High definition printing for critical Industrial applications

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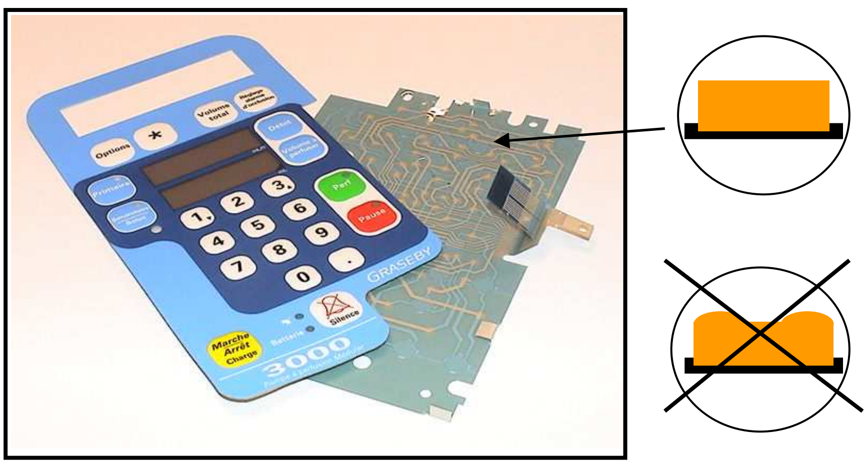
Introduction

One of the unique benefits of screen printing is the ability to print relatively thick deposits of specialist materials (ink) in the form of lines or shapes. One such example is silver conductive inks for printed circuitry and automobile windows. This article will concentrate in the main on this particular application, however many of the same issues apply to the printing of other critical deposit industrial applications such as bio-sensor materials, heater elements and even high build ceramics.



Square track profile from Autotype Capillex CX

Uneven track profile from a conventional stencil

In these applications the ink deposit is mostly controlled by the mesh. We say ‘mostly’ because over most of the area of such deposits the stencil has no effect.

Therefore the printer has to choose mesh and inks carefully to obtain the desired deposit. Once these are chosen the deposit *should* remain constant from day to day and from month to month. That, after all, is one of the beauties of screen printing.

The stencil, in an ideal world, would do nothing except define the edges of the print.

But we know that the stencil is never ideal. If you use a typical emulsion coated wet on wet, then you will have a very high roughness (Rz) and the printed line will show ‘positive sawtoothing’ i.e. where the ink leaks under the poor gasket between the stencil and the substrate.

The obvious cure for this is to use a wet on dry face coat emulsion coating regime. This certainly reduces the Rz and decreases positive sawtoothing, but it brings with it a

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number of different problems due to the increased EOM (Emulsion Over Mesh or Stencil Profile) with downsides which we will explore in a moment.

A good way of getting low Rz and high edge definition is to use a high quality capillary film. Unfortunately we quickly reach a compromise. If too thin a film is used on these relatively coarse meshes (i.e. 90 threads per cm) it tends to melt through easily on mounting and not surprisingly, shows a moderately high Rz. A thick film is easy to mount, has a low Rz, but ends up with a high EOM. And that's a problem.

High EOM leads to thick edges

Figure 1 shows a cross section through a stencil and mesh just after the squeegee has passed. Therefore, the stencil and mesh are just about to rise, leaving the ink deposit behind. Note that a low EOM (3m) stencil is being used.

