CONTROL OF THE GRAPHIC DATA TRANSMISSION PROCESS IN SCREEN PRINTING DECORATION

Vicente Lázaro*, Mila Paya* y Montse García.**

* Alicer (asociación para la promoción del diseño cerámico).
** Escuela de Artes y oficios

ABSTRACT

The present study was undertaken to improve the results of screen printing data transmission. All the studies conducted to date have basically focussed on the influence of certain variables relating to the screen printing paste, firing cycle, or working conditions of the screen printing machine, without going into the preceding process stages, i.e., transformation of a given design to the screen printing system.

This study was basically intended to standardise a method or guidelines that ensure homogeneous working conditions. Following these guidelines would favour the elimination of the problem of shades, which arises in this production stage.

INTRODUCTION

One of the problems that currently most affects ceramic tile quality is the change of colour or shade found between different production lots or batches.

The magnitude of this problem stems from the multiplicity of possible causes, which makes detecting the origin extremely difficult.

The problem is not new. Since product quality became a key priority in ceramic companies, producing lots with the same colour characteristics has become a major objective.

As a result, research centres in co-operation with sectoral companies have performed multiple studies to determine the main variables affecting this property throughout the production process.

However, the studies conducted to date have basically focussed on the influence of certain variables relating to the screen printing paste, firing cycle or working conditions of the screen printing machine, without going into the preceding stages in depth, i.e. the transformation of a given design to the screen printing system.[2, 3, 4 and 5]

With a view to complementing previous work, the present study has addressed the improvement of the results of screen printing data transmission, and by extension, also of other decorating systems currently being implemented used in the ceramic sector.

The whole graphic data transmission process implicitly involves a modification of these data known as dot gain. These variations depend on every chemical and physical process that develops, which need to be controlled. Thanks to this control a product can be assured (photolitho or screen), which possess the same properties as often as required.

The main purpose of this study was to standardise a method that would enable ensuring consistent working conditions amongst all the participating departments, whether in-company or outsourced.

Following these guidelines would favour the elimination of shades in screen printing decoration caused by different reproductions from the original.

DEVELOPMENT OF THE STUDY

As the overall objective was to provide a series of recommendations for improving product quality based on the foregoing analysis, it was decided first to perform a survey with a questionnaire on photolitho and screen processing, and conduct a comparative study on a sampling of screens and photolithos made at different sectoral companies.

---

[1] AMORÓS J.L., BELTRÁN V., BLASCO, A. ENRIQUE J.E., ESCARDINO A., NEGRE F., *Defectos de fabricación de pavimentos y revestimientos cerámicos.* AICE. Patrocinado por IMPIVA, Ministerio Industria, Comercio y Turismo y la Subdirección General de Industrias de la Construcción.

[2] PERIS-FAJARNÉS G., ALCAÑIZ M., OLIVARES M., LENGUA I. *Quantitative analysis of printing variables affecting shades in screen printed tiles.* Qualicer98, Tomo 1, Pag.265.

[3] BONET, G. ; CORMA P. ; BAKALI, J. ; PASCUAL A. ; TICHELL, M. ; SEGURA, J. *Estudio de factores industriales que influyen en la aparición de tonalidad en baldosas cerámicas* . Cerámica Información nº 242.

[4] PEÑALVER, J. ; MART, V. ; PORTOLÉS, J. ; NEGRE, P. ; BARBA, A. ; GIMÉNEZ, S.; MONFORT, E. *Study of screen printing apand their influence of shades in tile.* Pg. 323. Qualicer, Marzo 1996.

[5] PEISKENS, ANDRÉ. *Parámetros referentes a la fabricación serigráfica que afectan a la calidad de impresión.* Serigraf, Marzo/Abril 1992.

1. PHOTOLITHOS AND SCREEN PROCESSING SURVEY.

To obtain general information on the branch regarding the way of working and the controls run in the filming and screen processing stages, a questionnaire with ten questions was prepared on these areas and sent out to 124 companies in the sector.

The results are summarised in the following table.

