CHAPTER 6

RESULTS

6.1 General Characterization of Ball Clays

6.1.1 Chemical Composition

Table 6.1 Chemical Analysis of Ball Clays by XRF

Sample name.		% Chemical Analysis									
		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	LOI.
MS	I	61.20	0.55	24.2	1.71	0.24	0.63	2.20	0.24	0.03	9.94
MVW		57.40	0.59	25.3	1.79	0.34	0.67	1.77	0.21	0.03	12.39
MT		64.90	0.66	21.5	2.37	0.22	0.61	2.01	0.24	0.03	7.44
SB-75	II	52.90	1.10	29.10	0.95	0.16	0.40	2.08	0.48	0.07	12.74
HVC		52.80	1.08	29.5	1.03	0.17	0.36	1.94	0.21	0.07	12.56
Rex		61.90	1.61	24.8	0.63	0.11	0.28	1.50	0.54	0.08	8.06
BB		58.10	1.64	26.1	0.89	0.15	0.35	1.16	0.13	0.08	10.77
JK	III	55.00	0.57	28.9	2.22	0.30	0.81	2.77	1.05	0.04	8.32
KK		49.70	0.63	32.2	2.48	0.30	0.52	2.38	0.09	-	11.60
WN		67.90	0.82	18.2	1.60	0.50	0.47	1.00	0.13	0.03	9.98
PC		48.90	0.87	29.6	2.89	0.48	0.86	1.90	0.16	0.05	13.89

-Results of chemical composition by XRF (X-ray fluoresence) tested by Clay & Minerals (Thailand) Ltd. laboratory.

6.1.2 Mineral Composition

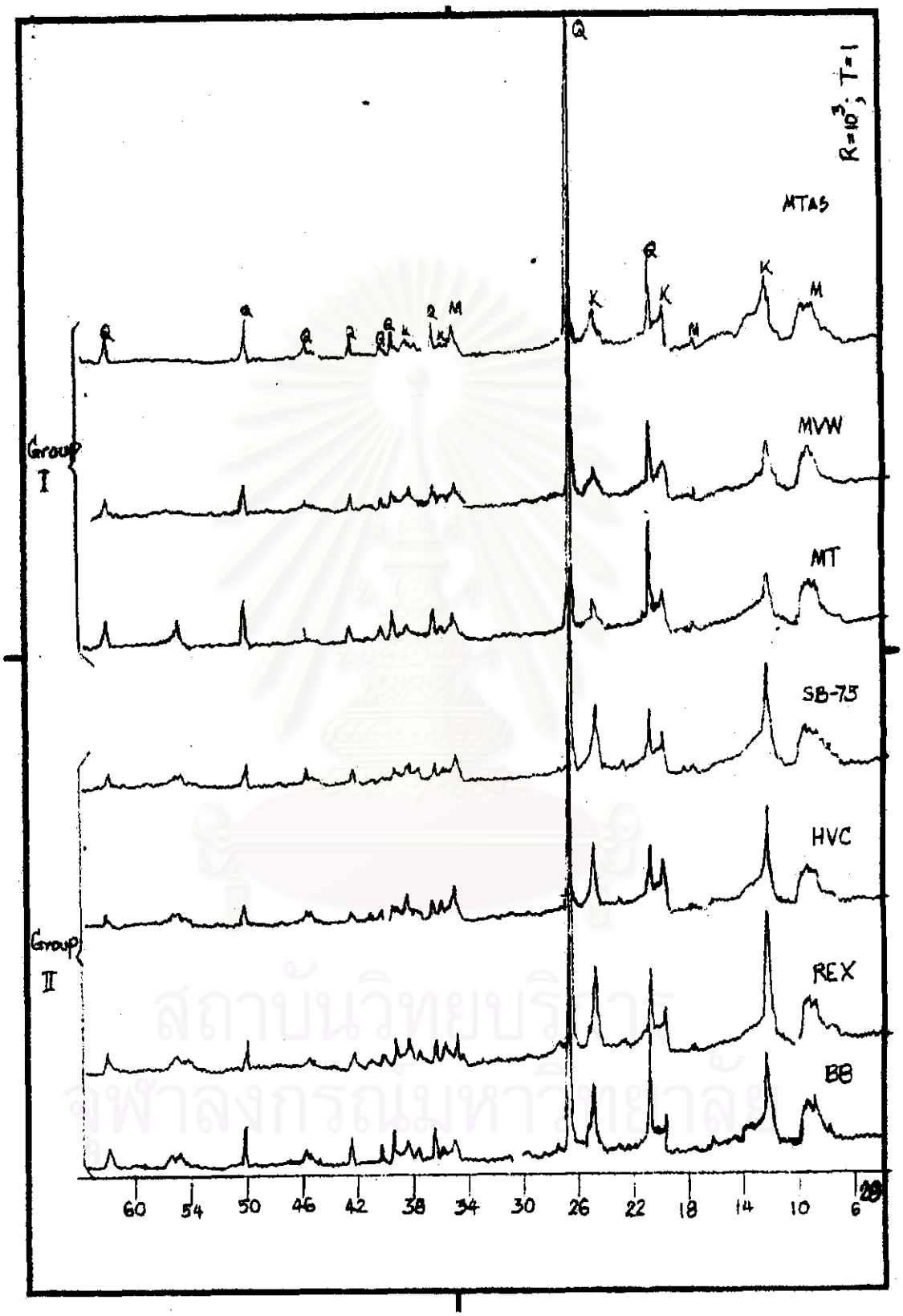


Fig. 6.1: XRD- patterns of Ball Clays Group I and II

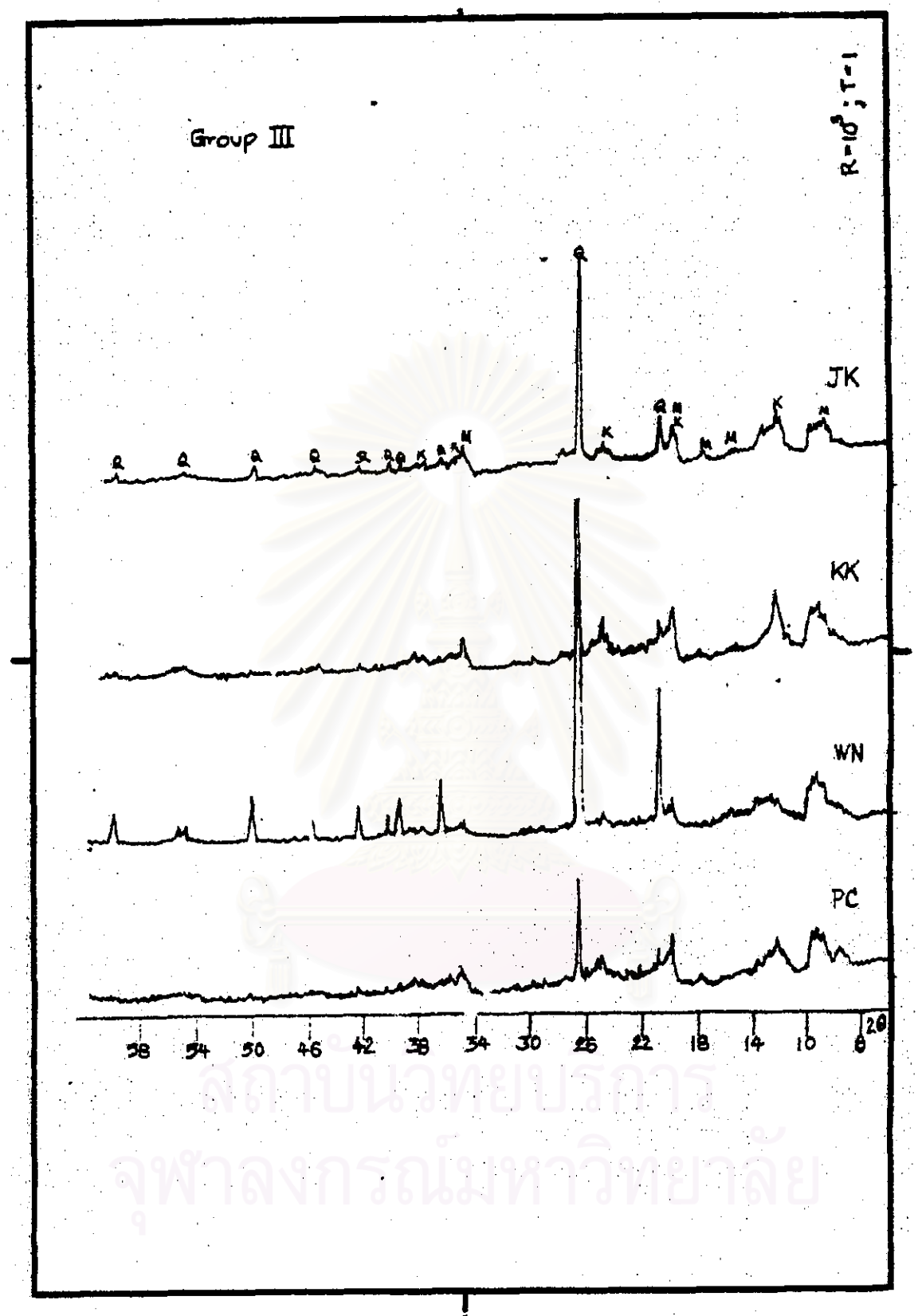


Fig.6.2: XRD-patterns of Ball Clays Group III

Table 6.2 Mineral Analysis of Ball Clays By XRD

MINERAL ANALYSIS %	SAMPLES										
		I			II			III			
	MS	MVW	MT	SB-75	HVC	REX	BB	JK	KK	WN	PC
Disordered Kaolinite	40	45	35	-	-	-	-	40	60	35	50
Medium Disordered Kaolinite	-	-	-	50	55	45	55	-	-	-	-
Moderately Crystalline Muscovite Mica	-	-	-	-	-	-	11	-	-	-	-
Poorly Crystalline Muscovite Mica	22	18	20	24	19	15	-	36	21	10	18
Mixed Layer Mineral Expandable with Glycol	-	-	-	-	-	-	-	-	3	-	20
Mixed Layer Mineral Partly Expandable with Glycol	3	3	-	-	-	-	2	-	-	-	-
Mixed Layer Mineral Non-expandable with Glycol	-	-	2	3	2	3	-	5	-	2	-
Quartz	29	22	35	17	18	24	27	15	4	39	7
Albite	-	-	-	-	-	3	-	-	-	-	-
Rutile	-	-	-	1	-	2	2	-	-	-	-
Anatase	-	-	-	-	1	-	-	-	-	-	-
Total	94	88	92	95	95	92	97	96	88	86	95

- Results of mineral composition by XRD (X-ray diffraction) tested by WBB Laboratory; 29 November 1997.

6.1.3 Microstructure

6.1.3.1 Scanning Electron Microscope (SEM)

I. Ball Clays Group I ; MS, MVW, MT

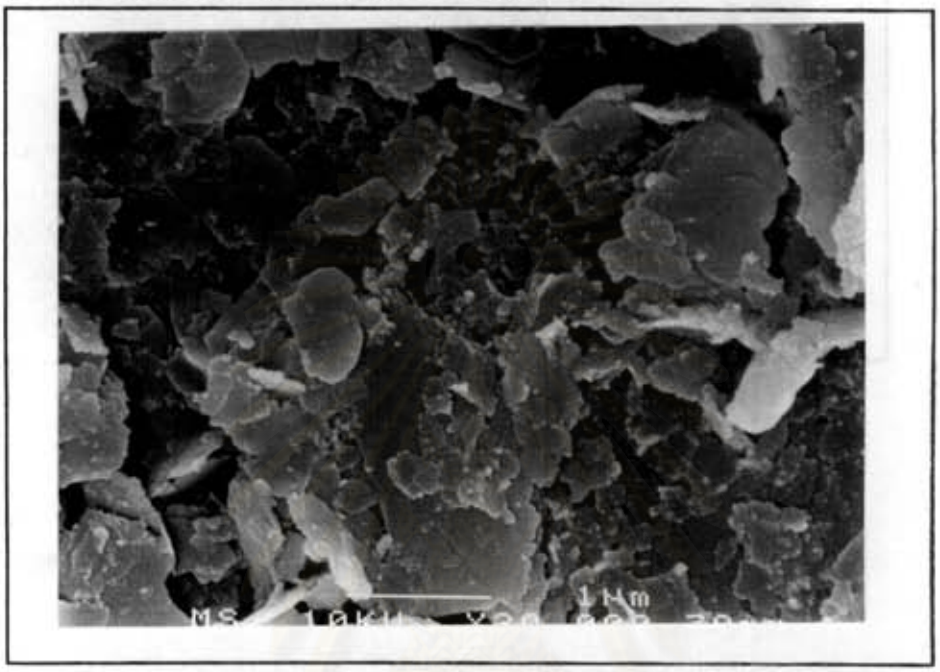


Fig. 6.3 SEM microstructure of MS (x 20,000)

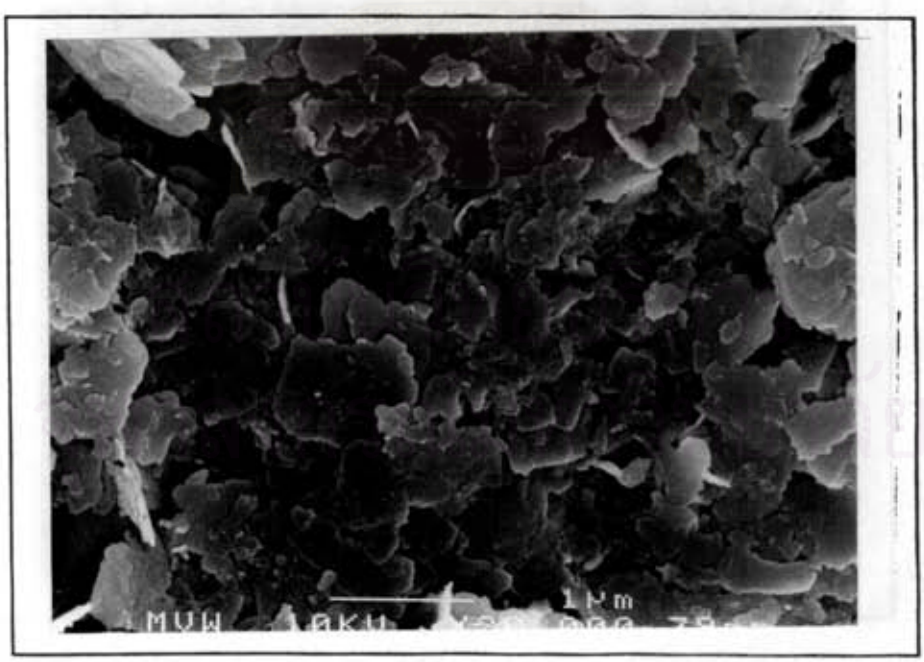


Fig. 6.4 SEM microstructure of MVW (x 20,000)

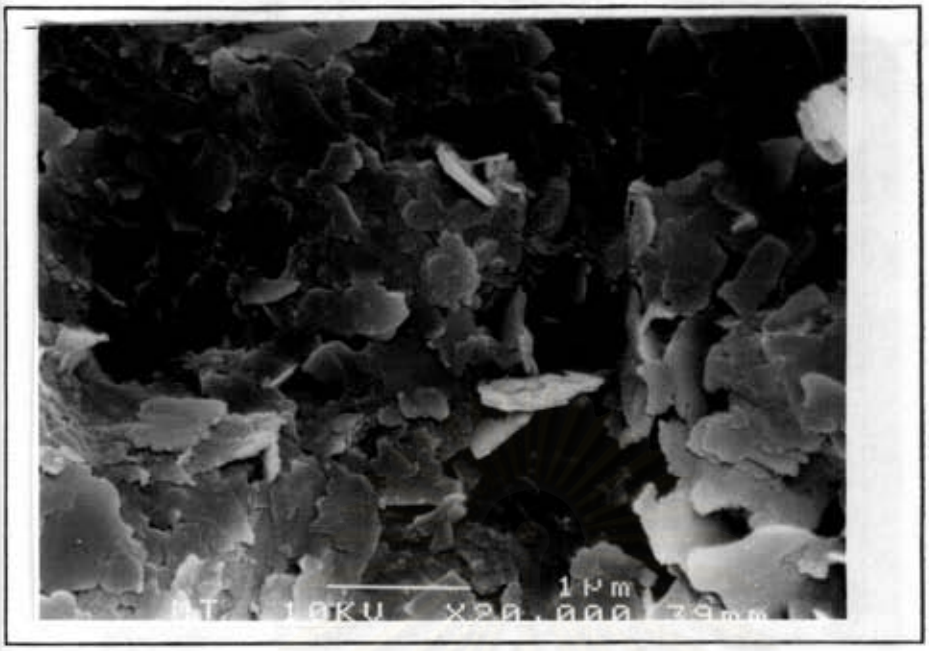


Fig. 6.5 SEM microstructure of MT (x 20,000)

II. Ball Clays Group II ; SB-75, HVC, REX, BB

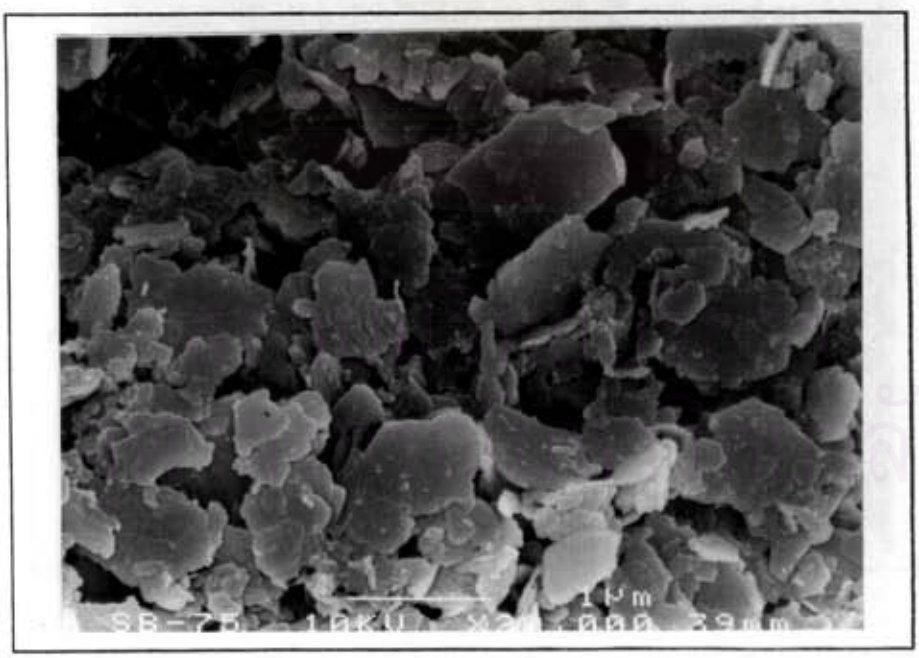


Fig. 6.6 SEM microstructure of SB-75 (x 20,000)

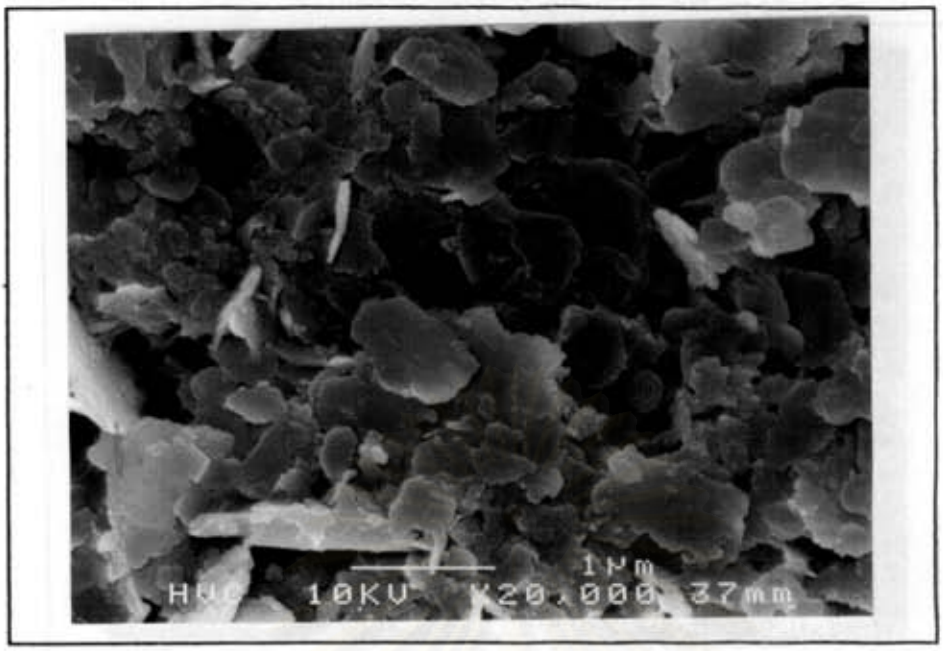


Fig. 6.7 SEM microstructure of HVC (x 20,000)

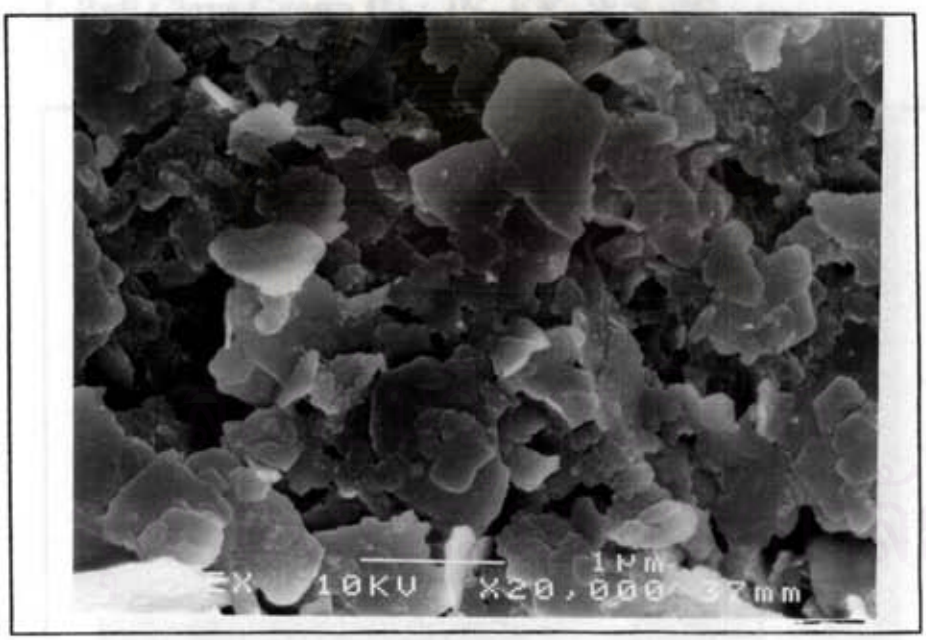


Fig. 6.8 SEM microstructure of REX (x 20,000)

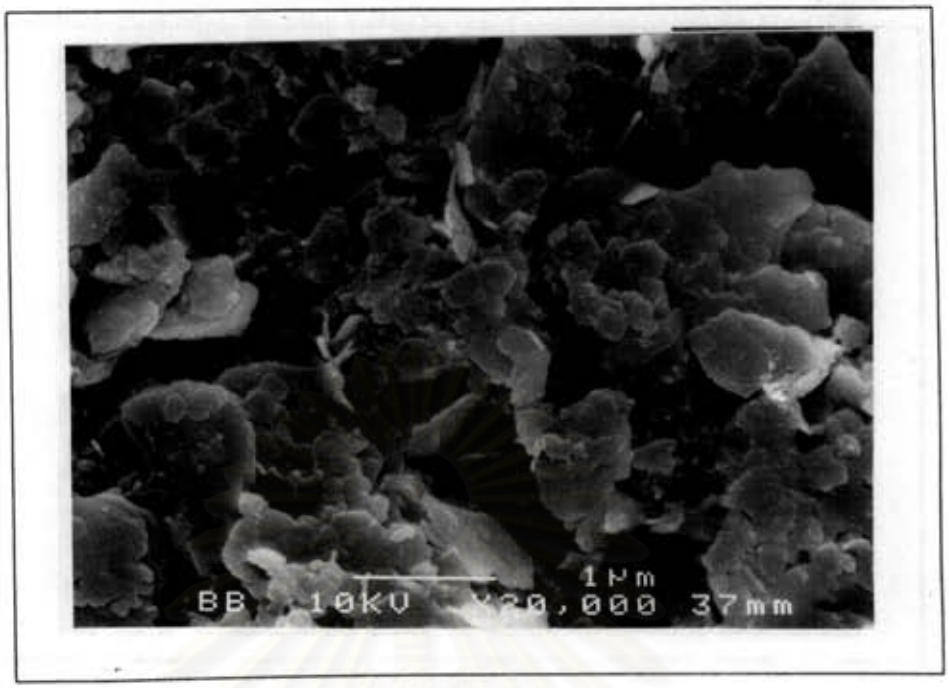


Fig. 6.9 SEM microstructure of BB (x 20,000)

III. Ball Clays Group III ; JK, KK, WN, PC

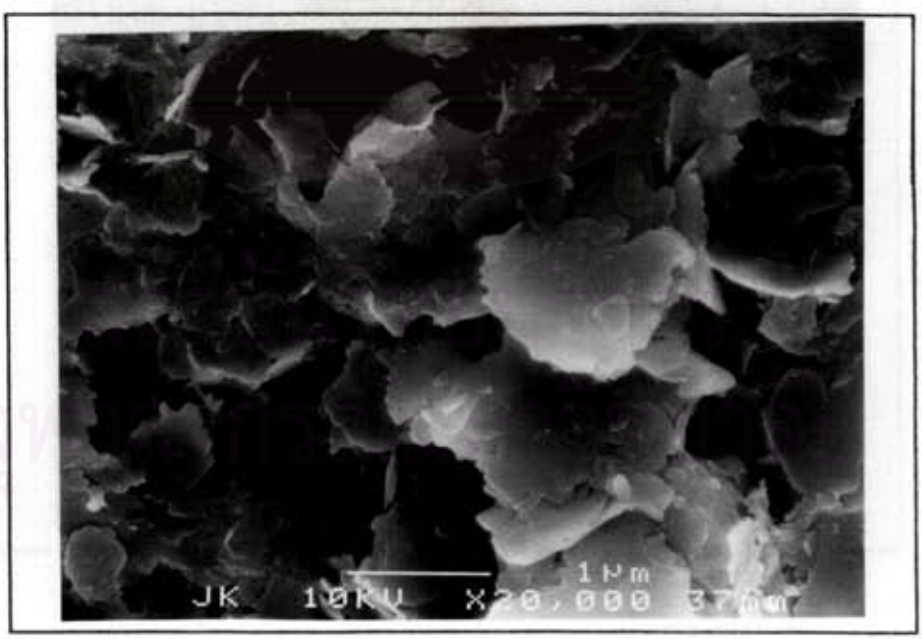


Fig. 6.10 SEM microstructure of JK (x 20,000)

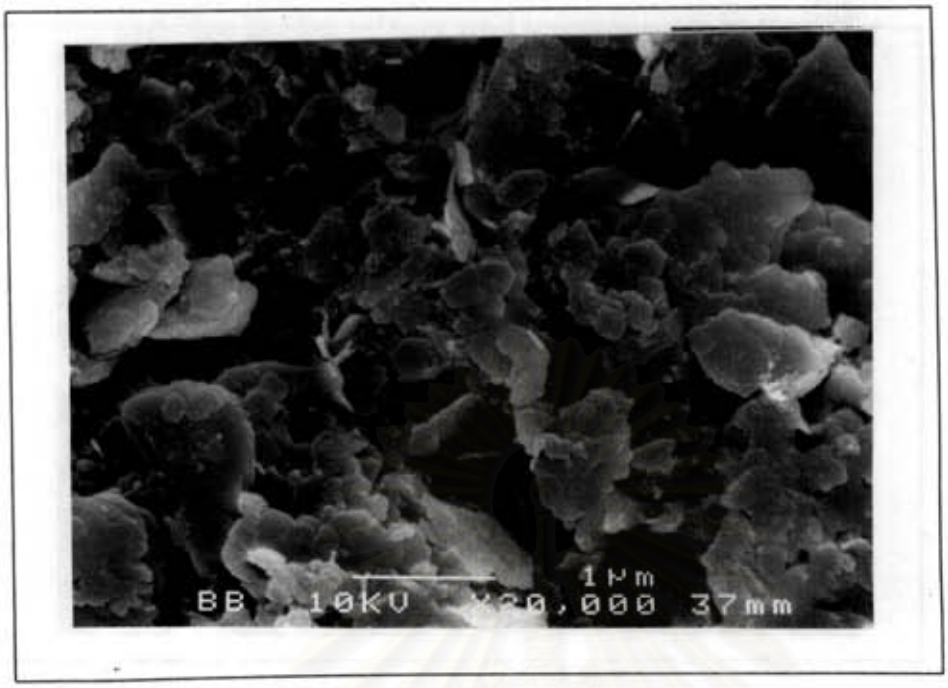


Fig. 6.9 SEM microstructure of BB (x 20,000)

III. Ball Clays Group III ; JK, KK, WN, PC

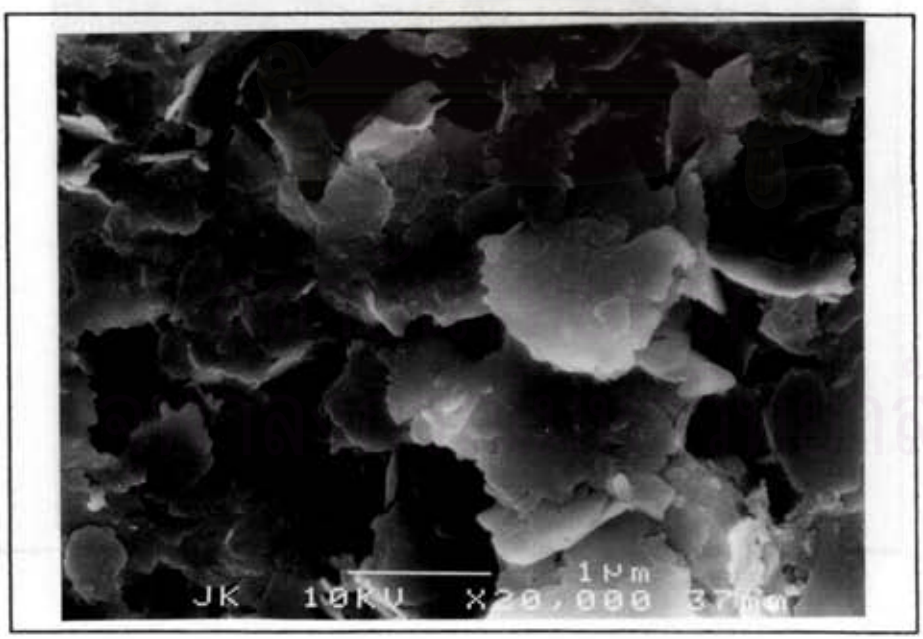


Fig. 6.12 SEM microstructure of WN (x 20,000)

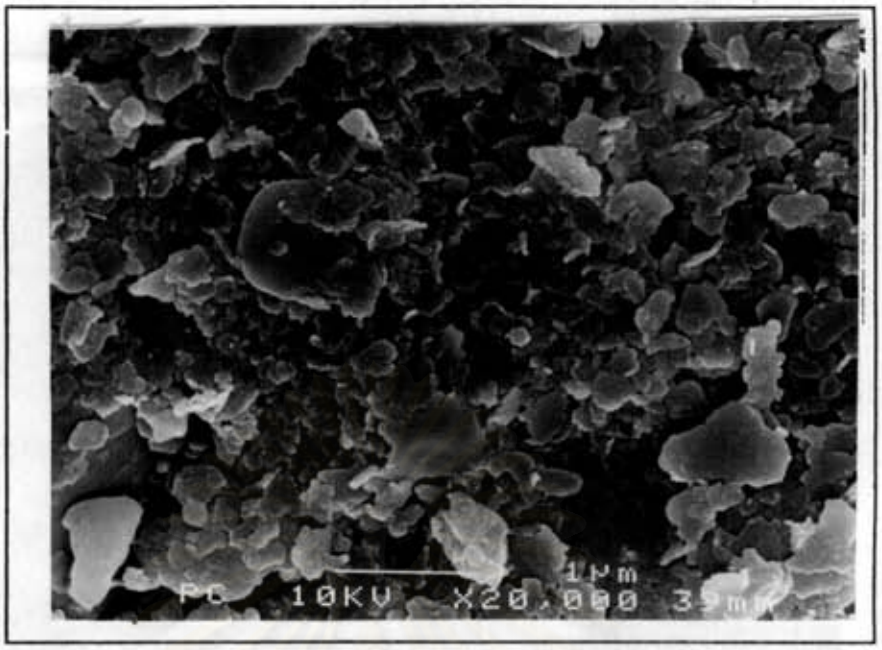


Fig. 6.13 SEM microstructure of PC (x 20,000)

6.1.3.2 Transmitted Electron Microscope (TEM

I. Ball Clays Group I ; MS, MVW, MT

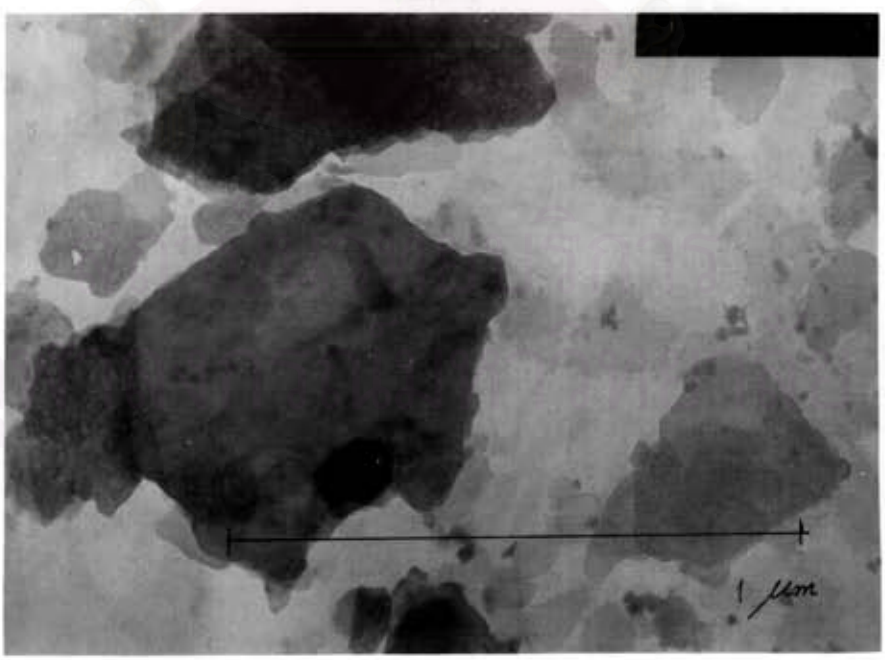


Fig. 6.14 TEM microstructure of MS (x 75,000)

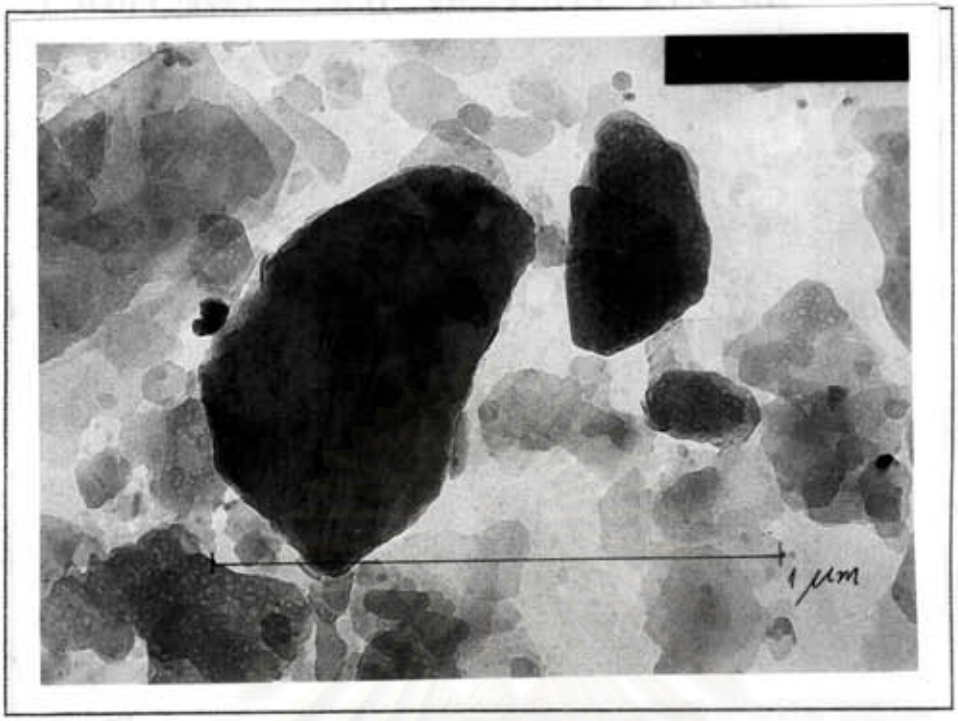


Fig. 6.15 TEM microstructure of MVW (x 75,000)

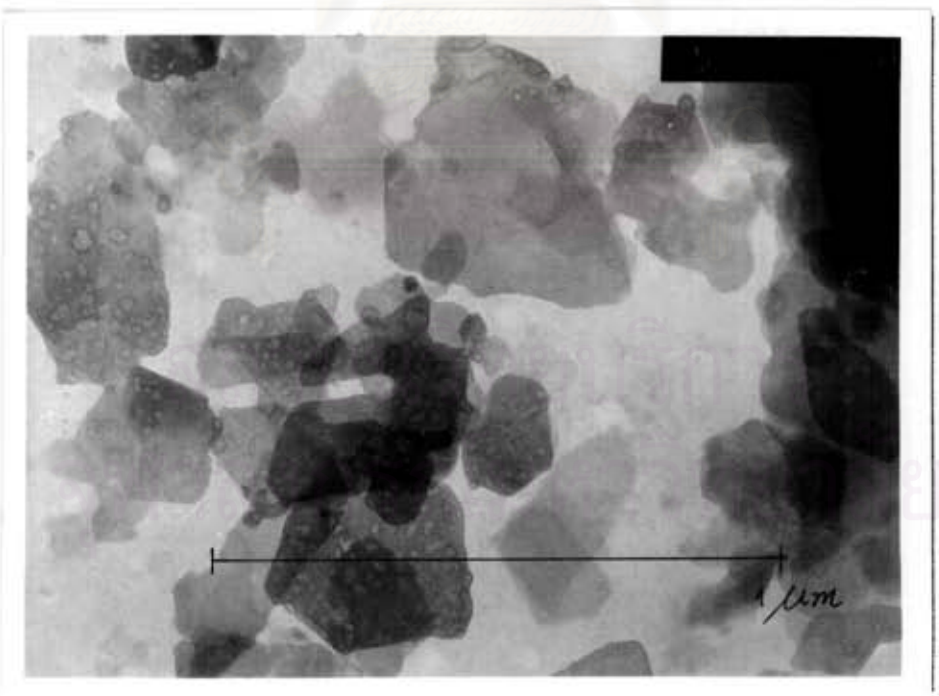


Fig. 6.16 TEM Microstructure of MT (x 75,000)

