CJSC ECOMET-S facility for reprocessing and utilisation of radioactive metal waste: operating experience

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Abstract: The principal objective of the paper is to present operating experience in management of radioactive metal waste, originating at nuclear power facilities of the Russian Federation. Issues of radioactive metal waste recycling by melting, with the purpose of unrestricted re-use in industry, or restricted re-use within the nuclear industry, have been considered. The necessity for using a method of melting at the final stage of radioactive metal waste recycling has been proved. Priority measures to be taken and results achieved in the implementation of the Governmental purpose-oriented programme 'Radioactive Metal Waste Reprocessing and Utilization' have been considered, the CJSC ECOMET-S being the main contractor on the Programme. Main specifications and results of operating a commercial melting facility, owned by CJSC 'ECOMET-S' and used to recycle low-level radioactive metal waste originated at the Leningrad Nuclear Power Plant, have been presented.

Keywords: metal radioactive waste; decontamination; melting; recycling.

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1 Introduction

At present, one among the factors of the problem of providing radiation safety at facilities of nuclear power industry and nuclear industry is that of radioactive waste management, including radioactive metal waste (hereinafter RMW) accumulated and generated in operating and decommissioning out-dated reactors and other facilities of nuclear power industry and nuclear industry.

The Joint-Stock Company ECOMET-S was established in 1994 with the purpose of introducing nature protective, resource saving, and environmentally safe technologies in the field of management of RMW, generated at the facilities of nuclear power industry and nuclear industry. Since 1995, ECOMET-S has been the main contractor for the purpose-oriented programme 'Radioactive Metal Waste Reprocessing and Utilization' approved by the Government of the Russian Federation Direction No. 1197-p of September 1st, 1995. Minatom of the RF is the Customer of the Programme.

To solve the problem of RMW management, the enterprise has developed a comprehensive technology for RMW reprocessing and utilisation, which allows to reduce considerably the volume of waste to be disposed of, re-use the major part of the recycled metal in industry and transfer the secondary waste arising from the recycling process waste (its volume being less than 2–8% of that of the original waste) into an environmentally safe form, convenient and safe for transportation and disposal. The technology is based on using melting at the final stage of radioactive metal waste management.

The level of a concept of RMW management, recycling technologies, and principles of regulating residual contamination of metals developed by ECOMET-S specialists, which provide for re-use of the decontaminated metal in industry, allowed their finding to be included in the legal-normative document of the federal level. The necessity of compulsory preliminary melting of waste that was previously decontaminated at radiation objects, prior to its sending to recycling facilities, was confirmed by including the statement into acting in the RF sanitary regulations ОСПОРБ-99 (2000) and СПОРО-2002 (2002).

In 2002, on the premises of Leningrad NPP, in the town of Sosnovy Bor, Leningrad region, CJSC ECOMET-S put into operation an industrial facility for reprocessing and utilising low activity metal waste. The facility was equipped with modern equipment and design documentation for its construction was developed by FSUE Sosnovy Bor State Design and Research Institute VNIPIET.

2 General description of the radioactive metal waste reprocessing and utilisation facility

2.1 Short description of the facility

The ECOMET-S RMW processing and utilisation facility is situated in separate buildings on the premises of Leningrad NPP. The site is at a distance of four kilometres from the town of Sosnovy Bor and of 0.75 km to the south-east of Leningrad NPP and of 0.5 km to the north-east of NITI. On the east, the site is adjacent to Leningrad Specialised Facility 'Radon'.

The facility consists of a main building in the shape of a one-storied single-span block with a metal frame and a span of 24 m. A three-storied ferro-concrete block is adjacent to the main building at its long side. The ground floor is 6 m high; the first and second floors are 4.8 m high. Auxiliary technological rooms, as well as private rooms and facilities for the personnel and administration offices are housed in the block. The main building is abutted with a two-storied single-span block; its ground floor is 6 m high and the roof girders of the first floor are at a level of 12 m. Auxiliary technological rooms and gas cleaning and ventilation systems are housed in the block.

Characteristics of the facility are given in Table 1.

