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METHODS for DEFINITION of PROBABILITY of PRESSURE VESSELS and PIPELINES DESTRUCTION

A. Getman

VNIIAES, Moscow, Russia

tel/fax: +7 495 3761322; E-mail: kcnbras@mail.ru

Approach for estimation of probability of components destruction allows:

- More precisely to estimate an actual condition of components;
- To define the new factors influencing on reliability of components;
- Quantitatively to estimate influence of various factors on components reliability;
- To prove actions for increase of components reliability.

Existing approaches to definition of probability of components destruction

№ /№	**Existing approaches**	**Characteristic of the approach**
1	Approach of Rzganicin	Does not allow to take into account defectiveness
2	Approach of Afanasjev	It is difficult to take into account of microstructural heterogeneity of metal
3	Approach of Veibull	Formal - statistical phenomenological approach
4	Approach on the basis of Monte Karlo method	There is no physically enough proved model of destruction
5	Approach on the basis of the fracture mechanics	Not correctly enough take into account actual defectiveness of a components
6	Approach of VNIIAES	High accuracy of the forecast because most full takes into account an actual condition of a components

- VNIIAES approach is developed in view of lacks of existing approaches. In the same time it has keep advantages of other approaches and methods.
- As the initial data for calculation of probability the data of the tool control of a condition of a researched element of a component uses that provides high accuracy probabilistic estimations
- End results of calculations are probabilistic characteristics of a gamma - percent residual resource, of destruction of a component, occurrence in it leaks or defect.
- Methods of the tool control cover non destructive examination, the control of mechanical properties and crack resistance characteristics, the control of operational modes, a number of other quality monitoring.

- The special attention is given to experimental researches of ageing of constructional steels during their operation. These researches carried out as on a regular basis in each 100000 hours of operation, 150000 and 200000 hours of operation, and also in case of damage of metal;
- The list of the basic steels of the NPP with VVER-440, VVER-1000, RBMK-1000 and volumes of their researches during operation are resulted in table 2.

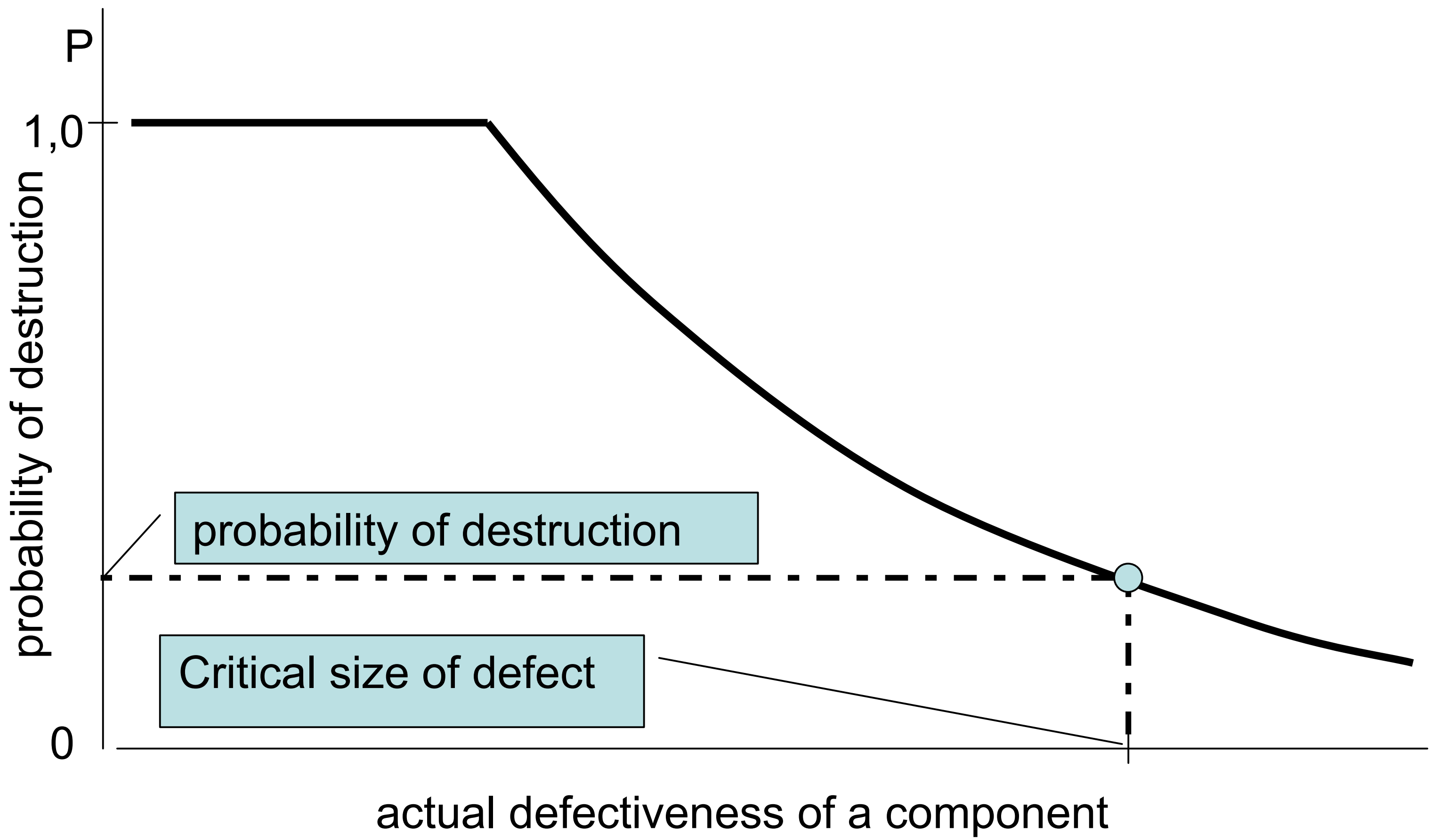
Researches of changes of properties constructional steels (ageing) during operation NPP

