IN-SERVICE INSPECTION OF PRIMARY COOLING SYSTEM OF ET-RR-1 REACTOR

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ABSTRACT

The main primary cooling system (PCS) retaining components are inspected by non-destructive test methods, NDT). The main objectives of the in-service inspection programme (ISI) are to verify the state of reactor components and to assess the significance of the existing defects for safety operation. The programme includes welds identification and examination by liquid penetrant method and thickness measurements by ultrasonic technique. Also, piping circumferential measuring length have been done. Visual and function testing for PCS valves showed improper function of the manual suction valve of pump No. and drainage valves of spent fuel storage tank and heat exchangers. General reactor problems are discussed.

1- INTRODUCTION

Over 550 research reactors have been constructed world-wide and of these approximately 320 are still in operation. About 70% of the operating reactors are over 20 years old with many over 30 years old. Because of this , it is necessary to develop an improved understanding of the effect of age related degradation phenomena on safety and utilization of research reactors. An understanding of degradation mechanism , assessment techniques and appropriate mitigation process are necessary to develop corrective response to maintain safety.

The problems of aging and operational NDT of reactor components have recently been of primary importance on international levels. For these purposes, the IAEA started activities on the topic of management of research reactor aging, in November 1992 [1]. Before that date many international symposiums studied the effect of age related degradation phenomena on safety and utilization of research reactors, [2].

ET-RR-1 has been operating for 32 years. It has been deemed necessary to conduct extensive inservice inspection of its Primary Cooling System (PCS) and selected critical components. In the framework of the IAEA technical assistance and co-operation project Nr.(EGY/9/024), Two Polish Experts cooperated with the staff of Inshass reactor, NRC, and NRSC to develop the Safety Analysis Report (SAR) and Inservice Inspection Programme (ISI) for ET-RR-1 Reactor, in Nov./Dec. 1989.

In view of the long operational history of 32 years, there is need to plan and implement inservice inspection of components and structures to detect degradation due to corrosion or stresses and to assess aging, particularly at weld joints.

2- BACKGROUND INFORMATION

2.1 *Reactor Operational History*

ET-RR-1 is a 2 Mw thermal pool type reactor. The Annual Cumulative Energy since First Startup in 27/8/1961, up till 27/8/1993 is about 26000 Mw-hr. [3]. Modernization of control and radiation protection instruments as well as parametric measuring systems are installed through the IAEA technical assistances (EGY/09/15 , EGY/04/28 , and EGY/09/ 025) [4,5].

2.2 *ISI Programme of Reactor Vessels and Spent Fuel Storage Tank*

An intensive work for the inspection of the main components of reactor vessels and spent fuel storage tank have been carried out during the period from 26-8-1992 to 15-9-1992 in co-operation with

Petersburg Nuclear Physics Institute (PNPI), Russia [6]. The available results are satisfactory for reactor vessels surfaces, weld joints and horizontal channels, but for the spent fuel storage tank, continuation of the ISI programme is still necessary owing to insufficient access to the areas under fuel bundles to be examined (Bottom Plate and Welds).

3-OBJECTIVE OF ISI PROGRAMME

The main goals of ISI programme are:

- To verify the state of reactor components particularly those have influence on safety. To reveal and identify the character of imperfections / manufacture or inservice imperfections /, to determine the form, localization, orientation, distribution and the individual and accumulated dimensions of the relevant imperfections.
- To evaluate the defects revealed on the basis of existing standards.
- To assess the significance of the basis of the existing defects for further operation of the reactor.
- To elaborate and submit to approval the ISI results and programme of further ISI activities and acceptance criteria. Inservice inspection of ET-RR-1 is a complex and non routine task involving different NDT methods, particularly in case that the initial quality of reactor components are unknown. Pre-Service Inspection (PSI) records are not available. Therefore any significant NDT indication/ material response/ shall be thoroughly analyzed in order to distinguish the operational damages of materials from fabrication and assembling defects.

4- ISI PROGRAMME

The first executable stage was reactor vessels and spent fuel storage tank [5]. The second stage boundary is limited to PCS components installed in pump room, Figure (1). The programme includes:

1- Weddings identification
 - Number of Circumferential welds.
 - Longitudinal welds.
 - Branches
 - Pipe to vessel welds.

2- Piping circumferential measuring length.