ACTIVITY	PERCENTAGE
FILMING	70.0%
SCREEN PROCESSING	37.5%
FILMING SYSTEM CALIBRATION	43.0%
COLOURED FABRIC (ALWAYS)	2.5%
COLOURED FABRIC (SPECIFIC WORK)	60.0%
TENSION CONTROL	73.3%
EMULSION LAYER THICKNESS MEASUREMENT	26.7 %
AUTOMATIC EMULSIFYING	33.3%
EXPOSURE LAMP CONTROL	53.3%

Table 1.

All the values indicated with regard to control and calibration are habitually and not sporadically associated with the performance of these activities. The low percentages found for control and calibration tasks are to be noted.

2. COMPARATIVE STUDY OF PHOTOLITHOS AND SCREENS.

Taking these photolithos and screens as a working basis, the following variables were measured:

- Photolitho dot density.
- Screen percentage open area.

The purpose of the comparative study was to reflect the variations that can arise in processing photolithos and screens made in different workplaces graphically and quantitatively.

With a view to clearly setting out these results, each case is presented separately.

2.a Photolitho dot density.

Each of the co-operating companies was given a computerised dot density scaling. Each company then used its own filming system to make the corresponding photolitho for study.

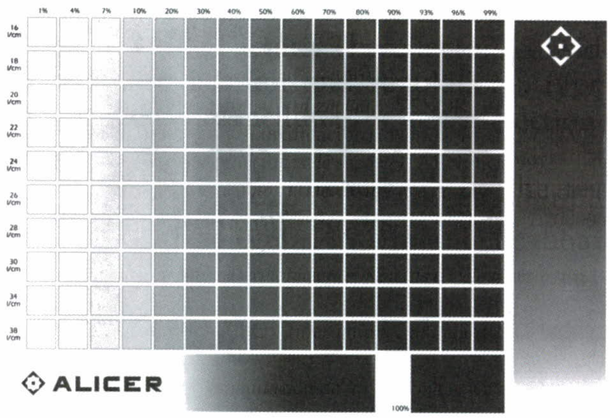

Figure 1. Photolito studied.

The measuring unit to be compared was dot density, whose theoretical value is given on the photolitho shown above. The measurement system used was a transmission densitometer with an integrated light source and accuracy of ±0.5.

Graphs 1 and 2 present the results.

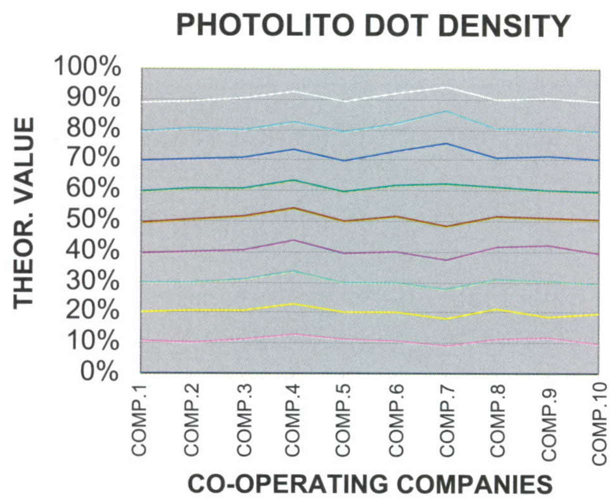

Figure 2. Graph 1.

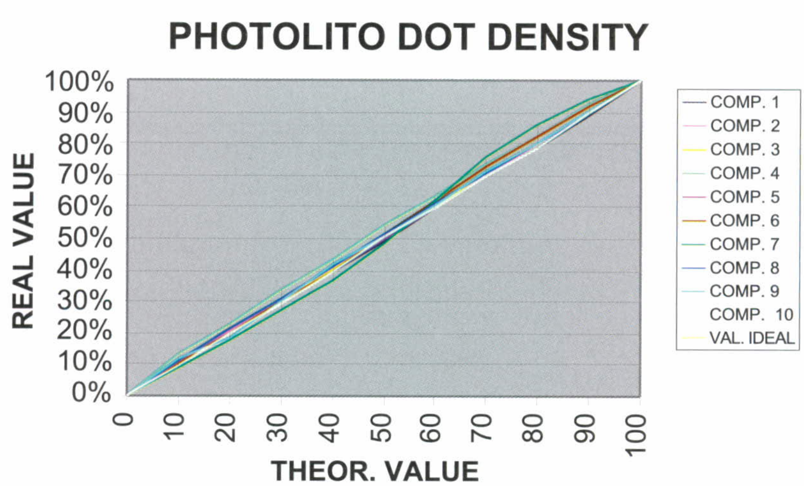

Figure 3. Graph 2.