№/№	Steels	Components of NPP	Mechanical properties	cracks resistance	Microstructure	Chemical compound
1	St20, 22K	Main pipelines RBMK, steam lines and vessels of VVER-440	+	+	+	+
2	10ГН2МФА	Main pipelines and vessels of VVER-1000	+	+	+	+
3	0Х18Н10Т	Main pipelines of VVER-440	+	+	+	+
4	48ТС 15Х2НМФА	Pressure Vessels of reactors VVER-440 and VVER-1000	+	+	+	+

Definition of probability of destruction on VNIIAES method consists of the following stages:

- Definition of distribution of mechanical properties;
- Definition of distribution of loadings;
- Definition of actual defectiveness of a component;
- Definition of forthcoming conditions of operation;
- Definition of change of defectiveness during operation;
- Definition of changes of mechanical properties during operation;
- Definition of the mechanism of destruction: brittle, quasi-brittle or ductility;
- Definition of probability of destruction and its change during operation.

The simplified model of definition of probability of destruction



Example: equation for calculation of probability on the **brittle** mechanism destruction

$$P_p = \int_{K_{1c\min}}^{K_{1c\max}} \rho_{K_{1c}}(K_{1c}) \int_{\sigma_{\min}}^{\sigma\max} \rho_\sigma(\sigma) P_a(a \geq a_{kp})\, da\, dK_{1c}$$

Where

P_p - probability of destruction;

$?_{K1c}$ - function of distribution K_{1c};

ρ_s - function of distribution s ;

P_a - function of distribution sizes of defects;

Special cases of the equation

1) Distribution of loadings aspires to zero:

$$P_p = \int_{K_{1c\,\min}}^{K_{1c\,\max}} \rho_{k_{1c}}(K_{1c}) P_a(a \geq a_{kp}) dK_{1c}\, da$$

2) Distribution of fracture toughness K_{1c} aspires to zero:

$$P_p = \int_{\sigma_{\min}}^{\sigma_{\max}} \rho_{\sigma}(\sigma) P_a(a \geq a_{kp}) d\sigma\, da$$

