2.17	Z_3
Polyol #8	50.25	3.46	Z_3+1/2
Polyol #9	50.50	2.02	W+1/4
Polyol #10	51.30	3.60	Y+1/4

Table A.2 Molecular weight and molecular weight distribution[1] of acrylic polyol

Polyol	M_w	M_w/M_n
Polyol #3	112,773	3.17
Polyol #4	142,124	2.62
Polyol #5	66,513	3.37
Polyol #6	64,841	5.36
Polyol #7	122,416	6.99
Polyol #8	133,165	6.83
Polyol #9	63,615	3.35
Polyol #10	77,066	3.67

[1] The experiments were conducted by MCI's laboratory, Japan

Table A.3 Specification of hardener

1.NBDI Isocyanurate	11.7	65	n-Butyl Acetate
2.IPDI Isocyanurate	9.52	55	Xylene

Table A.4 The quantity[2] of hardener used with eight polyols

Sample	Quantity of NBDI /100 g. of resin	Sample	Quantity of IPDI /100 g. of resin
3N	19.88	3I	24.43
4N	19.78	4I	24.32
5N	19.87	5I	24.42
6N	20.17	6I	24.79
7N	25.37	7I	31.18
8N	25.77	8I	31.67
9N	25.90	9I	31.83
10N	26.31	10I	32.42

[2] Calculation method can be seen in appendix C.

Appendix B

Abbreviation name

Table B.1 Name of catalyst

AIBN	α,α'-Azobis-iso-butyro nitrile
PBO	t-butyl peroxy octote
BPO	Dibenzoyl peroxide

Table B.2 Name of monomer

ST	styrene
AN	Acrylonitrile
MMA	Methyl methacrylate
EMA	Ethyl methacrylate
i-BMA	i-Butyl methacrylate
n-BMA	n-Butyl methacrylate
MA	Methyl acrylate
EA	Ethyl acrylate
n-BA	n-Butyl acrylate
2EHA	2-Ethylhexyl acrylate
DMAEMA	Dimethylaminoethyl methaacrylate
HEMA	2-Hydroxylethyl methacrylate
HPMA	2-Hydroxylpropyl methacrylate
HEA	Hydroxylethyl acrylate
2-HPA	2-Hydroxylpropyl acrylate
AAc	Acrylic acid
MAc	Methacrylic acid

Appendix C

Example of Calculation

C.1 Calculation glass transition temperature of polyol

Formula:

$$T_g(°C) = \frac{1000}{\text{Total Factor}} - 273 \qquad \text{(C.1-1)}$$

$$\text{Total Factor} = \sum_{i=1}^{M}\left[\frac{\%wt_i}{100} \times T_g(Factor)_i\right] \qquad \text{(C.1-2)}$$

$$T_g(Factor) = \frac{1000}{273 + T_{g_i}} \qquad \text{(C.1-3)}$$

Table C.1 T_g of monomer

Monomer	T_g (°C)
MMA	108
HEA	-35
n-BMA	20
DMAEMA	18
HEMA	55
EA	-22
n-BA	-56
MAc	104

Example C.1/1

In this example the Tg of polyol #3 is determined from data in the table C.1

Monomer	wt	%wt/100	Tg(factor)	%wt/100*Tg(factor)
MMA	573.00	0.3904	2.63	1.0268
n-BMA	146.70	0.1000	3.41	0.3409
EA	275.70	0.1879	3.97	0.7458
n-BA	275.70	0.1879	4.61	0.8660
HEA	184.80	0.1259	4.2	0.5289
MAc	7.20	0.0049	2.65	0.0130
DMAEMA	4.50	0.0031	3.44	0.0105
Total	1,467.60	1.0000		3.5319
Tg =	10.13 °C			

C.2 Determining the quantity of hardener.

Following the condition of 1:1 mole ratio of polyol : hardener, the quantity of hardener used with 100 g of polyol is calculated by this formula.

Formula :

$$\text{Quantity of hardener (with resin 100 g.)} = \frac{7.5 \times \text{OH value (varnish)}}{\%\ \text{NCO}} \qquad \text{(C.2-1)}$$

Note:

$$\text{OH value (Varnish)} = \text{OH value (solid)} \times \%\text{NV}/100 \qquad \text{(C.2-2)}$$

$$\text{OH value (solid)} = \frac{56100 \times \%\ \text{wt of hydroxyl monomer}}{100 \times \text{MW of hydroxyl monomer}} \qquad \text{(C.2-3)}$$

Example C.2/1

In this example , HEA is hydroxyl monomer used for synthesizing the polyol.

From table 1, for polyol #3 the following data is available.

HEA weight	=	184.8	g.
Total monomer weight	=	1,467.6	g.
Molecular weight of HEA	=	116.0	g.

So.

$$\text{\% wt of HEA (relatives to monomer)} = \frac{184.8 \times 100}{1{,}467.6} = 12.59\ \%$$

$$\text{OH value (solid)} = \frac{56100 \times \text{\% wt of hydroxyl monomer}}{100 \times \text{MW of hydroxyl monomer}} = \frac{56100 \times 12.59}{100 \times 116} = 60$$

$$\text{OH value (Varnish)} = \text{OH value (solid)} \times \text{\%NV}/100 = 60.9 \times 50.92/100 = 31.01$$

From equation C.2-1

$$\text{Qt of hardener (IPDI) (for resin 100 g)} = \frac{7.5 \times 31.01}{9.52} = 24.43\ \text{g.}$$

C.3 Estimate the number of bar coater

$$\text{Number of bar coater} = \frac{\text{thickness } (\mu m) * 100}{\text{\%NV of paint}} - 10 \qquad \text{(C.3-1)}$$

Example C.3/1

In this example, the number of bar coater used for the sample 3I is estimated.

NV of polyol #3 = 50.92 %

%NV of IPDI = 55.00 %

Qt. of thinner = 40.00 g.

Qt. of polyol #3 = 100.00 g.

Qt. of IPDI = 24.43 g.

Thickness = 25-30 μm

$$\%NV \text{ of paint} = \frac{(100*.5092+24.43*.55+0)*100}{100+24.43+40}$$

$$= 39.14\ \%$$

$$\text{No. of bar coater} = \frac{27.5*100}{39.14} - 10$$

$$= 60$$

C.4 Calculation of crosslinking density of films

$$Mc = \frac{8.31*(273+Tg)*10^6}{(G'*10^7)} \qquad (C.4\text{-}1)^3$$

$$XLD = 1/Mc \qquad (C.4\text{-}2)$$

Note:

Mc = The entanglement molecular weight of film, cc/mol.

Tg = The temperature at maximum tan δ , °C

G' = The storage modulus at 95 °C , Pa

XLD = The crosslinking desity, mol/cc.

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[3] Ikeda, 1973; Kano, 1999.

Example C.4/1

The XLD of 3N can be calculated from table D.43

Tg = 65.4 °C G' = 4.8 Pa

$$Mc = \frac{8.31*(273+65.4)*10^{6}}{4.8*10^{7}}$$

$$= 58.59 \quad cc/mol$$

$$XLD = 1/58.59$$

$$= 1.7*10^{-2} \quad mol/cc$$

Appendix D

Experimental result

1.Dupont impact

Table D.1 Dupont impact of IPDI at 1/2" diameter, 500 g

Sample	Height (mm)				Average
3I	300	300	300	300	300.0
4I	350	350	350	300	337.5
5I	250	250	250	200	237.5
6I	250	250	250	200	237.5
7I	200	200	250	250	225.0
8I	250	250	250	250	250.0
9I	200	200	200	250	212.5
10I	250	250	250	250	250.0

Table D.2 Dupont impact of NBDI at 1/2" diameter, 500 g

Sample	Height (mm)				Average
3N	500	500	500	500	500.0
4N	500	500	500	500	500.0
5N	500	500	500	500	500.0
6N	500	500	500	500	500.0
7N	400	350	350	350	362.5
8N	500	500	500	500	500.0
9N	450	400	400	400	412.5
10N	400	400	400	400	400.0

Table D.3 Dupont impact of NBDI at 3/8" diameter, 1 kg

Sample	Height (mm)				Average
3N	500	500	500	500	500.0
4N	250	250	250	300	262.5
5N	300	300	300	250	287.5
6N	500	500	500	450	487.5
7N	100	150	100	100	112.5
8N	300	250	250	250	262.5
9N	150	150	150	100	137.5
10N	150	150	150	150	150.0

Table D.4 Average dupont impact at 1/2" diameter, 500 g

Sample	Height (mm)	Sample	Height (mm)
3I	300.0	***3N***	500.0
4I	337.5	***4N***	500.0
5I	237.5	***5N***	500.0
6I	237.5	***6N***	500.0
7I	212.5	***7N***	362.5
8I	250.0	***8N***	500.0
9I	212.5	***9N***	412.5
10I	250.0	***10N***	400.0
Average	***254.7***	***Average***	***459.4***

Table D.5 Average dupont impact of NBDI at 3/8" diameter, 1 kg

Sample	Height (mm)
3N	500.0
4N	262.5
5N	287.5
6N	487.5
7N	112.5
8N	262.5
9N	137.5
10N	150.0

2.Acid-Base resistance

Table D.6 Dupont impact of IPDI after dipping in acid at 1/2" diameter, 500 g

Sample	Height (mm)				Average
3I	250	250	250	250	250.0
4I	300	300	300	300	300.0
5I	250	250	250	300	262.5
6I	250	250	250	200	237.5
7I	200	250	250	200	225.0
8I	250	250	250	250	250.0
9I	200	200	200	200	200.0
10I	200	200	200	200	200.0

Table D.7 Dupont impact of IPDI after dipping in base at 1/2" diameter, 500 g

Sample	Result				Average
3I	250	250	250	300	262.5
4I	250	250	250	250	250.0
5I	250	250	250	250	250.0
6I	200	200	250	250	225.0
7I	200	250	200	200	212.5
8I	200	200	250	200	212.5
9I	200	200	200	250	212.5
10I	200	200	200	200	200.0

Table D.8 Dupont impact of NBDI after dipping in acid at 1/2" diameter, 500 g

Sample	Height (mm)				Average
3N	500	-	-	-	500.0
4N	500	-	-	-	500.0
5N	450	-	-	-	450.0
6N	450	-	-	-	450.0
7N	325	-	-	-	325.0
8N	450	-	-	-	450.0
9N	350	-	-	-	350.0
10N	300	-	-	-	300.0

Table D.9 Dupont impact of NBDI after dipping in acid at 3/8" diameter, 1 kg

Sample	Height (mm)				Average
3N	200.0	150.0	150.0	150.0	162.5
4N	250.0	200.0	200.0	200.0	212.5
5N	150.0	150.0	150.0	100.0	137.5
6N	200.0	200.0	200.0	150.0	187.5
7N	100.0	100.0	100.0	100.0	100.0
8N	200.0	200.0	200.0	250.0	212.5
9N	150.0	100.0	150.0	100.0	125.0
10N	100.0	100.0	100.0	50.0	87.5

