FLEXO PRINTABILITY OF PUBLICATION GRADES - TECHNICAL CHALLENGES OF PUBLICATION FLEXOGRAPHY

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KEYWORDS: FLEXOGRAPHY, PUBLICATION PAPER GRADES, WATER-BASED INK, PRINTABILITY, SHOW-THROUGH

ABSTRACT: Three publication grades (news, supercalendered and light weight coated paper) were printed on Comco Commander 3-color flexo press at 700 ft/min using two types of ink: general purpose water based publication flexo ink and news water based flexo ink. Printability differences between the three grades printed with two different inks are shown. Mottling was worst at LWC substrate using both types of ink. The best print uniformity was found at SCA paper with both ink types. SCA, on the other hand, caused the worse show-through.

INTRODUCTION

Flexographic technology has been improved over the past decade and is still improving [Cushner, 1992]. Machinery has upgraded to offer registration

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accuracy to within 0.001 inch [Casatelli, 1996], which has enabled complex multicolor graphics and continuous tone images. The industry has gone from single color "commercially acceptable" standards to multi color standards [Miller, 1998]. The anilox roll, which has a uniform cell pattern engraved across the entire surface, was a significant contributing factor to the success of flexo printing [Jacob, 1991]. Nowadays, ink metering is done by laser engraved ceramic anilox rolls [Deamer, 1996]. The tendency is to use finer anilox roll engraving and ceramic coatings, which accurately control ink transfer, thus ensuring color consistency. Photopolymer afforded less variation in dot size than traditional molded rubber. Flexographic printing plates are becoming thinner. Thin (0.045 to 0.110 inch) photopolymer plates offer several advantages, such as less tendency to curl and lift at the edges, improved print quality with less dot gain and sharper highlight dots, and improved printing consistency.

Improvements on the direct print side of the business also include 1) printing presses with chambered-blade inking systems to lay down thinner ink films and servo drives to improve registration accuracy, 2) improved printing plate materials with less variability across the plate, plate mounting accuracy, and 3) ink formulations changed to increase color strength and drying time speed. [Miller, 1998]. The level of flexo print quality achieved is markedly influenced by the choice of printing ink [Gartaganis, 1975; Jensen, 1989]. Enhanced graphics inks have been developed with a higher resin content and more sophisticated blend of various polymers providing proper rheology of ink flow [Cassatelli, 1996]. Publication flexography uses water-based rub-free inks with no solvents, ensuring problem-free recycling of newsprint. Flexo is environmentally friendly and easy to operate, and it gives brighter colors and higher ink-rub resistance, elimination of ink smudging, tighter registration, and finer halftones for news publishing [Liotta , 1997].

In 1993, seven out of nine new press commitments by North American newspapers went to flexo, and it was predicted that by the year 2000 at least 100 newspapers in North America will have flexo printing capability [D'Amico, 1994]. The reality in the year 1998: about 50 of the 1600 newspaper printers in North America were using flexography [DeRosa, 1998]. There are some problems in publication flexography slowing down its implementation. Therefore, flexo printability of selected publication grades has been tested in this work with the hope that it might bring a new light into this problem.

EXPERIMENTAL

Substrates

Commercially manufactured publication grades - newsprint paper, light weight coated (LWC), and supercalendered A grade (SCA) stock were used for printing. The papermaking properties of these substrates are described below.

Printing

Comco Commander 3-color web flexo press was employed for printing web width 10" at 700 ft/min speed. Conventional hot air dryers were set up to 105°C. Anilox rolls 550 lpi were mounted for yellow and magenta print stations with 150 lpi plates. Cyan anilox had 350 lpi and 100 lpi plate was employed. Two different water based ink systems from different manufacturers were used to determine how the ink quality affects the show-through. The inks are referred to as "A", general purpose water-based publication flexo ink and "B", news flexo ink. The viscosity of inks was measured as "efflux time" by means of a Zahn #2 cup. All the inks were adjusted to efflux time of 28 seconds which corresponds to 62 cP according to the Dietzgen conversion chart (Dietzgen Co., U.S.A.).

Analytical

Show Through using Brightness Tester

The show through was measured at 457 nm using the Brightimeter Micro S4-M, Technidyne Corporation. Paper brightness was measured from the back (non-printed side) before and after printing. Printed image is illustrated at **Figure 1**.

