DISPENSER FOR WATER SAMPLING FROM SUPERCRITICAL CONVECTION LOOP

V.N. Boriskin, Yu.V. Gorenko, G.G. Kovalev, V.A. Momot, A.N. Savchenko, V.I. Solodovnikov, S.V. Shelepko, G.N. Tsebenko
National Science Center "Kharkov Institute of Physics and Technology", Kharkov, Ukraine

Since 2009, the Kharkov Institute of Physics and Technology is working towards the development of equipment and methods for testing the materials for reactors SCWR (STCU project P4841). Supercritical water convection loop with a vessel, which is exposed to electron irradiation of the electron accelerator LU-10 (8…10 MeV, 10 kW), provides an opportunity to study corrosion and mechanical damage of sample materials. Small quantity water sample (1…3 ml) dispenser is designed for sampling the water out of the loop which is under 23.5 MPa pressure.

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INTRODUCTION

For the experiment, the hydraulic scheme of convection loop CU-EITF (Fig. 1) was designed, which should perform the following functions:

- Initial increase of pressure in the system up to 23.5 MPa.
- Monitoring and measurement of pressure up to 30 MPa in the loop.
- Measurement of the amount of fluid flowing in heating loop.
- Pressure stabilization at 23.5 MPa ± 0.2 MPa.
- Sampling of water (1…3 ml) from the system under pressure of 23.5 MPa.
- Chemical analysis of the water coming from the loop (pH measurement and oxygen content).
- The degassing and decontamination of the water, and feed it back into the system at a given speed.

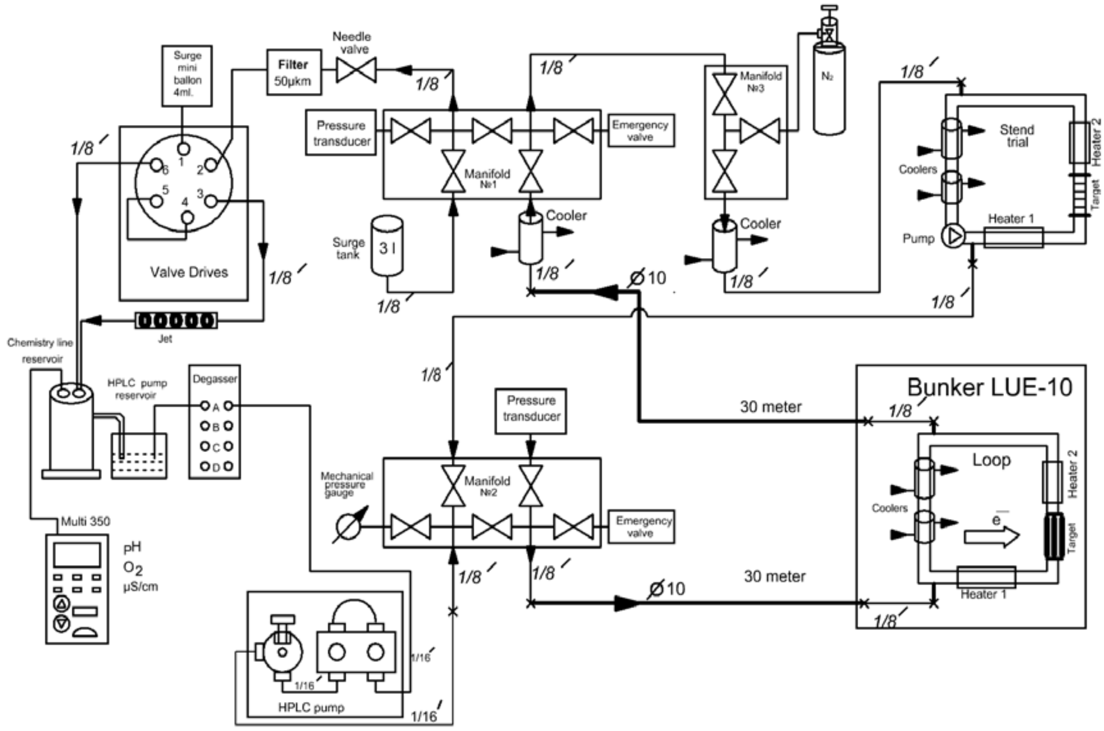

Fig. 1. Hydraulic circuit loop CU-EITF at the time of experiments 20.07-20.08. 2012

1. DISPENSER CONSTRUCTION

The control rack for the loop was made (Fig. 2). The right side of the rack is control panel for system management. Left side performs the functions:

- mechanical purification and degassing;
- discharge of excessive water;
- pumping and pressure maintaining;
- chemical analysis.

