2024 International Nuclear Atlantic Conference – INAC 2024
Escola de Guerra Naval, Rio de Janeiro, RJ, May 6 - 10, 2024

ISBN: 978-65-594-1256-3

Study of the renewed pipework of the TR-1B Cooling Tower of the IEA-R1 RR

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1. Introduction

IEAR1 is a 5MW research reactor located at the Institute for Energy and Nuclear Research (IPEN) in São Paulo - Brazil, which was commissioned in 1957. It is a pool type reactor, with a light water moderator and Graphite/Beryllium reflectors. Since the start of operation, the IEA-R1 reactor has been modified for various reasons, such as changing structures and components, modernizing systems and adapting the plant to safety standards, which are updated over time. The reactor can reach up to 5MW heating power and coolant by two systems composed of the primary and secondary systems. The primary coolant system consists of a piping system, a decay tank, two pumps, and two heat exchangers. The secondary system consists of piping system, two pumps, two heat exchangers and two cooling towers [1], [2]. All parts of the primary and secondary system are monitored by maintenance program which provides data for the Maintenance Management Program. This maintenance program detected an excessive corrosion in part of the secondary piping system. After some studies was identify that the excessive corrosion occurring due to its exposure to air during intermittent operation between Tower A and Tower B. In normal operation part of the pipe is emptied as consequence the inside piping is fully of air, thus increasing its corrosion. For this reason, it is planned to replace the stretch of pipe between the CS-VGV-14 valve and the water discharge system piping at the TR-1B Cooling Tower. Originally this part of the pipework was fabricated in CarbonSteel, otherwise to avoid future oxidation the new piping is planned to be fabricated in Stainless Steel. In addition, the pipe supports on the same stretch will be refurbishment and optimize the water flushing system in the TR-1B Cooling Tower, changing from 2 holes/nozzles of 10" nozzles to 94 holes/nozzles of 1.1/2". Finally the CS-VGV-14 valve will also be relocated to a horizontal position in order to facilitate its operation.
This report is focused in present the results of the stress calculations and simulations to replace this part of the piping system of the secondary circuit of the IEA-R Research Reactor, mainly the pipeline from Valve CS-VGV-14 to the distributor of the TR-1B Cooling Tower.

2. Methodology

The new stretch of piping demands no modifications in the piping trace, therefore the introduction of different piping material (SS), new water flushing distribution, new position of the valve, support relocation and consequently redistributing of the values of the forces and moments in the piping system, a stress analysis [3] was demanded. A structural analysis of the pipework was carried out with a calculation model between the nozzles of the CBC and IESA heat exchangers up to the inlet of the TR-1A Cooling Tower and the outlet nozzles of the TR-1B Cooling Tower. The calculation model [3] was done in accordance with the new piping condition and was simulated with the computer program CAESAR II [4].
The Figure 1 shows the analyzed part of the secondary piping system from Valve CS-VGV-14 to Cooling Towers including the proposal of the new configuration (spotted in red color).