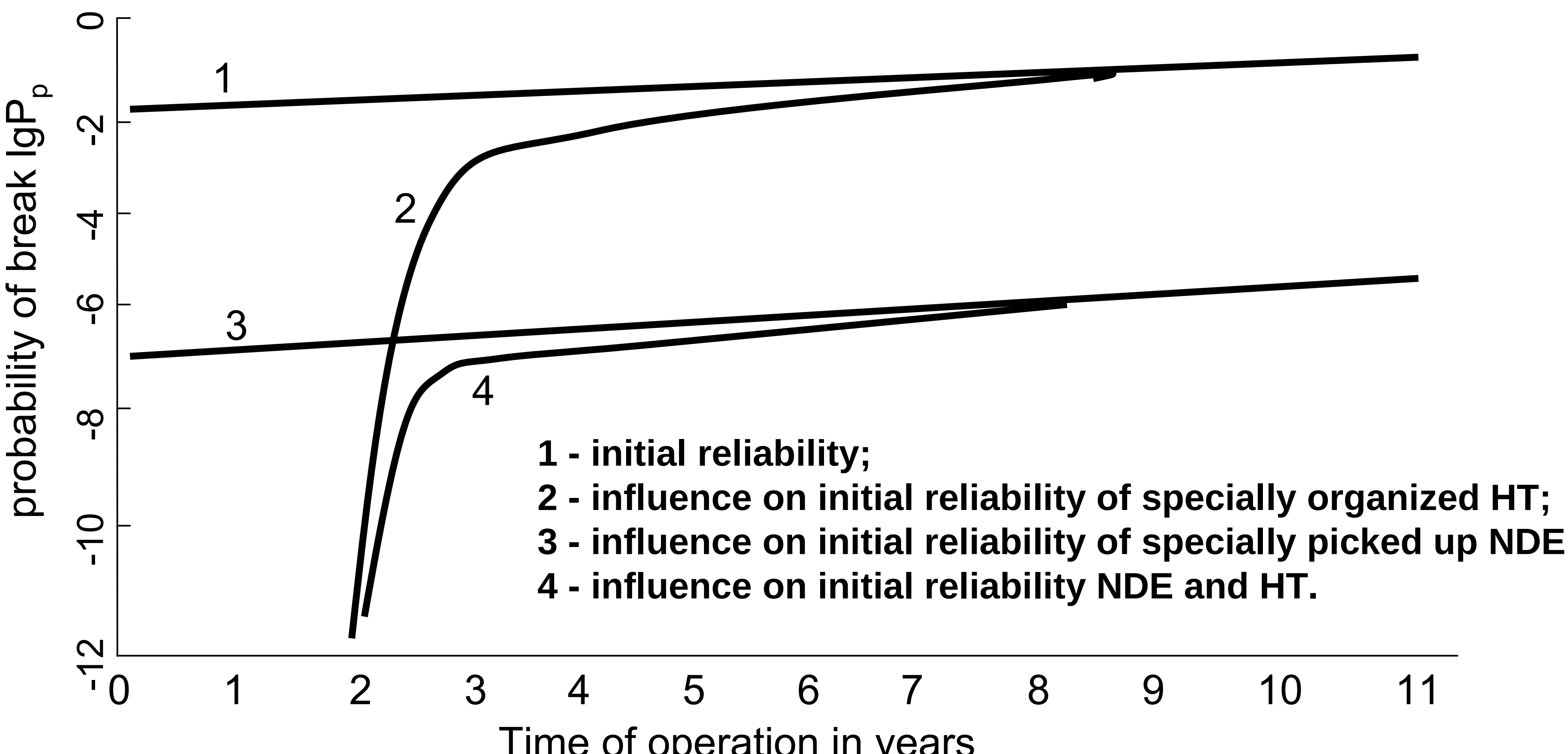
3) Distribution of loadings s and fracture toughness K_{1c} aspires to zero:

$$P_p = P_a(a \geq a_{kp})$$

Technique of VNIIAES was applied to the decision of practical problems on NPP.