3- Thickness measurements by ultrasonic techniq

4- Weld examinations by visual inspection and li penetrant method.

5- Visual and function examination for all valves

6- Maintenance procedure for pumps and exchangers.

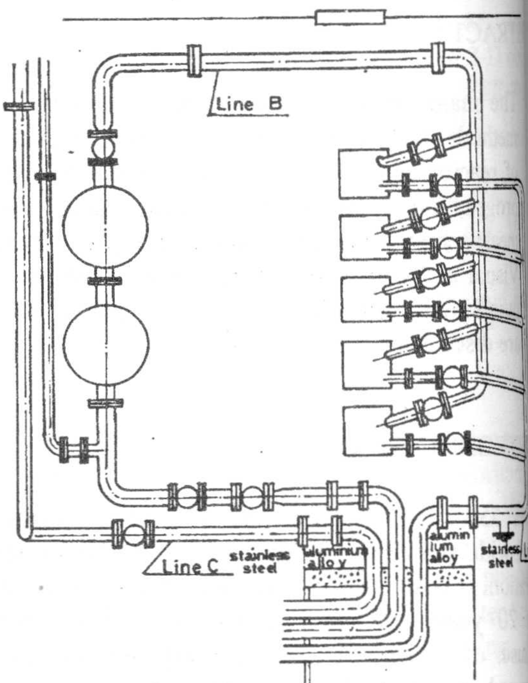

Figure 1. Primary cooling circuit.

5- TECHNICAL PROCEDURE

The piping system are classified into three lines

Line A: the suction header from reactor outl pumps inlet.

Line B: the pressure collector from pumps out reactor inlet through heat exchan containing the branches to deaerator an exchange filter.

Line C: from deaerator to reactor inlet and dra branch.

The practical ISI work was organized as follows

1- Collecting original documentation.
2- Material identification (Aluminum allo Stainless steel).
3- Implementing the ISI Programme.
4- Verification of design review.
5- Stating reactor problems.

-Original Documentation

Reactor construction and coolant system are described in catalogue 7A [7]. Some specific information are not included particularly those are necessary for ISI Programme. Russian vendor PSI, however, are not available. Therefore detailed recognition between fabrication faults and inservice origin discontinuities should be endeavored from the beginning of the ISI activities.

-PCS Material Identification

All sectors of the conduit pipe connecting directly with the reactor core are made of Aluminum alloy CAB-1, 350 mm. diameter. The remaining parts of the PCS including piping, valves, pumps, heat exchangers, filter casing, deaerator, water and waste tanks and drainage circuit are all made from 1x18H9T Stainless Steel. This type of steel is stabilized austenitic stainless steel containing Chromium, Nickel and Titanium. It has the following characteristics:

- Material Properties

Tensile Strength	Kg/mm 2	55
Yield Point	Kg/mm 2	20
Elongation %		40
Reduction in cross section area %		55

- Chemical Composition

C <0.12 Mn <2.0 Cr 17.0 Ni 8.0 Ti 0.5-0.8 S 0.03 Si 0.0 P 0.36 .

Special changeable Aluminum inserts are provided for connection joints of the sectors made of different materials to protect main Aluminum pipes against corrosion at joints with stainless steel conduit pipe, Figure (1).

-Inspection Techniques

The ISI Programme was implemented using NDT on the components of the PCS as follows:

-Thickness Measurements

An ultrasonic digital device type DM2 was used. Technical data of this device is as follows:

- Accuracy +0.1 mm.
- The range limits depend upon the probe type and the sound attenuation in the specimen to be measured as follows:

Probe Type	DA201	DA203
Sound attenuation, MHZ	5	2
Measuring range, mm.	1.2-200	5-300
Material 2	steel	steel
Specimen temperature °C	-10 to 70	-10 to 200

Radius of curvature of test specimen >10 mm. with minimum wall thickness 2 mm.

Ambient temperature -10 to + 50 °C

Reference standard : steel block 5.0+0.05 mm. thick.

Thickness measurements is based on the following equation:

$$d = c\,t$$

where c is the acoustic velocity of the material being tested. For Structural steel, Stainless steel and Aluminum c = 5940, 6010 and 6320 m/sec. respectively. t = transit time. Measuring method was done by introducing pulse-echo sound beam through the metal and evaluating on a digital scale the average transit time.

