The International Journal of Engineering and Science (IJES)
|| Volume || 7 || Issue || 11 Ver.II || Pages || PP 06-09 || 2018 ||
ISSN (e): 2319 – 1813 ISSN (p): 23-19 – 1805

Equipment Testing Under LOCA Conditions

Martin Brezina[1a], Roman Mohyla[1b], Michaela Rabochová[1c]
[1]Centrum výzkumu Řež s.r.o., oddělení Diagnostika a kvalifikace
Hlavní 130, 250 68 Husinec - Řež
Corresponding Author: Martin Brezina

----------***ABSTRACT:***----------
Safety is the highest priority of nuclear power plant operation. Nuclear power plants are designed with the safety in mind, while taking into account the anticipated operational occurrences and accidents. Despite the low probability of these events occurring, it is important to have the safety systems, strategies, trained operators and durable equipment in place. The safety systems and equipment have to stay functional during normal operation, but also under harsh conditions, that may occur in case of an accident. Equipment that is essential for safety systems and may be subjected to harsh conditions have to be tested and subsequently qualified to ensure their long-time durability. The process of testing involves subjecting the equipment to harsh conditions, comparable to a real accident. The purpose of LOCA Laboratory is simulation of harsh conditions of Loss of Coolant Accident. The laboratory is used in development process of new equipment for current and future generations of Nuclear Power Plants.

Date of Submission: 15-11-2018 Date of acceptance: 29-11-2018

I. INTRODUCTION

LOCA laboratory is used for testing and development of new equipment designed for nuclear power plants[2].Harsh conditions of design basis accidents and also beyond design basis accidents can be tested in LOCA laboratory. The available parameters of our technology are suitable for current and future generations of nuclear power plants.

Harsh conditions are simulated in three different pressure vessels. Two of them are called Large LOCA and Small LOCA and they are used to simulate the effects of LOCA on equipment. The vessels are different in dimensions and volume. The thermodynamic parameters, which are achievable are identical in both pressure vessels.

The third pressure vessel is called H2 simulation pressure vessel. It has different size, volume and also obtainable thermodynamic parameters compared to other two pressure vessels. It is used to simulate the explosion of hydrogen inside containment, and its effects on equipment. The temperatures are achieved by heating the vessel with electric heaters, so there is actually no real hydrogen, and no explosion.

II. LOCA LABORATORY

The laboratory is composed of four main parts, which complement each other and create a well-functioning technology. The main parts of the laboratory are:

1. Pressure vessels for harsh conditions simulations
2. Steam cycle, Hot air cycle
3. Water and condensate management system
4. Measurement and control system

Steam cycle of our laboratory is composed of gas-powered boiler with steam accumulator and two superheaters. The gas-powered boiler produces saturated steam and if the test requires superheated steam, the steam passes through superheaters to gain desired properties. Hot-air cycle consists of electric heaters and fans, which power the air through heat exchanging surfaces, to supplement the heating of the steam.

Water and condensate management system is composed of containers with spray and flood solutions. Those solutions are usually a mix of distilled water and boric acid, to simulate chemical effects on tested equipment.

Measurement and regulation system is used to control the whole process of testing. The measurable parameters of testing are steam temperature and pressure inside the vessels. The composition of the atmosphere inside the vessels can be also measured, as the atmosphere can be altered with synthetic air and nitrogen. The mass flow of steam is measurable only on H2 simulation vessel.

Electrical equipment and cables can be connected and tested during LOCA and hydrogen explosion simulation, to verify their functionality under harsh conditions of these accidents.

Fig. 1 LOCA Laboratory (Left – Hot air cycle), Bottom – Small LOCA, Top – Superheaters

Tab. 1 Pressure vessel parameters

Pressure Vessel	Large LOCA	Small LOCA	H2 Simulation Vessel
Volume (m^3)	3,5 (2,5)	0,6 (0,3)	0,4 (0,4)
Inner Dimensions Saturated steam (m)	ø 1,5 x 2,1	ø 0,8 x 1,3	ø 0,6 x 1,5
Inner Dimensions Superheated steam (m)	ø 1,3 x 1,9	ø 0,6 x 1,1	ø 0,6 x 1,5
Maximum temperature (°C)	300	300	800
Maximum pressure (Bar)	20	20	20

2.1 Equipment testing

Equipment is tested under various thermodynamic conditions that are achievable in the pressure vessels. The LOCA technology is designed to replicate the conditions similar to those encountered in a real accident. The equipment is tested under those conditions and evaluated during and after testing.