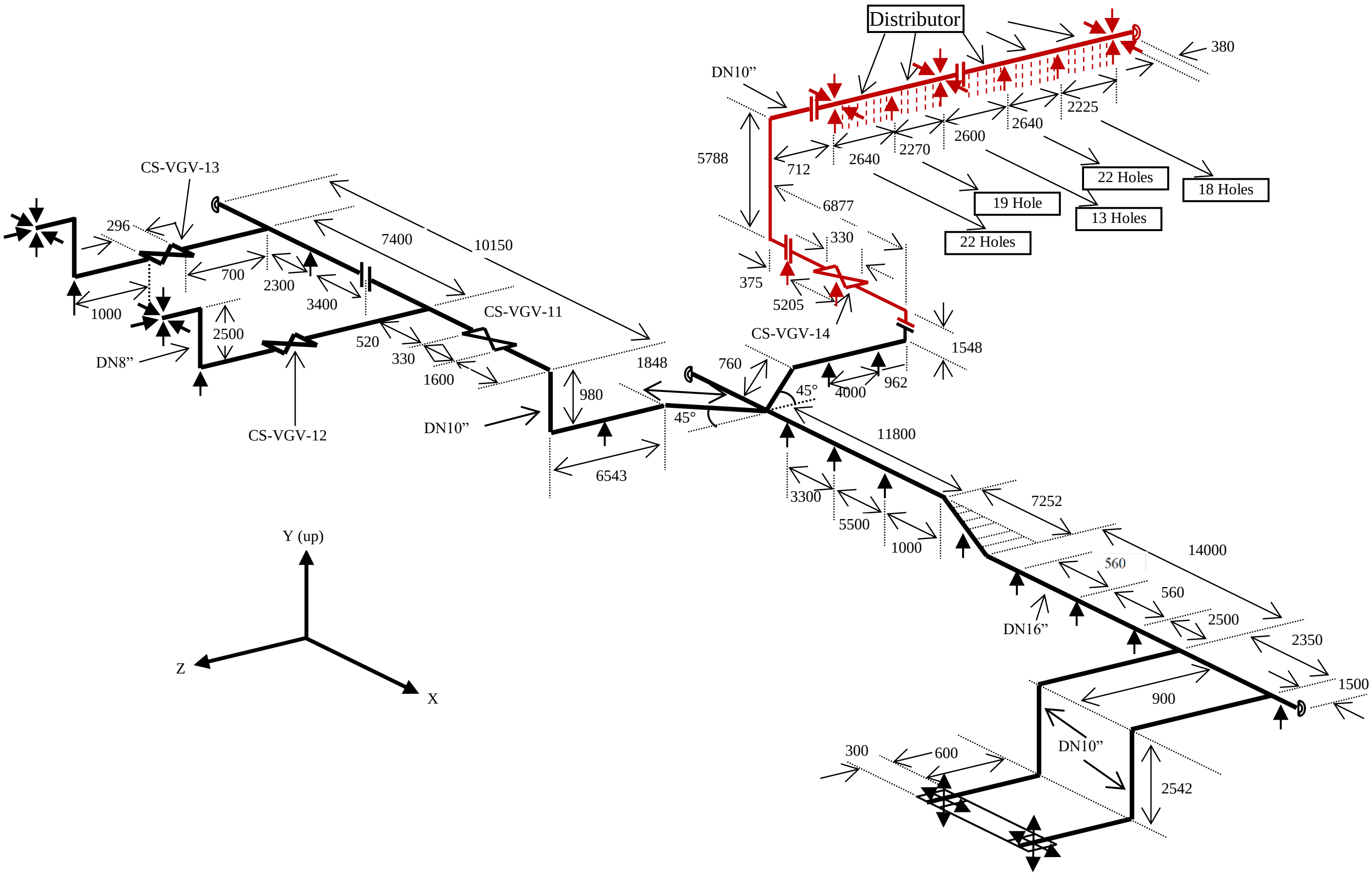

Figure 1: IEA-R1 Secondary System
Source: Autor

To initiate the study, data process data and material data of the reactor cooling system were collected. The process data of Design and Operational (Service) condition are presented in Table I.

Table I: Design and Operational process data of the Reactor [2].

Condition	Pressure (N/mm^2)	Temperature (°C)
Design	0.689	65.6
Service	0.44	36.6

The Table II presents the properties of the Secondary Piping material for this part of the system considered in this study. It was adopted the same material used in the Primary System.

Table II: Piping material specification. [5]

Material	**α**	**E**(N/mm^2)	S_H(N/mm^2)	S_Y(N/mm^2)
A106 A	15.6x10-6	203400	110.3	206.8
A285 A	15.6x10-6	203400	103.4	165.5
A312-TP304	15.6x10-6	195100	137.9	206.8

The Table III presents the geometric properties of the Secondary Piping material for this part of the system considered in this study. It was adopted the same material applied in Primary System.

