CR, Can It Work In The Canadian Oil Patch?

Abstract

The benefits of digital radiography are unattainable in practical applications, especially field radiography, unless the resultant digital image can be acquired within an acceptable production time frame, and provide an image that gives the required results

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CR, Can It Work In The Canadian Oil Patch?

A Film VS CR Comparision For Weld Quality Code Applications

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Computed radiography (CR) is emerging as an alternative to analog film, and offers radiographers and end-users alike benefits such as sharing, storage and retrieval, management, the addition of annotations, the accuracy of measurements, and improved safety to mention only a few. Environmental benefits are also possible with the elimination of chemical film processing. Reducing the requirements for exposure time, reshoots, radiation energy and source activity enables a probable reduction in the size of exclusion areas and in user-accumulated dose.

However, these benefits are unattainable in practical applications, especially field radiography, unless the resultant digital image can be acquired within an acceptable production time frame, and provide an image that gives the required results.

This paper gives a brief overview, examines some of the attributes of CR in industrial radiography, and then tries to answer the question of whether CR is capable, from a quality and production stand point, of replacing film.

Information has been gathered by the authors' involvement in digital technologies over the last 12 years, and common knowledge now available from the growing use of CR by service companies for code compliance in weld quality work. The authors also examine a film vs CR comparison trial that took place in Northern Alberta on a large diameter pipeline.

CR Overview

Computed Radiography (CR)

Computed radiography uses a reusable imaging plate in place of traditional film. The image plate employs a coating of storage phosphors to capture images. When exposed to x-rays or gamma-rays, electrons inside the phosphor crystals are excited and then trapped in a higher-energy state. The CR reader then scans the plate with a precision laser of a predetermined spot size which releases the trapped electrons from their high-energy state back to their normal state; this release causes a predictable quantity of visible light to be emitted that is captured and converted to a digital image.

The storage phosphors on the imaging plates offer an extremely wide dynamic range. This gives a high tolerance for varying exposure conditions and considerable freedom in selecting the total exposure. This can reduce shot times and allow a greater range of material thicknesses to be viewed in one radiograph, reducing the need for double or even triple loads.

