NON-DESTRUCTIVE EVALUATION UTILIZING IMAGING PLATES FOR FIELD RADIOGRAPHY APPLICATIONS

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Abstract. The oil and gas industry has utilized film radiography for the evaluation of pipeline welds for many years. The world has evolved, and today people are easily sharing digital images as part of the information revolution. Computed radiography is ready to replace film radiography for portable outdoor use applications. Computed radiography technology adoption has been contingent upon achieving acceptable image quality and getting enough imaging plate use cycles to be profitable. Image quality is dependent upon shot conditions, imaging plate type, reader settings, and scatter control. Likewise, the number of achievable use cycles is dependent upon the imaging plate design for durability and the user's operating environment. This presentation reviews the basic principles of storage phosphor imaging plates. Usage criteria and guidelines for optimum image quality and maximized overall use cycles will be discussed for various imaging plate types. A comparison of film and computed radiography imaging plate technology will be presented.

1. *Introduction*

Film radiography has been employed for nondestructive evaluation of oil and gas pipeline welds for the last 75 years. Typically, small crews of radiographers operate out of the back of a truck in remote conditions. Pipeline environmental conditions can be extreme for temperature, moisture, and cleanliness. The radiography crew follows the welders as the pipeline is assembled. Film is exposed with radioisotope gamma sources, typically iridium, due to its portability and ease of use. For iridium exposures, frontside and backside leads are utilized inside flexible cassettes, and the cassette is wrapped around the pipe with a bungee cord. Contact shots are done directly on the pipe at three different placements; each oriented 120 degrees from each other. The source is placed in contact with the pipe on one side, and the radiation exposes the imaging plate on the other side.

Field radiography utilizing film has remained viable because it follows well-established procedures and meets code requirements. It is easy to perform, and people are comfortable doing it. There is an extensive history of results for specific methods and techniques. Intensification from front and backside lead screens inside flexible cassettes enable a large degree of amplification at high energy, which allows for good image quality at short exposure times. Film radiography does not require considerable specific knowledge or training, which allows for cost savings relative to workforce development.

Digital imaging dominates the world in the areas of photography and medical radiology. Most people are now sharing digital images through their cell phones, tablets, or computers. Computed radiography (CR) is a mature technology that was first introduced for medical imaging 30 years ago. CR is viewed as a replacement technology for film in industrial applications, utilizing flexible imaging plates inside of flexible or rigid cassettes. Technology advancements in the portability of CR readers and improvements in the imaging plate overcoat technology now make CR viable for pipeline radiography.

2. *Discussion*

Figure 1 is a cross sectional comparison of a typical industrial film versus two specific industrial imaging plate types at the same magnification[1]. Film is duplitized, which means that the photosensitive imaging layer is coated on both sides of the plastic support. As studied, film imaging layers were approximately 8 µm thick with a 1 µm protective overcoat. Imaging plates were much thicker. High resolution (HR) plates were 160 µm thick for the phosphor imaging layer with a 4 µm overcoat, and general purpose (GP) imaging plates were 290 µm thick for the phosphor imaging layer with an 11 µm overcoat. Because imaging plates are thicker than film, they are more prone to exposure from scatter.

Fig. 1. Cross Sectional Comparison of Film and Imaging Plate Technology.

Radiographers can utilize their film techniques as a starting point for CR gamma radiography. Many gamma shots are under-exposed; therefore, image quality can generally be improved by increasing the dose. For a given radioisotope, the source energy and activity are fixed, so exposure time is the only variable that can be lengthened to increase the dose. Scatter should always be controlled for gamma radiography by utilizing front and or backside leads. Weld quality images can be achieved with HR imaging plates. Table 1 has plate recommendations as a function of energy level. The GP imaging plates should be utilized for very high energy applications, or for profile shots. The ultra-high resolution (UHR) blue plates should not be utilized for gamma radiography because of their higher noise level.

Table 1: Imaging Plate Selection as a Function of Energy Level and Energy Type.

