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Utilizing the Horizontal and Vertical Size Presses for Optimum Two-Sided Color Correction under Acid and Neutral Conditions

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UTILIZING THE HORIZONTAL AND VERTICAL SIZE PRESSES FOR OPTIMUM TWO-SIDED COLOR CORRECTION UNDER ACID AND NEUTRAL CONDITIONS

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TABLE OF CONTENTS

ABSTRACT

This Engineering Problem investigates the utilization of the horizontal and vertical size presses for optimum two-sided color correction.

This was accomplished by making paper at the Western Michigan University Pilot Plant Fourdrinier papermachine. Paper was made under an acid system and a neutral system. A red anionic direct dye was added at the wet-end to internally dye the sheet. Color two-sidedness was induced by manipulating the wet-end vacuum elements, as well as the Fourdrinier shake. In addition, the red anionic direct dye that was used is known for it's "topsided" characteristics.

The paper was then surface colored using the size presses. Trials were performed using a red anionic direct dye, a red cationic direct dye, and a red acid dye. These dyes were applied to the "lighter" wire side, along with ethylated starch: the felt side of the sheet had only ethylated starch applied at the size press.

Results show that anionic direct dye is the most economical dye to use in the size press for color two-sided correction. This is the case for either size press (horizontal or vertical). The results were also the same for both wet-end systems (acid and neutral). The ranking of the surface dyes, based on the addition rates required to maintain quality two-sided correction, were the anionic direct dye, followed by the acid dye, followed by the cationic direct dye (which was the most expensive to use at the size press.

INTRODUCTION

This project recommends a dye classification to be used on the size press (horizontal or vertical for surface coloring) that best corrects color two-sidedness for a specific wet-end condition (acid sizing system or neutral sizing system).

Since a large percentage of the specialty mills use anionic direct dyes internally at the wet-end, this project also used an anionic direct dye at the wet-end. The vertical and horizontal size presses used in this project applied starch to the felt side and starch/color to the wire side. This was done to bring up the "weaker" colored wire side to a color comparable to the felt side color (which is deeper in color). This color difference between the felt and wire side was purposely induced at the time of paper manufacture. The dyes used in the size press for surface coloring were an anionic direct dye, a cationic direct dye, and an acid dye. These three dye classifications (anionic direct, cationic direct, and acid) were compared as to which is the most economical dye to use in the size press, and still have quality color two-sidedness correction.

The systems that were evaluated were the acid sizing system corrected with the horizontal size press, the neutral sizing system corrected with the horizontal size press, the acid sizing system corrected with the vertical size press, and the neutral sizing system corrected with the vertical size press.

The results from this project should aid the papermaker in reducing the cost of correcting color two-sidedness with the size press.

Background

Color two-sidedness is a major problem that faces every papermaker who internally dyes paper. Producing paper at faster speeds, using more hardwood fiber to give better printablility of the sheet surface, and using higher filler content for cost savings are strategies that must be followed if the papermaker is to be competitive. However, all of these strategies have dramatically increased color two-sidedness.

Dye companies and papermakers have worked together many years trying to alleviate the color two-sidedness problem. By using different dye classifications (acid, basic, and direct), modifying the wet-end chemistry (using fixing agents, retention aids, etc ...), and surface coloring (size press coloring and calender coloring), color two-sidedness can be minimized.

Traditionally, using a dye in the size press for surface coloring to help reduce color two-sidedness has been with the same type (classification) of dye that was used at the wet-end (internal dye). In other words, if the papermaker used a red anionic direct dye internally at the wet-end, the same red anionic direct dye would be used at the size press for surface coloring. The primary reason for this is economics; the papermaker does not have the luxury of taking valuable papermachine time to experiment with all of the types and classifications of dyes that are available. What is used in the size press is what is handy and available: the dye which is at the wet-end (internally). Also, it would be far too expensive for a dye company to rent papermachine time for the above mentioned study.