Show Through using CIE L*a*b*

Show through was measured as CIE L*a*b* values from back of the printed sheet (non-printed side) before and after printing by means of Datacolor Spectraflash 600 VIS specrophotometer. L* value only was used in show-through calculations. Calibration curve of reflective density vs. L* was done on tone steps of 3-color black (**Fig.1**). Reflective density was measured on printed tone steps, respective L* was measured from the back on the same spot.

Opacity

Paper substrate opacity (contrast ratio) was measured according to TAPPI Method T425 om-91by means of BNL-2 Opacimeter, Diano Corporation.

Porosity, Roughness and Compressibility

A Parker Print-Surf Model ME 90 (Messmer Instruments Ltd., U.K) was employed for both porosity and roughness measurements. Porosity was measured using a clamping pressure of 1000 kPa; roughness was measured at 500 and 1000 kPa. The compressibility was calculated as the ratio of roughness at 500 kPa and 1000 kPa clamping pressure.

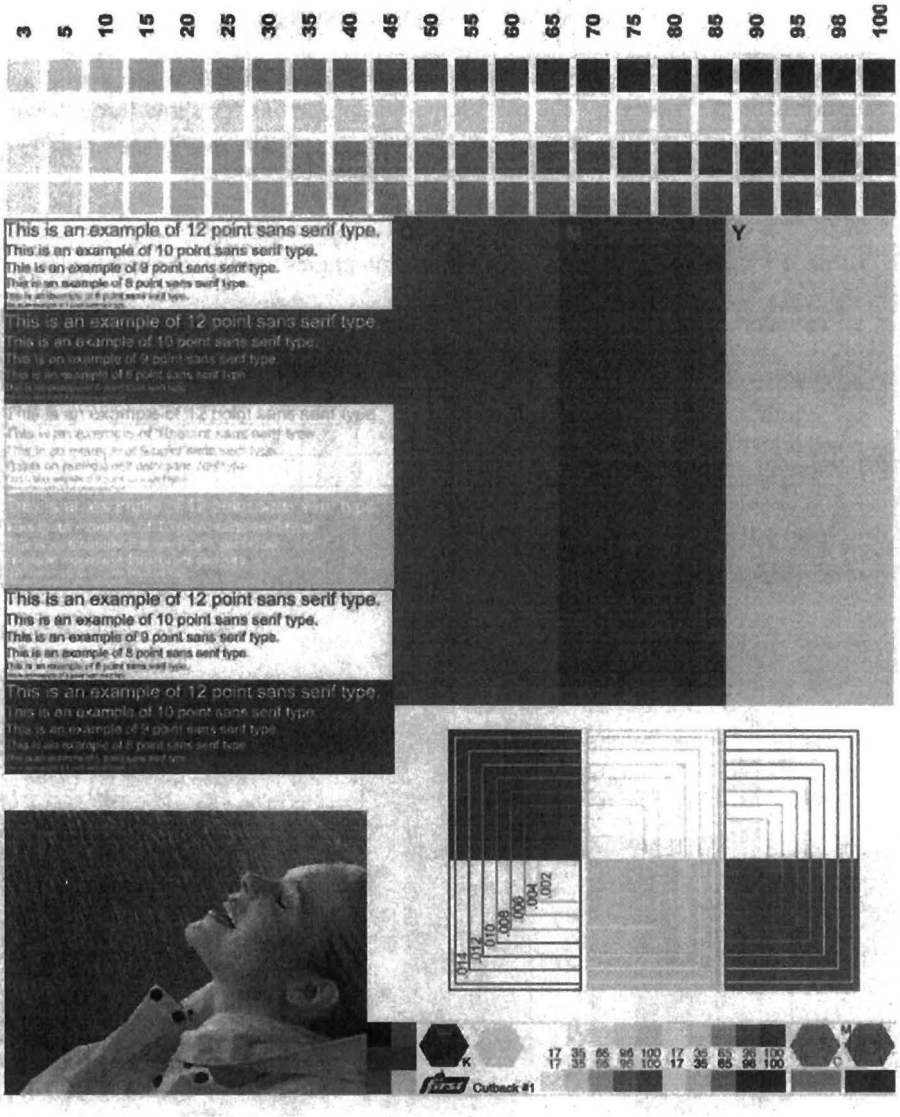

Figure 1: Test image printed in 3 process colors at Comco Comander 10 " web flexo press

RESULTS AND DISCUSSION

The papermaking properties of paper substrates used in the printing trial are described in the **Table I.** The most important properties for show through will probably be the porosity, opacity, and the caliper – which was thinnest at LWC, 41.5 micron, and found thickest at newsprint, being 63.5 micron.

