

Mini Review

Development of Gamma Flaw Detectors for Non-Destructive Testing

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Abstract

The radiographic method of control is implemented by a set of control tools in the form of gamma flaw detectors, which are distinguished by: mobility, reliability, radiation safety, adaptability to a wide climatic range, ease of operation, and the ability to control products with small and large radiation thicknesses. The paper describes portable gamma flaw detectors manufactured by JSC NIITFA: Gammarid 2010R, UNIGAM R, Stapel-5 Se75 Ir192, Stapel-5 Se75W, gamma flaw detector γ -RID-75/80R and stationary gamma flaw detectors RID K-100 and RID K-400. Also paper describes a brief technology for the production of ionizing radiation sources Ir-192 with activity of 120 Curie, a technology for rolling the source holder with Ir-192 source and completing the Ir-192 source with a portable gamma flaw detector Gammarid-192/120M in the INP AS.

Introduction

For the radiographic method of Non-Destructive Testing (NDT) quality control of welds and the degree of destruction of metal structures (process equipment, pipelines and various products), closed sources of ionizing radiation with radionuclides are used: Thulium-170 (Tm-170) for determining defects up to 10 mm; Selenium-75 (Se-75) for determining defects up to 40 mm, Iridium-192 (Ir-192) for determining defects up to 80 mm and Cobalt-60 (Co-60) for determining defects up to 200 mm are used. Radiographic control is designed to control the quality of welded joints of steel pipes and metal structures with a wall thickness of 5 mm to 200 mm, assemblies and parts of industrial products in the areas of thermal and nuclear energy, oil and gas complex, mechanical engineering, shipbuilding, and chemical production. The radiographic method of NDT provides: - reliability of information about the defect in the control object; - the possibility of monitoring the dynamics of the development of defects in the process of operation of the controlled object; - the possibility of archiving and documenting information about the controlled object. In the oil refining industries, numerous spectral methods of non-destructive testing are widely used: ultrasonic, radiographic, magnetic particle, acoustic emission, capillary, and all of them have their advantages and disadvantages. However, in

the last resort, the radiographic method of control is used, because for all its shortcomings (high cost of equipment, the need to ensure the safety of personnel), only it allows you to determine with great accuracy the size of the defect and its location in the thickness of the metal of the pipe or weld. In addition, only the radiographic method of control allows monitoring the condition of pipelines without removing the insulation and preliminary surface preparation, which increases its economic viability, and the method can also be applied without stopping the operation of the pipeline [1-3]. Given the very diverse range of pipelines - from main pipes with a diameter of more than 1 meter with a wall thickness of up to 30 mm to pipes with a diameter of 10-14 mm with a wall thickness of 2 mm, radiographic control equipment should be universal, which is achieved by using a wide range of ionizing radiation sources as Tm-170 for short focal lengths, Se-75 for medium focal lengths, and Ir-192 and Co-60 for long focal lengths.

Joint-Stock Company "Scientific Research Institute of Technical Physics and Automation (JSC NIITFA) has many years of experience in the development and manufacture of gamma flaw detectors of various modifications: Gammarid 2010R (Gamma source Ir-192 2010 release), UNIGAM R

More Information

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Keywords: Gamma flow detector; Neutron irradiation; Ionization radiation source; Iridium-192



(Universal gamma radiation), Stapel-5 Se75 Ir192 (Slipway-5 for Se-75 and Ir-192), Stapel-5 Se75W (Slipway-5 for Se-75 with tungsten protection), gamma flaw detector γ -RID-75/80R (Gamma source Se-75 with activity 80 Ci) and stationary gamma flaw detectors RID K-100 (Gamma source Co-60 with activity 100 Ci) and RID K-400 (Gamma source Co-60 with activity 400 Ci). One of the areas of development of JSC NIITFA is portable and stationary gamma flaw detectors and radioactive closed ionization radiation sources (Se-75, Tm-170, Ir-192, Co-60) for them.

Gamma flaw detectors of Gammarid-192/120M (gamma flaw detector with source Ir-192 with maximal activity 120 Ci modernized) based on Ir-192 ionization radiation sources with an activity of 4440 GBq (gigabecquerel) or 120 Ci are widely used in the Republic of Uzbekistan for quality control of products in industrial enterprises. However, the import of Ir-192 sources to Uzbekistan is associated with certain difficulties associated with meeting the requirements for the movement and customs clearance of radioactive sources. Therefore, the manufacture of Ir-192 sources of domestic production and their completion with gamma flaw detectors Gammarid-192/120M, which are the property of the Institute of Nuclear Physics of the Academy of Sciences (INP AS) of Republic Uzbekistan was an urgent task. The goal of the project was to develop a technology for the production of highly active Iridium-192 sources and their equipment with gamma flaw detectors Gammarid-192/120M based on the WWR-SM reactor and the Republican Central Isotope Laboratory (RCIL). INP AS has developed a unique technology for producing the ^{192}Ir radionuclide by irradiating natural iridium disks with reactor neutrons in the vertical channels of the WWR-SM reactor (water-water reactor serial modernization) based on the $^{191}\text{Ir}(n, \gamma)^{192}\text{Ir}$ nuclear reaction and manufacturing sealed sources of Ir-192 with activity of 120 Ci, developed technology of rolling the source holder and loading the source holder into the radiation head of the Gammarid-192/120M gamma flaw detector and also technology for recycling spent Iridium-192 sources.

