

Safety Notice

Application of radiography to measure the remaining wall thickness of external corrosion

Summary of issue

Tangential (profile) radiography is commonly used for in-service inspection of externally corroded components in the oil and gas industry. Recently it has become apparent that for some forms of localised corrosion, significant underestimates of severity can be obtained. In extreme cases, almost through-wall corrosion can be missed completely, unless the radiation source and film/detector are aligned optimally so that the tangent position is at the point of greatest wall loss. Even then, the measurements of minimum remaining wall thickness may be significantly higher than the actual value. The magnitude of this under-sizing however depends on the morphology of the corrosion, and more extended areas of corrosion can be less affected and hence may be more accurately sized.

Tangential/Profile radiography

Industrial radiography is commonly used for in-service inspection of externally corroded components in the oil and gas industry. Both computed radiography and film are widely employed as detectors, typically in conjunction with Iridium 192 or Selenium 75 isotope sources of radiation.

The tangential (or profile) radiographic technique gives a direct image of the pipe walls, and allows dimensional measurement of remaining wall thickness at the tangent positions. The advantage of this technique is that, in principle, the remaining wall thickness can be measured in cases where the corrosion product (e.g. scab) is still in-situ, and when the corrosion is under insulation (CUI).

Limitations for external corrosion assessment

The tangential radiographic technique provides measurements of remaining wall thickness only at two circumferential locations, i.e. the tangent positions which are separated by nearly 180° around the pipe circumference, as shown in Figure 1:

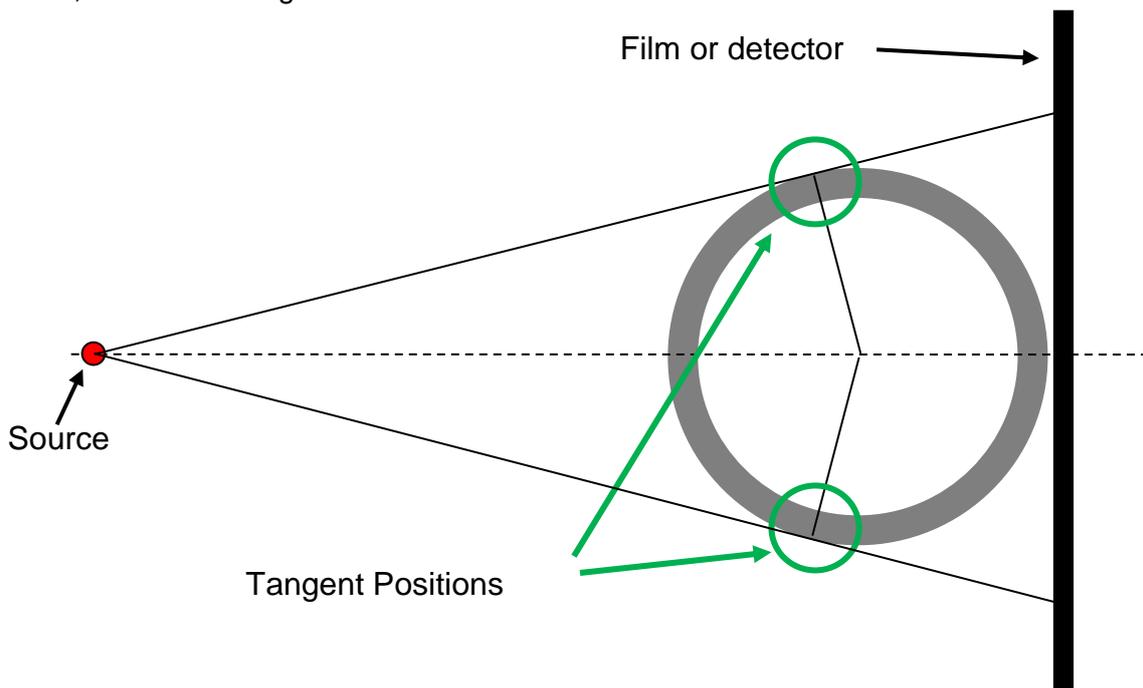


Figure 1. Setup for tangential (profile) radiography showing the tangent positions

It is common practice to take only one radiographic image, or two orthogonal images, which result in only two or four spot measurements of remaining wall thickness at about 90° or 180° intervals, respectively.