-Welds Inspection

Florescent Liquid Penetrant for welds examination was used as NDT on five weld joints at the pressure side of the pumps, Figure (9), as follows:

1- Cleaning Surface Condition

The tested area and its surrounding was wrapped by a clean cloth moisted with acetone. The surface was flushed by a cleaner and then dried by an absorbent paper.

2- Surface Examination

The tested area was sprayed by the penetrant for about 30 minutes allowance before removing by paper towels. The developer was agitated and then sprayed uniformly on the test area. The surface is closely examined in dark environment to monitor the behavior of indications which tend to bleed out and glow brilliantly under the excitation of ultraviolet or black light of wave length 360 nm in the darken background. Final interpretation was done after allowing the penetrant to bleed out for about 15 minutes.

3-Acceptance Criteria

Indications having dimensions greater than 1.5 mm was considered revelant. The following revelant indications are unacceptable:

- any cracks or linear indications.
- rounded indications with dimension greater than 4.7 mm.
- four or more rounded indications in a line separated by 1.5 mm or less.

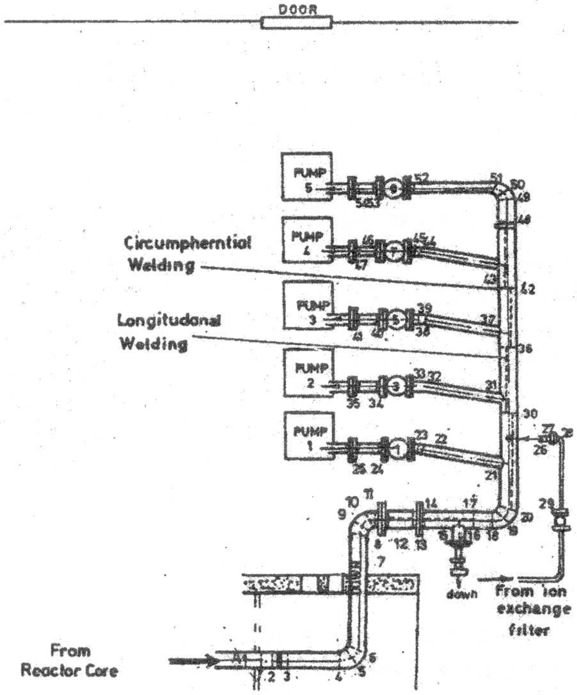

Figure 2. Welding identifications.

6- RESULTS OF ISI ON RCS

6.1 Assessment of Weld Joints

Figure (2) illustrates cirumferential and Longitudinal welds identification of pipe line A. It has 54 circumferential weld joints. About 20 circumferential weld joints are extended from reactor body to line A on that subpart of line A located inside the subroom under reactor core. Piping System were originally assembled by Longitudinal weld process on 10 mm. metal sheet segments.

Figure (3) illustrates welds identification of pipe lines B & C. They have 101 and 37 cirumferential welds respectively. Only 10 % of welds were examined radiography during erection time as written on drawings according to Russian Vendor requireme

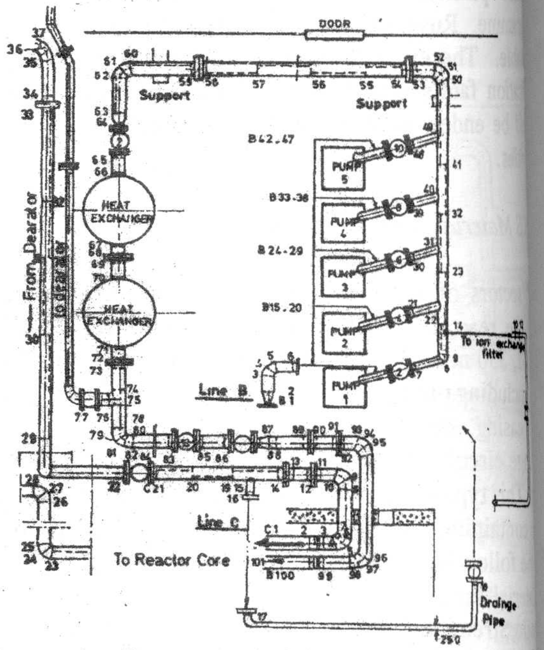

Figure 3. Circumpherntial and longitudanal we identifications in reactor primary cooling system.
Line B. 101 circumpherntial welding (pressure side)
Line C 37 circumpherntial welding.