Table 1 Characteristics of ECOMET-S RMW reprocessing and utilisation facility

Plot area		0.85 ha
Developed area		0.41 ha
Overall building dimensions		33.45 × 90.45 m
The main building dimensions (single -span block with a metal frame	Length	90.45 m
	Width	24.0 m
	Height	17.1 m
Installed power of consumers	up to 1000 V	2024 kW
	up to 6000 V	1600 kW
Annual power consumption		6344 kW
Utility and production cold water consumption		2.145m^3/hour
Hot water consumption		2.376 m^3/hour
Re-circulated cooling water consumption		50 m^3/hour
Heat consumption (heating, ventilation)		2,198 Gcal/hour
RMW recycling capacity		5,000 t/year

The facility is designed to decontaminate radioactive metal waste consisting of stainless chrome-nickel and carbon steels, copper and its alloys, as well as aluminium alloys, with the purpose of the metal re-use or to reduce the waste volume.

The RMW to be recycled include out-dated and dismantled equipment if its radioactive contamination level corresponds to the category of low-level solid radioactive waste according to ОСПОРБ-99 and СПОРО-2002. Level and radionuclide content of RMW contamination are shown in Table 2.

Table 2 Radiation characteristics of RMW recycled at the facility

Radionuclide	*Average specific activity,* Bq/g (*design*)*	*Total annual activity,* GBq (*design*)	*Percentage* (%)
Waste from nuclear power plants and nuclear propulsion plants			
Mn-54	40	200	2–10
Co-60	15	75	60–90
Sr-90	10	50	3–10
Zn-65	55	275	1–5
Ru-106	150	750	2–20
Cs-134	20	100	1–5
Cs-137	50	250	5–30
Ce-144	150	750	2–5
Eu-154	30	150	0.1–0.2
Waste from uranium mining and enrichment facilities			
Ra-226	37	185	50–60
Th-232	30	150	50–60
U-238 (natural)	10	50	100

*Ten times increase in specific activity is allowed.

The RMW facility consists of three main sections: a RMW delivery and fragmentation section, a fragments decontamination section, a melting section, radiation control units, a gas cleaning system, radiochemical and physical-chemical laboratories, a decontamination solutions preparation and distribution unit, a sewage reception and discharge unit, clean and an off-grade ingots storage site, an air supply system, and a container decontamination site.

2.2 RMW delivery and fragmentation section

The delivery and fragmentation section is designed to cut RMW to the sizes that allow carrying out its decontamination and melting, as well as to sort it out according to the type of metal and level of contamination.

RMW is cut to fragments to the maximum length of 500 mm; long-sized components (pipes and rolled stock) are cut to the maximum length of 800 mm.

The section is equipped with the following equipments:

- A mechanised air-plasma cutting unit and a semi-automatic plasma cutting unit, which are installed in an enclosure under negative pressure. Thus, providing for confinement of harmful factors, such as powerful infrared and ultraviolet radiation, gas and dust releases, and sparks and noise in a closed space. Maximum thickness of metal that can be cut is 100 mm and 50 mm, respectively.
- Hydraulic shears designed for cutting metal in cold state. At the reception side the shears have an automatic hydraulic clamp to hold down the scrap at the time of cutting. Maximal cross-section of metal components is as follows: rounds – 115 mm, metal sheet (thickness – 38 mm, width – 457 mm)
- Alligator shears designed for cutting shaped rolled stock, maximal thickness of metal is 25 mm.

2.3 Decontamination section

The decontamination section consists of a thermal decontamination site, an abrasive grit/shot blasting site and a container decontamination site.

The thermal decontamination site is designed for decontaminating copper and its alloys, as well as for removing paint coats and organic impurities from the RMW surface. The site is equipped with an electric annealing oven (maximal temperature is 1150^{o}C), a cooling table, and a vibro-impact table. The vibro-impact table and the cooling table are equipped with a swivel hood for container cooling. Air extraction rate is 5000 m^3/hour.

The abrasive grit/shot-blasting site is designed for deep decontamination of RMW consisting of stainless and carbon steels, as well as for additional cleaning of non-ferrous RMW to the levels that allow the re-use of the decontaminated metal after melting. The site is equipped with an abrasive grit/shot-blasting machine having capacity of 3 tons/hour (batch load weight is 1 ton, treatment time varies from 10 minutes to 30 minutes).

The abrasive grit/shot-blasting machine is installed in a welded module and is equipped with a bucket loader and a gas cleaning system (its capacity is 10000 m^3/hour), which consists of a cartridge dust collecting filter and a fine cleaning filter. Total effectiveness of air cleaning is not less than 99.99%.

