

Second Magenta

Windshield Uniformity (WUS) Test Software

User Manual

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Contents

1	Introduction.....	3
2	Software Installation	4
3	Using the Software.....	5
3.1	Initialisation and Connecting the Thermal Camera	5
3.2	Catalogue	5
3.3	FLIR A310.....	6
3.4	Power Constants	6
3.5	Temperature Spread	7
3.6	Windshield Data.....	7
4	Software functions.....	8
4.1	Catalogue	8
4.1.1	Editing an Existing Windshield	8
4.1.2	Defining a New Windshield.....	9
4.1.3	Deleting an Existing windshield	10
4.2	Power Constant Test Procedure	10
4.2.1	Test Procedure.....	11
4.2.2	Initiate Test	11
4.2.3	Power Test	12
4.2.4	Power Test Results.....	13
4.2.5	Save.....	14
4.2.6	Print.....	14
4.3	Temperature Spread Test Procedure	14
4.3.1	Test Procedure.....	15
4.3.2	Align the Heated Zone (if defined).....	15
4.3.3	Capture Temperatures	16
4.3.4	Unfreeze.....	18
4.3.5	Save.....	18
4.3.6	Print.....	19
ANNEX 1: Power Constant Measurement for Heated Aircraft Windshields Using Thermal Camera.....		i

1 Introduction

The Windshield Uniformity (WUS) Test Software is designed to measure the thermal uniformity of an electrically heated aircraft windshield using a Thermal camera. The WUS software operates with the FLIR A310 Thermal Camera and is part of the test procedure.

The outer face-ply is tested separately during the windshield fabrication process. This can be a dynamic test using the temperature rise during the powering up phase from ambient temperature, or a steady-state test, to determine the thermal uniformity across the surface of the windshield.

NOTE: In addition to the provision of a suitable working area and method of heating the windscreen at the required voltage, a practical small hot heat source arrangement is needed to reference the windscreen within the Thermal Camera's field of view. An example of such a heat source might be a small tungsten filament bulb or a soldering iron with a small tip.

The WUS software calculates the power constants for the windshield under test, based on using a dynamic approach. The power constants are quality control parameters used by windshield manufacturers in supply of product. The requirements are specific to a windshield product and the pass/fail criteria are provided in the windshield product specification. Within the test constraints, the temperature rises are proportional to the power dissipation across the windshield. The theoretical background for this is provided at Annex A, along with the mathematical calculation description.

In addition, this version of WUS (130607) includes a new feature for temperature spread measurement and display designed for steady-state testing. This allows the user to capture a thermal image at any time and, using the cursor, determine the temperature spread based on any number of user-selected locations.

The WUS software is designed and written to run on a modern PC platform with the following minimum requirements:

- Processor speed: >2 GHz; Intel Pentium or equivalent
- Available RAM: >256MB
- Available Disk space: >100 MB
- CD Reader: >48x
- Screen Resolution: >1024 x 768

The WUS software relies on the following system and supporting software being installed on the PC platform:

- Operating system: Microsoft Windows 8, 7, Vista or XP
- Enabled software: Microsoft .NET Framework version 4.0 or higher
- Enabled software: Microsoft Internet Explorer version 6 or higher
- Enabled software: FLIR A310 supporting software, including SDK v2.06 and an appropriate licence

2 Software Installation

The WUS Test Software is supplied on CD. The contents of the CD are protected by copyright. The WUS source code is written in C# and no source code is provided on the CD.

The CD application WUS-Test-Software-Installer, contains all the files necessary to run the software on a PC platform as specified in section 1, with the exception of

- Microsoft .Net 4.0
- The FLIR A310 Thermal Camera Drivers

The FLIR Thermal Camera drivers need to be installed separately before the WUS Test Software will work properly with the camera.

To install the software, insert the CD into the disk drive and run WUS-Test-Software-Installer. This will automatically create a [WUS Test Software] folder in c:\ Program Files and copy the software application and its associated files and folders into that folder.

The installer will check whether Microsoft .Net 4.0 is installed on the target computer and will display an error message if it is not available. If the installer cannot detect it then .Net 4.0 will need to be installed separately. Microsoft .Net 4.0 is available for download from the Microsoft web site.

It is advisable to set up a desk-top icon shortcut for ready access to starting the software. Help on setting up a desk-top icon is available through the Microsoft Windows 8, 7, Vista or XP help menu.

Any files created or accessed by the software application are not encoded or protected. Since the data structure within the files is proprietary format, bespoke to the software, it is not advisable to manually alter their contents. Editing or manipulating these files manually could result in the software becoming unstable, not functioning correctly or producing erroneous data results.

To uninstall the software, use the uninstaller [WUS Test Software] folder in c:\Program Files.

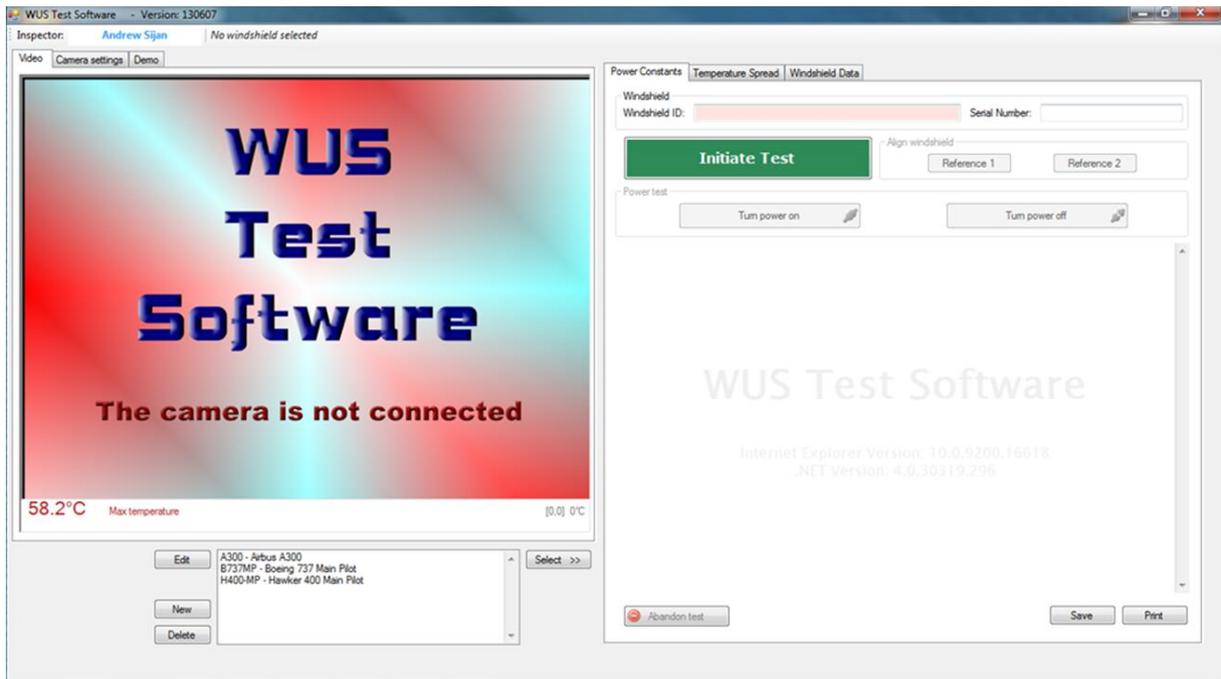
3 Using the Software

3.1 Initialisation and Connecting the Thermal Camera

Turn-on the FLIR A310 Thermal camera and allow it to reach operational status.

Start up the software by clicking on the desk-top icon (if installed) or by selecting WUS Test Software application from Program Files.

The following screen is displayed:



Note: the Software will take the current computer user as the default operator. If the inspector is someone other than the default computer user, the inspector name should be changed.

From the [Camera settings] tab, select the settings option and confirm the correct camera type has been selected. Click on the [Connect] button to connect to the Thermal camera and a real-time image from the camera will appear in the window. Check the other camera settings are as required by the test procedure and product specification for the windshield under test.

For User instruction on control and setting of the Thermal camera, refer to the appropriate camera user manual. This user manual covers the navigation and operation of the WUS Test Software.

