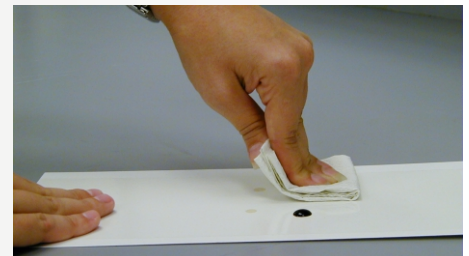
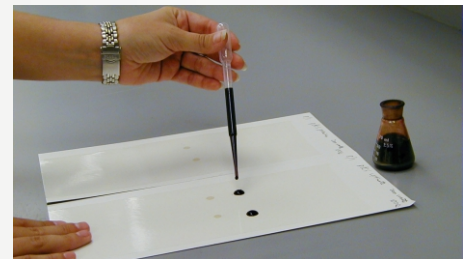


UV Coating Cure Stain Test - KMnO4 v1.1

Testing Method

Scope	This test can qualitatively and objectively measure the degree of cure for a UV coating film applied to a substrate.
Test Measurement Instruments	<ul style="list-style-type: none"> - 1% KMnO4 Stain Solution; this solution is available from CAC - Dispensing Pipette - Gloves - Paper Towel/Rag - Densitometer/Spectrophotometer - Timer
Test Considerations	<ul style="list-style-type: none"> - Ideal for use as an “off-press” testing process for Operators to make immediate UV film cure adjustments. - Once excess stain solution is blotted from the UV coating film surface, the resulting stain color will fade or lose intensity over time. - Visual comparisons or digital measurements should be conducted within 5 minutes of blotting away the stain solution from the UV coating film surface. - The stain intensity can be observed as the degree of UV coating film cure. - A well-cured coating film will have a lighter visual and lower measurable stain compared to a less-cured film that will have a darker visual and higher measurable stain. - Care should be taken to avoid contaminating skin, clothing or porous surfaces with the KMnO4 stain solution as exposure can result in staining. The use of gloves is recommended.
Measurement Procedure	<ol style="list-style-type: none"> 1.) Obtain the printed sample or proof to be tested that contains a cured UV coating film; there must be ink-free areas that contain UV coating film for stain application. 2.) Obtain 1% KMnO4 stain solution for testing. Shake the stain solution bottle prior to each use. 3.) Apply the stain solution to an area with UV coating without any underlying ink and/or varnish films. Apply approximately enough solution to cover a 0.5” diameter area, usually equal to one large drop of solution from a disposable polyethylene transfer pipette, of test solution to the UV coated sample. Make certain that there are no air-bubbles in the applied solution droplet. 4.) Allow KMnO4 solution droplet to remain on the test area for precisely 5 minutes in duration. The testing should be conducted on a flat surface to ensure the test solution does not run off of the test area. Do not move the sample during testing. 5.) At the end of the test time, blot the sample dry with a dry paper towel or rag. A light brown/orange stain will be observed in the area of the droplet.



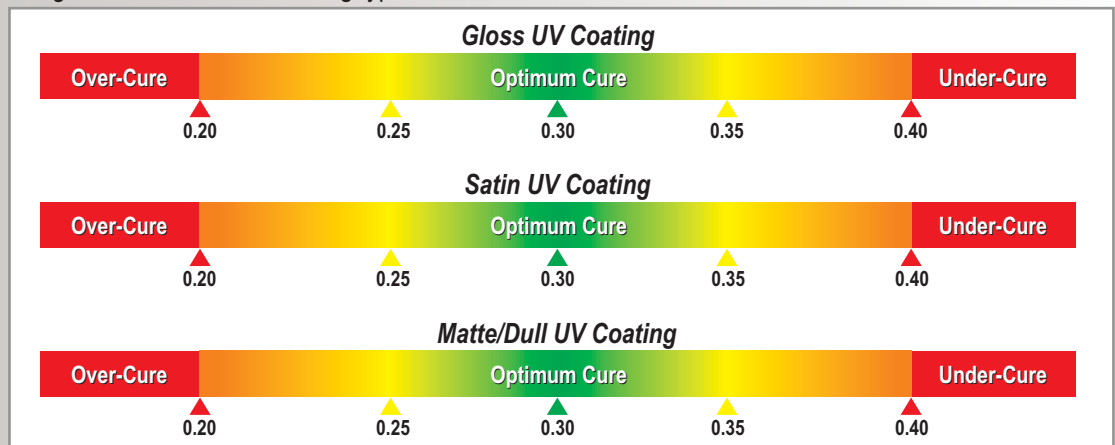
Testing Method - *continued*

Measurement Procedure (*continued*)

- 6.) Observe the stain area for intensity/darkness. The stain color intensity can be visually compared to a color standard, or for a more precise determination of cure, can be measured for density using a densitometer or spectrophotometer. When measuring for density, the measurement must be a **RELATIVE** measurement using the Yellow(Y) density filter; a **RELATIVE** measurement is the (Y) density of the stain minus the (Y) density of the paper. An automatic **RELATIVE** density measurement can be achieved by setting the measurement device for a “relative” measurement in the device “settings/options” which will require measuring the paper white area and stain area separately for an automatic calculation by the measurement device. A manual **RELATIVE** density measurement can be achieved by setting the color measurement device for an “absolute” measurement in the device “settings/options” which will require measuring the paper white area and stain area separately and manually calculating the deviation by subtracting the paper density from the stain density.
- 7.) The calculated difference in the (Y) stain density and (Y) paper density is the degree of cure of the UV coating film. Use the “Test Result Guidelines” charts below to determine degree of UV film cure.