Graph 1 shows the values for each company and how they differ from the theoretical value. It can be observed that where there is a deviation, the magnitude depends on the analysed dot density percentage.

The black line in Graph 2 marks the difference between the maximum and minimum values, in order to visualise the maximum difference found amongst the workplaces. This is quantitatively set out in the following table:

THEORETICAL VALUE	REAL VALUE OF THE PHOTOLITHO		
	MAXIMUM	MINIMUM	DIFFERENCE
10%	13%	9%	4%
20%	23%	18%	5%
30%	34%	28%	6%
40%	44%	37%	7%
50%	55%	49%	6%
60%	64%	59%	5%
70%	76%	69%	7%
80%	86%	79%	7%
90%	94%	89%	5%

Table 2.

The table presents the maximum and minimum values found for the photolithos studied for each dot density. The column on the right lists the difference between both values, i.e., the difference that could appear between a different filming of the same design.

These variations are attributable to lack of calibration and control, so that they could occur in the same company unless a rigorous control programme was implemented in filming.

2.b Screen open area percentage.

Using the designed photolitho as the working photolitho, it as filmed 10 times on a perfectly calibrated filming system to distribute a copy to each co-operating company.

The measurement unit in this case was dot diameter. The measurements were run on a Kiowa stereoscopic microscope with an EMS995 video measuring system at an accuracy of ±1 μm. The value of the diameter was used to calculate screen open area, comparing this to the original or theoretical value.

Graphs 3 and 4 show the findings.

Graph 3 plots the values for each company and the difference with regard to the theoretical value. The differences between the screen values are greater than between the photolithos. This is mainly because part of the process is done manually, and the number of variables that can affect the end result is much greater. For this reason, process automation and control of these variables are indispensable to ensuring screen reproducibility.

As before with the photolithos, Graph 4 shows the open area percentage profile for each company, indicating the maximum differences with a black line.

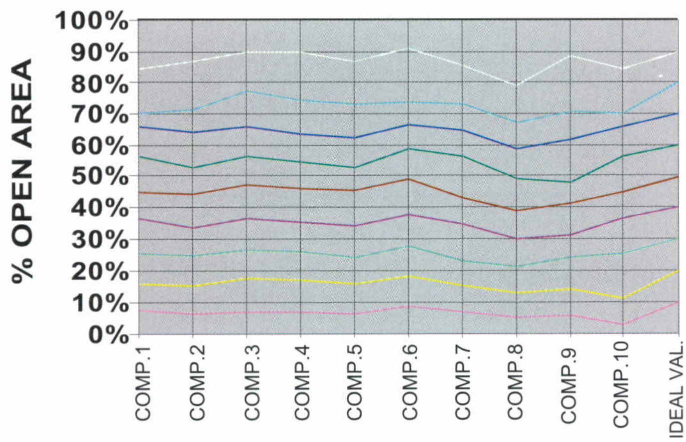

Figure 4. Graph 3.

