Specifics of oil vacuum pumps operation in handling radioactive materials

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Abstract. Some problems of operation of oil pumps in handling radioactive materials are addressed. Simple and safe methods of spent oil liquid radioactive waste treatment in-situ are proposed.

1. Introduction
Different types of oil pumps are widely used in operation of vacuum systems and apparatus containing radioactive materials including tritium. Urgency of using oil vacuum pumps remains despite a large number of recently developed new types of dry pumps with rather high dynamic behavior. Wide range of application of this type of equipment is stimulated by several positive factors: relatively low initial cost, long service life, maintainability in-situ, etc. Selection of oil pumps is often determined by the fact that the Russian enterprises have successfully mastered manufacture of the required spectrum of such pumps. The scope of this article considers the problems which arise in the process of operation of oil vacuum pumps in handling radioactive materials including those with tritium.

2. Research done and results obtained
Periodic routine efforts on changing oil are required during operation of vacuum pumps in order to maintain an adequate level of specs. In some cases radioactive materials are accumulated in vacuum oil of the pump. For example, in handling tritium-containing materials, tritium is accumulated in oil as a result of reactions of isotopic exchange, oxidation and tritium water sorption. When specific activity of tritium in replaceable oil exceeds 100 Bq/g, it turns to a category of liquid radioactive waste (LRW). LRW of vacuum oil can be formed when handling other radioactive materials especially if they are fine-dispersed and volatile. The Federal Law “On Radioactive Waste Management” [1] binds all entities whose activity entails generation of radioactive waste to carry out recovery operations for their own expense. Maintaining a required safety level constitutes a key aspect of LRW management as a source of ionizing radiation. One of the methods of solving this problem lies in decreasing a class of LRW hazard through extraction of insoluble high-level solid components with subsequent solidification of a liquid phase. Conditioning of LRW in-situ appears to be the most reasonable measure from the viewpoint of ensuring environmental safety and economic effectiveness. If LRW of vacuum oil include insoluble fine-dispersed suspended solid high-radiated radioactive components than separation of phases is necessary since such components may initiate significant radiolysis of the liquid phase accompanied with release of hydrogen during storage. Filtering seems to
be a principal approach to separate liquid from insoluble impurities distributed in it. Though use of filters for separation of the fine-dispersed phase has some disadvantages – short life and large number of secondary RW being in the first place. Methods of physical and chemical binding of the dispersed phase with follow-on detachment of formed deposit became also predominant. However, deposition leads to concentration of solid components in one part of the fluid which does not solve the problem completely.

The authors propose spinning as a new technique for extraction of the fine-dispersed phase from LRW of vacuum oils [2]. The proposed technique implies feeding of the second fluid, which can be conditionally called “spacer fluid”, to LRW of oil prior to spinning. Density of spacer fluid should be higher than that of LRW base and should not mix with them. Spinning of the LRW – spacer fluid mixture involves concentration of suspended fine-dispersed particles into the bulk of the latter. The authors suggest using water as the spacer fluid for LRW of vacuum oil with particles distributed in it. The two fluids do not practically mix. Upon localization of fine-dispersed particles in water, they can be safely separated and bound into a solid matrix by applying the known technique.

Water and oil are separated after suspended fine-dispersed particles have been transferred into water. To do this, water with fine-dispersed particles and refined oil (contains neither water nor fine-dispersed particles) are exposed to negative temperature up to water freeze-up. Remaining liquid oil is removed and, as it might have residual activity, is transferred into a solid aggregate state. Water can be used to spin next portions of LRW of oil.

A hardening agent consisting of a mixture of saturated hydrocarbons – paraffin, stearic acid and ceresin – was proposed in research for oil solidification [11]. Upon transfer into liquid state at T <70 °C, this hardener mixes well with vacuum oil and, after solidification, forms solid homogeneous hydrophobic compound which ensures safe storage. Filling of the final compound with vacuum oil comes to up to 60 % of the final mass. Radiation safety of the proposed compound was verified experimentally by performing comparative studies of extraction of tritium from tritium-containing oil specimens prior and upon solidification. A laboratory installation in the form of a looped circuit was assembled to do the research. The circuit comprised a cell to locate the specimen, a membrane pump and an ionization chamber. The membrane pump pushed gas medium through the cell with the specimen and the ionization chamber which recorded tritium volumetric activity. Volumetric activity of gas medium in the installation grew continuously during blowdown of tritium-containing medium-activity vacuum oil specimen. It increased 10-fold within an hour as against background level. Periodic control exercised within 2 months revealed no tritium extraction when the same oil specimen was blown down after solidification.

In order to assess applicability of the proposed hardening agent for conditioning of LRW on the basis of several commercial organic solvents (solvent, xylene, kerosene, white spirit, rubber solvent) we defined their solubilities. According to the results obtained, concentration of solvents in the final compound makes up, at least, 10 wt. %. Solubility limit for these materials was not defined as chemical composition of materials can vary over a wide range within one and the same standard. Therefore, preliminary prototype tests are needed for practical solidification of LRW of a particular organic solvent.

3. Conclusions

It should be mentioned that the class of waste-posed hazard goes down upon solidification. This factor significantly affects radiation safety in further newly formed RW handling. The developed technologies rely on methods never proposed before. Their uniqueness lies, primarily, in simple implementation. This enables to harden LRW in-situ under any in-lab or production conditions without applying high-tech dedicated equipment. Introduction of the proposed technologies will permit (1) to rule out necessity of LRW storing in-situ, thus, improving production radiation safety; and (2) to significantly cut down costs of the enterprise for transportation to a recovery site and LRW conditioning by the third party. No secondary RW is generated which is very important for ensuring environmental safety of the proposed methods.
The proposed methods are of general purpose, can be applied to a large spectrum of materials, do not require any special labware and are capable of reaching high practical efficiency. Possibility of carrying out the entire process of extraction and subsequent fixation of a dispersed phase in a stable matrix material in the absence of any contact with environment (in a hermetically sealed box) is a major factor in handling such radionuclides as tritium. Radiation monitoring performed at all stages of operation demonstrated their safety for personnel and environment. Values of volumetric activity in the air of a workroom and at the external surface of a container with produced compound as well as internal radiation doses of personnel involved are tens times lower than existing reference levels.

References

[1] Federal Law “On Radioactive Waste Management and Making Amendments into Separate Legislative Acts” 190-FZ of 11.07.2011
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