Table D.10 Dupont impact of NBDI after dipping in base at 1/2" diameter, 500 g

Sample	Height (mm)				Average
3N	300.00	300.00	-	-	300.0
4N	350.00	300.00	300.00	-	316.7
5N	350.00	300.00	350.00	-	333.3
6N	250.00	300.00	-	-	275.0
7N	350.00	350.00	400.00	-	366.7
8N	350.00	350.00	-	-	350.0
9N	350.00	350.00	-	-	350.0
10N	350.00	350.00	300.00	-	333.3

Table D.11 Dupont impact of NBDI after dipping in base at 3/8" diameter, 1 kg

Sample	Height (mm)				Average
3N	150.0	200.0	150.0	200.0	175.0
4N	200.0	200.0	150.0	150.0	175.0
5N	200.0	150.0	150.0	150.0	162.5
6N	200.0	200.0	150.0	150.0	175.0
7N	100.0	100.0	100.0	100.0	100.0
8N	200.0	200.0	200.0	200.0	200.0
9N	100.0	100.0	100.0	50.0	87.5
10N	50.0	50.0	50.0	100.0	62.5

Table D.12 Difference in dupont impact of IPDI at 1/2" diameter, 500 g

Sample	Before (mm)	After acid (mm)	After base (mm)	Δ acid (mm)	Δ base (mm)
3I	300.0	250.0	262.5	50.0	37.5
4I	337.5	300.0	250.0	37.5	87.5
5I	237.5	262.5	250.0	- 25.0	- 12.5
6I	237.5	237.5	225.0	-	12.5
7I	225.0	225.0	212.5	-	12.5
8I	250.0	250.0	212.5	-	37.5
9I	212.5	200.0	212.5	12.5	-
10I	250.0	200.0	200.0	50.0	50.0

Table D.13 Difference in dupont impact of NBDI at 1/2" diameter, 500 g

Sample	Before (mm)	After acid (mm)	After base (mm)	Δ acid (mm)	Δ base (mm)
3N	500.0	500.0	300.0	0.0	200.0
4N	500.0	500.0	316.7	0.0	183.3
5N	500.0	450.0	333.3	50.0	166.7
6N	500.0	450.0	275.0	50.0	225.0
7N	362.5	325.0	366.7	37.5	-4.2
8N	500.0	450.0	350.0	50.0	150.0
9N	412.5	350.0	350.0	62.5	62.5
10N	400.0	300.0	333.3	100.0	66.7

Table D.14 Difference in dupont impact of NBDI at 3/8" diameter, 1 kg

Sample	Before (mm)	After acid (mm)	After base (mm)	Δ acid (mm)	Δ base (mm)
3N	500.0	162.5	175.0	337.5	325.0
4N	262.5	212.5	175.0	50.0	87.5
5N	287.5	137.5	162.5	150.0	125.0
6N	487.5	187.5	175.0	300.0	312.5
7N	112.5	100.0	100.0	12.5	12.5
8N	262.5	212.5	200.0	50.0	62.5
9N	137.5	125.0	87.5	12.5	50.0
10N	150.0	87.5	62.5	62.5	87.5

3.Drying time

Table D.15 Drying time

Sample	t_1 (min)	t_2 (min)	t_3 (min)	Sample	t_1 (min)	t_2 (min)	t_3 (min)
3I	4' 40"	6' 00"	30'	*3N*	3' 40"	5' 00"	17'
4I	4' 20"	5' 00"	29'	*4N*	3' 40"	5' 00"	18'
5I	4' 45	5' 20"	31'	*5N*	4' 10"	4' 50"	16'
6I	4' 15	5' 20"	32'	*6N*	4' 00"	4' 40"	20'

4.Exposure Test

Table D.16 Gloss (60°) at 0 week

Sample	Gloss				Average
3I	88.1	85.2	88.5	89.1	87.7
4I	83.5	85.3	87.4	88.6	86.2
5I	88.4	87.2	86.6	87.7	87.5
6I	85.8	89.3	89.1	90.1	88.6
7I	88.2	87.5	87.3	88.8	88.0
8I	86.8	89.0	87.8	88.6	88.1
9I	87.9	90.0	87.8	90.5	89.1
10I	90.0	80.4	89.7	88.2	87.1
3N	89.9	86.3	89.7	89.5	88.9
4N	87.0	90.0	89.0	89.7	88.9
5N	87.8	90.3	87.7	88.5	88.6
6N	88.4	90.6	90.4	90.1	89.9
7N	90.2	89.6	90.2	90.3	90.1
8N	90.8	91.1	90.5	91.1	90.9
9N	90.3	86.5	90.2	88.2	88.8
10N	89.6	90.5	89.9	89.9	90.0

Table D.17 Gloss (60°) at 2 week

Sample	Gloss				Average
3I	83.2	83.6	84.6	85.4	84.2
4I	80.6	81.6	81.0	82.0	81.3
5I	84.3	84.0	85.1	85.0	84.6
6I	84.0	83.8	84.7	84.3	84.2
7I	84.2	84.6	85.1	84.9	84.7
8I	80.3	80.7	81.5	83.1	81.4
9I	84.3	84.6	85.7	85.8	85.1
10I	83.2	85.6	84.2	83.4	84.1
3N	85.7	85.1	87.6	86.4	86.2
4N	85.1	86.9	87.1	88.5	86.9
5N	86.7	82.9	84.8	82.8	84.3
6N	83.5	87.6	85.1	86.2	85.6
7N	84.3	89.3	85.3	84.7	85.9
8N	84.3	87.0	84.3	83.2	84.7
9N	86.0	85.4	87.4	86.0	86.2
10N	86.3	89.0	84.7	84.0	86.0

Table D.18 Gloss (60°) at 4 week

Sample	Gloss					Average
3I	75.7	78.9	81.6	77.6	84.5	79.7
4I	83.5	82.3	82.5	81.3	78.8	81.7
5I	83.0	81.1	82.1	81.2	84.3	82.3
6I	80.1	82.4	80.7	82.1	77.5	80.6
7I	80.4	80.6	79.6	79.4	79.1	79.8
8I	79.0	81.8	82.6	79.5	75.3	79.6
9I	81.3	82.1	82.5	80.9	83.9	82.1
10I	80.8	83.0	82.2	82.1	84.1	82.4
3N	84.2	83.9	84.4	83.4	86.0	84.4
4N	83.5	84.0	83.8	84.6	86.2	84.4
5N	85.0	82.2	84.7	83.5	80.5	83.2
6N	85.0	85.1	84.6	85.1	83.0	84.6
7N	84.4	85.6	84.3	85.5	84.9	84.9
8N	85.7	85.8	86.9	87.6	83.5	85.9
9N	85.8	86.2	85.1	85.9	84.3	85.5
10N	85.5	83.4	83.1	84.3	86.1	84.5

Table D.19 Gloss (60°) at 6 week

Sample	Gloss					Average
3I	82.8	80.5	77.1	80.2	82.0	80.5
4I	83.5	83.0	81.2	84.1	82.2	82.8
5I	80.0	78.2	81.3	80.2	79.1	79.8
6I	81.9	79.7	82.0	80.9	81.2	81.1
7I	79.4	82.4	80.6	80.1	83.8	81.3
8I	83.0	78.5	82.2	80.8	83.2	81.5
9I	80.3	80.3	78.8	80.3	81.1	80.2
10I	82.5	83.4	81.3	80.7	78.1	81.2
3N	85.5	86.9	84.9	86.4	86.6	86.1
4N	83.2	83.4	84.8	86.1	83.8	84.3
5N	88.3	86.0	87.0	84.0	85.6	86.2
6N	84.3	85.3	82.0	87.4	86.7	85.1
7N	82.2	83.7	85.0	83.4	84.5	83.8
8N	86.2	84.9	84.1	82.4	87.2	85.0
9N	87.0	87.0	81.6	86.9	82.8	85.1
10N	84.2	84.7	84.7	85.0	85.5	84.8

Table D.20 Gloss (60°) at 8 week

Sample	Gloss					Average
3I	84.2	83.8	78.8	79.6	77.9	80.9
4I	76.4	74.5	74.0	76.9	77.2	75.8
5I	82.8	85.5	80.7	83.8	82.6	83.1
6I	79.8	81.2	79.4	80.8	80.1	80.3
7I	79.1	80.1	78.5	76.9	81.1	79.1
8I	82.3	81.3	80.8	83.4	84.5	82.5
9I	81.8	82.4	80.6	81.4	82.1	81.7
10I	83.3	81.9	81.1	80.8	85.5	82.5
3N	86.3	84.1	84.3	86.0	86.6	85.5
4N	86.9	84.1	85.4	85.4	84.7	85.3
5N	88.2	86.9	85.5	83.3	86.8	86.1
6N	86.0	85.3	85.3	86.8	85.9	85.9
7N	86.0	84.5	84.9	84.3	84.2	84.8
8N	85.6	83.7	82.6	84.5	85.7	84.4
9N	86.0	84.7	86.9	84.5	85.9	85.6
10N	87.2	84.5	86.7	85.8	87.7	86.4

Table D.21 Gloss (60°) at 10 week

Sample	Gloss					Average
3I	81.3	80.5	76.4	76.6	78.0	78.6
4I	76.4	75.0	77.8	73.1	75.4	75.5
5I	81.1	82.3	79.0	79.8	80.6	80.6
6I	78.8	75.6	72.9	75.2	77.0	75.9
7I	81.3	78.3	79.2	77.4	77.5	78.7
8I	78.1	78.6	74.3	78.8	76.5	77.3
9I	80.7	80.0	80.3	80.7	80.4	80.4
10I	78.1	83.3	76.7	80.5	79.2	79.6
3N	83.5	86.7	81.0	85.0	82.5	83.7
4N	82.8	83.4	80.4	84.5	81.7	82.6
5N	85.9	83.6	76.5	83.1	85.9	83.0
6N	80.6	81.7	76.9	84.6	83.0	81.4
7N	83.6	80.6	82.3	82.2	81.7	82.1
8N	76.3	82.2	78.7	82.3	81.7	80.2
9N	83.8	84.0	83.0	83.2	82.7	83.3
10N	82.0	83.4	82.7	84.8	82.5	83.1

Table D.22 Gloss (60°) at 12 week

Sample	Gloss					Average
3I	80.5	80.7	77.6	74.3	70.6	76.7
4I	73.8	76.9	72.8	72.3	76.4	74.4
5I	75.0	78.2	72.2	76.0	74.5	75.2
6I	76.8	72.8	74.6	69.1	79.0	74.5
7I	71.6	70.9	73.6	73.0	76.3	73.1
8I	76.2	77.1	69.2	75.5	74.4	74.5
9I	73.9	75.3	79.0	72.8	72.9	74.8
10I	77.2	81.4	79.2	77.6	79.8	79.0
3N	83.0	76.6	83.2	76.8	82.2	80.4
4N	77.0	78.7	77.0	78.2	78.5	77.9
5N	79.0	78.1	77.7	79.4	78.9	78.6
6N	78.9	77.7	76.2	81.0	78.2	78.4
7N	80.0	79.8	73.8	77.8	77.2	77.7
8N	75.1	74.1	74.1	70.7	76.2	74.0
9N	79.9	79.4	75.8	79.4	81.2	79.1
10N	82.8	80.1	76.3	83.4	82.2	81.0

