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SOLID AND LIQUID WASTE PROCESSING AND REDUCING OF PERSONNEL DOSES

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In order to minimize the radioactive waste volume at the Ukrainian NPP (nuclear power plants) solid waste is burned and compressed and liquid one evaporated. This dramatically increases their activity as well as their radiation doses during of operation process. In accordance with the ALARA principle the technological solutions that reduce doses to personnel were proposed. First part of the complex built on Zaporozhye NPP consists of processing waste incinerators and pressing facilities. The characteristics of the radiation fields for varying geometries of this facility and isotopic composition of obtained waste was simulated using PENELOPE and GEANT codes. Part of the results was performed using the software packages developed by the authors using point sources method. During operations with burned waste pressed ash the wall thickness of buildings, where equipment is placed is needed, up to 40 cm of concrete. Thickness of the steel technological doors for these premises is required to be of about 12 cm. The alternate design of technological doors (≈ 2cm of steel) by adding special gateway system is to be proposed.
KEY WORDS: radioactive waste, burned radioactive waste, pressed radioactive waste, liquid radioactive waste, radiation doses.

ПЕРЕРАБОТКА ТВЕРДЫХ И ЖИДКИХ ОТХОДОВ И УМЕНЬШЕНИЕ ДОЗ ПЕРСОНАЛА

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С целью минимизации объема радиоактивных отходов на украинских АЭС твердые отходы подвергают сжиганию и прессованию, а жидкие – упариванию. Это значительно повышает их удельную активность и дозу облучения в процессе переработки. В соответствии с принципом ALARA были предложены технологические решения, которые сокращают дозы персонала. Первая очередь комплекса, возводимого на Запорожской АЭС, состоит из установок сжигания и прессования отходов. Характеристики радиационных полей для разных геометрий этих установок и изотопного состава принимаемых отходов были рассчитаны с помощью программ PENELOPE и GEANT. Часть результатов была получена с использованием программного обеспечения, разработанного авторами на основе метода точечных источников. При операциях с прессованной золой сожженных отходов толщину стен в помещениях, где эксплуатируется оборудование, потребовалось увеличить до 40 см бетона. Необходимая толщина стальных технологических дверей для этих помещений составляет около 12 см. Предложен альтернативный вариант конструкции технологических дверей (порядка 2 см по стали), который содержит специальное защитное ограждение.
КЛЮЧЕВЫЕ СЛОВА: радиоактивные отходы, сжигаемые радиоактивные отходы, прессуемые радиоактивные отходы, жидкие радиоактивные отходы, дозы излучения.

ПЕРЕРОБКА ТВЕРДИХ І РІДКИХ ВІДХОДІВ ТА ЗМЕНШЕННЯ ДОЗ ПЕРСОНАЛУ

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З метою мінімізації об’єму радіоактивних відходів на українських АЕС тверді відходи спалюють і пресують, а рідкі – випаровують. Це значно підвищує їхню питому активність і дозу опромінення в процесі переробки. У відповідності до принципу ALARA було запропоновано технологічні рішення, які зменшують дози персоналу. Перша черга комплексу, який споруджується на Запорізькій АЕС, складається з установок спалювання і пресування відходів. Характеристики радіаційних полів при різних геометріях цих установок і ізотопному складі перероблюваних відходів були розраховані за допомогою програм PENELOPE і GEANT. Частину результатів було отримано за допомогою програмного забезпечення, розробленого

авторами на основі методу точкових джерел. При операціях із пресованою золою спалених відходів товщину стін у приміщеннях, де експлуатується устаткування, було потрібно збільшити до 40 см бетону. Необхідна товщина стальних технологічних дверей у цих приміщеннях складає 12 см. Запропоновано альтернативний варіант конструкції технологічних дверей (близько 2 см сталі), який передбачає спеціальну захисну огорожу.
КЛЮЧОВІ СЛОВА: радіоактивні відходи, радіоактивні відходи які спалюються, радіоактивні відходи пресуються, рідкі радіоактивні відходи, дози опромінення.

The complex of solid radioactive waste (RW) and liquid radioactive waste (LRW) reprocessing is intended for higher productivity of utilization process of the RW stored at Zaporozhye nuclear power plant (NPP) warehouses and minimization of the amount of RW produced as a result of the RW recycling. The amount of RW produced both in the process of regular operation of a nuclear power plant and during carrying out of any repair work as well as during an accident (any emergency) is considerable enough. In the sequel these volumetric RW are stored at the nuclear power plant (NPP). The problem how to make the waste compact is the matter of topical interest for all the NPP in Ukraine.

