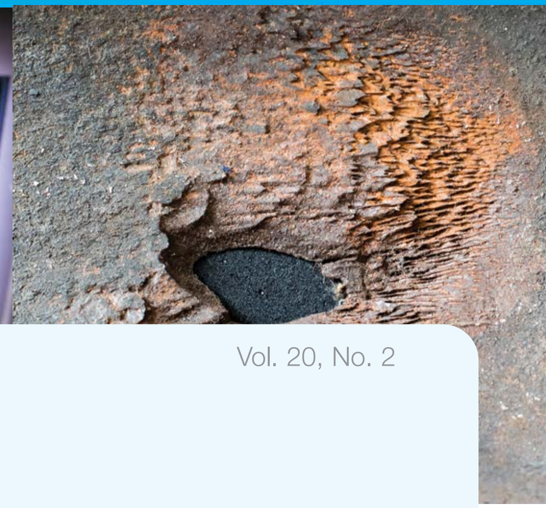
The NDT Technician



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FOCUS

Digital and Computed Radiography: A Brief Introduction and Comparison

by Aziz U. Rehman and George W. Jaques

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With the current technical advancements and the emergence of high-powered computers, sophisticated software, and most importantly the steady drop in prices, industrial radiographic testing (RT) is gradually shifting, though it is still a long way away from film radiography. Companies providing industrial radiography services now have two available choices: digital radiography (DR) and computed radiography (CR), which is a form of DR. While working on modernizing radiography practices, it is important for the user to carry out some basic research for choosing between DR and CR by weighing the abilities of each along with the needs of both the company and the clients. This article attempts to provide readers with a basic understanding of both DR and CR and covers the advantages and disadvantages of both. Furthermore, it provides readers with a comparison of both digital techniques and adds a comparison between digital (DR/CR) imaging and conventional film.

Digital Radiography

DR is a modern inspection technique that involves a detection system where digital radiation sensors are used instead of radiographic film. The application does not require the use of a cassette, and an image is displayed directly on the computer screen.

The main benefits include efficiency gains on film development time, because the costly chemical processing is eliminated, and the ability to digitally transfer and enhance the radiographic images. In addition, with the ability of radiographic enhancements, less radiation can be used to produce an image of similar contrast and definition compared to conventional RT.

Digital image capture devices give the advantages of immediate image preview and availability. The process consists of converting the radiation into an electric charge and then to a digital image using flat panel detectors (FPDs). FPDs are classified as a solid-state X-ray digital

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device that is used for imaging. The resultant images provide a wider dynamic range, which makes it more forgiving for over- and underexposure, as well as the ability to apply special image-processing techniques that enhance the overall display quality of the image.

The two main classifications of FPDs are direct and indirect. Direct FPDs (Figure 1) are composed of amorphous selenium (a-Se), the most used material in commercial FPDs, which converts radiation photons directly into charge. The outer layer of the FPD is typically a high-voltage bias electrode. Radiation photons create electron-hole pairs in a-Se, and the transit of these electrons and holes depends on the potential of the bias voltage charge. As the holes are replaced with electrons, the resultant charge pattern in the selenium layer is read by a TFT (thin-film transmitter, a type of LCD flat panel screen) array, active matrix array, electrometer probes, or microplasma.

Indirect FPDs are manufactured by combining an amorphous silicon (a-Si) detector with a scintillator in the detector's outer layer, which is composed from caesium iodide (CsI) or gadolinium oxysulfide (Gd_2O_2S), which converts radiation to light. This conversion makes the detector an indirect imaging device. The light is then channeled through the a-Si photodiode layer, where it is converted to a digital output signal. The digital signal is then read out by TFTs or similarly approved devices.

Advantages of DR include reduced exposure times, elimination of costly chemical processing, and reduced costs coupled with higher production rates. Inspection applications are faster. Insulation removal is not required, because of image enhancement capabilities. Images can be digitally stored, with the possibility of electronic transfer. With image enhancements, the image densities can also be altered in accordance with the inspection code requirements. The grayscale resolution is superior, and exposure failures are reduced, with possible software improvements applied to the captured images. The radiographic detail and image definition is higher, and produced images have a greater range of latitudes (up to 1000× greater than film). DR offers increased portability and reduced film artifact possibilities. DR shows a better sensitivity to environmental conditions than CR systems.