II. Ball Clays Group II ; SB-75, HVC, REX, BB

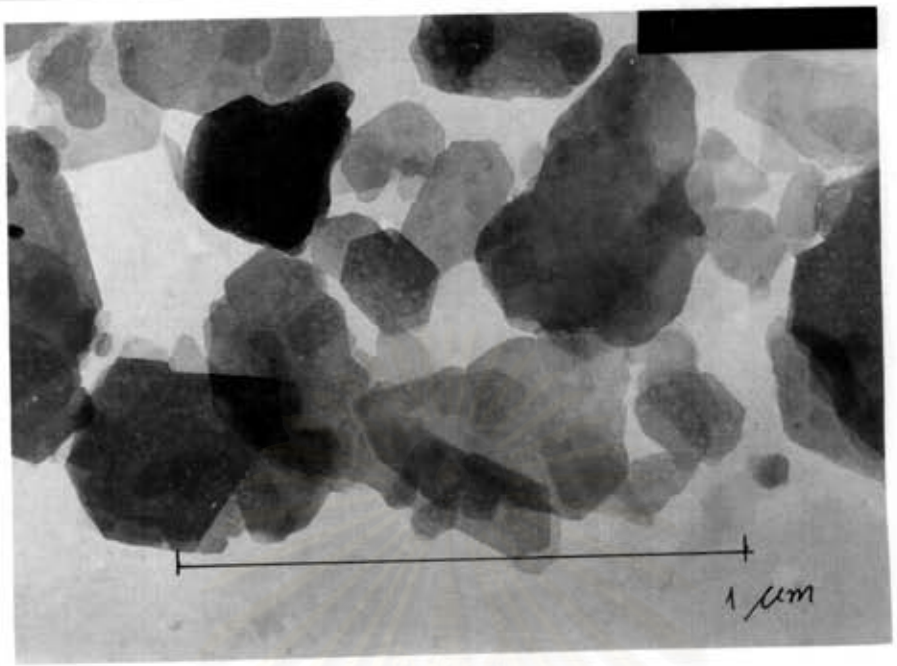


Fig. 6.17 TEM microstructure of SB-75 (x 75,000)

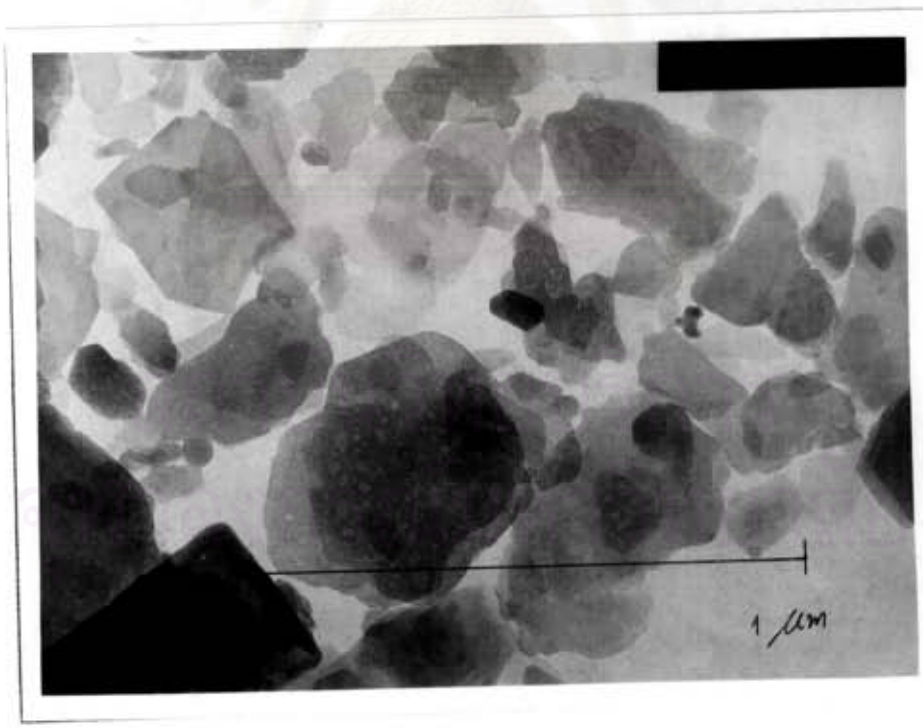


Fig. 6.18 TEM Microstructure of HVC (x 75,000)

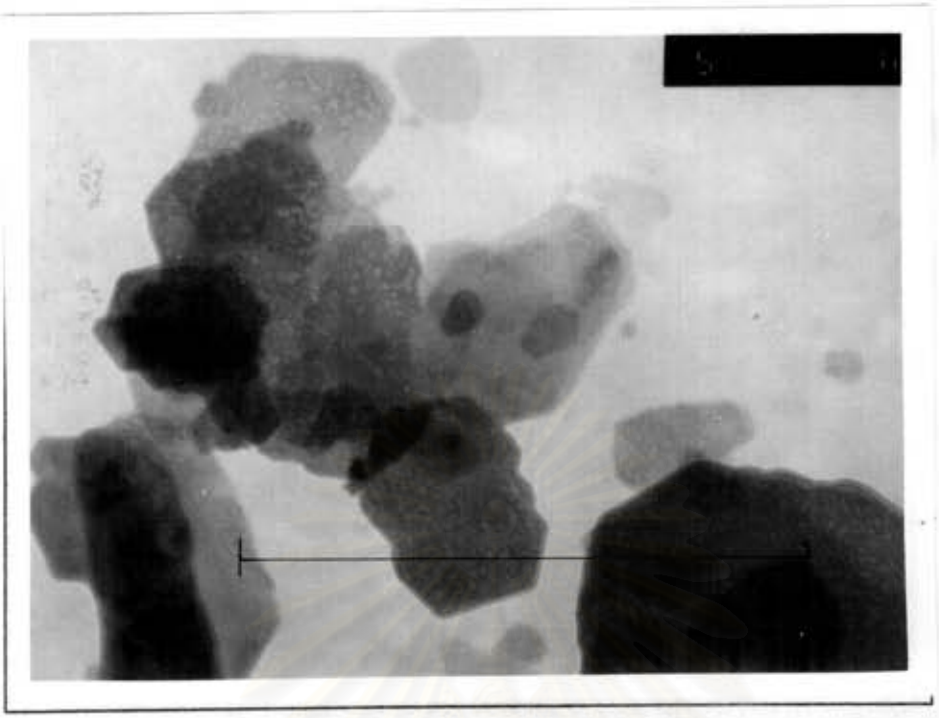


Fig. 6.19 TEM microstructure of REX (x 75,000)

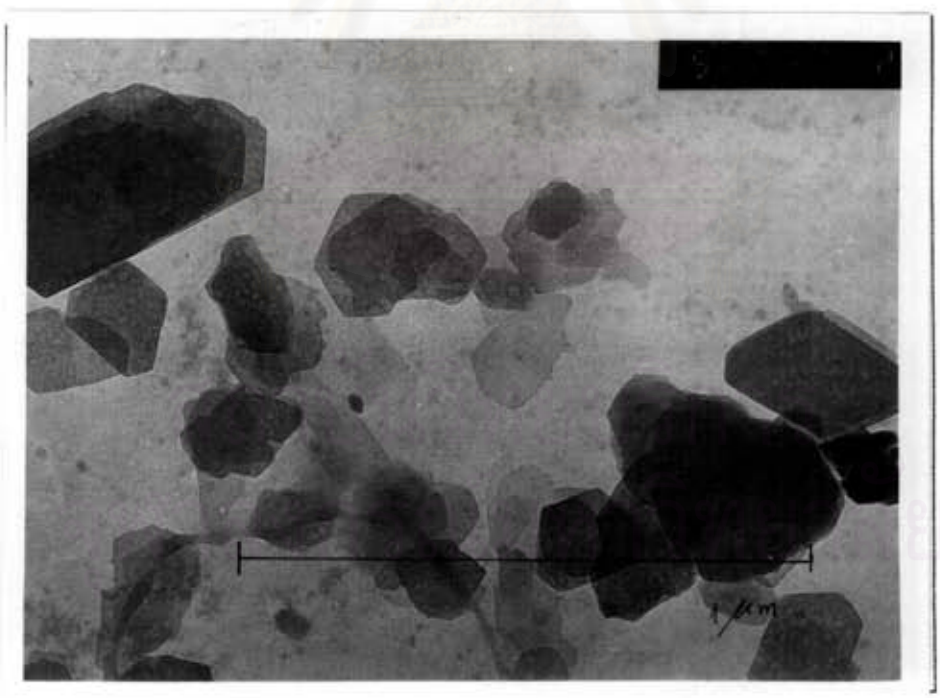


Fig. 6.20 TEM microstructure of BB (x 75,000)

III. Ball Clays Group III ; JK, KK, WN, PC

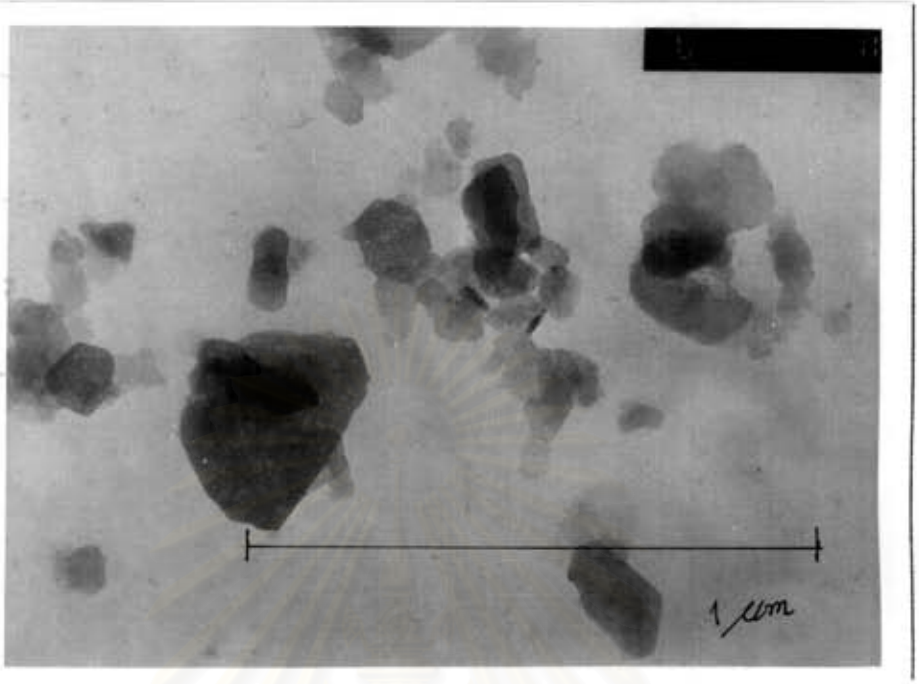


Fig. 6.21 TEM microstructure of JK (x 75,000)

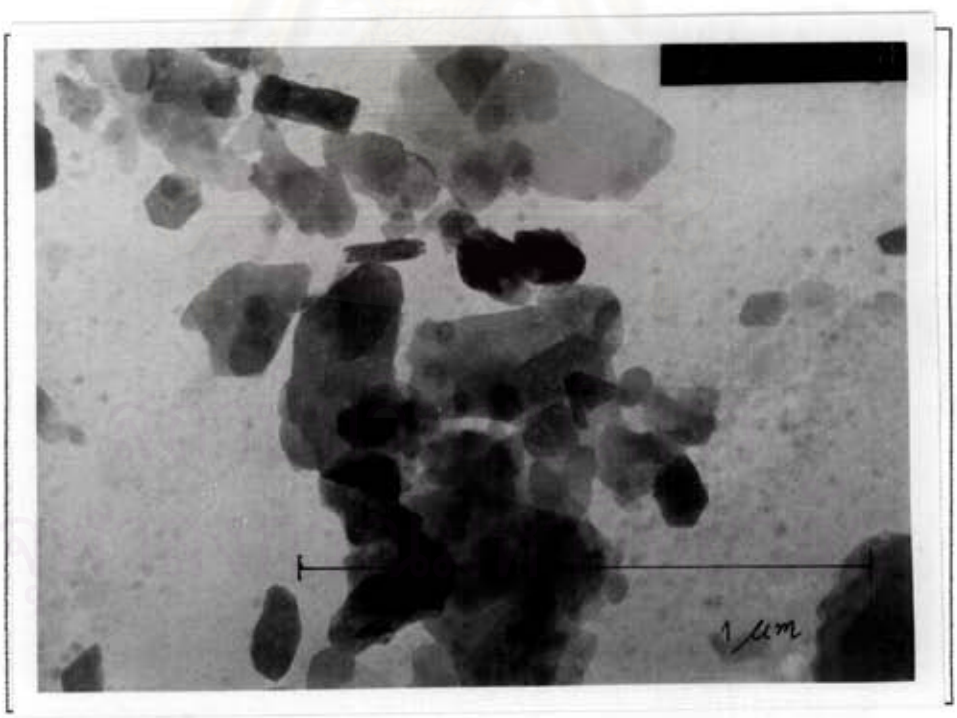


Fig. 6.22 TEM microstructure of KK (x 75,000)

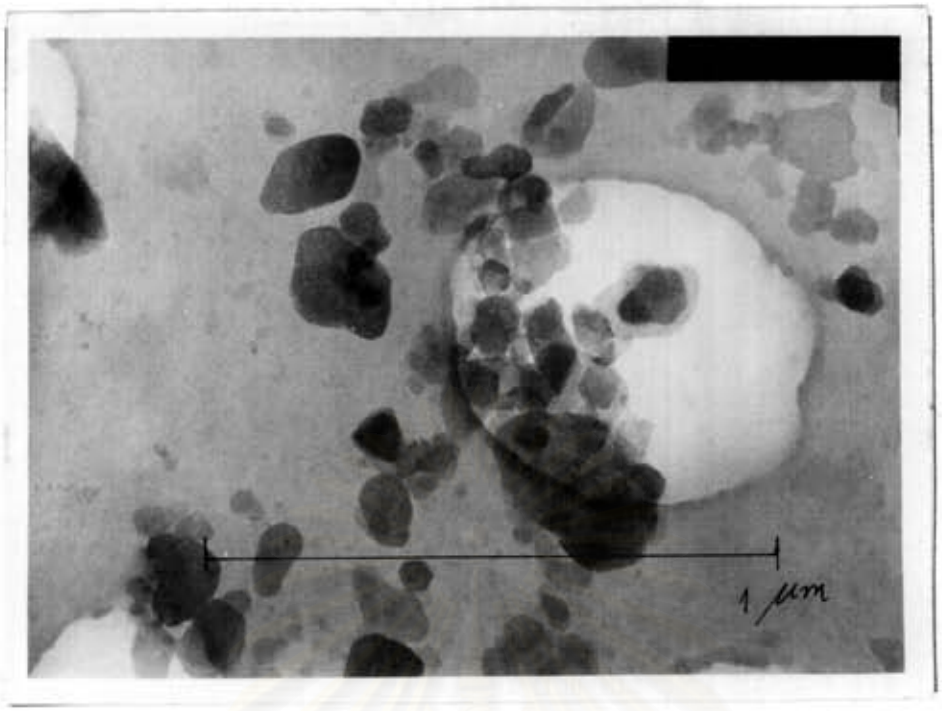


Fig. 6.23 TEM microstructure of WN (x 75,000)

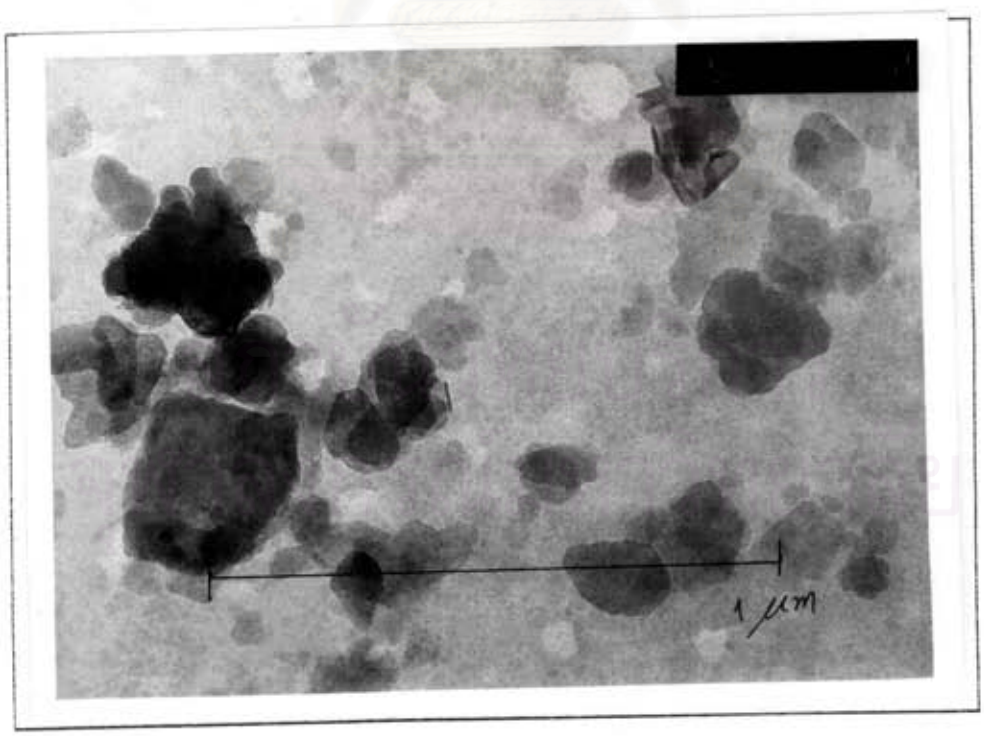


Fig. 6.24 TEM microstructure of PC (x 75,000)

6.1.4 Particle Size Distribution

Table 6.3 Particle Size Analysis of Ball Clays

Particle Size Analysis (%)		MS	MVW	MT	SB-75	HVC	REX	BB	JK	KK	WN
		←	I	→	←	II	→	←	III	→	
Screen residue on (%)	120#	2.18	1.50	2.71	0.25	3.66	0.50	2.80	1.24	1.20	2.39
	200#	2.84	2.91	4.25	0.69	5.12	1.90	4.70	1.46	1.44	5.49
	325#	3.61	4.27	5.94	1.42	6.22	5.70	9.20	1.61	1.62	9.25
Particle size (%) Equivalent Spherrical Diameter (esd)	- 20μm.	98.8	96.1	95.8	97.8	97.4	88.0	82.5	98.7	98.9	95.3
	- 10μm.	95.7	92.1	90.0	94.7	93.2	84.5	72.5	96.9	97.6	88.5
	- 5μm.	89.2	85.9	80.0	90.0	85.1	76.0	58.5	94.1	96.3	79.1
	- 2μ	67.1	71.1	57.0	78.5	67.8	61.1	51.1	84.4	91.2	65.3
	- 1μ	50.3	57.7	42.0	70.0	56.8	38.1	39.1	72.3	85.4	57.5
	- 0.5μ	35.6	42.6	29.5	56.5	41.3	31.1	35.1	56.1	75.0	50.7
	- 0.2μ	15.8	19.5	12.7	28.8	17.7	18.1	21.1	28.1	47.9	35.3

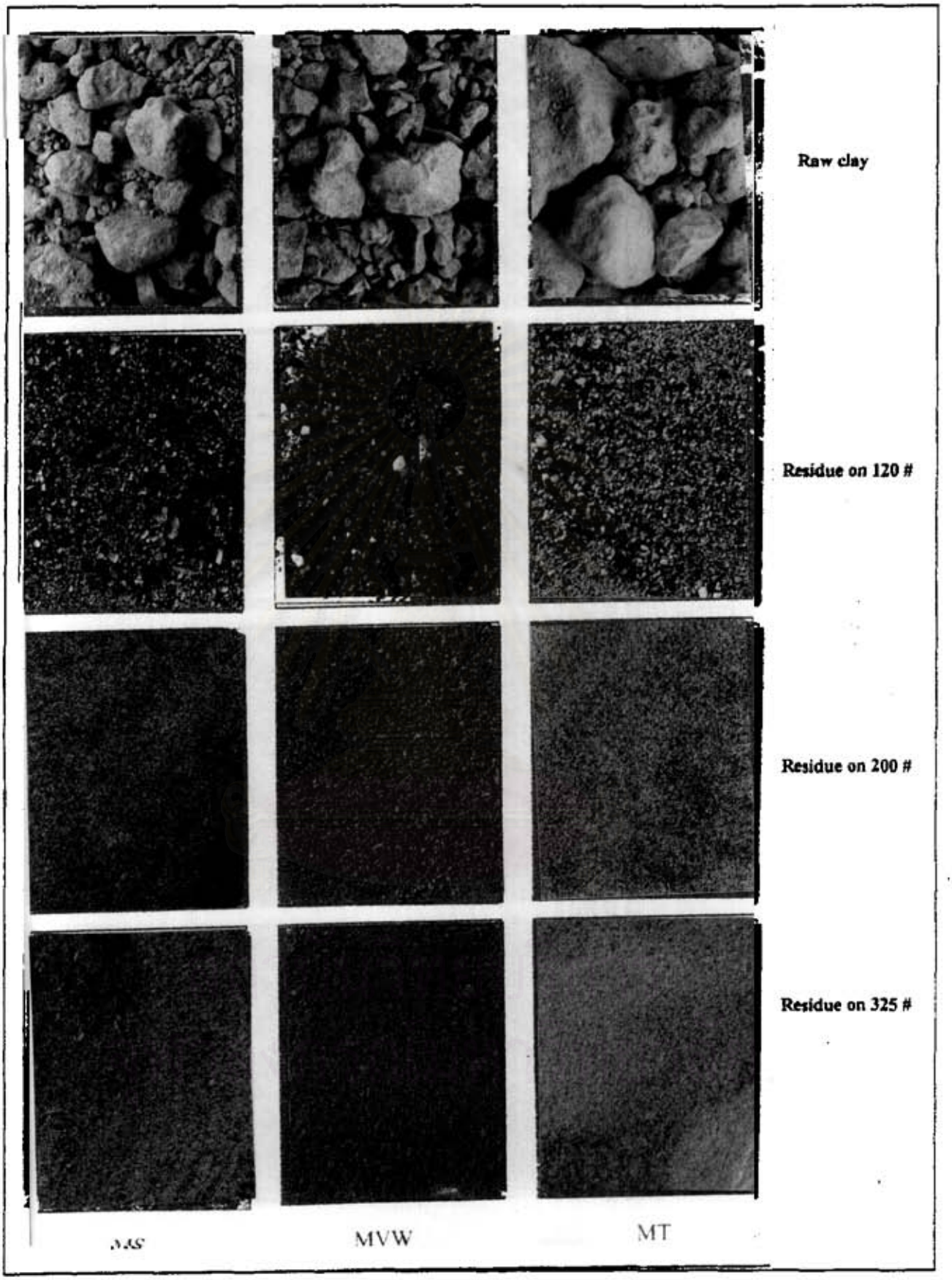


Fig.6.25 Raw clays and residue of ball clays in group 1 (MS, MVW, MT)

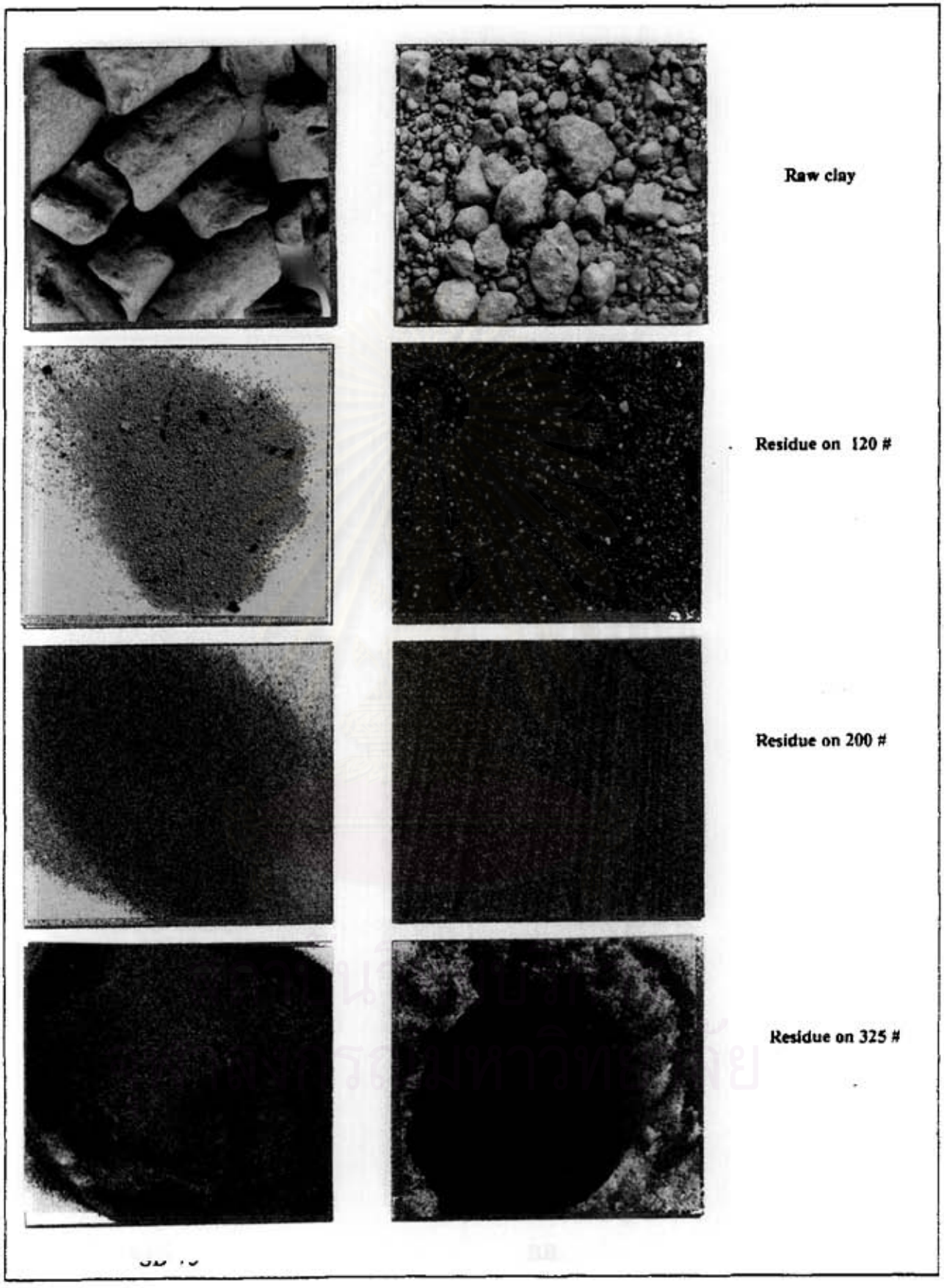


Fig.6.26 Raw clays and residue of ball clays in group II (SB-75, HVC)

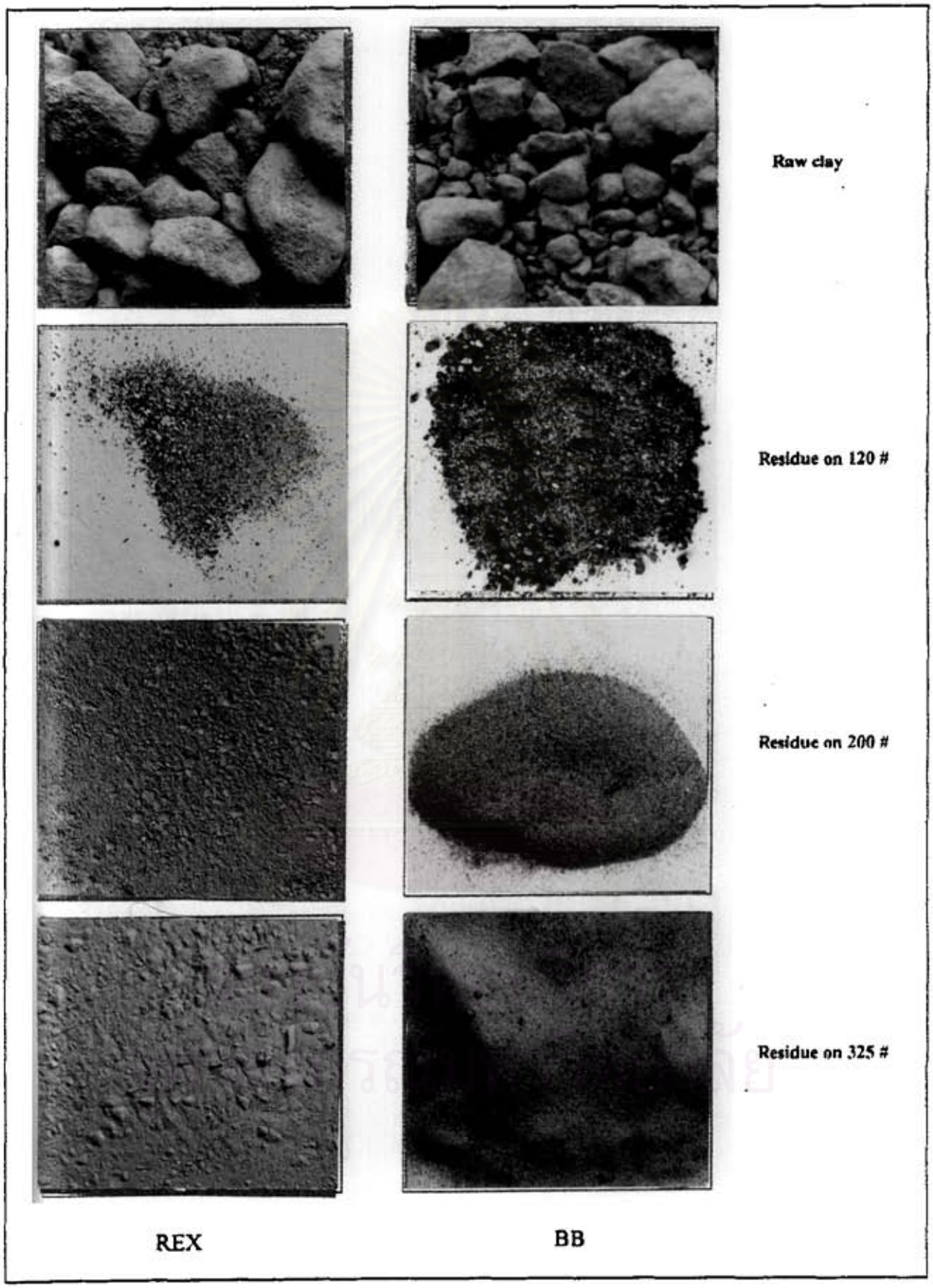


Fig.6.27 Raw clays and residue of ball clays in group II (REX, BB)

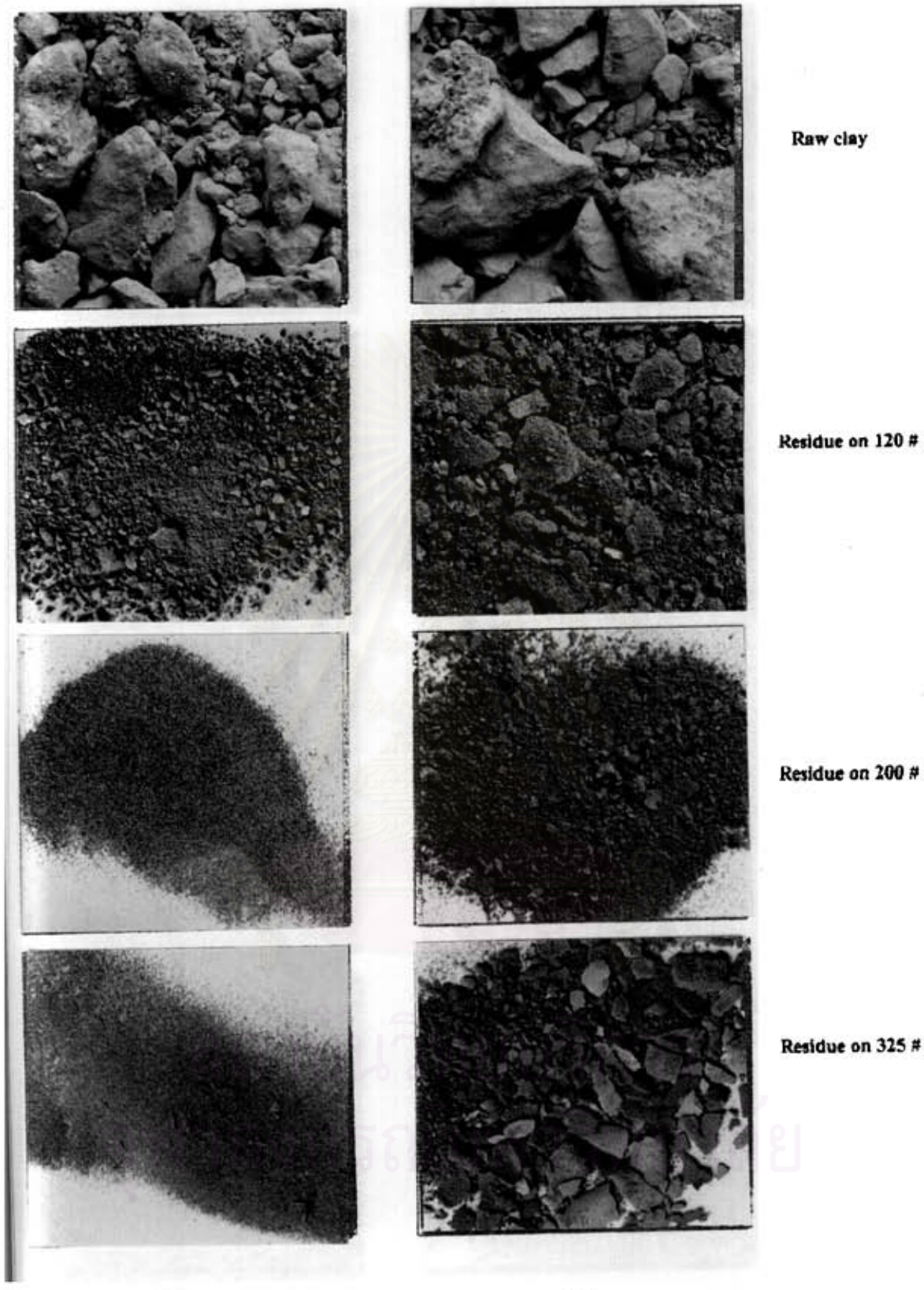


Fig.6.28 Raw clays and residue of ball clays in group III (JK, KK)

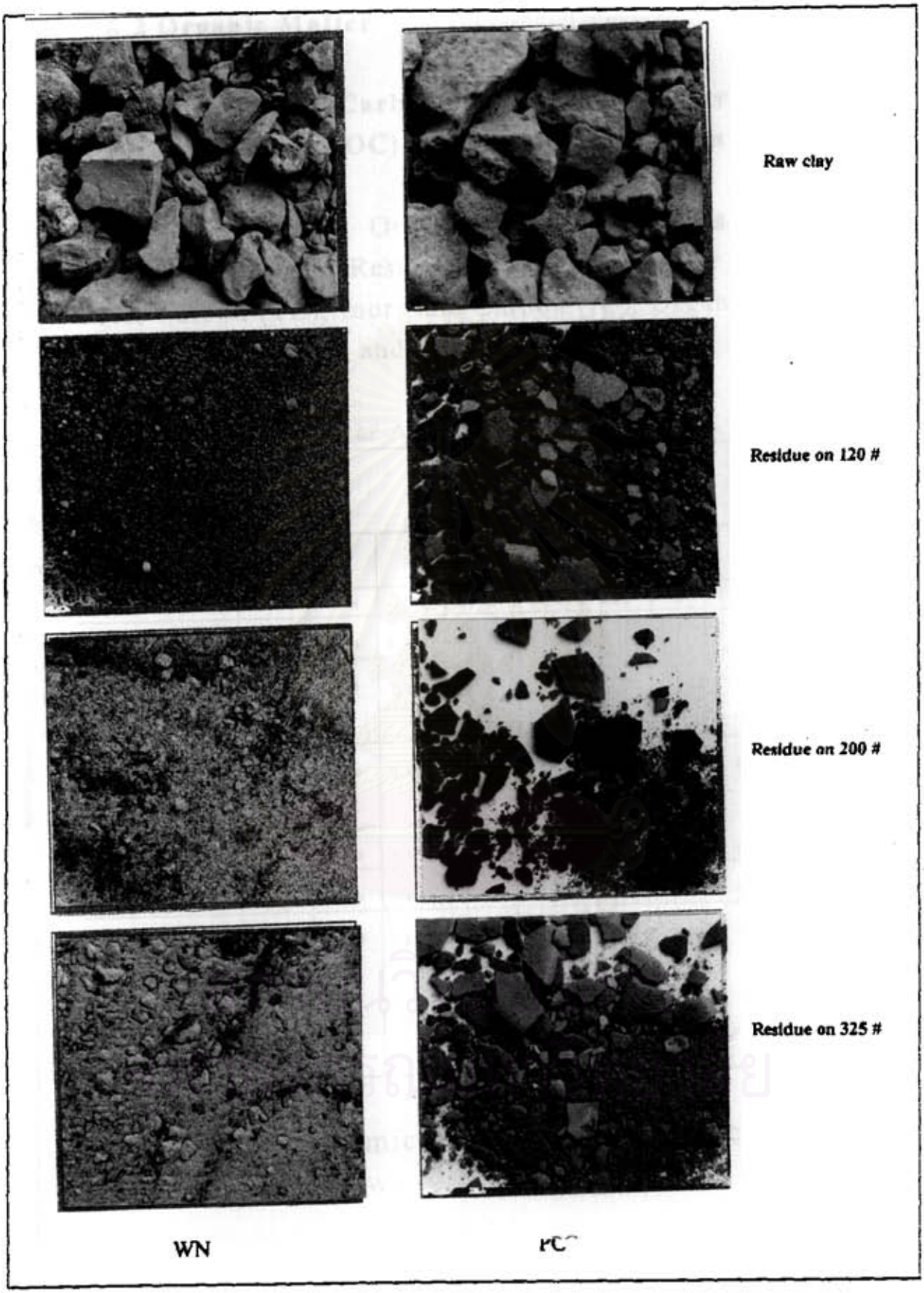


Fig.6.29 Raw clays and residue of ball clays in group III (WN, PC)

6.2 Organic Matter

6.2.1 Total Carbon (TC), Inorganic Carbon (IC) and Organic Carbon (OC) by Leco EC-12 Carbon Analyser

-Results of Organic Matter contents from the Department of Mineral Resources can be illustrated in the terms of Total Carbon (TC), Inorganic Carbon (IC), Organic Carbon, Extractable Humic acid and β-humus.

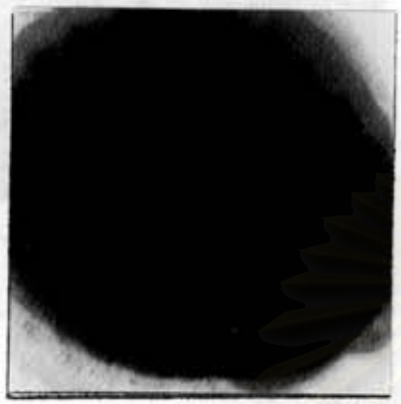
Table 6.4 Organic Matter Analysis of Ball Clays

ORGANIC MATTER ANALYSE %	SAMPLES										
		I			II				III		
	MS	MVW	MT	SB-75	HYC	REX	BB	JK	KK	WN	FC
TotalCarbon (TC)	1.102	2.790	0.434	2.680	2.080	0.116	1.272	0.138	1.659	1.913	1.953
Inorganic Carbon (IC)	0.014	0.670	0.016	0.050	0.060	0.021	0.020	0.003	0.085	0.005	0.066
Organic Carbon (OC)	1.088	2.120	0.418	2.630	2.020	0.095	1.252	0.135	1.574	1.908	1.887
Humic acid	0.103	0.274	0.058	0.996	0.510	0.015	0.981	0.058	0.252	0.308	0.216
β-humus	0.059	0.099	0.045	0.096	0.190	0.077	0.270	0.077	0.761	0.863	0.266
% humic subs. (humic acid & β-humus) by Organic Carbon	14.89	17.59	24.64	41.52	34.65	96.84	99.92	100.0	64.36	61.37	25.54

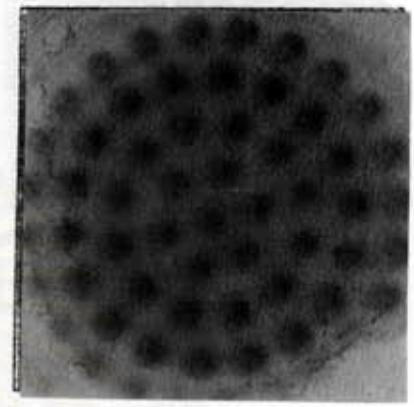
Remark: Color of Humic acid is brownish black ;
β -humus is light brown.

