BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXV No. 3/2013	1 - 8	Seria Tehnică

Consideration on Inspection and Maintenance Programs Designed for Isotopic Exchange Columns at RAAN ROMAG Drobeta Turnu Severin

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Abstract

The equipments of the Heavy Water Production Facility have a significant service life of more than 50,000 real service hours. Isotopic exchange technology implies the use of an extremely high volume of gaseous H_2S, a dangerous, corrosive and toxic gas. Unit safety, reliability and durability, respectively are key issue for the facility operator. This paper is a short review of the inspection and maintenance programs developed for isotopic exchange columns in accordance with Romanian regulatory framework on pressure vessels.

Key words: *izotopic exchange columns, flaw*

Introduction

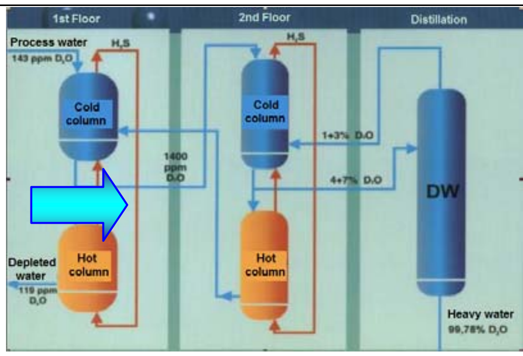
Isotopic exchange facilities from RAAN – Subsidiary ROMAG PROD had a significant age from commissioning, with more than 50,000 real service hours. In this period, the constitutive materials of the process equipments were damaged by long term action of mechanical and thermal stresses in the presence of an active and aggressive technological environment.

Based on evaluations performed in the above mentioned period it was considered as mandatory the development, in the first stage, of an experimental program for the evaluation of long term behavior of steels that are serviced in hydrogen bearing environments, particularly for fine grained C-Mn steels. The collected information correlated with those resulted from examinations, verifications and investigations performed on equipments manufactured from this steel grade allowed the development of a secure methodology of action in order to guarantee the increase of service safety as well as the increase on health security within facilities in discussion.

During service years the experience gained by all interested parties in the heavy water production led to the development of a “clean” technology for heavy water by improvement and safety strengthening.

Main characteristics of the Romanian heavy water (fig. 1) are maintained by rigorous technological operation programs and, also, by the development of an extensive inspection, maintenance and repairs program.

Historically, the unit was shut down for about three years (between 1990 – 1992). During this period technological equipments were modernized and, also, the environmental surveillance and protection systems.



Heavy Water Quality As per Technical Sheet (that met AECL requirement for CANDU type reactors – Technical Specification TS-XX-38000-001, AECL, 01.02.1999)		
Parameter	**Value**	**Unit**
Isotopic concentration	Min. 99.78	% wt. D_2O
Conductivity	Max. 5	μS/cm
Turbidity	Max. 1	NTU (ppm SiO_2)
Organics ($KMnO_4$ demand)	Max. 10	mg/kg
Chloride	Max. 0.5	ppm
Tritium	none	μCi/kg

NOTE:

1. Also, could be delivered one grade of heavy water with concentration greater than 99.96 D_2O and four grades of depleted low-weight water with concentration ranging between 0 and 80 ppm D_2O. These grades are patented and homologated.
2. Considering high heavy water quality, ROMAG PROD is recognized on European and Asian markets, being exporter of nuclear grade heavy water supplies in South Korea, China, Germany, etc.

Fig. 1. RAAN ROMAG PROD heavy water manufacturing process and heavy water quality parameters (source: RAAN ROMAG PROD website)

Basic consideration that lead to the development of the experimental program consists in the fact that the process equipments from ROMAG PROD are made from items manufactured from rolled and forged material of G52/28 steel grade. This steel was produced in the eighties at Siderurgic Plant Galati based on National Technical Normative NTR 440/83.

The modernization process and, also, further inspection, maintenance and repairs programs led to the improvement of the plant feasibility, shortening the manufacturing time for a new supply of heavy water to about four years.

State of the Art – Metallurgical Based Service Life Extension for the Isotopic Exchange Columns

As already mentioned in previous chapter, the process equipments from ROMAG PROD are made from rolled and forged material of G52/28 steel grade. At the date of plant designing and erection, this material was fully characterized in order to establish its fitness for use in hydrogen bearing environments as structural steel for isotopic exchange columns walls.

After more than 50,000 real service hours, the designers and regulatory body were interested to demonstrate if the constitutive materials of the process equipments (columns, pipelines and related components) were damaged by long term action of mechanical and thermal stresses in the presence of an active and aggressive technological environment.

