Proceedings of the National Seminar & Exhibition on Non-Destructive Evaluation
NDE 2011, December 8-10, 2011

USE OF PROFILE RADIOGRAPHY TECHNIQUE FOR IN-SERVICE INSPECTION IN PETROLEUM REFINERY- CASE STUDIES

V. S. Desai, Mahendra Pal, Mayank Banjare, Chandana Nancharaiah, Sushil Guria and Harsh Vardhan
Indian Oil Corporation Limited, Guwahati Refinery, Guwahati, Assam, India- 781020

ABSTRACT

Profile radiography is a powerful, effective and simple technique for inspection of piping vulnerable to internal and external corrosion. There are situations during inspection where it is not possible to cut open the piping or remove the external insulation of the piping for inspection. In such circumstances this technique comes handy. This technique was used to inspect hydrogen reformer outlet pigtail / weldolet for determination of remaining pipe wall thickness, as conventional UT thickness measurement was not possible (due to geometry of the weldolet). This technique was also employed for CUI (corrosion under insulation) study of insulated piping in ISOSIV unit to detect any deterioration by external corrosion. In both the cases, this technique gave excellent results which were cross checked with visual findings.

Keywords: Profile Radiography, Corrosion under Insulation (CUI), Weldolet, Pigtail

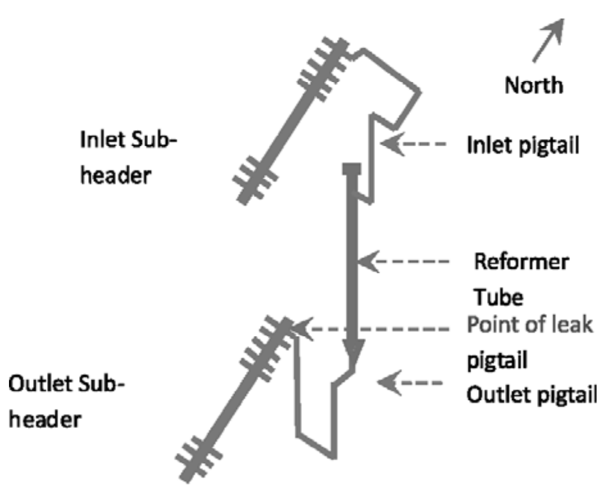
INTRODUCTION

Reliability of a process unit operation is to a large extent dependent on the reliability of its mechanical equipments. In refineries there are huge networks of pipelines running in kilometer length , to examine the health of these pipelines it is not possible always to remove external thermal insulation of the pipelines during service or even at short shutdowns. At the same time, if pipelines are not examined and maintained in good condition it may lead to failures by means of leakage which will not only lead to upset in the unit operation but also cause indirect throughput loss/ shutdown of its dependent units or even lead to a disaster.

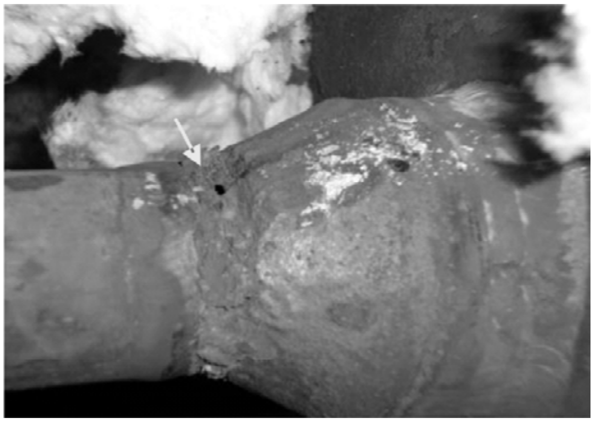
This paper describes use of profile radiography technique as an inspection tool for quick determination of remaining pipe wall thickness and extent of external/ internal corrosion in two situations namely, in-service and another during shutdown where other NDT like ultrasonic test cannot be performed due to constraint in geometry of the pipe sections.

CASE-I: USE OF PROFILE RADIOGRAPHY FOR HYDROGEN REFORMER OUTLET PIGTAIL WELDOLET INSPECTION

Reformer section is the heart of Hydrogen generation unit. The reforming reaction takes place inside the reformer tubes operating at 900-920 °C in the presence of nickel based catalyst. The process gases coming out of the reformer furnace is a mixture of H_2, CO, CO_2 and CH_4. A Pinhole leakage developed during operation from one of the reformer outlet weldolet. This weldolet assembly is a forged product where conventional ultrasonic inspection is not possible due to the geometry of the part. Also, inspection using videoscope /or boroscope is not possible. Cutting the part is also not allowed, as it is a costly material and can cause catalyst damage. The best method available is therefore profile radiography. Sketch-1 below shows the reformer configuration and the leaking weldolet location.



Sketch 01: Reformer Inlet-Outlet Pigtail Arrangement



Photograph No. 01: Leaky weldolet showing 5mm dia. hole at neck portion. Severe external scaling marks can also be seen.

Photograph No. 02: Pitting marks and general surface grooving (1.5 mm deep) noticed on external surface of weldolet.

Process Parameters

- Design Pressure (normal operation): 27 kg/cm^2 (g)
- Design Temperature: 880°C
- Operating temperature for outlet pigtail is in the range of 820-822 ° C.

Material of Construction (M.O.C.)

- Weldolet: Alloy 800HT (B408 UNS 8811), 36nos.

Visual Observation

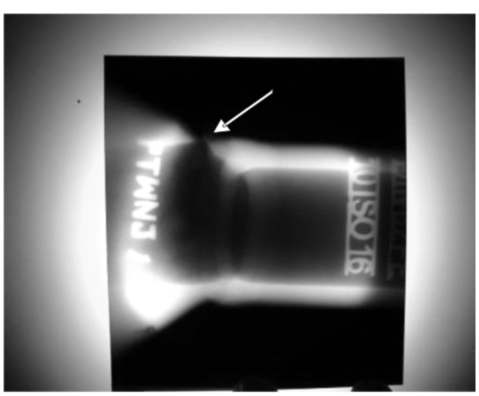
A leak was noticed in one of the outlet pigtail weldolet from 12 o'clock position. A hole of approximately 5 mm diameter was noticed at the leaky spot (Photograph no. 1). Grayish color loose scales were noticed on weldolet external surface. Uniform roughening and pitting was also noticed on entire surface of the weldolet. Approx. 1-1.5 mm thick external surface of the weldolet was found corroded/ scaled-up leading to shining appearance (photograph no. 2).

Connected pigtail and header external surface showed greenish black hard adherent scale typical of nickel based alloys. Neither oxidation mark nor excessive scaling/ corrosion were noticed on either of pigtail or outlet common header. Welding joint of pig tail to weldolet and weldolet to out let header also appeared to be in good condition without any sign of deterioration - scaling/ oxidation. The metal surface was found smooth. During visual inspection for inner side of pigtail, deposits were noticed.

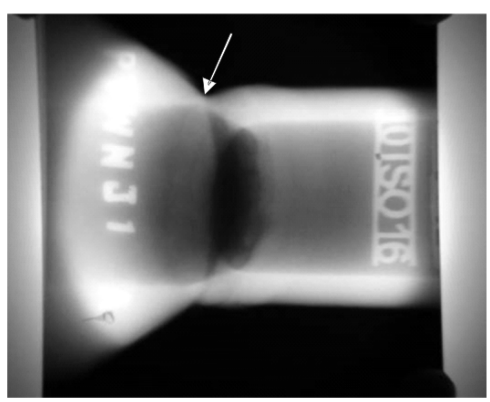
Profile Radiography Examination

As discussed previously, Profile radiographic examination was selected for identifying the remaining wall thickness and corrosion behavior on the inner surface of all 36 nos of outlet weldolets, including the leaking weldolet assembly , for accurate decision making. Ir-192 source of 5 Curie activity was used for carrying the radiography. It can be seen from the radiograph that there is no thickness loss in the pigtail pipe (photographs 03 ,04). The weldolet neck portion has corroded from external side at 12 o'clock position. The corrosion in the neck portion is preferentially in the 3 o'clock thru 12 o'clock to 9 o'clock position. There is no visible or appreciable corrosion from inner side.

Radiography of remaining 35 numbers of outlet weldolet assembly were matching with the visual observations. The deterioration was primarily on the external surface in the neck portion of the weldolet.



Photograph No. 03: RT Film



Photograph No. 04: RT Film

Jobs Carried Out

Failed weldolet was repaired by replacing approx. 4" length of the pigtail starting from the weldolet. The new insert piece was provided by cutting a length of approx.100mm from the available spare new outlet pigtail (Alloy 800HT, 42.16mmX6.35mm). The external surface was ground to match the profile of the weldolet (to avoid stress concentration at this location).

In remaining 35 nos. of pig tail tubes, the externally corroded grooved portion of weldolet was weld built up to make up for the thickness loss detected by profile radiography using Inconel 625 (ER NiCrMo3) filler wire. Hard scale deposits near the corroded/ grooved neck of weldolet was removed by pencil grinder prior to weld built-up. After weld build up, these joints were DP tested and radiographed. Finally all the weld joints were tested by pressurizing with nitrogen for 3 hrs to observe any pressure drop.

It can be concluded that because of profile radiography technique it was possible to accurately and quickly identify all locations affected by corrosion and carryout timely repair to prevent a catastrophe. The plant was also put back in operation in minimum time.

CASE-II: USE OF PROFILE RADIOGRPAHY FOR CORROSION UNDER INSULATION EXAMINATION IN ISOSIV UNIT

What is Corrosion under Insulation (CUI)?

When CS metal surface comes in contact with aerated water, corrosion takes place (formation of corrosion cell).Corrosion rate depends on the metal temperature, pH and many other factors. Water infiltrates the damaged insulation and condenses on the metal surface surface. During this process the leach able chloride, halides or sulfates present in the insulation material & binder makes the environment conductive and conducive for corrosion. In an open system corrosion rate drops below 80^{o}C whereas in closed system it increases. CUI in CS is more prevalent in the temperature range –4 to 120^{o}C

The 18/8 series austenitic stainless steels(ASS) like SS304, 321, 316 etc, are most susceptible to CUI in the critical temperature range, also called “hot water range”, between 50 to 150^{o}C . The major corrosion mechanisms are External stress corrosion cracking (E.S.C.C) and Liquid metal embittermen LME. ESCC takes place due to the presence of leach able chlorides & halides from the insulation material or environment coming in contact with the stressed ASS component leading to such failures.

Methodology adopted for Examination:

Identifying locations prone to CUI involves following steps:

I) *Pre-inspection:*

(i) Location of the equipment: Identify the environment around the equipments from the plant layout. Equipments surrounded by high humidity areas like cooling tower or river, corrosive contaminants in the atmosphere like H_2S,SO_2, Chloride etc are more prone to CUI.

(ii) Temperature and Material of construction: For CS –4 to 150 deg C or cycling below or above the dew point temperature. For ASS 50 to 150 deg C or cycling below or above the dew point temperature.

Classification of piping circuits & process equipments based on operating temperature and prioritize them into category I,II and III.

- -4 to 120 Deg C – Priority I
- 120 to 150 Deg C – Priority II
- above 150 Deg C – Priority III.

(II) *Visual Inspection:*

Perform Visual inspection to establish moist insulations:

- By prioritizing the damaged insulations,
- Dead ends.
- Lowest points
- Moist insulation
- By passed line segments etc.

(III) *NDT for detection of CUI:*

Sometimes visual inspection may miss prone locations. Therefore, visual inspection must be supplemented by NDT inspection using:

a) Infrared thermography

b) Profile Radiography

Quantum of shots to be performed in Profile Radiography is as follows:

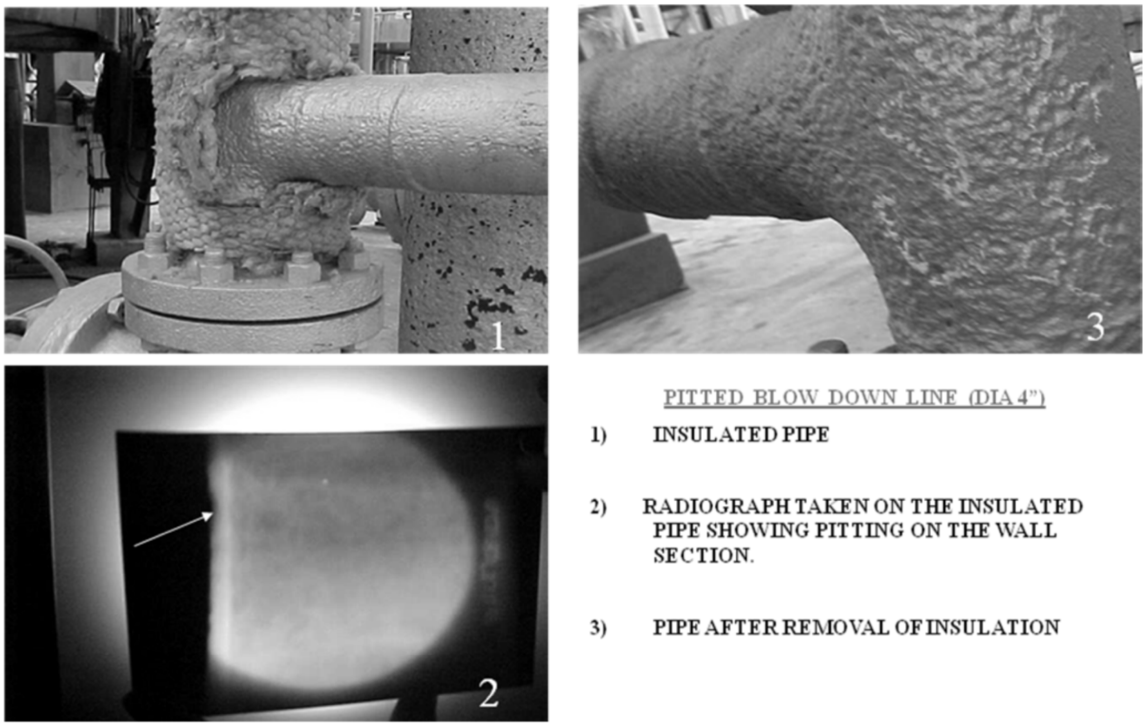
- Priority I circuits 20% of identified locations
- Priority II circuits 10% of identified Locations
- Priority III circuits random

Opening the insulations based on the visual, thermo graphy and profile radiography findings for

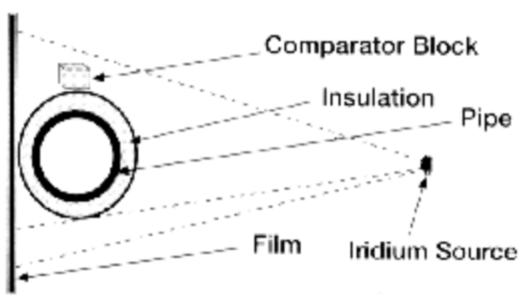
- Correlation
- Repair, painting, inspection etc
- Replacement

Establishment and execution of profile radiography technique for CUI:

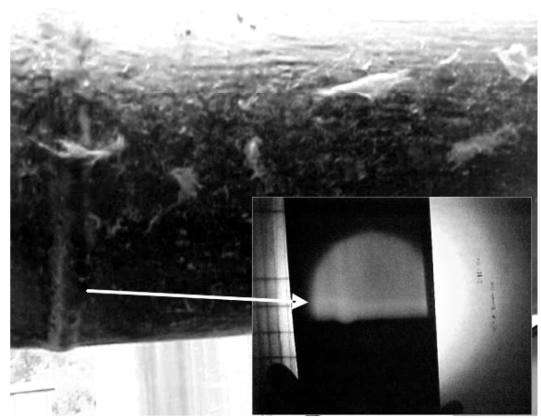
Profile radiography technique was established for CUI interpretation by taking profile radiographs of insulated lines having pitting. The pits were clearly identifiable on the radiography films and to confirm it the insulation was opened



Photograph No. 05: Profile Radiography Technique for CUI for pipeline



Sketch No.:02 : Schematic Sketch of Profile Radiography



Photograph No 06: Priority II location in ISOSIV Technique for CUI unit

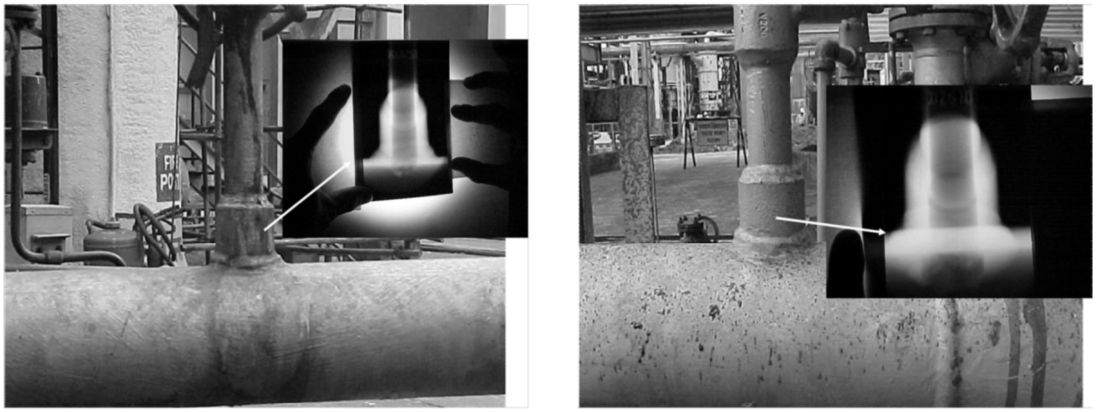
and the radiography observations and actual visual observation after insulation removal were matching (photograph no. 5)

The sketch -2 below shows schematically as to how a profile radiographs is carried out over an insulated pipe section. It can be noticed that the source to film distance (SFD) has to be kept high in order to cover the entire pipe. It was observed based on our field experience that upto 6 inch dia. pipe section there was no problem in carrying out radiography in one shot. But for higher size pipes, the radiograph has to be taken for a section of the pipe wall (both walls can't be covered in one shot) and the exposure time also increases. The results obtained are however representative of the actual corrosion taking place beneath the insulation. This was verified after physical opening of the insulation (photograph no 6 ,7).

Observations

During infrared thermography survey in ISOSIV unit for CUI identification, study moist insulation was noticed in only chiller circuit. On visual inspection of piping in ISOSIV unit , insulation damage was noticed at small bore piping end cap

These locations were inspected after removal of insulation, no significant corrosion was noticed. The priority-I & II locations were inspected by profile radiography techniques.



Photograph No 07 : Photographic and Radiographic Images of ¾ "small bore piping on 3" & 4" main pipelines respectively.

No corrosion sign or indications were noticed in the radiograph. These observations were corroborated with the actual conditions after removal of the insulations.

At Priority-III locations the insulations were removed at random and the condition of metal surface was found good.

Jobs carried out:

Damaged end caps of small bore piping were repaired with new caps and sealed using mastic material. The moist chiller circuit insulation was completely renewed.

CONCLUSION

It can be concluded from the above two case studies that profile radiography is a reliable, quick and economical assessing tool for solving real time and critical reliability issues related to corrosion, defects in weld/ pipe section ,corrosion under insulation and many more applications. This technique can be used in conjunction with real time radiography to see the actual image of the corrosion pattern and take quick decisions.

ACKNOWLEDGEMENTS

The authors acknowledge the help provided by the management of Indian Oil Corporation Limited, Guwahati Refinery in carrying out the study and extending full support at all stages.

REFERENCES

1. API Standard 571, "Damage mechanism affecting fixed equipment in refining industry". First edition, Dec 2003, American Petroleum Institute.
2. API Standard 560, "Fired Heaters for General Refinery Service". First edition, Dec 2001, American Petroleum Institute.
3. Corrosion Manual, M&I department, Indian Oil Corporation Limited.
4. Welding Manual, M&I department, Indian Oil Corporation Limited.