The accuracy of the spot wall thickness measurements obtained with this technique depends on a number of factors. Recent trials performed within the HOIS JIP in accordance with the recently published standard EN 16407-1 have shown that errors up to about 0.5mm may occur when using the most accurate analysis technique on uniform wall thickness (i.e. uncorroded) pipes. Some simpler techniques (e.g. those based only on cursors superimposed on a digital radiograph) may well give larger errors up to about 1mm. Even larger errors may be expected for visual interpretation of a film radiograph where “burn-off” can blur the measurement from the pipe OD, although no studies within HOIS have been performed to assess the magnitude of this effect.

For external corrosion however a number of examples have been found of larger under-sizing errors, three of which are described below.

Case Study 1: Localised 6mm high scab on 6" schedule 40 pipe

For an ex-service 6" schedule 40 pipe with a 6mm high external corrosion scab (see Figure 2), it was found that a series of exposures needed to be taken with an angular increment of 5° or less around the tangent position to find the deepest point on the corroded area, which extended over about 30° of the circumference. At the thinnest point, the interpretation of the corresponding digital radiograph was complicated by the presence of features within the pipe wall. If these were ignored, the remaining ligament measured from the radiograph was 3.4mm, which was 1.5mm larger than the accurate value of 1.9mm derived by precision internal ultrasonic inspection. Alternative interpretations, using the internal features within the pipe wall gave values closer to the actual value on this image but on others, at different angles, the remaining ligament measured in this way was less than the actual value.



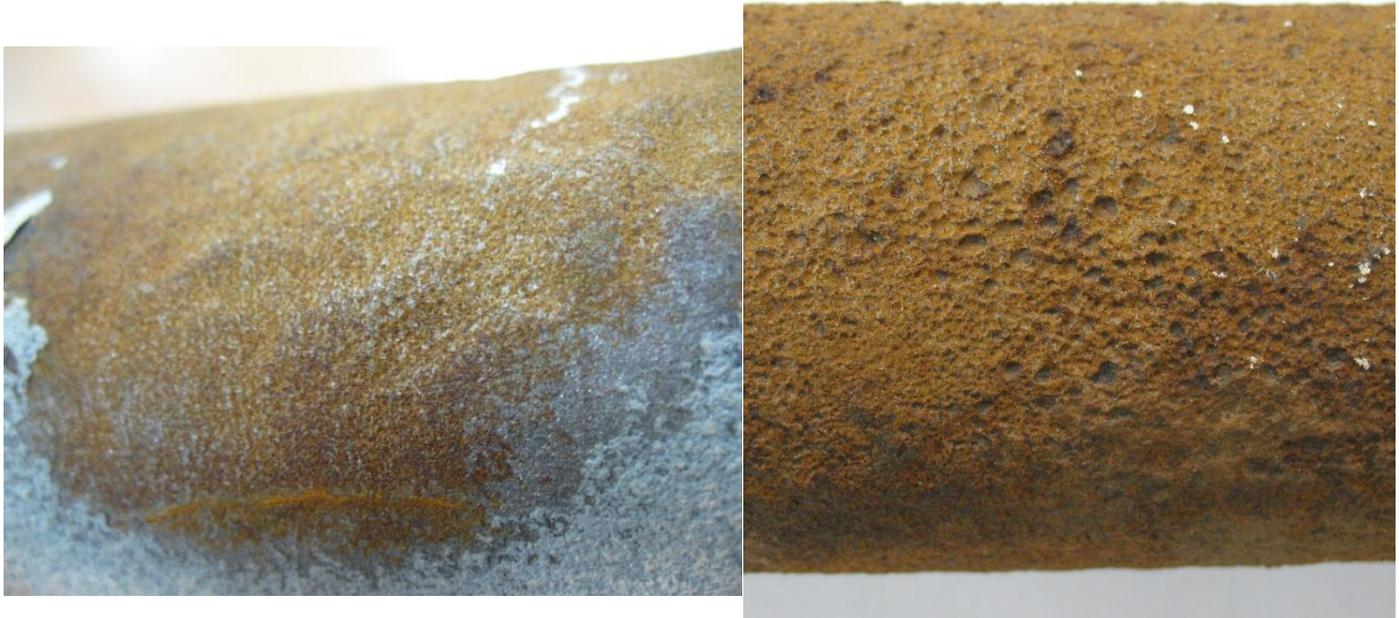
Figure 2. Corrosion scab under sized by ~1.5mm using tangential radiography

