References

1 Tippett, B.G. The Future of Textile Printing. *Proceedings of IS&T NIP17: International Conference on Digital Printing Technologies, Springfield, VA*, (2001): pp. 418-422.

2. Le, H.P. Progress and Trends in Ink-Jet Printing Technology. *J. Imaging. Sci. Technol.*: **42** (1998) : 49-62

3. Andreottola, M.A. Ink Jet Ink Technology. In Diamond, A.S. (eds), *Handbook of Imaging Materials.*; Marcel Decker: New York. 1991; pp. 527-544.

4. Thompson, B. Ink Jet Printing. *Printing Material: Science and Technology.*; Pira International: Wiltshire. 1998; pp. 462-467.

5. Wnek, W.J.; Andreottola, M.A.; Doll, P.F. and Kelly, S.M. Ink Jet Ink Technology. In Diamond, A.S. (eds), *Handbook of Imaging Materials.*; 2nd ed.; Marcel Decker: New York. 2002; pp. 531-535.

6. Fishman, D.H. Ink Jet Technology. *American Ink Maker*. **76(6)**(1997): 36-39

7. Moffatt, J.R. and Tsang, J.W. US Patent 6,323,257 (2001).

8. Gregory, P. Dyes Versus Pigment: The Truth. In I. Rezabka and R. Eschbach(eds.), *Recent Progress in Ink Jet Technology.*; USA. 1996; pp. 276-278.

9. Erdtmann, D.; Pitt, A.R.; Kocher, T.E. and Martin, T.W. US Patent 6,352,340 (2002).

10. Biegeleisen, J.I. *Screen Printing.*; Watson-Guptill Publication: New York. 1971; pp. 9-16.

11. Leach, R.H.; Joannou, J.; Armstrong, C.; Brown, J.F.; Mackenzie, M.J.; Randall, L. and Smith, H.G. *The Printing Ink Manual.*; 4th ed.; Blueprint: London. 1988; pp. 481-504.

12. Biegeleisen, J.I. *Screen Printing.*; Watson-Guptill Publication: New York. 1971; pp. 91-99.

13. Christic, R.M. *Pigments Structures and Synthetic Procedures.*; Burgess Science Press: Basingstoke. 1993; p. v.

14. Biegeleisen, J.I. *Screen Printing.*; Watson-Guptill Publication: New York. 1971; p. 122.

15. Sanders, J.D. *Pigments for Inkmakers.*; SITA Technology: London. 1989; pp. 5-6.

16. Marsh, J.T. *Textile Science (An Introductory Manual).*; Chapman&Hall: London. 1958; pp. 262-263.

17. Joseph, M.L. Natural Cellulosic Fibers. *Essentials of Textiles.*; Holt, Rinehart and Winstone: New York. 1971; pp. 33-41.

18. Hollen, N.; Saddler, J. and Langford, A.L. *Natural Cellulose Fibers and Cotton.*; 5th ed.; Macmillan Publishing: New York. 1979; pp.36-40.

19. Ingamells, W. The Attributes of Fibers. *In Color for Textile A User's Handbook.*; Society of Dyers and Colorists: West Yorkshire. 1993; pp. 51-53.

20. Lyle, D.S. Cellulose Fibers. *In Modern Textiles.*; John Wiley & Sons: New York. 1982; pp. 79-80.

21. Smith, B.F. Natural Fibers. *In Textiles in Perspective.*; Prentice-Hall: Englewood Cliffs. 1982; pp. 70-77.

22. Tortora, P.G. Textile Testing and Standards. *In Understanding Textile.*; Macmillan Publishing: New York. 1978; pp. 355-367.

23. Minolta Co, Ltd. *Precise Color Communication.*; IGHAJ: Osaka. 1994; p. 14.

24. Ingamells, W. The Modern Approach to Coloration. *In Color for Textiles A User's Handbook.*; Society of Dyers and Colourists: West Yorkshire. 1993; pp. 138-157.

25. Eldred, N.R. and Scarlett, T. Color. *In What the Printer Should Know about Ink.*; Pennsylvania: Graphic Arts Technical Foundation: New York. 1990; pp. 17-26.

26. Tortora, P.G. Fabric Structure: The Sum of Its Parts. *In Understanding Textile.*; Macmillan Publishing: New York. 1978; pp. 368-376.

27. Hamby, D.S. The Cotton Fiber. *In the American Cotton Handbook.*; 3rd ed.; Interscience Publishers: New York. 1965; pp. 76-77.