Table D.23 Gloss (60°) at 14 week

Sample	Gloss					Average
3I	75.4	77.0	76.6	80.2	80.5	77.9
4I	71.6	70.9	70.2	73.0	72.7	71.7
5I	72.0	71.4	69.7	73.6	76.6	72.7
6I	73.7	71.0	67.0	73.0	70.9	71.1
7I	72.4	69.8	70.9	69.1	72.9	71.0
8I	66.5	68.4	74.4	71.7	75.4	71.3
9I	70.5	71.1	73.8	73.1	70.1	71.7
10I	73.3	76.3	74.0	76.2	77.2	75.4
3N	77.5	79.2	72.4	79.7	77.5	77.3
4N	80.1	77.1	73.8	76.3	78.8	77.2
5N	81.7	78.5	71.9	76.5	76.8	77.1
6N	80.2	75.4	74.2	77.5	77.3	76.9
7N	82.9	78.3	77.8	77.5	78.9	79.1
8N	78.6	73.0	70.7	73.2	71.3	73.4
9N	78.9	81.1	79.5	80.4	80.1	80.0
10N	83.7	81.6	80.5	80.9	79.1	81.2

Table D.24 Gloss (60°) at 16 week

Sample	Gloss					Average
3I	78.8	79.1	70.3	78.6	74.3	76.2
4I	70.1	72.0	74.3	71.9	75.0	72.7
5I	77.2	75.3	74.0	70.1	76.7	74.7
6I	74.6	74.3	73.6	73.9	70.5	73.4
7I	70.7	76.1	73.6	76.5	72.9	74.0
8I	75.7	72.4	75.9	71.8	75.2	74.2
9I	71.0	74.9	72.1	71.3	72.7	72.4
10I	82.7	78.4	75.9	81.1	77.4	79.1
3N	72.5	70.4	71.5	70.3	69.0	70.7
4N	69.1	67.7	69.4	70.2	71.8	69.6
5N	72.2	73.2	67.0	76.7	63.7	70.6
6N	72.8	67.0	67.3	69.4	71.6	69.6
7N	68.3	72.4	71.7	74.4	69.9	71.3
8N	73.2	74.0	74.2	73.3	72.4	73.4
9N	79.9	76.2	71.9	72.1	79.4	75.9
10N	78.1	72.8	71.6	75.9	76.2	74.9

Table D.25 Gloss (60^{o}) at 18 week

Sample	Gloss					Average
3I	79.9	82.5	77.9	76.4	79.3	79.2
4I	72.8	70.6	70.5	75.1	75.3	72.9
5I	76.5	77.4	75.6	73.9	75.0	75.7
6I	71.7	70.7	72.0	76.0	72.4	72.6
7I	73.2	74.6	71.6	71.9	74.0	73.1
8I	73.4	74.5	65.4	70.3	74.5	71.6
9I	66.7	70.8	74.4	71.4	75.1	71.7
10I	76.4	77.0	77.0	73.0	80.0	76.7
3N	80.1	79.4	75.1	81.9	80.5	79.4
4N	78.3	77.5	76.9	77.5	80.6	78.2
5N	78.0	78.8	73.7	77.5	78.3	77.3
6N	77.7	76.5	74.1	72.4	76.0	75.3
7N	76.5	75.4	71.4	76.4	73.7	74.7
8N	77.6	77.5	75.6	75.2	75.5	76.3
9N	78.2	78.2	75.9	79.0	78.9	78.0
10N	82.1	78.8	78.5	78.4	78.8	79.3

Table D.26 Gloss (60°) at 20 week

Sample	Gloss					Average
3I	80.5	76.6	79.3	74.3	80.2	78.2
4I	75.4	74.8	73.9	75.2	69.3	73.7
5I	74.2	79.0	74.1	71.0	75.1	74.7
6I	74.2	74.4	71.4	71.8	78.8	74.1
7I	77.0	75.5	69.9	73.7	74.6	74.1
8I	75.1	74.1	72.4	74.0	72.0	73.5
9I	66.1	71.7	71.4	72.6	71.1	70.6
10I	75.4	75.6	77.9	76.4	80.0	77.1
3N	79.3	80.7	76.3	81.8	80.7	79.8
4N	79.8	76.4	75.8	76.8	78.8	77.5
5N	79.4	79.5	76.4	74.4	78.7	77.7
6N	81.0	77.7	73.3	77.0	79.2	77.6
7N	77.9	77.4	77.6	79.3	78.8	78.2
8N	74.4	78.4	72.5	77.0	75.7	75.6
9N	79.0	81.3	79.7	79.3	81.8	80.2
10N	78.1	79.8	74.9	78.5	83.6	79.0

Table D.27 Gloss (60°) at 22 week

Sample	Gloss					Average
3I	77.8	77.5	79.1	77.7	76.7	77.8
4I	73.9	69.6	70.7	71.3	72.0	71.5
5I	65.3	71.7	69.2	70.7	76.8	70.7
6I	69.9	70.6	70.2	64.5	73.7	69.8
7I	72.5	72.5	71.6	69.1	74.7	72.1
8I	72.5	68.4	72.1	75.3	74.8	72.6
9I	64.3	69.9	72.7	72.3	74.9	70.8
10I	71.3	69.2	67.5	65.5	78.6	70.4
3N	82.3	76.5	80.3	79.0	81.0	79.8
4N	73.5	72.9	69.8	71.1	76.3	72.7
5N	75.7	73.8	74.1	78.2	77.9	75.9
6N	75.3	74.0	76.5	70.5	77.2	74.7
7N	75.6	74.6	74.7	74.6	77.9	75.5
8N	72.8	76.0	73.5	74.4	77.5	74.8
9N	73.3	74.9	74.7	74.1	78.4	75.1
10N	78.6	77.3	76.9	76.2	77.8	77.4

Table D.28 Gloss (60°) at 24 week

Sample	Gloss					Average
3I	78.4	77.2	75.1	76.8	70.9	75.7
4I	73.6	71.2	71.1	71.6	71.3	71.8
5I	71.9	71.2	70.5	74.8	68.8	71.4
6I	70.7	73.4	69.4	72.0	70.9	71.3
7I	69.6	68.3	67.4	66.7	68.2	68.0
8I	69.4	69.7	69.5	72.9	73.9	71.1
9I	62.2	67.9	66.1	67.9	71.8	67.2
10I	72.1	69.6	67.8	71.2	66.5	69.4
3N	79.1	77.0	80.3	79.2	79.1	78.9
4N	76.2	72.8	72.5	73.8	77.2	74.5
5N	77.6	74.2	73.6	76.4	74.1	75.2
6N	75.5	76.6	71.0	73.7	74.5	74.3
7N	72.4	70.4	73.2	69.8	76.3	72.4
8N	74.0	73.9	71.2	75.4	70.1	72.9
9N	75.5	73.4	74.3	76.2	80.0	75.9
10N	76.7	76.5	76.3	74.4	77.2	76.2

Table D.29 Conclusion of Gloss (60°) of exposure test

Time (week)	3I	4I	5I	6I	7I	8I	9I	10I	Avg.
0	87.7	86.2	87.5	88.6	88.0	88.1	89.1	87.1	87.8
2	84.2	81.3	84.6	84.2	84.7	81.4	85.1	84.1	83.7
4	79.7	81.7	82.3	80.6	79.8	79.6	82.1	82.4	81.0
6	80.5	82.8	79.8	81.1	81.3	81.5	80.2	81.2	81.1
8	80.9	75.8	83.1	80.3	79.1	82.5	81.7	82.5	80.7
10	78.6	75.5	80.6	77.0	77.5	76.5	80.4	76.6	77.8
12	76.7	74.4	75.2	74.5	73.1	74.5	74.8	79.0	75.3
14	77.9	71.7	72.7	71.1	71.0	71.3	71.7	75.4	72.9
18	79.2	72.9	75.7	72.6	73.1	71.6	71.7	76.7	74.2
20	78.2	73.7	74.7	74.1	74.1	73.5	70.6	77.1	74.5
22	77.8	71.5	70.7	69.8	72.1	72.6	70.8	70.4	72.0
24	75.7	71.8	71.4	71.3	68.0	71.1	67.2	69.4	70.7
Time (week)	**3N**	**4N**	**5N**	**6N**	**7N**	**8N**	**9N**	**10N**	**Avg.**
0	88.9	88.9	88.6	89.9	90.1	90.9	88.8	90.0	89.5
2	86.2	86.9	84.3	85.6	85.9	84.7	86.2	86.0	85.7
4	84.4	84.4	83.2	84.6	84.9	85.9	85.5	84.5	84.7
6	86.1	84.3	86.2	85.1	83.8	85.0	85.1	84.8	85.1
8	85.5	85.3	86.1	85.9	84.8	84.4	85.6	86.4	85.5
10	83.7	82.6	83.0	81.4	82.1	80.2	83.3	83.1	82.4
12	80.4	77.9	78.6	78.4	77.7	74.0	79.1	81.0	78.4
14	77.3	77.2	77.1	76.9	79.1	73.4	80.0	81.2	77.8
18	79.4	78.2	77.3	75.3	74.7	76.3	78.0	79.3	77.3
20	79.8	77.5	77.7	77.6	78.2	75.6	80.2	79.0	78.2
22	79.8	72.7	75.9	74.7	75.5	74.8	75.1	77.4	75.7
24	78.9	74.5	75.2	74.3	72.4	72.9	75.9	76.2	75.0

Table D.30 Conclusion of Gloss retention of exposure test

Time (week)	3I	4I	5I	6I	7I	8I	9I	10I	Avg.
0	100	100	100	100	100	100	100	100	100.0
2	96	94	97	95	96	92	96	97	95.3
4	91	95	94	91	91	90	92	95	92.3
6	92	96	91	92	92	93	90	93	92.3
8	92	88	95	91	90	94	92	95	92.0
9	90	88	92	87	88	87	90	88	88.7
10	87	86	86	84	83	85	84	91	85.8
14	89	83	83	80	81	81	80	87	83.0
18	90	85	87	82	83	81	80	88	84.5
20	89	85	85	84	84	83	79	89	84.9
22	89	83	81	79	82	82	79	81	82.0
24	86	83	82	80	77	81	75	80	80.6
Time (week)	3N	4N	5N	6N	7N	8N	9N	10N	Avg.
0	100	100	100	100	100	100	100	100	100.0
2	97	98	95	95	95	93	97	96	95.8
4	95	95	94	94	94	94	96	94	94.6
6	97	95	97	95	93	94	96	94	95.0
8	96	96	97	96	94	93	96	96	95.5
9	94	93	94	91	91	88	94	92	92.1
10	90	88	89	87	86	81	89	90	87.6
14	87	87	87	86	88	81	90	90	86.9
18	89	88	87	84	83	84	88	88	86.4
20	90	87	88	86	87	83	90	88	87.4
22	90	82	86	83	84	82	85	86	84.6
24	89	84	85	83	80	80	85	85	83.8

Table D.31 Gloss at 60° of QUV test.