Using the size press for surface coloring to minimize color two-sidedness is a fairly common practice in the paper industry. However, no work has been found that actually recommends what type of dye classification to use in the size press (for surface coloring) that would be compatible with a wet-end (internal) dye that would best (economically) correct color two-sidedness. Investigation through manual and computer literature search, as well as direct contact with the two major dye suppliers for the paper industry, has turned up no work of this kind.

Besides the obvious design and operational differences, it is well known that different size press configurations (horizontal, vertical, and inclined) each impart slightly different surface treatment characteristics. Since a paper machine will have only one size press configuration, the knowledge of which dye classification to use (for that particular size press) that would best correct color two-sidedness would be tremendously important.

Since some of the acid sizing paper mills are, or have, converted to alkaline or neutral sizing, this dye compatibility problem previously described would have to be investigated for both the acid and neutral systems.

This project looked at the compatibility of three dye classifications (acid dye, anionic direct dye, and cationic direct dye) for surface coloring (with a vertical or horizontal size press) to that of a wet-end condition (acid system or neutral system). In industry terms, whichever size press configuration is employed in the mill (be it vertical or horizontal) and, whichever wet-end condition is used (be it acid or neutral) this project recommends a dye classification for surface coloring at the size press that would be the most economical to use to correct color two-sidedness for a sheet that is internally dyed with an anionic direct dye.

EXPERIMENTAL PROCEDURE

The experiment consisted of two phases, the papermaking phase (Phase I) and the size press phase (Phase II).

Phase I -- Papermaking

Paper was made on the Western Michigan University Pilot Plant Fourdrinier papermachine. Table I shows the conditions of the acid sizing system. Table II shows that conditions of the neutral sizing system.

The furnish for both the acid and neutral systems consisted of 50 % Northern Hardwood and 50 % Northern Softwood. There was a total of eight beaters prepared. The ranges for the freeness values for the acid system are given in Table I. The ranges for the freeness values for the neutral system are given in Table II. The individual freenesses for each beater are given in Appendix I. The softwood was refined with a doubledisk refiner: the hardwood was "tickled" with a Claflin refiner. Table I shows that neuphor addition was adjusted to obtain 100 seconds on the Hercules Sizing Tester. The individual HST values from random "spot" checks are listed in Appendix II. Table II shows that the Hercon addition was adjusted to obtain 100 seconds on the Hercules Sizing Tester. Before a sizing test was made on the Hercon sized paper, the sample was oven-aged

Table I.
Papermachine Conditions Under the Acid System

Freeness (Northern Hardwood)	563-567 ml CSF
Freeness (Southern Softwood)	418-428 ml CSF
Alum (aluminum sulfate)	2 % addition
Clay (filler clay)	20 % addition
Neuphor	adjusted to 100 HST
pH	4.8
Internal Red Anionic Direct Dye	30 lbs./ton

Table II.

Papermachine Conditions Under the Neutral System

Freeness (Northern Hardwood)	565-575 ml CSF
Freeness (Southern Softwood)	420-423 ml CSF
Calcium Carbonate (filler)	20 % addition
Hercon	adjusted to 100 HST
pH	7.2
Internal Red Anionic Direct Dye	30 lbs./ton

for five minutes at 105^{O}C (AKD internal sizing). The individual HST values from random "spot" checks are listed in Appendix II.

The WMU Pilot Plant papermachine has a vertical size press. While the paper was being made (Phase I), the vertical size press was bypassed (opened). Therefore no surface treatment was applied at the size press during this paper manufacturing phase. The sheet was dried to 2.0 - 2.2 percent moisture at the reel. Once a paper roll was built, it was moisture proof wrapped immediately after the "turn-up". This was done to minimize any moisture changes to the sheet during the interim time before the size press applications.

Table III shows the papermachine variables held constant for the acid and neutral systems. Appendix III lists the actual papermachine conditions for both the acid and neutral systems.

During this papermaking phase, a red anionic direct dye was added at the wet-end. This particular red anionic direct dye is known as a top-sided dye. The addition rate at the wet-end for this dye was 30 lbs./ton (see Table I and II). Besides using this top-sided dye, the wet-end vacuum elements, as well as the Fourdrinier shake, were manipulated to maximize the color two-sidedness.