Gamma flaw detectors manufactured by JSC NIITFA

It is preferable to use gate-type gamma flaw detectors that create a collimated radiation beam, which can be perceived by the detection system with an online image on a computer monitor while the radiation source is constantly moving along the pipeline. The high degree of reliability and proposed design of the movement of the gamma flaw detector, rigidly connected to the radiation detector, will make it possible to determine not only the exact location of the weld and the degree of its wear but also defects in the base metal of pipes, such as thinning of the walls as a result of corrosion, violation of geometry as a result of unforeseen static loads, cracks and accumulations of microcracks, as well as other deviations that are not allowed in accordance with the regulations for the operation of pipeline valves. Figure 1 shows portable gamma flaw detectors manufactured by JSC NIITFA.

We also see the technical characteristics of portable gamma flaw detectors GAMMARID 2010 R and Stapel-5 Se75 Ir192, Stapel-5 Se75W, γ -RID-75/80R manufactured by JSC NIITFA in Tables 1 and 2, respectively [4].

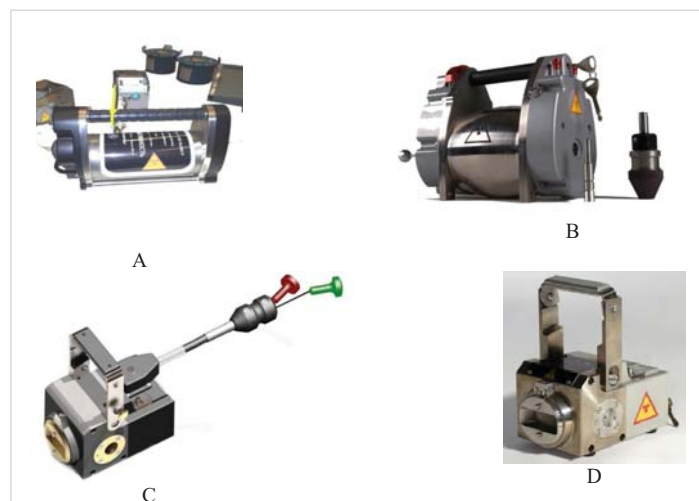


Figure 1: Portable gamma flaw detectors manufactured by JSC NIITFA: A - Gamma flaw detector "Gammarid 2010R" universal - hose type with a universal collimator; B - Portable gamma flaw detector "UNIGAM R" with an axial gate channel; C and D- Gamma flaw detector "Stapel-5 Se75 Ir192" shutter type.

Table 1: Technical characteristics of the radiation heads of the gamma flaw detector GAMMARID 2010 R [4].

Parameter	Ir-192 source with activity 150 Ci	Ir-192 source with activity 300 Ci
Weight of the radiation head, kg	20.0	19.7
Dimensions (H x B x L) radiation head, mm	197 x 120 x 352	227 x 168 x 310
Radiation source: Type; ratings Exposure Dose Rate, A/kg; Activity, Becquerel - Bq (Ci)	Ir-192 type GIID-192M34.6; Ir-192 type GIID-192M34.7; 5.1 x 10 ⁻⁶ ; 5.6 x 10 ¹² (150)	Ir-192 GIID-11a-4; 6.8 x 10 ⁻⁶ ; 11.1 x 10 ¹² (300)
Bio-protection material	depleted uranium	depleted uranium and metal tungsten

Table 2: Technical characteristics of portable gamma flaw detectors Stapel-5 Se75 Ir192, Stapel-5 Se75 W and γ -RID-75/80R.