Radiation Source	Energy Type	Energy Level	Plate
Linear Accelerators	X-ray	2–15 MeV	GP
Betatron	X-ray	2–10 MeV	GP
Tubes	X-ray	>220 kVp	GP
Tubes	X-ray	<80 < 220 kVp	HR
Tubes	X-ray	<80 kVp	UHR
Cobalt 60	Gamma	peaks at 1.17, 1.33 MeV	GP
Iridium 192	Gamma	seven peaks between 200–600 keV	HR
Selenium 75	Gamma	nine peaks between 66–401 keV	HR

The durability of imaging plates has been an issue for artifact formation, and it determines the number of achievable use cycles. It has been shown that both film and imaging plates have similar physical properties[2]; however, because imaging plates are utilized for more than one use cycle, artifact formation becomes an issue over time[3]. There are several potential sources of radiographic imaging artifacts: scratches, abrasion, dust, fingerprints, yellowing from moisture and or cleaners, and cracking.

Figure 2 provides an example of two imaging plate structures, each employing different overcoat technology. The function of the overcoat is to protect the phosphor imaging layer from damage that can potentially cause radiographic imaging artifacts. Imaging plate manufacturers utilize either chemical or laminate overcoat technology. The chemical overcoat technology is a polymer or polymer blend that may or may not be radiation hardened to promote cross linking of the polymer. The laminate overcoat technology is a thin sheet of polyethylene terephthalate (PET) that is adhered to the phosphor layer with an adhesive. Figure 3 provides a cross sectional comparison of the two overcoat technologies.

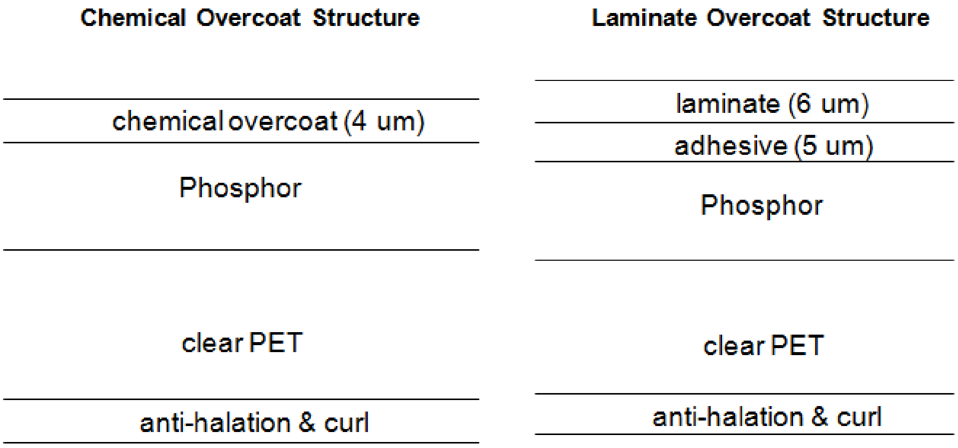

Fig. 2. Chemical Overcoat versus Laminate Overcoat Plate Structure.