6.2 Piping Circumferential Length

Piping inner diameter can be deduced by measu its circumferential length and its thickness. Figur illustrates 28 measuring points on line A. The collector from reactor core has 120 cm circumfere length. Piping sectors extended with decreasing slope where pumps suction branches are extended constant hydraulic resistance. Circumferential leng suction and pressure branches is 70 cm. Figur illustrates 55 measuring points on line B and o points on line C due to inaccessibility. The pre collector extended with increasing its slope in direction to 117 cm circumferential length. After exchangers, piping diameter increases from 102 c 120 cm at the aluminum section of the piping sy before reactor entrance.

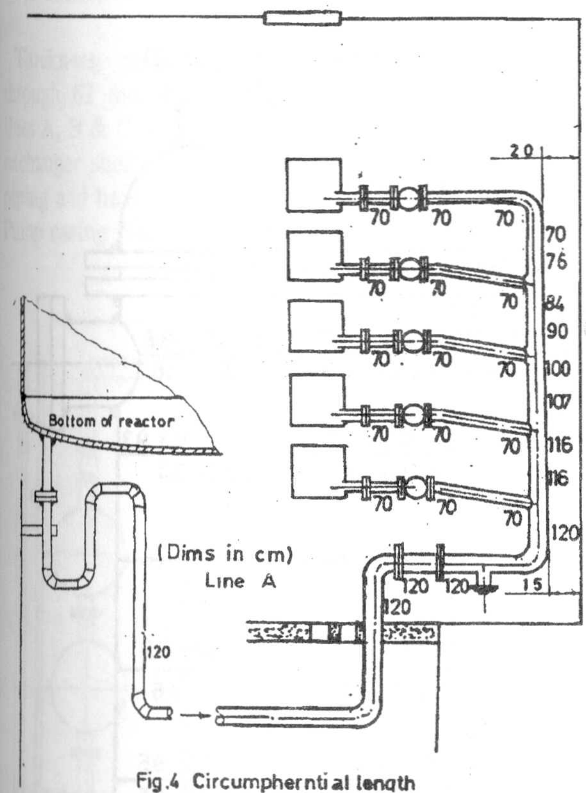

Figure 4. Circumpherntial length 28 measuring points.

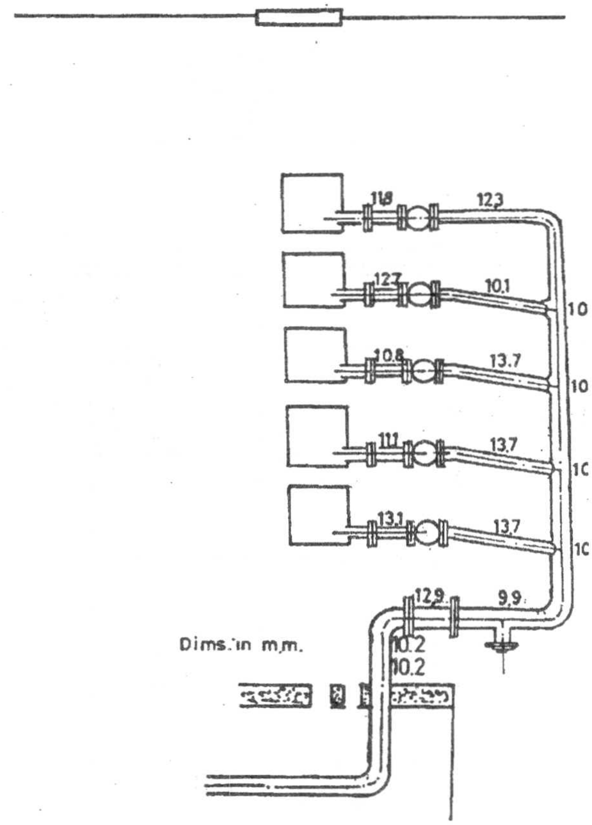

Figure 6. Thickness measurements 18 measuring points.