In the process of grit/shot blasting, radioactive sediments, as well as a layer of metal, up to 100 mm thick are removed from the RMW surface. The shot is regenerated and re-used. Metal dust and radioactive oxides are separated from the grit/shot and collected in special collectors. Decontaminated metal is loaded into technological containers and delivered to a special box in the technological process control unit. All operations at the abrasive decontamination site are fully mechanised. The site has provision for operating the grit/shot-blasting machine in the automatic mode.

2.4 Radiation technological control unit

The radiation technological control unit is designed to determine radionuclide content and to measure levels of radioactive contamination of the RMW, delivered from the fragmentation site to the decontamination site, and from the decontamination site to the melting site. The unit consists of two boxes equipped with highly sensitive gamma spectrometers, data processing, and logging being provided by computers. Depending on the results of measurements, a decision on methods of further treatment is made.

2.5 Melting section

The melting section is designed to provide for additional cleaning metal of radioactive contamination and for reducing its volume (compacting).

The section consists of a melting site, a cooling water circuit, a site for casting metal into moulds, for cooling and extracting ingots, for ingots storage and transportation, for preparation fluxes and anti-sticking mixtures and refractory materials, for secondary waste storage and the inductor maintenance, and preparation for operation.

The melting site is designed for melting metal in an induction furnace of ИСТ-2, 5/1,6-M4 type. The site consists of a work platform, a furnace operation control unit, a lifting swivel hood for evacuating air-gas mixture from the furnace crucible (air extraction capacity is 5,000 m^3/hour) a turnover slag pan, and an emergency reservoir for pouring metal in case of a failure.

Technical characteristics of the ИСТ-2,5/1,6-M4 furnace are shown in Table 3.

Table 3 Technical characteristics of the ИСТ-2, 5/1,6-M4 furnace

Characteristics	*Value*
Wattage rating, kW	1,500
Rated voltage, V	
Supply main	6,000
Main circuit	1,500
Control circuit	220
Rated frequency, Hz	
Supply main	50
Main circuit	400
Maximal temperature, oC	1,600
Furnace capacity, ton	2.5
Rate of melting and overheating, ton/hour	2.5
Specific power consumption, kW/hour	679
Cooling water consumption, m^3/hour	50–100

The reverse cooling water supply site is designed for cooling electrical equipment and the furnace components. It provides for a two-loop cycle with a closed first loop, which is filled with special additionally cleaned condensate.

The metal casting site is designed for casting metal into moulds that are installed on a self-propelled ingot-casting car of a semi-gantry type. There are five moulds and a slag pan installed on the car; the car is operated from the operation console located at the work platform. Ingots are cooled on the car for one hour. After that, the moulds are removed from the car by a crane and delivered to the ingot-cooling site. After cleaning the platform, new moulds that were prepared before are installed on the car and the car is moved to the initial position.

The ingots cooling and extraction site is designed for ingots cooling and extraction. Partially cooled ingots are extracted from moulds by turning those at an angle of 180^{o} by means of a hoist cable system, which is hung on the hook of a travelling crane. The ingots are cooled due to natural air circulation.

2.6 Radiation safety control system

On-line inspection of the radiological situation, monitoring of contamination levels on the surfaces of equipment and building structures are carried out by using radiometers-dosemeters МКС-01 and portable dosemeters ДРГ-01Т, ДБГ-06Т.

To monitor contamination of skin surface and clothes of personnel at the entrance to and exit from sanitary inspection boxes, stationary units for beta-contamination detection of РЗБ-04 type, counting-rate meters of УИМ2-2 type equipped with beta sensors of УДПБ-01П type are installed. Registration of the personnel's individual exposure doses is carried out by using the Fluorad ДРГ-711-РФЛ individual control system.

Automated monitoring of gamma-background rate in rooms and monitoring of the air discharged into the atmosphere by gas cleaning systems are carried out at two ten-channel data collection stations of the automated radiation safety control system developed by CJSC SNIIP-ASKRO.

The data collection station is equipped with:

- gamma-radiation dose rate detection blocks of БДМГ-08Р type
- radioactive aerosols detection blocks of БДАС-03П type
- ten-channel data processing unit of УНО-84Р type.

Information on radiation parameters is passed to УНО-84Р at the radiation safety switchboard control panel and to the central computer in the head of radiation safety department office. Checkout and inspection of the stations and condition of measuring channels are controlled from the switchboard control panel.