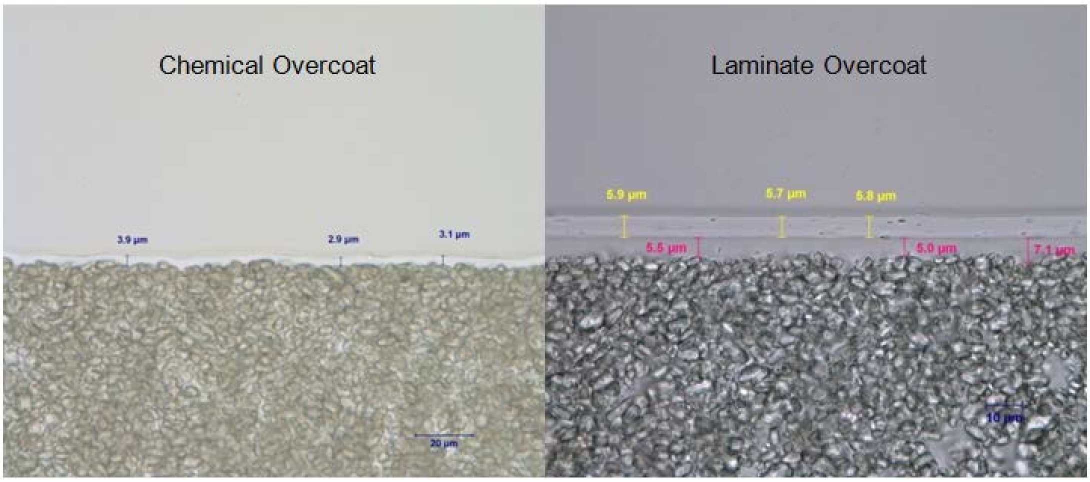

Fig. 3. Cross Sectional Comparison of Chemical Overcoat versus Laminate Overcoat.

Laminated overcoat imaging plates have been developed specifically for applications that encounter rugged environmental conditions and extensive handling. The laminate overcoat produces fewer radiographic artifacts as a function of time, which extends the achievable number of use cycles. The advantages of the laminate overcoat imaging plate over the chemical overcoat imaging plate include improved abrasion resistance, ability to clean, chemical and moisture resistance, and cracking resistance.

There are usage criteria and guidelines for maximizing field radiography imaging plate lifetime. When not in use, plates should be stored flat, in dark and dry conditions, and they should be handled by the edges with cloth gloves. They should not be creased or kinked because permanent and irreversible cracks can be created. Extreme humidity or wet conditions should be avoided because this can shorten lifetime. Refrain from surface temperatures greater than 212°F (100°C), and plates should only be used in the temperature range of –22°F (–30°C) to 120°F (49°C). Clean only with a manufacturer-recommended solution and a lint-free cloth.

Figure 4 provides radiographs of a 0.37-inch steel weld coupon for four different imaging plate types. The plates were placed inside a flexible vinyl cassette with a 10 Mil backside lead and a 5 Mil backside copper. An iridium-plus-radioisotope source was used to expose the imaging plates. The source-to-detector distance was 12 inches, and the plates were exposed for 1 minute 47 seconds for an exposure factor of 7R, read at a 100 µm pixel size.

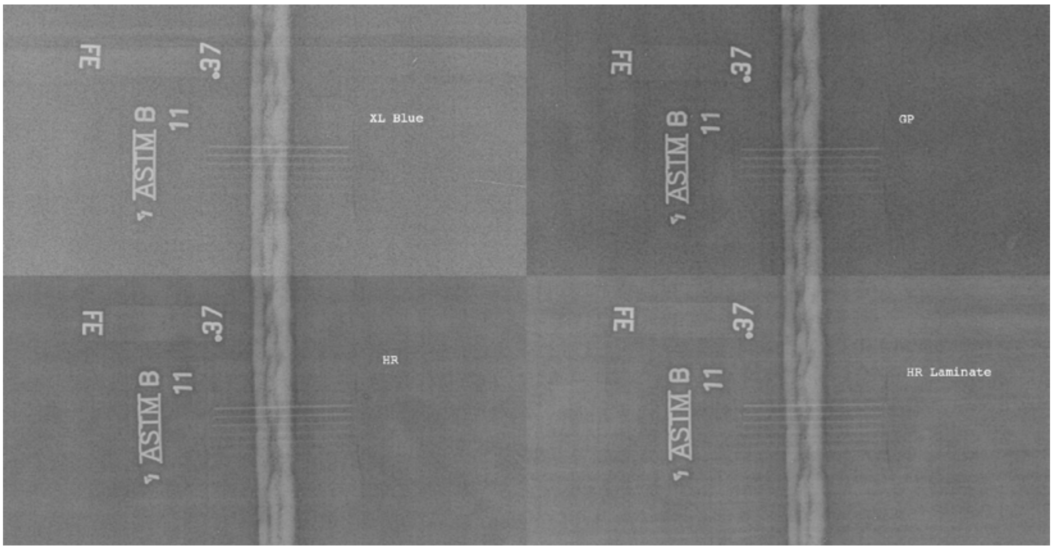

Fig. 4. Weld Coupon Radiographs with Iridium Exposure.