In the first stage of testing, the equipment is exposed to saturated or superheated steam at high pressure and temperature. After a certain period of time, the emergency showering systems starts to operate. Emergency showering systems of the LOCA technology are similar to those installed in containment. Solutions act as a coolant but they expose the equipment to chemical degradation effects. In the last phase of testing, the equipment is flooded in a flooding solution, where it gradually cools down. The equipment might be operated during testing to

Fig. 2 LOCA Laboratory (Left – Gas separator, Center – H2 simulation vessel)

2.1.1 Thermodynamic profiles

The test is initiated by releasing superheated steam into a Large LOCA vessel. The temperature and pressure consequently rises rapidly. The thermodynamic para-meters are maintained at a certain level (300 °C, 20 bar) for a period of time, and then it starts to cool gradually. Maximum parameters of this test are achieved in 60 s.

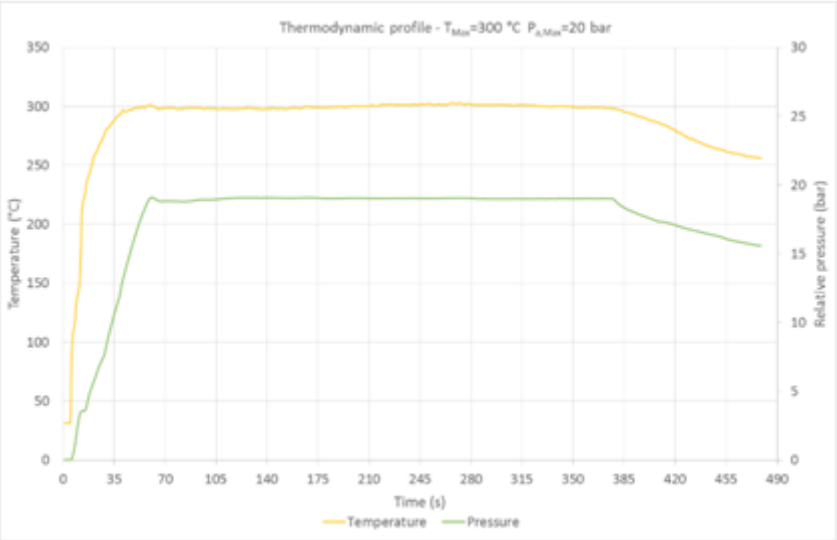

Fig. 3 Large LOCA test profile

The test shown on Fig. 2 was done in a Small LOCA vessel, saturated steam was used as a test medium. The desired parameters (200°C, saturation pressure) were achieved in 10 s. The parameters are maintained for a period of time and then the vessel is gradually cooled.