Evaluation of Color Two-Sidedness Before Size Press Application

At this point (between Pase I and Phase II), color twosidedness generated by the wet-end was visually evaluated. This was done because there needs to be a starting point to determine dye addition rates for the size press application. The method for calculating dye addition rates (at the size press) was based on estimated starch pick up rates. Also used for these calculations was "rule-of-thumb" strength differences between the acid, anionic direct, and cationic direct dyes. Appendix IV shows these calculations, including the relative strengths of the acid, anionic direct, and cationic direct dyes.

The color two-sidedness for the acid system was visually judged to have a five percent difference between the felt and wire sides, the wire side being the weaker side. The color two-sidedness for the neutral system was visually judged to be fifteen percent different between the felt and wire sides, the wire side being the weaker side.

Table III.
Papermaking Phase (Phase I)
Acid and Neutral Systems

Basis Weight (24 x 36 - 500)	60 lbs./rm
Production	160 lbs./hr
Moisture at the reel	2.0 - 2.2 %

Size Press Applications (Phase II)

Vertical Size Press-

For the vertical size press application, the paper rolls (under acid & neutral conditions) that were previously manufactured were placed between the first dryer section and the wet press. The WMU Pilot Plant papermachine is designed so that the wet-end can be shut down while the dryer section and the remainder of the papermachine can still keep running. In other words, a size press trial can be performed on rolls already manufactured.

The roll placed between the first dryer section and the wet press was threaded through the dryer section, bypassing the dryer cans, except for the dryer can immediately before the vertical size press. The paper was threaded around this dryer can, which was used as a preheater to raise the sheet temperature before it entered the size press.

There were three trials performed on the acid system paper and three trials performed on the neutral system. Trial one was ethylated starch on the felt side and ethylated starch/anionic direct dye on the wire side. Trial two was ethylated starch on the felt side and ethylated starch/cationic direct dye on the wire side. Trial three was ethylated starch on the felt side and ethylated starch/acid dye on the wire side. The addition rates are presented on Table IV, which are based on the calculations in Appendix IV. Table V shows the size press variables that were held constant.

Horizontal Size Press-

The horizontal size press trial was performed at Simpson Plainwell Paper Company, Plainwell, Michigan. They have a pilot horizontal size press that is equipped with IR sheet preheaters before the size press and steam dryer cans after the size press. The deckle of the horizontal size press is 12 inches. To accomodate this deckle, the wet-end water squirts were narrowed during the paper manufacturing phase. The horizontal size press trial was an exact duplicate of the vertical size press trial. There were three trials performed on the acid system paper and three trials performed on the neutral system. Trial one was ethylated starch on the felt side and ethylated starch/anionic direct dye on the wire side. Trial two was ethylated starch on the felt side and ethylated starch/cationic direct dye on the wire side. Trial three was ethylated starch on the felt side and ethylated starch/acid dye on the wire side. The addition rates are presented on Table VI, which are based on the calculations in Appendix IV. Table V shows the size press variables that were held constant.

Table IV
Dye Additions for the
Vertical Size Press
(Acid & Neutral Sizing Systems)

Acid System --
Anionic Direct Dye:
1.52 grams dye/25 lbs. surface starch
4.54 grams dye/25 lbs. surface starch
7.56 grams dye/25 lbs. surface starch

Cationic Direct Dye:
1.52 grams dye/25 lbs. surface starch
7.56 grams dye/25 lbs. surface starch
15.12 grams dye/25 lbs. surface starch

Acid Dye:
0.76 grams dye/25 lbs. surface starch
1.52 grams dye/25 lbs. surface starch
2.27 grams dye/25 lbs. surface starch

Neutral System --
Anionic Direct Dye:
7.56 grams dye/25 lbs. surface starch
15.12 grams dye/25 lbs. surface starch
22.68 grams dye/25 lbs. surface starch

Cationic Direct Dye:
15.12 grams dye/25 lbs. surface starch
22.68 grams dye/25 lbs. surface starch
30.24 grams dye/25 lbs. surface starch

Acid Dye:
1.52 grams dye/25 lbs. surface starch
3.79 grams dye/25 lbs. surface starch
6.05 grams dye/25 lbs. surface starch

Table V.