For this reason, for about ten years, it was developed and constantly updated an experimental program for the evaluation of long term behaviour of steels that are serviced in hydrogen bearing environments, particularly for fine grained C-Mn steels serviced in H_2S environments.

All informations were used to guarantee the increase of service safety and of course of occupational health safety leading to the development of methodologies of action for long term serviceability of the equipments and other technological components at RAAN ROMAG PROD.

The Romanian regulatory authority for pressure equipments – ISCIR – initiated and developed a methodology to evaluate the technical state of pressure vessels with extended service life or to evaluate those equipments to be re-started after a long shutdown period for which must be estimated the remaining service life.

In a previous paper it was emphasised the schedule for flaw remediation on the inside equipment surfaces (fig. 2). This schedule was developed based on a complex experimental program that consists in measurements, analytic procedures, material characteristics, NDT examinations, acceptance criteria etc. All qualitative and quantitative data were collected in order to establish the remaining service life or the limits for the extension of the service life. For all involved parties it was clear that must be demonstrated that the service safety and health security, environmental impact are not impaired by hazardous releases of technologic fluid. Once assessed the state of the investigated equipments, the regulatory authority was informed about the developments, findings and methodology to be used to recover and to demonstrate the safe service state.

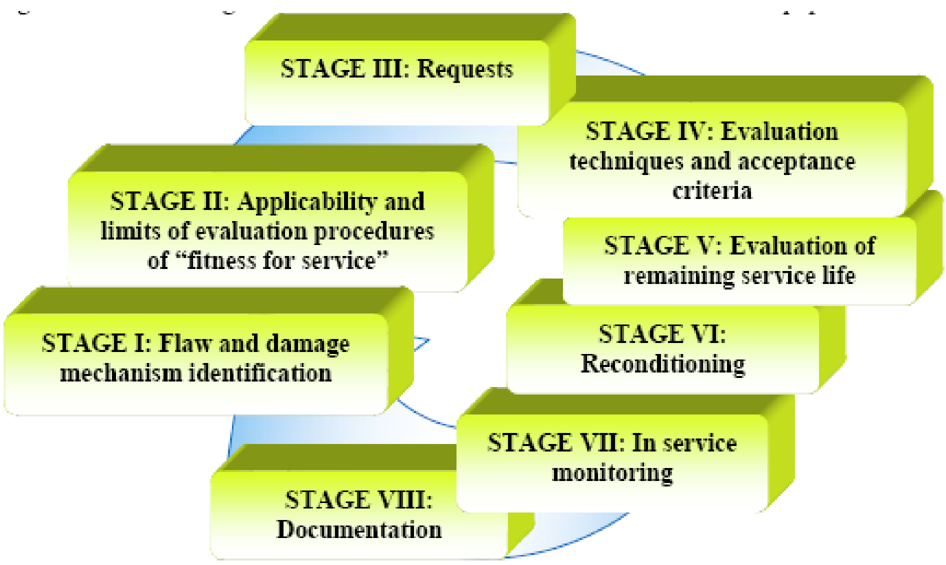


Fig. 2. Short presentation of the evaluation procedure for in service behavior of pressure equipment damaged by ongoing processes due to technological fluids

A short review of the experimental data allows several conclusions based on laboratory and in-situ characterization of steel susceptibility to environmental induced corrosion phenomena. The evaluation of uniform corrosion rate demonstrates a dissimilar behavior of material depending on exposure condition. The most unfavorable condition seems to refer to lower service temperatures. With the increase of the exposure period occurs significant differences due probably of protective layers formation and because of their morphologies. Certain collateral degradation mechanisms superposed on main mechanisms specific for stress corrosion cracking. Thus, together with the effects due to the erosion-corrosion mechanisms, after significant exposure periods, on specimens exposed “in-situ” were identified hydrogen induced cracks.

Locally, cracked surfaces revealed an apparent internal propagation of the initial concentrator crack tip. Also, there were noticed evidences of overstress with fibrous breakage. The internal propagation of the crack was attributed to the existence of hydrogen induced cracks. The tendency for the protective layer formation is lower and for this reason was favored the occurrence of erosion phenomenon and, also, an obvious DCB specimen lateral arms consumption.

With these laboratory and in-situ data it was expected that the examination of the damaged areas during the evaluation of the columns internal surfaces will demonstrate the existence, also, of other aspects related to localized corrosion phenomena, such as pitting corrosion, erosion – corrosion, hydrogen induced cracking and an expected propagation of the defect preferential on maximum stress direction (fig. 3).