As a rule to make solid RW compact they are pressed, and as for combustible waste, they are burned and then pressed. Liquid RW are evaporated, and the combustible, such as oil, for example, are burned. Three units of a complex for RW utilization, namely, units for burning and super-pressing, and also a fragmentation module, are planed to be put into operation at the Zaporozhye NPP. To place the units for burning and super-pressing a special building is under design and the fragmentation module will be disposed in the existing building of the storage site for solid RW. According to the design, in the new building some import processing equipment, delivered under TACIS program, is stipulated to be installed: a burning unit, with productivity of 30 kg/hour; a super-pressing unit, with pressing effort of 150 tons.

The aim of this work is to analyze radiation environment in the premises of RW processing complex both under normal operation of the units, and when any emergency occurred. The layout of the basic burning unit elements is shown on Fig. 1.

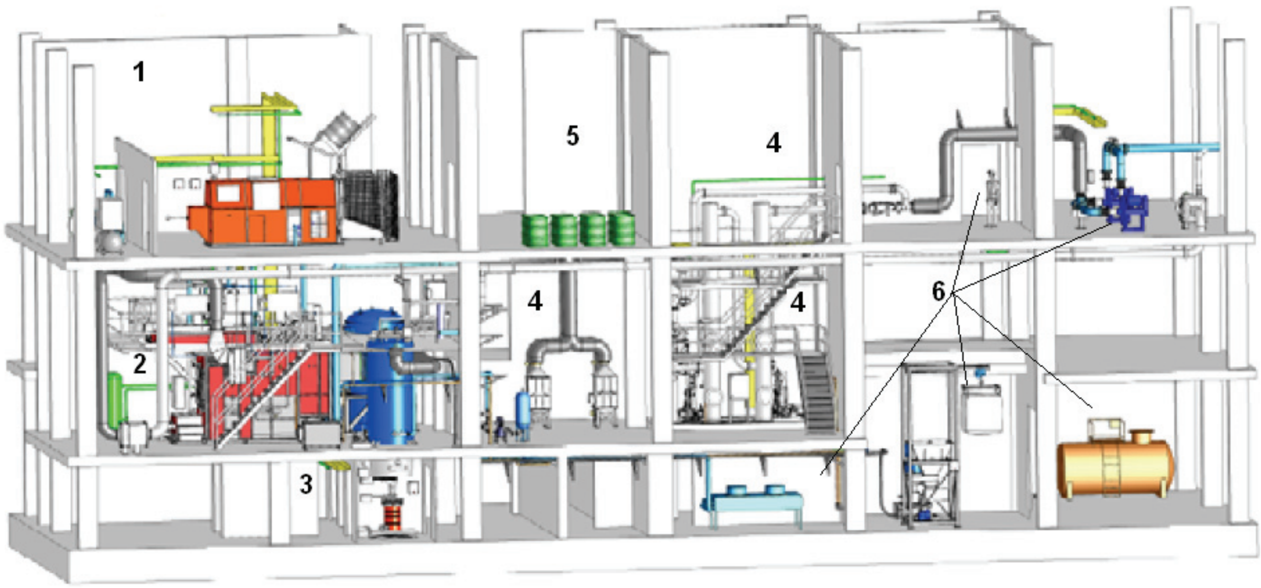

Fig. 1. General layout of the burning unit.
1 – load of RW to be burned, 2 – combustion furnace, 3 – ash unloading; 4 – gas cleaners; 5 – burned RW storage; 6 – service premises.

RADIATIONS CHARACTERISTIC OF RW

Radio nuclide composition of RW and LRW consist of such nuclides: ^{95}Zr, ^{95}Nb, ^{124}Sb, ^{65}Zn, ^{51}Cr, ^{59}Fe, ^{58}Co, ^{110m}Ag, ^{144}Ce, ^{54}Mn, ^{60}Co, ^{134}Cs, ^{137}Cs. Spectrums of gamma radiation for all types of the waste taking into account these nuclides were obtained by SpectrOJAT package [1]. To determine the flow density of beta-particles at the RW exposed surface the total beta-ray spectrums for RW, ash, oil and pressed solid RW were calculated taking into account isotopic composition of the radio nuclides contained in them. The calculation results are given in Fig. 2. The given data show that the radio nuclides contained in oil, generate electrons with high enough energy due to the presence of ^{124}Sb in it. Obtained were used further for estimation of the dose rate in the premises of RW processing complex.