Figure 1 A low EOM stencil just before separation from the substrate

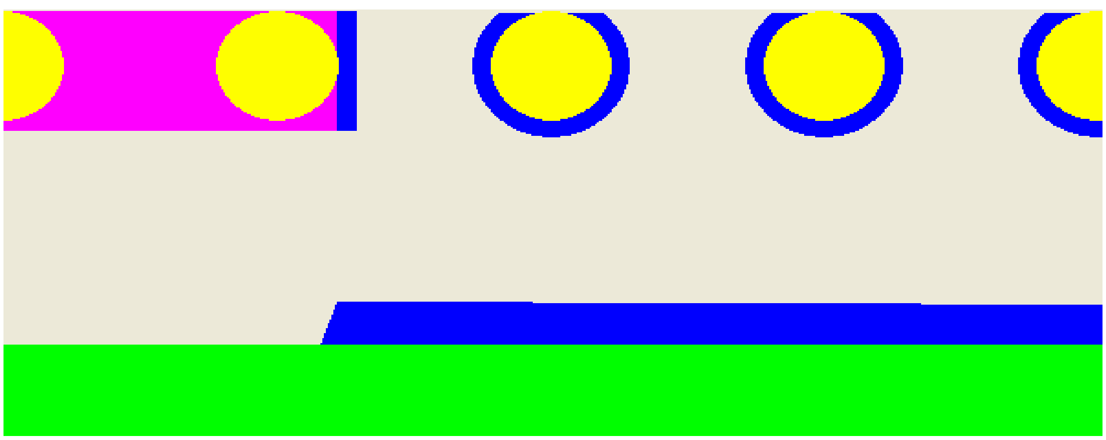


Figure 2 The same system after the mesh has lifted off the substrate

Figure 2 shows the final print. The amount of ink deposited on the substrate, is determined by how much ink is in the mesh at the start, minus the amount of ink left on the stencil and the mesh at the end. Please note that in this example the ink deposit is fairly flat.

Now let us print the same image, but this time with a high (EOM 13µ) stencil profile.
Figure 3 shows that we have a very different situation.

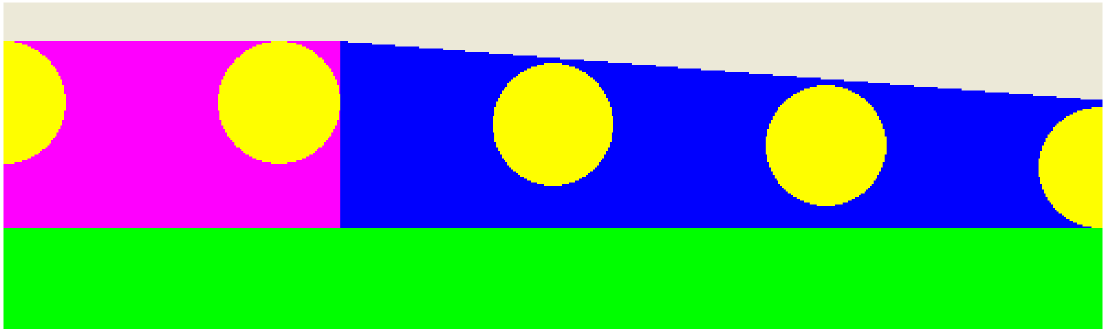


Figure 3 Printing with a high EOM stencil. Note that mesh threads are not in contact with the substrate towards the image edge.

The high EOM makes it impossible for the mesh to flex enough to touch the substrate at the image edge. Therefore, the volume of ink near the edge is much higher than in Figure 1.

Figure 4 shows the final printed result. Again, ink deposit is the amount in the mesh at the start minus the amount on the stencil and mesh. The ink on the mesh at the end is unchanged, but the amount in the mesh at the start is larger, so there is a larger ink deposit.