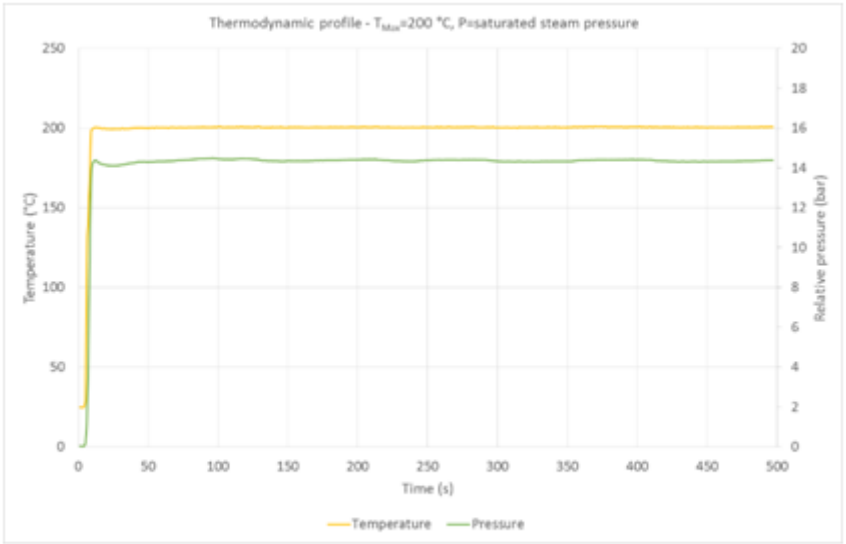

Fig. 4 Small LOCA test profile

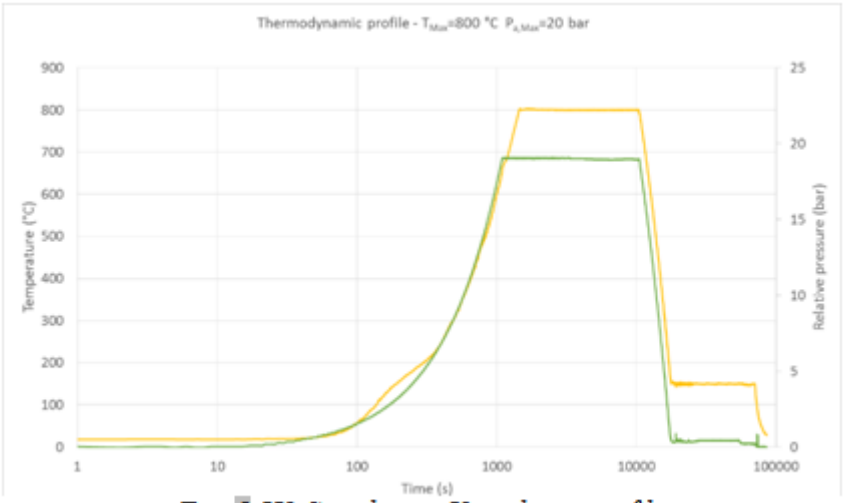

Fig. 5 H2 Simulation Vessel test profile

The H2 Simulation Vessel allows us to perform high temperature tests on equipment. The conditions of the test are similar to the ones in case of an H2 explosion. The desired parameters (800 °C, 20 bar) are reachable in 3 h. These parameters are maintained for a while and then the vessel is cooled until the temperature decreases to 150 °C and afterwards to an ambient temperature.

III. CONCLUSION

The LOCA laboratory allows us to support the development of new devices for nuclear power plants and also verify their functionality under harsh conditions. Equipment testing is essential for safe operation of nuclear power plants. The tests can be harsher and due to the size of vessels in this laboratory, it is possible to test larger devices compared to other similar laboratories.

ACKNOWLEDGEMENT

The presented work was financially supported by the Ministry of Education, Youth and Sport Czech Republic - project LQ1603 Research for SUSEN. This work has been realized within the SUSEN Project (established in the framework of the European Regional Development Fund (ERDF) in project CZ.1.05/2.1.00/03.0108 and of the European Strategy Forum on Research Infrastructures (ESFRI) in the project CZ.02.1.01/0.0/0.0/15_008/0000293, which is financially supported by the Ministry of Education, Youth and Sports - project LM2015093 Infrastructure SUSEN.

REFERENCE

[1]. Návody a doporučení pro kvalifikaci zařízení důležitých pro bezpečnost jaderných elektráren typu VVER [Online] [Citation: 19. 3. 2018.] https://www.sujb.cz/fileadmin/sujb/docs/dokumenty/publikace/MP_kvalifikace_zarizeni-pro_VVER440.pdf

[2]. Nuclear fuel behaviour in Loss-of-coolant Accident (LOCA) conditions [Online] [Citation: 19. 3. 2018.]https://www.oecd-nea.org/nsd/reports/2009/nea6846_LOCA.pdf

[3]. Erhart, J., Rabochová, M. Nová LOCA laboratoř v Centru výzkumu Řež s.r.o. [editor] Ing. Pavel Kovář. Bezpečnost jaderné energetiky/Bezpečnosť jadrovej energie. 2017, Sv. 25, 1/2, stránky 14-17.

[4]. Research Centre Rez Ltd. SUSEN and R4S. [Online] 2018. http://susen2020.cz.

Martin Brezina "Equipment Testing Under LOCA Conditions " The International Journal of Engineering and Science (IJES),), 7.11 (2018): 06-09