CALCULATION PROCEDURES

The RW processing complex at Zaporozhye NPP includes a combination of ionizing radiation sources of various shape and composition, namely: cylindrical volume radiation sources in the form of steel barrels with volume of 170, 200 and 280 l; solid RW, inside a box with a “glovebox”, packed into packages of 15 kg, which when moving over a table, take the form of a cylinder with diameter of ~ 45 cm and height of ~3.5 m; the RW, being in a powdery-gaseous state, filling up the cylindrical volumes of a boiler and of a bag filter. The radiation sources as a part of the RW processing complex are exposed radiation sources and represent hybrid beta-gamma emitters.

When calculating the dose rate from the mentioned radiation sources, the following techniques and program codes were used:

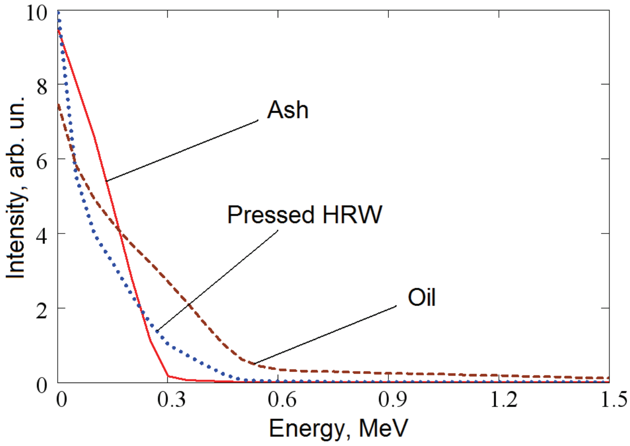

Fig. 2. Spectrums of beta particles of the major in-process RW (ash, pressed solid RW, oil)

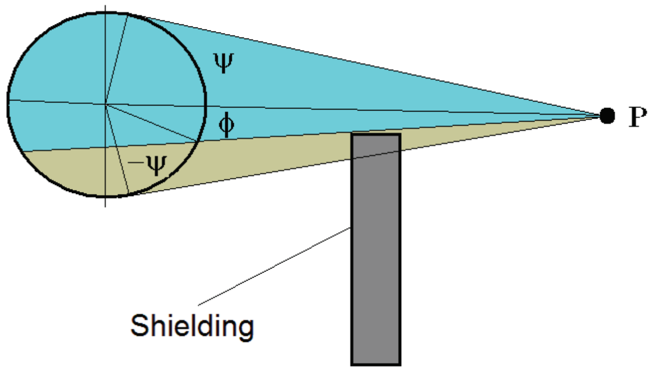

Fig. 3. Geometry of a self-absorbing cylindrical volumetric radiation source with partial shadowing

VOLUME_M – The program complex developed in KhNU, as well as the well known **MicroShield** package based on the method of volumetric or surface integration of point sources, allowing calculating gamma-quantum flows from the sources of different shape provided that some protective constructions are present [2]. Often enough situations occur when a radiation source (RS) is partially shadowed with a protective construction or any other radiation source. In this case the source radiation is divided in two parts: direct radiation and radiation transmitting through the shielding (Fig. 3).

Using **MicroShield** package one cannot calculate a situation like this, but at the same time solution of such problems is possible when using **VOLUME_M** package. During the process of reload and transportation of the RW prepackaged in barrels (solid RW for pressing, ash, briquettes) the barrel may fall down and the radioactive waste may spill out on the floor. The doze rates from the barrel's content spilled out (volume – 170, 200 and 280 l) depend both on the RW composition, and on the shape (the geometrical sizes) of the generated radiation source. For calculation of the dose rate of the spilled out RW (ash, solid RW) different model geometries of radiation sources, such as: a semi-cylinder lying on a surface and hemisphere were used.

EMID Package. EMID program module [3] is based on the use of empirical formulas and algorithms of electrons transport. The package allows calculating various characteristics both of electrons, and of a matter when fast electrons are passing through heterogeneous structures. The package allows to calculate the path range of electrons with different spectral composition in various materials and to determine dose characteristics.

PENELOPE – the program code for carrying out calculations on transport of electrons and gamma-quanta through various objects and mediua [4]. The code is used for calculations of the dose rate provided that protection is heterogeneous. In the given paper some geometrical blocks describing geometry of the radiation sources: barrels, furnaces, «glovebox" , super-pressing device components were created for the PENELOPE package.