In contrast, for another 6" schedule 40 pipe with a more circumferentially extended corrosion scab, the interpretation of the images were not complicated by additional structure within the pipe wall and the sizing agreed with the benchmark data to within about ±0.5mm.

The presence of structure/features apparently within the pipe wall, on the radiographs from the localised scab shown in Figure 2, may provide a method for recognising when interpretation is difficult and under-sizing, using the apparent outer edge of the wall, can occur, but does not give more accurate values.

Case Study 2: Scabs on small bore pipes with external wall loss some of which contained fine pitting

A number of similar looking externally corroded small bore (2") pipes were radiographed at 10° intervals and the minimum wall thickness was derived for each radiograph. Subsequently the corroded areas were blasted to remove the external corrosion product. It was only then found that the corrosion underneath the scabs was of two very different forms. For some of the pipes, the corrosion had left a gently undulating steel surface, Figure 3(a), whereas for others, a finely pitted steel surface was revealed by the blasting, with an almost honeycomb like appearance, Figure 3(b).



(a)

(b)

Figure 3. Two different forms of corrosion revealed after removal of the corrosion product (a) an even, undulating surface and (b) finely pitted surface.

Comparison of the radiography measurements of remaining wall thickness with benchmark values derived from the blasted pipes showed that for the finely pitted surface, the remaining wall thickness had been overestimated by up to 1.3mm, whereas for the more undulating surface much better agreement was found, to within ± 0.5 mm. Careful examination of the corresponding radiographs for the finely pitted pipes showed some evidence for the pitting in the double-wall double image (DWDI) region of the image, and in addition the OD profile was somewhat ragged or irregular, as illustrated in Figure 4.