Table III: Geometric Pipe specification. [3]

Nominal Diameter(mm)	SCH	External Diameter(mm)	Thickness (mm)
200	40	219.07	8.18
250	40	273.10	9.27
250	5S	274.64	3.40
400	30	406.40	9.53

A hydraulic study [6] about the water flow in the top of the pipework of TR-1B tower was carried out in the area of the flushing system the tower, this way parameters were specified and presented in table IV.

Table IV: Geometric holes/nozzles specification [6]

Nominal Diameter(mm)	Holes	Holes distance (mm)	Flow velocity (m/s)	Pressure drop (ΔP)
38,1	94	100	1,66	4116

Methodologies for calculating the following items have been developed:

- Minimum pipe wall thickness; [7]
- Distributor reinforcement area; [7]
- Minimum spacing between distributor holes; [7]
- Water jet force; [6]
- Calculation model for analyzing pipe stresses. [3]

Stress analysis based on the ASME code [8] was carried out which establishes the criteria for calculating the stress of components and pipework based on two categories of loads related to self-limiting, mechanical loads inducing primary stress, and non-self-limiting stresses thermal forces inducing secondary stress.

Table V: Operational condition x Failure Mode x Stress

Condition	Failure Mode	Stress
Design	Structural Fail	Primary
Thermal Expansion	Plastic deformation	Secondary

The stress analysis to predict structural failure in the pipework due to primary loads must meet the criteria for general primary stress and localized primary stress established in paragraph 302.3.5 (1) of the ASME B31.3 code [8]. This equation establishes that the Longitudinal Stresses considering internal pressure, self-weight, mechanical loads and distributor loads must meet the stress limit in the plant's design condition. The stress analysis of the pipe to avoid failure due to accumulation of plastic deformation must meet the secondary stress limit criterion, as prescribed in paragraph 302.3.6 (2) of the ASME B31.3 code [8]. This equation states that the longitudinal stresses resulting from thermal expansion due to plant heating must meet the secondary stress limit. The ASME B31.3 equations for the Design Condition (1) and Thermal Expansion (2).

Design

$$\frac{P\ x\ D_o}{Z} + (0.75\ x\ i)\frac{M_a}{Z} \leq 1.0\ x\ S_H \qquad (1)$$

Thermal Expansion

$$(302.3.6)\ \frac{\boldsymbol{i\ x\ M_c}}{\boldsymbol{Z}} \leq \boldsymbol{S_A} \qquad (2)$$

3. Results and Discussion

The complete study including minimum pipe wall thickness (Sch 5s, approved), distributor reinforcement area (reinforcement not required), minimum distributor hole spacing (100 mm, approved) and water jet force (F=8N low force) resulted in approval of the specifications and details proposed for the refurbishment. These positive results provide consistent data for the stress analysis of the segment to be replaced. From the calculation model of the analyzing pipe stresses calculated in the Caesar II Program, resulting in stress loads that not reach the limit prescribed in B31.1 ASME Code as shown in Table VI.

Table VI: Stress Analysis Results

	Design		Thermal Expansion	
	Stress (N/mm^2)	Limit (N/mm^2)	Stress (N/mm^2)	Limit (N/mm^2)
Pipe TR1-B	39.0	137.9	106.6	206.8
Distributor	24.2	137.9	112.8	206.8
Other Pipes	18.1	137.9	7.8	206.8

4. Conclusions

As stated before, the results obtained with the calculation methodologies mentioned above and the computer simulation of the numerical calculation model for stress analysis with the CAESAR II program [3], for the Design Condition and Thermal Expansion (paragraphs 302.3.5 and 302.3.6 of B31.3), indicate full compliance with the requirements laid down in ASME VIII division 1 [7] and ASME B31.3 [8].

Acknowledgements

The authors are grateful to IPEN/CNEN for the support of this work and the help of colleagues in doing this work, particularly the staff from the IEAR1 Reactor.

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