SpectrOJAT – a package allowing to calculate spectral composition and intensity of gamma radiation from spent nuclear fuel or any combination of radio-nuclides at any given moment of time [1]. A special feature of the package is feasibility to calculate gamma-quanta spectrum with partition into any arbitrary specified energy intervals. Databases for quantum yields of each radionuclide were generated on the basis of JEF2.2 package [5] with addition of the data from JEF3.2 package [6].

MCNP – the program code developed by Los-Alamos National Laboratory [7] for Department of Energy in the USA. MCNP program is widely used for the analysis of protective shielding in the nuclear industry of the USA. In the present paper the MCNP was used for check and verification of the gained results.

RESULTS OF CALCULATIONS

Calculations of gamma radiation dose rate for the above mentioned radiation sources existing in the devices of the RW processing complex were carried out at different points near them. Ash as well as pressed ash has the greatest specific activity. For the radiation source in the form of cylinder (barrels of 170 and 200 l) dependences of the dose rate on the distance at points laying at semi-height of the cylinder filled with ash whose density is 0.65 g/cm^3, and pressed ash with density of 2.2 g/cm^3, calculated using VOLUME and MCNP packages, are presented in Fig. 4. The dose rate calculated using VOLUME package, exceeds the dose rate, calculated using MCNP package by 5÷10 %. Attention should be paid to high values of the dose rate near surface of the objects under consideration. For safety improvement during transportation of the barrels filled with ash and any other kinds of the RW on special carts it was offered to install protective shields. The most effective in this case are shields made of lead. In comparison with a steel shield of the same weight (1-cm of Pb and 1.45-cm of Fe) the dose rate behind the shield made of Pb is lower by ≈1.3 times. Fig. 5 presents dependences of the dose rate on the distance in presence of a Pb-shield with thickness of 1 cm for ash, pressed ash as well as for solid RW and liquid RW. For the cases with complex geometry of radiation sources and shielding elements in PENELOPE package a geometrical model was designed and calculations of the dose rate for improvement of biological shielding characteristics were carried out in order not to exceed the norms of radiation safety.

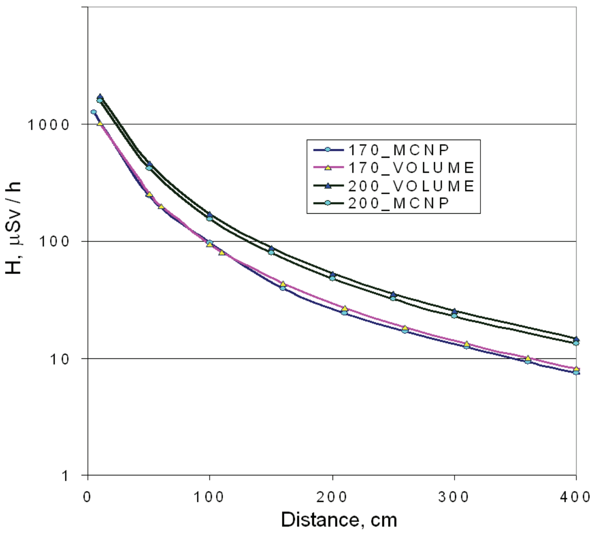

Fig. 4. Dependences of the dose rate on the distance for radiation sources in the form of cylinders (barrels of 170 and 200 l) filled with ash and the pressed ash.

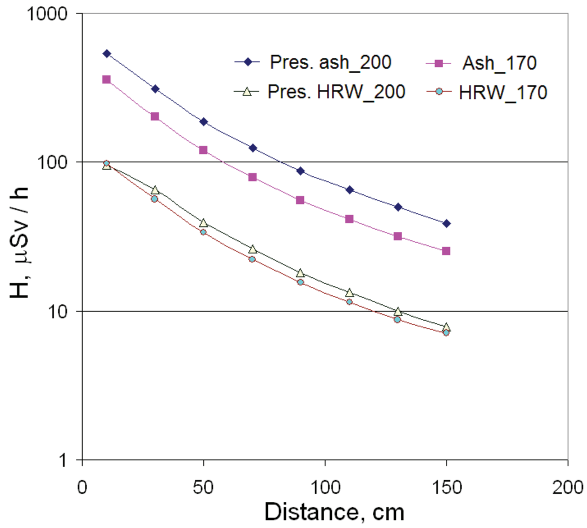

Fig. 5. Dependence of the dose rate from the barrel with ash on the distance in the presence of a 1-cm lead shield.

