RADIATION-HYGIENIC CONCEPTIONS ANALYSIS OF HANDLING WITH REACTOR COMPARTMENTS OF BEING UTILISED NUCLEAR-POWERED SUBMARINES

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Elaboration of conception for disjunction and utilisation of ships and vessels with nuclear-powered plants (NPP) removed out of exploitation includes the following main decision:

- Tentative estimation of time-limit after removal of concrete object out of exploitation on the expire of which reactor's compartment (RC) utilisation will come possible, and utilisation technology option;
- The choice of version for RC temporary storage or burial;
- The choice of disjunction and utilisation technology of bow and stern compartments.

The key moment under these questions decision is the radiation state of removed out of exploitation and prepared for utilisation of ship NPP. After discharge of liquid and solid radioactive waste there remain the sources of 2-types radiation in reactor compartment volume: volumetric-radiating-activated material of NPP equipment and superficial-radiating-contaminated by radionuclides equipment's and constructions' surfaces.

Incidentally these sources integral activity with 1-3 years delay time reaches $(1\text{-}2)\cdot10^{15}$ Bq. More than 90 % of long-lived radionuclides are localised in intrareactor constructions that amount to not more of 5-7 % of total radioactive materials mass.

Radiation contamination's level of intrareactor constructions surfaces may reach 2 millions Bq/sm^2, of internal surfaces of the 1-st circuit equipment elements - 100 thousand Bq/sm^2, of the surfaces of the 3-d circuit equipment elements, of desiccation and repair cooling tanks - 20 thousand Bq/sm^2 depending on construction period the surfaces contamination's activity can be conditioned by corrosion products (by Co-60 on the whole) or by radionuclides of fragmentation origin: Cs-137, Cs-134, Ce-144, Ru-106, Sr-90.

Actinide radionuclides activity in the 1-st circuit communications volume of water-cooled ship's NPP can reach $4.5\cdot10^{11}$ Bq.

By 1-3 year delay-time induced activity of construction of exploitation ship's NPP in the places most close to the active zone for reactor casing reaches $2.6\cdot10^{11}$ Bq/kg order value, for reactor caisson - $1.5\cdot10^{11}$ Bq/kg, for steam generator case - $4\cdot10^{8}$ Bq/kg, for pressure hull under reactor - $2\cdot10^{10}$ Bq/kg.

Two conceptions of handling with RC radioactive saturation have been discussed: the first one consists of the absence at present of enterprises with appropriate equipment for disjunction of RC with high-activity equipment and their long-term keeping is necessary for natural activity decay (during 50-80 years) defined by method worked out in our institute. After long-term keeping RC can be disintegrated without large dose expenditures and as a rule - without special remote and protective equipment. Thus for 70 years of keeping the rate of activated gamma-radiation sources will reduce in 1000 times on average.

The alternative conception provides for complete utilisation (remelting) of RC equipment and case.

However RC disassembling immediately after ship's removal out of exploitation is connected with considerable dose loading, heightened risk of environmental radioactive contamination and necessity of using special equipment with remote control. Really, at being

repaired NPS the dose rate in reactor caisson was up to 400 mSv/h, near the reactor case 20-40 mSv/h, in steam generator caisson - 2 mSv/h. Thus, the present conception realisation is possible only after creation of specialised ship disintegrating enterprise, equipped with appropriate technology, that requires large-scale capital investments. Owing to the told the idea of disassembling of RC radioactive equipment before its maintenance did not obtain spreading neither in home nor in foreign practice and in spite of its attractiveness can be regarded only as perspective while keeping in containers ship's NPP equipment of NPS pressure hull and pressurising bulkheads upon its face planes has been realised both in our country and in USA. For normalisation of the radiation situation in conformity with sanitary requirements in the lower part of compartment, in the reactor's arrangement zone, separate areas of pressure hull (container) are covered by proper biological protection. The thickness and configuration in every concrete case can be determined by dosimetric inspection results.

