

ER-021

REPORT AND OUTCOME OF ROUND ROBIN CAMERA DETECTION PROCESS VERIFICATION AND VALIDATION TO COMPLEMENT ED-105 TEST METHODS

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CHAPTER 1

OVERVIEW

1.1

BACKGROUND

This paper is about developing a new technique for assessing how far a visible light detected during a lightning test has to be considered as a potential ignition source or not. Identification of ignition sources is necessary for demonstrating the compliance of fuel tank structure or system assemblies with the FAA and EASA regulations (25.981 and / or 25.954).

The current ED-105A (ARP5416 Rev A) provides two possible ways which are not fully equivalent. The first technique is based on the use of a calibrated explosive gas. Calibrated means that 90% of the time the gas is ignited when exposed to a 200 μ J voltage spark. The second technique is based on the use of a camera that must be proved sensitive to sparks developing at least 200 μ J of energy. It is usually recognised that the second technique is more conservative than the first one but this can vary with the nature of the ignition source.

The Revision A introduced the use of modern digital cameras because the supply of Polaroid film, which was the previous test standard, has disappeared.

It is still necessary to prove that the digital camera is capable to detect any voltage spark that would have more than 200 μ J. However, there is no real standard practice to do so, and the capability to detect extremely faint light makes the use of the digital camera even more conservative than the previous method with the Polaroid. In addition, the absence of a standardized procedure and standard camera detection process verification makes the results potentially different from laboratory to laboratory. This motivated the need to develop a more robust and controlled procedure, taking benefit of the performances of the digital camera but configured in a way that the results given by the camera and the results given by the gas test procedure are based on the same statistical foundations.

This procedure aims to make results independent of the digital camera settings (lenses, distance, sensitivity...) and at relying on a quantitative pass/fail criteria rather than a judgment of the test images to decide if the light is visible or not.

ED-105A (ARP5416 Rev A) section 7.7.1.1 currently states that "the photographic method used must be capable of detecting 200 μ J $\pm$ 0/-10% electrical sparks." This qualitative method creates a challenge when aiming to ensure consistency of results between different test labs. Consequently, the EUROCAE WG31 and SAE AE2 working groups suggested the use of a quantitative threshold determination specified as the allowable false-pass rate for the detector (e.g. camera).

A white paper was issued in October 27th, 2017 (refer to Appendix A) to specify the new image evaluation method proposed to detect the ignition sources and aimed to become the new standard in the Revision B.

Both the EUROCAE WG-31 and SAE AE2 decided to launch a round robin test based on the specified evaluation method. The purpose of the Round Robin was twofold. The first objective was to verify that the camera detection process verification procedure is operational and gives equivalent results in different labs operating different cameras and test chambers. The activity answering to this objective is called the **camera detection process verification phase**. The second objective was to verify that a camera configured as per the procedure is capable to detect ignition sources of other nature and created in different conditions than the one used for the camera detection process verification. This step was essential to the WG-31 to ensure that other types of ignition source are detectable to ensure the universality of the detection method. The activity answering to this objective is called the **validation phase**.

This document details and reports the result of the Round Robin tests obtained by the contributing European laboratories and the conclusions that have been established and agreed during the different committee sessions.

The final validated procedure is given in Appendix A to this document.

CHAPTER 2

DESCRIPTION OF THE DIFFERENT TEST PHASES

2.1 DESCRIPTION OF THE ROUND ROBIN CAMERA DETECTION PROCESS VERIFICATION PHASE

Round Robin camera detection process verification phase has been launched in 2016. The initial intention of the round robin camera detection process verification was to check that the proposed procedure based on the photographic method results gives equivalent results in all laboratories

The retained procedure to be followed by all the laboratories is detailed in the Appendix A section 4.

The following European laboratories: ELEMENT (UK), DGA-TA (France) and LCOE (Spain) agreed to participate to the round robin camera detection process verification phase and to provide their results to both the WG31 and the SAE AE-2 committee. They are detailed later on in this document.

