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HIGH-LEVEL ADVICE ON PROPER UTILIZATION OF COMPUTERIZED COLOUR MATCHING (CCM)

SI/BRA/89/801/11-01

BRAZIL

Technical report: Advising on proper utilization of computerized colour matching*

Prepared for the Government of Brazil
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of R. Hirschler,
Expert in CCM

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Vienna

* Mention of company names and commercial products does not imply the endorsement of UNIDO. This document has not been edited.

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EXPLANATORY NOTES

Abbreviations and acronyms used in the report

ACL	Applied Colorimetry Laboratory
BASF	Badische Anilin und Soda Fabrik
BCRA	British Ceramic Research Association
CCS	Ceramic Colour Standards
CCM	Computer(ized) Colour Matching
CETIQT	Centro de Tecnologia da Indústria Química e Têxtil (Technology Center of the Chemical and Textile Industry)
NPL	National Physical Laboratories
SENAI	Serviço Nacional de Aprendizagem Industrial (National Service for Industrial Training)

ABSTRACT

The purpose of this project (with split missions of the expert in CCM from 3 November to 31 December 1989 and from 1 February to 20 July 1990) was to survey CCM techniques in the Brazilian textile dyeing and finishing industry, to give selected factories direct assistance in the better utilization of CCM systems and to give high-level advise to professionals of SENAI/CETIQT in this area.

The project has succeeded in

- making a survey of the practice of CCM in a number of selected factories and giving them orientation in the better utilization of their systems;

- providing high-level technical advise for CETIQT professionals to enable them performing their work in the field of CCM according to the state-of-the-art techniques and current international standards;

- acquiring the necessary books, standards and demonstration material to perform the required tasks.

All recommendations regarding the above activities have been implemented by the counterpart institution (SENAI/CETIQT). The project has also contributed significantly to the general acceptance and recognition of UNIDO activities, increasing interest in future UNIDO projects within the SENAI system and creating it within industry.

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INTRODUCTION

In 1988 a technical co-operation project [DP/BRA/87/033] was started concentrating on the fields of dyehouse automation, effluent treatment and garment manufacturing, aimed at strengthening the Applied Research Unit of CETIQT, and also providing direct assistance to industry. In the course of factory visits, some factories were visited which already had computerized colour matching systems. When checking the performance of the spectrophotometers, serious problems were found in many cases in the repeatability, reproducibility and the accuracy of the instruments (TABLES 1-3 in ANNEX 1.)

The cause of this low performance often may be, but isn't necessarily, the instrument itself. In addition to the eventual in- stability of the instrument, problems may be caused by:

- taking the reflectance values of the $BaSO_4$ = 100.00 at all wavelength readings instead of the standardized absolute values;
- using a white standard with a damaged (non-uniform) surface;
- using a cover glass in some cases while not using it for another instrument;
- thermochromism: i.e. the changes of the colour of the samples due to small changes in temperature;
- using (within the colour matching software itself) non-standard calculation methods for the derivation of tristimulus values.

Some of the companies using computerized colour matching systems complained about the "inaccuracies of the program" and "not being able to use the system with reactive dyes on cotton" - problems normally arising not from computerized colour matching itself, but the laboratory work (the dyeing process) on which the data bank is based.

Finally, in most companies the dyehouse planned to use the system for quality control, but ran into trouble when trying to set up the tolerance limits.

In order to help the Brazilian textile industry in solving these problem, SENAI requested an SIS project from UNIDO to give high-level technical assistance to the industry and the then newly established Applied Colorimetry Laboratory (ACL) of CETIQT. At the same time MATHIS Ltda., the manufacturer of the MATHISCOLOR computerized colour matching systems donated a spectrophotometer (with the necessary CCM software by BASF) to CETIQT. This facilitated the work of the expert by providing necessary demonstration tools and infrastructure for his work.

ACTIVITIES AND FINDINGS

The main fields of activity for the expert in computerized colour matching were the following:

- visual colour assessment - verbal colour communication;
- standardization of colour measurement;
- characterization of dyestuffs;
- computerized colour matching.

A. Visual colour assessment - verbal colour communication

The description of colours based on visual observation and verbal colour communication have been the only practical ways for centuries, and the colouration industry somehow managed, but it has never been without problems.

In modern industry we still have to rely on human visual observations (by definition the eye must be the final arbitrator) but now we may - and have to - use more sophisticated, accurate, standardized methods to comply with the higher level of today's requirements.

One important device used fairly widely is the colour matching booth, equipped with standard light sources providing standardized, repeatable viewing conditions. The CETIQT Applied Colorimetry Laboratory - based on the expert's recommendations - has acquired three different types:

- SPECTRALIGHT (MACBETH) with filtered tungsten for daylight;
- TRU-VUE (ACS-DATACOLOR) with fluorescent tube for daylight;
- THE JUDGE (MACBETH) portable colour matching booth.

Having the three main types makes it possible to compare their performance by using special metameric scales, and give advice to industry in selecting and using the visual colour matching booths.

Standardizing the light sources is not enough. The visual observer's accuracy and colour discrimination ability also has to be tested. For this, either the ColorRule may be used, or the special set of samples called the FARNSWORTH-MUNSELL 100-Hue Test. With this the colour discrimination aptitude (i.e. their suitability for the job) of colourists or would-be colourists may be quantified, indicating whether the test-person has above-the-average, average or below-the-average capabilities in this field. This screening test will be one of the regular services to be offered by the Applied Colorimetry Laboratory.

In the industrial practice, particularly for the fashion industries of textile and apparel, colours often have to be expressed verbally, and this is very difficult. The only reasonably accurate way of describing colours verbally is to compare them to either a "well-known" colour ("moss-green", "sky-blue", "cherry-red"), or to an existing colour sample in a colour sample collection, which can be pointed at.

There are several systematic colour sample collections available, some of the best-known and most widely used ones are based on the MUNSELL system.

In the MUNSELL system colours are arranged by three attributes: Hue, Value and Chroma. All surface colours (i.e. colours of objects) can find their place in the three-dimensional space, so by giving the MUNSELL designation any colour can be described verbally with a high degree of precision.

The CETIQT Applied Colorimetry Laboratory has received through the project all the major MUNSELL collections: the matte and glossy Books of Color, the Color File and Student Sets, to be used in training courses for demonstrating and practicing the description of colours by MUNSELL co-ordinates.

In the textile industry world-wide two systems - both related to MUNSELL - are used: PANTONE and SCOTDIC.

PANTONE is better known in this country. It is available in the form of paper chips, recommended for designers, and also as a set of 1200 cotton samples (the Textile Color Selector) for general textile applications.

SCOTDIC is relatively unknown in Brazil (only few companies have it yet), although it has some distinct advantages:

- closely follows the structure of the MUNSELL system;
- has twice as many colours as PANTONE;
- available as cotton or PES fabric, PES/CO yarn or wool tops.

Its main disadvantage is the relatively high price. Each sample in the SCOTDIC collections is characterized by a six-digit number: the first two for MUNSELL Hue, the second two for Value and the third two for Chroma. In the SCOTDIC albums colours are arranged exactly the same way as in the MUNSELL Book of Color: each page contains samples of constant Hue, arranged according to Value and Chroma. For practical work, the same colours are available in bigger-size stripes both in cotton and in polyester, and there are collection of selected colours for special purposes: the TC Yarn Collection (PES/CO), the Fashion Colour Selectors, the Search Board, etc. These colour collections have also been purchased for the CETIQT Applied Colorimetry Laboratory for demonstrations and also for studying them before a company makes a purchase decision. The full list of colour collections acquired through the project is given in <u>ANNEX 2.1</u>.

B. Standardization of Colour Measurement

The basic information used in colorimetry and computerized colour matching is the spectral reflectance of the sample measured by a suitable spectrophotometer. The instrument used at the A.C.L. is that donated by MATHIS, which is the most widely used type in the Brazilian textile industry (many factories have the older model of MATHISCOLOR using the same basic structure as the new one). Some factories use the MACBETH/COMEXIM, and some others the DATACOLOR. In order to be able to help these users, and also for research purposes the expert has recommended for the A.C.L. to purchase a DATACOLOR CCM system,which has been done through a World Bank - financed project.

How can colour measurement be standardized, and the precision (accuracy, reproducibility and repeatability) of reflectance measurement be increased? The A.C.L. has received special white and black standards calibrated by the National Physical Laboratory to check the correct 100% and 0% lines ("perfect white" and "perfect black") of the spectrophotometers. The acquisition of a set of 12 calibrated colour tiles with which the accuracy of instruments may be controlled has also been recommended, and these have also been purchased for the project (see ANNEX 2.1).

A number of textile dyeing/printing/finishing factories (HERING, KARSTEN, SULFABRIL, LINHAS CIRCULO and RENAUX in Santa Catarina, SAO JOSE in Minas Gerais, RENDAS ARP, NOVA AMERICA and MULTIFABRIL in Rio de Janeiro, ALPARGATAS, MEIAS SCALINA, TINTURARIA TEXTIL LEAO in Sao Paulo) and other users of CCM systems (COMEXIM, MATHIS, ICI, CIBA-GEIGY) were visited, and the correct methods of checking and calibrating their colour measuring instruments demonstrated. Reports prepared for some of the companies (HERING, SAO JOSE, RENDAS ARP, NOVA AMERICA AND MULTIFABRIL) are reproduced as ANNEXES 4. to 6. resp.

Following the expert's recommendations the CETIQT A.C.L. is going to offer calibration services for the industry checking the performance of spectrophotometers regularly (e.g. every 3 months). For those companies, who want to have their own set of colour tiles it is recommended to purchase a set directly from the British Ceramic Research Association (for c. US$ 450.00), and have it calibrated by CETIQT with their own instrument for a much smaller fee then that charged by NPL (c. US$ 4,500).

The precision of colour measurement also depends on the way samples (yarns, knitted and woven fabrics, etc.) are presented to the instrument, and the A.C.L. can provide technical assistance in developing the best way for any particular substrate.

C. Characterization of Dyestuffs

One of the most important applications of instrumental colour measurement is the characterization of dyestuffs: first of all quantifying dyestuff strength, and describing the colour gamut which can be achieved by a range of dyestuffs. In order to have information on all the dyestuffs used in the Brazilian textile industry the A.C.L. has started to collect samples from all the manufacturers together with the relevant technical information.

For the systematic study of the behavior of dyestuffs - and also to ensure the high level of precision necessary to prepare calibration dyeings - the CETIQT A.C.L. has installed an AHIBA TURBOMAT laboratory dyeing machine with up-to-date process controller, and two other machines, which are widely used in the Brazilian textile industry: a MATHIS TINGIOMAT and a BFA HT WASH-TESTER (both with process controllers).