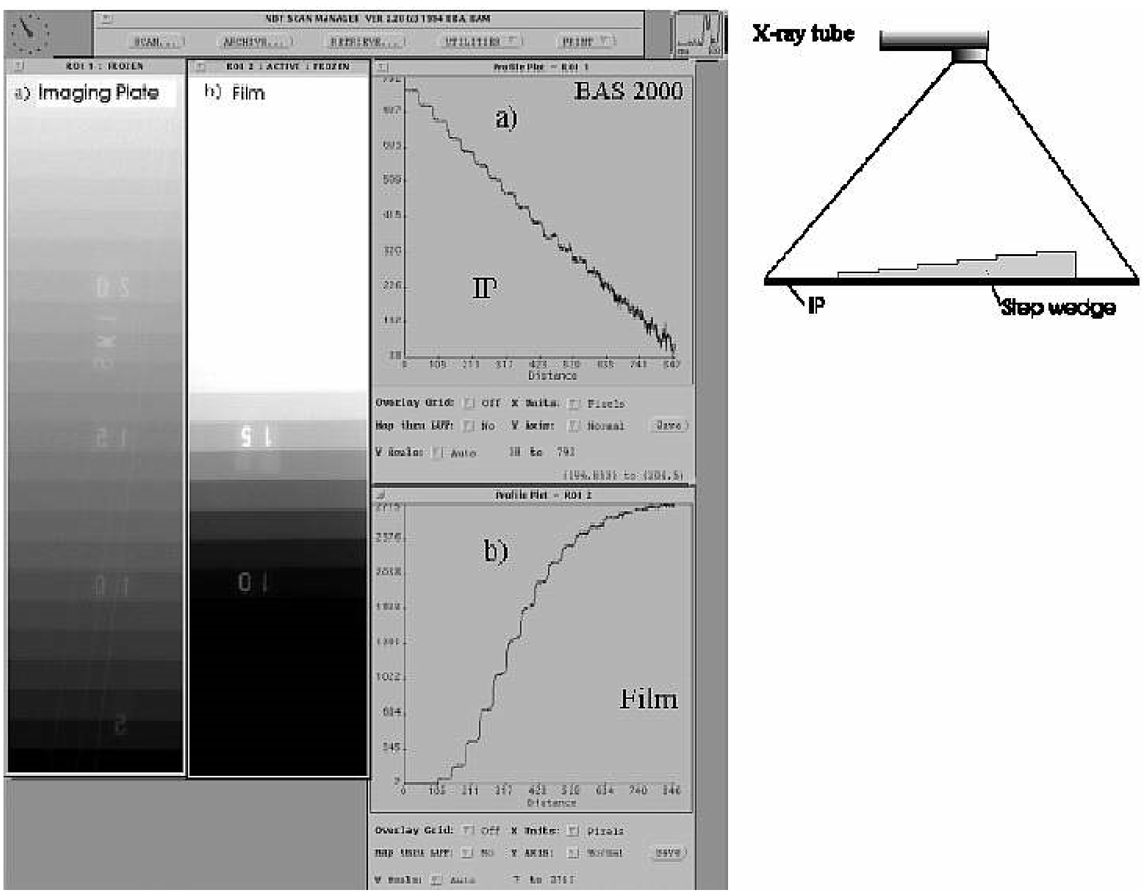
CR equipment and software has "plug and play" capability, in compliance with ASME Section V, Article 2, Appendix VIII as well as CSA Z662 and other industry codes and standards. CR requires no calibration or justification process, unlike Direct Reading Radiography (DR) systems that usually need to be qualified for each technique using manufactured test specimens.

The down side to CR is that equipment has often been large and bulky and the images have to be scanned at a rate of speed determined by the quality needs of the operator. Software has often been developed from medical platforms that use nonindustrial terms with reporting tools that also lack features and terms used daily in Industrial settings.

Dynamic Range

CR Plates have an extremely wide dynamic range (also be referred to as “latitude”). The phosphor of the CR plates has a much higher saturation point than the silver halide crystals in film. This makes exposure times less critical for CR plates. This wide range can be shown visually using a step wedge.

As shown in the accompanying figure, storage phosphor crystals exhibit a roughly linear response to varying absorbed energy, whereas film’s silver halide crystals show an exponential response.



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Health and Safety

The wide dynamic range of CR techniques is connected to benefits in health and safety. By using CR it is often possible to reduce exposure times. The time saving seems to be dependent on material; improvements of 60% for concrete and 25% or more for steel are not uncommon. Reducing exposure time allows lower activity gamma-emitter isotopes to be used, and lower photon energy is required from the gamma or x-ray source. Lower photon energy requirements can often be met with Selenium-75 in place of Iridium-192, and Iridium-192 in place of Cobalt-60, with attendant safety and economic benefits. For example, CR has been proven to increase the thickness of concrete that can be successfully radiographed using Iridium-192; film radiographs of large thicknesses would require a high-energy Cobalt-60 source at considerable additional expense.

Processing chemicals for film are another safety concern, and are classified as hazardous materials. Workers in the radiography industry must be trained in their handling, use and disposal.