The best weld quality images were obtained with the HR and HR-laminate imaging plates. The XL Blue plate was too noisy for gamma exposures, which influenced contrast and detection. Relative to HR, the GP imaging plate was not as sharp, which influenced the ability to resolve details in the image.

Figure 5 provides radiographs of a 4-inch schedule 80 pipe with 0.337 inch (8.6 mm) walls for four different imaging plate types. The plates were placed inside a flexible vinyl cassette with a 10 Mil backside lead and a 5 Mil backside copper. An iridium-plus-radioisotope source was used to expose the imaging plates. A double-wall contact shot was executed, with the plates exposed 42 seconds for an exposure factor of 7R, read at a 50 µm pixel size.

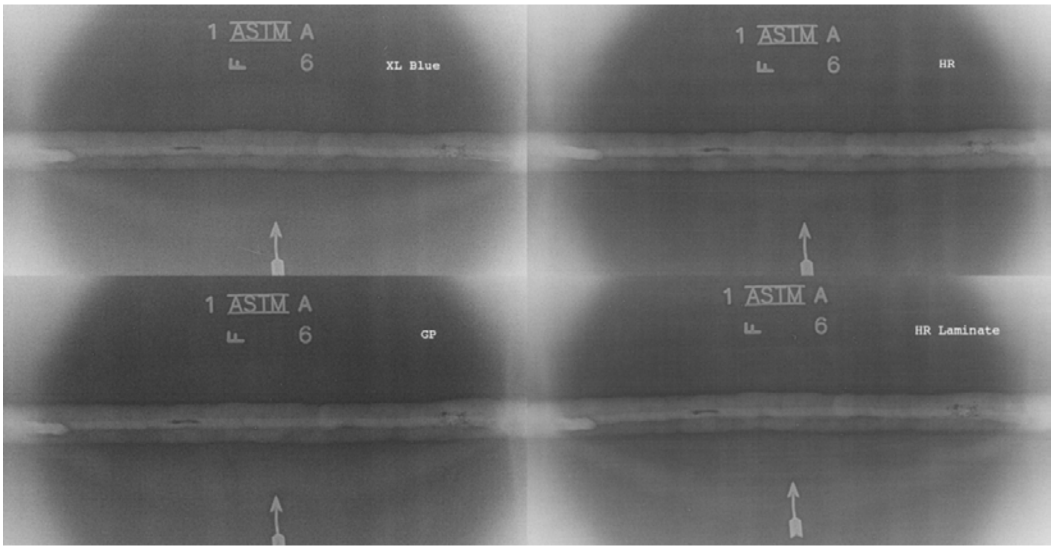

Fig. 5. Four-Inch Schedule 80 Pipe Weld Radiograph with Iridium Exposure.

The essential wire Number 5 could be detected with HR, HR laminate, and the GP imaging plates. The best images were with the HR and HR laminate plates. Wire Number 5 could not be detected with the XL Blue imaging plate.

Figure 6 provides a comparison of the fast-scan interpolated basic spatial resolution (iSRb) utilizing a duplex wire gauge for four different imaging plate types. The plates were placed inside a flexible vinyl cassette with a 10 Mil backside lead and a 5 Mil backside copper. An iridium-plus-radioisotope source was used to expose the imaging plates. The source to detector distance was 12 inches, and the plates were exposed for 1 minute for an exposure factor of 3.5R, read at a 100 µm pixel size.

