ADVANCING PRODUCTIVITY IN PORTABLE X-RAY INSPECTION

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Abstract

As one of the most important NDT techniques, X-ray inspection has a long history of successful application in many fields. It is also the NDT technology with the greatest safety and environmental concerns. In the spotlight are applications that demand flexible use of portable X-ray equipment in various situations, with many different inspection set-up procedures.
GE Sensing & Inspection Technologies has been closely involved in portable X-ray inspection for more than 100 years, and is acknowledged for the contributions it has made in continuously improving safety and productivity in this environment.
This paper introduces and explains some new productivity features for portable X-ray inspection solutions, helping inspection businesses to improve set-up and imaging performance, allowing them to use efficient tools throughout the entire inspection workflow.

Maximizing productivity in portable inspection

The decision to invest in capital equipment is in many cases no longer a decision that is purely down to a minimum set of technical requirements and an acceptable price tag. Productivity is a key term used by engineers, buyers and owners equally, and is a strong metric for the final decision to buy.

As this counts generally for all bigger industrial investments expected to give a certain return, it is especially true for in-service equipment, as their contribution is directly measured by the performance, flexibility, ease-of-use and long-term endurance they provide for the business. Each shot, each operating hour, each additional application set-up and imaging choice, is a productivity factor and value that contributes to any given business calculation.

So what does that mean, specifically, for modern, portable X-ray generators and imaging devices that provide on-site diagnoses?
To answer this question we need to look more closely at the portfolio of applications done with that particular equipment, and often done by one and the same service provider. Then we need to examine the steps necessary to perform different inspection jobs, the environment in which the inspection is carried out and the result of the inspection. Each step in the sequence has specific requirements and contributes to the overall productivity. While there is a maximum that can get achieved when specializing on single applications, we will certainly acknowledge, that a broad range of application coverage is as well a desired productivity value that can and will in most of the cases be even stronger than that of a very specialized single application solution. And here is, where the right recipe between the application specific solution and the flexibility of use for the equipment must be found. Only by having both can we achieve a desirable maximized productivity.

Productivity metrics

The metrics leading to the desired productivity advantage need to be divided into product specific advantages and combined advantages given by the specific choice of set-up for the particular application. In this respect the desirable product values of each device in the setup are categorized in a so-called Productivity Matrix as shown below. The Product Matrix identifies distinctive factors throughout the whole value chain of the inspection task that contribute to overall productivity.

	Energy range	**Exposure time**	**Endurance and duty cycle**	**Application Setup time**	**Evaluation and Administration time**	**Environmental Conditions**
Portable X-ray sources	Flexible range increases material bandwidth e.g. from steel to composites or from thin wall to thick wall	Medium Frequency, leads to clean DC output, which reduces Exposure time.	Metal Ceramic technology, has longer in-service times, and is easier to keep in operation conditions through better cooling → Productivity through 100% duty cycle equipment.	X-ray source can be activated / deactivated (in relation to isotopes, it simplifies handling, storage and general safety aspects) Less leakage radiation, reduces cordon-off distance of safety zone Scaffolding, lifting and positioning of X-ray source Suitable accessories for mounting and positioning of X-ray source Provision of external power supply requires electricity infrastructure (power grid, power generator or batter pack) Simple interaction on the control device with big display with clear messages and keypad / cursor pad Import or Creation of Exposure Programs from Inspection Planning Comprehensive overview on the operational setup and parameters Electronic tools to automatically calculate exposure times, adjust setup specific parameters such as FFD and max. current	Documentation of exposure: Electronic Export of exposure settings (kV, mA, time, comments) Manual notes on paper reports	IP 65 rating for outdoor use in harsh environment Rugged housings, cable, and connectors Gas-filled generators, to reduce weight for easier handling Weight / dimension optimized housings with proper shielding to maximize leakage protection
Film	No restrictions	Considered as reference	Single use	Very flexible, easy to attach, different sizes, no special fixtures needed	Off-line development process and evaluation	Withstands harsh environments