Radiography when performed using CR can:

1. Reduce dose to operators by reducing dose needed to obtain the exposure
2. Reduce exclusion areas by using low-activity or low-photon-energy sources
3. Reduce the need to remedy over- or under-exposures by reshooting, thus reducing accumulated dose to workers
4. Eliminate hazardous chemicals used for processing film

THE PIPE LINE TRIAL

This white paper explores the use of radiography in a pipeline construction project. The project consisted of a 406.4mm x 6.35mm (16" x .250") pipeline constructed in Northern Alberta and radiographed using conventional large-diameter radiographic techniques, equipment and mobile labs. The equipment was optimized for film radiography and no effort was made to alter it for use with the CR format. The radiography crew had no prior training in CR, but an expert from Carestream NDT was present to optimize the HPX PRO system and offer advice, along with a veteran CGSB RT Level 2 technician an employee from IR Supplies and Services Inc. (IR). IR also provided cassettes and screens and some technical support as needed. Exposure times and set ups were the same for both the CR and film work with one exception; image plate availability was limited, so the CR image plates used were 431.8mm x 70mm (17" x 2.75"). Ten sets of four overlapping plates were employed vs. one continuous film load consisting of D5 lead pack. In addition, IR supplied prototype cassettes designed to reduce lint accumulation on the reusable image plates. X-ray tube settings and exposure times were identical at 25 sec for each image taken. The dynamic range of the image plates might have allowed reduced exposure times, however this was not attempted for two reasons; firstly, the dynamic range allowed for both the film and CR trials to remain identical for production comparisons and secondly time constraints were such that it made sense to use the existing film exposure time.

X-RAY SOURCE

Internal pipe crawlers are the fastest radiograph-shooting equipment available for pipeline construction projects in the petrochemical industry. They offer productivity benefits when measured by footage of film per weld unit over a given period of time. The pipeline industry is universally known for its production requirements and difficult environmental conditions. In short "pipe-liners" can shoot a lot of film in a hurry in the most difficult environmental situations.

The energy source was a 200kV panoramic x-ray source mounted on an internal pipe crawler. Tube settings used were the same for the CR image plates and for the film. The pipeline was first radiographed using AGFA D5 ready pack film and then subsequently re-radiographed using the digital computed radiography system, employing Carestream NDT HR image plates, loaded into 17” prototype cassettes with .010 lead screens front and back. The factory protective coating on the lead was left in place. Image plates were scanned using a laser spot size setting of 100 microns. A total of 50 welds were radiographed with both film and CR methods, and interpreted by the same CGSB level 2 radiographer.

Environmental Conditions

The trial was done in January on a windy, cloudy day with a temperature of -28C at the job site.

CR Scanner Technology Carestream NDT HPX PRO

The newest CR scanner in the Carestream NDT product group is the HPX PRO. The top priorities in the development of the HPX PRO were for the device to withstand the rigors of the day to day environments of in-field pipeline construction in all climates, while additionally being extremely portable. The HPX PRO is a small and light CR system designed specifically for NDT use. Weight is 35 lbs., width is less than 31cm (12”), height is 35.5cm (14”) or 31cm (12”) with handle removed, and length is 40.6cm (16”); it can be hand-held and carried by one person easily. Laser scanning spot size options are 25, 50 and 100 microns.

The HPX-PRO’s software incorporates a new user interface designed to minimize set-up wait time, with batch mode capability to keep pace with extreme process conditions like pipeline imaging. The new software tools include common industry language and also provide quick image analysis and customized reporting for generating reports instantly by selecting the appropriate key. It can be operated using an outlet (110/220V) or a common 24V power tool battery.

Image Security “DICONDE”

The main attribute of CR is the production of digital images. However, as with any digital image they could be subject to additions and deletions of digital artifacts through intentional manipulation or carelessness. In accordance with the standard “DICONDE” all digital images produced for NDE are preserved in their original form.

DICONDE is an evolving standard that provides a way for nondestructive evaluation (NDE) manufacturers and users to share image data. It is based on the American College of Radiology (ACR)/National Electrical Manufacturers Association (NEMA) standard, DICOM (Digital Imaging and Communications in Medicine). The DICONDE standard encompasses all NDE specific imaging methods and technologies, such as infrared thermography, ultrasound, computed radiography, computed tomography, eddy current, and acoustic emission, and harmonizes these with the DICOM standard as unique imaging modalities and stands for Digital Imaging and Communications in Nondestructive Evaluation. (Source; ASTM, American Society of the International Association for Testing and Materials)

Significance of the Trial

It was our belief at the time of this trial that no other side-by-side comparison had been undertaken in Alberta, and certainly no trial using the HPX PRO. The trial was intended to compare the HPX PRO performance in a real life pipeline construction environment versus film, both from a production and an image quality stand point. Though the number of welds was not large (50 in all), the participants felt that the sample was revealing and answered all questions asked.