Extractable Humic Substance of Ball Clay.

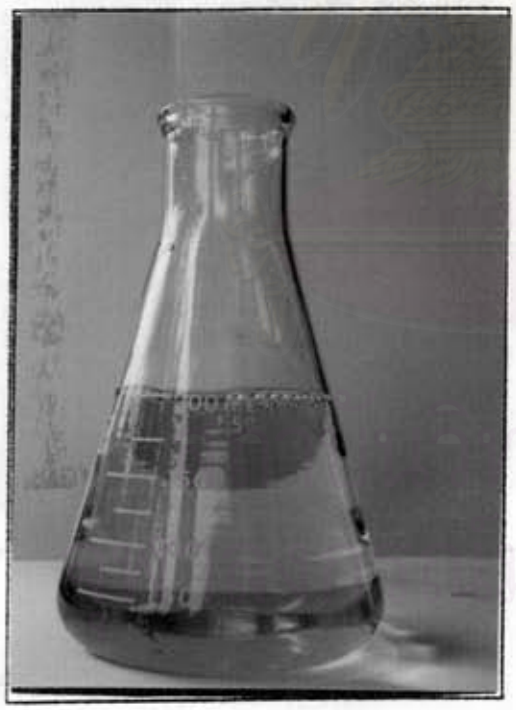
I.Ball Clays Group I ; MS, MVW, MT



Humic acid of MS



β-Humus of MS



Fulvic Solution of MS

Fig.6.30 Extractable humic acid, β-humus and fulvic solution of MS.

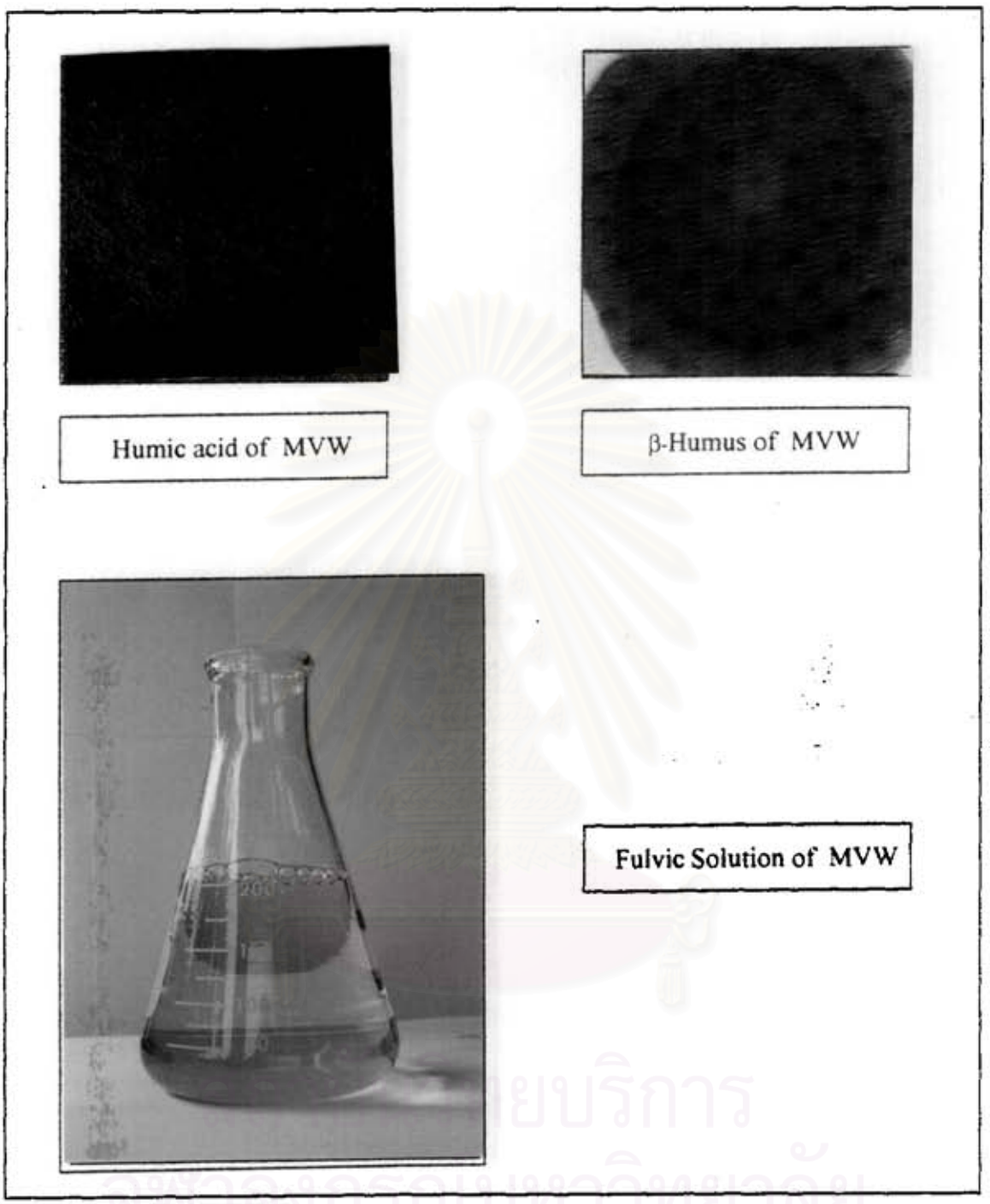
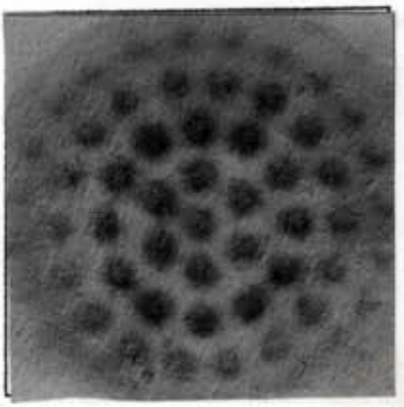
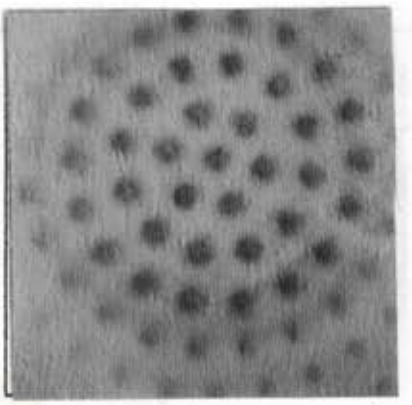


Fig.6.31 Extractable humic acid, β-humus and fulvic solution of MVW.



Humic acid of MT



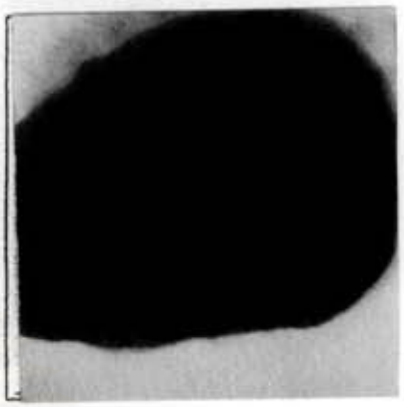
β-Humus of MT

Fulvic Solution of MT

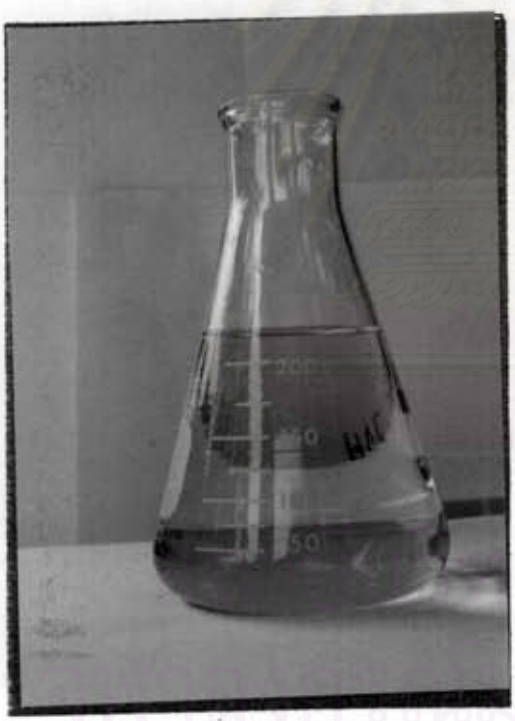
Fig.6.32 Extractable humic acid, β-humus and fulvic solution of MT.

II.Ball Clays Group II ; SB-75, HVC, REX, BB

Humic acid of SB-75



β-Humus of SB-75



Fulvic Solution of SB-75

Fig.6.33 Extractable humic acid, β-humus and fulvic solution of SB-75.

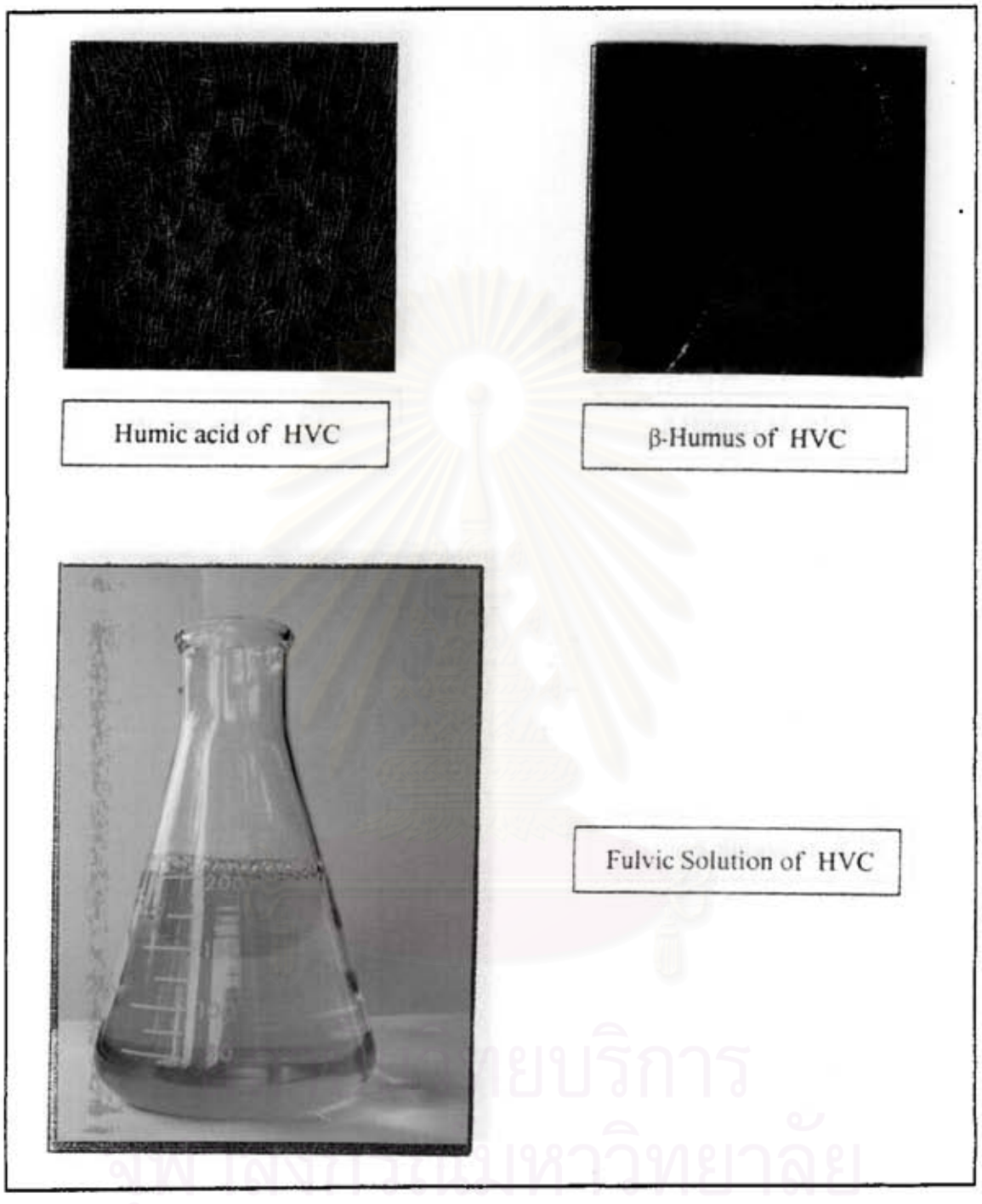
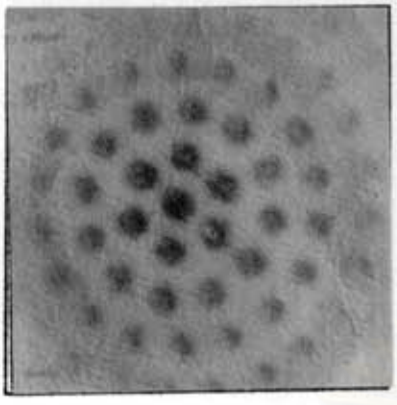
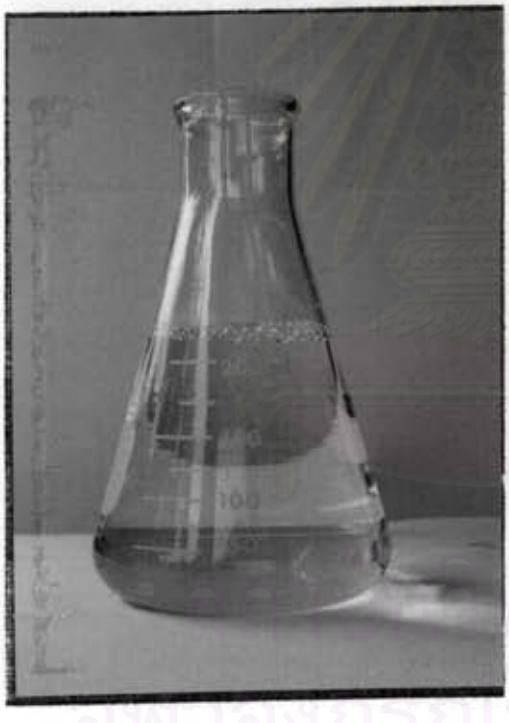


Fig.6.34 Extractable humic acid, β-humus and fulvic solution of HVC.



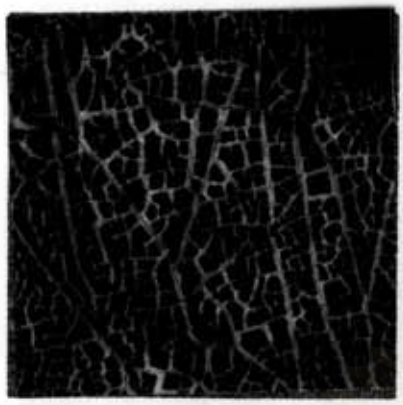
Humic acid of REX

β-Humus of REX



Fulvic Solution of REX

Fig.6.35 Extractable humic acid, β-humus and fulvic solution of REX.



Humic acid of BB

β-Humus of BB

Fulvic Solution of BB

Fig.6.36 Extractable humic acid, β-humus and fulvic solution of BB.

III. Ball Clays Group III ; JK, KK, WN, PC

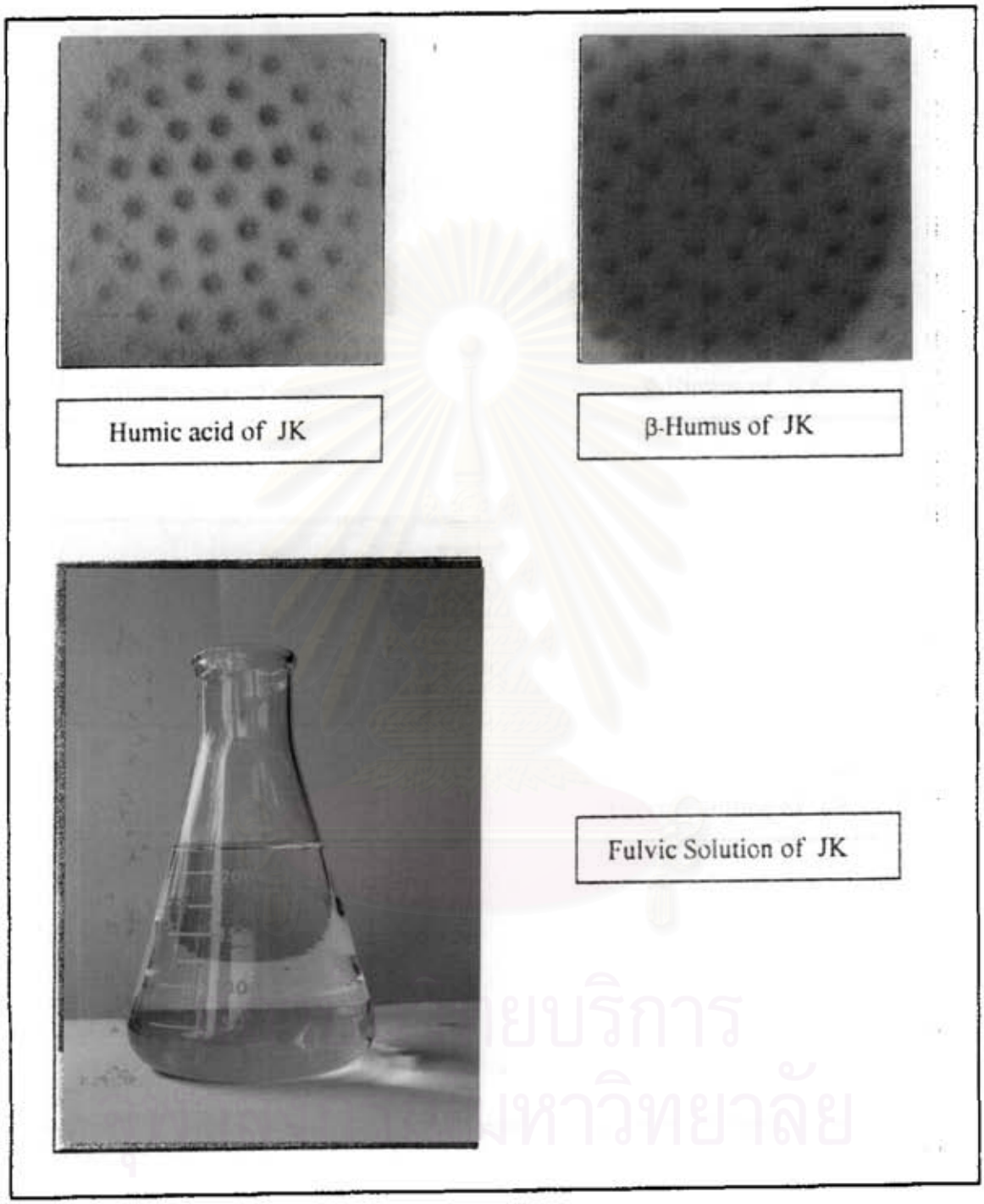


Fig.6.37 Extractable humic acid, β-humus and fulvic solution of JK.

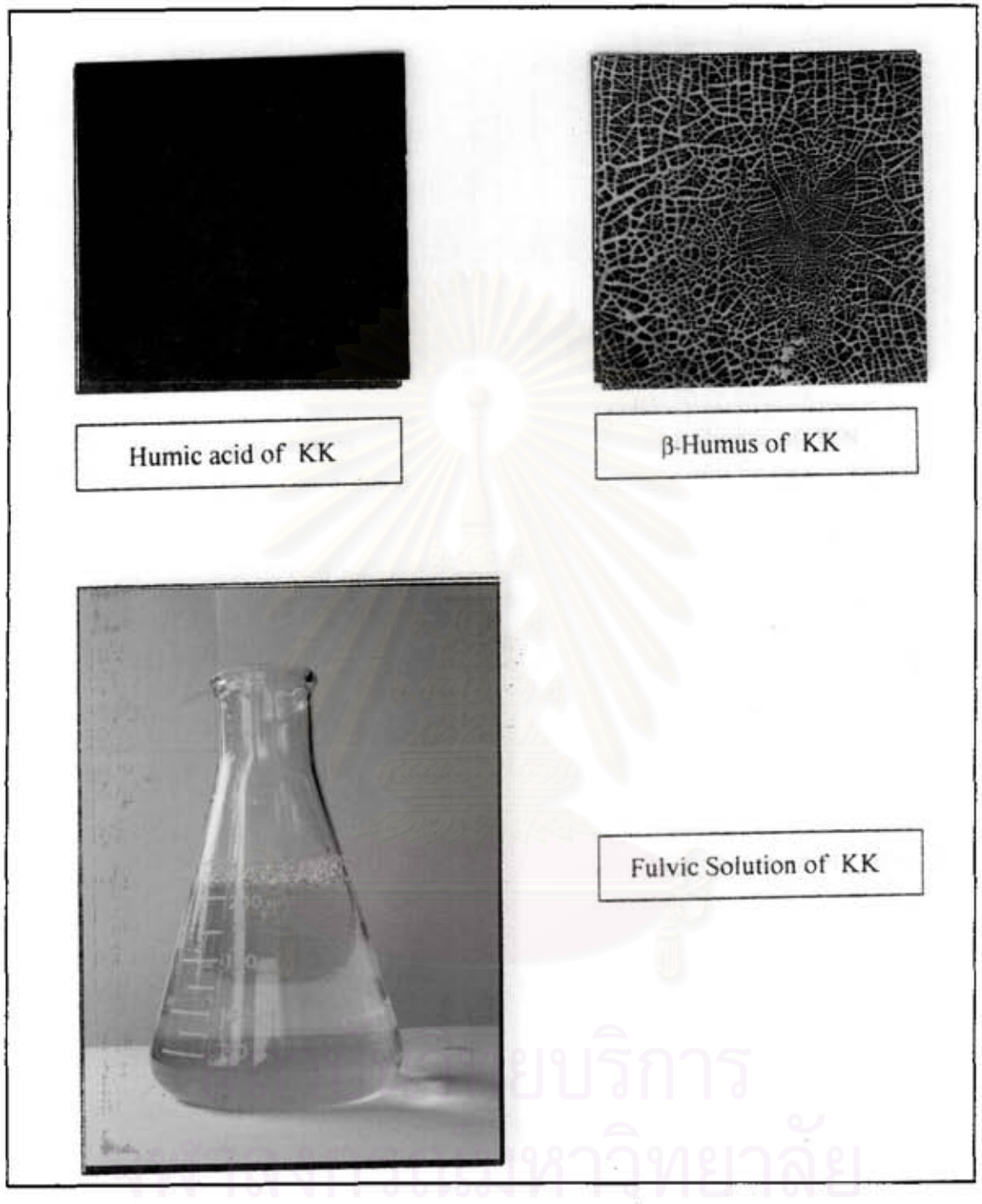


Fig.6.38 Extractable humic acid, β-humus and fulvic solution of KK.

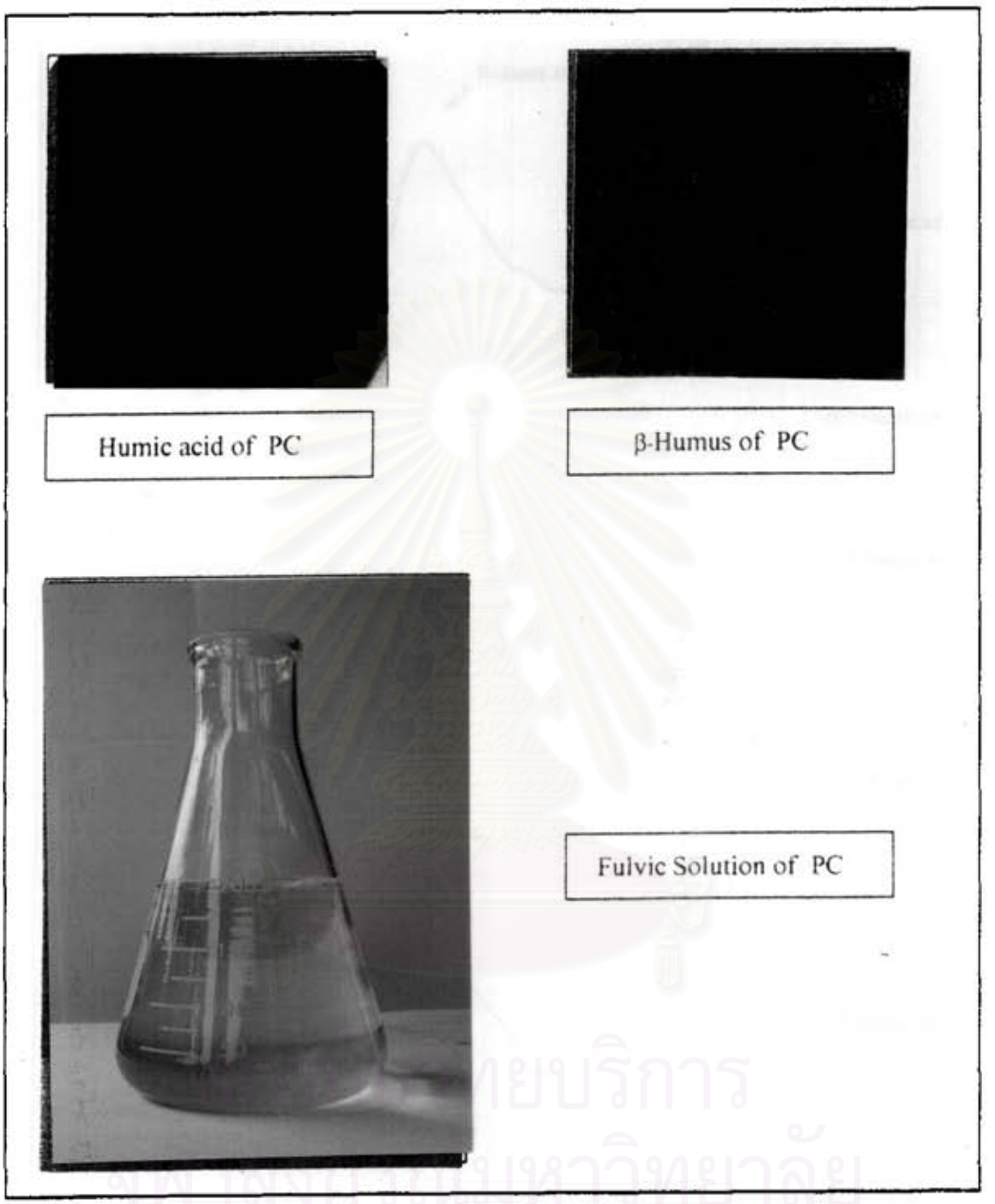


Fig.6.39 Extractable humic acid, β-humus and fulvic solution of WN.

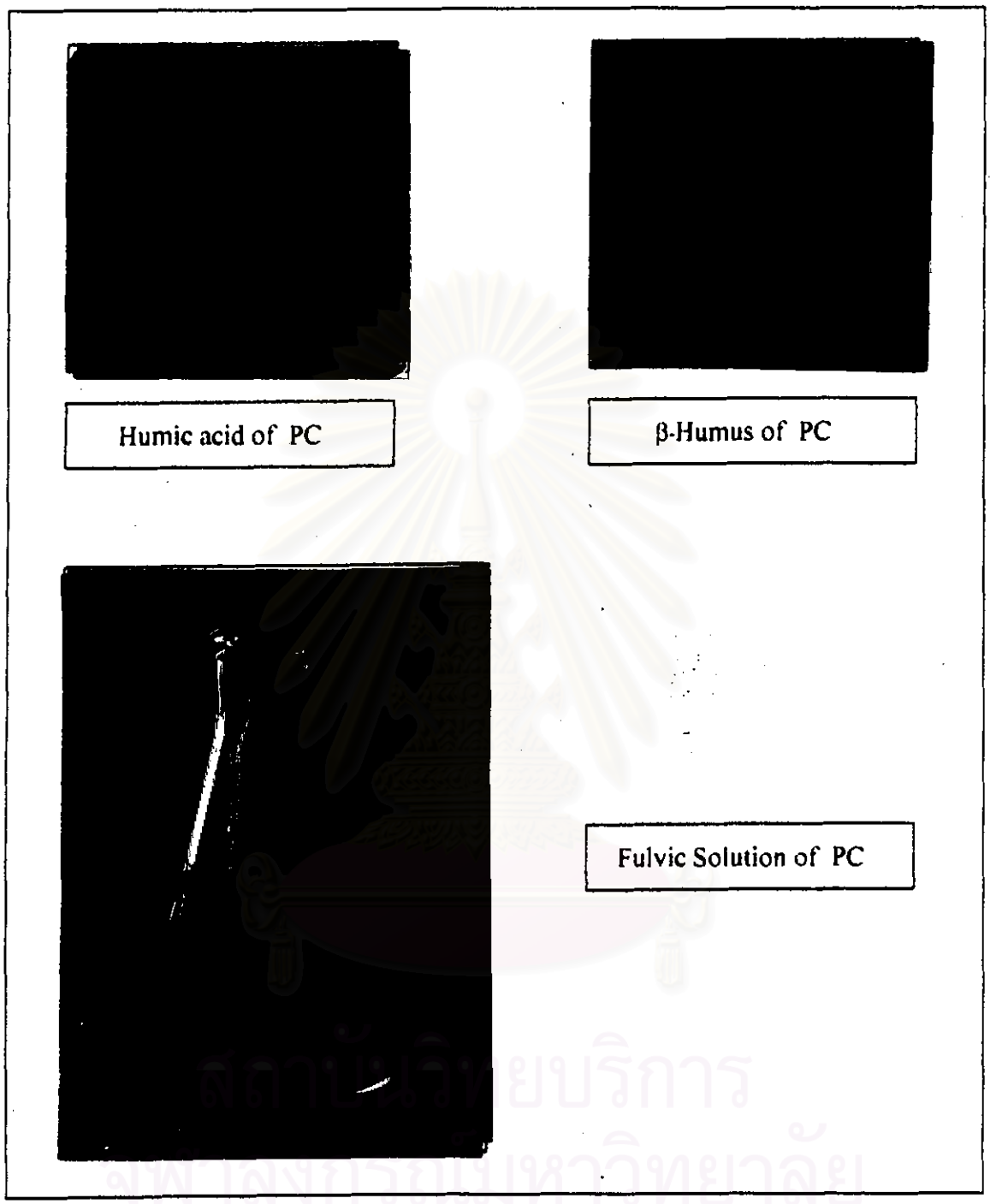


Fig.6.40 Extractable humic acid, β-humus and fulvic solution of PC.

6.2.2 Humic and Fulvic Identification by NMR

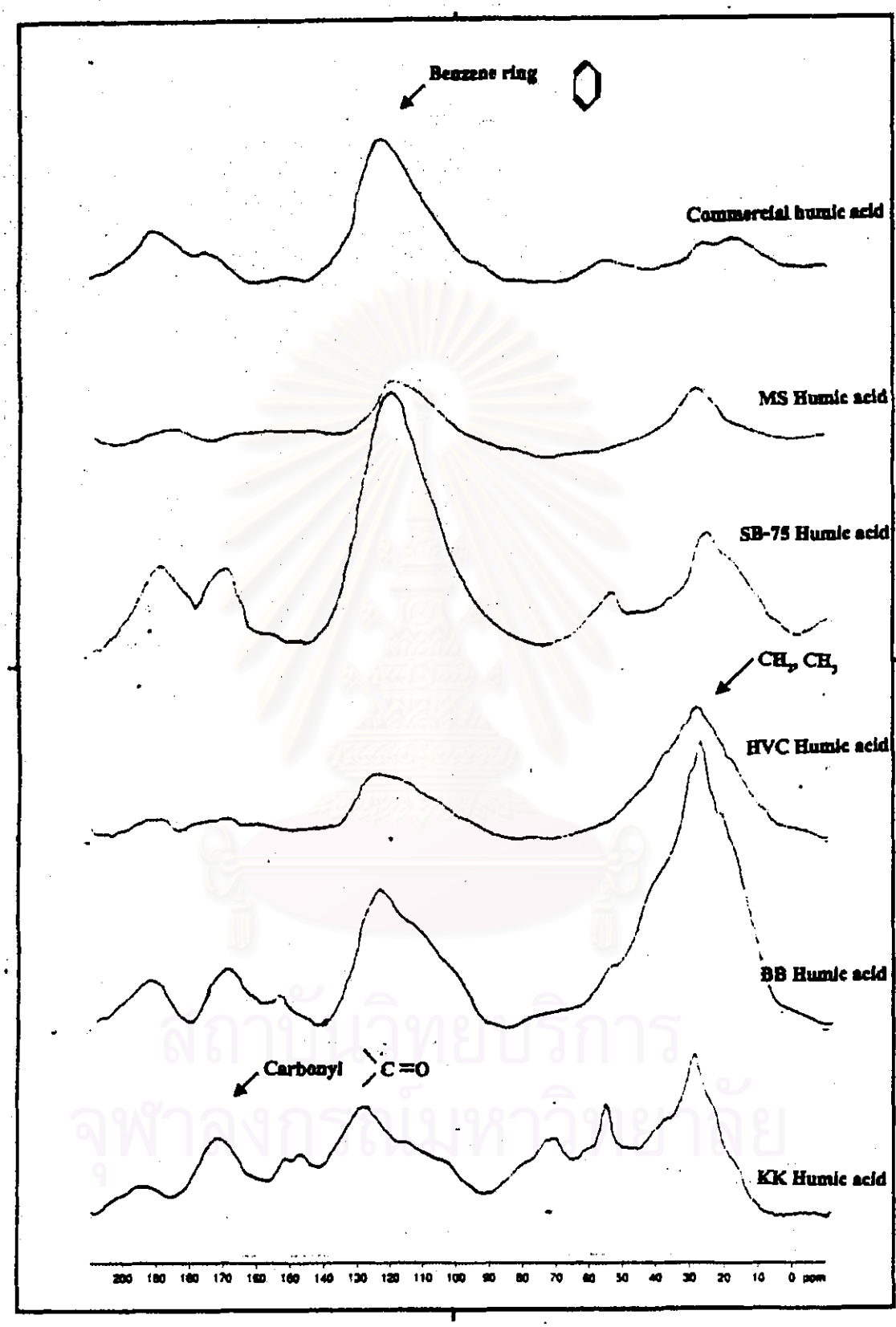


Fig. 6.41 CP/MAS ^{13}C NMR spectra of extractable humic acids and commercial humic acid.

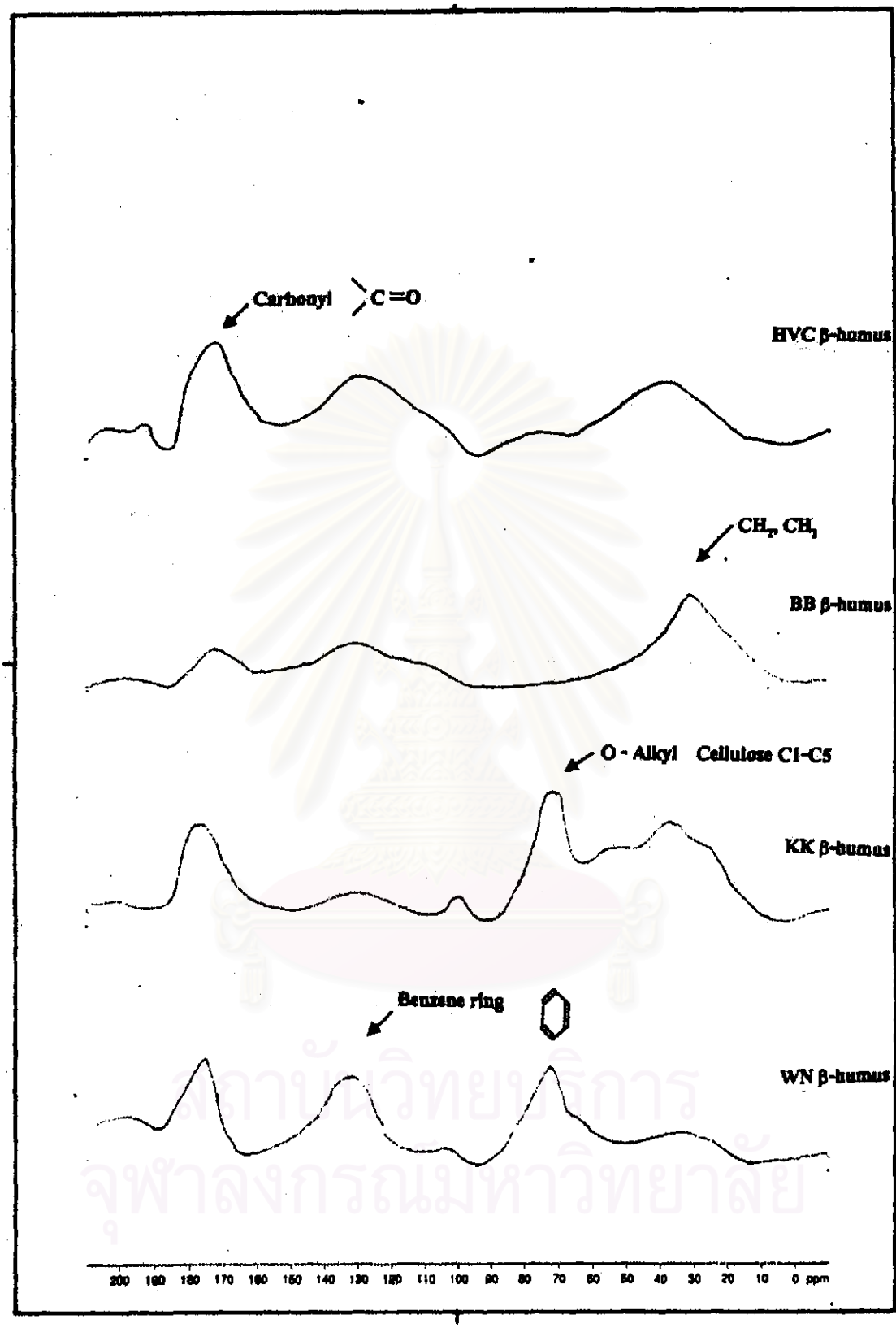


Fig. 6.42 CP/MAS ^{13}C NMR spectra of extractable β-humus.

6.3 Soluble Salts Analysis

Table 6.5 Soluble Salts Analysis of ball Clays.

Composition Analysis %	Samples										
		I			II				III		
	MS	MVW	MT	SB-75	HVC	REX	BB	JK	KK	WN	PC
Ca	74	55	37	9.0	31	6.6	51	0.0	21	7.7	11
Mg	38	22	16	4.5	14	2.0	21	5.8	13	1.4	6.5
Na	16	18	9.2	58	14	9.2	6.9	32	23	14	12
K	7.8	5.0	0.9	0.8	3.6	1.6	2.6	0.8	0.3	0.5	0.6
Fe	0.02	0.22	0.14	0.04	0.3	0.22	3.1	0.08	0.24	0.20	0.20
Mn	0.41	0.18	0.17	0.04	0.21	0.00	0.10	0.04	0.33	0.00	0.07
Cl	4.8	2.8	2.8	5.6	2.8	1.6	1.2	4.4	7.2	6.4	3.6
SO_4	320	210	150	81	120	32	240	22	65	18	27
HCO_3	25	43	28	100	31	9	9	70	63	36	43
NO_2	0.18	0.06	0.27	0.05	0.05	0.04	0.04	0.12	0.05	0.05	0.05
NO_3	11	1.1	12	0.6	0.5	0.1	0.1	5.4	0.0	0.0	0.4
F	0.2	0.1	0.3	1.3	0.5	0.1	0.3	2.1	0.1	0.0	0.1
Total dissolved solids	485	335	243	210	201	58	327	107	161	66	82
Total hardness as $CaCO_3$	340	230	160	41	130	25	210	24	110	25	54
Noncarbonate hardness	320	190	140	0	110	17	200	0	55	0	18

Unit: milligram per kilogram.