There are some disadvantages of DR. The technique requires high-end training, the lack of which can create undesirable performance and questionable results. Initial setup and start-up costs are higher. Image magnification, if not applied judiciously, can result in misinterpretation as the indications are altered from original sizes. Currently, spatial resolution (size of the smallest detail) is comparably smaller than conventional RT. FPDs are not life-proof; they are affected over time with the amount of radiation absorbed and the radiation energy levels, therefore needing to be replaced over time. FPDs at higher energy levels are subject to fading of the image known as ghosting, primarily caused by the incomplete collection of charges.

Figure 1. An example of the flat panel detectors used in digital radiography (DR).

Computed Radiography

CR is an application of DR. DR and CR are similar, as they both contain a medium to capture radiation and both provide an image that can be digitally enhanced. The imaging does not require chemical processing. In DR, the radiation is emitted to a FPD without the use of a cassette, whereas in CR, radiation is emitted to an imaging plate housed in a cassette, similar to conventional RT. The cassette serves the purpose of protecting the imaging plate from light and related handling issues (Figure 2).

CR imaging plates contain photostimulable storage phosphors; these phosphors store the radiation as a latent image. As the image plate is scanned by a scanning laser beam, the release of stored energy within the phosphor is stimulated and emits light to be detected by a photo-multiplier tube and converted to a digital signal using an analog-to-digital converter, which can be further intensified. The generated image can then be viewed on a computer monitor for evaluation.

Figure 2. An example of the imaging plates used in computed radiography (CR).

Imaging plates can be reused multiple times and may often result in damage after extended use due to the industrial nature of the RT field. The plates can be erased by exposing them to room-level lights, but most laser scanners automatically erase the plates by using the red laser light of the scanner. The image requires processing, almost immediately after exposure, to prevent the loss of image as the trapped electrons can return to a lower energy level.

There are several advantages to CR. Testing can be performed with insulations and coatings in place. There are no temperature limitations. CR has a very high sensitivity to corrosion and pitting and is able to generate accurate corrosion measurements. There are no chemicals or film required for processing. Image contrast and brightness can be modified. There are reduced storage costs.

Along with the advantages of CR come a few disadvantages. CR requires long preparation times before the radiograph can finally be viewed. The processing application takes about the same amount of time as conventional film. There is a risk of overexposure. Care and maintenance is on the higher side, and imaging plates are costly. The manual handling of cassettes presents the risk of film artifacts. CR is sensitive to scattered radiation, and there is a low signal-to-noise ratio.

Comparison of DR and CR

Both DR and CR use a medium to capture radiation energy, and a digital image is produced. CR uses imaging plates whereas DR uses detectors as the medium. DR uses less radiation energy to produce an image, which is formed within seconds of an exposure, making it faster than CR. CR is slower; the time required to remove the cassette from the tray, take it to the reader (or scanner), and clearing the same can take several minutes. CR can also provide less resolution with a similar radiation dose. DR has superior quality compared to CR.

The following is a summary list of comparisons:

- DR has a lesser requirement on radiation to produce a high-quality image and provides enhanced radiation exposure protection to radiographers.
- CR does not reach as high of a sensitivity as DR.
- DR has a wider range of latitude.

Comparison of DR/CR with Conventional RT

A short comparison between conventional RT with CR and DR is a must before even trying to advance a company into the world of digitalization. Following is a summarized list of major comparisons:

- DR and CR do not require physical film.
- Conventional RT has limited film latitude, whereas DR and CR images have up to 1000× greater latitude.
- DR and CR have faster exposure times (requiring 5 to 20× less radiation than conventional RT).
- DR and CR require no costly processing.
- DR and CR are not restricted by the temperature of the material under inspection.
- DR and CR produce less radiation exposure in a given time due to reduced exposure times.
- Performing DR with high-energy sources such as cobalt 60 is very efficient for thick valves and fittings.
- Transporting radiation images can be accomplished immediately through electronic transfer.
- Film densities can be enhanced to reduce any miscalculations resulting in reduced exposure failures.
- Both DR and CR have the benefit of easier, accessible, and less expensive archiving. They also provide access to share data through the newly evolving standard DICONDE, which conventional film does not.