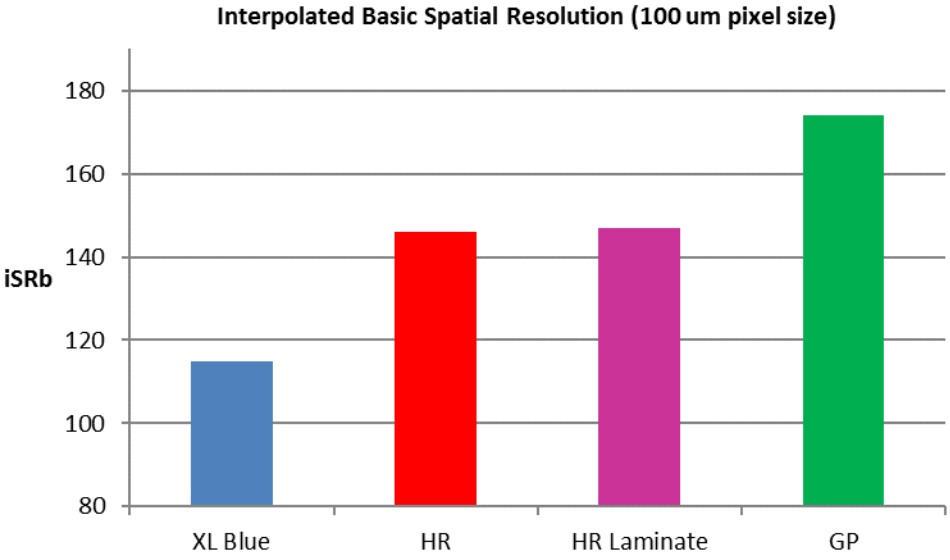

Fig. 6. Interpolated Basic Spatial Resolution.

The XL Blue plate yielded the best sharpness, followed by the HR and HR laminate plate, and then the GP plate.

Figure 7 provides a comparison of the normalized signal-to-noise ratio (SNR) as a function of dose for four imaging plate types. The plates were placed inside a flexible vinyl cassette with a 10 Mil backside lead and a 5 Mil backside copper. An iridium-plus-radioisotope source was used to expose the imaging plates. The source-to-detector distance was 12 inches and the plates were read at a 100 µm pixel size. The SNR was normalized to a basic spatial resolution of 100 µm, measured through 0.5-inch of steel.

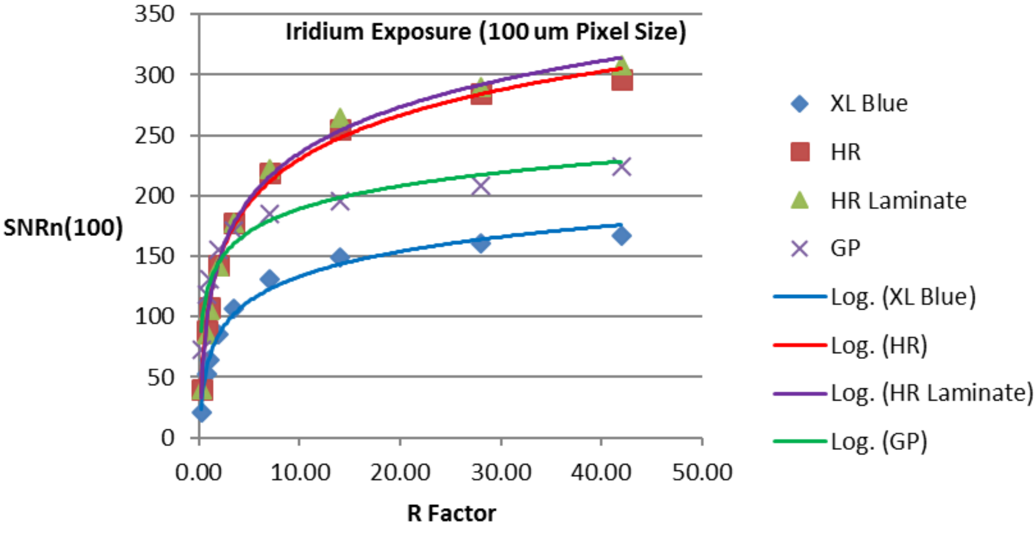

Fig. 7. SNR_{100} as a Function of Dose Level.