28. Grover, E. and Hamby, D.S. Analysis of Stress-Strain Curves. *In Handbook of Textile Testing and Quality Control.*; 2nd ed.; Wiley Eastern: India. 1988; pp. 406-407.

29. Miller, E. Fastness to Perspiration: Rubbing. *In Textiles Properties and Behaviour.*; BT Batsford: London. 1968; pp. I58-I59.

30. Schindler, S.; Wolfrum, J. and Weinsdorfer, I. H. New Comfort Weaves Using PET Filament Yarns. *ITB International Textile Bulletin*: **47**: 69-72.

31. Tortora, P.G. Fabric Structure: The Sum of Its Parts. *In Understanding Textile.*; Macmillan Publishing: New York. 1978; pp. 374.

32. Work, R.A. Challenges of Digital Ink Jet Pigment Textile. *Proceedings of IS&T NIP14: International Conference on Digital Printing Technologies, Springfield, VA*, (1998): pp. 247-249.

33. Chang, S.Y.P. High Color Performance in Industrial Application of Textile Ink Jet Printing. *Proceedings of IS&T NIP16: International Conference on Digital Printing Technologies, Springfield, VA*, (2000): pp. 536-539.

34. Smith, B. and Simonson, E. Ink Jet Printing for Textiles. *Textile Chemist and Colorist.*: **19(17)** (1997): 23-29.

35. Tincher, W.; Hu, Q.; Li,X.; Tian, Y. and Zeng, J. Coloration Systems for Ink Jet Printing of Textile. *Proceedings of IS&T NIP14: International Conference on Digital Printing Technologies, Springfield, VA*, (1998): pp. 243-246.

36. Tse, M.K. ang Briggs, J.C. Measuring Print Quality of Digitally Printed Textiles. *Proceedings of IS&T NIP14: International Conference on Digital Printing Technologies, Springfield, VA*, (1998): pp. 250-256.

37. Tsutsumi, T.; Sawada, M. and Nakano, Y. Polymer Emulsion-Based Ink Jet Colorant and Ink. *Proceedings of IS&T NIP15: International Conference on Digital Printing Technologies, Springfield, VA*, (1999): pp. 133-136.

38. Dawson, T.L. Ink Jet Printing of Textile under the Microscope. *JSDC*; **116** (February 2000): 52-59.

39. Grant, A. Pigmented Jet-Inks for Textile Applications. *Proceedings of IS&T NIP17: International Conference on Digital Printing Technologies, Springfield, VA*, (2001): pp. 431-434.

40. Komasatitaya, J. *Binder for Pigmented Inkjet Printing on Textiles.* Master's Thesis Department of Photographic Science and Printing Technology, Faculty of Science, Chulalongkorn University, 2001, pp. 71-72.

41. Sapchookul, L. *Effects of Ink Dispersion Fabric Printing by Pigmented Inkjet Inks.* Master's Thesis Department of Photographic Science and Printing Technology, Faculty of Science, Chulalongkorn University, 2001, pp. 116-117.

42. Marrion, A. *The Chemistry and Physics of Coating.*; Royal Society of Chemistry: Cambridge. 1994; pp. 28-29, 37.

43. Komasatitaya, J. *Binder for Pigmented Inkjet Printing on Textiles.* Master's Thesis Department of Photographic Science and Printing Technology, Faculty of Science, Chulalongkorn University; 2001; pp. 39-43.

44. Sapchookul, L. *Effects of Ink Dispersion Fabric Printing by Pigmented Inkjet Inks.* Master's Thesis Department of Photographic Science and Printing Technology, Faculty of Science, Chulalongkorn University, 2001; p.92.

45. Shaw, D.J. *Introduction to Colloid and Surface Chemistry.*; 3rd ed.; Butterworth: Boston. 1980; p. 223.

46. Schramm, G. *Introduction to Practical Viscosity.*; Gebruder HAAKE GMBH: West Germany. 1981, pp. 17-18.

47. Paul, S. *Surface Coating Science & Technology.*; 2nd ed.; John Wiley & Son.: Chichester. 1996; p. 454.

48. Nylen, P. and Sunderland, E. *Modern Surface Coatings.*; Interscience Publishers: New York. 1965, pp. 553-554.

49. Miles, L.W.C. *Textile Printing.*; 2nd.; West Yorkshire: The Society of Dyers and Colorists Publicating: Manchester. 1981; pp. 257-262.

50. Oliver, J.F. *Wetting and Penetration of Paper Surfaces.*; American Chemical Society: Washington D.C. 1992, pp. 399-407.