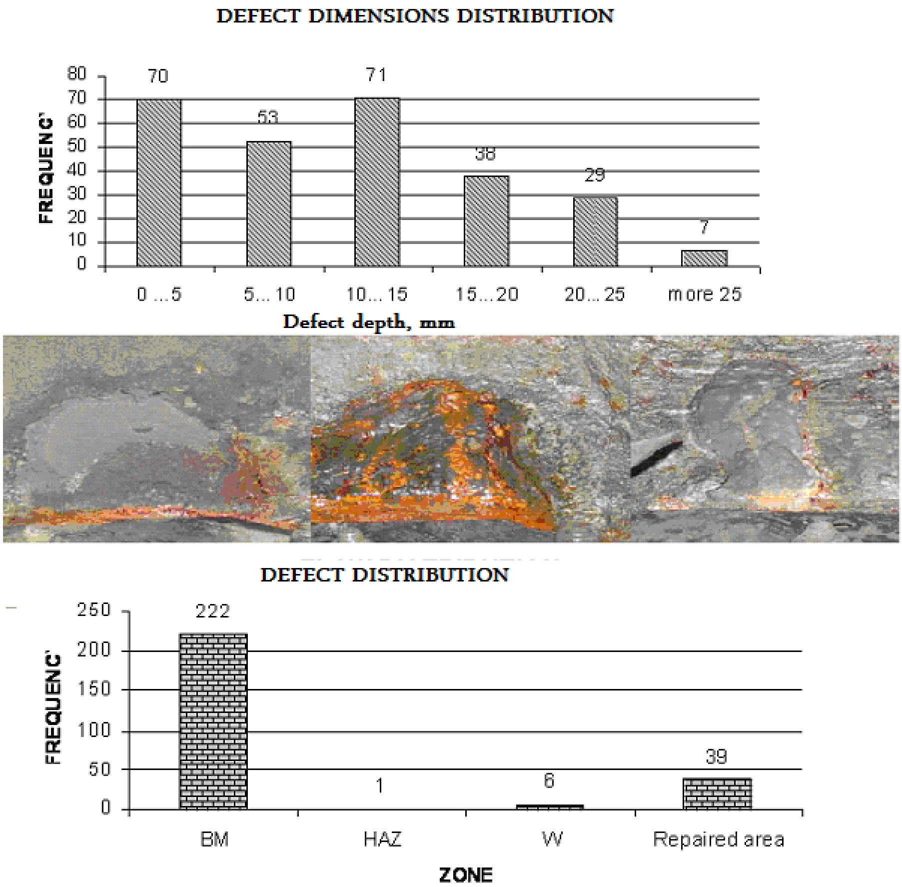


Fig. 3. Defect size distribution and frequency.
Defects were identified during the inspection performed within the scheduled maintenance period prior to development of the repair programs for isotopic exchange columns.

The methodology to evaluate the technical state of pressure vessels with extended service life and the repair program for the isotopic exchange columns were developed and agreed with the Romanian regulatory body for pressure vessels (ISCIR). This extremely complex program is settled considering that the following items are important for the development of repair and further monitoring schedule, as follows: the type of equipment to be evaluated, technical expertise and available resources.

Based on all the above findings it was developed a repair program for flaw remediation on the inside equipment surfaces:

Action 1. Visual identification of a nonconformity of “cavity” type.

Action 2. Preparation by mechanical grinding of the nonconformity surface area.

Action 3. Examination with penetrant liquids of the polished surface.

Action 4. Execution of first welding layer on polished surface accepted for penetrant liquids examination.

Action 5. Cavity fill-up with multiple welding layers until its fully repaired

Action 6. Polishing of the internal surface of the equipment of the deposit made by welding in order to repair the cavity.

Action 7. Examination with penetrant liquids of polished surfaces.

Action 8. Heat treatment of repaired area.

Action 9. Re-examination with penetrant liquids of polished surfaces after heat treatment.

Future Developments: Expectations and Constraints

Were performed based on the 9 steps program previously mentioned, repairs by welding of cavities developed as result of erosion – corrosion phenomenon on the internal surfaces of the C1106 isotopic exchange column shell and, also, the closure of openings developed as result of sampling program. In Figure 4 there is presented the succession of actions (designated 1 to 6 in the previous chapter) for the repair technology by welding of a defect performed four years ago during the scheduled maintenance program, and in Figure 5 it is analyzed the actual state of the internal surfaces of the isotopic exchange column as from the inspection program developed during 2011.