Example 1:

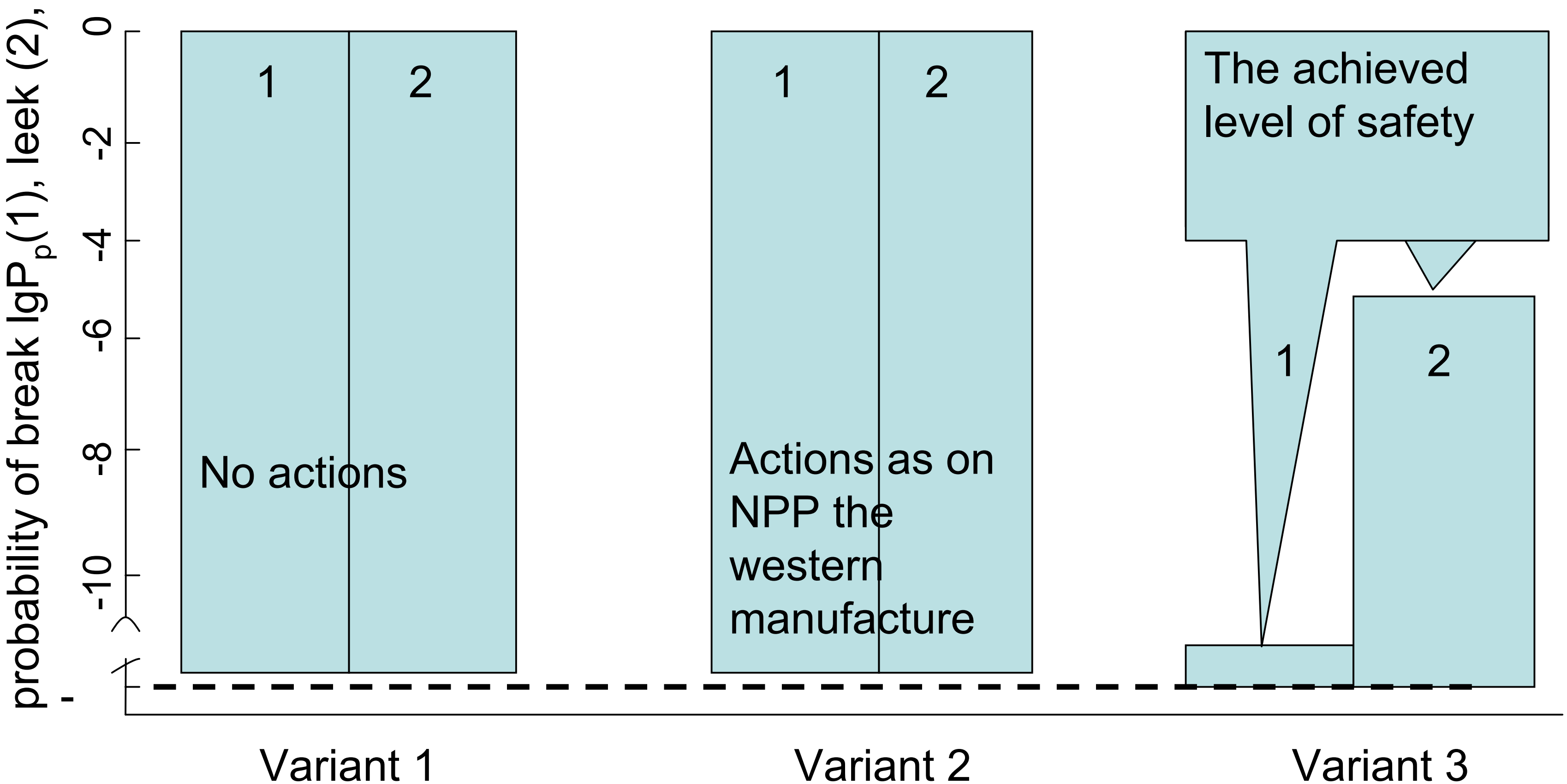
Development of actions for decrease of probability of break of the main pipeline of reactor VVER440



Technique of VNIIAES was applied to the decision of practical problems on NPP.

Example 2:

Development and selection of actions for maintenance of SG tube integrity of VVER reactors



Experience of application of calculations on the working NPP has shown their high accuracy.

In particular, in 1996 on unit 2 Balakovskaja NPP has been predicted leaking for 2-3 tubes.

Actually leakings were formed on 2 tubes.

Calculation carried out for 33000 tubes.

Conclusions

1. Methods for definition of probability of pressure vessels and pipelines destruction is developed.

2. These methods use of the data of experimental control of a researched elements condition.

3. The experimental control is carried out during operation and maintenance service and does not demand additional experimental researches.

4. The method has high accuracy and reproducibility of results.