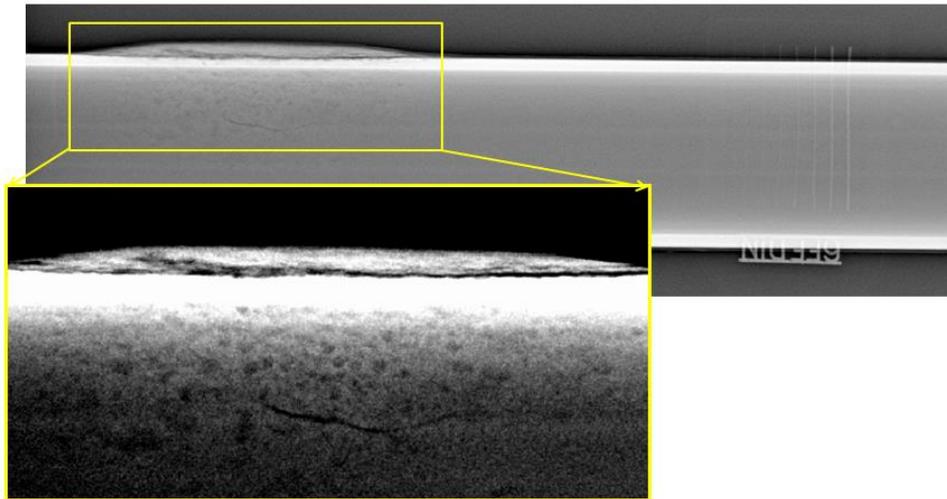


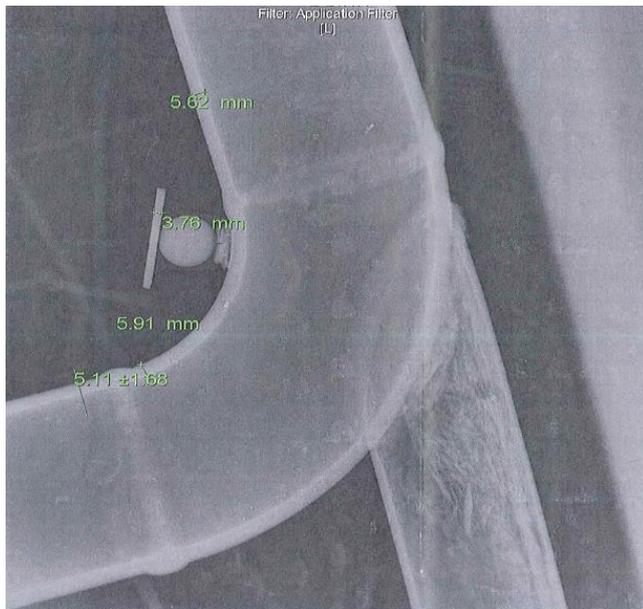
Figure 4. High pass filtered digital radiograph and magnified section with contrast settings optimised to show the fine pitting in the DWDI region of the image

However these features were not immediately apparent and required some optimisation of the image contrast and high pass filtering to show them clearly. Hence they could be missed unless specifically searched for by an experienced operator trained to look for them. Thus as with case study 1, careful examination of the radiographs can provide a method for recognising when under-sizing occurs, but does not, in itself, give more accurate values.

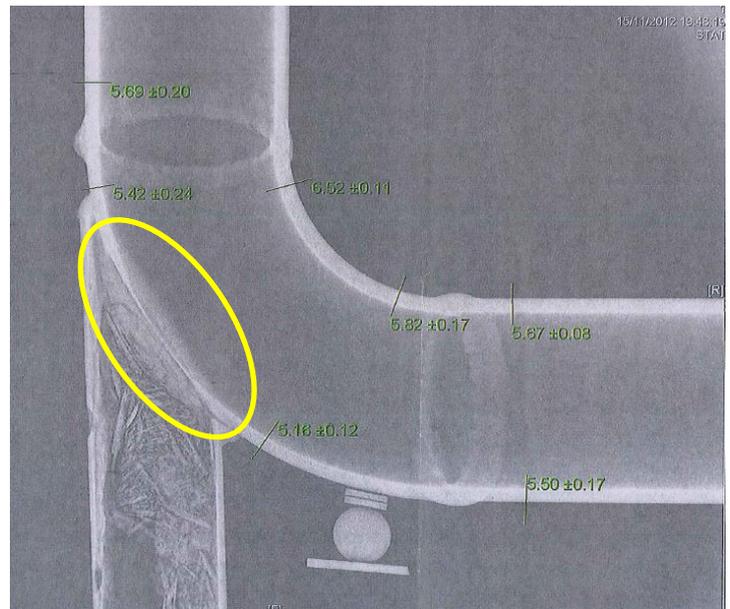
Case Study 3: Leak at trunnion support

In-service tangential computed radiography (CR) was performed on a trunnion support, but the area of external corrosion was not accurately aligned with the tangent position due to site constraints (adjacent pipework prevented the source and detector being positioned in the optimum locations). As a result, there were difficulties in the interpretation of the image, and no significant corrosion was reported from the CR image (see Figure 5 - left), but there was a known leak due to corrosion in the area. On Figure 5 (left) note that there is no sign of substantial wall loss. However, there are clues to the experienced operator that the image is misaligned and therefore unreliable for wall thickness measurement i.e. the edges of the pipe are not well delineated and the elliptical nature of the trunnion to pipe weld image.

This component was then cut-out and removed from service. Subsequent CR images were obtained with improved quality and without the site restrictions in the positioning of the source and detector, so that the corroded area could be better aligned with the tangent position. In addition, the source to detector distance was increased to reduce geometric unsharpness. This second CR image (see Figure 5 - right) clearly shows major corrosion, with a considerable section of the bend extrados having near zero apparent wall thickness.