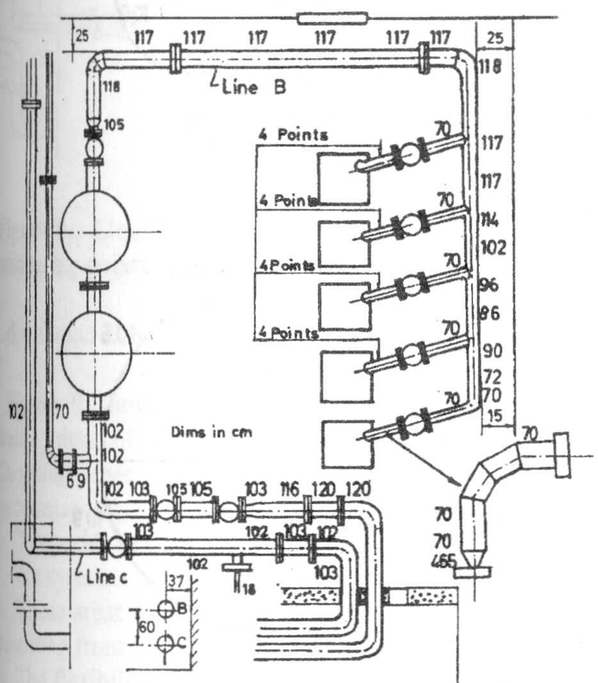

Figure 5. Circumpherntial length 55 measuring points (line B) 8 measuring points (line C).

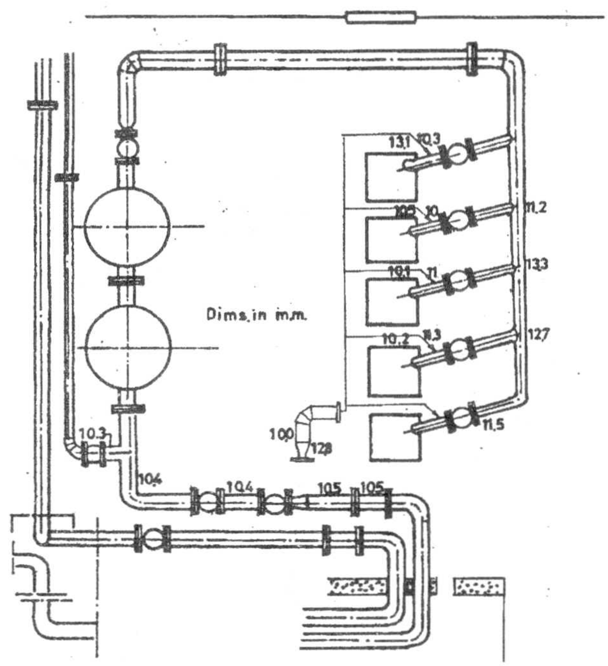

Figure 7. Thickness measurements 18 measuring points.

