

The Importance Of A Measurable And Repeatable Screening Process

By P J Mason MSEE

“If you cannot control the application and measure the effectiveness of a process then you cannot improve or repeat it”.

Finding the faulty product is only half the answer as the real benefit comes when you correct the cause of the defect. Therefore if you cannot repeat the screen you cannot test the effectiveness of the fix. It follows that unless you control the application and measure the effectiveness of the screen you will not be able to draw any useful conclusions from the process yield data.

How do we predict the effectiveness of a screen?

A single factor for the fundamental definition of a screen is used. This factor is called “Screen Strength” and it is used to quantify the expected effectiveness of a screen.

Definition

“Screen Strength” is the probability that the process will turn all the latent defects into hard failures. Provided that the defects exist, and can be turned into hard failures by that process”.

To explain:

If you specify a Screen Strength of “0.9” then, using an appropriate screen, you can expect to precipitate 90% of failures that would otherwise have occurred during the early life of the product.

Screen Strength for thermal screening is derived from the “Hughes Equations for Screen Strength”. The background and development of these empirically derived formulae is explained in the next section.

Background to the development of the Hughes Equations for Screen Strength.

- The Hughes Equations for Screen Strength were derived as part of a study to develop methodologies and techniques for planning, monitoring and evaluating stress screen programmes during electronic equipment *development and production*.
- This study was documented as a Final Technical Report in May 1982 and published by the Rome Air Development Center under the title “Stress Screening of Electronic Hardware”, document code RADC-TR-82-87.
- Screen Strength equations are developed for:
 - random vibration
 - swept sine vibration
 - fixed sine vibration
 - constant temperature
 - temperature cycling
- The vibration models were derived from raw data supplied by the Grumman Aerospace Corporation as detailed in Grumman report ADR 14-04-73.2.
- The temperature cycling models were derived from the temperature cycling curves of NAVMAT P-9492. These curves relate failure rate of electronic equipment to the number of temperature cycles applied for different levels of equipment complexity (measured in parts count).
- The constant temperature model is derived by adapting the temperature cycling model for a fixed value of temperature gradient and zero cycles.
- In the absence of published alternatives to the Hughes equations for screen strength, and in the light of recorded correlation between measured and calculated screen strengths, the Hughes equations are generally accepted as reasonable models for the selective determination of cost effective thermal screen parameters.
- The Hughes equations are valid for measured product mechanical and thermal response values. Specified values for vibration equipment drive profiles and thermal chamber air temperature profiles must not be used as parameters for use in the Hughes equations without knowledge of product response to vibration and thermal stimuli.

Thermal Screening uses two of the Hughes formulae:

The Hughes formulae used in thermal screening are the “Constant Temperature” and “Temperature Cycling Equations”.

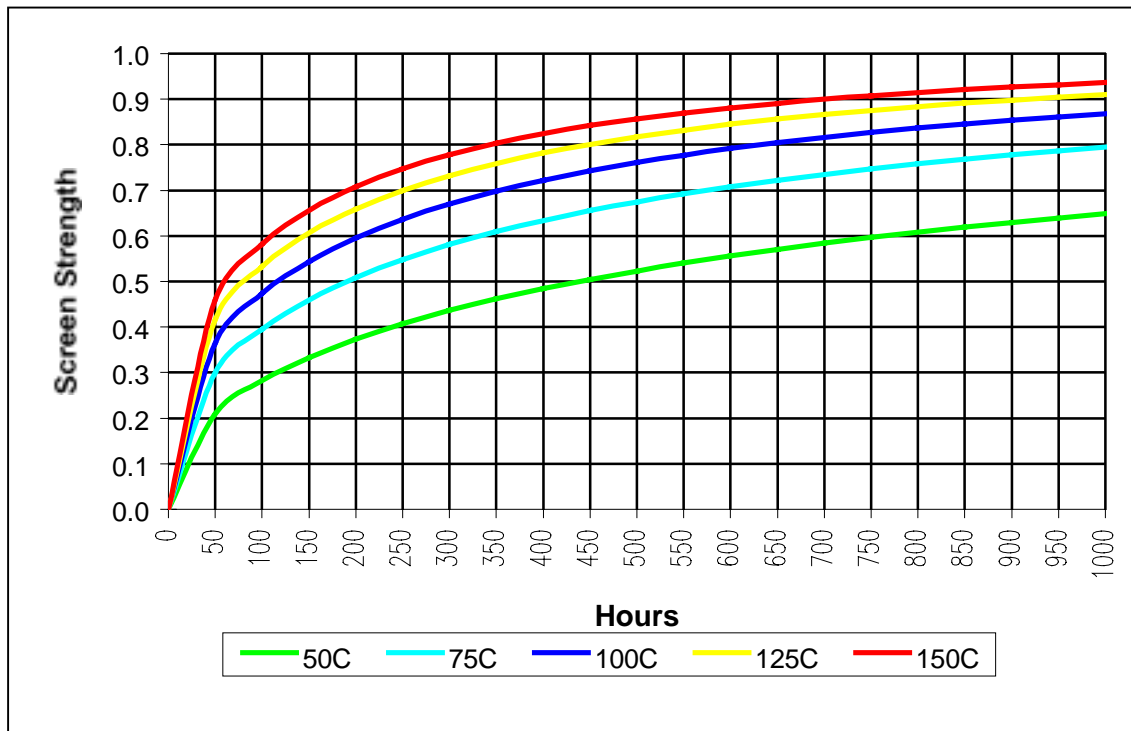
The Hughes equation for Constant Temperature.

$$S.S. = A(1 - \exp\{-0.0023 [\ln(e+1)]^{2.7} T^{0.5} R_D^{0.6}\})$$

T = duration of dwell in hours.