Size Press Variables Held Constant

	Horizontal	Vertical	Units
Moisture Entering S/P	2.0-2.2	2.0-2.2	%
Moisture After S/P	5.85-6.0	5.75-6.0	%
Starch Temp., felt side	125	125	^oF
Starch/Color Temp., wire side	125	125	^oF
Starch Solids	5.8-6.2	5.8-6.2	%
Size Press Loading	40	40	psi
Size Press Speed	100	100	fpm

Table VI
Dye Additions for the
Horizontal Size Press
(Acid & Neutral Sizing Systems)

Acid System --
Anionic Direct Dye:
1.52 grams dye/25 lbs. surface starch
4.54 grams dye/25 lbs. surface starch
7.56 grams dye/25 lbs. surface starch

Cationic Direct Dye:
1.52 grams dye/25 lbs. surface starch
7.56 grams dye/25 lbs. surface starch
15.12 grams dye/25 lbs. surface starch

Acid Dye:
0.76 grams dye/25 lbs. surface starch
1.52 grams dye/25 lbs. surface starch
2.27 grams dye/25 lbs. surface starch

Neutral System --
Anionic Direct Dye:
7.56 grams dye/25 lbs. surface starch
15.12 grams dye/25 lbs. surface starch
22.68 grams dye/25 lbs. surface starch

Cationic Direct Dye:
15.12 grams dye/25 lbs. surface starch
22.68 grams dye/25 lbs. surface starch
30.24 grams dye/25 lbs. surface starch

Acid Dye:
1.52 grams dye/25 lbs. surface starch
3.79 grams dye/25 lbs. surface starch
6.05 grams dye/25 lbs. surface starch

Color Evaluation After the Size Presses -

The color two-sidedness after the size press applications was visually judged, as well as measured with a Brightimeter Micro S4-M. This instrument is automatically controlled by a microprocessor, which measures TAPPI brightness, as well as opacity, color, and a wide range of other optical parameters. Only the color measuring feature was utilized for this project. The color measurements were given in L, a, b values. Where "L" is the measure of lightness and varies from 100 for a perfect white to 0 for absolute black. +a indicates redness: -a indicates greeness. +b indicates yellowness: -b indicates blueness. Another number that is printed out is the delta E value. The delta E value takes into account the overall color differences generated by the differences in lightness/darkness as well as the chromatic differences.

When using the color instrument, it initially prompts the user to load a color standard. The color standard loaded was the felt side of the colored paper. When prompted for the sample that was to be measured, the paper was turned over and the wire side was used. Therefore, the delta L, delta a, delta b, and delta E printed out was the difference between the felt and wire sides of the paper.

The visual judging was actually performed before the L, a, b measurements; this was done so there would not be any influencing of judgement. The delta L, delta a, delta b, and delta E values perfectly supported the visual judgement. Appendix V gives individual L, a, b, and E values as well as the visual color ratings.

RESULTS

Table VII shows the cost for the dyes used at the size presses (January 1, 1989 dollars). Using the visual judgment, as well as the L, a, b values to choose the dye addition from each size press configuration and wet-end condition application that comparably corrects the color two-sidedness, a cost analysis of the application was able to be made. Table IX shows the ranking of the relative cost for the vertical size press under the neutral sizing system at the wet-end. Table XI shows the ranking of the relative cost for the horizontal size press under the neutral sizing system at the wet-end. Table VIII shows the ranking of the relative cost for the vertical size press under the acid system at the wet-end. Table X shows the relative cost for the horizontal size press under the acid sizing system at the wet-end. These tables (VIII-XI) indicate that the anionic direct dye is the least expensive, followed by the acid, followed by the cationic direct dye to use in the size press to correct color two-sidedness. The results show that it did not matter which size press configuration was used (vertical or horizontal), or which wet-end sizing system was used (acid or neutral), the ranking was the same.