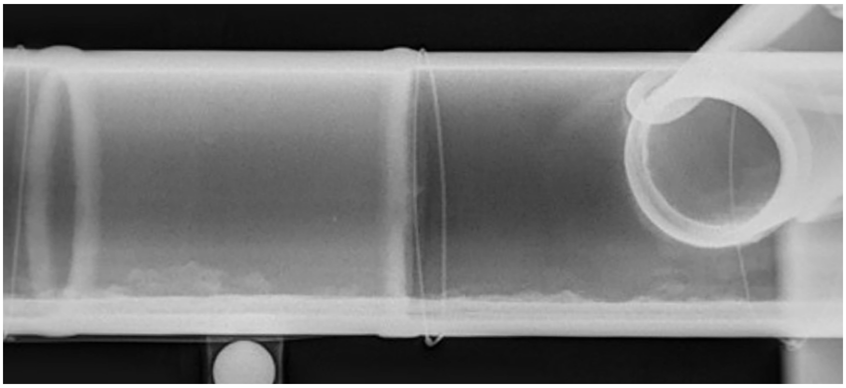

Figure 3. A digital radiograph showing debris in pipe before cleaning.

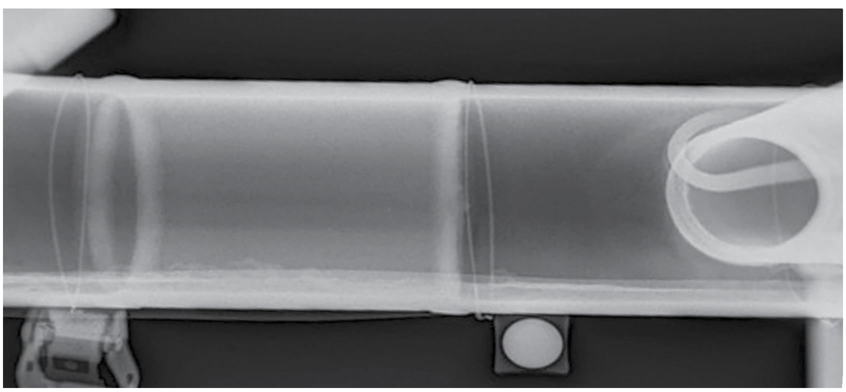

Figure 4. A digital radiograph showing removal of debris in pipe after cleaning.

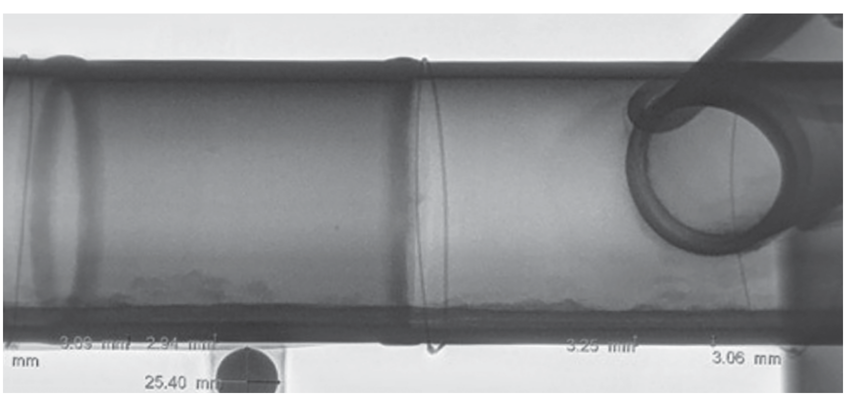

Figure 5. An inverted image of the digital radiograph shown in Figure 3 for contrast density comparison.

Field Application

In industrial RT, certain inspections will require a specific technique and/or method. There are several factors, such as cost, time, and quality, that govern the selection of conventional RT, DR, or CR for field application. Not only are DR and CR faster than conventional RT, they both provide a greater range of latitudes when thickness differences are present with welds and other structural components.