Sample	Time (hrs)			
	0	200	400	700
Base	84.6	85.2	85.2	87.4
3I	84.8	89.2	89.3	89.4
4I	88.4	88.4	88.5	89.3
5I	87.7	87.8	88.6	89.7
6I	87.0	88.3	89.3	88.7
7I	83.7	85.5	86.2	87.1
8I	86.5	88.1	89.5	87.7
9I	85.3	88.9	88.4	87.0
10I	86.9	87.8	88.0	89.2
Average	86.3	88.0	88.5	88.5
3N	87.0	88.5	90.4	89.5
4N	88.1	88.0	90.6	90.4
5N	88.5	88.0	88.5	89.0
6N	85.2	88.4	89.9	89.8
7N	88.9	87.8	89.0	91.1
8N	88.7	89.6	89.5	91.0
9N	88.4	89.1	88.9	90.8
10N	88.7	89.5	89.9	91.3
Average	87.9	88.6	89.6	90.4

Table D.32 Gloss retention at 60° of QUV test.

Sample	Time (hrs)			
	0	200	400	700
Base	100.0	100.7	100.7	103.3
3I	100.0	105.2	105.3	105.4
4I	100.0	100.0	100.1	101.0
5I	100.0	100.1	101.0	102.3
6I	100.0	101.5	102.6	102.0
7I	100.0	102.2	103.0	104.1
8I	100.0	101.8	103.5	101.4
9I	100.0	104.2	103.6	102.0
10I	100.0	101.0	101.3	102.6
Average	100.0	102.0	102.6	102.6
3N	100.0	101.7	103.9	102.9
4N	100.0	99.9	102.8	102.6
5N	100.0	99.4	100.0	100.6
6N	100.0	103.8	105.5	105.4
7N	100.0	98.8	100.1	102.5
8N	100.0	101.0	100.9	102.6
9N	100.0	100.8	100.6	102.7
10N	100.0	100.9	101.4	102.9
Average	100.0	100.8	101.9	102.8

Table D.33 Yellowness (ΔE) of QUV test.

Sample	Time (hrs)		
	200	400	700
Base	0.58	0.70	0.87
3I	0.59	0.88	1.24
4I	0.45	0.65	0.97
5I	0.44	0.53	0.95
6I	0.49	0.67	1.19
7I	0.54	0.76	1.06
8I	0.65	0.89	1.54
9I	0.70	0.88	1.49
10I	0.74	0.95	1.50
Average	0.58	0.78	1.24
3N	1.01	1.11	1.35
4N	0.96	1.21	1.38
5N	0.99	1.15	1.44
6N	1.03	1.26	1.43
7N	1.68	2.04	2.09
8N	1.21	1.28	1.51
9N	1.06	1.30	1.47
10N	1.28	1.75	1.93
Average	1.15	1.39	1.58

Table D.34 Tensile property of sample 5I

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
5I/1	69	1.1	1.830
5I/2	81	2.7	2.422
5I/3	59	1.2	1.902
5I/4	61	1.3	1.910
5I/5	64	1.8	2.090
5I/6	86	2.9	2.312

Table D.35 Tensile property of sample 6I

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
6I/1	59	2.0	2.237
6I/2	81	2.5	2.515
6I/3	100	2.1	2.750
6I/4	76	1.3	2.317
6I/5	82	2.5	2.285
6I/6	90	1.8	2.467
6I/7	79	2.7	2.642

Table D.36 Tensile property of sample 9I

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
9I/1	63	1.6	2.420
9I/2	68	1.4	2.587
9I/3	59	1.4	2.315
9I/4	57	1.2	1.907
9I/5	70	1.1	2.470
9I/6	71	1.4	2.555
9I/7	70	1.3	2.585

Table D.37 Tensile property of sample 10I

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
10I/1	57	1.7	2.382
10I/2	75	2.1	2.757
10I/3	73	1.4	2.712
10I/4	71	1.5	2.492
10I/5	52	1.5	2.212
10I/6	60	1.8	2.282
10I/7	65	1.1	2.312
10I/8	75	2.0	2.687

Table D.38 Tensile property of sample 5N

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
5N/1	70	8.0	1.457
5N/2	67	15.9	1.492
5N/3	70	7.2	1.570
5N/4	75	10.4	1.647
5N/5	78	10.7	1.665

Table D.39 Tensile property of sample 6N

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
6N/1	90	12.1	1.860
6N/2	87	13.3	1.845
6N/3	79	5.4	1.802
6N/4	84	9.3	1.925
6N/5	90	8.9	1.852
6N/6	68	8.4	1.742

Table D.40 Tensile property of sample 9N

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
9N/1	78	14.3	2.110
9N/2	81	16.8	2.120
9N/3	80	15.5	1.987
9N/4	76	13.6	1.710
9N/5	62	11.8	1.627
9N/6	70	15.0	1.655

Table D.41 Tensile property of sample 10N

Sample	Thickness (μm)	ΔL (mm)	Force (kg_f)
10N/1	78	18.5	1.905
10N/2	59	15.6	1.687
10N/3	70	8.4	1.725
10N/4	74	8.5	1.782
10N/5	73	8.9	1.745
10N/6	76	16.2	1.912
10N/7	88	6.8	2.050
10N/8	90	18.7	2.224

Table D.42 Conclusion of average tensile property

Sample	Strength (kg_f/cm^2)	% Elongation
5I	299	6.1
6I	308	7.1
9I	367	4.5
10I	379	5.5
5N	218	34.8
6N	223	31.9
9N	251	48.3
10N	248	42.3

Table D.43 Dynamical mechanical analysis (DMA) result.

Sample	tan δ (°C)	G'*10^7 Pa at 95 °C	Mc	XLD
3N	65.4	4.8	58.59	1.71E-02
4N	69.8	5.1	55.86	1.79E-02
5N	64.6	5.6	50.10	2.00E-02
6N	65.3	4.7	59.81	1.67E-02
7N	79	4.5	65.00	1.54E-02
8N	-	-	-	-
9N	69.9	4.6	61.95	1.61E-02
10N	74.8	4.7	61.49	1.63E-02
5I	78.3	5.5	53.08	1.88E-02
6I	74.7	5.8	49.82	2.01E-02
9I	80.2	6	48.92	2.04E-02
10I	76	5.8	50.00	2.00E-02

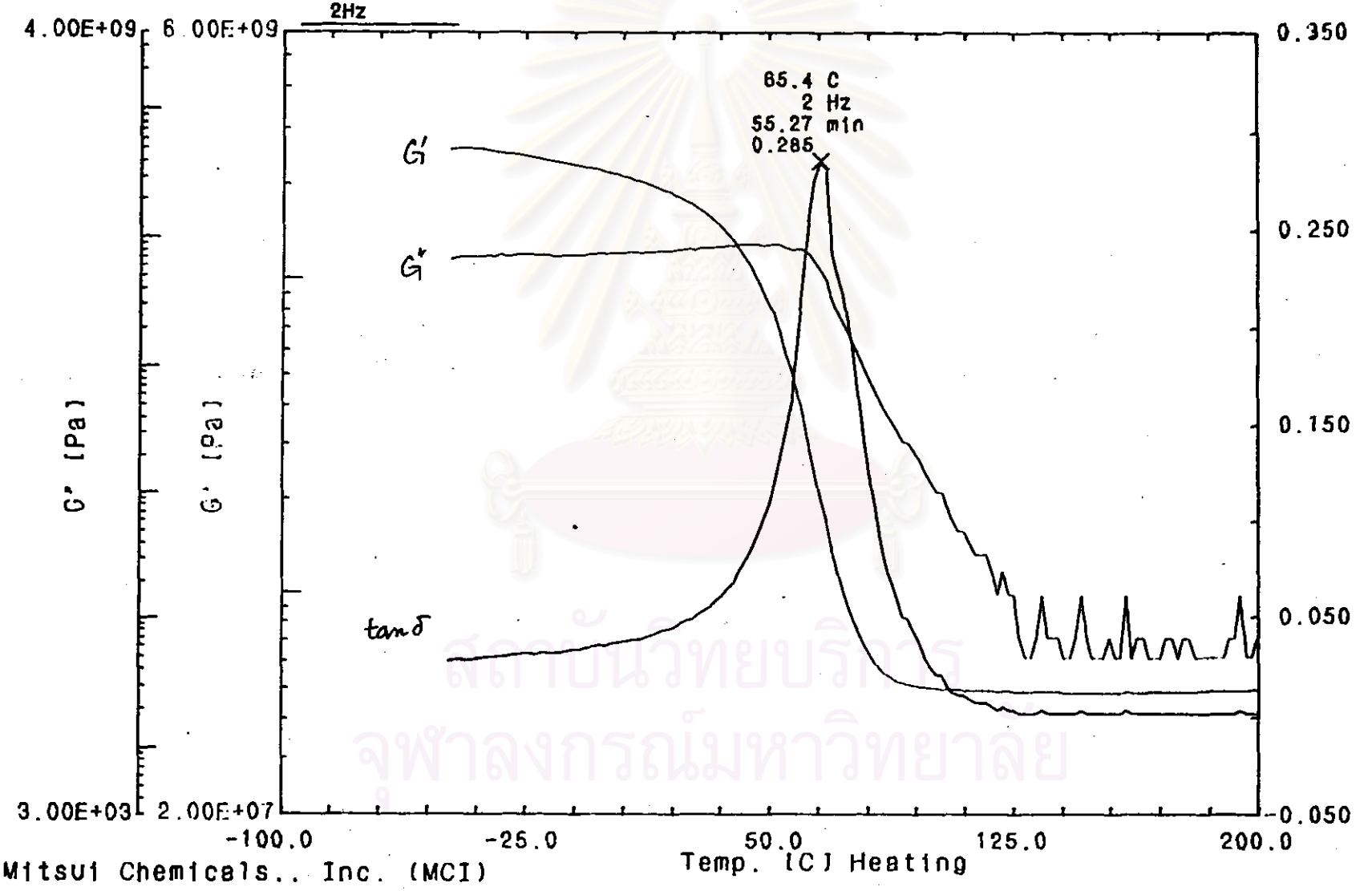
Dynamic Mechanical Analysis

Results

DMS

Name: Sample 3N
Date:
Comment: ----------

Sample: 3N
Temp. mode: Ramp
Deform: Shear
1*s: 20.000 mm * 0.800 mm2
Frequency: 0.5 ~ 10 Hz