It should be stated that the cost of the dyes used in the size press is not important: what is important is the relative ranking of the dyes used in the size press. The actual cost of using a particular dye will depend upon the characteristics of the system being used. The relative ranking of the dyes to each other should be the same no matter what system is used.

Table VII.
Purchase Cost of the Dyes

Anionic Direct Dye	$ 2.95 / lb.
Cationic Direct Dye.	$ 6.35 / lb.
Acid Dye	$ 11.31 / lb.

Table VIII.
Relative Dye Cost for the
Vertical Size Press
(Acid Sizing System at the Wet-End)

Anionic Dye Application:	$ 0.30 per ton of paper
Acid Dye Application:	$ 1.14 per ton of paper
Cationic Dye Application:	$ 3.18 per ton of paper

Table IX.
Relative Dye Cost for the
Vertical Size Press
(Neutral Sizing System at the Wet-End)

Anionic Dye Application:	$ 1.48 per ton of paper
Acid Dye Application:	$ 2.83 per ton of paper
Cationic Dye Application:	$ 6.35 per ton of paper

Table X.
Relative Dye Cost for the
Horizontal Size Press
(Acid Sizing System at the Wet-End)

Anionic Dye Application:	$ 0.30 per ton of paper
Acid Dye Application:	$ 0.57 per ton of paper
Cationic Dye Application:	$ 0.64 per ton of paper

Table XI.
Relative Dye Cost for the
Horizontal Size Press
(Neutral Sizing System at the Wet-End)

Anionic Dye Application:	$ 4.43 per ton of paper
Acid Dye Application:	$ 4.52 per ton of paper
Cationic Dye Application:	$ 12.43 per ton of paper

CONCLUSIONS

This project indicates that when an red anionic direct dye is used internally (at the wet-end), and a size press is used to correct color two-sidedness (surface coloring), the most economical red dye to use in the size press is an anionic direct dye. The cost analysis comparing the three dye classifications shows that the anionic direct dye is the least expensive, followed by the acid dye, then the cationic direct dye (which is the most expensive to use at the size press).

The ranking of these three dyes was the same for both the acid sizing system and the neutral sizing system. The dye ranking was also the same for the horizontal size press and the vertical size press. In other words, it does not matter which system is used (acid or neutral) or which size press is used (horizontal or vertical), the economic ranking of the dyes was the same.

It should be stated that the cost of the dyes used in the size press is not important: what is important is the relative ranking of the dyes used in the size press. The actual cost of using a particular dye will depend upon the characteristics of the system being used. The relative ranking (to each other) of the dyes should be the same no matter what system is used.

RECOMMENDATIONS

This project used a red anionic direct dye internally at the wet-end. Further investigations should use a cationic direct dye internally at the wet-end to see if behavior is the same, or different, (as far as color two-sidedness correction in the size press is concerned) as compared to the anionic direct dye.

Since this project used the color red, it would be beneficial if further studies used a different primary color from the color spectrum.

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APPENDIX I
Freeness values from the Beaters

Hardwood	Softwood
563 ml CSF	418 ml CSF
567 ml CSF	428 ml CSF
575 ml CSF	423 ml CSF
555 ml CSF	420 ml CSF

These are the individual freeness values for the hardwood and softwood furnishes.

The hardwood was refined in the Claflin refiner for 1½ minutes.

The softwood was refined in the double disk refiner for 24 minutes.

APPENDIX II
Random HST Values from the Papermaking Phase

Acid Sizing System -

114 HST Units	98 HST Units
127 HST Units	110 HST Units
108 HST Units	105 HST Units
99 HST Units	107 HST Units
105 HST Units	110 HST Units
115 HST Units	110 HST Units
107 HST Units	101 HST Units
94 HST Units	101 HST Units

Neutral Sizing System -

127 HST Units	115 HST Units
115 HST Units	124 HST Units
119 HST Units	112 HST Units
125 HST Units	118 HST Units
130 HST Units	96 HST Units
118 HST Units	110 HST Units
110 HST Units	101 HST Units
120 HST Units	95 HST Units

The HST values for the neutral system were determined after the samples were oven-aged for 5 minutes at 105 ^{O}C.