There exists a beneficial aspect related to the inspection and repair programs developed for isotopic exchange columns at RAAN ROMAG PROD due to the availability of data for initial design and for “as-build” design, for characterization of base material, including manufacturing data for steel sheets and qualification data for base material, for repairs programs by welding etc.

Considering resultant data from actual inspection program it was developed a new characterization schedule for the structural steel of isotopic exchange columns in order to demonstrate the preservation of its serviceability (fig. 5). This program is continuing and results are to be presented in a future paper with decisions considered regarding remaining service life of the equipment. Depending on material response designers and regulatory body will reflect on the appropriate action plan to be followed.

Figure 6 illustrates service behavior of the repaired internal surfaces of the isotopic exchange columns considering the re-occurrence frequency of defects on repaired zones, and the existence of any previous heat treatment on the inspected area.

Also, potential and collateral damaging processes were identified. For this reason the experimental program was extended to the selection, development and implementation of “in-situ” alternative evaluation methods in order to cover a wider range of corrosion phenomena and mechanisms that could be active during the experiments.

Overall analyze of experimental data showed that specimens behavior is influenced by exposure zone within facility, by operating temperature, respectively, and, implicit, by hydrodynamic and temperature regime. The most frequent corrosion phenomena, identified, are due to the nonlinear superposing of dissimilar mechanisms, i.e. hydrogen induced cracking, localized corrosion and uniform corrosion. It is minimum necessary the extension of the offline monitoring programs or demands on some online monitoring procedures implementation. Mechanisms, such as uniform corrosion, hydrogen induced cracking, stress corrosion cracking, are sometimes exceeded by predominant erosion-corrosion processes, with high localization in geometrical unfavored areas and for this reason it is imposed to continue the offline/online inspection and monitoring programs to permit predictions on remaining service life of these facilities.

Action 1

Action 2

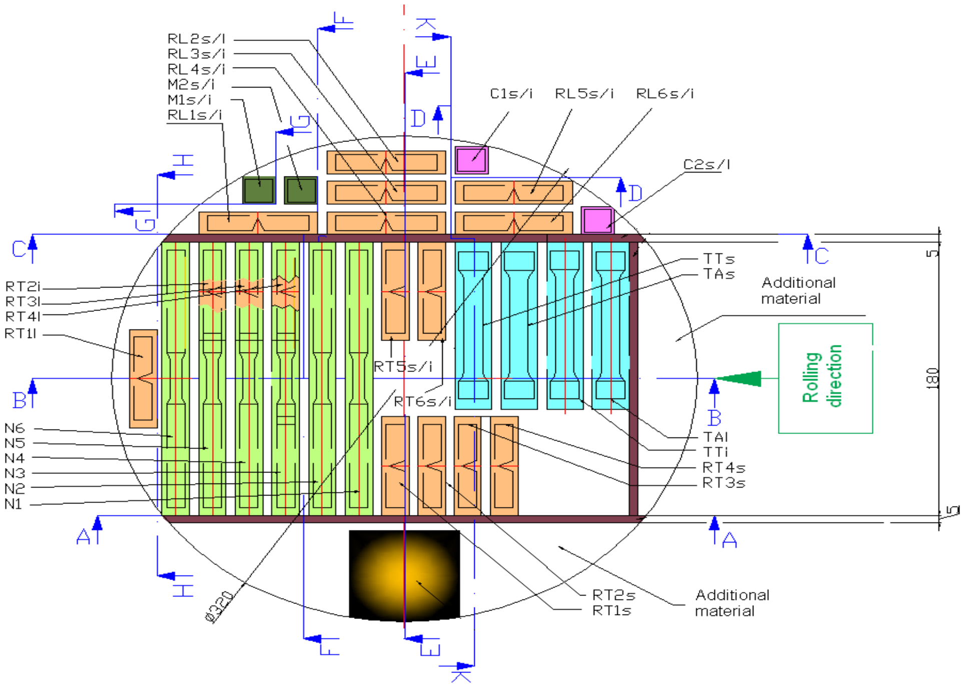
Action 3

Action 4

Action 5

Action 6

Fig. 4. Short visual review of aspects related to the repair welding technology for a pressure equipment damaged due to ongoing processes induced by technologic fluids (courtesy of Subsidiary ROMAG PROD from RAAN)



Legend: N – stress corrosion test specimens; RT – transversal impact energy (Charpy) test specimens; RL – longitudinal impact energy (Charpy) test specimens; TT – tensile test at elevated temperature specimens; TA – tensile test at ambient temperature specimens; C- sample for chemical analyze; M – specimen for Brinell hardness testing; s – index that indicate the sampling position, i.e. near external surface; i – index that indicate the sampling position, i.e. near internal surface; 1 … n – ranking number for specimens and samples.