The basic information on every single dyestuff is provided by a series of dyeings made with 6-10 concentration levels. This can directly be used in a colour matching system for instance for strength comparison by an appropriate program, but also to be used as calibration dyeings for recipe prediction. These techniques have been amply discussed and demonstrated both in the factories visited and in the ACL.

In the future those factories which have computer colour matching facilities may have calibration dyeings prepared by the ACL, while for those which do not have access to instruments quantitative strength evaluation and dyestuff-comparison is going to be offered.

D. Computerized Colour Matching (CCM)

Without any doubt the most spectacular results with colorimetry can be achieved by the application of computerized colour matching, i.e. the calculation of a great number of alternative recipes.

There are three main advantages of the instrumental as compared to visual colour matching:

- reduction of the number of trials needed in the laboratory to match a new colour, typically from 4-8 attempts to 1 or 2;
- the possibility of selecting recipes which are nearest to the target colour under daylight ("colour difference"), but also under a second or third illumination ("metamerism");
- significant (10-30%) savings in dyestuff costs.

Practical results illustrating these advantages are shown in Table 4. (ANNEX 1.). Further advantages are offered by the possibility of quickly replacing missing dyestuffs by available ones in any number of recipes, reduction of dyestuff inventory, etc.

The following fields of offering complex assistance in the field of colour matching have been discussed and demonstrated:

- feasibility study to support a decision on investing in CCM;
- technical specification of a CCM system;
- help in installation a start-up;
- training;
- preparation of calibration dyeings;
- application assistance.

For those factories which do not have - and at least for the time being do not want to have - a CCM system full colour matching services are going to be offered by the ACL: recipe calculation and optimization with any dyestuff range specified by the user.

E. Training and demonstration aids

One of the major objectives of the project was to select and establish at the ACL a complete collection of training and demonstration aids in the field of computerized colour matching. In addition to the colour collections and standards described above the expert has provided copies of his own collection of colour slides, which, together with those prepared within the frame of the project form a comprehensive collection of visual aids to be used in training courses, lectures etc. in all fields of industrial colour science (see ANNEX 2.2)

The expert has also prepared recommendations for the purchase of the most important books and publications in the field (see ANNEX 2.3.).

RECOMMENDATIONS AND RESULTS

1. In order to standardize viewing conditions at the ACL the purchase of the following colour matching booths have been recommended:
   - SPECTRALIGHT (MACBETH) with filtered tungsten for daylight;
   - TRU-VUE (ACS-DATACOLOR) with fluorescent tube for daylight;
   - THE JUDGE (MACBETH) portable colour matching booth.

2. For the testing of the visual acuity of colourists and would-be colourists the purchase of the Color Rule (MUNSELL) and the MUNSELL-Farnworth 100 Hue Test has been recommended.

3. For teaching and demonstration purposes as well as an aid to verbal colour communications the full set of MUNSELL, PANTONE, SCOTDIC and COLORCURVE collections have recommended for the ACL. (Details of the colour systems purchased are given in <u>ANNEX 2.1</u>).

4. The establishing of a comprehensive collection of colour slides illustrating various aspects of industrial colour science for training and demonstrations has been recommended. (The list of slides is given in <u>ANNEX 2.2</u>).

5. A list of the most important books and publications in the field has been recommended (<u>ANNEX 2.3</u>).

6. For standardization purposes a sets of black, white and colour standards have been recommended (<u>ANNEX 2.4</u>).

7. Recommendations for the regular procedure for the standardization of industrial colour measuring spectrophotometers have been elaborated (see *APPENDICES 1. to 3.* in <u>ANNEX 3.</u>)

8. For the preparation of calibration dyeings for computerized colour matching the AHIBA TURBOMAT, the MATHIS TINGIOMAT and the MATHIS BFA HT dyeing machines have been recommended by the expert. These have been purchased through an other UNIDO project (DP/BRA/87/033).

9. To realize computerized colour matching at the state of the art level the purchase of a DATACOLOR TEXFLASH spectrophotometer with the OSIRIS 2.3 colour matching software package has been recommended for the ACL. This system has been purchased through a World Bank project.

10. Recommendation for individual companies are not repeated here, they can be found in the relevant reports (ANNEXES 3. to 6.)

Table 1. Accuracy of colour measurement as practiced in the Brazilian textile industry

NPL TILE	INSTRUMENTS					
	A	B	C	D	E	Average
PALE GREY	0.26	0.70	0.54	0.24	0.27	0.40
MEDIUM GREY	0.11	0.80	0.74	0.28	0.50	0.49
DIFF. GREY	0.32	0.86	0.34	0.31	0.54	0.47
DARK GREY	0.62	0.91	1.06	0.85	0.72	0.83
PINK	0.80	0.74	0.64	0.99	0.99	0.83
RED	0.70	1.05	1.68	1.92	0.86	1.24
ORANGE	1.41	1.17	1.62	1.40	1.11	1.34
YELLOW	1.26	0.74	1.20	1.44	0.57	1.04
GREEN	1.40	1.57	1.90	1.41	1.39	1.53
DIFF. GREEN	1.43	1.57	1.90	1.46	1.42	1.56
CYAN	2.19	1.19	2.36	2.18	1.54	1.89
DEEP BLUE	1.44	1.30	1.72	2.11	1.18	1.55
AVERAGE	1.00	1.05	1.31	1.22	0.92	1.10
MAXIMUM	2.19	1.57	2.36	2.18	1.54	2.36

Accuracy: DE^*_{ab} colour difference between standard and measured values of the 12 BCRA CCS-s. Maximum acceptable value: (for the average of the 12 tiles) DE^*_{avg} < 0.5

Ref. Instr. (A):	without cover glass,	$BaSO_4$ = 100%
Instrument B:	with cover glass,	BaSO4 = absolute values
Instrument C:	with cover glass,	BaSO4 = 100%
Instrument D:	without cover glass,	BaSO4 = 100%
Instrument E:	with cover glass,	BaSO4 = absolute values

Table 2. Reproducibility of colour measurement as practiced in the Brazilian textile industry

NPL TILE	INSTRUMENTS B	C	D	E	Average
PALE GREY	0.45	0.31	0.25	0.07	0.27
MEDIUM GREY	0.69	0.58	0.11	0.41	0.45
DIFF. GREY	0.73	0.60	0.09	0.34	0.44
DARK GREY	0.36	0.52	0.25	0.16	0.32
PINK	0.87	0.53	0.26	0.51	0.54
RED	0.81	0.54	0.68	0.72	0.69
ORANGE	1.70	0.62	0.26	1.24	0.95
YELLOW	1.22	0.43	0.39	0.30	0.58
GREEN	0.71	0.58	0.24	0.50	0.51
DIFF. GREEN	0.65	0.57	0.27	0.42	0.48
CYAN	0.64	0.52	0.08	0.74	0.49
DEEP BLUE	0.54	0.50	0.77	0.34	0.54
AVERAGE	0.78	0.52	0.30	0.48	0.52
MAXIMUM	1.70	0.62	0.77	1.24	1.70

Reproducibility: $\overline{DE}^*_{ab}$ colour difference calculated from the L^*, a^*, b^* values of the 12 BCRA CCS-s measured on instrument "A" as reference resp on the instruments B, C, D and E as test instruments. Maximum acceptable value (for the medium of the 12 tiles, between any two instruments of the same type):

$$DE^*_{repr} < 0.2$$

Ref. Instr. (A):	without cover glass,	BaSO4 = 100%
Instrument B:	with cover glass,	BaSO4 = absolute values
Instrument C:	with cover glass,	BaSO4 = 100%
Instrument D:	without cover glass,	BaSO4 = 100%
Instrument E:	with cover glass,	BaSO4 = absolute values

Table 3. Repeatability of colour measurement as practiced in the Brazilian textile industry

NPL TILE	INSTRUMENTS A	B	C	D	E	Average
PALE GREY	0.02	0.03	0.03	0.15	0.04	0.05
MEDIUM GREY	0.02	0.02	0.03	0.09	0.03	0.04
DIFF. GREY	0.03	0.02	0.02	0.08	0.03	0.04
DARK GREY	0.05	0.03	0.03	0.14	0.04	0.06
PINK	0.04	0.04	0.04	0.15	0.06	0.07
RED	0.07	0.09	0.05	0.25	0.07	0.11
ORANGE	0.07	0.07	0.07	0.20	0.05	0.09
YELLOW	0.05	0.06	0.05	0.12	0.05	0.07
GREEN	0.04	0.04	0.05	0.11	0.05	0.06
DIFF. GREEN	0.04	0.06	0.04	0.12	0.03	0.06
CYAN	0.04	0.03	0.04	0.06	0.04	0.04
DEEP BLUE	0.03	0.06	0.03	0.15	0.10	0.07
AVERAGE	0.040.05		0.04	0.14	0.05	0.06
MAXIMUM	0.07	0.09	0.07	0.25	0.10	0.25

Repeatability: the average of the colour differences $\overline{DE^*_{ab}}$ between the L^*, a^*, b^* values of single measurements and the average of 10 measurements on the same samples ($\bar{L}$, $\bar{a}$, $\bar{b}$). Maximum acceptable value (for the average of the 12 tiles) $DE^*_{rm} < 0.05$

Ref. Instr. (A):	without cover glass,	BaSO4 = 100%
Instrument B:	with cover glass,	BaSO4 = absolute values
Instrument C:	with cover glass,	BaSO4 = 100%
Instrument D:	without cover glass,	BaSO4 = 100%
Instrument E:	with cover glass,	BaSO4 = absolute values

Table 4. Colour Matching - Visual vs. Instrumental

	Instrumental			Visual Average of 3 laboratories			Cost reduction %
SAMPLES	*1	*2	*3	*1	*2	*3	*4
YELLOW	2	0.4	0.4	4.3	4.9	0.8	37.2
RED	2	2.3	0.5	5.0	2.4	1.0	40.0
BROWN	1	0.9	0.6	8.0	1.9	1.5	20.1
DEEP PURPLE	1	0.8	0.4	7.7	1.2	1.9	65.3
LIGHT PURPLE	1	0.4	0.2	2.3	1.7	0.5	--
KHAKI	1	1.1	0.5	5.3	1.9	0.3	64.8
LIGHT GREEN	1	0.7	0.4	10.3	2.2	0.9	13.4
DARK GREEN	1	0.6	0.7	7.3	2.7	1.5	12.2
BOTTLE GREEN	2	0.6	0.1	4.7	1.5	0.9	52.7
BLUE	1	0.7	0.1	5.7	1.6	0.3	20.1
AVERAGE	1.3	0.8	0.4	6.0	2.2	1.0	32.6

*1 - Number of attempts necessary to achieve acceptable colour

*2 - Colour difference $DE_{ANLAB(40)}$ between standard and accepted sample

*3 - Index of metamerism $DE_{ANLAB(40)}$

*4 - Cost reduction (%) = 100 - 100 * $\frac{\text{Cost of instrumental recipe}}{\text{Average cost of 3 visual recipes}}$

where "cost" is the total price of dyestuffs necessary to dye 100 kg substrate

Colour systems purchased through the project

Color Atlas 5510
ColorCurve Professional System
MUNSELL Book of Color Matte Edition
MUNSELL Book of Color Glossy Edition
MUNSELL Color File
MUNSELL Color Tree
MUNSELL Student Sets
MUNSELL - Farnworth 100 Hue Test
MUNSELL Color Rule
PANTONE Textile Color Selector
PANTONE Professional Color System (Color Guide + Color Selector)
PANTONE Color Selector XR
SCOTDIC 2450 Polyester Collection (Book + swatches)
SCOTDIC 2020 Cotton Collection (Book + swatches)
SCOTDIC Polyester/cotton yarn collection
SCOTDIC Fashion Colours
SCOTDIC Near-white colours

List of colour slides obtained for the A.C.L.

1. INTRODUCTION

1.1 The monochrome world - French painter Rousseau
1.2 The world in colour - You get much more information.
1.3 Newton was the first scientist who dealt with colours in a systematic way, but prior to him...Robert Boyle - 1664
1.4 Sir Isaac Newton - 1666

1. Himself
2. Philosophical transactions
3. Optics - 1704
4. Newton's Spectrum
5. The spectrum through a prism. He placed another prism after the monochromatic light and nothing happened. There was no second splitting.
6. The spectrum

1.5 Colour communication (1) - 1930's
1.6 Colour communication (2) - 1975
1.7 Moses Harris - 1766 - Prismatic Colours. This is the first Colour Circle, the oldest one that remains until nowadays.
1.8 Moses Harris - Compound Colours - Mixture of Colours.
1.9 Oswald Hue Circle - In this century, it was made by a German chemist.
1.10 Oswald Constant Hue Chart - white content; black content.

2. THE MUNSELL SYSTEM - The most important colour order system.

2.1 The Munsell Color Scales - The Color Tree

1. Albert H. Munsell and the Scales (solid and hue order).
2. The Color Tree
3. The Color Sphere
4. Color Scales (black and white)
5. Color Scales (Grammar of Color)
6. Color Scales (colour)
7. Color Sphere from 10RP (10 Red Purple)
8. Color Sphere from 10G (10 Green)
9. Color Tree Green-Yellow-Red
10. Color Tree Blue-Red-Yellow
11. Color Tree Yellow-Green-Blue
12. The Color Tree model
13. The Color Tree (Text. Chem.)
14. Munsell and ANLAB (CIELAB) Scales (they were made on the basis of the Munsell System).
15. H-V/C and R-G/Y-B scales (polar coordinates)

2.2 Constant Hue Charts

1. Constant Hue Pages
2. Vertical slice (B-Y) through Color Tree I.
3. Vertical slice (B-Y) through Color Tree II.
4. Vertical slice (B-Y) through Color Tree III.
5. Designations on constant Hue (Red) chart - B/W
   Hue is designate by letters, the first number is lightness and the last one is Chroma. We can have 100 Hues division.

6. - 10. 5.0 R (a+b); 5.0 Y; 5.0 G; 5.0 B; 5.0 P

2.3 Constant Value Charts

1. Horizontal cuts through colour sphere.
2. 10 Hues at 5/Value

3.-8. 20 hues at 3/ - 8/ Value

2.4 Constant Chroma Charts

1. Cylindrical cuts through colour sphere.
2. 10 Hues at 16 Chroma.

3.-9. 2, 4, 6 (2x), 8 (2x), 10 Chroma.

10. Hue special (max. Chroma) R-Y-G section.
11. Hue special (max. Chroma) B-P-R section.

2.5 Constant Hue and Value Charts in Textile (wool) from the Munsell Book of Color.

1.- 7. 5R, 10YR, 10Y, 10B, V=4, V=5, V=6

2.6 Color Harmony in Munsell

1.-2.-3.	YR Chart - Drawing - Samples
4.-5.-6.	Y 8/3 (G-B) - PB 3/4 Chart - Drawing - Samples
7.-8.	Y 8/9 (R-P) - PB 3/4 Drawing - Samples
9.-10.	Opposite Colours (YR 7/10 - B 3/5)
11.-12.	G 5/6 - RP 5/6 Constant Value and Chroma
13.-15.	Y 7/12 - PB 3/13 Graph/Drawing/ Blouse

2.7 Munsell products

1. Book of Color, Glossy (a-c)

2.8 ISCC-NBS Universal Color Language - Centroids

1. "Piece of cake" - Purple
2. Constant Hue Chart with modifiers
3. Red/Pink
4. Green
5. Purple
6. 10 Hues
7. 13 Hues
8. 26 Hues

2.9 Munsell - SCOTDIC

2.10 OSA

1. Space Model
2. - 5. L=0; L=3; j + g = 0; L + j = 0
6. - 8. Cuts parallel to "pyramid sides"

2.11 Standard Depth

1. White contents / Lightness / Saturation / Std. Depth
2. Std. Depth of Cotton 1/1 - 16 Hues; 1/25, 1/3, 2/1
3. AATCC/DIN Std. Scales
4. Constant Grayness lines in Munsell

3. PHYSICS AND PSYCHOPHYSICS OF COLOUR

3.1 Visible light, the spectrum

3.2 The three elements of colour - source/sample/detector

3.3 Light sources and illuminants

1. Paper samples under 3 different light sources.
2. Fluorescence: (a) without U.V. (b) with U.V.

3.4 How materials modify light

1. Effect of particle size on scattering (Hunter).
2. Transparent to white liquids: scattering.
3. Transparent to black liquids: absorption.
4. Absorption by red and green filters.
5. Absorption by blue and magenta filters.
6. Complex reflection theory absorption and scattering.
7. Color slide process.

3.5 Reflectance measurement (general) - Instruments see under 4.

1. Surface characteristics: matte, glossy, transparent, metallic (Hunter).
2. Effect of gloss - water lilies
3. - 4. Goniospectrophotometer.
5. Goniophotometric curve.
6. - 7. Colour change due to different illuminant/observer angle.

3.6 Colour vision and the human eye.

1. The human eye (from Chemical Eng.)
2. The eye and the brain.
3. Colour illusions.
   1. - 2. Contrast (grey circle on red/blue).
   3. - 4. Contrast (blue on yellow/black).
   5. Grey arrows on yellow/black ground.
   6. Blue on yellow and black.
   7. Spreading effect.

3.6 Colour vision and the human eye (contd.)

4. Additive colour mixing - colour vision.
   1. Maxwell bicolour.
   2. Dufay colour slide.
   3. - 4. Projection TV.
   5. - 6. TV Screen.
5. Defective colour vision
   1. Monochromatism.
   2. Ishihara
   3. - 9. Confusion plates.

3.7 The CIE System, colour diagram.

1. X, Y, Z space.
2. x, y diagram (Wright)
3. x, y diagram (coloured).

3.8 Metamerism.

1. Cars.
2. Glenn Color rule.

4. COLOUR MEASURING INSTRUMENT AND COMPUTER COLOUR MATCHING SYSTEMS.

4.1 Calibration.

1. DC White
2. DC Black
3. ICS White
4. ICS Black (+ colour tiles)
5. Sphere inside.

4.2 Sample preparation and presentation.

1. Flock, yarn, compact yarn (Bayer).
2. Polytex.
3. ICS carpet yarn (tuft) 1. before 2. after cutting
4. DC Telescope.
   1. DC 7100 with operator.
   2. DC 7100 inserting the sample.
   3. DC 7100 checking sample positioning.
   4. DC 3500
   5. Dataflash / Texflash.
   5. ICS Sample port.
      .1 Measuring position.
      .2 Control of sample positioning.

4.3 A bit of history.

1. The Lovibond (visual) photometer (1908).
2. The MEECO Colormaster.
3. The DIANO Chromascan (with ICS automation).
4. The Beckman DB-G.
5. Photomatch by Photomarker
   1.
   2.
   3.
6. The Trilac II goniospectrophotometer (a,b)
7. The Pretema.
   1. FS-2
   2. FS-3A
   3. FS-4
8. Zeiss
   1. DMC 25
   2. DMC 26
   3. Elrepho
   4. RFC 3/24
   5 RFC 16
   6 Elrephomat

4.4 The Hardy spectrophotometer.

1. The "stovepipe" (early 1930's).
2. The "new model" GERS (up to 1960's).
3. Modified Hardy for transmission work.
4. Hardy with DIANO "Automate".
5. The DIANO Hardy II in a Computer Colour Measurement system.
6. - 7. The DIANO Hardy II: the "reversible optics" feature.

4.5 From IDL to Kollmorgen.

1. The small sphere - Color Eye.
2. The large sphere - Color Eye.
3. The KCS-40.
4. The KCS-18 - Automatic Color Eye.
5. The Macbeth MS-2000.
6. Keyboard of the MS-2000.
7. The MC-1010.
8. Measurement of moving samples.

4.6 DATACOLOR.

1. The DC 7100-7400.
   1. DC 7000 measuring head.
   2. DC 7000 with white standard.
   3. DC 7400 terminal, measuring head, teletype.
   4. DC 7400 measuring head, teletype, computer.
   5. HP-1000 E
   6. HP disc (5 MB).
   7. - .8 Dicom Floppy.
   9. Tape punch.
2. The DC 3500 (cf. 4.2.44)
3. Elrepho 2000.
4. DC 3890/DATACOLOR 3890.
5. TEXFLASH.
   1. Measuring head.
   2. System.
6. OSIRIS software.
   1. OSIRIS Textile Programs.
   2. Colour Measuring Program - R(l) curves
   3. Colour Measuring Program - CIELAB a-b plot
   4. - .5 Colour Control - DL - DC - DH - DE + plot
   6. - 7. Search/Sort.
   8. Recipe prediction.
   9. Recipe library.

4.7 HUNTER/ACS

1. HUNTER LAB
   1. Tristimulus with sphere.
   2. Tristimulus 2 * 45/0 degree.
   3. The first HUNTER spectrophotometer.
   4. Sphere geometry.
   5. 8 * 45/0 degree geometry.
   6. Optical sketch of
   7. The silicone diode array.

2. The ACS SpectroSensor I and II.
   1. Spectro-Sensor.
   2. The Spectro-Sensor sphere.
   3. The monochromator.
   4. The Single Beam principle.
   5. The Spectro-Sensor II.

3. The Chroma-Sensor CS-3 and CS-5.
   1. The CS-3.
   2. The CS-5.

4. The VCS-9 and 11.
   1. The Maxwell disc (VCS-)
   2. The VCS in Stationary position.
   3. The VCS rotating.
   4. The VCS 11.
   5. The VCS in a complete system.

5: The Chroma Calc. SW
   1. Colour Difference.
   2. Recipes sorted accordingly to cost.
   3. idem.