Table I: Papermaking properties of publication grades used in printing trial

Property	LWC	SCA	News
Roughness at 500 kPa [μ]	1.42	1.51	3.51
Roughness at 1000 kPa [μ]	1.03	1.18	3.03
Compressibility	1.38	1.28	1.17
Porosity at 500 kPa [mL/min]	9.85	33.10	229.71
Porosity at 1000 kPa [mL/min]	8.86	32.53	214.73
Opacity [%]	73.7	73.8	63.2
Caliper [μ]	41.9	45.7	63.5

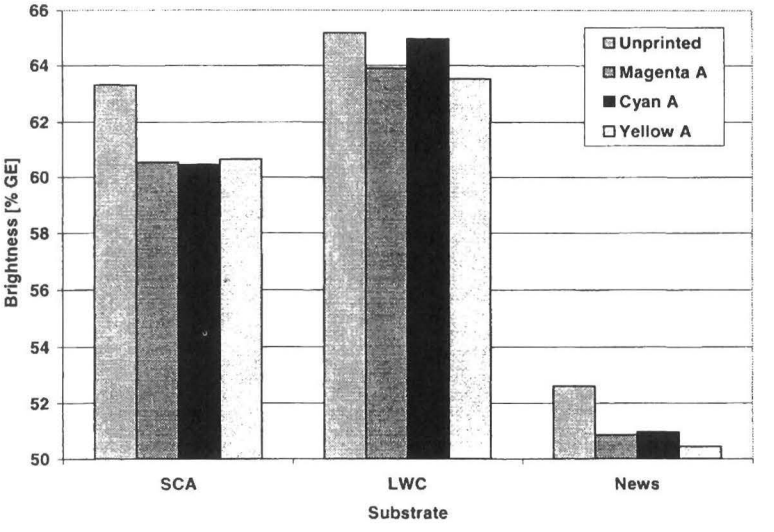

Figure 2: Show-through measured as the GE brightness from the back-side of the substrate printed with A set of inks

The substrate porosity is probably also an important factor for ink show-through. The porosity, measured by PPS method, was 8.86 mL/min at LWC grade, 32.53 mL/min at SCA and 214.73 mL/min at newsprint grade. The opacity was approximately the same for LWC and SCA (73.7-73.8%) and slightly lower at newspaper 63.2 %.

Printability properties are shown in the **Table II A** for cyan inks and **Table II B** for magenta inks. Inks A gave higher reflective density and specular gloss values than inks B for both colors. Reflective density was the highest at LWC substrate and the lowest at newsprint for both inks, but the difference between SCA and news print density was negligible. The specular gloss was much higher at inks A than inks B, especially at LWC and SCA substrates. However, the mottle index was also the highest at LWC substrate and for both inks. SCA resulted in lowest mottle (best print uniformity) at both process colors at both inks. Mottling was relatively the worse at newsprint printed with ink B (102.8 for cyan and 99.8 for magenta) when considering the lowest reflective density achieved on this substrate (1.04 and 0.89 respectively).

Table II A: Flexo printability properties of publication grades printed with two different cyan inks (STD = Standard Deviation)

PROPERTY	News Ink A	News Ink B	LWC Ink A	LWC Ink B	SCA Ink A	SCA Ink B
Reflective Density	1.12	1.04	1.53	1.27	1.15	1.11
STD Density	0.01	0.01	0.02	0.01	0.02	0.02
Print Gloss	4.51	3.21	15.81	8.44	11.67	4.22
STD Gloss	0.22	0.09	0.99	0.45	0.65	0.13
Mottle Index	91.5	102.8	133.3	119.0	86.0	76.4
STD Mottle	5.2	10.8	8.4	6.5	6.0	5.2

Table II B: Flexo printability properties of publication grades printed with two different magenta inks (STD = Standard deviation)

