# “The IR measurement of the valuable secured circulated paper documents’ life spans.”

**By:**
**Dr. Ahmed Mahmoud Yosri Ahmed**
**Professor assistant-faculty of Applied Arts \ Printing , publishing & packaging sector \ Helwan university \ Giezah \ Egypt.**

## Introduction & problem:

Virtually the circulated long life printed paper documents ((ex; banknotes, certificates, stamps, cheques, bills, pass ports, residence documents, working or transmission permissions & etc)) all have unavoidable mechanical & optical deterioration ratios. Yearly; capitals of millions dollars are spent worldwide reissuing the torn or fade ones.

To predict the longevity period ((the circulation life span)) of a printed paper document, we have just two options. Practically, both of them yield wide tolerances ((guessed)) results; because their methodologies are far from the real printed paper circulation actual force loads, ambient circumstances & soiling agents ((contaminators)). The first option is to issue, distribute & circulate the paper document for long periods ((months)); then the physical and optical properties deterioration ratios are measured. The longevity period is estimated relatively to these deterioration ratios. Obviously; this methodology is like jumping from the tenth floor, waiting for the result!

The second choice is pre-distribution physical & optical properties profiles measuring. Beside, the artificial aging profile ((by both dry and wet testing methods)) & printing inks fastness ((fadness resistance)) are evaluated. In contrary of all these, the circulation simulation technology comes.

The banknote circulation simulation technology has been innovated by the R&D sector of Crane & Co., Inc ((the American secured paper manufacturer)) some years ago.

As this methodology is too close to the actual circulation mechanical forces & ambient severe circumstances; its results almost doesn’t deviate from reality ((or deviate too tightly)).

High speed is also an advantage of this methodology. As an example, by just one too quick simple testing step followed with optical digital analysis, the any of paper document tested samples' mechanical deterioration, optical deterioration, mechanical or chemical printing inks fadness or its soilability values or ratios could be detected, and soon its longevity could be preciously inferred.

## Definitions:

***Paper mechanical deterioration****:* dramatic losses of paper physical properties profiles. The tensile strength, folding endurance, tear resistance & perforation resistance all fall down. Holes, tears, cuts, separated parts & ragged uneven edges appear on the paper document. The mechanical paper deterioration resulted from paper inner or ambient outer acids. Hence, the neutral pH profile & anti acids additives contents are most critical for long life circulated paper documents. The high humidity ratios & temperature degrees in the paper document's circulation ambient environment catalyze the mechanical deterioration reactions.

***Paper optical deterioration****:* deviations of the original paper optical properties profiles. The hue, ISO brightness, whiteness, Y value & gloss all change positively or negatively. The photochemical reactions between the exposure light ((day white light & UV)) and the pulp stuff lignin content is the cause of optical deterioration looks. Structuring the long life paper document using chemical pulp or zero kappa No. fibers ((cotton or linen)) is the only way, resisting but not fully inhibiting, the paper inescapable optical deterioration influences.

***Printing inks mechanical fadness***: decreasing of the inks color properties profiles under mechanical rubbing forces & loads. The hues, densities & saturation all are getting fade. Human fingers, winds carrying dust particles & scratches are common mechanical rubbing forces.

***Printing inks chemical fadness****:* decreasing of the inks color properties profiles under chemical agents contact or just their vapors. The hues, densities & saturation all fade. High concentrations solvents, bleachers, salty sweats, acids & alkalines all have fadness effects on printing inks.

***Paper soiling****:* the paper whole optical appearance becomes dirty and its basis weight gets bigger with the sticky ambient environment liquid or solid soiling agents. The higher the paper porosity is and the wider its pores are, the more the paper soiling ratio is. Coating the paper document with a soiling proof ((a higher surface tension giver)) transparent protective varnish layer, has excellent soling resistance result.

***Printing methods of the long life circulated documents:*** commonly they are printed using the rotogravure mechanism; its raised texture is excellent for the security issues. Also dry offset ((indirect flexography)), conventional wet lithoffset, waterless lithoffset or even silk screen methods are used. Sometimes, a combination of printing techniques is applied, making the long life paper document ((more secured)).

## Scope & Objective:

This scientific research is trying to output some parameters more standardize & develop the circulation simulation methodology used for prediction of paper documents longevities. That is to say: the idea of using the IR scanning and the application of gradual test loads and exposure times. Also the prescription of the steps finding a relationship ((standard equation)) between the test exposure period and what it represents of actual circulation duration is an innovation contained in this research.