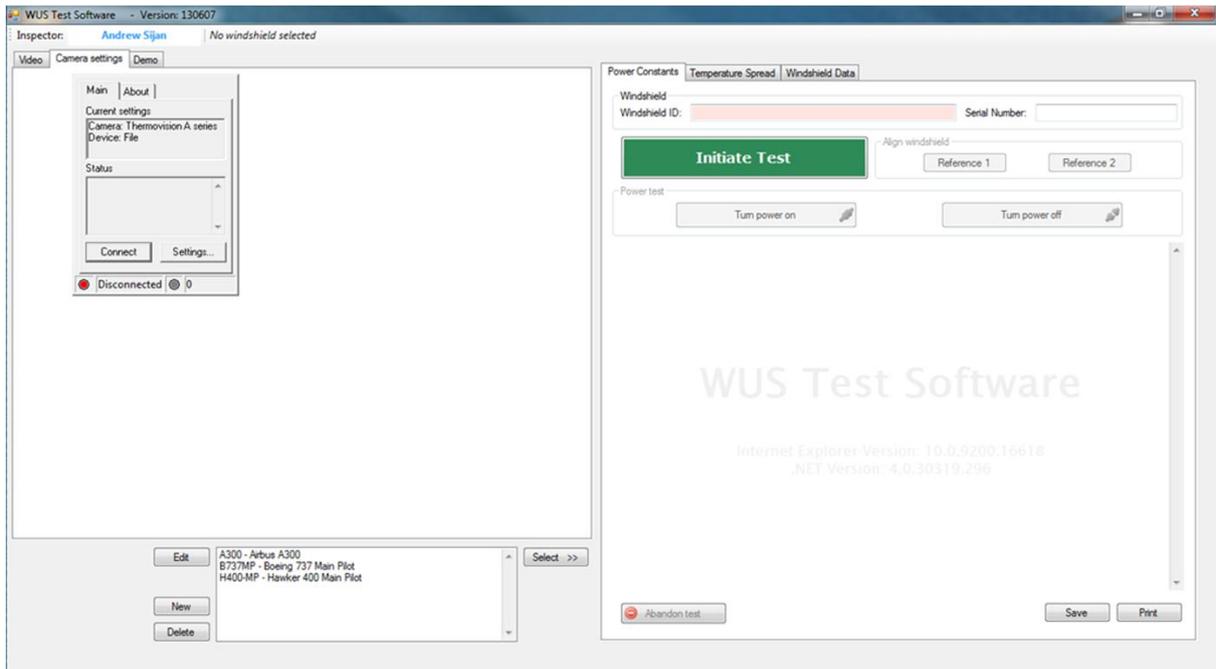
3.2 Catalogue

The Catalogue is used to store and recover essential data about specified windshield products in order to perform the thermal uniformity testing. The specified windshield products are listed in the lower left hand side of the display panel. This Catalogue stores the measurement points and sensor position data, as well as the power constants pass/fail criteria for the products. The Catalogue reduces the need for entry of key data at each thermal uniformity test.

The buttons [New], [Edit], [Delete] and [Select] allow the user to select existing windshield products from the catalogue for thermal uniformity testing, add new windshield products to the catalogue or delete unwanted windshields from the catalogue. It also allows the data to be modified or amended.

3.3 FLIR A310

This function is used to connect to, or disconnect from, the FLIR A310 Thermal Camera. The camera type is selected from the Settings option and the camera settings can be reviewed and re-configured, if required, from this panel.



The Demo panel is used of software testing purposes and is not described in this User Manual. FO further information on this facility, contact Second Magenta.

3.4 Power Constants

This function allows the User to start the test procedure for determining the Power Constants of the windshield. It will require the User to enter the serial number of the windshield and the inspector's identity before the test can begin.

The test procedure falls into two distinct phases:

- Identify the reference points with the bulb procedure
- Apply power to the windshield to capture thermal images of the windshield as it heats up

The WUS Test Software will map the specified measurement points and sensor positions for the windshield product onto the actual windshield presented within the field of view of the Thermal camera. It will mark the video image with the sensor positions and measurement points, allowing the User to verify that the windshield appears to be correctly aligned.

The WUS Test Software will then request the User to start powering up the window and to turn off the power at the appropriate times. It will record an initial thermal image at the specified time delay after the WUS Test Software has been notified that power has been applied to the windshield under test.

3.5 Temperature Spread

This function allows the User to capture a thermal image of the windshield. This can be done at any stage, but normally it will be done when the windshield is being controlled by a temperature controller.

It will require the User to enter the serial number of the windshield before the test can begin.

The test procedure falls into three distinct phases:

- Define the heated zone on the windshield (default is not heated zone)
- Freeze the live thermal image and capture the temperatures,
- Select locations on the image for recording the temperature using the cursor

The WUS Test Software will automatically find and display the maximum temperature and will recorded temperature at user-selected locations once the image is captured. The temperatures will be displayed both on the thermal image and in the results table. If a heated zone is defined, the WUS Test Software will also automatically find and display the minimum temperature in the zone.

3.6 Windshield Data

This function presents the current data for a selected windshield product, its existing values and test variables. It is also the area where the User can enter a new windshield product values-set and test pass/fail criteria, or edit those for an existing windshield product values-set and test variables.

Note: Data for both Power Constants and Temperature Spread tests are set in Windshield Data

4 Software functions

4.1 Catalogue

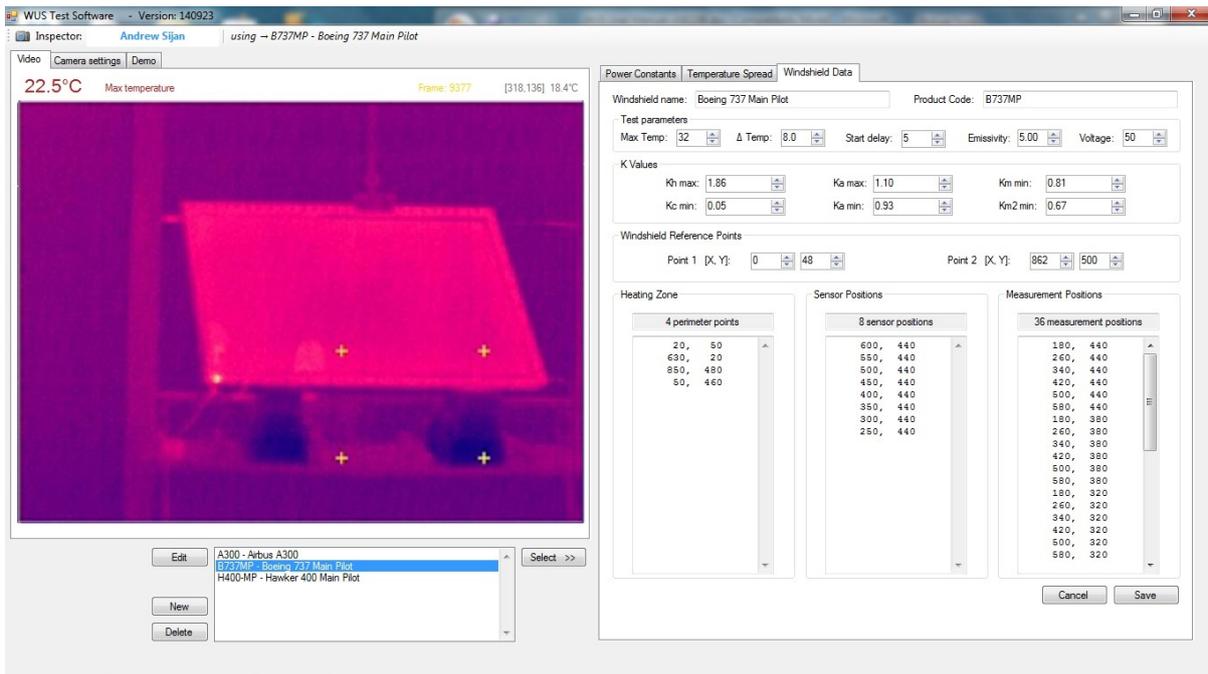
The Catalogue is displayed in the lower left hand side of the display panel under the heading [List of windshields to be used under test]. In addition, below these, there are four (4) buttons:

- SELECT >> – Use the highlighted windshield in the Power Constants panel
- NEW – Add new windshield products to the Catalogue
- EDIT – Edit the details of the highlighted windshield
- DELETE – Delete the selected windshield from the Catalogue

4.1.1 Editing an Existing Windshield

When an existing windshield in the Catalogue needs to be updated:

- Select the windshield to be edited from the list
- Select the [Windshield Data] tab. Below is an example screen-shot for the B737 MP windshield:



- Enter the data directly or use the up/down icons where available
- The Temperature Spread parameters are individual entries
- The Power Constant parameters, K value limits and windshield parameters are individual entries
- The heated zone (if defined), the sensor position and measurement points are entered as coordinate pairs, each coordinate separated by a comma and each pair on a separate line

- The heated zone coordinates must be entered in a continuous circular fashion around the perimeter, either clockwise or anticlockwise.