Procedure

In the same fashion as processing film, the CR plates were scanned on site immediately after exposure in a batch format. The crawler crew would expose the image plates and pass them to the RT level 2 for scanning. Once scanned and erased, the image plates were returned to the crawler crew to be re-exposed.

Scan Time Comparison

The trial showed that the supply of image plates was scanned as fast as the crawler crew could expose them, with no down time resulting from the exposure or scanning process using the ten weld sets provided.

Image Quality Comparison

Image quality was assessed on site by the same Level 2 radiographer who had performed the equivalent task the day before using film. He found the radiographs to be acceptable with at least equal quality to the previous day's film. Appropriate wires for code compliance were visible on both film and CR images.

The Level 2 technician did however indicate that looking at film was different than looking at the digital image and that it would require some acclimatization.

Third Party Assessment

A third party assessment was sought to independently review the radiographs. A CGSB Level 3 radiographer with over 25 years' experience was hired to compare the analog film images and the CR digital images. The criteria given to the radiographer were to find and note all indications on a randomly selected number of welds from first the CR images and then the film radiographs. The Level 3 was not given any special training but allowed to use the preset filters of the PRO software.

It should be noted that the welds radiographed contained discontinuities including porosity, both in clusters and singularly, worm holes, hollow bead, both internal and external undercut, slag inclusions, slag lines or wagon tracks, stop-starts showing lack of penetration, and reinforcement irregularities. The discontinuities were considered mostly irrelevant as far as the code requirements but they did offer a great opportunity for comparisons.

Once the Level 3 had completed his assessment, it was clear that a problem existed. The CR radiographs were criticized for their lack of contrast compared to the film radiographs. The comparison of the radiographs was also disappointing as the Level 3 missed most of the external undercut that was seen on the film but did see all other indications.

Images are made up from pixels that have distinct tone, termed grey scale. The bit depth of the image determines the number of available shades of grey; 10-bit offers 1024, 12-bit 4096 and so on. This contrast, or lack of it, is a result of what is called windowing and leveling of the image. This can be done using preprogramed settings provided by the manufacturer or done manually. Essentially the window and level function adjusts the dark and light pixels and gives "contrast" to the image. (See Dynamic Range).

A second review was done by the same Level 3 technician but significantly more training was given in the use of the software including using window and leveling settings and filters. The Level 3 was once again given the same task with a different randomly selected number of welds. This time the Level 3 was successful in seeing all indications present in all the radiographs and was completely satisfied with the CR method.

The level 3's comments are as follows;

bold bracketed type indicates the author's words for clarity

"After this film review **(the second review)** I feel the digital radiographs of the HPX PRO are an acceptable form of medium for radiographs to be interpreted from. However, I also see that there must be some sort of training program in place that any technician or person must go through before being allowed to interpret these radiographs to any code or standard. Also, it is very apparent that parameter settings are crucial to proper interpretation of radiographs".

QUESTIONNAIRE

After the project was completed, a short questionnaire was verbally responded to by the Level 2 technician on the jobsite and the lead crawler operator. Important observations from both technicians are presented as additional information.