Neuphor from Hercules, Inc., was used for the acid system.

Hercon from Hercules, Inc., was used for the neutral system.

APPENDIX III
Papermachine Conditions

Acid System - Machine Chest Consistency (%)	2	2	2	2
Stock Flow - machine chest (gpm)	15	15	15	15
Headbox flow (gpm)	88	88	88	88
Headbox pH	4.8	4.9	4.8	4.9
Wire speed (fpm)	60.4	60.4	60.5	60.4
#3 vacuum box (in. Hg)	5	5	5	5
#4 vacuum box (in. Hg)	5	5	5	5
Couch vacuum (in. Hg)	12	12	12	12
1st Press pressure (psi)	40	40	40	40
1st dryer temp. (^{o}F)	190	190	190	190
1st dryer section (^{o}F)	190	190	190	190
2nd dryer section (^{o}F)	245	245	245	245
# of nips	3	3	3	3

APPENDIX III
Papermachine Conditions
CONTINUED

Neutral System - Machine Chest Consistency (%)	2	2	2	2
Stock Flow - machine chest (gpm)	15	15	15	15
Headbox flow (gpm)	88	88	88	88
Headbox pH	7.2	7.2	7.2	7.2
Wire speed (fpm)	60.5	60.5	60.5	60.5
#3 vacuum box (in. Hg)	5	5	5	5
#4 vacuum box (in. Hg)	5	5	5	5
Couch vacuum (in. Hg)	10	10	10	10
1st Press pressure (psi)	40	40	40	40
1st dryer temp. (^{O}F)	195	195	195	195
1st dryer section (^{O}F)	195	195	195	195
2nd dryer section (^{O}F)	245	245	245	245
# of nips	3	3	3	3

APPENDIX IV
Calculated Size Press Addition Rates
and
Relative Dye Strengths
CONTINUED

Dye Strengths -- (the anionic direct dye was used as a basis)

A "rule of thumb" given by Ciba-Geigy is that the Cationic Direct Dye has roughly 60 % the dye strength of the anionic direct dye. The acid dye is roughly 3½ times the dye strength of the anionic direct dye.

Acid System -

5% difference between felt and wire sides
25lbs. estimated dye retention per ton of fiber

(5%) (25 lbs. dye retained) = 1.25 lbs. dye
Since roughly twice the dyeing strength in the size press as compared to the wet-end addition:
1.25 lbs./ 2 = 0.625 lbs. dye

Since applying the dye to one side of the sheet (not both sides of the sheet):
0.625 lbs. dye/ 2 = 0.3125 lbs. dye

Expected roughly 1500 lbs starch pick-up/ton of paper:
750 lbs. starch pick-up/ton of paper for each side.

Therefore, 0.3125 lbs. anionic direct dye to 750 lbs. total starch solution.

0.3125 lbs./60% = 0.5208 lbs. cationic dye to 750 lbs. total starch solution.

0.3125 lbs./3½ = 0.0893 lbs. acid dye to 750 lbs. total starch solution.

APPENDIX IV
Calculated Size Press Addition Rates and Relative Dye Strengths

Dye Strengths -- (the anionic direct dye was used as a basis)

A "rule of thumb" given by Ciba-Geigy is that the Cationic Direct Dye has roughly 60 % the dye strength of the anionic direct dye. The acid dye is roughly 3½ times the dye strength of the anionic direct dye.

Neutral System -

15% difference between felt and wire sides
25lbs. estimated dye retention per ton of fiber

(15%) (25 lbs. dye retained) = 3.75 lbs. dye
Since roughly twice the dyeing strength in the size press as compared to the wet-end addition:

3.75 lbs./ 2 = 1.875 lbs. dye

Since applying the dye to one side of the sheet (not both sides of the sheet):

1.875 lbs. dye/ 2 = 0.9375 lbs. dye

Expected roughly 1500 lbs starch pick-up/ton of paper:
750 lbs. starch pick-up/ton of paper for each side.

