High End Inspection by Filmless Radiography on LSAW Large Diameter Pipes

Thomas Kersting [1], Norbert Schönartz [2], Ludwig Oesterlein [3], Andreas Liessem [4]

[1] EUROPIPE GmbH, Wiesenstrasse 36, Mülheim a.d. Ruhr, Germany,
Phone: +49 208 976 4371, Fax: +49 208 976 3371 Thomas.Kersting@europipe.com
[2] Salzgitter Mannesmann Forschung GmbH, Ehinger Str. 200, Duisburg, Germany, n.schoenartz@du.szmf.de
[3] EUROPIPE GmbH, Wiesenstrasse 36, Mülheim a.d. Ruhr, Germany, Ludwig.Oesterlein@europipe.com
[4] EUROPIPE GmbH, Wiesenstrasse 36, Mülheim a.d. Ruhr, Germany, Andreas.Liessem@europipe.com

Abstract
Longitudinally submerged arc welded pipes for gas and oil transportation are subject to the most severe safety requirements. To further enhance the NDT process, EUROPIPE has invested in the digital X-ray inspection technology and herewith completely replaces the X-ray film. The new installation consists of two separate X-ray chambers in order to keep up with the production flow. In each chamber two digital detector arrays and two X-ray tubes are installed. This installation replaces three old X-ray chambers with twelve X-ray tubes. EUROPIPE is one of the first companies which have implemented this technology in an automated serial production of large diameter pipes.
Keywords: Filmless radiography, flat panel, large diameter pipes, digital detector array, X-ray testing, weld seam, automated testing

1. Introduction

EUROPIPE is the world market leader for longitudinally submerged arc welded pipes for gas and oil transportation. The production line in Mülheim a.d. Ruhr produces up to 10.000 meters of line pipe per day.

Since its foundation EUROPIPE has been committed to continuous and sustained improvement of products and processes by advanced research and development. To further improve its leading position EUROPIPE has invested in the digital X-ray inspection technology and herewith completely replaces the X-ray film. The conceptual design of the installation with the name E-FLORAD (Filmless Radiography after Expansion) was developed by EUROPIPE together with the research institute Salzgitter Mannesmann Forschung (SZMF). Beside the introduction of modern technology the main challenge was the integration into a serial production flow (40 pipes/hour) with automated monitoring of traceability and quality assurance.

2. Requirements for X-ray testing in a LSAW pipe mill

2.1 General requirements

Since LSAW pipes are typically used for the transport of combustible materials the requirements on the NDT process are very high. The whole weld seam is generally tested with an automated ultrasonic testing (UT) system. Each indication of the UT system has to be checked by X-ray testing. In addition, both pipe ends must always be tested with X-ray.

Due to the highest quality requirements, high standards must be applied for the X-ray testing process and a high probability of detection is required. The large throughput in the mill with a cycle time of 90 s per pipe calls for a quick, safe and reliable testing process. In addition, all X-ray images must be archived for at least 12 years. The large number of X-ray images recorded each year enforces a solution with low costs of operation.

2.2 Pipe dimensions and mechanical restrictions

The pipes produced in the Mülheim works of EUROPIPE have the following range of dimensions:

Length:	9.0 m ..... 18.3 m
Outside diameter:	610 mm ... 1524 mm (24” ... 60”)
Wall thickness:	8 mm ..... 50 mm

It was a major challenge to devise a mechanical set-up by which the digital detector arrays (DDAs) could be positioned inside the pipe with the required speed and precision.

3. Targets for the move from film to digital radiography

The following main targets were defined for the transition from film to a digital system:

- Avoid re-shots necessary e. g. by scratches on the films
- Avoid chemistry for film processing and costs for proper disposal
- All documents of the pipe should be digital documents available anywhere in the mill
- General improvement of the NDT process by digital administration of all documents in the release process of the pipe
- Automated long-term archival of all documents including X-ray images
- Reduced number of X-ray tubes (4 tubes in 2 chambers instead of 12 tubes in 3 chambers)
- Increased reliability of evaluation by optimised viewing conditions and automated evaluation assistant

The complexity of these targets makes it obvious that it was impossible to reach them by just re-fitting the X-ray chambers. The whole NDT process had to be reconsidered and adapted.