Fig. 6 illustrates geometrical models and arrangement of detectors (MCNP package) when calculating the dose rate chart from 3 caissons in which the barrels are filled with ash.

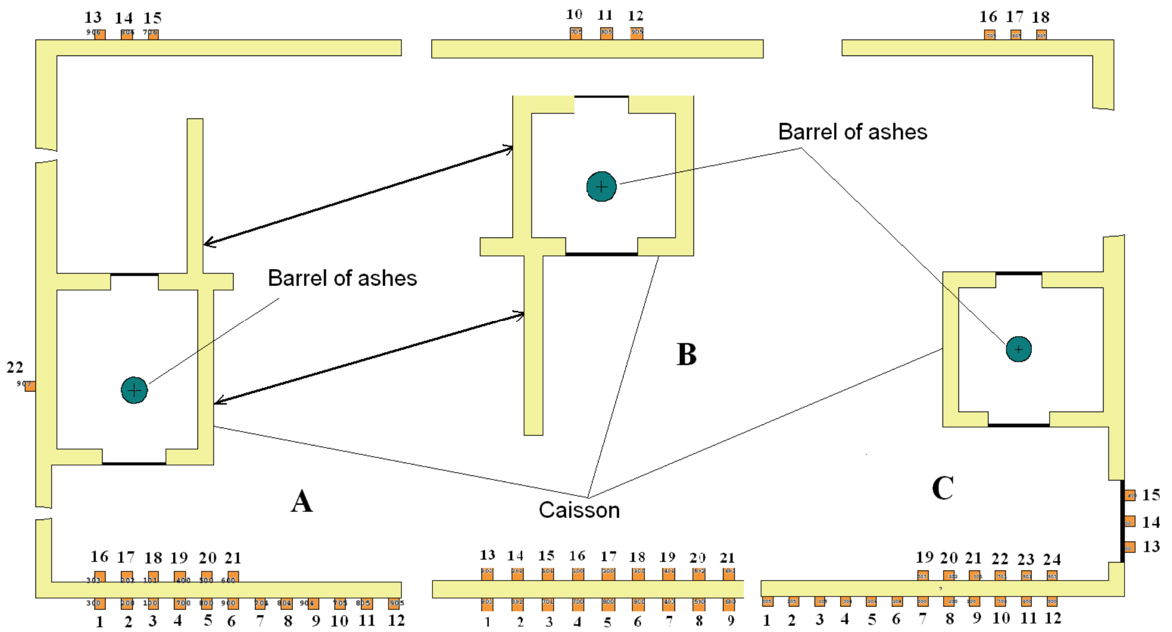

Fig. 6. Geometrical model for calculation of dose rate in the room where the ash channel caissons are placed.

The dose rate from each caisson was calculated, and then the dose loads were added together. As is evident from the data presented in Fig. 4,5 the dose rate, generated by the 1-st container with ash, and especially with the pressed ash, is great enough. This imposes some restrictions on quantity of containers with ash (pressed ash), that are temporarily housed in buffer warehouses with reasonable parameters of biological shielding observed.

Fig. 7 represents distribution of the dose rate from 7 barrels with ash (disposed in a buffer warehouse) behind a concrete wall whose thickness is 40 cm. Figures on the insulated lines correspond to the dose rate in μZv/h, the sizes in the figures are given in cm. Increase in quantity of the barrels, their arrangement near a wall or decrease of the wall thickness would lead to excess of the admissible dose rate indoors behind the wall of the buffer warehouse.

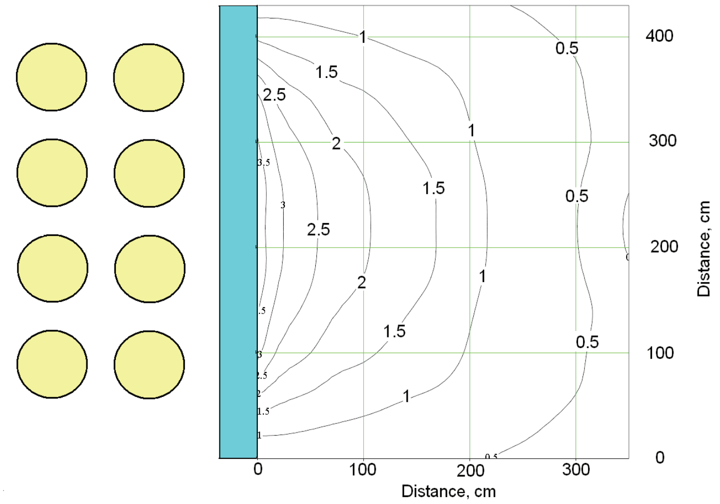

Fig. 7. Distribution of the dose rate from 8 barrels with ash indoors behind a concrete wall with thickness of 40 cm. Figures on insulated lines indicate the dose rate in μZv/h.