PROPERTY	News Ink A	News Ink B	LWC Ink A	LWC Ink B	SCA Ink A	SCA Ink B
Reflective Density	1.04	0.89	1.36	1.09	1.08	0.92
STD Density	0.01	0.02	0.01	0.01	0.01	0.01
Print Gloss	5.58	4.33	15.81	9.83	11.67	8.23
STD Gloss	0.11	0.13	0.99	0.53	0.65	0.34
Mottle Index	83.2	99.8	93.4	75.9	82.6	56.4
STD Mottle	4.5	7.3	7.9	6.0	6.2	3.2

The show-through was measured as a GE brightness (**Fig. 2**) and as a CIE L* value (**Fig. 3**) on the back side of the printed solid areas of process yellow, magenta and cyan. The aim was to find value which would be the most practical to measure and evaluate on single ink film as well as on the 3-color black flexo overprint. Comparison of L*a*b* values showed that the L* value is probably the most useful one for show-through evaluation and of the 3-color overprint. The reason for that is that a* value representing redness or greenness and the b* value representing blueness or yellowness will drastically change depending on the process ink hue printed.

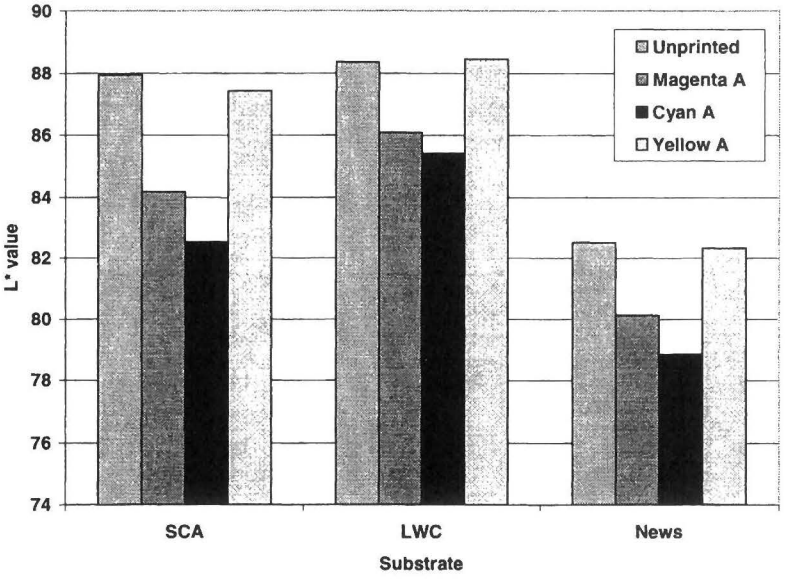

Figure 3: Show – through measured as the L* value from the back-side of the substrate printed with A set of inks

The relative change of brightness change and the L* value change from non-printed sheet to printed was evaluated as:

$$\% \text{ change} = (BRIGT_{org} - BRIGHT_{print})/BRIGHT_{org} * 100$$

or

$$\% \text{ change} = (L^*_{org} - L^*_{print})/L^*_{org} * 100$$

where :

$BRIGT_{org}$	brightness of non-printed sheet on the back side of printed solids
$BRIGHT_{print}$	brightness of printed sheet on the back side of printed solids
L^*_{org}	CIE L* value of non-printed sheet on the back side
L^*_{print}	L* of printed sheet on the back side of printed solids

The relative % of change for brightness and L* values for all three substrates and two different sets of inks are listed in the **Table III** and **Table IV**.

Table III: GE Brightness and its relative change after printing due to the ink show-through

BRIGHTNESS [%]	**Non-printed**	**Magenta A**	**% Change**
SCA	63.30	60.54	4.36
LWC	65.16	63.89	1.95
News	52.62	50.85	3.36
BRIGHTNESS [%]	**Non-printed**	**Magenta B**	**% Change**
SCA	63.30	61.99	2.07
LWC	65.16	64.22	1.44
News	52.62	51.60	1.94
BRIGHTNESS [%]	**Non-printed**	**Cyan A**	**% Change**
SCA	63.30	60.46	4.49
LWC	65.16	64.96	0.31
News	52.62	50.96	3.15
BRIGHTNESS [%]	**Non-printed**	**Cyan B**	**% Change**
SCA	63.30	62.48	1.30
LWC	65.16	65.20	-0.06
News	52.62	51.6	1.94