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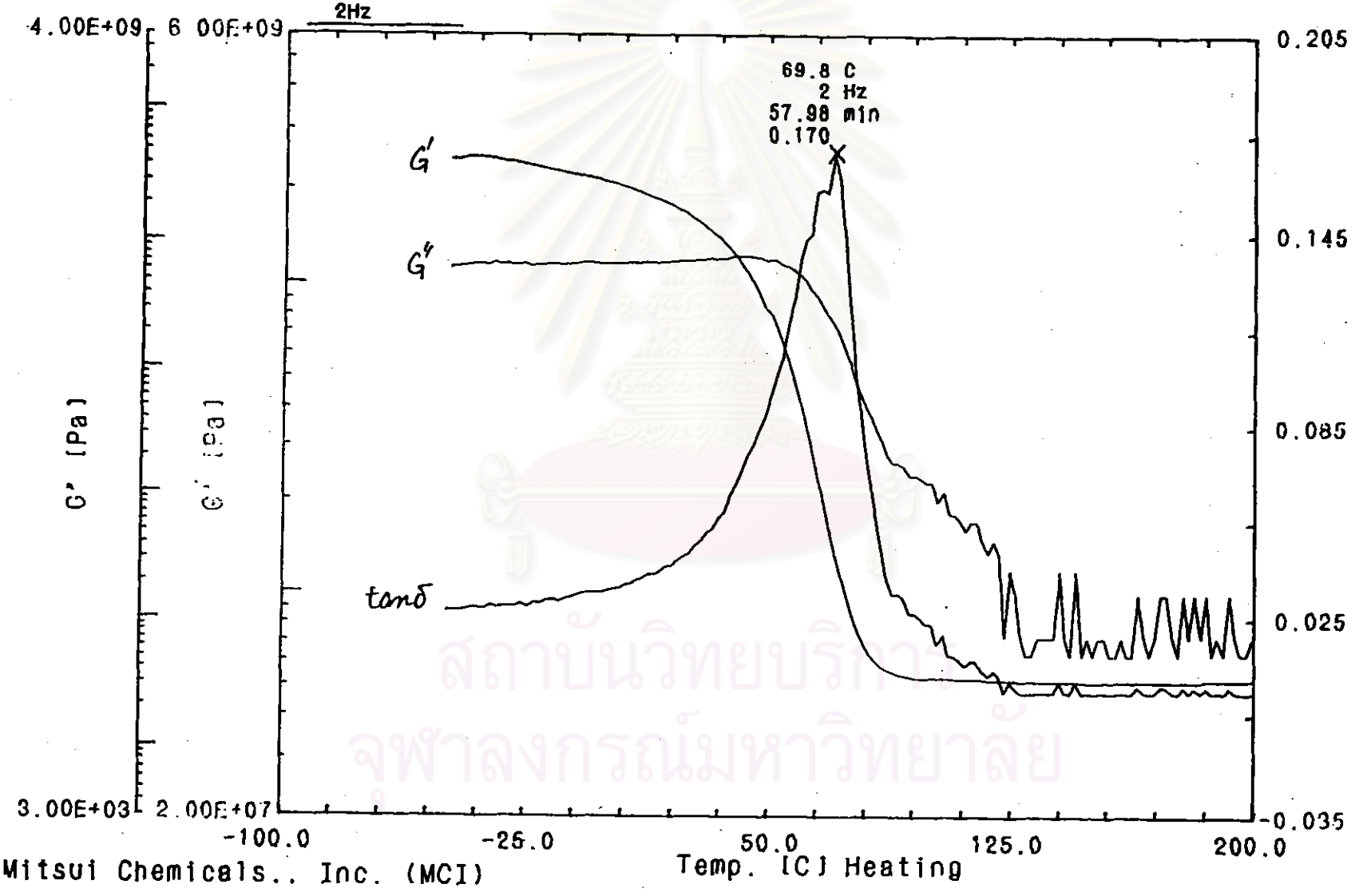
DMS

Name: Sample 4N
Date:
Comment: ----------

Sample: 4N
Temp. mode: Ramp
Deform: Shear
1*s: 20.000 mm * 0.770 mm2
Frequency: 0.5 ~ 10 Hz



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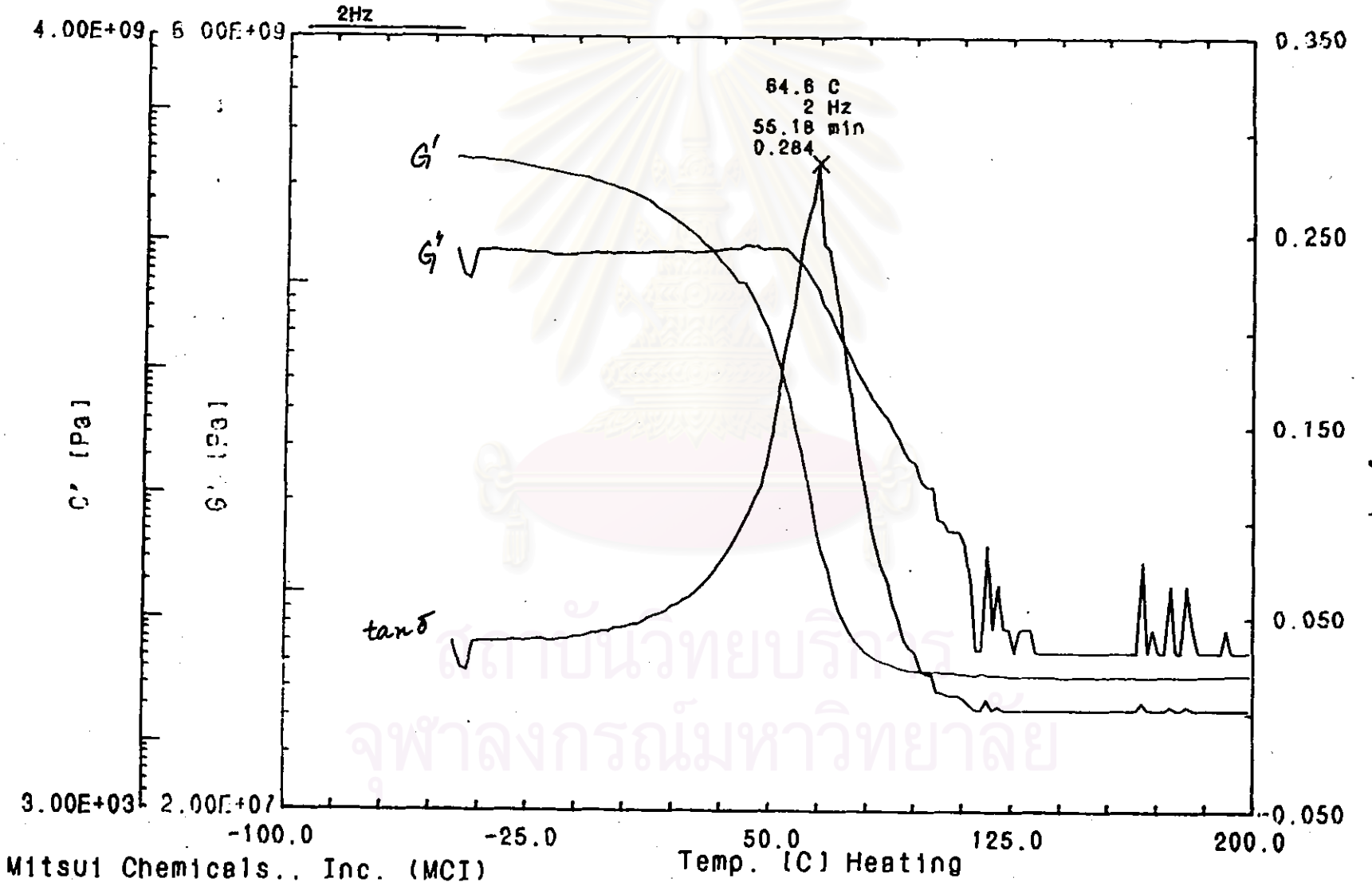
DMS

Name: Sample 5N
Date:
Comment: ----------

Sample: 5N
Temp. mode: Ramp
Deform: Shear
1*s: 20.000 mm * 0.640 mm2
Frequency: 0.5 ~ 10 Hz