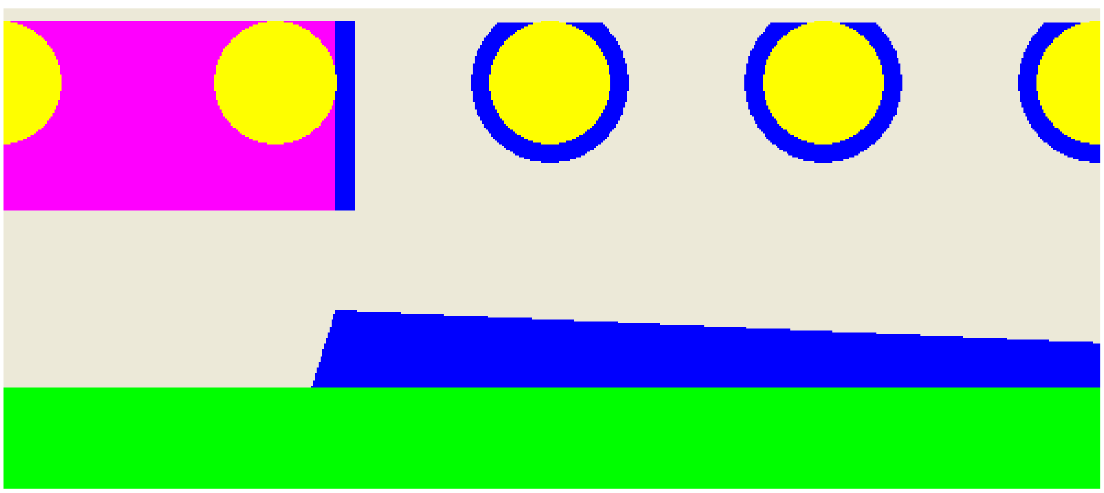


Figure 4 The increase in ink deposit at the edge caused by the high EOM

Obviously these images (taken from the Autotype Screen Print Animator) are idealizations of what really happens. But careful measurements from numerous test prints made with both low and high EOM stencils confirm this effect.

Thick edges lead to wasted ink

The thick edge created is undesirable as it consumes more of your ink. Especially if you are using expensive conductive silver inks or precious bio-diagnostic materials, the cost of that