Misaligned in-service CR image (no clear wall loss)



Better aligned CR image showing extensive external wall loss

Figure 5 Computed Radiography (CR) images – original in-service image (left) and image with source and detector better aligned (right), following removal from service

Lessons Learned

- The tangential radiography technique is only capable of providing measurements of the wall thickness of a pipe at positions very close to the tangent position(s), which depend on the exact positions of the source and detector.
- For some forms of localised external corrosion, which are misaligned from the tangent position by as little as 10-20°, the resulting measurements of wall thickness may be significantly higher than the actual minimum value, and may even miss the wall loss completely.
- Even with optimum positioning of the source and detector, some examples of external corrosion can be significantly undersized. In one case in which the corrosion extended over 30° of the circumference of a 6" pipe, covered by a 6mm high scab, the resulting radiographs were difficult to interpret and using the location of the apparent outer edge of the pipe wall in the image, under-sizing was as much as ~1.5mm (the radiography gave a minimum ligament of 3.4mm, compared with an accurate value of only 1.9mm). Alternative interpretations of the radiographs, using features within the pipe wall may overestimate the extent of the wall loss. In another example, the external corrosion resulted in fine pitting, superimposed on larger scale wall loss. The fine pitting was not included in the resulting measurements of remaining wall thickness which again resulted in substantial (~1.3mm) under-sizing of the corrosion when using tangential radiography.
- Careful interpretation of the radiographic images of the pipe wall under localised corrosion scabs, and those scabs that cover fine pitting, can show characteristic features that are indicative of the likelihood of complex interpretation and the risk of significant under-sizing but does not, on the basis of current knowledge, provide a means for improved sizing.
- For more circumferentially extended and/or less deep corrosion, without any fine pitting, these issues are less significant and a typical accuracy of $\pm 0.5\text{mm}$ is likely to be achievable using optimal sizing techniques applied to digital radiography images.

Recommendations

- All in-service radiography of pipes should be performed in accordance with the newly published European standards EN 16407 parts 1 and 2, and Issue 2 of the HOIS recommended practice for in-service computed radiography, which can be downloaded from www.hoispublications.com.

- If localised external corrosion is known to be present, extending over a small fraction of the pipe circumference, when performing tangential (profile) radiography, care must be taken in aligning the source and detector such that the tangent position is as close as possible to the centre of the corroded area or the highest point of the scab (i.e. the point of apparent greatest severity of the corrosion).
- Exposures at different angles are needed either side of the apparent position of greatest severity of the corroded area to find the point of maximum wall loss/minimum thickness. The angular increment for these radiographs depends on the pipe diameter and corrosion morphology/circumferential extent. Typical values may be as small as 5° for significant corrosion extending over only a small fraction of the circumference of a 6" OD pipe, and 10-15° for more extended corrosion on small bore piping.
- If any fitness for service (FFS) assessments are performed based on the measurements from tangential radiography of localised external corrosion, a substantial tolerance should be applied with the minimum ligament for FFS being *less than that measured*. There is limited information currently on the magnitude of this tolerance, but a value of about 1.5 mm is indicated from an example of a 6mm high external corrosion scab extending over ~30° of the circumference in a 6" OD pipe. A similar value is indicated for an example of corrosion that gave a finely pitted surface, superimposed on larger scale wall loss. In safety critical cases, for radiographs showing evidence for under-sizing of the corrosion, it may not be appropriate to use tangential CR measurements for FFS assessments.
- In other cases, involving more extended and/or shallower corrosion without any fine pitting, smaller tolerances of about 0.5mm may be possible, provided the sizing method is based on careful analysis of grey level profiles taken from digital radiographic images. This smaller tolerance could only be justified if the corresponding radiographs have been assessed by a suitably trained and competent operator to be free of any of the features which can cause significant under-sizing (structure in the pipe wall image, irregular or poorly defined OD profile or evidence for fine pitting in the double-wall double image region of the image).
- In any case where the measurements from tangential radiography of localised external corrosion are used to support live surface preparation by shot blasting, a substantial tolerance may need to be applied similar to that noted for FFS above.

For further information or comments, please contact

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