17th World Conference on Nondestructive Testing, 25-28 Oct 2008, Shanghai, China

The Automated Device For Leak-testing Of Nuclear Fuel On Their Manufacturing

Igor I. LOKTEV [1], Eugene FROLOV [2]
[1] JSC "TVEL", JSC "Novosibirsk Chemical Concentrates Plant";
94, B. Khmelnitsky Str., Novosibirsk, Russia, 630110,
Tel: +7(383) 274-83-46; Fax: +7(383) 274-30-71; E-mail: nzhk@nccp.ru
[2] JSC "TVEL", JSC "Mashinostroitelny Zavod",
12, K. Marksa str., Electrostal, Moscow region, Russia, 144001,
Tel: +7 (495) 702-9901; Fax: +7 (495) 702-9221; E-mail: zymsz@elemash.ru

Automation of manufacture and quality control of nuclear fuel is a necessary condition of achievement of ambitious plans for atomic power development in the countries which join in process of an intensification of nuclear energy development. The modern automated industrial line is complex of modern machinery, automatized and computerized systems. As for leak testing of industrial products, it is very difficult to automatize them. As a rule, it is necessary to adapt technology of the control and automatized control device to each other.

The aim of this paper is description of the automatized leak-testing devices for fuel elements for light water reactors which are used at factories of concern JSC "TVEL" (Russia). The leak-testing devices are intended for work in the modern automated lines of nuclear fuel manufacturing. Its main feature is the open vacuum system representing the tube with inlet and outlet vacuum sluice. The length of all chamber is smaller then length of a separate fuel element. Part of the tube between two sluices is high-vacuum test chamber with own exhaust unit. Fuel elements one by one pass through the high-vacuum chamber connected with helium leak-tester. Thus all length of each fuel element tests for leakage consistently. Due to small volume of the vacuum chamber, the device has short the response time and high sensitivity. All parts of the device operate under computer control under special program. If any leak had been detected, a defected fuel element will be rejected from product flow; place of defect will be marked.

Keywords: leak-testing, automated device, nuclear fuel, test chamber, exhaust unit.

1. Features of leak-test automation.

There is necessity of control operation automation as the decision of task increasing of an intensification of modern industrial nuclear fuel production. Thus, reliability of the control should be on a high level, and productivity of automatic control devices should not be lower than productivity of all industrial line. Transition to manufacturing and the control on a automated lines is connected to a number of features which need to be taken into account at designing such lines. Concerning of an automated leak-test device (ALTD) it can be done following description of such features [1]:

- Technological and control operations have not subjective mistakes of the personnel;
- Productivity of control devices, which were built - in a line, should not be less productivity of total line;
- products can move or not under control in a line;
- Criteria of quality, procedure of the control, conditions of realization of technological and control operations must be adapted to those conditions, at which mechanization and automation of the processes is realizable;
- The technological processes which are carrying out on automatic lines, as a rule, give high and stable quality and reproducibility; products in this period are in well-known conditions with known intervals of time; these circumstances promote simplification of the process flow sheet, reduction of control operations.

One important feature of leak testing is maintenance of required sensitivity of the control. Today's minimal level is established at several units in a degree of 10^{-10} m^3Pa/s. Besides it, they try sometimes to keep temperature of testing products at operation range, if it is possible. From here there is the number of mistakes connected with concentration of molecules of probe gas which defines a level of a leak tester output signal and is inversely proportional to temperature of the gas. Products heat up before the control, but, before the moment of test becomes, a product have time for lowering of the temperature.

Hot products, also, are a source of virtual flows which prevent estimation true value of outflow from tested products. The virtual flows depend on product surface area, which increase with number of simultaneously tested products. Transition time of a signal of leak tester after a set of vacuum in the test chamber depends on volume of this chamber. So, it is not so simple to take into account and lower all factors preventing a unequivocal estimation of a condition of tightness of products. This problem becomes sharply and complicated at creation ALTD.