Note: The coordinate system required is set by the FLIR A310 Thermal Camera. This defines the origin (0, 0) at the top left corner of the array. Thus the

x values increase from left to right, and

y values increase from top to bottom.

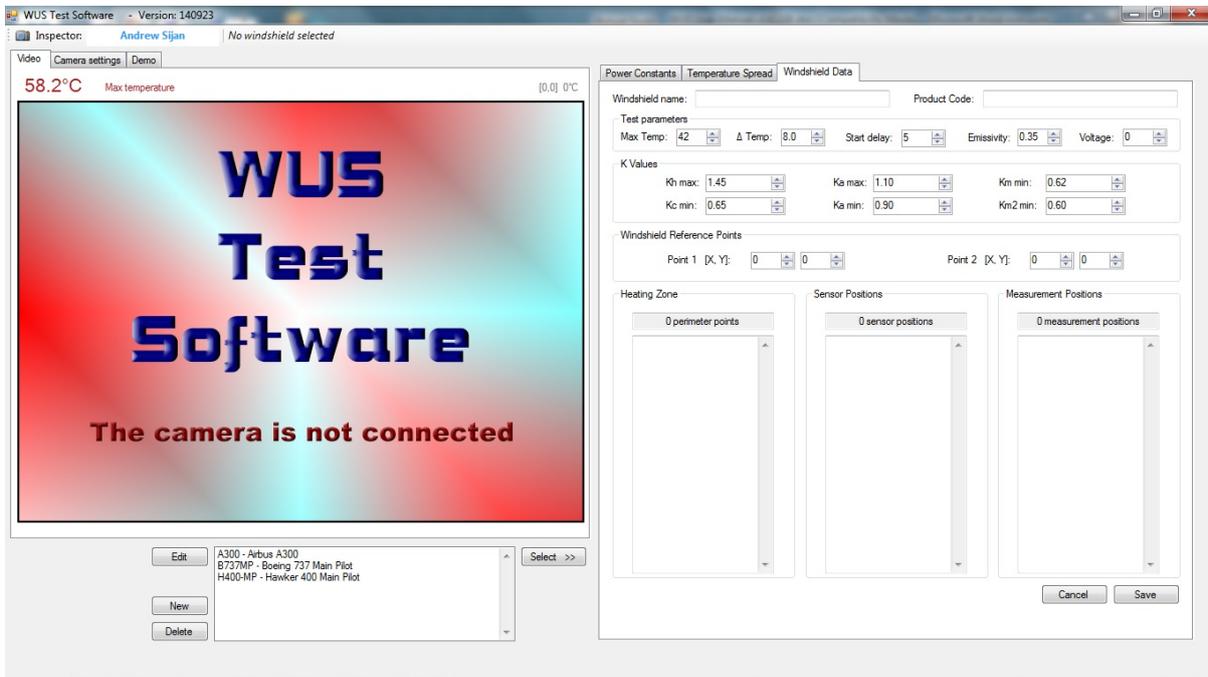
This same coordinate system MUST be used for defining the sensor positions and measurement points of the windshield.

Once the data has been entered satisfactorily, click on [Save] to save the information to disk and the pick list will be updated automatically.

4.1.2 Defining a New Windshield

When a new windshield is required to be added to the Catalogue

- Click [New] under the list and the following window will appear



- Enter the appropriate data for the new windshield name and its part number. This includes parameter limits for both Power Constant testing and the Temperature Spread testing.
- Default data is provided for a number of the required data entries. Enter the new data directly, or use the up/down icons where available
- The heated zone (if defined), the sensor position and measurement points are entered as coordinate pairs, each coordinate separated by a comma and each pair on a separate line. This can allow for using the Microsoft Windows Copy and Paste facility to bring in the data from other sources, if desired, rather than having to enter manually
- Click [Save]

After clicking [Save], the information will be saved to disk and the selection list will be updated automatically.

4.1.3 Deleting an Existing windshield

When a windshield is required to be deleted from the Catalogue

- Click [Delete].
- Confirm delete in the dialogue box that appears

The windshield and its associated data will be permanently deleted and the pick list will be automatically updated.

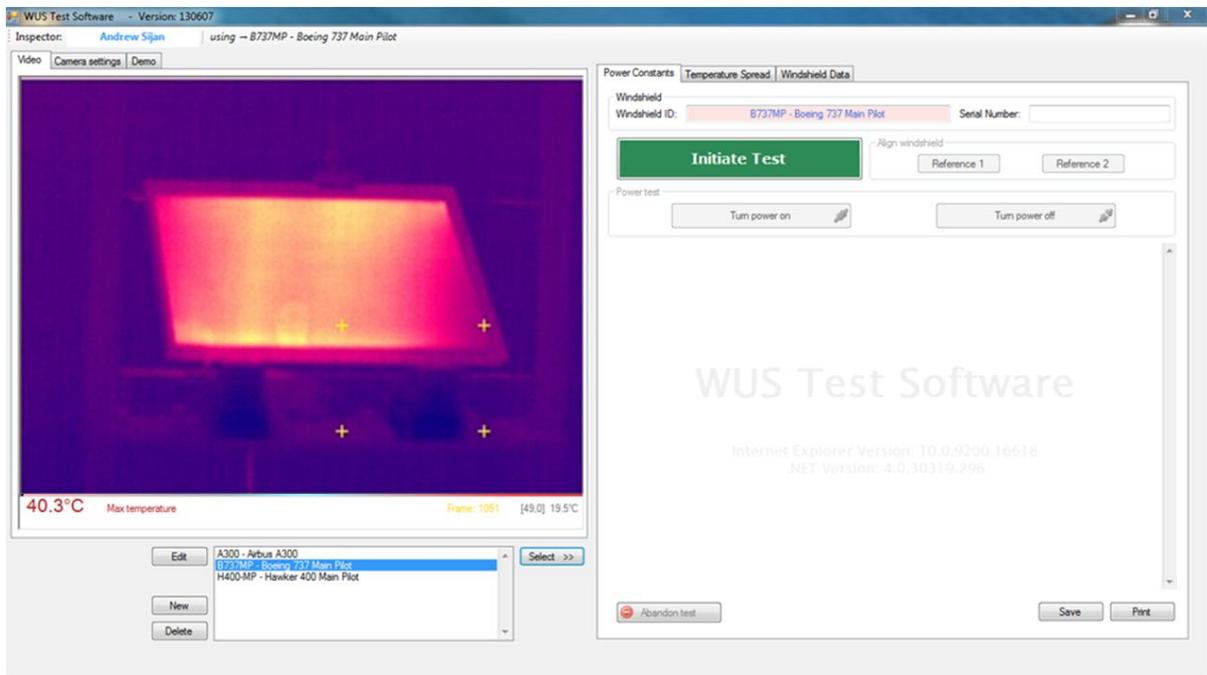
4.2 Power Constant Test Procedure

The [Power Constants] tab allows the User to:

- Enter the serial number of the Windshield under test
- Initiate the Test by aligning the windshield reference points using the bulb procedure
- Perform the Test (Turn power on / Turn power off)

In order to perform a Test, first the User must select a windshield from the Catalogue. If the desired windshield is not in the Catalogue, the User must then enter the new data as described in Section 4.1.2

On selecting the [Power Constants] tab, a screen will appear, similar to the one below. This example demonstrates a B737 MP windshield from the Thermal Camera video stream. The current location of the sensor positions and measurement points are also shown in the [Video] panel.



Note: In this example, the coordinates are larger than the frame size and so they do not all appear within the frame, only four (4) points can be seen.

