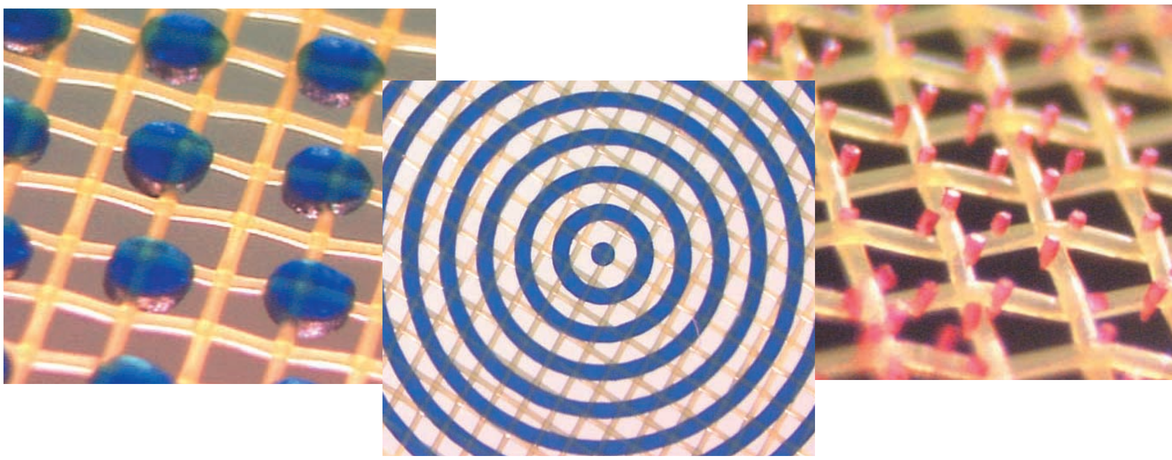
Using an Exposure Calculator: Determining the Degree of Resistance



What Is an Exposure Test?

An exposure test conducted with an exposure calculator helps to find the optimal production exposure time for stencil making. An exposure calculator combines two films — a neutral density film and an artwork film. When exposed to a stencil, each film produces separate results. The neutral density film's steps help to evaluate the stencil's resistance; the artwork film's results are to evaluate the stencil's resolution. It is the screen maker's job to judge the results and establish the best balance of resolution and resistance for the specific production application.

This article provides an explanation of several methods used to judge the resistance of a stencil, as well as, the advantages and disadvantages of each method.

Dissecting the Exposure Calculator

Exposure calculators typically have several sections that vary in density (or degree of darkness). When exposed to a screen, each filter/density area produces varying degrees of exposure on the screen. The darkest filters/areas transmit the least amount of light; the lightest/clear areas transmit the most light. For an exposure calculator with 10 density ranges (10%, 20%, 30% … to 100%) the resulting exposures would be: 100% of the original exposure, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, and 10% of the original exposure.

Which exposure test provides the best indication that the stencil has achieved its highest resistance? Here's a comparison of the six most common methods.

See Figure 1.

The darker the neutral density filter, the less UV-light transmitted through the film to the screen.

For example, a screen exposed at 120 units results in 10 different exposures on the screen: 120, 108, 96, 84, 72, 60, 48, 36, 24 and 12 unit exposures.

These side-by-side exposures can be judged to help determine the exposure time needed to achieve the stencil's highest potential resistance. The traditional method used to make this judgement is called the "Diazo No-Color-Change." This method, however, is only one of several methods used to establish "No-Color-Change" or "No-Step-Change."

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A screen that has been underexposed remains somewhat green; a screen that has been fully exposed or overexposed would be blue

The No-Color-Change (NCC) or No-Step-Change (NSC) refers to a comparison of side-by-side exposures on one screen to determine a step of exposure where there is no difference to the next.

Here's something to keep in mind: Each method produces a slightly different result in finding the point of NCC/NSC.

See Figure 2.

The important thing to remember is how each NCC/NSC is achieved and how it relates to the reaction of the stencil with UV-light.

See Chart 1 for an overview of the methods.

General Procedures

1. Obtain an exposure calculator to conduct an exposure test and find the "optimal" production exposure.

2. Develop the test screen. The following methods require a wet screen to evaluate the NCC/NSC.

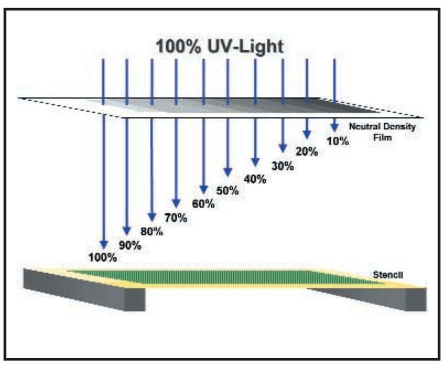


Figure 1: A 10-step exposure calculator. Darker density filters restrict the amount of UV-light transmitted to the screen.