	Energy range	Exposure time	Endurance and duty cycle	Application Setup time	Evaluation and Administration time	Environmental Conditions
Computed Radiography	No restrictions	10% - 50% of film exposure time	Up to 3000 shots / foil	Depending on mounting / exposure situation (weld vs. corrosion monitoring)	Off-line scanning and evaluation	Withstands harsh environment
Digital Radiography	No restriction, current technology functions up to 350 kV and above	10% - 30% of film exposure time	Theoretically, no restrictions; in reality, performance degradation over time	Requires mounting support for portable application	Almost real-time, theoretically, field evaluation possible	Temperature restrictions
Software	n.a.	n.a.	n.a.	Workflow management (consistent documentation) Interface for data-input from inspection planning "Guided inspection", inspector is guided through each step Parameter and device control of connected detector and X-ray source	Image acquisition, enhancement and correction On-line documentation of shot / exposure Image achieving Fast determination whether shot needs to be repeated	SW must be operated on field proven hardware and robust (IP rating, harsh environment) Ruggedized laptop / workstation Battery powered Portability

Table 1: Productivity Matrix

Looking at the imaging devices available today, we have to evaluate on a range of parameters that all contribute to the image quality and defect detect ability. It becomes evident that a single advantage on a specific metric cannot be isolated to form a statement concerning the image quality.

	Film Radiograph	Computed radiography CR-plates	Mobile digital Panel in real Time mode	Mobile digital Panel in Still imaging mode with Software Enhancement
Resolution	0.1 to 0.06 mm (0.004 to 0.002 inch)	0.5 to 0.25 mm (0.02 to 0.01 inch)	0.5 to 0.25 mm(0.02 to 0.01 inch)	0.5 to 0.25 mm(0.02 to 0.01 inch)
Contrast Sensitivity IQI	~2%	1 to 2%	up to 1%	Down to 0.5%
Speed	5 to 8 min/image	Up to 1/10th of a radiographic film	1/30 sec. 33 frames per sec.	1/30 to several sec/image
Test perspective	Fixed	Fixed	Flexible	Flexible
Imaging Geometry	1:1 geom. mag. aprox.1 low influence from focal spot size	1:1 geom. mag. aprox.1 low influence from focal spot size	1:1.5 or higher geom. mag. Larger than 1 high influence of focal spot size	1:1.5 or higher geom.. mag. Larger than 1 high influence of focal spot size

Table 2: Technology comparison for different imaging methods

To complete the overview with a focus on productivity, the below table compares the different technologies.