6.4 Rheological and Casting Properties

6.4.1 Effect of Temperature on Rheology

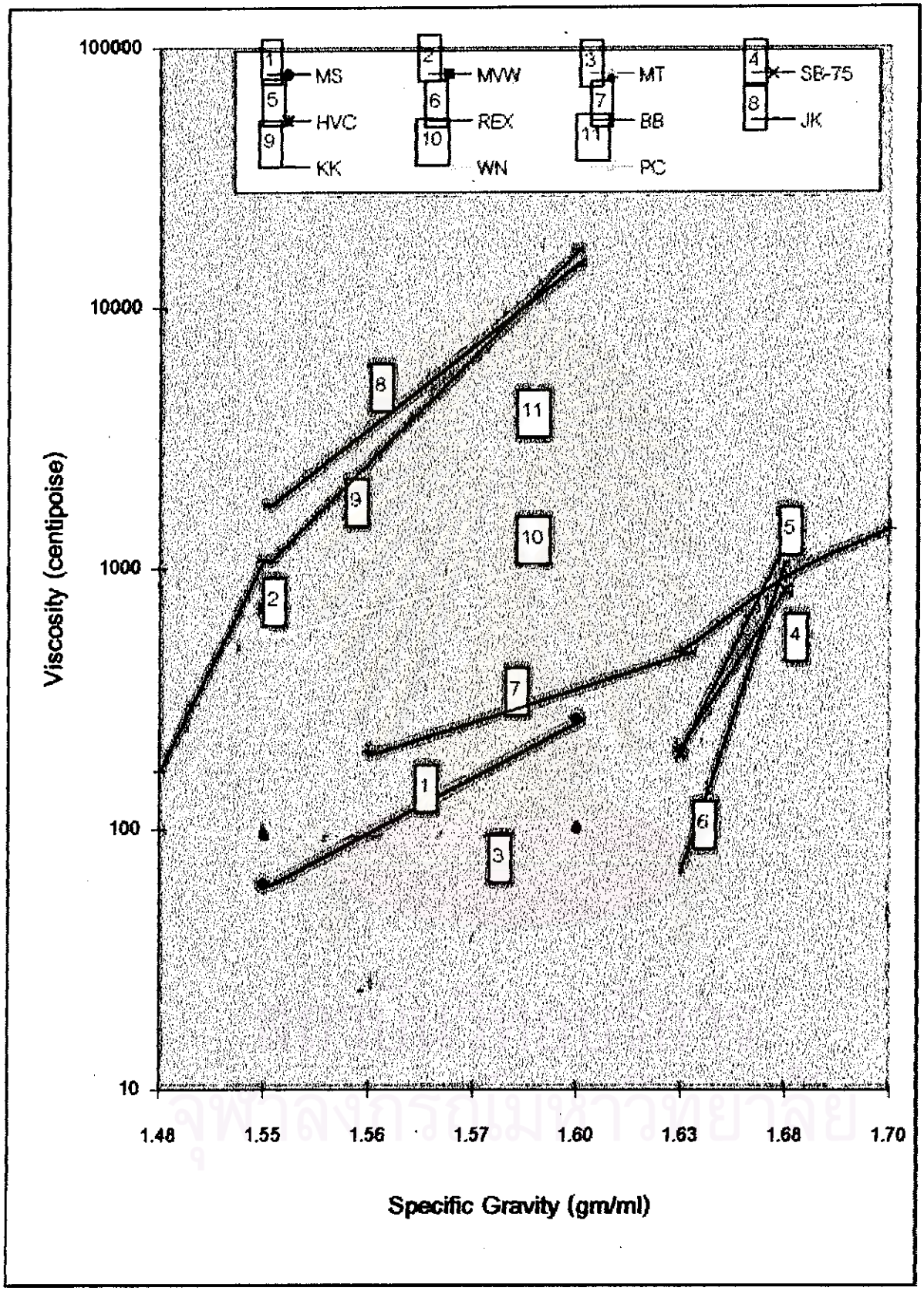


Fig. 6.43 Viscosity vs specific gravity of ball clays used in this study.

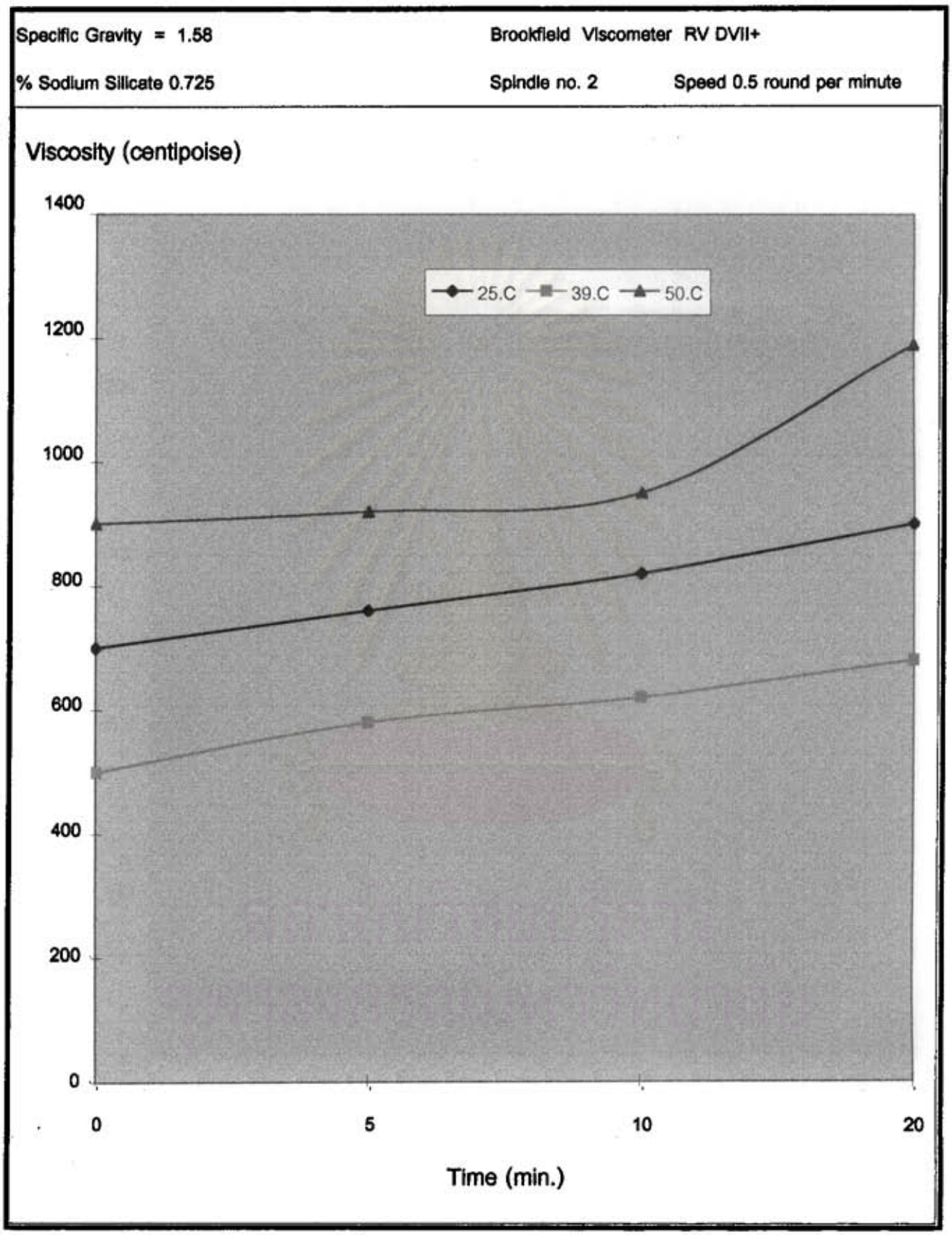


Fig. 6.44 Effect of temperature on MS gelation 25 °C, 39 °C and 50 °C .

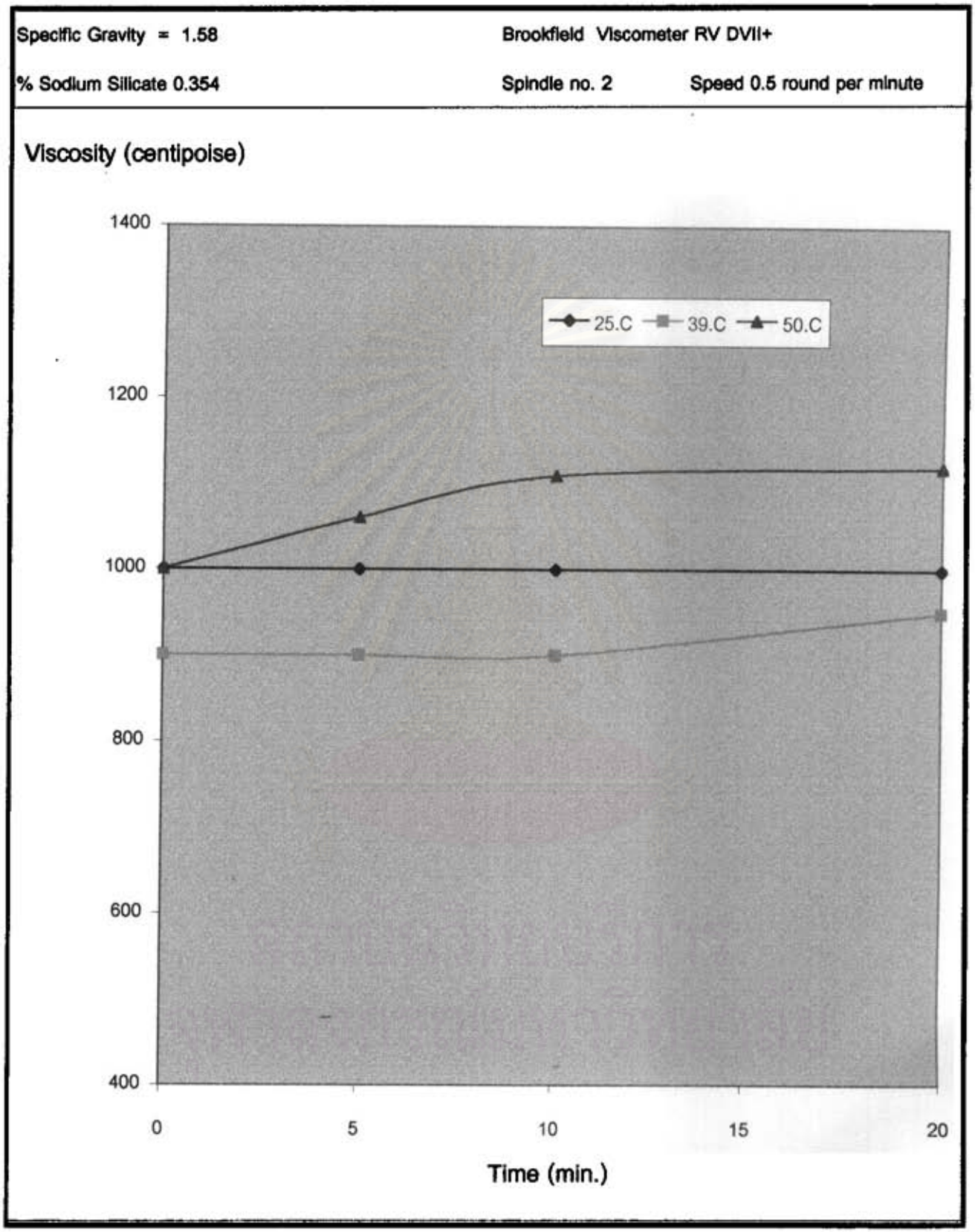


Fig.6.45 Effect of temperature on SB-75 gelation 25 °C, 39 °C and 50 °C.

6.4.2 Deflocculation Response

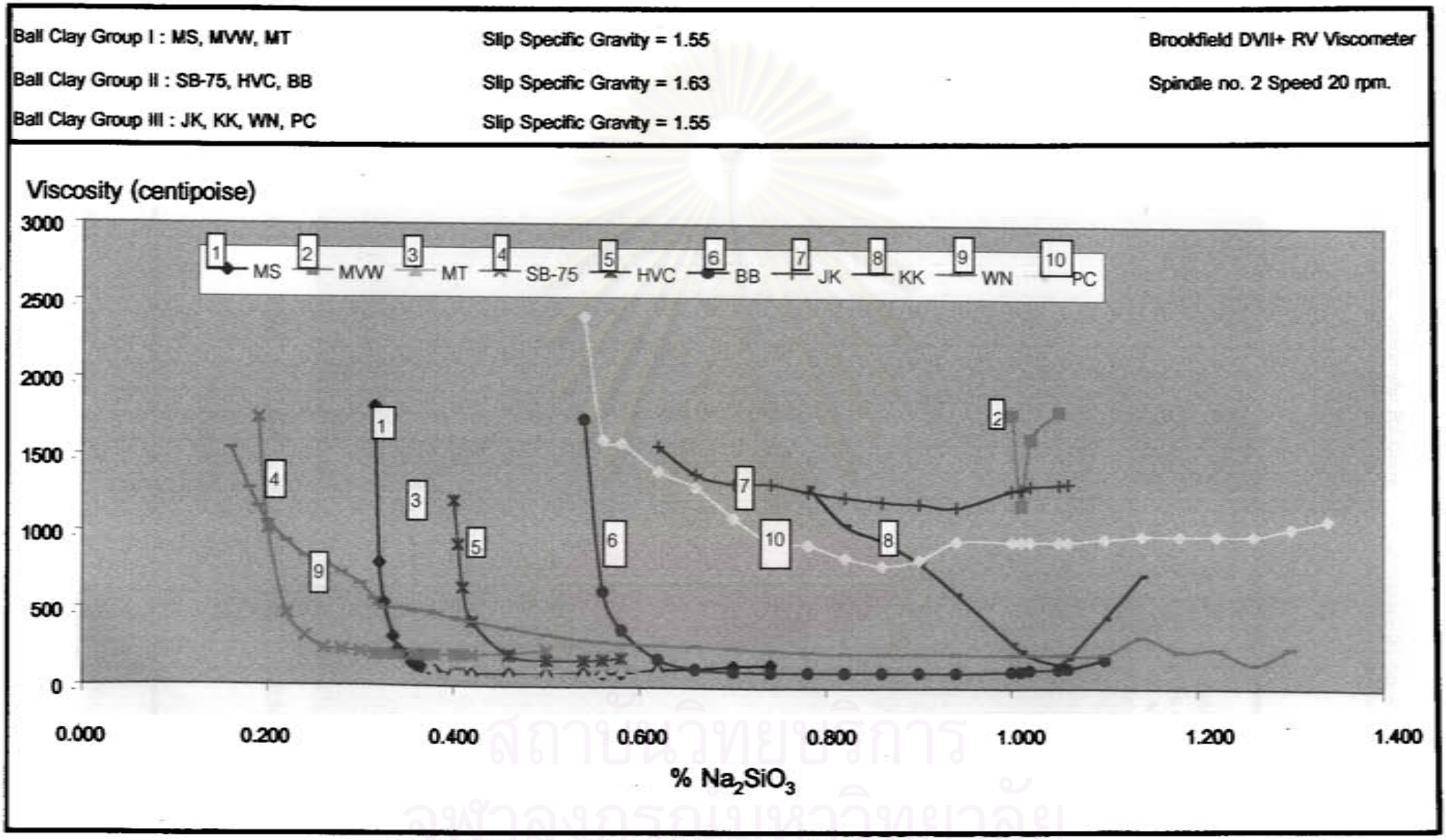


Fig. 6.46 Deflocculation Response of Ball Clays

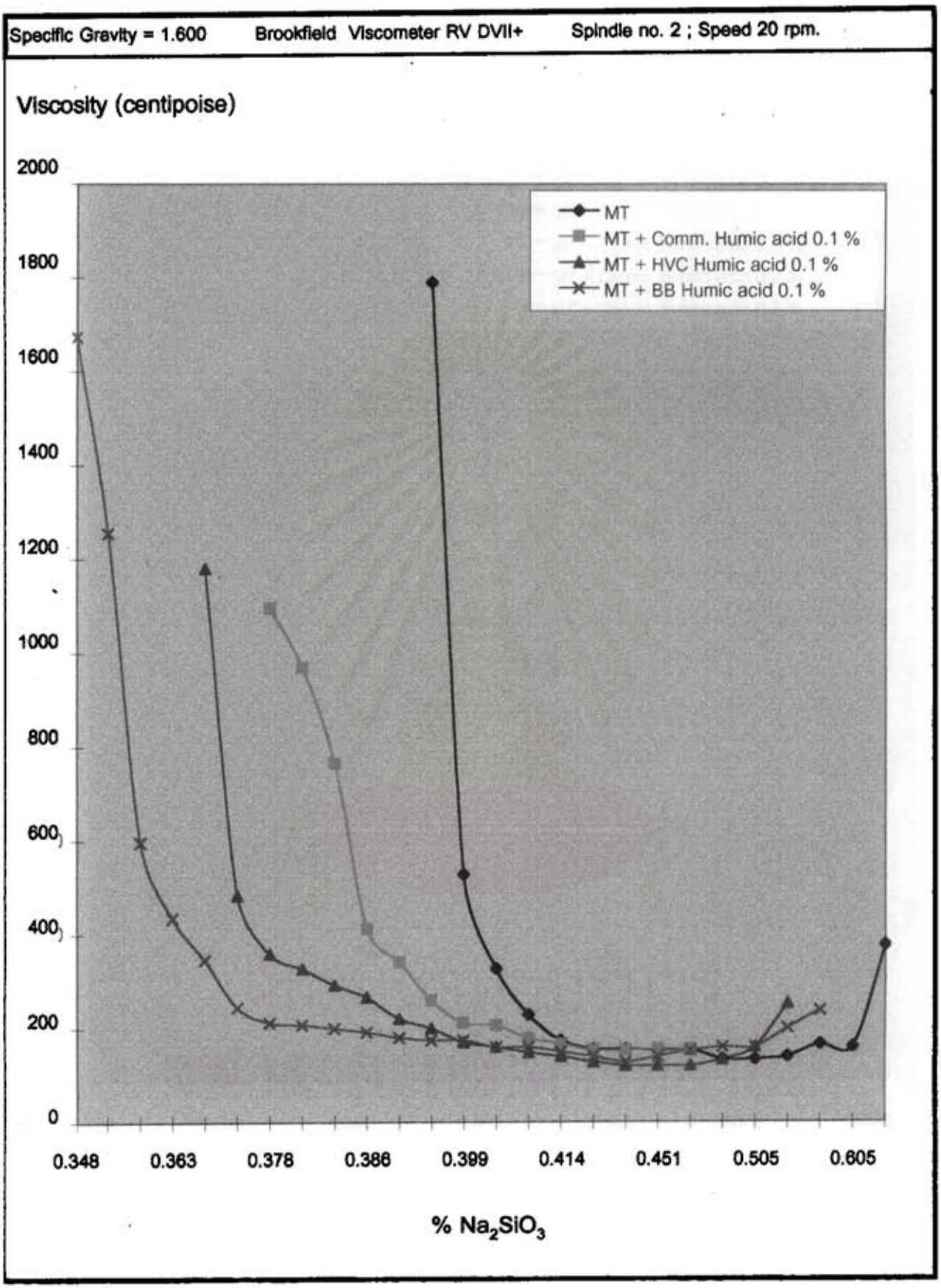


Fig. 6.47 Deflocculation response of MT and MT added different sources of humic acid

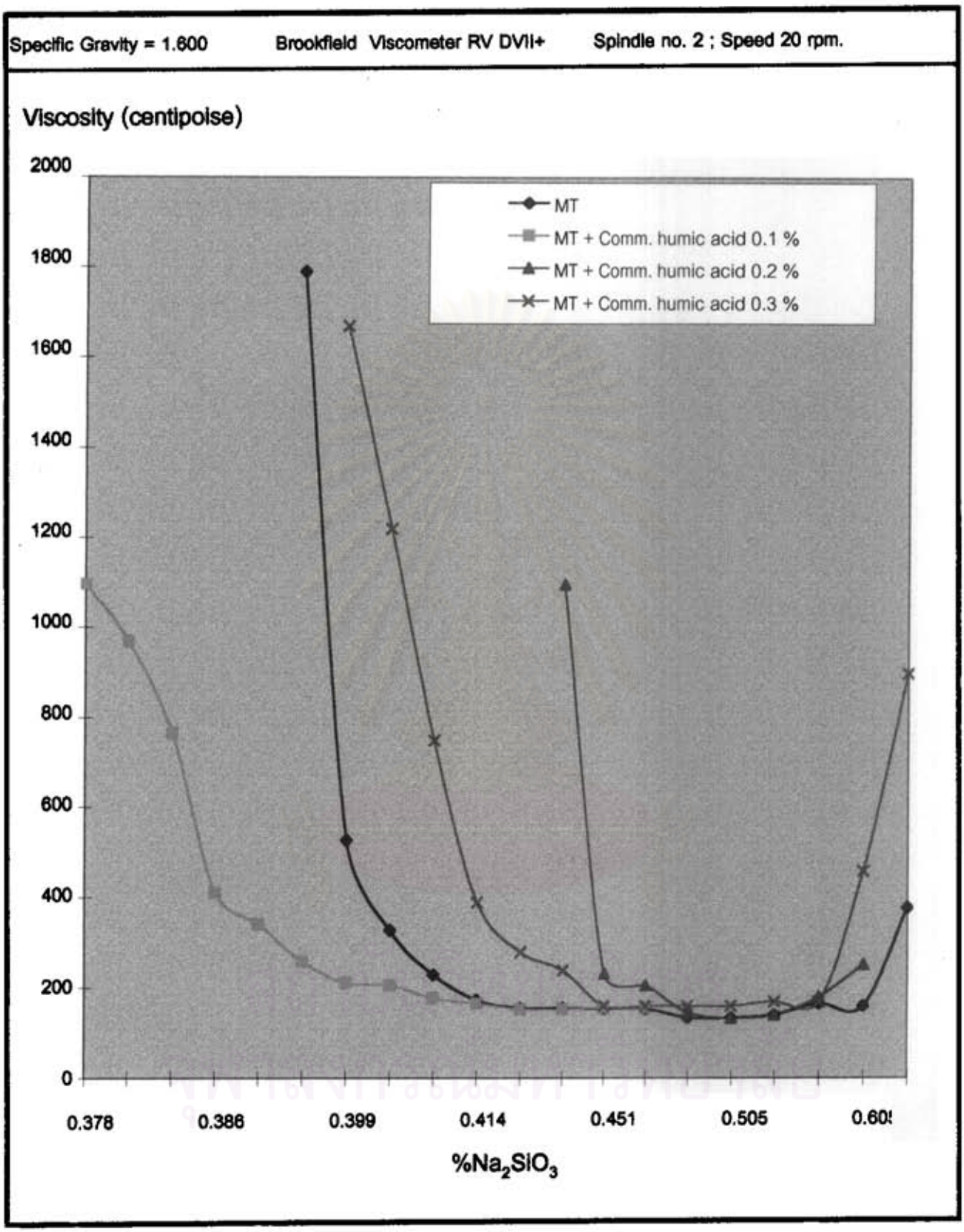


Fig.6.48 Deflocculation Response of MT and MT added 0.1 - 0.3 % commercial humic acid.

6.4.3 Gelation and Relative Gel-strength

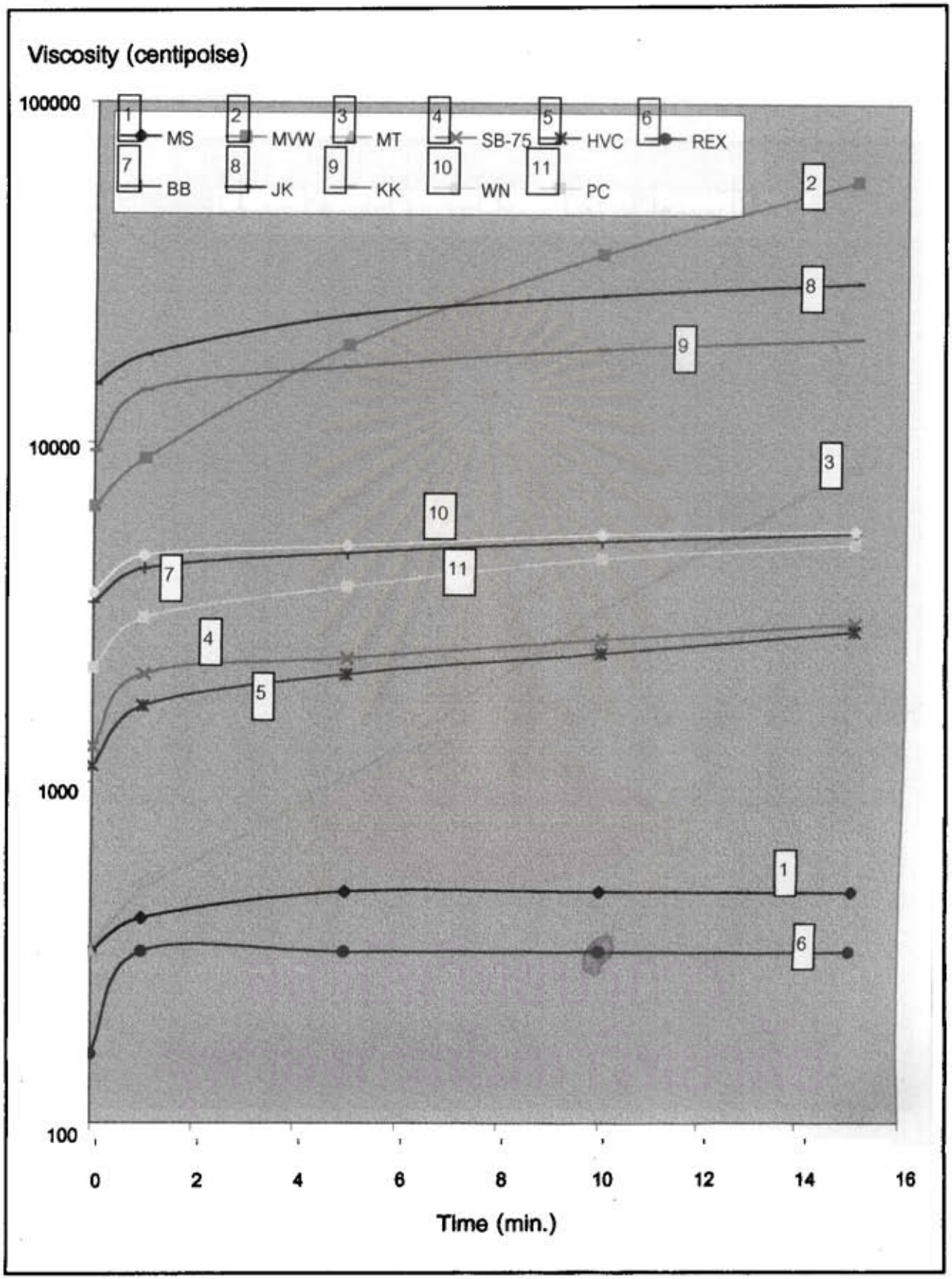


Fig .6.49 Gelation of Ball Clays

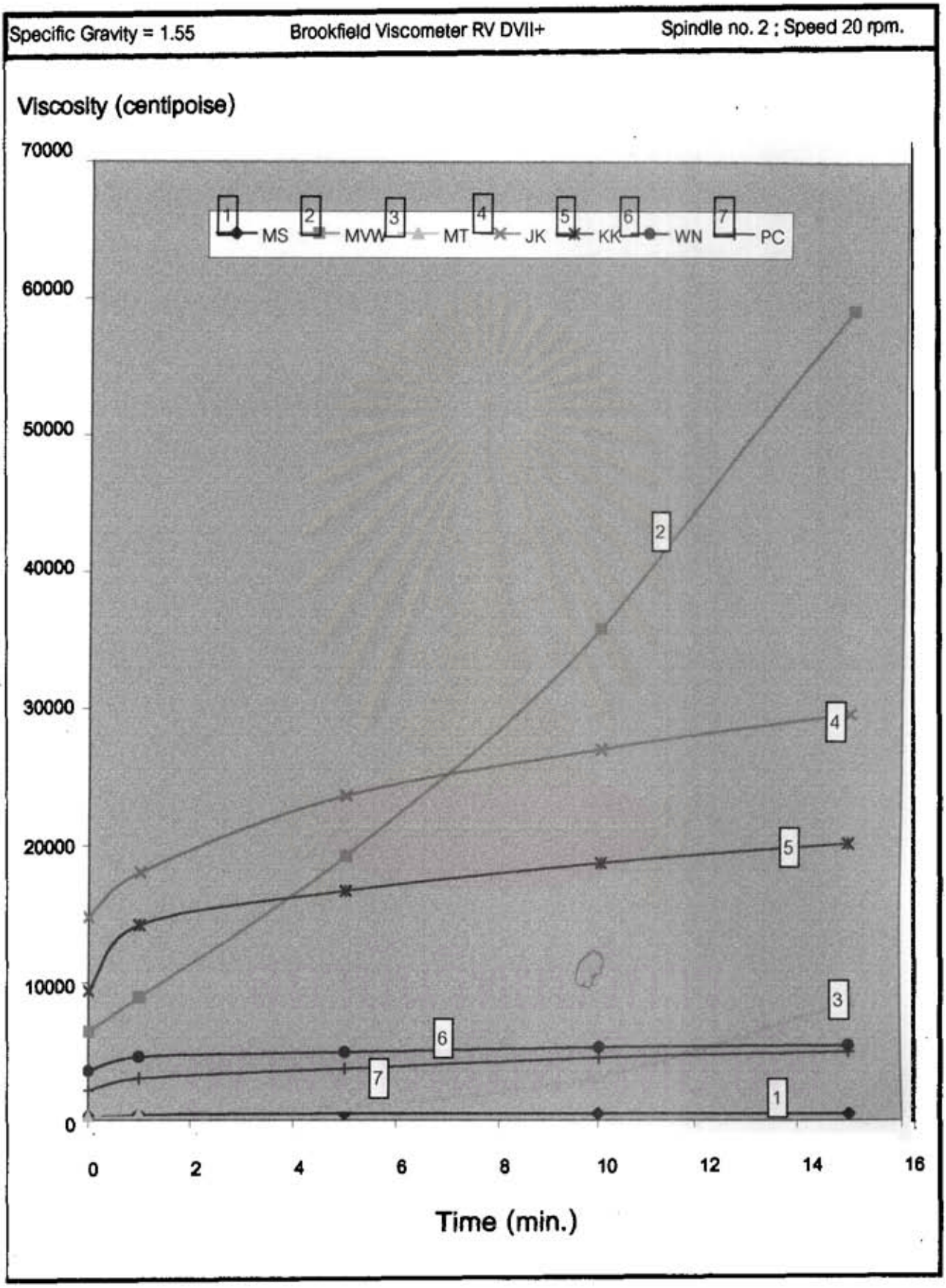


Fig .6.50 Gelation of Ball Clays in Group I and III

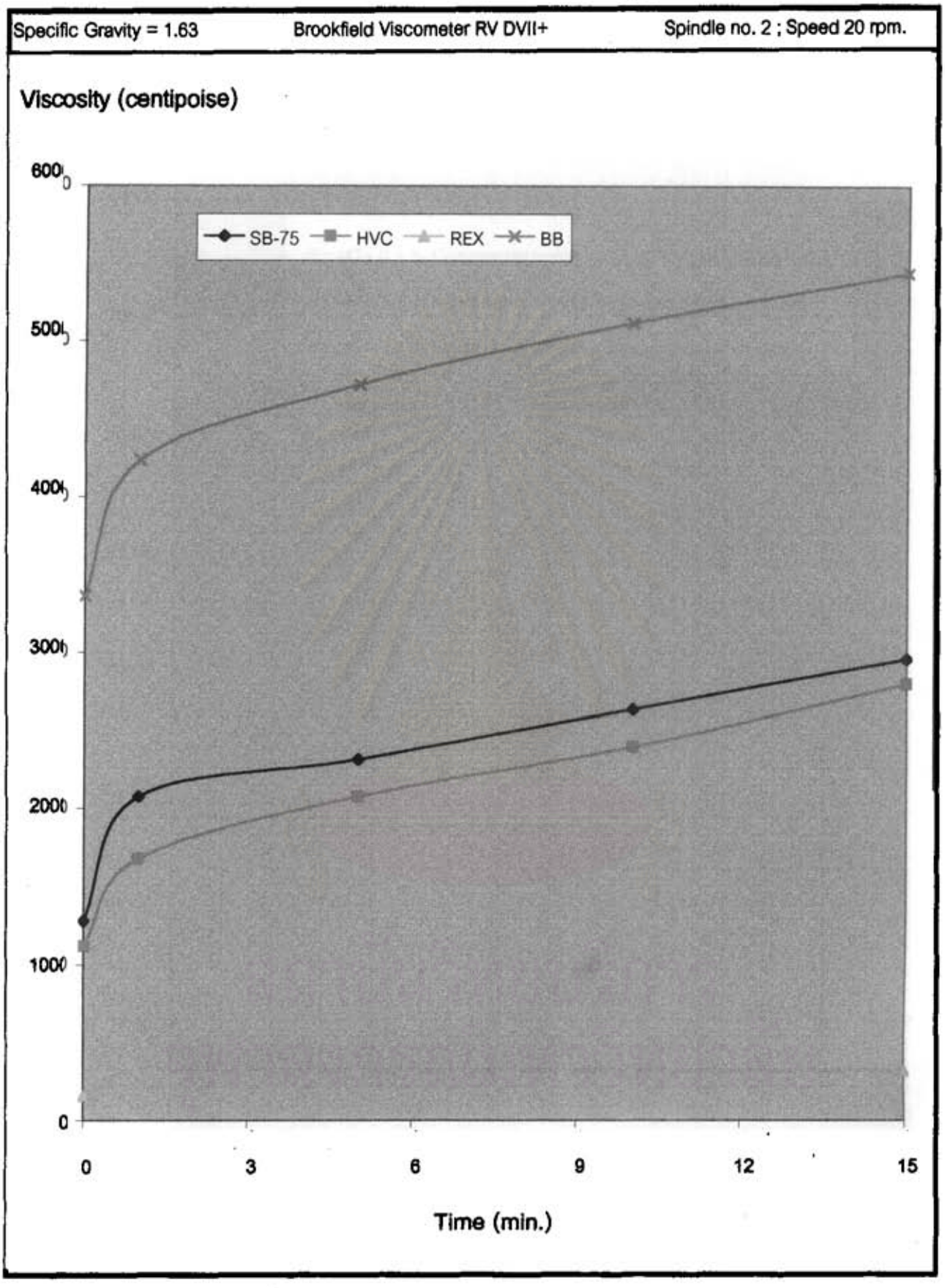


Fig .6.51 Gelation of Ball Clays in Group II

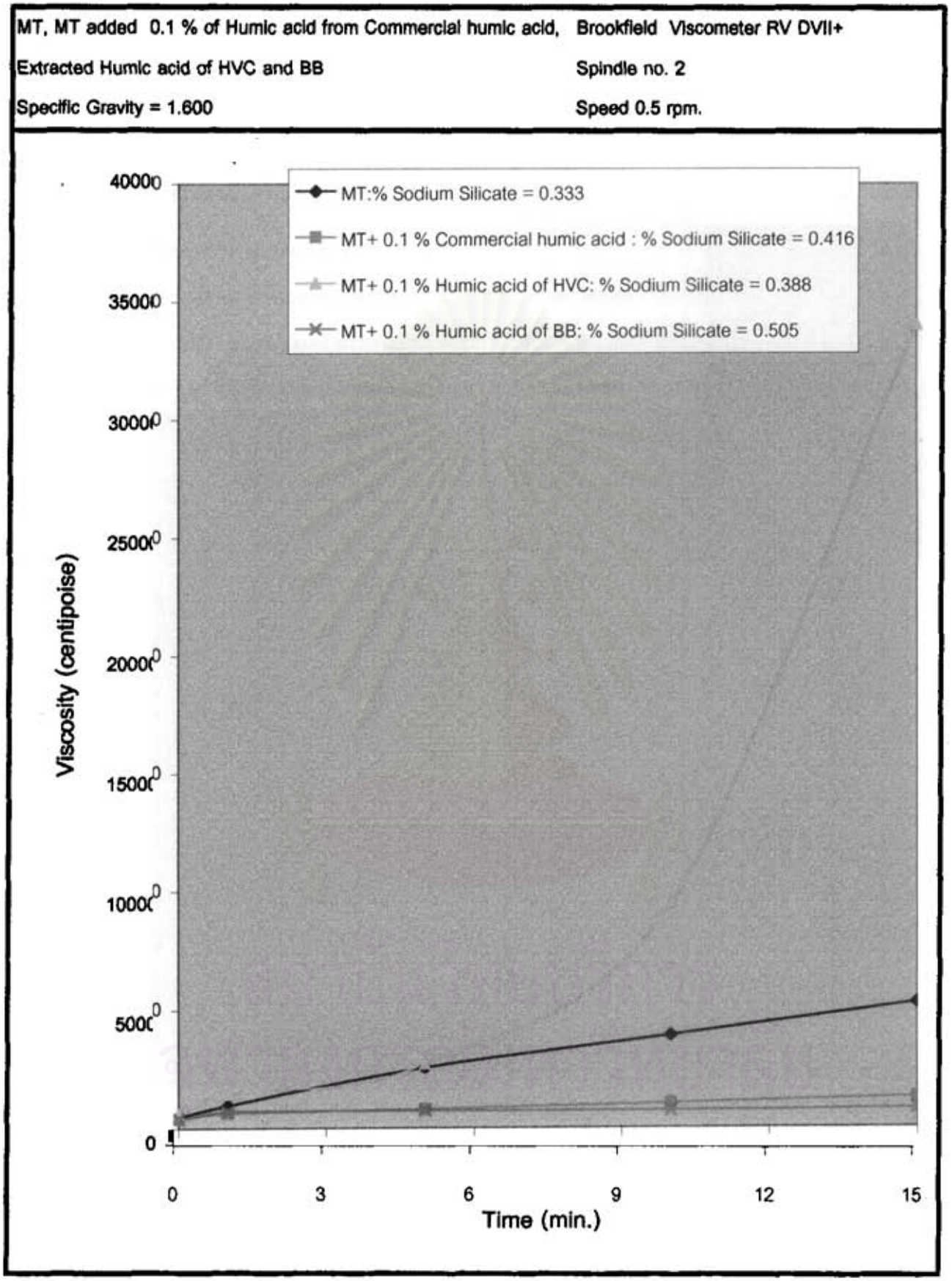


Fig. 6.52 Gelation of MT and MT added different sources of humic acid

MT, MT added 0.1 , 0.2, 0.3 %
of Humic acid from Commercial humic acid,
Specific Gravity = 1.600

Brookfield DVII+ RV Viscometer
Spindle no. 2
Speed 0.5 rpm.