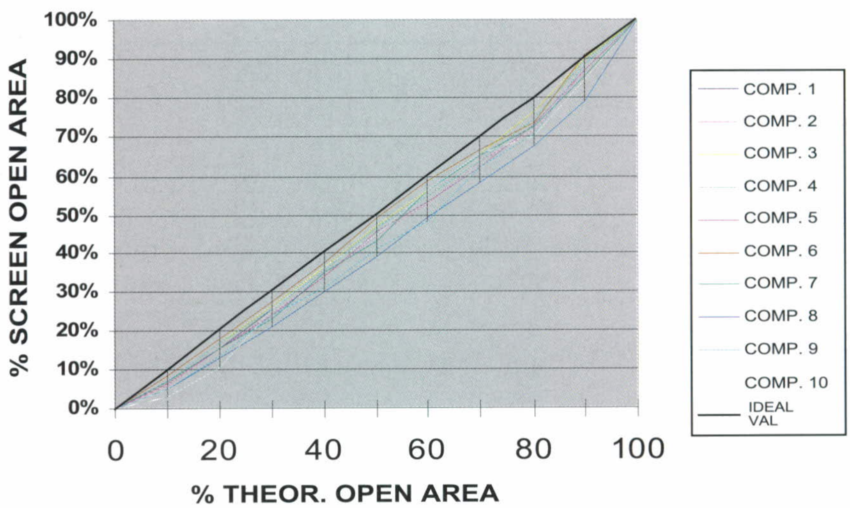

Figure 5. Graph 4.

The values shown correspond to the data set out in the following table::

THEORETICAL VALUE	REAL VALUE OF THE SCREEN		
	MAXIMUM	MINIMUM	DIFFERENCE
10%	9%	3%	6%
20%	18%	11%	7%
30%	28%	21%	7%
40%	38%	30%	8%
50%	49%	41%	8%
60%	59%	48%	11%
70%	67%	58%	9%
80%	77%	67%	10%
90%	91%	79%	12%

Table 3.

We have similarly indicated the values in screen open area percentage for the extreme cases, indicating the difference in the column on the right. As mentioned, the variations in screen processing are greater.

However, they should not be dealt with separately. If the step from the virtual image in the computer to the finished screen is considered as a single process, dot gains are found that could present greater ranges of variations.

Depending on whether the difference between both dot gains is additive or subtractive, ranges of variation of up to 17 % could be found, as the following table reveals.

Assuming a negative situation, the following open area percentages could appear:

THEORETICAL VALUE	VARIATION RANGE
10%	2-10 %
20%	2-12%
30%	1-13%
40%	1-15%
50%	2-14%
60%	6-16%
70%	2-16%
80%	3-17%
90%	7-17%

Table 4.

THEORETICAL VALUE	REAL VALUE
10%	0%
20%	8%
30%	17%
40%	25%
50%	36%
60%	44%
70%	54%
80%	63%
90%	73%

Table 5.

If this photolitho has 20 l. /cm and is developed on a 77 thread screen, in practice everything that is below 10-12 % real, i.e., a 25% theoretical value, cannot be printed. On the other hand, no area will appear with a value exceeding 80 %. That is to say, a working range of between 25 % and 80 % will be involved, with an excessive departure of real values from theoretical values.

With screens made with the same fabric, and an emulsion layer of the same thickness, under the same screen printing conditions to previous productions, the open area percentage is directly proportional to the quantity of ink deposited on the tile, which affects tile colour.

As found in the sector survey, only 43 % of the surveyed companies regularly use filming control systems. With regard to screen processing, tension was measured in 73 % of the cases, light-exposure lamp intensity in 53 % and emulsion layer thickness in 27 % of the companies. Emulsifying was automatic in 33 % of the companies.

Consequently, the colour problems stemming from variations in these production stages increase when a screen needs to be reproduced during the useful life of a design.

3. PROPOSED SYSTEMATISATION.

The influence of the variables listed below, which have been the subject of studies elsewhere [5, 6 and 7], are well known in the filming and screen production process.

PROCESS	VARIABLES
FILMING	CHANGE OF REAGENTS
	TYPE OF FILM
	TEMP. OF THE MEDIUM
	TIME IN DEVELOPER
TENSIONING	THREAD DIAMETER
	FABRIC TENSION
EMULSIFYING	TYPE OF EMULSION
	APPLICATION
	LAYER THICKNESS
LIGHT EXPOSURE	EXPOSURE TIME
	LAMP POWER
	DISTANCE FROM LAMP
	FABRIC COLOUR

Table 6.

Filming

This is the photolitho processing stage. Four process characteristics were found to be the main causes of practically all the arising variations in this stage.

Changing reagents produces changes in the developing concentrations. The concentration, together with liquid temperature and photolitho contact time with the liquid affect the degree of reaction and hence photolitho dot size.

The type of film used in filming is also important as it can exhibit greater or lesser sensitivity depending on film quality. Furthermore, each film has a different degree of transparency, which also affects the exposure stage.