51. David, H.F. Pigmented Ink for Ink Jet System. *American Ink Maker.*: **77(2)**(1997): 36-39.

52. Byrne, C. Ink Jet Printing in the Textile Industry: Drawing up the Battleline. *A.T.A. Journal*: **5(12)** 2001: 33-40

53. Sime, K. and Bentley, P. Use of Analytical Techniques to Characterize the Stability of Difficult Ink Jet Pigment System. *Proceedings of IS&T NIP17: International Conference on Digital Printing Technologies, Springfield, VA*, (2001): pp. 87-91.

54. Kulbe, H.M. and Hawkyard, C.J. Fabric Pretreatment and Inks for Textile Ink Jet Printing. *ITB Dyeing/Printing/Finishing,* **(13)(4)**(1996): 5-12.

55. Yang, L. and Kruse, B. Chromatic Variation and Color Gamut Reduction due to Ink Penetration. *TAGA 2001*; Technical Association of the Graphic Arts: Rochester. 2001, pp.399-407.

56. Elias, H.G. *An Introduction to Polymer Science.*; 1st ed.; VCH Publishers: New York. 1997, p. 329.

57. Billmeyer, F.W. *Textbook of Polymer Science.*; 3rd ed.; Wiley Interscience: New York 1984, pp.339-340.

58. Stevens, M.P. *Polymer Chemistry An Introduction.*; 2nd ed.; Oxford University Press, Inc.,: New York 1990, p. 139.

59. Mortimer, A. *Color Reproduction in a Digital Age.*; Pira International: Wiltshire. 1998, pp. 108-109, 278.

APPENDICES

APPENDIX A

THE PARTICLE SIZE OF PIGMENT INKJET INK EVALUATED BY LASER ZETA POTENTIOMETER

Table A-1 The particle size of pigment dispersion and binder

Chemical type	Particle size (nm)
Cyan: PB 15:3	98 ± 45.3
Magenta: PR 122	177 ± 55.2
Yellow: PY 155	200 ± 100.5
Black: PBk 7	132 ± 65.1
NK Vanatex S-711 binder	161 ± 20.8
BR-700 binder	980 ± 650.6

Table A-2 The change of particle size of inkjet inks after 60-day stage under the room temperature, around at 25-30 °C

Pigmented inkjet inks	Particle size (nm): Stage time (wks)								
	Freshly prepared	1	2	3	4	5	6	7	8
C	127.3±70.4	125.4±41.3	114.9±37.5	119.4±44.5	121.8±38.8	121.8±42.5	126.8±44.5	122.9±32.7	123.1±45.3
M	180.8±85.4	175.9±54.44	178.2±55.4	175.8±51.7	178.5±60.7	178.5±69.1	155.4±49.8	172.3±46.4	185.6±45.7
Y	227.3±62.6	232.9±85.9	225.0±99.8	218.1±79.6	238.6±84.7	238.6±80.7	228.9±66.7	205.5±80.5	261.7±100.5
K	132.0±65.1	131.6±43.8	123.5±38.9	123.9±39.4	126.0±33.9	126.0±79.9	116.2±30.4	127.3±31.5	144.3±37.1

APPENDIX B

THE METHOD OF CALCULATION FOR COLOR GAMUT VOLUME

Method of Calculation of Color Gamut Volume

Mathematical Value of Image Data

To evaluate the SHIPP Image, the following 3 items are carried out.

1. Mathematical value of Image (minimum value, maximum value, average value, dispersion, co-dispersion, single dimensional histogram)

2. Analysis of color information using a principal component analysis

3. Special frequency characteristics (self correlation function)

Procedure Check Sum is calculated for checking justification of image data

B.1 Mathematical Value of Image

The average value, dispersion, and co-dispersion matrix for each plane are given by following equations, when N is the total number of image pixels.

[Average Value of Image]

$$\begin{pmatrix} \overline{P_1} \\ \overline{P_2} \\ \overline{P_3} \end{pmatrix} = \begin{pmatrix} \sum \overline{P_1} \\ \sum \overline{P_2} \\ \sum \overline{P_3} \end{pmatrix} \quad \text{(B-1)}$$

