SUPERCRITICAL WATER CONVECTION LOOP CONTROL SYSTEM

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The Convection Loop control system for research of water parameters in supercritical and "nearby" critical state is considered. Results of experiments are presented.

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INTRODUCTION

Reactors cooled by water in a supercritical state (Supercritical Water-Cooled Reactor, SCWR) are one of new nuclear technologies [1 - 2]. For an estimation of reliability of potential structural materials for the SCWR reactors, the Supercritical Water Convection Loop (SCWCL) is designed and created [3 - 8]. All component parts of the SCWCL are designed for safe operation at temperatures up to 450°C and pressures up to 25 MPa. The automatic control system for management of the supercritical water convection loop is developed and tested. The monitoring system provides measurement of pressure, speed of water stream and temperature on a surface of a loop. In an automatic mode capacity of electric heaters is adjusted, the pump work and emergency valves is supervised. If the temperature or the pressure of SCWCL components exceed the established values, the monitoring system disconnects heaters, a beam current of the linear accelerator [9 - 11] and the pump. The emergency mechanical valve, which operates at up 27 MPa pressure, is established in the monitoring system for the additional protection.

1. CONTROL SYSTEM DESCRIPTION

In the Fig. 1 the block diagram of a Supercritical Water Convection Loop control system at the moment of carrying out of experiments is presented.

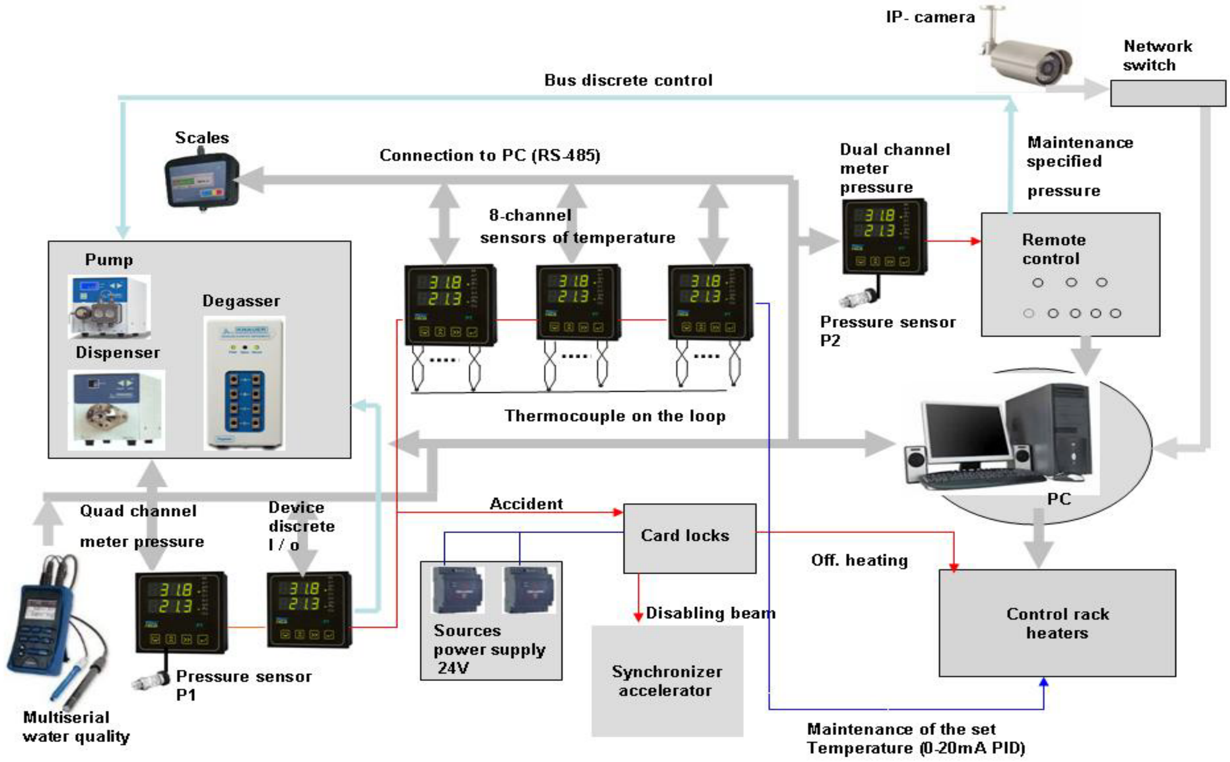

Fig. 1. The block diagram of a loop control system

Basic functions of the control system are:

- automatic (on the operator commands) switching-on or switching-off of the linear electron accelerator (LU-10);
- automatic emergency switching-off of the accelerator systems in the case of the inadmissible deviations of the beam parameters;
- automatic emergency switching-off of the SCWCL systems in the case of the inadmissible deviations of temperature and pressure values in the contour of the loop;
- measurement and indication of the SCWCL parameters.

Structurally the SCWCL control system consists of the central rack of the control, the rack of the heater management, an operator's console and `a set of sensors.

Functionally the control system includes:

- the block of the temperature measurement in the loop. It makes possible the control and measurement of temperature (Fig. 2) up to 450ºC in 24 points on the loop surface;

- the block of the pressure measurement in the loop up to 30 MPa;

- the pressure stabilization block in the loop. It includes pump HPLC with productivity up to 10 ml/min, a four-channel deaerator, and discrete dispenser. It allows a pressure supporting at the set level (less than 25 MPa) up to ± 0.2 MPa using the developed block of discrete dispenser control;

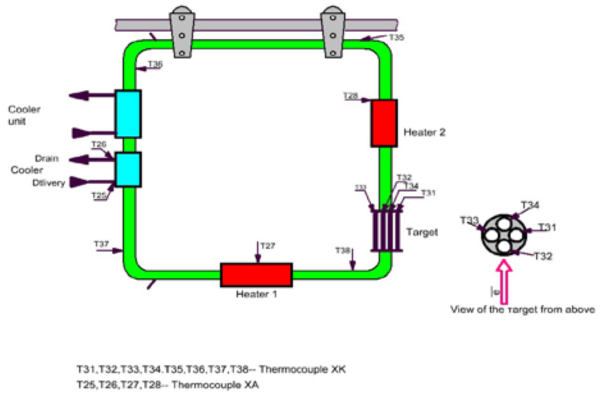

Fig. 2. Diagram of the temperature measurement on the loop surface

- the block of the chemical analysis of the loop water. It allows measurement of the water acidity and oxygen presence in the water. For the chemical analysis and degassing the small portion of water is issued from a loop through capillaries, valves and the filter in the memory tank. The high pressure pump (HPLC) ensures the water recirculation (back to the loop) after degassing. The personal computer on the basis of Intel ™CPU oversees work of the automatic valves and the pump;

- the-block of the quantity liquid measurement, which flow out from the heated loop. The measurement makes on-line by the electronic balance;

- the block of the accelerator beam switching-off. At emergencies (the output for the established borders of values of temperature and of pressure in system SCWCL) heaters and a electron beam of the accelerator LU-10 are disconnected;

Fig. 3. Camera video observation, which used in the electron accelerator bunker, enclosed in the protective lead housing

- a control panel. Two computers are used. The first computer controls the system work through the use of the RS485 interface. The second computer is applied- to video observation. It is connected on a local network;

- video observation system. It consists of the two Web-cameras. The first video camera tracks (supervises) the test facility room, the second video camera is disposed in the bunker (Fig. 3) and may be used for the video observation and for the precision adjustment of the electron beam in the irradiation chamber plane (Fig. 4);