Therefore, 0.9375 lbs. anionic direct dye to 750 lbs. total starch solution.

0.9375 lbs./60% = 1.5625 lbs. cationic dye to 750 lbs. total starch solution.

0.9375 lbs./3½ = 0.2679 lbs. acid dye to 750 lbs. total starch solution.

APPENDIX V
Cost Calculation for Dye
Addition at the Size Press
CONTINUED

Horizontal Size Press
Acid System
Anionic Direct Dye at the Size Press

1.52 g ADD	$2.95	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $0.30 per ton of paper (anionic direct dye)

Cationic Direct Dye at the Size Press

1.52 g CDD	$6.35	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $ 0.64 per ton of paper (cationic direct dye)

Acid Dye

0.76 g Acid dye	$11.31	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $0.57 per ton of paper (acid dye)

APPENDIX V
Cost Calculation for Dye Addition at the Size Press

Horizontal Size Press
Neutral System
Anionic Direct Dye at the Size Press

$$\frac{22.68\text{ g ADD}}{25\text{ lbs starch}} \quad \frac{\$2.95}{\text{lb. Dye}} \quad \frac{1\text{ lb.}}{453.6\text{ g}} \quad \frac{750\text{ lbs. starch}}{1\text{ Ton Paper}}$$

= $4.43 per ton of paper (anionic direct dye)

Cationic Direct Dye at the Size Press

$$\frac{30.24\text{ g CDD}}{25\text{ lbs starch}} \quad \frac{\$6.35}{\text{lb. Dye}} \quad \frac{1\text{ lb.}}{453.6\text{ g}} \quad \frac{750\text{ lbs. starch}}{1\text{ Ton Paper}}$$

= $12.43 per ton of paper (cationic direct dye)

Acid Dye

$$\frac{6.05\text{ g Acid dye}}{25\text{ lbs starch}} \quad \frac{\$11.31}{\text{lb. Dye}} \quad \frac{1\text{ lb.}}{453.6\text{ g}} \quad \frac{750\text{ lbs. starch}}{1\text{ Ton Paper}}$$

= $4.52 per ton of paper (acid dye)

APPENDIX V
Cost Calculation for Dye
Addition at the Size Press
CONTINUED

Vertical Size Press
Acid System
Anionic Direct Dye at the Size Press

1.52 g ADD	$2.95	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $0.30 per ton of paper (anionic direct dye)

Cationic Direct Dye at the Size Press

7.56 g CDD	$6.35	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $ 3.18 per ton of paper (cationic direct dye)

Acid Dye

1.52 g Acid dye	$11.31	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $1.14 per ton of paper (acid dye)

APPENDIX V
Cost Calculation for Dye
Addition at the Size Press
CONTINUED

Vertical Size Press
Neutral System
Anionic Direct Dye at the Size Press

7.56 g ADD	$2.95	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $1.48 per ton of paper (anionic direct dye)

Cationic Direct Dye at the Size Press

60.48 g CDD	$6.35	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $ 6.35 per ton of paper (cationic direct dye)

Acid Dye

3.79 g Acid dye	$11.31	1 lb.	750 lbs. starch
25 lbs starch	lb. Dye	453.6 g	1 Ton Paper

= $2.83 per ton of paper (acid dye)

APPENDIX V
Delta L, a, b, & E values
after Size Press Color Correction

Acid System -- Horizontal Size Press

Anionic Dye --

	delta L	delta a	delta b	delta E	
***	**-0.28**	**0.31**	**0.15**	**0.45**	**1.52**
	-0.56	0.52	0.21	0.79	4.54
	-0.36	0.53	0.40	0.76	7.56

Acid Dye --

	delta L	delta a	delta b	delta E	
***	**-0.38**	**0.54**	**0.26**	**0.72**	**0.76**
	-0.41	0.51	0.46	0.85	1.52
	-0.50	0.75	0.37	0.98	2.27