4.2.1 Test Procedure

In the [Power Constants] panel:

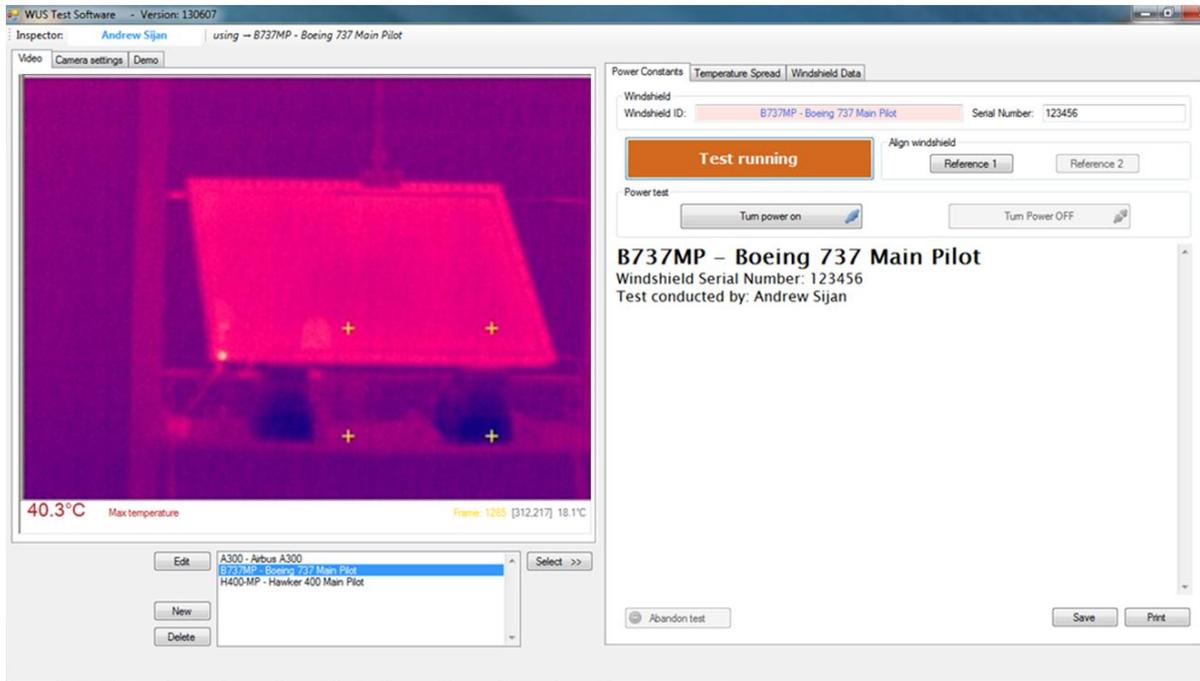
- The windshield data product code is automatically entered when selected from the Catalogue.
- Enter the windshield face-ply serial number
- Check the Inspector identifier. The default taken is the current user on the computer and is displayed above the [Video] panel. Change if required

4.2.2 Initiate Test

Immediately prior to performing a windshield thermal uniformity test, it is necessary to map the measurement points contained in the Catalogue onto the test windshield currently in the field of view of the Thermal Camera. This is done by using a small light bulb, as described below.

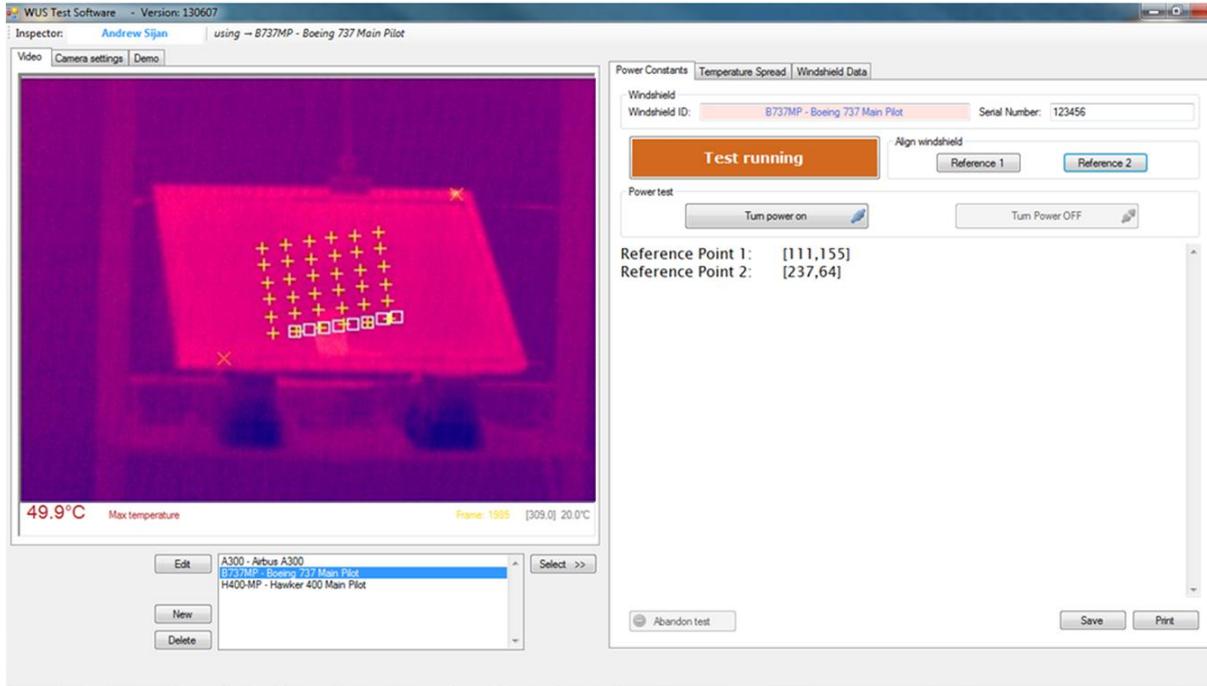
NOTE: The practical light bulb arrangement will be subject to the local area facilities and constraints. The User will need to make the light bulb available to undertake the test and use the WUS Test Software.

- Click [Initiate test]
- When the bulb is in view it will also be seen in the [Video] panel
- Place bulb at reference position 1. An example of this stage is shown below



- Click [Record Reference 1] and the captured (x, y) coordinate will appear on the main screen
- Place bulb at reference position 2
- Click [Record Reference 2] and, similarly, the captured (x, y) coordinate will appear on the main screen

The location of both the sensor positions and measurement points mapped onto the windshield are now shown in the [Video] panel. The following screen-shot shows the status after both reference points have been captured. At this point the User should ensure that the positions are as expected, before conducting the Thermal Uniformity Test:



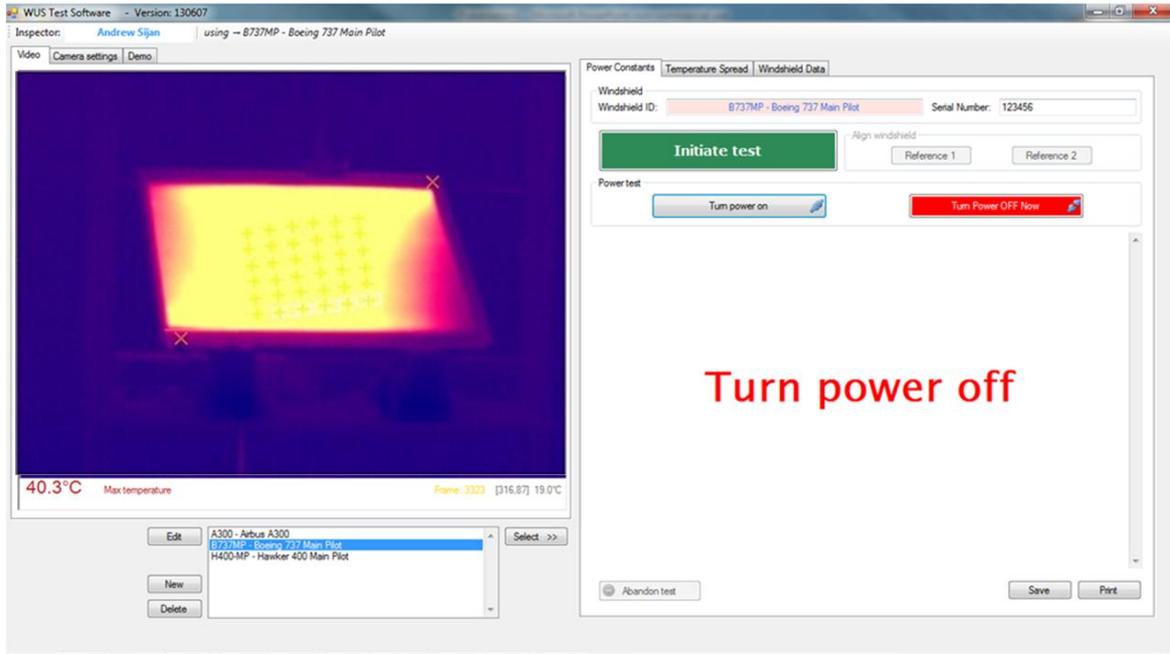
4.2.3 Power Test

When ready to perform this aspect of the test, ensure the bulb (and any other significant heat sources) are out of the field of view of the Thermal Camera:

- Turn on the power to the windshield
- Click [Turn power on]

The WUS Test Software will respond with [Test will begin in [x] secs] to the value specified in the template file.

- WUS reports the maximum temperature seen on the windshield by the Thermal Camera every single second until it reaches the limit value specified in the template file.
- When the limit is reached, WUS reports [Turn power off] in the main panel and the [Turn Power-OFF Now] button turns red to alert the User, as shown below.



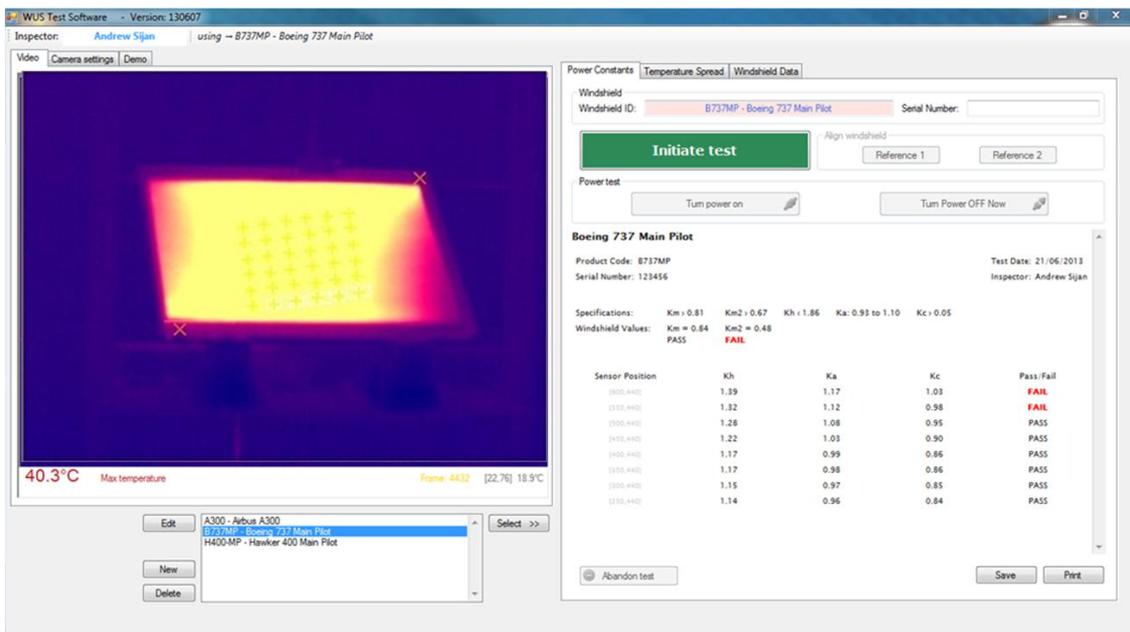
- Once the User clicks the [Turn Power Off] button to confirm the test is finished, the software calculates the power constants.

Note: The User can abort the thermal uniformity test by clicking on the [Abandon Test] button, after the test has started.

Note: WUS will record the final image and calculate the power constants based on the information it has in memory.

4.2.4 Power Test Results

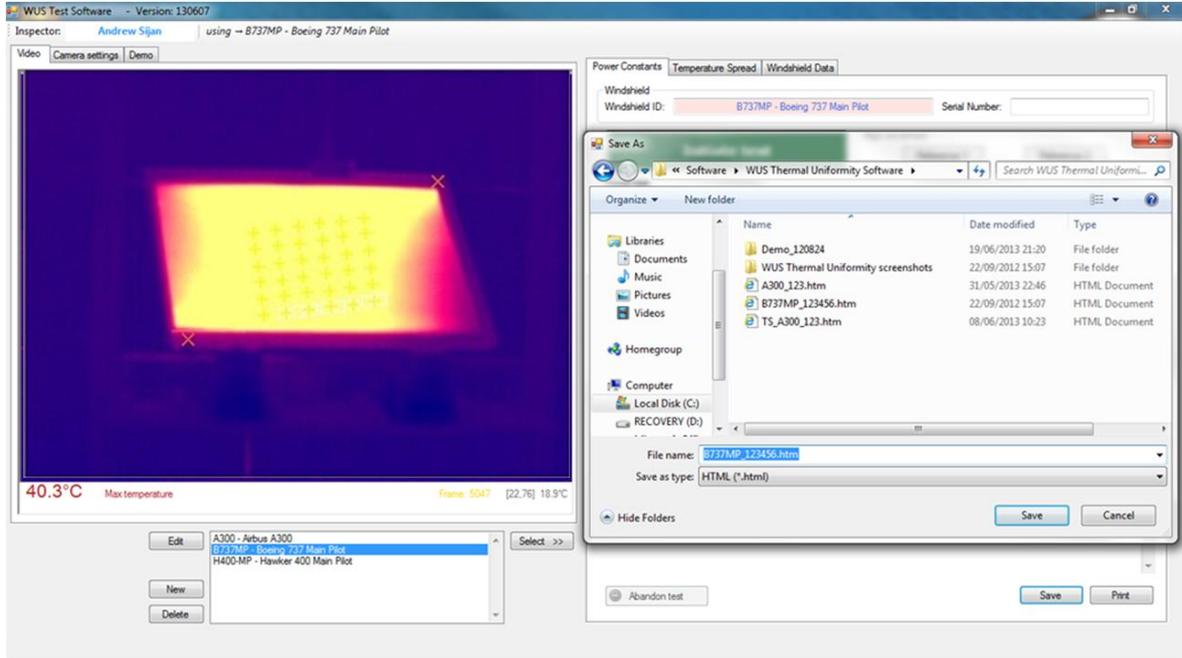
The WUS Test Software will automatically calculate the power constants and present them on the screen. An example screen-shot of the results is shown below:



4.2.5 Save

Click [Save] to save the thermal uniformity test results for this windshield.

The default filename structured as *[product code]_[serial number].html*, for example: B737MP_123456.html.



The default location for the saved file is the folder [Application data] associated with the WUS application. The User can choose alternative folders if required.

The User should not change the filename or its structure unless specifically required or directed to by an appropriate authority.

HTML files can be viewed and printed using browser software such as Microsoft Internet Explorer.

4.2.6 Print

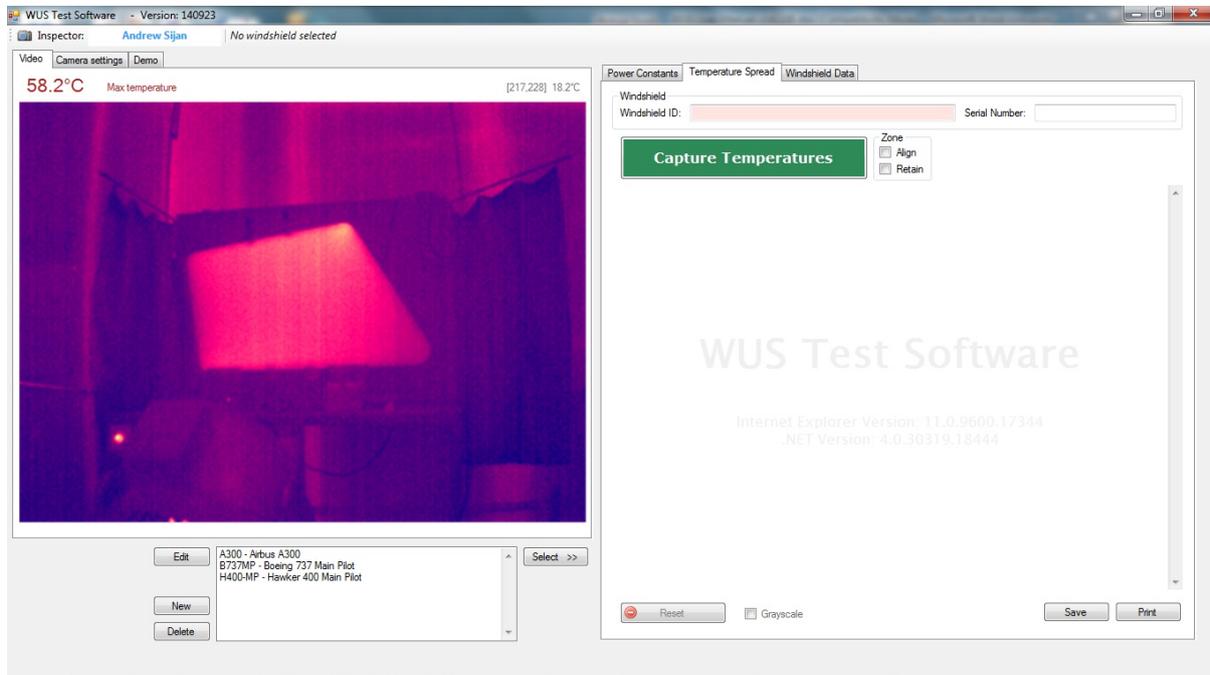
Ensure the printer is connected to the PC, then click [Print] to print the current contents on display in the results panel.

