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THE EVALUATION OF RESIDUAL RESOURCE OF THE TECHNOLOGICAL CHANNELS OF THE 1-ST CHNPP'S UNIT

E.U. Grynik, L.I. Chyrko, A.A. Shynakov,
Ju.S. Gulchuk, O.V. Drogaev, V.N. Revka, Ju.V. Chajkovsky

The result of study of the technological channels (TC) of the 1-st Chernobyl NPP's unit after 18 years of operation are analyzed in this work. It is showed that zirconium alloy of TC operated at normal conditions has satisfactory plastic and strength properties; hydrogen concentration doesn't exceed 60 ppm; the joint devices have safety factor more 2 even at presence of microcracks. The conclusion is done that residual resource of normal operating TC after 18 years of service doesn't still exhaust.

The safe work of reactor installations of RBMK-type is largely defined by the state of technological channel (TC) metal. The results of postreactor researches of TC after 13 years of service in Kursk NPP and Leningrad NPP showed, that the operation design resource of TC (30 years) should be essentially reduced. In this aspect the state of TC after 18 years of operation in Chernobyl NPP is interesting. The postreactor researches are conducted on three TC (the upper and the lower joint devices and three branch pipes from the central part of each TC) and also on defective parts of 10 TC which were cut out during the next scheduled maintenance by the results of ultrasonic monitoring (USM) and of internal diameter measurements in the correspondence with the rules of NPP operation.

The internal diameters of the studied TC change from 80,15 mm on the ends of zirconium pipes up to 81,25 mm at the center of the active zone; the external diameter - from 88,14 mm up to 89,14 mm, accordingly (fig. 1). The "alive" section cut changes from 3,94 mm up to 4,07 mm in different positions of the pipes.

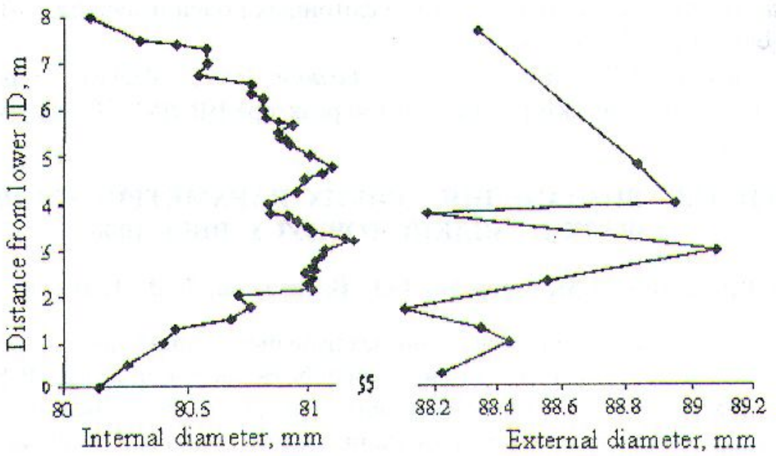

Fig. 1. The dependence of value of internal and external diameters of TC pipes of the 1-st ChNPP's unit after 18 years of operation.

The outside surface of the branch pipes is covered by black uniform protective corrosion film with the thickness not exceeding 3 microns. The alternation of more dark and more light bands corresponding graphite rings differs precisely. On the outside surface of two TC at the distance ~1 м from the lower joint device (JD) there were the longitudinal defects of length 163 mm and 306 mm and depth of ~1 mm and ~0,75mm accordingly. The indicated damages have not affected at value of internal and outside diameters of these pipes. The observable defects are, apparently, the result of development thermomechanical damages, appeared owing to the incident in 1982.

The internal surface of TC pipes is covered by dark-brown loose deposit with the thickness, not exceeding 2 microns, under which there is light-gray layer of zirconium oxide with the thickness from 5 up to 22 microns. The density of oxide film is disturbed and it is observed exfoliation of it in the positions where the thickness of light oxide reaches 20 microns. The longitudinal defects of length from 50 up to 292 mm and breadth of ~1 mm founded on the internal surface by USM were the longitudinal scratches of different length with developed nodular corrosion by depth 10 - 15 micron and breadth 1- 2 mm. Apparently, it is the result of oxide film damage of the internal TC surface by distant grates under overload of the assemblies. The nodular corrosion is initiated in these places and penetration of hydrogen in matrix of Zr + 2,5 % Nb alloy intensifies (the table).