[Dispersion Co-dispersion Matrix]

$$\begin{pmatrix} V_{P_{11}} & V_{P_{12}} & V_{P_{13}} \\ V_{P_{21}} & V_{P_{22}} & V_{P_{23}} \\ V_{P_{31}} & V_{P_{32}} & V_{P_{33}} \end{pmatrix} = \frac{1}{N} \begin{pmatrix} \sum\left(P_1 - \overline{P}_1\right)^2 & \sum\left(P_1 - \overline{P}_1\right)\left(P_2 - \overline{P}_2\right) & \sum\left(P_1 - \overline{P}_1\right)\left(P_3 - \overline{P}_3\right) \\ \sum\left(P_2 - \overline{P}_2\right)\left(P_1 - \overline{P}_1\right) & \sum\left(P_2 - \overline{P}_2\right)^2 & \sum\left(P_2 - \overline{P}_2\right)\left(P_3 - \overline{P}_3\right) \\ \sum\left(P_3 - \overline{P}_3\right)\left(P_1 - \overline{P}_1\right) & \sum\left(P_3 - \overline{P}_3\right)\left(P_2 - \overline{P}_2\right) & \sum\left(P_3 - \overline{P}_3\right)^2 \end{pmatrix} \quad \text{(B-2)}$$

V_{11}, V_{22} and V_{33}, the diagonal component, are dispersions for each image data on each plane. Out diagonal components are co-dispersion between corresponding planes.

The correlation between planes is given by Eq. (B-3)

$$\begin{pmatrix} R_{P_{11}} & R_{P_{12}} & R_{P_{13}} \\ R_{P_{21}} & R_{P_{22}} & R_{P_{23}} \\ R_{P_{31}} & R_{P_{32}} & R_{P_{33}} \end{pmatrix} = \begin{pmatrix} 1 & \frac{V_{P_{12}}}{\sqrt{V_{P_{11}}}\cdot\sqrt{V_{P_{22}}}} & \frac{V_{P_{13}}}{\sqrt{V_{P_{11}}}\cdot\sqrt{V_{P_{33}}}} \\ \frac{V_{P_{21}}}{\sqrt{V_{P_{22}}}\cdot\sqrt{V_{P_{11}}}} & 1 & \frac{V_{P_{23}}}{\sqrt{V_{P_{22}}}\cdot\sqrt{V_{P_{33}}}} \\ \frac{V_{P_{31}}}{\sqrt{V_{P_{33}}}\cdot\sqrt{V_{P_{11}}}} & \frac{V_{P_{32}}}{\sqrt{V_{P_{33}}}\cdot\sqrt{V_{P_{22}}}} & 1 \end{pmatrix} \quad \text{(B-3)}$$

Generally, the co-relation between RGB images is high, therefore, it is difficult to only calculate the dispersions of each plane to check the width of the distribution of color data. Therefore, the width of distribution of image data is given using the principal component analysis.

It has to dealt with great care on calculating the mathematical data in which its individual natural image contains characters of "SHIPP RGB", "SHIPP LAB", "SHIPP XYZ" as a discrimination mark. The part of character corresponds to 0 or 255 for "SHIPP RGB" and "SHIPP LAB". It is not reasonable to include these character data to accept the properties of image by such a calculation of mathematics. From this reason, one has to eliminate this character area in the original image data before carrying out the calculation.

The positions of character are pointed out in the Figure B.1 as A and B where in the position data are written in Table B.1.

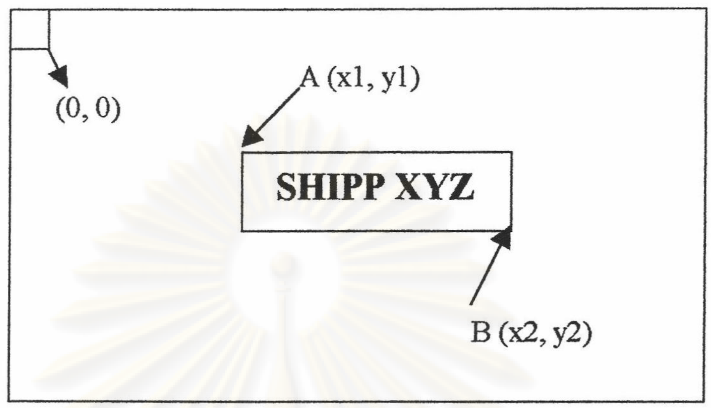


Figure B.1 The positions of character

Table B.1

Image	A (x1,y1)	B (x2, y2)	Size
Bride RGB	(2770, 35)	(3035, 71)	266 x 37
Harbor RGB	(34, 35)	(299, 71)	266 x 37
Wool RGB	(3794, 35)	(4059, 71)	266 x 37
Bottles RGB	(2770, 35)	(3035, 71)	266 x 37
Bride LAB	(2770, 36)	(3021, 72)	252 x 37
Harbor LAB	(34, 36)	(285, 72)	252 x 37
Wool LAB	(3784, 36)	(4045, 72)	252 x 37
Bottles LAB	(2770, 36)	(3021, 72)	252 x 37
Bride XYZ	(2770, 36)	(3016, 72)	247 x 37
Harbor XYZ	(34, 36)	(280, 72)	247 x 37
Wool XYZ	(3794, 36)	(4040 72)	247 x 37
Bottles XYZ	(2770, 36)	(3016, 72)	247 x 37

B.2 Principal Component Analysis

The principal analysis is the method that gives effectively the information on original space of minimum variables by converting the orthogonal axis transformation under the minimum correlation for each variable. To get this principal component, one needs solve the inherent value of dispersion and co-dispersion matrix.

