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Radiation Model of a Technological Pipe of Nuclear Power Plant

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---***ABSTRACT***---

In this paper, a description of the model of the radiation state of anuclear facility is developed and the composition of the model is outlined.The problems of the formation of the engineering-radiation model of the nuclear facility are considered on the basis of the engineering model of radiation inspectionand gamma radiation calculations depending on the radionuclide composition, the activity of radiation sources, and also their geometric sizes and shapes.Knowing the flux density of gamma quanta of all energies at a given point, one can obtain the absorbed dose rate in the detector and calculate the equivalent dose rate at that point.

KEYWORDS:-Radiation,technological pipe, radionuclides, decommissioning, environment, nuclear, power, plant, facility, model, transformation, cylindrical, attenuation, gamma, dose, geometry, coordinates, isotropic, monoenergetic, engineering, flux.

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I. INTRODUCTION

The world’s increasing population and industrialization requires a continuous, sustainable source of energy to sustain our energy demands. There is however the need to tackle this problem without any negative effect on humans and the environment, and this remains the greatest challenge to scientists, engineers and politicians across the globe. For this reason, nuclear energy appears to be the best energy source because of it little effect on the environment as well as it cheap cost in terms of generation relative to most sources used today in most part of the world. Most countries are now adding nuclear energy to their energy mix, there are a total of 442 reactors in the world.

Decommissioning is the final stage in the life cycle of the nuclear facility, which is comparable in complexity and duration to a stage in the life cycle, such as operation.

Preparation for decommissioning of the atomic nuclear facility is a complex process involving several stages in which a local concept and decommissioning program is developed, a comprehensive engineering and radiation survey of the facility is conducted, from operation, work is carried out to decontaminate and dismantle the equipment and structures of the facility, to handle radioactive waste, and so on. Safety of the human, environment and the future generation is the greatest task in decommissioning of a nuclear facility. For these reasons, most enterprises mainly perform direct measurement monitoring of radioactive contamination of premises and the site of the atomic nuclear facility, while modern techniques and methods of radiation monitoring allow for the conduct of model monitoring of radioactive pollution of the environment on the basis of automation of all calculations and measurements.

Creation of a model of the radiation condition of the nuclear facility will allow to carry out a calculation forecast of changes in the radiation status at the site, ensure the fulfillment of design tasks, forecast the formation of radioactive waste and dose loads on staff. It will also select the optimal version of the decommissioning operation, visual navigation through information and visualization of data, preliminary refinement of equipment dismantling procedures, systems, designs, verification, testing and optimization of solutions laid down in the decommissioning project, which ultimately leads to a decrease in the economic costs of carrying out work on decommissioning of the nuclear facility.

1.0 Radiation model of the technological pipe

The technological pipe is an elementary object of the engineering and radiation model, which is part of almost all technological systems of the nuclear facility. Within the framework of the radiation model, the pipe is considered as a source of ionizing radiation due to radioactive contamination of the inner surface. Pollution was formed during the operation of the technological system, which includes the pipe, as a result of prolonged contact with the radioactive working medium.

Radiation model of the pipe designed for calculation of gamma ray flux density and the equivalent dose (hereinafter radiation characteristics) caused by radioactive contamination of the inner surface at any given point in three-dimensional space outside the tube.

Unambiguous coordinate position of the pipe end and a constant diameter dimensions in three-dimensional space relative to a given coordinate system is defined by:

a. The radius vector$\boldsymbol{r}_0(x_0, y_0, z_0)$is the starting point of the pipe axis (cm)
b. Radius vector $\boldsymbol{r}_1(x_1, y_1, z_1)$end point of the pipe axis(cm)
c. external diameter $d_{out.}$ or outer radius $r_{out.}$ of pipe (cm)

The geometric and physical parameters of the tube, necessary for calculating the radiation characteristics within the framework of the approximations made, included the following:

a. internal diameter $d_{in.}$ and inner radius $r_{in.}$ pipe (cm)
b. length of pipe $L = \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1 - z_0)^2}$ (cm)
c. thickness $t_{cm.}$ of wall of pipe (cm)
d. density ρ of wall materials (g/cm^3)
e. mass coefficient of attenuation of gamma radiation $\mu_m(E_\gamma)$
f. linear coefficient of attenuation of gamma radiation $\mu(E_\gamma)$ of material tube wall (cm^{-1})
g. weight of tube m (g) was specified as the design parameter $m = \pi(r_{out.}^2 - r_{in.}^2)L\varrho$;
h. specific per unit mass activity a_m (Bq/g)

The coordinates of the point at which the radiation characteristics are calculated (detector) given by the radius – vector$\boldsymbol{r}_D(x_D, y_D, z_D)$.