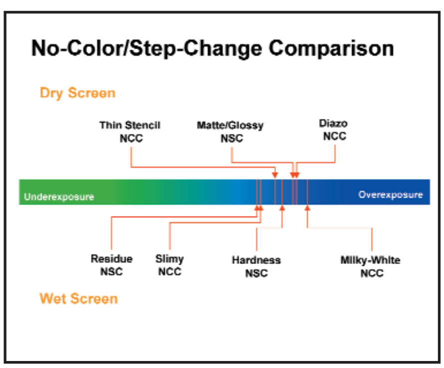


Figure 2: No-Color/Step-Change Comparison

- Method 2: Milky-White NCC
- Method 3: Hardness NSC
- Method 6: Residue on Paper NCC
- Method 7: Slimy NSC

3. Dry the test screen. The following methods require a dry screen to evaluate the NCC/NSC.

- Method 1: Diazo NCC
- Method 4: Thin Stencil NCC
- Method 5: Matte/Glossy NSC

4. Calculate the production exposure based on the resulting exposure values.

Method 1: Diazo No-Color Change

Diazo NCC refers to the diazo sensitizer changing color when reacted to UV-light. The diazo is yellow in color. When added to the emulsion or manufactured into a capillary film, the emulsion takes on a yellowish hue. For example, a blue emulsion or film becomes green. When the stencil material is applied to a screen and exposed to UV-light, the diazo reacts and becomes somewhat clear again.

For the given example, the green emulsion would turn back to blue. The point at which the stencil no longer becomes bluer is an indication that all of the sensitizer has been reacted. A screen that has been underexposed remains somewhat green; a screen that has been fully exposed or overexposed would be blue.

Look at a dry screen with white back lighting. Compare each exposure area to the area receiving 100% of the light. For some exposure calculators, look between the arrows. The exposure areas that show a yellowish-hue difference are considered underexposed. The area where NCC is apparent is the point where most/all of the diazo has been reacted.

See Figure 3.

With more underexposure, the stencil retains a yellowish tint. A color difference is seen from step to step until the diazo is reacted.

Advantages

- This is the most widely known method, industry wide, for establishing NCC/NSC.
- This is the best method for determining if all of the diazo has been reacted throughout the stencil.
- A yellow color difference is fairly easy for most people to see.

Disadvantages

- This method cannot be used with SBQ-photopolymer emulsions. These products do not contain diazo.
- The diazo can expose slightly with white backlighting. The evaluation needs to happen somewhat quickly after processing.
- It can be difficult to distinguish slight differences on fine, dyed mesh.

See Chart 1 for more information on the application of each method.

Method 2: Milky-White No-Color-Change

The Milky-White NCC refers to the color of an underexposed screen in contact with water. As a stencil is exposed to UV-light, the areas receiving enough UV-light harden and become insoluble to water; the areas receiving not enough light or no light remain water-soluble. During developing, water-soluble emulsion rinses off of the stencil.

With the contact to water, any area remaining somewhat water-soluble is vulnerable to water and takes on a milky-white color.

Looking at a wet screen from either the print side or the squeegee side of the screen, the underexposed areas exhibit more of a milky-white color difference than the areas of the stencil with longer exposure. The point at which there is NCC can be seen when the stencil is resisting as much water as possible (for the given stencil product). This method is most easily seen on a fully developed screen that has been wetted on both sides.

See Figure 4.

In comparison with the Diazo NCC, the Milky-White NCC tends to show differences at a longer exposure because in most cases, the stencil requires slightly more UV-light to make it achieve its highest resistance to water.

See Figure 2 for a comparison in exposure times.

Advantages

- This method can be used with diazo sensitized products and SBQ sensitized products.
- This method provides the best indication that the stencil has achieved its highest resistance.
- This method can be used with direct emulsion and capillary films.

Disadvantages

- Evaluating the stencil is best done at the completion of developing. Once the screen has been dried, it needs to be re-wetted to evaluate it again, however the results may not be the same.

See Chart 1 for more information on each method.

Method 3: Hardness No-Step-Change

The Hardness NSC refers to how rigid the stencil is after developing, yet before drying. When a stencil is fully exposed and complete reaction or crosslinking has occurred, the stencil exhibits a certain degree of hardness. This degree of hardness can be evaluated by scraping a fingernail across the print side of a developed screen.

An underexposed stencil tends to be softer and scrapes away. However, a fully exposed or an overexposed stencil exhibits a hard stencil and is more difficult to scrape away. The point where

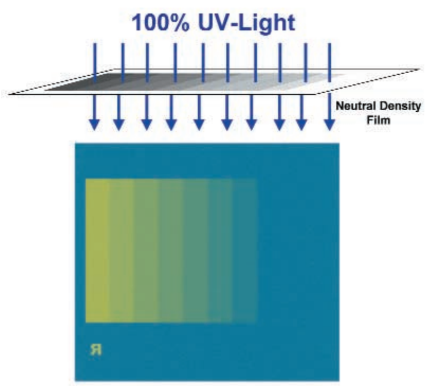


Figure 3: A comparison of exposure areas on a dry screen.

a fingernail cannot scrape away the stencil indicates the stencil has been fully hardened. The stencil has not only been hardened on its surface, but it has also hardened enough to hold even during the extreme mechanical abrasion of the scraping fingernail.

In finding the point of NSC, this method resembles exposure times of the Diazo NCC. Keep in mind, the hardness of the stencil is very dependent on the type of stencil product and its characteristics.

See Figure 2.

Advantages

- This method provides a good tactile judgment with which most people can agree.
- This is a good method to use in conjunction with other methods.
- This method can be used with capillary film, but these products do not encapsulate threads. The mechanical resistance to a scraping fingernail will be less with a capillary film than a direct emulsion.

Disadvantages

- Stencil hardness depends greatly on the stencil product. Some products are manufactured to be softer or harder than others.
- This method can only be done after the initial developing of the screen. The screen cannot be re-wetted and tested.
- The scraping of the stencil damages the stencil.
- This method is very dependent on the user's technique.

See Chart 1 for more information on each method.

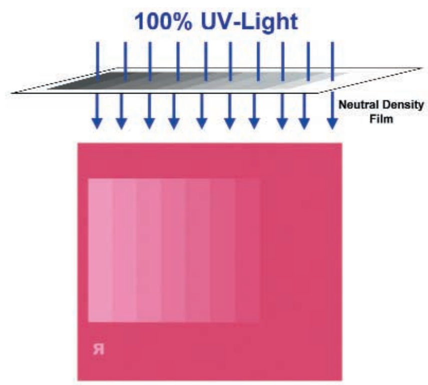


Figure 4: A comparison of exposure areas on a wet screen.

Method 4: Thin Stencil No-Color-Change

When UV-light exposes a stencil, the emulsion layers closest to the UV-light use the energy to react with the sensitizer. Once the sensitizer has reacted in these top layers of emulsion, the UV-light transmits through to the next layers of emulsion. With more and more UV-light, all of the layers will react with UV-light and reach the squeegee side of the screen.

If a stencil has been underexposed so that only the top layers of the emulsion have been reacted, water washes off the emulsion layers on the squeegee side of the screen during developing. With underexposure, the stencil will be thinner. At full exposure and overexposure, all of the emulsion layers will have been reacted. The stencil will be as thick as it possibly can.

See Figure 5 and Figure 6. Both of these stencils are viewed from the squeegee side of the screen.

Figure 5 is an underexposed stencil.

Stencil hardness depends greatly on the stencil product. Some products are manufactured to be softer or harder than others

After developing, the emulsion washed away from the squeegee side of the screen; the threads were left exposed. The stencil is physically thinner.

Figure 6 is a fully exposed stencil; the stencil has been exposed through all the layers of emulsion. The threads are encapsulated with emulsion. The stencil is physically thicker.

Viewing a dry stencil with a white back lighting shows a color difference between a physically thinner stencil (underexposure) and a thicker stencil (full or overexposure). The thicker stencil has no emulsion washed away during developing; and because of this, appears darker in color on the dry screen. The point where there is no color difference between one exposure step and another is the point of NCC.

For this method, the stencil only needs to be exposed long enough to not wash emulsion off the squeegee side of the screen. The point of NCC for this method tends to be established at a shorter exposure time compared to the Diazo NCC. *See Figure 2.*

Advantages

- This method works with capillary film and direct emulsion; however, the results are easier to distinguish with a direct emulsion.
- This is a good method to use in conjunction with other methods to help pinpoint the NCC/NSC.

Disadvantages

- This method is hard to use with undyed stencil products.
- The results depend greatly on the developing technique. If the stencil is not fully developed, some of the emulsion layers may stay on the screen. An underexposed stencil could appear to have NCC.
- The results may vary depending on the characteristics and type of stencil.

See Chart 1 for more information on each method.

Method 5: Matte/Glossy No-Step-Change

When a direct emulsion is coated onto the mesh, the emulsion encapsulates the mesh threads. At full exposure, the emulsion coating still encapsulates the threads.

As stated in the Thin Stencil NCC method, emulsion washes away from the squeegee side of the screen when underexposed. Greater underexposure results in more emulsion layers washing away from the screen. The washed away emulsion layers do not encapsulate the threads. The threads are bare of emulsion.

View the squeegee side of the dry screen at a low angle to white light. The underexposed areas result in uncovered mesh threads on the squeegee side of the screen, creating a matte finish on the surface.

At full exposure, the emulsion encapsulates the mesh threads and the finish on the screen becomes glossy. When there is no Matte/Glossy step difference, the emulsion has been exposed through all the layers of emulsion. *See Figure 5, 6 and 7.*

This method provides the closest results to the Diazo NCC method, especially if the stencil has been developed well on the squeegee side of the screen. This method is similar to the Thin Stencil NCC, but more subtle differences with this method can be distinguished. *See Figure 2.*

Advantages

- From person to person, this is a very consistent method of judgement. This method does not rely on a color judgment — provided the development procedures are the same.
- This is an excellent technique for fine, dyed mesh.

Disadvantages

- This method cannot be used with capillary film. The capillary film does not penetrate all the way through the mesh.
- Like the Thin Stencil NCC method, this method is somewhat dependent on developing technique.

See Chart 1 for more information on each method.

Method 6: Residue on Paper No-Color-Change

As stated in the Thin Stencil NCC method, emulsion layers wash off the squeegee side of the screen when underexposed. Not all of the underexposed emulsion washes off the screen during developing.

By placing a paper towel on the squeegee side of the screen and pressing it into the stencil, the soft residue transfers to the paper towel. By pulling the paper towel away from the stencil, a color difference may be seen from one exposure step to another. The point at which there is no color difference is the point of NCC and full exposure.

This method only shows broad differences from exposure area to area. It is difficult to pinpoint differences. If Residue on

Paper NCC is found, it tends to be at an exposure closest to being underexposed. *See Figure 2.*

Advantages

- This method is especially effective with capillary films where most of the stencil developing takes place on the print side of the screen.
- This is a good method to use in conjunction with other methods to help make judgements as to the NCC/NSC.

Disadvantages

- The results are very dependent on developing technique and stencil product.
- This method cannot be used with undyed stencil products.

See Chart 1 for more information on each method.

Advantages

- Most screen makers are already aware of the sliminess of the stencil on the squeegee side of the screen.
- This is a good method to use in conjunction with other methods to help pinpoint the NCC/NSC.

Disadvantages

- This method is very dependent on developing technique and stencil product.
- This method is difficult to use with capillary film. The capillary film does not penetrate all the way through the mesh.

See Chart 1 for more information on each method.

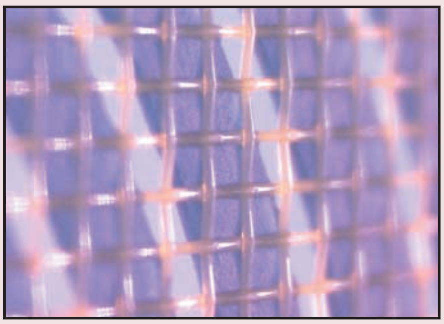


Figure 5: After developing, the underexposed stencil resulted in the threads being exposed. The exposed threads make the surface appear to have a matte finish.

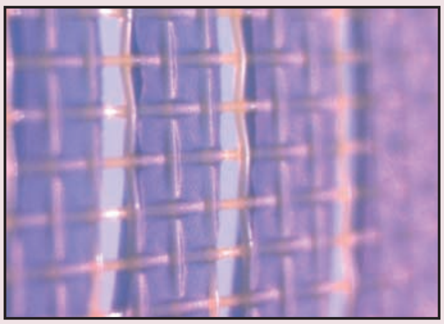


Figure 6: After developing, the fully exposed stencil resulted in the threads being encapsulated. The encapsulated threads make the surface appear to have a glossy finish.

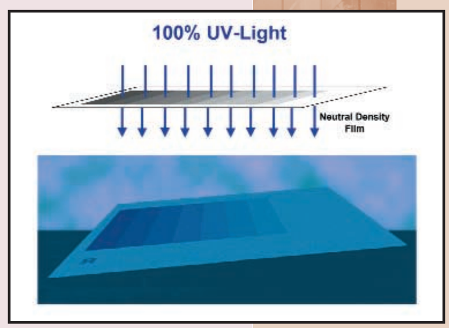


Figure 7: This illustration represents a screen seen from the squeegee side showing the matte versus glossy difference with under to over exposure.

Method 7: Slimy No-Step-Change

As explained in the Thin Stencil NCC, emulsion on the squeegee side of the screen washes off the screen if the stencil is underexposed. By only washing/developing the screen lightly on the squeegee side, the unexposed emulsion becomes slimy before it completely washes off. By running a finger along the squeegee side of the screen, the degree of sliminess can be compared. Where the stencil no longer feels slimy is an indication that all of the layers of the stencil have been exposed.

Like the Residue on Paper NCC method, this method only shows general differences; slight differences are difficult to determine. In addition, this NCC/NSC tends to be closer to underexposure. *See Figure 2.*

Conclusion

The Milky-White NCC provides the best indication of full exposure, or full reaction, of the sensitizer. By using this method with the other methods, screen makers should be able to establish procedures for determining the NCC/NSC, which can help determine the required production exposure.

Here are the recommended methods to use for establishing NCC/NSC, in order of their effectiveness:

- Method 2: Milky-White NCC
- Method 1: Diazo NCC
- Method 5: Matte/Glossy NSC
- Method 6: Residue on Paper NCC

The additional methods provide support information to help make judgements as to which exposure is the best choice.

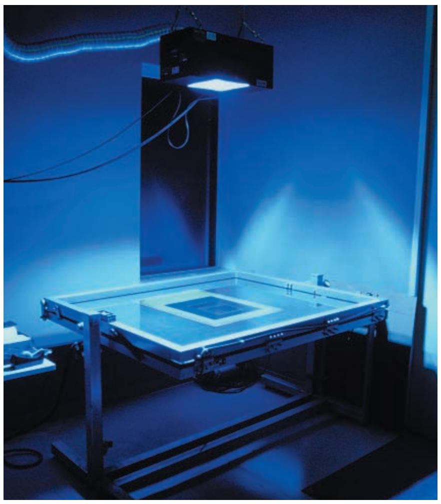
Throughout the industry, other methods are used to establish the NCC/NSC, but they tend to be even more specialized.

With NCC/NSC established, the resolution of the stencil can be evaluated. The exposure time for the resolution and the resistance may be different, so the best compromise between the two would need to be established. □

Balance of Resolution and Resistance in a Stencil

When considering what exposure time to use for production based on information found by using an exposure calculator, keep in mind:

1. The point of "No-Color-Change" indicates high resistance.
   - Longer exposure times increase resistance.
   - Shorter exposure times decrease resistance and create the potential for more breakdown on press.
2. The point of "Acceptable Resolution" should be a balance of reproducing the same size positive and negative lines, text and halftones.
   - Longer exposure times fill in negative detail in the stencil, but increase the size of the positive detail in the stencil.
   - Shorter exposure times open negative detail in the stencil, but decrease the size of the positive detail in the stencil.
3. The artwork for an exposure calculator is produced to represent a majority of the processing applications used in screen printing. To get a closer repre sentation of your specific production results with a calculator, create your own artwork and output it on the imaging system and film carrier your process uses. Then combine your artwork with the neutral density filter to create a tailor made exposure calculator specific to your process.



A ceiling-mounted exposure unit.

	Capillary Film	Direct Emulsion	Diazo sensitizer	SBQ sensitizer	Dyed Emulsion	Undyed Emulsion	Dyed Mesh	Undyed Mesh	Recommended Method	Use Method with other Methods
Diazo NCC	+✓	+✓	+✓	☒	✓	✓	✓–	✓	✓	
Milky-White NCC	+✓	+✓	+✓	+✓	+✓	+✓	+✓	+✓	+✓	
Hardness NSC	✓–	✓	✓	✓	✓	✓	✓	✓		✓–
Thin Stencil NCC	✓–	✓	✓	✓	✓	✓–	✓	+✓		✓–
Matte/Glossy NSC	☒	+✓	+✓	+✓	+✓	+✓	+✓	+✓	+✓	
Residue NCC	✓	✓–	✓	✓	+✓	☒	+✓	+✓	✓–	
Slimy NSC	✓–	✓	✓	✓	✓	✓	✓	✓		✓–

+✓ Strongly Recommended ✓ Recommended ✓– Somewhat Recommended ☒ NOT Recommended

Chart 1