2.2 DESCRIPTION OF THE ROUND ROBIN VALIDATION PHASE

Round Robin camera detection process verification phase addressed several points but also outlined the need to perform more investigations about the influence of some parameters. Some specific questions were considered to demonstrate the relevance of the method and potentially for introducing a margin to address possible uncertainties.

This new phase was called the validation phase. The main purpose was to assess the capability of the technique to discriminate ignition sources produced in different conditions than the one used for the camera detection process verification. For that purpose, several parameters were considered for creating other ignition sources.

The criteria agreed by the committee for validating the method was that 100% of the voltage spark of 300 uJ must be detected with a camera set to detect 90% of the 200µJ sparks. Another criteria was that any thermal spark barely igniting a gas calibrated at 200 µJ must be detected.

For the validation phase, the camera detection process verification phase has to be followed by all laboratories as a preliminary step to ensure consistency between the laboratories.

A quick summary of the procedure for the camera detection process verification of the camera is reminded below:

1st step: Freeze camera setting and take 100 pictures of a 200µJ voltage spark

2nd step: Extract for each picture the relevant quantitative criteria (e.g. max pixel value)

3rd step: Define the P/F threshold at 90% of the sample population

After camera detection process verification step has been performed, validation step can focus on:

- a. Checking that with spark gap used for the camera detection process verification, any spark with an energy of 300µJ or more is detected
- b. Checking that with spark gap different than the one used for the camera detection process verification, any spark with an energy of 300µJ or more is detected (different electrode shape and material had to be considered)
- c. Checking that an ignition source of a different nature than a spark (thermal spark created with glowing filament) and igniting a 200µJ gas is also detected by the photographic method

CHAPTER 3

OUTCOME OF THE DIFFERENT TEST PHASES

3.1 OUTCOME REGARDING THE INFLUENCE OF THE DIFFERENT PARAMETERS

The Round Robin camera detection process verification highlighted the necessity to investigate some factors potentially affecting the accuracy, the reproducibility and scatter of the method

Here are the main factors which have been investigated:

- Influence of the parameters retained for the photographic method (please refer to section 0)
 - a. Selection of a region of interest
 - b. Selection on the max pixel value
- Influence of the position of the camera (please refer to section 0)
- Influence on the noise background (please refer to section 0)
- Influence of dead pixels (please refer to section 0)
- Influence of the spark duration (please refer to section 0)
- Influence of the electrode shape (please refer to section 0)
- Influence of the electrode material (please refer to section 0)

3.1.1 Influence of the parameters retained for the photographic method

Before retaining the max pixel value for the photographic method several possibilities have been explored. The advantages and drawbacks of the different parameters are detailed below.

3.1.1.1 Selection of a Region of Interest (ROI)

When treating the whole image for the photographic method, it was revealed that the noise background could add some difficulties to treat the image with precision. The process of selecting a region of interest has then been considered to see if it could bring benefits to the photographic method.

The main advantages reported with the selection of a region of interest were:

- To lower the influence of dead pixel if they were not within the selected region
- To lower the influence of the background noise

Here are results obtained with and without a region of interest selection:

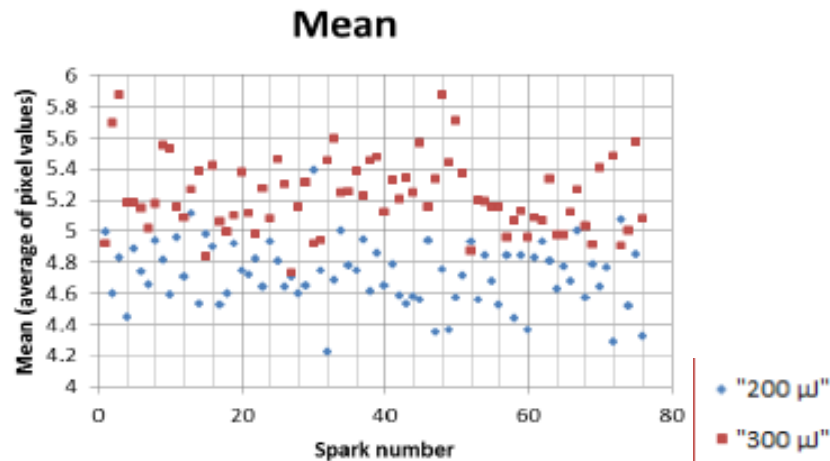


FIGURE 1: MEAN VALUE WITHOUT SELECTION OF REGION OF INTEREST (DATA FROM DGA-TA)