4.3 Temperature Spread Test Procedure

The [Temperature Spread] tab allows the User to:

- Enter the serial number of the windshield under test
- Align the heated zone of the windshield to the image displayed
- Capture a thermal image of the windshield
- Determine the temperature spread across the windshield at the time of the capture image by manually selecting multiple locations using the cursor

In order to perform a test, first the User must select a windshield from the Catalogue. If the desired windshield is not in the Catalogue, the User must then enter the new data as described in Section 4.1.2. On selecting the [Temperature Spread] tab, a screen will appear, similar to the one below. This example demonstrates an unspecified windshield and uses the B737 data, including a defined heated zone, from the catalogue is used for convenience.



4.3.1 Test Procedure

In the [Temperature Spread] panel:

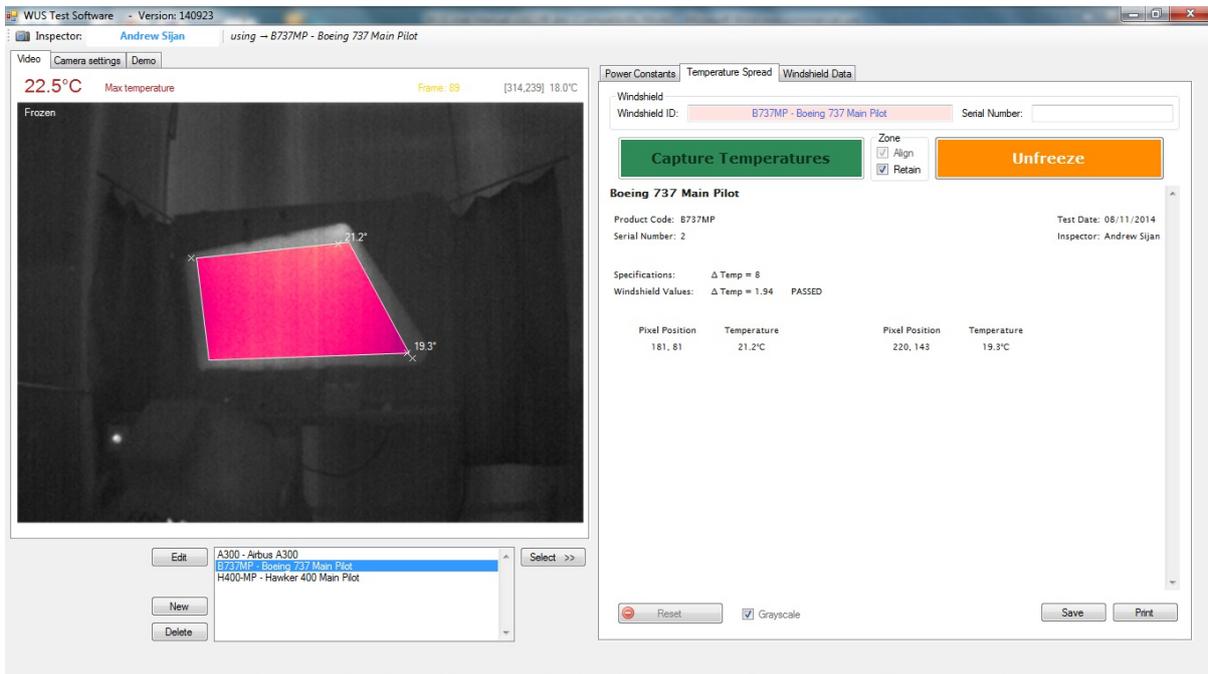
- The windshield data product code is automatically entered when selected from the Catalogue.
- Enter the windshield face-ply serial number
- Check the Inspector identifier. The default taken is the current user on the computer and is displayed above the [Video] panel. Change if required

4.3.2 Align the Heated Zone (if defined)

To align the windshield accurately, the bulb (or other point heat source) technique described in Section 4.2.2 should be used. In the [Temperature Spread] panel:

- Click the [Align] check box.
- By default, the [Retain] check box will become ticked.
- Identify Reference point 1 on the real windshield with a point heat source and click [Capture Temperatures].
- Double-click at Reference Point 1 on the image in the [Video] panel. A cross will appear at the selected point.
- Click [Unfreeze].

- Re-enter the windshield serial number.
- Identify Reference point 2 on the real windshield with a point heat source and click [Capture Temperatures].
- Double-click at Reference Point 2 on the image in the [Video] panel. A cross will appear at the selected point, the heated zone will be outlined on the image and the maximum and minimum temperatures in the heated zone will be displayed.
- To enhance the heated zone in the image click [Greyscale]. An example of this stage is shown below.
- Click [Unfreeze] and the windshield is now ready for the Temperature Spread Test.

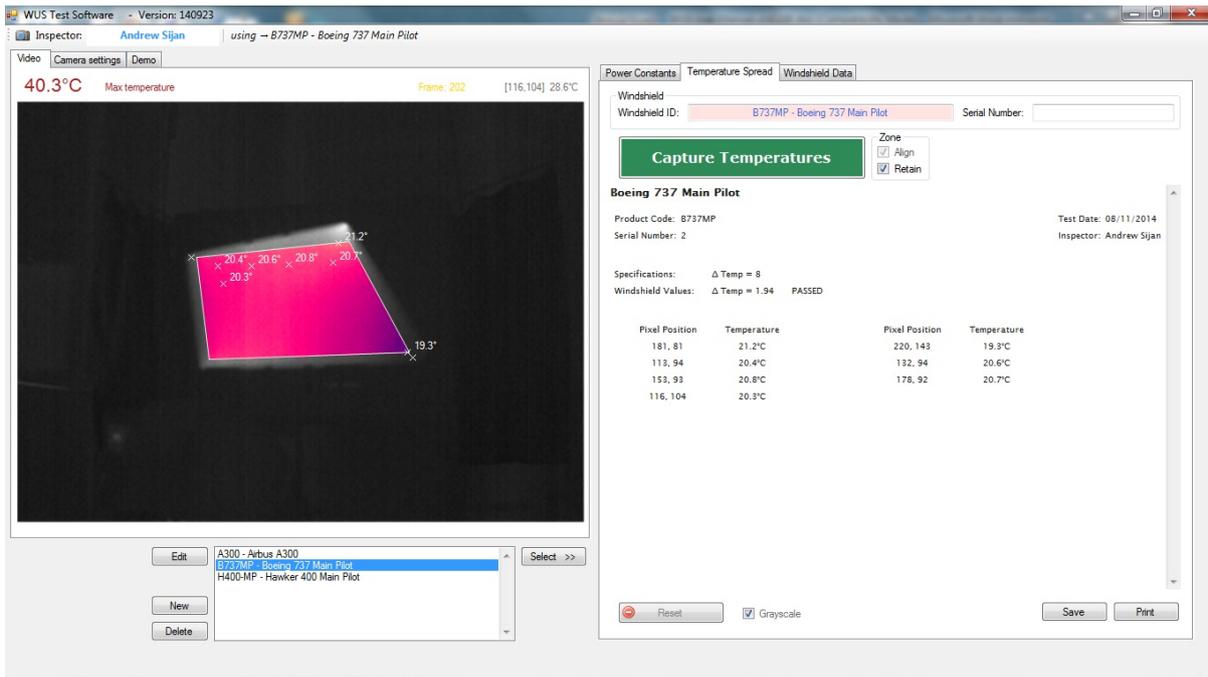


Note: to re-define the Reference points on the image, for example when moving on to test a new windshield, click [Reset] and start again.