Name	Stapel-5 Se75 Ir192	Stapel-5 Se75W	γ -RID-75/80R
Weight of the protective radiation head, kg	10	10	6
Closed Ionizing radiation source	Ir-192; Se-75	Se-75	Se-75
Effective energy of gamma radiation, MeV	Ir-192 – 0,40 Se-75 – 0,215	Se-75 – 0,215	Se-75 – 0,215
Optimum controlled thickness (steel), mm	Ir-192 – 10-80 Se-75 – 5-40	5 - 40	5-35
Half-life of a radionuclide, T _{1/2}	Ir-192 – 74 days Se-75 – 120 days	Se-75 – 120 days	Se-75 – 120 days
Source activity, Ci, up to	Se-75 – 80; Ir-192 - 70	Se-75 - 80	Se-75 - 80

JSC NIITFA has developed and manufactured stationary gamma flaw detectors using a source based on radionuclide ^{60}Co for NDT of welded joints with a transmission depth of up to 200 mm in steel, or for detecting discontinuities and heterogeneous inclusions in critical products from other materials. Ionization radiation source Co-60 in these devices moves along the ampoule line using an electromechanical drive when transmitting commands from the control panel with movement both horizontally and vertically. Figure 2 shows stationary gamma flaw detectors manufactured by JSC NIITFA. The technical characteristics of stationary gamma flaw detectors RID K-100 and RID K-400 are presented in Table 3.

Gamma flaw detector manufactured by INP AS

In the INP AS a unique technology for the production of a sealed ionization radiation source of Iridium-192 with an activity of 120 Ci was developed, a technology for rolling the source holder with an Ir-192 source and technology of completing the Ir-192 source with a portable gamma flaw detector Gammarid-192/120M [5].

Briefly about the manufacturing technology of the Ir-192 source and its complication with Gammarid-192/120M: Metal disks of natural iridium (diameter, $\varnothing = 2.7$ mm; thickness, $h = 0.2$ mm; weight, $m = 31.7$ mg) in quantity 20 - 30 pieces packed in aluminum foil, which were irradiated in the vertical channel of the reactor in the block container EK-20 (experimental channel with a diameter of 20 mm) [6] at a nuclear WWR-SM reactor with power of 10 MW, thermal neutrons flux density is $0.9 \cdot 10^{14}$ neutron/cm²sec and irradiation time - from 600 to 1680 hours. In the reactor "hot chambers" packages with irradiated iridium disks are placed on a special device for radiochemical processing, where radioactive iridium disks are released from the packaging, treated with an alkali solution, water, and dried. On the special device neutron-irradiated iridium disks were placed in a magnetic stainless steel capsule, the capsule was closed with a lid and welded by spot argon-arc welding the tightness of the Ir-192 source was checked by the immersion method [7]. In a protective chamber with manipulators on a special installation, the Ir-192 source was placed into the source holder capsule, which was provided with a lid, and the holder was rolled, then the holder to a flexible shaft was connected. The holder with the Ir-192 source to the flexible shaft of the ampoule wire was connected and the recharge container was charged by remote method. Table 4 shows the main technical characteristics of the Ir-192 source manufactured by INP AS [8]. The main technical characteristics of the gamma flaw detector Gammarid-192/120M are shown in Table 5. Also, Figure 3 presents the gamma flaw detector Gammarid-192/120M of the INP AS.

The gamma graphic method was carried out at the Kandym gas processing plant, Figures 4 and 5 show X-ray images of samples of welded joints of pipelines obtained by the

Gammarid-192/120M with an Ir-192 source manufactured by the INP AS.



Figure 2: Stationary gamma flaw detectors manufactured by JSC NIITFA: A – stationary gamma flaw detector RID K-100; B- stationary gamma flaw detector RID K-400.

Table 3: Technical characteristics of stationary gamma flaw detectors RID K-100 and RID K-400.

Parameter	Description	
	RID K-100	RID K-400
Co-60 ionization radiation source activity, Ci	100	400
Half-life of radionuclide Co-60, year	5,27	5,27
Effective energy of gamma radiation, MeV	1,25	1,25
Controlled thickness range (steel), mm	30... 200	30...200
Weight of the radiation head, kg	152	293
Dimensions (H x B x L) radiation head, mm	450 x 270 x 320	50 x 270 x 320
Bio-protection material	depleted uranium	depleted uranium

Table 4: Main technical characteristics of the source Ir-192 [8].

Name, characteristic, and unit of measure	Data
1. Worksurface	bottom
2. The value of the Exposure Dose Rate (EDR) of gamma radiation measured by direct measurements by using a dosimeter of the IdentFinder Target type (No. 910385 - 495) at a distance of 1.0 m from the surface of the radiation head of the Gammarid 192/120M gamma flaw detector (No. 706 – 1990) of source Ir-192 A/kg (R/h), mR/h	$3,87 \cdot 10^{-6}$; (54); 1.0
3. Confidence limits of the total error of the results measurements of the exposure dose rate of a source at a probability of 0.95, in %	± 20
4. Date of measurement of the exposure dose rate of gamma radiation from the source	18.07.2023
5. Activity of the radionuclide iridium-192 in the source, Bq (Ci)	$4.44 \cdot 10^{12}$ (120)
6. External dimensions of the source, mm	$\varnothing - 4,5$; $h - 8,0$
7. Dimensions of the active part of the source, mm	$\varnothing - 3,0$; $h - 4,5$
8. Capsule material	Stainless steel 12X18H10T
9. Source tightness	sealed capsule
10. The level of radioactive contamination of the source with radioactive substances when determined by the method- smear removal, Bq, no more	185