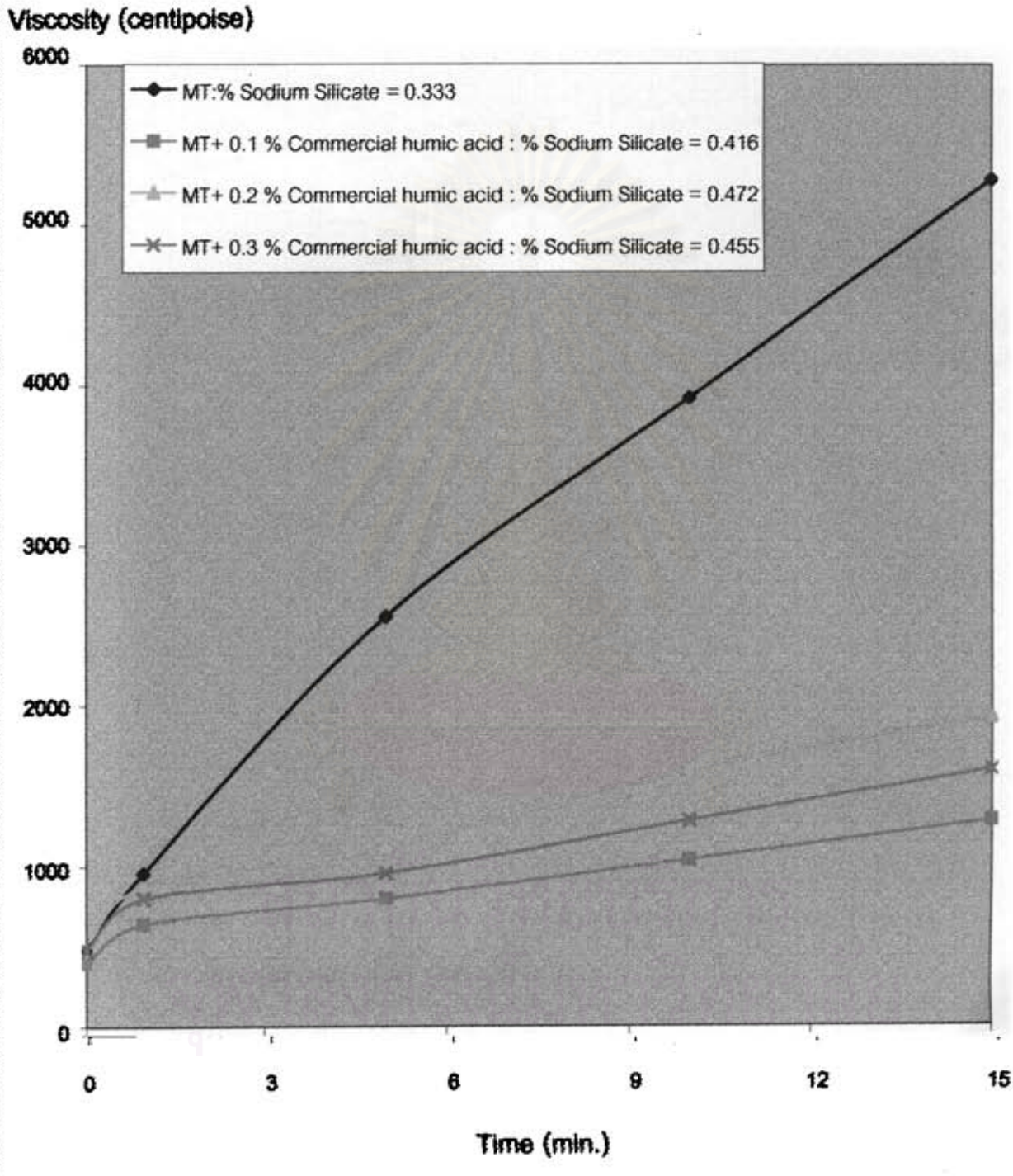


Fig. 6.53 Gelation of MT and MT added 0.1 - 0.3 % commercial humic acid.

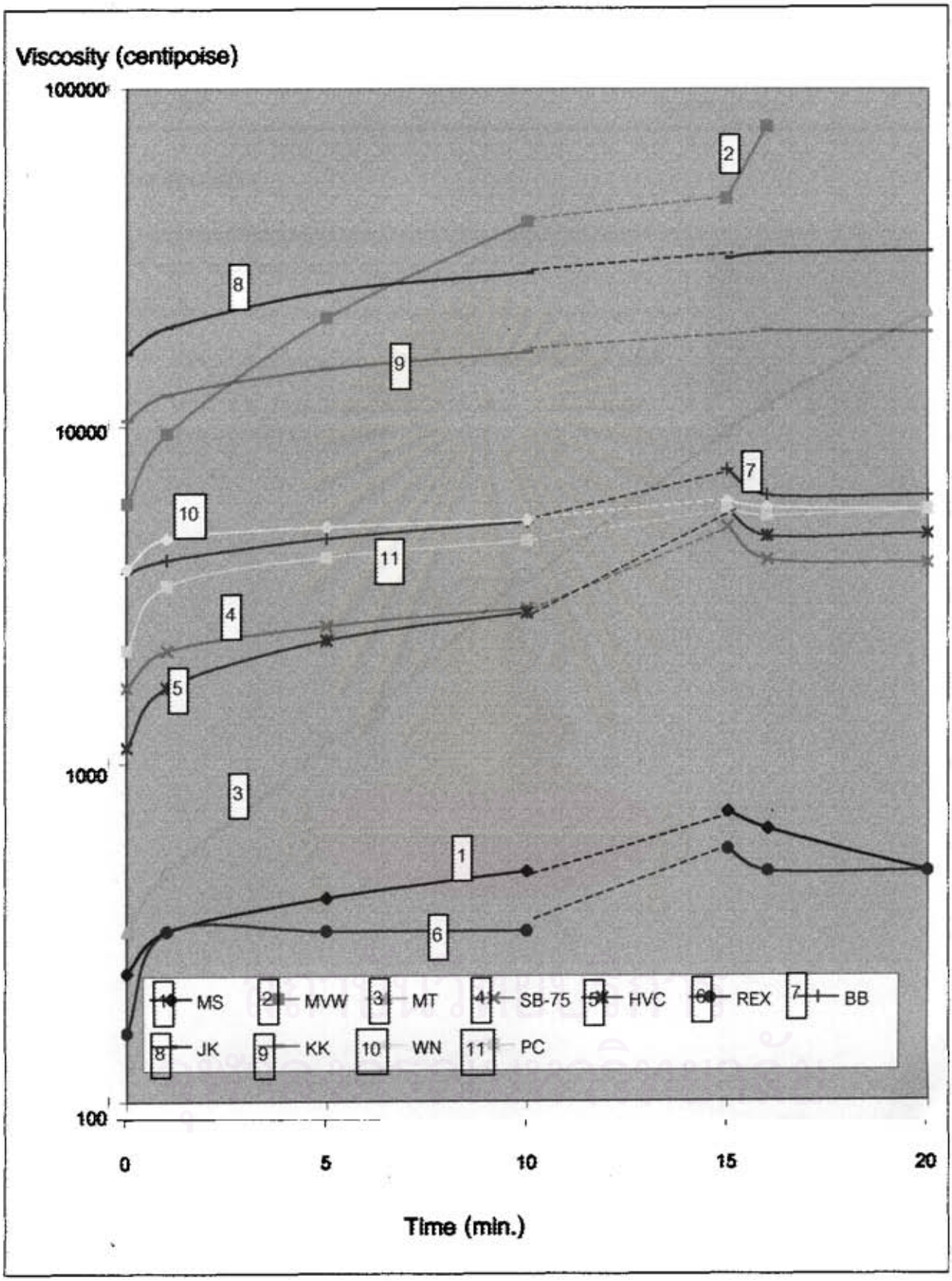


Fig. 6.54 Relative Gel-strength of Ball Clays

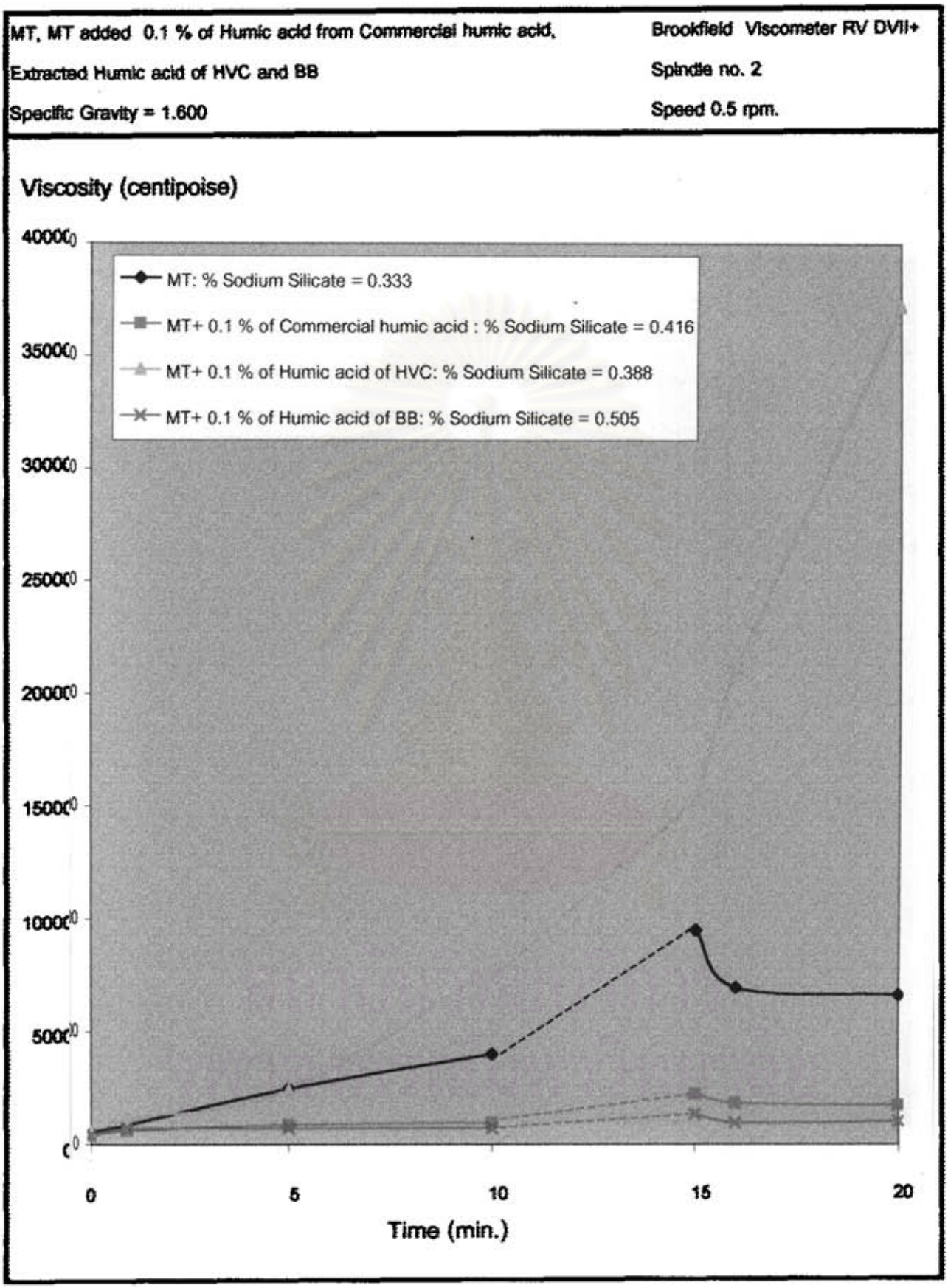


Fig. 6.55 Relative Gel-strength of MT and MT added different sources of humic acid

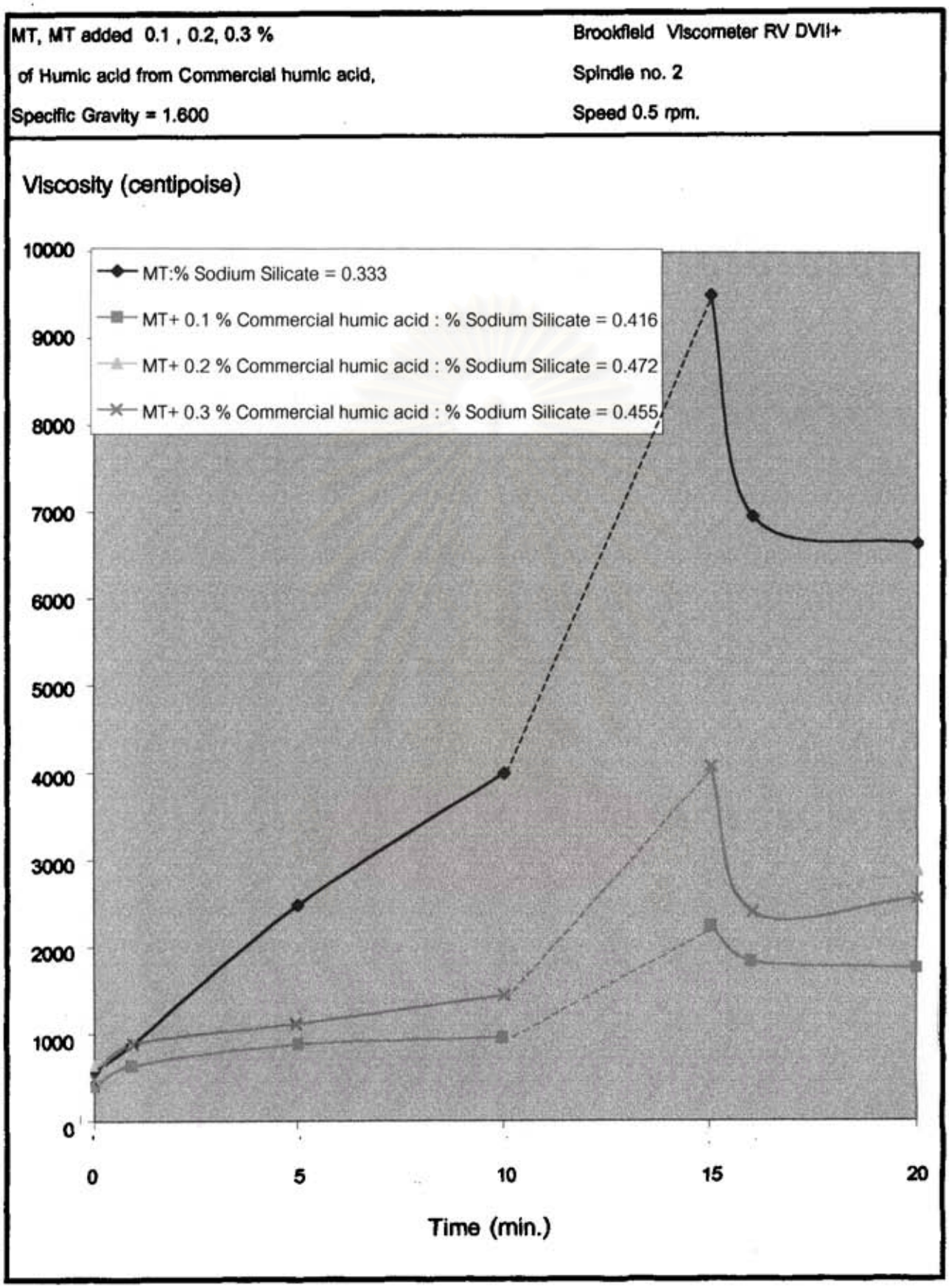


Fig. 6.56 Relative Gel-strength of MT and MT added 0.1 - 0.3 % commercial humic acid.

6.4.4 Shear Response

Slip Specific Gravity = 1.55				Brookfield Viscometer RV DVII+						
% Sodium silicate = 0.500				Small sample adapter SC4 Series Spindle						
Remark : Change rpm. At 5 sec. Interval				Spindle no. SC4-21						
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress (dynes/cm.^{2})	1.86	2.32	4.19	3.26	3.26	4.19	5.12	8.37	15.30	26.50
Shear stress (dynes/cm.^{2})	0.93	1.39	2.79	2.32	3.26	4.19	5.12	7.44	14.90	26.50

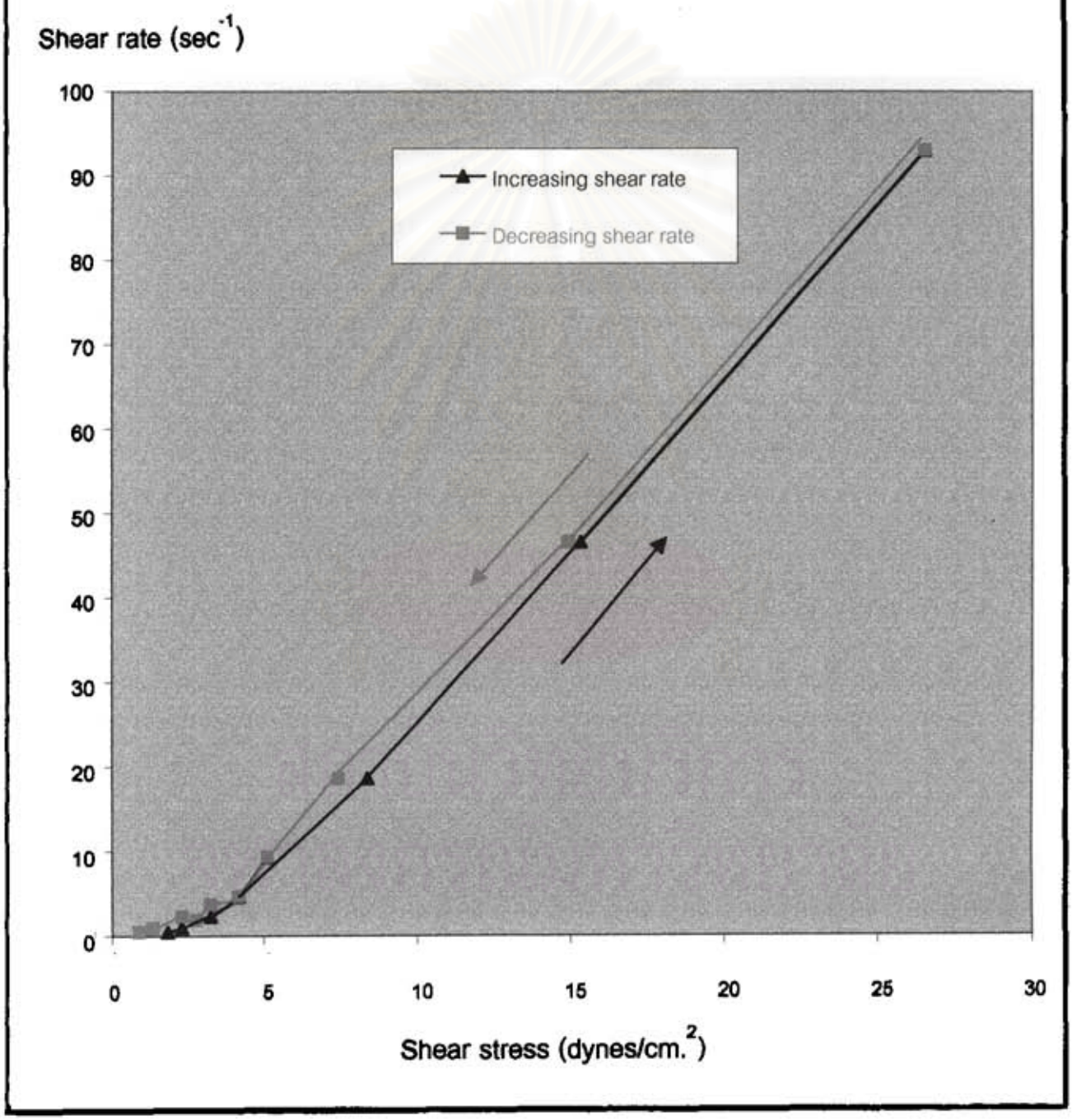


Fig. 6.57 Shear response of MS (shear rate - shear stress curve)

Slip Specific Gravity = 1.55					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.500					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	400	250	225	140	87.5	90	55	45	33	28.5
Viscosity (centipoise)	200	150	150	100	87.5	90	55	40	32	28.5

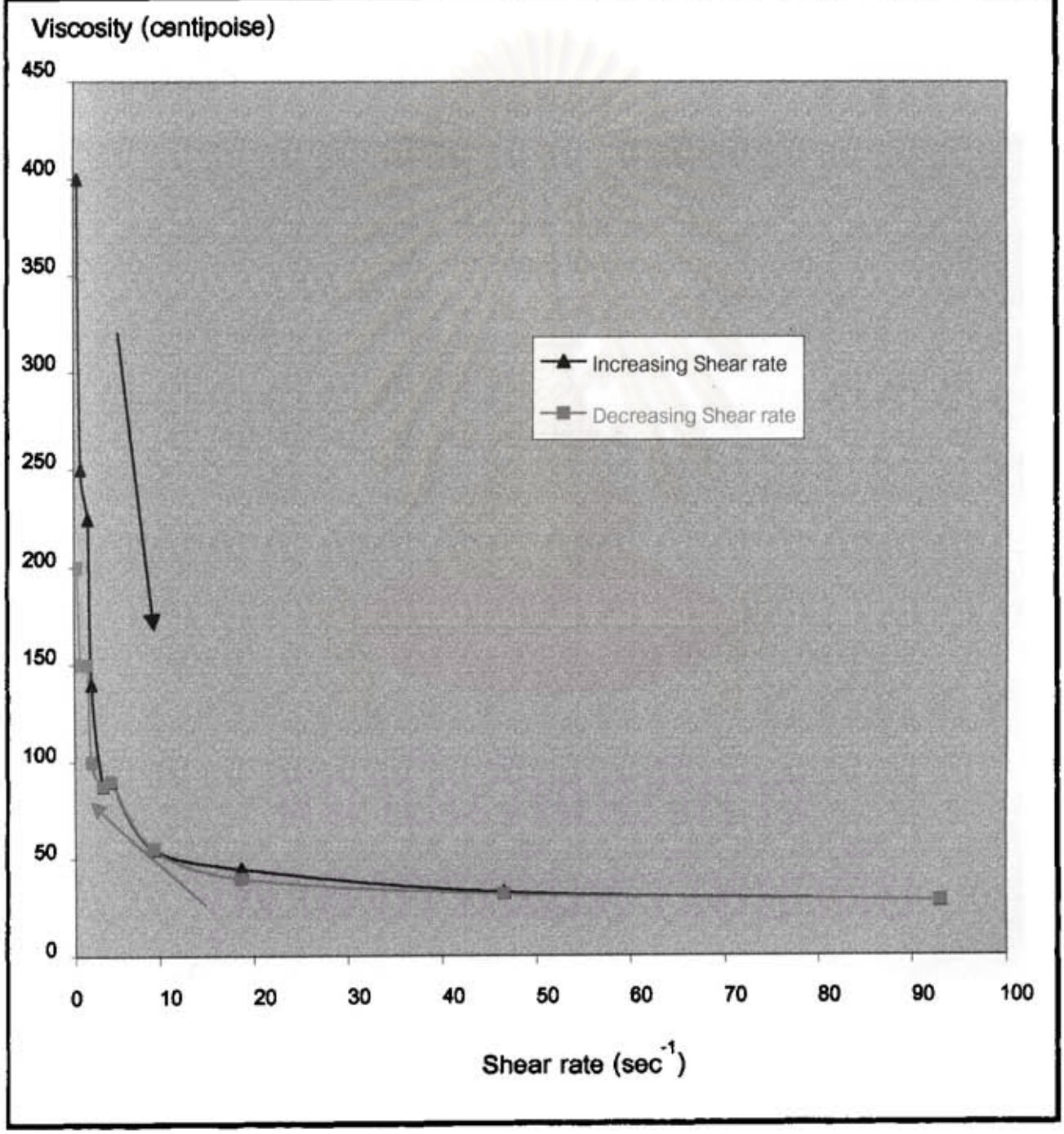


Fig. 6.58 Shear response of MS (shear rate - viscosity curve)

Slip Specific Gravity = 1.55					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.970					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate ($sec.^{-1}$)	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress ($dynes/cm.^{2}$)	11.6	17.2	23.2	24.6	28.8	32.5	47.4	70.2	126.0	215.3
Shear stress ($dynes/cm.^{2}$)	20.0	24.2	30.2	33.9	39.1	41.4	56.3	84.6	145.1	215.3

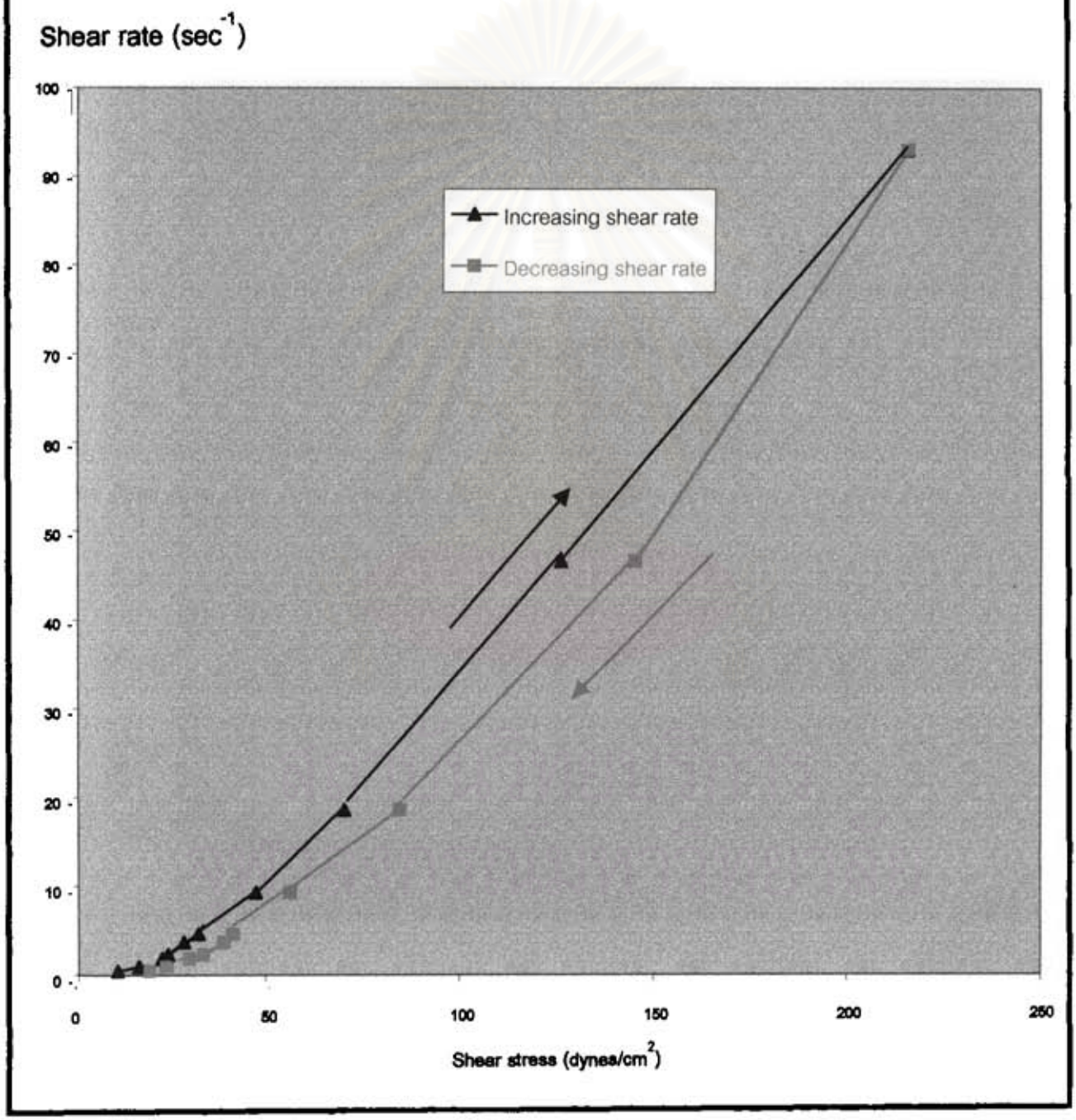


Fig. 6.59 Shear response of MVW (shear rate - shear stress curve)

Slip Specific Gravity = 1.55				Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.970				Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval				Spindle no. SC4-21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	2500	1850	1250	1080	775	700	510	378	271	232
Viscosity (centipoise)	4300	2600	1625	1460	1050	890	605	455	312	232

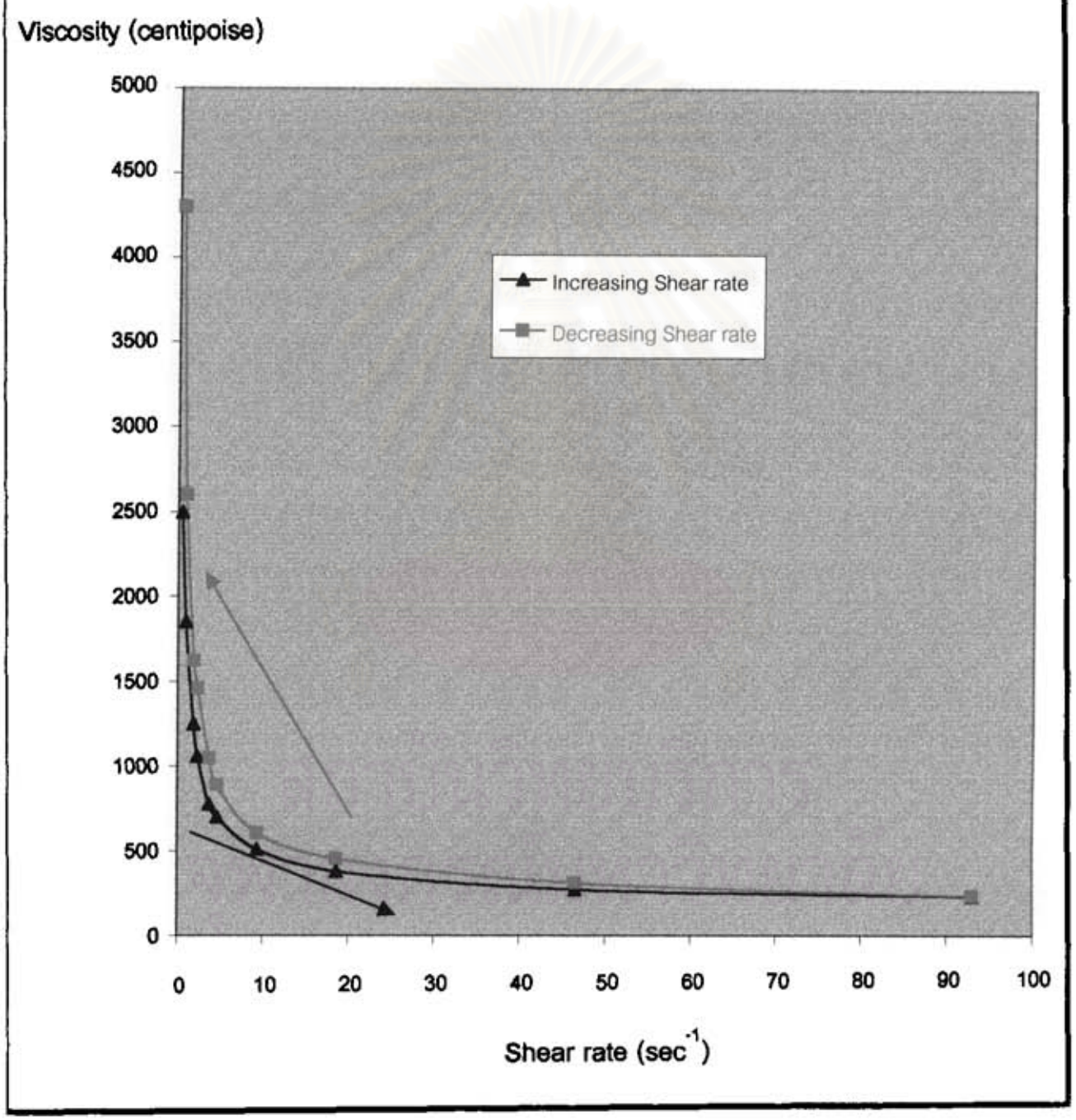


Fig. 6.60 Shear response of MVW (shear rate - viscosity curve)

Slip Specific Gravity = 1.55			Brookfield Viscometer RV DVII+							
% Sodium silicate = 0.344			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate (per second)	**0.47**	**0.93**	**1.86**	**2.33**	**3.72**	**4.65**	**9.30**	**18.60**	**46.50**	**93.00**
Shear stress (dynes/sq.cm.)	**0.93**	**0.93**	**1.40**	**1.86**	**1.86**	**2.79**	**4.19**	**7.44**	**17.20**	**38.60**
Shear stress (dynes/sq.cm.)	0.93	1.40	1.86	1.86	2.79	3.26	5.58	9.30	20.50	38.60

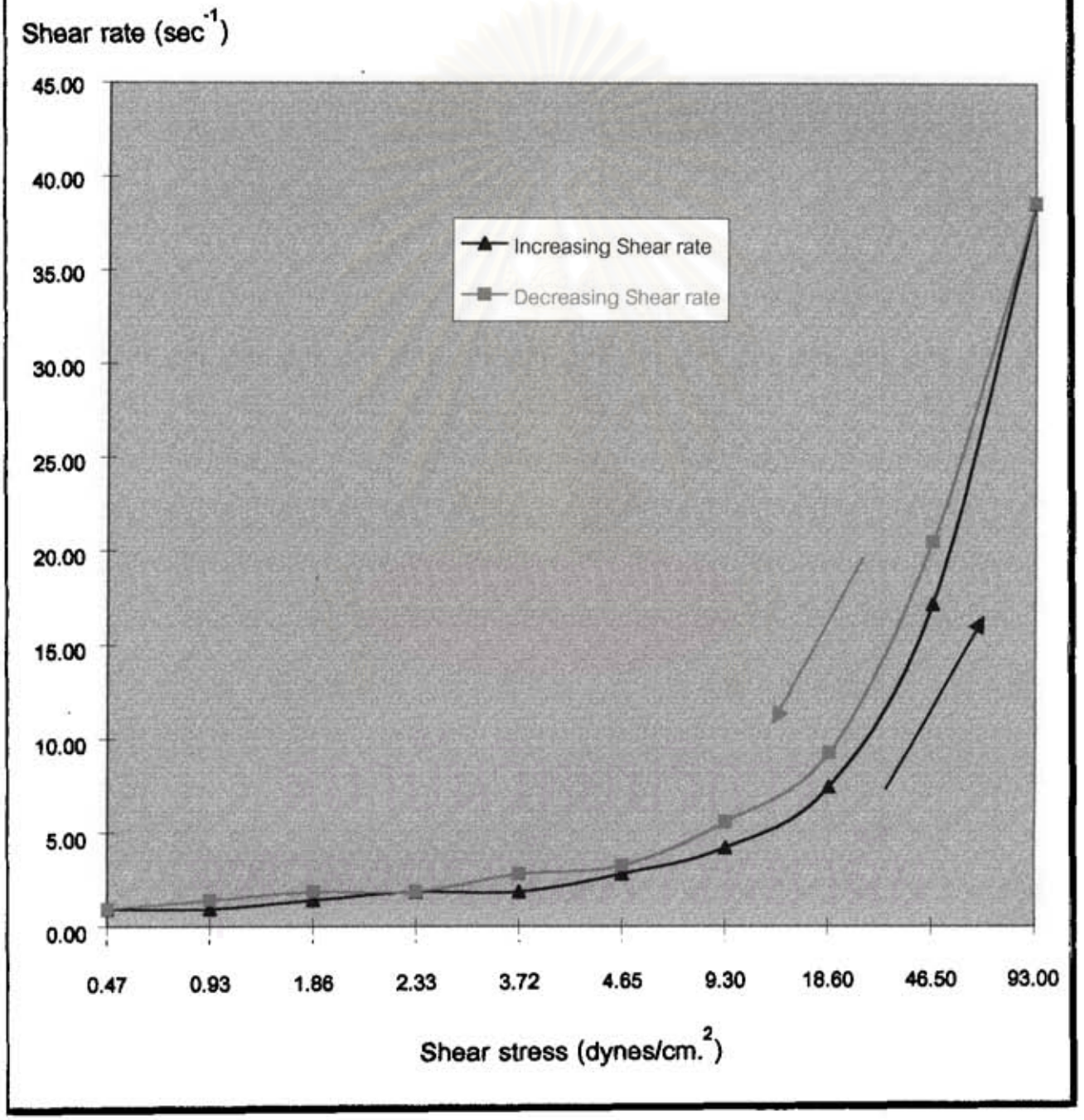


Fig. 6.61 Shear response of MT (shear rate - shear stress curve)

Slip Specific Gravity = 1.55			Brookfield Viscometer RV DVII+							
% Sodium silicate = 0.344			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	200	100	80	75	60	50	45	40	37	42
Viscosity (centipoise)	200	150	100	80	75	70	60	50	44	42

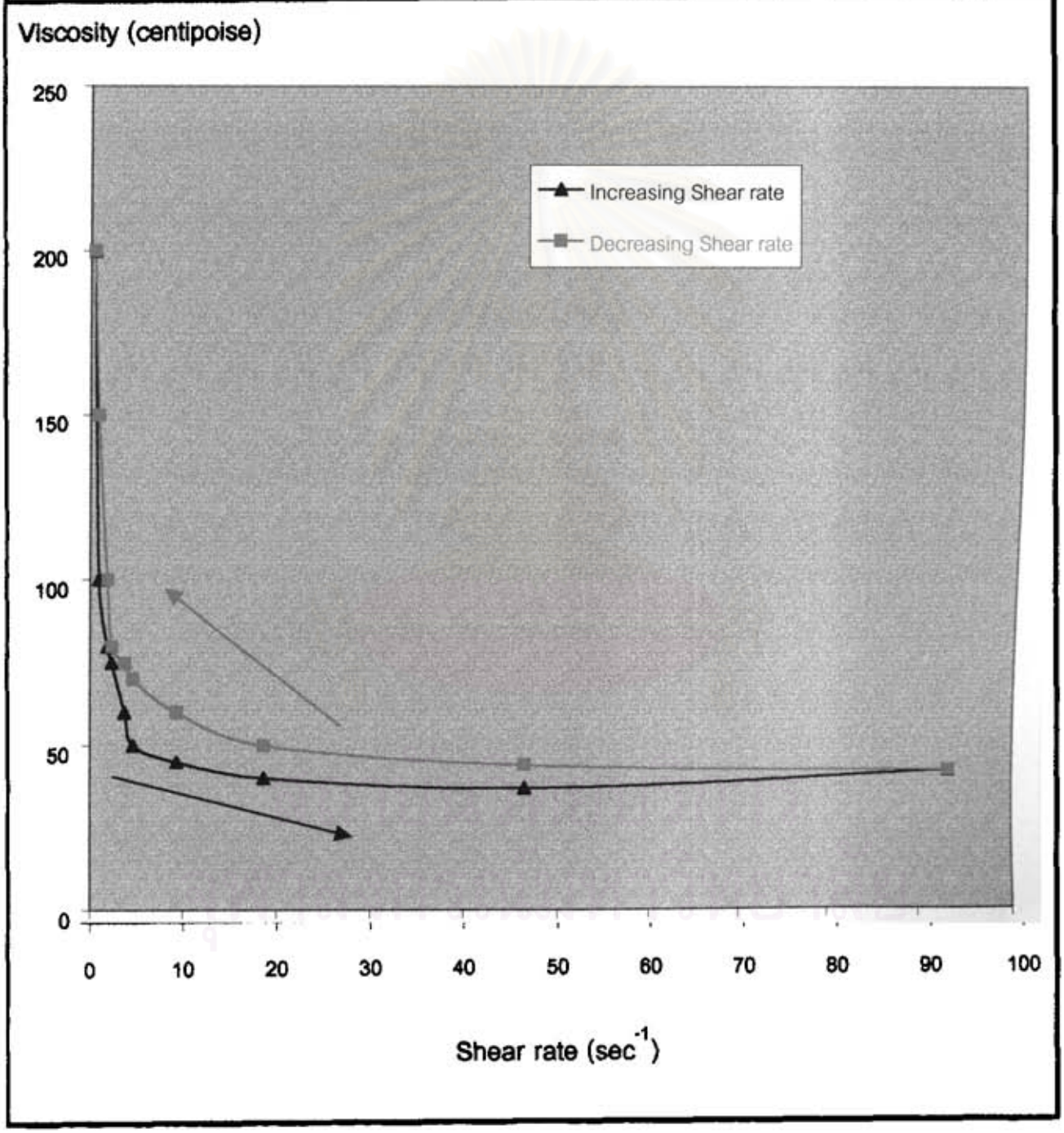


Fig. 6.62 Shear response of MT (shear rate - viscosity curve)