4.8 DIANO/MILTON-ROY

1. The Match Scan I and II.
   1. Match Scan I.
   2. Match Scan I - the optical diagram.
   3. Match Scan II.
   4. Match Scan II - the optical diagram.

2. The Color Scan.

3. The Color Graph.

4.8 DIANO/MILTON-ROY (contd.)

4. Color-Mate HDS and COLOR MATE
   1. The full system with HDS.
   2. The stand-alone HDS (Oostende).
   3. The Color Mate.
   4. The Color Mate in (Oostende).

4.9 ICS-TEXICON - COMEXIM.

1. The measuring head.
   1. The Ms 2020 - optical diagram.
   2. Measuring head vertical for specially large samples.

2. The MM 9000.
   1. The full MM 9000.
   2. The DEC PDP 11/23.
   3. The Olivetti PC (M 28).
   4. Measuring head = 4.1.4
   5. VDU + keyboard.

3. MM 2000/3000 QC

4. Colour Terminal (measuring head + Olivetti M 28)

5. The Eagle Eye.
   1. Measuring head.
   2. Optical diagram.

9. Macbeth/COMEXIM.
   1. At the CETIQT conference.
   2. in Sao Paulo.

4.10 "The others".

1. Keiltronix.
   1. The spectrophotometer.
   2. The system.

2. IBM
   1. The system.
   2. The measuring head (4 * 45/0 degree).

3. Pacific Scientific.
   1. The Spectrogard
   2. The system
   3. The Color Machine

4.10 "The others" (contd.)

4. OPTRONIK/MATHIS

   1. The OPTRONIK/MATHIS Spectrophotometer (old).
   2. Idem with printer (old).
   3. New model OPTRONIK at CETIQT.
   4. OPTRONIK screen.

5. COLOUR DIFFERENCE, UNIFORM COLOUR SPACES, TOLERANCES, COLOUR SORTING.

5.1 Colour differences.

   1. Knitted dress.
   2. - 4. Colour difference pairs with DE values.

5.2 The Macadam data.

1. D. L. Macadam
2. RGB primaries of Macadam instrument.
3. Macadam colour difference instrument.
4. Macadam ellipses.
5. Macadam ellipsoids.
6. 1964 CIE UCS

5.3 The CIELAB System (cf. MUNSELL-CIELAB/ANLAB)

1. The Birth of CIELAB.

5.4 Colour tolerances, tolerance models and formulae.

1. Limit samples (Munsell)
2. Limit samples (Saltzman)
3. Tolerance models

5.5 Colour Sorting

1. The 555 model
2. - 6. ICS color sorting models

6. FACTORS INFLUENCING THE COLOUR OF DYED TEXTILES (cf.overheads)

7. DYESTUFF SELECTION, COLOUR MATCHING.

7.1 Plotting dyeings in CIELAB, colour gamuts

1. Classic colour triangle.
2. "ICI colour map".
3. 3-dye combinations
4. Adding a fourth dye.
5. Range of dyes.
6. 3 dyes.
7. Enlarging the gamut.
8. Full colour gamut.
9. White vs. yellowish wool.

7.2 Calibration dyeings.

1. Gelb R
2. Gelb GRL
3. Rot GG
4. Bordo
5. Blau
6. Grau

7.3 R (λ) curves of "Standards" (to be matched).

1. 1-3
2. 5-8

7.4 Colour matching printout.

1. Alternative recipes.

7.5 Corrections.

7.6 Correction to different colours.

1. Beige - brown
2. Green - brown

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A method of Assessing the Quality of Daylight Simulators for Colorimetry (1981) Nr. 51
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Wyszecki, Gunter and Stiles, W.S.: *Color Science: Concepts and Methods, Quantitative Data and Formulae.* 2nd ed. New York: John Wiley and Sons, 1982. 950 p.

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Colour standards purchased through the project

1 set of BCRA-NPL colour tiles
12 colour tiles prepared by the British Ceramic Research Association, calibrated by the National Physical Laboratories

1 Russian opal glass (NPL white standard)

1 Black ceramic white standard (NPL calibrated)

1 set of DIN-AATCC Standard Depth standards

PROJETO UNIDO SI/BRA/89/801
Visita a São Paulo

Perito: Dr. ROBERT HIRSCHLER
Acompanhante: CYRO EDUARDO FERNANDES
Periodo: 12 a 16 de fevereiro de 1990

A visita de cinco dias a São Paulo teve o objetivo de saber em que estagio se encontra o sistema de colour matching e tambem de oferecer a ajuda do CETIQT nesta area. A fim de alcancar um bom resultado, nos solicitamos a DCI que contactasse o DR/SP e selecionasse uma quantidade significativa de companhias texteis em São Paulo.

Uma lista de companhias as quais nos visitamos segue-se:

- INDUSTRIA DE MEIAS SCALINA LTDA. (TRIFIL)
- APARELHOS DE LABORATORIO MATHIS
- CIBA-GEIGY QUIMICA S/A
- ICI
- TINTURARIA TEXTIL LEAO

Nos tivemos tambem a oportunidade de ir a FENATEC e a ESCOLA SENAI FRANCISCO MATARAZZO.

No primeiro dia nos visitamos o escritorio do DR/SP e o Dr. Hirschler expos brevemente ao Sr. Narciso Vicentini Ferraz (Diretor da ESCOLA SENAI FRANCISCO MATARAZZO), Sr. Aecio Batista de Souza (Diretor de Tecnologia Educacional)e ao Sr. Paulo Antonio Gomes a finalidade do projeto e o Sr. Aecio demonstrou estar interessado em ter um projeto de cooperacao com a UNIDO. No horario de almoco, o Sr. Paulo Tolle (Diretor do SENAI DR-SP) juntou-se ao grupo e o nosso programa de visitas foi discutido.

Apos o almoco nos fomos a FENATEC e vale a pena salientar que o estande do CETIQT encontrava-se fechado.

No dia 13 de fevereiro, nos visitamos a Fabrica de Meias Scalina (Trifil) acompanhados pelos senhores Erico de Freitas (Agente de Treinamento da Escola Francisco Matarazzo) e Walter Silvestre (Tecnico de Beneficiamento Textil) sendo recebidos pelo Sr. Ronald Heilberg que e um dos proprietarios da fabrica. Ele demonstrou interesse em recuperacao de agua e energia; nessa ocasiao foi recomendado o contato com o setor de efluentes do CETIQT.

Na parte da tarde, visitamos a planta da MATHIS onde alguns equipamentos para tingimento foram mostrados. Nos recebemos informacoes adicionais sobre o sistema MATHIS de colorimetria.

No dia 14 de fevereiro, acompanhados novamente pelo Sr. Erico e pelo Sr. Vladimir Valerio (Instrutor Textil). Fomos recebidos pelo Sr. Frits Herbold e pelo Sr. Siegfried Unglert. Eles nos informaram que a CIBA-GEIGY cooperars com produtos quimicos, cursos e informacoes sempre que o CETIQT necessitar. Foi tambem discutida a possibilidade do CETIQT receber, como doacao, um vaporizador de laboratorio que a companhia nao utiliza no momento.

Na parte da tarde, nos conhecemos o sistema de colorimetria da ICI e a senhora Tania Martinez nos disse que apreciaria poder assistir a um curso deste assunto pois eles possuem muitas dificuldades.

No dia 15 de fevereiro, nos visitamos a Tinturaria Leao, acompanhados pelo Sr. Bernardo Martim (Assistente de Direcao da Escola Textil). Nos discutimos com o Sr. Carlo Giacomo (Gerente de Producao) e com o Sr. Enio (Diretor Tecnico) sobre as dificuldades iniciais na implantacao do sistema de colorimetria.

Eles demonstraram bastante interesse em que um curso fosse ministrado em São Paulo pelo Dr. Robert Hirschler.

No dia 16, nos visitamos a Escola Textil onde o Dr. Hirschler discutiu com o Sr Narciso sobre o curriculo da Escola e tambem sobre um possivel apoio da UNIDO na fase de reestruturacao da Escola. Voltamos a nos reunir com o Sr. Aecio onde ficou combinada uma segunda visita a São Paulo, possivelmente em abril.

Foi possivel notar que o DR-SP esta bastante interessado em conseguir um projeto de cooperacao com a UNIDO.

CIBA-GEIGY Colorimetry workshop
São Paulo, 2-5 April, 1990.

Participants:

SENAI/CETIQT	Cyro Eduardo Fernandes Kelson dos Santos Araujo
CIBA-GEIGY:	Ms. Ingrid Schmitz (Head of Colorimetry, Basel) Mr. Frits V. Herbold (Head of Marketing/dyestuffs) Ms. Vania de Faria Mr. Luis F. Pauvolid Mr. Aloisio Claudio Mr. Sigfried Unglert Mr. Valdir Pereira Mr. Cesar V. Pinho

Program:

2nd April	Reflectance, transmittance, absorption, Kubelka-Munk, G-factors, recipe calculation with G-factors, colorant selection. Commercial computerized recipe prediction programs: concepts, examples, exercizes. Colour measuring equipment: construction details, spectrophotometers, computers, programs. Colour, colour perception. Light sources, standard illuminants.
3rd April	The human eye, colour vision mechanisms. The standard observer, colour vision deficiencies. Tristimulus values, chromaticity coordinates, the CIE system, principles, limitations.
4th April	Colour differences, the McAdam limits, the CIELAB System. Calculation of CIELAB coordinates and colour differences: modified formulae. The coloristic strength concept: the proprietary CFU method. Comparison of the dyeing strength of dyestuffs. Colour systems DIN, MUNSELL, NCS, Pantone, Chromatone, Color Base (PAC 3019). The measurement of whiteness: optical brighteners, fluorescence, whiteness formulae, the GANZ formula.
5th April	The economic significance of colorimetric methods. Applications, possibilities and limitations. Rentability, amortization, personnel.

COMPUTERIZED COLOUR MATCHING AS PRACTICED IN THE BRAZILIAN TEXTILE INDUSTRY

UNIDO PROJECT SI/BRA/89/801

TECHNICAL REPORT TO HERING (BLUMENAU)

Prepared by Dr.Robert Hirschler,
Expert in Computerized Colour Matching

1. EVALUATION OF THE PRACTICE OF COLOUR MEASUREMENT AT HERING

The DATACOLOR 3890 (DATACOLOR 3890) spectrophotometer with the OSIRIS software is one of the best and most sophisticated colour matching systems in the world today used in the textile industry. The system is located in an enclosed space within the laboratory, an adequate - but somewhat tight - arrangement.

The staff engaged in this work has shown good working knowledge of the basic principles and techniques applicable, they are familiar with and comfortable in operating the system. They also show keen interest in their work, trying to improve and extend it.

This is reflected in the state of the system, it is well taken care of, properly maintained and operated. Performance tests were conducted on the spectrophotometer with the following results.