There are not enough large inclusions in a structure of zirconium alloy. The hydrides are small (~1 - 2 microns), uniformly distributed in the material of channel walls, if the pipe's surfaces have not defects. Thin layer (~1 microns) of hydride plates is observed immediately under oxide film of the internal surface (fig. 2). If corrosion damages being present on the internal and outside surfaces the thickness of hydride layer increases and reaches 10 micron in local places. The thickness of hydride layer decreases at removal from damaged place.

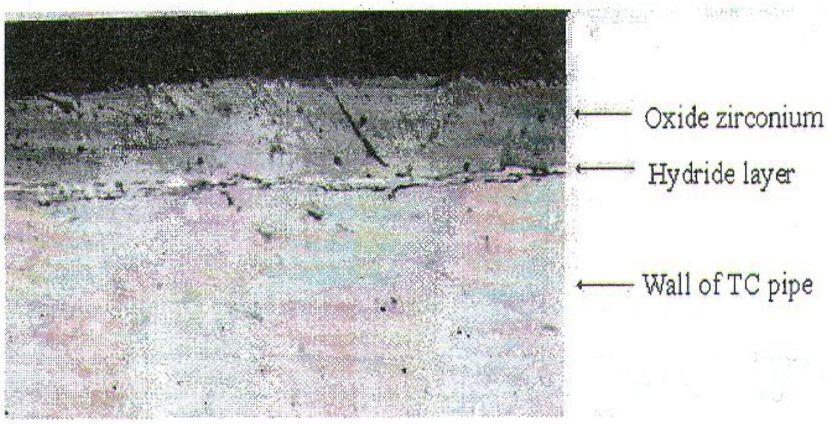

Fig. 2. Hydride layer in zone of TC internal surface oxidation. Enlargement is 1200.

The larger hydride emission by size to 10 - 15 microns, and also increased contents of other second-phase inclusions: ZrC and interrelates of type Me-Zr (fig. 3) are observed in the region of the microcracks progressed inwards from the part of inside defects. There is not detected large hydride inclusions in matrix of alloy in region of the scratches on the internal surface where more developed nodules are observed.

Fig. 3. Hydrides in the region of defect top progressed from TC external side. Enlargement is 200.

The contents of hydrogen in zone of defects both on the internal, and on the outside surface doesn't exceed 60 ppm, but on the distance 10 - 15 mm over perimeter falls down up to average level 25 - 30 ppm (fig. 4), which is characteristic for all nondefect parts of studied zirconium pipes (table).

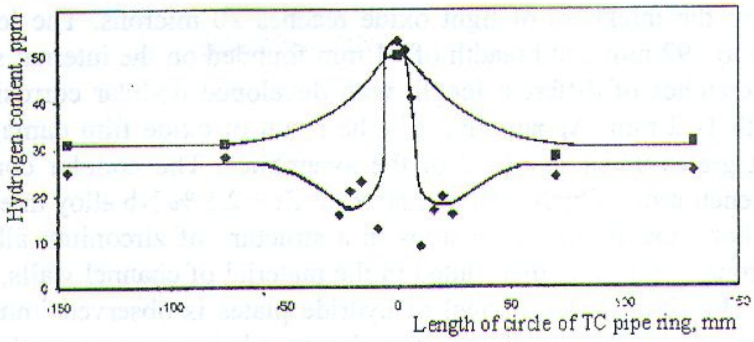

Fig. 4. Distribution of hydrogen content over perimeter of the 1-st ChNPP's unit TC pipes, which have corrosion damages on internal surface (■) and on external surface (◆); data for ring mechanical tested at T_{test} = 20 °C, which has failure near brittle.

The hydrogen contents in TC pipes of the 1-st unit of ChNPP coordinate well with the same data of NIKIET in TC pipes of LNPP and KuNPP after different operation terms (fig. 5). Hence it is followed that the rate of hydrogen concentration keeps for TC of different RBMK-1000 what allows to prognosticate the absence of hydrogen embrittlement at least to the 21-st year of TC operation.

Distribution of hydrogen over perimeter of channel pipe's ring

Character of defect	Distance from defect, mm	Quantity of hydrogen, H, ppm	< H >, ppm
Longitudinal defect on outside part of TC pipes	0	49; 58; 46; 55; 43;33	53
	3.5	51	51
	6.0	41	41
	10	9	9
	16	17	17
	20	20	20
	24	16	16
	70	22; 30; 29	24
	130	23; 20; 27; 45; 32; 12; 27; 22	25
	200	15; 41	28
	250	16	16
	255	21	21
	260	23	23
	267	13	13
Longitudinal scratches on internal surfaces of TC pipes	0	63; 66; 37; 6; 52; 64; 60; 35; 24; 62; 79; 54; 49	50
	70	32; 24	28
	140	43; 34; 21; 26; 31; 39; 35	31
	210	31	31