Fabric characteristics

Two characteristics will be dealt with, which do not receive enough attention.

Thread diameter

Thread diameter is often not specified in the accompanying screen data. Not much attention is paid to this, but it is a source of great differences in deposited ink.

[5] PEISKENS, ANDRÉ. *Parámetros referentes a la fabricación serigráfica que afectan a la calidad de impresión.* Serigraf, Marzo / Abril 1992.

[6] SEFAR. *Handbook for screen printers* . Febrero 1999.

[7] MAX KENNEDY. *Mesh selection for Halftone Printing* . Screenprinting, Marzo 1996.

The theoretical deposited ink volume varies depending on thread diameter:

THREAD DIAMETER (microns) IN 90 THREADS/CM SCREENS.	INK THEORETICAL VOLUME (cm^3/m^2)
40	26
48	22
64	18

Table 7.

The table shows that compared to a fabric with a thread diameter of 64 μm (for 90 threads/cm screens), 22 % more ink is deposited with the 48 μm and 33 % more with the 40 μm diameter threads.

Traditional nomenclature for fabric thickness can also be a source of error as the table shows:

THREAD QUALITY	COMPANY S. (DIAMETER / THEOR. V.)	COMPANY S. (DIAMETER / THEOR. V.)
90-S	40/26	30/27
90-T	48/22	43/25
90-HD	64/18	50/22

Table 8.

It can be observed that for the same quality thread, each company distributes a fabric with a different diameter and therefore different theoretical ink volume (value on the right). The difference reaches up to 22% in the case of HD, the most widely used thread owing to its greater strength. However, a change in supplier will entail a change in deposited ink.

Fabric colour

Coloured fabrics are currently only used when great accuracy is sought in the screens to reproduce the finest detailing.

It is well known that using white fabric entails a loss of definition owing to lateral light diffraction during exposure. Using coloured fabric avoids this diffraction, and hence produces a much more accurate register.

The reason is that the coloured fabric absorbs virtually all the beams produced by the exposure lamp. The purpose of these beams is to produce a photochemical reaction in the emulsion for it to harden. If there is no diffraction (coloured cloth), only the areas exposed to the light beam will harden. If diffraction occurs (white cloth) this will take place in the areas reached by diffracted light.

To confirm the foregoing, a series of tests was run with white fabric, varying exposure time and keeping the other variables steady. The ideal time for the characteristics of the test screen was chosen as central value, testing at 20 units of time lower (underexposure) and 20 units of time higher (overexposure) than this value.

The open area percentages found are detailed in the following table:

Theoretical value	t=50 u.	t=70 u.	t=90 u.
100%	100%	100%	100%
90%	87%	85%	81%
80%	75%	72%	66%
70%	64%	61%	53%
60%	53%	49%	37%
50%	45%	41%	29%
40%	33%	29%	19%
30%	24%	20%	9%
20%	14%	11%	4%
10%	5%	2%	0%
0%	0%	0%	0%

Table 9.

Graph 5 plots these values:

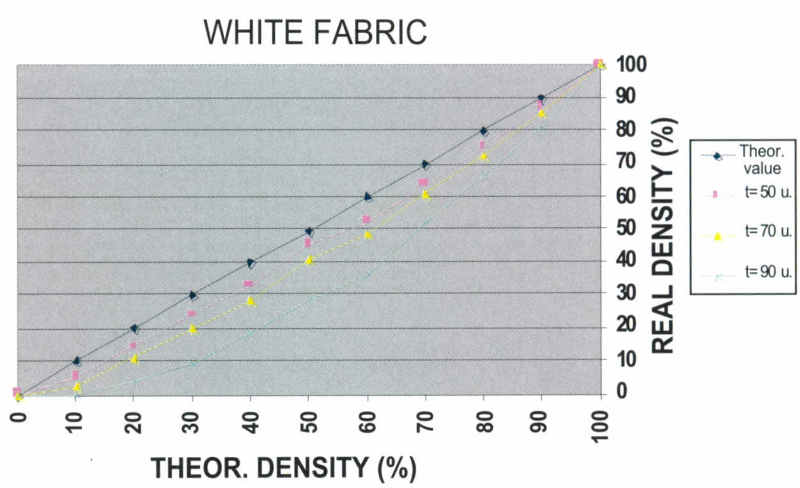

Figure 6. *Graph 5.*

Tests were run analogously at different exposure times on screens with a yellow fabric instead of a white one. As the exposure time for yellow fabric is theoretically twice that for white, the previous exposure times were multiplied by two in this case. On doubling the exposure times, the exposure ranges also doubled. The following table sets out the results:

Theoretical value	t=100 u.	t=140 u.	t=180 u.
100	100%	100%	100%
90	88%	87%	87%
80	77%	76%	75%
70	66%	66%	65%
60	54%	54%	52%
50	46%	46%	46%
40	36%	35%	33%
30	26%	26%	24%
20	16%	16%	15%
10	7%	7%	6%
0	0%	0%	0%

Table 10.

Graph 6 plots these values:

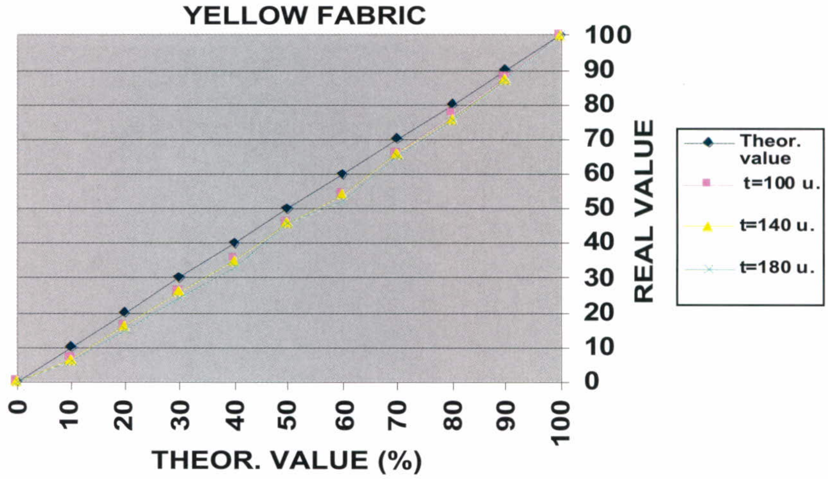

Figure 7. Gráfica 6.

Figure 8 shows the change in register on the screen on varying exposure time for the white and the yellow fabric. The variation is quantitatively confirmed by the value of dot diameter in mm, at the bottom of each picture.