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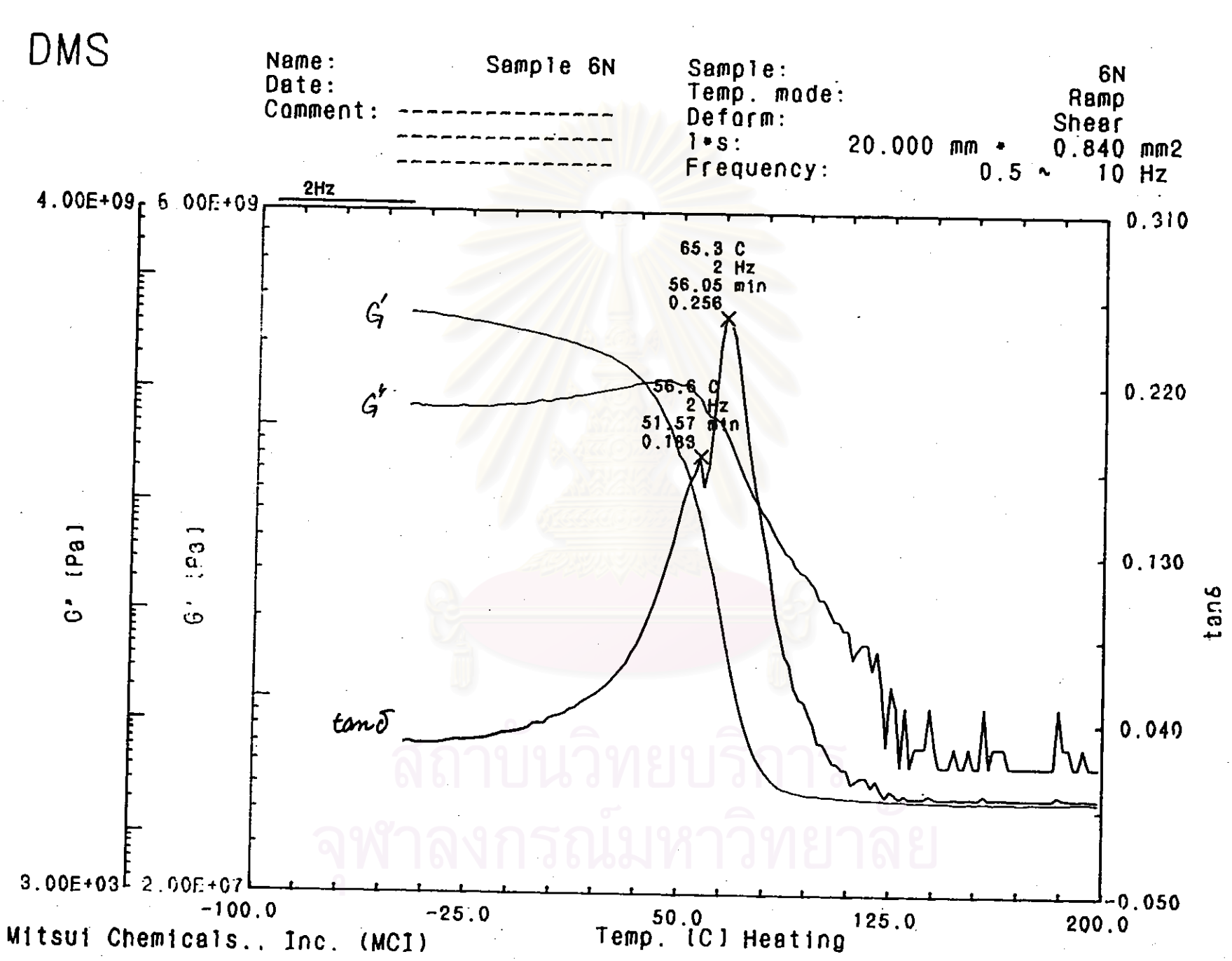
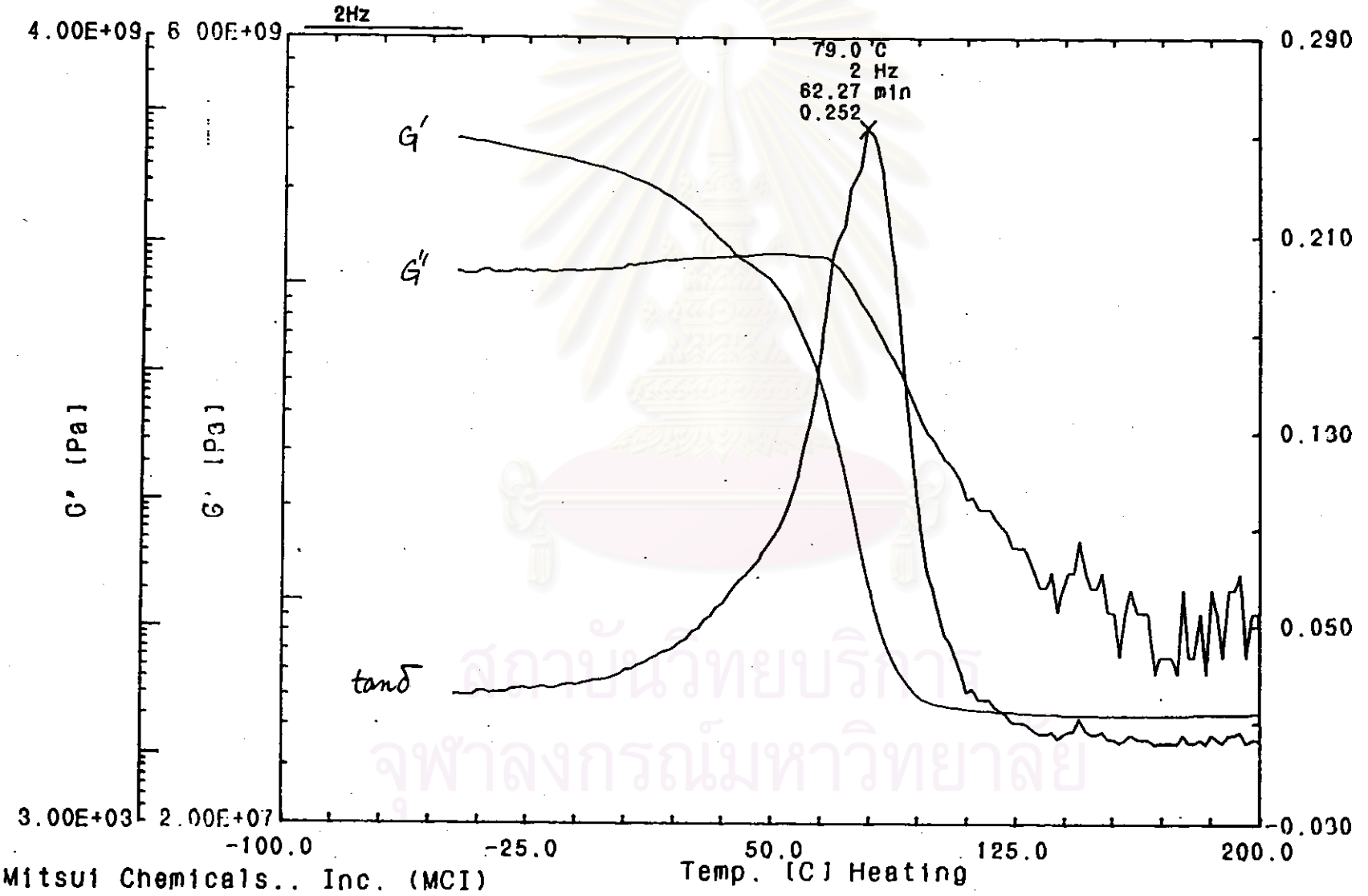
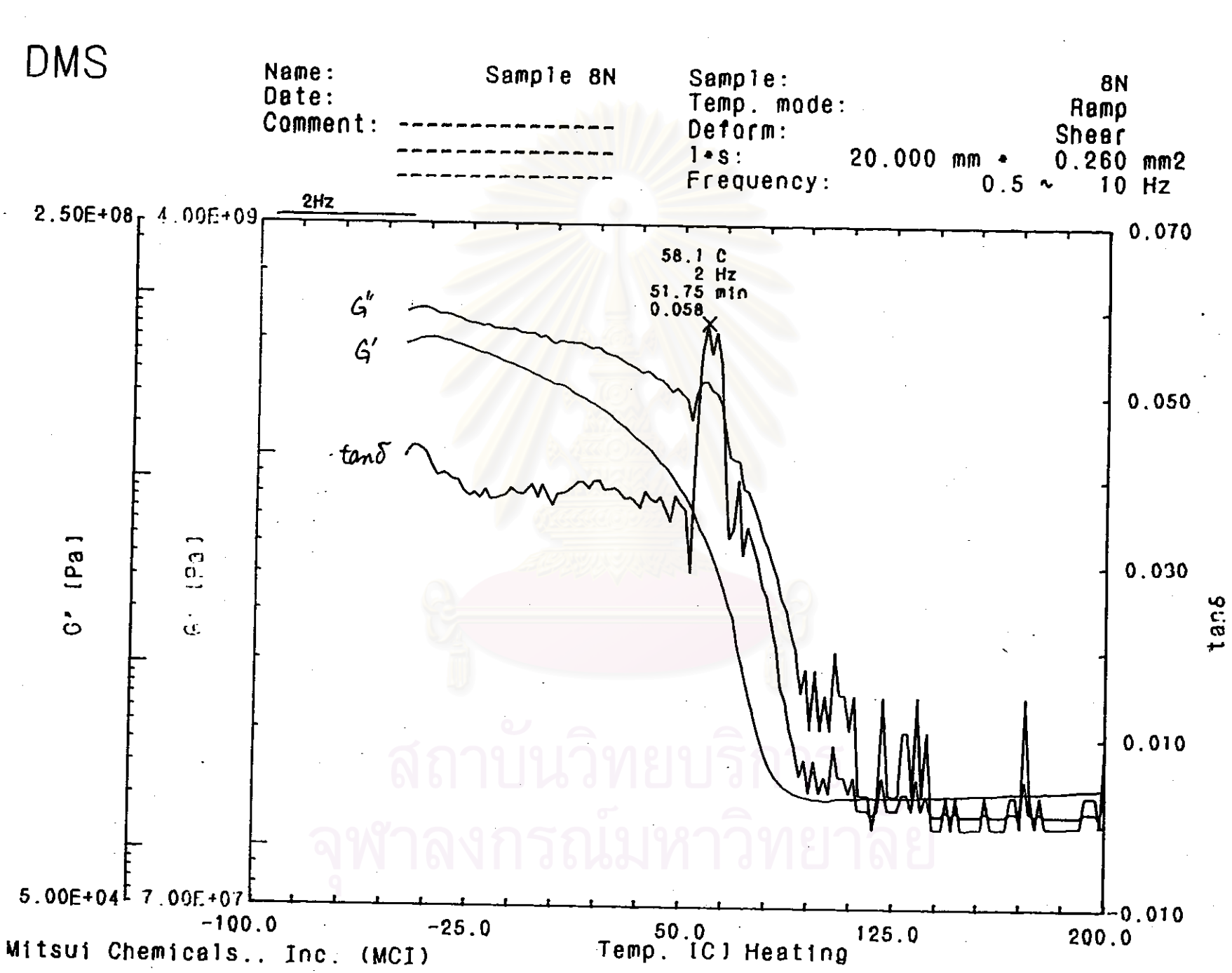


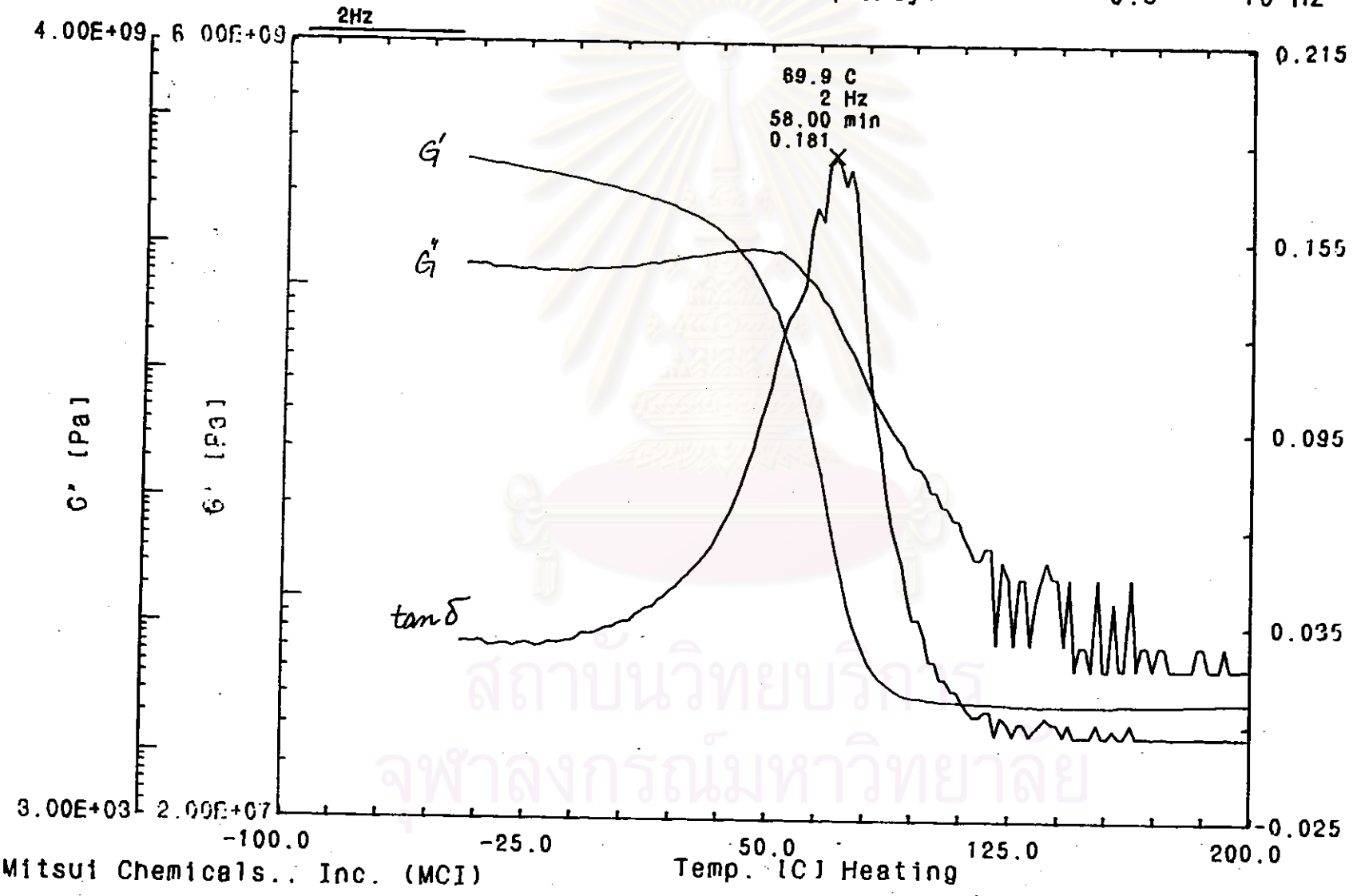




DMS

Name: Sample 9N
Date:
Comment: ----------

Sample: 9N
Temp. mode: Ramp
Deform: Shear
1*s: 20.000 mm * 0.750 mm2
Frequency: 0.5 ~ 10 Hz