1.1 Short term repeatability

Short-term repeatability shows how well the spectrophotometer can repeat measurements on a well-defined sample (such as a ceramic colour standard) within a short time (typically some hours), and it is expressed in DE^*_{ab} colour difference units. The best instruments give an average repeatability of $DE^*_{rpt} < 0.05$, but average values up to $DE^*_{rpt} < 0.1$ are acceptable. The results are summarized below, with full details given in APPENDIX 1.

Due to the limited time available only the 5 most critical of the 12 NPL-BCRA ceramic colour standards were measured 10 times, the others only 3 times, giving only approximate values. For reference we also include the corresponding values measured on the same instrument in 1989.

SHORT-TERM REPEATABILITY OF THE DATACOLOR 3890

TILE COLOUR	REPEATABILITY DE^*_{rpt} (short term) 1989	1990
PALE GREY	0.03	0.03*
MEDIUM GREY	0.02	0.02*
DIFFERENCE GREY	0.01	0.02*
DARK GREY	0.02	0.01*
PINK	0.01	0.02
RED	0.06	0.09
ORANGE	0.03	0.07*
YELLOW	0.02	0.03
GREEN	0.03	0.05*
DIFFERENCE GREEN	0.02	0.02*
CYAN	0.02	0.02
DEEP BLUE	0.03	0.12
Average	0.03	0.04
Maximum	0.06	0.12

* approximate values calculated from 3 parallels.

The average value of 0.04 is still excellent, but there is a slight deterioration as compared to last year's values. We have been informed, that the company is due to have a set of ceramic colour standards soon. It is recommended that this repeatability test be performed regularly (at least once a month), and should the results deteriorate further, the manufacturer be notified.

It has to be emphasized, that the values obtained are as good as or better than those for other types of instruments (see details in APPENDIX 1.), they are only slightly worse than the outstanding values normally provided by this generation of DATACOLOR spectrophotometers.

In addition to short-term repeatability, the drift (keeping the calibration values) as well as medium and long-term repeatability have also to be checked regularly in order to ensure that values in the data bank for colour matching and for quality control can be used safely, yielding accurate results. A brief description on these tests is given in APPENDIX 1., and it is recommended that as soon as the ceramic colour standards become available for the company these tests be performed regularly.

1.2 Reproducibility

Reproducibility (DE^*_{repr}) is the measure of conformance between instruments of exactly the same type, such as two DATACOLOR 3890 spectrophotometers. It needs measurements on the same samples (e.g. ceramic colour standards) performed on both instruments.

The CETIQT Applied Colorimetry Laboratory hasn't yet succeeded in measuring the current set of the NPL-BCRA standards on any other DATACOLOR 3890, thus reproducibility figures are not available. It is recommended however, that the two instruments of the company (in Blumenau resp. in Recife) be compared regularly, at least every 6 months, to enable accurate color communication within the company. The maximum permissible colour difference (for the average of the 12 colour of the NPL-BCRA set) is $DE^*_{repr} < 0.2$, but high-performance instruments, such as the DATACOLOR 3890 should perform better then that, the typical values being $DE^*_{repr} < 0.1$. Details of the method are given in APPENDIX 2.

It has to be pointed out that reproducibility only has importance if measurement values (such as those of a data bank for colour matching of quality control) are to be transferred from one instrument to another.

1.3 Accuracy

Accuracy is given by the colour difference calculated between measured values and those given by a standardizing laboratory (such as the National Physical Laboratory in Teddington, U.K.). Although - like reproducibility - it has practical significance only if measurement values are to be transferred to other systems (with not necessarily of the same type of spectrophotometer) accuracy also can indicate, if the practice of calibration and measurement procedures is adequate or not, and also show eventual problems with the spectrophotometer itself. High-performance spectrophotometers should have an accuracy (average of 12 ceramic colour standards) of $DE^*_{acy} < 0.5$.

Since absolute values of reflectance (and naturally all derived quantities, like XYZ or L^*. a^*, b^*) depend on a number of factors, it has to be made sure, that the measurements are performed using standardized methods, and comparisons are only made between values obtained under identical conditions (e.g. specular excluded or included, etc.).

In the accuracy tests at HERING we have taken the average of 3 measurements on each sample for the calculation of accuracy, and compared the results to those obtained at NPL on the same set of 12 ceramic colour standards.

The current practice at Hering (following DATACOLOR recommendations, but nor international standards) is to use the value 1.00 at all wavelengths for the barium sulphate white reference, and we have made measurements with both geometries (specular excluded and included) with both sets of reference values, i.e. 1.00 for all wavelengths resp. the absolute values of barium sulphate as given in the spectrophotometer manual.

The results obtained during this visit are summarized below, with full details given in APPENDIX 3.

ACCURACY OF DATACOLOR 3890 SPECTROPHOTOMETER
DE^*_{xy} compared to NPL

	Specular included			Specular excluded	
	Abs.	BaSO4 = 1.00		Abs.	BaSO4 = 1.00
TILE COLOUR		1990	1989*		
PALE GREY	0.2	0.7	0.2	0.2	0.5
MEDIUM GREY	0.2	0.6	0.4	0.2	0.7
DIFFERENCE GREY	0.5	0.7	0.5	0.3	0.5
DARK GREY	0.8	1.0	0.1	0.2	0.5
PINK	0.9	1.1	0.7	1.1	1.1
RED	0.8	0.9	0.8	1.4	1.4
ORANGE	0.9	1.6	1.9	1.7	1.6
YELLOW	3.1	2.9	1.0	3.3	2.9
GREEN	2.0	1.9	1.1	2.1	2.1
DIFF. GREEN	1.9	2.0	0.3	2.1	2.1
CYAN	0.4	0.7	0.3	0.4	0.5
DARK BLUE	0.2	0.2	0.3	3.0	2.6
Average	1.0	1.2	0.6	1.3	1.4
Maximum	3.1	2.9	1.9	3.3	2.9

* using a different set of Ceramic Colour Standards.

For reference we have included the accuracy values obtained on this same instrument with a different set of ceramic colour standards in 1989.

Analyzing the values we can see that

- the accuracy of the instrument is worse than expected, particularly for some highly chromatic colours;
- the accuracy has deteriorated since last year;
- in the case of the grey samples significant, in most other cases slight improvement of accuracy may be achieved by using the absolute values of the reference white.

If we compare the average and the maximum values obtained with those of other instruments (see details in APPENDIX 3.) we can see, that the average picture is not yet alarming (it is comparable to other types of instruments used widely in the Brazilian textile industry with success), but it's not up to the level expected from this instrument.

The colour difference attributable to the values of the reference white (1.00 versus absolute values) is relatively small, for the 12 tiles we have found it to be between 0.2 and 0.6, explaining also the relatively small improvement that can be achieved for non-grey samples.

Experiments with other systems (e.g. the MATHIS-OPTRONIK or the DATACOLOR TEXFLASH) support these results: the use of absolute white values does not increase the accuracy. Also, experiments with the DATACOLOR OSIRIS software indicate, that - at least partly - the weighing factors used for the calculation of the XYZ tristimulus values lead to anomalies.

Since the practical importance of accuracy is secondary to the repeatability of the instrument, these results should only be taken as a mild warning that something might not be perfect with the instrument.

It is recommended, that this problem be discussed with the technical experts of ACS-DATACOLOR, and any eventual action be taken only thereafter. It is hereby offered, that the Chief Technical Adviser of the project will raise this question with ACS-DATACOLOR during his visit to the company's Princeton Headquarter in May 1991, and the results be communicated to Hering upon his return to Brazil (in June 1991).

2. VISUAL COLOUR CONTROL

Visual colour control still plays (and is going to play) a significant role in industrial practice. The importance of using well-defined, constant and standardized illuminating and viewing conditions cannot be emphasized too strongly. Unfortunately, many of the colour matching cabinets (booths) used in the Brazilian textile industry do not conform closely to international standards, and the way colour or colour difference assessment is performed also deviates from standard methods.

Problems with the illumination are related both to the quality (spectral power distribution) of the light sources, and the way samples are often viewed under "mixed illumination" i.e. switching on both daylight and tungsten sources. This problem will gain even more importance when the company tries to introduce instrumental colour quality control, and visual decisions will be compared to instrumental values.

Unfortunately it is rather difficult to assess the conformance of the illumination in a visual colour control booth to international standards. The CETIQT Applied Colorimetry Laboratory is currently working on this problem, and as soon as a reliable practical method is available it's going to offer services for the industry in this field. Until then a copy of the relevant ASTM standard (D 1729-82: VISUAL EVALUATION OF COLOR DIFFERENCES OF OPAQUE MATERIALS) is enclosed with this report.

3. DISCUSSIONS ON APPLIED COLORIMETRY

Practical aspects of colorimetry were discussed in detail with a group of c. 15. Instead of a formal presentation the event took the form of a "guided discussion", with questions - or indeed more detailed explanations - interrupting the speaker whenever necessary. The questions placed by the audience were relevant and showed much interest in the topic. A video recording has been made of the entire discussion.

One of the most interesting - and most complex - questions discussed was that of instrumental quality control, most precisely which point of the production process should be controlled by color measurement, and what are the possibilities of setting tolerance limits at a an earlier stage (e.g. directly after dyeing) and controlling thereby the end-colour (i.e. the colour of the chemically finished product). There is of course no easy or simple answer to that question. It has to be studied in detail, and following a well-planned experimental design the method has to be elaborated as applied to the actual situation in the factory. Since the company is expecting a student from Germany (Ms. Jennifer Gay) to return to Hering and preparing her thesis there, this topic would be ideal for her and the company as well. Consultation and guidance is hereby offered by the CETIQT Applied Colorimetry Laboratory in this work.

Instrument performance tests.

The performance of colour measuring instruments (colorimeters and spectrophotometers) is characterized by their short-(eventually medium and long)-term repeatability, their reproducibility and accuracy. The measurements determining these properties are usually conducted on a set of Ceramic Colour Standards (C.C.S.) prepared by the British Ceramic Research Association (BCRA) and calibrated by the National Physical Laboratory (NPL) in Teddington, U.K.

The set consists of the following 12 colour tiles:

PALE GREY (PGREY)

MEDIUM GREY (MGREY)

DIFFERENCE GREY (DIFF G)

DEEP GREY (DGREY)

DEEP PINK (PINK)

RED (RED)

ORANGE (ORANGE)

BRIGHT YELLOW (YELLOW)

GREEN (GREEN)

DIFFERENCE GREEN (DGREEN)

CYAN (CYAN)

DEEP BLUE (DBLUE)

The tiles are measured in succession, and normally 10 single measurements are made on each tile for short-term repeatability, and 3-5 averaged measurements for the determination of reproducibility and accuracy. Generally the averages over the set of colour standards are given as a measure of the performance, sometimes the maximum values are also quoted. Since some of the tiles are thermochromic, the measurements should always be conducted under constant, controlled temperature, preferably 25°C ± 1°C.