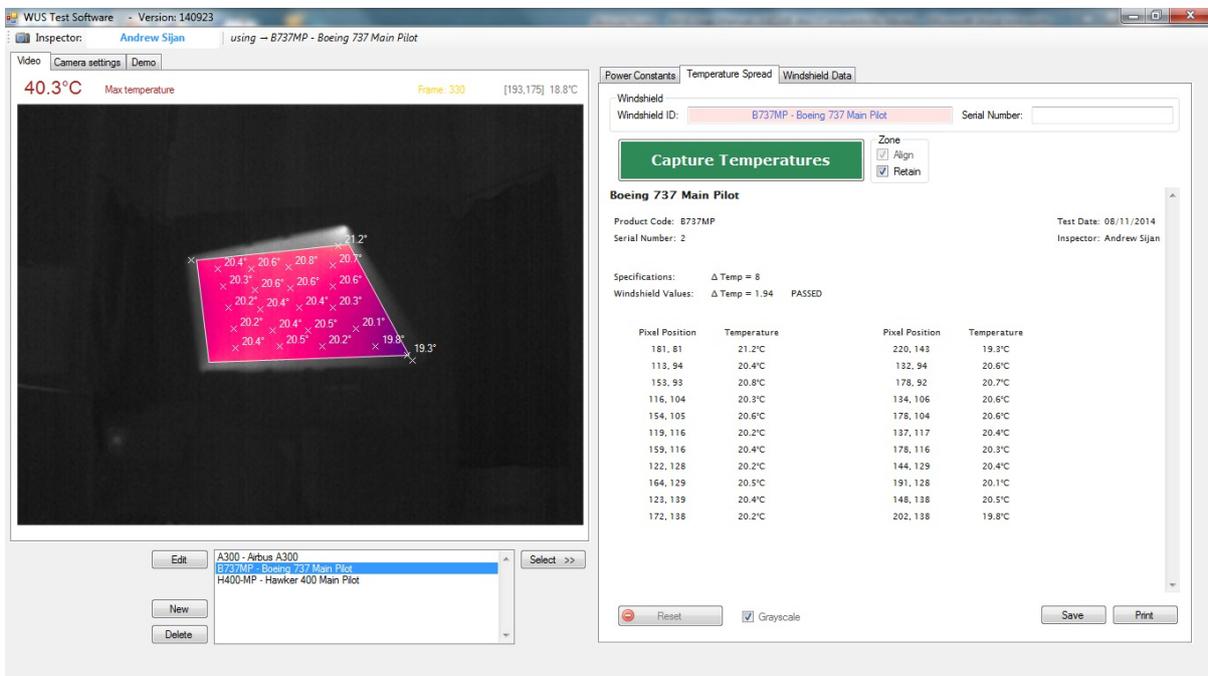
4.3.3 Capture Temperatures

At the desired time, typically when the windshield has reached the control temperature or the power to the windshield is being actively controlled:

- Click [Capture Temperatures]
- Move the cursor over the thermal image in the [Video] panel to the first desired location to report the temperature
- Double-click and a cross will mark the location and report the temperature at that location
- The temperature will also be reported in the Results Table on the [Temperature Spread] panel. An example of this stage is shown below



- Repeat the process to select further locations for displaying the temperature and calculating the temperature spread across the windshield.
- The temperature at the locations will build up both on the thermal image and on the results table as shown in the example below



Note: In the case where a heat zone is defined, temperature measurements can be taken at locations outside the heated zone, but the software will notify the user and require confirmation to proceed.

4.3.4 Unfreeze

When the desired number of locations has been selected as described in 4.3.2 above,

- Click [Unfreeze]
- The [Video] panel will return to the live feed from the Thermal camera.
- The software will calculate the temperature spread based on the maximum and minimum values recorded and automatically compare this value to the criteria set in the [Windshield Data] panel
- The Report will be composed and include the captured image from the [Video] panel with marked measurements at their locations.

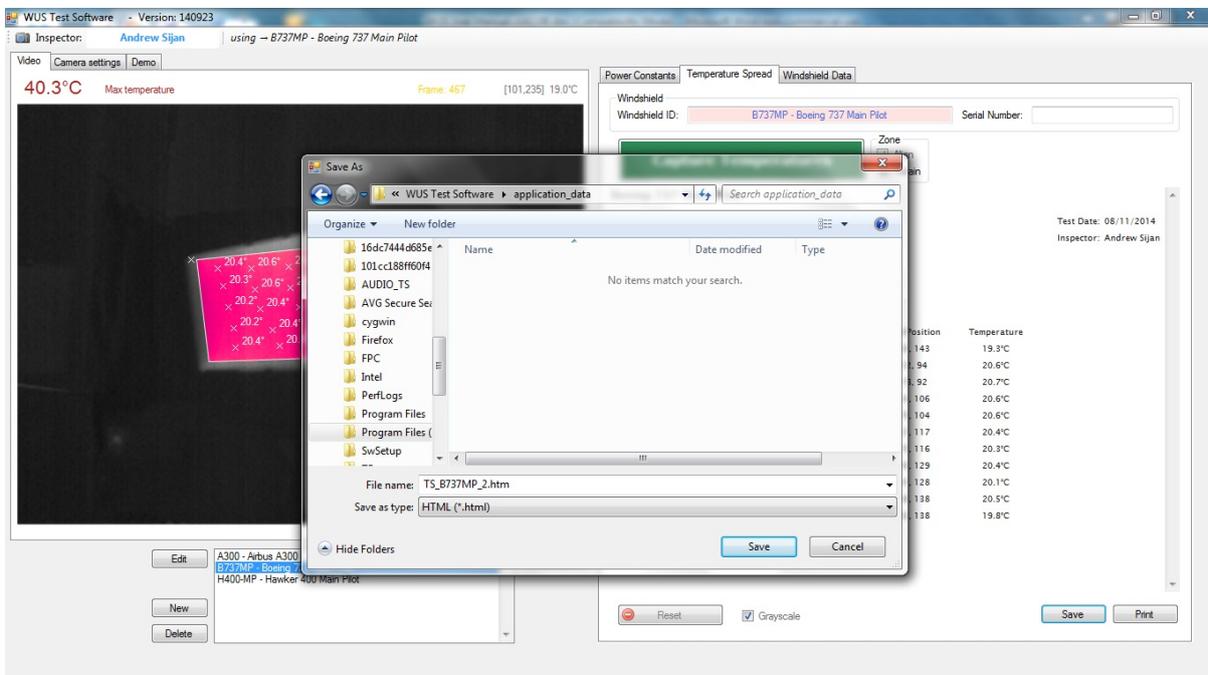
Note: The User can unfreeze the thermal image at any time and re-start or repeat the test with a new capture image.

Note: The User cannot undertake a Temperature Spread test at the same time as a Power Constant test. However, a Temperature Spread test can be undertaken immediately after a Power Constant test.

4.3.5 Save

Click [Save] to save the temperature spread test results for this windshield.

The default filename structured as TS_*[product code]*_*[serial number]*.html, for example: TS_B737MP_123456.html



The default location for the saved file is the folder [Application data] associated with the WUS application. The User can choose alternative folders if required.

The User should not change the filename or its structure unless specifically required or directed to by an appropriate authority.

HTML files can be viewed and printed using browser software such as Microsoft Internet Explorer.

4.3.6 Print

Ensure the printer is connected to the PC, then click [Print] to print the current contents on display in the results panel.