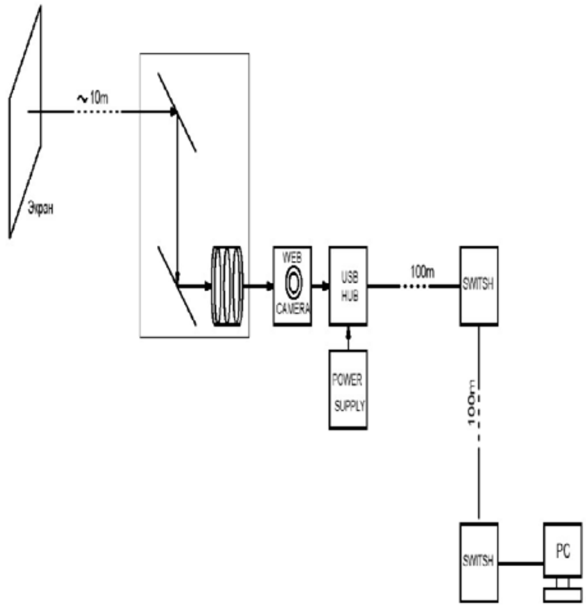

Fig. 4. Functional chart of the display system of the linear accelerator beam imprint

- the block of the heater control. Capacity in heaters is remotely adjusted by the operator by means of a computer. The chart of the recalculation of operating influence units in kilowatts is resulted on the Fig. 5.

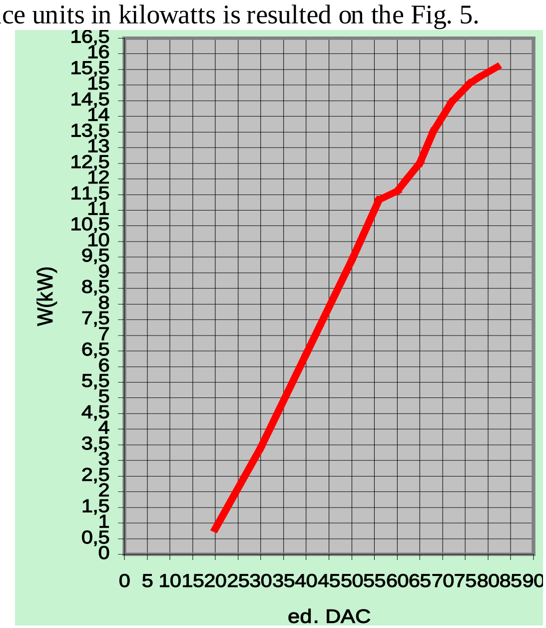

Fig. 5. The chart of recalculation of operating influence units in kilowatts

The parameters of the electron beam (Fig. 6) are supervised by the operator of the LU-10 accelerator and kept in archive (Fig. 7).

Fig. 6. The display screen on an operator's console of the LU-10 accelerator

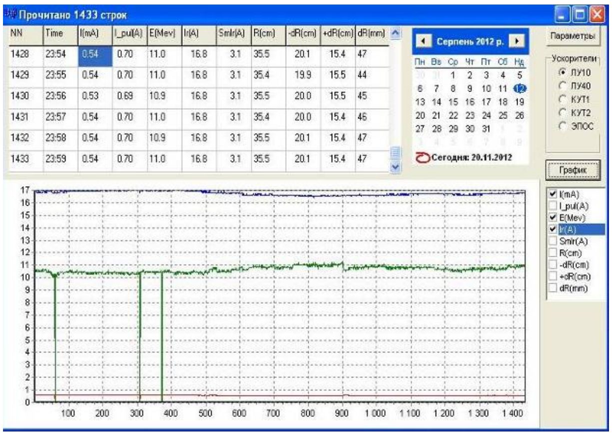

Fig. 7. It is the information for 12.08.12. from the parameter archive of the LU-10 accelerator

2. EXPERIMENT

The prolonged experiment (500 hours persistence) was spent to research supercritical water. Observation results are presented on Figs. 8-10.

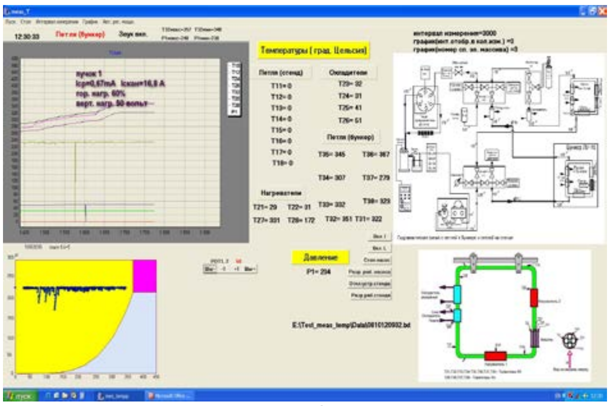

Fig. 8. The representation of the measured parameters on the monitor screen when the experiment has been performed

The developed automated system of data gathering and data processing, allows to transfer to a computer the information on measurement results of temperature, pressure, capacity of heaters. The data are displayed on the computer monitor in a on-line mode.