extra ink can be significant. Another program, the Autotype Line Edge Demonstrator, calculates the extra ink consumption in a typical side-by-side comparison. Figure 5 shows the results from a 13µ EOM stencil compared to a 3µ stencil; the thicker stencil consumes an extra 7% of ink. Independent verification of the model's predictions by careful weighing of ink and prints gave results that were very close.

Figure 5 Calculation of the extra ink deposit from a thick edge

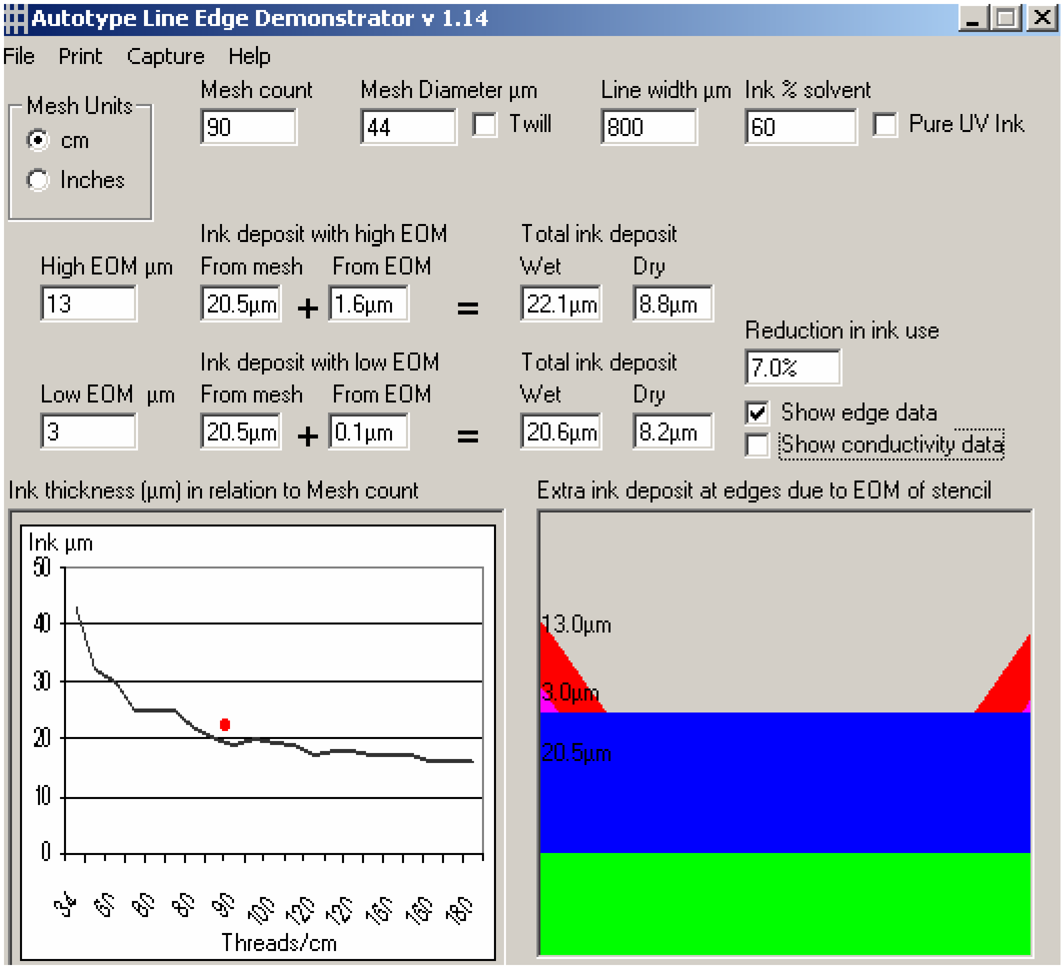
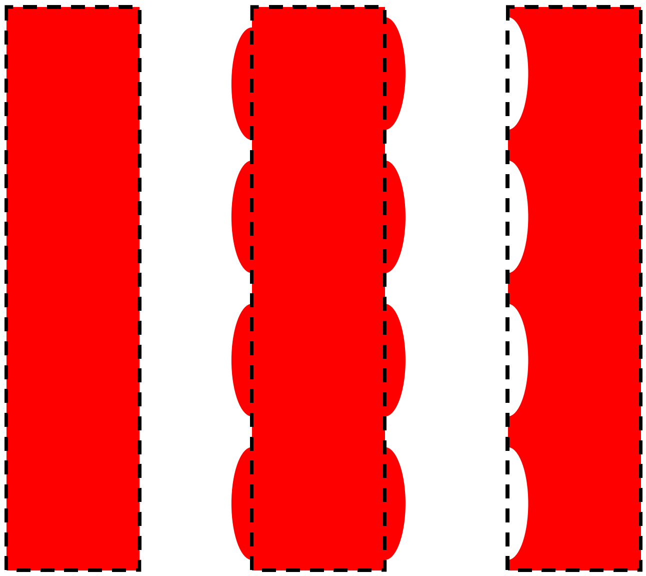