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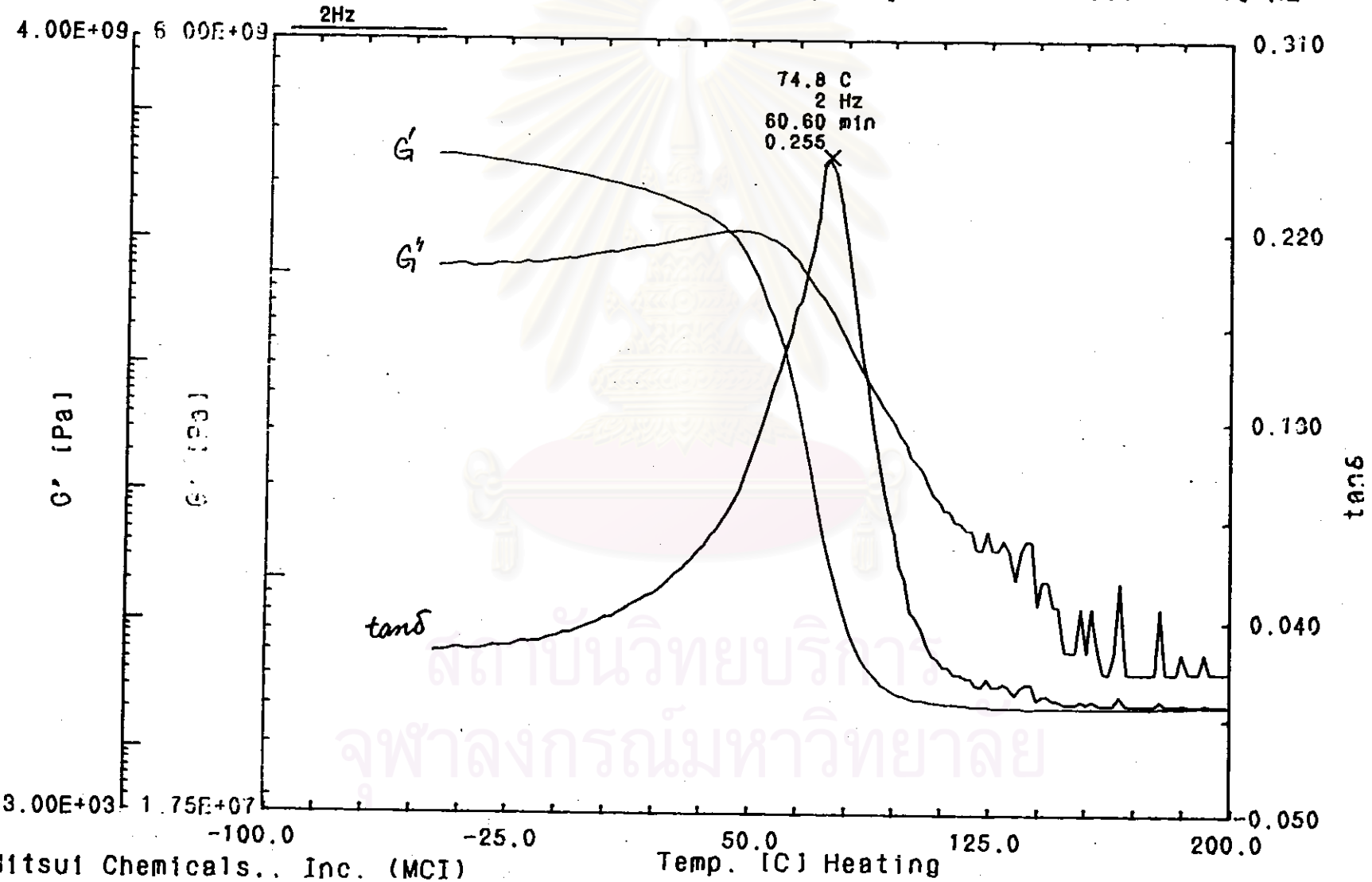
64.7°C
0.166

75.0°C
0.177

DMS

Name: Sample 10N
Date:
Comment: ----------

Sample: 10N
Temp. mode: Ramp
Deform: Shear
l*s: 20.000 mm * 0.920 mm2
Frequency: 0.5 ~ 10 Hz

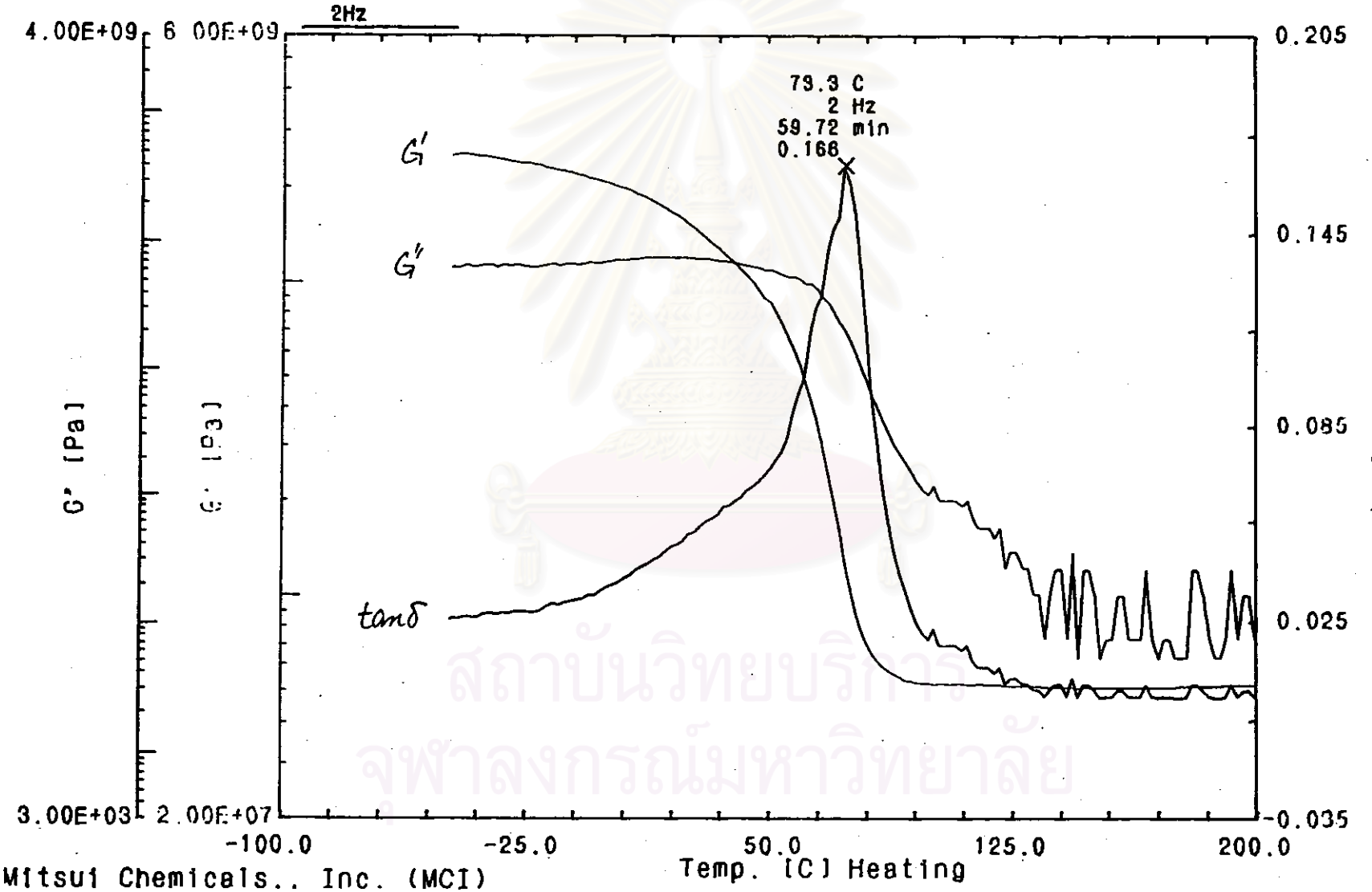


Mitsui Chemicals., Inc. (MCI)