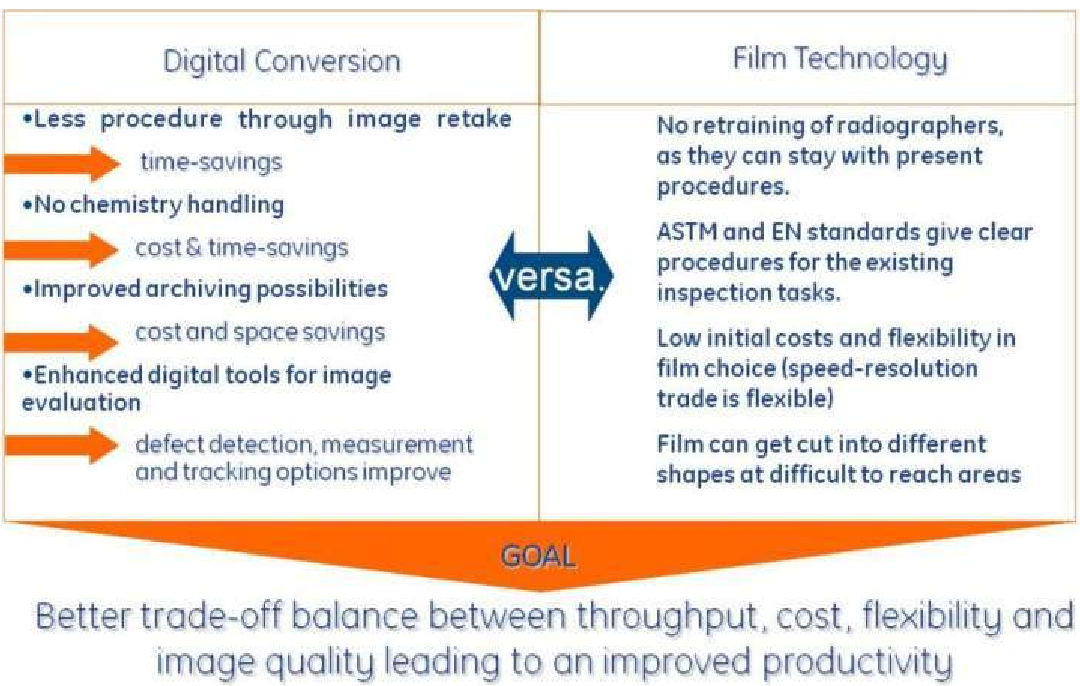


Table 3: Productivity impact of digital vs. analog technology

Applications covered by portable X-ray inspections

a) Pipeline construction in the Oil & Gas segment

For operation in the Oil & Gas environment, we need to focus on two main situations.
Firstly, the inspection is mainly on pipes with different thicknesses and diameters.
Secondly, the inspection needs to be carried out in an outside environment in accordance with relevant standards such as ISO 10893-07.
These two points make the Oil & Gas construction sites the ideal environment for portable inspection set-ups with portable units being highly flexible in the energy range. Efficient units with either directional or panoramic emission can do the inspections on pipes from 5mm wall thickness to a maximum of 65 mm wall thickness with a single continuous shot.
They deliver excellent image performance on standard D7/C5 film as well as on High performance CR imaging plates. Easy and efficient set-up performance on site, by use of the provided accessories, as well as the choice of the right imaging device for the application and the inspection volume, will determine the most practicable and productive set-up here. A productivity gain can only get achieved with an optimized combination of the right unit and the corresponding imaging solution.
The outside environment, which puts a challenge on most units in use at such sites, is the ideal place for a Constant Potential (CP) Medium frequency unit with an ingress protection of IP65 or above, in order to fully utilize the units even when working in very harsh environment.
The inspection volume, mainly defines whether to choose a radiographic film or a computed radiography solution.
In any case, from above Table 3, we can see, that a better productivity of the overall process gets achieved, when using a CR model. However, the quality of the imaging plate, the scanner and the software package, are vital factors in achieving the required imaging quality, and need to allow fast and customized evaluation.
The main productivity driver here is software. The software package offers productivity solutions for archiving, defect analysis and report generation.
High initial equipment costs can limit the use of CR, if the inspection volume is not sufficient. From an image quality perspective, inspection with film is sufficient, with inspection costs being moderate and most of all providing a straight pay- ff from the application. However film handling and environmental factors will notably slow down the job’s productivity.
Diagram 1 illustrates how process steps in the imaging chain are eliminated, by changing from film usage to CR technology. Some of the steps in this process are dependent on the application and the environment. Film archiving, as an example, is not mandatory to all NDT inspections, but needs to be implemented in environments such as Nuclear Power or Aerospace.

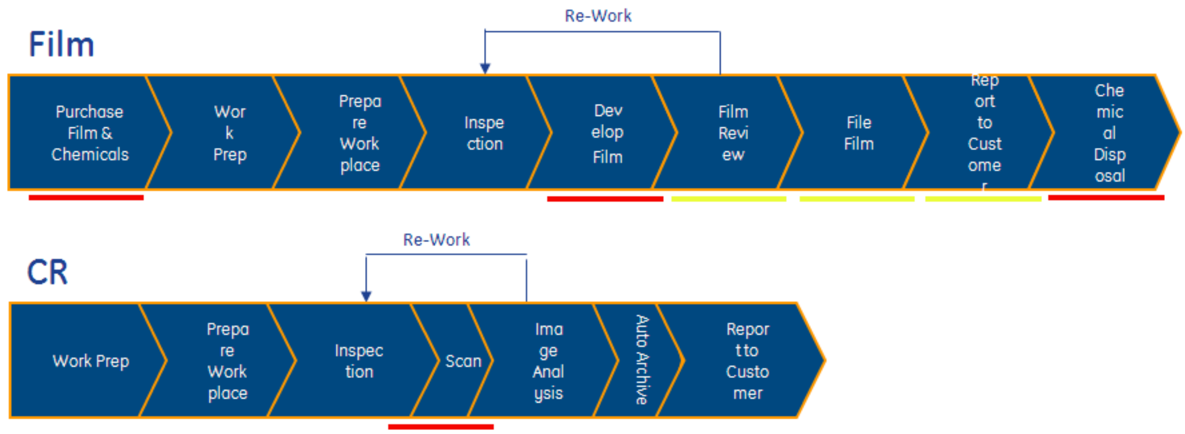
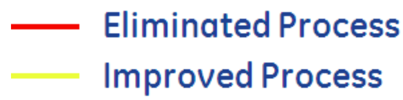