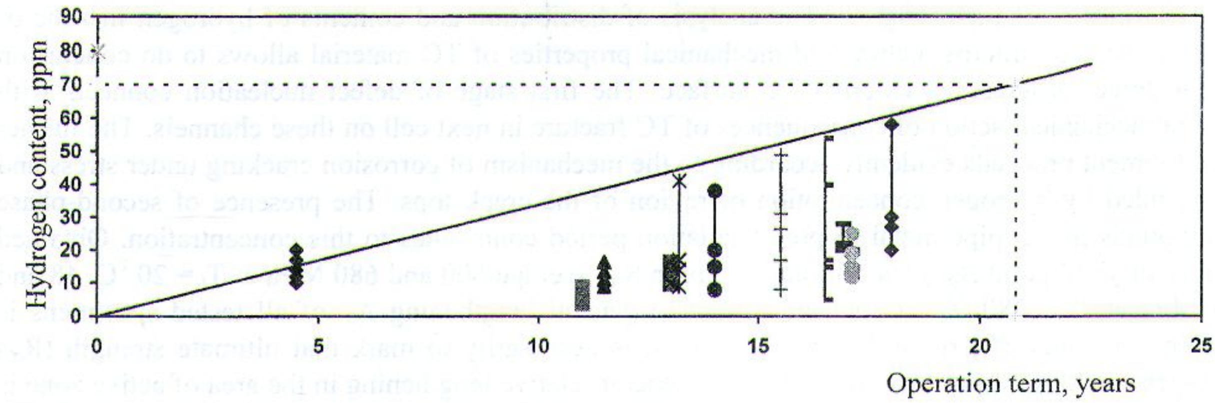

Fig. 5. Hydrogen accumulation in the metal of TC pipes of Leningrad NPP and Kursk NPP according to results of postreactor studies; different signs of points correspond to samples which cut from different channels (data of NIKIET). The point connected by vertical line equal to data of hydrogen contents in TC pipes of the 1-st ChNPP's unit.

The strength characteristics of zirconium alloy of TC were measured by tensile on the rings of height 6 mm on remote UMD-5, possessing the rings so that the being available external or outside defects were in the rectification field.

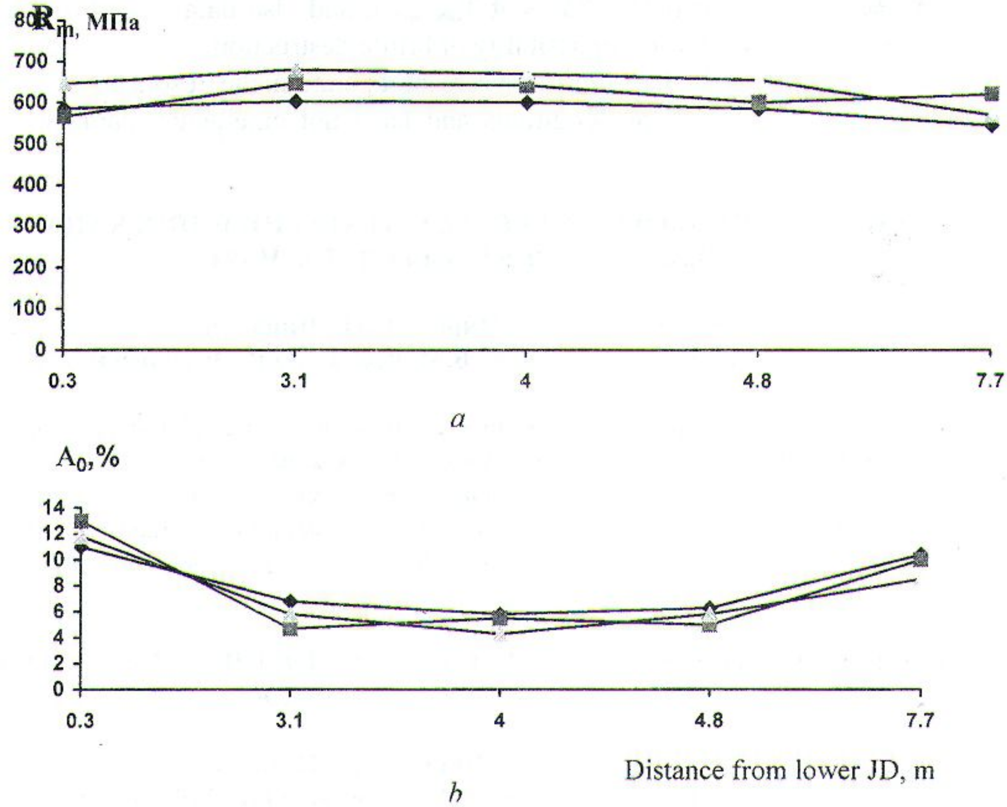

Fig. 6. The change of ultimate strength (*a*) and relative general elongation (*b*) along TC pipes after 18 years of operation, $T_{test} = 20$ °C.