Prepared for burial compartment must correspond to IAEA requirements (1) for type "B" radiation packings (by tightness and impact strength) and PTBRV-73 (2) for the 4-th transport category (by external gamma-radiation levels).

In this case equipment of bow-and stern compartments is disassembled, extracted and either comes for utilisation or is reserved for the second employment. Stage by stage ship's constructions are disintegrated in blocks.

Personnel doze loads under reactor compartment cutting in lower point of external line (without additional protection) average 1 MSv/h magnitude order (under 3-5 years delay). The direct works under reactor's external line require supplementary technological protection, otherwise dose limits will be exceeded in several days or even hours. Our experience indicates that by carrying out factory NPS repairs including opening and decontamination of biological protection tanks, personnel irradiation doses do not exceed 20-30 mSv/year. As well in USA personnel was not exposed to gamma-radiation doses exceeding 20 mSv/year under cutting and preparation for burial NPS reactor compartments (3).

By maintain of main principles of conception various versions of prolonged RC keeping organising can be offered:

- afloat at allocated region of water area;
- inundation in shallow water of allocated region of water area;
- in underground workings-galleries;
- in concrete trenches or on the surface-type grounds protected from precipitation;
- in encirclement of artificially frozen ground, in conditions of permafrost and polar climate (at present thus proposal is being working out in reference to conditions of Novaya Zemlya archipelago).

Afloat storage of ship NPP removed out of exploitation (forming part of NPS, three - compartments blocks or reactor compartments) are of radiation-ecological danger and contradict standards and international recommendations (4-7), being in force forbidding storage of radioactive waste on flooded and waterlogged territories, what is more afloat or under water, in shallow water.

So, this practice should be regarded as forced and provisional. The terms of afloat storage as well as quantity of objects should be reduced to a minimum.

Being in force sanitary regulations and ICRP recommendations exclude the possibility of radioactive waste depots arrangement in flooded and waterlogged places, in regions situated nearer than 500 m from the reservoirs, as well as by ground waters level above 4 m from the depot floor (4-6). Specified requirements should be carried out beyond dependence upon the degree of depot waterproofing, that significantly makes difficult the practical realisation of version NPS' RC arrangement in underground workings-galleries.

The most reasonable and ecologically safe version in organising RC long-term storage of NPS removed out of exploitation is their arrangement in concrete trenches (holes), protected from atmospheric precipitation, or in polar climate conditions in permafrost or artificially frozen ground.

Organising RC storage on the ground surface or in shallow holes (10-20 m deep) and in permafrost ground encirclement also does not contradict with sanitary-hygienic documents requirements.

From the point of view of environmental radioactive contamination the version of storage on specially equipped coast region is of less danger. In this case depot should have not less than two bars on the possible environmental radionuclides route entry. The first includes engineering equipment of storage place for prevention of meteorological and hydrological factors influence, which may break compartment's tightness (covering shield) and engineering system for prevention of radionuclides entry in environment in case RC loss of sealing (spreading shield). Geological formations in depot's arrangement place which must limit radionuclides dissemination are the second bar.

Requirements, similar to arrangement and equipping of points for radioactive waste burial are brought for plot choice.

By execution of all necessary requirements for the storage place the danger of activity dissemination in environment is insignificant and is clearly defined primary by possibility of outward reasons influence (hurricane, whirlwind, aircraft's fall).

As the advantage of version for RC burial in permafrost is the unlimited heat capacity of surrounding rocks and absence of activity dissemination with ground waters as in conditions of frozen rocks of arctic geocryologic region free water completely freezes solid forming so called constitutional ice in which migration process physically cannot be realised.

RC burial in five meters deep from the top part of compartment down to permafrost surface ground satisfy IAEA requirements and home regulating documents for radioactive waste burial (4-6).

The final decision about carrying out of utilisation of equipment materials and constructions of RC removed out of exploitation NPS may be accepted only on the basis of results of materials radiometric examination.

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