Slip Specific Gravity = 1.63					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.330					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress (dynes/cm.^{2})	2.79	4.65	6.51	6.98	7.91	9.30	13.50	20.00	33.90	53.50
Shear stress (dynes/cm.^{2})	3.72	5.12	6.51	6.98	8.84	8.84	13.50	19.10	33.50	53.50

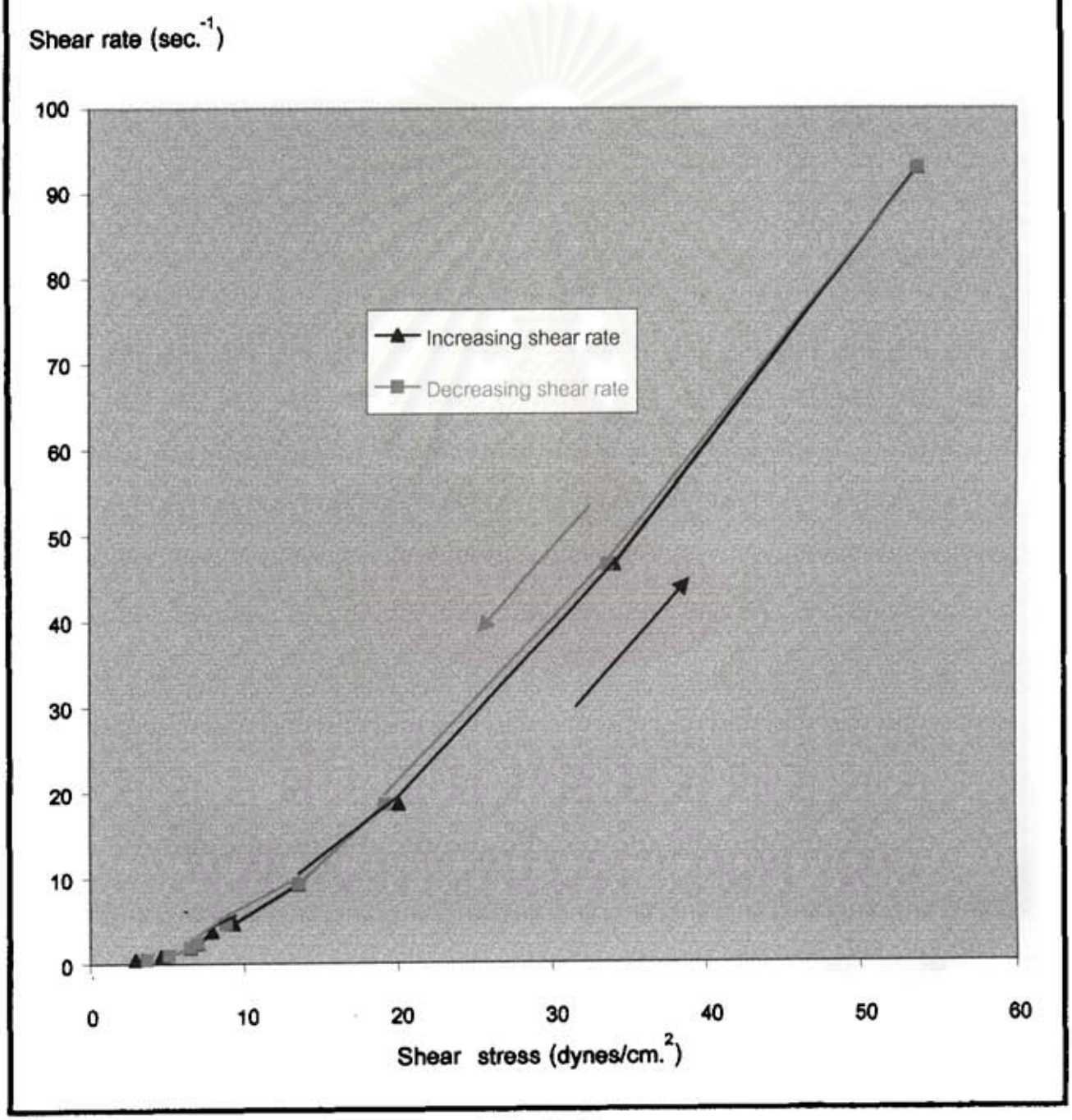


Fig. 6.63 Shear response of SB-75 (shear rate - shear stress curve)

Slip Specific Gravity = 1.63					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.330					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	600	500	375	280	213	200	145	108	73	58
Viscosity (centipoise)	800	550	350	300	238	190	145	103	72	58

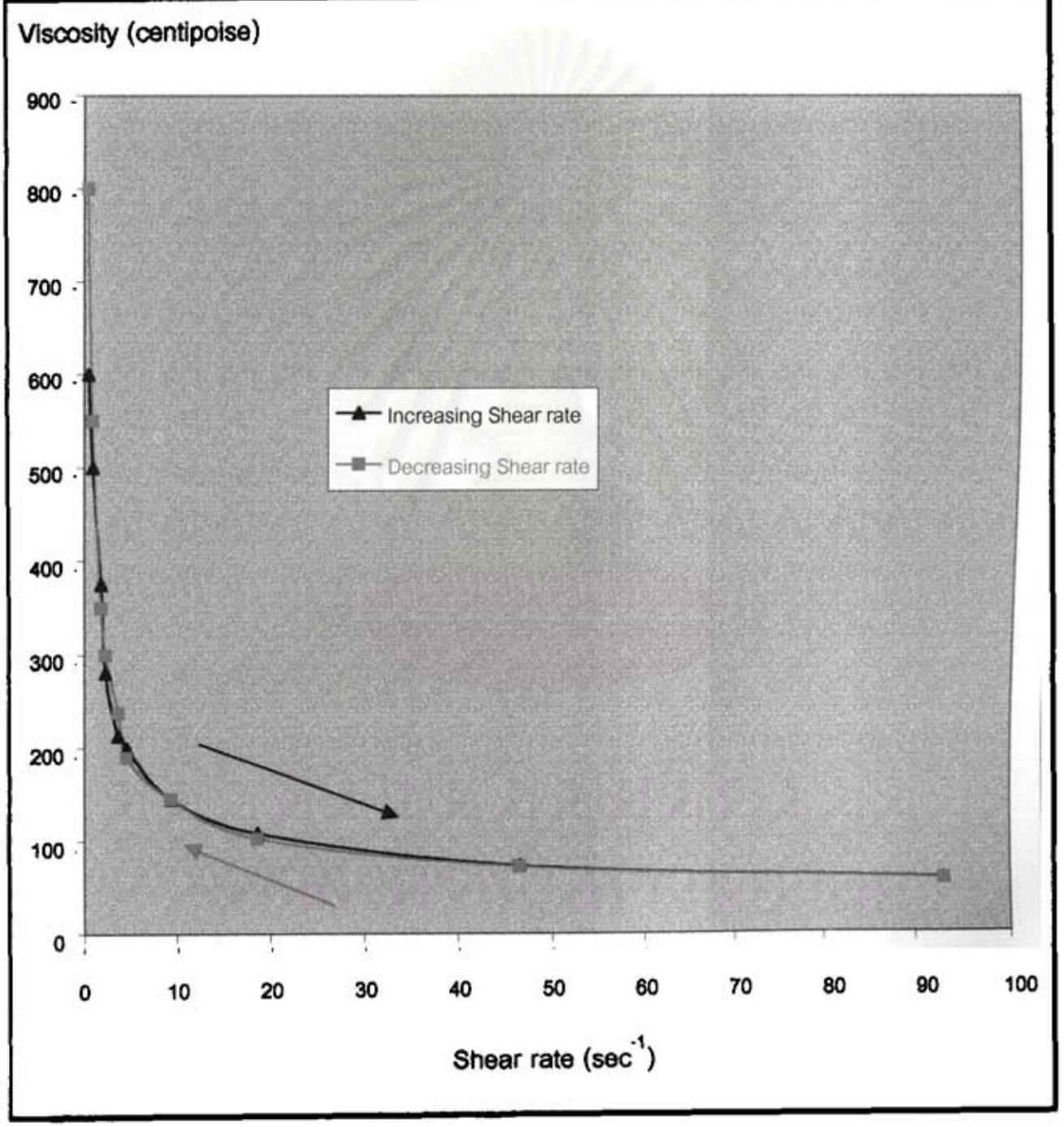


Fig. 6.64 Shear response of SB-75 (shear rate - viscosity curve)

Slip Specific Gravity = 1.63					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.403					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress (dynes/cm.^{2})	2.79	4.19	5.58	5.58	7.91	8.84	13.50	21.40	40.50	70.20
Shear stress (dynes/cm.^{2})	2.33	3.72	4.19	6.05	7.91	8.84	13.00	20.00	40.00	70.20

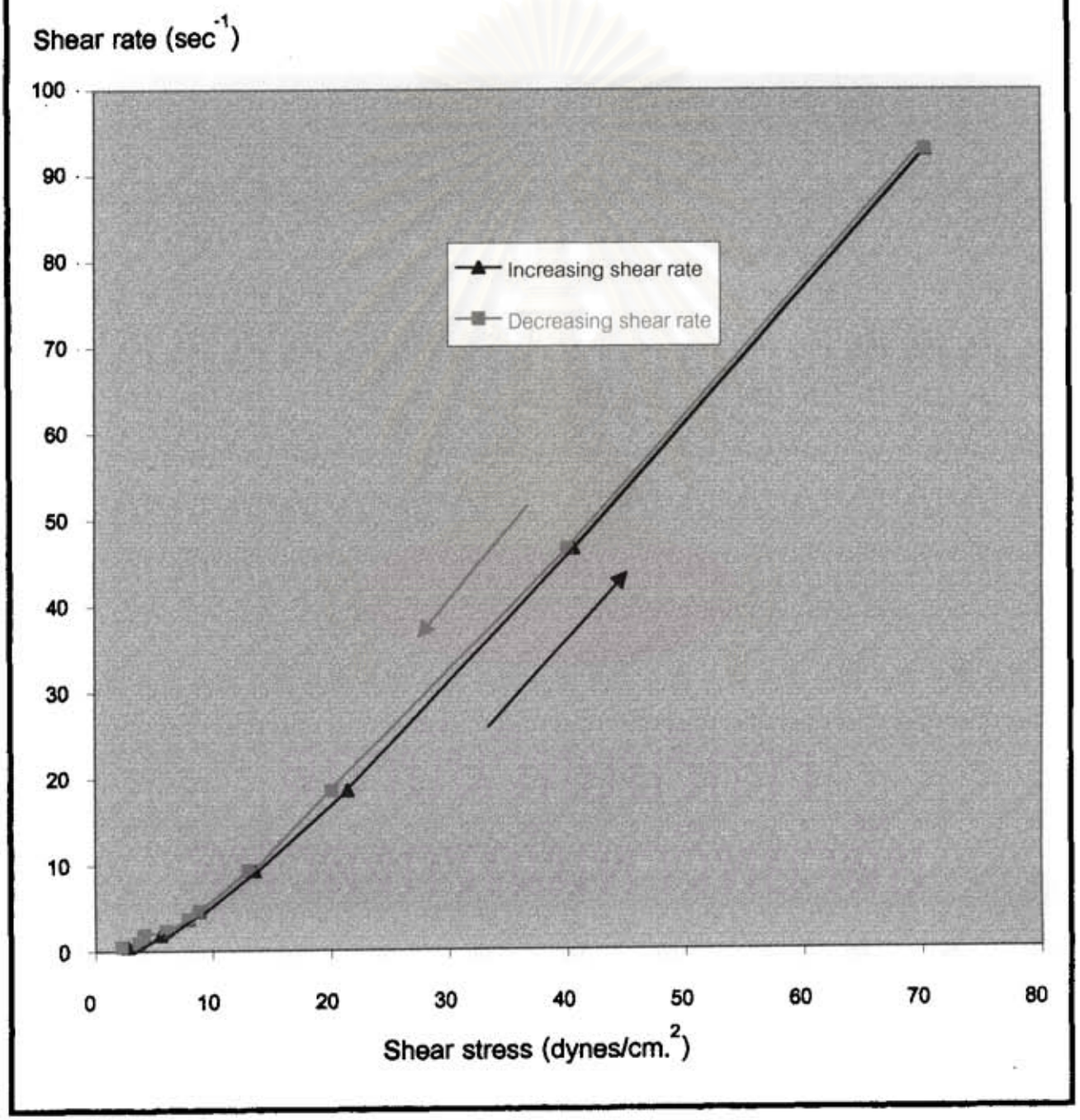


Fig. 6.65 Shear response of HVC (shear rate - shear stress curve)

Slip Specific Gravity = 1.63			Brookfield Viscometer RV DVII+							
% Sodium silicate = 0.403			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	600	450	300	240	213	190	145	115	87	76
Viscosity (centipoise)	500	400	225	260	213	190	140	108	86	76

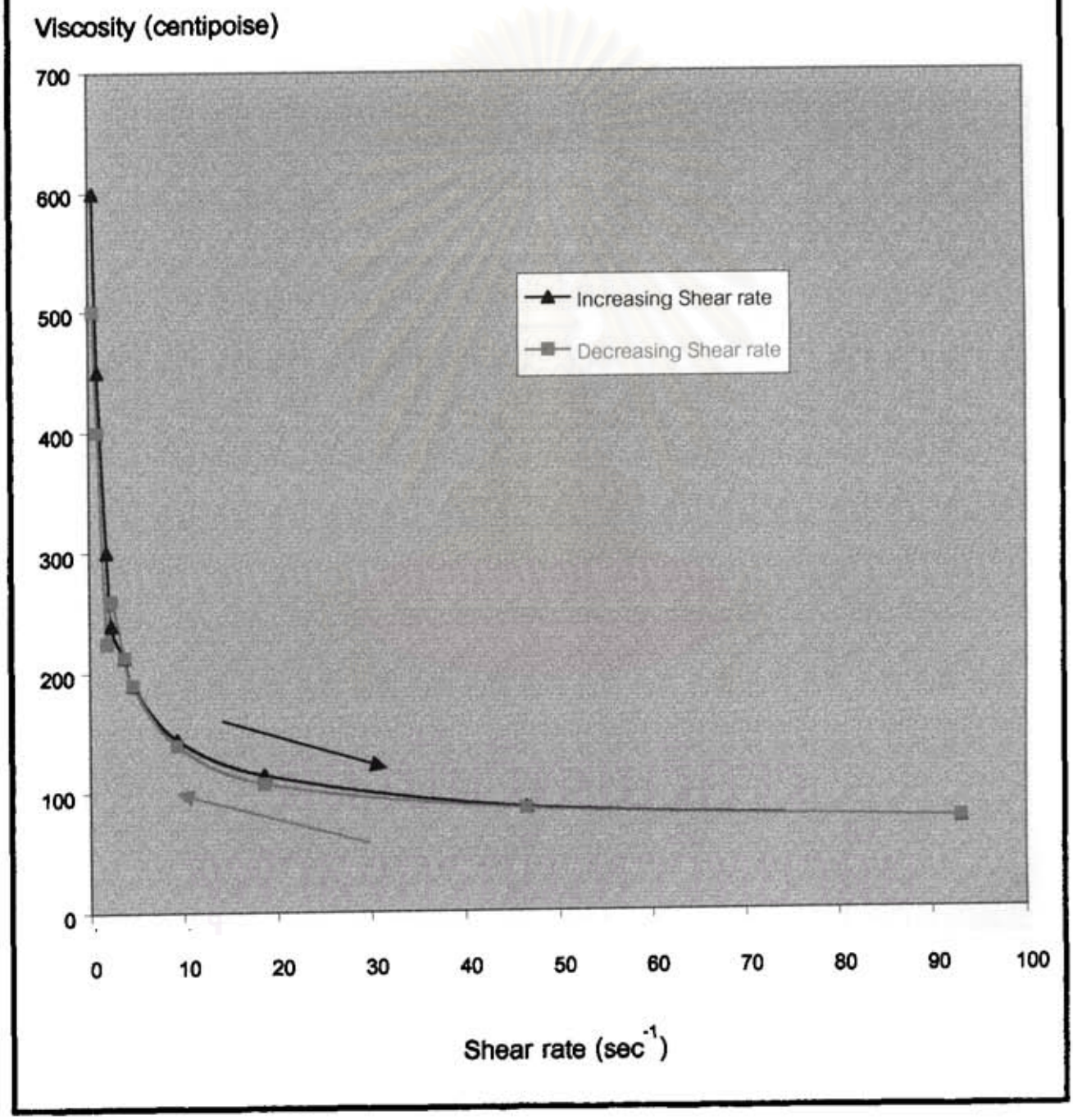


Fig. 6.66 Shear response of HVC (shear rate - viscosity curve)

Slip Specific Gravity = 1.63				Brookfield Viscometer RV DVII+						
% Sodium silicate = 0.350				Small sample adapter SC4 Series Spindle						
Remark : Change rpm. At 5 sec. Interval				Spindle no. SC4-21						
Shear rate ($sec.^{-1}$)	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress ($dynes/cm.^2$)	1.39	1.86	1.86	2.32	3.26	4.19	5.58	8.83	18.60	34.40
Shear stress ($dynes/cm.^2$)	0.93	1.39	1.86	2.32	3.26	3.26	5.12	8.37	18.10	34.40

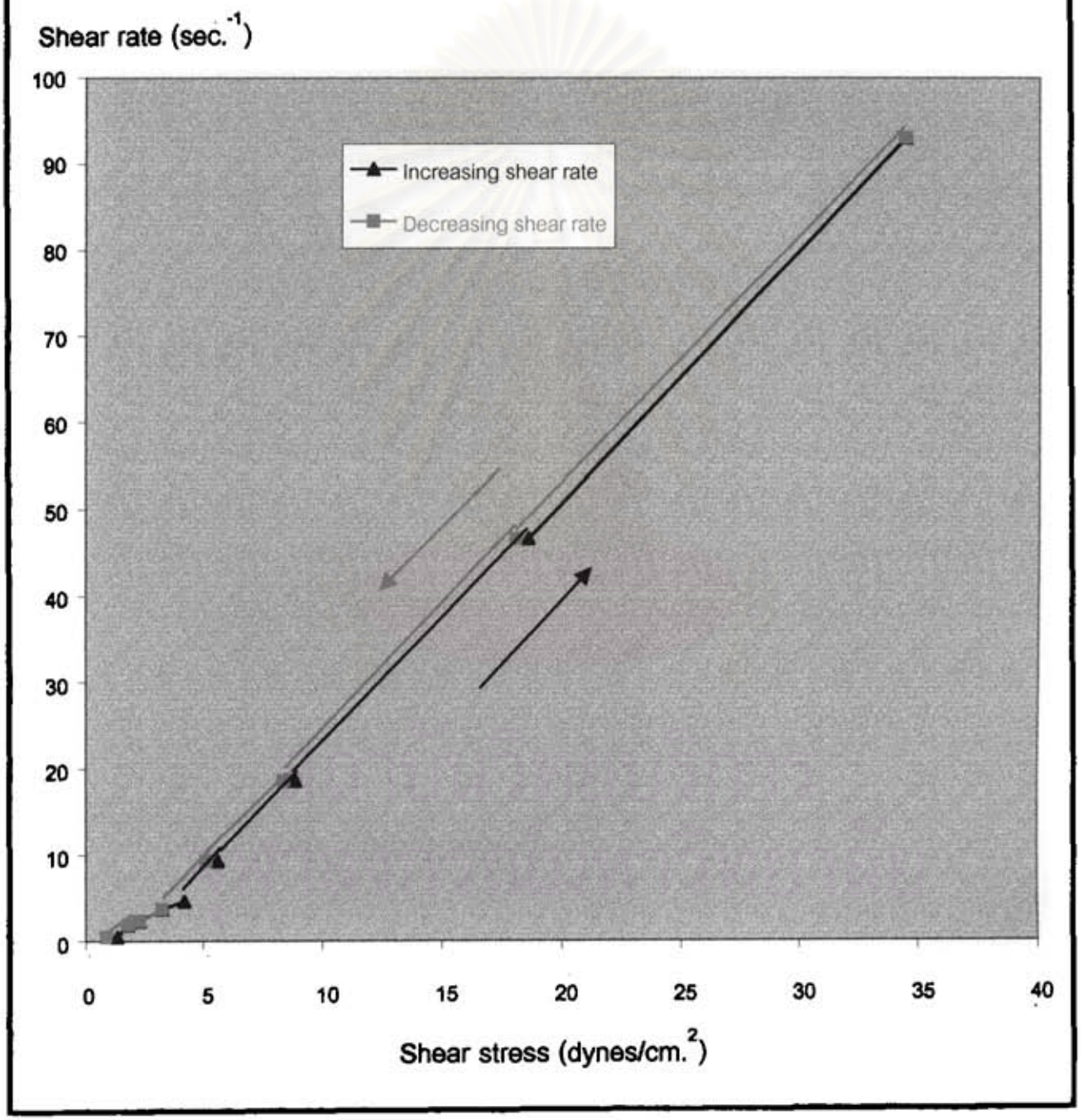


Fig. 6.67 Shear response of REX (shear rate - shear stress curve)

Slip Specific Gravity = 1.63				Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.350				Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval				Spindle no. SC4-21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	300	200	125	90	88	80	60	48	40	37
Viscosity (centipoise)	200	150	100	100	88	70	55	45	39	37

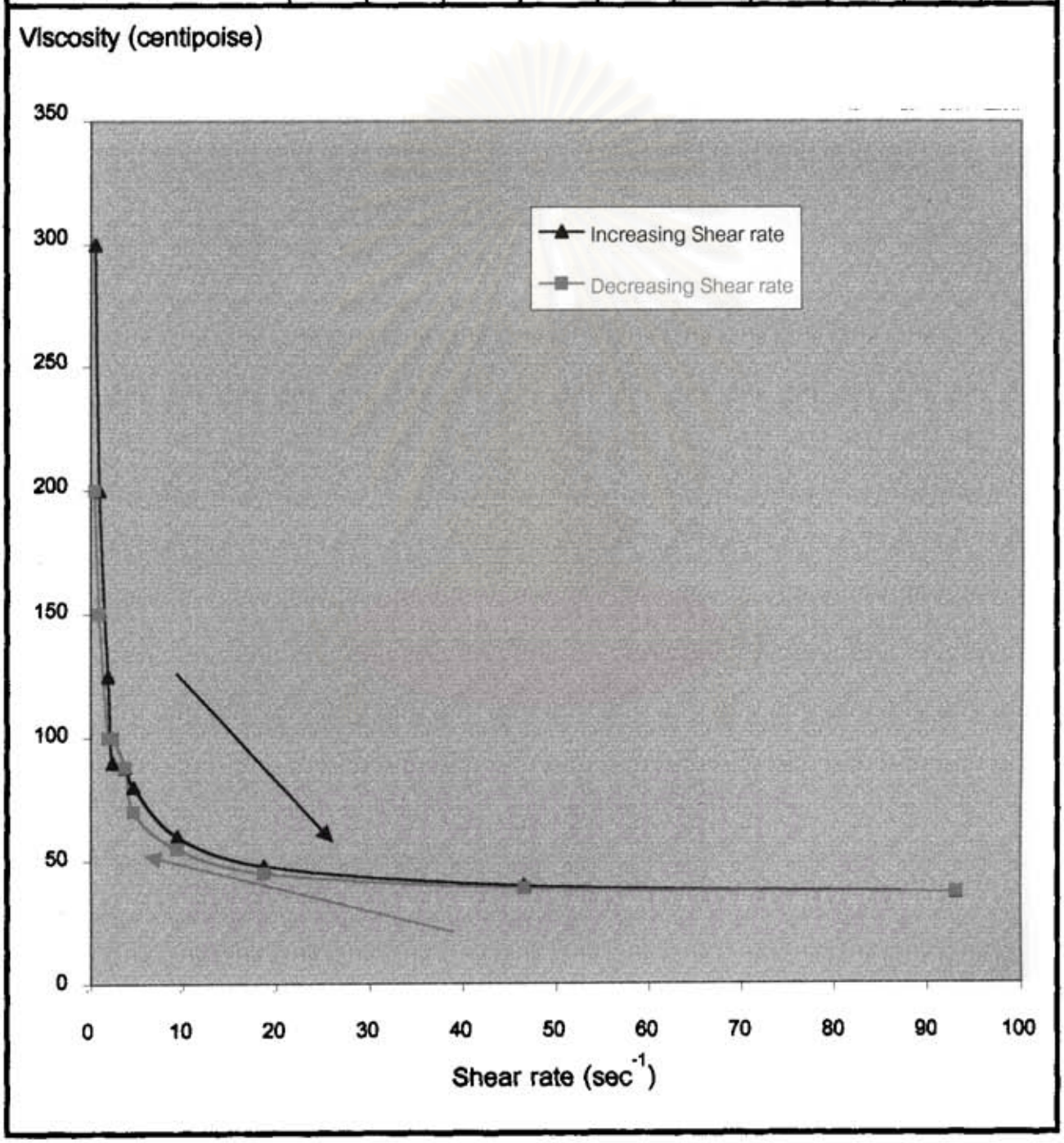


Fig. 6.68 Shear response of REX (shear rate - viscosity curve)

Slip Specific Gravity = 1.63					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.800					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.66	9.30	18.60	46.50	93.00
Shear stress (dynes/cm.^{2})	22.8	31.6	43.2	47.9	60.4	67.9	99.0	147.9	260.4	417.6
Shear stress (dynes/cm.^{2})	26.5	33.0	44.6	48.4	59.5	65.6	94.4	140.0	253.9	417.6

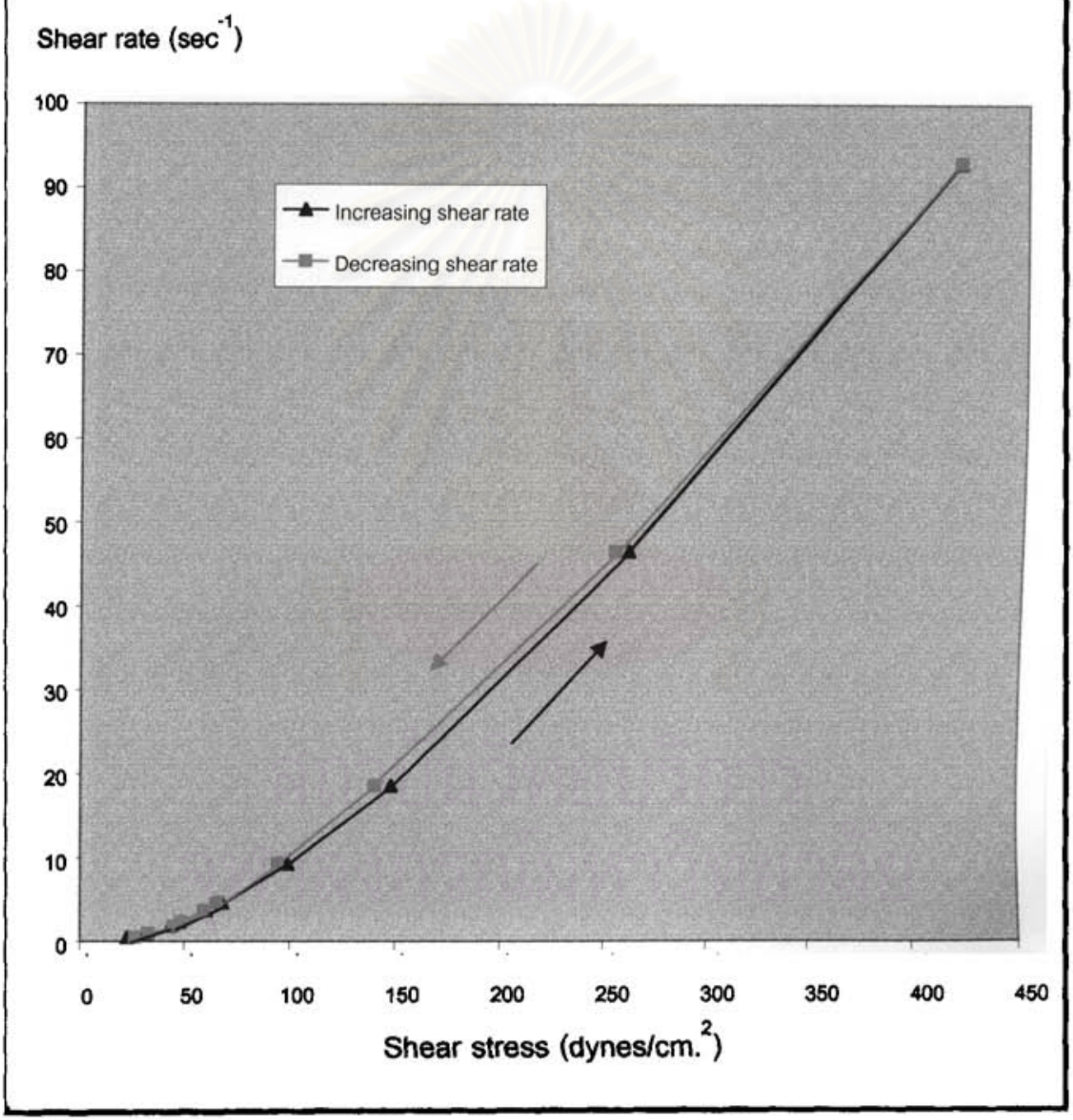


Fig. 6.69 Shear response of BB (shear rate - shear stress curve)

Slip Specific Gravity = 1.63			Brookfield Viscometer RV DVII+							
% Sodium silicate = 0.800			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.66	9.30	18.60	46.50	93.00
Viscosity (centipoise)	4900	3400	2325	2080	1625	1460	1065	795	560	449
Viscosity (centipoise)	5700	3550	2400	2080	1600	1410	1015	753	546	449

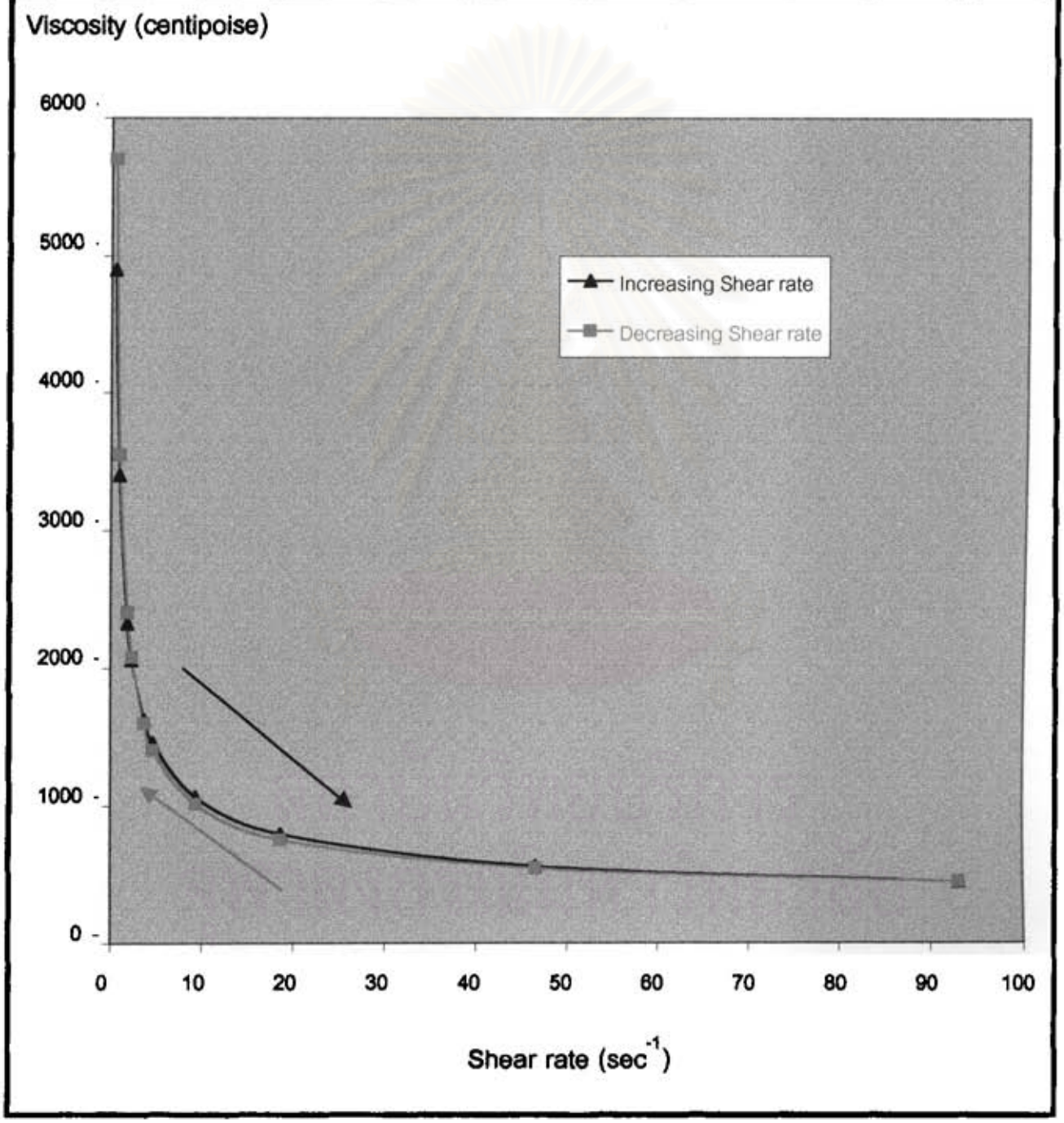


Fig. 6.70 Shear response of BB (shear rate - viscosity curve)

Slip Specific Gravity = 1.55			Brookfield Viscometer RV DVII+							
% Sodium silicate = 0.700			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate ($sec.^{-1}$)	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress ($dynes/cm.^2$)	55.0	57.2	64.6	67.4	75.3	79.3	96.3	112.5	145.1	178.1
Shear stress ($dynes/cm.^2$)	48.4	55.8	63.7	65.1	72.1	75.3	88.3	104.2	138.1	178.1

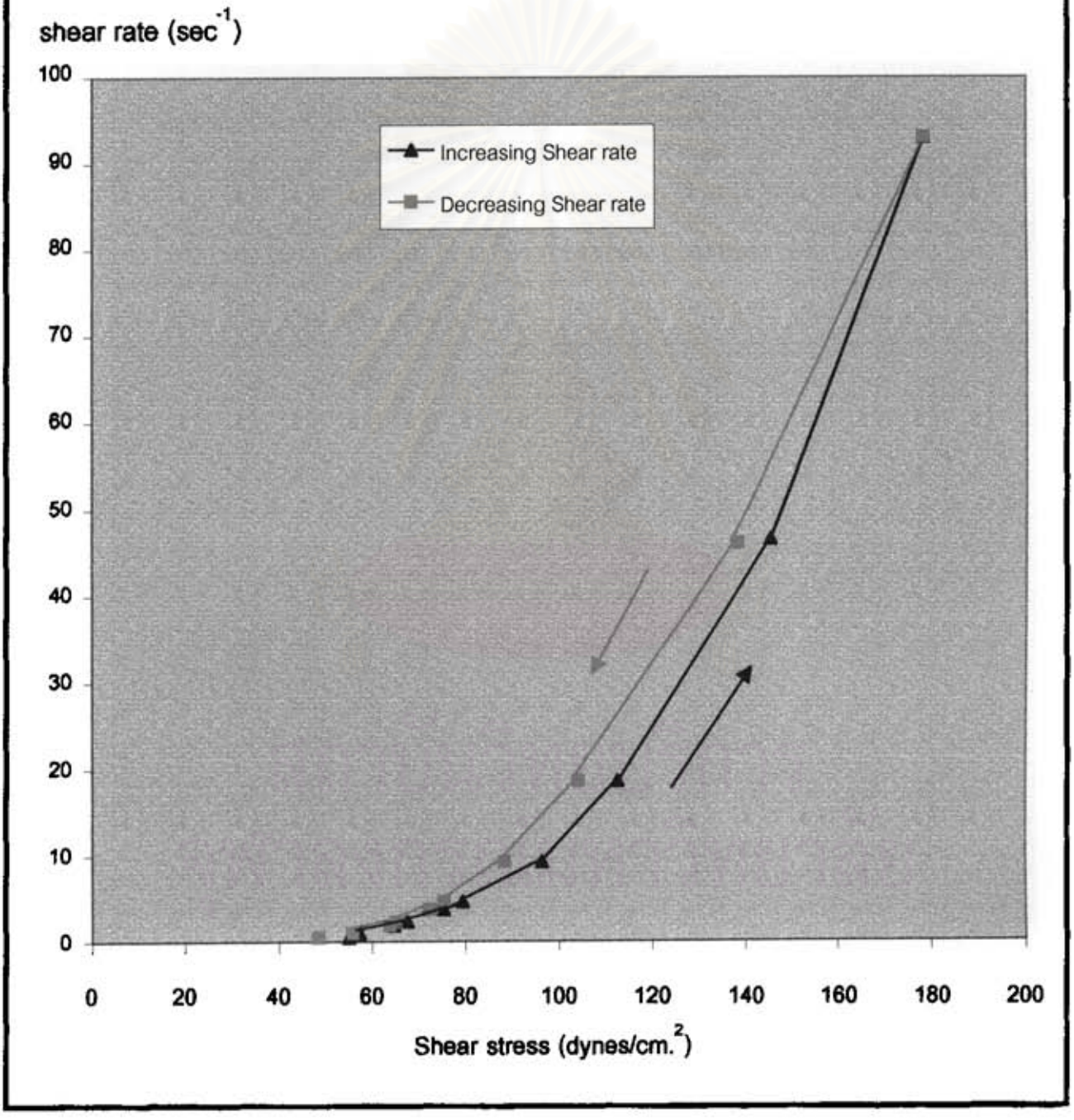


Fig. 6.71 Shear response of JK (shear rate - shear stress curve)

Slip Specific Gravity = 1.55					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.700					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	17300	6150	3175	2900	2025	1710	1035	605	312	192
Viscosity (centipoise)	10400	6000	3425	2800	1937	1620	950	560	297	192

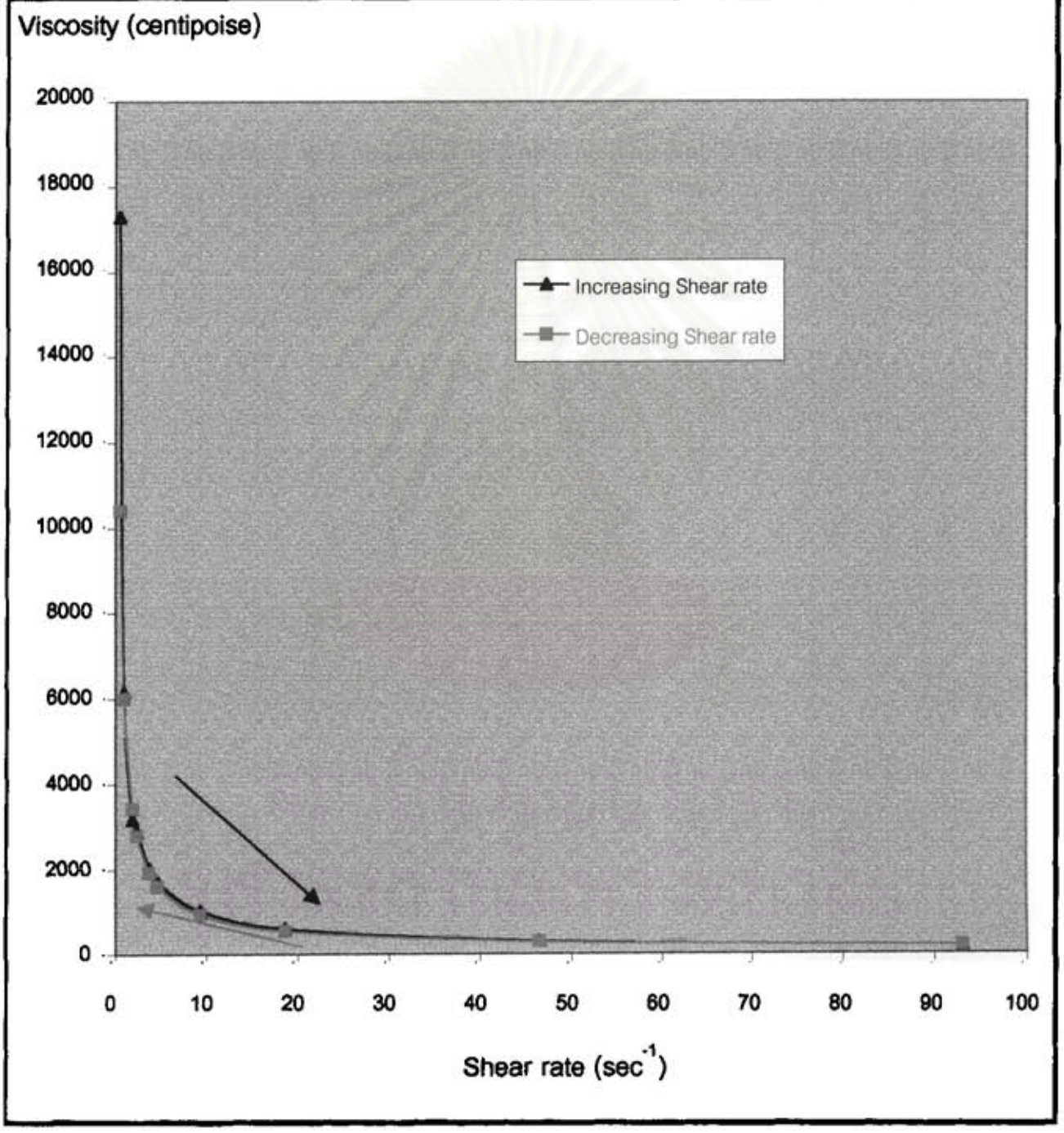


Fig. 6.72 Shear response of JK (shear rate - viscosity curve)