It is established, that the deep outside corrosion defects have reduced in significant deterioration of the mechanical properties of TC pipes. The destruction of specimens from zone of damage at temperature of testing $T = 20\ ^0C$ happened sometimes even under loads corresponding to the elastic part of the extension diagram but at rather high values R_m (550 - 600 MPa at $T = 20\ ^0C$).

Outside of the observable defects the mechanical characteristics of pipes are satisfactory and close for all studied TC pipes (fig. 6). The analysis of distribution and contents of hydrogen in zone of outside damage, microstructure and mechanical properties of TC material allows to do conclusion about defect progress on external TC surface. The first stage of defect nucleation connects with thermomechanical action of consequences of TC fracture in next cell on these channels. The further development proceeds evidently according to the mechanism of corrosion cracking under stress and is attended by hydrogen concentration of region of the crack tops. The presence of second-phase compounds in TC pipe metal in pre-installation period contributes to this concentration. Obtained values of yield point $R_{p0,2}$ and ultimate strength R_m average 600 and 680 MPa at $T_t = 20\ ^0C$, 48 and 50 MPa at $T_t = 280\ ^0C$, accordingly. Relative general lengthening A_m of all tested specimens is within the limits of 4,6 - 6,9 % for both T_t. It is necessarily to mark that ultimate strength (R_m) changes small over length of channel, while general relative lengthening in the area of active zone is smaller approximately in two time than on ends of TC what evidently deals with radiation workhardening. Sorry to mark that it is not possible to analyse the obtained data as the function of fluence in connection with the absence of the data on density neutron flux.

The researches have shown, that the state of all upper joint devices is satisfactory. From 8 studied lower joint devices two had open microscopic defect of length ~15 and ~20 mm along external circle and with maximum breadth of uncovering ~24 and ~60 microns, accordingly, in region of the 1-st zirconium tooth. The calculation made according to our data in Institute of Strength Problems showed that joint devices with such microcracks had safety factor more than 2. Noninclination of steel of all studied joint devices to intercrystallytic corrosion and its high plasticity (47 - 55 % T = 20 ^{0}C and 18 - 25 % at $T_{operation}$), and also data of Institute of Strength Problems of NAS of Ukraine, testify to impossibility of brittle destruction.

Thus it is possible to tell, that after 18 years of operation the resource of technological channels, which worked in the regular conditions and have not emergency damages, is not yet reached.

ОЦІНКА ЗАЛИШКОВОГО РЕСУРСУ ТЕХНОЛОГІЧНИХ КАНАЛІВ РЕАКТОРА РБМК 1-го БЛОКА ЧАЕС

Е.У. Гринік, Л.І. Чирко, О.О. Шинаков, Ю.С. Гульчук, О.В. Дрогаєв, В.М. Ревка, Ю.В. Чайковський

Проаналізовано результати фізико-механічних досліджень технологічних каналів І-го блока ЧАЕС після 18 років експлуатації. Показано, що матеріал тих каналів, що працювали в штатних умовах, мають задовільні пластичні та міцностні властивості; вміст водню не перевищує 60 ppm; перехідні з'єднання мають коефіцієнт запасу міцності не менший 2 навіть при наявності мікротріщин. Зроблено висновок, що ресурс штатних каналів після 18 років експлуатації ще не вичерпано.

ОЦЕНКА ОСТАТОЧНОГО РЕСУРСА ТЕХНОЛОГИЧЕСКИХ КАНАЛОВ РЕАКТОРА РБМК 1-го БЛОКА ЧАЭС

Э.У. Гриник, Л.И. Чирко, А.А. Шинаков, Ю.С. Гульчук, О.В. Дрогаев, В.Н. Ревка, Ю.В. Чайковский

Проанализированы результаты исследований технологических каналов 1-го блока ЧАЭС после 18 лет эксплуатации. Показано, что материал каналов, эксплуатировавшихся в штатных условиях, имеет удовлетворительные пластические и прочностные свойства; наводороживание не превышает 60 ppm; переходные соединения имеют коэффициент запаса прочности не менее 2 даже при наличии микротрещин. Сделан вывод, что ресурс штатных каналов после 18 лет эксплуатации еще не исчерпан.