Data received as a result of experiments are brought in memory of a computer for the further analysis.

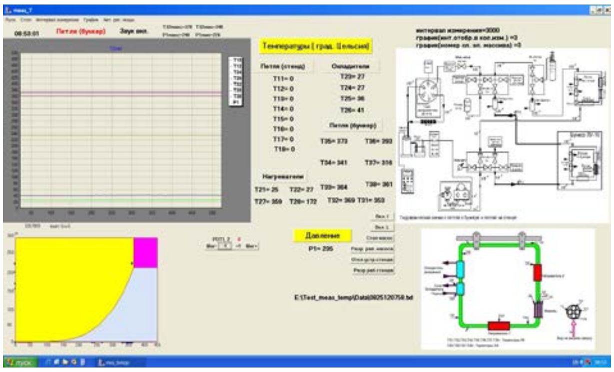

Fig. 9. The representation of the measured parameters on the monitor screen, the super critical regime: P=23.5…24 MPa, T=350…380ºC

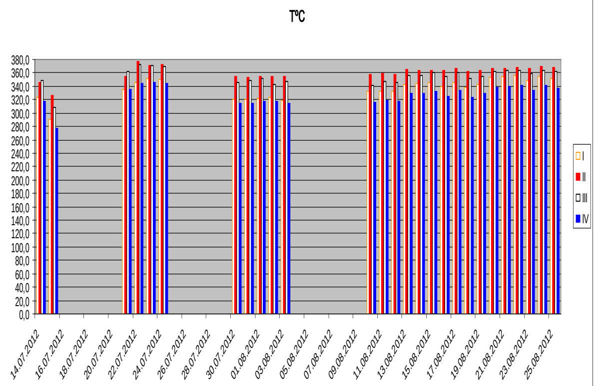

Fig. 10. Average temperature on an external surface of the top part of channels (I-IV) of the irradiation chamber

CONCLUSIONS

1. The developed control system demonstrated long-term reliability during 500 hour experiment on the LU-10 accelerator.

2. The way of pressure stabilization of the set level (25 MPa) by the discrete batcher control is found.

3. The created software effectively automatized the experiment realization.

4. The results received in experiments were put in the computer memory and further were analyzed by means of various applied programs.

5. An application of gland heaters of the closed type has made processes of a loop heating up to temperatures 300ºC and above more safe (in comparison with heaters of the open type).

6. An application of video observation during an irradiation of a loop in bunker LU-10 has allowed to spend the positioning a beam in on-line mode.

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СИСТЕМА УПРАВЛЕНИЯ СУПЕРКРИТИЧЕСКОЙ ВОДНОЙ КОНВЕКЦИОННОЙ ПЕТЛЕЙ

В.Н. Борискин, В.А. Момот, С.К. Романовский, А.Н. Савченко, В.И. Солодовников, С.В. Шелепко

Разработана и изготовлена система управления сверхкритической конвекционной водной петлей. Представлены структурная схема и характеристики системы управления. Выбраны режимы управления для проведения экспериментов. Приведены результаты экспериментов со сверхкритической конвекционной водной петлей на ускорителе ЛУ-10.

СИСТЕМА КЕРУВАННЯ НАДКРИТИЧНОЮ ВОДНОЮ КОНВЕКЦІЙНОЮ ПЕТЛЕЮ

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Розроблена і виготовлена система управління надкритичною конвекційною водною петлею. Представлені структурна схема та характеристики системи управління. Обрано режими управління для проведення експериментів. Наведено результати експериментів з надкритичною конвекційною водною петлею на прискорювачі ЛУ-10.