1. Repeatability

Repeatability shows how well measurements on the same instrument, on the same, well-defined sample can be repeated under controlled conditions, and it is characterized by the average colour difference determined between individual measurement and the average of n measurements (on the same sample). It is calculated for each colour by DE^*_{rpt}:

$$DE^*_{rpt} = \frac{1}{n}\sum DE^*_i = \frac{1}{n}\sum [(\overline{L^*}-L^*_i)^2+(\overline{a^*}-a^*_i)^2+(\overline{b^*}-b^*_i)^2]^{1/2}$$

where DE^*_{rpt} is the average CIELAB colour difference of *n* measurements characterizing repeatability on one sample;

DE^*_i is the CIELAB colour difference between the *i*th individual measurement and the average of n measurements;

L^*_i, a^*_i and b^*_i are the CIELAB values of the *i*th individual measurement; and

$\overline{L^*}$, $\overline{a^*}$ and $\overline{b^*}$ are the average values of n, usually 10 measurements.

Sometimes the DE^*_{max} value (the largest of the DE^*_i values) is also given as additional information.

Short-term repeatability is usually determined by 10 measurements, each performed within a short period after recalibrating the instrument. One way of checking the short-term repeatability is to calibrate the spectrophotometer, measure the series of colour standards e.g. the BCRA-NPL Ceramic Colour Standards (single measurements on each sample!), repeat the calibration-measurement cycle ten times, and perform the calculation described above. Short-term repeatability is regarded as acceptable if $\overline{DE^*_{rpt}}$, the average of the DE^*_{rpt} values calculated as above for each of 12 NPL-BCRA tiles is

$$\overline{DE^*_{rpt}} < 0.05 \quad \text{short-term}$$

The DE^*_{rpt} values for individual tiles can range from 0.01 (GREY) to 0.08-0.12 (ORANGE, RED, DEEP BLUE).

Medium-and long-term repeatability is determined by the same method, but performed over a longer time-span.

The following performance check routine is recommended to be introduced:

a. Run the short-term repeatability test once every month by measuring the series of 12 BCRA ceramic colour standards ten times (i.e. calibrate the spectro, measure Tile #1, then #2 etc. through #12, then recalibrate, measure #1 again, #2 again, etc.). Calculate the average of 10 measurements for each tile either averaging L^*_i, a^*_i and b^*_i values or, if possible, $R(\lambda)_i$ values, and calculate DE^*_{rpt} (short-term) using the above formula. The $\overline{DE^*_{rpt}}$ value for the 12 tiles should be < 0.05.

b. Repeat this procedure month after month, and calculate medium-term repeatability using the average ($\overline{L^*}$, $\overline{a^*}$ and $\overline{b^*}$) values of the 10 measurements taken every month (in the place of individual L^*_i, a^*_i and b^*_i values), while the new $\overline{L^*}$, $\overline{a^*}$ and $\overline{b^*}$ values will be the average values of the monthly averages. We speak about medium-term repeatability below 1 year, and long-term repeatability above 1 year. Both are regarded as acceptable if the average for the 12 NPL-BCRA tiles is

$$\overline{DE^*_{rpt}} < 0.1 \text{ (medium or long term)}$$

<u>Drift</u> shows how long the instrument is able to hold its calibration values. Modern instruments are supposed to be self-calibrating, i.e. they only need calibration once a day. It is recommended to check the stability of the calibration once a week. 30 minutes after switching on the instrument in the morning measure e.g. the 3 most sensitive tiles (RED, ORANGE and DEEP BLUE) every hour without recalibration, and record the L^*, a^* and b^* values as well as the colour difference between the first and the subsequent individual measurements. The DE^*_{ab} values should not exceed 0.05 - 0.1, and the individual L^*, a^*, b^* values should not exhibit a tendency of increasing or decreasing (i.e. they should not exhibit drift).

The short-term repeatability of the DATACOLOR 3890 instrument had been determined in 1989, and for some selected tiles (giving the highest values) it was repeated in 1990. For the sake of comparison in TABLE 1. corresponding values are also given for other types of spectrophotometers, such as those of Applied Color Systems (ACS), 3 MACBETH (MS 2020) instruments with ICS-TEXICON software, 5 OPTRONIK instruments with BASF/MATHIS software (the most widely used type in Brazil), and the Spectrogard (SQ) and The Color Machine (TCM) of Gardner Pacific Scientific. These instruments are widely used all over the world, and may be regarded as a good cross-section of up-to-date industrial spectrophotometers.

Table A1. Short-term repeatability DE^*_{rpt} of the DATACOLOR 3890 spectrophotometer compared to other instruments on the 12 NPL/BCRA C.C.S. tiles.

TILE	DATACOLOR 3890 1989	DATACOLOR 3890 1990	ACS	MS2020	OPTR.	SG	TCM
PGREY	0.03	0.03	0.01	0.02	0.05	0.01	0.03
MGREY	0.02	0.02	0.01	0.02	0.04	0.01	0.02
DIFF G	0.01	0.02	0.01	0.01	0.04	0.01	0.02
DGREY	0.02	0.01	0.01	0.02	0.06	0.03	0.03
PINK	0.01	0.02	0.02	0.02	0.07	0.06	0.04
RED	0.06	0.09	0.03	0.04	0.11	0.14	0.12
ORANGE	0.03	0.07	0.04	0.03	0.09	0.12	0.08
YELLOW	0.02	0.03	0.04	0.03	0.07	0.09	0.04
GREEN	0.03	0.05	0.04	0.03	0.06	0.08	0.06
DGREEN	0.02	0.04	0.03	0.04	0.06	0.09	0.06
CYAN	0.02	0.02	0.02	0.04	0.04	0.07	0.04
DBLUE	0.03	0.12	0.01	0.03	0.07	0.07	0.08
Average	0.03	0.04	0.02	0.03	0.06	0.06	0.05
Maximum	0.06	0.12	0.04	0.06	0.25	0.14	0.12

* approximate values
** old model, the new version has been improved

2. Reproducibility

Reproducibility shows how well measurements on the same, well-defined samples can be repeated under controlled conditions on different instruments of the same type (such as two or more DATACOLOR 3890 spectrophotometers). It is characterized by the average colour difference between measurements on the tested instruments for a set of selected samples such as the NPL-BCRA C.C.S. set.

If more than two (let's say *n*) instruments are involved, then the L^*_j, a^*_j and b^*_j - or, even better, $R(\lambda)_j$ - values for each instrument are averaged, and colour differences calculated from the average according to

$$DE^*_{repr} = \frac{1}{n}\sum DE^*_j = \frac{1}{n}\sum [(\overline{L^*}-L^*_j)^2+(\overline{a^*}-a^*_j)^2+(\overline{b^*}-b^*_j)^2]^{1/2}$$

where DE^*_{repr} is the CIELAB colour difference characterizing repeatability on one sample;

DE_j is the CIELAB colour difference between measurements on the *j*th instrument and the average of *n* instruments;

L_j, a_j and b_j are the CIELAB values measured on the *j*th instrument; and

L^*_j, a^*_j and b^*_j are the average values of n instruments.

Reproducibility of an instrument is usually characterized by $\overline{DE^*_{repr}}$, which is the average of DE^*_{repr} values for the 12 NPL-BCRA tiles, and it is considered acceptable, if

$$\overline{DE^*_{repr}} < 0.2$$

(the manufacturers of the latest generations of spectrophotometers claim average inter-instrument reproducibility of $\overline{DE^*_{repr}} < 0.1$).

There are no values available with the current set of C.C.S., but last year the DATACOLOR 3890 in Blumenau was compared to one instrument in Zurich, and the following results were obtained:

Table A2. Reproducibility $\overline{DE}^{*}_{repr}$ of the DATACOLOR 3890 spectrophotometer compared to other instruments on 12 BCRA C.C.S. tiles.

TILE	DATACOLOR 3890 1989	OPTRONIK (4 instr.)	MS-2020 (3 instr.)
PGREY	0.20	0.27	0.04
MGREY	0.22	0.45	0.08
DIFF G	0.12	0.44	0.05
DGREY	0.40	0.05	0.32
PINK	0.45	0.06	0.54
RED	0.93	0.04	0.69
ORANGE	0.56	0.11	0.95
YELLOW	0.97	0.58	0.10
GREEN	0.30	0.51	0.08
DGREEN	0.43	0.48	0.07
CYAN	0.33	0.49	0.14
DBLUE	0.14	0.54	0.09
Average	0.42	0.52	0.08
Maximum	0.97	1.70	0.21

*older model

3. Accuracy

Accuracy shows how close measurements on one instrument are to measurements of the same sample sets performed by a standardizing laboratory. One of the most widely used set is the NPL-BCRA Ceramic Colour Sample set of 12 ceramic tiles with nominal (standard) values determined by the National Physical Laboratory in Teddington, U.K.

Accuracy is thus characterized by the colour difference DE^{*}_{acy} between measured and nominal values, and it is regarded as acceptable, if the average for the 12 tiles is

$$\overline{DE^{*}_{acy}} < 0.5$$

When evaluating the accuracy of an instrument, a number of factors (particularly those of measurement geometry and calibration procedures) have to be taken into consideration.

The detailed figures of the accuracy determination for the DATACOLOR 3890 instrument are shown in TABLE A3., while in TABLE A4. these values are compared to accuracy values of the MATHIS/OPTRONIK [M(5), average of 5], ACS, MS2020 (3), [MACBETH 2020 with ICS-Texicon software, average of 3], Spectrogard (SG) and The Color Machine (TCM) spectrophotometers. TABLE A5. shows the colour difference caused by changing the calibration values of the reference white from 1.00 at all wavelengths to the absolute values given in the manual of the spectrophotometer.

Table A3. Accuracy $\overline{DE}^*_{xcy}$ of the DATACOLOR 3890 spectrophotometer as compared to the 12 NPL-calibrated BCRA Ceramic Colour Standard tiles (specular included). The last column shows for comparison the accuracy values obtained in 1989 with a different set of BCRA tiles.

	Specular included			Specular excluded	
	Abs.	BaSO4 = 1.00		Abs.	BaSO4 = 1.00
TILE COLOUR		1990	1989*		
PALE GREY	0.2	0.7	0.2	0.2	0.5
MEDIUM GREY	0.2	0.6	0.4	0.2	0.7
DIFFERENCE GREY	0.5	0.7	0.5	0.3	0.5
DARK GREY	0.8	1.0	0.1	0.2	0.5
PINK	0.9	1.1	0.7	1.1	1.1
RED	0.8	0.9	0.8	1.4	1.4
ORANGE	0.9	1.6	1.9	1.7	1.6
YELLOW	3.1	2.9	1.0	3.3	2.9
GREEN	2.0	1.9	1.1	2.1	2.1
DIFF. GREEN	1.9	2.0	0.3	2.1	2.1
CYAN	0.4	0.7	0.3	0.4	0.5
DARK BLUE	0.2	0.2	0.3	3.0	2.6
Average	1.0	1.2	0.6	1.3	1.4
Maximum	3.1	2.9	1.9	3.3	2.9

* using a different set of Ceramic Colour Standards.