Figure 5 – Calculation of the extra ink deposit from a thick edge.

Obviously the % reduction depends on the track width. The thick edge has less impact on wider tracks. However, the industry is heading in one direction – towards finer tracks, so the issues of thick edges are becoming more and more critical.

Thick edges also lead to negative sawtoothing

Earlier in the article we referred to the gain along Rz channels as positive sawtoothing. With thick stencils we often see the opposite – negative sawtoothing where there are what appear to be, little bite marks taken out of the line.



The print on the left shows good reproduction as it reproduces the film positive shown in the dotted line

The print in the centre shows positive sawtoothing as the ink flows outside of the line

The print on the right shows negative sawtoothing as the ink does not flow out to the image edge

Figure 6 Comparison of good definition, positive and negative sawtoothing

Figure 7 compares two prints made with silver conductive inks under a controlled production environment. On the left is what the printer wants, and was obtained with the low (3µ) EOM stencil. On the right is what the printer often gets, and was obtained with the high EOM stencil.

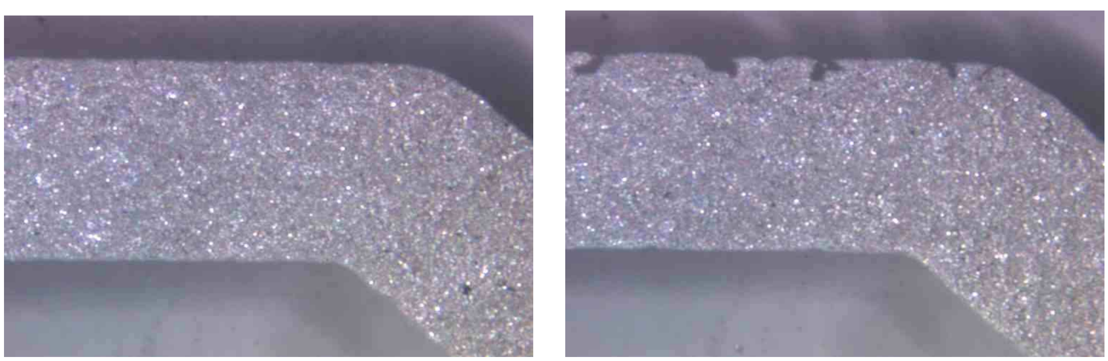
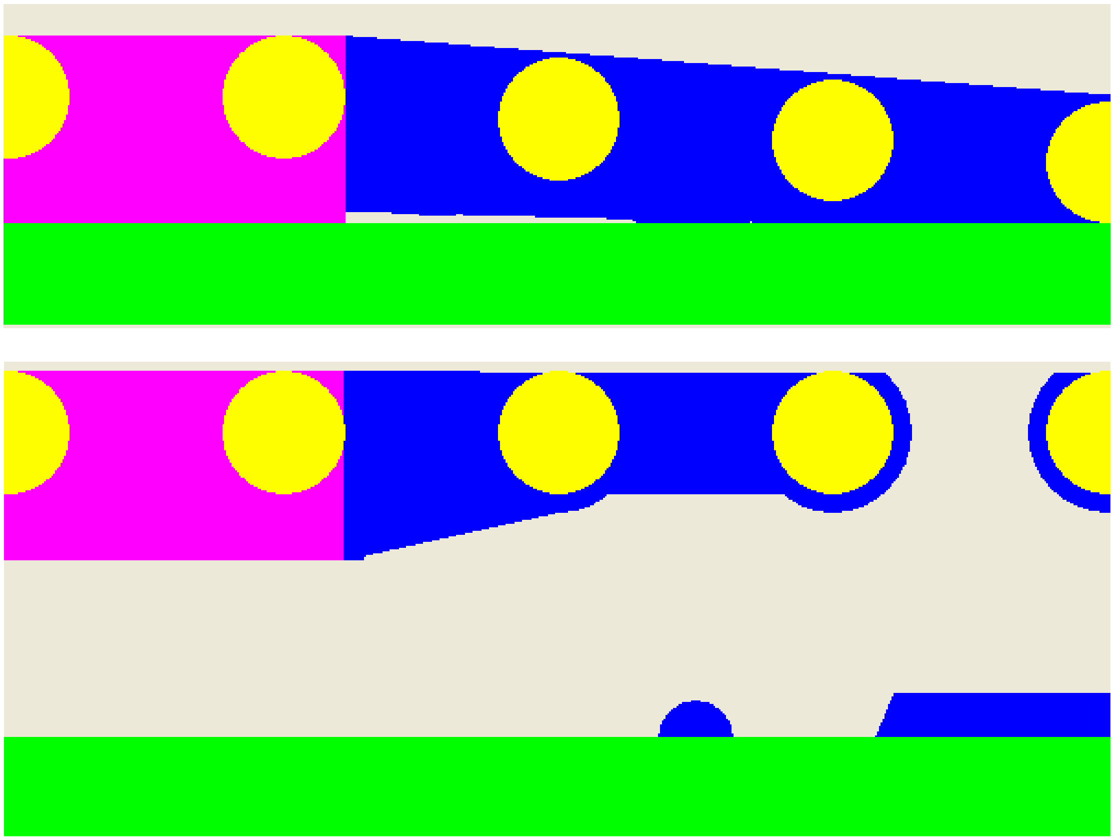


Figure 7 Negative sawtoothing (shown in the right hand print) is a function of high EOM

Figures 8 and 9 show the root cause of this problem. Quite simply, the squeegee and flood pressure used was insufficient to fill the large well volume of the mesh + stencil and consequently the ink does not transfer cleanly to the substrate. This problem typically occurs where a mesh fibre crosses the image hence the illusion of ‘mouse bites’ out of the line. In many ways this is reminiscent of ‘skipping’ in 4-colour printing.



Figures 8 and 9 Negative sawtoothing explained.

Negative sawtoothing leads to a failure to meet quality standards

If you think about the explanation for negative sawtoothing you soon realize that it only applies to the leading edge of tracks that are being printed parallel to the squeegee direction. Notice how there is no negative sawtoothing on the bottom edge of the line in Figure 7. This means that vertical lines will have no negative sawtoothing.

It’s possible to calculate the relative conductivity of a conducting track with a thick edge and with/without negative sawtoothing. The Autotype Line Edge Demonstrator performs such calculations. Figure 10 shows the values obtained in our test case.