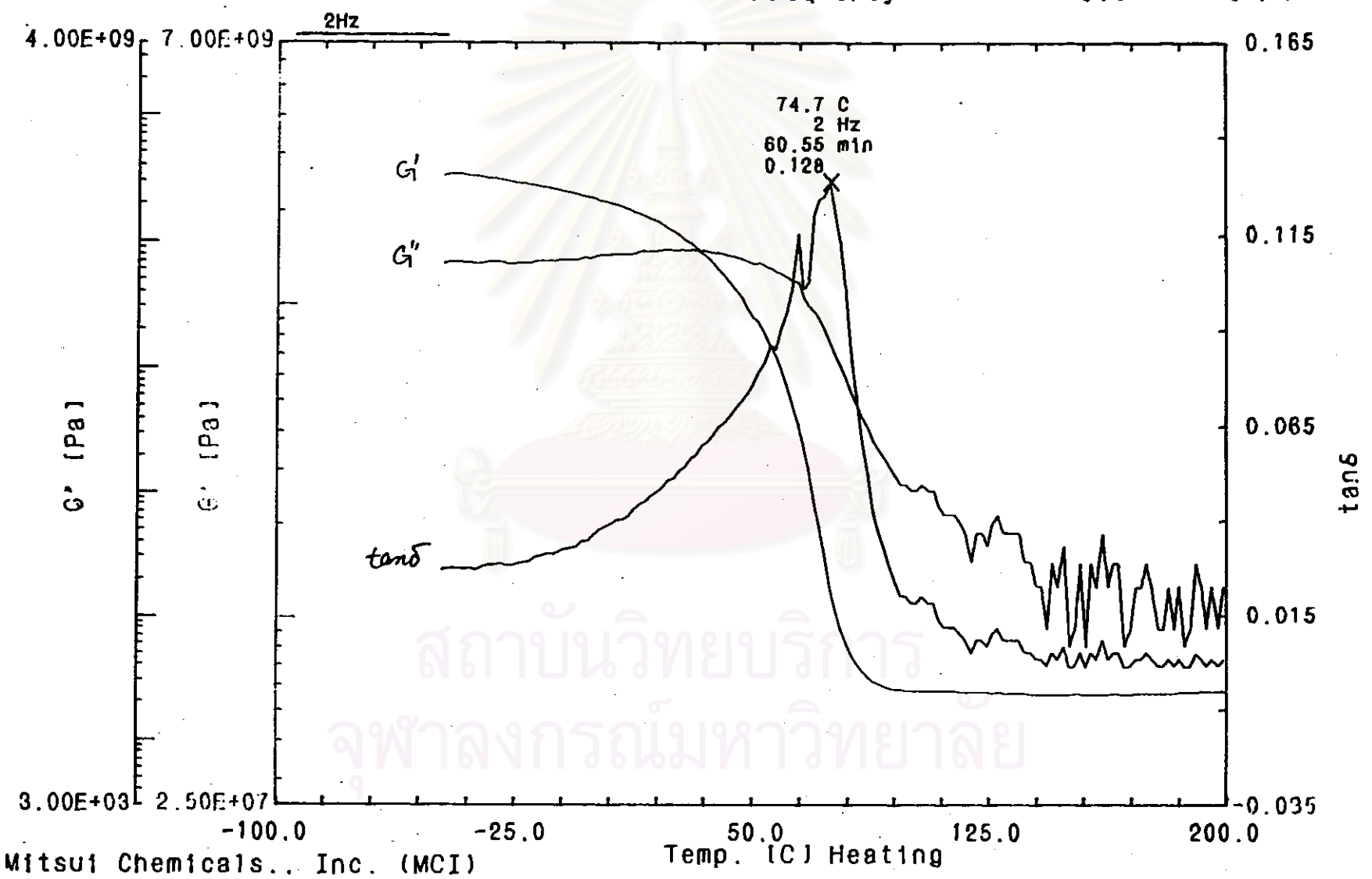
DMS

Name: Sample 5I
Date:
Comment: ----------

Sample: 5I
Temp. mode: Ramp
Deform: Shear
1*s: 20.000 mm * 0.750 mm2
Frequency: 0.5 ~ 10 Hz



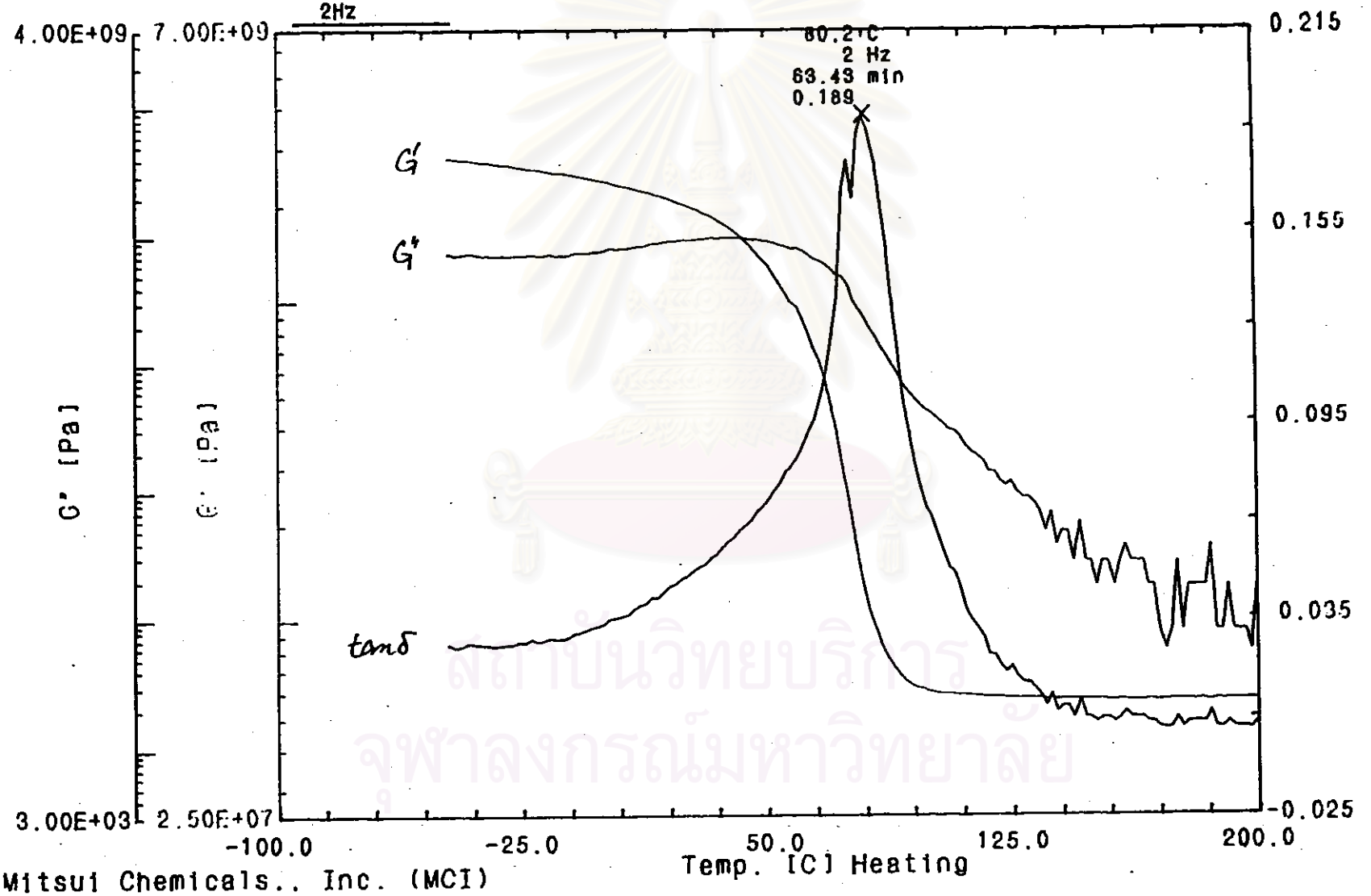
Mitsui Chemicals.. Inc. (MCI)



DMS

Name: Sample 9I
Date:
Comment: ----------

Sample: 9I
Temp. mode: Ramp
Deform: Shear
l*s: 20.000 mm * 0.690 mm2
Frequency: 0.5 ~ 10 Hz

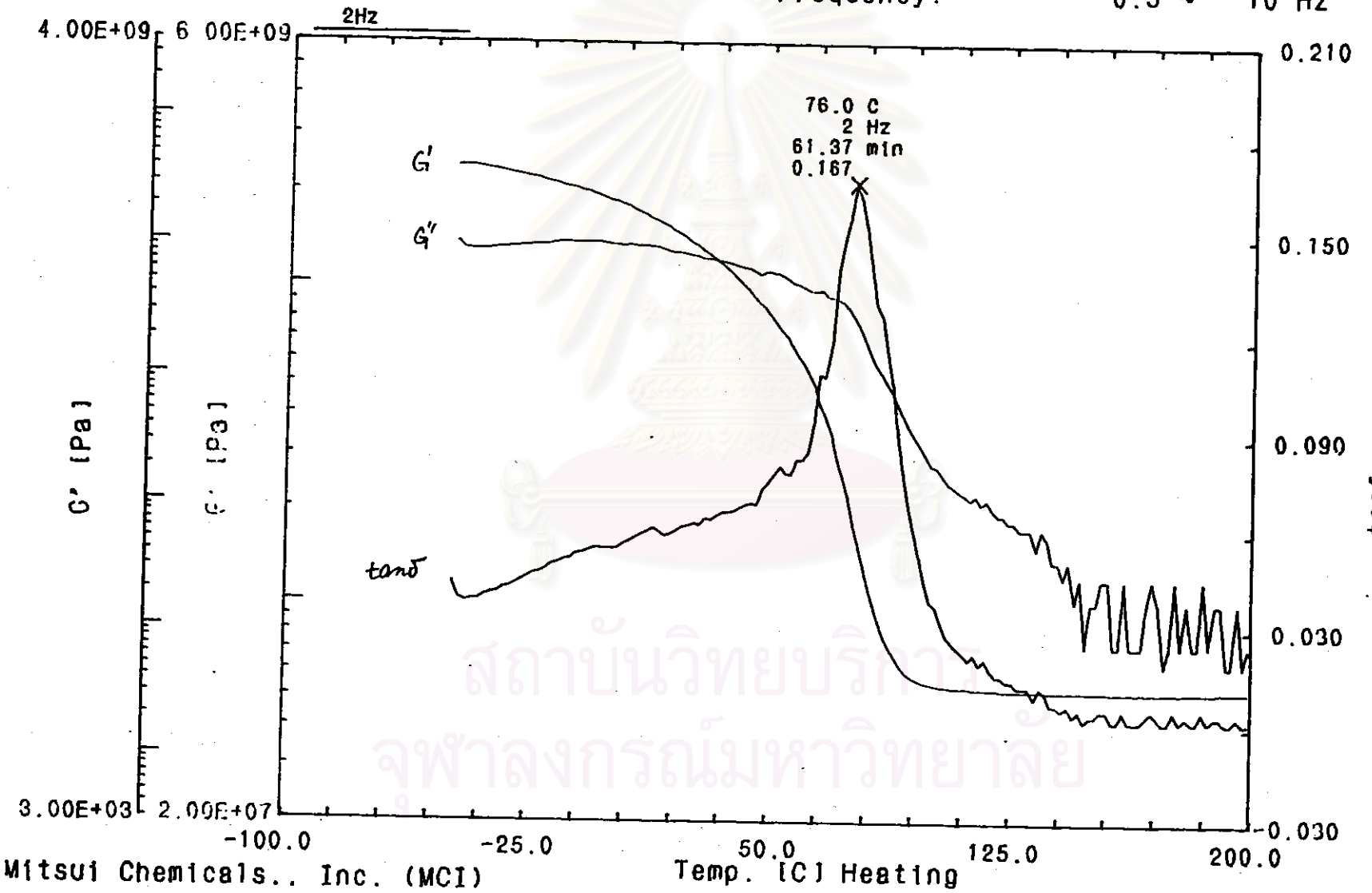


Mitsui Chemicals., Inc. (MCI)

DMS

Name: Sample 10I
Date:
Comment: ----------

Sample: 10I
Temp. mode: Ramp
Deform: Shear
1*s: 20.000 mm * 0.740 mm2
Frequency: 0.5 ~ 10 Hz



Mitsui Chemicals.. Inc. (MCI)

VITA

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