CORRODION EVALUATION OF PIPES BY RADIOGRAPHY

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Abstract: This study is a new attempt followed the research project conducted by IAEA in a Contract Research Project (CRP). In this new challenge, the reference blocks designed to minimize the deficiencies occurred in previous project, which also covers higher diameters. Different artificial defects were made in the reference blocks consisting step reduction in thickness to represent the general corrosion, flat bottom holes with different depth in each step and a groove for pitting and local corrosion. Diminutions of defects are related to the thickness of the portion to give better density evaluation and respectively more precision. Density evaluation of Double Wall Radiography of prepared reference blocks as well as Tangential Radiography showed that these methods can be implemented with acceptable reliability for pipe wall corrosion evaluation which could lead to draft a standard procedure.

Introduction: Corrosion in the pipes and remaining wall thickness measurements are major concern in the piping service life. This problem is vital when pipe carries hazardous substance. Lifetime estimation depends highly on the operating and environmental condition. So routine inspection is quite necessary which usually requires removing the insulation and applying the required method. This inspection takes time and is more costly due to repair of insulation.

Evaluation of corrosion by radiography has been studied before but quantitative evaluation and standardization have not achieved yet. Industries would prefer to apply this method with more reliability. Two techniques can be implemented in this respect:

Tangential Radiographic Technique (TRT) (shown in Fig. 1a) [1,2,3,4,5]

Double Wall Radiographic Technique (DWT) (shown in Fig. 1b) [6,7]

The aim of present study is to investigation of the accuracy of radiographic method for evaluation of internal and external corrosion in 6 and 10 inch pipes.

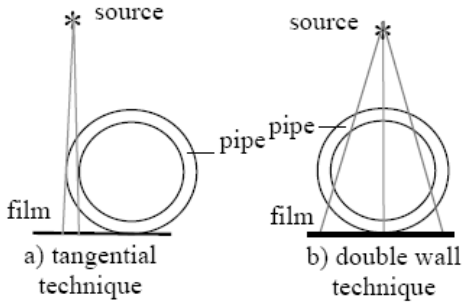


Figure 1: Radiography techniques for corrosion evaluation in pipes: a) TRT and b) DWT

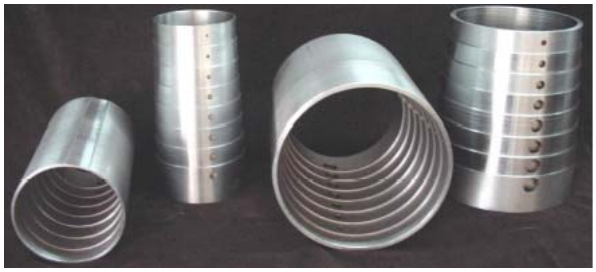


Figure 2: Reference blocks fabricated from 6 and 10 inch pipes

Materials and Methods: Four reference blocks, as shown in Fig. 2, with specification shown in Tables 1 to 4, were prepared. Material of blocks was St-37. Step reduction of wall thickness from inside and outside the pipes, three flat bottom holes with depth of 10%, 20% and 50% on each step with diameter of holes to be equal to step thickness, a flat surface with 1.5 mm depth for 6 inch and 2.7 mm for 10 inch outside and along the axes and groove of about 1.5 mm inside and opposite to the steps of the pipe was considered.

For density evaluation, DWT was used with the arrangement as shown in Fig. 2b, and TRT was done in the arrangement as shown in Fig. 2a. A gamma projector with Ir-192 source and Kodak AA-400/pb films were used for exposures. Film processing was done manually in 21 °C, according to specifications and an X-Rite densitometer was used for optical density measurements of radiographs.

In TRT exposure times were chosen so that density in maximum penetration length of step 4 was reached to 1.0 to 1.5. In DWT the exposure times were chosen so that on the middle step of the reference blocks the density was reached to 2.0. For interpretation the density was not below 1.0 and the maximum density was 4.5. Density on the wall and object was determined and by the following equation the corroded depth was determined:

$$h = \frac{1}{\mu} Ln\left(\frac{D_c - D_f}{D_b - D_f}\right) \quad (1)$$

where h is the corrosion depth, μ is the effective linear atomic absorption coefficient and was assumed $0.041 mm^{-1}$ which is different than its real value, D_c, D_f and D_b are optical density of corroded area, fog density and density in none corroded area of pipe, respectively.

In TRT thickness was measured on the film and by the following equation due to magnification factor real thickness was calculated:

$$w = w'.\left(1 - \frac{OD}{2.SFD}\right) \quad (1)$$

Where w' is measured wall thickness on film, w is real wall thickness, OD is outer diameter of pipe and SFD is source to film distance.

Table 1: Technical data for 6 inch pipe with outside machining

Step Number	Step Wall Thickness, mm	Step Width, mm	Hole 10% mm		Hole 20% mm		Hole 50% mm	
			Dia.	Depth	Dia.	Depth	Dia.	Depth
1	15.0	69.3	15.1	1.5	15.0	3.0	15.0	7.5
2	13.5	35.0	13.5	1.4	13.5	2.7	13.5	6.7
3	12.0	35.0	12.1	1.3	12.0	2.4	12.0	5.9
4	10.5	35.0	10.5	1.1	10.5	2.1	10.5	5.2
5	9.0	35.0	9.0	0.9	9.0	1.8	9.0	4.6
6	7.5	35.0	7.5	0.7	7.5	1.5	7.5	3.7
7	6.0	35.0	6.1	0.6	6.0	1.2	6.0	3.0
8	4.5	34.4	4.4	0.4	4.4	0.9	4.4	2.2

Table 2: Technical data for 6 inch pipe with inside machining

Step Number	Step Wall Thickness, mm	Step Width, mm	Hole 10% mm		Hole 20% mm		Hole 50% mm	
			Dia.	Depth	Dia.	Depth	Dia.	Depth
1	14.7	69.4	14.7	1.5	14.7	2.9	14.6	7.4
2	12.0	34.9	12.8	1.2	12.8	2.7	12.8	6.5
3	11.5	35.1	11.4	1.2	11.4	2.2	11.4	5.6
4	10.1	34.7	10.2	1.1	10.1	2.2	10.0	5.1
5	8.6	33.1	8.6	0.9	8.6	1.9	8.6	4.2

6	7.1	36.9	7.1	0.6	7.0	1.6	7.1	3.5
7	5.6	35.0	5.7	0.5	5.6	1.1	5.6	2.8
8	4.2	35.0	4.3	0.4	4.3	0.8	4.2	2.1

Table 3: Technical data for 10 inch pipe with outside machining

Step Number	**Step Wall Thickness, mm**	**Step Width, mm**	**Hole 10% mm**		**Hole 20% mm**		**Hole 50% mm**	
			Dia.	Depth	Dia.	Depth	Dia.	Depth
1	28.4	69	28.7	2.9	28.6	5.6	28.6	14.3
2	27.0	35	27.4	2.9	27.3	5.4	27.3	13.8
3	24.0	35	24.4	2.4	24.4	4.9	24.4	12.2
4	21.0	35	21.4	2.1	21.4	4.2	21.3	11.0
5	18.0	35	18.2	1.8	18.2	3.6	18.2	9.0
6	15.0	35	15.4	1.6	15.4	3.1	15.3	7.7
7	12.0	35	12.3	1.3	12.2	2.5	12.2	6.0
8	9.0	35	9.3	1.0	9.3	1.8	9.3	4.6

Table 4: Technical data for 10 inch pipe with inside machining

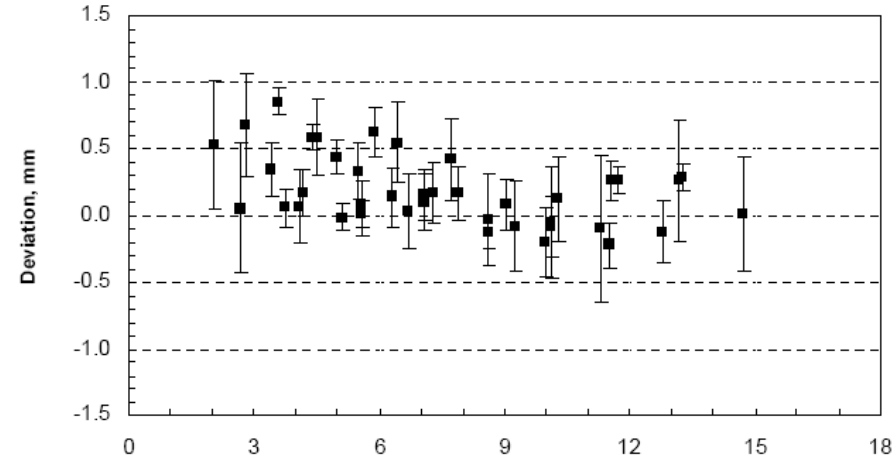
Step Number	**Step Wall Thickness, mm**	**Step Width, mm**	**Hole 10% mm**		**Hole 20% mm**		**Hole 50% mm**	
			Dia.	Depth	Dia.	Depth	Dia.	Depth
1	28.5	70	28.5	3.0	28.6	5.7	28.6	14.4
2	25.6	35	25.7	2.7	25.6	5.1	25.6	12.6
3	22.2	35	22.9	2.1	22.8	4.4	22.7	11.0
4	19.4	34	19.7	1.9	19.8	3.9	19.5	9.8
5	16.4	35	16.4	1.7	16.6	3.25	16.4	8.1
6	13.1	35	13.8	1.3	13.8	2.8	13.7	6.7
7	10.2	35	10.2	1.0	10.4	2.0	10.4	5.1
8	7.4	35	7.4	0.7	7.4	1.4	7.4	3.6

Results and Discussion: The error of thickness measurements by TRT for inside-machined and outside-machined 6 inch blocks can be seen in Figs. 3a and 3b, respectively. Unfortunately due to high beam path thickness in 10 inch pipes, Ir-192 radiation can not be used for TRT of these pipes and a high energy source such as Co-60 should be used for this purpose. It is observed that maximum error of measurements is 1.0 mm and the maximum standard deviation is almost 0.5 mm. Also it is observable that the accuracy of TRT for internal corrosion is better than external corrosion. It is due to burn out effect.

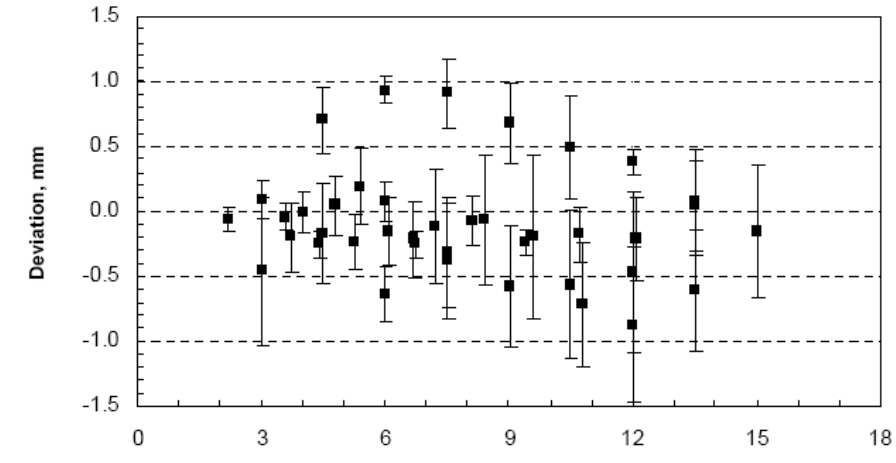
The beam should be passed from the internal tangential thickness in the TRT. So, the required radiation energy and exposure for this method is higher than that one required in DWT. For example the exposure in DWT for 6 inch pipes was 200 ci.min and for TRT was 600 ci.min. But TRT provides more advantages over DWT in determination the thickness of insulates, pipe and deposit as well as detecting internal and external corrosion. Also DWT is more practical in pipes with liquid filler substance as compared with DWT.

The results of corroded depth measurements for 6 and 10 inch pipes are observed in Figs. 4a to 4d. It can be seen that this method has a maximum deviation of 0.5 mm in 6 inch pipes and almost 1 mm in 10 inch pipes. This accuracy is comparable with ultrasonic measurement results. The most important difficulty in this method is determining the linear atomic absorption of pipe material, due the effect of build up factor.

Other investigations of authors show that numerical methods can be used for determination of remained pipe wall thickness by densitometry [8].

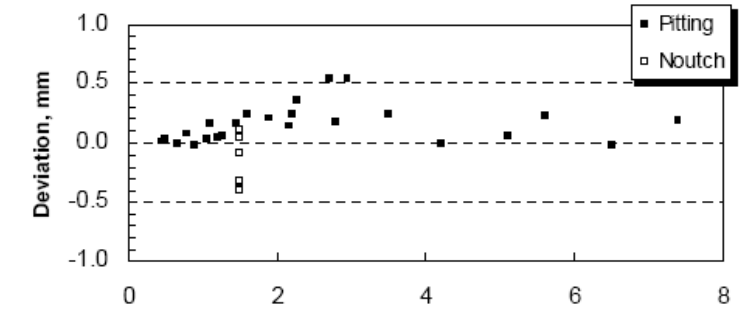


a)Inside-machined
6 inch step block

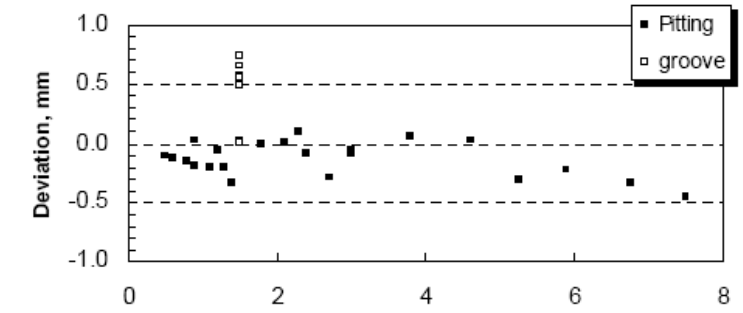


b) Outside-machined
6 inch step block

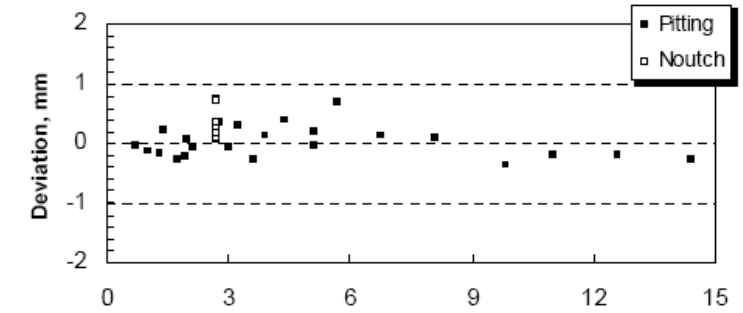
Figure 3: The deviation of TRT as a function of remained pipe wall thickness for 6 inch reference blocks



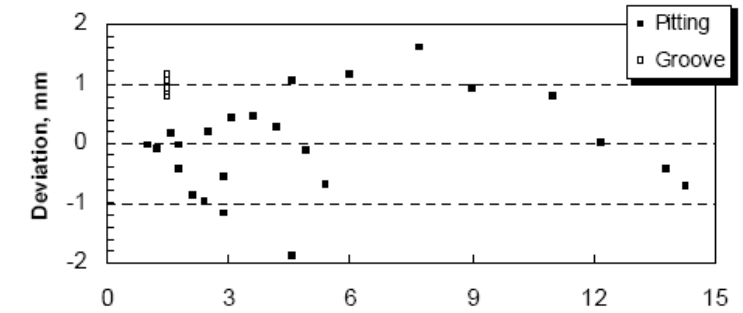
a) Inside-machined
6 inch step block



b) Outside-machined
6 inch step block



c) Inside-machined
10 inch step block



d) Outside-machined
10 inch step block

Figure 4: The deviation of DWT as a function of corroded depth for 6 and 10 inch reference blocks

Conclusions: Tangential radiography and double wall radiography (by density evaluation) was used for corrosion evaluation in 6 and 10 inch pipes. Results indicated that in tangential radiography, deviation of thickness measurements was almost 0.5 mm and in double wall radiography, deviation of corrosion depth measurements was 0.5 mm in 6 inch pipes and almost 1 mm in 10 inch pipes. Also it is observed that 10 inch pipes could not be evaluated by Ir-192 in TRT.

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