BRIGHTNESS [%]	Non-printed	Yellow A	% Change
SCA	63.30	60.65	4.19
LWC	65.16	63.52	2.52
News	52.62	50.43	4.16
BRIGHTNESS [%]	**Non-printed**	**Yellow B**	**% Change**
SCA	63.30	61.53	2.80
LWC	65.16	63.81	2.07
News	52.62	51.71	1.73

Table IV: CIE L* value of non-printed sheet, printed measured on back-side of the print and relative change of L* after printing due to the ink show-through

L*	Non-printed	Magenta A	% change
SCA	87.94	84.18	4.28
LWC	88.36	86.08	2.58
News	82.51	80.13	2.88
L*	**Non-printed**	**Magenta B**	**% change**
SCA	87.94	85.66	2.59
LWC	88.36	86.20	2.16
News	82.51	80.49	2.45
L*	**Non-printed**	**Cyan A**	**% change**
SCA	87.94	82.52	6.16
LWC	88.36	85.42	3.33
News	82.51	78.84	4.45
L*	**Non-printed**	**Cyan B**	**% change**
SCA	87.94	84.98	3.37
LWC	88.36	85.95	2.73
News	82.51	79.18	4.04
L*	**Non-printed**	**Yellow A**	**% change**
SCA	87.94	87.44	0.57
LWC	88.36	88.45	-0.10
News	82.51	82.32	0.23
L*	**Non-printed**	**Yellow B**	**% change**
SCA	87.94	88.44	-0.57
LWC	88.36	88.2	0.18
News	82.51	82.51	0.00

It is obvious that the brightness and L* values are changing due to the paper substrate, type and color of the ink. The inks A, printing considerably higher optical density than inks B, were consistently causing higher show-through than the inks B. This was true for all 3 process colors and all three substrates, measured as the brightness or as the L* value. SCA resulted in the highest show-through in all substrates and colors when printed with ink A. Printing with inks B resulted in very similar show-through values for the news and SCA. News had higher show-through than SCA in some cases (3 color black, cyan B). The highest relative % change was found at SCA printed with cyan ink A, measured both as the brightness (4.49 %) or the L* change (6.16 %). The show-through of three-color black was measured as L* value from the back of the overprint (**Tab. V**). The highest % change found for ink A was 4.73 % at SCA and for ink B 4.18 % at newsprint.

Table V: The show-through measured as L* value on three-color black

L* value	Non-printed	Black A	% change	Black B	% change
SCA	87.94	83.78	4.73	84.60	3.34
LWC	88.36	85.53	3.20	86.01	2.66
News	82.51	78.98	4.28	79.06	4.18

As already shown in the **Table II A** and **II B**, the reflective density of printed ink film was higher when printing with A inks compare to B inks. This was true for all colors as well as for 3- color black. The show through probably depends on the reflective density. Therefore, the correlation of the reflective density versus relative % change of L* value was done for all three substrates and both inks (**Fig. 4**). The plot showed that the ink color and the type of the substrate influence the show-through. The yellow ink film had the lowest influence on show-through. Cyan and magenta had higher relative influence than 3-color black. For example at SCA, the density of 3-color black was 1.18-1.38, but the relative % change was no more than 4.7 %, while the density of cyan was 1.1-1.15 and the corresponding % change was 3.3-6.2 %. The dried previous ink down probably acts as a barrier to further penetration of next printed ink. It was not possible to plot any correlation function of reflective density versus % change of L* value when including all paper substrates and all inks (**Fig. 4**). The problem is more complex, as the show-through depends not only on the reflective density of ink film, but most likely also on absorptive and optical properties of paper substrate.