Slip Specific Gravity = 1.55			Brookfield Viscometer RV DVII+							
% Sodium silicate = 1.500			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate ($sec.^{-1}$)	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress ($dynes/cm.^{2}$)	40.0	46.0	43.2	47.0	53.0	53.5	71.6	95.3	143.2	201.8
Shear stress ($dynes/cm.^{2}$)	26.0	31.6	39.1	40.9	47.9	51.1	67.0	89.3	138.1	201.8

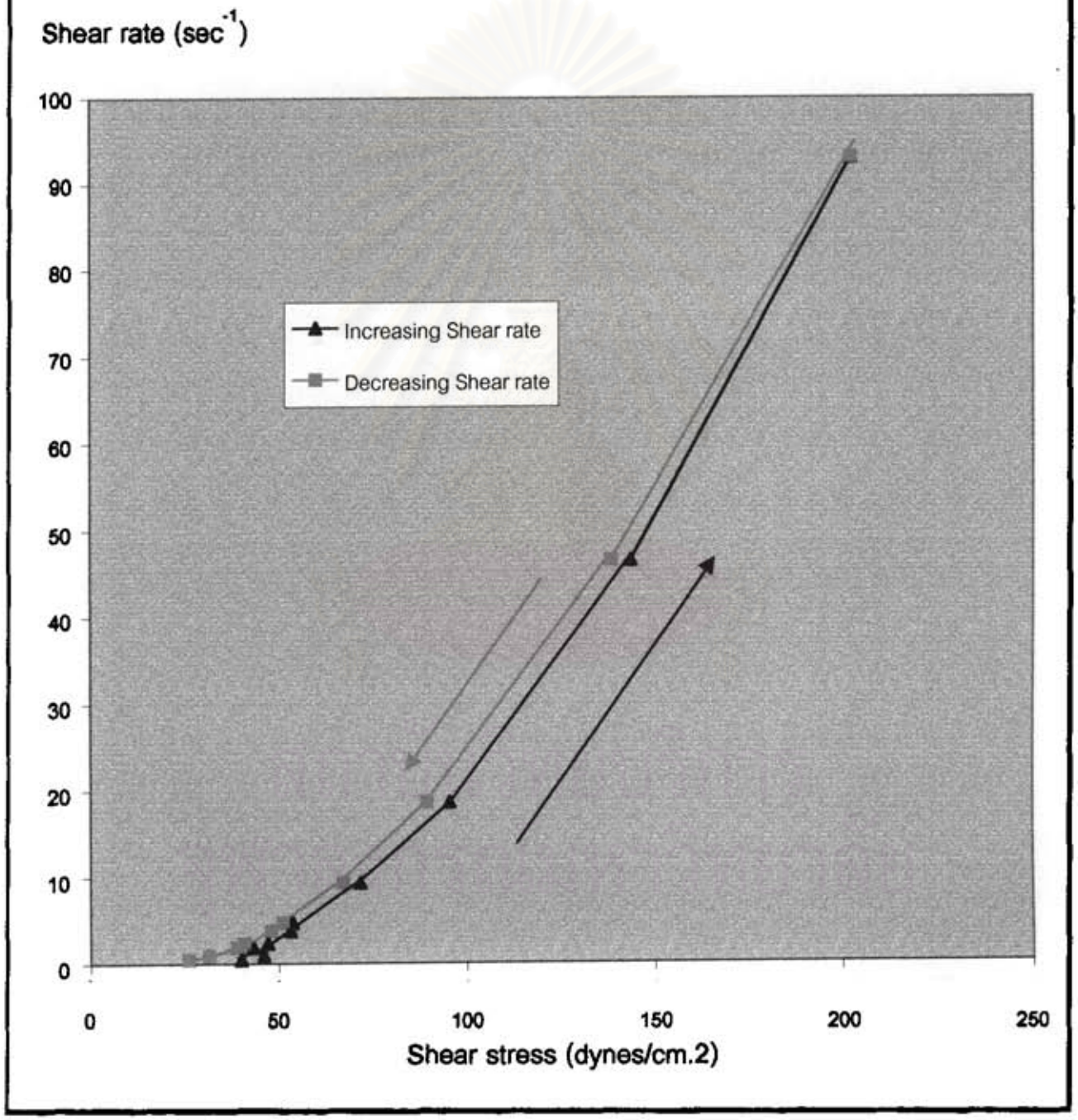


Fig. 6.73 Shear response of KK (shear rate - shear stress curve)

Slip Specific Gravity = 1.55			Brookfield Viscometer RV DVII+							
% Sodium silicate = 1.500			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate (sec^{-1})	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	13600	4950	2325	2020	1425	1150	770	512	308	217
Viscosity (centipoise)	5600	3400	2100	1760	1287	1100	720	480	297	217

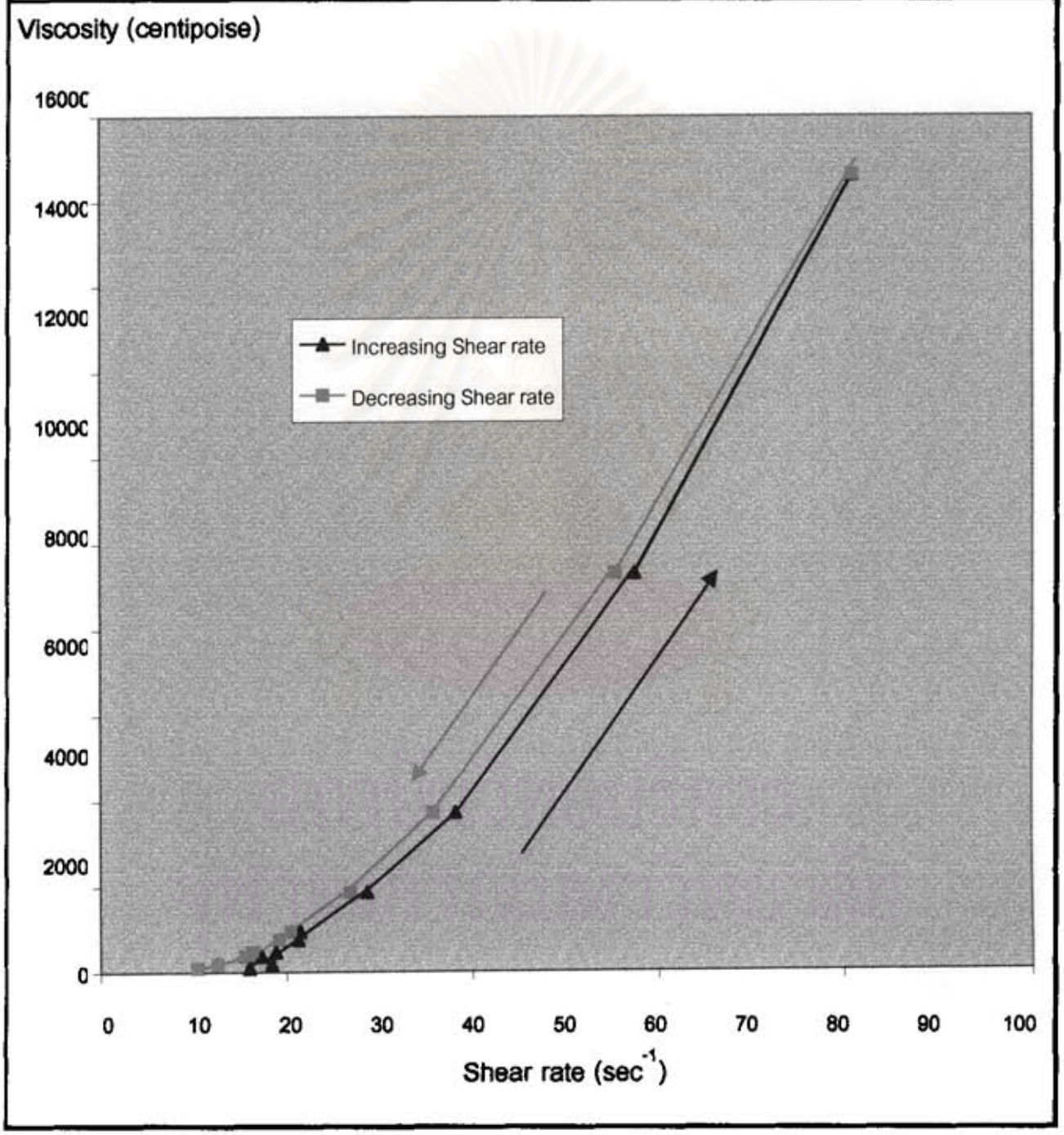


Fig. 6.74 Shear response of KK (shear rate - viscosity curve)

Slip Specific Gravity = 1.55			Brookfield Viscometer RV DVII+							
% Sodium silicate = 0.500			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate ($sec.^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress ($dynes/cm.^2$)	14.0	19.1	25.6	27.0	30.7	33.9	45.6	63.2	97.2	135.8
Shear stress ($dynes/cm.^2$)	12.6	17.7	23.3	24.6	30.2	33.5	46.0	62.8	96.7	135.8

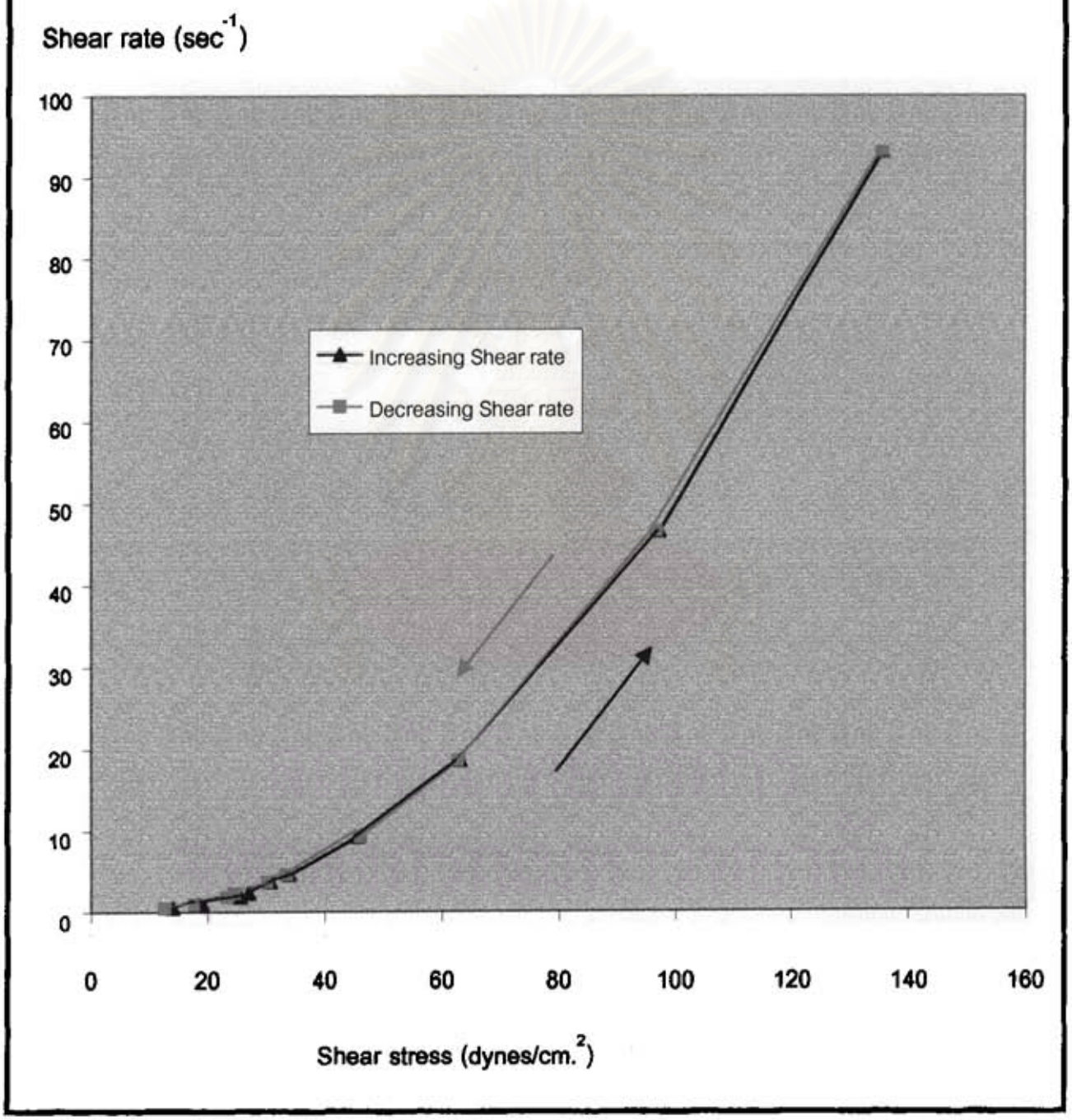


Fig. 6.75 Shear response of WN (shear rate - shear stress curve)

Slip Specific Gravity = 1.55					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.500					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	3000	2050	1375	1160	825	730	490	340	209	146
Viscosity (centipoise)	2700	1900	1250	1060	813	720	495	338	208	146

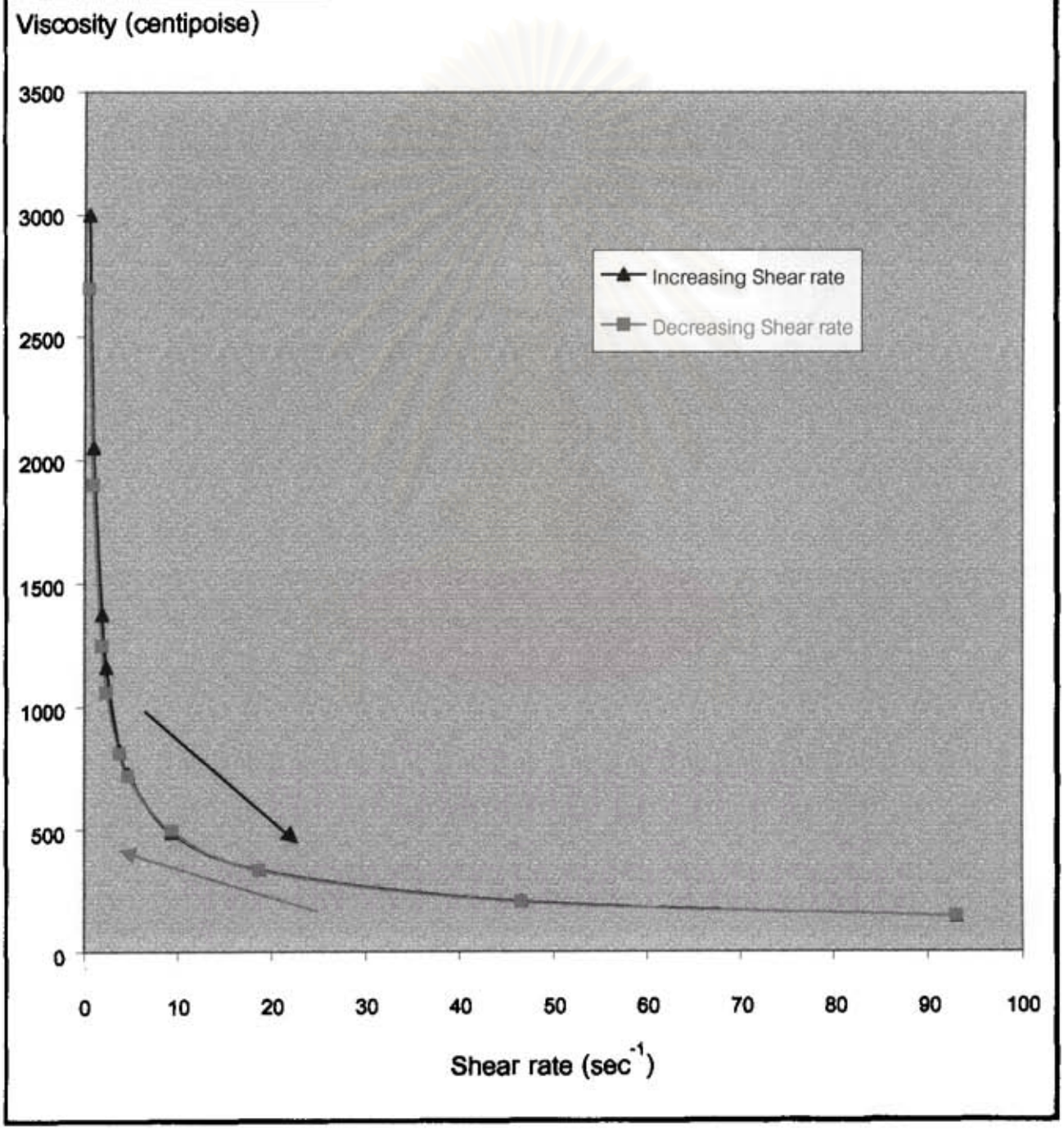


Fig. 6.76 Shear response of WN (shear rate - viscosity curve)

Slip Specific Gravity = 1.55					Brookfield Viscometer RV DVII+					
% Sodium silicate = 0.775					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle no. SC4-21					
Shear rate ($sec.^{-1}$)	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear stress ($dynes/cm.^2$)	6.51	8.83	13.00	13.50	17.20	19.10	27.90	41.40	71.10	109.70
Shear stress ($dynes/cm.^2$)	6.05	9.30	12.60	13.00	17.70	18.60	26.50	40.00	70.20	109.70

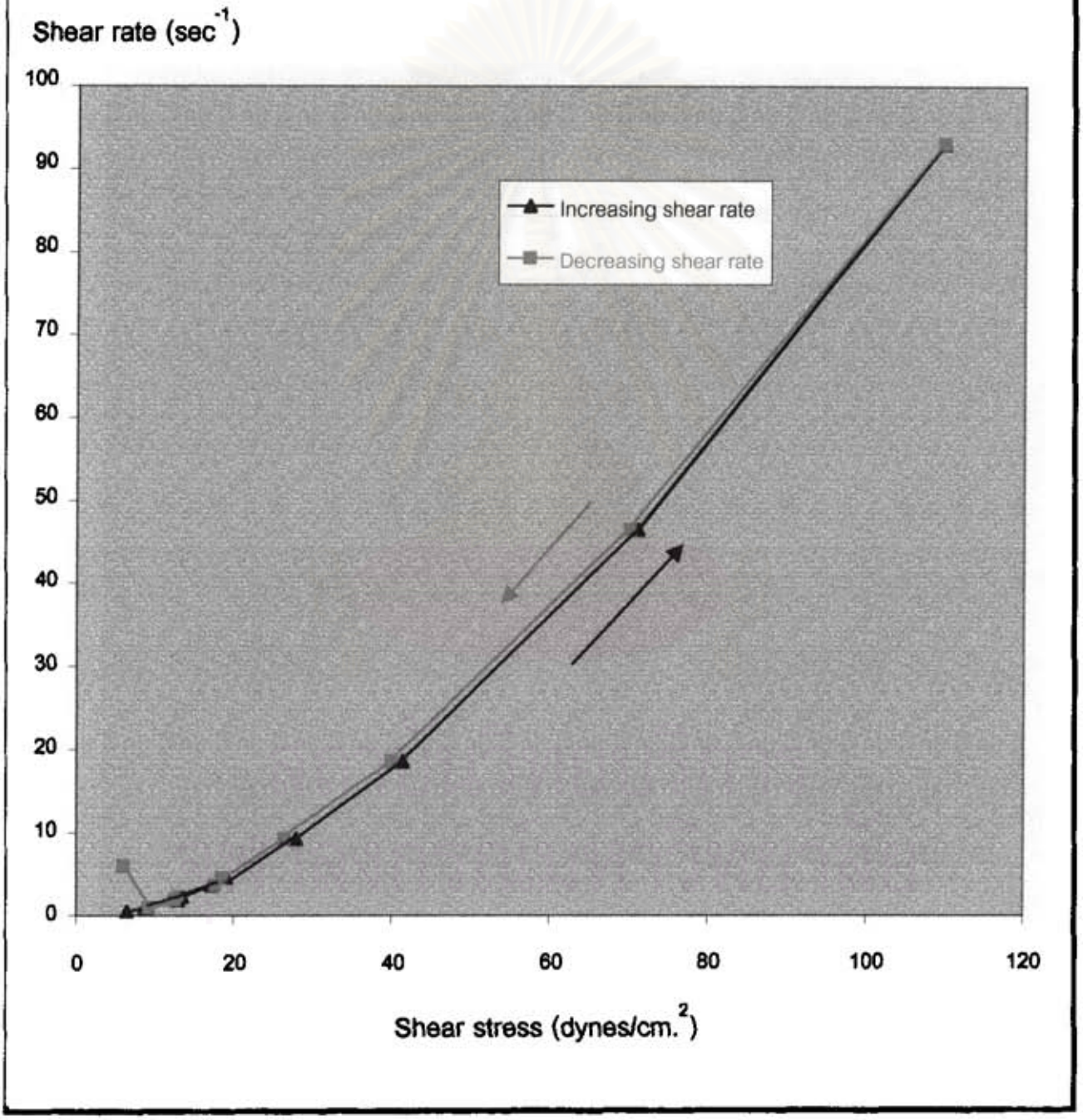


Fig. 6.77 Shear response of PC (shear rate - shear stress curve)

Slip Specific Gravity = 1.55			Brookfield Viscometer RV DVII+							
% Sodium silicate = 0.775			Small sample adapter SC4 Series Spindle							
Remark : Change rpm. At 5 sec. Interval			Spindle no. SC4-21							
Shear rate (sec^{-1})	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Viscosity (centipoise)	1400	950	700	580	463	410	300	223	153	118
Viscosity (centipoise)	1300	1000	675	560	475	400	285	215	151	118

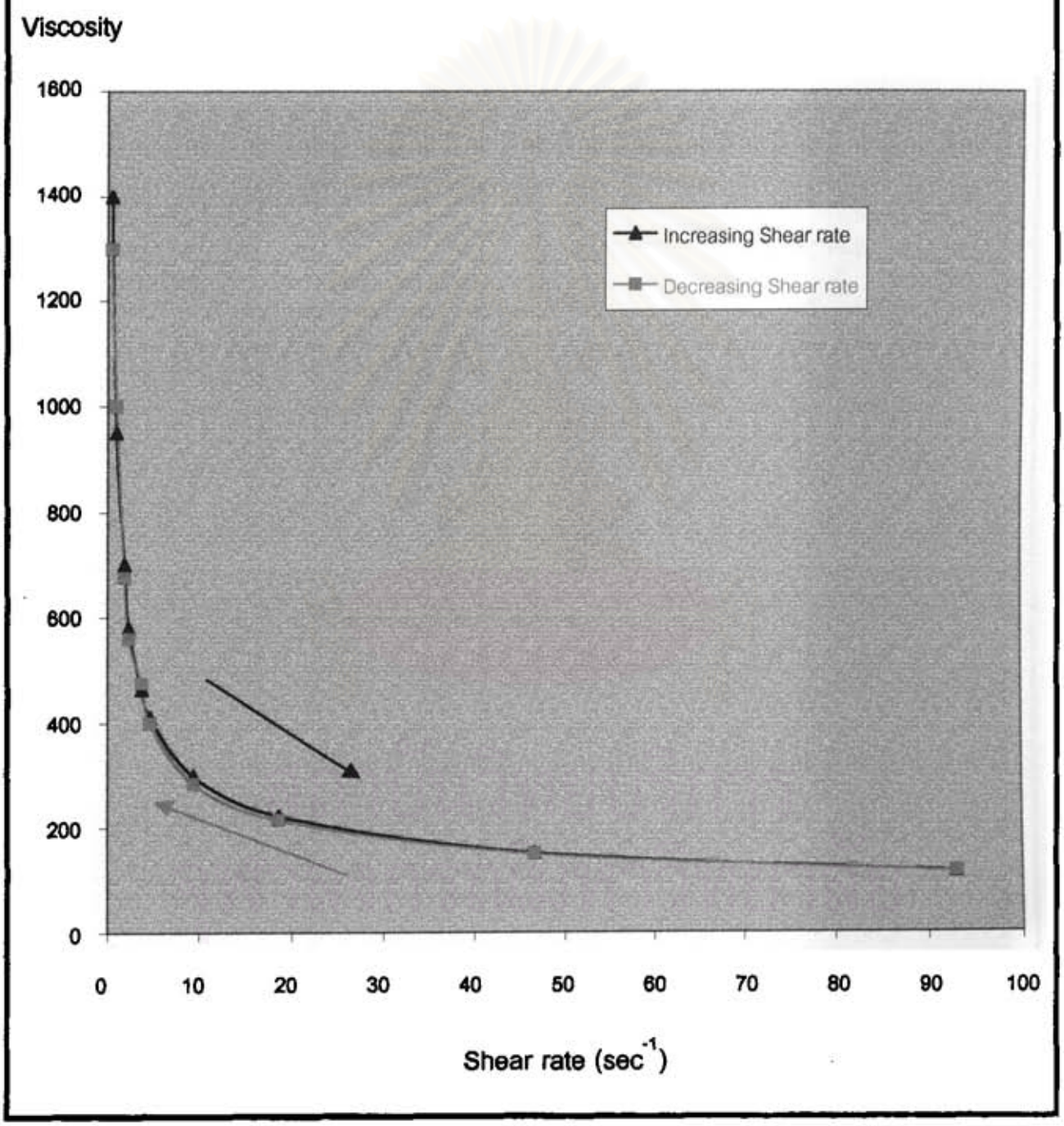


Fig. 6.78 Shear response of PC (shear rate - viscosity curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.333					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate ($sec.^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.3	18.6	46.5	93
Shear stress ($dynes/cm.^{2}$)	0.93	1.86	2.79	2.79	4.19	5.12	8.37	12.6	23.7	41.8
Shear stress ($dynes/cm.^{2}$)	1.39	1.86	3.26	3.26	4.19	5.12	7.44	11.6	23.2	41.8

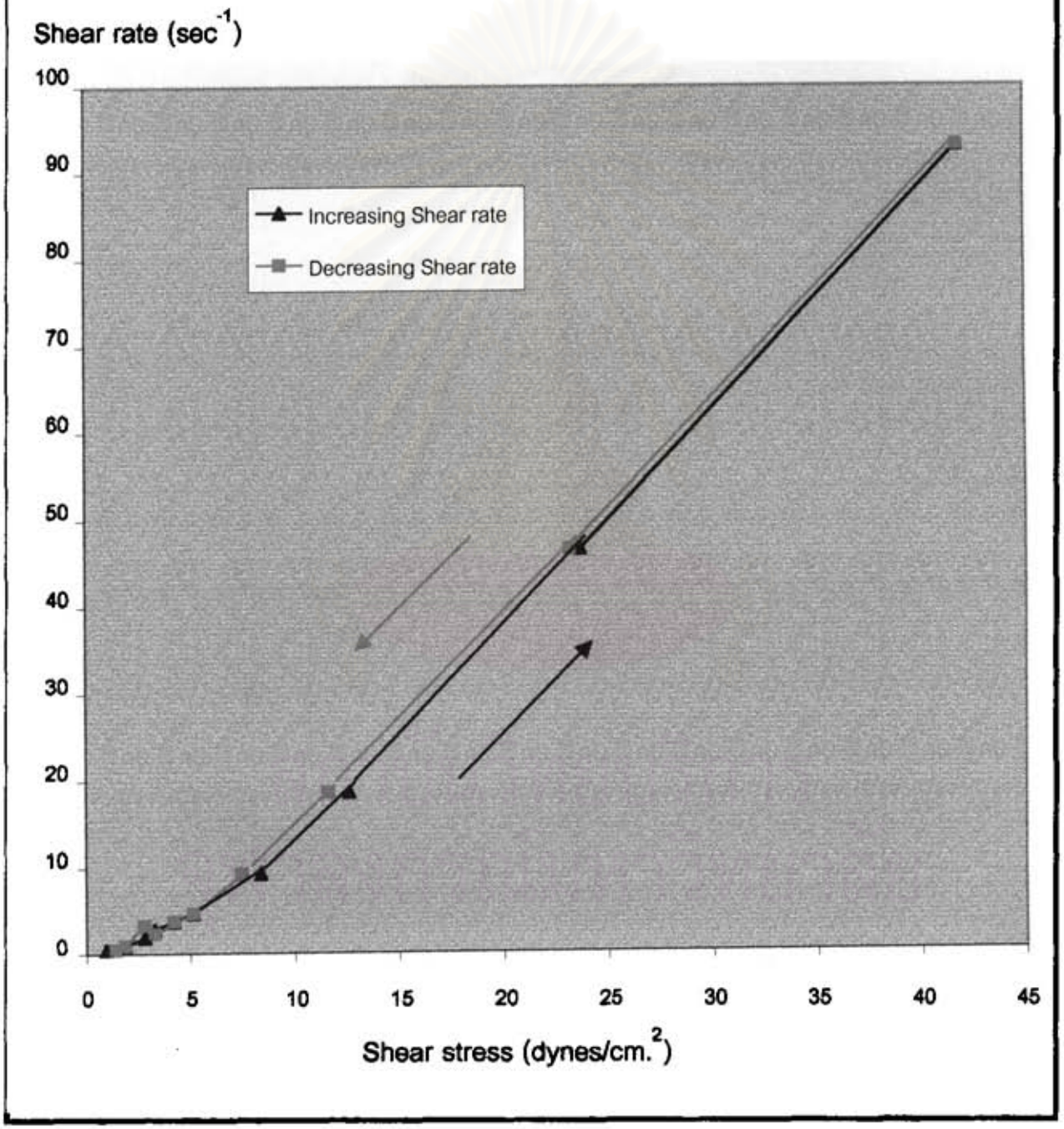


Fig. 6.79 Shear response of MT (shear rate - shear stress curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.333					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.3	18.6	46.5	93
Viscosity (centipoise)	200	200	150	120	113	110	90	68	51	45
Viscosity (centipoise)	300	200	175	140	113	110	80	63	50	45

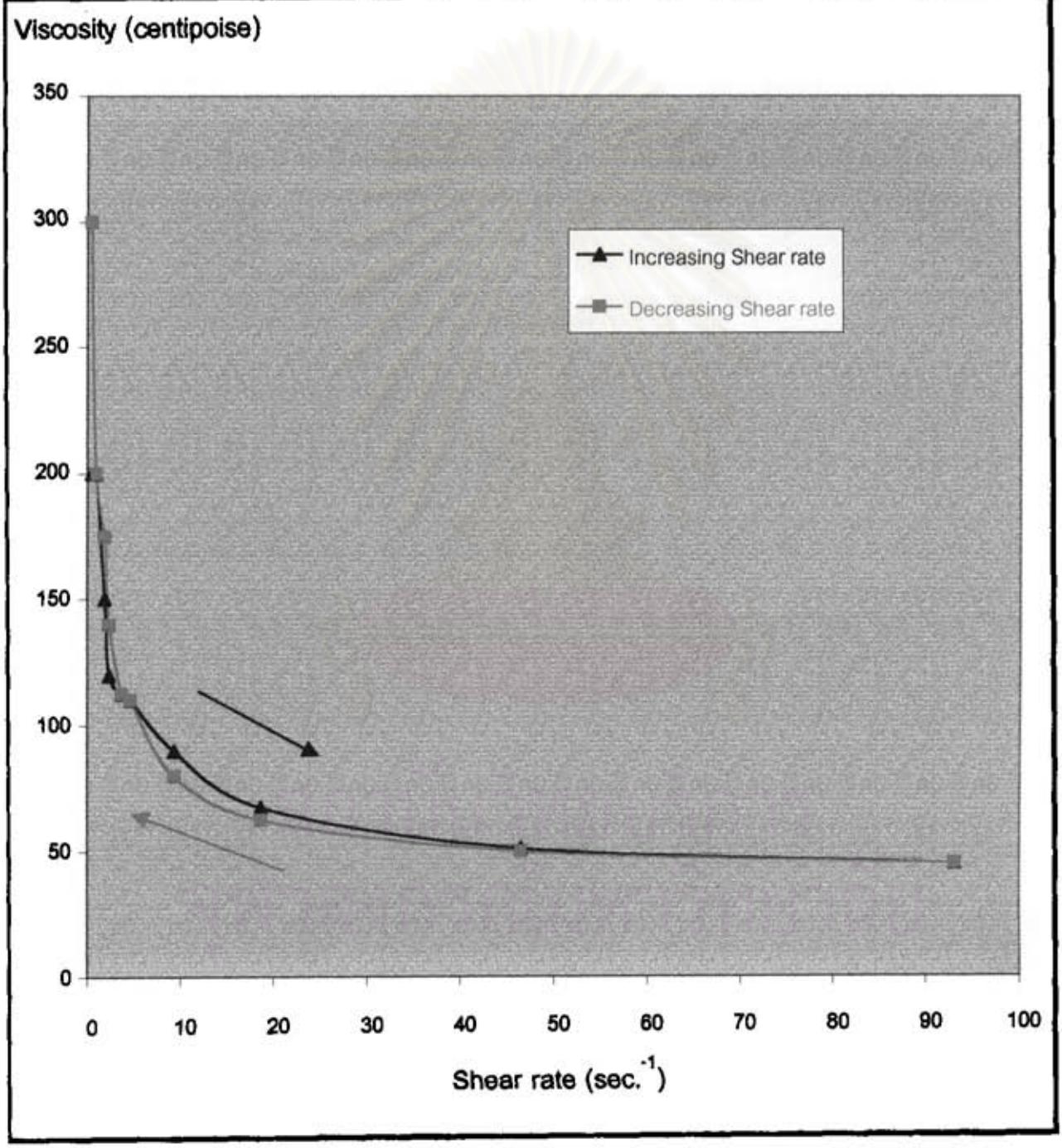


Fig. 6.80 Shear response of MT (shear rate - viscosity curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.388					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Shear Stress (dynes / cm^2)	2.33	2.79	3.72	4.65	5.12	5.58	9.30	16.30	39.10	119.00
Shear Stress (dynes / cm^2)	3.72	5.58	6.98	7.91	11.20	11.60	20.90	34.90	75.80	119.00

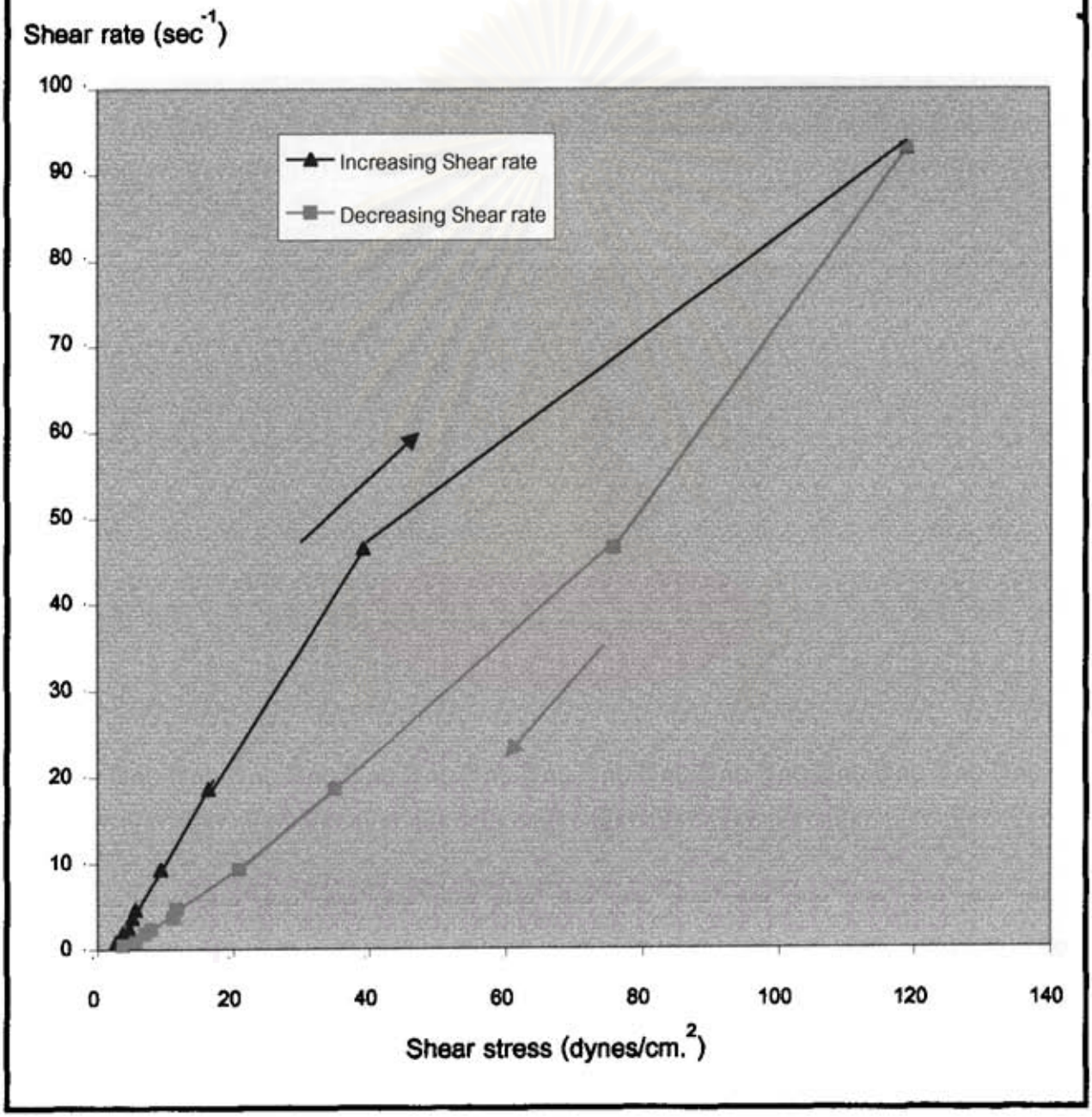


Fig. 6.81 Shear response of MT added 0.1 % HVC Extractable humic acid (shear rate - shear stress curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.388					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.3	18.6	46.5	93
Viscosity (centipoise)	500	300	200	200	138	120	100	88	84	128
Viscosity (centipoise)	800	600	375	340	300	250	225	188	163	128