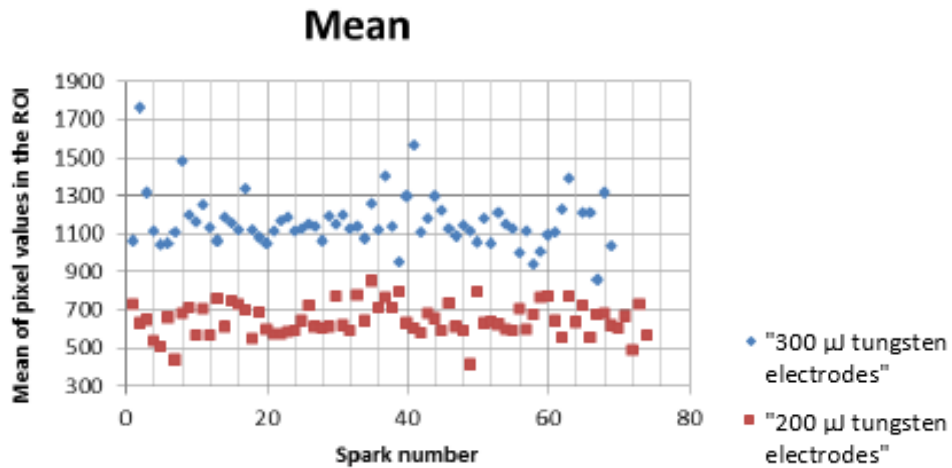


FIGURE 2: MEAN VALUE WITH A SELECTION OF REGION OF INTEREST (DATA FROM DGA-TA)

Comparison of [FIGURES 1&2](#) illustrates that the selection of a region of interest allows also to easily discriminate the 200µJ sparks from the 300µJ sparks.

The main drawbacks reported to introduce this parameter were:

- addition of some complexities to the treatment. A precise definition of the ROI needs to be done to ensure consistency between the labs.
- treatment is still sensitive to the noise background even if it reduces it.

It was then decided not to retain it for the photographic method, but dead pixels need to be managed.

3.1.1.2

Selection of Max Pixel value

The max pixel value parameter has also been investigated for the photographic method purpose.

The main advantages reported with the maximum pixel value were:

- easier image processing
- lower the influence of the noise background

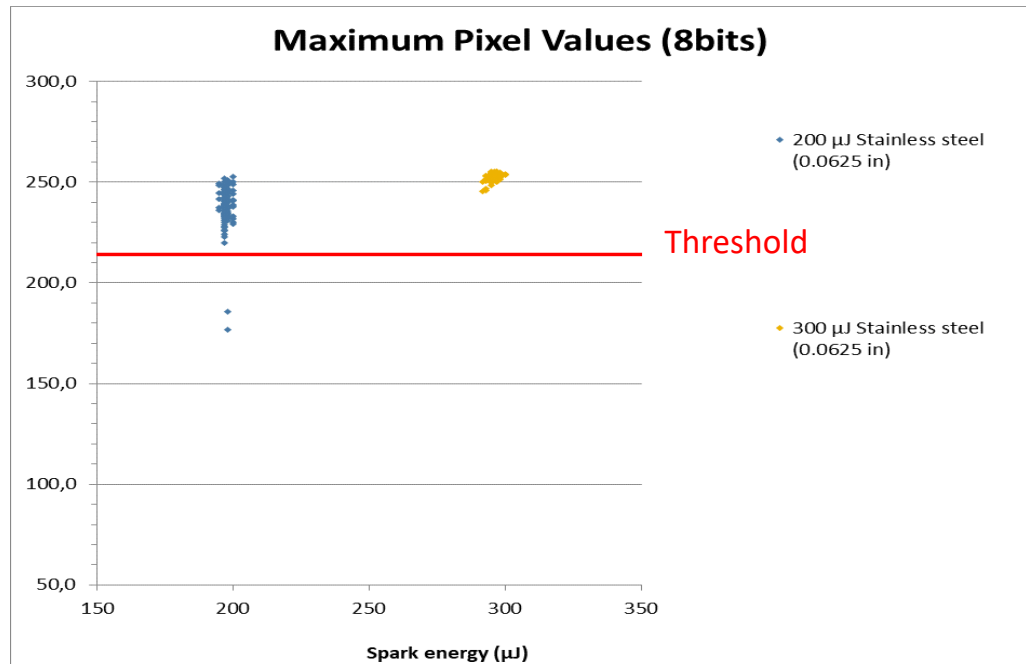


FIGURE 3: MAXIMUM PIXEL VALUE WITH STAINLESS STEEL 1.6MM ELECTRODES (DATA FROM DGA-TA)

FIGURE 3 illustrates the fact that once the camera is configured the maximum pixel value allows an easy and not ambiguous discrimination between 200μJ and 300μJ hence the decision was to keep this criteria.

An important parameter to keep in mind with the max pixel value selection is to set up a camera setting so that the resulting threshold value for 200μJ sparks is not too close to saturation in order to allow the discrimination of higher energy sparks.

3.1.2

Influence of the position of the camera

During the round robin camera detection process verification, some test setup with 2 cameras have been analysed to better understand the influence of the position of the camera. A test setup with 2 cameras with different distance and from a different angle have been performed within LCOE premises (please refer to **FIGURE 4**:)

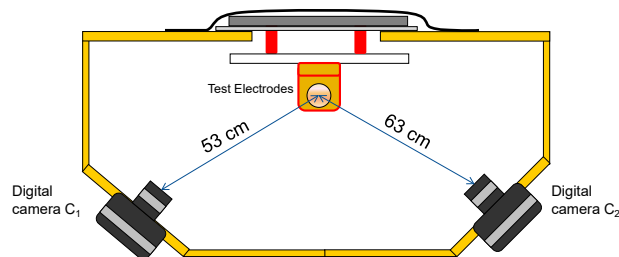


FIGURE 4: TEST SETUP WITH 2 CAMERAS (DATA FROM LCOE)

The max pixel values recorded by the 2 cameras are shown below:

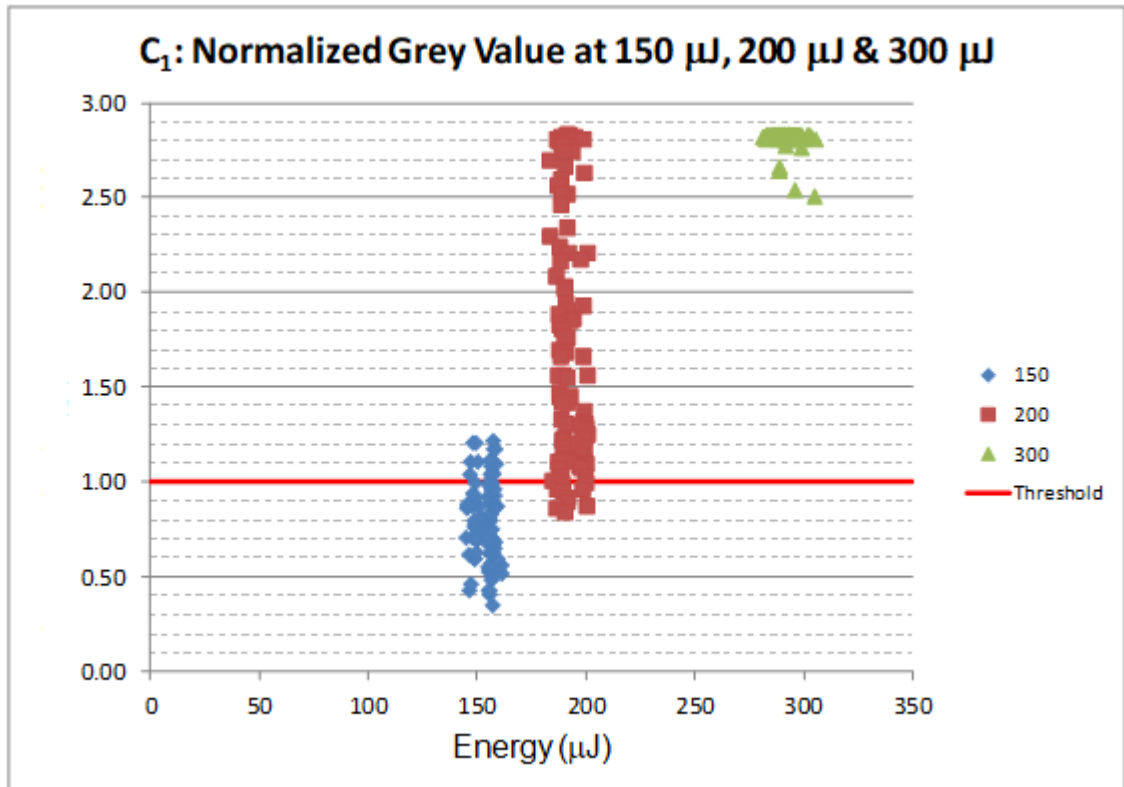


FIGURE 5: MAX PIXEL VALUE WITH CAMERA 1 (DATA FROM LCOE)

