Performance Evaluation of Industrial Computed Radiography Image Display System

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Abstract
Isotope Production and Applications Division (IP&AD) has recently installed Computed Radiography (CR) imaging system Durr HD-CR 35 NDT for radiographic testing of industrial specimens. It consists of a constant potential X-ray source, read out unit, image acquisition and processing software, and image display system (monitor). Image display system has a direct effect on the quality of the radiograph that is viewed. According to ASTM Digital Industrial Radiology (DIR) standards, digital image display systems shall have minimum display capabilities and require Quality Control (QC) on regular basis. This paper presents performance evaluation of CR image display system using standard SMPTE RP 133 test pattern as part of QC. The test was performed by individual certified in Digital Radiographic Testing (RT-D) Level II. Studies include both visual and quantitative measurements of performance characteristics such as spatial resolution and uniformity. The obtained results show that the CR image display system meets the requirements of ASTM E 2698-10 and yielding stable temporal performance.

Keywords: Computed Radiography (CR), Digital Industrial Radiography (DIR), SMPTE RP 133 test pattern, Quality Control (QC)

1. Introduction

Computed radiography (CR) is one of the digital radiography modalities of Non-destructive Testing (NDT) in place of conventional screen film systems. CR uses X-rays to reveal defects in an object and also allow a fast acquisition of radiographic images with higher dynamic range than film [1,2]. There are important differences in the quality control approach between the traditional film screen radiography and CR. In conventional radiography, the radiation detector and the display device of the radiograph are the same object. In case of CR technology, the detector is a phosphor imaging plate (IP). Digital image data are extracted from the exposed IP and used to provide the image on a display device i.e. high resolution monitor. Therefore, CR allow us to distinguish between the quality analysis of detector and the analysis of the image display system. Image display system has a direct effect on the quality of the radiograph that is viewed. According to ASTM Digital Industrial Radiology (DIR) standards, digital image display systems shall have minimum display capabilities and require Quality Control (QC) on regular basis [3]. The test was performed by individual certified in Digital Radiographic Testing (RT-D) Level II. In this study, as part of
QC, performance evaluation of CR image display system has been carried out using standard SMPTE RP 133 test pattern as per ASTM E 2698-10 [4,5]. The standard recommends that this procedure needs to be performed on the image display system on daily basis.

2. Materials and methods

2.1 Equipment

Fig. 1 shows Durr HD-CR 35 NDT CR imaging system [6] used for the evaluation, which has recently installed at Isotope Production and Applications Division (IP&AD), BARC for radiographic testing of industrial specimens. The system consists of 450 kVp/3.3 mA constant potential X-ray source with specified focal spots of 1.0 mm x 1.0 mm (large focal spot) and 0.4 mm x 0.4 mm (small focal spot), read out unit (scanner or reader), image acquisition and processing software, and image display system. The image display system is a high resolution (3.8 mega pixels) Dell UP2716D monitor with brightness 300 cd/m2 (typical) and contrast ratio 1000:1 (typical). The test phantom used was SMPTE test pattern which is in the imaging software of the CR system and can be retrieved to perform the test.

![Fig. 1: (a) Photograph of CR system-Durr HD-CR 35 NDT at IP&AD. The SMPTE test pattern used for the study is displayed on the monitor. (b) Schematic diagram showing the basic components of the CR system.](image)

2.2 Description of the SMPTE test pattern

Fig. 3(a) is the snap shot of the test pattern. This test pattern was designed by the Society of Motion Pictures and Television Engineers. The background of the pattern (4) is a uniform grey at a 50% video or average picture level. This provides the ability to detect uniformity problems and artifacts in the images. Both low and high contrast resolution test patterns (1 and 2) are included in the center of the test patterns and in the four corners. The
low contrast patterns are all of the same frequency but vary in contrast from 1% to 5%. The high contrast resolution patterns are at 100% modulation and vary in frequency with the highest frequency being limited by the pixel size of the digital system, i.e., one black pixel followed by one white pixel. A cross-hatch pattern and border (8 and 9) are provided at 75% of the maximum picture level to assist in determining the effect of spatial distortion and to determine if all of the picture area is displayed or recorded on film.

A grey scale (3) is placed around the center of the image in order to avoid, as much as possible, any falloff in output or light associated with the image display or recording system. The entire dynamic range of the image is represented in 11 steps from 0 to 100% (in 10% increments). At either end of the step wedge a smaller 5% incremental patch (5) is inset in the larger patch. For example, a 5% patch is inset in the 0% patch and a 95% patch is inset in the 100% patch. These inset patches are useful in determining if the entire range of information available in the test pattern image is being displayed on the image display device or the film. In fact, these patches allow one to easily adjust the contrast and brightness controls of image displays and hard-copy recorders for optimal images in a consistent manner.

Finally, a white and a black window (6 and 7) are provided to stress the system and test for transient and low frequency response. A well designed imaging system should produce a transition from white to black, or black to white. Clearly, without ringing, overshoot, or smearing [5].

2.3 Evaluation procedure

The ASTM E 2698-10 evaluation procedure involves display of the SMPTE test pattern on the viewing monitor and performing checks for the following minimum requirements [3]:

- The minimum brightness as measured off the image display screen at maximum Digital Driving Level (DDL) shall be 250 cd/m².
- The minimum contrast as determined by the ratio of the screen brightness at the maximum DDL compared to the screen brightness at the minimum DDL shall be 250:1.
- The image display shall be capable of displaying linear patterns of alternating pixels at full contrast in both the horizontal and vertical directions without aliasing.
- The display shall be free of discernable geometric distortion.
- The display shall be free of screen flicker, characterized by high frequency fluctuation of high contrast image details.
3. Test results and Discussion

Performance of the CR display system was evaluated both visually and quantitatively. The visual parameters used for the study and results are presented in Table 1. To check temporal variations of the CR display system, performance characteristics such as spatial resolution, uniformity, and luminance ratio are measured and monitored for continuous operation of eight hours. Spatial resolution of the imaging system is characterized using Modulation Transfer Function (MTF) [7]. Mathematically, MTF can be calculated according to the equation:

$$\text{MTF} (\%) = \frac{\text{Max} - \text{Min}}{\text{Max} - \text{Base}}$$

Where Max, Min, and Base are maximum, minimum, and base grey values, respectively, in the drawn line profile for evaluation.

The MTF was measured by drawing line profiles of 1% and 100% contrast lines at the phantom center and top right corner are shown in Fig. 4(a). These profiles have been repeated over eight-hour period. All the bars in the patterns were resolved with 100% MTF implies no degradation in spatial resolution of the display system. Fig. 4(b) shows line profiles taken on test targets indicated by numerical value 4 in Fig 3(a), for uniformity check. it has been observed no change in grey value occurred during testing period.

Table 1: visual test results of various performance parameters

<table>
<thead>
<tr>
<th>Requirement &amp; Test target no.</th>
<th>ASTM/DDA Standard</th>
<th>Test phantom</th>
<th>Measurement</th>
<th>Result &amp; Requirement achieved (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display spatial resolution</td>
<td>E 2698-10</td>
<td>SMPTE RP 133</td>
<td>Visual- alternating 1% and 100% contrast lines at the display center and in all four corners</td>
<td>Resolved all vertical and horizontal bars (Y)</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>E 2698-10</td>
<td>SMPTE RP 133</td>
<td>Visual-steps from 0 to 100% (in 10% increments)</td>
<td>All contrast squares were resolved (Y)</td>
</tr>
<tr>
<td>Uniformity</td>
<td>E 2698-10</td>
<td>SMPTE RP 133</td>
<td>Visual- grey squares at 50% picture level background</td>
<td>Detected uniformity in grey squares and they</td>
</tr>
<tr>
<td>Display contrast and brightness</td>
<td>E 2698-10</td>
<td>SMPTE RP 133</td>
<td>Visual- 5% DDL patch in the 0% DDL patch and a 95% DDL patch in the 100% DDL patch</td>
<td>Two patches were clearly perceptible (Y)</td>
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<tr>
<td>Luminance ratio (LR)</td>
<td>E 2698-10</td>
<td>SMPTE RP 133</td>
<td>Visual- top and bottom long horizontal bars</td>
<td>Observed a white on a black bar and a black on white bar without geometric distortion (Y)</td>
</tr>
<tr>
<td>Image area coverage</td>
<td>E 2698-10</td>
<td>SMPTE RP 133</td>
<td>Visual- boarder appearance</td>
<td>All the picture area was displayed (Y)</td>
</tr>
<tr>
<td>Spatial distortion</td>
<td>E 2698-10</td>
<td>SMPTE RP 133</td>
<td>Visual- cross-hatch pattern appearance</td>
<td>No effect of spatial distortion (Y)</td>
</tr>
</tbody>
</table>

Fig. 3: (a) SMPTE test pattern used for the study. Test targets are indicated with numerical values from 1 to 9 (b) Spatial resolution obtained for 1% contrast lines as function of operated time.
Fig. 4: (a) line profile drawn for the temporal study of spatial resolution of the CR display system (b) line profile drawn for the temporal study of uniformity of the CR display system

Conclusions

As CR image display system has a direct effect on the quality of the radiograph that is viewed, it requires Quality Control (QC) on daily basis as per the ASTM E 2698-10 Digital Industrial Radiology (DIR) standard. This paper details QC of the display system using SMPTE test pattern. The obtained results show that the CR image display system meets the requirements of the standard and gives stable performance over time. The test pattern helps in identifying any potential issues with the image display system immediately.

Acknowledgments

The authors are grateful to current Head of Division Shri. K.S.S. Sarma and Dr. Tomar, Director, Radiochemistry and Isotope Group, BARC for their support and encouragement.

References

4. SMPTE test pattern can be downloaded from Rich Franzen's PNG Gallery, http://r0k.us/graphics/pngLibrary.html