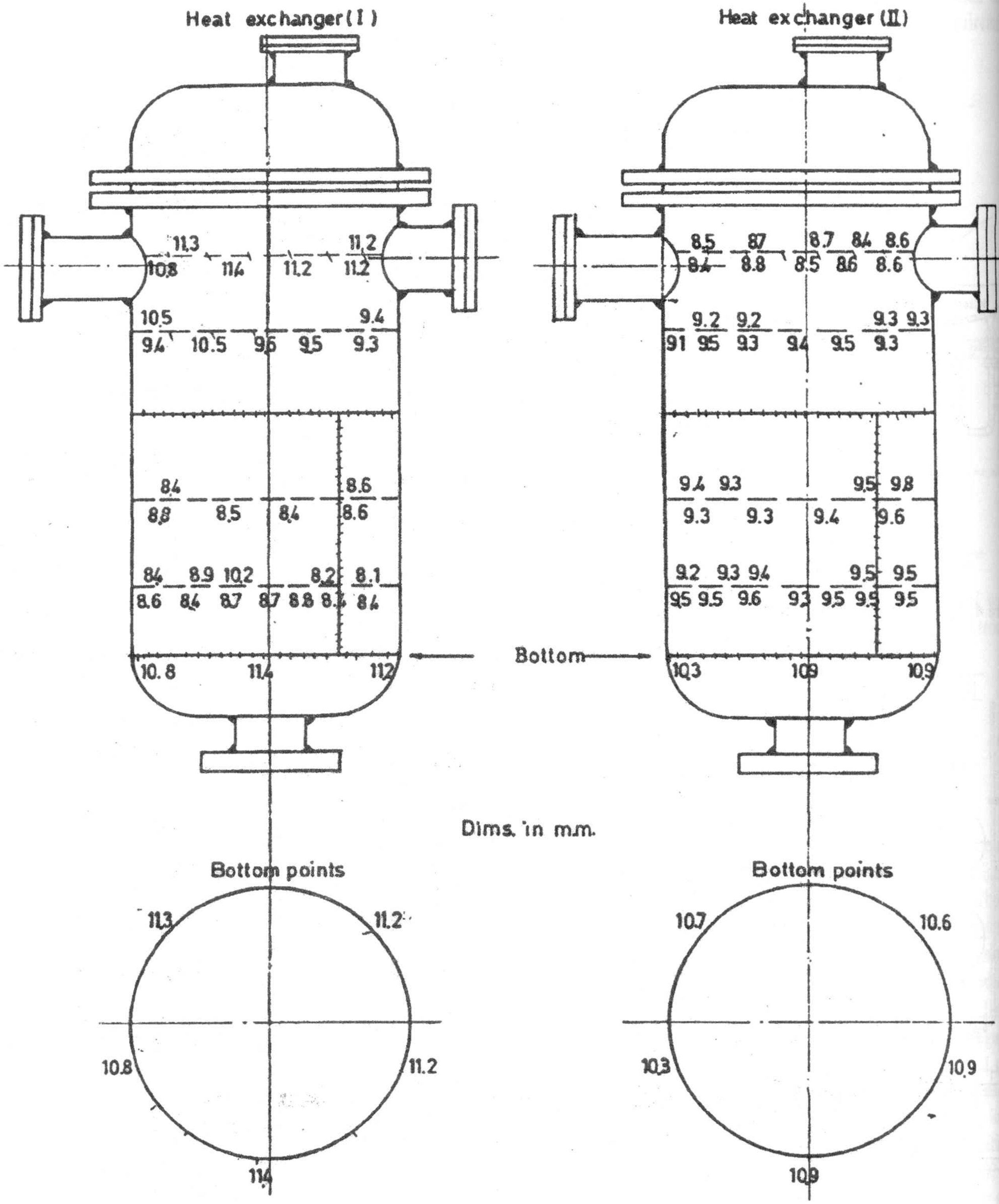

Figure 8. Wall thickness measurement 81 measuring points

6.3 Thickness Measurements

Thickness measurements have been performed through 62 measuring points on the piping system, lines A, B & C as well as 81 measuring points on heat exchanger shells, Figures (6-8). Average thickness of piping and heat exchangers metal sheets is 10.5 mm. Pump casing thickness is about 12.8 mm.

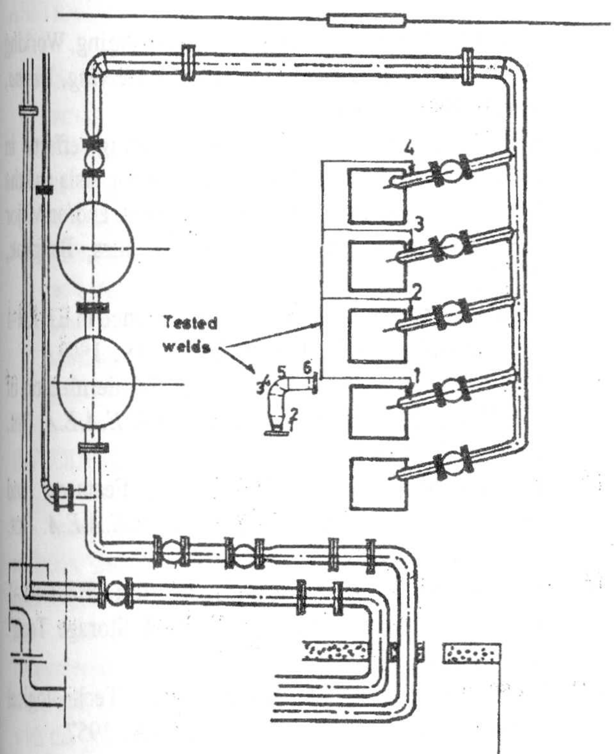

Figure 9. Liquid penetration measuring points 4 measuring points.