Content of radioactive substances in the air of the rooms, at entrance, and exit from gas cleaning filters, and in the air discharged into the atmosphere is controlled by air sampling to standard analytical filters with further analysis of the air in laboratories. The same samples are used to determine the presence of heavy metals in the air, by using the СПЕКТРОСКАН-LF roentgen-fluorescent spectrometry unit.

Radionuclide content in waste, metal ingots and in liquid waste is determined at the following units:

- a gamma-spectrometry unit based on a semiconductor detector made of particularly pure germanium
- a scintillation gamma-spectrometry unit of СЕГ-08Т type with detectors based on NaI crystals
- a beta-gamma spectrometer of УСК 'Gamma Plus Beta' type.

Element content in RMW, ingots and presence of metals in liquid waste is determined by using the СПЕКТРОСКАН-LF roentgen- fluorescent spectrometry unit.

Between the fragmentation and decontamination sites and between the decontamination and melting sites, protected measuring chambers equipped with gamma-spectrometry units (radiation technological control unit) are installed, to carry out technological control of the RMW loaded into containers.

2.7 Exit control of metal ingots

To control the quality of ingots at the exit, a special chamber is installed. This chamber is protected with shield blocks, and is equipped with a cantilever crane to move ingots and instruments to control exposure dose rates and levels of surface contamination in full compliance with developed techniques. Besides, provision is made to control contamination of ingot batches by sampling and measuring the liquid melts samples at the gamma-spectrometer, before casting metal into moulds.

Residual contamination of metal ingots is regulated by the State Standard (ГОСТ Р 51713-2001) “Carbon Steel and Non-Ferrous Metal Ingots, Permissible Levels of Gamma-Emitting Nuclides, and Method of Radiation Control” (ГОСТ Р 51713-2001, 2001).

2.8 Radioactive waste management

Solid secondary waste from the three sections is loaded into standard metal containers used at Leningrad NPP and through the delivery section it is transported by special trucks to Leningrad NPP for treatment. Liquid waste (sewage water from rooms and equipment decontamination) is collected in reception reservoirs in the basement of the decontamination section and then piped through a special sewage pipeline to LRW reservoirs at LNPP.

Radioactive effluents undergo cleaning treatment to appropriate standards separately for each of the following systems:

- general exchange ventilation
- air evacuated from the fragmentation section
- air evacuated from the decontamination section
- air evacuated from the melting section
- Effluents are released into the atmosphere through 20–24 metre high stacks.

2.9 Results of the facility operation

Since construction works were completed, and in 2001 works on putting the facility into operation began, 3880 tons of RMW have been reprocessed at the facility. During the time of its operation, CJSC ECOMET-S has recycled more than 7,000 tons of contaminated metal waste, the main part of which was delivered from Leningrad NPP. Some of the RMW was reprocessed at the industrial pilot plant, which was situated at Leningrad Specialised Facility ‘Radon’. The results of the facility performance in 2003 and its environmental impact assessment are given in Table 4.

On the basis of the facility operating experience, some changes and additions have been made in the RMW processing technology with the purpose of widening the scope of recycled RMW, making the technology less labour consuming, and improving working conditions.

According to design documentation for the delivery and fragmentation, section maximal thickness of metal to be cut was limited to 100 mm. In practice, it turned out that wall thickness of some large-sized equipment (the total amount of which was some hundred tons) reached 400 mm. In order to cut equipment with thick walls, the site was also equipped with a flux injection cutting unit. Moreover, taking into account the fact that the thermal cutting process is more labour consuming, and that there is a probability that radioactive contamination might be melted into metal at the places of cutting, there arose a need in installation more powerful mechanical shears in the process of facility operation (those of alligator type).

A considerable part of waste delivered to the facility consists of aluminium alloys waste (electric motors, components of valves, external heat insulation sheets, etc.). Since recycling of such waste was not considered in design documentation, a new technology based on weeping-out melting technique has been developed. An electric heating oven with the working camber dimensions of $1600 \times 780 \times 780$ mm is used for melting such waste. Waste is loaded into a special container with the volume of approximately 0.2 m^3. From every melt, a dipper sample is taken, which is analysed on its chemical content and residual radiation. The plant is also used for melting lead waste, which is used to make some components of the biological shield.