According to the norms of radiation safety, a biological shielding in the form of walls (made of concrete), and doors (as a rule made of steel) should bar from exceeding of the dose loads. At thickness of a concrete wall of 40 cm, equivalent thickness of a steel door ≈10÷12 cm as to radiation protection (depends on geometry of radiation sources arrangement).

Using **ALARA** principle**,** we offered to restrict the free access zone by mounting Rabitz fence. The Rabitz fence is mounted at a distance providing non-excess of the dose rate with essential reduction of the doors thickness in the premise containing radiation sources. It should be noted that reduction of the doors thickness would not lead to increase of the personnel body burden due to decrease of time necessary for opening and closing of the doors. Fig. 8 presents the layout of Rabitz fence at the entrance and exit of a premise which houses a pressing device and a buffer warehouse for barrels with ash (the zone of free access is shaded). Taking of such measures would provide the steel doors thickness of ≈1÷2 cm to be sufficient.

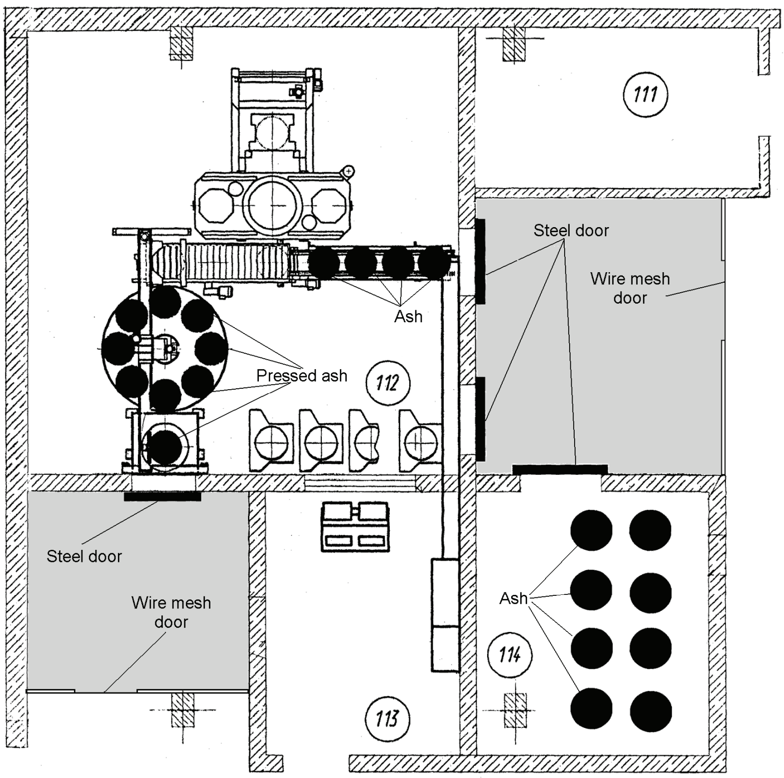

Fig. 8. Layout of Rabitz fence at the entrance and exit of a premise housing a pressing device and of the buffer warehouse for barrels with ash

CONCLUSION

The radiation environment in the premises of the RW processing complex both under normal operation of the units, and when any emergency occurred was analyzed. The design characteristics of the mentioned units specified by their manufacturers, as well as operative norms and rules in Ukraine on the RW treatment were taken as the initial data for the paper.

1. For radiation sources of complex geometry and isotopic composition **VOLUME_M** package, allowing to calculate protective properties and dose loads in real problems, was modified.
2. It was shown that when processing RW, treatment of such waste demands application of special accident control measures (protective shields) because of essential increase of the RW specific activity.
3. Some measures for improving safety of the personnel work in the premises where the radiation sources are disposed were offered. That allows essential improvement of the biological shielding design, in particular, reducing thickness of the doors between premises.

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