The best normalized SNR as a function of dose was achieved for the HR and HR laminate plates, which was due to their lower noise level. The next-best normalized SNR was the GP plate, followed by the XL Blue plate, which had the highest noise level and the lowest brightness.

Figure 8 demonstrates the dose (R factor) required to achieve various levels of radiographic penetrameter sensitivity for four imaging plate types. The plates were placed inside a flexible vinyl cassette with a 10 Mil backside lead and a 5 Mil backside copper. An iridium-plus-radioisotope source was used to expose the imaging plates. The source-to-detector distance was 12 inches, and the plates were read at a 100 µm pixel size. The sensitivity was measured through 0.75 inches of steel with two hole-type penetrameters.

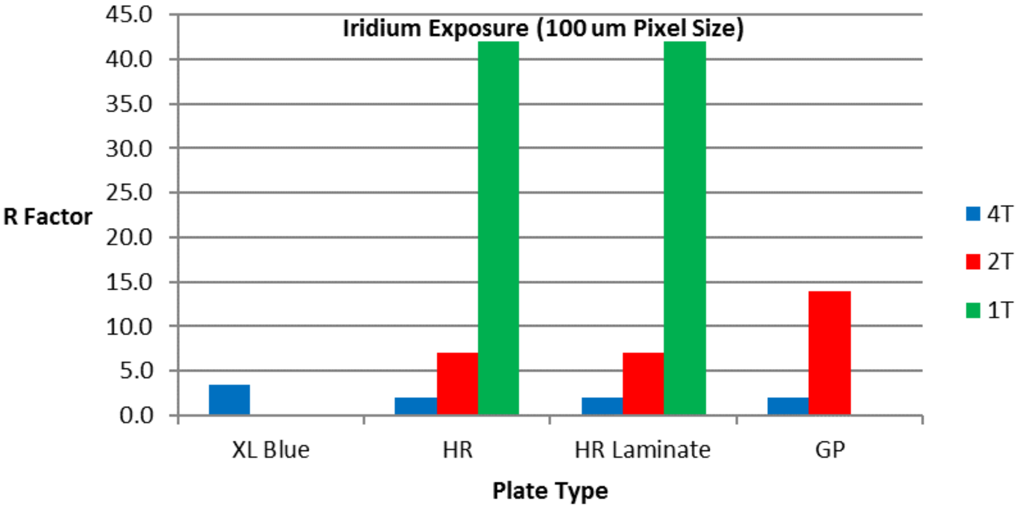

Fig. 8. Hole Penetrameter Sensitivity as a Function of Dose Level.

The HR and HR laminate imaging plates had the best sensitivity to visualize 4T, 2T, and 1T holes. The XL Blue could only see the 4T hole starting at 3.5R. Results no better than the 4T hole could be achieved, even with increasing dose, as the XL Blue had poor detection capability. The HR and HR laminate imaging plates could see the 4T hole at 2R, the 2T hole at 7R, and the 1T hole at 42R. The HR type plates had the best detection capability. The GP plate could see the 4T hole at 2R, the 2T hole at 14R, but it was unable to detect the 1T hole even at increasing dose levels. The HR or HR laminate plate should be utilized for weld quality gamma radiography applications.

3. Summary

Digital imaging is ready for outdoor pipeline radiography. Advancements in reader portability and laminated plate technology enable CR as a replacement for film. Laminate overcoat imaging plates have equivalent image quality relative to legacy imaging plates, and they can achieve a higher number of use cycles as a result of reduced image artifact formation, making CR both accessible and profitable for oil and gas applications.

4. Acknowledgements

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5. References

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