4. Technical description of the E-FLORAD system

4.1 Detector and X-ray tube

The detector type used is a Varian Paxscan 2520 system with a Gadox scintillator screen. One key advantage of this detector for this application is its relatively small size of 267mm x 328 mm which makes it possible to use it inside even the smallest pipes. The pixel area is 194 mm x 244 mm with a pixel pitch of 127 µm. The grey level resolution of 12 Bit is absolutely sufficient for this kind of weld seam inspection.

The X-ray tube type used is a GE ISOVOLT 320/7. The maximum power with the small focal spot is 960 W.

4.2 Layout of X-ray chambers and testing procedure

The layout of the X-ray chamber is sketched in figure 1. The pipe is moved over a cantilever type spar into the chamber via a roller table. The chamber gate (not shown) is closed and the spar is supported at the free end to avoid vibrations (support not shown). The pipe is turned to the 12 o’clock position. The detectors mounted inside the spar and the X-ray tubes are automatically moved to the testing positions and the images are recorded. When the testing

process is finished, the pipe is moved out of the chamber. The whole process is completely automatic. For each image recorded, an associated parameter file is created which completely documents the whole testing process including all X-ray parameters and pipe data.

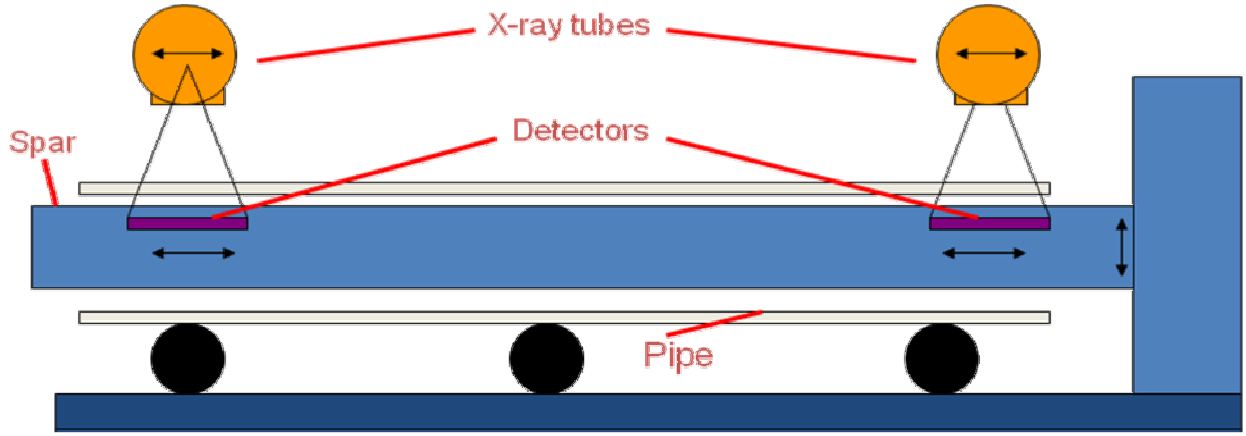

Figure 1: Layout of X-ray arrangement

Figure 2 shows a photo of an X-ray chamber with a pipe, the green spar and the two carriages above the pipe containing the X-ray tubes. When the pipe ends are tested, lead plates are pneumatically attached to the pipe ends in order to protect the detectors.