It is known that when V is 3x3 of dispersion and co-dispersion matrix, x is the length of a 3 row vector, λ is a scholar, the principal components are the general solution of the following equation.

$$V \cdot x = \lambda \cdot x \quad \text{(B-4)}$$

The 3 values satisfing this equation are called the inherent value λ, and the inherent vector x.

The principal component is equal to the inherent vector in the dispersion and co-dispersion analysis. The dispersion of principal component equals to the inherent value. The contribution of each principal component is given by Equation (B-5):

The contribution of n-th principal component = n-th inherent value / sum of inherent value (B-5)

The value indicates how the principal component reflects the extent of information of original data.

The 3-principal components, which are mutually orthogonal, so the multiple of standard deviation of each principal component (= root of the inherent value), express the distribution of color on 3 dimensional spaces, i.e., Volume.

Volume V_{3D} on 3 dimensional spaces is defined as the following:

$$V_{3D} = \sqrt{\lambda_1} \cdot \sqrt{\lambda_2} \cdot \sqrt{\lambda_3} \qquad \text{(B-6)}$$

APPENDIX C

FT-IR SPECTRA OF POLYMER BINDERS

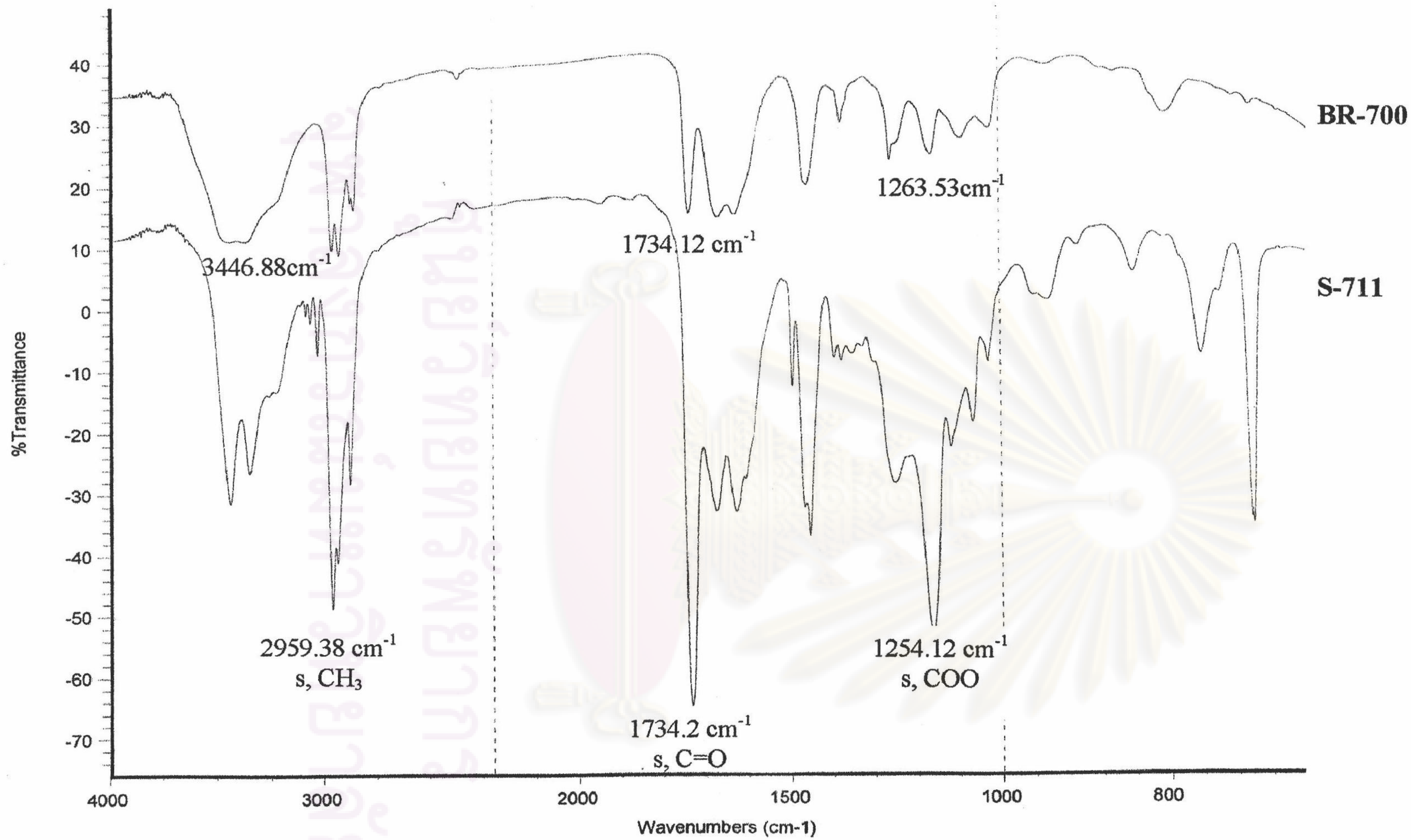


Figure C-1 FT-IR Spectra of BR-700 and S-711 polymer binders

APPENDIX D

MODULUS AND GLASS TRANSITION TEMPERATURE OF POLYMER BINDERS

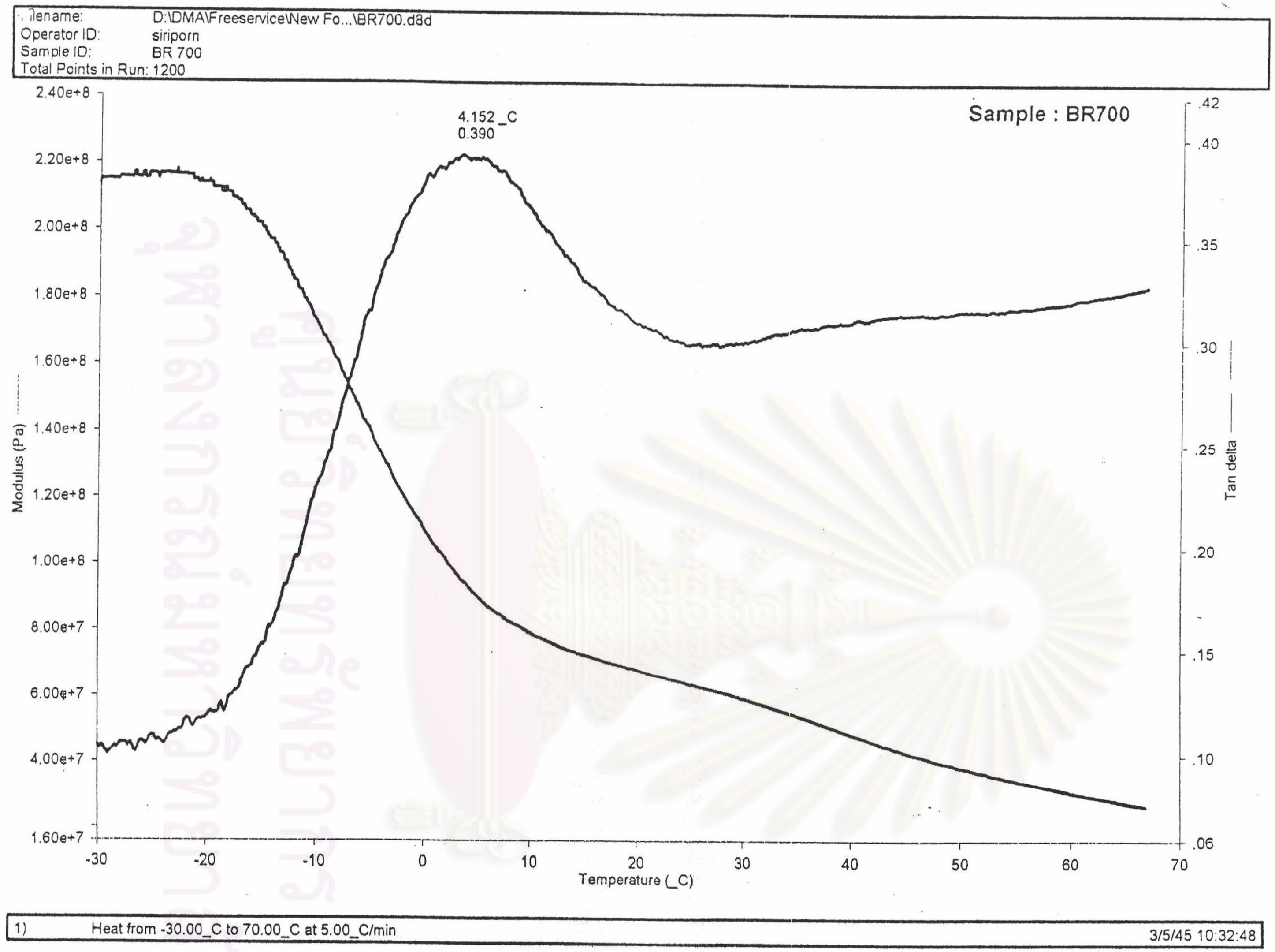


Figure D-1 Modulus and glass transition temperature of BR-700 polymer binder

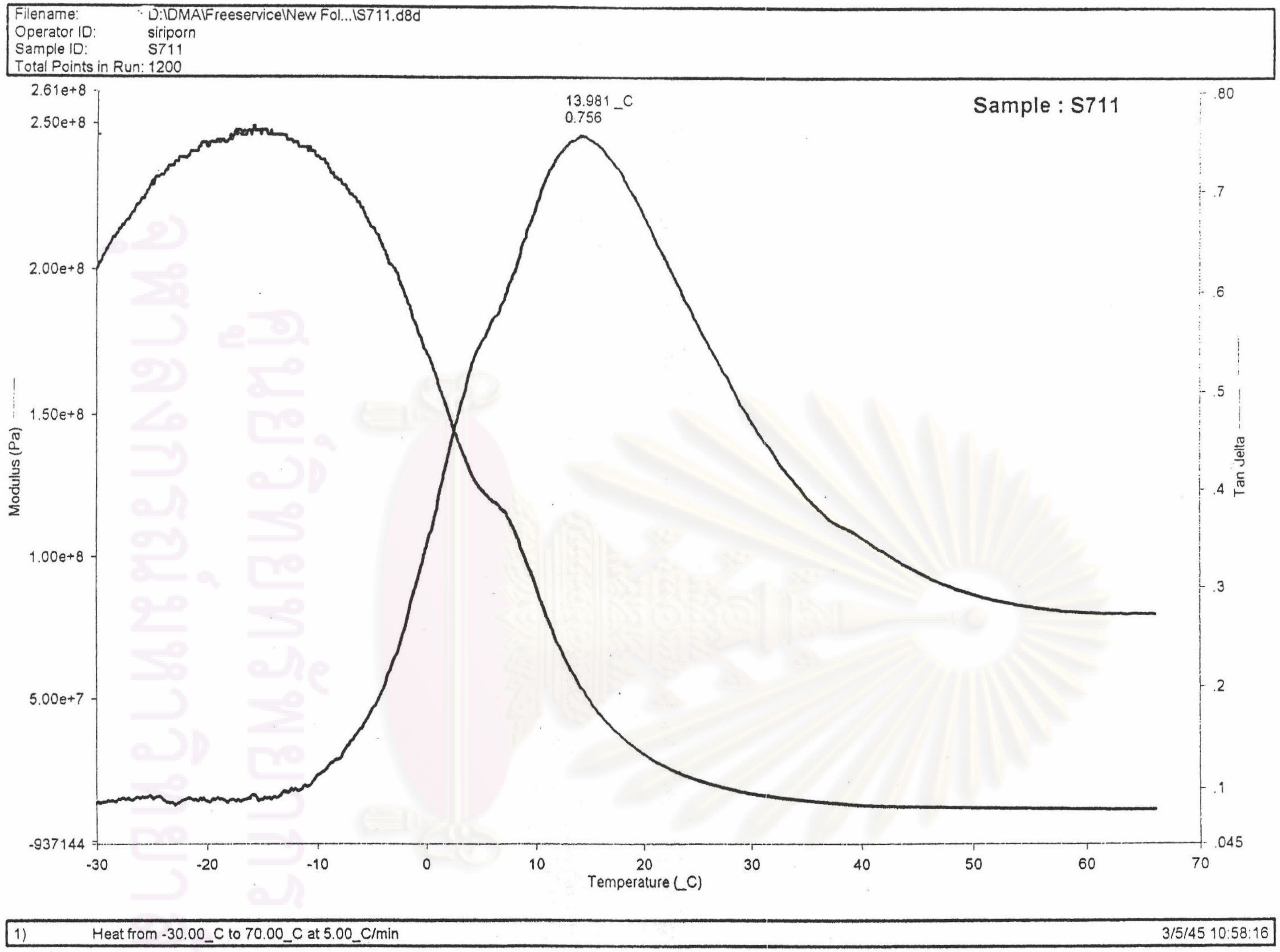


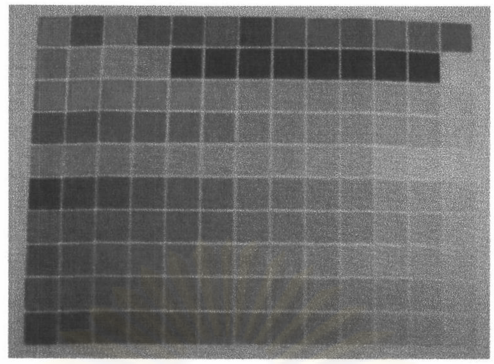