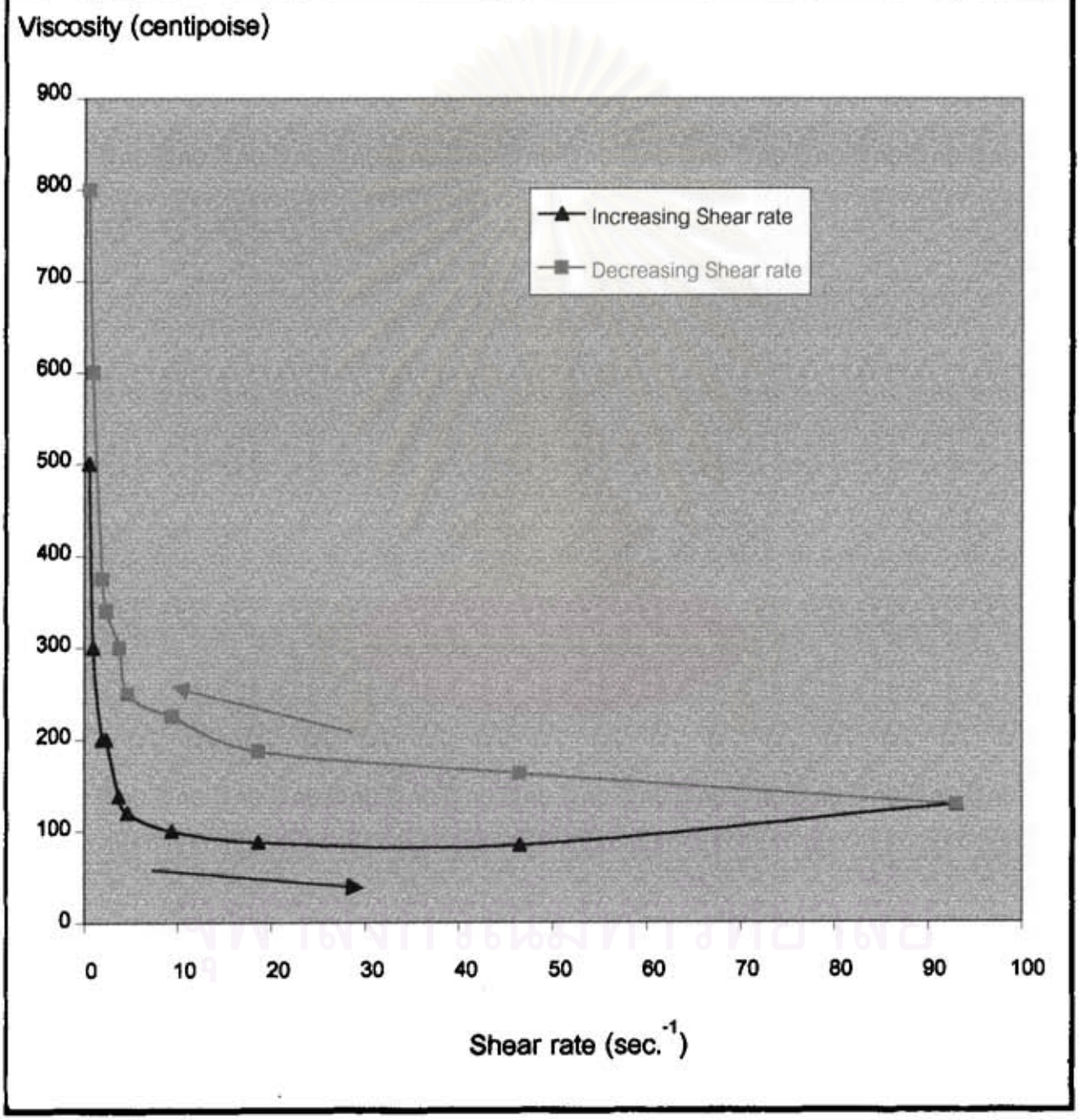


Fig. 6.82 Shear response of MT added 0.1 % HVC Extractable humic acid

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0..505					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Shear Stress (dynes / cm^2)	2.33	2.33	2.79	3.26	4.19	4.65	6.51	9.77	19.10	33.90
Shear Stress (dynes / cm^2)	1.40	2.33	2.33	3.26	4.19	4.65	6.51	9.30	18.60	33.90

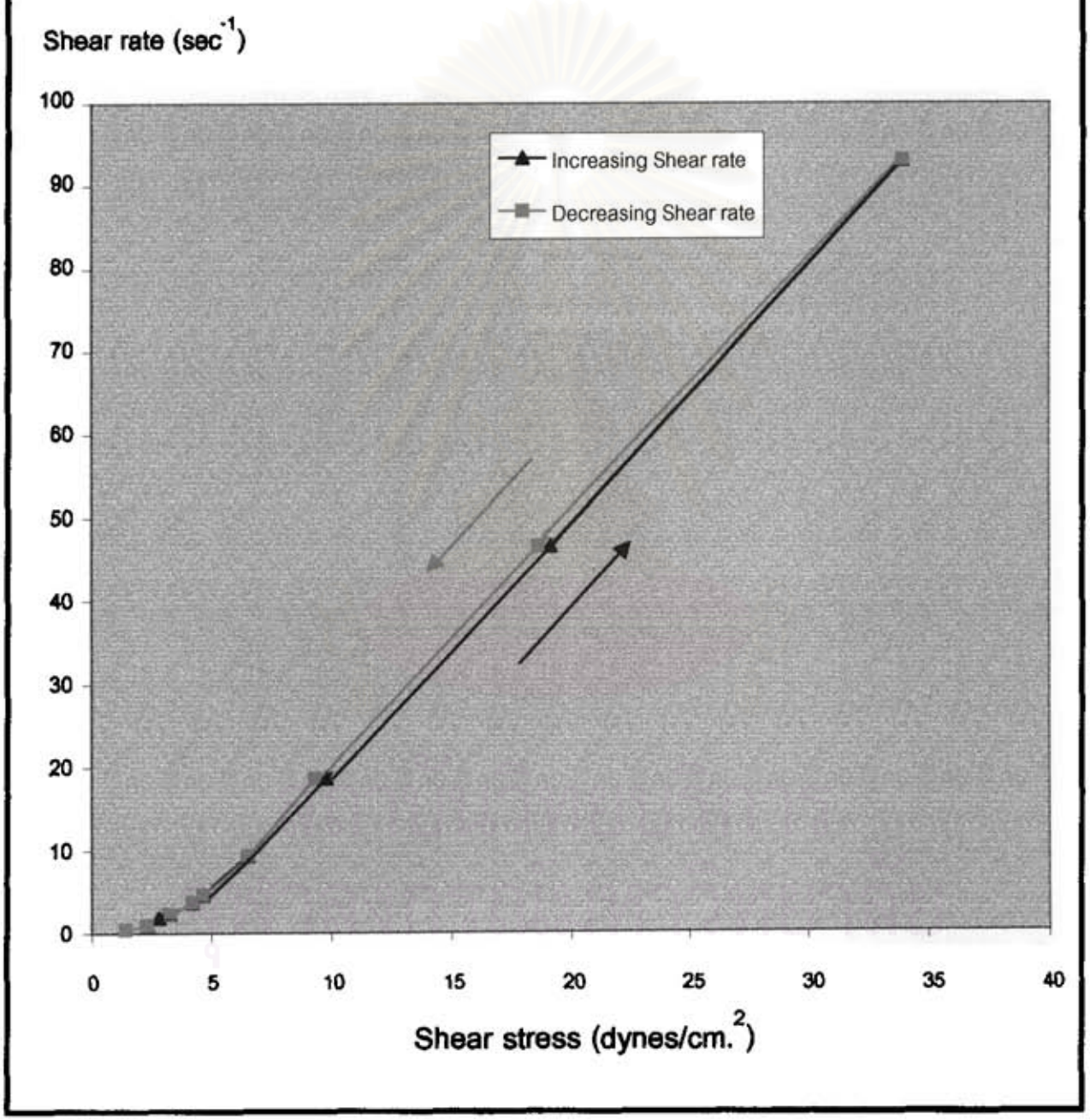


Fig. 6.83 Shear response of MT added 0.1 % BB Extractable humic acid (shear rate - shear stress curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.505					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.3	18.6	46.5	93
Viscosity (centipoise)	500	250	150	140	113	100	70	53	41	37
Viscosity (centipoise)	300	250	125	140	113	100	70	50	40	37

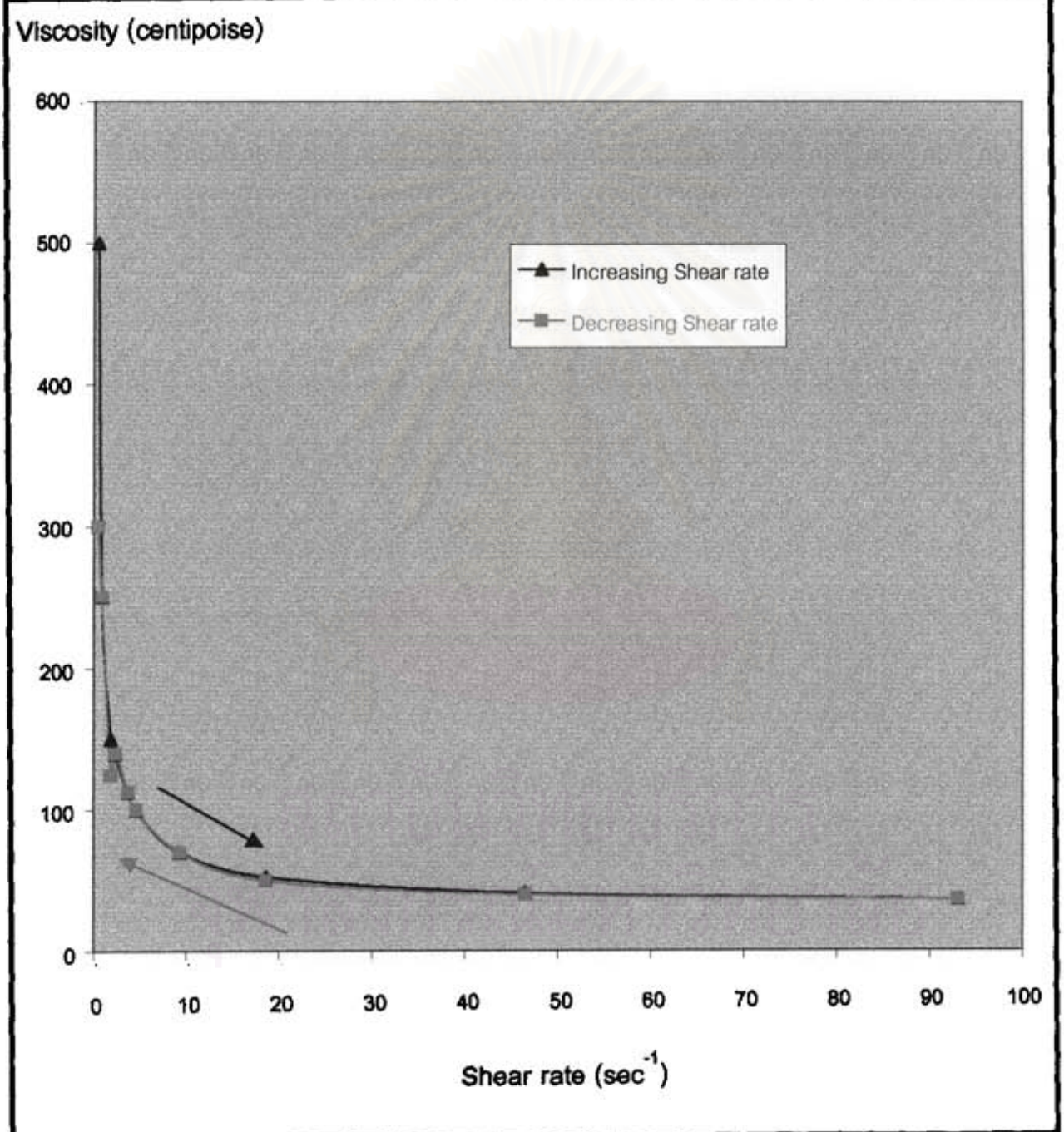


Fig. 6.84 Shear response of MT added 0.1 % BB Extractable humic acid (shear rate - viscosity curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0..416					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.33	3.72	4.65	9.30	18.60	46.50	93.00
Shear Stress (dynes / cm^2)	1.86	2.20	2.79	2.79	4.19	4.19	6.05	10.70	20.90	40.50
Shear Stress (dynes / cm^2)	1.39	1.86	2.79	2.79	3.72	4.19	6.97	10.20	21.40	40.50

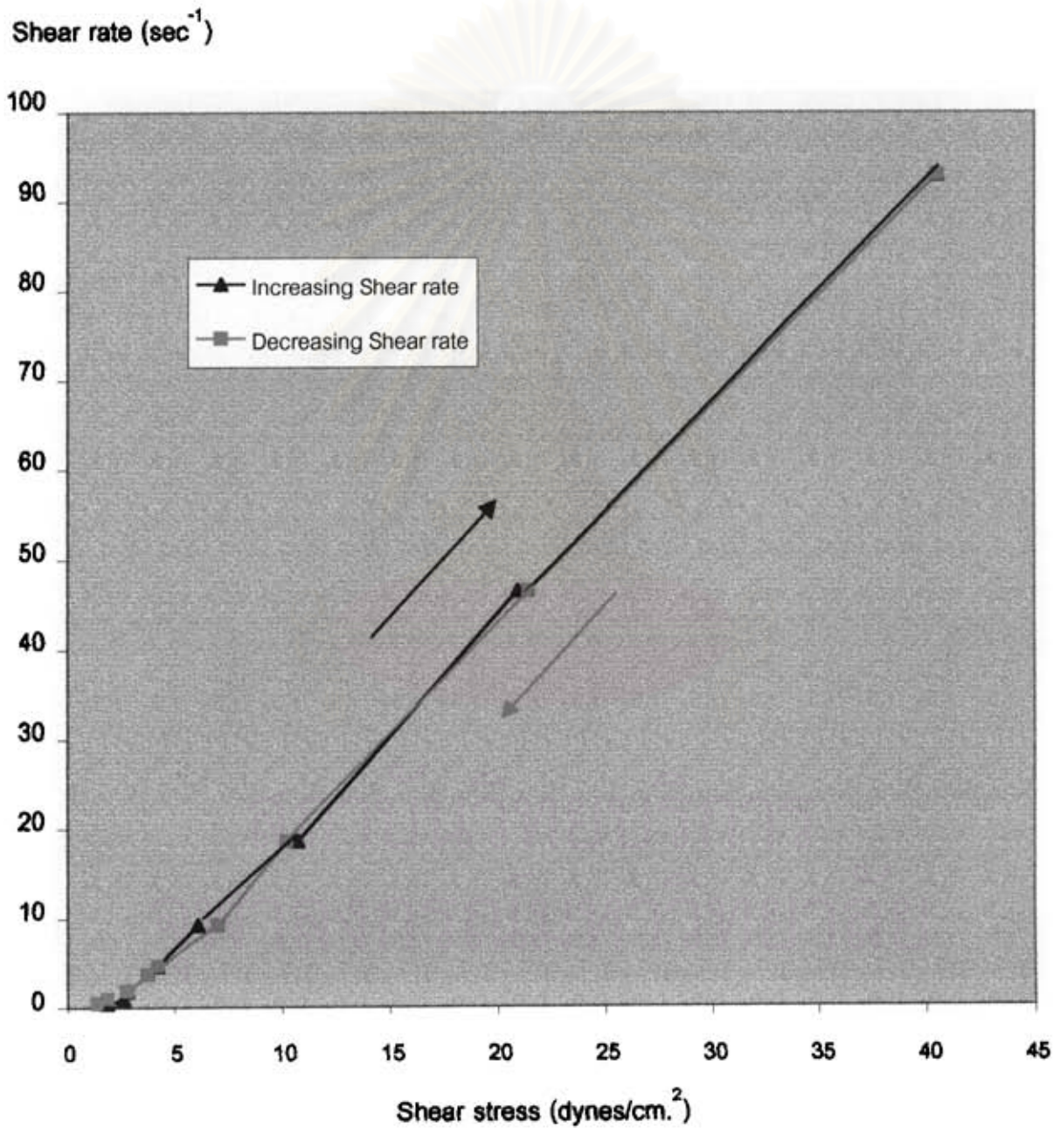


Fig. 6.85 Shear response of MT added 0.1 % Commercial humic acid (shear rate - shear stress curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.416					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.3	18.6	46.5	93
Viscosity (centipoise)	400	350	150	120	113	90	65	58	45	44
Viscosity (centipoise)	300	200	150	120	100	90	75	55	46	44

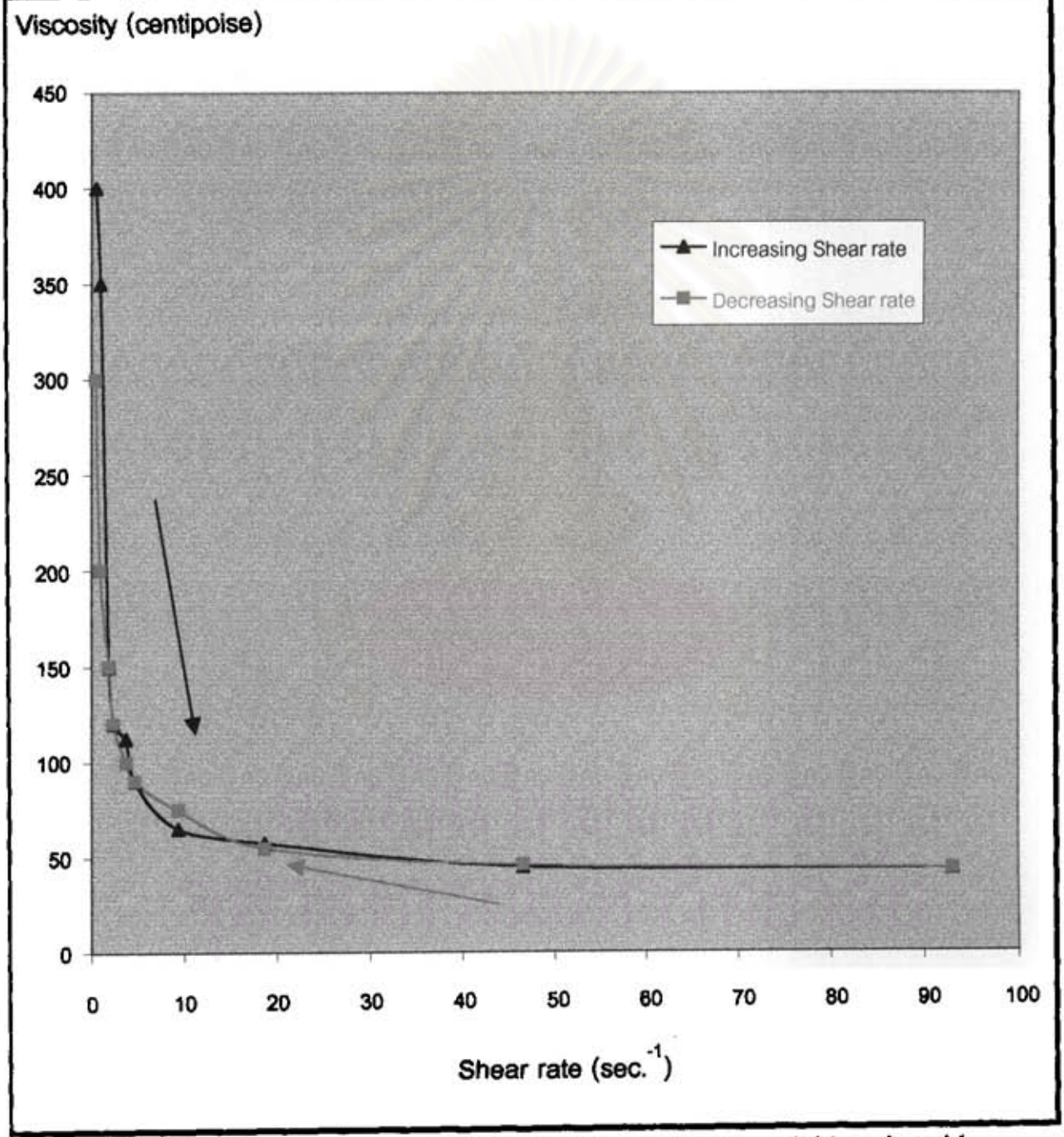


Fig. 6.86 Shear response of MT added 0.1 % Commercial humic acid (shear rate - viscosity curve).

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0..472					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear Stress (dynes / cm^2)	3.72	2.79	2.32	4.19	5.12	5.12	7.44	11.60	22.30	41.80
Shear Stress (dynes / cm^2)	2.32	2.79	3.26	4.65	4.65	4.65	7.44	11.20	22.30	41.80

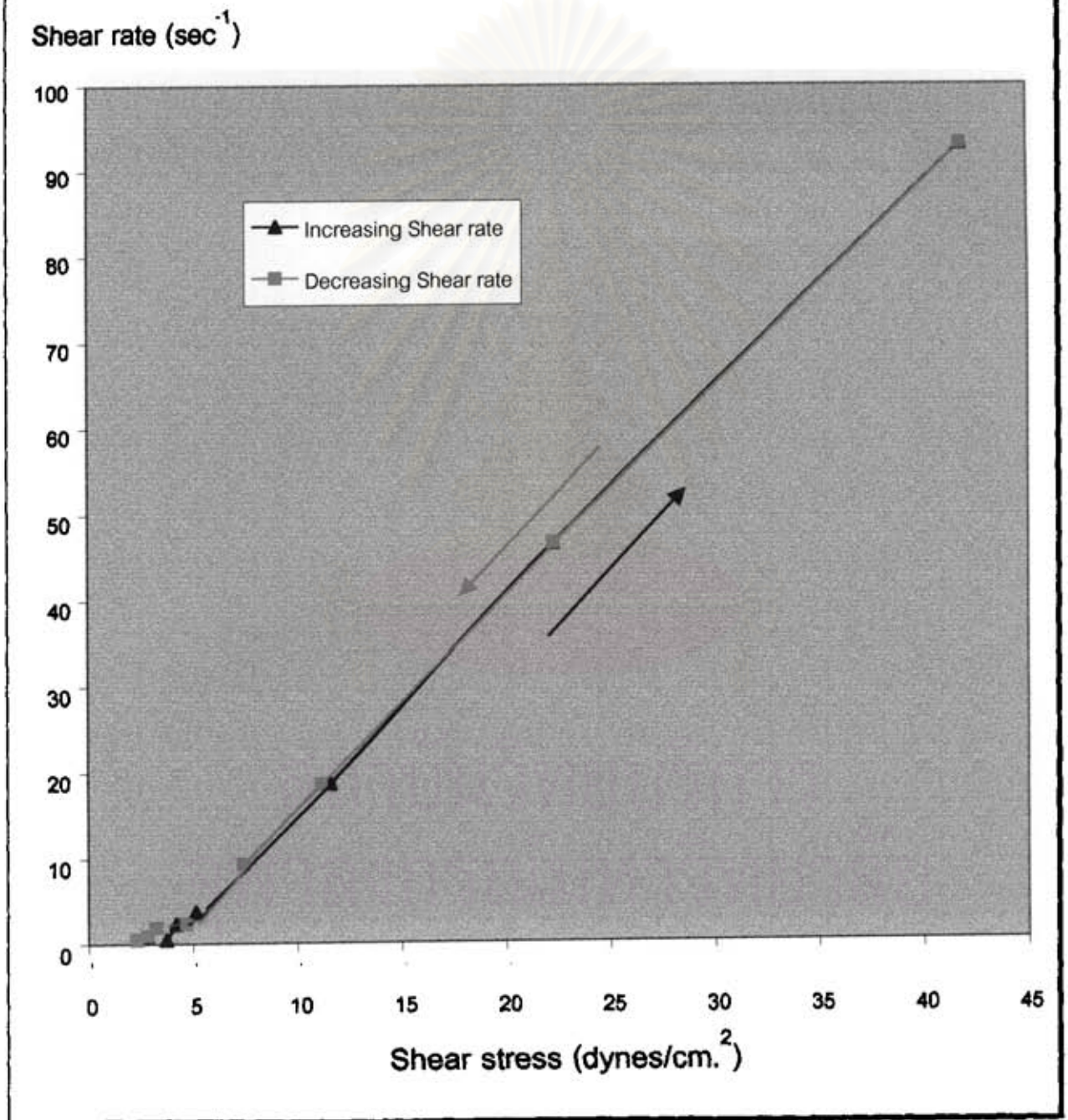


Fig. 6.87 Shear response of MT added 0.2 % Commercial humic acid (shear rate - shear stress curve).

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.472					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.3	18.6	46.5	93
Viscosity (centipoise)	800	250	180	150	138	110	80	63	48	45
Viscosity (centipoise)	500	300	250	140	125	100	80	60	48	45

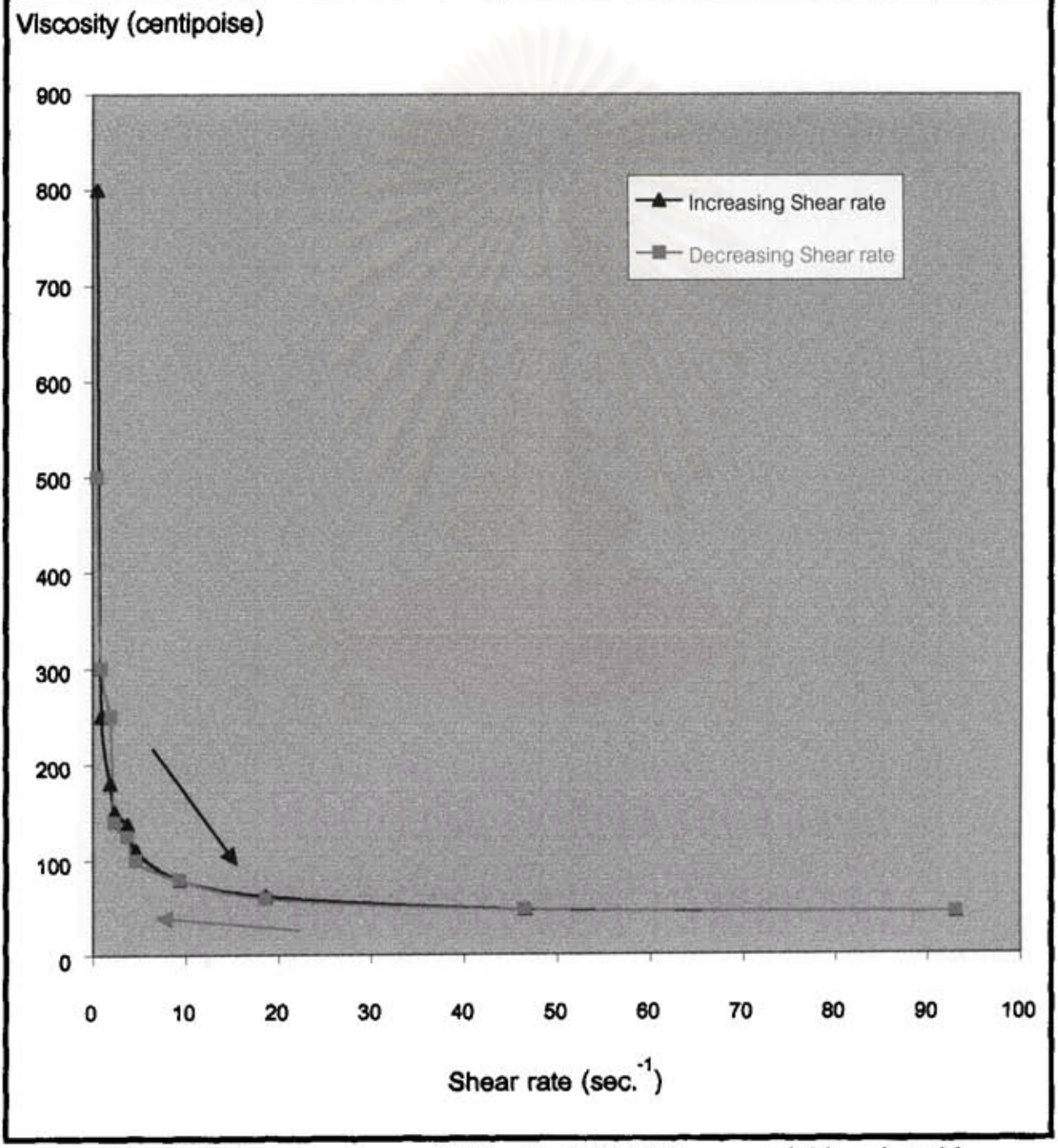


Fig. 6.88 Shear response of MT added 0.2 % Commercial humic acid (shear rate - viscosity curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.455					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec^{-1})	0.47	0.93	1.86	2.32	3.72	4.65	9.30	18.60	46.50	93.00
Shear Stress (dynes / cm^2)	1.86	2.79	4.19	2.79	4.19	4.65	6.51	10.70	20.50	38.10
Shear Stress (dynes / cm^2)	1.39	2.32	2.32	3.26	4.19	4.65	6.51	10.20	20.50	38.10

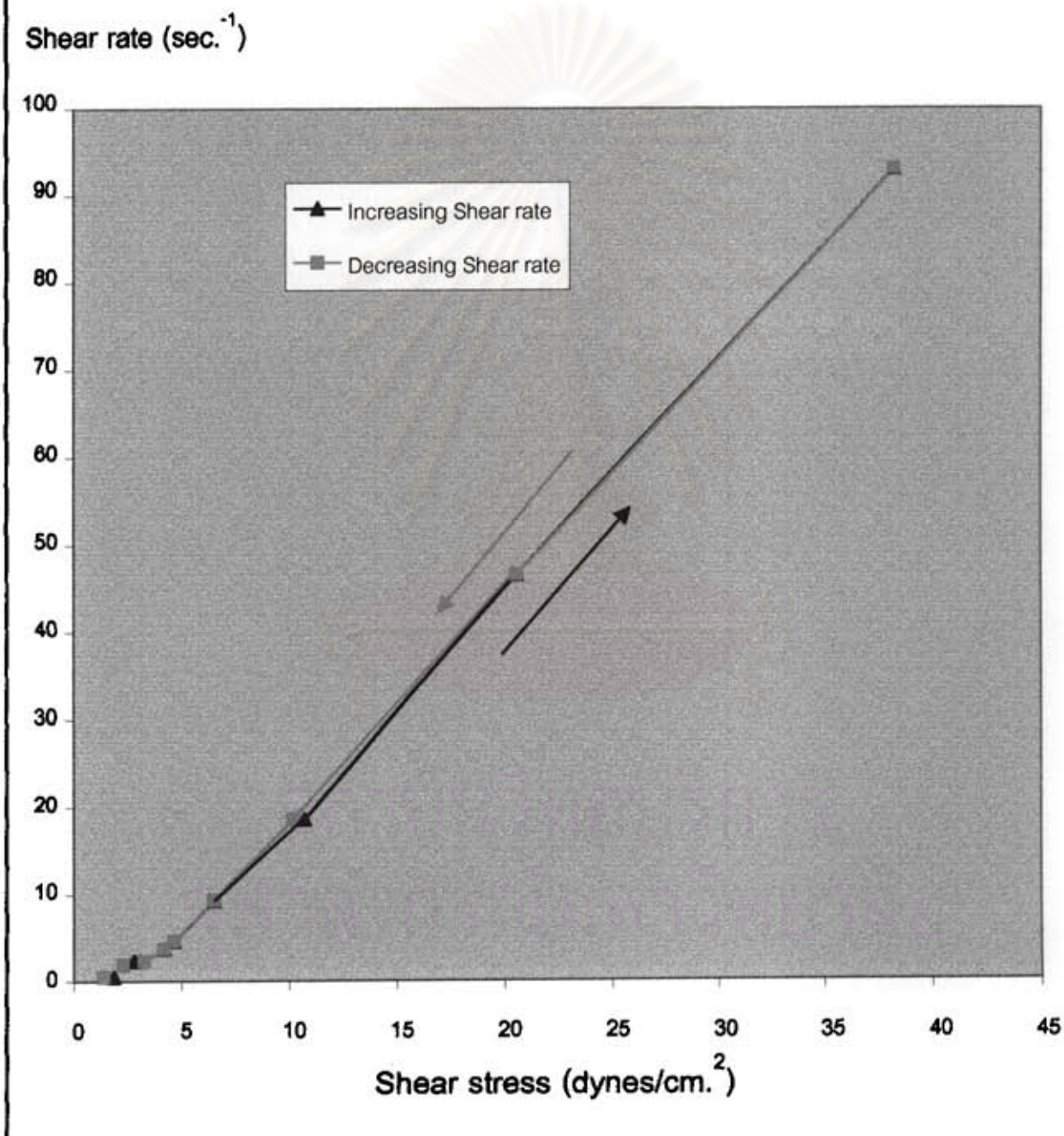


Fig. 6.89 Shear response of MT added 0.3 % Commercial humic acid (shear rate - shear stress curve)

Specific Gravity = 1.600					Brookfield Viscometer RV DVII+					
% Sodium Silicate = 0.455					Small sample adapter SC4 Series Spindle					
Remark : Change rpm. At 5 sec. Interval					Spindle NO. SC4 - 21					
Shear rate (sec.$^{-1}$)	0.47	0.93	1.86	2.33	3.72	4.65	9.3	18.6	46.5	93
Viscosity (centipoise)	400	300	225	120	113	100	70	58	44	41
Viscosity (centipoise)	300	250	125	140	113	100	70	55	44	41

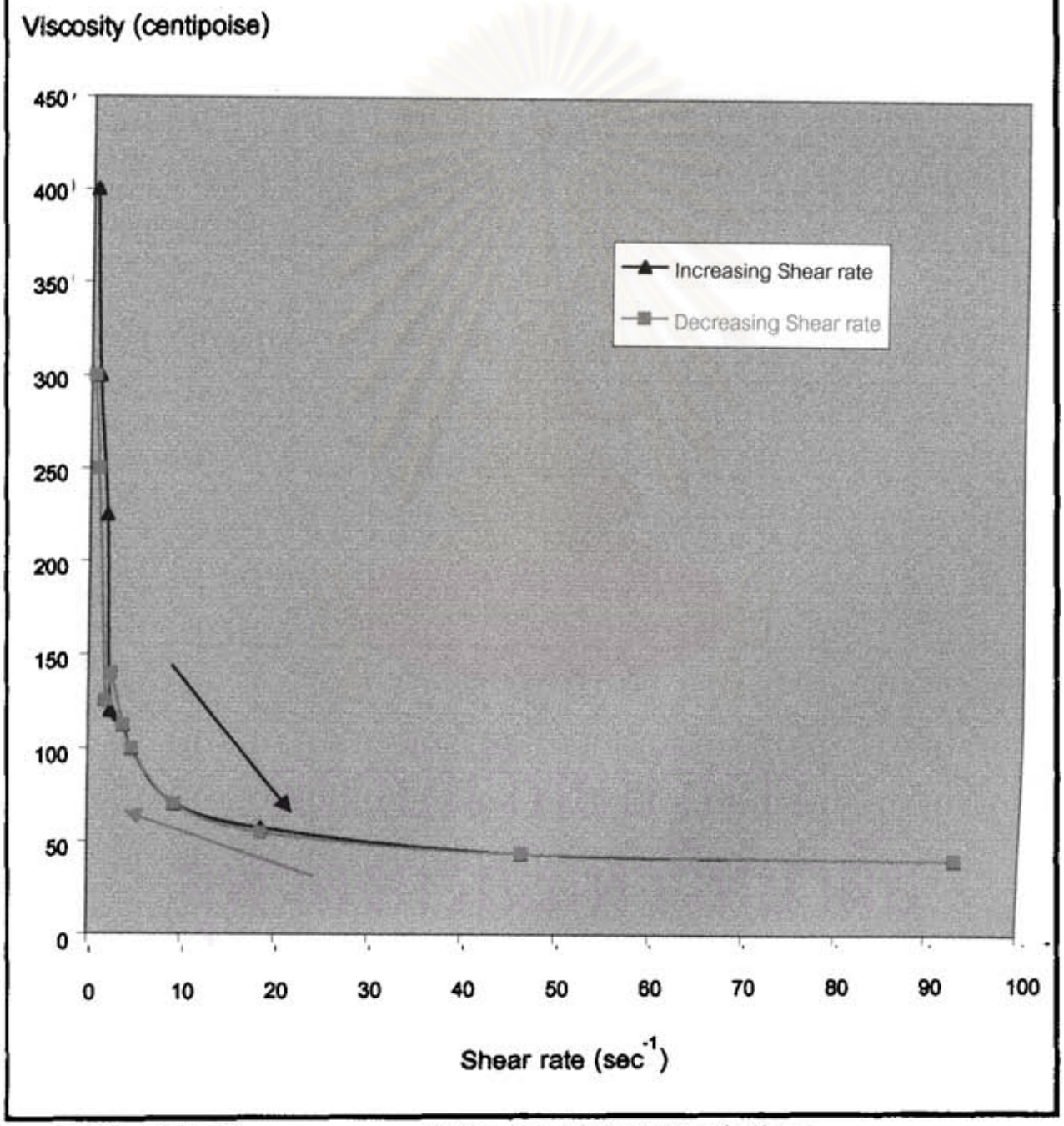


Fig. 6.90 Shear response of MT added 0.3 % Humic ligno (shear rate - viscosity curve)

6.4.5 Casting Properties

Table 6.6 Casting Properties of Ball Clays

Samples / Casting Properties	I			II				III		
	M8	MVW	MT	SB-75	HVC	REX	BB	JK	KK	WN	PC
Specific Gravity (gm/ml)	1.55	1.55	1.55	1.63	1.63	1.63	1.63	1.55	1.55	1.55	1.55
% Sodium Silicate	0.500	0.970	0.344	0.330	0.403	0.350	0.800	0.700	1.500	0.500	0.775
Viscosity (centipoise)	62	700	96	206	196	68	478	1746	1070	558	340
Overswing	355	345	355	343	345	355	345	315	260	325	345
Thixo (1 min.)	1	40	1	1	3	5	9	-	50	3	5
Cast Rate 30 min.(mm.)	1.8	3.0	5.0	1.5	2.0	2.0	2.0	2.5	3.0	1.5	1.5
Baroid Wet Cake (gm.)	40.14	57.43	97.10	27.61	48.43	50.40	47.75	31.16	28.24	20.22	23.89
Dry Cake (gm.)	29.91	39.06	68.31	20.89	35.91	38.69	35.98	20.23	19.18	14.47	16.57
%Water Retention	25.49	31.99	29.65	24.43	25.86	23.23	24.65	35.08	32.08	27.07	30.64
Weight of Filtrate (gm.)	10.57	7.81	21.28	4.49	7.70	11.76	8.11	4.43	4.20	4.95	4.09

Table 6.7 Casting Properties of MT and MT added with different sources of humic acid

Samples / Casting Properties	MT	MT + 0.1 % HVC Humic acid	MT + 0.1 % BB Humic acid
Specific Gravity (gm/ml)	1.60	1.60	1.60
% Sodium Silicate	0.333	0.388	0.505
Viscosity (centipoise)	110	156	86
Overswing	355	350	350
Thixo (1 min.)	0	1	0
Cast Rate 30min. (mm.)	3.8	4.7	2.0
Baroid Wet Cake (gm.)	80.34	99.97	43.88
Dry Cake (gm.)	58.94	73.42	33.53
% Water Retention	26.64	26.56	23.59
Weight of Filtrate (gm.)	16.75	16.37	10.67

Table 6.8 Casting Properties of MT added with different contents of commercial humic acid.

Samples / Casting Properties	MT + 0.1 % Commercial humic acid	MT + 0.2 % Commercial humic acid	MT + 0.3 % Commercial humic acid
Specific Gravity (gm/ml)	1.60	1.60	1.60
% Sodium Silicate	0.416	0.472	0.455
Viscosity (centipoise)	86	114	104
Overswing	351	350	351
Thixo (1 min.)	1	0	0
Cast Rate 30 min. (mm.)	3.0	2.8	2.5
Baroid Wet Cake (gm.)	60.85	58.17	52.19
Dry Cake (gm.)	45.35	44.20	39.78
% Water Retention	25.47	24.03	23.78
Weight of Filtrate (gm.)	12.97	12.24	11.25