ANNEX 1: Power Constant Measurement for Heated Aircraft Windshields Using Thermal Camera

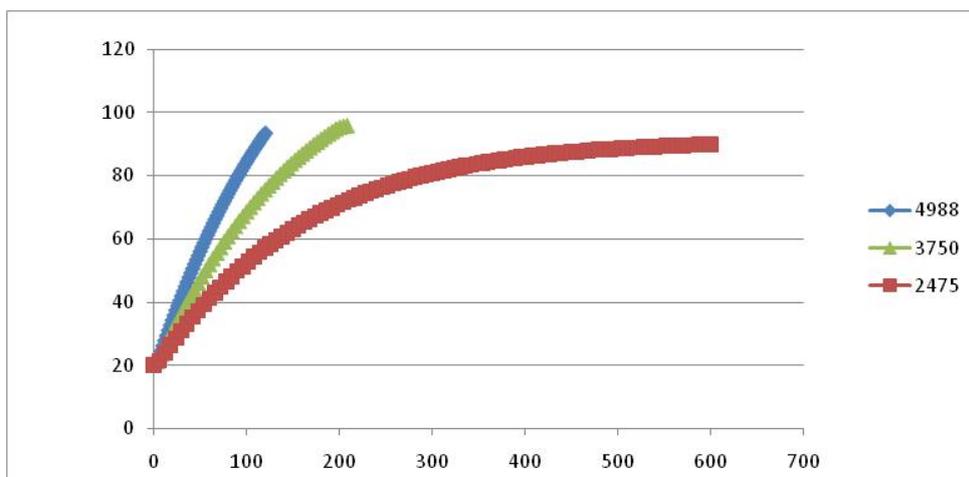
In aircraft windshield specification and manufacture, it is normal to specify the thermal uniformity requirement of the windshield in terms of, what are known as, power constants. These have specific definitions, but in general relate the average power dissipated across the whole windshield to the power dissipated in specific areas such as, for example, the temperature sensor positions.

An accepted method for determining the power constants is with the use of a Thermal camera, which can capture the temperature distribution across a windshield quickly and accurately, with a very high resolution.

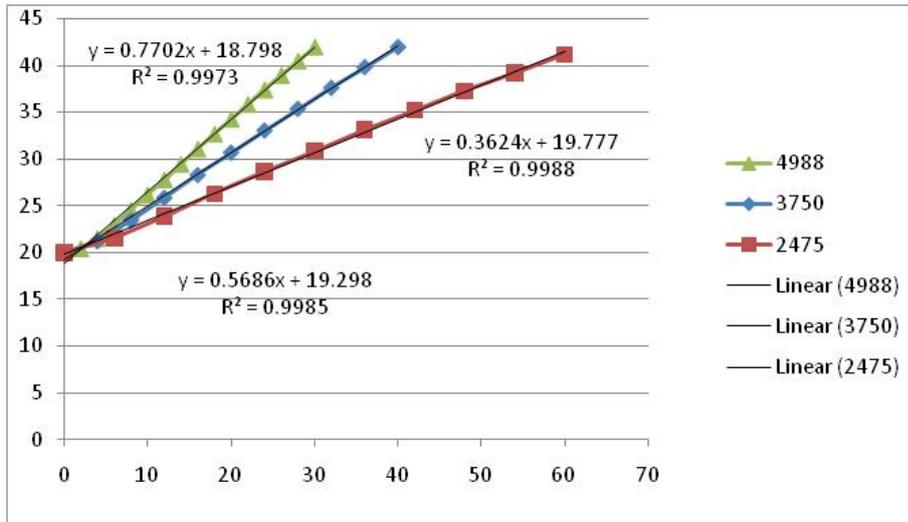
This document shows that there is a direct relationship between temperature rise and power constants and describes the theory and practice used in the WUS Test Software supplied by Second Magenta.

Relationship between Temperature Rise and Power Dissipation.

When a constant power is applied to a conducting coating on a windshield face-ply, the temperature of the face-ply rises until a steady-state temperature equilibrium is reached. The graph below provides the modelled transient temperature time profile for a typical windshield face-ply on power-up from ambient. The three lines shown represent three different power dissipation levels on the windshield, exemplifying a hot-spot, the average and a cold spot for a poorly graded windshield. For the purposes of this illustration, values of 4988, 3750 and 2475W/m² have been used.



A closer examination of the early stages of the transient state produces the graph below:



It is evident that during the early stages of power-up, the temperature rises are very linear (the correlation coefficients very close to 1) and the gradient is directly proportional to the power density, certainly to within experimental error. This is used to good effect in a measurement system using a thermal camera by capturing the trial temperature distribution across the windshield at the start of the linear region and again at a second point in the linear region.

For the purposes of a test, the linear portion can be specified by time, or more usually temperature, but needs to ensure that the end-point measurements are still in the linear region. This is readily determined by thermal modelling or practical measurements.

Measurement Points, Co-ordinates Systems and Transformation

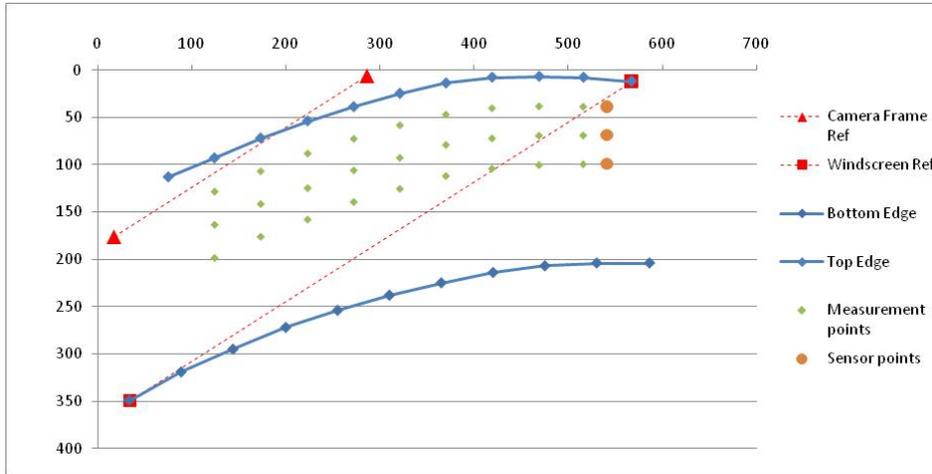
As indicated above, in order to calculate the power constants, the trial temperature distribution needs to be determined. For practical measurements, this is most easily done by defining discrete measurement points, either as per the customer’s windshield specification or by the design rules used by the company. In addition to the measurement points, the temperature sensor positions are defined.

Generally, measurement points are a series of regularly spaced coordinates over the heated area to be measured. Typically 20-40 measurements points are required to provide a reasonable representation on the heating distribution. Although a modern Thermal camera can provide a much higher resolution, this number of points has historical links to accommodate other test methods used in the industry.

Measurement points and Sensor positions are given as (x,y) coordinates in a Windshield Reference system, such as the product drawings. Setting up the windshield for a test with an Thermal camera, creates a new Camera Frame Reference system defined by the camera’s

focal plane array and it is necessary to transform between coordinate systems to perform the power constant calculation.

The following image shows the data points required to perform the calculation of power constants and this example is based on the Hawker 400 geometry for illustration only.



The windshield position in the Camera Reference System is created by use of a small hot source, such as an electric bulb. Two reference points are required (as shown in the previous image) and the transformation, which is a general mathematical treatment, is in two parts:

First is a linear scaling factor:

$$L = \frac{\sqrt{(a_2-a_1)^2 + (b_2-b_1)^2}}{\sqrt{(x_2-x_1)^2 + (y_2-y_1)^2}}$$

Second is an angular scaling factor

$$\theta = \arctan2[(a_2-a_1), (b_2-b_1)] - \arctan2[(x_2-x_1), (y_2-y_1)]$$

The transform function then is

$$X = [(x - a_1).L\cos\theta + (y - b_1).L\sin\theta] \cdot x_1$$

$$Y = [-(x - a_1).L\sin\theta + (y - b_1).L\cos\theta] \cdot y_1$$

Calculation of Power Constants

The power constant criteria are defined by the windshield specification.

The power constants for the Sensor Positions are calculated as

$$K_h = \frac{\text{Highest temperature rise of the Measurement Points}}{\text{temperature rise at the Sensor Position}}$$

$$K_a = \frac{\text{Average temperature rise for all the Measurement Points}}{\text{temperature rise at the Sensor Position}}$$

$$K_c = \frac{\text{Average of the four Measurement Points with smallest temp rise}}{\text{temperature rise at the Sensor Position}}$$

The more critical performance of the windshield is also calculated as

$$K_m = \frac{\text{Average temperature rise for all the Measurement Points}}{\text{Highest temperature rise of the Measurement Points}}$$

$$K_{m2} = \frac{\text{Average temperature rise for all the Measurement Points}}{\text{Highest temperature rise anywhere on the windshield}}$$