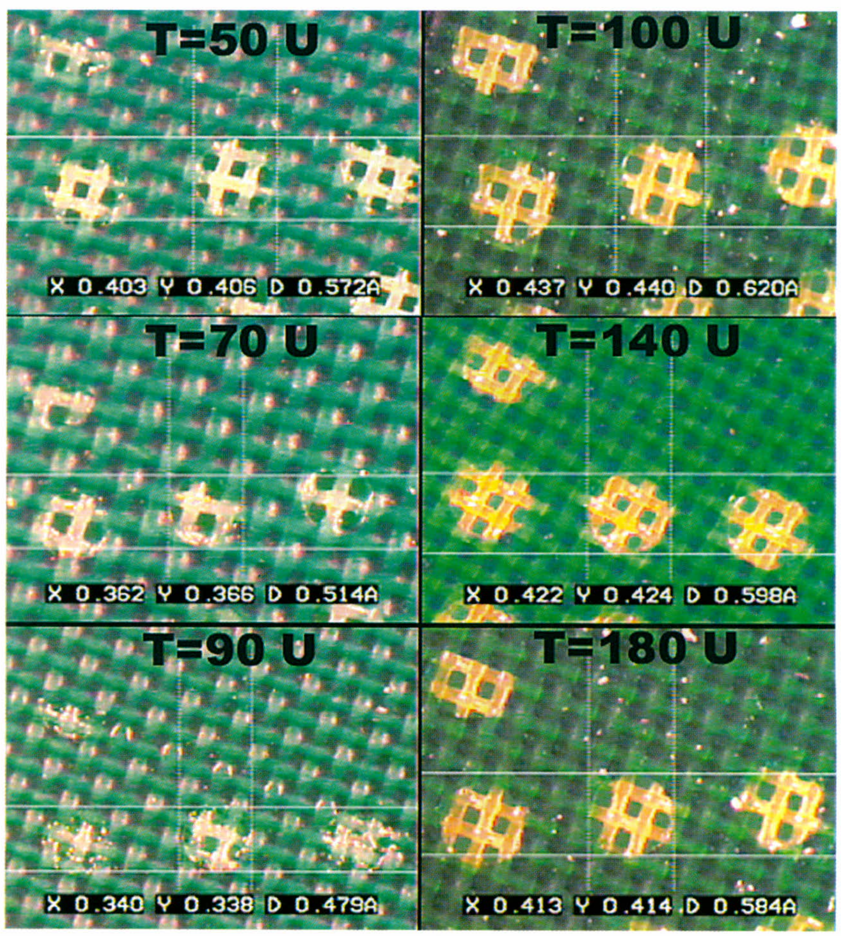

Figure 8.

The following table numerically details the differences found on using the two fabrics:

COLOURED FABRIC				WHITE FABRIC		
Theoretical value	DIFFERENCES WITH THEOR.			DIFFERENCES WITH THEOR.		
	t=100 u.	T=140 u.	t=180 u.	t=50 u.	t=70 u.	t=90 u.
100%	0%	0%	0%	0%	0%	0%
90%	2%	3%	3%	3%	5%	9%
80%	3%	4%	5%	5%	8%	14%
70%	4%	4%	5%	6%	9%	17%
60%	6%	6%	7%	7%	11%	23%
50%	4%	4%	5%	5%	9%	21%
40%	4%	5%	7%	7%	11%	21%
30%	4%	4%	6%	6%	10%	21%
20%	4%	4%	5%	6%	9%	16%
10%	3%	3%	4%	5%	8%	10%
0%	0%	0%	0%	0%	0%	0%

Table 11.

The following conclusions can be drawn from this part of the study:

- There is an inherent loss of open area in the exposure process, independently of the exposure time used. The loss is greater when a white fabric is employed than when a yellow fabric is used.

- The longer the exposure time, the greater is the loss of open area. This loss differs considerably depending on the fabric used:

<u>Coloured fabric</u>: There is a minimum variation of open area attributable to the fact that at lamp working wavelengths the coloured fabric absorbs 90 % of the light, diffracting 10 %.

<u>White fabric</u>: The variations in open area with time are tremendous for this type of fabric, exhibiting a wide range of values up to over 20 percentage units. The white fabric only absorbs about 10 % of the incident light, while the rest is diffracted producing decreased tone values.

4. CONCLUSIONS

The following series of proposals has been drawn up, based on the results of the study:

- **<u>Need for systematising the filming process to ensure photolitho reproducibility</u>**

This can be done by using an appropriate control system (transmission densitometer) to periodically measure dot density percentage, as well as whenever one of the following variables are altered: change in developing chemicals, change in developing liquid temperature, residence time of the photolitho in developing and change of film.

- **Need for thorough screen production control**

All the process variables mentioned need to be measured and controlled to ensure a consistent open area in the same design. For greater assurance, it would be necessary to periodically prepare a control screen to verify that the tone values being obtained are correct.

Process mechanisation favours control. As the survey has shown, a third of the companies used automatic emulsifying systems. This is still a low percentage, owing to their relative newness, but the percentage can be expected to grow rapidly and needs to do so, owing to the excellent results obtained in the application and consistency of applied layer thickness..

- **Evaluation of the repercussions of using non-coloured fabric in the ensuing non-quality costs**

When producing a screen, any uncontrolled change of thread diameter, emulsion layer thickness, type of emulsion used or applied exposure time will have direct repercussions on screen open area. If a white fabric is used, the variation will clearly affect the end result of the screen, while if it is coloured, the variation will be minimal and probably negligible.

The only disadvantage lies in the price. Coloured fabric cost, depending on mesh count and supplier, is 15-20 % higher than the normal white fabric. Although the long-term economic benefits of investing in this type of fabric are obvious, it is the ceramic tile manufacturer who will need to compare the costs of non-quality with the extra capital outlay required.