Table 4 Results of the facility performance in RMW recycling and utilisation and environmental impact assessment (2003)

Item	*Design characteristics*	*Actual data*
Quantity of RMW processed (ton)	5000	1173*
Activity (GBq)	100	18.9
Type of metal	Stainless and carbon steels, non-ferrous metals	Stainless and carbon steels, aluminium, copper-nickel alloys
Radionuclide content	Mn-54, Co-60, Sr-90, Zn-65, Ru-106, Cs-134, Cs-137, Ce-144, Eu-154, Ra-226, Th-232, U-238 (natural)	Mn-54, Co-60, Cs-134, Cs-137
Volume of solid secondary waste in the shape of slag, scale, etc		
(ton)	450	191
Activity (GBq) in the shape of ingots	75	6.0
(ton)	1200	436
Activity (GBq)	25	10.7
Radioactive substances release (MBq)	1,639	263
Harmful chemical substances release:		
Gaseous (ton)	5.67	4.0
Solid (ton)	1.04	0.08

Table 4 Results of the facility performance in RMW recycling and utilisation and environmental impact assessment (2003) (continued)

Item	*Design characteristics*	*Actual data*
Liquid radioactive waste discharge:		
Volume, m^3	400	184
Activity, MBq	1,500	45.8
Concentration of HCS above surface on the boundaries of sanitary protection zone (3000 m), fractions of the MPC (maximum permissible concentration)	10^{-3}–10^{-6}	10^{-4}–10^{-7}
Concentration of RS above surface on the boundaries of sanitary protection zone (3000 m), fractions of the MPC (maximum permissible concentration), mcBq/m^3	10	2
Annual individual exposure dose for the population on the boundaries of sanitary protection zone, mcSv	9.9	0.78
Annual individual exposure dose for the personnel, mSv	20	1.49

*All the RMW was delivered by Leningrad Nuclear Power Plant branch of Rosenergoatom Concern.

At present works have been carried out to modernise the facility with the purpose of recycling RMW contaminated with alpha-nuclides, which originate at facilities of gas and oil industry.

To carry out low activity scrap metal transportation by rail and by truck from other regions to the facility, CJSC ECOMET-S uses a solid waste transport container of the KTBN-3000 type (weight capacity – 3 ton, volume 2 m^3).

The container meets all the requirements to A-type packages (Confirmation No 2011 of 29.09.99, issued by Minatom of the RF, Revision No 3580 of 11.09.2003).

On the whole, the three years of the facility operating experience in the field of RMW recycling and utilisation have shown that design, engineering, and technological solutions provide for safe operation of the facility and make it possible to carry out the whole range of activities concerning management of various kinds of RMW regardless of the type of material (stainless and carbon steels, non-ferrous metals, and alloys), features of construction and size of equipment (pipelines, fixtures, large-sized thick-walled components, etc.), radionuclide content and levels of radioactive contamination. The equipment of the facility and the techniques used allow to obtain the result of RMW melting charge ingots that can be used in industry, without any restrictions in full compliance with acting SanPiN (Sanitary Regulations and Standards).

3 Conclusion

At present, CJSC ECOMET-S has become a specialised enterprise and has obtained from the Ministry of Atomic Energy of the RF the Decision of considering ECOMET-S as an organisation, which is capable of operating facilities belonging to the nuclear sector (the Status of an Operating Organisation).

To carry out activities in the field of RMW management, ECOMET-S has a license issued by Gosatomnadzor (Federal Nuclear and Radiation Safety Inspectorate) and relevant authorising documents from other supervising and regulatory bodies.

To control both the process of low activity scrap metal recycling and hazardous substances discharges into the environment, CJSC ECOMET-S is operating specialised laboratories accredited by Gosstandart (State Standard Inspectorate) of Russia.

Availability of industrial capacities, wide practical experience, and scientific-engineering potential allow ECOMET-S to hold the leading position in the field of radioactive metal waste management in the country. The enterprise is capable of and ready to render a wide range of services in the field of RMW management, and it also has all the technical means to accept from other facilities up to 4000 tons of RMW a year to recycle the waste at ECOMET-S facilities.

References

ГОСТ Р 51713-2001 (All-Russia State Standard) (2001) 'Carbon Steel and Non-ferrous Metal ingots. Permissible Levels of Radionuclide Specific Activities of Gamma-emitting Radionuclides. General Radiation Control Requirements', Gosstandart of Russia, Moscow.

ОСПОРБ-99 (2000) 'General sanitary regulations on radiation safety', СП 2.6.1.799-99, Ministry of Health of the Russian Federation, Moscow.

СПОРО-2002 (2002) 'Sanitary regulations on radioactive waste management', СП 2.6.61168-02, Ministry of Health of the Russian Federation, Moscow.