TABLE A4. Accuracy $\overline{DE^*_{xy}}$ of different types of colour measuring spectrophotometers compared to NPL nominal values

TILE	M(5)	ACS	MS 2020			SG	TCM
			#1	#2	#3		
PGREY	0.40	0.12	0.17	0.12	0.11	0.15	1.85
MGREY	0.49	0.11	0.26	0.24	0.19	0.20	1.38
DGREY	0.47	0.06	0.18	0.15	0.15	0.20	1.37
DIFF G	0.83	0.45	0.32	0.36	0.37	0.64	0.44
PINK	0.83	0.45	0.28	0.36	0.25	0.98	1.13
RED	1.24	0.48	0.29	0.35	0.27	1.29	0.82
ORANGE	1.34	0.78	0.48	0.61	0.43	1.56	2.44
YELLOW	1.04	0.19	0.39	0.36	0.27	0.62	2.47
GREEN	1.53	0.98	0.63	0.62	0.59	1.12	1.38
DGREEN	1.56	0.77	0.55	0.57	0.53	1.13	1.40
CYAN	1.89	0.96	0.41	0.54	0.30	0.66	1.03
DBLUE	1.55	0.72	0.86	0.72	0.90	1.80	2.69
Average	1.10	0.50	0.40	0.42	0.36	0.86	1.53
Maximum	2.36	0.98	0.86	0.72	0.90	1.80	2.69

M(5) average of 5 MATHIS/OPTRONIK instruments
ACS Applied Color Systems/Spectrosensor
MS 2020 3 Macbeth MS 2020 spectrophotometers with ICS-TEXICON software
SG Pacific Scientific/Spectrogard
TCM Pacific Scientific/The Color Machine

<u>TABLE A5.</u> Colour difference DE^*_{ab} between absolute calibration and BaSO4 = 100 as measured on the DATACOLOR 3890 spectrophotometer for 12 NPL-BCRA Ceramic Colour Standard tiles.

	Specular included	Specular excluded
PGREY	0.5	0.4
MGREY	0.4	0.3
DIFF G	0.3	0.3
DGREY	0.2	0.2
PINK	0.2	0.3
RED	0.2	0.5
ORANGE	0.3	0.4
YELLOW	0.5	0.6
GREEN	0.2	0.3
DGREEN	0.2	0.3
CYAN	0.4	0.3
DBLUE	0.2	0.4
Average	0.3	0.4
Maximum	0.5	0.6

ANNEX 5.

REPORT ON THE VISIT MADE ON THE
21ST NOVEMBER 1989

FIACAO E TECELAGEM SAO JOSE S.A. - BARBACENA
MINAS GERAIS - BRAZIL

This report is the work of
dr Robert Hirschler, Expert in
Computerized Colour Matching
UNIDO - Vienna - Austria

INTRODUCTION

The purpose of this visit was to review and discuss possibilities for the application of colour matching and related areas in the dyeing and finishing plant of São Jose.

Other topics (the use of Roberto Rolls prior to dyeing operations; possibilities for dyeing synthetic fibres - primarily polyester - and blends; problems with uniformity of dyeings) have also been briefly discussed with

Mr. Vandir Meller, General Manager
Mr. Aloisio A. Neves, Dyeing and Finishing Manager, and
Mr. Kurt Walter, Technical Consultant.

The report of Dr. Maurice Aspinall, UNIDO consultant in dyeing and finishing, contains all the principle data on the plant, so these will not be repeated here, neither will the questions also dealt with in that report. It must be emphasized however, that - as discussed already during the visit - the author of this report is in full agreement with Dr. Aspinall in the necessity to stop the practice of mercerizing greige cloth and to mercerize scoured or scoured and bleached fabric (in order to improve uniformity of quality and also to save chemicals); and in recommending the use of Roberto Rolls in order to increase throughput in the drying and also to save energy.

When looking for possible fields of automation in a dyehouse, the type of processes/operations, type, age and condition of machine available and human factors must be considered together. The São Jose plant is one using exclusively continuous preparation and dyeing methods, with machinery of an average age of 15-20 years. The main quality problems in the dyehouse - colour differences between and within lots - can be traced back to preparation (bleaching, scouring, mercerizing) problems (see above), but also to those of weighing the dyestuffs and chemicals, preparation of dye liquors and printing pastes, and uniformity of dye pick-up in padding.

With all this considered, the possible fields of automation in dyeing/printing/finishing are discussed below.

1. AUTOMATIC DISPENSING/DOSING OF CHEMICALS

One major factor contributing to problems with reliability in the plant is manual dosage of chemicals and auxiliaries. Significant improvement could be achieved by automatic dosing of liquid chemicals (detergents, sodium hydroxide, hydrogen peroxide, etc.) by one of the following ways:

(a) dispensing from dissolving tanks placed in the central colour kitchen, and connected individually to the production machines;

(b) central chemicals dispensing system with network of pipelines;

(c) individual dispensing for each machine from tanks or containers.

Ad (a)

Dispensing liquid chemicals from a central colour kitchen is not recommended for the São Jose plant. The bleaching, mercerizing and washing machines use most of the time only a few, standard chemicals which can be - and generally are - dispensed directly from the original barrels or containers. It is normally not worth while, and in many cases not easily possible for these kinds of operations, to pump and measure the large amounts needed into the dissolving tanks in the colour kitchen, and then dispense them from there.

Ad (b)

In those factories where the same chemicals are used in a number of machines (such as a dyehouse with 10-20 jiggers, HT-beams, jets, etc.) a network of pipelines connects the large volume storage tanks to each dyeing machine. This is not the case in the São Jose plant, where the number of machines using the same chemicals is only 2 or 3, so this method is not recommended here.

Ad (c)

The most cost-effective method in this factory for the automatic dispensing of chemicals would be the use of individual dosing pumps for each machine, automatically dispensing the liquid chemicals into the appropriate tank or compartment of the production machine. Details of the arrangement would of course depend on the final lay-out of the plant after the current reconstruction.

In its simplest form the system would consist of metering pumps for each chemical with 1, 2, 3, or 4 heads leading to the appropriate compartment(s) of the machine(s) using that particular chemical. These pumps can probably be purchased from, and installed by a local supplier.

A more advanced solution is based on the same principle, but the pumps would be controlled by micro-processor based controllers or microcomputers. Details of such systems may be obtained from suppliers in Europe (ICS-Texicon or Schermuly) or eventually from companies represented in this country (e.g. THEN, Vald. Henricksen or Stork). This would be viable in the São Jose factory, particularly in the course of the planned modernization, so this is the recommended option.

The most sophisticated systems available in Europe and the USA consist of a network of pipelines with full computer control (via microprocessor based process controllers) such as those offered e.g. by Foxboro or Arel. This level is not recommended for São Jose yet, because with the present - or even somewhat modernized - machinery the full potentials should not be utilized.

2. COLOUR KITCHEN

The role of the colour kitchen in dyehouses and printing factories is to store, measure, dissolve and dispense colorants (dyes and pigments). In traditional colour kitchens all this is done manually, a modern one has the following features:

(a) Appropriate storage of dyes and pigments, spatially separated from the dissolving resp. production area to avoid excess moisture pick-up from humid air;

(b) Computer controlled weighing of dyes and pigments with electronic balances, the computer providing also lot cards (recipes, etc. for each lot), inventory, etc.;

(c) Dissolving of dyes and auxiliaries in 1 or 2 dissolving vessels for each dyeing machine, and dispensing the solutions by gravity or pumps into the machines; or preparing the printing paste stocks, and dispensing the necessary amounts into the appropriate containers.

Although there are at present only 3 dyeing (Pad-batch and Pad-steam) and 2 printing (Stork rotary screen) machines in the factory, colour kitchen for dyeing and for printing are recommended to be separated. Neither the dyes resp. pigments, nor most of the chemicals/auxiliaries are the same for the two fields, so even if there was a joint colour kitchen only the electronic balances could be used for both, and this would offer very little savings. Under the circumstances envisaged for after the reconstruction, a twin solution with two separate colour kitchens is recommended.

In the dyeing area the colour kitchen (dissolving vessels with valves, network of pipelines, pumps, even computer controlled weighing, etc. can be designed, projected and installed by a Brazilian company (e.g. Mendes Engenharia), who may also have custom-tailored answers for the factory in other fields of the reconstruction. In colour kitchens for printing probably Stork has the largest experience among the companies represented in Brazil, but of course the selection of suppliers would best be made by a sender for the whole project or parts of it.

The main advantages of a modern colour kitchen for the factory would be a much better reproducibility (due to computer controlled weighing), better control of dye liquor and printing paste preparation and instant information on dyes and chemicals stock.

3. PROCESS CONTROLLERS

The continuous preparation (bleaching, mercerizing), washing, dyeing (Pad-Roll, Pad-Steam) and finishing machines - which are on the average 15-20 years old - do not lend themselves easily to automation with process controllers. Two of the most important parameters (speed and temperature) are controlled by conventional means, and the mere replacement of these controllers by microprocessor based ones on old machines does not generally improve reliability (provided the existing ones are in good working order). For new machines, naturally, up-to-date controllers are recommended.

On the other hand, significant improvement in process reliability can be achieved by controlling liquor pick-up in continuous dyeing, and savings in energy by controlling air-flow during dyeing. Both need special measuring and control devices, which could, in principle, be installed on the existing machinery, but this - due to the not faultless mechanical condition of the machines - may not bring the required results. Such automation is only recommended if the machines (pad-mangles resp. stenter frame) are to be simultaneously completely overhauled. For the new machines it is recommended that they be purchased with automatic pick-up control for dyeing, and air-flow control for drying and finishing stenters.

Full automation - with microprocessor based controllers connected to a central computer, or into a network - is recommended for São Jose only as a second step, after all basic processes have been streamlined and controlled, along the lines recommended by Dr. Aspinall. For a philosophy and general guidelines of automation a seminar paper on "Dyehouse Automation" is attached to this report.

4. COLOUR MEASUREMENT AND COLOUR MATCHING

The São Jose factory has so far no experience in using instrumental colour measurement methods. It is recommended that some of the professionals (textile chemists and colourists) be acquainted with it, a good opportunity being an introductory training course to be organized by CETIQT early next year.

Before deciding on purchasing a colour matching system (which, eventually, is recommended) trials in the following fields are recommended to test the viability of these methods under the condition of the factory.