2. ALTD for leak testing of nuclear fuel rods in manner of one by one.

Industrial using of ALTD in Russia began at 60-s'. Since 2000 it has taken place at the enterprises of Russian atomic concern JSC "TVEL" at factory JSC "MSZ", and since 2007 - at factory JSC "NZHK". Now the modernized devices of the individual control (one by one) of fuel elements WWER, and other types of ones, are made at full strength with modern vacuum equipment at factory JSC "MSZ" [2-4]. The arrangement of ALTD clearly from figures 1-3.

Developers of ALTD had found such constructive principles which have solved simultaneously two complexes of tasks:

- minimization of the basic metering errors specified in item 1;
- continuous work of the device together with industrial automated line.

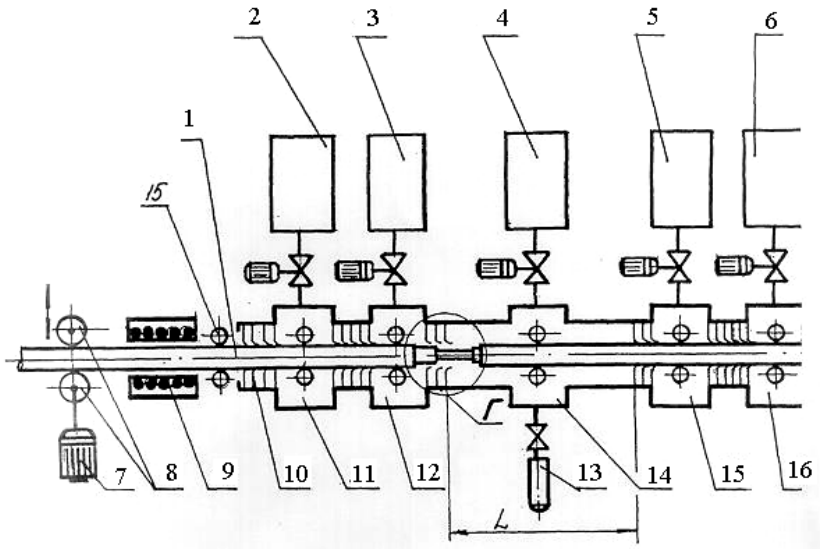

Fig. 1. The drawing of ALTD.
1 - fuel rod ; 2, 3, 4, 5, 6 - fore vacuum and high vacuum pumps; 7, 8 - a drive of fuel rod moving; 9 - a pneumatic system of cleaning fuel rod from a dust; 10 - a labyrinth seal; 11, 12, 15, 16 - supporting rollers; 13 - standard leaks.

Main principles of construction of installation ALTD:

- the test chamber represents a pipe with diameter, which hardly more, than diameter of fuel rod, length about 1 meter. Length of different fuel rods about 2,5-4,5 meters;
- there are lock-chamber on input of vacuum chamber and on its output for smooth reducing of pressure in the device from atmospheric up to the worker on an entrance and again up to

atmospheric on an exit of chamber so that any flow-over air and trial gas in lock-chambers and in test chambers can not be;

- movement of fuel rod occurs through the test chamber closely one after another. As soon as leak in a welded seam or in clad of the rod will be detected, an actuator reject two neighboring fuel rod;
- the device detect of large leak as pressure drop in the low vacuum chamber;
- a ring ejector with help of compressed air clears entrance rod from a dust before an input in sluice chamber;
- minimal gaps between fuel rod and constructive elements, as well as drive and supporting rollers, provide absence of contact interaction as a result of which the surface of fuel rod could be damaged.

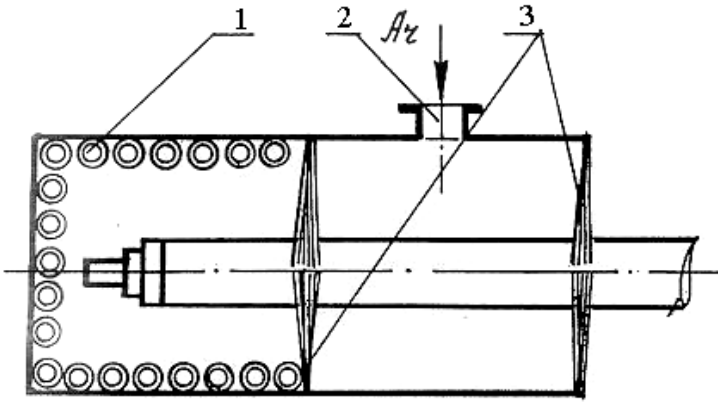

Fig. 2. Heating modul.
1 - heating elements; 2 - input of inert gas for prevent oxidation of fuel rods 3 - barrier for air.