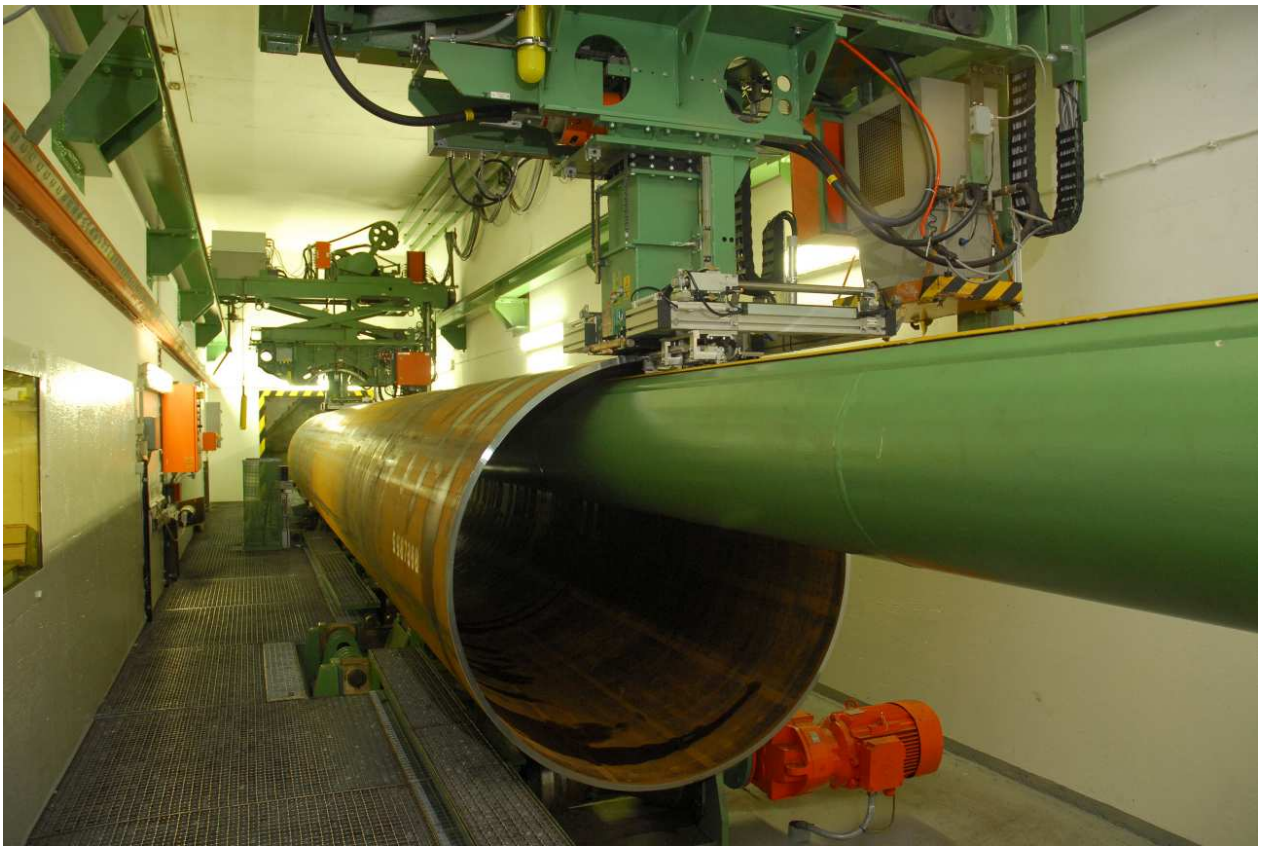

Figure 2: Photo of X-ray chamber

4.3 The PRODIS mill information system

PRODIS is a mill information system used within EUROPIPE which controls and keeps track of each pipe during the whole production process. Therefore, with the transition from film to digital detectors, the new possibilities of digital document administration were included into PRODIS.

4.3.1 PRODIS and the testing process

When the pipe arrives in front of the X-ray chamber, PRODIS transmits all data required for the testing process to the E-FLORAD system which automatically carries out the tests with the help of a PLC. The images themselves and the parameter files are stored on the storage system of the E-FLORAD computer cluster.

4.3.2 PRODIS, E-FLORAD and the image evaluation process

PRODIS always keeps a list of all images recorded. The image evaluators select a pipe at their PRODIS terminal and immediately see the list of images ready for evaluation. They select an image at the PRODIS terminal and the image is automatically displayed on the associated E-FLORAD image evaluation station. The E-FLORAD image viewer provides all the tools necessary to judge the image, including the usual brightness and contrast adaptations, filters, geometrical measurement tools to determine the size of defects (the calibration is automatically determined by the geometrical data stored in the parameter file) and to measure the signal to noise ratio of the image. The result of the evaluation is stored in the PRODIS system.