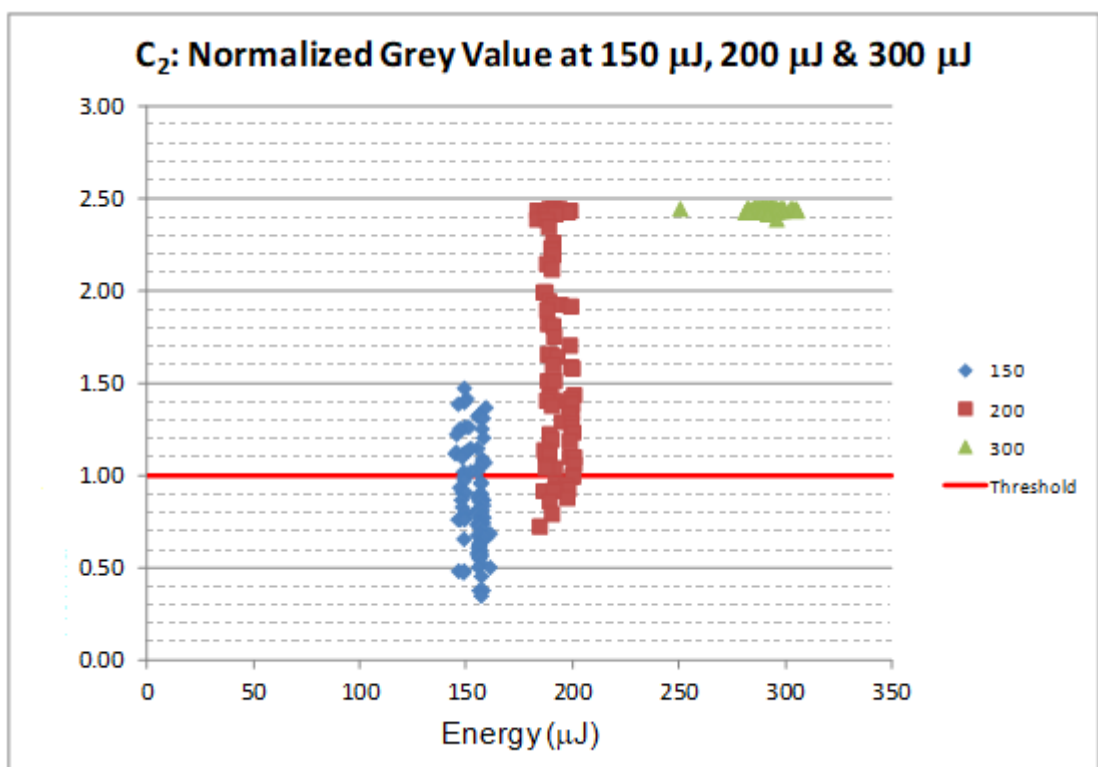


FIGURE 6: MAX PIXEL VALUE WITH CAMERA 2 (DATA FROM LCOE)

The comparison between the max pixel value of camera 1 and camera 2, allows us to observe that values are different between the 2 cameras for the same spark. But the 300 μ J spark are easy to discriminate compared with threshold for both camera. It has then been concluded that a difference in distance of no more than 20% between the camera and spark during camera detection process verification and camera and spark during testing is acceptable. In case of more than 20% difference, camera detection process verification needs to be reconsidered.

Another test setup with 2 cameras at the same distance but with a different angle has been experimented by DGA-TA (refer to [FIGURE 7](#)):

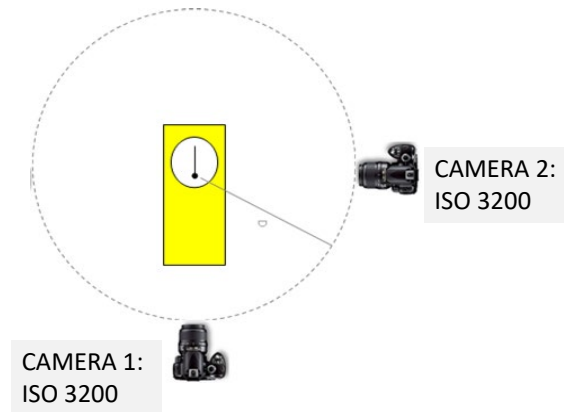


FIGURE 7: TEST SETUP WITH 2 CAMERAS (DATA FROM DGA-TA)

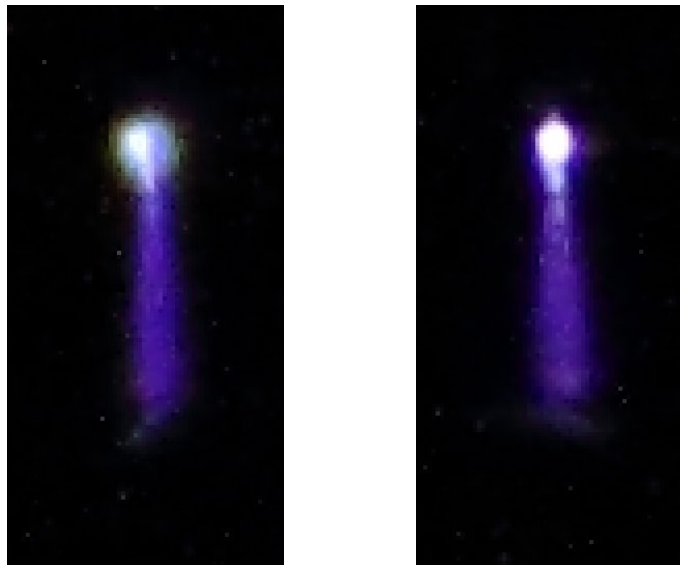


FIGURE 8: PHOTO OF A SPARK OF 190 μ J WITH CAMERA 1 ON THE LEFT-HAND SIDE AND CAMERA 2 ON THE RIGHT-HAND SIDE WITH AN ELECTRODE GAP OF 1.5MM (DATA FROM DGA-TA)

It can be observed with [FIGURE 8](#) that the shape of the spark is not the same between camera 1 and camera 2. The values recorded for the maximum pixel value with the 2 cameras are recorded below: