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Non-Destructive Testings of the Lifting Hook and Heat Exchanger Circuits of the Research Reactor TRICO II by Liquid Penetrant and Ultrasonics Testing Methods

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ABSTRACT

For its restart, components of research reactor TRICO II are subject of Non-Destructive Testings (NDT). Its STAHL hoist lifting hook 5000kg was inspected by colored liquid penetrant method for the research of surfaces defects, through white light in 750 lux. Result obtained indicates that it is not degraded. Indirect visual inspection by the multifunction video endoscope KC 350 was used to control internal wall of heat exchanger secondary circuit piping, some photos of internal wall were captured. The ultrasonic method consisted in measuring thickness of internal and external part of piping of the heat exchanger secondary circuit using thickness gauge ATG II with built-in 4.00mm calibration block. Results obtained by visual inspection showed the presence of rust and corrosion. The ultrasonic method showed thickness variation on controlled surface due to deposit rust (high value of thickness) and corrosion (low value of thickness). This work is carried out as part of maintenance, periodic testing and inspection for proper management of the TRICO II reactor.

I. INTRODUCTION

The field of Non-Destructive Evaluation (NDE) or Non-Destructive Testing (NDT) involves the identification and characterization of damages or defect on the surface and interior of materials without cutting apart or otherwise altering the material. In other words, NDT refers to the assessment or evaluation and inspection process of materials or components for characterization or finding defects and flaws in comparison with some standards without altering the original attributes or harming the object being tested (Sandeep Kumar Dwivedi and al 2017) [1].

Nowadays, non-destructive testing represents a way out for maintenance of industrial equipment in general and particularly in the nuclear industry. Good maintenance increases the life-time of equipment and structures. Nuclear equipment and structures are subject to strict control given the sensitivity of the field. Their control must be carried out under the supervision of operators and safety authorities.

The TRICO II of the General Commission for Atomic Energy / Regional Center for Nuclear Studies of Kinshasa in its restart phase was the subject of non-destructive testing of some of its components.

The control consisted in visual inspection of some components of the heat exchanger secondary circuit piping, all the lifting hook and the internal walls of the heat exchanger circuit piping. The inspection was performed within specificities of TRICO II.Informations

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are available in In-service inspections contains a program of maintenance, inspections and testing, to establish sufficient safety and to handle deterioration and aging effects [2].

Many methods and techniques may be used in the programme for maintenance, periodic testing and inspection. They range from the well-known methods of dimensional and electrical measurements and chemical analysis to the more sophisticated methods of non-destructive examination of the surface and volume of structures. Regardless of the methods or techniques employed, the method selected should be qualified for the examination to be done. The work should be done according to appropriate procedures by personnel who are qualified to use the methods and techniques employed. Similarly, the results should be evaluated by qualified personnel and compared with baseline data to detect changes.

Many of the examinations to be done in the testing and inspection programme involve the methods and techniques of non-destructive testing and examination. [3] and [4].

Inspections and testing using the techniques described above should be performed by specialists who are qualified to use the techniques and to interpret results according to international standards ISO9712 or equivalent [5] and [6].

To perform the inspection, three Non-Destructive Testing were used: liquid Penetrant Testing (PT), indirect visual inspection and Ultrasonic Testing (UT). Liquid penetrant Testing is a type of nondestructive testing quite frequently used in industry practice. They allow identifying surface irregularities such as: cracks, lapping, delamination, no welds, porosity, leaks and other open irregularities on the surface. These methods are used during receipt, production, final control or conservation, for the entire surface or only locally. They enable to identify defects in nonporous materials, parts or molded products, plastically shaped, welded, soldered, raw or already processed products. They are also used for controlling parts of connected elements of various shapes and sizes made from ferromagnetic and non-ferromagnetic materials, which cannot be tested with the magnetic method. The choice of testing system: the penetrant, remover, fixative (developer), depends on a range of factors, mainly on the type of the tested element, the material used, the surface condition, the overall conditions, e.g. the temperature, and on the assumed sensitivity of the testing (D. Woźniak and al) [7].

The PT was used to find surface defects on the hoist STAHL5000kg hook.

A visual test can be defined as an activity in which one locates and assesses the surface characteristics of an object, such as: discontinuities, deformations, the overall surface condition, with the naked eye or by using optical, optoelectronic or measuring instruments etc. A large scope of the usage of this technology often carries the necessity of using additional equipment. Therefore, visual testing can be divided into: - direct visual testing - remote visual testing. The aim of such testing is mainly the assessment of the surface condition (e.g. corrosion, erosion or cracks), controlling any deviations in shape, the connections (especially the welded ones), and, finally, controlling the object after its repair. (Woźniak and al) [7].

The indirect visual inspection was used to find corrosion, dust of the external piping of the secondary circuit of the heat exchanger.

Ultrasonic testing is a type of nondestructive testing most frequently used in industry practice.

They allow identifying cracks, lapping, delamination, no-welding, porosity, leaks and other irregularities inside the tested elements (D. Woźniak and al) [7].In addition, ultrasonic waves are strongly reflected at boundaries where material properties change, and thus are often used for thickness measurements and crack detection [8].It is also use for the detection and classification of corrosion (H. Jalali and al 2022) [9].

Ultrasonic technique was used to determine thickness of the external piping of the secondary circuit of the heat exchanger to complete the indirect visual inspection.

II. MATERIAL AND METHODS

PT inspection of the lifting hook of the hoist STAHL 5000kg made of ordinary steel

Products

CRM CR50 liquid penetrant for penetrant inspection;

Type II;

Day light visible penetrant spray;

Used for detection of surface flaws in all metal parts;

Solvent removable;

Highly contrast red color.

Specifications: AMS 2644/ AMS 2647/ ISO 3452/ MIL-1-25135 E ASTME165 &E1417, type II, methods BC&D, non-chlorinated solvent, very low halogen &Sulphur contents. For military, automotive components manufactures, marine, fabrication shops, tools shops, pipelines, shipyards, railroads,, utilities-Nuclear Power Plants & Electric and Gas utilities.

CRM CR70 developer for penetrant inspection

Form solvent based developer spray;

Used for detection of surface flaws in all metal parts;

Solvent developer;

Highly contrast & smooth film;

Specifications: AMS 2644/ AMS 2647/ ISO 3452/ MIL-1-25135 E ASTME165 &E1417, type I&II, methods ABC&D, non-chlorinated solvent, very low halogen &Sulphur contents. For military, automotive components manufactures, marine, fabrication shops, tools shops, pipelines, shipyards, railroads, utilities-Nuclear Power Plants & Electric and Gas utilities.

CRM CR60 (solvent) cleaner & remover

Used for detection of surface flaws in all metal parts;

Specifications: AMS 2644/ AMS 2647/ISO 3452/ MIL-1-25135 E ASTME165 &E1417, class 2, methods ABC&D, non-chlorinated solvent, very low halogen &Sulphur contents.:

Name		Multifunction video inspection
Model		KC-350
Recommended use		Indoor
Image sensor		CMOS image sensor
Viewable angle		60°
Diameter of head camera	Standard camera head	12mm (magnetic tip, hook tip, mirror tip included)
	Optional camera diameters	9mm (hook tip, Mirror, Magnet, Thread for protection)
		5mm (Mirror, ball guide, Thread protector for selection)
Focal length	12mm standard	50mm and 50cm for your choice
	9mm optional	50mm
	5,5mm optional	10mm
Probe length for choice	12mm camera	1m/2m/3m or customized (max length 5m including extension)
	9mm camera	1m/2m/3m or customized (max length 5m including extension)
	5,5mm camera	1m/2m/3m or customized (max length 15m including extension)
Extension choice		1m,2m,3m
Protection level	Probe and camera	IP67

Main body	IP54
Light source	Ultra bright LED
Image display	3.5’’TFT/LCD
Image resolution	640x480 pixels
LCD resolution	320x240 pixels
Image zooming	4 times
TV output format	NTSC/PAL
USB output mode	Portable storage mode (USB Disk)
	Real time image output mode (USB camera)
Image storing medium	64MB internal memory
	Micro SD (support up to 16GB), optional
Accessory	TV cable, USB cable, driver CD
Power supply	4 AA alkaline or rechargeable batteries (LR6 or KR6)
Battery continuous working time	>2 hours
Working temperature	0°C ~45°C
Working humidity	5% ~ 95%RH non-condensing
Storage Condition	-20°C ~+60°C, ≤ 85% (w/o batteries)
Main body dimension	270mmx75mmx100mm (w/o probe)
Main body weight	About 405g (w/o batteries and probe)

These products (fig.1b) were used to examine the lifting hook of the hoist STAHL 5000kg made of ordinary steel (fig.1a).

To inspect the surface, the hook was first cleaned and dried, and then the colored red penetrant was sprayed. After ten minutes, the excess of colored red penetrant was removed. Finally, the developer was sprayed and the observation was done with white light of 750 lux.

Indirect visual inspection of internal wall piping of the secondary circuit of Trico II

The multifunction Video Inspection KC-350 endoscope (fig.2b) was used to inspect the internal wall piping of the secondary circuit of the heat exchanger (fig.2a).

Specifications

The inspection concerns only the external part of the heat exchanger of the secondary circuit piping.

The multifunction video was introduced through the wall of the pipe and pictures were captured.

Measurement of galvanic piping of secondary circuit of Trico II:

The thickness gauge ATG II (fig.3b) was used to determine thickness of external part of the heat exchanger secondary circuit piping (fig.3a).

Specification of ATG II thickness gauge

SPECIFICATION	DESCRIPTION
Size (mm)	155x80x35
Weight (g)	275(including batteries)
Operating temperature	-20~45
Power	Three 1.5V alkaline batteries
Battery life	40 hours
Display	320x240 dot-matric true color screen
Probe	Dual element probe
Measuring range(mm)	0.65-650
Digital resolution(mm)	0.01
Velocity range(m/s)	500~9999
Display unit	Inch/mm
Language	English
Waveform display mode	Full wave, +RF, -RF
Pulser voltage	150 negative spike
dB gain setting	12-52Db
V-pass correction	Automatic calibration
Display mode	Normal, Min/Max capture, Diff, PR%, digital, AScan, BScan
Measurement point storage	128,000 points
LCD intensity light control	
Output	USB port
Report software	Data view,win7,win8

a) **b)**

Fig. (1): Photo a) shows the hoist STAHL 5000kghook and photo b) liquid penetrant testing products used for PT

a)

b)

Fig. (2): Photo a) shows the end of external secondary circuit piping of TRICO II and photo b) the multifunction video inspection KC-350 used for the indirect visual inspection

b)

b)

Fig. (3): Photo a) External pipe of secondary circuit of TRICO II reactor and photo b) the gauge thickness ATG II used for the measurement of thickness

First, the calibration of the thickness gauge ATG II was done by applying couplant on the surface of 4.00 mm steel block calibration. Next, putting the probe on the part via the couplant, completely permitted to couple it with the part, then pressing arrow key until the screen echo waveform was moved and displayed on 4.00, the gain is automatically adjusted by software as well. After the waveform moved and displayed 4.00, the calibration was done and the unit was ready for inspection.

To measure thickness following steps was achieved: add couplant on the pipe surface and coupled with the probe completely. Press arrow key until the screen echo waveform move and display into the value of the thickness of the pipe, read and repeat.

III. RESULTS

Figures 4, 5 and table 1 show the results obtained:

Figure 4 shows the result obtained after applying developer CRM CR70, figure 5 shows the internal view of the secondary circuit piping and table 1

IV. DISCUSSION

The fig.4 shows the photo of hoist STAHL 5tonnes hook after the application of developer.

No surface defect was found around weakness zone. The hook is not degraded.

No remedial action is required for now.

The fig.5 shows the photo of internal wall of secondary circuit pipe of TRICO II reactor. There is presence of rust and corrosion.

Remedial action: pipe must be replaced.

The table 1 shows thickness of the external piping of the secondary circuit of TRICO II reactor.

There is thickness variation of controlled surface due to presence rust and corrosion. The nominal thickness of the pipes being 5mm, three groups of values are presented in our table:

Values which are greater than 5mm, values which are more or less equal to 5mm and values which are less than 5mm.

Values greater than 5mm show the presence of dust which has settled on the walls of the pipes by adhering to them. Three values 7.66mm, 6.14mm and 6.02mm illustrates this case well.

Values more or less equal to 5mm show zones where there is a slight variation in thickness.

Values lower than 5mm show the presence of corrosion.

Remedial action: the replacement of pipe is required.

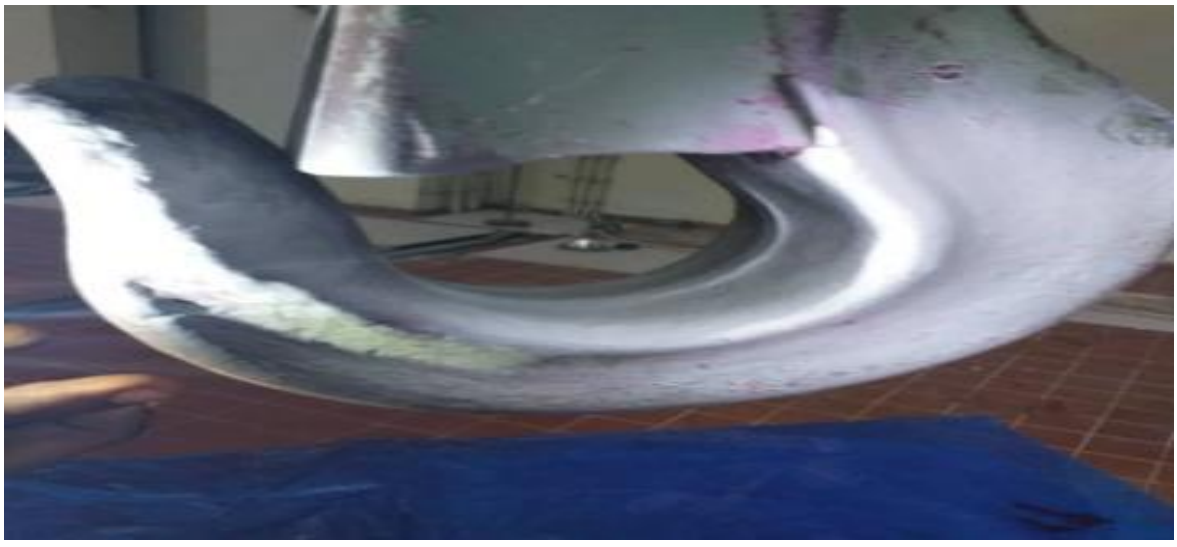

Fig. (4): photo of the Hook of hoist STAHL 5000kg inspection after applying developer

Fig. (5): View of internal wall of secondary circuit pipe of TRICO II reactor after visual inspection with the multifunction video KC350

Table (1): Thicknesses of secondary circuit external pipe of TRICO II reactor in millimeter

5.22	4.99	5.55	5.20	5.37	5.85	5.66	5.33	5.54	5.39	4.85
5.37	4.77	5.65	7.66	5.17	4.18	5.25	4.63	5.62	4.44	4.84
4.87	5.55	4.74	5.29	4.75	4.92	5.33	5.68	5.07	4.76	5.40
4.91	5.44	5.22	5.37	5.70	5.40	6.14	5.99	5.55	5.36	5.55
5.25	5.40	5.32	5.22	5.50	5.29	5.11	5.45	4.92	4.11	6.025
4.70	4.03	5.22	5.74	5.70	4.51	5.47	5.49	5.63	5.81	5.81
5.11	5.37	5.32	5.44	5.98	5.55	5.11	5.58	5.59	5.00	5.37
5.37	5.48	5.44	5.66	5.03	5.48	5.39	4.99	5.62	4.96	5.66
5.37	5.44	4.74	5.03	5.02	5.29	5.11	5.07	4.66	4.85	4.86
5.18	5.06	4.91	4.85	5.70	4.92	5.37	5.55	5.33	5.44	5.33
5.59	5.63	5.54	5.58	5.32	5.25	5.51	5.16	4.29	5.62	5.62

V. CONCLUSIONS

Non-destructive testing of the lifting hook and heat exchanger circuits of the research reactor TRICOII by liquid penetrant and Ultrasonics testing methods was the beginning inspection for the restart of this research reactor.

Liquid penetrant testing of the STAHL 5000kg hoist hook shows no indication (defects emerging like cracks) on the surface.

However, indirect visual inspection and thickness measurement of secondary circuit of the TRICO II show presence of corrosions, loss of thickness and rust.

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