Test Result Guidelines

The below charts can be used to correlate the measured density result of the stain and the degree of UV coating film cure based on coating type:



Over-curing of UV coating film

Over-curing the UV coating film has been found to promote coating film brittleness, flaking, poor adhesion, cracking along scores and folds, and an over-all loss of film flexibility. Over-curing the UV coating film will contribute to film hardness which can lower COF/AOS results to below target specifications. When using a contrast/migration varnish product in conjunction with a UV coating, over-curing the coating film can slow/impair the migration process and provide insufficient and un-desirable contrast results.

Optimum-curing of UV coating film

Optimum-curing the UV coating film ensures that desired characteristics are achieved in respect to formulation and intended use. Proper UV coating film cure creates the highest probability of adequate adhesion being achieved while promoting desired results for gloss, COF/AOS, rub protection, chemical resistance, adhesion of additional surface applications and film flexibility.

Under-curing of UV coating film

Under-curing the UV coating film has been found to create a soft coating film, poor rub/scratch/mar protection, clinging/sticking, poor chemical resistance and COF/AOS results that are higher than target specifications.

Testing Method - *continued*

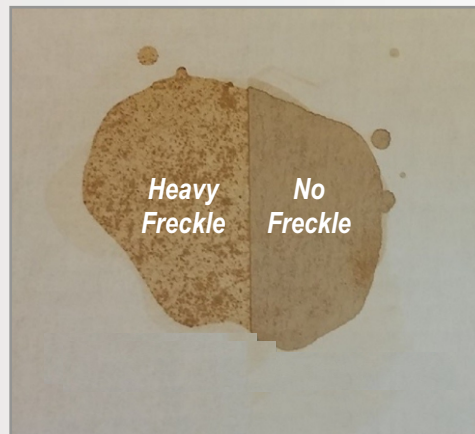
Stain Test Result - Visual Inspection

In addition to providing qualitative measurable guidance to the degree of UV coating film cure, visual inspection of the stain result can provide details related to the quality of the applied film in regards to:

- UV coating film coverage, uniformity
- Foaming/entrained-air resulting in voids/pin-holes in the applied coating film
- Clogged/worn anilox roll supplying insufficient coat-weight
- Voids/pin-holes in beneath primer coating layer
- Uneven/irregular substrate hold-out

When observing the resulting stain, the results should be homogenous in color throughout the stain area. In circumstances where 'freckles' are observed as darker spots within the stain test area, this is an indication that the stain solution has absorbed at an irregular rate within the stain area, with the stain solution becoming concentrated in areas and being absorbed by the substrate creating the darker 'freckle' spots. This can be due to the coating film having voids/pin-holes which allows excess stain solution to penetrate the coating film and become absorbed by the substrate. In cases where a waterbased primer coating is used to impart hold-out to the substrate, voids/pin-holes in the applied primer coating film can create uneven hold-out of the stain solution from the substrate. If the substrate offers very uneven/irregular areas of hold-out of the stock surface, the absorbency of the stain solution can result in a mottled stain appearance. In the event that the anilox is worn/clogged and the applied coat-weight is insufficient, the engraving pattern of the anilox may become visible in the stain area.

The below image shows the visual difference side-by-side between a stained test area that exhibits 'freckles' due to uneven/irregular stock hold-out versus a stained area that has even stain hold-out:



When encountering a 'freckled' stain result, the coating should be examined for adequate coat-weight, coverage and lay. If the coating is starved on the substrate or suffers from entrained-air/foaming which can create pin-holes in the applied film, measures should be taken to remedy these issues. If these results are determined to be substrate related, the use of a primer coating to size the sheet and improve the surface hold-out/barrier properties of the substrate surface prior to applying a UV coating is recommended. Changing to a different substrate with better surface characteristics may improve/eliminate the 'freckle' results.

When 'freckles' are observed in the stain area, this can result in a false measurement as the darker stain spots can contribute to a higher measured density reading. In this case, the darker spots yielding a higher density reading would give a false indication of the coating film being under-cured. When significant 'freckles' are observed in the stain area, the density measurement should not be considered for use.

Testing Method - *continued*

Stain Test Result - UV Curing System Condition

The stain test can be used as a qualitative method to determine the condition of the UV curing system as it relates to consistent output across the coated sheet, DS to OS. Measuring the stain result across the sheet width can give an indication of lamp/reflector deficiencies which can appear as inconsistent stain density measurements. In most cases, the edges of the sheet which correlate to the ends of the UV lamp/reflector may measure as being less cured compared to other areas within the sheet width due to lamp degradation or reflector contamination on the ends due to dust/debris. Additionally, stain testing can be conducted from gripper to tail on the coated sheet to measure for inconsistencies that may be attributed to gripper shadow or sheet turbulence that might contribute to varying degrees of UV exposure across the sheet length.

Over the course of a UV lamp life, a slow drift in stain test results may be observed as the lamp loses efficiency. Over-time, constant settings for coating application/coat-weight, coating product, press speed and UV lamp settings will result in the stain density yielding less cured measurements. Compensation of press speed and UV lamp power will be required to ensure that the cure results of the stain test remain constant. This drift of stain test results of being less cured can be an indication of degradation of the UV system necessitating UV lamp replacement and/or reflector maintenance/replacement before the system becomes underperforming for the proper curing of UV coating regardless of press speed/UV power.

Stain Test Result - UV Curing System Condition

The stain test can be used to determine any inconsistencies in coat-weight across the sheet, which can result in varying stain density results. In most cases, a thicker/heavier film of UV coating will have a better cure response than a thinner film, which can be observed in the stain test results. Inconsistent coat-weight across the sheet width or sheet length can appear as inconsistent stain test results, with thicker film areas measuring for more effective cure compared to thinner film areas.