(a) Colour sorting -

One of the main problems in the factory is the colour difference from batch to batch, or even between pieces within a batch. The factory often sorts these pieces into more or less homogeneous lots; it could be done much faster and with much higher precision by the instrumental method.

(b) Efficiency of mercerizing -

Due to the frequent use of mercerizing greige fabric, the not really optimal machine conditions and process parameters, the efficiency of mercerizing is not uniform, and it is below the achievable level. Instrumental colour measurement can show numerically the effect of mercerizing both in terms of dyestuff up-take and apparent depth of shade, giving thus quantitative control over the process.

(c) Recipe formulation -

The factory produces a new shade card with c. 20 colours every season (4 times a year). This low number of recipes makes it possible to use the services of and even remotely located colour matching center (such as the one to be set up at CETIQT) for recipe formulation and optimization, in connection with the process and recipe optimization program recommended by Dr. Aspinall.

5. COMPUTER AIDED DESIGN AND MANUFACTURING (CAD/CAM) IN PRINTING

The factory produces about 30 new designs (120-150 screens) every month. A feasibility study should be made to evaluate the potential advantages and commercial viability of installing a CAD/CAM system for making print-designs (with instant colour hard copy in any number of colour ways); films for diapositives or eventually the screens themselves by a laser-engraver. The main advantage would be the quick response to customer's orders: screens may be ready in 2-3 days from the moment the customer (or the designer) explains or shows the design-idea.

RECOMMENDATIONS

(i) To improve the reliability of the washing, scouring, bleaching and mercerizing processes individual dosing pumps are recommended to be installed for the liquid chemicals used regularly. It should be investigated, which supplier can offer the best system for automatic control of the dosing pumps, and for the planned modernization of the factory such a system - see 1. (c) - should be projected.

(ii) For the storage, dissolving and dispersing of colorants separate but adjoining - colour kitchens are recommended, with either common, or separate electronic balances connected to a microcomputer for controlled weighing of dyes and pigments.

(iii) It is not recommended at the present state of the machinery to upgrade existing preparation and dyeing machines by installing process controllers. In the course of the reconstruction, simultaneously with the thorough and complete overhaul of the machines, pick-up controllers for the dyeing pad mangles, and air-flow controllers for the drying and finishing stenters should be considered to be installed.

Every new machine should be ordered with electronic controllers for:

(a) liquor pick-up, speed and temperature (Pad-Batch and Pad-Steam) and

(b) air-flow, speed, temperature and width (stenters).

Should the factory start producing synthetics or blends in larger quantity, a fully automated stenter frame is indispensable for heat-setting.

(iv) The following colour measurement and colour matching methods can be introduced as a final step:

- colour sorting;
- evaluating the efficiency of mercerizing;
- recipe formulation `nd optimization.

It is recommended that the factory send some professionals to CETIQT for a basic training course early next year, and also make trials in the above mentioned areas before deciding on the eventual purchase of a colour matching system.

(v) A feasibility study is recommended to be made to evaluate the potential advantages and commercial viability of the application of CAD/CAM methods in printing.

(vi) It is recommended, that the complex project of automation be designed and executed by a professional company specialized in this field (e.g. Mendes Engenharia of Blumenau, of THEN, Thies, V. Henricksen or Stork who have representatives of daughter companies in Brazil).

REPORT ON THE VISIT MADE ON THE 14th MARCH 1989

- NOVA AMERICA (Fonte Limpa)
- MULTI FABRIL (Pau Grande)

This report is the work of
dr Robert Hirschler, Expert in
Computerized Colour Matching
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The primary purpose of this very brief visit to two of the dyeing, printing and finishing factories of Multi Fabril /Nova America was to establish contact and to discuss briefly the possibilities of technical co-operation between the company and CETIQT, with particular reference to the planned continuation of the UNIDO project at CETIQT, launching an "International Technical Assistance" program.

The consultant - in the company of Prof.Alexandre Figueira Rodrigues, General Director, and Prof. Lucio T. Tenan, Technical Director of CETIQT - was cordially received by

- Marcelo Silveira da Rocha, President
- Robert W. Schofield, Vice-President, Production and
- Edelmar Patury Monteiro Filho, Vice-President, Industry.

Both plants visited - Fonte Limpa and Pau Grande - appeared to be clean and tidy, but running at less than 50% capacity. This was explained to be the result of the difficult market situation, i.e. lack of orders. At the Fonte Limpa factory the machinery - with a few exceptions - looked very old, much used and badly in need of modernization. The condition of the pins on at least one of the stenter frames was disastrous, making the operator wasting 3-4 cm on both sides of the fabric.

The machinery in the Pau Grande plant appeared to be somewhat less obsolete, but also vastly under-utilized.

During the visit the following topics were briefly discussed:

1 - Computer program in the dyehouse.

The computer program in the dyehouse offers a simple but efficient way to store all the necessary information on fabrics, machinery, dyes and chemicals. Production recipes may be printed by the computer for each individual lot, with the advantage of simultaneous inventory-control. The program also offers the possibility of running simulated production, for pre-calculating the expectable dyes and chemicals consumption for the coming period (e.g. 1 month).

This program stores all the information necessary to implement "computer controlled weighing". This can fairly easily be done by channelling the output signals of the electronic balances into the computer, which than can compare the actual weights being measured to the ones in the recipe, and giving error signals if the actual values are out of tolerance. The software house originally writing the computer program should have no difficulty in writing these programs and also making the necessary hardware connections for computer controlled weighing.

2 - Application of colour measurement and colour matching.

One of the major problems the dyehouse of the company (like all the others in Brazil) has to face day-to-day is that of the irregularities of dyestuff supply. Even though the Fonte Limpa plant tries to use only one range of reactive dyes, lack of one or the other of the individual dyes makes them introduce dyes of other manufactures, which, particularly, in the case of reactive dyes, very often may cause compatibility problems.

The application of computer colour measurement may in many cases help, by providing alternative recipes with only the available dyes. Should it not be possible (i.e. the colour to be matched is outside the gamut of the available dyes) a number of alternative recipes with dyes of other manufactures - with similar application properties, and full compatibility - may quickly be provided using computer colour measurement.

As the company has streamlined its standard shade range, reducing the number of colours to around 40, it would be viable - at least for a trial period - for the company to utilize the computer colour measurement services of CETIQT. When the necessary preparation work (data-bank) has been done, alternative recipes for dyestuff-replacement may even be asked for on the phone (for standard colours), reducing significantly the time needed in the laboratory of the dyehouse for matching the colours with the new recipes.

3 - CAD/CAM.

The company's plans to install a CAD/CAM system (a design workstation with laser engraver) were also briefly mentioned. One supplier - GV High-Tex System - has so far been seriously considered by the company, who have been offering CAD/CAM for printing, with possible connection to the Stork laser engraver, and also incorporating a colour matching system by DATACOLOR or ICS/TEXICON.

Since these systems are fairly complicated to start working with, full application support of the supplier is absolutely vital, and guarantees in this aspect are strongly advised to be obtained prior to ordering any system. GV High-Tex are still a rather small company, and support from Europe to Brazil may be somewhat problematic for them. It is therefore recommended, that the company get information from other suppliers as well, the addresses of some of them having CAD systems for printing are listed in the APPENDIX to this report.

It may also be interesting for the company to consider introducing CAD/CAM in the field of embroidery, some of the suppliers offering CAD/CAM for embroidery are also listed in the APPENDIX.

4 - International Technical Assistance

A new UNIDO project at CETIQT is envisaged to concentrate more on direct assistance to the industry. For this purpose an "International Technical Assistance Unit" is to be established at CETIQT with the participation of international experts and consultants capable of giving technical assistance in the following ways:

- trouble shooting;
- preparation of investments/projects,
- specification, selection of equipment and machinery;
- optimization of layouts, production, recipes and technologies;
- product and process development;
- applied research specified by the receiving company;
- training;

in all fields of textile manufacturing (from spinning, weaving and knitting to garment manufacturing), with special emphasis on process optimization in dyeing, printing and finishing, on the reduction of effluent load and on garment manufacturing.

RECOMMENDATIONS:

1 - The company should consider the extension of the existing dyehouse computer program with computer controlled weighing. There is a possibility for further discussions on this topic within the framework of the ongoing UNIDO project at CETIQT.

2 - Prior to buying their own computer colour measurement system the company may find it beneficial to run trials with the CETIQT Colour Measurement Laboratory, starting after May 19... It is also recommended, that interested dyers and colourists of the factories be sent to the training course on "Application of Colour Measurement and Computer Colour Matching in the Textile Industry" to be organized at CETIQT in May.

3 - A number of suppliers (some of the major ones listed in the APPENDIX) may be considered for the selection of a CAD/CAM system for printing, and eventually embroidery. One of the services envisaged for the "International Technical Assistance" unit would be to provide expert help in the selection and the installation (with initial training) of complex systems, such as CAD/CAM.

4 - The ways and means of the participation of textile companies in the "International Technical Assistance" scheme, have to be clarified during the project preparation phase. Multifabril/Nova America is invited to submit proposals for the eventual cooperation.

Some of the major suppliers of CAD/CAM systems:

(A) Printing

CGS- Computer Graphic System, Bahnhofstrasse 31, A-6300 Worgl, Austria

CDI- Computer Design Inc., 5270 Northland Dr., Sulte A. Grand Rapids, MI 49505, USA

DAINIPPON Screen Mfg. Co. Ltd., 5F, Sunshine Bldg., 1-1, Koyama Nishihanaike-cho, Kita-ku, Kyoto 603, Japan

EIKONIX Corp., 23 Crosby Drive, Bedford, MA 01730, USA

GV: HIGH-TEX - Gaensler + Voller GmbH & Co. KG, P.O. Box 1165, D-7430 Metzingen, FRG

M & S International, Zonnebaan 36, 3606 CB Maarsen, THE NETHERLANDS

MICRODYNAMICS Inc., 10461 Brockwood Road, Dallas, Texas 75238 USA

SILICON GRAPHICS -Pte Ltd. ASEAN-India HQ,111 North Bridge Road,# 11-04/06, Peninsula Plaza, Singapore 0617

SOPHIS Systems - n.v., Losschaert 29/4, 8710 Kortrijk-Heule, BELGIUM

TCS - TEXTILE COMPUTER SYSTEMS Ltd., Enterprise House, Science Park, Lloyd Str. North, Manchester M15 4EN, ENGLAND

VAN DITMAR ELECTRONICS, Rijksweg 118, 1981 LD Velsen-Zuid, THE NETHERLANDS.

(B) Embroidery

G & S - Gunold & Stigma D-8751 Stockstadt, FRG

SAURER - Adolph Saurer AG, Arbon, Switzerland

ZSK - Stickmaschinen GmbH, Elbestr.31., Pf 4180, D-4150 Krefeld-Bockum, FRG