## Apparatuses, equipment & materials:

1- The paper documents Circulation Simulator \ CS tester ((artificial accelerated circulation tester)), equipped with samples revolving tube ((mixer)).
2- Grippers to hold and attach the paper samples inside the revolving tube while hitting.
3- Too durable hitting marbles in same millmetric diameter, with specified standard number and net weight. The marbles' weight, moving speed & fall distance on the attached samples simulate the real human fingers circulation various directions stresses & forces. The marbles surfaces also work as chemical ink fadness or paper soiling agents' carriers. It's advisable to keep various: diameters & surface roughness profiles groups.
4- Multi standards solid or liquid soiling agents ((contaminators)), selected simulately to the actual paper document circulation environment ambient circumstances. Greases, lubricates, fats, oils and detergents are just examples.
5- Multi standards various concentrations chemical printing inks fadnees agents ((artificial salty sweat, acids, alkalines, domestic solvents like acetone and chloroform, common bleachers like $H_2O_2$ and $NacLO_2$)).
6- Digital video Infra Red/IR scanner loaded with geometric dimensions measuring Soft Ware S\W and equipped with a displaying screen.
7- Lab digital optical measurement spectrophotometer.

## Samples:

1- Dozens of new **uncirculated** samples of the tested secured paper printed document.

2- **Withdrawn samples** of the same types of the tested secured paper documents which have been circulated for **known periods** under normal circumstances.

## Testing procedures:

| ***Test*** | ***Steps*** |
|---|---|
| ***A-Detection the paper*** | 1- One of the pre-conditioned **new** paper samples is chosen randomly as the reference sample, then one of its physical strength properties ((folding endurance, tensile strength or tear resistance)). Bending resistance as the |

| | |
|---|---|
| ***document mechanical deterioration average ratio.*** | most critical paper stiffness properties may be also the measured one.<br>2- The rest pre-conditioned paper samples are closely attached lying flat inside the tester revolving tube, using the flexible grippers.<br>3- On one too high speed and for pre-fixed time period, the samples are hit with the ((clean surface)) marbles. The hitting period ((exposure time)) sure is in linear parallel relationship with the required or assumed actual paper document real circulation period.<br>4- After the end of the hitting period, the average of the same strength or stiffness property profile on the hit samples is measured. Comparatively with the ex-measured reference value, the mechanical deterioration ((or conversely the strength retention)) ratio is calculated.<br>5- Using the IR scanning and geometric dimensions measuring S\W all the mechanical deterioration indications could be viewed on the screen, photographed & also measured. For example, the circumference of the paper sample ragged edges is counted and the less it's from the original circumference, the larger the missed parts of the hit sample are. In the same way by the IR scanning, the sizes & dimensions of the samples inner tears and holes are measured.<br>*6*- Repeat under increasingly samples hitting periods ((emulate increasingly real long months circulation periods)), and under various diameters & surface roughness profiles of hitting marbles. |
| ***B-Detection the paper document printing inks mechanical fadness average ratio.*** | 1- Using the digital spectrophotometer, the printing inks color properties profiles ((hue, density & saturation)) on one randomly chosen pre-conditioned printed paper sample are measured, making it the reference sample.<br>2- Repeat the previous test A steps No. 2 & 3.<br>3- The same printing inks color profiles averages are measured on the hit samples. Comparatively with the ex-measured reference value, the printing inks mechanical fadness average is calculated.<br>4- Evaluate the readability deterioration of the hit samples printed or written text & information in an analogue way by naked eyes.<br>5- Repeat the previous test A step No.6. |
| ***C- Detection the paper document printing inks chemical fadness average ratio.*** | ((Esp. for artificial salty sweats, acids, alkalines, solvents & bleachers as fadness agents)).<br><br>1-Repeat the whole steps of the previous test B, but using hitting marbles pre-coated with specified weight and concentration of the desired chemical fadness agent. |

| | |
|---|---|
| ***D- Detection the paper document soiling average ratio.*** | ((Esp. for Greases, lubricates, fats, oils and detergents as soiling agents)).<br>1- One of the pre-conditioned paper samples is chosen randomly as the reference sample & its basis weight profile is measured.<br>2- Repeat the previous test A steps No. 2 & 3 but using hitting marbles pre-coated with specified weight of the desired soiling agent.<br>3- Evaluate the paper sample soilability ((soiling tendency)) in an analogue way by naked eyes or under magnification.<br>4- Detect numerically the paper samples soilability, by calculating their basis weight increases averages after soiling comparatively against that of the reference sample.<br>5- Repeat the previous test A step No.6. |