Fig. 5. Inspection and characterization schedule for test specimens sampling with indication on destructive tests to be performed to demonstrate the service life extension for an isotopic exchange column during the scheduled maintenance period

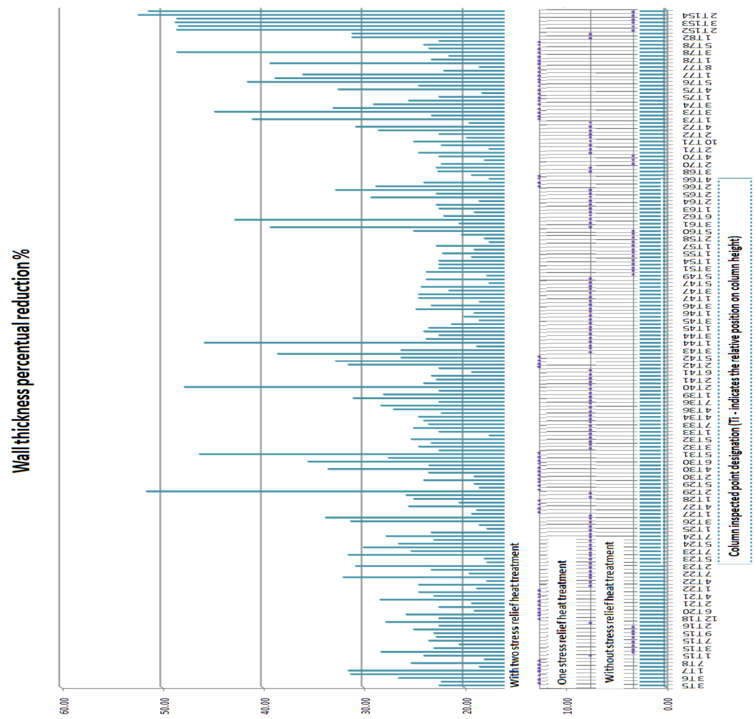


Fig. 6. Wall thickness reduction measured during the inspection of damaged areas. Some positions were previously repaired during 2003, 2006 intervention programs. To be further detailed in a future paper.

It was emphasized the importance of operating condition and, also, the mixed mechanisms that support the damage phenomena assisted by internal environment of the mentioned columns. These elements are main input data for the development of inspection programs and for statements on remaining service life of heavy water plant isotopic exchange equipments – as main components of security assurance during the operation of these facilities and, implicit, for the increase of safe running.

Integration of information received from experimental program with information from measurement program (examination, testing and investigation programs) applicable on considered equipments allows the definition of the most trustful methodologies attempted for recovering of the safe serviceability for at least one service cycle; layers by welding in those areas reported as nonconformity areas after the examination.

Conclusion

This paper demonstrated the efficiency of past inspection, maintenance and repairs programs for safe operation of some pressure equipments at RAAN ROMAG PROD. It was showed that it was possible to recover the capability of these equipments by repairs performed on metallic structure that consists in deposition of metallic layers by welding in those areas reported as non-conformity areas after examination.

Considering the strategic position of the heavy water plant and, also, the quality, environmental and safety requirements it resulted the need for further careful analyzes of any statement referring to the remaining service life of heavy water plant isotopic exchange equipments.

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Consideraţii privind programele de inspecţie şi mentenanţă dezvoltate pentru coloanele de schimb izotopic de la RAAN ROMAG Drobeta Turnu Severin

Rezumat

Echipamentele Uzina de Apă Grea (RAAN ROMAG PROD) au o durată de exploatare semnificativă mai mare de 50000 de ore reale de operare. Tehnologia de schimb izotopic implică utilizarea unor volume extrem de mari de H_2S gazos, un gas periculos, coroziv şi toxic. Securitatea instalaţiei, implicit fiabilitatea şi durabilitatea componentelor, este un aspect primordial pentru operatorul instalaţiei. Această lucrare este o scurtă analiză a programelor de inspecţie şi mentenanţă dezvoltate pentru coloanele de schimb izotopic în conformitate cu cadrul de reglementare din România pentru recipientele sub presiune.