Before starting the experiment, the loop was filled with distilled water. Water poured into a loop through the lower tube that would avoid the formation of air pockets. Then using the pump *Smartline Pump 100-V5010A* (capacity of 0.001 to 10 ml/min and a maximum pressure of 40 MPa) (Fig. 3) the pressure in the system was raised up to P = 23.5 MPa.

During heating the loop, pressure rapidly increases (up to ~ 0.1 MPa/s) due to thermal expansion of water. Excessive water is discharged from the loop in order to allow further pressure increase. The amount of discharged water is controlled by "block measuring the amount of the flowing fluid".

After reaching the desired temperature and pressure in the system, water selection and water injection, switches to closed loop.

Next, the water injection was carried out as follows: after passing through the 4-channel degasser *Knauer Online Degasser V7620* (decontamination performance up to 10 ml/min) (Fig. 4). The distilled water was supplied to the loop through 1/8 inch capillary using *Parker* pump *Smartline Pump 100-V5010A* with adjustable speed from 0.001 to 10 ml/min.

Fig. 2. General view of the control rack

Fig. 3. Smartline Pump 100-V5010A

Fig. 4. Knauer Online Degasser V7620

Sampling of water is performed through the capillary 1/8 inch Parker and mechanical filter 5 microns *Parker*. Due to the complexity of implementing the continuous collection the pressure, it was decided to use a discrete dispenser *Smartline Valve Drives S6* (Fig. 5) in combination with throttle and expansion vessel (Fig. 6) with volume V = 4 ml filled with helium. Helium is used because of its low solubility in water comparing to other gases (Fig. 7).

Fig. 5. Digital dispenser Smartline Valve Drives S6

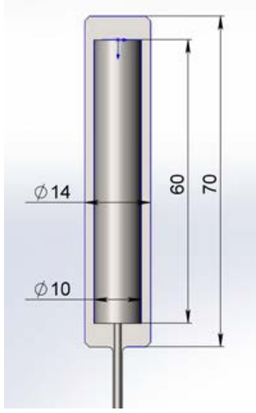

Fig. 6. Expansion vessel with helium

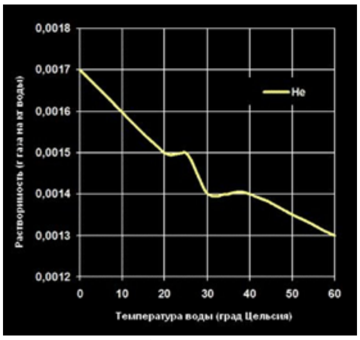

Fig. 7. Solubility of the helium -He- in water

The principle of operation of the scheme is as follows: expansion vessel filled with helium through a discrete dispenser *Smartline Valve Drives S6* connected to the loop in position «I» and during the pressure increasing, water fills the pressure expansion vessel, and compresses the helium. When the pressure reaches up to P = 23.5 MPa, electronic circuit switches the dispenser in position «L», that water (~ 3…3.5 ml), from the expansion vessel, by compressed helium through the capillary was dropped to the open container in which the chemical analyzer *WTW Multi 350i SET* is placed (Fig. 8), and then returns the dispenser in position «I».

Fig. 8. WTW Multi 350i SET

Thereby, the pressure in the system drops ~ 0.2…0.4 MPa (Fig. 9). At the initial stage of the experiment, when the temperature and the pressure in the loop grows fast ~ 0.1 MPa/s, the water dropped from the loop manually, by button placed on the electronics scheme system via the nozzles of the dispenser. For further protection, on the monitoring system installed mechanical emergency valve Relief Valves (RH4 Series) Parker and and the pressure sensor is triggered when pressure exceeds 27 MPa.