Calculation of radiation characteristics is conveniently carried out in a coordinate system associated with a hollow cylinder approximating a pipe of finite size. In the radiation model, all coordinate parameters of the problem were transformed into a new coordinate system, in which:

a. the origin coincides with the initial point of the pipe axis;
b. axis $Oz'$is directed along the axis of the tube;

The principle of transformation of the coordinate system is shown in the figure.

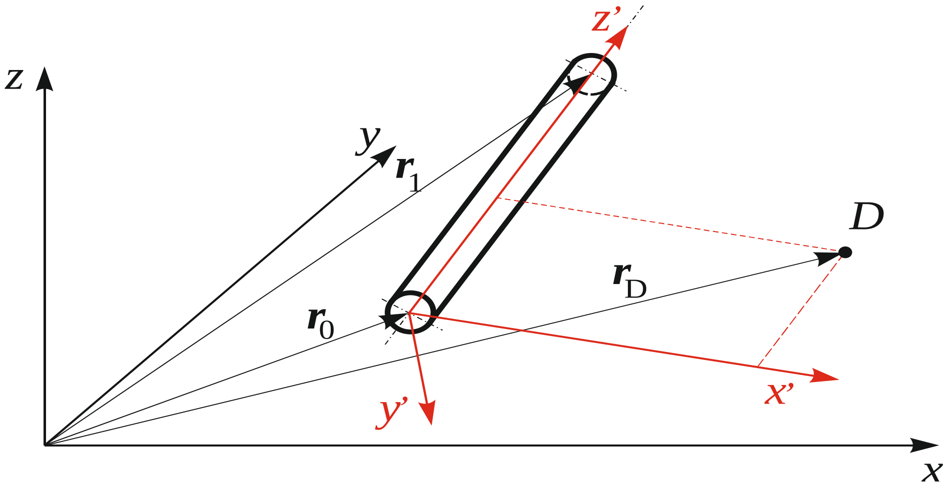

Figure 1 - Principle of transformation of the coordinate system

In the new coordinate system, the radius vector of the initial point of the pipe axis is defined as $x_0 = 0, y_0 = 0, z_0 = 0$. The radius vector of the end point of the tube axis has the coordinates $x_1 = 0, y_1 = 0, z_1 = L$. The coordinates of the detector are defined as the coordinates $x_D = x`, y_D = 0, z_D = L * 0{,}5$.

The geometric parameters of the pipe do not change during the transformation of the coordinate system.

Consider an arbitrary point source in accordance with Figure 2, located on the inner surface of the pipe. In the new coordinate system (here and below, the dashes in the coordinate notations in the new system are omitted), the point source is determined by the radius vector $\boldsymbol{r}_s(x_s, y_s, z_s)$.