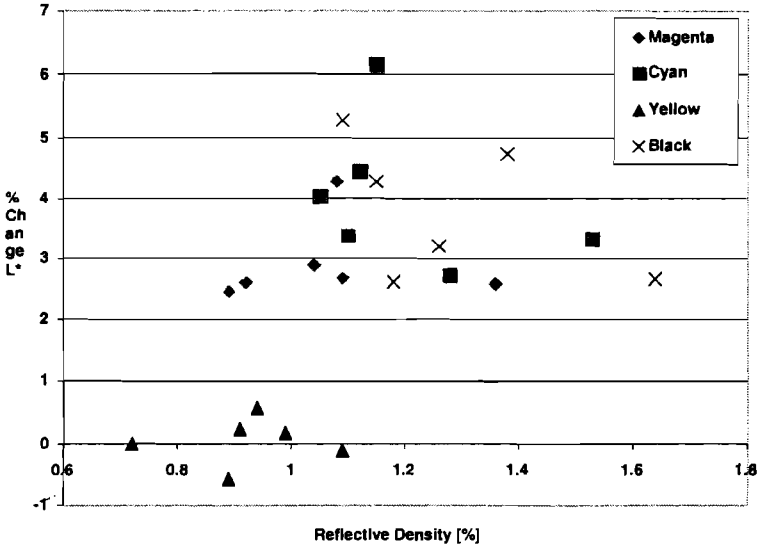

Figure 4: The influence of reflective density on show- through (show- through was measured as relative % change of L* value on all substrates and both inks)

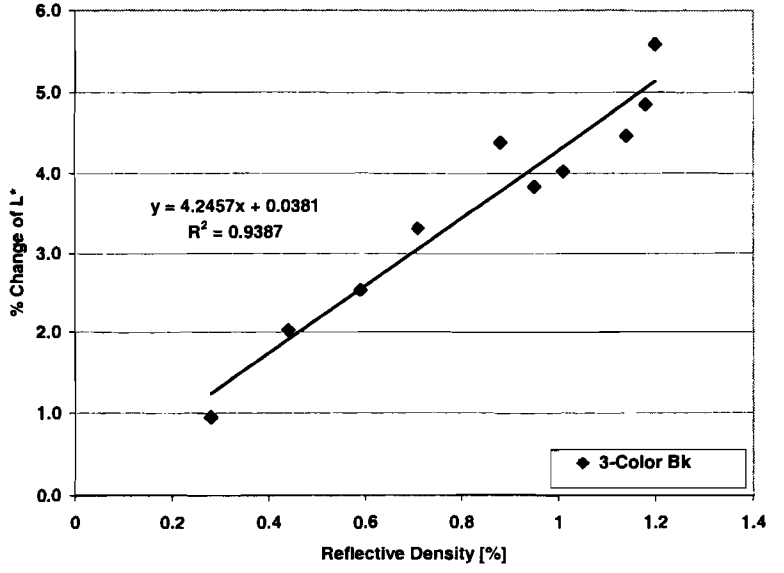

Figure 5: Calibration curve of reflective density vs. relative % change of L* for newsprint A inks. (Reflective density was measured on 3-color black overprint tone curve)

Calibration curve of relative % change of L* versus reflective density for individual inks and individual substrates was done. Linear correlation resulted in quite high correlation coefficients for all substrates being in the range of R^2= 0.73 (SCA) to R^2= 0.93 (News). **Figure 5** shows calibration curve of reflective density vs. relative % change of L* for newsprint substrate and 3-color black overprint of A inks. The show-through was found to be a linear function of reflective density for each individual substrate. However, the linearity was best up to reflective density of about 0.8 at all substrates, as optical densities higher than 0.8 the sensitivity of L* measurement decreased. When the calibration curve for reflective density versus L* change was done for both A and B ink on individual substrates, good linear correlation was also achieved, with R^2 = 0.69 for SCA substrate; R^2 = 0.79 for LWC and R^2 = 0.91 for news. Thus, it shows that the type of substrate affects the show-through vs. density relationship more than the type of ink does.

CONCLUSION

The experiment of three-color flexo publication printing was executed with the aim to compare the similarities and differences between LWC, SCA and newsprint. Two different ink systems were employed. The ink giving higher optical density and specular gloss (the general purpose flexo publication ink) also caused higher show-through and higher mottling at all substrates. Comparison of printability between LWC and SCA showed better optical density and specular gloss at LWC, but LWC resulted also in higher mottling. This was true for both ink systems tested. SCA had the best print uniformity (the lowest mottling) of all of the substrates, but also the highest show-through with one ink system, and predominantly the worst show though with the other ink system. The show-through was found to be the linear function of print density for particular ink and substrate. No general relationship was found for reflective density versus show-through.

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