One processor controls all components of the device, takes into account all supernumerary situations, if necessary cuts off high vacuum units of device, preventing outage of monitoring system.

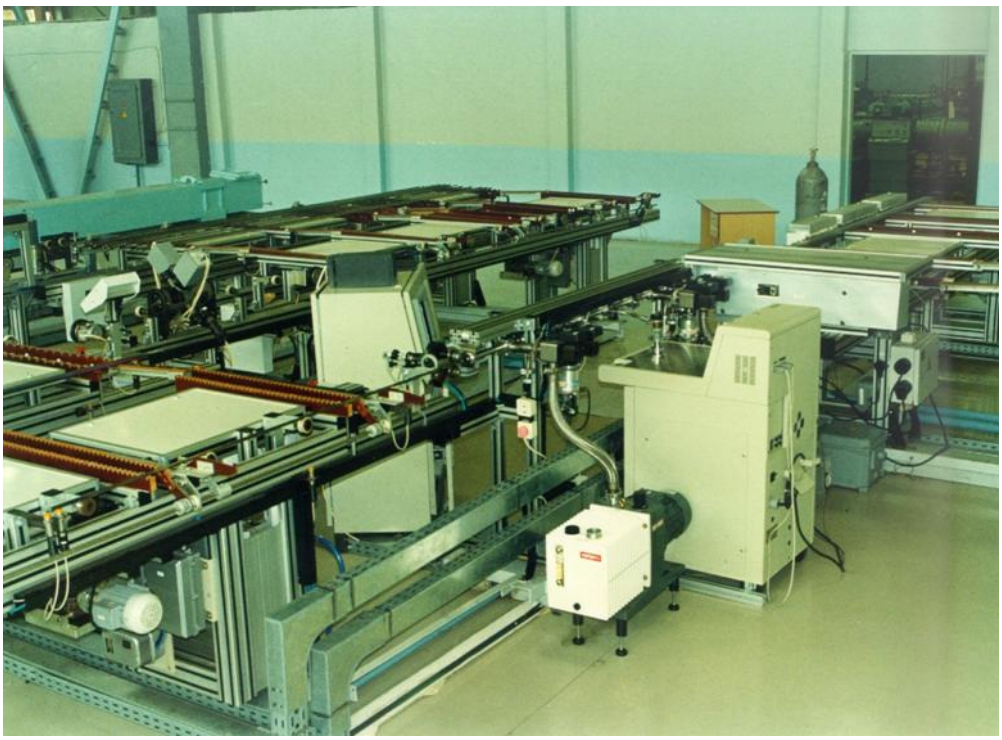

Fig. 3. General view of ALTD.

ALTD is supplied with the module, which, if necessary, can heat up controllable products in a zone of welded seams and to dry up possible defects if there was an opportunity of their filling by the condensed or atmospheric moisture. The module is shown on fig. 2.

Fig. 4. Test chamber of ALTD.

Conclusion

In spite of the fact that ALTD is sufficiently complicated and precision construction, demanded highly skilled service and adjustment, given ALTD has successfully sustained the period of operation for a number of years. The device was modernized and accepted today as base at creation of the modern automated manufacture of fuel for nuclear stations at the enterprises of concern JSC " TVEL ". Providing productivity up to 60 products at one o'clock, the device allows flexibly to build technological process of manufacturing of fuel rods with last changes in technology.

Reference

1. Nondestructive testing. The Manual under edition of V.V.Kluev in 7 volumes. Vol. 1. Leak testing. Moscow, «Machinebuilding», 2003
2. Patent RF, №1402046 , JSC “MSZ”, G01M3/02, 1994.03.15
3. Patent RF, № 2164672, JSC “MSZ”, G01M3/04, 2001.03.27
4. Patent RF, № 2225048, JSC “MSZ”, G21C21/02, 2004.02.27