Diagram 1: Typical workflows for inspections using film or CR



b) Tank and Vessel Construction in the Power Generation segment

Tank and vessel construction uses steel panels of thicknesses from 10 to 35 mm. The advantage of portable units with 100% duty cycle and short exposure times is, to shoot welded sections continuously without rest between the shots. Therefore the achieved number of exposures per shift can be increased significantly, which means that welders return to the construction site earlier, and finish the project sooner.

The unit's accessory range is essential to help tank and vessel constructors perform their set-up fast and with the right tools to achieve better image quality in shorter exposure time. Tools include the 4-legged, laser-positioning device and various diaphragms to reduce scatter and improve image quality. The weld-inspection job on Tank and Vessels needs to be performed in accordance with relevant standards such as ASTM or EN (See table 4).

CEN standards:
EN 14784-1 : Industrial CR with storage phosphor imaging plates
Part 1 : Classification of systems
EN 14784-2 : Industrial CR with storage phosphor imaging plates
Part 2 : General principles for examination of metals using X-rays and gamma rays

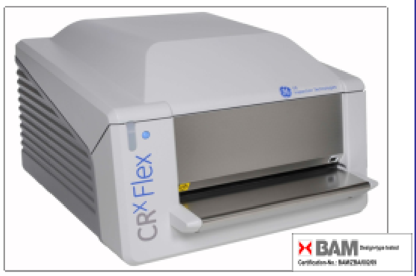
ASTM standards:
ASTM 2007-00 : Standard Guide for Computed Radiography
ASTM 2033-99 : Standard Practice for Computed Radiography
ASTM 2445-05 : Standard Practice for Qualification and Long-Term Stability of CR systems
ASTM 2446-05 : Standard Practice for Classification of CR systems
ASTM 2339-04 : Digital Imaging and Communication in NDE (DICONDE)

ASME code:
ASME Code Case 2476 : Radiography using phosphor imaging plates

Table 4: Overview about relevant standards for computed radiography

It is important that the use of CR equipment in this environment is compliant with the standards with regard to the equipment itself as well as from the perspective of the application set-up and execution.

A scanner with a proper certification, as shown in Picture 1, enables the inspector to perform his inspection in accordance with the Standards. With A Medium Frequency CP unit of high flexibility in the energy range and an optimized duty cycle through Power Mode operation, as shown in Picture 2, the inspector can perform his X-ray inspection in shorter time and with better image Quality. A PC and Software-setup as shown in Picture 3 will help to gain productivity in the overall process, and allow repeatable secure detection of any welding defect.

		
Picture 1: CR Flex with BAM certificate	**Picture 2**: ERESCO Portable MF4 Generator family	**Picture 3:** PC with Rhythm Image & Archive Software suite

The use of CR foils will further improve productivity, as the exposure dose needed is significantly less compared with film, and the image acquisition is faster when processing the CR plate with the appropriate High-resolution scanner as shown in Picture 1.
In this field of application, a further advantage is the possibility to use the CR plates in rigid cassettes. The handling is therefore improved and faster, and the plate is protected against scratches from handling and environmental conditions. A modern scanner can handle the rigid cassettes fully automatically, and improve the speed of processing as well as the overall lifetime of the imaging plates. This increases productivity and will make the usage of CR plates economically feasible even with high initial equipment costs and secures a quicker return on investment.
The latest development in mobile digital panels should also be considered as an option for this sort of application. The advantage is the possibility to get an instant image and to be able to move through the inspection without any image retake. The digital information can be used for very quick reporting on the condition of the weld. However, for the use of mobile panels, we have to review the panel properties and we need to adjust our inspection set-up to meet certain requirements, resulting from those physical properties of the panel. Also another Standard comes into play, when using digital Flat panel Detectors. This ASTM 2597-07 Standard describes the panel properties needed, and the methods to evaluate, calibrate and qualify the panel for the inspection task.
While the general advantage is further productivity gain, by eliminating another step in the application process, we also need to look at our required set-up conditions.