As compared to CR, DR provides an image of higher quality and speed, but for field applications, the FPDs used in DR are not as suitable as the imaging plates of CR. FPDs are not as flexible and durable as the imaging plates, which are more industrial oriented with the flexibility of adapting to curved components. The major drawback associated with both DR and CR is the sensitivity, which is not as apparent as the very fine grain film of conventional RT.

Evaluation of an imaging system depends on size, shape, and flexibility of sensors, whereas the scan rate and performance of the imaging system is affected by the correct sensitivity (such as 8 bit versus 12 bit) and the pixel size.

DR provides an excellent source for performing radiography for informational purposes as it provides a quick and detailed image of the object examined. Figures 3, 4, and 5 show radiographic images of pipe before and after cleaning. In the "before cleaning" image, the radiograph depicts debris on the bottom of the pipe. When the radiograph is retaken after cleaning, the debris has been removed as shown in the radiograph (Figure 4). The third radiograph (Figure 5) is an optional inverted image for contrast comparison.

Corrosion evaluation is one of the major applications of CR. The following are some examples: in-service (on stream) radiography for corrosion/erosion in noninsulated pipes; internal and external corrosion under thermal insulation; erosion and corrosion adjacent to the welds;

scaling; concrete and castings inspection; and weld inspection.

Digitalization Software

One of the major components of radiographic digitalization, either digital or computed, is the software, which is often associated with a particular equipment/system manufacturer. Though the software is of a proprietary nature, they all follow the same ASTM standards for digital imaging and communications in nondestructive evaluation (DICONDE) (ASTM 2015, 2018a, 2018b, 2020). The standardization of radiograph digitalization provides users with a portability between different equipment and software platforms, without compromising the details and related information. The DICONDE standard is backward compatible, which will also allow consumers to archive their films (digital radiographs) for many years to come, and all details, such as part, technique, and user information associated with the disposition (accept/reject) are retrieved without compromise.

The data retrieval will require authentication when communicating between DICONDE-compatible software platforms. The basic pixel data will never change; only the overlays can be altered. It is always recommended to refer to manufacturer instructions and be trained by a competent qualified technician prior to operating the DR equipment and associated software.

With the pursuit of NDE 4.0 (the fourth industrial revolution), the industry will see a very diverse digitization of NDE applications, systems, and software. Other DR advancements in medical technology have worked their way into the industrial applications, such as computed tomography (CT). We are only in the early stages and will witness further groundbreaking technologies with the use of artificial intelligence, smart NDE, and DICONDE (Figure 6). Regardless of the number of advancements in technology, the industrial radiography specialist will always be required to support all DR applications and its software.

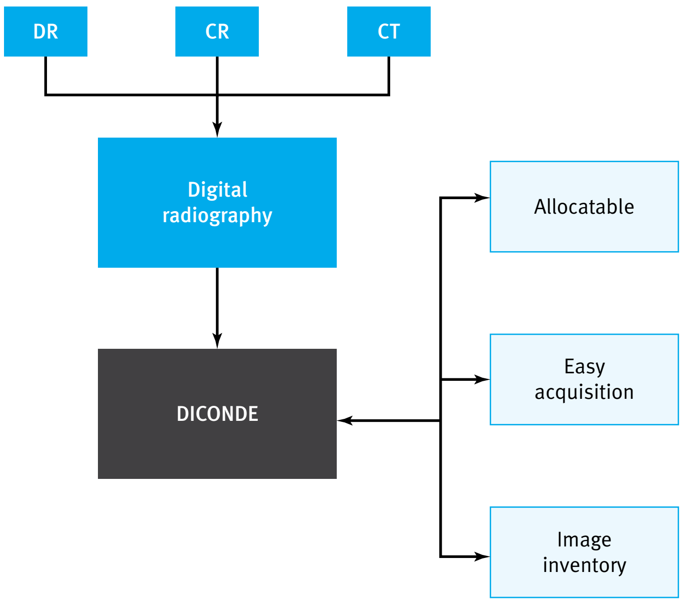

Figure 6. Interconnectivity and portability of DICONDE (digital imaging and communications in nondestructive evaluation) protocols across formats.

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Digital Extra: Visit the authors' YouTube Channel "RTFIPro," which provides a range of educational videos on the topic of industrial field radiography.