Question	Level 2 Technician	Crawler Technician
Have you ever used a digital system before?	No	No, I took a short service company course
Was production comparable to film?	Yes, much faster, easily kept up to the crawler	Yes totally, perhaps even quicker
Any specific production issues?	The darkroom was not ideal	No
How did the images compare?	Need some time to get use to them	N/A
Did you see everything you wanted to on the images?	Yes and more	N/A
How did the IQIs compare to the film images in your opinion?	As good as the film	N/A
Did you have any concerns with the images?	Training, and mastering the software	N/A
How did the overall system work?	Really good considering the HPX PRO was just added to the existing film lab	Slick, no film, speed was there and quality
Did the HPX PRO perform above or below your expectations?	Way above	Exceeded expectations
How did the HPX PRO adapt to the work environment?	Awesome considering we just added it to what we already had on site	Totally worked fine no problems and it was cold
Is there anything you really like about the HPX PRO CR system?	The digital image on a monitor, no more darkroom, no film processing, no density concerns, no drying time	Compact size
Was there anything you disliked about the HPX PRO?	No	Nothing
Any additional comments?	I can't wait to have it full time	Looking forward to working more with digital

Conclusion

In this trial it was in the darkroom where the speed and efficiency of CR and specifically the HPX PRO allowed production to increase. The reduced time in processing allowed for faster image plate turn-around, thus maximizing crawler utilization and producing more exposures in a given period of time than film can. This trial showed that the utilization of the HPX PRO and the digital imaging of CR image plates enabled time savings by eliminating the film processes of developing, washing, drying and packaging. There is also the real expectation that reporting time will also be reduced considerably using the HPX PRO's reporting software, but it was not used as part of this trial.

Image quality was found to be equal to that offered by film. It should be noted that AGFA D5 film was used and better film could be used that might have created better images than the CR images. Similarly, the Carestream NDT HR image plates could have been scanned at a small laser spot size of 50 or even 25 microns. Changes to the film (with increased exposure times) or smaller laser spot size (with increased scan times) would each have had an effect on production times.

Both the level 2 and level 3 technicians made comments about the difference in contrast between the film and the digital image. This is not uncommon and is usually the first thing noticed by first time users. Training on the software and especially optimization of images was a concern raised by the Level 3. In the case of the Level 3, training was critical for identifying and interpreting the images, and presetting the images for viewing. It is important to note that formal training was not given to any of the technicians or the third party Level 3, and was only provided to the level 3 informally by IR after the first viewing. When required, such as if purchasing an HPX series CR system, extensive formal training is provided by Carestream NDT.

Acceptance of the HPX PRO and the CR image plate was universal; the radiography and crawler crew saw no encumbrances to its use, in fact, they found many reasons it should be considered. One outstanding item was that the darkroom could use some modifications to optimize the HPX PRO and the use of CR image plates. This would surely be looked at by a service company upon purchasing a HPX PRO CR system, but it is useful to point out that even though the HPX PRO was added into the radiography production process as an afterthought, it performed exceptionally well and above the expectations of the operators.

All site personnel agreed that the HPX PRO CR digital system performed at least as well as the traditional film and after minimal training, image quality and interpretation of the radiographs was also accepted by our independent Level 3 as, at least, comparable to the film radiographs.

Summary

The HPX PRO was developed to produce code-quality digital radiographs in high production situations in common environments found on typical petrochemical construction sites throughout the world. The trial discussed in this paper tested the production capabilities and image quality of the resultant radiographs in comparison with traditional film.

There was no effort to optimize the CR images by adjusting the exposure times and energy settings of the x-ray tube; all exposure parameters were those used for film. This gave an excellent comparison of CR production capabilities all things being equal, but as we have stated CR is not constrained to the same settings as film. The wide dynamic range of CR, if explored in this trial, might have exceeded film in both speed and image quality. This could have conceivably reduced shot times and/or reduced exclusion areas and improved image sensitivity.

It is the author's opinion that the HPX PRO, in this trial was capable of producing images of at least equal quality to the film type used and that production was able to exceed that of traditional manually processed film.

The authors would like to thank all those involved who generously gave their support and time to make this trial possible. We would especially like to thank the technicians involved in performing the work as it is not often that time is given so freely. Without their co-operation this trial would not have been possible.