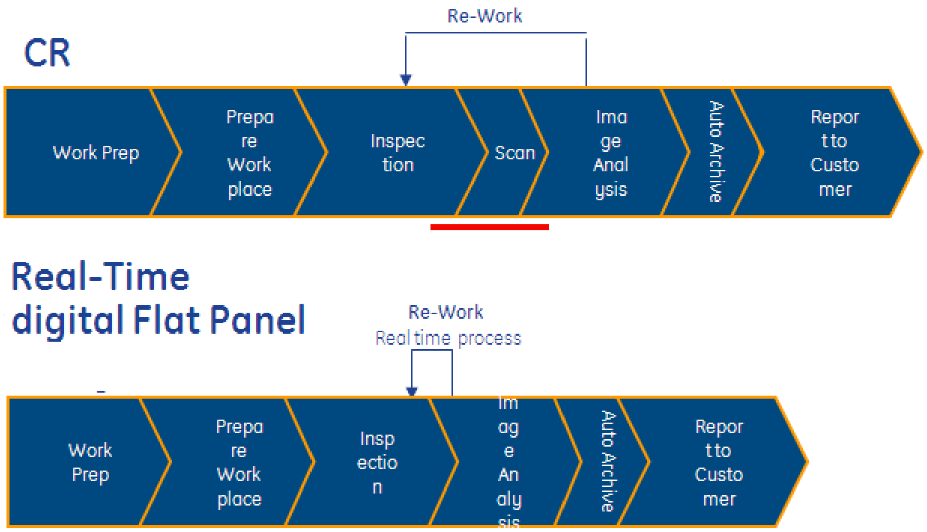


Diagram 2: Typical workflows for inspections using CR or portable Real-Time Digital Panels

Required setup:
Due to the detector properties showing a comparatively high inherent unsharpness of the Flat Panel device, compared to film and CR (see Diagram 2), the set-up requires compensating with a geometric enlargement. This leads to a smaller section of the viewed weld, and also requires a portable source, with a focal spot small enough to produce images without geometric unsharpness.
This compromise often results in a more difficult set-up, and requires additional accessories to hold the detector panel in place in such a way, that a proper image can get achieved and the geometrical relationships can be measured to ensure reproducible set-ups. As this is often a difficult process, also involving procedures that need to meet certain standards of radioscopic weld inspection and equipment setup, such as the ASTM 2597 and EN 13068 1-3, this technology is still in its very early stages. However, although not yet practicable for a productive portable weld inspection setup, this technology certainly has great potential.
A state-of-the-art portable digital Flat Panel detector is shown in Picture 4.

Picture 4: Direct Radiography **DXR250P** portable X-ray Detector

c) Structural Integrity on Aircraft composites in the Aerospace segment

During aircraft maintenance and servicing, it is often necessary to carry out radiography in very restricted spaces. The quality of images is therefore very much dependent on the inspection arrangement and requires that radiography systems are extremely flexible.

The X-ray inspection of composite parts, honeycomb structures and the inspection of part assemblies, demand an X-ray unit that delivers high current at a range of 25 kV upwards. Most units only start as high as 60kV and have limited current of less than half that of a good portable Medium Frequency unit with separate filament transformer and circuitries. Their image quality and POD capabilities do often not match the increased requirements. This is why a well-considered selection of X-ray source equipment and imaging equipment is essential for a good aircraft inspection. A portable source here needs to provide more than a flexible and easy adjustment. Extended programming and reporting features to embed set-up and configuration parameters in documentation and workflows are as important as the image quality itself.

An integrated solution, where X-ray generation, imaging and the related Software platform is integrated into one portable system is illustrated in Diagram 3.