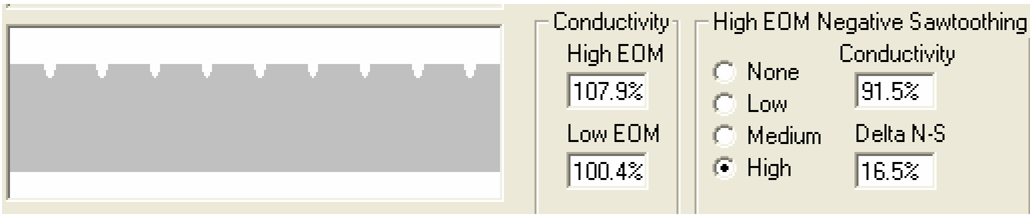


Figure 10 The effect on conductivity of thick edges and negative sawtoothing

First the model shows that the high EOM stencil in general produces a track with 107.9% of the conductivity of the ideal flat track. But with a ‘high’ level of sawtoothing (illustrated in the figure, and quite close to that observed on real tracks) the conductivity is reduced by 16.5% down to 91.5%. This means that in production there can be differences in resistance between horizontal and vertical tracks of as much as 16.5%! The degree of negative sawtoothing will vary according to ink viscosity and squeegee pressure/angle/speed, so this variation is itself variable.

In short, for many demanding industrial applications there is a requirement to accurately deposit a controlled volume of ink (to give the required conductivity/resistance etc.) in a well defined pattern (i.e. good edge definition and resolution). The traditional method of achieving this is to use a coarse/medium mesh count 62 – 120/cm and a stencil that gives a low Rz. Unfortunately though, conventional stencil systems that are tough enough for industrial printing i.e. direct emulsions or capillary films produce a high stencil profile in order to achieve acceptable stencil flatness (low Rz). It can clearly be seen from the above that these thick/flat stencils causes problems with thick edges and negative sawtoothing. Whereas, if the stencil profile is reduced then the Rz increases and the image quality deteriorates due to positive sawtoothing.

Autotype Capillex CX – a vital part of the solution

The investigation above concludes that the only real solution to this problem is to use a thin, flat stencil that controls the track definition but does not influence the ink deposit. The traditional indirect film system does give a thin, flat stencil, but this system is simply not robust enough for these demanding industrial applications. However, a recent technological breakthrough in the Research and Technical laboratories at MacDermid Autotype, has resulted in the development of a radically new 'controlled profile' stencil system consisting of two new products Autotype Capillex CP for fine mesh counts and Autotype Capillex CX for medium/coarse mesh counts.

Autotype Capillex CX is a revolutionary new stencil that produces a thin, flat but very tough stencil on coarse and medium mesh counts to produce prints that have both good edge definition and no thick edges. Unlike any conventional stencil material, Autotype Capillex CX will give a controlled 3 - 4µ stencil profile and a 7µ Rz on a 62 – 100/cm mesh range. This gives the printer the perfect print combination – that is, to use the mesh to control the ink deposit and the stencil to control the edge definition and resolution.

The left hand print in Figure 7 shows the excellent print quality that is typically achieved with Autotype Capillex CX. Figure 11 below, shows the square profile print that results from this low controlled stencil profile on the right hand side, compared to the thick edges common with conventional stencil systems.

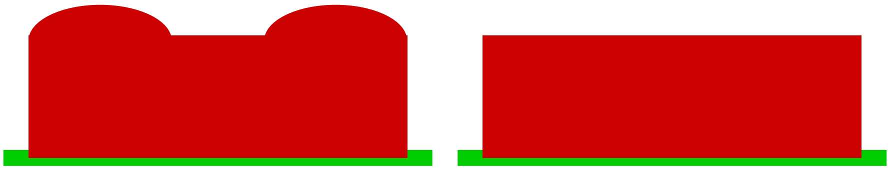


Figure 11

Autotype Capillex CX is exceptionally easy to use, especially when used in conjunction with the new Autotype Caplicator film applicator (see figure 12). This simple, yet ingenious device enables even large pieces of film to be applied without the fear of dust or dirt entrapment as the built in wipes clean the film surface immediately before the film is applied to the mesh. In addition to the benefits covered above, Autotype Capillex CX has also the normal quality features that you would expect from any Autotype stencil film: - a wide processing latitude, superb cosmetics and easy decoating.

Figure 12

Conclusion

Autotype Capillex CX can help printers save money in a number of ways:

- Reduced ink consumption through the elimination of 'thick edges'
- Less wastage and better productivity as ink transfer is improved resulting in less spoiled prints
- Greater predictability and process control as the ink build is controlled by the mesh and the definition is controlled by the stencil

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