**Table ((1)) Tests steps.**

## Results evaluation:

| *Measured parameter* | *Results evaluation* |
|---|---|
| *Paper document* ***wearability***. | - The higher the physical strengthens retentions, the shorter the ragged circumferences, the smaller the holes & the tighter the tears averages of the hit paper document samples are…….so the lower their wearability is. |
| *Paper document* ***printing inks mechanical & chemical fastness***. | - The less the averages decreasing degrees of the printed paper document hit samples printing inks densities & saturation values are…..so the higher their mechanical & chemical fastness profiles are. |
| *Paper document* ***soilability ((contaminatability))***. | - The smaller the increase averages of the basis weight of the paper document hit samples are….so the lower its soilability is. |

**Table ((2)) Results analysis.**

## Findings:

After the **comparison with the gradual periods real circulated samples**, the linear relationship index between the tested paper document samples hitting ((exposure)) time period, inside the circulation simulator tester revolving tube, and what it presents of real actual circulation time periods could be calculated.

Then, this index is implemented to extrapolate a calculation equation formula, the latter results in a **longevity factor index** ((with too tight - unavoidable - deviation range from reality)) for this paper documents.

## Example of assumed: results, evaluation & findings:

*Crane & Co., Inc the innovator of this testing methodology itself, hasn't yet declared an equation relate between the testing ((samples hitting)) times with what they represent of actual circulation times…. But that's the main target of this article.*

Assuming that the pre-explained & scheduled testing methodology steps have been followed and applied for evaluating the mechanical deterioration ratios of an **already actual launched** paper document ((using hundreds of new pre-distributed samples)). Then the results were compared with real deterioration ratios of withdrawn copies of the same document have been circulated for known periods under normal circumstances.

As what is viewed in the next table (3).

| ***The assumed ((imagined)) mechanical deterioration testing times*** | ***The assumed ((imagined)) actual circulation periods having the same mechanical deterioration ratios & appearance looks.*** | ***The calculated mechanical deterioration factor indexes ((what 1 minute testing equals...))*** |
|---|---|---|
| 15 min | 140 days | 140 / 15 = 9.3 days |
| 30 min | 250 days | 250 / 30 = 8.3 days |
| 45 min | 350 days | 350 /45 = 7.7 days |
| 60 min | 570 days | 570 / 60 = 9.5 days |
| 75 min | 660 days | 660 / 75 =8.8 days |
| 90 min | 810 days | 810 / 90 = 9 days |
| 105 min | 905 days | 905 / 105 = 8.6 days |
| 120 min | 950 days | 950 /120 = 7.9 days |
| 135 min | 980 days | 980 / 135 = 7.25 days |
| 150 min | 1005 days | 1005 / 150 = 6.7 days |
| 165 min | 1020 days | 1020 / 165 = 6.18 days |
| 180 min | 1300 days | 1300 / 180 = 7.2 days |
| | | Index average = 96.2 / 12 = **8.01** days |

**Table ((3)) Assumed ((imagined)) mechanical deterioration test results analysis.**

After that, we have repeated this mechanical deterioration test ((for another 5 times)) with different diameters & surface roughness profiles of the hitting marbles.

The other assumed ((imagined)) 5 calculated mechanical deterioration indexes were: ((12\ 8.8\ 10.1\ 9.3 \ 7.8)) days

So; the final mechanical deterioration index for this assumed long life paper document = ((8.01 + 12 + 8.8 + 10.1 + 9.3 + 7.8)) / 6 = **9.3** days

***Interpretation***: **one minute** hitting ((of this assumed specific kind of paper)) inside the artificial accelerated circulation tester equals average of **9.3 days** of real actual circulation under normal circulation circumstances, as they both result in the same mechanical deterioration ratios & wear performance looks.

So for the next **future** new production & quality control of this same paper grade long life document, the mechanical deterioration index of it is **already pre-found**, and easily its **standard strengthens profiles life span period** will be tested & preciously determined directly.

In the same way, the all printing inks mechanical or chemical deterioration & the paper soiling ratios indexes could be calculated and used determining more standard paper documents span lives periods.

## Bibliography:


1- " Predicting banknote longevity \ developing a test method for repeatable results", An article by Timothy T Crane, Director Research & Development and Security Technology, Crane & Co., Inc. www.crane.com. May 2004.

2- Giesecke & Devrient / GMBH. Currency Automation and Services – Sector. Catalogues & publications (2004: 2007). Munich / Germany.www.gi-de.com.

3- Trub AG – Switzerland – Publications – 2006 www.Trueb.com.