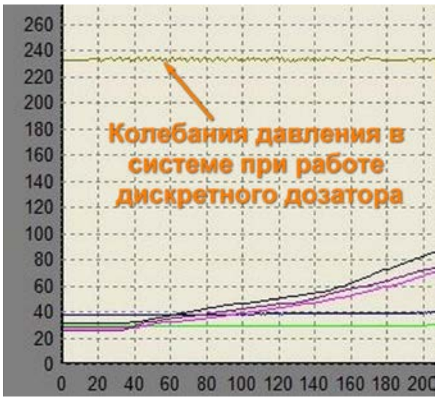

Fig. 9. Pressure fluctuations in the system when using discrete dispenser

2. WATER'S CONTROL PARAMETERS

In August 2012 with the help of the LUE-10 accelerator held four sessions of exposure 16 (8+8) samples Inconel 690 and Zr in a convection loop (see Fig. 1). Loop mode of operation – (P = 23.5 MPa, the maximum temperature on the surface of the irradiation chamber to 400ºC). Total sessions time is 574 hours (of which 497 hours with a electron irradiation), maximum fluence on the surface of the irradiation chamber to 1020 electrons/cm^2. 9…11 MeV electron energy, the average current electron beam of 0.5…0.8 mA. Pulse repetition rate is 250 Hz. Pulse duration 3.4 µs. Scanning frequency 3.5 Hz. The water flow in the loop evaluated by simulation 70…80 g/s. Accordingly, the linear velocity of the subcritical water in the irradiation chamber to the cassette 0.5 m/s. Chemical analysis of the water coming from the loop (pH measurement and the content of oxygen) was performed throughout the experiment using *WTW Multi 350i SET*.

The loop is filled with water with pH = 6.5, conductivity 7…11 µS/cm, oxygen ppb = 0.5. Water came out of the loop at 5 ml/min flow rate. The delivery time of samples on the 30-meter line was 5 hours. Parameters of water exiting the pH = 5.3…6.0 conductivity 7…23 µS/cm, oxygen ppb = 3…4. After degassing, the water was putted back into the loop. Increase in conductivity was about 0.1 µS/cm per hour, i.e. the amount of salts in the water increases. When conducting elemental chemical composition analysis of water samples using a spectrometer ICPE-9000 by "Sumadzo" it was found that all samples contained chromium (8…54 mg/l) and there is no zirconium. A rough estimate of the increase in conductivity of water in the loop for 120 hours amounted to 0.1 µS/cm per hour. Evaluation increasing amounts of chromium in water for the same period of about 0.1 mg/l per hour.

CONCLUSIONS

This hydraulic circuit (pump *Smartline Pump 100* and discrete dosing *Smartline Valve Drives*) allows you to maintain the required system pressure P = 23.5 ± 0.2 MPa and collect water samples for monitoring the parameters throughout the experiment.

Described discrete dispenser worked ~ 1.000 hours.

Using *WTW Multi 350i* device, the parameters of the water were controlled on its way out the system.

Knauer Online Degasser device provides the "water degassing" before returning it in to the system.

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ДОЗАТОР ДЛЯ ОТБОРА ПРОБ ВОДЫ ИЗ СВЕРХКРИТИЧЕСКОЙ КОНВЕКЦИОННОЙ ПЕТЛИ

В.Н. Борискин, Ю.В. Горенко, Г.Г. Ковалев, В.А. Момот, А.Н. Савченко, В.И. Солодовников, С.В. Шелепко, Г.Н. Цебенко

С 2009 года в Харьковском физико-техническом институте ведутся работы, направленные на разработку оборудования и методологии для оценки реакторных материалов, предназначенных для реакторов SCWR (проект УНТЦ Р4841). Специально разработана в ХФТИ сверхкритическая водяная конвекционная петля с камерой для облучения ускорителем электронов ЛУ-10 (8…10 МэВ, до 10 кВт) дает возможность изучения коррозии и механических повреждений материалов при облучении пучком электронов. Разработан дискретный дозатор для отбора проб воды (1…3 мл) из системы, находящейся под давлением 23,5 МПа.

ДОЗАТОР ДЛЯ ВІДБОРУ ПРОБ ВОДИ З НАДКРИТИЧНОЇ КОНВЕКЦІЙНОЇ ПЕТЛІ

В.М. Борiскiн, Ю.В. Горенко, Г.Г. Ковальов, В.А. Момот, А.М. Савченко, В.І. Солодовнiкoв, С.В. Шелепко, Г.М. Цебенко

З 2009 року в Харківському фізико-технічному інституті ведуться роботи, що спрямовані на розробку устаткування та методології для оцінки реакторних матеріалів, призначених для реакторів SCWR (проект УНТЦ Р4841). Спеціально розроблена в ХФТІ суперкритична водяна конвекційна петля з камерою для опромінення прискорювачем електронів ЛУ-10 (8…10 МеВ, до 10 кВт) дає можливість вивчення корозії і механічних пошкоджень матеріалів при опроміненні пучком електронів. Розроблено дискретний дозатор для відбору проб води (1…3 мл) з системи, яка знаходиться під тиском 23,5 МПа.