Samples of the X-ray images of NDT obtained by Ir-192 source manufactured in INP AS (Figures 4 and 5), in terms of sensitivity and quality, meet the requirements of the international standards for non-destructive testing [9]. Gamma graphic NDT images obtained by specialists of the Limited Liability Company "VBM-Engineering" and foreign partners working at these production facilities, as a third-party inspection, were assessed as fully meeting the requirements of the international darts standards [10,11], valid on the territory of the Republic of Uzbekistan.

Table 5: Technical characteristics of gamma flaw detector Gammarid-192/120M.

Parameters	Description
Weight of the radiation head, kg	16
Radiation source: Type, ratings EDR, A/kg; Activity, Bq (Ci)	Ir-192; $3.58 \cdot 10^{-9}$; $4.44 \cdot 10^{13}$ (120)
Bio-protection material	depleted uranium

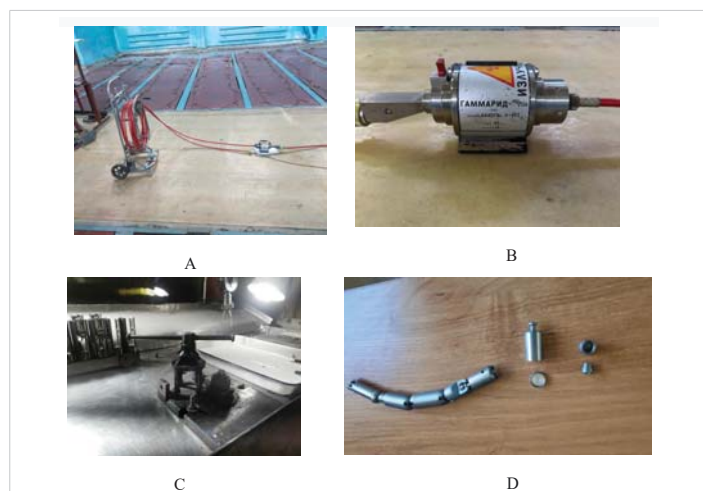


Figure 3: Gamma flaw detector Gammarid-192/120M: A - Trolley, ampoule line 17 m long and radiation head; B- Radiation head of the gamma flaw detector; C - Photo of a device for remote rolling the Ir-192 source holder inside a protective box of RCIL; D - Flexible shaft ampulla wire, holder for Ir-192 source with lid, source simulator with cover.



Figure 4: X-ray image of a weld sample with a diameter of 1020.0 mm, obtained using the method of gamma radiography with an Ir-192 source, where accumulations of gas pores and slag inclusions are clearly visible in the weld sample.

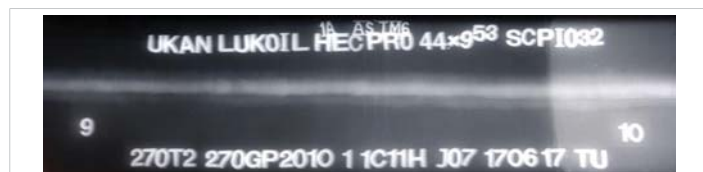


Figure 5: X-ray image of a weld sample with a diameter of 1020.0 mm, obtained after eliminating defects in the weld (Figure 4), repeated using the gamma radiography method with an Ir-192 source, where the image shows that there are no defects in the weld.

Conclusion

The high technological level and competitiveness of high-tech products of JSC NIITFA are confirmed by the fact that gamma flaw detectors and radioactive sources produced were supplied to the CIS countries and more than twenty other countries of the world, including the USA, England, Germany, Belgium, Finland, China, Vietnam, India, Bangladesh, Portugal, Peru, Cuba, Bulgaria, Czech Republic, Slovakia, Poland.

The Iridium-192 sources produced by the INP AS together with gamma flaw detectors Gammarid-192/120M were successfully used in Talimarjan TPP (Kashkadarya region), Takhiatash TPP (Karakalpakstan), Syrdarya TPP (Syrdarya region), Kandym gas processing plant (Bukhara region). Gamma graphic NDT images obtained by specialists of the Limited Liability Company "VBM-Engineering" and foreign partners working at these production facilities, as a third-party inspection, were assessed as fully meeting the requirements of the international darts standards valid on the territory of the Republic of Uzbekistan.

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