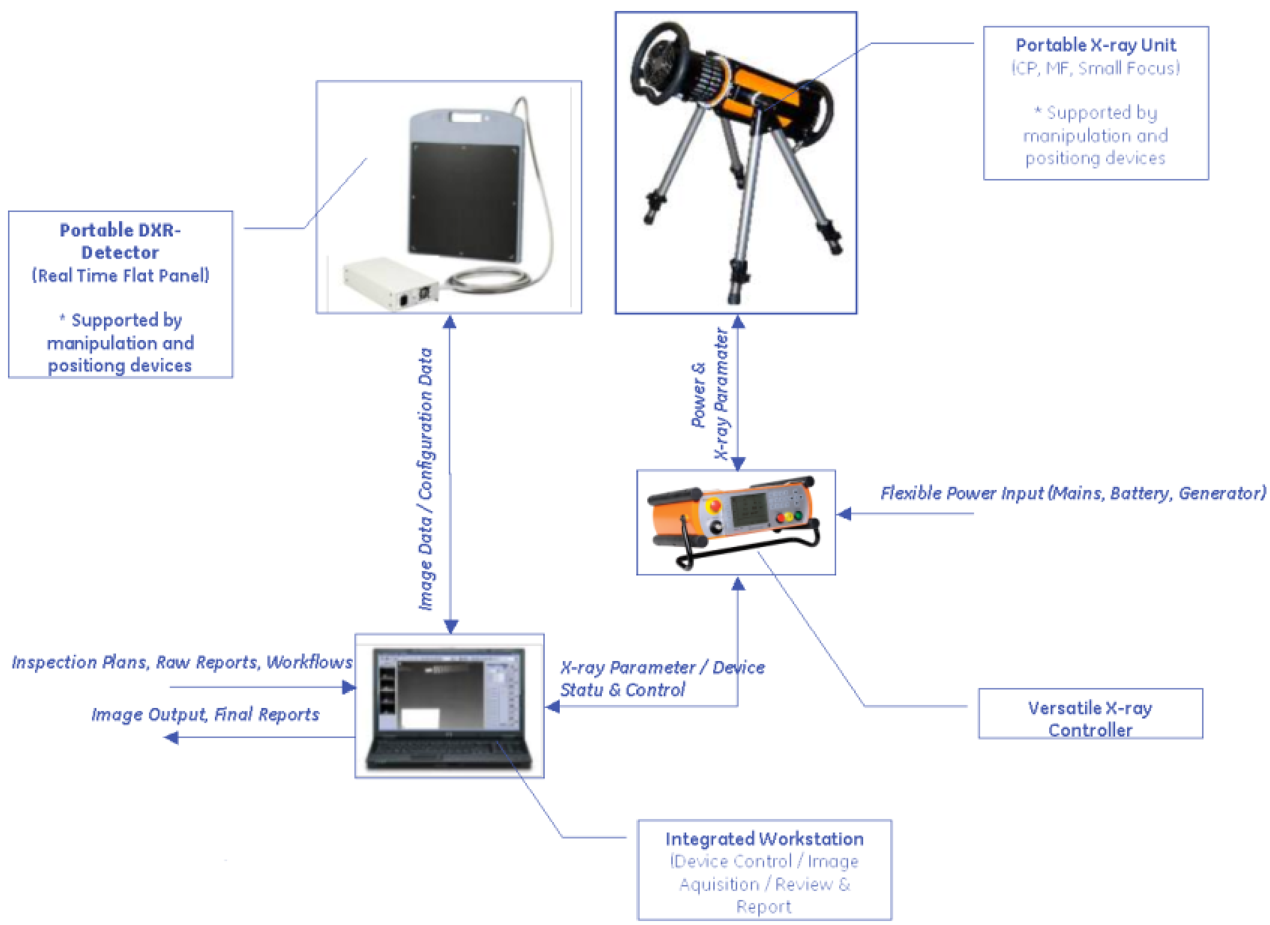


Diagram 3: Integrated workflow driven solution for portable X-ray inspection

This will again eliminate process steps from the workflow, and will consistently improve the overall productivity.

Changing inspections from film to digital is the future in this segment. A digital portable panel in combination with a small focal spot portable X-ray source delivers instant images that can be adjusted to quickly provide information about the condition of the part under evaluation. Archiving and reporting, as well as information sharing and forwarding, is done without loss of time. Additionally a sound software package will provide evaluation tools that help to have issues resolved quickly, and reduce aircraft ground time.

Conclusion

While there are many ways to keep improving productivity in radiographic inspections, new digital technologies in combination with flexible high-end X-ray generators have certainly driven this process further and continue to be the key for future productivity gains in this field. As we are just beginning to discover the contribution that mobile digital Flat Panels can make, we must also bear in mind that a solid, well designed software suite is a major driver in speeding up detection, ensuring traceability and highlighting ways to introducing greater efficiency in the overall inspection.