6.4 Liquid Penetrant

Figure (9) shows 5 testing areas located at the elbows weld joints of the pressure side of the pumps. Choosing these areas based on the following circumstances:

1- The welds are subjected to the highest pressure in the system.
2- These areas are highly stressed due to vibrations resulting from pumps rotation, (dynamic stresses).
3- The flexibility of such areas are limited as a result of using the weld to assemble the elbows and reducers
4- Susceptibility of stress corrosion cracking existence due to high flow rate and stress.

Testing results were satisfactory.

6.5 Aluminum Sleeve Dimensions

Dimensions of a spare part aluminum sleeve similar to that mounted at reactor outlet to the PCS was measured.

Inner diameter	350 mm
Circumferential diameter	1200 mm
Length	480 mm

Dimensions of another spare part aluminum sleeve similar to that mounted at reactor inlet from the PCS was measured.

Inner diameter	300 mm
Circumferential diameter	1020 mm
Length	480 mm

Drainage stainless steel sleeve dimensions

Inner diameter	95 mm
Circumferential diameter	360 mm
length	280 mm

Reactor documents indicated that core conduit pipe is 350 mm diameter, [7]. Diameter variation at pumps suction and pressure collectors are not indicated. Estimating piping inner diameter from thickness and circumferential measurements is shown in the following table:

Location	circumferential length	thickness	Inner Diameter
1	1200 mm	10.5 mm	360 mm
2	1030 mm	13 mm	300 mm
3	1200 mm	10.5 mm	360 mm

1&3 reactor core inlet & outlet
2 reactor core inlet from dearator.

Suction collector inner diameter diameter varies from 360 mm to 250 mm. Pressure collector inner diameter varies from 200 mm to 340 mm.

Visual Inspection of Primary Cooling System Components

The reactor was initially designed and constructed on the basis of using materials and components of Russian type designed before the time of construction in 1961, particularly the mechanical systems (Valves, Filter,...etc.) . Experience was limited in that time to predict the expected lifetime, meanwhile the aggressive environments and operating conditions caused degradation of some components below their initial specifications, for example:

- Corrosion near the weld joints of the ion exchange vessel, Figure (10). The remaining life of this components and durability of repair are probably very limited.
- Valves of drainage system under heat exchangers and spent fuel storage tank have to be changed completely. Also the manual suction valve of pump No.1 is not functioning. Problem of spare parts arise particularly now a days where manufacturing those components becomes not available.
- Spent fuel storage tank status and capacity is one of the main problems which need more inspection. System of water purification is necessary. Second rack for increasing storage capacity may be constructed.

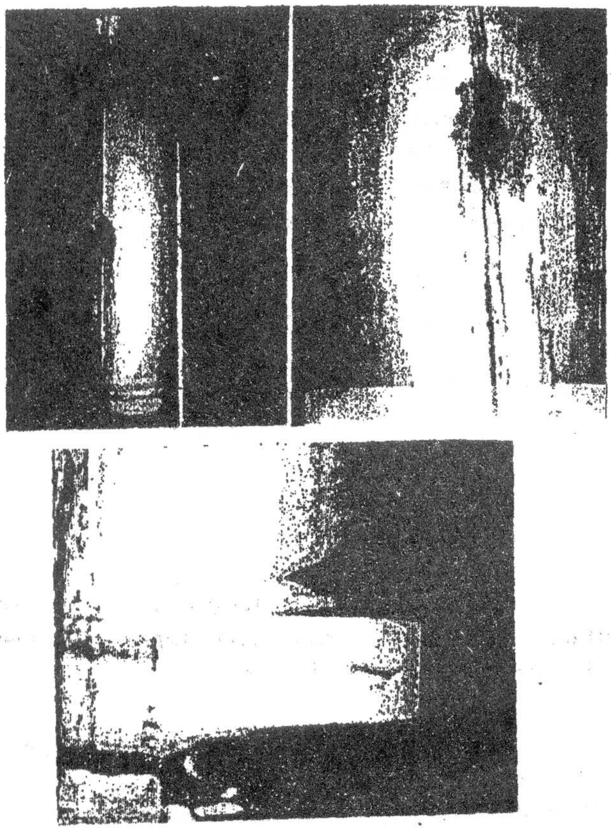

Figure 10. Pitting corrosion.

CONCLUSIONS

Inservice Inspection manual for ET-RR-1 is neces to plan future inspection and to prepare equipments specialists. Project of reactor development has t reviewed, approved and financially supported. Re of ISI programme are satisfactory.

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