Figure D-2 Modulus and glass transition temperature of S-711 polymer binder

APPENDIX E

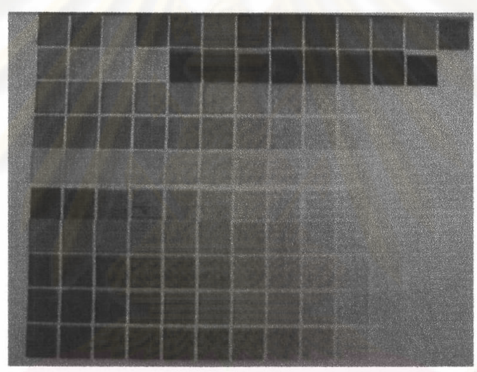
PATTERN OF COLOR CHART FOR INKJET PRINTING AND SCREEN PRINTING

(a) (b)

Figure E-1 Pattern of color chart: (a) inkjet printing and (b) screen printing



(a)



(b)

Figure E-2 Pattern of tone reproduction: (a) inkjet printing and (b) screen printing

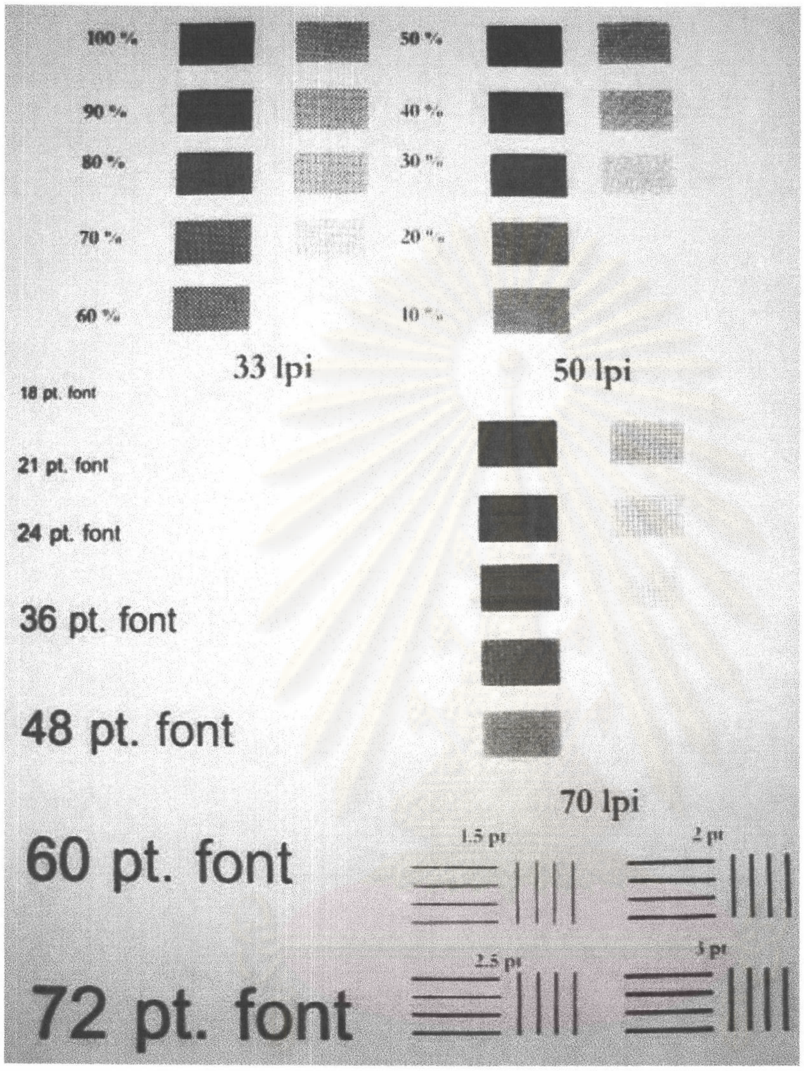


Figure E-3 Pattern of screen printing

VITA

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