R_D = elevated temperature minus 25°C.

Example: For **R_D** = 100°C, actual temperature = 125 °C.



This equation supports a technique used in the semiconductor industry to screen devices at elevated temperatures for prolonged periods, typically 100°C above ambient for a week. Return on Screen Strength against process time is very poor and the elevated temperatures necessary make this method inappropriate for most other applications.

It is important to mention that this process is often confused with “Soak Testing”. Soak Testing is popular and cheap, but ineffective in turning latent defects into hard failures. It consists of testing within the operating range of the product for extended periods of time, 96 hours is quite common for no good reason other than 96 hours equals one working week. The reality is that all that can be deduced from this test is that the product would or would not have survived the first 96 hours of it’s life.

The Hughes equation for Thermal Cycling

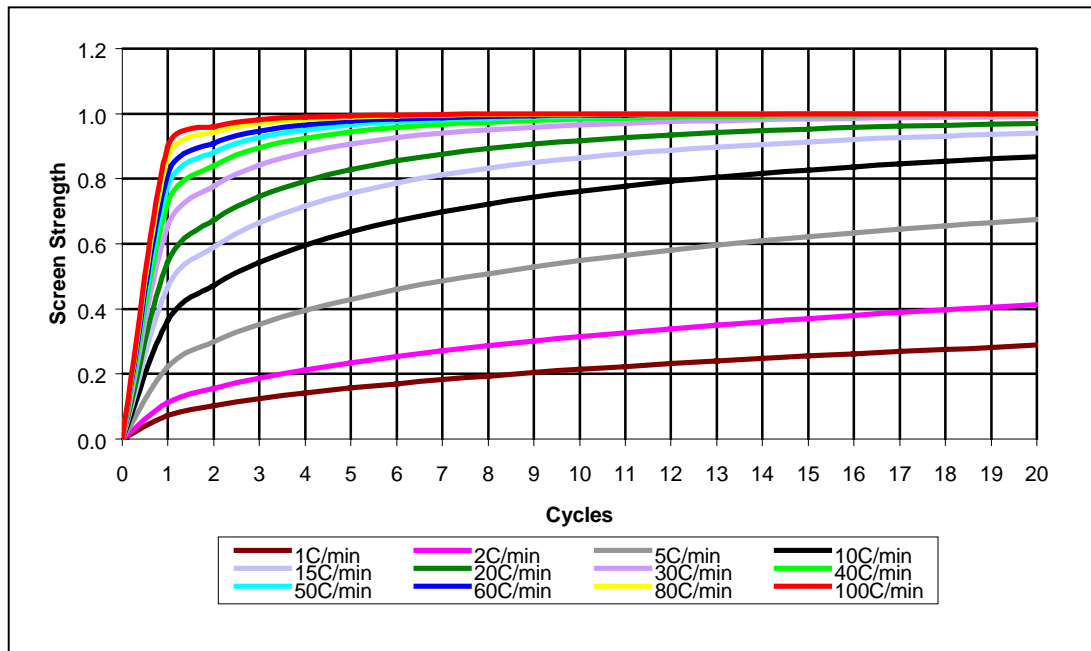
$$\text{S.S.} = A(1 - \exp\{-0.0023 [\ln(e+dT)]^{2.7} N^{0.5} R^{0.6}\})$$

dT = product temperature gradient in °C /min.

N = number of applied cycles.

R = range of temperature extremes in °C.

This Hughes Equation is much more effective in the production of electronic hardware and is the fundamental basis for the screen development within our business. If the screen is developed correctly the resultant process is Controllable, Measurable and Repeatable. Return on screen strength against time can be very high when conducted by the latest in chamber technology so this process can form part of a production line providing dynamic information for process improvement.



The variables in the formulae are:

“**dT**” which must be emphasised is product rate of change and is the average of the rising and falling ramps.

“**R**” the range over which the product not the chamber is exercised.

“**N**” the number of cycles which for a given Screen Strength is determined by the formulae when “**dT**” and “**R**” are known.

The constant “**A**” is recommended to be 1. “**A**” can be varied to reflect a more accurate S.S. when linked to other elements in the production line i.e. if your test coverage is 90% then **A=0.9** which will put a maximum limit of 0.9 on Screen Strength. It is however desirable to be able to specify Screen Strength on a basis that is independent of other specific process limitations. For this reason the users of the Hughes Equation for thermal cycling generally prefer to use $A=1$.

It is also important to note that in this equation dwell has no impact on screen strength.

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