Cationic Dye --

	delta L	delta a	delta b	delta E	
***	**-0.35**	**0.25**	**0.28**	**0.52**	**1.52**
	-0.47	0.49	0.27	0.74	7.56
	-0.66	0.59	0.22	0.91	15.12

Neutral System -- Horizontal Size Press

Anionic Dye --

	delta L	delta a	delta b	delta E	g / 25 lb starch
	0.74	-1.28	-1.10	1.43	7.56
	0.32	-0.92	-0.83	1.29	15.12
***	**0.17**	**-0.53**	**-0.55**	**0.78**	**22.68**

Acid Dye --

	delta L	delta a	delta b	delta E	
	0.73	-1.26	-1.18	1.88	1.52
	0.54	-0.78	-0.78	1.19	3.79
***	**0.48**	**-0.73**	**-0.80**	**1.16**	**6.05**

Cationic Dye --

	delta L	delta a	delta b	delta E	
	0.69	-1.19	-1.27	1.87	15.12
	0.57	-1.38	-1.19	1.91	22.68
***	**0.47**	**-1.12**	**-1.12**	**1.66**	**30.24**

APPENDIX V
Delta L, a, b, & E values
Size Press Color Corrected
CONTINUED

Acid System -- Vertical Size Press

Anionic Dye --

	delta L	delta a	delta b	delta E	g / 25 lb starch
***	**-0.09**	**-0.07**	**-0.13**	**0.18**	**1.52**
	0.17	-0.25	-0.54	0.62	7.56
	0.02	-0.13	-0.24	0.28	4.54

Acid Dye --

	delta L	delta a	delta b	delta E	g / 25 lb starch
	-0.20	0.13	-0.21	0.32	0.76
***	**-0.03**	**-0.12**	**-0.26**	**0.29**	**1.52**
	-0.12	0.24	-0.16	0.32	2.27

Cationic Dye --

	delta L	delta a	delta b	delta E	g / 25 lb starch
	0.51	-0.83	-0.64	1.17	1.52
***	**-0.15**	**-0.02**	**-0.41**	**0.44**	**7.56**
	-0.04	-0.23	-0.40	0.47	15.12

Neutral System -- Vertical Size Press

Anionic Dye --

	delta L	delta a	delta b	delta E	g / 25 lb starch
***	**-1.03**	**1.40**	**1.11**	**2.07**	**7.56**
	-1.03	1.52	1.15	2.25	15.12
	-1.35	1.87	1.21	2.61	22.68

Acid Dye --

	delta L	delta a	delta b	delta E	g / 25 lb starch
***	**-0.95**	**1.37**	**0.92**	**1.91**	**1.52**
	-1.63	2.31	1.50	3.21	3.79
	-1.71	2.38	1.75	3.42	6.05

Cationic Dye --

	delta L	delta a	delta b	delta E	g / 25 lb starch
***	**-1.11**	**1.28**	**0.65**	**1.81**	**15.12**
	-1.21	1.56	1.00	2.22	22.68
	-1.52	1.60	0.93	2.36	30.24

APPENDIX VI
Furnish and Additive Names Used in this Project

Pulp:
- Hardwood - Marathon (262)
- Softwood - DCX (258)

Internal Sizing:
- Neuphor (for acid system) - Hercules, Inc.
- Hercon - 70 (for neutral system) - Hercules, Inc.

Filler:
- Clay -- KWW
- Calcium Carbonate -- Omya H - 30

Surface Starch:
- Penford - 280 Ethlyated Starch

Dyes:
- For The Size Press (surface coloring):
  - Anionic Direct Dye - Pergasol Red NAS Lq. (Ciba-Geigy)
  - Cationic Direct Dye - Pergasol Red F - 2B Lq.(Ciba-Geigy)
  - Acid Dye - Pergacid Red 2G Conc. (Ciba-Geigy)
- For The Wet-End (internally):
  - Anionic Direct Dye - Pergasol Red NAS Lq. (Ciba-Geigy)