4.3.3 PRODIS and the release process

PRODIS administers the data access of all orders by login and password for the third party inspectors. It assists the release process by an interactive release list. Herewith it guarantees a quick access to all relevant inspection reports and X-ray images. Through online connection with the NDT department additional activities like re-shots can easily be initiated by inspectors. PRODIS assures the highest amount of traceability and integrated quality management.

4.4 The E-FLORAD computer system

The E-FLORAD computer system is a completely redundant cluster of highly reliable OpenVMS servers all of which are redundantly attached to a common high-performance fibre channel RAID-1 storage system.

E-FLORAD is connected via TCP/IP to PRODIS, the PLCs for the control of the mechanics of the X-ray chambers and to the long-term archival system DOKAS described in section 4.5. Furthermore, an unlimited number of image evaluation stations may be attached to the E-FLORAD system via TCP/IP. Thus, the image evaluators, the responsible NDT engineer, the external inspector or whoever in the mill has the right to see the X-ray images may inspect them, with the access rights administered by PRODIS.

4.5 The DOKAS archival system

E-FLORAD has the capacity to store all images locally for several months. Due to the redundant design, absolute data safety and integrity is guaranteed. However, for the long term storage the images are transferred to a redundant archival system called DOKAS. DOKAS consists of 2 identical systems equipped with high-capacity tape storage robots located in

different buildings on the Mülheim premises in order to provide a high degree of disaster tolerance. The whole archival process also works completely automatically. Data integrity is guaranteed by use of a checksum stored independently on PRODIS and DOKAS. In case off-line images are required they are automatically restored to E-FLORAD from DOKAS.

5. Image quality and standardisation

5.1 Film radiography

For film radiography a comprehensive set of standards exists which describe every aspect from the films themselves over exposure geometries, film processing required optical density up to the film viewing conditions. By adhering to the standards sufficient image quality is guaranteed.

5.2 Digital detector arrays

Currently there are no standards for digital detector arrays. Neither are there standards for the measurement of detector properties nor for the application of the detectors. Nevertheless, the knowledge about the properties of DDAs has increased considerably in the past years which makes it possible to define rules for the proper use of DDAs for a special application.

One of the most renowned institutions in the field of DDAs is the Bundesanstalt für Materialforschung und –prüfung (BAM) in Berlin. Therefore EUROPIPE and SZMF have asked BAM for a qualification of the E-FLORAD components and procedures before the system was installed in the mill. The required trials were carried out in the X-ray laboratory of SZMF.

In the qualification statement, BAM has defined guidelines to prove image quality by

- Single wire IQI for contrast resolution (as with film)
- Double wire IQI for spatial resolution (additional requirement)
- Measurement of S/N ratio (equivalent to film density and class)

When these guidelines are followed the E-FLORAD system fulfils all applicable standards (API 5L, DNV–OS-F101, EN 1435, EN 10246-10, EN 13068-3). Of course, these guidelines are fully implemented in the work instructions for the operation of the system in the mill.

6. Conclusion

By the image integration technique a signal-to-noise ratio which is at least twice as good as a conventional C4 X-ray film is achieved. Combined with an enlarged display on a high resolution monitor and a contrast improvement of the 12 bit images the probability of detection of weld seam defects is even better than with conventional film technique. As a matter of course this set-up fulfils all requirements defined for X-ray films. With the benefit of directly available digital images, E-FLORAD improves the complete NDT process. All reports referring the pipe like hydrostatic report, UT-report, X-ray images are directly accessible via network, which enables easy communication between third party inspectors and the NDT department. All data are stored for at least 12 years and are accessible within minutes.

For EUROPIPE, the transition to filmless radiography has been a great success. In the first quarter of 2007, film costs of about 125,000 € were saved. The number of re-shots was

reduced from 7.5 per cent to 1.5 per cent. Maintenance contracts for the developer machines and hazardous chemicals are no longer needed. Disposal of film envelopes and expensive film archival are obsolete.

All customers so far have appreciated the system and confirmed as a step into the future.

Acknowledgement

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