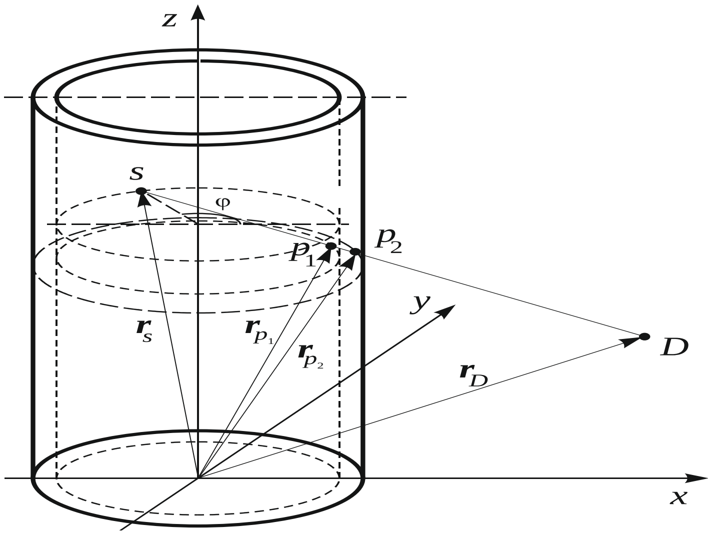

Figure 2 - A point source on the inner surface of the tube

The point sources are distributed uniformly along the cylindrical surface (the inner surface of the tube) at the nodes of a uniform grid, the parameters of which are conveniently specified in cylindrical coordinates. Defining the grid steps as $\Delta\varphi = 2\pi/I_m$ and $\Delta z = L/J_m$ (where I_m and J_m- are the number of nodes in coordinates $\varphi \in [0,2\pi]$ and $z \in [0, L]$ respectively), we obtain the radius vector of the point source in cylindrical coordinates.

II. BEHAVIOR OF GAMMA QUANTA GENERATED FROM A POINT SOURCE

The point source is isotropic, that is, it emits gamma rays equally in all directions of the total solid angle 4π. If the intensity of the point source is$Q$ (c^{-1}),then the gamma-quantum flux density at a distance r determines the uniform distribution of gamma quanta over a spherical surface with a radius r.

$$q = \frac{Q}{4\pi r^2}, \quad \left(\frac{1}{\text{см}^2 \cdot \text{с}}\right). \tag{1}$$

Gamma quanta generated in a point source and moving in the direction of the detector move along a rectilinear trajectory connecting points s and$D$. Generally, gamma quanta are partially absorbed from the beginning in the air in the cavity of the tube, then in the material of the pipe wall, air outside the pipe. Accordingly, in order to account for the absorption of gamma quanta in different media, it is necessary to determine the lengths ofsp_1, p_1p_2 and $p_2D$segments in accordance with Fig. 3. Consider the projection of the geometry of the problem onto thexOy

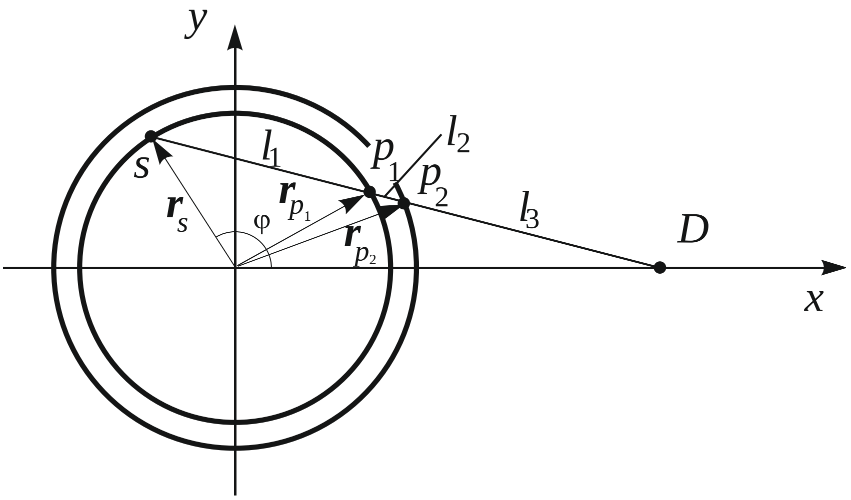

Figure 3 - Projection of a pipe on a plane

The flow of monoenergetic gamma quanta, passing through a layer of matter of linear dimension, $l$where l is the total length of the gamma-ray trajectory,loses part of the gamma quanta due to absorption in the direction of flow. The change in the flux density is determined by the thickness of the layer and by the absorbing properties of the medium

$$q(l) = q_0 \exp(-\mu l), \qquad (2)$$

Where q_0 is the initial flux density, μ is the linear coefficient of attenuation of gamma quanta with energy E.

III. CONCLUSION

Radioactive contamination of the inner surface of the pipe is approximated by superposition of point sources distributed along the cylindrical surface at the nodes of a uniform grid. To determine the gamma-ray flux density at point D, it is necessary to sum the gamma-ray flux densities of all energies entering the detector from each point source describing the radioactive contamination. It is obvious that for each point source we will have our own local geometric parameters that absorb the properties of the medium and the partial energy coefficients of gamma quanta of which do not depend on the coordinates of the point sources. Knowing the flux density of gamma quanta of all energies at a given point D, one can obtain the absorbed dose rate in the detector and calculate the equivalent dose rate at point D.

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